Appendix 3

Kennebec River Fishery Management Plans

a) 1993 Kennebec River Resource Management Plan

2-1993

Kennebec River Resource Management Plan

Maine State Planning Office

07 EXECUTIVE DEPARTMENT

105 STATE PLANNING OFFICE

Chapter 1: KENNEBEC RIVER RESOURCE MANAGEMENT PLAN: BALANCING HYDROPOWER GENERATION AND OTHER USES

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INTRODUCTION

PURPOSES OF THE KENNEBEC RIVER RESOURCE MANAGEMENT PLAN

The Kennebec River Resource Management Plan represents a comprehensive examination by the State of Maine of the various resources and beneficial uses of the Kennebec River. The Plan discusses each of these resources and beneficial uses and, consistent with existing State policies, makes certain recommendations that reflect the State's determination of how those resources and beneficial uses should be balanced against one another in various circumstances.

This Resource Management Plan is intended to serve several purposes. A primary purpose of the Plan is to comply with the requirements of a Maine statute enacted in 1989. This statute, titled "An Act to Ensure Notification and Participation by the Public in Licensing and Relicensing of Hydroelectric Dams and to Further Ensure the Equal Consideration of Fisheries and Recreational Uses in Licensing and Relicensing," is codified at 12 MRSA §407 (see Appendix A, page). The statute requires the State Planning Office (SPO) to work with the natural resource agencies of the State to develop a management plan for each watershed in the State with a hydropower project currently or potentially regulated by the Federal government. "These plans shall provide a basis for State agency comments, recommendations and permitting decisions and shall at a minimum include, as applicable, minimum flows, impoundment level regimes, upstream and downstream fish passage, maintenance of aquatic habitat and habitat productivity, public access and recreational opportunities. These plans shall update, complement and, after public notice, comment and hearings in the watershed, be adopted as components of the State's comprehensive rivers management plan." The Plan responds to the requirements of the Maine statute with respect to the Kennebec River.

The Kennebec River Resource Management Plan also serves as the State's "comprehensive plan" for the Kennebec River for purposes of consideration by the Federal Energy Regulatory Commission (FERC) regarding hydroelectric licensing and relicensing within the Kennebec basin. Under section 10(a) (2) (A) of the Federal Power Act, FERC is required to consider the extent to which proposed hydroelectric projects, and the continued operation of existing projects, are consistent with "comprehensive plans" prepared by federal and State agencies. The Plan is intended to be used by FERC in its analysis of beneficial uses of the Kennebec River. To the extent that previous State publications have identified goals and objectives for Kennebec River resources, those goals and objectives either have been included within the Plan or have been balanced against other goals and objectives in developing the Plan's recommendations and conclusions. The Plan also incorporates existing State policies regarding Kennebec River resources.

This river resource management plan has been developed with considerable citizen and public agency input. Consistent with State policy and the provisions of the Maine Administrative Procedure Act, this plan is intended to combine professional judgements by the State Planning Office, the state agency charged with comprehensive watershed planning, with comments and opinions by all elements of the political process, including citizens, other state agencies, the State Legislature, resource users, and interested organizations.

Although it is recognized that case-by-case review of individual hydroelectric projects will occur, the Plan is intended to provide a comprehensive review of various competing beneficial uses of the Kennebec, so that individual license applications can be reviewed in light of basin-wide issues and policies.

Individuals who wish to be apprised of the status of particular projects may send their names and addresses, along with the name of the project of interest, to the Hydropower Coordinator, State Planning Office, Station 38, Augusta, ME 04333.

Four informal hearings were held in October 1991 in Skowhegan and Augusta concerning a previous draft of the Plan. Formal public hearings were held on the most recent draft of the Plan in Bingham on August 26, 1992, and in Augusta on August 27, 1992. The deadline for receipt of public comments was extended from September 25 until November 2, 1992 at the request of representatives of municipalities between Augusta and Waterville.

GEOGRAPHIC SCOPE OF THE PLAN

The Kennebec River basin, located in west central Maine, has a total drainage area of 5,893 square miles, constituting almost one-fifth the total area of the State of Maine. The Androscoggin River basin lies to the west, the Penobscot River basin to the north and east, and a section of the Maine coastal area to the south. The northwesterly limit of the basin forms a part of the international boundary between the United States and Canada. The basin has a length in the north-south direction of 149 miles and a width of 72 miles.

The following watersheds in the Kennebec River system have existing, or potential for, federally licensed dams and are therefore considered by this plan:

- Main stem
- Moxie Stream
- Dead River
- Carrabassett River
- Sandy River
- Messalonskee Stream
- Sebasticook River
- Cobbossee Stream
- Moosehead Lake
  - Roach River
  - Moose River

DAMS UNDERGOING RELICENSING BY FERC

There are currently 27 FERC licensed generating facilities and storage dams on the Kennebec and tributaries; of these, ten have licenses set to expire in 1993 (see) while three have had licenses renewed. All ten have initiated the relicensing process and were required to submit applications for relicensingto FERC by December 31, 1991.

**Dams in the Kennebec River Basin Subject to Relicensing;
All Licenses set to Expire in 1993**

Project	FERC #	Owner	Installed Capacity in MW
Edwards	2389	Edwards Manufacturing Co.	3.5*
Union Gas	2,556	Central Maine Power Company	1.5
Fort Halifax	2,552	Central Maine Power Company	1.5
Automatic	2,555	Central Maine Power Company	0.8
Rice Rips	2,557	Central Maine Power Company	1.6
Oakland	2,559	Central Maine Power Company	2.8
Weston	2,325	Central Maine Power Company	12
Wyman	2,329	Central Maine Power Company	72
Moosehead Lake (East Outlet)	2,671	Kennebec Water Power Company	storage
Moxie	2,613	Central Maine Power Company	storage

Union Gas, Oakland, Rice Rips and Automatic have been consolidated into one application which is now entitled the MessalonskeeProject.

**Applicantis also requesting an 8.2 MW expansion.*

Hydropower Licenses Reissued Prior to 1989

Project	FERC #	Owner	Status
Hydro-Kennebec	2611	United American Hydro	Relicensed 10/15/86 for 50 years; 13.8 MW expansion for total of 17.5 MW
Shawmut	2322	Central Maine Power Co.	Relicensed 1/5/81 for 40 years; 4.0 MW expansion for total capacity of 8.6 MW
Williams	2335	Central Maine Power Co.	Relicensed 1/22/88 for 30 years at 14.5 MW of capacity

SOCIOECONOMIC CHARACTERISTICS AND HISTORICAL CONTEXT

The basin's physical characteristics, the distribution of its natural resources, and establishment of Maine's capital at Augusta on the lower main stem have had considerable impact on cultural development. The following sections trace the history of development in the Kennebec basin and summarize its present demographic and economic environment.

Before the influx of European settlers to New England, the basin was inhabited by the Abenaki Indians who controlled the entire Kennebec River. They named the waterway for its twisted course through Merrymeeting Bay to the ocean; purportedly the name means either "snakey monster" or "long quiet water".

English colonization began in the 1600's along the lower Kennebec River. Popham colony was established in 1606. Although Plymouth Colony was the first lasting European settlement in the northeast, Popham Colony predated it.

In April of 1606, King James granted a charter for the permanent settlement of the east coast of America. An expedition launched in May of the same year and lead by Sir John Popham, was concerned mainly with trading rather than settlement prospects. The expedition consisted of two ships and 120 passengers and made land fall in August.

Based on the explorations of the previous year, it had been decided before leaving England that the colonists should proceed directly to the Kennebec River. It had been chosen for its size and central location to facilitate a vigorous trade in furs with the native inhabitants. It is believed that by the end of the year, both of the original ships had departed the New World, leaving behind only 45 colonists in the village.

The colony survived until 1608 when the governor was recalled to England. Without a leader to govern the enterprise, the colony was abandoned.

The Indians and early settlers depended on the Kennebec River for transportation and commerce. Small craft, often bearing furs or fish, could navigate as far upstream as Solon. Plentiful stocks of spruce and pine provided the raw materials for home and ship construction, and fertile land sustained agriculture. Tributaries, rather than the river itself, were used for water power; early settlers' crude saws and grist mills could not withstand the Kennebec's swift current.

As a transportation and communication corridor, the river gained strategic significance during the French and Indian wars and the American Revolution when forts were built at Augusta and Waterville. In particular, Benedict Arnold journeyed up the river on the way to attacking Quebec.

After the Revolution, industry grew and riverine settlement rapidly increased, spreading northward along the main stem and branching out along the southern tributaries. Commercial shipyards were built along the river from Gardiner to Waterville. Dams constructed on the lower Kennebec main stem and some of its tributaries accommodated log drivers and supplied power to the basin's timber and textile industries. The needs of these industries soon took precedence over other riverine uses. In 1837, a dam was built at Augusta, despite the fact that the structure blocked navigation and anadromous fish runs upstream of the city.

During the 1820's, large lumber and logging associations replaced individual and partnership operations, and by 1930 the Kennebec Log Driving Association controlled all log driving on the river. This private association maintained control until 1976 when the Maine Legislature halted log driving throughout the State.

The trend toward consolidating ownership of the basin's timber resources was prompted in part by the emergence of new land ownership patterns. When Maine separated from Massachusetts, becoming a state in 1820, the two states shared millions of acres of land in northern Maine. The State of Maine divided the land into townships (usually 36 square miles each). Retaining 1,000 acres of each parcel, the State then sold the remaining land for needed revenue. The buyers, in an effort to minimize economic risks, established a system of "common ownership and undivided interest;" they would buy a township and distribute all profits and losses from the land in proportion to each owner's share. An outgrowth of this system was the formation of land management companies where groups of landowners formed corporations or delegated to one of the owners all responsibility for managing the land.

The northern half of the Kennebec basin is comprised primarily of unorganized territory.[1] Because of the harsh climate and rugged terrain of this remote area, it remained virtually unsettled and undeveloped. However, land sales in the mid 1800's prompted new interest in harvesting this area's extensive spruce-fir forests and boosted the basin's lumber industry.

In the mid 1800's when wood-pulp began to replace rag fibers as the prime material in paper, demand for the northern basin's timber increased again. Fir, previously unimportant, joined spruce and pine as a valuable commodity. Pulp and paper companies began to acquire large tracts of the basin's unorganized territory, and by the late 1800s pulp and paper manufacturing surpassed the lumber industry in economic importance.

During the 19th century, the present-day character of the basin was established. Industrial development and the siting of the state capitol at Augusta brought people to the towns and cities clustered along the southern waterways. Good agricultural land in the lower basin provided both subsistence and commercial enterprise. Abundant surface water offered the basin's residents recreation opportunities, and in the late 1800's resort development around some of the southern lakes drew vacationers from all over New England. Dam construction continued to satisfy increasing power demands and facilitate log drives from the north. Because forest products companies owned large parcels of land in the upper basin, development in this area was minimal. Furthermore, when the anticipated migration of settlers to the 1,000-acre public parcels did not occur, Maine sold the timber rights of these lands for state revenue.

Today, the lower Kennebec River bisects the basin's only urbanized area. Industrial activity is located predominantly in the south, and pulp and paper manufacturing remains the mainstay of the basin's economy. Agriculture, while not a major land use in the basin, still holds an important place in the southern rural economy. Recreational development continues along the shoreline of many southern lakes, especially in the Belgrade and Cobbossee Lake drainages. The river provides excellent spawning and nursery habitat for Landlocked salmon and brook trout, and supports a popular, high quality sport fishery.

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1 Land which has no local government but is under the State's jurisdiction.

The upper basin, while remaining the raw materials base for the forest products industries, has evolved into a popular recreational area. Improved logging roads provide greater access to the scenic north country which draws tourists year-round. In recent years, Maine has begun a movement to recover use of its northern public land and, through a series of land trades with private owners, is consolidating this land into state holdings (Figure 1).

The most recent land trade was approved by the Maine Legislature in April 1990. In a trade with Scott Paper, the Bureau of Public Lands (BPL) acquired 7,275 acres of Days Academy Grant and 17.8 shoreline miles on Moosehead Lake. A conservation easement 500' deep covers 9.5 miles of the total shoreline and includes the opportunity to develop one wilderness campsite per mile of shore. BPL also gained acreage that was added to the agency's holdings in Big Squaw Township and Bald Mountain.

The State has also undertaken conservation land acquisition through bond issues: the $5 million 1986 bond for wildlife habitat protection administered by the Department of Inland Fisheries and Wildlife (IF&W) and the 1987 $35 million Land for Maine's Future (LMF) Fund. Several acquisitions have been made through both programs in the Kennebec River basin and a map showing all public lands in the watershed follows on page 7.

In May 1989, 800 acres of Mount Kineo were acquired by using $750,000 of the LMF Fund. Mount Kineo is the dominant land feature on Moosehead Lake, offering spectacular views from its summit. The mount's sheer cliffs serve as nesting habitat for a pair of peregrine falcons.

In November 1989, IF&W acquired a corridor of 500 feet on each side of the Roach River, a primary Moosehead Lake tributary, for $950,000. The mouth of the shallow river is exemplary spawning habitat for land-locked salmon and brook trout, offering world-class catch-and-release fishing. The corridor acquisition includes 250 feet in fee and a second 250 feet structured as a conservation easement on each side of the main stem.

The IF&W bond was also the source of funding for a 670 acre addition to the Sebasticook River Wildlife Management Area, increasing it to over 1,600 acres. Much of this land, along the floodplain of the main stem of the Sebasticook, is forested with mature cedar and is heavily used by deer. The area also supports populations of waterfowl and furbearers.

Figure 1

Kennebec River Basin with Public Lands

Note: This map is not available in machine readable form; contact the State Planning Office for a paper copy.

The Army Corps of Engineers has a long history of involvement with the Kennebec River dating back to 1827. Initial improvements of the river continued through 1888. These included removing obstructions, such as ledge rock, to provide a 13-foot-deep channel from river mouth to Swan Island in Richmond, about 25 miles upstream, with its depth decreasing to 10 feet at Augusta. A secondary channel was constructed around the west side of Swan Island. In 1898, three jetties were constructed on the west side of Swan Island and one at Beef Rock Shoals, at the southeast end of Swan Island.

Additional projects by the Corps were completed in 1943 and consist of:

- A channel 27 feet deep and 150 feet wide extending from the river mouth to a point 13 miles upstream at Bath.
- A channel 17 feet deep and 150 feet wide along the east side of Swan Island and extending to Gardiner. The channel depth increases to 18 feet through rock at Lovejoy Narrows, at the northeastern corner of Swan Island.
- A training wall at Beef Rock Shoals, at the southeast corner of Swan Island.
- A training wall above Sands Island, near the Dresden/Pittston town line.
- A 16-foot-deep channel at Gardiner.
- A channel 11 feet deep and 150 feet wide to the head of navigation in Augusta.[2]

HISTORY OF HYDROPOWER REGULATION IN MAINE

The initial licenses for most existing projects, in Maine and nationwide, were issued by FERC during the 1950's and 60's. Before the early 1950's, FERC did not concern itself with hydropower licensing or questions of navigability or water quality. However, the courts expanded FERC's jurisdiction during the 1950's. These early licenses were backdated and set for expiration between 1987 and 1993 by the Federal Power Commission, forerunner of today's FERC.

The Maine Rivers Policy (12 MRSA §§401-406) and the Maine Waterway Development and Conservation Act (MWDCA) (38 MRSA §§630-637) were enacted in 1983 as the Maine Rivers Act. These statutes are part of the *Maine Comprehensive Rivers Management Plan* submitted to FERC during the spring of 1987 as fulfillment of the State's obligation for comprehensive river planning. The 1987 Plan also includes projections of the State's hydropower potential, a Statewide Fisheries Plan, the core laws regulating use of Maine's rivers, and the Maine Rivers Study, a comprehensive review of river resources worthy of protection.

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[2] *Maine Water Resources Development*. U.S. Army Corps of Engineers, 1991.

In the Maine Rivers Act, 1983, the Legislature declared that certain rivers, because of their unparalleled natural and recreational values, provide irreplaceable social and economic benefits to the people in their existing state. The Act prohibited the construction of new dams on these river and stream segments without the specific authorization of the Legislature and required that additional development or redevelopment of existing dams be designed and executed in a manner that either enhances or does not diminish the significant resource values of these river and stream segments. The Act identified the following "Outstanding River Segments" of the Kennebec as qualifying for this special protection. Additional segments were protected by the Subdivision Law (30 MRSA §4401).

- Kennebec River

  -- Bay Point to the Father Curran Bridge (from Thorne Head Narrows in North Bath to the Edwards Dam in Augusta, excluding Perkins Township [Subdivision law]).

  -- Route 148 Bridge in Madison to the Caratunk and Forks Plantation townline, excluding the western shore in Corncord township, Pleasant Ridge Plantation and Carrying Place Township and excluding Wyman Lake [Subdivision law].

  -- Confluence of the Dead and Kennebec Rivers up to but not including the Harris Dam.

- Dead River from its confluence with the Kennebec to the upstream limit of Big Eddy.

- Moose River from its inlet into Attean Pond to its confluence with Number One Brook in Beattie Township.

- Carrabassett River from the Kennebec River to the Carrabassett Valley and Mt. Abram Township townline [Subdivision law].

For a listing of those stream and river segments in the Kennebec basin identified as having unique and/or significant resource value by the Maine Rivers Study see Appendix E.

This document is the first in an effort to apply statewide policies to specific rivers; as such, it is a logical next step in the State's continuing efforts to protect its invaluable river resources.

ECOLOGICAL CHARACTERIZATION OF THE KENNEBEC RIVER BASIN

PHYSICAL DESCRIPTION OF THE KENNEBEC RIVER AND WATERSHED

The Kennebec River basin, located in west central Maine, has a total drainage area of 5,893 square miles, constituting almost one-fifth the total area of the State of Maine. The Androscoggin River basin lies to the west, the Penobscot River basin to the north and east, and a section of the Maine coastal area to the south. The northwesterly limit of the basin forms a part of the international boundary between the United States and Canada. The basin has a length in the north-south direction of 149 miles and a width of 72 miles. The upper two-thirds of the basin, generally above Waterville, is hilly and mountainous, being part of the Appalachian Mountain Range. The lower third of the basin, including the Sebasticook River and Cobbosseecontee Stream tributary areas, has a more gentle topography representative of the coastal area. The Kennebec River Basin lies in a large section of Somerset County, the eastern part of Franklin County, most of Kennebec County, and smaller portions of Penobscot, Waldo, Sagadahoc, and Androscoggin Counties.[3] A map of the Kennebec basin including hydropower sites is shown on page 35.

The Kennebec River originates at the outlet of Moosehead Lake and flows southerly 145 miles to the head of Merrymeeting Bay at Abagadassett Point, about seven miles above Bath. From Merrymeeting Bay the Kennebec waters continue south, through the Maine coastal area, another 20 miles to the Atlantic Ocean at Hunniwell Point. The main river is tidal as far as Augusta, 25 miles above Abagadassett Point. Between its origin and mean tide at Augusta, the river falls about 1,026 feet in a distance of 120 miles, as average gradient of 8.5 feet per mile. One "S" curve in the river, between Madison and Skowhegan, forms the only large digression in the river's southward course.

The principal headwater tributary is the Moose River which drains 716 square miles of mountainous watershed area easterly to Moosehead Lake. The tributary area of the Moose River represents about 58 percent of the total Moosehead Lake watershed (1,268 square miles). The Moosehead Lake watershed, in turn, represents about one-fifth (20 percent) of the total Kennebec basin area.

Principal downstream tributaries (draining at least 400 square miles) are the Dead, Carrabassett, Sandy, and Sebasticook Rivers. Individual drainage areas are listed in . The combined drainage area of the four principal downstream tributaries are about 2,800 square miles, representing 47 percent of the total basin area and about 60 percent of the area below Moosehead Lake.

Kennebec River- Principal Tributaries

[3] *Maine Water Resources Development*. U.S. Army Corps of Engineers, 1991.

Tributary	Drainage Area (square miles)	Length (miles)	Fall (feet)
Moose River	722	76	750
Dead River	874	23	570
Carrabasset River	401	35	636
Sandy River	596	69	1544
Sebasticook River	946	48	270

Flagstaff Reservoir, another large regulated lake, is located in the Dead River tributary watershed. The Carrabassett and Sandy Rivers are hydrologically flashy, draining unregulated mountainous terrain, whereas the Sebasticook River drains flatter, more hydrologically sluggish, terrain.[4]

FISH AND WILDLIFE HABITAT

Nontidal Mainstem Waters.

The East Outlet flows for 2.6 miles between Moosehead Lake and Indian Pond. It provides spawning, nursery, and adult habitat for coldwater game fish species. Because of the gradient (average drop of about 25 feet per mile), the channel configuration, and the substrate, the river is comprised of riffles and rapids throughout much of its length. When provided with a flow adequate to wet the entire natural stream channel, it contains nearly 275,000 square yards of excellent nursery habitat for salmon. As there are very few gravel areas, suitable salmon and trout spawning habitat is limited. Several deep pools and runs provide cover and serve as resting habitat for adult salmonids.

Flows in the East Outlet are controlled by the dam at the outlet of Moosehead Lake. Normal mean monthly flows range between 1,400 and 3,900 cubic feet per second. A minimum flow of 200 cubic feet per second is required by the present FERC license for the Moosehead Project, and minimum flows occur most often in late winter. This minimum flow is not adequate to cover the entire river bottom from bank to bank across the natural channel. Higher than normal flows are normally associated with spring runoff, and occur after Moosehead Lake has filled. Maximum flows which exceed 10,000 cubic feet per second have also been discharged at other times of the year after major storm events that occurred when Moosehead Lake was full.

Although the West Outlet is longer than the East Outlet (approximately 8 miles in length), it is a much smaller stream with less gradient. Two shallow ponds (Long Pond - 173 acres, Round Pond - 40 acres) and several deadwater areas are located along its course, with short sections of rocky riffles interspersed between longer, slow-moving sections.

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[4] *Kennebec River Basin Study, Vol. 1* Army Corps of Engineers.

Flows in the West Outlet are also controlled by the dam on Moosehead Lake. A minimum flow of 25 cubic feet per second is required by the present FERC license for the Moosehead Project, but historically the required minimum flow has been exceeded . Flows have averaged close to 80 cubic feet per second throughout much of the year, except when Moosehead Lake is drawn down in late winter. During periods of peak runoff, when Moosehead Lake is full, higher-than-normal flows are occasionally discharged through the dam. Several tributary streams enter the West Outlet downstream from Long Pond. Their natural flows augment water discharged into the West Outlet through the dam at Moosehead Lake.

Harris Dam to the Forks. The twelve mile long reach of river from Harris Dam to the Forks is characterized by a steep gradient and fluctuating water flows. The river drops about 355 ft. from Indian Pond, the impoundment formed by Harris Dam, to The Forks. Water flows are regulated at the Harris Dam to provide electric power during hours of peak demand. Consequently, daily flows vary widely. A reconnaissance survey conducted by IF&W in 1983 showed that the minimum flow of 140 cubic feet per second (cfs) results in the loss of otherwise available fish habitat through streambed dewatering. At Carry Brook, about 40-50% of the river bed was dewatered and at Fish Pond outlet where the river is wider, about 75% was dewatered.

High flows used for power generation as well as for whitewater rafting are thought to conflict with fisheries needs within this reach. Peak generating flows occur rather abruptly, raising water levels at the base of Harris Dam as much as 8 ft. in less than 10 seconds. The resulting flow velocities have not been quantified but they are thought to reduce the fishery potential in this reach by reducing the amount of useable coldwater fish habitat during high flow periods.

The combination of high flows and difficult access limits fishing opportunity. However, anglers who adjust to the release schedule at Harris Dam catch landlocked salmon and brook trout. Sporadic catches of rainbow trout have also been reported in the lower end of the reach. Most fish are from natural reproduction but some are fish which are dropped from stockings in Indian Pond and elsewhere in the drainage.

The Forks to Wyman Dam. The 8+/- mile long river section from The Forks to the upstream limit of the Wyman Lake, the impoundment formed by Wyman Dam, is almost continuous riffle. Pools are few and the stream bed is predominantly cobble. The section is subject to daily flow fluctuations from regulation at Harris Dam on the Kennebec and from Flagstaff Dam on the Dead River, a major tributary which enters the Kennebec at the Forks.

Wyman Lake covers 3240 acres at normal elevation. The impoundment, which averages about 0.5 miles wide, extends 14.4 miles upstream, just above the confluence of Pleasant Pond Steam and Pierce Pond Stream. The lake is unusual in that the thermocline, the narrow layer of cool, well oxygenated water lying between the warm surface layer and cold bottom layer, is located at 80 ft. Normally, the thermocline is located nearer the surface. The deep thermocline is thought to be caused by drawing water for power generation at Wyman Dam from a depth of 50 ft. and from the large volume of warm inflowing water from the Kennebec. The deep thermocline reduces but does not eliminate coldwater fish habitat.

Wyman Lake has both a winter and summer fishery for salmon, lake trout, pickerel, and smelts. There is also a spring dip net fishery for smelts at the upper end of the lake. Anglers report catching salmon, rainbow trout, and brook trout in the flowing water section. Fishing is not uniform throughout the section. Rather, anglers tend to concentrate at several specific areas.

The coldwater fish species in the fishery are from direct lake stocking and from natural reproduction occurring within the reach as well as from upstream waters. Unauthorized stockings of small mouthed bass and white perch in upstream waters will eventually establish themselves in this river reach with unpredictable results. Fishing in Wyman Lake may improve as a result but an overall reduction in the coldwater fishery is expected.

Wyman Dam, Moscow to Williams Dam, Solon. The mainstem of the Kennebec River from Williams Dam in Solon to Wyman Dam in Moscow is 8.4 miles long. The lower 4.2 miles of this reach are impounded by Williams Dam. When full, this impoundment is 426 acres in size; however, water levels normally fluctuate 5-7 feet/day as a result of upstream discharges from Wyman Dam. These discharges range from 490 cfs to 6,240 cfs. Wyman's maximum generating flow is 8,500 cfs. Average depths of the Williams impoundment vary from about 15 feet 1/3 mile above the dam to about 3 feet near the upper limit of the impoundment. Despite the depths in the lower section, the water quality is more riverine than lacustrine due to the high flushing rate.

The entire section supports coldwater sports fisheries for rainbow trout, brook trout, landlocked salmon, and to a lesser extent, lake trout and round whitefish. Other fish species present include brown trout, chain pickerel, yellow perch, rainbow smelt, suckers, sunfish, and minnows. Smallmouth bass and white perch, which are present upstream, can be expected to eventually migrate downstream. All of these species are self-sustaining. Rainbow trout were introduced above Solon in 1933, and were stocked by IF&W as recently as 1979. This species spawns during the early spring in several tributaries to the mainstem of the river, including Jackson Brook, Joe Foss Brook and Austin Stream. The other salmonids are fall spawners. Lake trout and landlocked salmon, better adapted to lacustrine than riverine habitat, grow slowly. Reduced length limits are therefore in effect for these species. No stocking is currently being done in this river section, though there may be escapement from private hatcheries near the river.

Although angling occurs throughout this section, the most popular sites include the tailrace below Wyman Dam, the gravel bar at the mouth of Austin Stream, the Cool Farm site (approximately 3.5 miles below Wyman Dam), and trolling is popular between Wyman Dam tailrace and the Route 16 bridge in Bingham. In a 1987 IF&W creel survey, 59% of the angling activity occurred during the months of May and June. Samples from that survey indicated that legal landlocked salmon and rainbow trout were II to IV years old; legal brook trout ages ranged from II to III.

A study conducted as part of the Wyman Dam relicensing evaluation concluded that fish populations below the dam are adversely affected by fluctuating flows. Negotiations to alter the flow regime or to provide mitigation are underway.

Solon Dam to Augusta Dam. Water flows in this section are controlled to a large extent by KWPC. KWPC attempts to operate upstream reservoirs to provide an average annual regulated flow of at least 3600 cfs at Madison. At Solon Dam, a near constant flow of 3200 cfs is passed. Inflows from the Carrabassett River and other smaller tributaries increase the flow to 3600 cfs at Madison when water is available. Dams at Madison-Anson operate run of the river providing stable flows to Skowhegan dam, with additional inflow from the Sandy River.

The 14 +/- miles long river section from Solon Dam to Madison-Anson contains both coldwater and warmwater fish habitat. Most of the coldwater fish habitat is in the 8 mile long reach from Solon Dam to the upstream limit of the impoundment formed by Anson Dam. It is riffle and pool type with gravel-cobble substrate. The 5.9 mile long impoundment is riverine in nature, better suited to warmwater fish species, with only seasonal coldwater fish habitat.

The 14 mile long river section from Madison to Skowhegan Dam is mostly impoundment formed by Weston Dam. The 12.5 mile long impoundment covers about 930 acres at full pond elevation. Average width is 620 ft. and it is riverine in character. The upstream limit of the impoundment is about 4000 ft. upstream from the confluence of the Sandy River.

Guides and anglers report catching brook trout, landlocked salmon, brown trout, and smallmouthed bass. All species reproduce naturally. Only brown trout are stocked at the present time but in the past all of the above named coldwater fish species have been stocked. There may also be escapement of rainbow trout and salmon into this section of the Kennebec River from private hatcheries located in the towns of Bingham and Embden. There is also a winter fishery, mainly for pickerel, in the Weston Island area. Most of the coldwater fish species between Madison and Skowhegan are caught in the 1.5 miles of flowing water between Abenaki Dam in Madison and the upstream limit of the Weston impoundment.

The area below the Solon/Embden bridge is considered to be excellent wildlife habitat. The Embden side of the river has high value as wildlife habitat.

The segment from Madison to Anson contains some of the most fragile riverine ecosystems in this corridor. The Savage to Weston island sector of the river in the middle of this segment is one of the most valuable wildlife areas in the river corridor.[5]

Near Skowhegan there is a considerable amount of wildlife habitat from Oak Islands to Hinckley Reach.[6]

Tributaries.

Roach River

The following description of fish habitat in the Roach River is taken from the *Roach River Strategic Plan for Fisheries Management* prepared by IF&W in 1985.

First Roach Pond to Moosehead Lake. From its origin at the outlet of Third Roach Pond, the Roach River flows 19 miles (9 miles through Second Roach Pond and First Roach Pond) to Moosehead Lake. There are three geographically distinct sections to the Roach River. They will be described individually as follows: from the outlet of First Roach Pond to Moosehead Lake; from the outlet of Second Roach Pond to First Roach Pond, and from the outlet of Third Roach Pond to Second Roach Pond.

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5 *Kennebec River Corridor Plan*, North Kennebec Regional Planning Commission, September 1974.

6 *Kennebec River Corridor Plan*, North Kennebec Regional Planning Commission, September 1974.

The section best known for its fishery and most important for its contribution to the natural reproduction of landlocked salmon and brook trout for Moosehead Lake is the 6.3-mile section below First Roach Pond. From the base of the dam at First Roach Pond to Moosehead lake at its normal pool elevation (1,029 feet), the Roach River drops approximately 190 feet, an average gradient of about 32 feet per mile. The river width varies from approximately 50 feet to 132 feet during normal flows, averaging 75 feet. However, when water covers the entire river bed, the average width is approximately 100 feet. The depth varies from about 1 to 6 feet during normal flows. The river flows through well-defined banks, once heavily forested. Except for narrow green-belts on either side of the river, the forest was clearcut in the 1960's and early 1970's.

Approximately 90% of the river bottom consists of rock and boulder riffles providing excellent nursery areas for salmon and brook trout. The remaining 10% is small rocks, gravel, and sand; the rubble's coarseness is best suited for salmon spawning. The most extensive gravel area is located in the river's lowest 200 to 300 yards. Another major salmon spawning site is within the upper one-half-mile below the pool at the First roach Pond dam. There are scattered salmon and brook trout spawning sites among the larger rocks or at the edges of bars in the river's wider sections. There are few resting pools available for adult salmon and trout.

Two major tributaries enter this section of the Roach River. Jewett Brook enters less than 1 mile from Moosehead Lake. This small stream has some brook trout in the springy areas, but salmon spawning areas are not available and trout spawning areas are limited.

Lazy Tom Stream, entering approximately 1 mile below First Roach Pond, has spawning and nursery facilities available in the 2-mile section between the river and an old dam at the outlet of Lazy Tom Deadwater. The flowage was used to store pulpwood that was driven through the dam on high water and into the river. Bulldozed streamside landings and the pulpwood drives widened the stream and removed much of the bank and stream cover during the wood driving years. Recovery has been slow but the stream banks are again vegetated. Electrofishing has provided evidence that a limited number of salmon parr are again using Lazy Tom Stream as a nursery area.

A minimum flow of 75 cfs has been established for the Roach River from First Roach Pond to Moosehead. Lesser flows are injurious to aquatic insects and plant life so necessary for fish populations, destroy eggs of fish and insects, reduce the size of salmon and trout nursery areas, and make fish more vulnerable to preying birds and mammals.

In July 1971, the entire reach from First Roach Pond to Moosehead Lake was surveyed to evaluate its spawning and nursery suitability. Determination of spawning suitability was made based on visual comparisons of the river bottom to areas within the river where salmon spawning was known to occur annually. Since 1971, the two major areas deemed suitable for salmon spawning have been repeatedly visited during the subsequent spawning seasons and both spawning adults and redds have been observed. No attempt was made to calculate actual acreage of suitable spawning gravel. Nursery areas were rated based on visual comparison with area where salmon parr had historically been electrofished in significant numbers. Areas suitable for brook trout reproduction were noted when observed. At the time of the survey, the flow through the First Roach Pond dam was estimated at 50 cfs. Lazy Tom Stream contributed an additional estimated 10 cfs. A summary of field observations is given in . The widths shown in the table are of the wetted area of the river channel.

The total area of this section of the Roach River was calculated to estimate the amount of salmon nursery area available. Measurements were made from aerial photographs (scale 1:15,840 or 4 inches to the mile) obtained from Scott Paper Company. The length was measured, using a map measurer, three times and the results averaged. Also from the aerial photos, twenty measurements of width were made and the mean calculated. The potential nursery area on the Roach River from the dam at First Roach Pond to Moosehead Lake is 2,502 units (one habitat unit equals 100 square yards). Estimates of parr abundance have been made using standard electrofishing techniques. The area sampled is, on appearance, typical of most of the river that was rated as "very good" nursery habitat. The two most recent estimates were made in August 1978 and 1979 (4.68 parr and 5.12 parr per habitat unit. Based on these estimates the total potential parr production for the roach River might average 12,250 per year. Using observations made by biologists equipped with SCUBA gear who floated sections of the river counting salmon parr, and estimates based on electrofishing done prior to 1978, the actual number of parr per habitat unit may be as high as 7.0. AuClair chose to use 7.0 parr per unit to determine potential production for the Roach River.[7] The resulting estimate was approximately 17,500 salmon parr, approximately one-half of the total estimated parr production from all of the Moosehead Lake tributaries.

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7 Moosehead Lake Fishery Management Plan AuClair, Robert P., Maine Department of Inland Fisheries and Wildlife, Fishery Research Bulletin No. 11: 75pp., 1982.

Table 4
Summary of Field Observations on the Roach River, July 1971

Section	Length	Width*	Gradient	Spawning	Nursery	General Description
1	0.5 mi	60'-80'	moderate	very good	very good	alternating boulders and gravel; pools and riffles; 3 small tribs.
2	0.5 mi	75'-85'	moderate	poor	very good	boulder riffle with patchy gravel; no pools; 1 small trib. and Lazy Tom Str.
3	0.5 mi	75'-85'	moderate-steep	fair to good	very good	boulder riffle; gravel fair to good; pools and riffles; 1 small trib.
4	0.5 mi	75'-85'	moderate	fair	very good	mixed riffle and pool; boulders and patchy gravel; 1 good pool and gravel area
5	0.75 mi	50'-60'	moderate-steep	poor	very good	boulder riffle; 2 good pools at base of steep banked area; good gravel at head of first pool; 3 small tribs
6	0.5 mi	80'-100'	low-moderate	good	very good	boulder riffle; 1 pool near steep banks; good gravel; 4 small tribs
7	0.5 mi	70'-85'	low-moderate	good	good	large area of big gravel; most only fair; 2 small tribs
8	0.5 mi	60'-80'	moderate	good brook trout & salmon	very good	boulder riffles; small pools and riffles; 2 large bars of salmon gravel
9	0.75 mi	60'-70'	moderate-steep	poor	good	boulder riffle; ledges; small pools; patchy gravel and shale; 2 small tribs
10	1.50 mi	80'-100'	moderate	good-very good at mouth	very good	boulder riffle; few pools; abundance of gravel at mouth; Jewett Brook

* Wetted area

Second Roach Pond to First Roach Pond. The Roach River between Second Roach Pond and North Inlet on First Roach Pond is 1.75 miles long. The vertical drop is approximately 35 feet from the outlet of Second Roach Pond to First Roach Pond. This section of the Roach River is comprised of a variety of runs, riffles and small, shallow pools. The upper half of this section was surveyed in 1971 and the remainder was completed in 1983.

The river bottom is generally covered with small rock and cobble, unlike the river below First Roach Pond. The most suitable gravel areas for spawning are found near the mouth of the river above North Inlet. Future visits to this and other areas along the river are needed to confirm actual use by adult salmon.

There is an area of larger rocks and boulders in the section below the Scott Paper Company bridge that crosses the river. This appears to have the maximum potential for salmon parr habitat of any area between Second Roach Pond and First Roach Pond. The site was electrofished in 1982 and 1983 and produced estimates of 1.5 and 2.5 (average 2.0) parr per habitat unit. Young-of-the-year salmon were reported as very abundant. With abnormal low flow of approximately 10 cfs, the river width averages 30 feet. The calculated potential nursery is 308 habitat units. At 2.0 parr per unit, the potential production is 616 salmon parr.

With the loss of the barrier dam at the outlet of Second Roach Pond and the subsequent cleaning of the bottom within the long access channel to the pond, some additional suitable spawning area has been created. The remnants of the old dam (bed logs and apron) should be removed to guarantee access to the site. When the dam and its fishway were operational, adult salmon were observed using this site in the fall. Unfortunately, no additional nursery has been created.

Third Roach Pond to Second Roach Pond. The Roach River from Third Roach Pond to Second Roach Pond drops about 40 feet in 1.7 miles. Historically, beaver dams have created barriers to upstream migration on this section of the river. When surveyed in 1984, four old and two new beaver dams were observed.

The river immediately above Second Roach Pond is rocky riffle with an occasional boulder. The river below the outlet of Third Roach Pond is similar except for the absence of any large boulders. Both areas have some suitable nursery habitat for salmon. The combined length of these two areas is about 0.8 miles (4,375 feet) with an average width of 35 feet. Only 3,000 feet of the combined areas is suitable nursery for salmon, providing 118 habitat units.

In the middle section of the river between Third Roach Pond and Second Roach Pond are two deadwaters (4.3 acres and 9.5 acres) joined by an area of wide (average 52 feet) slow moving water. The outlet from Trout Pond enters the lower end of the upper deadwater.

Suitable trout spawning habitat can be found within the mouth of the stream. At the upstream end of the same deadwater there is a limited amount of spawning gravel typical of what salmon are known to use elsewhere in the drainage. The deadwaters provide little measurable benefit to the young salmon that might be produced in the river. A previous owner of the sporting camp at the outlet of Second Roach Pond kept a boat or canoe hidden near the deadwaters for his guests to use during the early-season brook trout fishery. When surveyed in 1984, the river above Second Roach Pond showed little evidence of angler use. Adult salmon have been observed in the late fall upstream as far as the beaver dams at the lower end of the deadwaters.

Recent electrofishing (1983) at the site of the old bridge crossing above Second Roach Pond confirms the continued presence of young salmon within this section. Young-of-the-year and parr were taken but in relatively low numbers. A few young brook trout were also taken. Electrofishing records from 1959 and 1963 indicate that young salmon were more abundant within this section of the river than they are at present. An estimate of 3.3 parr per habitat unit in 1959 may reflect the potential for this section of river. At that rate, the Roach River between Third Roach Pond and Second Roach Pond might produce 389 salmon parr.

The combined calculated potential production of salmon parr from the two sections of the Roach River above First Roach Pond is approximately 1,000 fish. It is not known to what degree salmon dropping out of the river as young-of-the-year might contribute to the salmon populations in the waters within the Roach River drainage. A limited salmon fishery for wild salmon in Second Roach Pond may be sustained through the natural reproduction occurring in the two upper river sections.

Moose River

No. 1 Brook to Holeb Stream. An 18.7 mile section with a drop of about 340 feet in elevation. Short stretches of rock and boulder riffle interspersed among longer stretches of gravel riffle and runs provide excellent coldwater fish habitat. Several small falls are present in the section, but they appear passable to upstream fish movement.

Holeb Stream to Attean Pond. This 20.7 mile section comprises the river portion of the "Bow Trip". Total drop in elevation is about 73 feet, most of which occurs at Holeb Falls. Much of the river flows between high clay banks. Shallow to deep runs over gravel bottom, with occasional deep pools, provide good coldwater habitat for adult fish, as well as areas suitable for spawning. There are only three short sections of rocky riffles over this entire distance. They are associated with Holeb Falls, Spencer Rips, and Attean Falls. Thus nursery habitat in this section is limited. Although Holeb Falls are impassable to fish movement upstream, a boulder field river channel bypasses the falls and provides access upstream at high river flows.

Attean Pond to Big Wood Pond. Between Attean and Big Wood Ponds 0.9 miles of moderately deep run with many large submerged boulders provides good cover for adult coldwater species, most of which are moving between the two ponds. There is little gradient between the two ponds, and very little salmonid spawning or nursery habitat.

Big Wood Pond to Long Pond. This 6.8 mile section is generally deep and slow-moving between high banks, with several large, deep pools. (There is also little gradient between Big Wood and Long Ponds.) It provides good salmonid adult habitat, and some spawning habitat in gravel areas found immediately downstream from Big Wood Pond. There is very little nursery habitat in this section.

Long Pond to Brassua Lake. There is an 84 foot drop in elevation between Long Pond and Brassua Lake. Most of the river is comprised of rock and boulder riffle, with a few sections of deep run, mostly at the upper end, and a few good pools. Some spawning gravel is found immediately downstream from Long Pond. This section provides very good salmon nursery habitat, and adult salmon and trout are present throughout.

Brassua Lake to Moosehead Lake. Pools, runs, and riffles comprise the first mile of river immediately downstream from the dam on the outlet of Brassua Lake. The lower two miles of river are more lacustrine in nature due to flowage up from Moosehead Lake. Total drop in elevation of this section is about 14 feet. The river provides spawning and nursery habitat for both salmon and brook trout, as well as adult habitat for salmon, brook trout, and, seasonally, lake trout.

Public lands along the Moose River, called the Holeb Unit, provide good habitat for waterfowl, as ponds, brooks, and wetlands are abundant and well distributed throughout. Twelve waterfowl (duck) boxes are maintained on the Unit by BPL, providing nesting sites where adequate natural conditions for this purpose do not exist. Extensive wetlands are found in the north central part of the Unit in Holeb Township, south of Loon Pond, along the western shore of Holeb Pond, along the Moose River and Holeb Stream, and on the southeast shore of Attean Pond. Wetlands serve a number of important ecological purposes, including absorption of nutrients, storage of ground water, stabilizing surface water, curbing erosion, and providing part of the life cycle requirements for many species of wildlife.[8]

The Skowhegan to Augusta reach of the Kennebec is approximately 38 miles in length. Habitat in this portion of the Kennebec is dominated by a series of hydroelectric projects. Dams in Fairfield, Winslow, Waterville, and Augusta have created several reservoirs intermixed with short reaches of run and/or rapids. The total surface area of aquatic habitat in the reach is approximately 3,500 acres of which just 500 acres could be considered free-flowing. The reservoirs created by Edwards Dam and Shawmut Dam are the two largest impoundments with the former being about 1,200 acres and the latter about 1,400 acres.

Brown trout, smallmouth bass, largemouth bass, white perch, and chain pickerel are among the more important gamefish species found in this part of the Kennebec. The bass, perch, and pickerel populations are maintained by natural reproduction while the river's brown trout population is maintained by an annual stocking program.

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[8] *Holeb Unit Management Plan*. Maine Department of Conservation, Bureau of Public Lands, December 1989.

Dead River

The Dead River has a drainage area of 867 square miles. The upper portion of the drainage is composed of the North Branch, which originates at Saddleback Lake, near Rangeley. A dam near the mouth of the North Branch in Eustis presents a barrier to upstream fish migration. These two branches flow into Flagstaff Lake, a 22,833 acre reservoir. The river below Flagstaff is a combination of deadwater, falls, and whitewater which enters the Kennebec at The Forks. Both Long Falls Dam, which forms Flagstaff Lake, and Grand Falls, located seven miles downstream, are barriers to upstream fish passage.

Brook trout are distributed throughout most of the Dead River drainage, and the river fishery is provided by wild trout except that spring yearlings are stocked in portions of the South Branch and the North Branch. The mainstem of the Dead River and Spencer Stream also have native populations of salmon, but their slow growth in the river environment limits their potential as a sport fishery. Fishing in the north branch of the Dead River is limited by law to fly fishing only. The majority of brook trout angled from the Dead River average 8.5 to 10 inches in length. There are no bass in the drainage, but both yellow perch and chain pickerel are present in the mainstems of both branches.

The major tributary streams to the Dead River include Spencer, Kibby, and Enchanted Streams in the northern part of the drainage; Tim Brook and Alder Stream in the west part of the drainage; and Nash and Redington Streams in the southern part of the drainage. All of these streams support wild brook trout populations; some also have populations of slow-growing landlocked salmon.

Flagstaff Lake forms the northern boundary of the Bigelow Preserve and affects public use and enjoyment of the Preserve. Flagstaff is a large, shallow, man-made impoundment that was formed by the damming of the Dead River in 1950. The Long Falls Dam is owned by Central Maine Power Company (CMP) and operated by Kennebec Water Power Company (KWPC). It controls the water levels on the lake to the 1,150 foot contour. The lake is used as a storage reservoir for hydroelectric facilities further down the Kennebec River drainage. Water levels fluctuate considerably and are usually lowest in mid-to-late March.

Although large in size, Flagstaff Lake is shallow and is drawn down annually. Pickerel, yellow perch, and hornpout thrive in this environment, but landlocked salmon and brook trout do not. Rainbow smelt provide an important spring dip net fishery, and brook trout are abundant in some of the lake's tributaries.

The lake only receives light fishing pressure as the fluctuating water levels and the presence of other excellent coldwater fishing opportunities nearby discourage use of the lake. However, Flagstaff Lake does appear to be important, or have the potential to be important to wildlife, particularly waterfowl.

The shores of the lake in the Bigelow Preserve are designated by BPL as riparian zones. A riparian zone is comprised of a 330-foot corridor, the primary purpose of which is to provide wildlife habitat. Research has shown that the areas adjacent to water are particularly important to wildlife as travel corridors, as well as home range habitat. Timber harvesting is allowed in the riparian zone; in fact, harvesting is important to maintaining the quality of the habitat by providing for a healthy, diverse environment. Timber management will be conducted on an uneven aged basis to enhance and maintain the riparian zone. The fluctuating water levels, which are a function of hydrogeneration and flood control, limit the lake's desirability for wildlife habitat.[9]

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[9] *Bigelow Preserve Management Plan*, Maine Department of Conservation, August 1989.

In contrast to Flagstaff Lake, the other 104 named lakes and ponds in the Dead River drainage are mostly well-suited to coldwater fish. Eighty percent of these waters are less than 100 acres in size; 69% are less than 50 acres. Of the larger lakes, Spencer Lake, Spring Lake, Jim Pond, Chain of Ponds, King and Bartlett Lake, and Tea Pond all have populations of lake trout, landlocked salmon and brook trout. Most are routinely or periodically stocked with these species. The remaining 95 ponds in the drainage are mostly brook trout waters, the majority of which have self-sustaining populations. Public access to more than a dozen lakes and ponds in the drainage is limited due to restrictions imposed by land owners or lessees.

Overall, the Dead River drainage has an abundance of coldwater fish habitat, much of it free from warmwater fish competition.

Carrabasset River

The Carrabassett River drains 401 square miles. From Mt. Abraham Township to Anson, where it enters the Kennebec River, it is 39 miles long and drops 2,800 feet (72 feet/mile). It has a falls impassable to upstream fish migration near its mouth at North Anson. There is also an impassable dam at Kingfield, and one at the outlet of Caribou Pond at the headwaters. The upper river, downstream to East New Portland, is mostly rapids; this portion of the river is restricted to fly fishing only. Below East New Portland the river is primarily glide/run until the falls at North Anson, about a mile before the confluence with the Kennebec. Because of its steepness and the lack of large headwater lakes, the Carrabassett's flow varies greatly with storm events and snow melt.

The major tributary streams to the mainstem are the West Branch, which enters at Kingfield, Gilman Stream, at East New Portland, and Mill Stream, at North Anson. The largest lakes in the drainage, Embden, Hancock, and Porter, have populations of lake trout, landlocked salmon, and brook trout. Higher in the drainage are 9 ponds which support brook trout and approximately 10 named ponds which contain warmwater fisheries.

The mainstem of the upper river, essentially a mountain stream, is relatively sterile and rocky. Brook trout are present but are slow-growing as a result of low productivity and cold water temperatures. Brook trout in the lower section of the river exhibit better growth rates. The wild population of brook trout in the section of the river below Kingfield is supplemented with annual stockings of spring yearlings. Rainbow trout were stocked in the section of the river below East New Portland and in Porter Lake in the 1970's, but are no longer present. Smallmouth bass are present in the mainstem below Kingfield and provide a good fishery. A wild population of brown trout occurs in Gilman Stream as far upstream as Highland Plantation. Warmwater fish present in the shallower ponds and in the slower-moving sections of the streams in the lower drainage include chain pickerel, bullhead, sunfish, yellow perch, white sucker, white perch (in Porter Lake), and smallmouth bass (in the lower river and the Mill Brook drainage, including Embden Lake and Hancock Pond).

Factors limiting the coldwater sport fishery in the streams of the drainage include the extreme variations in flows, the sterility of the upper section, and lack of pools to serve as adult habitat. Within these limitations, however, the upper portion of the drainage provides both riverine and lacustrine brook trout fisheries free from warmwater fish competition, while the lower section contains habitat for both coldwater and warmwater fisheries.

Sandy River

The Sandy River has a drainage area of 596 square miles. It is a mountain stream, with no large bodies of water to store runoff. Consequently, it is subject to extreme changes in flow rates. Although only 60 miles long, the Sandy drops 1,544 feet in elevation, averaging 22.4 feet per mile. The river originates at the Sandy River Ponds, drops over Smalls Falls, a barrier to upstream fish migration, and continues primarily as rapids to Phillips where the two main tributaries, Orbeton Stream and the South Branch, join the mainstem. Below Strong, the lower 47 miles of the river are intermittent quick water and runs. As more tributaries enter, the river valley widens to form fertile bottom land. Extensive farming activity along this stretch is responsible for non-point nutrient loading. A power generating dam just above the confluence with the Kennebec at Norridgewock is a barrier to upstream fish migration.

The section of the river upstream of the Strong-Phillips area supports a wild brook trout fishery, while brown trout and smallmouth bass dominate the lower river. Many of the tributaries, even in the lower section of the river, support brook trout fisheries also.

Thirty-nine great ponds, totaling 3,695 acres, lie within the Sandy River drainage. The three largest lakes in the drainage support populations of lake trout, landlocked salmon, and brook trout. Of the smaller lakes and ponds in the drainage, those in the lower portion support warmwater fisheries, while those at the higher elevations support coldwater fisheries - primarily brook trout. The upper section of the drainage lies in rugged hills and mountains, and many small, isolated ponds provide suitable coldwater fish habitat. Competing warmwater species are kept out by natural barriers to migration.

The Sandy River's brown trout population is periodically supplemented by stockings of hatchery-reared fish from Phillips to New Sharon. Legal-sized wild brook trout angled in the river average 8.6 inches in length; brown trout of both wild and hatchery origin average 12.3 inches, and smallmouth bass average 12.2 inches in size.

Sebasticook River

The Sebasticook River, the largest of the tributaries to the lower Kennebec River, has a drainage area of approximately 946 square miles. For many years human cultural activity including municipal, industrial and agricultural waste discharges and the manipulation of flows for water power and waste disposal have severely compromised the sport fishery potential of this river. More recently, water quality on the river has begun to improve with the implementation of a variety of water quality treatment programs.

Impoundments created by the three dams on the mainstem of the Sebasticook include a 417 acre pond in Winslow, an 83 acre pond in Benton, and a 304 acre pond in Burnham. The ten mile reach from the dam in Burnham to the upstream confluence of the Benton Falls project constitute the longest section of free flowing habitat on the river's mainstem. Smaller sections of riverine habitat occur upstream of the Burnham Project and just below the Benton Falls and Fort Halifax projects in Benton and Winslow, respectively.

Despite its water quality problems, the Sebasticook does support sport fisheries for a variety of species such as smallmouth bass, largemouth bass, black crappie, white perch, and chain pickerel. Brook trout, brown trout, and landlocked salmon occur seasonally. Fishing effort is increasing on this river as water quality and public perception of the value of this resource improves.

IF&W intends to initiate a brown trout management program on the Sebasticook, predicated upon continued improvement in water quality, the assurance of sufficient, stable flows; the availability of sufficient hatchery fish to support a viable program, and the demonstrated ability of the river to support a brown trout population. IF&W plans to begin a series of experimental stockings of brown trout with a planting of 5,000 fall fingerlings in 1992. The program is expected to focus on the free flowing habitat below the Burnham Project. Evaluation of the program will be primarily through angler diaries.

Messalonskee Stream

Messalonskee Stream supports excellent populations of warmwater gamefish including largemouth and smallmouth bass, white and yellow perch, chain pickerel, and hornedpout.[10] Water level manipulations related to the production of hydroelectric power have an important impact on the stream's fish populations and on angler effort. Fishing effort and fish production are also negatively impacted by poor water quality resulting from waste discharge from the city of Oakland's wastewater treatment plant and from a variety of nonpoint sources.

Other tributaries of the lower Kennebec for which IF&W has habitat inventory and biological data include Carrabassett Stream, Martin Stream, Bond Brook, and Seven Mile Stream. Data for the Seven Mile Stream inventory has been summarized in tabular form and habitat maps have been prepared.[11] Survey data for the other three waters has not been summarized but is available in Regional files.

Lakes and Ponds

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[10] *Messalonskee Stream Fishery Management*. Woodward, William, Maine Department of Inland Fisheries & Wildlife, 6pp., 1989.
[11] *Seven Mile Stream Habitat Inventory*. Woodward, William; Maine Department of Inland Fisheries and Wildlife, Unpublished report, 12pp., 1985.

A total of 100 lakes and ponds having a combined surface area of 60,067 acres occur within the Fishery Region B portion of the Kennebec drainage. These waters support important sport fisheries for a variety of warmwater and coldwater species. Fishing effort on the waters of Fishery Region B rank second highest among IF&W's seven fishery regions.

Among the more important sport fisheries in the lakes and ponds of the lower Kennebec are the black bass fisheries of the Belgrade chain of lakes and the Cobbossecontee Stream subdrainage of the Kennebec, the landlocked salmon fishery of Long Pond, and the brown trout fisheries of China Lake, Salmon Lake, and Togus Pond. These fisheries play a significant role in the recreational and economic well being of the communities in which they are found. For example, based on 1988 data, annual fishing effort on Great Pond (at 8,400 acres Great Pond is the largest water in the Belgrade chain of Lakes) was over 30,000 angler-days and estimated economic impact of the lake's sport fisheries was about $750,000.

Tidal Waters.

The Kennebec River, at its mouth, drains an area of 9,524 square miles (). This total encompasses the drainage area of the Androscoggin River and the smaller tributaries of Merrymeeting Bay.[12] The drainage area of the Kennebec River at head-of-tide at the Augusta Dam is 5,493 square miles.

Both the Kennebec and Androscoggin Rivers flow into a large freshwater tidal bay called Merrymeeting Bay. This freshwater bay also receives freshwater inflow from several smaller drainages: the Eastern River (50 mi^2), the Cathance River (70 mi^2), and the Abagadasset River (20 mi^2).

Although the entire tidal section of the Kennebec River from the Edwards Dam in Augusta to Bay Point, Georgetown, is commonly called an estuary, the tidal section from Merrymeeting Bay to Augusta does not fit most definitions of an estuary. The U.S. Fish & Wildlife Service (USFWS) defines the upstream limit of an estuary as "estuaries extend upstream and landward to the place where ocean-derived salts measure <0.5 ppt during the period of annual low flow."13 The Department of Marine Resources (DMR) has been measuring salinities from the mouth of the Kennebec River at Bay Point to the Edwards Dam in Augusta annually since 1976. The normal limit where salinities do not exceed 0.5 ppt varies slightly from year to year. The upstream limit of the true estuary in most years is between Abagadasset Point in Merrymeeting Bay and the Route 197 bridge in Richmond, which is a distance of eight miles. The USFWS characterized the Kennebec River from the outlet of Merrymeeting Bay to the Augusta Dam as "tidal riverine."14 Although salinities normally exceed 0.5 ppt in Merrymeeting Bay, this line of demarcation (outlet of Merrymeeting Bay) is a convenient one to separate the tidal riverine subsystem from the estuarine subsystem. The riverine tidal wetland subsystem of Merrymeeting Bay is characterized by nonpersistent freshwater emergent plants.15

[12] *Drainage Areas of Surface Water Bodies of the Androscoggin River Basin in Southwestern Maine* and *Drainage Areas of Surface Water Bodies of the Kennebec River Basin in Southwestern Maine*. Fontaine, R.A., 1979 and 1980 respectively; U.S. Dept. of the Interior, Geological Survey, Open File Report.

[13] *Classification of Wetland and Deepwater Habitats of the United States*. Cowardin, L.M., V. Carter, F.C. Golet, E.T. Laroe, and J.H. Sather, 1979; U.S. Dept. of the Interior, Washington, D.C.

[14] *An Ecological Characterization of Coastal Maine*. Fefer, S.I. and P.A. Schettig, 1980; FWS/OBS-80/29, Biological Services Program, U.S. Fish and Wildlife Service.

[15] *Merrymeeting Bay Investigations*. Spencer, H.E., 1966; Job Completion Report 4-A, Project W-37-R-9, Maine Dept. of Inland Fisheries and Game, Augusta, Maine.

Drainage Areas (mi^2) of the Kennebec River and its Tributaries

River	Drainage Area(mi^2)	Average[16] Discharge	Period of[17] Record(yrs)
Kennebec River at:			
North Sidney	5,403	9,104 ft^3/s	13
Augusta Dam	5,493		
Above mouthof Cobbosseecontee Stream	5,535		
Mouth of Cobbosseecontee Stream	217	346 ft^3/s	89
Richmond Bridge (Rt. 197)	5,823		
Mouth of Eastern River	50		
Inlet to Merrymeeting Bay	5,893		
Androscoggin River near Auburn	3,263	6,145 ft^3/s	62
Mouth of Androscoggin River	3,524		
Mouth of Abagadasset River	19.6		
Mouth of Cathance River	70.6		
Mouth of Kennebec River	9,524		

The large amount of tidal freshwater riverine habitat found in the Kennebec/Sheepscot Rivers' estuaries makes this system unique in the State of Maine. There is a total of 11,140 acres of tidal riverine habitat in this system with most of it being above the outlet of Merrymeeting Bay (). This represents 84% of the total tidal riverine habitat found in the State of Maine north of Cape Elizabeth.[18] This subsystem can be further divided into classes of types of habitat, such as open water, nonpersistent emergent wetland, flats, and beach/bar (). There are 5,682 acres of open water habitat in this subsystem which represent 80% of this type of habitat in Maine north of Cape Elizabeth. There are 3,133 acres of nonpersistent emergent wetland which represent 98% of that found above Cape Elizabeth. This tidal riverine section constitutes one of the most important spawning and nursery areas for anadromous fish north of the Hudson River.

The Kennebec River estuary below Chops Point (outlet of Merrymeeting Bay) forms a complex with that of the Sheepscot River estuary. Less saline surface water from the Kennebec River flows through the Sasanoa River into Hockomock Bay on an outgoing tide, whereas highly saline water from the Sheepscot River enters Hockomock Bay through Goose Rock passage on the incoming tide as bottom water in the Sasanoa. Water is also exchanged in Montsweag Bay between Hockomock Bay and the Sheepscot River in Wiscasset. Thus, both Hockomock and Montsweag Bays act as mixing basins for the Kennebec and Sheepscot Rivers' water, with there being an indirect exchange between the two systems.[19] Hockomock Bay is also connected with the Kennebec River through Back River, which is very shallow near Hockomock Bay. The dynamics of water exchanged between the two systems and the exact influence one river system exerts upon the other has not been extensively studied.

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[16] *Water Resources Data for Maine, Water Year 1991*. U.S. Geological Survey Water Data Report, 91-1, 1992, 187 pages.
[17] ibid.
[18] *An Ecological Characterization of Coastal Maine*. Fefer, S.I. and P.A. Schettig, 1980; FWS/OBS-80/29, Biological Services Program, U.S. Fish and Wildlife Service.
[19] ibid.

Area (acres) of Tidal Riverine Subsystems and Classes in the Kennebec/Sheepscot Rivers Estuarial Complex

Beach/bar	1,102
Nonpersistent Emergent Wetland	3,133
Flat	1,211
Unconsilidated Bottom	12
Open Water	5,682
Rocky Shore	0
TOTAL	11,140

Source: adopted from FWS/OBS-80/29, 1980

The Kennebec River estuary can broadly be characterized as being a narrow, relatively shallow estuary with a low tidal volume and a large freshwater flow with a large tidal exchange. This results in relatively short flushing time for the estuary in comparison to the Sheepscot and Penobscot Rivers.

The shallow entrance to the Kennebec River (about 35') prevents the entrance of nutrient rich deep water from the Gulf of Maine. The Kennebec River estuary would not be expected to be a highly productive estuary based on the fact the shallow shelf prevents the entrance of nutrient rich deep ocean water and the moderate flushing rate reduces residence time of nutrients, although an unknown amount of nutrient rich Sheepscot River water could enter through the Sasanoa River. Nitrate samples taken at Bath were higher than predicted, even allowing for a higher Sheepscot River input than probably occurs.20 These high rates were attributed to the discharge of the local sewerage discharge plant and not from freshwater input. Based on nitrate values at Bingham, freshwater input was not considered significant source. The majority of nitrate inputs from municipal and industrial sources occurs below Bingham. The input of nitrates (and ammonia) from sewage treatment plants and agriculture runoff needs to be studied in more detail to determine its impact on productivity in the Kennebec River estuary. The dominant nutrient pathway in the Kennebec River is probably from the extensive marsh systems, especially those in the Merrymeeting Bay region. Thus, the food web is probably mainly based on organic detritus derived from the nonpersistent emergent vegetation from the fresh and salt marshes. The estuarial complex of the Kennebec and Sheepscot Rivers contains approximately 26% of estuarine habitat (33,419 acres) found north of Cape Elizabeth (). The emergent wetlands comprise 4,975 acres of this total and represents 36% of this class of habitat available north of Cape Elizabeth (). This estuarine complex is an important nursery area for the anadromous fish species produced in the riverine sections of both rivers, as well as for marine species.

[20] *An Ecological Characterization of Coastal Maine.* Fefer, S.I. and P.A. Schettig, 1980; FWS/OBS-80/29, Biological Services Program, U.S. Fish and Wildlife Service.

The vertical salinity gradient in the Kennebec River estuary stratifies only slightly. Francis and coworkers21 sampled the estuary during low flow periods in the fall and found the estuary to be only slightly stratified. They noted that the two sharp bends below Bath (Doubling Bends) and the very narrow portion of the river between Doubling Bends and Bluff Head shore resulted in very intense mixing based on the amount of turbulence seen in this area. This turbulent section did not appear to impact the vertical salinity gradient at the time they sampled the river. The Department of Marine Resources has found similar results based on salinities measured in August at high slack tide, although the degree of mixing varied from year to year probably with the freshwater inflows and lunar cycle.

[21] *Observations of Turbulent Mixing Processes in a Tidal Estuary.* Francis, J.R., D.H. Stommel, H.G. Farmer, and D. Parsons, 1953; Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Area (acres) of Estuarine Subsystems and Classes in the Kennebec/Sheepscot Rivers Estuarial Complex

Aquatic Bed	718
Open Water	17,993
Subtidal Total	**18,711**
Estuarine Total	**33,419**
Unconsolidated Bottom	-----
Rock Bottom	-----
Aquatic Bed	163
Beach/Bar	-----
Emergent	4,975
Emergent/OW	-----
Emergent/UB	-----
Flat	9,432
Flat/EM	-----
Flat/SS	-----
Reef	-----
Rock Shore	130
Scrub/Shrub	8
Intertidal Total	**14,708**

Water Quality.

Water quality of the Kennebec River Basin has improved dramatically since 1978 when most of the major discharges were provided treatment. As a consequence of this significant cleanup effort, the Legislature revised the water quality classifications of the basin in 1989 to reflect the gains made in water quality improvement (see Appendix C). Much of the watershed has been raised to class AA, A and B in recognition of the excellent water quality found. This assures protection of a high quality aquatic habitat and multiple use of the resource.

The most recent evaluation of water quality[22] finds that much of the water of the Kennebec River Basin achieves the standards of the designated classes. While most of the waters listed that do not attain their classification standards are small tributaries, a few notable exceptions exist. Foremost, are two segments in the basin which have health advisories for the consumption of fish due to dioxin contamination. These include a 56 mile segment of the Kennebec River from Skowhegan to Merrymeeting Bay and a 13 mile segment of the West Branch of the Sebasticook River from Hartland to Pittsfield. Other significant segments not attaining standards are portions of Messalonskee Stream which is eutrophic, has high levels of coliform bacteria and low dissolved oxygen, and segments of the Sebasticook River and its two main branches which are eutrophic, have high levels of bacteria, low dissolved oxygen and significantly impaired aquatic life communities. The lower Kennebec River has low dissolved oxygen and bacteria problems in segments below Waterville/Winslow and Augusta.

Cause of nonattainment problems in the Kennebec Basin can be attributed to a number of factors. Pollutants from nonpoint (diffuse) sources such as farms, forestry, and urban development are, collectively, the greatest source. These pollutants account for much of the eutrophication and dissolved oxygen problems particularly in the small tributaries and in impounded segments of rivers. Combined sewer overflows (combined storm and wastewater systems) cause some of the more severe bacteria contamination problems. The dioxin problem is associated with processes in the pulp and paper and tanning industries. Other toxic problems have been associated with the tanning and textile industries. Improved management of each of these sources will be required to resolve these problems.

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[22] *State of Maine 1990 Water Quality Assessment.* Maine Department of Environmental Protection, 1990.

HYDROPOWER REGULATION

ROLE OF THE FEDERAL GOVERNMENT IN HYDROPOWER REGULATION

FERC regulates the construction and operations of hydropower projects pursuant to the Federal Power Act, first enacted in 1920. FERC's jurisdiction extends to all projects on navigable waters and to projects on non-navigable waters constructed or modified after 1935.

A river is considered to be navigable if it is or has been used to transport persons or property in interstate or foreign commerce. The historic floating of logs to sawmills and paper mills is sufficient to establish navigability. A project on a non-navigable waterway must affect interstate or foreign commerce in order to come under federal jurisdiction. Participation in interstate commerce is assumed when project power is conveyed to the public utility power grid or when project power displaces electricity that would otherwise be purchased from the grid. FERC has found the Kennebec River to be navigable from its mouth at least up to Moosehead Lake.

The Federal Power Act allows for competition during relicensing. Two or more competing applications for a new license may be filed for the same project. FERC will issue a license for the project judged to be the "best adapted to a comprehensive plan for improving or developing a waterway."23 Alternatively, FERC may recommend a federal takeover of a project. This must be authorized and funded by an act of Congress. New licenses are issued for terms varying from 30 to 50 years. The applicant makes a proposal to FERC of the license term and FERC makes the decision based on the following rules of thumb. New projects and total redevelopments are usually granted 50-year licenses and if moderate redevelopment or reinvestment is proposed, a 40-year license term is likely. In cases where no changes or no substantial investments are proposed to the facility, a 30-year license is likely to be issued.

All applications for relicensing must be filed with FERC no later than two years prior to the license expiration date. However, FERC is under no self-imposed time limitation in acting on these applications. If a new license has not been issued or a federal takeover has not occurred by the license expiration date, FERC will issue annual licenses to the applicant until relicensing action has occurred.

Many of the projects slated for relicensing were first licensed before the enactment of the National Environmental Policy Act (NEPA), the Clean Water Act and other federal environmental laws. However, the relicensing of these dams will require an assessment of the impacts using these current statutes.

THE FERC CONSULTATION PROCESS

FERC's regulations require that all potential applications for licensing or relicensing participate in a detailed pre-filing consultation process with the appropriate State and federal resource agencies. This three-stage process requires approximately five years for each project and involves a considerable amount of time and effort by all parties.

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[23] Federal Power Act, 1986 Amendments, Electric Consumers Protection Act.

SPO is designated as the lead State agency in the FERC relicensing process and is charged with the duty of processing applications, monitoring application status, and coordinating and reviewing agency requests and comments. Policy and procedures were developed in 1989 to expedite the State's role in federal licensing and relicensing (See Appendix C, "Revised Procedure to Ensure that State Agency Comments in Federal Hydropower Proceedings are Timely, Coordinated and Consistent", September 1989). Emphasis is also focused on the substance of State agency review. The new policy requires all State agencies to consider their comments, study requests and recommendations to ensure that they are not unnecessarily burdensome to the applicants. The objective of the State is to achieve the best possible balance between power generation and the preservation and enhancement of natural resource and recreational values.

FERC consultation during the relicensing process will allow the State an opportunity to assess the impacts of many of the major hydropower projects in Maine and to re-evaluate the uses of the public river resources. Among the issues to be considered by the State agencies in their review for a new FERC license are: flood control, floodplain management (National Flood Insurance Program), energy generation and conservation, economics, geological and botanical resources, restoration of sea-run fish, inland fisheries and wildlife management, protection and improvement of water quality, historical and cultural resources, and improvement of recreational opportunities.

FERC licensing is also required for water storage dams and reservoirs that provide stream flow regulation to downstream licensed hydropower facilities.

In rules adopted May 24, 1989, FERC made provision for public participation from the beginning of the consultation process. Previously, public participation had been limited to the final application filed with FERC, when most studies were complete. When the licensing process is initiated, by the filing of an initial consultation document, the applicant is obligated by FERC rules to hold a public meeting during the first stage of consultation.[24] (The State's provisions for public participation are discussed in the next section.)

In addition to the above, natural resources are specifically protected by the following Federal statutes and executive order:

* *Section 18 of the Federal Power Act* mandates that FERC shall require licensees to construct and operate such fishways as are prescribed by the USFWS, and the National Marine Fisheries Service.

* *The Fish and Wildlife Coordination Act* (P.L. 85-624), administered by the Department of the Interior, requires federal agencies which license dams (and other activities) to consult the federal departments and state fish and wildlife agencies to determine how fish and wildlife may be conserved and enhanced.

* *The Endangered or Threatened Species Act* (P.L. 93-205): Threatened Species may be added to the Endangered Species List and regulations may be issued by the Secretary of the Interior to protect the species. The regulations may include designation of a range or critical habitat in which commercial activity may not take place without permission of the Secretary.

* *Section 401 of the Clean Water Act* requires that any applicant for a federal license or permit for an activity which may result in a discharge to navigable waters must obtain state certification that the activity will not violate applicable water quality standards.

[24] *Maine Hydropower Relicensing Status Report*, Maine State Planning Office, January 1990.

* *Section 404 of the Clean Water Act* and the *National Environmental Policy Act* are also relevant for the protection of wetlands and examination of environmental impacts caused by federal action.

* *Executive Order 11988 on Floodplain Management, May 24, 1977* requires all Federal agencies to review any actions they take in light of any adverse effects and incompatible development in the floodplain.

THE ROLE OF STATE GOVERNMENT

A permit is required under the MWDCA for the construction, reconstruction or structural alteration of a hydropower project. The MWDCA is administered by the Department of Environmental Protection (DEP) and the Land Use Regulation Commission (LURC) in their respective jurisdictions. Statutory review criteria include consideration of financial capacity and technical ability, public safety, public benefits, traffic movement, LURC zoning, environmental impacts and mitigation and energy benefits. In relicensing, a State hydropower permit will only be required if project redevelopment or expansion is proposed in conjunction with relicensing. Thus, the State's authority to condition the operation of most hydro projects upon relicensing is contingent upon Section 401 of the Clean Water Act which requires that any applicant for a federal license or permit for an activity which may result in a discharge to navigable waters must obtain state certification that the activity will not violate applicable water quality standards.

The Maine Comprehensive Rivers Management Plan, submitted to FERC in 1987, will ensure that during FERC relicensing proceedings the State of Maine will have a strong voice on issues regarding the development and management of its rivers. FERC officially recognized Maine's plan as a comprehensive plan in November 1988, although it was referenced as a comprehensive plan in the FERC order amending the license for the Brassua project issued July 28, 1987.

As amended by the 114th Legislature, 38 MRSA §640 now requires State agencies that review and comment on Federal licensing and relicensing procedures to allow for public participation:

• ***Publication.*** At the commencement of the consultation, review and comment process, the State agencies involved shall publish notification of this fact, informing the public of the issues anticipated to be involved in the licensing or relicensing process, the timetable for processing of the license and the opportunities the public has to comment on and participate in the process. The notice shall be designed to reach readership both statewide and in the vicinity of the hydropower project, including all persons that have contacted the agencies with an interest in this matter and all potentially interested persons.

• ***Written notification of status.*** During the entire consultation process and including the filing of the license application under the Federal Power Act, the State agencies shall inform in writing all members of the public that have indicated an interest in the particular licensing process of the status of that process, including all requirements that the agencies may be placing upon the license applicant. That information shall be provided no less than once every 4 months.

• ***Public comment.*** State agencies shall provide meaningful opportunities for public comment on the plans, studies, terms and conditions to be recommended by the agencies for inclusion in the license.

- ***Release of public information.*** All information submitted to the agencies by the applicants for a license under the Federal Power Act shall constitute a public record pursuant to 1 MRSA §402, unless such information is otherwise exempted from public disclosure by state law. Release of the information to members of the public shall be governed by 1 MRSA §408.

With regard to public participation, the SPO Hydropower Coordinator makes every possible effort to include all interested parties in the consultation process. Lists of individuals interested in particular projects undergoing relicensing are on file at SPO. At appropriate times, these individuals are notified through status reports of review and comment periods, filings with FERC and ongoing events associated with the consultation and licensing process. Public notices are published in three newspapers to solicit participation in public meetings and the consultation process and to inform the public when initial hydropower applications are received and when FERC filings are accepted.

RELATIVE COST OF RELICENSING ACTIVITIES

The relicensing process may require applicants to conduct studies and design and implement mitigation programs. Although the breakdown of the cost of these activities varies considerably from project to project, it can be roughly estimated as shown in .

Breakdown of Relicensing Expenses

40%	Archaeology: surveys, studies and mitigation
40%	Fisheries: studies, stocking and fishways
8%	Recreation: studies and improved access
7%	Engineering design
5%	Miscellaneous

SUMMARIES OF STATUS OF PROJECTS UNDERGOING RELICENSING

The following summaries reflect the results of the consultation process wherein the State assessed proposals for relicensing according to an analysis of the balance of resources and uses at each project.

Edwards - FERC #2389. The Augusta Hydroelectric Project, better known as the Edwards Dam, is owned and operated by the Edwards Manufacturing Company and is located on the Kennebec River between Augusta and Waterville, Maine. The project is presently rated with an installed capacity of 3.5 MW and the applicant is proposing to upgrade and expand the facility to 11.7 MW. The Edwards Dam is located in the city of Augusta and the impoundment formed by the dam extends upstream from the dam a distance of approximately 15 miles and comprises an area of approximately 1,143 acres. Existing facilities consist of a 917' long concrete-capped timber crib spillway, an 8' long gatehouse, 450' long power canal and three powerhouses. The water quality classification for most of the project impoundment is Class C. The reach of river from its confluence with Messalonskee Stream to the Sidney/Augusta town line is classified as Class B.

The expanded project will involve the construction of a new powerhouse located at the downstream end of the existing main power canal which will house one vertical Kaplan turbine and generator with a capacity of approximately 8 MW. Powerhouses 7 and 8 will be decommissioned, the new power canal widened, a new canal intake structure and new fish passage facilities constructed, repairs and improvements to the existing dam will be accomplished and present plans specify the addition of an inflatable crest control device along the entire length of the primary spillway.

Enhancements proposed by the applicant involve the construction and operation of new upstream and downstream fish passage facilities at the project. The upstream facilities as proposed consist of fish transportation channels, a central fish attraction pool, a duplex fish lift, sorting and holding tanks, and an exit channel to the power canal. The proposed downstream facilities consist of a gated concrete entrance chamber at the intake to each powerhouse and sluice pipes to tailwater. The proposed facilities are intended to provide passage for design populations of 1,548,000 alewives, 385,000 American shad, and 7,500 Atlantic salmon annually.

The State of Maine has taken the position that removal of the Edwards Dam is necessary to achieve the State's goals for restoration of the Kennebec's fisheries and recreational resources. The State resource agencies recommend that the no dam alternative be considered and that dam removal studies be conducted.

The State resource agencies find that the applicant has failed to address the State's goal of restoring striped bass, rainbow smelt, Atlantic sturgeon, and shortnose sturgeon to their historical range which includes the river segment from Augusta to Waterville. The applicant has failed to address upstream and downstream passage requirements for striped bass, Atlantic sturgeon, shortnose sturgeon, and rainbow smelt, in addition to American shad, Atlantic salmon, and alewives. It is likely that the Federally endangered shortnose sturgeon migrate to the Edwards Dam and potentially spawn in the immediate area. Field studies should be conducted to determine if shortnose sturgeon are spawning in the project area. American shad, smelt, striped bass, and the sturgeon should be used as study species to determine the impacts of the proposed redevelopment on the habitat between the dam and the Memorial Bridge. Field studies should be designed with input from the fishery agencies to determine if, when, and where striped bass, smelt and Atlantic sturgeon spawn in the project area and to determine what impact the diversion of flows will have on this life stage of these species. The applicant should determine if smelt utilize the project area prior to spawning. The applicant should clarify that proposed techniques for holding and sorting of trapped fish is effective in preventing upstream passage of undesirable species. Studies should also determine the effect of the proposal and the no dam alternative on the abundance of brown trout. Detailed soil erosion and sedimentation plans for project redevelopment are also recommended.

Assuming that Edwards Dam is not removed, the State also recommends studies on recreational use below the dam to address fishing opportunity for striped bass, American shad, Atlantic salmon, brown trout and smallmouth bass. The State contends that the projected increase in recreational use of the impoundment is underestimated and that additional recreational access should be planned. A portage trail around the dam is warranted and consistent with other hydroelectric projects on the Kennebec. Consultation meetings with the Bureau of Parks and Recreation (BPR) and towns on the impoundment resulted in the following specific proposals being recommended:

1. Development of riverfront trail and picnic area at the existing Sidney boat launch.
2. Primitive campsites at Seven Mile Island.
3. Park and handicapped fishing access at Old Mill site in Augusta.
4. Canoe portage route around the Edwards Dam.

Messalonskee Project. The Messalonskee Project is comprised of four small and discrete hydroelectric generating facilities and one storage facility located on Messalonskee Stream in Kennebec County, Maine. The developments that comprise the Messalonskee Project are currently licensed as four separate projects. These projects are: Oakland (includes the Messalonskee Lake Dam and the Oakland Dam), Union Gas, Automatic and Rice Rips. FERC has agreed to consider relicensing of these five developments as a single hydraulically-related project. Messalonskee Stream from the Messalonskee Lake dam to the Kennebec River is an approximately ten mile long tributary which drains an area of 177 square miles at the Messalonskee Lake Dam. Messalonskee Lake Dam is the storage facility, impounds Messalonskee Lake, and is operated to provide water to the downstream generating stations with specific and voluntary restrictions on the amount and timing of drawdown.

The Water Classification of Messalonskee Stream is currently classified as Class C "from the outlet of Messalonskee Lake to its confluence with the Kennebec River." Class C is the 4th highest classification of fresh surface waters. Absent any other statutory provisions, this would mean that the entire length of Messalonskee Stream through the project area is Class C. However, the Rice Rips impoundment (Lake Hutchins - 87 acres) and the Automatic impoundment (67 acres) qualify as "great ponds" and are not specifically classified at Class C but must be considered to be Class GPA waters.

Oakland - FERC # 2559. The Oakland facility is the most upstream of the Messalonskee developments and consists of a 115 foot long concrete gravity dam, intake structure, penstock, powerhouse, one vertical Francis turbine, one vertical Allis-Chalmers generator, tailrace, and appurtenant facilities. It has an installed capacity of 2.8 MW.

Rice Rips - FERC # 2557. The Rice Rips Development receives its inflow from the Oakland Development which is 1.9 miles upstream. The 1.6 MW project consists of a 219' long concrete Ambursen dam, an intake structure, a penstock, surge pond, powerhouse with appurtenances and a tailrace.

Automatic - FERC # 2555. The Automatic facility is located 5.6 miles downstream of the Rice Rips Dam and has an installed capacity of .8 MW. The 80' long concrete gravity dam, powerhouse and appurtenant structures are located in the city of Waterville while the impoundment extends into Oakland.

Union Gas - FERC # 2556. The Union Gas Development is the furthest downstream of the Messalonskee Stream generating facilities and has an installed capacity of 1.5 MW. The dam is located 0.9 mile upstream of the confluence of the Kennebec River and Messalonskee Stream. The development's structures consist of the stone masonry dam 343' in length, adjacent powerhouse, appurtenances and the tailrace.

The applicant proposal for the Messalonskee Project involves no alteration of existing project but initiates and sustains several measures for protecting and enhancing environmental resources including:

• Providing a minimum flow release from the Messalonskee Lake Dam and through the Rice Rips bypass of 15 cfs or inflow, whichever is less, in order to protect and maintain fish resources and aquatic habitat;

• Providing a minimum flow release from the Union Gas Development of 15 cfs or inflow, whichever is less, in order to protect and maintain fish resources and aquatic habitat;

• Investigating the engineering feasibility and potential environmental benefits of reducing the downramping rate at the Union Gas Development (i.e., rate of change from generating to non-generating flows during store and release operations), in order to protect and maintain fish resources;

• Limiting normal water level fluctuations in Messalonskee Lake during daily and seasonal store and release operations to a maximum of 0.5 feet from full pond during the summer months and a maximum of 1.0 foot from full pond during the remainder of the year, in order to protect and enhance fish and wildlife resources, recreational use and wetland values;

• Continuing to maintain stable water levels (within one foot of full pond) under normal run-of-river operations in the Oakland, Rice Rips and Automatic impoundments, in order to protect and maintain fish and wildlife resources;

• Limiting normal water level fluctuations in the Union Gas impoundment during store and release operations to a maximum of 1.3 feet from full pond in order to protect and maintain fish and wildlife resources;

• Continuing to clean Messalonskee Lake fish screen, owned by the Town of Oakland, in order to protect and maintain fish resources;

• Maintaining existing informal day-use access at the Messalonskee Lake Dam and investigating the feasibility of providing new recreational facilities including: improved day use area at Messalonskee Lake Dam, a managed green belt along the east side of Messalonskee Stream from the Oakland Dam to the Rice Rips Dam, improved angler parking along the Rice Rips access road, day use access sites along the Rice Rips impoundment and additional walk-in angler access below the Union Gas Dam. These improvements would be implemented in order to protect and enhance public recreational access and use to the project area.

The State finds that the proposal to relicense the Messalonskee project represents an appropriate balnce of resources and uses and that it conforms with State policy.

Fort Halifax - FERC #2552. Fort Halifax is a 1.5 MW project owned and operated by Central Maine Power Co. (CMP) located in Kennebec County on the Sebasticook River, 1,400 ft. upstream of the confluence with the Kennebec River. The dam and powerhouse are located in the Town of Winslow and the impoundment extends 5.2 miles upstream into the Town of Benton. The impoundment has a surface area of approximately 417 acres at full pond level. The project consists of a concrete Ambursen dam with a maximum height of 29 ft. and powerhouse which houses two generating units rated at 750 KW each. The water quality classification for the Ft. Halifax Dam impoundment and tailrace areas is Class C. CMP is currently proposing to enhance water quality by monitoring dissolved oxygen, and flushing when a level of 5 ppm is reached. The applicant's proposal involves no alteration of existing energy capacity but initiates and sustains several measures for protecting and enhancing environmental resources including:

• Providing a minimum flow release from the project of 150 cfs or inflow, whichever is less, for a period of April through November annually, in order to provide a zone of passage for migrating anadromous fish;

• Limiting normal impoundment fluctuations during daily cycling operations to a maximum of 2.5 feet from full pond (to elevation 49.0 feet MSL), in order to protect fish and wildlife resources in the impoundment;

• Installing permanent downstream and upstream fish passage facilities at the project by December 31, 1993 and May 1, 1999, respectively, in accordance with the Agreement between the State of Maine and the Kennebec Hydro Developers Group (KHDG), in order to restore anadromous fish to the river above the dam;

• Maintaining and improving as necessary existing recreational facilities (a carry-in boat access site on the project impoundment and a downstream fishing access trail) and providing new recreational facilities (a trailored boat launching facility serving the project impoundment and a marked canoe portage trail around the project dam) in order to protect and enhance public recreational access to and use of project waters.

During second stage consultation with the State agencies, points of disagreement between CMP and the agencies were identified. One unresolved area involves minimum flows. Based on the results of the IF&W study, IF&W would prefer a minimum flow release of 400 cfs to provide optimal habitat for both life stages of brown trout, the species of concern for that agency's management program. IF&W concurs with the DMR and the USFWS recommendation for operation of the project in a run of river mode during upstream anadromous migration period (May 1 - June 30). The 400 cfs minimum flow release would apply for the rest of the year when the project was operated in a peaking mode.

DMR recommends adoption of a slightly lower minimum flow of 350 cfs, instantaneous minimum flow or inflow, whichever is less, from mid-July through October.

Weston - FERC #2325. The Weston Project, located on the Kennebec River in Somerset County, Maine, is a run-of-river, 12 MW facility owned and operated by CMP. The project is comprised of a powerhouse containing four generating units, two dams separated by an island, a 930 acre impoundment and appurtenant facilities. The powerhouse and dam are located in Skowhegan, 37.8 miles above the head-of-tide. The applicant is investigating the feasibility of replacing the existing turbine runners with new more efficient ones which would increase the total station hydraulic capacity by about 1,180 cfs and generating capacity by 2 MW. The water quality classification for the Kennebec River from the Route 201A bridge in Anson/Madison to the Skowhegan/Fairfield town line (which includes the entire Weston Project area) is Class B. Class B is the third highest water quality classification. The applicant proposal involves several measures for protecting and enhancing environmental resources including:

- Continuing to operate the project in a run-of-river mode, with minimal impoundment fluctuations under normal operating conditions, in order to protect water quality and fish and wildlife resources in the river above the dam;

- Providing a minimum flow release from the project of 1,947 cfs or inflow, whichever is less, in order to protect water quality and fish and wildlife resources in the river below the dam;

- Installing permanent upstream and downstream fish passage facilities at the project by May 1, 2001, in accordance with the Agreement between the State of Maine and the Kennebec Hydro Developers' Group in order to restore anadromous fish to the river above the dam.

- Maintaining and improving the landscaped area in front of the powerhouse, providing signage regarding the Arnold Trail at the powerhouse and expanding the existing parking area at Oosoola Park in Norridgewock. A proposal to lengthen the existing boat ramp is being investigated and will be implemented if needed. All of these efforts are being made to preserve and enhance recreational opportunities in the project area.

The State finds that the proposal to relicense the Weston project represents an appropriate balnce of resources and uses and that it conforms with State policy.

Wyman Dam - FERC # 2329. The Wyman Project is the second largest hydropower project in Maine with an installed capacity of 72 MW. It is owned and operated by CMP and is an intermediate peaking facility on the Kennebec River in Somerset County in the towns of Moscow, Bingham, and Caratunk and the unorganized territories of concord Township, Pleasant Ridge Plantation and Carrying Place Township. The Wyman Project consists of a powerhouse, a 3,246 foot long dam, a 3,240 acre impoundment and appurtenant facilities. The water quality classification for the main stem of the Kennebec River from the Wyman Dam to Route 201A bridge in Anson and Madison is Class A which necessitates having aquatic life as naturally occurs. The Wyman impoundment is considered a Great Pond and is classified GPA.

The applicant's proposal involves a number of changes in project facilities and operation including:

• Restricting normal impoundment fluctuations to a maximum of 2 feet from full pond in order to protect fish and wildlife resources in Wyman Lake;

• Reserving the right to draw the impoundment down as necessary by up to eight feet during periods of heavy runoff in order to provide some measure of downstream flood control;

• Increasing project minimum flow releases from 490 cfs to 750 cfs in order to protect and enhance fish resources in the Kennebec River below Wyman Dam;

• Limiting the simultaneous shut-down of all three project generating units to cases of emergency in order to protect fish resources in the Kennebec River below Wyman Dam;

• Constructing a canoe portage trail, constructing loon rafts at Caratunk, allowing continued access for fishermen to impoundment and tailwater area, providing parking for ice fishermen and snowmobilers, and assisting with paying the operating costs for the Pleasant Ridge Municipal Recreation Area in order to protect and enhance public recreational use in the area. In connection with relicensing, a number of enhancements have already been implemented including construction of a hard surface boat ramp in Moscow and a day-use area, covered picnic areas, an outhouse and two primitive campsites at Caratunk.

The State finds that the proposal to relicense the Wyman project represents an appropriate balnce of resources and uses and that it conforms with State policy.

Moosehead Lake - FERC #2671. The Moosehead Project is the largest hydro storage project in the state. It provides significant control of the flow on the Kennebec River and serves to regulate the river for the benefit of downstream resources and for 10 downstream hydroelectric projects. The Moosehead Project is owned and operated by KWPC, which in turn is owned by CMP, Edwards Manufacturing Company Inc., Merimil Limited Partnership, Scott Paper Company, and Madison Paper Industries. The project consists of two gated outlet dams (East Outlet and West Outlet), a 74,200 acre impoundment and appurtenant facilities. There are no generating facilities at the project. It is located near Greenville at the head of the Kennebec River in Somerset and Piscataquis Counties, Maine. The water quality classification for the East Outlet is Class A for the first 1,000 feet below the dam and Class AA from this point to the confluence with Indian Pond. Both Class A and AA water shall have aquatic life as naturally occurs.

The applicant's proposal involves no alteration of existing project but initiates and sustains several measures for protecting and enhancing environmental resources including:

• Establishment of a formalized lake level agreement which would include a water level management plan targetting a fall maximum drawdown date of October 10th, with a provision to draw down the lake an additional 2 feet during the winter if necessary. The use of target levels will allow the licensee, in consultation with the resource agencies, to balance the competing interests affected by abnormal water conditions;

• Restricting any drawdowns after the October 10th maximum drawdown to protect fish and wildlife resources with a provision of an additional two feet if required due to abnormal climatic conditions;

• Increasing minimum flow releases from the East Outlet Dam from 200 cfs to 500 cfs, in order to protect and enhance salmon and brook trout habitat;

• Increasing minimum flow releases from the West Outlet Dam from 25 cfs to 80 cfs, with a further increase to a target flow of 120 cfs during the summer recreation season, in order to protect and enhance salmon and brook trout habitat and recreational canoeing;

• Conducting additional field work in the East Outlet to quantify the amount of salmon and trout spawning habitat that remains watered at the proposed 500 cfs minimum flow release, and examining additional enhancement measures in the event that a substantial portion of the available spawning habitat is dewatered at the proposed flow release;

• Managing East Outlet flows to limit weekly flow fluctuations (in accordance with post-1984 project operation), in order to protect fish habitat;

• Maintaining the existing fishway at the East Outlet Dam and operating the gates at the East Outlet Dam to increase the efficiency of the fishway, in accordance with the recommendations of IF&W;

• Maintaining existing fishing and carry-in boat access facilities at the West Outlet Dam, improving existing fishing and carry-in boat access facilities at the East Outlet Dam, and enhancing public recreational use and access in the project area;

• Establishing a telephone service to provide information on actual flows and forecasted flows in the East Outlet, with daily updates, in order to reduce concerns about the unpredictable nature of recreational conditions; and

• Hosting an annual meeting with commercial and private recreation interests to discuss project operations and important recreational concerns.

The State finds that the proposal to relicense the Moosehead Lake project represents an appropriate balance of resources and uses and that it conforms with State policy.

Moxie - FERC #2613. The Moxie Project is a storage project located on Moxie Stream in Somerset County, Maine. The Moxie Project is owned by CMP, Madison Paper Industries, Scott Paper Company, Merimil Limited Partnership, and Edwards Manufacturing Company Inc., and is operated by KWPC; it is comprised of a concrete dam located across the main stream channel, with four small separate closure dams located in the immediate vicinity of the main dam and a 2,231 acre reservoir. The project is operated as a water storage facility to regulate flows to the Kennebec River for downstream hydroelectric generation and flood control. The water quality classification for Moxie Stream is Class A for the first 1,000 feet below Moxie Dam and Class AA from that point to the confluence with the Kennebec River. Both Class A and Class AA shall have aquatic life as naturally occurs.

The applicant's proposal involves no alteration of existing project but initiates and sustains several measures for protecting and enhancing environmental resources including:

- Continuing current spring and summer water level management (reservoir refilled beginning in mid to late March and held to within approximately one foot of full pond level throughout the summer), in order to protect and maintain fish and wildlife resources and recreational uses;

- Restricting annual fall drawdown to a maximum of 3 feet (elevation 967.3 feet prior to November 15) in order to enhance tributary access for spawning salmonids;

- Restricting total annual drawdown to a maximum of 8 feet (elevation 962.3 feet), in order to protect and enhance fish and wildlife resources;

- Restricting flow releases from Moxie Dam during annual fall drawdown to a maximum of 145 cfs plus inflow, whenever possible, in order to reduce scouring and to protect and enhance aquatic habitat in Moxie Stream;

- Providing a minimum flow release from Moxie Dam of 25 cfs or inflow, whichever is less and whenever feasible, in order to protect and enhance fish resources and aquatic habitat in Moxie Stream; and

- Maintaining and improving as necessary existing trailored boat launch, parking and picnic facilities adjacent to the Moxie Dam, in order to protect and enhance recreational use and access in the project area.

The State finds that the proposal to relicense the Moxie project represents an appropriate balnce of resources and uses and that it conforms with State policy.

RESOURCES AND BENEFICIAL USES

HYDROPOWER GENERATION

One of the most important historical uses of the Kennebec River has been the generation of electricity through hydropower facilities. Today, hydropower continues to be a critical use of the river as the flow generates power which is highly reliable, renewable and generally non-polluting. Hydro projects frequently have useful lives of over 50 years and enjoy no fuel costs, and low maintenance and overall operating costs. However, potential negative environmental impacts, including oxygen depletion, impact on fish migration, riverine ecosystem structure and function, and recreational use, can offset the advantages of hydropower.

In the 1970s hydropower supplied 35% of Maine's electric energy needs; increases in demand for electric power supplied from other sources reduced that figure to 23% in 1986, 33% in 1990, and 31% in 1991.[25]

Existing Facilities.

There are 27 Federally licensed generating facilities and storage dams on the Kennebec and its tributaries. These facilities provide 257 MW of generating capacity which represents 36% of the State's hydropower capacity and 9% of the State's total generating capacity. This is roughly the equivalent of the energy needs of 200,000 homes in the State. Three additional dams have been found to be within FERC's jurisdiction and have begun the licensing process. Four dams with generating facilities are licensed only by the State. (See for a full listing and Figure 2).

Ten dams located on the main stem Kennebec have 95 percent of total generating capacity in the basin. All mainstem hydropower dams are run-of-river except Harris (Indian Pond), Wyman and Williams which have storage capacity only for daily or weekly load fitting operations.

There is a total of about 1,300,000 acre-feet of reservoir storage in the Kennebec basin, used for hydropower regulation, with about 86 percent of that storage located in the upper 46 percent of the watershed, upstream of Bingham, Maine. The other 14 percent is generally distributed between the Sebasticook, Messalonskee, and Cobbosseecontee tributary watersheds in the lower part of the basin below Waterville. Available reservoir storage in the upper basin has a marked effect on upper basin flood flow contributions to the Kennebec River. Principal storage reservoirs in the basin above Bingham are listed in . There are 1,132,000 acre-feet of storage in the upper basin and 1,016,500 acre-feet, or 90 percent at the three lakes: Brassua, Moosehead, and Flagstaff.[26]

Industrial use of dammed waters in lower tributaries has declined in recent years and these watersheds are primarily regulated for recreation and water supply.

Available Reservoir Storage, Kennebec River Basin above Bingham, Maine

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[25] *Final Report of the Commission on Comprehensive Energy Planning*. Maine State Planning Office, May 1992.
[26] *Kennebec River Basin Study, Vol. 1*. Army Corps of Engineers.

Project	Drainage area (sq.mi.)	Full Pool Surface area (acres)	Drawdown (feet)	Storage (acre/feet)	Precent
Brassua Lake	710	8,979	30	196,500	17
First Roach Pond	63	3,270	7	21,500	2
Moosehead Lake	1,268	74,000	7.5	544,000	48
Indian Pond (Harris)	1,355	3,747	5	19,000	2
Moxie Pond	80	1,747	8	14,700	2
Flagstaff Lake	520	17,950	35	276,000	24
Wyman Lake	2,595	3,145	20	60,300	5

Three licensed storage projects (Flagstaff, Moosehead, and Moxie) on tributaries of the Kennebec River are operated by the KWPC which is owned by CMP, Edwards Manufacturing Co. Inc., Merimil Limited Partnership, Scott Paper Company and Madison Paper Industries. In conjunction with Brassua Hydro Limited Partnership, KWPC also operates a third project (Brassua) which is a combination generating and storage project, located on a tributary of Moosehead Lake. Regulated flow by KWPC is monitored at Madison.

In addition, KWPC currently operates one unlicensed storage dam (First Roach Pond Dam) located on a tributary of Moosehead Lake. This dam was most likely originally constructed to store water for log driving. This dam appears to be located either on navigable waters or on a non-navigable tributary of a navigable waterway. The State has asked FERC to review the licensing status of First Roach Lake dam, currently unlicensed. Because this dam poses potentially significant hazards to public safety and risks to the environment, the State would like to clarify regulatory authority for managing these risks. Action by FERC on this request is pending.

The Eustis Project and the Pittsfield/Burnham Project owned by Consolidated Hydro, Inc., and the Madison Project owned by Madison Electric Works Department have been found to be within FERC jurisdiction due to navigability; licensing consultation has been initiated.

Figure 2 -- Kennebec River Basin with Hydroelectric Generating Facilities

Note: This map is not available in machine readable form. Please contact the State Planning Office for a paper copy.

Kennebec River Basin
Generating Facilities and Storage Dams

Dam	Installed Capacity (MW)	Location	Exp Date of FERC License	Owner
Benton Falls	4.3	Benton	2/28/2034	Benton Falls Associates
Edwards Dam	3.5	Augusta	12/31/1993	Edwards Manufacturing Co. Inc.
Lockwood Hydro Station	6.5	Waterville	4/30/2004	Kennebec Hydro Resources, Inc.
Hydro Kennebec	17.5	Waterville	9/30/2036	Scott Paper Company
Shawmut	8.6	Benton	1/31/2021	Central Maine Power Company
Weston Dam	12	Skowhegan	12/31/1993	Central Maine Power Company
Abenaki Dam	16.98	Madison	4/30/2004	Madison Paper Industries
Anson Dam	9	Anson	4/30/2004	Madison Paper Industries
Williams Station	14.5	Embden	12/31/2017	Central Maine Power Company
Wyman Hydro Station	72	Moscow	12/31/1993	Central Maine Power Company
Harris Dam	76.6	Indian Stre	12/31/2001	Central Maine Power Company
East Outlet Dam[1]		Big Squaw Twp	12/31/1993	Kennebec Water Power Co.
West Outlet Dam[1]		Taunton & R	12/31/1993	Kennebec Water Power Co.
American Tissue Dam	0.9	Gardiner	4/30/2019	Consolidated Hydro Maine, Inc.
New Mills	0.12	Gardiner		Gardiner Water District
Union Gas Dam Messalonskee	1.5	Waterville	12/31/1993	Central Maine Power Company
Automatic Dam Messalonskee	0.8	Waterville	12/31/1993	Central Maine Power Company
Rice Rips Dam Messalonskee	1.6	Oakland	12/31/1993	Central Maine Power Company
Oakland Dam Messalonskee	2.8	Oakland	12/31/1993	Central Maine Power Company
Fort Halifax	1.5	Winslow	12/31/1993	Central Maine Power Company
Pittsfield/Burnham	1.05	Burnham	pending	Consolidated Hydro Maine, Inc.
Pioneer Dam	0.3	Pittsfield		Town of Pittsfield
Waverly Dam (Upper Dam)	0.7	Pittsfield		Town of Pittsfield
Lombard	0.06	Vassalboro	-----	Eugene Roderick
Morneau's	0.03	East Vassalboro	-----	Paul J. Morneau
Sevey	0.01	Ripley	-----	Ernest Sevey
Madison	0.3	Norridgewock	pending	Madison Electric Works Dept.
Gilman Stream	0.1	New Portland	-----	North New Portland Energy Co.
Eustis	0.25	Eustis	pending	Consolidated Hydro Maine, Inc.
Moxie Dam[1]		East Moxie	12/31/1993	Owners of Moxie Dam
Crocker Pond Dam[2]		Dennistown Plt.	inactive	Birch Island Realty Trust, Inc.
Starks[3]	0.05	Starks		Mark Vaughn
Flagstaff[1]		T3 R4	12/31/1997	Central Maine Power Company
Brassua	3.4	Rockwood Twp	3/31/2012	Owners of Brassua Dam/ Brassua Hydro Ltd. Partners
First Roach Dam[1]		Frenchtown Twp		Kennebec Water Power Co.
TOTAL	**257.MW**			

[1] storage dams
[2] a generating facility has been approved for this dam but has not yet been constructed
[3] this is a generating facility but has no dam

Hydropower Potential.

The hydropower potential of the Kennebec River has been examined using a method supplied by Central Maine Power[27] which compares developed head to total available head.

The developed head of the Kennebec River is calculated as follows:

Developed Head of the Kennebec River

Project	**Gross Head (in feet)**
Moosehead	7
Harris	149
Wyman	141.5
Williams	45
Madison	67
Weston	34
Shawmut	24.5
Kennebec Hydro	27
Lockwood	18.5
Edwards	19
Total Developed Head	532.5 feet

The total available head on the Kennebec River is 1,029 feet, the drop in elevation from Moosehead to Tidewater. Therefore, the proportion of the available head that has been developed can be calculated as follows:

$$\% \text{ Developed} = \frac{\text{Total Developed Head}}{\text{Total Available Head}} = \frac{532.5}{1{,}029} * 100 = 51.7\%$$

A large proportion of the remaining 496.5 feet of available head has been protected from hydropower development.

Recommendations.

[27] Letter from Central Maine Power to the State Planning Office dated September 29, 1992.

As noted throughout this report, the Kennebec River serves multiple purposes and is utilized by citizens of our State in a wide variety of ways. One of the most important uses of the river is the generation of electricity through hydropower facilities. We are now utilizing an estimated 52% of the total hydropower potential of the Kennebec, beyond the utilization rate for any other use. As a general premise, it is assumed that the dams in the Kennebec River basin will continue to play a significant role in supplying a predictable quantity of energy at a predictable price to the State's energy consumers; however, each license to be renewed must be assessed on a case-by-case basis.

After careful analysis of balances of uses and resources, the State finds that appropriate actions have been taken or have been proposed to be taken by the hydrodevelopers to achieve an appropriate balance at eight of the ten Kennebec Basin dams whose licenses expired in 1993.

At Fort Halifax, State and federal agencies recommend operation of the project in run of river mode during upstream anadromous migration (May 1 - June 30) and minimum flows of 350 -400 cfs during the rest of the year.

Analysis of Edwards Dam has resulted in a recommendation by the State that removal conditions be established during relicensing. Edwards Dam is unique among the Kennebec Basin's hydro facilities in terms of the potential benefit to be gained by its removal. It is located at head-of-tide on the Kennebec River which potentially provides the most significant anadromous fish habitat in the State.

In addition, removal of Edwards would actually reduce electric rates because power is currently purchased from the owners of Edwards at approximately 3 times the cost of replacement power. In present value terms, it will cost Maine ratepayers approximately $6.3 million if the Edwards Dam is relicensed and is permitted to operate from 1994 through 1998. The benefits of dam removal in the form of improved water quality, restored anadromous fisheries and increased recreational opportunities, and economic benefits derived from these beneficial uses outweigh the loss of 0.13% of the State's generating capacity (0.4% if the proposed expansion is considered), especially given the extraordinarily high cost of that capacity through 1998.

The removal of the existing Edwards hydroelectric dam is not recommended lightly. It is recognized that removal of any hydroelectric facility has costs as well as benefits, both of which can only be estimated. It further is recognized that dam removal is an extraordinary resource management tool that should be employed only in unusual situations. The balancing of the costs and benefits of all uses of the Kennebec River resource weighs strongly in favor of removing Edwards Dam for the reasons discussed at length in this Management Plan and in the referenced documents.

The recommendation for removal of the Edwards Dam does not represent either a sudden or a dramatic shift in State policy and should certainly not be interpreted as a precedent for management of other state water resources. As explained throughout this Management Plan, the Kennebec River is an unusual resource. Improving, developing, and conserving that resource calls for an unusual management tool. Readers should not interpret this recommendation as an invitation to seek wholesale removal of the State's hydroelectric dams.

FLOWS

Reservoir Levels and Flow Regime.

Reservoir levels and flow regimes on the upper river are managed by the KWPC. The following summary of flow management strategy for the upper river has been provided by KWPC:

Upper river management focuses on the governing of water contained in storages; regulating storage outflow to ensure a year-round availability of water for power generation and other uses, and providing an added benefit of flood control, by storing run-off in the spring and, when possible, during periods of excessive precipitation, consistent with a Charter by the Maine Legislature granted in 1893.

Operation of the Kennebec Storage reservoir system and management of flows on the Kennebec River consider the following objectives:

a. Establish a more uniform year-round flow than is possible on an unregulated system;

b. Maximize benefit for power production for industrial and private consumption, while providing for other multiple uses;

c. Reduce impacts of flooding.

Some of the multiple uses include, but are not limited, to the following:

• *Hydroelectric Power Generation.* Ten generating stations currently are in operation on the Kennebec River, with nearly 220 megawatts of installed capacity for industrial and private sector needs.

• *Recreation.* A variety of recreational opportunities and uses currently exist on the Kennebec River and in the area of each storage project. It appears that the dominant forms of recreation are fishing and boating. However, a variety of other uses occurs within the basin, including whitewater boating and rafting, both seasonal and year-round residents along various shorelines, and recreation related businesses (fishing guides, sporting camps, campgrounds, boat rentals, etc.).

• *Fisheries and Wildlife.* River Flows are maintained as well as water levels of impoundments to enhance fish and wildlife habitat preservation.

• *Industrial Requirements.* Provide process water for a variety of industrial operations.

• *Municipal Requirements.* Provide enhanced flows during normally low flow periods to increase assimilation capacity and protect water quality.

Numerous conditions and requirements must be complied with which recognize various uses of the water resource. Included in the constraints are the following:

• *FERC, LURC/DEP Project License Conditions.* Minimum flow releases, ramping rates for flow releases, reservoir level management, among others.

• *Fish Habitat Enhancement.* Reservoir level control during the lake trout (togue) spawning and incubation period, as well as complying with certain conditions developed by IF&W.

• *Reservoir Level Control.* Consideration of recreational uses during the prime summer vacation season at all reservoirs. Regulating levels of storage to provide beneficial capacity to hold the spring rains and snowmelt.

• *Minimum Flow to Kennebec River.* Provide adequate river flows to enable necessary assimilation of effluent streams from the numerous municipal and industrial waste treatment facilities along the Kennebec River.

Additional fish habitat considerations include reservoir level control to improve or maintain access into tributaries for salmon and/or trout spawning and management of minimum flows and flow fluctuations.

Water Management Regime.

The amount and time of occurrence of fluctuations in water levels and flows, which occur as a result of the needs of hydrogenerating facilities and flood control, are important to various wildlife and fish species. Waterfowl benefit from stable water levels for nesting and brood rearing. Furbearers can be flooded out if water levels are raised after they go into winter quarters, or stranded if areas are dewatered after they become established for the winter. Drawdowns in early spring could prevent smelt from reaching spawning areas in lake tributaries. Lake trout (togue) eggs could be exposed and frozen by winter drawdowns. Bass spawn along shallow shorelines in late spring and early summer. Drawdowns during this period can destroy nests. Anadromous (alewife, Atlantic salmon, shad, smelt) and catadromous (eels) fish need good stream flows to migrate to spawning areas. Trout and salmon resident in streams often must move to particular areas to spawn successfully. Adequate year-round minimum stream flows are critical to the survival of stream-dwelling fish species (especially salmon, brook trout), as well as to the production of all aquatic life required to support these fish.

Where significant waterfowl, loon, or other shorebird nesting habitat may be affected by project-induced impoundment fluctuations, IF&W generally recommends no greater than one foot surface elevation change during the period from ice-out to July 15. Greater fluctuations as a result of natural, unregulated causes are acknowledged to occur at some projects. Impoundments containing significant bass populations dependent upon natural spawning will also be subject to recommendations for restricting the degree of fluctuations to one foot during the period May through July 1, or for the same period as for waterfowl if both are of concern.

Impoundment drawdown regulation is also recommended for the protection and success of fall spawning lake trout populations. Water elevations adequate to cover identified spawning areas are to be established and specified. Drawdown to this level should occur prior to October 1 in northern portions of the State and October 15 in southern areas. During the overwinter period (November 15 to May 1) the impoundment level may be allowed to rise and fall provided it does not drop below the elevation occurring during the October/November spawning period.

Aquatic furbearer populations can be protected by regulating impoundment fluctuations to no greater than one foot surface elevation change during the period October 15 through ice-out in the spring.

Impoundments used primarily for annual storage and release present special problems for maintenance of fish and wildlife resources due to the degree and timing of fluctuations. Specific recommendations require a detailed description of the hydraulic cycle, species present, and habitat affected.[28]

In all cases, management of water levels for protection of fish and wildlife must be balanced against the need to protect lives and property against the threat of flooding, particularly during the period March 15th to May 15th.

Flood Damage Reduction.

The Kennebec River is subject to frequent and major flooding. In the past decade, there have been four significant floods on the river, usually occurring in the spring when heavy rains and snowmelt combine to cause flooding conditions. In April 1987, Kennebec River flooding caused more than $22 million in damages.[29]

After the April 1987 flood, additional stream gages were recommended. However, budget constraints have prevented installation of additional gages.

Following the 1987 flood, the Army Corps of Engineers conducted a reconnaissance study of flood damage reduction alternatives in the Kennebec River Basin. Work entailed data collection and delineation of damage areas based on information received from local officials from 14 communities hit hardest by the flood. Analysis of two flood control reservoir alternatives, requested by State officials, found them to be impractical. Design and cost estimates of structural alternatives for the individual communities revealed they were also not economically justified. It is likely, with further study, that cost efficient nonstructural flood damage reduction measures would be formulated for Waterville, Winslow, Augusta, Hallowell, Randolph, Gardiner, Farmington, Madison, and Pittsfield. A basin-wide automated flood warning system and reservoir regulation were also found to be cost efficient.[30]

All but two of the communities on the Kennebec River participate in the National Flood Insurance Program (NFIP). This national program provides a non-structural approach to flood damage reduction by mandating that all new construction in the floodplain meet certain minimum development standards such as elevating above the 100-year flood elevation.

Federal Emergency Management Agency (FEMA) has invested tens of thousands of dollars in detailed flood insurance studies identifying the 100 year flood boundaries along the Kennebec. If these floodplain boundaries are significantly altered by structural modifications, the cost of new studies should be borne by those creating the alteration.

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[28] *Administrative Policy Regarding Hydropower Projects*. Maine Department of Inland Fisheries and Wildlife, December 1987.
[29] *Maine Water Resources Development*. U.S. Army Corps of Engineers, 1991.
[30] *Water Resources Study: Kennebec River Basin, Maine*. U.S. Army Corps of Engineers, February 1990.

The Land and Water Resources Council, a cabinet level affiliation of the State's natural resource agencies, promotes informed and cooperative flood damage reduction through its standing committee, the River Flow Advisory Committee. Comprised of federal, state and private river basin managers, the River Flow Advisory Committee meets annually to review snowpack and stream gage data, assess potential spring runoff, and review various river management issues.

In an effort to promote flood preparedness, SPO has required applicants involved in the relicensing process to identify precautions and management procedures in the event of a 50-100 year flood. SPO has requested applicants to produce an operational procedure for the project in the event of severe flood conditions if one has not already been established. The procedure is required to include at a minimum information on spillway capacity, plans for flashboard failures, gate settings for various conditions, high water guidelines and delegation of authority to essential personnel.

Recommendations.

Flow management, reservoir levels, ramping and flood control are managed by the private sector according to FERC regulations which govern generating facilities and storage dams. FERC relicensing regulations require an extensive consultation process with appropriate State and Federal resource agencies. State agencies, including SPO, the Department of Economic and Community Development (DECD), and the Maine Emergency Management Agency (MEMA) in particular, should identify which issues, procedures and standards relating to flow management should be addressed in the consultation process. Augmentation of the existing system of stream gages and implementation of a basin-wide automated flood warning system should be a top priority.

WATER QUALITY

The current water quality condition of the Kennebec River basin is presented in the *State of Maine 1992 Water Quality Assessment*.[31] Most of the Kennebec basin achieves its assigned classification except the following segments:

- Carabassett River and certain tributaries - bacterial contamination
- Certain tributaries of the Sandy River - nonpoint sources
- One tributary to Wilson Stream - dissolved oxygen
- Messalonskee Stream - dissolved oxygen and bacteria
- Certain tributaries to the Sebasticook River - nonpoint sources
- West Branch Sebasticook River - dioxin and chromium
- Certain tributaries to the Kennebec River - combined sewer overflows and nonpoint sources
- Certain tributaries to Cobbossee Stream - nonpoint sources
- Kennebec River below Wyman Dam - flow modification
- Kennebec River, Fairfield to Sidney - dissolved oxygen and dioxin
- Kennebec River below Sidney - dioxin and bacteria

Preliminary information for water quality certification of the Fort Halifax project indicates that there may be portions of that impoundment that do not meet the dissolved oxygen standards, requiring possible modification of that project.

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[31] *State of Maine 1992 Water Quality Assessment*. Maine Department of Environmental Protection, 1990.

In 1990, legislation was submitted to improve the fishery resources of the Kennebec River. This legislation provided for the State to purchase and subsequently remove the Edwards Dam. Consideration was given to any water quality problems which might be associated with such a plan and a report was prepared by DEP.[32] [33] That study found that there would be significant water quality benefits to be derived from the dam's removal. These included an expected increase in the dissolved oxygen level of the water and a more abundant and diverse aquatic community. Concern was expressed for the possibility that contaminated sediments might be mobilized if the dam were removed. Sampling of the impoundment in preparation for that report, and as followup to that study, found that the substrate throughout the impoundment is predominantly coarse sand, gravel, and cobble which is essentially free of any detectable contamination, and therefore, poses no threat if the dam were removed.

Recommendations.

On Messalonskee Stream, the water quality effects from a municipal treatment facility in Oakland and a combined sewer overflow in Waterville are elevated due to the impoundments downstream of the discharges and due to flow regulation in the upper Belgrade Lakes. Changes in the amount of treatment provided, location of discharge points and flow management will be required to bring this stream into compliance with the standards for Class C.

The Sebasticook River is eutrophic primarily from nonpoint source nutrient contamination but also from several municipal treatment facilities which discharge in the watershed. Increased residence time of the watershed allows for increased algae growth leading to low dissolved oxygen in the impoundments. Several projects are presently ongoing in the watershed to reduce nutrient loading. Changes may also be required in flow management of the impoundments to dissipate algae growth.

The DEP may assess the need to seek modifications of the operation of the Wyman project to bring aquatic life conditions below that dam into compliance with water quality standards. In addition, DEP may assess the need to seek modifications of licensed discharges in Fairfield and downstream and/or modification of the operation of Edwards Dam to bring this segment into compliance with water quality standards.

FISHERIES

Anadromous Fisheries.

The Maine Rivers Study identified the Kennebec River as of highest significance regarding anadromous fisheries due to its high habitat quality and quantity, species diversity and abundance, presence of endangered species, and high recreational importance.

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[32] *State of Maine 1990 Water Quality Assessment.* Maine Department of Environmental Protection, 1990.
[33] *Expected Water Quality Changes from Removal of the Edwards Dam, Augusta.* Maine Department of Environmental Protection, 16 February 1990 and addendum 23 February 1990.

The Kennebec's estuarial complex hosts a very diverse assemblage of finfish species. The upper estuary, including the Androscoggin River, Merrymeeting Bay, and its tributaries, is essentially tidal freshwater habitat. This section contains most of the finfish species commonly found in inland freshwater systems. It is an important spawning and nursery habitat for many anadromous species, such as American shad, rainbow smelt, alewife, shortnose and Atlantic sturgeon, and striped bass.

A few marine species -- such as bluefish and menhaden -- also enter Merrymeeting Bay occasionally.

The mid-Kennebec River estuary from Chops Point at the outlet of Merrymeeting Bay to Doubling Point just below Bath is an area of transition. The salinities vary both seasonally and over a tidal cycle. During spring freshets this section is entirely freshwater, but during summer low flows salinities can reach 18 ppt at Doubling Point. Freshwater, marine, and anadromous fish species can be found in this section of the river, with the marine species being found mainly in the summer months.

The lower Kennebec River from Doubling Point to Bay Point is highly saline. Mostly marine and anadromous species are found in this section. Some seasonal migrants such as menhaden and bluefish are very abundant in the lower Kennebec River during August and September. Large fish kills of menhaden and bluefish occurred in 1984 and 1985 in the mid- and lower Kennebec River due to the inability of the river system to meet the respiratory demands of the large schools of menhaden. Although this section is highly saline, many freshwater species have been captured in this section. A list of marine finfish species which have been captured in the adjacent Sheepscot River estuary, and which probably occur in the lower Kennebec as well, are listed in[34].

In its natural state, the Kennebec was tidal at least above Augusta; ecologically, the river from Merrymeeting Bay to Waterville can be considered an extension of the bay. The stretch of river between Augusta and Waterville was major spawning habitat, the juveniles there using the stretch below the dam and into the bay as nursery habitat.

Anadromous fish runs constitute a valuable renewable fishery resource of great importance to the coastal fishing industry. In the Kennebec River below the Augusta dam alewives, Atlantic salmon, rainbow smelt and striped bass support significant recreational and/or commercial fisheries. American shad and alewives are of particular importance as existing and potential food and bait fish resources. Self-sustaining shad and alewife runs co-exist with cold and warm water fisheries on numerous Maine river segments. American shad in southern New England are highly sought after as a food fish and as a sport fish. With proper protection and management, this species can make a major contribution to the commercial and recreational fishery of the coast. The alewife is a particularly important commercial fishery resource that is extensively used as bait by the Maine lobster fishery. In addition to commercial and recreational values of anadromous fish, adult alewives and juvenile shad/alewives provide a significant forage feed for freshwater and marine sportfish and as food for avian predators, such as bald eagles, ospreys, kingfishers, cormorants and herons.

[34] *Maine Yankee Atomic Power Company Environmental Surveillance Reports, 1970-1976.* Maine Yankee Atomic Power Company, Augusta, Maine.

The principal fisheries for anadromous species occur in the home rivers as the adults return from sea to spawn in fresh water. Most of the harvesting gear used in these fisheries is stationery gear and the homing characteristic of the species makes them readily available to coastal fishermen.

The development of hydroelectric generating plants can have adverse impacts on existing and potential anadromous fish runs unless adequate fish passage facilities are incorporated into the projects.

Anadromous Fisheries Goals and Objectives

The State's goals and objectives related to anadromous fish resources, as stated in the *State of Maine Statewide River Fisheries Management Plan, June 1982*, are as follows:

Goals:

* To restore, maintain, and enhance anadromous fish resources for the benefit of the people of Maine.

Species not Found in DMR Surveys but Found in nearby Sheepscot River and Suspected to be Found in the Lower Kennebec River[36]

[35] *Maine Yankee Atomic Power Company Environmental Surveillance Reports, 1970-1976.* Maine Yankee Atomic Power Company, Augusta, Maine.

Common Name	Scientific Name
Spiney dogfish	*Squalus acanthias*
Little skate	*Raja erinacea*
Winter skate	*Raja ocellata*
Thorney skate	*Raja radiata*
Capelin	*Mallotus villosus*
Goosefish	*Lophius americanus*
Red hake	*Urophycis chuss*
White hake	*Urophycis tenuis*
Ocean pout	*Macrozoarces americanus*
Blackspotted sticleback	*Gasterosteus wheatlandi*
Cunner	*Tautogolabrus adspersus*
Rock gunnel	*Pholis gunnellus*
Wrymouth	*Cryptacanthodes maculatus*
Butterfish	*Peprilus triacanthus*
Ocean perch (redfish)	*Sebastes marinus*
Northern searobin	*Prionotus carolinus*
Sea raven	*Hemitripterus americanux*
Grubby	*Myoxocephalus aenaeus*
Longhorn sculpin	*Myoxocephalus octodecemspinosus*
Shorthorn sculpin	*Myoxocephalus scorpius*
Alligatorfish	*Aspidophoroides monopterygius*
Windowpane	*Scophthalmus aquosus*
American plaice	*Hippoglossoides platessoides*

* To provide increased employment through expansion of commercial and recreational fisheries for anadromous fish resources.

Objectives:

* To determine the current status of anadromous fish stocks and their potential for expansion.

* To identify, maintain, and enhance anadromous fish habitat essential to the viability of the resource.

* To provide, maintain, and enhance access of anadromous fish to and from suitable spawning areas.

* To provide technical assistance to resource users.

* To promote multiple use management of the river fisheries of Maine.

With respect to the Kennebec River, it is the State's goal to restore all anadromous fish (except for lamprey eels) to their historical range. Striped bass, rainbow smelt, Atlantic and shortnose sturgeon historically migrated to Ticonic Falls in Waterville. These species do not use fishways and the quantity and quality of the spawning and nursery habitat between the Edwards Dam and Ticonic Falls has been severely reduced by the impoundment created by Edwards Dam. Restoration of striped bass, rainbow smelt, Atlantic and shortnose sturgeon to their historical range will require removal of the Edwards Dam.

The goal of anadromous fish restoration in the Kennebec River is:

To restore striped bass, rainbow smelt, Atlantic sturgeon, shortnose sturgeon, American shad, and alewives to their historical range in the mainstem of the Kennebec River.

A goal for American shad and alewives for the Kennebec River above Augusta has been previously established and will remain the same (see page).

The following objectives addressing this goal have been developed.

I. To restore a native striped bass population to the Kennebec River including the segment from the Edwards Dam to the Milstar Dam in Waterville.

II. To restore and enhance rainbow smelt populations in the Kennebec River including the segment from Edwards Dam to the Milstar Dam in Waterville.

III. To restore and enhance Atlantic sturgeon populations in the Kennebec River including the segment from Edwards Dam to the Milstar Dam in Waterville.

IV. To restore and enhance shortnose sturgeon populations in the Kennebec River including the segment from Edwards Dam to the Milstar Dam in Waterville.

V. To restore and enhance American shad populations in the Kennebec River. This objective includes the already established and approved objective of achieving an annual production of 725,000 shad above Augusta.

VI. To restore and enhance alewife populations in the Kennebec River. This objective includes the already established and approved objective of achieving an annual production of 6.0 million alewives above Augusta.

The strategy developed to meet these objectives is outlined as follows by species:

I. Striped Bass-An active restoration program which includes an ongoing stocking program of fall fingerling striped bass will continue through 1997 if fry remain available. Expand the available spawning habitat available in the mainstem of the Kennebec River by seeking removal of the Edwards Dam in Augusta.

II. Seek removal of the Edwards Dam to allow rainbow smelt access to spawning habitat now inundated by the dam.

III. Seek removal of the Edwards Dam to allow access of Atlantic sturgeon to their historical range. Investigate the feasibility of accelerating restoration of Atlantic sturgeon by culture methods.

IV. Seek removal of the Edwards Dam to allow shortnose sturgeon to have access to spawning habitat above Augusta.

V. Reduce the cumulative impacts of dams on the shad restoration program by seeking removal of the Edwards Dam. Investigate the feasibility of accelerating the restoration program through fish culture. Take management action to reduce and/or maintain low levels of fishing mortality during the restoration mode.

VI. Reduce the cumulative impacts of dams on the alewife restoration program by seeking removal of the Edwards Dam.

Shad, Alewife and Atlantic Salmon Restoration Plans

Shad and alewives. The goal of the Strategic Plan and Operational Plan for the Restoration of Shad and Alewives to the Kennebec River above Augusta is:

"to restore the alewife and shad resources to their historical range in the Kennebec River System."

The following objectives addressing this goal have been developed. They are:

I. To achieve an annual production of 6.0 million alewives above Augusta.

II. To achieve an annual production of 725,000 shad above Augusta.

These objectives are based on the projected potential of the Kennebec River from Augusta to the lower dam in Madison including the Sebasticook River, Sandy River, Seven Mile Stream, and Wesserunsett Stream.

The strategy developed to meet these objectives involves restoration planned in two phases. They are:

Phase I *(January 1, 1986 through December 31, 1998)* -- Require removal of the Edwards Dam (FERC #2389). Restoration of alewives will be initiated to selected lakes and ponds in the Seven Mile Stream, Sebasticook River, and Wesserunsett Stream drainages. During Phase I, restoration of alewives will be accomplished by trap and truck.

Originally, the Edwards Dam was chosen to be the primary site for capture of broodstock for this restoration program. However, this dam's owners chose not to participate in the program supported by owners of the remaining dams above the head of tide, who cooperate as the Kennebec Hydro Developers Group (KHDG). No facilities were available at Edwards in 1987 and 1988. An experimental fish pump installed in 1988 proved ineffective in capturing sufficient numbers of alewives for restocking. Since 1987, broodstock have been collected on the Androscoggin River from the Brunswick Dam fish passage facility owned by CMP and operated by DMR. American Shad have been obtained from the Connecticut and Merrimack Rivers in Massachusetts and the Narraguagus River in Maine.

Phase I of the plan includes alewife stocking of those lakes which have been mutually agreed upon by DMR and IF&W. The stocking rate for these Phase I lakes is six (6) adult alewives per surface acre of lake habitat. This amounted to 11 of the 21 lakes. DEP has requested that stocking of the 3 ponds in the Seven-Mile Stream drainage system be deferred in order for them to establish a longterm water quality data base for these environmentally stressed systems. This results in a total stocking requirement for the remaining 8 lakes of 57,750 adult alewives.

The objective for shad during Phase I is to pass 2,500+ adults per year at the Edwards Dam with restoration to be initiated to the river segment between Augusta and the Lockwood Dam. Nonexistent or ineffective fish passage at Edwards Dam since 1987 has required that shad be obtained from other sources; however, the numbers stocked have not approached the goal of 2,500 fish. Therefore, unless new sources become available, the goal for American shad is to stock 1,000 fish annually.

Phase II *(Starting in 1999)* -- Fish passage will be required at all mainstem dams on the Kennebec River up to the Abenaki Dam (FERC #2364) in Madison, on the mainstem dams on the Sebasticook River up to the confluence of the east and west branches, and at the Madison Electric Works Dam on the Sandy River. Passage will be required at one year intervals proceeding upstream with the exceptions that passage will be required concurrently at the Lockwood Dam (FERC #2574), Winslow Dam (FERC #2322), Fort Halifax Dam (FERC #2552), and the Benton Falls Project (FERC #5073). The required fish passage in these dams is mainly for the benefit of American shad and Atlantic salmon.

The feasibility of truck stocking alewives as a substitute for fish passage facilities will be evaluated during Phase I. It may be decided to continue the truck stocking of alewives during Phase II.

The introduction of alewives into the following lakes during Phase II is dependent on the outcome of a joint study by the DMR and IF&W: Great Moose Lake, Spectacle Pond, China Lake, Big Indian Pond, Little Indian Pond, Wassokeag Lake, Clearwater Pond, and Norcross Pond. This study is for the purpose of assessing the interactions of alewives with smelts and salmonids. Based upon the results of these studies, a cooperative decision will be made regarding future alewife introductions into the above listed waters.[36]

[36] Based on *Strategic Plan and Operational Plan for the Restoration of Shad and Alewives to the Kennebec River above Augusta*, DMR, 1986, and *Statewide Fisheries Management Plan*, June 1982; and *Lower Kennebec River Anadromous*

Atlantic Salmon. The ASRSC has had a legislative mandate to restore and manage Atlantic salmon populations to Maine's rivers for nearly 45 years. The Commission's Statewide Strategic Management Plan for Atlantic Salmon in Maine (1984) targets the Kennebec River (and other Group "C" rivers) for Atlantic salmon restoration when resources for that project can be made available for the Kennebec without detracting from existing management and restoration programs (the Group "A" and Group "B" rivers), as outlined in that document.

The interim plan for Atlantic salmon is to move whatever salmon become available at the Edwards Dam upriver.

Self-sustaining Atlantic salmon populations co-exist with other coldwater and warmwater fisheries on several Maine river systems. It is the ASRSC's belief that an Atlantic salmon population and fishery can exist in the Kennebec watershed without jeopardizing existing fisheries.

Achieving the ASRSC's long-term restoration goal for the Kennebec River is dependent upon the availability of adequate fish passage facilities at all Kennebec River dams. As the first obstacle encountered by anadromous fish upon their return to the river, fish passage at the Augusta dam or dam removal is critical to future salmon restoration efforts on the Kennebec River. Although a minor amount of salmon nursery area exists between Augusta and Waterville in tributaries, most of the salmon rearing area in the Kennebec lies upstream from other impassable dams.

Significant numbers of suitable hatchery reared-stocks are currently available from the aquaculture industry and from the captive broodstock program at Green Lake National Fish Hatchery for a Kennebec River Atlantic salmon restoration program. Stocking has not occurred to date because the Commission felt that stocking of upriver areas in the Kennebec should coincide with a commitment to fish passage at the Augusta dam and the Commission did not have adequate staffing to oversee and coordinate an active restoration program on the Kennebec. Assurance of fish passage or dam removal at the Edwards Dam will most likely result in implementation of a more active program on the Kennebec.

Interim Atlantic salmon passage on the Kennebec River is needed until such time as significant numbers of hatchery salmon are committed to the Kennebec salmon restoration and a long-term fish passage program is adopted. An interim passage program for upstream fish passage will involve trapping at Augusta and transport of salmon to selected upstream areas, in a manner that makes use of their reproductive potential. Long-term fish passage needs involve upstream and downstream fish passage facilities at dams above Augusta.

All anadromous fish species found in Maine have reproducing populations in the Kennebec River. These species are listed in with a brief summary of their life histories. Detailed life histories of the alewife, shad, rainbow smelt, Atlantic sturgeon, Shortnosed sturgeon, and striped bass are described below.[37]

Life Histories

Fish Restoration Plan and *Inland Fisheries Management Overview*, 1986.

[37] *Anadromous Fisheries in the Kennebec River Estuary*, Squiers, T.S., Maine Department of Marine Resources, 1988.

Alewife. The anadromous alewife, *Alosa pseudoharengus*, is one of the most abundant of the ten anadromous fish species native to the State of Maine. In recent years, this species has become Maine's most valuable commercial anadromous fishery resource. The 1975 landings of 3,407,110 pounds represented a record value of $127,573 for this species. Because of its value as lobster bait and the great potential for development of this resource, increased emphasis has been directed toward rehabilitation of runs in watersheds which historically supported large populations of the alewife. Results of recent surveys suggest that Maine rivers have the capability to support an alewife harvest of 3θ50 million pounds annually.

The alewife, a member of the herring family (*Clupeidae*), is easily distinguished by its silvery sides, deep body flattened sidewise, and deeply forked tail. It has large, smooth scales which are easily lost when the fish is handled. The species is differentiated from the true sea herring by its sharp, saw-toothed scales along the midline of the belly and the fact that the dorsal fin originates just forward of the midpoint of the back. The sea herring, by comparison, has weakly saw-toothed scales along the midline of the belly and the dorsal fin originates to the rear of the midpoint of the back. In body form, the alewife is generally one-third as deep as it is long, while the sea herring is about one-fourth as deep as long. Alewives on the spawning run average 11-12" in length and are slightly over 1/2 pound in weight.

The geographical range of the alewife is the Atlantic coast from Newfoundland and the Gulf of St. Lawrence to North Carolina. Landlocked populations of the alewife occur in the Great Lakes and in certain lakes of New York State. Historically, the sea-run alewife probably occurred in every stream of Maine where access was available to lakes, ponds, and river dead water areas. Commercially exploitable runs occurred in the St. Croix, Pennamaquan, Dennys,

Table 13
Generalized Life History Summary of Anadromous Fish Species in Maine

Species	Age at 1st Maturity	Adult Weight (Range in lbs.)	Time in Fresh Water	Time in Ocean (Estuary)	Time in Adult Migration	Spawning Time	Egg Incubation	Downstream Migration (Juvenile)
Rainbow Smelt* (*Osmerus mordax*)	2-3 years	0.1-1.0	15-30 days	1.5-3 years	Dec - May	Apr - May	8-14 days	May - Jul
Atlantic Salmon (*Salmo salar*)	2-6 years	2-40	1-3 years	1-3 years	Apr - Nov	Oct - Nov	150 days	May - Jun
American Shad (*Alosa sapidissima*)	3-6 years	1.5-12	6 months	2.5-5.5 years	May - Jun	Jun - Jul	6-15 days	Jul - Dec
Alewife (*Alosa pseudoharengus*)	3-5 years	0.4-1.8	6 months	2.5-4.5 years	May - Jun	May - Jun	6-10 days	Jul - Dec
Blueback Herring (*Alosa aestivalis*)	3-4 years	0.3-1.4	1-6 months	2.5-3.5 years	Jun - Jul	July	2-5 days	Aug - Dec
Sea Lamprey (*Petromyzon marinus*)	5-7 years	1.0-2.5	3-4 years	2-3 years	May - Jun	June	---	Aug - Dec
Striped Bass* (*Morone saxatilis*)	2-6 years	1.5-70	1-2 years	1-4 years	May - Jul	Jun - Jul	1-3 days	Jun - Dec
Atlantic Sturgeon* (*Acipenser oxyrhynchus*)	12-20 years	25-200	3-8 years	4-20 years	Dec - Jul	July	3-7 days	Aug - Nov
Shortnose Sturgeon* (*Acipenser brevirostrum*)	8-12 years	2.5-25	3-40 years	1-5 years	Oct - Apr	Apr - May	13 days	Aug - Nov

*do not use fishways

Orange, East Machias, Narraguagus, Tunk, Union, Orland, Penobscot, Ducktrap, Megunticook, St. George, Medomak, Sheepscot, Kennebec, Androscoggin, Presumpscot, Saco, Kennebunk, Mousam, York, and Salmon Falls Rivers. The Damariscotta River alewife run, which presently supports the largest commercial alewife fishery in Maine, was originally established by stocking adults from the Sheepscot River run into Damariscotta Lake in 1803. In 1806, a rock fishway built around an impassable 50' natural falls allowed fish for the first time to gain access to the lake spawning habitat. Previous to establishment of this fishway, the Damariscotta River did not support an alewife run of commercial significance.

The alewife makes its growth in the sea and returns to freshwater to spawn. The majority of adults return as first-time spawners at ages four and five. The numbers of repeat spawners vary according to the adult escapement and may be as high as 25% of the total run. Adults enter Maine rivers from early May to early June and run upstream into lakes, ponds, and dead water areas to spawn. Each female produces 60-100,000+ eggs, depending on the size of the individual fish. The majority of the surviving spent adults then make their way downstream shortly after spawning. Early spawners can be seen migrating seaward and passing later run spawners which are still migrating upriver. The spawning temperatures range from 55-60ºF. The eggs, which are about 0.05" in diameter, hatch in about 3 days at 72ºF and 6 days at 60ºF. Young alewives have been observed moving seaward in Maine rivers as early as mid-July. The seaward migration of young occurs from mid-July through early December. The size of seaward migrating juveniles ranges from 1 1/4" to 6" long, depending on the availability of feed in the lakes, the total numbers of young produced in a particular watershed, and the length of time the fish remain in the freshwater environment.

The alewife is primarily a plankton feeder. Major food items include copepods, amphipods, and mysid shrimp. On occasion, adult alewives consume small fish and fish eggs.

Although considered an inshore species, alewives are sometimes taken 70-80 miles offshore in the Gulf of Maine and on Georges Bank at water depths ranging from 150-480'. Available evidence suggests that the majority of the Maine alewives remain inshore where they congregate in schools of fish of the same size.

Shad. The American shad, the largest member of the true herring family, is characterized by a laterally compressed body that is 1/4-1/5 as deep as it is long. It has soft-rayed fins with the dorsal fin situated well forward of the middle of the body. The lack of teeth in the roof of the mouth easily distinguishes the shad from the sea herring. The most reliable difference between the shad, alewife, and blueback herring is that the upper outline of the shad's lower jaw is slightly concave without a sharp angle, whereas the outline of the alewife and blueback herring is deeply concave with a pronounced angle. In addition, the shad has a row of pronounced dark spots beginning just behind the upper part of the gill cover, always more than four spots, and up to 27. The coloration of the large, loosely attached scales varies from dark-bluish or greenish above to whitish-silvery on the sides and belly. A golden tinge occurs over much of the body during its migration in the sea.

The natural range of the American shad is the Atlantic coast of North America from southeastern Newfoundland and the Gulf of the St. Lawrence to the St. Johns River in Florida. Introduced on the Pacific coast in 1871, the species has spread from southern California to Cook Inlet, Alaska. Historically, the largest populations occurred in Chesapeake Bay, the mid-Atlantic, and southeastern United States.

The American shad is an anadromous fish species which makes its growth in the sea and returns to freshwater to spawn. Returning adults range from 2-5 years old, with males usually maturing one year earlier than females. The shad runs in the northeastern United States and Canadian Maritimes are dominated by four- and five-year old fish. Males average three pounds and females, four, in weight. Older fish may exceed 12 pounds and 30" in length.

As is the case with its close relatives, the alewife and blueback herring, the shad spawns in the spring. Depending on weather conditions, the adult fish normally enter Maine rivers from mid-May to the latter part of June. Female shad carry from 20-600,000 eggs, depending on the size, age, and river of origin of the fish. Populations that spawn north of Virginia are composed of a high proportion of repeat spawners. Southern populations have a higher number of eggs per pound of females, which is an apparent compensation for the higher postspawner mortality rate (100% in most cases) of these populations. Most Canadian shad produce from 20-150,000 eggs per female, which is probably representative of the fecundity of Maine shad.[38]

The eggs are spherical, about 1/8" in diameter, and slightly heavier than water. The adults spawn in river areas with current velocities of 1-3' per second and at water depths ranging from 3-20'. Fertilized eggs may be carried by river current for several miles downstream from the spawning site. Viable eggs may be found on river bottom types ranging from fine sand to coarse rubble to ledge, but never on silty or muddy bottom areas. The eggs hatch in 12-15 days at 52°F and 6-8 days at 63°F.[39] The larvae are 0.4" long at the time of the hatching and very slender. Some drift down into brackish water shortly after hatching, while others remain in the freshwater throughout the summer months. At 2-3" long, the young fish leave the rivers in late fall as water temperatures decline below 54°F.[40] Overwintering of juvenile fish from most Atlantic seaboard rivers is believed to occur in the middle Atlantic area. Young shad join with the adults on coastal migrations, moving into the Gulf of Maine and Canadian waters in summer and then southward to the Carolinas in fall and winter. As the young fish mature with the approach of the spawning period, they move into their parent streams to deposit their eggs and repeat the life cycle. The average life cycle is from 3-6 years, but some repeat spawners may live as long as 10 or 11 years.

The dominant food items of shad are planktonic organisms. In the freshwater environment, larval and juvenile shad eat copepods, related crustaceans, and insect larvae, primarily chironomids. While in the marine environment, shad of all sizes feed chiefly on copepods and mysids as well as small fishes, such as immature smelt and sand lance, which make up a very small part of their food.[41]

Smelt. Smelt, like other anadromous species such as Atlantic salmon, alewives, and shad, attain most of their growth in the marine environment, but ascend coastal streams to spawn in freshwater. In the summer, smelts are found in the inshore areas of the coast and may be found in bays and estuaries if not forced out by high water temperatures. In early autumn, schools of smelt move into bays, estuaries, and the lower tidal reaches of rivers where they feed through the winter months. Smelt ascend to freshwater to spawn as the ice goes out and the water temperatures increase.

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[38] Fishes of the Atlantic Coast of Canada Leim, A.H. and W.B. Scott, Fisheries Research Board of Canada, Bulletin #155, 1966.

[39] Fishes of the Gulf of Maine Bigelow, H.B. and W.C. Schroeder, U.S. Fish and Wildlife Service Fishery Bulletin #74, Vol. 53, 577 pp., 1953.

[40] *Distribution of Early Life Stages of American Shad in the Hudson River Estuary.* Stira & Smith, Proceedings of a Workshop on American Shad, Amherst, Massachusetts, 1976.

[41] Fishes of the Atlantic Coast of Canada Leim, A.H. and W.B. Scott, Fisheries Research Board of Canada, Bulletin #155, 1966.

There is a wide range of variation in the timing of runs and types of spawning areas used. Some smelts spawn immediately after ice-out in the deeper waters of the main rivers, while others spawn in the tributary brooks and streams.[42] McKenzie[43] found that smelt in the Miramichi River (New Brunswick) arrived at head-of-tide in the main branches and larger tributaries as temperatures reached 4-5°C, whereas they did not enter the smaller streams and tributaries until temperatures reached 6-7°C. Flagg has observed spawning to occur in Maine streams from 0-6°C to 11°C, peaking between 4 and 9°C. It is very unlikely that the time of spawning is controlled by one factor such as temperature, but probably the cumulative effect of a number of both intrinsic and extrinsic factors.

Spawning occurs in a variety of habitats, ranging from swift water to dead water pools and on a variety of substrates, from silt to gravel and rock ledge.[44] Spawning takes place mostly at night, although limited spawning has been observed during daylight hours.[45] The eggs are adhesive and become attached to sticks, stones, gravel, or other submerged objects by means of "stickfast," a stalk formed by the outer coat of the egg.[46]

Percentage hatch is probably dependent on a number of variables, such as substrate, temperature, stream flow, and density of egg depositions. McKenzie found with increasing egg densities that the percentage hatch decreased. At 487 eggs 1 ft^2, he found a 3.6% hatch and at 180,200 eggs 1 ft^2, a 0.03% hatch. The most larvae produced per square foot occurred at a density of 12,000 eggs 1 ft^2. Concentrations as high as 180,200 eggs 1 ft^2 are commonly found below obstructions. Hulbert[47] found that eggs incubated on substrates with flat surfaces, such as sand, may experience more severe fungal infection than eggs on substrates with large interstitial spaces, such as gravel. Hatching usually occurs in 15-30 days, depending on water temperatures. McKenzie found that hatching in the Miramichi River took 29 days at 6-7°C, 25 days at 7-8°C, and 19 days at 9-10°C.

Smelts are not able to negotiate a vertical drop of more than 6-8".[48] Thus, much of the potential spawning habitat of coastal streams is inaccessible due to natural or artificial obstructions and some areas are only accessible at high tide. Age composition of smelts on the spawning run is predominantly two- and three-year olds.

The main diet of smelt in the marine environment consists mainly of planktonic and benthic crustaceans. The dominant food item of smelts sampled in Casco Bay consisted of euphausid shrimp. Other food items were caprellids, polychaetes, insects, fish remains, and plant debris. The dominant food item of smelt collected in the lower reaches of the Kennebec River was gammarids, particularly *Gammarus oceanicus*.[49]

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[42] *Striped Bass and Smelt Survey, Annual Report for 1971.* Flagg, L.N., AFS-4-3, 1972.

[43] Smelt Life History and Fishery in the Mirimichi River, New Brunswick. McKenzie, R.A., Fishery Research Board, Bulletin #144, ix +77pp., 1964.

[44] Fishes of the Gulf of Maine. Bigelow, H.B. and W.C. Schroeder, U.S. Fish & Wildlife Service Fishery Bulletin #74, Vol. 53, 577pp., 1953.

[45] Smelt Life History and Fishery in the Mirimichi River, New Brunswick. McKenzie, R.A., Fishery Research Board, Bulletin #144, ix +77pp., 1964.

[46] Fishes of the Gulf of Maine. Bigelow, H.B. and W.C. Schroeder, U.S. Fish & Wildlife Service Fishery Bulletin #74, Vol. 53, 577pp., 1953.

[47] Factors Affecting Spawning Site Selection and Hatching Success in Anadromous Rainbow Smelt (*Osmerus mordax*, Mitchell). Hulbert, P.J., M.S. Thesis, University of Maine, Orono, 44pp., 1974.

[48] Smelt Life History and Fishery in the Mirimichi River, New Brunswick. McKenzie, R.A., Fishery Research Board, Bulletin #144, ix +77pp., 1964.

[49] *Striped Bass and Smelt Survey, Completion Report.* Flagg, L.N., AFS-4, 1974.

Atlantic & Shortnose Sturgeon. The Atlantic sturgeon (*Acipenser oxyrhynchus*) and the shortnose sturgeon (*Acipenser brevirostrum*) belong to the family *Acipenseridae*, one of the most primitive families of the bony fishes. Sturgeon originated over 300 million years ago and have remained relatively unchanged for over 40 million years. Although their ancestors had a bony skeleton, the present day sturgeon have a cartilaginous skeleton. Sturgeon have a protrusible, toothless mouth, with bulbous lips on the underside of the head with two pair of barbels preceding the mouth. They are armored with five rows of plates called "scutes," and have a heterocercal (sickle-shaped) tail.

The Atlantic sturgeon are an anadromous species which attain most of their growth in the marine environment but return to freshwater to spawn. Shortnose sturgeon are also considered an anadromous species. Although they are not known to leave the influences of the river systems in Maine, they are found in brackish water during part of their life cycle.

Both species of sturgeon are found mainly in the larger river systems of Maine. Shortnose sturgeon are known only to occur in the estuarial complex of the Kennebec and Sheepscot Rivers and in the Penobscot River. Atlantic sturgeon are known to occur in the Kennebec, Penobscot, and Piscataqua Rivers and may occur in the St. Croix River and other smaller drainages. The Atlantic sturgeon is distributed from Labrador to the northern coast of South America. The shortnose sturgeon is distributed from the St. John River in New Brunswick, Canada, to the St. Johns River in Florida.

Atlantic sturgeon enter the river in the early summer at water temperatures from 55-70ºF. Ripe Atlantic sturgeon have been found in the Kennebec River from mid-July through early August. Spawning habitat consists of small rubble, gravel, or hard bottom in running water or in pools below waterfalls. Historical records indicate that the major spawning area for Atlantic sturgeon in the Kennebec River was between Augusta and Waterville. The construction of the Augusta dam in the early 1800s was believed to have caused the commercial catch to decline over 50%. A female Atlantic sturgeon may spawn from 1-4,000,000 eggs depending on the size of the fish. The adhesive eggs vary in diameter from 2-2.9mm and attach to rocks, sticks, shells, etc. in strung clusters of ribbons. The eggs hatch in 3-7 days, depending on water temperature.

The larvae grow rapidly and are 4-5 1/2" long at a month old. At this size, the young sturgeon bear teeth and have sharp, closely spaced spine-tipped scutes. As growth continues, they lose their teeth, the scutes separate and loose their sharpness. The young spend up to six years in the Kennebec River system and reach a length of 3' before migrating to sea.

Atlantic sturgeon feed on molluscs, polychaeta worms, gastropods, shrimps, amphipods, isopods, and small fishes in the marine environment. The sturgeon "roots" in the sand or mud with its snout, like a pig, to dislodge worms and molluscs which it sucks into its protrusible mouth, along with considerable amounts of mud. The Atlantic sturgeon has a stomach with very thick, muscular walls that resemble the gizzard of a bird. This gizzard enables it to grind such food items as molluscs and gastropods.

The age at which the Atlantic sturgeon returns to the river system to spawn varies between sexes and increases with latitude. The youngest ripe male observed in the Kennebec River was 17 years old and the smallest was 57", fork length. The youngest ripe female was 25 years old and 67", fork length. Dovell[50] found that spawning male Atlantic sturgeon in the Hudson River were at least 12 years old and ranged in length from 3 1/2 to 6 1/2'. The youngest female was 19 years old and 6 1/2' in length.

The age of sturgeon is usually determined by counting growth rings (annuli) in a basal cross section of the first pectoral ray. Atlantic sturgeon have been found to attain an age of 60 years in the St. Lawrence River. The oldest sturgeon aged in the Kennebec River was 40 years old. The largest Atlantic sturgeon observed in the Kennebec River to date was 7'2" in length. The largest Atlantic sturgeon on record was a 14' female, 811 pounds, caught off the mouth of the St. John River, New Brunswick, Canada, in July 1924.[51]

The shortnose sturgeon is a much smaller fish and slower growing than the Atlantic sturgeon. A 3' long shortnose sturgeon from the Kennebec River would be approximately 28 years old, whereas a 3' long Atlantic sturgeon would be only six years old.

To distinguish an adult shortnose sturgeon from a juvenile Atlantic sturgeon, one has to compare the ratios of the mouth width/interorbital width (bony width between the eyes). As a general rule, if the mouth width/interorbital width x 100 exceeds 60%, it is a shortnose sturgeon. In addition, all juvenile Atlantic sturgeon checked to date in the Kennebec River have had small, bony plates (supra-anal scutes) present between the anal fin and the lateral scutes. No supra-anal scutes have been found on any of the shortnose sturgeon checked from the Kennebec River.

The shortnose sturgeon also differs from the Atlantic sturgeon in its life cycle. The shortnose sturgeon spawns at lower temperatures, thus, earlier in the season than does the Atlantic sturgeon. In the Kennebec River, the shortnose spawns in late April and early May at temperatures of 10-15°C. The spawning sites on the Kennebec River (including the tidal portion of the Androscoggin River) are characterized by a substrate of gravel, rubble, and large boulders adjacent to deep, turbulent areas. The eggs of the shortnose sturgeon are slightly larger than those of the Atlantic sturgeon. The average diameter of fully matured eggs is 3.10mm. The number of eggs per female averaged 5,250 eggs/lb. for St. John River fish.[52]

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[50] *Biology and Management of Shortnose and Atlantic Sturgeons of the Hudson River, Annual Report*. Dovell, W.L., Federal Aid Project AFS-19-R-2, 130pp., 1977.

[51] Fishes of the Atlantic Coast of Canada. Leim, A.H. and W.B. Scott, Fisheries Research Board of Canada, Bulletin #155, 1966.

[52] *Biology and Population Characteristics of the Shortnose Sturgeon, Acipenser brevirostrum, LeSeur 1818 (Osteichthyes Acipenseridae) in the St. John River Estuary, New Brunswick, Canada*. Dadswell, M.J., Canada J. Zoology, 57:2186-2210, 1979.

Juvenile shortnose sturgeon remain in the upper freshwater portion of estuaries where they feed mainly in deep channels over sandy mud or gravel/mud bottoms. The adult shortnose sturgeon, at least in the northern part of their range, are confined to the river systems. The migratory movements of the adult shortnose sturgeon in the river system involves movements between the spawning, feeding, and wintering areas. The spawning areas in the Kennebec/Sheepscot River estuarial complex are located close to head-of-tide in the Kennebec River and in the Androscoggin River, and possibly in the tributaries of Merrymeeting Bay. Although the shortnose sturgeon feed throughout the estuarial complex, it appears that the greatest concentration is in the mid-estuary around Bath. It is believed that the majority of the shortnose sturgeon overwinter in the lower estuary, although occasionally one is caught in the upper estuary during the winter smelt hook and line fishery.

Striped Bass. The following account of the life history of striped bass was adopted from Flagg:53 The striped bass, *Morone saxatilis*, is known by a variety of local names such as striper, rock, rockfish, linesides, or roller. These names refer to the general description or habits of the striped bass. "Rock" or "rockfish" is a name commonly used in the Chesapeake Bay and south Atlantic states. The name "linesides" refers to the longitudinal black or dusky colored strips along the sides of the striper. This feature readily distinguishes the striper from the closely related white perch.

The sea bass family, or *Percicthyidae*, is an extremely numerous tribe of fishes but is represented by only four species in the Gulf of Maine. These are the striped bass, white perch, sea bass, and wreckfish. The striper is easily differentiated from the others by seven or eight longitudinal black or dusky colored stripes along the sides. There are two well-developed dorsal fins (each of about equal length with the first being spiny and the second soft-rayed), and a moderately stout forked tail. Three spines form the front part of the anal fin and the base of the tail fin (caudal peduncle) is moderately stout. The striper has a projecting lower jaw, a head almost as long as the fish is deep, and a mouth which gapes back to the eye. The separation of the two dorsal fins definitely distinguishes it from the white perch in which the two dorsal fins are attached. The color is dark olive green to bluish on the back, with pale sides and a silvery ventral surface. The general form is elongated with the body 3 1/3 to 4 times as long as it is deep. There are other finer characteristics which distinguish the striper, but the above description suffices to distinguish it from other Gulf of Maine fishes.

With respect to growth, striped bass are generally 4-6" long at the end of the first summer, 10-12" at age 2, 14-15" at 3, 18-20" at 4, 21-23" at 5, 24-27" at 6, and 43-47" at 14. Striped bass angled in Maine are comparable in size and weight for a given age to those of Chesapeake Bay.

The spawning habits of striped bass have been well documented and observed, both on the east and west coasts. Spawning seasons are generally governed by water temperatures with spawning known to occur at temperatures ranging from 50-75ºF. Shannon and Smith54 have found that the optimum temperature for egg incubation and larval development is 65ºF. Incubation time is dependent on water temperatures, with eggs hatching in 30 hours at 72ºF and 74 hours at 58ºF. Eggs subjected to temperatures exceeding 75ºF result in such rapid development that a high proportion of malformed fry occurs.

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[53] *Striped Bass and Smelt Survey, Completion Report*. Flagg, L.N., AFS-4, 1974.

[54] Preliminary Observations of the Effect of Temperature on Striped Bass Eggs and Sac Fry. Proc. Shannon & Smith, 21st Annual Conference Southeastern Association of Game and Fish Comm.: pp. 257-260, 1967.

The spawning areas range from head-of-tide in Chesapeake Bay to small tidal river systems 12 miles upstream to 80 miles above tidewater on the Roanoke River in North Carolina and 200 miles above tidewater on the St. John River in Canada. The location of spawning is probably an adaptation of certain stocks to the water temperatures at the time of spawning. Upriver spawners are probably early run fish while tidal river spawners would probably be late run spawners in order for egg incubation times to coincide with availability of freshwater flow. This would allow for adequate incubation time before the fry reach high salinity waters. Studies by Rathjen and Miller[55] demonstrated that live striped bass eggs in the Hudson River were not found in areas of salinity in excess of 1:1,000. Therefore, upriver and near head-of-tide stocks of striped bass have to be very temperature sensitive in order to accommodate egg incubation time with extent of freshwater flow. The high egg production per female also compensates for the very restrictive requirements for egg incubation and fry development.

During the spawning act, single females are surrounded by several to many males. Spawning usually occurs in slow to moderate currents and near the mid-channel of the river. Miller and McKechnie[56] provide an accurate observation of striped bass spawning in California's Sacramento River. Females roll on the surface and as eggs are extruded males fertilize them. The newly fertilized eggs expand to about 1/8" in diameter and become semi-buoyant, requiring a current or water turbulence to remain suspended in the water column. Because of these requirements of fresh flowing water and minimum incubation time of 24-30 hours, it would appear that the best spawning areas would be large coastal rivers of moderate gradient, slow to moderate current, and stable flow during the egg incubation and larval development period. The large expanse of low salinity water in Chesapeake Bay and Albemarle Sound of North Carolina lend themselves as ideal spawning habitats for striped bass. The low range in tidal fluctuations in the middle Atlantic states lessen the possibilities of high salinity intrusions which could cause high mortality of eggs and larvae. With respect to Maine, striped bass populations would appear to be more restricted in spawning habitat because of high salinity gradients in the tidal portions of most Maine rivers. The exception to this situation is Merrymeeting Bay, where the restricted access of tidal intrusion at "The Chops" (a constriction at the seaward end of Merrymeeting Bay) and large volumes of freshwater discharge from the Kennebec and Androscoggin Rivers creates an extensive freshwater estuary.

Atlantic Salmon. The Atlantic salmon is an anadromous species, which means it reproduces in fresh water where the young grow to five to seven inches (usually in one to three years) before migrating to salt water. In the ocean the young salmon grow to a mature size of two to three feet (one to three years of ocean residence) before returning to fresh water to reproduce.

Adult Atlantic salmon ascend rivers in New England throughout the spring, summer, and fall with spawning occurring in late October through November. During spawning, the female salmon chooses a gravel area and excavates a pit called a redd into which eggs are deposited. More than one male will usually participate with a single female in spawning.

The adult fish after spawning are called kelts and may return to the sea immediately or, more typically, during the following spring. A small portion of the kelts will successfully make the journey back to salt water and return again as repeat spawners.

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[55] Aspects of the Early Life History of the Striped Bass (*Roccus saxatilis*) in the Hudson River, New York, Rathjen & Miller, Fish & Game Journal 4(1): 43-60, 1955.

[56] Miller & McKechnie, 1968.

The salmon eggs deposited in the redd normally hatch in late March and April, followed several weeks later by the emergence of fry from the gravel. The fry rapidly assume the coloring of the life stage referred to as parr.

In New England rivers salmon parr remain in fresh water for a period of one to three years undergoing morphological and physiological changes (a process called smoltification) during the spring that prepares the young fish (now called smolts) for migration and the transition from a fresh water to a salt water habitat.

Once the smolts enter the ocean they will migrate to distant feeding grounds, frequently north of the Arctic Circle. The salmon will spend one or more years at sea before returning to their natural stream.

Fish that return after one winter at sea are called "grilse". The majority of the salmon will spend two winters at sea and are referred to as "large salmon" or "multi-year" fish.

Potential size and distribution of Atlantic salmon populations in New England rivers are determined largely by the quality, quantity and accessibility of the spawning and nursery habitats. Adult resting and holding areas, and environmental features impacting in-river migration can also be of major importance.

Good spawning habitat will contain sufficient gravel areas with substrate material of a size 0.5 to 4 inches in diameter;[57] [58] to permit movement of well-oxygenated water through the redd. Free movement of water through the substrate is critical since salmon eggs may be deposited as deep as 12 inches[59]

Salmon nursery habitat is typically composed of shallow riffle areas interspersed with deeper riffle and pool reaches. Substrate material ranging from one-half inch to greater than nine inches in diameter affort adequate cover for the juvenile salmon[60]

Juvenile salmon will exhibit little growth at water temperatures below 45°F[61] and experience optimal growth in those streams having daily peaks of 72 to 77°F.[62] Water temperatures that exceed 83°F can be harmful to the young salmon[63]

Resting areas used by adult salmon are composed of pools that provide temporary refuge from the swift currents during the upstream spawning migration. These pools usually lack cover and can have a higher temperature regime than stream portions used as holding areas.

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[57] *Physical Characteristics of Atlantic Salmon Spawning Gravel in some New Brunswick Streams*, Fisheries and Marine Service Technical Report 785, 28 pp. Peterson, R.H., 1978.

[58] Natural Spawning Success of Landlocked Salmon, (*Salmo salar*), Trans. Am. Fish. Society, 92 (2): 161-164. Warner, K., 1963.

[59] ibid.

[60] Unpublished data, Mad River, NH FWS. Knight, A.E., Laconia, New Hampshire, 1981.

[61] Estimated Escapement of Atlantic Salmon (*Salmo salar*) for Maximum Smolt Production in Rivers of Different Productivity, Canada J. Fish. Research Board, 35:175-183. Symons, P.E.K., 1979.

[62] Atlantic Salmon Rivers, Smolt Production and Optimal Spawning: An Overview of Natural Production, IASF Special Publication 6, New England Atlantic Salmon Conference, pp. 96-119. Elson, P.F., 1975.

[63] Temperature Relations of Salmonids, Proc. 10th Meeting Nat. Committee on Fish Cult., App. D.F.R.B. Fry, F.E.J., Canada, 1947.

Holding areas are normally located close to the spawning grounds and consist of pools having the cover, depth, temperature, and water velocities preferred by adult salmon. The pools have a gravel substrate with large boulders, logs, or ledge outcroppings providing cover. Water depths exceeding six feet and water velocities under 1.6 feet per second are preferred.[64] Optimum water temperatures in adult holding areas are 50 to 54ºF, but temperatures of 60ºF and daily fluctuations to 77ºF are tolerated if the water cools to 68ºF or less at night.[65]

Atlantic salmon streams in most of New England typically lack substantial buffering or acid neutralizing capacity. Consequently, these waters are sensitive to acid precipitation. Long distance atmospheric transport of air pollutants containing sulfur and nitrogen compounds is the primary cause of acid precipitation. The potential exists for such precipitation, either in the form of rain or melting snow, to lower the pH of a salmon stream to (or below) the critical level of 4.7 where successful reproduction is jeopardized.

The life stage of salmon most sensitive to low pH is the egg-to-fry stage. Values of less than pH 5.5 may result in egg mortality, while pathological changes have been noted during incubation at pH 5.0 or less.[66] Several Nova Scotia streams that contained viable salmon fisheries during the 1950's now have pH levels less than 4.7 and are too acid to support Atlantic salmon reproduction.[67] The potential for such problems in New England streams is greatest in smaller tributaries in central Maine and least in large mainstem areas and in basins with significant buffering capacity such as the Connecticut and Aroostook.

Various chemical and physical factors can have a significant impact on the migratory behavior of salmon. Salmon are sensitive to temperature, flows, pH, dissolved gas concentrations and concentrations of various pollutants such as dissolved heavy metals.

Salmon smolts receive migrational timing cues from photoperiod, temperature, and stream flow. Water temperatures greater than 50ºF may retard downstream movement.[68]

The upstream movement of adult salmon can be stimulated by a rising water temperature accompanied by an increasing flow as occurs with a spring freshet. Water temperatures greater than 73ºF and dissolved oxygen concentrations less than 5 (ppm) can, however, retard or entirely halt migration.[69] Small amounts of zinc or copper in the water can impact the movement of adult salmon by initiating avoidance reactions.

Historical Fisheries

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[64] *The Creation of Artificial Salmon Pools*. Frenette, M., C. Rae, and B. Tetreault, Department of Civil Engineering, Laval University, Quebec, pp.17-24, 1972.

[65] Atlantic Salmon Rivers, Smolt Production and Optimal Spawning: An Overview of Natural Production. IASF Special Publication 6, New England Atlantic Salmon Conference, pp.96-119. Elson, P.F., 1975.

[66] Reproduction in Fish Experiencing Acid and Metal Stress, in: *Acid Rain/Fisheries*, 177-196. Peterson, R.H., P.G. Days, G.L. Lacrois, and E.T. Garside, American Fishery Society, Bethesda, Maryland, 1982.

[67] Evidence of Acidification of some Nova Scotian Rivers and its Impact on Atlantic Salmon (*Salmo salar*), Canada J. Fish and Aquatic Sciences, 40(4):462-473. Watt, W.D., C.D. Scott, and W.J. White, 1983.

[68] *Water Quality Requirements for Atlantic Salmon*. DeCola, J.N., USDI Federal Water Quality Administration, N.E. Region, Massachusetts, 42 pp., 1970.

[69] *Water Quality Requirements for Atlantic Salmon*. DeCola, J.N., USDI Federal Water Quality Administration, N.E. Region, Massachusetts, 42 pp., 1970.

Alewife. Historically, alewives ascended the Kennebec River in immense numbers as far as Norridgewock Falls, 89 miles from the sea on the main stem.[70] They ascended the Sandy River as far as Farmington and bred in Temple Pond until a dam was built at New Sharon in 1870.[71]

Alewives ascended the Sebasticook River at least as far as Stetson Pond in Stetson on the East Branch and Great Moose Pond in Hartland on the West Branch.[72] It is probable that alewives ascended as far as Wassokeag Lake in Dexter on the East Branch, as Atkins[73] stated that, "nearly every mile" of the 48 square miles of lake surface was accessible to alewives.

Seven Mile Stream was considered one of the "principal breeding places" for alewives in the Kennebec River.[74] It is probable that alewives historically had access to at least Webber Pond and Three Mile Pond. Seven Mile Brook continued to support an alewife run until 1837, when the Augusta Dam finally cut them off.

The Cobbosseecontee Stream drainage was also a "principal breeding place" for alewives. Atkins[75] gave the following account: "The first of these (Cobbosseecontee Stream) afforded an extensive breeding ground in its 21 square miles of lakes and ponds, but it was early closed. In 1787 we find the Town of Wales (then including Monmouth) appointing a fish committee, which the next year was designated a `committee to see that the fishways are kept open according to law.' The dams at Gardiner, however, were impassable, fishways were not maintained, and very early in the present century this brook of alewives were extinguished."

Atkins[76] further stated, "Winthrop for several years appointed a committee to obtain the opening of a fishway through the dam at Gardiner. But they were unsuccessful; reporting on one occasion that Squire Gardiner refused to do anything about it. The stream is now obstructed by dams at Gardiner to such an extent as to render the opening of the upper waters to fish a considerable undertaking. There are eight dams within one mile of the Kennebec, and they are generally high. There are ten dams to the first lake, and most of the others are cut off by them."

Nehumkeag Stream and Worromontogus Stream, which enter the Kennebec River in Pittston below Augusta, were also rendered impassable at an early date.[77]

One can get some indication of the historical value and magnitude of the alewife runs on the Kennebec River system from the early Reports of the Commissioners of Fisheries of the State of Maine. The most important of the alewife fisheries occurred on the Sebasticook River and Atkins gave the following account:

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[70] *Reports of the Commissioners of Fisheries of the State of Maine for the Years 1867 and 1868*. Atkins, C.G. and N.W. Foster, 1869.

[71] ibid.

[72] ibid.

[73] The River Fisheries of Maine- Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

[74] ibid.

[75] The River Fisheries of Maine- Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

[76] *Reports of the Commissioners of Fisheries of the State of Maine for the Years 1867 and 1868*. Atkins, C.G. and N.W. Foster, 1869.

[77] The River Fisheries of Maine- Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

"The most fish were taken in the Town of Clinton, now Benton, and the town was vested with the right to take the fish by their agents, a fish committee, subject to certain conditions. They were to distribute a certain number gratis to the poor, and then sell to the inhabitants at a set price, and finally could dispose of the residue as they saw fit. Great quantities were sold to strangers, the ordinary price being 25¢ a hundred. Newport also had full control over the fisheries in that town. There were free fisheries on all other parts of the river and its tributaries. Indeed, the fisheries were all free until a falling off in the supply warned the people that there must be some regulations. On this point we have the testimony of Mr. Beriah Brown of Benton, now 78 years old. Seventy years ago he followed the man who took the fish. Also of Maj. Japeth Winn, who has lived at Benton fifty-five years. The tributaries of the Sebasticook were very early obstructed by dams through which, in most cases, efficient fishways were left -- generally a mere gap, or a pile of stones; and the number of fish had been falling off for many years before the Town of Clinton assumed control of its fisheries. The dam at the upper falls at Clinton was built before the war of 1775, but a gap for fish was left in it. About 1809 a dam was built at the lower falls twelve feet high with no fishway. It stood five or six years, and in that time had so impoverished the fisheries that the selectmen cut it away, and allowed the fish to ascend to their breeding grounds. The town in 1814 obtained the act authorizing them to control the fisheries, and the first year after cutting away this dam the fishery was leased for two or three years to one James Ford, he agreeing to pay yearly 200 fish to each man, woman, and child in Clinton, and to sell as many more as should be wanted at a set price. From this time the fish increased again rapidly and the town began to sell the fishery yearly at auction. The price obtained varied from $500 to $1,200 or $1,500; the purchaser being bound to distribute gratis to the poor, and sell to all townsmen at a fixed price. The year of the closing of the Augusta Dam the fishing sold for $225. One or two years before for $500.

Mr. John Holbrook, 65 years of age, has lived in Newport all his days. Within his memory alewives came here in great numbers, with a few shad and now and then a salmon. Forty-five years ago they were not so plenty as formerly. Thirty years ago they began to diminish rapidly, and in a few years were entirely gone.

The obstructions on the Sebasticook now existing are six dams, situated as follows:

From Kennebec, miles.

34	Newport pond, outlet
34	Newport Mills, built before 1837
29	Detroit, 7 feet; built about forty years ago
10	Clinton, 5 feet
5	Benton - upper falls, 8 feet; built before 1775
4	Benton - lower falls, 5 feet; old dam 1809; new 1847

The dam at Benton lower falls has a sluiceway twenty feet wide and three feet deep, near its west end, which was not closed during the last season until the 20th of June. With a suitable arrangement of the plank this might answer for the passage of fish. Over the upper dam a way might easily be constructed at the east end by bolting down some timbers and blasting a short passage out of the ledge.

At Clinton and Detroit the task would be easy, but they must be guarded against ice. At Newport the mill-dam would require a fishway, but presents no difficulty. The dam at the outlet hardly hinders the passage of fish. The river was not examined above this point, although the alewives used to run as far as Stetson Pond.

Of the branches we examined, the Pittsfield branch as far as Moose Lake or Pond, the Twenty-five Mile Stream, - and have gathered some information about others. The west branch from Moose Lake has three dams, one at Pittsfield and two at Hartland, neither of which presents any difficulty in constructing fishways; all three would require them. At Hartland there has been a dam for 67 years, but as long as the alewives came there was a hole left for them to pass into Moose Lake. Into the latter runs Main Stream, crossed by several dams which were not examined.

The Twenty-five Mile Stream is the outlet of Unity Lake. Near its mouth, in the Town of Burnham, is a dam built 35 years ago, 12 feet high. Seven miles up the stream is another dam, and beyond that Unity Lake. Tributary to Twenty-five Mile Stream is Sandy Stream of rapid flow, obstructed by two dams.

The streams draining Lovejoy's and Pattee's Ponds are obstructed each by one dam. The latter has a dam which has stood without a fishway for 60 years. The stream draining Plymouth Pond has four dams. The Vassalboro Stream is much obstructed, but was not examined.

All the lakes and ponds of Sebasticook River are admirably adapted to the breeding of alewives. The restoration of these fish would be a comparatively easy matter. Plenty of live fish or their spawn can be obtained at Augusta or below. The construction of ten fishways would give them access to the three largest lakes with a surface of 10,000 or 12,000 acres. If undertaken on the right scale and perseveringly carried forward great return might be expected in a few years. Abijah Crosby, of Benton, was an enthusiast on this subject who might have accomplished much had he been supported by the public opinion. He went so far as to introduce live alewives to Pattee's Pond, Unity and Newport Lakes; they bred there, the young fish were seen going down the stream, and some of them caught; fishways were built over several of the dams on the Sebasticook, and had that built at Augusta proved a success, the alewives would now have been again established in the Sebasticook River."

The Commissioners estimated the yearly catch of alewives in Clinton to be 3,000 barrels.[78] There were approximately 400 alewives in a barrel[79] which translates into an annual catch of 1,200,000 alewives at the Town of Clinton alone. Alewives produced in the Sebasticook River were subject to fisheries from the mouth of the Kennebec River to Winslow in addition to fisheries which occurred in the river itself.

Seven Mile Brook was also considered an important tributary for the production of alewives. The Commissioners of Fisheries in their First Report (1867) gave the following account:

"The Seven Mile Brook is a very important stream, although in size only third rate. It drains several ponds, and these formerly produced great quantities of alewives. The fishery has been regulated by six different acts. There are several dams on the stream which would require fishways should the alewives be restored."

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[78] *Reports of the Commissioners of Fisheries of the State of Maine for the Years 1867 and 1868.* Atkins, C.G. and N.W. Foster, 1869.

[79] *Third Report of the Commissioners of Fisheries of the State of Maine for 1869.* Atkins, C.G., 1870.

There is mention of the alewife fishery in Seven Mile Stream as early as 1777 in the Town Records and by 1780 the town was auctioning the run to the highest bidder.[80] In 1818, the "Fish Privilege" was at a premium and the following sums of money were paid to the town for the privilege: "Elisha Barrows paid $291 for one privilege, John Homans paid $56 for the one near Snells Mills and Samuel Folson paid $52 for the one near Homans' Mills".[81] Based on the fact that the harvest at Clinton on the Sebasticook River was estimated to average 3,000 barrels annually and the privilege usually went for $500 to $1,500, it may be estimated that the fishery may have harvested 320,000 to 900,000 alewives annually on Seven Mile Stream.

The Sandy River was not considered a principal alewife tributary because of its lack of ponded habitat and dead water areas. Atkins and Foster[82] gave the following account of anadromous fisheries of the Sandy River: "Although it has a great many miles of spawning ground for salmon, and but a limited extent suitable for shad or alewife. Both the latter, however, came into the river and ascended as far as Farmington. The lower part of the river maintained an excellent shad fishery.

But in 1804 the New Sharon Dam was built. This stopped shad and alewives but a fishway is said to have been maintained for a few years which permitted salmon to pass. A few years later another dam was thrown across the river nearer its mouth, and the fishways were no longer maintained."

Shad. The shad was a major species fished for in the Kennebec River, especially subsequent to the construction of the Augusta Dam in 1837. This dam prevented salmon from reaching the majority of its spawning habitat but, although the shad resource may have been reduced by 50%, there still remained over 20 miles of tidal freshwater from Merrymeeting Bay to Augusta.

Although the landings prior to 1887 are only estimates, Atkins reported that the average annual landings for shad in Bowdoinham, Dresden, and Woolwich were 120,000 fish for the years 1830-36. This same district was reported to have landed 180,000 shad in 1867 and the catch for the entire Kennebec River was estimated at 225,000 shad.[83]

In 1880, Atkins indicated that 108,000 shad were taken in the Merrymeeting Bay district.[84] In addition, 5,800 were taken above Richmond; 16,744 between Merrymeeting Bay and Bath; and 10,000 below Bath for a total catch of 140,000 shad in the Kennebec River system.

Although the landings do not reflect the loss of spawning and nursery habitat above Augusta due to the construction of the Augusta Dam, Atkins attributed this fact to the "use of a great number of far more efficient implements." A reduction of approximately 50% is indicated by the records of one weir in Merrymeeting Bay which averaged 5,961 shad yearly from 1826 through 1835, but caught only an average of 3,120 shad yearly from 1837-48 (no record for 1844).[85]

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80 *The History of Vassalborough, Maine, 1771-1971.* Robbins, A.P., Maine State Library, 1971.

81 ibid.

82 *Reports of the Commissioners of Fisheries of the State of Maine for the Years 1867 and 1868.* Atkins, C.G. and N.W. Foster, 1869.

83 ibid.

84 The River Fisheries of Maine - Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

85 *Reports of the Commissioners of Fisheries of the State of Maine for the Years 1867 and 1868.* Atkins, C.G. and N.W. Foster, 1869.

Shad historically ascended the Kennebec River as far as Norridgewock Falls (89 miles from the sea), the Sandy River a few miles from its mouth, and the Sebasticook River in small numbers to Newport.86 Atkins indicated that shad ascended the Sandy River as far as Farmington.87 Atkins mentioned several upriver sites where shad fisheries were conducted.

Following is a description by Atkins of the shad fishery at Ticonic Falls (Waterville):

> "At Ticonic Falls there is an island in mid-stream, where great facilities existed for catching shad with dip-nets. This island was private property. The proprietor, from 1804 down to the extinction of the fishery, has stated that in the early days of his fishing he used to take $600 worth of shad yearly. As remarkable feats he mentioned that with the assistance of his three boys he had taken 1,000 shad and 20 salmon in an afternoon and that one day four men dipped out and boated ashore 6,400 large shad. There was a similar but less productive dip-net fishery on the falls at Skowhegan."

A shad fishery was also conducted on the lower Sandy River. Although shad are reported as originally migrating to Farmington, their path was obstructed at New Sharon.88 A few years later a dam was constructed nearer the mouth. Thus, some habitat loss occurred prior to the construction of the Augusta Dam. Also a dam was built at Kendalls Mills in 1834 and one at Somerset Mills in 1836 on the main stem of the Kennebec River just above Waterville.89 Although salmon could pass these dams at high water, there is no indication given whether alewives or shad did.

From 1896 through 1906, shad landings ranged from 322,800 to 1,028,600 pounds for an average annual yield of 802,514 pounds. If an average weight of 3 pounds per fish is assigned, it would indicate a catch of 267,500 shad. Subsequent to 1900, the landings declined and after 1919, the shad fishery suffered a complete collapse. Taylor attributed the collapse to industrial pollution90

Smelt. The sea-run smelt, the smallest of the sea-run fish species, has played an important role in the river fisheries of the Kennebec River. It provided seasonal employment in the winter when jobs were scarce and today provides for a large recreational fishery.

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[86] The River Fisheries of Maine- Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

[87] *Reports of the Commissioners of Fisheries of the State of Maine for the Years 1867 and 1868.* Atkins, C.G. and N.W. Foster, 1869.

[88] ibid.

[89] ibid.

[90] *A Survey of Former Shad Streams in Maine.* Taylor, C.E., USFWS Special Scientific Report, Fisheries No. 66, 1951.

The fishery for smelt was pursued on a small scale as early as 1814 on the Kennebec River by hook and line and small gill nets.[91] Before 1850, smelt were mostly consumed locally and sold through local markets. Bag nets were introduced in 1852 and allowed for greater efficiency in harvesting and allowed expanded markets. After 1850, a great quantity of smelt were marketed in Boston and New York City. Bag nets were fished mainly between Bath and Richmond, with 114 bag nets employed in the winter of 1879-80. Bag nets accounted for approximately 1/3 of the catch. Below Bath, half-tide weirs were utilized. There was also a large hook and line fishery which developed in the Sasanoa River around 1878. Hook and line fisheries were also pursued in the tributaries of Merrymeeting Bay, especially in the Eastern River. Two of the earliest hook and line fisheries were at Hallowell and Gardiner, which were stated to be very productive around 1850.[92] The hook and line fisheries in Hallowell and Gardiner had fallen off to quite an extent by 1880, which some attributed to the introduction of bag nets.

Smelt assumed a dominant role in our river fisheries in the late 1800s. The landed value of smelt in the late 1800s was two to three times the landed value of salmon, shad, or alewives. Smelt and shad were the two dominant sea-run fish species in the Kennebec River from the late 1800s through the early 1900s.

The smelt resource was less affected by dam construction or pollution than the other sea-run fish species, with possibly the exception of the shortnose sturgeon. Historically, it is probable that smelt ascended the Kennebec River only as far as Waterville to Ticonic Falls. While a significant but unknown amount of habitat was eliminated by the construction of the Augusta dam, a significant amount of habitat remained below the dam. This was also true for shad, but increasing pollution in the 1900s had a greater impact on shad than smelt as shad spawned later and were more dependent on the river for juvenile nursery habitat.

Smelt spawn generally during the spring high water run-off and the larvae quickly leave the upper tidal section shortly after hatching. Thus, they are not as subject to adverse conditions experienced in the river system during the summer months.

Although the smelt resource was not as adversely affected by dam construction and pollution as the other sea-run fish species, the landings decreased sharply in the late 1940s. The bag net fisheries ceased around the early 1930s.

The hook and line fisheries in Hallowell and Gardiner also disappeared.

The impact of the severe pollution experienced in the 1940s, '50s, '60s, and early '70s on the smelt resource itself is not known, but the severity of the pollution certainly impacted the use of the resource.

Sturgeon. The first known fishery for sturgeon was at Pejepscot Falls in 1628. Thomas Purchase supposedly fished for salmon and sturgeon from time to time on quite a large scale until the commencement of King Philip's War in 1675. The only indication of the extent of the fishery was that Thomas Purchase caught about 90 kegs and 90 barrels of sturgeon in a three-week period.[93]

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[91] The River Fisheries of Maine - Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

[92] ibid.

[93] *History of Brunswick, Topsham, and Harpswell, Maine.* Wheeler, G.A. and H.W. Wheeler, Alfred Mudge & Son Printers, Boston, Massachusetts, 1878.

The fishery for sturgeon in the eighteenth and nineteenth centuries is described by Atkins as follows:[94]

"In the early part of the eighteenth century there existed a flourishing sturgeon fishery in the Province of Maine, which employed some years over twenty vessels and was an esteemed and important branch of industry. It does not appear, however, to have been prosecuted continuously. Very early in the present century a company of men came to the Kennebec and locating themselves on a small island near the outlet of Merrymeeting Bay, since known as "Sturgeon Island," engaged in the catching of sturgeon, which they soused, packed in kegs, and shipped to the West Indies where they sold at $1.00 a keg. This business was, however, suspended -- for what reason unknown -- and though sturgeon were very abundant in the Kennebec during the early part of the present century, at least until about 1840, no attempt was made to utilize them except occasionally for home use, until 1849.

In 1849, a Mr. N.K. Lombard, representing a Boston firm, came down to the Kennebec, established himself at "Burnt Jacket" in the Town of Woolwich (between Bath and Merrymeeting Bay) and undertook to put up the roe of sturgeon for caviar, and at the same time boil down the bodies for oil. A large number of fishermen engaged in the capture of sturgeon to sell to Lombard. The price paid was 25-50 cents apiece. The first year there were obtained 160 tons of sturgeon. They yielded oil of fine quality, superior to sperm oil for illuminating purposes in the opinion of the inhabitants of that vicinity who have been accustomed to use it when attainable. The attempt to utilize the roe was at first unsuccessful. It was put into hogsheads. Very lightly salted, and all spoiled. The next two years the roe was cured by salting heavier, drying, and laying it down with a little sturgeon oil, and was pronounced satisfactory. However, the business was discontinued after 1851. That year the sturgeon was quite scarce.

From this time there was a suspension of the sturgeon fishery until 1872, when some of the local fishermen of the Kennebec took it up again. In 1874 a crew of fishermen, headed by one John Mier of New York, went into the business catching and buying all they could and shipping them to New York where they supposed to smoke the flesh and utilize the roe for caviar and the sound for glue. They aimed to catch the sturgeon early in the season, while the roe was black and hard, and to keep the fish alive until the proper time for opening them. For the latter purpose, they constructed a great pen, in which they at one time had 700 live sturgeon. After five years, the sturgeon again became scarce and the business was relinquished to local fishermen who still continue to ship the flesh to New York but throw away all other parts. In 1880, the least successful season in recent times, 12 fishermen were engaged in the business on the Kennebec and the total catch was about 250 sturgeon, producing about 12,500 pounds of flesh which sold in New York at 7 cents per pound."

Since the 1880s, the sturgeon fishery has been almost nonexistent. Most of the recorded landings have been incidental catches. The most common gear in which they are caught incidentally are anchored gill nets and otter trawls.

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[94] The River Fisheries of Maine- Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

Striped Bass. The striped bass played a vital role in the development of colonial America, and along with the codfish, were probably the first natural resources of America brought under conservation legislation. The General Court of Massachusetts Bay Colony in 1639 forbade the use of either fish as fertilizer for farm crops. The first public (free) school in the New World was partially supported from monies derived from the sale of striped bass. A portion of the monies was also expended in helping widows and orphans of men engaged in service to the Colony.

Atkins, Commissioner of Fisheries (1887), in referring to Maine's striped bass resource, recounted: Bass were undoubtedly quite plenty in early times in most of the rivers west of the Penobscot. In reference to the Penobscot, old fishermen speak of having "plenty" but the degree of abundance was by no means equal to that existing in the Kennebec, and at no time has this species been marketed in any considerable numbers from the Penobscot or any river further east. On the Kennebec at Abagadasset Point, as late as 1830, bass were so plentiful that the fishermen had trouble disposing of those taken in the weirs. A single weir has been known to take 1,000 pounds at one tide. There was no demand for them and sometimes hired men would take them in pay.

A local fisherman recalled that about the time of their first decline in population he obtained a contract with General Millary, the keeper of the Bowdoinham town poor, to furnish 1,600 pounds of bass at 3/4 of a cent per pound, but the fish were not plentiful that year and he caught only 800 pounds. The extent of the decline is illustrated by comparing the above statement with the statistics representing the present condition of the bass fishery. The total catch of 22 weirs on and about Abagadasset Point in 1880 was only 3,510 pounds; the Kennebec River yielded a total of 12,760 pounds; and the entire State, 26,760 pounds."

In view of Atkins' observation, it is readily apparent that the historical striped bass resource of Maine supported a viable fishery. Unfortunately, before the striped bass became of any great demand, the resource was already on a downward trend, never to return to its former abundance as a resident species. It is also apparent that the largest resident population occurred in the Kennebec River, although the Penobscot, Androscoggin, and St. Croix were also known to have supported limited populations. The beginning of the end of large resident populations occurred around 1830 when a dam was constructed on the Penobscot River at Old Town. Unlike salmon, alewives, or shad, striped bass would not utilize fishways and the construction of dams completely eliminated those fish from upriver spawning grounds which were essential to their existence. The greatest blow to the Maine striped bass resource was the construction of the dam on the Kennebec River at Augusta in 1837. Limited reproduction continued in Merrymeeting Bay and the lower Kennebec to sustain a limited fishery in the lower river during the late nineteenth century. The last commercial fishery probably supported by resident striped bass ceased to operate shortly after World War I. This was a winter fishery on the Sheepscot and Dyer Rivers by fixed gill net. This high salinity estuary was probably an overwintering area for some of the last resident stocks of Merrymeeting Bay. The striped bass of Merrymeeting Bay faded away with the shad fishery which disappeared in the late 1930s as a result of increased pollution from the Androscoggin and Kennebec rivers.

Atkins[95] further describes the habits of and fisheries for the striped bass in Maine: "Bass are found in almost all brackish water of the State and ascend rivers a short distance at the various seasons of the year. On the Kennebec, it used to ascend the main river as far as Waterville; and the Sebasticook, a short distance above its mouth; but since the building of the dam at Augusta in 1837, its migration has been limited to that area. The principal run is in the month of June, at which time it feeds greedily, apparently ascending the rivers for that purpose. It continues to feed in weedy coves and bays until November. In the winter, great numbers of young, two or three inches long, are found in the rivers, and many of them fall into the bag nets and are captured along with smelts and tomcods. Larger individuals appear in many cases to retreat to quiet bays and coves of freshwater in the lower parts of the rivers, and pass the winter in a state of semi-hibernation."

Bass were taken by four methods: dip nets set under the ice, stop nets set in summer and autumn across the mouths of coves, gill nets, and by hook and line. Probably the stop net fishery was most efficient in catching large numbers of fish with one account telling of 11,000 pounds being taken close to Bath.

The abundance of striped bass is also mentioned in the early reports of the Commissioners of Fisheries of the State of Maine in 1867 and that the Kennebec River and particularly Merrymeeting Bay and the Eastern River were major concentration areas for bass.

Present Fisheries

Alewife. Since the early 1970s, water quality has improved dramatically and the tidal waters of the Kennebec River should support an alewife population similar to that found in the system after 1837. The tidal section of the Kennebec River is freshwater from the outlet of Merrymeeting Bay to Augusta, a distance of 20 miles, making it the only Maine river which will support significant shad and river herring runs below head-of-tide. This section of the river is excellent shad spawning and nursery habitat; it is marginal alewife habitat, but because of the large amount of accessible riverine area, the total production of alewives would easily approach two million fish, making it one of the largest runs in the State. While it is difficult to estimate the current population size, recent juvenile seine surveys show that the alewife is currently the most abundant of the three alosids (shad, alewife, and blueback herring).

American Shad. The water quality in the Kennebec River has improved dramatically since the era of gross pollution (the 1930s through the early 1970s). Since 1976, the Kennebec River has had adequate dissolved oxygen levels to support shad and other anadromous fish species in the lower river. DMR has been monitoring the shad resource in the Kennebec River. Experimental drift gill nets have been used to obtain an index of abundance for spawning adult shad and experimental seines are being used to obtain an index of abundance for juvenile shad. The present surveys indicate there is limited reproduction below the Augusta Dam and major areas of shad reproduction in the tributaries of Merrymeeting Bay, the Eastern, Cathance, and Abagadasset Rivers. Thus, the shad resource at the present time below Augusta is in a state of dynamic change. Because shad have a five-year life cycle and the stocks are reduced to extremely low levels, it is difficult to predict the rate of expansion. Based on experiences in other rivers, it is likely that significant recovery will occur within 2-4 life cycles. A very limited recreational fishery has developed below the Augusta Dam with approximately 30-50 adults being taken annually.

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95 The River Fisheries of Maine - Quoted in: Goode, G.B., 1887. Atkins, C.G., The Fisheries and Fishing Industries of the United States, Section V, Vol. 1, 1887.

Rainbow Smelt. The lower Kennebec River provides the largest winter recreational smelt fishery in the State of Maine. Colonies of smelt camps have been reestablished in the Hallowell and Gardiner areas as a result of the dramatic improvement in water quality. In 1985 there were over 700 smelt camps on the tidal waters of the Kennebec River system, including the tributaries to Merrymeeting Bay.

DMR conducted intensive creel surveys of the Kennebec River winter smelt fishery from 1974-1982. The estimated annual catches were variable, ranging from 20,000-96,000 pounds. Some of the fish harvested by hand line fishermen are sold through local markets. There are presently no other commercial fisheries for smelt on the Kennebec River.

This fishery provides for 14,000-29,000 man days of fishing per year. Approximately 12% of the fishermen are nonresidents. Based on an economic survey conducted in 1982, it is estimated that the fishery at 1985 costs would have a value of approximately $500,000 based on direct expenditures.

Sturgeon. No current research or management activities are being conducted in the Kennebec River on these species. Shortnose sturgeon are on the Federal Endangered Species List and are thus afforded full protection. Based on research accomplished under AFC-19 and AFC-20, it was decided that the Atlantic sturgeon stock in the Kennebec River was at a critically low level and the river was closed to the taking of Atlantic sturgeon. In addition, a six-foot minimum length was implemented statewide. In May 1992, a statewide moratorium on the taking of both Atlantic Sturgeon and Shortnose Sturgeon was implemented.

Striped Bass. From the early 1930s through 1986, there was no evidence of striped bass spawning in the Kennebec River and those fish available to the sport fishery in later years were believed to be migrants from Chesapeake Bay and the Hudson River, with Chesapeake Bay being the major contributor.

Historically, this estuary supported the largest population of resident Maine striped bass, as evidenced by accounts of many small stripers taken in the winter smelt fishery and of the commercial winter fishery for large striped bass. Even after the construction of dams at head-of-tide on the Kennebec and Androscoggin Rivers, which prevented migration of fish to upstream spawning areas, spawning populations of striped bass survived in the Merrymeeting Bay area and supported a limited commercial fishery until the post-World War I era. Industrial pollution from the Androscoggin and Kennebec Rivers completely eliminated the remaining population, probably about the same time as the shad disappeared from the Bay in the early 1930s. In recent years the water quality has improved to the point that it is believed possible that a resident population can be re-established in this area. In 1982, a juvenile striped bass stocking and tagging program was initiated to reestablish a self-sustaining native population of striped bass to the Kennebec/Androscoggin complex. In September of 1982, DMR captured 319 juvenile striped bass (fall fingerlings) in the Hudson River and transferred them to the Androscoggin River; in October 1983, a total of 572 fall fingerling striped bass were transported from the Hudson River to the Kennebec River estuary. In 1984, striped bass fry were obtained from Multi-Aquaculture System, Inc. of Amagansett, New York, and raised to fall fingerlings by the USFWS at its North Attleboro National Fish Hatchery. The fry were purchased with private funds by a non-profit organization known as the "Committee to Restore Resident Stripers to the Kennebec River in Maine," and in September, 2,306 fingerling striped bass were released into the Kennebec at Richmond. In 1985 and 1986, striped bass fry were obtained from Ecological Analysts' Verplanck Striped Bass Hatchery. These fry, of Hudson River origin, were raised to fall fingerling size by the USFWS at its North Attleboro National Fish Hatchery. In 1985, 46,769 striped bass fingerlings were stocked and in 1986, 30,246. No striped bass were available in 1987, but 1987 marks the first year in over 50 years that natural production occurred in the Kennebec River, as evidenced by the capture of 26 young-of-the-year striped bass. From 1988-92, an additional 183,333 striped bass juveniles were stocked in the Kennebec/Androscoggin estuarial complex. Wild young-of-the-year striped bass have been caught annually since 1987 with numbers ranging from 1 to 20.[96]

Habitat Assessment & Population Projections

General. No habitat assessments based on substrate types in the subtidal zone in the estuary of the Kennebec River have been completed. Habitat types for the intertidal zone were mapped at a minimum resolution of 3-5 acres by the USFWS.[97] Although the intertidal zone acts as a nursery area for various fish species, such as juvenile shad and alewives, it was not considered in estimating potential population sizes. The total amount of area for the intertidal zone of Merrymeeting Bay was estimated by IF&W to be 17,680,520 yds^2. The total estimated area for the intertidal zone for the entire Kennebec/Sheepscot Rivers estuarial complex was estimated to be 71,186,720 yds^2.[98] The total amount of area for the subtidal zone for the Kennebec/Sheepscot Rivers estuarial complex was estimated to be 90,561,240 yds^2.[99]

[96] *Anadromous Fisheries in the Kennebec River Estuary.* Squiers, T.S., Maine Department of Marine Resources, 1988.

[97] *An Ecological Characterization of Coastal Maine.* Fefer, S.I. and P.A. Schettig, FWS/OBS-80/29, Biological Services Program, U.S. Fish and Wildlife Service, 1980.

[98] *An Ecological Characterization of Coastal Maine.* Fefer, S.I. and P.A. Schettig, FWS/OBS-80/29, Biological Services Program, U.S. Fish and Wildlife Service, 1980.

[99] ibid.

Estimates of shad and alewife population sizes were based on the amount of subtidal freshwater habitat in the Kennebec River estuary. The surface area for the subtidal zone of Merrymeeting Bay and its tributaries was obtained from an aerial survey of Merrymeeting Bay by IF&W.[100] The total estimated surface area for this section of the river was estimated to be 28,280,120 yds^2.[101] The surface area of the subtidal zone of the main stem of the Kennebec River from the Richmond Bridge to the Augusta Dam was determined by multiplying the length by the average width, as determined from a navigational chart. The total estimated surface area for the subtidal zone of the Kennebec River from the Richmond Bridge to the Augusta Dam was estimated to be 11,185,240 yds^2. Thus, the total estimated surface area of the freshwater subtidal zone was estimated to be 39,465,360 yds^2 (). Fefer and Schettig estimated there were only 27,500,800 yds^2 of riverine subtidal area in the Kennebec/Sheepscot Rivers estuarial complex. A small section of Merrymeeting Bay was classified as estuarine subtidal by Fefer and Schettig, but would not account for the large discrepancy. It may be possible that the main stem of the Kennebec River, upriver of the Richmond Bridge, was not accounted for in the Fefer and Schettig survey.

Salmon. The Kennebec River currently has a small population of Atlantic salmon below the Augusta dam, composed of hatchery strays from other rivers, as well as wild fish originating from tributaries below Augusta. The salmon runs in the Kennebec below Augusta are of uncertain magnitude, but are believed to number less than 200 adults in most years. Those salmon present in the Kennebec support a significant fishery located below the Augusta dam. In 1990, the Kennebec River had the second largest rod catch of Atlantic salmon of any river in the State of Maine.

Alewife. Alewives mainly utilize lakes and ponds as spawning and nursery habitat, although deadwater areas of rivers are utilized as well as tidal freshwater habitat. The size of the alewife run as evidenced by the commercial yield is dependent on the amount of accessible habitat. An average yield per surface acre of ponded habitat for six (6) Maine watersheds ranged from 46-694 pounds/surface acre (). The yield/acre is influenced by many factors in addition to the quantitative amount of habitat available, such as the productivity of the lake system, the accessibility of the system to adults, the amount of nursery habitat in the estuarial system, factors associated with the mortality of downstream migrating juveniles, such as turbine mortalities, etc.

To obtain rough estimates of the potential production of alewives in the Kennebec River system, a commercial yield of 100 pounds per surface acre of ponded habitat was assumed. This is well within the range of yields experienced in other watersheds. The 100 pounds/surface acre represents the commercial yield and not the total run. It is assumed that the commercial catch represents an 85% exploitation rate. The theoretical basis for this is that most alewife runs are subjected to six (6) days of fishing per week. Estimates for adult escapement on the Damariscotta River reveal an exploitation rate ranging from 85-97% for the years 1979-1982.[102] Assuming a weight of .5 pounds per adult, the assumed commercial yield would be 200 adults/surface acre and when combined with a 15% escapement rate, would result in a total production of 235 adults/acre. This factor was used to determine the alewife potential for the Kennebec River. The total estimated alewife potential in the Kennebec River above the Augusta Dam was 5,782,410 ()[103]

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[100] Maine Department of Inland Fisheries & Wildlife, 1981. Aerial photos of Merrymeeting Bay, Wetland Estimates, Wildlife Division, (Mimeo).

[101] ibid.

[102] *Population Biology and Management of the Alewife (Alosa pseudoharengus) in Maine.* Annual Report: Maine AFC-21-3, 1981-82, Walton, C.J., 37pp., 1982.

[103] *Kennebec River Anadromous Fish Restoration and Evaluation.* Annual Report, Maine AFC-26-2, Squiers, T.S., 1987.

There is significant alewife habitat below the Augusta Dam currently accessible to alewives. This includes the tidal freshwater section of the Kennebec River, which has a potential to produce an estimated 1.9 million alewives, plus some small drainages with a potential of .56 million alewives (). There is also an additional potential of 2.7 million alewives in the Cobbosseecontee Stream drainage and .17 million in the Togus Stream. The total potential for alewife production below the Augusta Dam is estimated to be 5.4 million adults. This brings the total potential in the Kennebec River system, excluding the Androscoggin River, to over 10 million adults or 5 million pounds (&).

American Shad. A significant fishery for American shad existed in the freshwater tidal section of the Kennebec River and its tributaries after access to inland waters was obstructed by impassable dams at head-of-tide. From 1896 through 1906 the average annual landings of American shad in the Kennebec River were 802,514 pounds. This would represent 267,500 adult shad if an average weight of 3 pounds per fish was assumed. This also represents a commercial yield of 0.6778 shad per 100 square yard unit (). If it was assumed that the exploitation rate varied between 25-50%, then the total shad run may have been in the range of 535,000-1,070,000 shad in the freshwater tidal section of the Kennebec River (including Merrymeeting Bay and its tributaries). This represents a production of 1.4-2.7 adult shad per 100 square yard unit of freshwater tidal habitat.

It was stated by Atkins that the shad run decreased by 50% after the construction of the Augusta Dam in 1837. Thus, the shad run above the Augusta Dam may have been equivalent to that in the tidal section which would result in a run of one-half to one million adult shad above the dam. This would result in a total population estimate of 1-2 million adult shad for the Kennebec River system.

Historical Shad Production per 100 yds² of Mean Low Water Surface Area in the Lower Kennebec River and its Tributaries

	Surface Area (yds^2)	Average Shad Landings	Yield per 100 yds^2	Total Production (50% exploitation)	Production per 100 yds	Total Production (25% exploitation)	Production per 100 yds^2
Merrymeeting Bay (including tidal waters of the Eastern, Abbagadasset, and Androscoggin Rivers)	28,280,120[1]						
Kennebec River (Richmond Bridge to the Augusta Dam)	11,185,240[2]						
TOTAL	39,465,360	267,500[3]	.6778	535,000	1.3556	1,070,000	27112

Source: [1] *From IF&W (1981)*
[2] *Based on length of 15.25 miles and average width of 1,250'*
[3] *Based on 8 years' data from 1896-1906, when average annual yield was 802,514 lbs; 3 lbs/fish = 267,500 shad*

Commercial Yield of Alewives per acre of Spawning Habitat for Selected Maine Watersheds based on Landings from 1971-1983

Watershed	Average Annual Yield(lbs)	Average Yield(lbs)/Acre	Range High	Range Low
Damariscotta River[1]	641,210	144	233	42
St. George River	471,588	311	474	33
Orland River	403,153	97	140	47
Nequasset Lake[1]	158,621	369	488	242
Winnegance Lake	93,697	684	1,178	337
Narraguagus River	56,284	46	89	14

[1] *Exclusive of 1983*

Potential Alewife Production in the Kennebec River above Augusta

Ponded Area	Surface acreage	Total fish[1] production (235/acre)	Allowable[2] harvest (200/acre)	Spawning[3] escapement (35/acre)
Seven Mile Stream				
Webber Pond	1252	294,220	250,400	43,820
Spectacle Pond	139	32,665	27,800	4,865
Three Mile Pond	1,077	253,095	215,400	37,695
Three Cornered Pond	195	45,825	39,000	6,825
TOTAL	2,663	625,805	532,600	93,205
Sebasticook River				
Douglas Pond	525	123,375	105,000	18,375
China Lake	3,922	921,670	784,400	137,270
Pattee Pond	712	167,320	142,400	24,920
Lovejoy Pond	324	76,140	64,800	11,340
Unity Pond	2,528	594,080	505,600	88,480
Great Moose Lake	3,584	842,240	716,800	125,440
Big Indian Pond	990	232,650	198,000	34,650
Little Indian Pond	143	33,605	28,600	5,005
Sebasticook Lake	4,288	1,007,680	857,600	150,080
Wassookeag Lake	1,062	249,570	212,400	37,170
Plymouth Pond	480	112,800	96,000	16,800
TOTAL	19,326	4,541,610	3,865,200	676,410
Wesserunsett Stream				
Hayden Lake	1446	339,810	289,200	50,610
Sandy River				
Norcross Pond	122	28,670	24,400	4,270
Clearwater Pond	751	176,485	150,200	26,285
North Pond	170	39,950	34,000	5,950
Parker Pond	128	30,080	25,600	4,480
TOTAL	1,171	275,185	234,200	40,985
GRAND TOTAL[4]	24,606	5,782,410	4,921,200	861,210

[1] Based on an annual commercial yield of 100 lbs per surface acre and an escapement rate of 15%. Average weight of .5 lbs/fish.

[2] Assumes 100% fish passage efficiency (upstream and downstream)

[3] The escapement rate of 35 adult alewives per acre refers to the escapement needed into the pond or lake. Higher rates would be needed downriver depending on the number of dams and fish passage efficiency.

[4] Assumes there will be 100% survival of downstream migrating juvenile alewives. A 10% mortality at each hydroelectric facility (with downstream passage) would reduce the potential total production from 5,782,410 alewives to 4,047,800.

Potential Alewife Production in the Kennebec River and its Tributaries below the Augusta Dam

	Surface acreage	Total fish production (235/acre)
Cobbosseecontee Stream		
Pleasant Pond	746	175,310
Cobbosseecontee Lake	5,543	1,302,605
Annabessacook Lake	1,420	333,700
Maranacook Lake	1,673	393,155
Narrows Pond	537	126,195
Torsey Lake	770	180,950
Wilson Pond	574	134,890
Berry Pond	170	39,950
Dexter Pond	120	28,200
TOTAL	11,553	2,714,955
Togus Stream		
Togus Pond	648	152,280
Little Togus Pond	93	21,855
TOTAL	741	174,135
Small Drainages Presently Accessible		
Sewall Pond	43	10,105
Winnegance Lake[1]	137	187,394
Nequasset Lake[1]	430	317,242
Nehumkeag Pond	173	40,655
TOTAL	783	555,396
Kennebec River Freshwater		
Tidal Section	8,154	1,916,190
GRAND TOTAL		**5,360,676**

[1] *Winnegance Lake and Nequasset Lake are the average annual landings for 1971-83. The actual size of the run would be approximately 15% larger.*

For the "Lower Kennebec River Anadromous Fish Restoration Plan," the estimate for adult shad production above the Augusta Dam was made by multiplying the surface area as determined by field surveys or from topographic maps by a factor of 2.3 adult shad per 100 square yards.104 Based on the number of shad produced or passed into the Holyoke headpond on the Connecticut River, it was determined that on the average 2.3 adult shad were produced per 100 square yards.105 This method was used to determine the potential shad production for the Merrimack River Anadromous Fish Restoration Program. The amount of surface water on the Kennebec River system was determined by multiplying the average width times length as measured on U.S. Geological Survey Topographical Maps or from actual field surveys. The total number of 100 square yard units was determined to be 315,186. This resulted in an estimate of 725,000 adult shad (approximately).106 Since the completion of the "Lower Kennebec River Anadromous Fish Restoration Plan," field surveys on the main stem of the Kennebec River from Augusta to Waterville and on the Sebasticook River have been completed. The total estimated area has been revised to 299,900 units and the total estimate for adult shad potential above the Augusta Dam to 689,773. This estimate is within the range of the estimate of one-half to one million adult shad which was based on historical landings and surface area estimates.

Smelt. The sea-run smelt would be one of the major beneficiaries if the Edwards Dam was removed. Normally, smelt spawn just above head-of-tide, although in the Kennebec River some spawning occurs below head-of-tide. In the Miramichi River, New Brunswick, all spawning takes place above head-of-tide.107 It is likely that the prime spawning habitat in the Kennebec River was historically located above the Edwards Dam. Removal of the Edwards Dam would result in a free flowing river and allow smelt access to the prime spawning habitat now inundated by this dam.

To develop an estimate of the numbers of smelt that would result from restoring their spawning habitat above the dam by dam removal, it is necessary to first delineate how much habitat would be available. The Department of Marine Resources surveyed the Kennebec River from Augusta to Waterville in 1984 to obtain widths, depths, and substrate types. The total amount of wetted area was estimated to be 57,663,018 feet^2

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[104] *Kennebec River Anadromous Fish Restoration and Evaluation.* Annual Report, Maine AFC-26-2, Squiers, T.S., 1987.

[105] Knight, personal communication.

[106] *Kennebec River Anadromous Fish Restoration and Evaluation.* Annual Report, Maine AFC-26-2, Squiers, T.S., 1987.

[107] Smelt Life History and Fishery in the Mirimichi River, New Brunswick. McKenzie, R.A., Fishery Research Board, Bulletin #144, ix +77pp., 1964.

Surface Area (ft^2) between the Edwards Dam and Ticonic Falls

River Segment	Area (ft^2)
Edwards Dam Impoundment (Transect 1-135)	47,775,006
End of Impoundment to mouth of Sebasticook River (Transect 135-150)	6,648,012
Mouth of Sebasticook River to Ticonic Falls	3,240,000
TOTAL	57,663,018

This is an approximate estimate because the area would fluctuate depending on flows and headpond management at the Edwards Dam. Removal of the Edwards Dam would reduce the amount of wetted habitat, but it is difficult to predict exactly what the amount of habitat would be without an extensive hydraulic analysis. The DMR did obtain a copy of a survey of the Kennebec River between Augusta and Waterville done by the U.S. Engineer Department during the summer of 1826 (Abert, 1828). This document did provide information on the location, vertical drop, and length of rapids but we were not able to obtain the survey maps which might provide information on widths. A description of this section of river based on this survey was prepared by Squiers and King (1990). It was decided to classify two general types of habitat between Augusta and Waterville for the purposes of estimating smelt production. The areas identified as rapids in the 1826 survey was assumed to be prime smelt spawning habitat. Because no widths were available, an average width of 500 ft. was used to determine area at all rapids.

This is a conservative estimate because flows during the smelt spawning season (spring) would be higher than the average flow. The estimated areas of the rapids are listed in .

Estimated Total Area of Current and Former Rapids above Edwards Dam

Name	Linear feet in rapid	Distance upriver (miles) from Edwards Dam to head of rapids	Estimated area in square feet (500 ft. width)
Coons Rapids	1,655	.3	827,500
Bacons Rapids	1,460	4.8	730,000
Two Mile Rapids	10,560	11	5,280,000
Six Mile Rapids	3,300	11.7	1,650,000
Carter Rips	1,400	14.8	700,000
Petty Rips	1,850	16.2	925,000
	20,225		10,112,500

The area for the remainder of the riverine habitat was derived from the 1984 DMR survey.108 Based on observations made while the Edwards Dam was breached in 1974 and based on the fact that the banks are fairly steep sided, a reasonable estimate would be that areas influenced by the present impoundment should be reduced by 30%. The resulting estimates are given in .

Impact of Edwards Dam on Rapids

	Impoundment	Riverine*	Linear length of rapids
With Edwards Dam	79,200 feet	16,896 feet	1,850 feet
Without Edwards Dam Removal	None	96,096 feet	20,225 feet

** Free Flowing*

[108] *Kennebec River - Anadromous Stock Evaluation, Completion Report* Squiers, T.S., AFC-23, 1985, Augusta, Maine.

To then determine the number of smelt that would be produced above the dam, it was necessary to predict how many smelt would be produced per unit of habitat. Two general types of habitat were considered -- rapids and riverine. Data from the Miramichi River in New Brunswick was utilized to estimate the numbers of adult smelt that would be produced at the rapids. McKenzie found the optimum egg deposition density to be 10,000 to 12,000 eggs per square foot which resulted in a hatching success of 0.7 to 0.8% with a resultant production of approximately 120 larvae per square foot.109 There is no published data on survival of the larval stage to the adult, but conservatively it is probably in the order of 1 to 2% or 1.2 to 2.4 returning adults per square foot of rapids. To predict the number of smelts that would be produced in the riverine habitat excluding the rapids,data from the tidal section of the Kennebec River was used. Creel surveys and tagging studies were performed in the lower Kennebec River and tidal tributaries from 1979 through 1982. Catch of smelt varied from approximately 200,000 to 900,000 per year.110 Based on tagging/recapture studies, the average recapture rate was 2.32% and ranged from 0.56% to 4.0%.111 A tag loss study showed that for the period of the study tag loss and tagging-induced mortality was an insignificant factor (7-8%).112 These tagging/recapture ratios combined with the catch data resulted in estimated total population sizes of 6 to 90 million smelt below Edwards Dam. The estimated number of smelt, per square foot of tidal freshwater habitat below the Edwards Dam, returning to the Kennebec River estuarial complex annually from 1979 through 1982, was 0.02 to 0.25. This range of production was used to estimate the potential production of smelt above the dam in riverine habitat (excluding the rapids).

Three scenarios of smelt production with removal of the Edwards Dam were considered. There are no historical records indicating exactly how far upriver smelt migrated in the Kennebec River. There were no major obstructions until Waterville, so potentially smelt spawned all the way to Waterville. Scenario 1 assumed smelt only migrated 4.8 miles above the location of the present dam. This was probably below the historic head-of-tide. Scenario 2 assumed smelt migrated 11.7 miles above the location of the present dam. This was probably several miles above the historic head-of-tide. Scenario 3 assumed smelt migrated to Ticonic Falls in Waterville (18.2 miles above Edwards Dam). The total smelt production for Scenario 1 was estimated to be 2 million to 5.8 million smelt (). The total smelt production for Scenario 2 was estimated to be from 9.4 million to 19.7 million smelt (). The total smelt production for Scenario 3 was estimated to be from 12.8 million to 32.6 million smelt ().

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[109] Smelt Life History and Fishery in the Mirimichi River, New Brunswick McKenzie, R.A., Fishery Research Board, Bulleting #144, ix +77pp., 1964.

[110] *American Shad Restoration and Rainbow Smelt Population Dynamics, Final Report.* Flagg, L.N., AFS-21-R, 1978.

[111] ibid.

[112] *Tag Loss and Mortality of Rainbow Smelt Tagged with Floy Anchor Tags.* Squiers, T.S., M. Smith, and L.N. Flagg. In: *Evaluation of Anadromous Fish Resources,* Final Report, AFS-21-R. Flagg, L.N., 1984.

PROJECTED SMELT PRODUCTION ABOVE THE EDWARDS DAM WITH DAM REMOVED			
SCENARIO 1 - SMELT SPAWNING TO HEAD OF BACON RAPIDS - 4.8 MILES			
	AREA (FT2)	PRODUCTION #	
		MINIMUM	MAXIMUM
RAPIDS	1,557,500	1,869,000	3,738,000
RIVERINE	8,259,790	165,196	2,064,948
TOTAL AREA	9,817,290		
TOTAL PRODUCTION		2,034,196	5,802,948
SCENARIO 2 - SMELT SPAWNING TO HEAD OF SIX MILE FALLS - 11.7 MILES			
RAPIDS	7,758,230	9,309,876	18,619,752
RIVERINE	4,138,060	82,761	1,034,515
TOTAL AREA	11,896,290		
TOTAL PRODUCTION		9,392,637	19,654,267
SCENARIO 3 - SMELT SPAWNING TO TICONIC FALLS - 18.2 MILES			
RAPIDS	10,112,500	12,135,000	24,270,000
RIVERINE	33,218,016	664,360	8,304,504
TOTAL AREA	43,330,516		
TOTAL PRODUCTION		12,799,360	32,574,504
NOTE: TOTAL PRODUCTION BASED ON A RANGE OF 1.2 TO 2.4 RETURNING ADULTS PER SQUARE FOOD FOR RAPIDS AND .02 TO .25 FOR RIVERINE.			

McKenzie estimated the smelt population in the Mirimachi River, which has approximately the same drainage area as the Kennebec River, to be 365 million.[113] It should be noted that there were no dams on the Mirimachi River and all spawning was reported to take place above head-of-tide. Under Scenario 2 the Kennebec would only be producing up to 30% of what the Mirimachi was estimated to produce (including a production of 90 million below the dam). Under Scenario 3 the Kennebec River would still only produce approximately 35% of what the Mirimachi was estimated to produce. It is estimated that the removal of the Edwards Dam would result in an increase in smelt production in the Kennebec River of 10 to 30 million annually.

An additional value of the expanded smelt population would be the increased forage available for estuarine and marine finfish, especially for the striped bass population which the Department of Marine Resources is in the process of restoring.

Shortnose sturgeon. Shortnose sturgeon have been intensively studied in the Kennebec/Sheepscot Rivers estuary.[114] [115] [116] [117] Shortnose sturgeon utilize the entire Kennebec/Sheepscot Rivers estuarial complex.[118] [119] They are usually associated with large river systems where there is a lot of tidal riverine habitat available. The Kennebec/Sheepscot Rivers estuarial complex contains 84% of the total tidal riverine habitat found in the State of Maine north of Cape Elizabeth.

Removal of Edwards Dam would result in an estimated 91% increase in shortnose sturgeon production habitat and an 11.1% increase in fish production.

These estimates are based on data collected by DMR from 1977-1981, when extensive tag and recapture studies were carried out on the Kennebec/Androscoggin River estuary. Estimates of the adult population size in the Kennebec/Androscoggin estuary was 10,000 fish, ranging from 7,000-15,000 adults. Shortnose sturgeon production is proportional to the amount of freshwater (tidal and nontidal) habitat available. There are 8,154 acres of freshwater subtidal habitat in the Kennebec/Androscoggin River system. This results in a production of 1.23 adults per acre. If the Augusta Dam was removed, the additional 906 acres of habitat made accessible to shortnose sturgeon would result in an additional 1,115 adults or an 11.1% increase in the existing population.

Atlantic sturgeon. Unlike shortnose sturgeon, adult Atlantic sturgeon do not utilize the

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[113] Smelt Life History and Fishery in the Mirimichi River, New Brunswick. McKenzie, R.A., Fishery Research Board, Bulletin #144, ix +77 pp., 1964.

[114] *Occurrence of the Shortnose Sturgeon (Acipenser brevirostrum), an Endangered Species, Montsweag Bay, Maine.* Fried, S.M. and J.D. McCleave, Canada J. Fish Research Board, 30:563-564, 1973.

[115] *Distribution and Abundance of Shortnose and Atlantic Sturgeon in the Kennebec River Estuary.* Completion Report AFC-19, 1976-79, Squiers, T.S. and M.E. Smith, 51pp., 1979.

[116] *American Shad Enhancement and Status of Sturgeon Stocks in Selected Maine Waters.* Completion Report: Maine AFC-20, 1979-82, Squiers, et al, 72pp., 1982.

[117] *Evaluation of the Spawning Run of Shortnose Sturgeon (Acipenser brevirostrum) in the Androscoggin River, Maine.* Squiers, T.S., Maine Department of Marine Resources, 1983.

[118] *Occurrence of the Shortnose Sturgeon (Acipenser brevirostrum), an Endangered Species, Montsweag Bay, Maine.* Fried, S.M. and J.D. McCleave, Canada J. Fish Research Board, 30:563-564, 1973.

[119] *American Shad Enhancement and Status of Sturgeon Stocks in Selected Maine Waters.* Completion Report: Maine AFC-20, 1979-82, Squiers et al, 72pp., 1982.

riverine or estuarine environment for feeding and wintering habitat to any great extent. Atlantic sturgeon use the Kennebec River as a spawning and nursery area. It appears that the size of an Atlantic sturgeon population is related to the amount of freshwater (tidal and nontidal) habitat available. Historically, the largest Atlantic sturgeon populations were found in the larger river systems, such as the Kennebec, Hudson, and Delaware Rivers. Historical records indicate that a major spawning area for Atlantic sturgeon in the Kennebec River was above head-of-tide, between Augusta and Waterville. The construction of the Augusta Dam in the early 1800's was believed to have caused the commercial catch to decline over 50%.

Recent surveys in the Kennebec River indicate that only a remnant population of Atlantic sturgeon now exists. 120 121 The low number of Atlantic sturgeon in the Kennebec River is believed to be caused by the severe pollution present from the 1930's through the early 1970's.

Removal of Edwards Dam would result in an estimated 91% increase in Atlantic sturgeon production habitat and a 100% increase in fish production.

This estimate is based on the 1849 commercial fishery landings in the Merrymeeting Bay district. Most adult Atlantic sturgeon enter the river fishery at 16-20 years of age. Therefore, the 1849 fishery included sturgeon production which occurred above the Augusta Dam before the dam was built in 1837. The 1849 harvest was 320,000 pounds. It is assumed that 50% of the fish in the river were harvested because although the effort was believed to be high, fishing gear was rather primitive at the time (i.e. gillnets made of synthetic materials were unavailable). Thus, the river population was estimated to be 640,000 pounds of biomass. It is also assumed that 50% of the population was still at sea as alternate year adult spawners. Therefore, the total population biomass was estimated to be 1.28 million pounds of which it is estimated 50% were produced above Augusta (640,000 pounds). The average size of adults (male and female combined) is estimated at 125 pounds; this average size applied to the total biomass produced above Augusta yields a total of 5,120 fish. Since Atlantic sturgeon are a very slow growing species and the 1849 landings severely curtailed landings in subsequent years, it is estimated that a sustainable river fishery could be achieved with a 10% annual harvest rate. This sustainable harvest would be 64,000 pounds annually, of which 50% would be produced above the Edwards Dam (32,000 pounds).

Striped bass. Flagg evaluated the potential of Maine river systems to support striped bass and concluded that the Kennebec River system was the only system to have viable spawning habitat.122 The only limiting factor at the time of the evaluation was water quality. The criteria established by Flagg were: 1) a minimum of 12-15 miles of unobstructed river flow of fresh or very low salinity water; 2) an average minimum depth of 15'; and 3) dissolved oxygen concentrations of not less than 5ppm at any time of year. The Kennebec River presently meets all these conditions: there are over 20 miles of unobstructed freshwater riverine habitat between the outlet of Merrymeeting Bay and head-of-tide at Augusta; the average minimum depth at mean low water exceeds 15' and dissolved oxygen levels usually exceed 7ppm.

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[120] *Distribution and Abundance of Shortnose and Atlantic Sturgeon in the Kennebec River Estuary* Completion Report AFC-19 1976-79, Squiers, T.S. and M.E. Smith, 51pp., 1979.

[121] *American Shad Enhancement and Status of Sturgeon Stocks in Selected Maine Waters* Completion Report: Maine AFC-20, 1979-82, Squiers et al, 72pp., 1982.

[122] *Striped Bass and Smelt Survey, Completion Report* Flagg, L.N., AFS-4, 1974.

There are 26,526 acres of spawning and nursery habitat (1/2 subtidal and 1/2 intertidal area) for striped bass below the Edwards Dam. Biomass yield of striped bass from Chesapeake Bay ranges from 2-6 lbs.[123] per acre per year for the Bay fishery alone. Over 60% of the striped bass produced in Chesapeake Bay migrate to the coast and are harvested in coastal fisheries. Therefore, total striped bass production in the Chesapeake would be equivalent to 5-15 lbs. per acre based on commercial landings for the Chesapeake Bay vs Atlantic coast. The recreational fishery in Chesapeake Bay is equal to the commercial fishery. Therefore, the total striped bass yield would be 10-30 lbs. per acre of spawning/nursery area. Using these figures, the striped bass production in the Kennebec below Edwards Dam would be 26,526 acres x 10 = 265,260 lbs. to 26,526 x 30 = 795,780 lbs. There are two considerations regarding removal of the Edwards Dam and impacts on striped bass. First, the increase in nursery area: the area above the dam is currently 1,295 acres; if the dam were removed, this acreage would be reduced by 30% to 906 acres. Striped bass production above Augusta would equal 906 x 10, or 9,060 lbs. to 906 x 30, or 27,180. The second factor to consider is the increased spawning area for striped bass and increased probability of successful recruitment to the nursery habitat below the Augusta Dam. By doubling the length of the spawning reach, we conservatively estimate that probability of full utilization of downstream habitat is doubled. Therefore, we attribute 1/2 of downstream production to the removal of Edwards Dam. The striped bass production from dam removal is 132,630 plus 9,060 = 141,690 lbs. to 397,890 plus 27,180 = 425,070 lbs. Assuming the average fish weighs 5 lbs, the yield created from removal of the Augusta Dam would be 28,338 to 85,014 fish.

Atlantic salmon. Analysis of the Kennebec's Atlantic salmon stocks is not sufficiently complete to allow an estimate of potential production in the basin. Most of the spawning and nursery habitat for Atlantic salmon is in the upper reaches of the basin. Salmon stocks are therefore affected by a series of dams. Installation of adequate fish passage in these dams would allow for partial restoration of Atlantic salmon in the Kennebec. Removal of the Edwards Dam would improve restoration efforts by eliminating the estimated 10% loss experienced by fish stocks required to use fish passage facilities. More significantly, removal of the dam would increase the opportunity for riverine fishing for Atlantic salmon by ten fold.

Impacts of the Edwards Dam on Selected Fish Species which use Fishways and on Riverine Fishing Opportunity

Hydroelectric dams have unavoidable impacts on fish habitat as well as upstream and downstream passage of fish. Dams alter free flowing rivers by creating impoundments which are less desirable or unsuitable habitat for spawning of Atlantic salmon, American shad, blue-back herring, brook trout and sea lampreys. Only alewives prefer impoundment habitat for spawning, so dams generally enhance habitat for this species. Removal of the Edwards Dam would create additional or improved spawning habitat for Atlantic salmon, American shad, blueback herring, brook trout and sea lampreys. The spawning habitat quality above Augusta will improve substantially with removal of the Edwards Dam. This improved habitat quality should more than offset any production loss from the expected 30% loss of surface water area when the dam is removed.

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[123] The Feasibility of Augmenting Maryland Striped Bass Populations through Hatchery Stockings. Boone, J.G. and B.M. Florence, Maryland Department of Natural Resources; Mimeo, 1978.

Hydroelectric dams cause unavoidable fish losses during upstream and downstream fish passage. Although American shad, alewives, blueback herring, Atlantic salmon, brook trout and sea lampreys will use fishways, not all the fish will find the fishways and pass upstream. Downstream passage of spent adults and juveniles past hydroelectric dams results in some unavoidable turbine losses due to downstream passage inefficiencies. We estimate at least 10% of upstream migrants and up to 20% of downstream migrants could be lost in making their way to and from the spawning grounds. Unavoidable losses of Alewives and shad caused by the Edwards Dam are as follows:

Impact of Edwards Dam on Downstream Fish Passage

Species	Annual Adult Losses*
Alewife	449,756 fish
American shad	57,751 fish

* Based on production data contained in the *Lower Kennebec River Anadromous Fish Restoration Plan* and assuming an overall 10% loss of the populations due to the Edwards Dam. This represents optimum fish passage efficiency of 90%.

The commercial value of the losses of shad and alewives associated with the Edwards Dam are determined as follows: the average alewife weighs about 0.6 pounds and the average American shad is estimated to weigh 3.0 pounds. Applying the number of fish lost to average weight of each species in the spawning run results in 269,854 pounds of alewives and 173,253 pounds of American shad lost annually at the Edwards Dam.

Riverine Fishing Opportunity. The Augusta Dam impounds 15.0 miles of riverine habitat in the lower Kennebec River. Only Petty's Rips (1,850-foot long rapids) in Waterville is unaffected by the Augusta Dam impoundment. Over 18,375 linear feet of rapids is currently impounded by the Augusta Dam. These rapids are fairly evenly distributed at five locations throughout the length of the impoundment. These five rapids range in length from 1,400 feet up to 10,560 feet. Removal of the Augusta dam would result in a 1000% increase in rapids areas between Augusta and Waterville and create a 10 fold increase in riverine fishing opportunity in this river segment ().

Downstream Impacts of Dam Removal. The restoration of several anadromous fisheries that is expected to follow dam removal will restore large populations of fish to that portion of the Kennebec River downstream from the site of the Edwards Dam. In addition to supporting a potentially significant sport fishery in the tidal reach of the Kennebec, these populations will contribute to restoring the Kennebec's estuarine/tidal ecosystem to a more naturally functioning state.

Summary of Impacts of Dam Removal on Anadromous Fisheries

Removal of the Augusta Dam would have significant positive impacts on anadromous fish restoration in the Kennebec River. Estimates of these impacts are summarized in . These estimates have been derived from historical data and best available information. Specific dam removal studies should be undertaken by the Edwards Dam Licensee to allow for further refinement and updating of the estimates of habitat and population numbers. Figure 3 demonstrates the impact on anadromous fish populations of three different scenarios regarding the Edwards dam: dam removal, installation of state-of-the-art fish passage and continued use of the existing dam. Dam removal would have the most significant effect on anadromous fish in the Kennebec river. All species would benefit significantly from removal of this most seaward obstacle on the Kennebec mainstem. Alewives and shad would benefit somewhat less significantly from installation of fish passage facilities; however, smelt, sturgeon and striped bass would receive no benefit as they do not utilize fish passage facilities. Installation of fish passage would allow expansion of the dam resulting in a 3% increase in generating capacity. Figure 3 also demonstrates that the Edwards dam has a much greater impact on the potential production of anadromous fish in the Kennebec River than it does on the river's potential generating capacity. The dam today captures 2% of the river's potential generating capacity but constrains as much as 50% of the production of several anadromous species. With fish passage facilities and expanded generating capacity installed, the dam captures only another 0.5% of the river's generating capacity but still constrains anadromous fish production significantly.

Table 23
Fisheries Productivity and Hydropower Potential in the Kennebec Basin in Relation to the Status of Edwards Dam

Species	Current Production	Estimated Historical Production	Potential Production	Potential Production w/ fish passage at Edwards	% Change due to Dam Removal	% Increase with Fish Passage	% of Potential Production w/ current dam in place	% of Potential Production without Dam	% of Potential Production with Fish Passage
	in numbers of fish								
Alewife	5,400,000	11,100,000	9,900,000	9,400,000	+83	74	49	89	85
Shad	690,000	1,380,000	1,230,000	1,173,000	+78	70	50	89	85
Smelt[3]	122,600,000	152,200,000	152,200,000	122,600,000	+24	0.[2]	81	100	81
Atlantic Sturgeon	5,120	10,240	10,240	5,120	+100	0.[2]	50	100	50
Shortnosed Sturgeon	10,000	11,115	11,115	10,000	+11	0.[2]	90	100	90
Striped Bass	28,000	56,000	56,000	28,000	+100	0.[2]	50	100	50
Hydropower Potential (available head in feet)	532.5	102.9	513.5	538.5[1]	-3.6	1.[1]	51.7	49.9	52.3[1]

1 -- assumes to foot increase in height of dam
2 -- these species do not use fishways
3 -- includes production from Androscoggin River and Merrymeeting Bay

Figure 3

Fisheries & Hydropower: Percent of Potential Production

Note: This chart is not available in machine readable form; contact the State Planning Office for a paper copy.

Fish passage, minimum flows and mitigation policies

Fish Passage. Dams are a major cause of the significant decline in anadromous fish runs in the State of Maine. In order to assure restoration and protection of these resources, upstream and downstream fish passages are essential for rivers which have been identified and programmed for anadromous fish restoration. DMR is empowered to require a fishway in any dam within coastal waters (12 MRSA, §§6121-6122). In addition, both Federal and State hydropower regulatory processes contain provisions for fish passage consideration. Existing DMR policy for fish passage requirements is provided in 12 MRSA §§6121-6122 and is summarized as follows:

In order to conserve, develop, or restore anadromous fish resources, the Commissioner may require a fishway to be erected, maintained, repaired, or altered in any dam within coastal waters frequented by alewives, shad, salmon, sturgeon, or other anadromous fish species when a dam blocks:

1. upstream passage to suitable and sufficient spawning and nursery habitat that is capable of producing one or more species of anadromous or migratory fish in such numbers that they will support a substantial commercial or recreational fishery;

2. upstream passage to habitat necessary to protect or enhance rare, threatened, or endangered fish species;

3. adequate downstream passage necessary to maintain a substantial recreational or commercial fishery or to protect rare, threatened, or endangered fish species.

It is a widely accepted fact that even the most efficient state-of-the-art upstream and downstream fish passages do not pass all the fish reaching a dam. When fishways in several dams must be ascended and descended, a run of fish can be significantly depleted. Cumulative effects of fish passage at multiple dams must be addressed where applicable.

Fish passage facilities require a flow of water during the entire fish migration season and this water requirement may not be compatible with maximum hydropower generation. However, depending on their location, flows allocated to passage facilities could serve to satisfy wholly, or in part, the instantaneous minimum stream flow requirements at the project.[124]

As provided in Maine's Fishways and Dams Law, 12 MRSA §§7701-7702B, and summarized here, fish passage will be required by IF&W for Atlantic sea-run salmon, landlocked salmon, brook trout, brown trout, rainbow trout, alewives, shad, and other species as necessary when a dam blocks:

1. Upstream passage to usable spawning, nursery, or adult area capable of supporting a substantial recreational fishery;

2. Upstream passage from usable spawning, nursery or adult area to lake habitat capable of supporting a substantial recreational fishery;

3. Upstream passage to spawning and nursery habitat important to the maintenance of a substantial commercial fishery;

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[124] *Policy Concerning Hydropower Projects*, Department of Marine Resources, August 1988.

4. Adequate downstream passage needed to maintain a substantial recreational or commercial fishery.

Mitigation. Diadromous, estuarine, and marine fish populations support diverse recreational and commercial fisheries of significant economic value to the State of Maine. The Atlantic salmon populations of the State of Maine are resources of national significance, and priority is given to avoiding adverse impacts to salmon populations and historical or accessible salmon habitats and angling sites. In evaluating hydropower project proposals, the DMR will recommend measures that avoid or minimize adverse impacts to the fishery resources and habitat in the project area. Whenever a hydropower project is approved and unavoidable impacts occur, the DMR will recommend that appropriate mitigation be provided to offset population losses and losses of other fishery values associated with the hydropower project. Such mitigation may include improving biological productivity of remaining habitat or providing access to new and historically inaccessible habitat. Mitigation efforts should be applied within the same watershed where losses occur. However, the DMR may consider on a case-by-case basis, out-of-basin enhancement proposals to offset unavoidable losses.

In general, the Atlantic Sea-Run Salmon Commission (ASRSC) follows the USFWS Mitigation Policy for critical Atlantic salmon habitats, which require no net loss of in-kind habitat value. "In-kind" is interpreted to mean of a similar type (i.e. spawning habitat, parr nursery area) within the same watershed. The ASRSC does not consider the stocking of hatchery reared Atlantic salmon to be an acceptable substitute for losses of Atlantic salmon spawning and nursery habitat resulting from the construction of a new dam or major modification to an existing dam. The ASRSC recognizes that there may be extraordinary circumstances under which exceptions to this mitigation policy may be warranted. For less critical habitat types, the ASRSC may consider alternative mitigation proposals on a case specific basis and weigh the balance between resource values lost and benefits gained to the Atlantic salmon resource and fishery use opportunity.

Mitigation for losses of substantial amounts of significant fisheries or wildlife habitat or public resource use opportunity will be recommended by IF&W. The type and amount of mitigation may require use of formal studies such as the Habitat Evaluation Procedure as developed by USFWS, to evaluate the overall habitat value lost and to provide a comparative basis for proposed replacement.

Minimum flows. According to the MWDCA, "no person may initiate construction or reconstruction of a hydropower project, or structurally alter a hydropower project in ways which change water levels <u>or flows</u> above or below the dam, without first obtaining a permit" (38 MRSA §633(1)) (emphasis added). Permits may be conditioned to provide for "establishment of instantaneous minimum flows for the body of water affected by the a hydropower project" (38 MRSA §635(1)(B)).

State law regarding alteration of rivers, streams and brooks requires that dredging, filling and construction not "unreasonably interfere with the natural flow of any waters".

Stream flow has both biological and aesthetic considerations. Instantaneous minimum stream flows are essential to the maintenance of healthy aquatic communities. Water use associated with hydropower projects is often deleterious to fishery resources and other aquatic communities. Hydropower projects are often developed and operated to provide for energy production as system demand requires and are programmed in terms of average discharge from a dam, which may involve wide fluctuations of flow over a period of time. As far as fish and other aquatic organisms are concerned, even short periods of flow below a habitat-sustaining minimum quantity can be harmful. Therefore, instantaneous flow, the flow at any given time, should not be less than a determined suitable minimum. Atlantic salmon require an instantaneous minimum flow in order to maintain habitat productivity. Likewise, periodic flushes of high flows, followed by quick reduction to low flows, may disrupt normal aquatic organisms, reduce habitat productivity and affect fish behavior.

Fish and other aquatic organisms have adapted to natural seasonal changes in streamflows. Low flows which occur during summer, combined with warm water temperatures, are generally considered to cause periods of greatest stress on aquatic organisms in Maine waters. Requirements for maintenance of an instantaneous minimum flow which does not degrade aquatic habitat below natural summer low flow conditions will be recommended to sustain these organisms. Higher flows may be desired for certain periods for protection of certain life stages such as during spawning, egg incubation, or migration or to provide angling opportunity.

IF&W, DMR and the ASRSC endorse and will evaluate minimum flows based upon the Interim Regional Policy for New England Stream Flow Recommendations, developed by the USFWS. Basically, it recommends maintenance of at least an aquatic base flow which is the August median flow, unless a lower flow can be demonstrated to be biologically adequate to maintain aquatic organisms. An approximation of the median flow will be recommended on streams where inadequate gaging records exist for specific determination of the August median flow. This approximation has been calculated using historical flow records for appropriate regional unregulated streams and is 0.5 cubic feet per second per square mile of drainage area (cfsm) at the project. Higher flows may be recommended during spawning and incubation periods, for migration, or for optimizing angling opportunity. Whenever instantaneous inflow immediately upstream of the project is less than the aquatic base flow, outflow shall equal inflow.

Flows will generally be recommended in bypass channels if they contain significant productive Atlantic salmon or other fisheries habitat, angling opportunity or upstream and downstream fish passage. Gradual or phased changes (ramping) from generating to non-generating flows may be required to prevent stranding of fish as water levels drop below a project. Phased change from non-generating to generating flows (upramping) is also sometimes desirable during certain seasons (for upstream/downstream migration of diadromous fish). Both of these issues may require specific studies to develop recommendations.

IF&W, DMR and the ASRSC may request studies to develop site-specific flow recommendations. If desired, site specific studies may be performed by the project developer to demonstrate that fish and other aquatic organisms will be adequately protected by some other flow regime. Several techniques for field surveys and modelling of flow requirements have been developed. These are grouped under the title "Instream Flow Incremental Methodology" as developed by the USFWS and others.[125]

<u>KHDG Agreement</u>

[125] *Administrative Policy regarding hydropower projects*, Department of Inland Fish and Wildlife, Department of Marine Resources and Atlantic Sea Run Salmon Commission (summarized).

In anticipation of the expiration, during this decade, of many licenses for hydropower projects located on the Kennebec River, an agreement to address fish passage was reached in January, 1987 between a group of most of the relevant dam owners (CMP, Scott Paper Company, Pittsfield Hydro Company, Inc., and Benton Falls Associates) known as the KHDG, and the State. Under the so-called "KHDG Agreement," the KHDG agreed to provide a total of not more than $1.86 million in aggregate funding to facilitate the stocking and restoration of shad, alewives and Atlantic Salmon populations on the Kennebec River system in accordance with the Lower Kennebec River Anadromous Fish Restoration Plan and Inland Fisheries Management Overview. The KHDG Agreement established a twelve-year trap and truck program to initiate restoration efforts until fish passage facilities are built at dam sites. Edwards Manufacturing declined to participate making it more difficult to effectuate the State's goals for anadromous fish restoration in the Kennebec.

A portion of the funds provided by the agreement was earmarked for State-run, interim trap-and-truck operations. Another portion was designated for studies to determine upstream and downstream passage and habitat needs and efficiencies. As part of the agreement, the KHDG will provide immediate and interim downstream fish passage by passive means (controlled spills during migration periods, etc.) necessary to allow downstream migration until permanent downstream fish passage facilities can be installed. In addition, the agreement specified the dates when upstream fish passage would be required at specific dam sites. Specific aspects of the KHDG Agreement are as follows:

Interim Trap and Truck Operations.

a) Trapping of adult shad in the lower Kennebec or other suitable sites and transport to waters in the Kennebec system above the Augusta Dam;

b) Procurement of adult shad brood stock from the Merrimack or other suitable rivers and transport to waters in the Kennebec system above the Augusta Dam;

c) Trapping of alewives from the Royal River (or from other suitable locations chosen by the State) and transport to waters in the Kennebec system, above the Augusta Dam, which are described in Phase I of the State's modified plan;

d) Trapping of Atlantic salmon from Bond Brook in Augusta or from other suitable sites and transport to spawning areas in the Kennebec system above the Augusta Dam;

e) If the trap and truck operations described above become no longer practicable and effective, the program may be altered in order to provide trap and truck operations at other sites or to otherwise provide the most effective anadromous fisheries restoration effort for the waters described in Phase I of the State's modified plan;

f) It is the intent of the State and the KHDG that following the commencement of operations of a fish trapping or passage facility at Augusta, the shad, alewives and salmon acquired with the monies received under this Agreement shall be dedicated to stocking upstream of such facility, and additional fish shall be secured and transported with such moneys from other locations only as a second priority.

Studies. The KHDG Agreement also provided funds for studies to determine upstream and downstream fish passage and habitat needs and efficiencies, as follows:

a) Studies necessary for the determination of appropriate downstream fish passage facilities at dams on the Kennebec system owned by KHDG members;

b) Studies which will be undertaken by the State in the context of the State's modified plan, as follows:

- The number and species of fish trapped at the Augusta Dam will be monitored by the State to determine population sizes and trends throughout the period of trapping and trucking operations at that site;

- The State will sample stocking areas above Augusta to determine the growth rates of juveniles produced from the adult stocking program;

- The State will make such other studies, including those related to upstream fish passage needs, as it deems necessary to the restoration of anadromous fisheries in the Kennebec system.

Downstream Passage. KHDG agrees to provide interim downstream fish passage (e.g., controlled spills during downstream migration periods, the installation of temporary downstream fish passage facilities or other feasible measures) necessary to allow downstream fish passage at each of its dams above which anadromous fish have been stocked in accordance with Phase I of the State's modified plan. Such efforts shall continue until permanent downstream fish passage facilities are installed and operational.

Stocking. No shad or alewives will be stocked above the Lockwood Dam in Waterville before 1993. Notwithstanding the preceding sentence, the State in its discretion may undertake experimental stocking above Lockwood but such stocking shall not effectuate the obligation to install downstream passage pursuant to the terms of this Agreement. If shad or alewives are stocked above Lockwood after 1993 but before the installation of permanent fish passage facilities then temporary downstream passage facilities shall be provided in accordance with the previous section.

Sebasticook River. By December 31, 1991, permanent downstream fish passage facilities, approved by State and federal fisheries agencies, shall be installed and operational at all KHDG-owned dams downstream of locations on the Sebasticook drainage where anadromous fish have been stocked in accordance with Phase I of the State's modified plan.

Permanent Fish Passage. Except as provided in the previous section, permanent upstream and downstream fish passage facilities, approved by State and federal fisheries agencies, shall be installed and operational at the following dams in accordance with the schedule and conditions identified in .

Schedule for Completion of Fish Passage Facilities

Project	FERC #	Date	
Lockwood	2574	May 1, 1999	
Hydro-Kennebec	2,611	May 1, 1999	
Shawmut	2,322	May 1, 2000	
Weston	2,325	May 1, 2001	
Halifax	2,552	May 1, 1999	-- upstream passage*
Benton Falls	5,073	May 1, 1999	-- upstream passage*
Burnham Hydro		May 1, 2000	-- upstream passage*

** Permanent downstream passage requirements are provided under the previous section*

Implementation of the KHDG agreement, through amendment of the licenses in question by FERC, was slowed by appeals from groups that alleged a lack of a biological basis for the schedules described in the agreement and the procedures used by FERC in amending licenses. These groups further contended that the State acted inappropriately in attempting to make decisions regarding passage outside the context of imminent relicensing. In 1990, FERC granted intervention and stayed amendment of the relevant licenses to include the provisions of the KHDG agreement. On October 22, 1992, FERC denied a request for rehearing and let stand staff orders amending project licenses to incorporate the KHDG agreement. However, during the delay, restoration of fisheries on the Kennebec has proceeded. To date, DMR has completed the fifth of a twelve-year interim trap-and-truck program for shad and alewives on the upper Kennebec River.

***Restoration under KHDG to date*.**

Alewives. The introduction of alewives to the Kennebec basin during the first five years of the KHDG program is summarized in .

Summary of Adult Alewives Stocked above Augusta

Pond	**# of Alewives stocked**				
	1987	**1988**	**1989**	**1990**	**1991**
Douglas Pond	2,286	3,099	3,257	2,959	3,150
Lovejoy Pond	1,949	2,055	1,741	2,077	1,976
Pattee Pond	4,031	3,393	4,363	3,919	4,327
Pleasant Pond	2,688	2,648	4,614	3,475	4,689
Plymouth Pond	2,797	3,027	2,925	2,530	2,921
Sebasticook Lake	12,099	14,850	24,966	11,166	21,030
Unity Pond			3,301	559	4,632
Lake George					2,030
TOTAL	25,850	29,072	45,167	26,685	44,755

Juvenile alewives were sampled or sighted in each stocked pond in 1987, 1988, and 1990. In 1989, juveniles were sighted in all ponds except Lovejoy Pond which suffered severe algal blooms, hampering sampling efforts. The migration of these juveniles was monitored at several hydropower facilities. The data indicate that successful reproduction is occurring as a result of brood stock introductions.

Shad. The introduction of shad to the Kennebec basin during the first five years of the KHDG program is summarized in .

Summary of Adult Shad Stocked above Augusta

No. of shad stocked	**Year**
199	1987
616	1,988
619	1,989
604	1,990
639	1,991

No shad have been recovered in sampling of the impoundment above the Edwards Dam. One juvenile shad was recovered in the impoundment in 1988 and one in 1989. However, the numbers of juvenile shad captured in the headpond may not be indicative of the success of reproduction of transferred adults.

Atlantic Salmon. The transportation of Atlantic salmon above the Edwards Dam during the first four years of the KHDG program is summarized in .

Adult Salmon Passed above the Augusta Dam

No. of Atlantic salmon stocked	Year
1	1987
17	1,988
14	1,989
0	1,990
0	1,991

The Kennebec River currently has a small population of Atlantic salmon below the Augusta dam, composed of hatchery strays from other rivers, as well as wild fish originating from tributaries below Augusta. The salmon runs in the Kennebec below Augusta are of uncertain magnitude, but are believed to number less than 200 adults in most years. Those salmon present in the Kennebec support a significant fishery located below the Augusta dam. In 1990, the Kennebec River had the second largest rod catch of Atlantic salmon of any river in the State of Maine. In 1990, dozens of salmon were visible swimming in the vicinity of the Edwards Dam, however, none were captured by the fish pump. It had also been planned to capture Atlantic salmon at the mouth of Bond Brook and stock them above Edwards Dam. However, this plan was aborted at the advice of the ASRSC which felt that the intensive handling necessary when beach seining these fish would result in delayed, if not immediate mortality. In 1990, as many as 60 salmon were sighted by DMR personnel at the mouth of Bond Brook. Poaching and molestation did not appear to be as large a problem as in the past; the salmon were left undisturbed and moved in and out of the mouth of the brook with the changing tides126 127

Inland Fisheries.

The goals for the management of inland fisheries are as follows:

-- maintain optimum population levels of freshwater fishes and associated aquatic species;

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[126] *Atlantic Salmon Management in the Kennebec River: A Status Report and Interim Management Plan.* Atlantic Sea-Run Salmon Commission.

[127] *Kennebec River Anadromous Fish Restoration, Annual Progress Report 1990.* Maine Department of Marine Resources, 12/90, revised 2/91.

-- maintain optimum quality, quantity and diversity of habitat; and

-- provide for optimum and diverse uses of freshwater fishes for sport fishing, esthetic, economic, ecologic, scientific and educational purposes.

During the mid 1960's, studies were undertaken by biologists of the Maine Department of Inland Fisheries and Game (now IF&W) to provide the Department with information on the river's inland and anadromous fishery resources. These studies led to the publication of *Fish Management in the Kennebec River*. This publication addressed potentials within the drainage for a variety of sport and commercial species, taking into account problems facing the Department in developing and realizing the full potential for fish management in the drainage.

Fortunately, water quality in the main stem of the river and many of its tributaries has noticeably improved through the efforts of DEP with cooperation from industries and municipalities. Water degradation from wood bark deposits associated with log driving has also been greatly reduced with the termination of log driving in the Kennebec. Water quality in the Kennebec River above the Edwards Dam in Augusta is presently suitable for the management of several species of inland and anadromous fish. Dissolved oxygen levels in the main stem and its principal tributaries are now adequate to support fish life. Oxygen levels of 5 p.p.m. or higher now occur during periods of warm weather and low flow, a noticeable improvement since the 1960's.

Mainstem Waters

East Outlet. Although brook trout and lake trout are caught in the East Outlet in certain places, and at certain times, the river provides the best season-long (May-September) fishing opportunities for salmon. All brook trout and lake trout are wild fish. Although some of the salmon are wild fish, stocking in Moosehead Lake and Indian Pond contribute significantly to the fishery.

A submerged orifice fishway located in the center of the East Outlet Dam allows fish passage upstream from the outlet into Moosehead Lake. Salmon, brook trout, lake trout, and at least six other species use this fishway.

Most fishing in the East Outlet is done from shore, or by wading. In recent years, however, some fishing from drift boats has occurred, and due to the river's characteristics this activity will likely increase in popularity in the future.

In 1990, recreational studies conducted by Land and Water Associates (for relicensing of Moosehead Project) determined that fishermen spent about 4,700 days on the East outlet, of which about 3,000 occurred on the one half mile of river immediately below the dam. Fishing comprised 64% of the total use recorded on the Outlet in the summer of 1990.

Specific fishery management goals for the East Outlet include maintaining or improving water quality and the quality of the habitat, increasing the production of wild salmon, maintaining or improving fishing quality, and maintaining traditional access opportunities.

West Outlet. The West Outlet provides traditional fisheries for wild brook trout and salmon, as well as for some stocked salmon that move into the river either from Moosehead upstream, or Indian Pond downstream. As a result of the illegal introduction of small mouth bass in the Moosehead Drainage in 1974, reportedly in the West Outlet area, bass are now well-established in West Outlet waters and are providing a significant fishery.

There is no fishway in the West Outlet Dam to allow fish passage upstream from the outlet into Moosehead Lake. Due to the limited amount of nursery habitat to produce salmonids in the West Outlet for Moosehead Lake, a fishway is not necessary there.

In May, there is often a concentration of adult salmon and some trout in the pool immediately below the West Outlet Dam. These fish sustain a fishery for only a short period. Total use by fishermen on the West Outlet is unknown, but estimated to be in the hundreds, rather than in the thousands.[128] Use is increasing, however, largely due to the presence of smallmouth bass which are providing a season-long fishery, as opposed to the very seasonal nature of the salmon and trout fisheries.

Specific fishery management goals for the West Outlet include maintaining water quality and the quality of the habitat, maintaining wild fish production and the quality of the fishery, and maintaining traditional access opportunities.

The lower Kennebec River has long served as a depository for domestic and industrial waste with serious consequences for water quality. Concomitantly, the river's gamefish populations, particularly the salmonids, have suffered greatly. Conditions became so bad in parts of the Kennebec that even the common carp (*Cyprinus carpio*), a species considered to be fairly tolerant of poor water quality, was frequently involved in major fish kills.

Poor water quality also affected the recreational value of this resource in ways less dramatic than the massive fish kills that drew immediate press coverage and public attention. Anglers dropped in number to those few who fished in the early spring or late fall or those who directed their efforts to the mouths of tributaries, or just below dams. In short, while large water bodies are frequently the center of recreational attention for the human communities on their shores, the Kennebec, because of poor water quality, fell out of favor and the people of the valley satisfied their desire for water-based recreation elsewhere.

[128] Land and Water Associates, 1990.

Yearly minimum dissolved oxygen values hovered near zero from 1959 through 1975 but increased rapidly thereafter. Upgraded water quality standards and improved waste treatment led to dramatically improved water quality in the Kennebec. Public interest in the river began to grow, albeit slowly. The lowest dissolved oxygen value recorded at the Augusta dam in August of 1987 was 7.8 ppm. This dramatic increase in dissolved oxygen levels is particularly important because maximum summer water temperatures in the lower Kennebec sometimes near upper tolerable limits for brown trout and browns are better able to withstand warm water temperatures if dissolved oxygen values are high[129]

Fish species occurring in this portion of the Kennebec are listed in .

Major Gamefish Species of the Lower Kennebec River

Common Name	Scientific Name
Landlocked Atlantic salmon	*Salmo salar*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Chain pickerel	*Esox niger*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
White perch	*Roccus americanus*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*

Weston Dam to Edwards Dam A brown trout management plan was instituted on an experimental basis in 1983. Evaluation of the program in 1987[130] led to the adoption of a revised management plan ( ). Angler participation in the brown trout fishery has grown steadily since the inception of the program. Most of the fishing effort is expended in the free flowing portions of the river in Skowhegan, Fairfield, and Waterville/Winslow. Recent data indicate that the plan's target values for catch rate and fish size have been met or surpassed ().

Data collected incidental to the evaluation of the brown trout management plan indicates substantial angler interest in a variety of warmwater gamefish species, particularly smallmouth bass. There is considerable potential for a high quality smallmouth bass fishery in the lower Kennebec and a smallmouth bass management plan specific to the Skowhegan to Augusta reach of the river is being developed at this time.

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[129] *Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout*. Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson, U.S. Department of the Interior, Biological Report 82[10.124], 1986.

[130] *Kennebec River Brown Trout Management*. MacNeish, J. Dennis, Maine Department of Inland Fisheries & Wildlife, Progress Report No. 1 (1983-1987), 36pp., 1987.

A petition by anglers in 1989 led to the establishment of a special management section in the portion of the river lying between Shawmut Dam and the Route 95 bridge in Fairfield. The primary management goal of the section is to increase fishing opportunity for "quality size" brown trout in a riverine section (). Although formal evaluation of the management plan will not begin until 1993, the program has been enthusiastically received by area anglers.

Kennebec River Brown Trout Management Plan
Mainstem: Weston Dam to Edwards Dam in Augusta

Goal: to establish an open water sport fishery for brown trout in a riverine setting.

Objectives:
- I. to increase riverine fishing opportunity in Fishery Region B
- II. to provide a catch rate of 0.20 legal brown trout per angler day of fishing
- III. to provide a mean size of 15.0 inches and 1.5 pounds per legal size fish caught

Management Strategies:
- I. Updated, complete habitat inventory
- II. Annual stockings of 10,500 spring yearlings
- III. Regulations
  - A. season
    - 1. open to open water fishing year round
    - 2. closed to ice fishing
  - B. daily bag limit of 2 fish of the salmon, trout, and lake trout species
  - C. minimum length limit of twelve inches
  - D. terminal tackle restrictions, general law

Summary of Sport Fishery Statistics Obtained from Angler Diaries and Creel Survey Boxes, Lower Kennebec River, 1990

Variable	Observation
Number of angler-days	866
Number of trips	528
Number of anglers/trips	1.64
Average trip length (angler-hours)	4.58
Number of brown trout caught	314
Brown trout caught/angler-day	0.36
Percent of browns kept	27.4%
Number of browns kept	86
Brown trout kept/angler-day	0.1
Percent of brown trout of legal size	45.9%
Number of legal-size brown trout/angler day	0.17
Average length of legal-size brown trout caught	16.7 inches
Number of bass* caught	544
Number of bass caught/angler day	0.64
Percent of bass kept	0.7%
Number of bass kept	4
Number of bass kept/angler day	0
Percent of bass of legal size	34.7%
Number of bass of legal size	189
Number of legal-size bass/angler-day	0.22
Average length of legal-size bass caught	13.8 inches

*Anglers often did not distinguish between largemouth and smallmouth bass; consequently, both species are reported as "bass." It should be noted, however, that bass caught in the lower Kennebec River are most frequently identified as smallmouths.

Kennebec River Brown Trout Management Plan
Special Management Section: Shawmut Dam in Fairfield
to the Route 95 Bridge in Fairfield

Goal: to establish an open water sport fishery for "trophy" brown trout in a riverine setting.

Objectives:
- I. to increase fishing opportunity for "trophy" brown trout in this reach of the river
- II. to provide a catch rate of 0.10 legal brown trout per angler-day of fishing
- III. to provide for a mean size of 17.0 inches and 2.0 pounds per legal-size fish caught

Management Strategies:
- I. Updated, complete habitat inventory
- II. Annual stockings of 2,000 spring yearlings to be marked with standard finclips
- III. Regulations
  - A. season
    1. open to open water fishing year round
    2. closed to ice fishing
  - B. daily bag limit of one fish of the salmon, trout, and lake trout species
  - C. minimum length limit of 16 inches
  - D. terminal tackle restricted to artificial lures only

The removal of the Edwards Dam would result in the extension of the range of carp in the mainstem of the Kennebec as far upriver as the next impassable barrier in Waterville. Carp prefer sluggish, warm, soft-bottomed, vegetated waters. With the dam removed the habitat in the area of the current impoundment would revert to an open river with relatively rapidly moving water in a series of riffles, pools, and runs; carp would not be expected to do well in this type of habitat. Therefore, it is unlikely that the upriver migration of carp as a result of removal of the dam would produce any serious consequences in the fish populations of the mainstem of the river. Of the important tributaries of the Kennebec below Waterville, only Seven Mile Stream does not have a barrier to upriver migration of carp. In the event of dam removal, Seven Mile Stream will require construction of a barrier to carp migration in order to protect this tributary from damage due to carp.[131]

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[131] *Kennebec River Brown Trout Management*, MacNeish, J. Dennis, Maine Department of Inland Fisheries & Wildlife, Progress Report No. 1 (1983-1987), 36pp., 1987.

Roach River

The upper one-half to three-quarters of a mile of the Roach River below First Roach Pond is the most heavily fished section. The main access road from Greenville bridges the river approximately 100 feet below the dam on the outlet of the pond. There is no fishway in the dam, therefore fishing is permitted from the dam and along both shores of the large pool below the dam. It is rare to drive past the area without seeing at least one angler trying his luck from the dam, the bridge, or at pool-side. The increase in fishing pressure at this site has reflected the overall increase in fishing pressure observed throughout the general area.

The upper section provides a summer-long fishery. The dam and the so-called "dump pool" and "stripping pool" are some of the deepest water in the river and provide excellent holding areas for adult salmon and trout. The more accomplished fly fisherman can, with some patience, bring a salmon to his net even under the harshest conditions of late July and August. We have observed very little fishing pressure in the remainder of the river until late in the season.

Cooling water temperatures and increases in flow associated with fall rains and lake drawdowns cause a dramatic change in the Roach River fishery. Mature brook trout and salmon begin their annual spawning migration into the river from Moosehead Lake. We believe that some salmon and trout within First Roach Pond are also attracted by the increased flow through the dam and pass downstream into the river. The timing of these movements is quite variable, beginning from as early as mid-August to mid-September. The September fishery has become increasingly popular in recent years. Fishermen have located several down-river sites where suitable adult holding areas provide fishing opportunity. Access to these sites is by foot trails maintained by the anglers using old skidder roads and game (moose) trails.

Because of the pattern of fishing (early morning-late afternoon) and the hardships involved with access, it has been impossible to design an efficient ground survey of the Roach River anglers given current manpower and financial limitations. For some of the same reasons, it has not been possible to conduct an aerial survey to determine total angler use on the Roach River. In the summer of 1984, creel survey boxes were placed at various sites along the river in an attempt to collect angler-catch and fish-size statistics. In June, two boxes were placed (one on each side of the river) at the access trails to the upper river pools in Kokadjo. A supply of survey cards requesting specific information was maintained at each site. The boxes were tended at least weekly and completed cards were removed. We observed much more angler use than the card returns would indicate. We feel that the early season card returns from these two sites may be highly biased by the more successful anglers. In September, two additional boxes were placed at downstream access points, one at each of two sites. Based on our observations of use at these sites, we believe that we may have received completed cards from a greater proportion of the downriver fishermen. These data may also be biased by the more successful fishermen. A summary of the survey results is given in .

Summary of Angler Catch and Effort Statistics from Voluntary Angler Reports
Summer of 1984

	June, July and August sample		September sample		Total season sample	
No. anglers surveyed	70		259		329	
Angler hours	171		1,179		1,350	
Number (and percent successful) in catching a legal:						
Brook trout	19	(27%)	107	(41%)	126	(38%)
Salmon	26	(37%)	112	(43%)	138	(42%)
Lake trout	0		3	(1%)	3	(1%)
Number of legals kept:						
Brook trout	7		49		56	
Salmon	11		47		58	
Lake trout	0		0		0	
Number of legals released:						
Brook trout	21		94		115	
Salmon	25		115		140	
Lake trout	0		3		3	
Number (and percent) of sublegal fish:						
Brook trout	24	(46%)	35	(20%)	59	(26%)
Salmon	26	(42%)	75	(32%)	101	(34%)
Lake trout	---		---		---	
Legals kept per angler:						
Brook trout	.100		.189		.170	
Salmon	0.16		0.18		0.18	
Mean length (mm) of legals kept (and number reported):						
Brook trout	300	(3)	423	(43)	415	(46)
Salmon	476	-10	476	-46	476	-56

Based on the card survey, the percent of successful anglers is very high for the entire season (about 40%). Survey data collected from voluntary record books for 1981, 1982, and 1983 indicates a success rate somewhere between 20 and 30%. Very limited clerk survey data from 1979 and 1981 indicate an even lower, more realistic success rate in the 15 to 20% range.

The proportion of sub-legal salmon in the catch is quite constant at about 30 to 35%. The majority of the sub-legal salmon are reported as parr-size fish. The proportion of sub-legal brook trout in the 1984 card survey is unusually high. The legal length limit for brook trout is 6 inches. Lengths were not reported for all "short" brook trout, and it is likely that many small legal trout were released and reported as "shorts".

The Roach River between First Roach Pond and Moosehead Lake is being managed to maximize its parr production to Moosehead Lake. In order to minimize losses due to hooking mortality, the fishing method has been restricted to fly fishing only. The successful release of legal-size fish is also aided by the restriction. The daily bag limit on the Roach River has varied over the past, but in 1984 was reduced to one fish per day. This new limit applies to the entire season. Prior to 1984, the daily bag limit from May 1 to September 15 allowed an angler to possess 2 brook trout, 2 lake trout (very few are caught) and 1 salmon, for a total of 5 in the aggregate. Recent improvements in the growth and numbers of salmon and trout at Moosehead Lake have produced corresponding improvements in the quality and quantity of those species in the Roach River spawning runs. When conditions (temperature, flow, etc.) attracted salmon and trout into the river before the 15th of September, there was a potential for too great a harvest of the large, mature fish. With the dramatic increase in the number of anglers fishing the river, we felt it was necessary to restrict the catch over the entire season. These regulations allow for the catching of salmon and trout and the harvest of a limited number of each helps to assure sufficient escapement for spawning under the present conditions.

There is only a little information available concerning the fishery in the section of river between Second Roach Pond and First Roach Pond, and the section above Second Roach Pond. Neither section has been surveyed to determine the quality of its fishery. Various comments within the correspondence on file concerning the old dam at the outlet of Second Roach Pond indicate that a limited seasonal fishery for brook trout and salmon existed in the large outlet pool, at least through the early 1960's. There is no evidence that a significant summer fishery ever developed in the river between Second Roach Pond and First Roach Pond. One of the previous owners of the sporting camp at the outlet of Second Roach Pond stated that he was able to locate and catch a few adult salmon within this section in early September during some years. In recent years these fish were probably mature salmon moving upstream from First Roach Pond. Both sections of the Roach River above First Roach Pond are closed to fishing after the 15th of September, therefore, late season spawning run fisheries were never permitted. These upper sectionsare relatively small and offer little suitable adult salmon holding areas. Likewise, the number of suitable fishing sites (for salmon) would accommodate only a few anglers. Both upper sections of the Roach River do offer an early season fishery for brook trout.

The lower reaches of all three river sections provide an abundance of excellent smelt spawning habitat. Smelts provide an essential forage in waters where salmon occur. The smelt is also actively pursued by legions of spring "dippers" who are permitted to dipnet (2 quart limit) spawning adults in streams. The section of the Roach River that enters into Moosehead Lake has a tremendous potential to produce smelts to the lake. Since salmon are being intensively managed at Moosehead Lake, all smelt spawning runs have been closed to fishing in order to protect this important source of forage. We have not yet been able to document a smelt spawning run in the river between Second Roach Pond and First Roach Pond; however, the early season concentration of salmonids at the mouth of North Inlet (Roach River) is consistent with our observations of known smelt spawning runs. Because of its relative inaccessibility, this run has not been closed to the taking of smelts. The Roach River, tributary to Second Roach Pond, supports a large smelt run which is open to the dipping. Our management of Second Roach Pond is aimed toward providing a brook trout fishery. Because brook trout are not dependent upon smelts for growth, we feel that allowing the taking of smelts from this section of river will have no adverse effects on the pond management.[132]

Moose River

The Maine Rivers Study identified the Moose River as having a highly significant recreational fishery.

No. 1 Brook to Holeb Stream: A principal fishery for wild brook trout, with a secondary fishery for wild salmon (although salmon stocked in Holeb and Attean Ponds can move upstream into this section). Fishing from shore or by wading are the most practical means to fish this section. Present use by fishermen is unknown.

Holeb Pond is a large, shallow, productive pond whose principal fishery is brook trout and salmon. However, large populations of yellow perch, suckers, and minnows severely limit the coldwater fishery. Periodically, IF&W stocks the Pond with salmon. Lake trout were stocked on an experimental basis in 1986. The small area of deep water does not have enough dissolved oxygen below 25 feet for optimum conditions. Other species present include smelt, burbot (cusk), sticklebacks, sunfish, and sculpins. Holeb Pond is open to ice fishing.

The section of the Moose River within the Holeb Management Unit contains diverse habitat which is not only important to the seasonal river fishery, but also to the fisheries of the surrounding ponds. A large portion of the native populations of salmon and brook trout in Holeb and Attean Ponds are sustained by natural reproduction in the Moose River. Some sections of the River are fast moving with a mixture of riffles, boulders, and pools. These sections provide suitable spawning, development, and parr habitat for native salmon. Other sections of the River are slow and meandering with sandy substrate and pools as deep as fifteen feet. These areas can provide cover and cooler water for adult fish in the River.[133]

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[132] *Roach River Strategic Plan for Fisheries Management*. Roy, S., Maine Department of Inland Fisheries and Wildlife for the Land and Water Resources Council, November 1985.
[133] *Holeb Unit Management Plan*. Maine Department of Conservation, Bureau of Public Lands, December 1989.

Holeb Stream to Attean Pond: A principal fishery for wild brook trout, with a secondary fishery for both wild salmon and salmon stocked in Holeb and/or Attean Ponds. Most of the fishing in this section is done from canoes. Shore fishing opportunities are limited to the sections with quick water: mainly around Holeb Falls, Spencer Rips, and Attean Falls. In 1989, a survey by Land Vest and the Bureau of Public Lands indicated that total use on the Bow Trip was about 3,100 days. Fishing probably comprised at least 50% of that total use.

Attean Pond contains native populations of brook trout and salmon. Periodically, hatchery-reared salmon are stocked by IF&W to supplement the existing population. However, large areas of shallow water provide marginal habitat for these coldwater gamefish during the summer months. Only about 600 acres of the Pond have water deeper than twenty feet. Large populations of yellow perch, suckers, and minnows compete with coldwater species. Lake trout are occasionally found in Attean Pond. These fish have moved upstream from Big Wood Pond where they have been stocked by IF&W. Other species in Attean Pond include smelts and burbot (cusk). Attean Pond is closed to ice fishing.

Attean Pond to Big Wood Pond: As the Moose River provides a thoroughfare between these two waters, the fishery in this section is influenced by the fisheries in both. Principal species are wild brook trout, wild and hatchery salmon (stocked in both Big Wood and Attean), and splake stocked in Big Wood. Nearly all of the fishing is done from boats, as shore fishing opportunities are very limited. Most fishermen who use this section also do some fishing in either Big Wood or Attean as well. Total use at the present time is unknown.

Big Wood Pond to Long Pond: A principal fishery for salmon (mostly fish stocked in Big Woods), wild brook trout, and splake that drop down from Big Wood. Except for some shore fishing opportunity immediately downstream from Big Wood, fishing in this section must be done from boats or canoes. Total use by fishermen is unknown.

Long Pond to Brassua Lake: A principal fishery for wild salmon (though some stocked fish may move down from Big Wood or up from Brassua) and wild brook trout. Most of the fishing opportunity is from shore or by wading, except in upper sections where some fishing from a canoes occurs. Total use by fishermen is unknown.

Fishery management goals for the above five sections of the Moose River include maintaining water quality and the quality of the habitat, maintaining the production of all wild fish populations and contributions from hatchery fish, and maintaining both fishing quality and traditional fishing opportunities.

Brassua Lake to Moosehead Lake: This section of the Moose River provides an attractive and very popular fishery for both salmon and brook trout. Lake trout are also caught occasionally. All brook trout and lake trout are wild fish. The salmon fishery is comprised of wild fish, as well as hatchery fish stocked in both Moosehead Lake and Brassua Lakes.

As both white perch and smallmouth bass are established in the drainage downstream from Brassua Dam, and neither species is desireable upstream, there are no provisions for fish passage upstream through Brassua Dam.

Most (85%) of the fishing in the upper mile of this section is either from shore or by wading; the remainder from canoes. Nearly all of the fishing in the lower two miles is from either boats or canoes. From 198891, total estimated use on the upper mile of river has ranged between 2,000 and 2,500 days of fishing.

Specific fishery management goals for this section of the Moose River include maintaining or improving water quality and the quality of the habitat, maintaining or increasing the production of wild salmonids, maintaining or improving fishing quality, and maintaining traditional fishing access opportunities.

Management plans for the Roach River and Messalonskee Stream

Specific management plans have been developed for the Roach River and Messalonskee Stream.

Roach River. The management goals for the Roach River between First Roach Pond and Moosehead Lake are to maintain or improve the quality of habitat, maximize the number of young landlocked salmon and brook trout produced naturally, and maintain the quality of the fishery for salmon and brook trout, especially late season runs of adults. The management goals for the river sections above both First Roach Pond and Second Roach Pond are to maintain or improve the quality of the habitat, the number of young salmon and brook trout produced there, and the present quality of the fisheries for salmon and brook trout.

Management Objectives--

The management objectives for the Roach River between First Roach Pond and Moosehead Lake are:

- to maintain the integrity of the river bottom, its banks, and its water quality;

- to maintain production of young landlocked salmon and brook trout at or above present levels;

- to maintain or improve fishing opportunity; and

- to provide for angler success which allows both catch and harvest commensurate with the ability of the runs of salmon and trout to support this use with adequate escapement for spawning.

The management objectives for the two river sections above First Roach Pond are the same as stated above.

Management Problems--

1. Limitations on funds and personnel have prevented detailed study of the fishery for the determination of:

    - size of adult spawning runs
    - annual production of young
    - maximum sustainable yield
    - current total angler use and harvest

- optimum allowable harvest

2. Lack of adequate funds and personnel has also precluded needed stream improvement.

3. The apparent rapid increase in angler exploitation of the salmon and trout population may in the future exceed the capacity of the river to sustain the current high quality fishery and allow adequate spawning escapement to Moosehead Lake.

4. The presence of yellow perch, and the potential establishment of smallmouth bass and white perch threatens the brook trout fishery of Moosehead, and thus of the Roach River, and precludes the use of a fishway in the First Roach Pond dam.

5. Because of the limited number of pools, angler use is concentrated in a few areas of the river, causing congestion and undesirable interaction among anglers.

6. The remnants of old dams above First Roach Pond are partial barriers to migration.

***Management Strategies*--**

1. Maintain a minimum flow agreement of 75 cfs in the river between First Roach Pond and Moosehead Lake.

2. Obtain free, unobstructed fish passage in the two river sections above First Roach Pond by requesting complete removal of the remnants of the two old dams.

3. Assure the continued integrity of the river's bottom, its banks and its water quality through strict adherence to LURC and DEP standards, and support the re-zoning of all sections of the river by LURC to P-RR.

4. Maintain a barrier at the First Roach Pond dam to prevent the upstream migration of yellow perch, smallmouth bass, and white perch.

5. Maintain as first priority the management of all sections of the river for salmon and brook trout spawning and nursery.

6. Initiate a periodic sampling schedule (trap-netting) to determine the number, fish size and timing of the salmon and brook trout spawning runs.

7. Continue population estimates (electrofishing) of salmon parr and expand the number of sampling sites to represent a greater proportion of the river.

8. Discontinue the special extended fall season (September 1-30) if excessive removal of adult salmon and brook trout has an adverse effect on natural reproduction.

9. Investigate the possibilities of managing the extended season fishery by manipulating the timing and composition of fall runs of adults through water level management.

10. Maintain the integrity of the wild salmon and brook trout populations of the river by continuing the policy of not stocking in or near the river.

11. Investigate the feasibility of constructing and operating a "blind" fishway at the First Roach Pond dam.

12. Negotiate and maintain an agreement (currently informal) with KWPC regarding drawdown dates for First Roach Pond (October 15) and a date (November 1) when normal flow (75 cfs or inflow) would be resumed.

13. Maintain a low bag limit (1 fish per angler per day).

14. Maintain terminal gear and fishing method restrictions of fly fishing only.

15. Adjust length limits to conform to any length limit changes on Moosehead Lake.

16. Improve fishing opportunity through stream improvements to provide adult salmon and brook trout holding pools where physical alternations would not adversely affect nursery habitat.

17. Initiate a survey to determine total angler use and harvest with particular emphasis on the September fishery.

The order in which the above strategies are listed is in no way intended to imply priority of one strategy over another134

*Messalonskee Stream.*Messalonskee Stream has excellent production of black bass, the perches, pickerel, and hornpout. Natural events and flowage drawdowns temporarily displace the warmwater fishery until it is replaced either naturally or through stocking. Migration from above may be the most significant contribution to both the salmonid and warmwater fisheries in the upper four reaches between dams. The lowermost reach is probably supported by both dropdowns from above and migration upstream from the Kennebec River.

Stocking of brown trout at Messalonskee Stream appears to provide a moderate fishery. Other fish species contributing to the fishery of the area are the baitfishes, golden shiners, and silvery minnows. Production of these fishes is substantial and bait dealers take advantage of this resource.135

Recommendations for Messalonskee Stream include: 1) maintaining an annual stocking of brown trout at a rate of 150 fall yearlings in the Rice Rips Pond and 100 fall yearlings in flowage above the Automatic and Union Gas dams, and 2) maintaining flowage water levels at full bank to assure warmwater fish populations (allowing for temporary disturbances during dam inspections).

Certain of the lakes and ponds of the Kennebec River that lie within the area proposed for restoration of alewives support a wide variety of gamefish species including landlocked salmon, brook trout, brown trout, and lake trout, among others. The interaction of anadromous alewives with salmonids, smelts, and other inland fish is being assessed through a cooperative research project sponsored by DMR and IF&W. Based upon the results of these studies a cooperative decision will be made regarding future alewife introductions into certain waters.

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[134] *Roach River Strategic Plan for Fisheries.* Maine Department of Inland Fisheries and Wildlife, November 1985.

[135] *Messalonskee Stream Fishery Management Plan.* Woodward, William, Maine Department of Inland Fisheries and Wildlife, 6pp., 1989.

The introduction of alewives may also benefit freshwater gamefish. For example, in riverine situations, where smelts usually are not a significant part of the diet of coldwater gamefish, young alewives might provide forage for river dwelling salmonids. IF&W has recently initiated an experimental brown trout program in the lower reaches of the Kennebec River between Augusta and Skowhegan. The initial phase of the project, which began with the first stocking of browns in the spring of 1983, is designed to determine if browns can survive in the river and provide fishing for a minimum of two angling seasons. Since the long term goal of this project is to provide a brown trout sport fishery with a catch rate of 0.20 trout per angler day and an average size of 1.5 pounds per fish, it is obvious that a good growth rate is essential to the program's success. Young alewives, migrating from upriver lake systems, will be available as forage for browns that occupy the river. In fact, juvenile alewives might be the most abundant forage in the lower Kennebec from late July into October and it is hoped that they will enhance brown trout growth.

IF&W's primary management goal for the lower Kennebec River is to provide an open water fishery for brown trout. Increased fishery management activity in the Kennebec is a result of the overall goal for management of brown trout. This goal calls for increased abundance and fishing opportunity for brown trout in IF&W's administrative management regions A and B. The lower Kennebec is located in region B. This region has the second highest human population of the IF&W's seven administrative regions but just 4% of the supply of brown trout riverine fishing opportunity. IF&W's management goal for sea run brown trout is also to increase abundance and fishing opportunity136

[136] *Second Stage State Agency Comments on the Augusta Hydroelectric Project.* Maine State Planning Office, September 1991.

The restoration of anadromous fishes to the Kennebec River should play an important role in maximizing the river's sport fishery potential.[137]

Recommendations.

The State should contine to work with dam owners and landowners in the Kennebec basin to maintain access for fishing in all waters and to provide flows that maintain or enhance fishing opportunities.

The Edwards Dam is the first obstruction encountered by sea-run fish making their way up the Kennebec River to spawn. As such, it is the greatest obstacle to restoration of the Kennebec's fisheries resources and must be removed. It should be noted that one of the major reasons for designating the lower Kennebec and Merrymeeting Bay as an outstanding river segment (see page 9) is because of the diversity and uniqueness of anadromous fish resouces in the lower river. These anadromous fish resources are significantly dependent upon spawning habitat above the Augusta dam. As a head-of-tide dam on a major river, Edwards Dam is a serious obstacle to anadromous species which spawn above head-of-tide. These species, which include shad, alewives, Atlantic salmon, striped bass, rainbow smelt, and Atlantic and shortnose sturgeon, historically have spawned in the river stretch between Augusta and Waterville. While fish passage facilities would allow some alewives, shad, and Atlantic salmon to get above head-of-tide, unavoidable fish loss would still occur. To restore to their historical ranges those species which do not use fish passage facilities, including striped bass, rainbow smelt, Atlantic and shortnose sturgeon, the dam will have to be removed.

Riverine angling opportunity is scarce in central Maine in comparison to lake fishing. Few other areas are available for increasing angling opportunities for salmon and striped bass. Potential riverine fishing opportunities are outlined in "Description of the Kennebec River between Augusta and Waterville Prior to Construction of the Augusta Dam."[138] Removal of the Edwards Dam will result in a substantially improved recreational fishery, the economic value of which will more than offset economic benefits lost due to dam removal. The economic value of a Kennebec River fishery is generated from two sources, both of which are directly related to the use of the river for fishing purposes:

1. Users of the river for fishing purposes expend dollars for goods and services to support their fishing activities, dollars which flow into the local economy and create income for their recipients.

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[137] *Lower Kennebec River Inland Fisheries Management Overview.* Maine Department of Inland Fisheries and Wildlife, 1986.

[138] *Description of the Kennebec River between Augusta and Waterville Prior to Construction of the Augusta Dam.* Squiers, T.S., and King, Maine Department of Marine Resources, 1990.

2. Fishing, itself, is an activity which is valuable to those who participate. First, the catch has economic value both to recreational and commercial fishermen and may represent a source of income. Second, the sport is enjoyable and hence of value to those who participate.

Thus, the sources of economic value associated with breaching the Edwards Dam and developing a world class fishery on the Kennebec River are: the value of the expenditures of those who partake of this fishery, the value of the catch from the fishery; and the value of the fishing experience to those who participate. It is methodologically incorrect simply to add these three sources of economic value to arrive at the total economic value of the Kennebec River without the Edwards Dam, since each of these indicators measures something slightly different. Each must be treated separately.

There is no available data related specifically to the Edwards Dam which measures the total expenditures of anglers while fishing on the Kennebec River in or around Augusta. The best data available is reported in Boyle's 1988 study "Economic Values for and Uses of Maine's Inland Fish and Wildlife." Boyle's findings indicate that the average expenditure per day for freshwater anglers is $4 for residents and $25 for nonresidents, and the total fishing related expenditures in Maine in 1980 were $93 million, which, when inflated by the Consumer Price Index, translates into approximately $146 million today. Based upon this total statewide expenditure, it seems reasonable and probably conservative to estimate that an established high-quality fishery on the Kennebec River would increase this total by 1.5% or by approximately $2.2 million. This, in turn, would generate a total increase of $3.5 million, based upon a multiplier of 1.6, much of which would remain in the Augusta area. (Of course, this number can be increased by actions taken by the State and by the City of Augusta to maximize utilization of the river and capitalize on this utilization. In this regard, this is similar to a highway. In order to receive the full economic potential of the highway, a municipality must develop a strategy to take full maximum advantage of the economic activity the new highway will generate.)

The potential value of the fish taken from the Kennebec River is similarly difficult to estimate since it will depend on the numbers of fish of various species supported by the Kennebec without the Edwards Dam, the harvest rate of fishermen, and the price of the various species harvested. Firm numbers are not available at this time for the Kennebec River, although historical accounts suggest that the river can support very large runs of alewives, shad, salmon, striped bass, and sturgeon. In 1984, DMR estimated that a commercial fishery for shad alone could generate in excess of $250,000 a year in 1984. This number should be compared with the results of a very extensive study of shad restoration on the Susquehanna River which found that a restored population of 3 million shad would result in economic benefit to the area of $64 to $263 million over a 50 year period.

The value of the Kennebec River to those who use it for fishing is the most difficult of the three sources of value to estimate. Conceptually, this value is best thought of as the amount these fishermen would be willing to pay to create the fishing experience on the Kennebec River. This value goes by a number of different names including "consumer surplus" and the "value of a unit day," and this value can be significant. In 1985 the U.S. Forest Service estimated the value of a variety of recreational activities. Anadromous fishing in the northeast was valued at $38/day (as compared to $35/day for downhill skiing). When this value is multiplied by an estimate of the number of user days on the Kennebec River, the result is an estimated value of $6.7 million per year.

A recent draft report, "Economic benefits Accruing to Sport Fisheries on the Lower Kennebec River from the Provision of Fish Passage at Edwards Dam or from the Removal of Edwards Dam" by Kevin Boyle et al, 1991, concluded that anglers do not value improved fisheries resulting from the removal of the Edwards Dam. This report has a fatal shortcoming which limits its relevancy to a decision regarding Edwards Dam. Dam removal will create an entirely new fishery environment, one not effectively evaluated by surveying current anglers. Contingent valuation analysis has been thoroughly studied in situations where an amenity is to be removed or lost, as for example in a situation where a dam will eliminate opportunities for rafting or where fiscal pressures may necessitate the closing of a public park. However, there is no literature -- and the author fails to cite any examples -- which discusses the use of this technique in instances where a new amenity will be created. The problem is that individuals have little or no basis for determining the economic value of something which does not exist -- whether that something is a new fishery, highway, park or radio frequency. And without such an ability to evaluate the nonexistent, contingent valuation analysis will always underestimate the economic value of potential future amenities.

This is especially true for natural resource amenities. Today, we praise the foresight of our forefathers who set aside acreage in our metropolitan cities -- the Public Gardens and Boston Commons, Central Park, and Grant Park -- and who reserved vast tracts of wilderness areas -- Teddy Roosevelt and Governor Baxter, for example. Yet, had we applied contingent valuation analysis prior to taking those steps, total economic values would have been much lower than they are today and may have argued against going forward, simply because those surveyed would have had very little understanding of what resource would be created, how they might use that resource, and how they might benefit from its existence.

As a result of balancing the gain in anadromous fisheries, recreational activity and the resulting economic benefit to the Augusta area, against the loss of 3.5 MW of renewable energy (the loss of which will actually lower electricity costs and rates in Maine through 1998) and other potential negative impacts of dam removal such as the introduction of carp above Augusta, changes in the shoreline and wetlands in the area of the impoundment, loss of water fowl habitat, and loss of a flatwater recreational resource, it is concluded that the proposed relicensing of the Edwards Dam should only proceed within the context of the assured and eventual removal of the dam.

RECREATIONAL AND SCENIC RESOURCES

Recreation and Access Opportunities.

Upper Kennebec Basin to The Forks

The Maine Rivers Study identifies the upper Kennebec, Dead River, Carrabasset River and the Moose River as outstanding recreational resources (the State's most significant), the first three for white water boating, the latter for canoe touring.[139]

According to the Maine Rivers Study, the following segments of the Kennebec basin have unique and/or significant scenic value: the Dead River, the mainstem from Augusta to the Harris Dam, the Sandy River, and Moxie Stream.[140]

In addition to its own inherent qualities, the Moose River's recreational significance lies in its contribution to the Bow Trip. That trip can be characterized by a unique blend of lake paddling/fishing/camping on scenic Attean and Holeb Ponds and flatwater paddling on the river below Holeb, spiced with the grandeur of Holeb Falls, an abundance of wildlife, and long range views of mountain scenery.[141]

Goals for management of the Bow Trip will be to: 1) protect the associated resource values; 2) provide adequate signs, campsites, trails, and informational materials to meet the backcountry recreational needs; and 3) ensure that recreational use is done within the management framework of the private landowners.

Lowell and Company own most of the Attean Pond shoreline -- including a number of popular campsites, and most of the portage trail between the Ponds. The Forest Society is responsible for ensuring that certain conservation deed restrictions are complied with on Lowell and Company's land. The company that manages these lands -- Land Vest -- will be a particularly important member of the management agreement development team. During the summers of 1988 and 1989, Land Vest, Lowell and Company, Attean Resort, and BPL cooperated in a Bow Trip management experiment. An attendant was employed and stationed at Attean Landing. Responsibilities included managing vehicle parking and boat launching, surveying users, distributing information, and maintaining campsites on Attean Pond and at Attean Falls. Lowell and Company's current policies are responsible and should be maintained by any future owners of their land.

Seasonal recreation staff hired by BPL in 1988 maintained campsites and monitored use on Holeb Pond and the stretch of Moose River located on the western Unit section. These projects were conducted by a SERVE Maine volunteer during the 1989 season. BPL is generally satisfied with the results of these projects and will propose to expand and improve on them with the management agreement team. Results of the Attean Landing survey and of the Holeb Pond/Moose River monitoring will be further sources of information for Bow Trip management purposes.[142]

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[139] *Maine Rivers Access and Easement Plan*. Maine Department of Conservation, Bureau of Parks and Recreation, January 1985.
[140] ibid.
[141] ibid.
[142] *Holeb Unit Management Plan*. Maine Department of Conservation, Bureau of Public Lands, December 1989.

There are a variety of non-commercial whitewater recreational opportunities along the upper river. At the East Outlet of Moosehead Lake there are 3 1/2 miles of Class III below 2000 cfs, and III-IV above. East Outlet enjoys approximately 1500 user days a year according to the KWPC's study.[143] From Harris Station to Carry Brook there are 3 3/4 miles of Class IV. This section is primarily a commercial rafting area, but it does receive heavy use by kayakers and bolder canoeists. From April 15- October 19 in 1991 there were 2541 private canoeists and kayakers at Harris Station, as well as 3298 private rafters. These numbers may be a low estimate of use because the full season extends from March through November.[144]

There are also recreational opportunities on the tributaries in this area. From Carry Brook to The Forks there are 8 1/2 miles of Class IV rapids. On the Moose River between Long Pond and Brassua Lake there are approximately 2 miles of Class II and III rapids beginning below the logging road bridge. On the Roach River from Kokadjo to Moosehead Lake there are 6 1/2 miles of class II rapids. On the Dead River from Spencer Stream to The Forks there are 16 miles of good opportunities for Class II-III whitewater at levels around 1300 cfs, with Class IV rapids at 3500 cfs and up. This is one of the most popular runs in New England due to summertime releases. On the Dead River there were approximately 1753 private canoeists, kayakers, and rafters in 1991.[145]

The fluctuating water levels from Harris Dam curtail fishing opportunities because of the danger to boaters from the swiftly moving water. Also limited road access restricts use by fishermen.[146]

CMP and affiliates have a plan for recreational facilities around their dams.[147] Along the Moosehead Dam, CMP plans to develop a hard surface boat launch on the west shore and a carry-in boat launch below East Outlet Dam. They will also investigate the opportunity to provide campsites along west outlet. At the Moxie Pond Dam, CMP and other owners will investigate the potential for campsites at Joe's Hole. In addition, they will maintain and improve the existing trailored boat launch, parking and picnic facilities adjacent to the dam. Along the Dead River (Flagstaff to Forks), CMP will improve the campground at Spencer Stream, investigate the potential for campsites at Enchanted Stream, and develop a new take-out site at West Forks.

Flagstaff Lake forms the northern boundary of the State-owned Bigelow Preserve. The fluctuating water levels limit the lake's desirability for water-oriented recreational use.

The Forks to Caratunk

The beauty of this segment, along with its clean water, fast flow, and steep banks, establishes a high value for canoeing, fishing, hiking, and hunting. This area follows seven miles of freeflowing river, with an average gradient of 14 feet per mile. According to the Kennebec River Corridor Plan, this portion of the river resembles the flow of the unregulated Kennebec, even though it is regulated to some degree by upstream dams.[148]

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143 *Recreational Study for the Outlets of Moosehead Lake*. Land and Water Associates, 1991.

144 Brad Newell, Central Maine Power Company, personal communication.

145 John Cureton, International Paper, personal communication.

146 *Maine Rivers Access and Easement Plan*. Maine Department of Conservation, Bureau of Parks and Recreation, January 1985.

147 *CMP Recreational Facilities Plan*. Land and Water Associates, 1989.

148 *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.

There are no official public access points in this segment although The Forks and Martin and Pooler Pond areas are used.[149]

Caratunk

This is an eight mile segment covering the upriver portion of Wyman Lake. This segment is characterized by steep banks except for the flood plain at the confluence of Pleasant Pond Stream and Kennebec, where Caratunk is located. Carrying Place Stream is a point of historic significance as the jumping off point for Benedict Arnold's march to Quebec in 1775. There is little development in this segment due to shallow bedrock and steep slopes. The river along this segment is calm and only suitable to low impact recreation.[150]

Access to the west bank is limited to jeep trails and logging roads. There is a rest area and boat launching site near MacDougal Pond off Route 201 in the southern part of this segment. The Appalachian Trail crosses the Kennebec River corridor at Caratunk village.[151]

Wyman Lake

This segment is the wide lower seven miles of Wyman Lake, which is the largest impoundment on the river. The valley walls rise abruptly from the lake on both banks. The impoundment is considered a Great Pond and has a water classification of Class A. It is used for fishing and hiking.[152]

There are two organized public access points on Wyman lake. On the east bank immediately south of Decker Brook, the town of Moscow operates a public boat launch. The Moscow/Bingham Chamber of Commerce with Concord and Pleasant Ridge maintains a public swimming area on the west bank in a small cove where the Pleasant Ridge Road turns away from the river about one mile above the dam.[153]

CMP has proposed to clean up abandoned ice fishing shacks, add a fire permit site on the island at the north end, develop a canoe portage trail (proposed for 1993-94), create a hard surface ramp at the Moscow facility, and to move gates out to the end of the town road to the powerhouse (proposed for 1993). CMP has added parking for ice fishing, facilitated a stat launch facility in the Pleasant Ridge area and installed sanitary facilities at the Caratunk boat ramp.[154] In addition, they plan to construct loon rafts at Caratunk and to assist with paying the operating costs for the Pleasant Ridge Municipal Recreation Area. The hard surface boat ramp in Moscow has been completed, as well as the day-use picnic area, an outhouse, and two primitive campsites at Caratunk.

Bingham-Concord

This is the first major developed area in the corridor. It is enclosed by steep valley walls but contains areas of broad floodplain on both banks. There are numerous islands in the river below Bingham village, most of which flood.[155]

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[149] ibid.
[150] ibid.
[151] ibid.
[152] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
[153] ibid.
[154] *CMP Recreational Facilities Plan*. Land and Water Associates, 1989.
[155] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.

There is some fishing and hunting along this section of the river. It is curtailed to some degree by the fluctuations in water levels. There is public access above and below Wyman Dam.[156] This area is also used by kayakers and canoers. Following Austin Stream to Bingham there are approximately seven miles of natural flow Class II-IV rapids. On the south branch of the Dead River from Dallas School to Langtown Mill there is a 6 mile natural flow run of Class II-III rapids. On the Carrabassett River there are 6 miles above Carrabassett with up to Class V in difficulty, and 10 miles of Class I-III between Carrabassett and Kingfield. All of these areas are listed in the Appalachian Mountain Club's Maine River Guide.

At the Williams Dam, CMP has improved the access road, parking, and the canoe portage which was rough on the lower end, and developed a boat launch above dam. They will investigate multiple management potential for a new park in Bingham and carry in access to the upper limits of the impoundment.[157]

Solon-Embden

The northern part of this segment above Solon consists of flat waters behind the Williams Dam at Caratunk Falls. The valley is steep walled with virtually no floodplain. Below Caratunk Falls, the river widens and has a number of islands and a broad floodplain. Between the dam and the Solon/Embden bridge, the river has been channelized. Below the bridge area, the river flows slowly and freely. It was also the site of a major campground for Benedict Arnold's army. Between Caratunk Falls and the confluence of the Carrabassett River at North Anson, there are exceptional opportunities for low impact recreation, especially for canoeing, hunting, fishing, and hiking.[158]

The Carrabassett is probably best known for its whitewater canoeing/kayaking, but it is equally important for a variety of other natural features and recreational uses, including sightseeing. With low water during the summer months, developmental pressure increasing, and only a low-medium level of protection, the river is particularly vulnerable to exploitation and conflicts associated with competing uses.

The Nature Conservancy owns two islands near Solon. Below the bridge on the Solon bank, there is a major private campground and recreational area.[159]

Madison-Anson

The section is moderately developed all the way along. It is characterized by a broad, shallow valley with expansive floodplain. The Kennebec is a slow moving impoundment of two dams below the Madison urban complex. There is a fair amount of dairy farming on the east bank north of Madison. This area is well suited for low impact recreational uses.[160]

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[156] ibid.

[157] *CMP Recreational Facilities Plan*. Land and Water Associates, 1989.

[158] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.

[159] ibid.

[160] ibid.

The town of Madison leases access to the river from the Madison Paper Industries, Inc. on Nathan Street. The area is 1.5 acres with 50 feet of access and a graveled parking area. At the time of the writing of the plan there was adequate parking at the site. There are also two picnic areas owned by Madison Paper Industries, Inc. which are on the riverfront.[161]

[161] Madison Comprehensive Plan, 1989.

Norridgewock

This segment is where the Kennebec changes its southerly flow, turns and flows northeasterly to Skowhegan, where it turns again and continues its southward flow. From the Madison-Anson urban complex, past the confluence of the Sandy River, and through the Bombazee Rips, the shoreland contains extensive floodplains which are frequently backed by steep slopes. From here to the Norridgewock Village the southwest bank consists of a high bluff with steep slopes dropping to the river while the opposite bank is moderately sloped with some minor floodplain directly abutting the river. Between Norridgewock Village and Skowhegan, both banks consist of moderately sized floodplain backed by numerous steep slopes. Throughout most of this segment, the river consists of slow moving water. North of Norridgewock Village, the corridor is primarily forested with some large farms. East of the village the banks are primarily developed. The Old Point peninsula, across from the confluence of the Sandy river just below the Madison town line, is an important historic site. One of the earliest Abenaki Indian villages on the river was located there and a French mission was established there in 1646. In 1775, Benedict Arnold used the point as one of his primary campgrounds in the march to Quebec.

There is a privately operated park here. This area has high value for low impact recreation. The combination of fast and slow water create a great canoe trip.[162] Oosoola Park is a town-owned picnic area, play ground, and boat ramp on the Kennebec River. The park is approximately three acres.[163] On the Sandy River there are three opportunities for whitewater kayaking and canoeing listed in the Appalachian Mountain Club's *Maine River Guide*. From Smalls Falls to Phillips there are 11 miles of Class II-IV rapids and 6 miles of Class I-III rapids between Farmington Falls and New Sharon. There are 8 miles of natural flow Class I-II rapids between Drury Pond and the Sandy River.

Skowhegan

This is the most diverse segment of the river. It flows northeast over two dams, through a deep gorge that divides the Skowhegan urban center, and along a picturesque forest shore; the Kennebec swings ninety degrees at the bend to flow generally southward again. The mile long downtown gorge that begins at the base of the dams has steeply incised walls that constrict the Kennebec into a turbulent, whitewater river. Below the gorge, the river flattens out and flows gently through the rest of the segment. The northern half through Oak Islands is lined with fairly steep banks and the southern half contains moderately sloping banks with broad floodplain. The west bank is dotted with active and inactive farms, while the east bank is predominantly forested. There is a variety of open space along the shores. There is public and private access to the river.[164]

CMP plans to landscape the powerhouse, investigate expanding parking at Oosoola Park in Norridgewock, and create a portage trail in Skowhegan in 1992-1993.[165] In addition, CMP improved the landscaped area at the powerhouse, providing signage regarding Arnold Trail and expanding the existing parking area at Oosoola Park.

Hinckley

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162 *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
163 Norridgewock Comprehensive Plan, 1987.
164 *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
165 *CMP Recreational Facilities Plan*. Land and Water Associates, 1989.

This is a pastoral section of the river. It flows gently through the first half of the segment and then the river narrows below the Hinckley-Pishon Ferry village area. The valley is relatively flat throughout this segment with a broad floodplain on the west bank and moderately steep slopes on the east bank. Near the two villages of Hinckley, which is in Fairfield, and Pishon Ferry, which is in Clinton, there is considerable development. Below Pishon Ferry on the east bank, the land is primarily fields and forest with numerous large dairy farms.[166]

Shawmut Pond, created by the Shawmut Dam, has potential for all types of water sports.[167] Clinton will prepare a plan for public access to both rivers by March 1992.[168]

CMP will: landscape the powerhouse site, upgrade the fishing access site (east side) with added parking, a picnic area, and a trail, develop a new boat launch proposed for 1992 (hard surface on Clinton side), and investigate a site for a new carry in boat ramp below dam (Clinton side) at the Shawmut Dam.[169]

<u>Greater Waterville</u>

The valley is moderately flat, but with little floodplain due to the escarpment which keeps the river within its channel for the most part. The section of the river is highly developed with only three sizable open space areas. Two major tributary watersheds, the Sebasticook River and Messalonskee Stream, join the Kennebec River just below the Waterville-Winslow urban center. Three dams, three auto bridges, two railroad bridges, and an abandoned footbridge spans the river in this segment.[170]

The recreational uses of this area are limited due to the heavy development. There are some places for foot paths and riverfront parks.[171]

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[166] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
[167] ibid.
[168] Clinton Comprehensive Plan, 1991.
[169] *CMP Recreational Facilities Plan*. Land and Water Associates, 1989.
[170] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
[171] ibid.

CMP will investigate potential for a nature study and a demonstration forest area (cooperative with adjacent landowner) at the Union Dam. At the Automatic Dam they will investigate the potential for a carry-in boat access to the headpond. At Rice Rips, CMP will investigate the potential for a carry-in boat access to the headpond, public use areas along shoreline, and a multiple-use management status of open space, as well as exploring the feasibility of conserving the area as public open space. At the Oakland Dam they will improve the boat launch.[172] In addition, CMP plans to add an improved day use area at Messalonskee Lake Dam, a managed green belt along the east side of Messalonskee Stream from the Oakland Dam to the Rice Rips Dam, improved parking for fishing at Rice Rips and access below the Union Gas Dam. At the Fort Halifax Dam, CMP will improve the headpond access road and parking and trail for fishing below the dam, provide a new boat launching facility, and investigate opportunities for cooperative recreational facilities on the Winslow property. In the Fort Halifax's FERC application they add to this plan a trailored boat launching facility. CMP has completed a portage which can be used as part of the bypass around Waterville dams. At the Lockwood Dam, they have created a foot access trail and parking for fishing below dam. CMP is investigating a downstream boat launch or carry-in site and providing a boat ramp and picnicking area at the Lockwood dam. They will also provide mitigation access for Union Gas, Lockwood and Fort Halifax Dams.[173]

<u>Vassalboro-Sidney</u>

This deeply incised, 15 mile long corridor segment is located between the two major population centers in the Kennebec Valley, Augusta and Waterville/Winslow. The river is normally a very slow moving pool impounded by the Edwards Dam. The seventeen foot high Edwards Dam backs the river up to the confluence with the Messalonskee Stream. There is waterfowl and upland game habitat along this segment. Most development is on top of the ridges and cannot be seen from the river. The west bank is almost entirely of ice contact gravel deposits that are mined for sand and gravel.[174]

According to the North Kennebec River Planning Commission's (NKRPC) River Corridor Study, recreation would be enhanced in this segment by the removal of the Edwards Dam. With or without the dam this section is well suited for low impact recreational uses.[175] The Sidney boat launch is approximately 1 acre owned by the town off River Road. It includes a boat launch and parking; the ramp is paved. According to the report, the dams in Augusta and Waterville curtail river usage in this section. Future needs for this facility, according to the Sidney's Comprehensive Plan, depends on whether the Edwards Dam in Augusta is eventually removed thereby permitting access to the southern portion of the Kennebec River.[176]

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[172] *CMP Recreational Facilities Plan*, Land and Water Associates, 1989.

[173] ibid.

[174] *Kennebec River Corridor Plan*, North Kennebec Regional Planning Commission, September 1974.

[175] ibid.

[176] Sidney Comprehensive Plan, 1991.

If the Edwards Dam is removed, the project area impoundment would revert to a free-flowing 16 mile stretch of river. The section would contain a mixture of shoal and deeper stretches, with at least six rapids classed as easy to low/moderate difficulty for average canoeists. The probable depth in summer months would limit watercraft to canoes, kayaks and shallow draft boats, a detriment to those who currently utilize the deeper, flat water impoundment in larger boats. This variable watercourse would be more attractive to canoeists and small craft, particularly in a region with ample natural or impounded lakes. This unimpounded resource would have greater value as a scenic, critical/ecological, and historic resource, and as an inland fishery and for canoe touring than the current impoundment. A free flowing river would provide additional passive and active recreational opportunities due to reduced water levels. The impact on existing watercraft access points would be minimal, requiring minor site improvements while possibly making additional sites feasible for trailered, carry-in or pedestrian access that are inundated by the present impoundment. The existing dam represents an impediment to a more diversified recreational resource for the Kennebec region and lost potential for improved statewide resources that could have interstate as well as regional importance.

Augusta

This segment continues with steep banks and well developed upper banks. It includes Augusta, Hallowell, Farmingdale, and Gardiner. Fort Western, located on an east bank terrace, is a national historic site. This area is a park and is part of the open space system of the city of Augusta.[177]

From the river, this section is scenic due to the steep, undeveloped banks and quite suitable for low level recreation. Augusta, Hallowell, and Gardiner all have municipal boat landings.[178]

Lower Kennebec

According to the Maine Rivers Access and Easement plan, this section of the river is the largest freshwater/tidal bay north of the Chesapeake, with an outstanding diversity of wildlife, scenic features, and historic sites. Fishing, hunting, historical exploration, picnicking, and sightseeing are among the many recreational activities which take place along the lower portions of the Kennebec.[179]

Access to the river between Augusta and Bath is good, although public access is still lacking in Pittston and Woolwich and below Bath in Arrowsic and Georgetown. The recommendations of the plan for access are: to continue efforts to establish public boat landings at Arrowsic or Georgetown and Woolwich or Pittston; to encourage the establishment of a river corridor commission with regulatory authority to oversee recreational/commercial user and resource protection between Waterville and Bay Point; and to identify and evaluate potential access sites and campsites at Pittston on Sand Island and near the old icehouses and above Lovejoy Narrows in Dresden. Overall access to the river, with the growing demand, is considered to be inadequate. There are public boat landings in Augusta, Hallowell, Gardiner, Chelsea, Richmond, Dresden (Eastern R.), Bowdoinham (Cathance R.), Center Point Road, Bath, and Phippsburg.[180]

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[177] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
[178] *Maine Rivers Access and Easement Plan*. Maine Department of Conservation, Bureau of Parks and Recreation, January 1985.
[179] ibid.
[180] *Maine Rivers Access and Easement Plan*. Maine Department of Conservation, Bureau of Parks and Recreation, January 1985.

Commercial Rafting.

Recreational use of the upper Kennebec is dominated by commercial rafting on a scale that would have been unimaginable only a few years ago. Rafting is suited to the area, given the limitations on other uses imposed by the river corridor's own geography, the water release system at Harris Dam, and its minimal impact on the river itself.[181]

Use limits for commercial rafting were set legislatively for the Kennebec River based on a number of factors including days and durations of release and launch characteristics. These limits are currently as follows:

Kennebec River:

- Sunday (average 3 hr. release) -- 800 passengers/day
- Weekdays (average 4 hr. release) -- 1,000 passengers/day
- Saturdays (average 2 hr. release) -- 800 passengers/day
- Memorial Day, July 4th, Labor Day -- 800 passengers/day

Commercial use on all days is monitored by reviewing monthly reports filed by outfitters. On the Kennebec there are daily total passenger limits and use on days of expected heavy use is regulated by the allocation system. These days currently include Saturdays between mid-May and mid-September on the Kennebec. Outfitters are restricted to carrying a specified number of passengers on these days, the total of which does not exceed the use limit.

The allocation system is used to assure that river use limits are not exceeded on heavy rafting use days. The following are the statutory goals of the allocation system:

- To encourage a wide diversity of whitewater trip experiences and services;
- To provide a fair distribution of river use among existing and future users;
- To maximize competition within the recreational use limits;
- To allow for reasonable business stability for outfitters by allowing stable, well-qualified outfitters who are providing excellent service and meeting the conditions of their allocations to continue to do so, subject to periodic review when allocations are reviewed;
- To encourage efficient use of the allocation system;
- To be flexible enough to adapt to changes in river use or river conditions;
- To prevent evasion of the system; and
- To provide opportunity for public access.

The law requires that allocations be distributed among outfitters according to the following specific criteria: the experience of the outfitter (40 points); outfitter safety records (25 points); the level of financial investment in whitewater rafting (15 points); the level and quality of services provided to customers (15 points); performance in meeting past allocations (30 points); and other factors (5 points). The decision on the weight to be assigned to the various criteria is delegated to IF&W rulemaking and for 1989 was as indicated in the parentheses in the preceding sentence. The frequency of reassigning allocations is left to departmental rulemaking. Allocations have most recently been assigned for 3 years with the current period due to end in 1990. This past year the assignment period was extended to 5 years.

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[181] ibid.

In addition to the assignment of allocations, outfitters are also assigned to a launch time. This assignment is based on operator preference, with conflicts being decided in favor of the operator with the longer record of continuous operation.

There is an 80 passenger per day limit for any outfitter on any rapidly flowing river. (This number was adopted as a maximum largely because of traditional passenger loads on larger trips by established outfitters prior to regulation.) Thus, the maximum allocation an outfitter can receive is 80. The law also sets a minimum allocation of 20 on the Kennebec.

There is currently no restriction on the extent of non-commercial rafting, but registration is required for such trips. There is a provision in the law for setting aside for non-commercial rafting up to 10% of the use limit, should this be required. To date, IF&W has deemed this not to be necessary.

If one applies the formula developed in *A Determination of the Economic Activity Generated by Commercial Rafting*, Social Research Institute, University of Maine, March 1983, to the current passenger figures, it is determined that in 1989 the total economic activity due to rafting in Maine was approximately $35,000,000, with the Kennebec accounting for $20 million, the Penobscot $12 million, and the Dead $3 million.[182]

For the whitewater enthusiast, competent in Class II-III water, the Dead River is the premier whitewater river in New England. With 15 miles of nearly continuous Class II-III whitewater, an undeveloped river corridor with superb mountain views, excellent highway access to Southern Maine, a convenient boat shuttle, and a 5 month season (dam regulated flow from Flagstaff Lake), the Dead is in a class by itself. Recreational and possibly commercial whitewater use may be expected to climb, and that expectation ought to be the outstanding consideration in recreational planning for the river below Grand Falls.

Numbers of Commercial Whitewater Rafting Passengers by Year, Kennebec River

Year	Number	Percent change vs. previous year	No. change vs. previous year
1981	7341	+37	+2001
1,982	13,326	82	5,985
1,983	17,517	31	4,191
1,984	22,369	28	4,852
1,985	23,677	6	1,308
1,986	27,546	16	3,869
1,987	30,229	10	2,683
1,988	29,711	-2	-518
1,989	29,841	0	130
1,990	31,768	6	1,927
1,991	30,486	-4	-1,282

182 *Annual Report of the Whitewater Advisory Committee*, Office of Policy and Legal Analysis, 1990.

Since the Dead River has Class IV rapids, most outfitters and IF&W looked on it as a rapidly flowing river, and thus subject to certain regulations. However, prior to 1989 it was never designated as a rapidly flowing river by IF&W as required by statute, and a small number of outfitters were not considering it as such and not paying the required head fee. By rule, effective August 14, 1989, IF&W designated the Dead River as a rapidly flowing river, thus requiring reports of all outfitters.

With a reservoir capacity of 12,000 cfs, compared to 35,000 for the Kennebec and 57,000 for the Penobscot, and without the role of power provider of the other two rivers, the Dead River has a very different schedule for rafting. Recently, KWPC, the company responsible for the flow on the Dead, has released 5500 cfs at the Long Falls Dam on selected and published dates in the spring for the benefit of rafting activities.

In 1988, at outfitter request, the release pattern was changed to one Sunday and two Saturdays in May with releases of 5,500 and 7,500 cfs. Since 1989, releases of 5,500 in June, 3,500 in September, and 5,500 in October were added.[183]

[183] *Annual Report of the Whitewater Advisory Committee*, Office of Policy and Legal Analysis, 1990.

Passenger Trend on the Dead River by Year[184]

Year	Number	Percent change vs. previous year	No. change vs. previous year
1984	1946	n/a	n/a
1,985	1,951	0	7
1,986	2,914	42	963
1,987	3,144	8	230
1,988	2,954	-6	-190
1,989	3,747	27	797
1,990	5,372	43	1,625
1,991	3,957	-26	-1,415

Recommendations.

The State should continue to work with hydropower generators in the basin to provide for safe portages around dams. The Kennebec Valley Tourism Council is promoting creation of a canoe trail from Jackman to Popham Beach. The trail would cover 218 miles of the River and be expected to take 21 days to traverse. The Council would provide a guide to the trail, including portages, campsites, etc. Portages at several dams will be required to support a canoe trail. In addition, the need for speed limits on the flatwater portions of the river, due to the incompatability of fastmoving power boats with canoes and kayaks, should be addressed.

Recreational use of the Kennebec River and its tributaries has grown tremendously since the elimination of the log drives and improvements in water quality, especially in whitewater areas and where fishing opportunities are available. More growth can be expected, particularly in the underutilized flatwater portions of the river between the Forks and Augusta. The need for increased access should be assessed to ensure that the resource values being promoted are not degraded. The issue of fees is an area of increasing concern for many river users; this impediment to access should be assessed.

The whitewater rafting industry provides an important recreational benefit and is a significant contributor, along with private boating, to the economy of the rural northern Kennebec River basin. Although the current schedule of releases may result in the loss of some generating capacity, such losses are offset by the recreational and economic benefits provided by the private boating and the rafting industry.

The cooperation of the dam operators and private land holders in providing access and high flows is vital to the rafting industry as well as to private whitewater recreation.

[184] *Annual Report of the Whitewater Advisory Committee*, Office of Policy and Legal Analysis, 1990.

Removal of Edwards Dam would provide a recreational benefit to the State by replacing a flatwater impoundment with a free-flowing 16 mile stretch of river accessible by canoe, kayak or shallow draft boat. The existing dam represents an impediment to a more diversified recreational resource for the Kennebec region and lost potential for improved statewide resource that could have interstate as well as regional importance.

ARCHAEOLOGY

Archaeological and Historic Resources.

Since a small Indian campground was excavated at Popham in 1890, over 500 Native American archaeological sites have been identified in the Kennebec Watershed. It is possible that as many more remain undiscovered in unsurveyed areas. Judging from a modest sample investigated to date, roughly 1/3 of those discovered contain scientifically "significant" archaeological deposits, and are ultimately eligible for listing on the National Register of Historic Places.

The first Native Americans to live in Maine, called paleo indians, moved in from the south or west about 11,000 years ago as the land recovered from recent glaciation, and as tundra and open spruce woodland vegetation cover grew enough to support the large and small game they hunted (including mastodon and caribou). Because of poorly developed late glacial drainage, and perhaps because of major seasonal runoff and occasional catastrophic drainage of huge interior lake basins dammed by ice or glacial till, these people tended to camp on very well drained (sandy) soils outside of river valleys.

Between 10,500 and 9500 years ago, trees (pine, poplar, birch, oak, with other hardwoods later) colonized the Maine landscape, forcing inhabitants to live and travel along lakes and waterways and otherwise accommodate to a dense forest. An indication of such accommodation was the proliferation of stone axes and gouges during the Archaic period (between 10,000 and 3000 years ago), indicating exquisite skill in woodworking; examples of the latter unfortunately have not survived Maine's acid soil. Until 4000 years ago, we have reason to believe that people traveled in dugout canoes, on the ocean, the rivers and major lakes. Dependence on heavy dugout canoes to some degree limited mobility. Sometime between 4000 and 3500 years ago, the birchbark canoe was developed. Use of such light, back-portable watercraft allowed travel up and down small streams and beaver-flowages, and cross-drainage portaging. The birch-bark canoe opened up the Maine interior away from major lakes and rivers.

The Ceramic Period in Maine (3000 years ago to 1500 A.D.) is so-named because Maine's Native Americans adopted the use of pottery. The use of pottery with exterior designs resulted in the increased number and stylistic detail of artifacts now used to understand the archaeological record. After the first European explorers arrived off the Maine coast in the early 1500's, and began trading (the so-called Contact Period), many changes in Native American life occurred and European written records began.

For most of prehistory, Maine's Native American population supported itself by hunting, fishing and gathering, in band organized societies without complex political organization or monumental construction. In southwestern Maine corn, bean and squash horticulture was added to a pre-existing hunting and gathering economic base after roughly 1000 A.D., without drastic change in socio-political organization and with only subtle changes in the use of the landscape. Maine's early Native Americans were relatively mobile in lifestyle and lived in relatively small groups. The largest and most prominent occupations were multi-seasonal villages of several hundred individuals, from which most of the population would depart and disperse over the landscape at certain seasons. Economic activities (such as food processing, tool maintenance, production of objects such as canoes, snowshoes, clothing, and, for the last 3,000 years, pottery), may have been controlled to some degree by seasonal availability of raw material, but the manufacturing activities occurred at a wide range of locations. Thus, in the absence of monumental architecture, permanent villages and towns, we recognize four types of archaeological sites: (1) habitation/workshop sites, (2) lithic quarries, (3) cemeteries, and (4) rock art (petroglyphs and pictographs).

Lithic quarry sites are highly localized mines for primary lithic material at bedrock outcrops, or for cobble material along exposed and stony streams and river bottoms. Bedrock outcrop quarries occur at localized quartz, rhyolite, and chert sources which are predictable on bedrock geology maps of the State of Maine. Cemetery sites are locations for multiple interments of the dead, spatially separated from habitation sites. Cemeteries were produced only during specific portions of Maine prehistory, notably the Laurentian and Moorehead Late Archaic, the Susquehanna Tradition, and the Early Woodland period. They are always located on well-drained sandy or gravelly sand soils within 100 yards of a large or small river or lake shore, or within 100 yards of a major habitation site in the case of the Susquehanna Tradition. The Moorehead Phase or "Red Paint" cemetery does not occur west of the Kennebec Valley. Rock art sites include petroglyphs and pictographs. There are now approximately 10 petroglyph locations known in Maine, and one pictograph or rock painting site. All contain Shaman's mnemonic representations of spirit journeys or related designs which are clearly Algonquin in origin and probably date from the last 2,000 years or less. All are located immediately adjacent to canoe-navigable water on particular kinds of bedrock outcrops.

The vast majority of prehistoric sites in Maine are habitation/workshop sites, which combine a range of activities from food procurement and processing through tool maintenance and material culture manufacture. These sites comprise the majority, certainly more than 95%, of the known archaeological record. They exist in a continuum of size and density which is currently impossible to subdivide in any meaningful fashion.

Ninety-eight percent or more of prehistoric habitation/workshop sites in Maine are 10 yards or less away from canoe-navigable water. (This high percentage is thought not to be an artifact of nonrandom searching.) Of the remainder, roughly 1% are found on highly specialized locations such as aeolean sands in the case of Paleoindian sites, or alluvial tillable soils in the case of Late Woodland and Early Contact period sites. Well drained sandy soil of low slope seems to be a predictive factor for some proportion of the remaining 1%.

Habitation/workshop sites are found in two categories of depth in Maine: shallowly buried, and deeply buried. The majority are shallowly buried on soils derived from glacial till, reworked till, sand, gravel, and silt emplaced by geological processes before 12,000 years ago. In these situations there has been no net accretion of the land surface except by human agency, and archaeological material is found within the top 30 or 40 cm of active soil turnover (by frost and plant growth) on these types of soils. In this type of environment, which is representative of more than 95% of the land surface of the State of Maine, archaeological material is shallowly buried and can be discovered or destroyed by any process that disturbs the top 30 cm or so of the soil column. Deeply buried sites occur only in alluvial settings along rivers and streams, where periodic flooding has deposited silt or sand which separates sequential occupations. Such sites can be up to 3 meters deep.

Survey and Evaluation, Threats and Protection

The Maine Historic Preservation Commission recognizes two different levels of archaeological survey: Reconnaissance and Intensive survey. Reconnaissance surveys are designed to determine site presence or "prove" site absence with some level of reliability (often by shovel-test pit excavation with certain depths and intensity).

Intensive level archaeological survey is used to determine the vertical and lateral extent of an archaeological site, its contents, and often its "significance." Intensive survey is focussed on known sites and involves often extensive excavation.

Removal of a threatened archaeological site by careful excavation is called data recovery. Protection of a site from a threat (often involving a combination of data recovery, legal and physical protection) is called mitigation. Conservation of some sample of archaeological sites for future excavation is the primary principle of managing archaeological sites, because we assume that archaeological digging techniques, archaeological laboratory techniques (especially) and the questions archaeologists ask of their data will all improve in the future. Having the appropriate site to "dig" is often the only way to answer a question about the past.

A key concept in managing archaeological sites is determining which sites require attention and which would be a waste of resources. The legal term used to designate sites worthy of protection or excavation with public funds is "significant." A "significant" site is eligible for listing in the National Register of Historic Places, and vice versa. Criteria of eligibility depend upon site age, content, and condition. They are spelled out in detail in a series of archaeological "contexts", each addressing the state of knowledge of a particular portion of prehistory, written by MHPC staff.

Threats to archaeological sites, ie. those actions that can destroy a site's significance, include primarily erosion, vandalism, and development. Because most prehistoric sites in Maine are/were located along the shore of a body of water, erosion is perhaps the greatest threat. Erosion can be entirely natural, or it can be caused by human actions that raise water levels and allow waves and ice to chew away at archaeological deposits that were formerly dry land. A case in point is Moosehead Lake, where the water levels have been raised for at least a century, first by timber-industry dams and then by water storage dams for hydropower generation (downstream). Approximately 270 archaeological sites were found by a recent reconnaissance survey around the lake shore (above and just below full pool level). Intensive survey is not yet complete, but it is estimated that no more than 20% of those sites survive as "significant" archaeological sites.

Protection of archaeological sites for the future is a complex problem. Protection from purposeful vandalism (non-systematic digging for artifacts) relies upon anonymity, or a combination of physical (fencing) and legal protection (conservation easements) plus periodic monitoring. (Archaeological site location information is legally protected primarily to help deter vandalism.) Protection of archaeological sites from erosion can be accomplished at great expense with the construction of erosion-control walls or other devices. Often, it is more cost effective to recover a sample of the archaeological data within the area that will be lost to erosion within a certain period of time (e.g., within the license period for a hydroelectric project). Protection from development relies upon a combination of statute (e.g., shoreland zoning, site location of development), active review of proposals related to these laws, and conservation easements.

Existing Data Base and Survey Coverage

Lower Kennebec: The Chops to Popham. This portion of the Kennebec is a narrow tidal channel dominated by current. There have not been extensive systematic professional archaeological surveys in this portion of the river. Fifteen prehistoric sites are known, none are listed on the National Register. A "Red Paint" burial (stone tools, red ochre, no skeleton) was recovered by the State Museum from Popham, and the artifacts and fieldnotes are on display in the new Maine State Museum exhibit.

Archaeological survey of the shoreland zone in this section is badly needed.

Lower Kennebec Tributaries. The Sasanoa, Back River, and Nequasset Brook are mostly-tidal extensions of the lower Kennebec. There have not been extensive systematic professional archaeological surveys in this portion of the river. Seven prehistoric sites are known. None are listed on the National Register. Sites around Nequasset Brook contain some stone tools of Early and Middle Archaic age (circa 9000-7000 years old). The Sasanoa River was clearly the location of a major Contact Period Indian village, visited and described by Biard about 1611. The site has not yet been found.

Archaeological survey of the shoreland zone in this section is badly needed, as well as intensive level survey on some sites away from the shoreland zone. Locating the Biard-described village should be a priority for studying the Contact Period.

Tidal Kennebec: Merrymeeting Bay to Augusta. We exclude the western portion of Merrymeeting Bay here, which is part of the Androscoggin. The Chops, at the outlet of Merrymeeting Bay is a drowned waterfall. Our best guess, based on rate of coastal submergence, is that it was drowned about 5000 years ago. Before that time, The Chops would have been a massive waterfall, capable of impeding the entrance of anadromous fish into the Kennebec and Androscoggin. The increase in available anadromous fish resouces over time may in part be responsible for an increase in numbers and size of archaeological occupations over time in the drainage (i.e., many more Late Archaic sites than Early Archaic).

Systematic extensive professional archaeological survey has not been accomplished in this section. Eleven archaeological sites are known. None are listed on the National Register. Evidence from the Swan Island area of Richmond, in the form of an elevated beach with a circa 7000-5000 site, indicates that the Kennebec River had been downcutting into its bed, and therefore lowering the elevation of its shorelines, for thousands of years. Therefore, archaeological sites might be located on former shorelines well back from the modern shoreline along this stretch of river. Archaeological survey of the shoreland zone, and certain landforms back from the shoreland zone, in this section is badly needed.

The Cobbosseecontee Drainage. This drainage includes Cobbosseecontee Stream and Lake, and lakes further upstream in the Winthrop drainage. Systematic professional survey has been accomplished on much of the length of Cobbosseecontee Stream, and portions of the outlet area of the lake. Forty-one archaeological sites are known in this section. Several are known along the length of Cobbosseecontee Stream. There is a concentration of eroded (not significant) sites near the outlet of Jug Stream into Cobbosseecontee Lake, although many of them have yielded 5000-7000 year old stone tools. Three sites near the outlet of Cobbosseecontee Lake have yielded stone tools dating between 8000 and 1000 years to extensive professional excavations. Two of these sites are listed on the National Register.

Augusta to Waterville. This section of the river is defined to extend from the Edwards Dam upstream to the dam in Waterville. Sixty archaeological sites are known in this section. Eroding portions of the Edwards Dam impoundment margin have received professional reconnaissance survey. Removal of Edwards Dam would allow access to additional sites. Several sites around the Edwards impoundment may be eligible for listing in the National Register. This survey did not examine higher river terraces along the sides of the valley that may contain many more, early sites. Two other professional archaeological surveys have concentrated on the upper portion of this section of river. Survey of a right-of-way for a new bridge has located a group of 5 sites on the east bank of the river, one of which is eligible for the National Register. One is deeply buried in alluvium, several others are associated with an abandoned river channel perched at 20 feet elevation above the modern river. Other intensive level archaeological survey work has concentrated at the location of Fort Halifax in Winslow. Much work has been done on the circa 1760 vintage British Fort, but the entire area is underlain by stratified prehistoric deposits. The oldest so far dated under Fort Halifax is 3100 years old, containing burned bone remains of salmon and sturgeon. This site is listed on the National Register.

The Sebasticook River. The Sebasticook is an east bank tributary of the Kennebec at Winslow, and was a major canoe route connection to the Piscataquis River. It should, therefore, contain many archaeological sites. Sixty-five archaeological sites are known along the Sebasticook River below Sebasticook Lake. Reconnaissance archeological survey has been accomplished for the Fort Halifax dam and Benton Falls dam impoundments. Several huge archeological sites (and many small ones) are known around the Fort Halifax impoundment, all or most of them eroding. Intensive level archaeological survey fieldwork is completed but not yet reported. The Benton Falls impoundment yielded 8 archaeological sites to reconnaissance survey, of which one was significant, and subjected to data recovery excavation. Systematic extensive professional archaeological survey has not been accomplished on the river or lake above the Benton Falls impoundment. A few sites are known around Sebasticook Lake, but they seem to be totally eroded.

Systematic extensive professional archaeological survey has not been accomplished around China Lake. However, the Cates Farm site at the outlet of China Lake has received intensive testing and the site is eligible for listing on the National Register.

The Messalonskee Drainage. The Messalonskee drainage is a small tributary of the west side of the Kennebec at Waterville, with small headwaters lakes maintained by a dam. Reconnaissance level professional survey has been accomplished along the entire drainage due to hydroelectric relicensing studies and bypass route survey near Waterville. Thirty-three archaeological sites are known along the entire drainage. Intensive level archaeological survey has been accomplished around the hydroelectric impoundments, but the results are not yet available. Preliminary results indicate several sites with deposits in the 7000 year old range, and several which are National Register eligible. Site 53.38 near the Union Gas dam is a small, Susquehanna Tradition (circa 3500 year old) encampment. It is currently undergoing total data recovery, because it is located on the centerline for the new road/bridge between Waterville and Winslow.

Waterville to Skowhegan. In this section we include the main channel of the Kennebec upstream to the Weston Dam, and the Wesserunsett Drainage. Landforms along this portion of the river are complex, with many low, alluvial deposits now used as agricultural fields and several possible fossil river meanders. Systematic extensive professional archaeological survey has not been accomplished in this section. Only 10 archaeological sites are known in this section, reflecting the paucity of professional survey. Archaeological survey of the shoreland zone in this section is badly needed, with additional attention to fossil shorelines and deeply buried alluvial context. Judging by results upstream and downstream, this section of the river probably contains dozens of National Register eligible sites.

Skowhegan to Madison, and Sandy River. This section of the river extends from the Weston dam at Skowhegan upstream to the dam at Madison, most of which is impounded by the Weston dam. It contains extensive deposits of stratified alluvium, and some abandoned high river banks and meanders.

Forty-nine archaeological sites are known in this section. The Weston impoundment has received extensive reconnaissance archaeological survey and intensive survey of many of the sites. Only the reconnaissance survey has been reported, but preliminary results indicate that a dozen or more sites may be eligible for listing in the National Register. Many are deeply stratified in river alluvium. Occupation of this portion of the valley began at least 8000 years ago. The location of "Norridgewock" is particularly significant. One site is the location of Father Rasle's mission and associated village of 1690-1725, which was burned by Massachusetts militia. Much of this site has been looted, but some remains intact. A nearby site contains extensive deposits from the late Ceramic period and Contact period: apparently the village location before people were induced to move to Rasle's mission. Postmolds ("fossil" postholes), hearths and pits from an 80 meter long longhouse have been uncovered from a late Ceramic component, along with burned corn, beans and squash. This was probably the village of Abenaki first referred to by Champlain circa 1630.

Systematic extensive professional archaeological survey has not been accomplished in the section of the Sandy River above the Madison Electric Works dam.

Madison to Gray Island, south of Solon. This portion of the river contains similar landforms to the Skowhegan-Madison stretch. A reconnaissance archaeological survey of the Madison impoundment was accomplished, but it may not have included enough pit digging to detect deeply buried sites. Otherwise, systematic extensive professional archaeological survey has not been accomplished in this section. Only two archaeological sites are known in this section. Archaeological survey of the shoreland zone in this section is badly needed, along with survey of fossil river shore landforms.

Carrabassett River. Systematic extensive professional archaeological survey has not been accomplished in this river valley, with the exception of one test in Kingfield for a municipal well. One archaeological site is known in this section. Archaeological survey of the shoreland zone in this section is badly needed.

Solon Area. This is a short section of the Kennebec River, from Gray Island upstream about 1.5 miles to Williams Dam. Four archaeological sites are known, two on each side of the river. All four have been subjected to intensive archaeological survey. Three are listed in the National Register, and the fourth is eligible. Two sites contain deep, stratified sequences in river sites, beginning at least 5000 years ago. Two are shallow sites. One of the shallow sites contains a circa 1700 A.D. occupation which must be related to Rasle's mission at Norridgewock. Associated is a ledge which sticks into the river, covered with petroglyphs that date to the last one or two thousand years. This latter site, the Hodgdon site, is protected by a conservation easement.

Solon to The Forks. In this section of river, the height of hills bordering the Kennebec Valley increases, and the amount of alluvial floodplain in the valley bottom decreases. Twenty-two archaeological sites are known in this section.

The Williams project impoundment shoreline has been surveyed at the reconnaissance level and intensive level. Eleven archaeological sites were located. Two, the Smith site and Smith's landing site, were judged eligible and threatened, and subjected to major data recovery excavation. The Smith site contains a stratified series of occupations dating between 3800 and 2900 years ago, which is valuable for understanding that period of time.

The Wyman project impoundment has also been subjected to reconnaissance and intensive level survey. Eight archaeological sites are known in this section. Five are eligible for listing in the National Register and are ultimately scheduled for data recovery excavation. The oldest is apparently of Paleoindian age.

There are three archaeological sites around The Forks, although none have been subject to intensive archaeological testing.

The Dead River and Flagstaff Lake. Flagstaff Lake comprises a flooded portion of Dead River, although fossil shorelines at higher elevations indicate that the basin did contain a major lake at some time in the past. Systematic extensive professional archaeological survey has not been accomplished in the Dead River or around Flagstaff Lake, with the exception of the Eustis Dam impoundment.

Even so, 40 archaeological sites are known in this section below the Eustis dam, most of them eroded and covered with the waters of Flagstaff Lake. All of these sites are known from amateur reports, and they contain deposits as old as Paleoindian.

Reconnaissance and intensive archaeological survey of the Eustis dam impoundment has been accomplished, resulting in the discovery of two archaeological sites, and determination that one is eligible for listing in the National Register.

Indian Pond to Moosehead Outlet. Systematic extensive professional archaeological survey has not been accomplished in this section. Three archaeological sites are known in this section. Archaeological survey of the shoreland zone in this section is badly needed.

Moosehead Lake. Moosehead Lake is a huge natural lake which has been enlarged slightly by a pair of low dams that block two outlets. Reconnaissance level archaeological survey of the impoundment shore and area around each outlet has been accomplished. Approximately 270 archaeological sites are known around the impoundment. The sites contain occupations as old as Paleoindian and as young as the Contact period. Intensive level archaeological survey has begun but is not complete. Preliminary results indicate that a low proportion (10-30%) of these sites have survived the raised water levels and may be eligible for listing in the National Register.

In the fall of 1646 a French missionary accompanied a large number of Indian families from the Augusta-Waterville region of the Kennebec on an upriver trip to Moosehead. The families dispersed to small hunting camps around the lake for the winter, and reassembled for the downriver trip in April. There may not be enough archaeological evidence to test whether or not this seasonal use of the lake was a regular practice.

Brassua Lake. Brassua Lake consists of a smaller natural lake enlarged drastically by raised water levels behind a dam. Several years ago, the Brassua impoundment was drained for repairs, and all archaeological sites exposed around the former lakeshore and stream banks were located through a combination of professional and amateur reconnaissance survey. Approximately 109 archaeological sites were located. Virtually none of them retain enough of their original content to be determined significant. Brassua Lake is a good example of the damage done to Maine's archaeological sites by raised water levels.

Archaeological Impacts and Mitigation.

Section 106 of the National Historic Preservation Act and relevant sections of the Electric Consumer's Protection Act require consideration of potential adverse effect on significant archaeological sites as part of the process of licensing or relicensing hydroelectric projects. The following constitutes Maine Historic Preservation Commission/State Historic Preservation Office policy concerning mitigation of potential adverse impact.

License Responsibilities - Site Location and Significance. For a new license, new construction, or an increase in pool elevation or other substantive change in water management practices, the licensee is responsible for finding and assessing the significance of all archaeological sites within the area of direct impact. The direct impact area includes any construction area, flooded land, and area of erosion around the pool margins during the term of the license. For the relicensing of an existing project with no change in water management practices, the licensee is responsible for finding and assessing the significance of archaeological sites around the pool of the project or immediately downstream from the project (by the tailrace) which may experience adverse effect through erosion during the term of the license.

When an existing pool is involved, the license is responsible for determining site presence and significance for all archaeological sites located at an elevation above the normal annual low water mark of an impoundment. Licensee will not be responsible for the location of sites below the normal annual low water mark of the project except in cases when the impoundment is drained for major reconstruction of the dam.

Applicant is also responsible for finding and assessing the significance of archaeological sites for ancillary activities within the project area including recreational facilities, lease of project lands, timber harvesting, and other activities. In the case of a relicensing, it is the applicant's choice whether to proceed with complete Phase I and Phase II archaeological survey before relicensing, or to deal with recreational facilities and other ancillary activity areas, etc., on a case-by-case basis as they are proposed for construction or other action.

License Responsibilities - Mitigation. The licensee is responsible for mitigation of adverse impact to any significant archaeological sites. The National Register eligibility of archaeological sites discovered within project boundaries will ordinarily be judged by criterion D of the National Register of Historic Places (yielding "information important in prehistory or history"). Eligibility decisions will also be guided by additional detail set forth in the Maine State Plan for Prehistoric Archaeology, and any relevant thematic or individual National Register nomination forms applicable to the area of the hydroelectric project. Mitigation will usually take the form of data recovery from some portion of the site to be determined on a case-by-case basis.

For relicensing of an existing project, the licensee is responsible for mitigation of adverse impact for those portions of the site or sites that will be effected by erosion (including wave wash and ice scour, mass wasting, bank slumpage, and tree toppling) during the term of the license. Given that water management practices at the site will not change, the rate of erosion can be estimated by individuals with appropriate geological expertise, or by historical data including trees falling into the impoundment, or measurements of erosion from photographs or other data sources.

Determination of the proportion of the impact area to be mitigated by data recovery (archaeological excavation) will be done on a site-by-site basis, in response to Research Significance Themes outlined in the Maine State Plan for Prehistoric Archaeology, and as described in a detailed data recovery (research) plan developed by a Maine Historic Preservation Commission approved archaeologist.

Mitigation Plan. Upon completion of Phase I and Phase II archaeological studies, and at the time of application for license or relicensing, the licensee shall prepare an Archaeological Mitigation Plan, which shall consist of the following items:

* The detailed archaeological data recovery plan for each site for which data recovery has been deemed necessary by the State Historic Preservation Officer;

* Relevant draft text for National Register of Historic Places nomination(s) and applicable visual (photographic, graphic) documentation;

* A timetable for development of relevant conservation easements or good faith efforts to contact private landowners to obtain conservation easements on significant archaeological sites; and

* A plan for monitoring archaeological site integrity for the term of the license, if any significant archaeological deposits will remain after construction and/or data recovery. The archaeological site monitoring plan shall include an agreement between the licensee and the Maine Historic Preservation Commission for periodic monitoring of the site, and reporting site conditions to the Maine Historic Preservation Commission. It may include a contract which has been approved by the Maine Historic Preservation Commission between the licensee and a third party for that monitoring[185]

Recommendations.

Archaeological surveys of the shoreland zone should be conducted in the following regions of the Kennebec basin: the lower Kennebec (below the Chops) and its tributaries, Merrymeeting Bay to Augusta, Waterville to Skowhegan, Madison to Gray Island, the Carrabassett River and Indian Pond to Moosehead outlet.

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[185] Hydropower Policy: Maine Historic Preservation Commission.

MUNICIPAL PLANNING

SHORELAND ZONING

The Mandatory Shoreland Zoning Act, 38 MRSA §435-449 requires all municipalities to adopt, administer, and enforce ordinances which regulate land use activities within 250 feet of great ponds, rivers, freshwater and coastal wetlands, and tidal waters; and within 75 feet of streams as defined. These ordinances are intended to protect environmental quality, wildlife habitat, archeological resources, commercial fishing and maritime industries, public access to waters, visual resources and open space. Significant and permanent changes in the water level of impoundments in the Kennebec basin may alter the shoreland zone as designated by municipalities. The effect of such changes would have to be evaluated on a case-by-case basis.

MUNICIPAL PLANNING FROM HARRIS DAM TO AUGUSTA

There is not much development along the segment from the Harris Dam to Caratunk. The greatest concentration is along Route 201 at the Forks village and some seasonal development on the east bank of the Kennebec across from the Forks. This section is under the planning jurisdiction of LURC.[186]

There is some development at Caratunk, where there is considerable land for further development available in the southern section of the village. This entire segment is under the planning control of LURC.[187]

Moscow is the first incorporated town along the river. They have shoreland zoning ordinances and use the statutory criteria for reviewing subdivision proposals. There are a series of seasonal dwellings on the east bank just below the confluence of Dexter Brook and the Kennebec. Another settlement has developed across the river on the west bank. Pleasant Ridge Plantation is also an area with suitable land for development. Moscow is part of the NKRPC. The rest of this area is under the control of LURC.[188]

From Bingham to Concord is the first developed area in the corridor. It is on the east bank above and below Wyman Dam. The town of Bingham is in the historic floodplain but the risk of flooding has been mitigated by the dam.[189]

Most development in Solon and Bingham is restricted to the river because of the steep backcountry in this region. Use of the land adjacent to the river is restricted along the entire pool behind Williams Dam in Solon by CMP's ownership of flowage rights. Theoretically, the utility can raise the pool elevation behind the dam an additional 12 feet. Bingham is a Tier 3 town and part of the NKRPC. Bingham has a comprehensive plan and is part of the Federal Flood Disaster program. The rest of this area is under LURC's control.[190]

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[186] *Kennebec River Corridor Plan*, North Kennebec Regional Planning Commission, September 1974.
[187] ibid.
[188] ibid.
[189] ibid.
[190] *Kennebec River Corridor Plan*, North Kennebec Regional Planning Commission, September 1974.

Solon and Embden have exceptional protection of riverfront land through local zoning. Embden has restricted virtually all structure development along the river frontage. There are scattered exceptions where development already exists. Solon has zoned all of the land below the recreational area at the bridge as resource protection.[191] Solon is a Tier 2 town and Embden is Tier 3, both are part of the NKRPC.[192]

Madison and Anson have adopted municipal shoreland zoning ordinances based on the minimum State guidelines. There has been poor development control due to Route 201's proximity to the river and shoreland zoning has been ineffective. The floodplain extends as far as half a mile back from the river. Anson has a resource protection zone along its floodplain.[193] Both Madison and Anson are Tier 3 towns and part of the NKRPC.[194]

During development of its comprehensive plan, citizens in Madison were asked about the need for improved access to surface water: 38% strongly agreed and 22% somewhat agreed. Overall the response was statistically somewhat positive. When asked specifically about additional access to the Kennebec 30% felt it was very important, and 21% felt it was somewhat important. Overall the response was statistically somewhat positive. Madison plans to work with other communities to establish a Kennebec River Corridor Commission by 1994. The recreation goals include a plan to maintain and improve access to the river.[195]

Norridgewock has adopted shoreland and flood protection zoning.[196] Norridgewock is a Tier 3 town and part of the NKRPC.[197]

Skowhegan has adopted shoreland zoning, which is effective in this area due to the steep banks and small floodplain. There are pockets of developable land within the floodplain.[198] Skowhegan is a Tier 3 town within the NKRPC.[199]

Fairfield has townwide zoning that places all of the land along river in a rural zone, which has virtually no restrictions on use. They have adopted shoreland zoning and the islands are zoned for protection.[200] The plan also describes dangerous sections of the river from the I95 crossing south to the village where several drownings have occurred. Clinton has adopted shoreland zoning as well as a 75 foot setback on all streams in town.[201]

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[191] ibid.

[192] Office of Comprehensive Planning.

[193] *Kennebec River Corridor Plan.* North Kennebec Regional Planning Commission, September 1974.

[194] Office of Comprehensive Planning.

[195] Madison Comprehensive Plan, 1989.

[196] Norridgewock Town Plan.

[197] Office of Comprehensive Planning.

[198] *Kennebec River Corridor Plan.* North Kennebec Regional Planning Commission, September 1974.

[199] Office of Comprehensive Planning.

[200] Fairfield Town Plan, 1987.

[201] Clinton Comprehensive Plan, 1991.

Winslow has local ordinances for zoning including shoreland zoning and subdivision review. Much of the corridor land in the southern part of Winslow has been placed in resource protection. Winslow has an active conservation commission and recreation commission. Waterville has municipal zoning and special shoreland protection mechanisms. Waterville has zoned the area within fifty feet of numerous streams as resource protection to preserve natural drainage patterns. They have a conservation commission that is active in protecting the city's natural resources.[202] Benton is a Tier 1 town, while the other three are Tier 3, and all are part of the NKRPC.[203]

In Sidney shoreland zoning provides the highest protection of natural resources within the town. During comprehensive planning, citizens surveyed about whether the town should acquire shorefront property for recreation responded was as follows: 47% swimming, 42% park/picnic, 44% multipurpose area, 31% boat launch, and 20% no. This question did not differentiate between lakefront and riverfront acquisition. The town plan concentrates most of its surface water concerns on Messalonskee Lake, although the Kennebec is mentioned in terms of increasing boat launching area. When asked to list negative and positive changes in Sidney, survey respondents made no mention of the river. In the natural resources section of the plan, a concern was noted regarding the gravel pits on the river. The regional coordination efforts for natural resources outlined in the plan do not mention the river.[204]

Edwards Dam removal was specifically addressed in the Vassalboro Comprehensive Plan. According to the plan, dam removal would give boaters access to the ocean and fishing would improve due to the return of anadromous fish. This could provide significant economic benefits to Vassalboro. If the dam is removed, there would be some draining of submerged land but this may be a benefit as waterfowl habitat. In the 1974 River Corridor Study this segment of the river was considered excellent for a variety of recreational purposes: hiking on the railroad bed, fishing, and canoeing. The Study considered this area to hold a high potential for semi-wilderness experience between two larger population centers.[205] The plan recommends that development should be kept off steep slopes and back from the immediate riverfront. Development on the ridges should be screened to lessen visual impacts from the river. According to the plan, this should be coordinated with Sidney. In the town survey, 34.4% of people wanted to develop or improve access points on river. This was the second highest priority among the town residents. The plan includes a goal to improve access to the river by 1992.[206]

The city of Augusta has adopted a Kennebec River Greenway Plan as part of their Growth Management Plan. This greenway consists of the creation of a series of parks for different uses along the river, including picnic areas, walking trails and natural areas. The city of Augusta has a detailed comprehensive plan which was developed in 1988. The city has a detailed protection plan for the watershed with buffers around each stream, a prohibition on the filling of wetlands except for water dependant uses, and buffers around areas of high erosion, steep slopes, floodways, and areas designated critical for wildlife.[207]

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[202] *Kennebec River Corridor Plan*. North Kennebec Regional Planning Commission, September 1974.
[203] Office of Comprehensive Planning.
[204] Sidney Comprehensive Plan, 1991.
[205] Vassalboro Comp Plan, 1991.
[206] ibid.
[207] 1988 Growth Management Plan, Augusta.

CRITERIA FOR STATE AGENCY DECISION-MAKING

The MWDCA (38 MRSA, Sec. 630-637), which applies to the construction, reconstruction or structural alteration of a hydropower project, states that the Board of Environmental Protection or LURC shall approve a project when it finds that the applicant has demonstrated that the following criteria have been met:

1. *Financial capability.* The applicant has the financial capability and technical ability to undertake the project. In the event that the applicant is unable to demonstrate financial capability, the board may grant the permit contingent upon the applicant's demonstration of financial capability prior to commencement of the activities permitted.

2. *Safety.* The applicant has made adequate provisions for protection of public safety.

3. *Public benefits.* The project will result in significant economic benefits to the public, including, but not limited to, creation of employment opportunities for workers of the State.

4. *Traffic movement.* The applicant has made adequate provisions for traffic movement of all types out of or into the development area.

5. *LURC Zoning.* Within the jurisdiction of the LURC, the project is consistent with zoning adopted by the commission.

6. *Environmental mitigation.* The applicant has made reasonable provisions to realize the environmental benefits of the project, if any, and to mitigate its adverse environmental impacts.

7. *Environmental and energy considerations.* The advantages of the project are greater than the direct cumulative adverse impacts over the life of the project based upon the following considerations:

a. Whether the project will result in significant benefit or harm to soil stability, coastal and inland wetlands or the natural environment of any surface waters and their shorelands;

b. Whether the project will result in significant benefit or harm to fish and wildlife resources. In making its determination, the board shall consider other existing uses of the watershed and fisheries management plans adopted by IF&W, DMR, and the ASRSC;

c. Whether the project will result in significant benefit or harm to historic and archeological resources;

d. Whether the project will result in significant benefit or harm to the public rights of access to and use of the surface waters of the State for navigation, fishing, fowling, recreation and other lawful public uses;

e. Whether the project will result in significant flood control benefits or flood hazards;

f. Whether the project will result in significant hydroelectric energy benefits, including the increase in generating capacity and annual energy output resulting from the project, and the amount of nonrenewable fuels it would replace; and

The Board shall make a written finding of fact with respect to the nature and magnitude of the impact of the project on each of the considerations under this subsection, and a written explanation of their use of these findings in reaching their decision.

8. Water Quality. There is a reasonable assurance that the project will not violate applicable state water quality standards, including the provisions of section 464, subsection 4, paragraph F, as required for water quality certification under the United States Water Pollution Control Act (Clean Water Act), Section 401. This finding is required for both the proposed impoundment and any affected classified water bodies downstream of the proposed impoundment.

Section 401 of the Clean Water Act is also relevant to relicensing of hydroelectric facilities because it requires any applicant for a federal license or permit for an activity which may result in a discharge to navigable waters must obtain State certification that the activity will not violate water quality standards.

Maine's Supreme Judicial Court has recognized that Maine's water quality standards contain three parts: a list of designated uses, a set of numerical criteria for water chemistry (dissolved oxygen and bacteria counts), and a set of narrative criteria on the permissable level of pollutant discharges. The court has also held that designated uses provide goals for the State's management of its classified waters and that the Board of Environmental Protection must consider those water quality goals when it renews applications for water quality certifications for hydropower facilities208

MAINE RIVERS POLICY: SPECIAL PROTECTION FOR OUTSTANDING RIVER SEGMENTS

The Maine Rivers Policy, as laid out in Executive Order 1 FY 82/83 and dated July 6, 1982, established that the Dead River from The Kennebec to Flagstaff Lake and the Kennebec from Bay Point to the Edwards Dam and from The Forks to the Harris Dam be protected. Specifically, the Policy prohibited construction of new dams on these sections and required that additional development or redevelopment of dams be designed and executed in such a manner that either enhances the significant resource values of these river stretches, or does not diminish them.

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[208] Bangor Hydro-Electric Company v. Board of Environmental Protection, 595 A.2d (Mc. 1991).

SUMMARY OF RECOMMENDATIONS

HYDROPOWER

One of the most important uses of the Kennebec River is the generation of electricity through hydropower facilities. We are now utilizing an estimated 52% of the total hydropower potential of the Kennebec, beyond the utilization rate for any other use. As a general premise, it is assumed that the dams in the Kennebec River basin will continue to play a significant role in supplying a predictable quantity of energy at a predictable price to the State's energy consumers; however, each license to be renewed must be assessed on a case-by-case basis.

After careful analysis of balances of uses and resources, the State finds that appropriate actions have been taken or have been proposed to be taken by the hydro-developers to achieve an appropriate balance at eight of the ten Kennebec basin dams whose licenses expire in 1993.

At Fort Halifax, State and federal agencies recommend operation of the project in run of river mode during upstream anadromous migration (May 1-June 30) and minimum flows of 350-400 cfs during the rest of the year.

Analysis of Edwards Dam has resulted in a recommendation by the State that dam removal conditions be established during relicensing. Due to its location at head-of-tide, Edwards Dam is unique among the Kennebec Basin's hydro facilities in terms of the scale of its impact on anadromous fisheries. In addition, removal of Edwards would actually allow electric rates to decline because power is currently purchased from the owners of Edwards at at least 3 times the cost of replacement power. The benefits of dam removal in the form of improved water quality, restored anadromous fisheries and increased recreational opportunities, and economic benefits derived from these beneficial uses outweigh the loss of 0.13% of the State's generating capacity (0.4% if the proposed expansion is considered) and other potential negative impacts of dam removal such as the introduction of carp above Augusta, changes in the shoreline and wetlands of the area of the impoundment, loss of waterfowl habitat and loss of a flatwater recreational resource.

The recommendation for removal of the Edwards Dam does not represent either a sudden or a dramatic shift in State policy and should certainly not be interpreted as a precedent for management of other state water resources. As explained throughout this Management Plan, the Kennebec River is an unusual resource. Improving, developing, and conserving that resource calls for unusual management tools. Readers should not interpret this recommendation as an invitation to seek wholesale removal of the State's hydroelectric dams.

FLOWS

Flow management, reservoir levels, ramping and flood control are managed by the private sector according to FERC regulations which govern generating facilities and storage dams. FERC relicensing regulations require an extensive consultation process with appropriate State and Federal resource agencies. State agencies, including SPO, the Department of Economic and Community Development (DECD), and the Maine Emergency Management Agency (MEMA) in particular, should identify which issues, procedures and standards relating to flow management should be addressed in the consultation process. Augmentation of the existing system of stream gages should be a top priority.

WATER QUALITY

On Messalonskee Stream, the water quality effects from a municipal treatment facility in Oakland and a combined sewer overflow in Waterville are elevated due to the impoundments downstream of the discharges. Changes in the amount of treatment provided, location of discharge points and flow management will be required to bring this stream into compliance with the standards for Class C.

The Sebasticook River is eutrophic primarily from nonpoint source nutrient contamination but also from several municipal treatment facilities which discharge in the watershed. Increased residence time of the watershed allows for increased algae growth leading to low dissolved oxygen in the impoundments. Several projects are presently ongoing in the watershed to reduce nutrient loading. Changes may also be required in flow management of the impoundments to dissipate algae growth.

The DEP may assess the need to seek modifications of the operation of the Wyman project to bring aquatic life conditions below that dam into compliance with water quality standards. In addition, DEP may assess the need to seek modifications of licensed discharges in Fairfield and downstream and/or modification of the operation of Edwards Dam to bring this segment into compliance with water quality standards.

FISHERIES

The State should continue to work with dam owners and landowners in the Kennebec basin to maintain access for fishing in all waters and to provide flows that maintain or enhance fishing opportunities.

The Edwards Dam is the first obstruction encountered by sea-run fish making their way up the Kennebec River to spawn. As such, it is the greatest obstacle to restoration of the Kennebec's fisheries resources and must be removed. It should be noted that one of the major reasons for designating the lower Kennebec and Merrymeeting Bay as an outstanding river segment (see page 9) is because of the diversity and uniqueness of anadromous fish resouces in the lower river. These anadromous fish resources are significantly dependent upon spawning habitat above the Augusta dam. As a head-of-tide dam on a major river, Edwards Dam is a serious obstacle to anadromous species which spawn above head-of-tide. These species, which include shad, alewives, Atlantic salmon, striped bass, rainbow smelt, and Atlantic and shortnose sturgeon, historically have spawned in the river stretch between Augusta and Waterville. While fish passage facilities would allow some alewives, shad, and Atlantic salmon to get above head-of-tide, unavoidable fish loss would still occur. For those species which do not use fish passage facilities, including striped bass, rainbow smelt, Atlantic and shortnose sturgeon, to be restored to their historical ranges, the dam will have to be removed.

Riverine angling opportunity is scarce in central Maine in comparison to lake fishing. Few other areas are available for increasing angling opportunities for salmon and striped bass. Potential riverine fishing opportunities are outlined in "Description of the Kennebec River between Augusta and Waterville Prior to Construction of the Augusta Dam," Squiers and King, 1990. Removal of the Edwards Dam will result in a substantially improved recreational fishery, the economic value of which will more than offset economic benefits lost due to dam removal.

As a result of balancing the gain in anadromous fisheries, and the resulting economic benefit to the Augusta area, against the loss of 3.5 MW of renewable energy, it is established State policy that the proposed relicensing of the Edwards Dam should only proceed within the context of the assured and eventual removal of the dam.

RECREATIONAL AND SCENIC RESOURCES

The State should continue to work with hydropower generators in the basin to provide for safe portages around dams. The Kennebec Valley Tourism Council is promoting creation of a canoe trail from Jackman to Popham Beach. The trail would cover 218 miles of the River and be expected to take 21 days to traverse. The Council would provide a guide to the trail, including portages, campsites, etc. Portages at several dams will be required to support a canoe trail. In addition, the need for speed limits on the flatwater portions of the river, due to the incompatability of fast moving power boats with canoes and kayaks, should be addressed.

Recreational use of the Kennebec River and its tributaries has grown tremendously since the elimination of the log drives and improvements in water quality, especially in whitewater areas and where fishing opportunities are available. More growth can be expected, particularly in the underutilized flatwater portions of the river between the Forks and Augusta. Increased needs for access throughout the river basin should be anticipated to allow for maximum recreational benefit.

The whitewater rafting industry provides an important recreational benefit and is a significant contributor, along with private boating, to the economy of the rural northern Kennebec River basin. Although the current schedule of releases may result in the loss of some generating capacity, such losses are offset by the recreational and economic benefits provided by the private boating and the rafting industry. The cooperation of the dam operators and private land holders in providing access and highs flows is vital to the rafting industry as well as to private whitewater recreation.

If the Edwards Dam is removed, the project area impoundment would revert to a free-flowing 16 mile stretch of river. The section would contain a mixture of shoal and deeper stretches, with at least six rapids classed as easy to low/moderate difficulty for average canoeists. The presumed depth in summer months would probably limit watercraft to canoes, kayaks and shallow draft boats. This variable watercourse would be more attractive to canoeists and small craft, particularly in a region with ample natural or impounded lakes. This unimpounded resource would have greater value as a scenic, critical/ecological, and historic resource, and as an inland fishery and for canoe touring than the current impoundment. A free flowing river would provide additional passive and active recreational opportunities due to reduced water levels. The impact on existing watercraft access points would be minimal, requiring minor site improvements while possibly making additional sites feasible for trailered, carry-in or pedestrian access that are inundated by the present impoundment. The existing dam represents an impediment to a more diversified recreational resource for the Kennebec region and lost potential for improved statewide resources that could have interstate as well as regional importance.

ARCHAEOLOGY

Archaeological surveys of the shoreland zone should be conducted in the following regions of the Kennebec basin: the lower Kennebec (below the Chops) and its tributaries, Merrymeeting Bay to Augusta, Waterville to Skowhegan, Madison to Gray Island, the Carrabassett River and Indian Pond to Moosehead outlet.

EFFECTIVE DATE: April 3, 1993

EFFECTIVE DATE (ELECTRONIC CONVERSION): May 22, 1996

APPENDIX A

River Resource Management Plan Statute

12 MRSA § 407. Comprehensive river resource management plans

The State Planning Office, with assistance from the Department of Inland Fisheries and Wildlife, the Department of Marine Resources, the Department of Environmental Protection and other state agencies as needed, shall develop, subject to the Maine Administrative Procedure Act, Title 5, chapter 375,[209] a comprehensive river resource management plan for each watershed with a hydropower project licensed under the Federal Power Act[210] or to be licensed under the Federal Power Act. These plans shall provide a basis for state agency comments, recommendations and permitting decisions and shall at a minimum include, as applicable, minimum flows, impoundment level regimes, upstream and downstream fish passage, maintenance of aquatic habitat and habitat productivity, public access and recreational opportunities. These plans shall update, complement and, after public notice, comment, and hearings in the watershed, be adopted as components of the State's comprehensive rivers management plan.

1989, c. 453, § 1; 1989, c. 878, § A-29, eff. April 20, 1990.

Historical and Statutory Notes
Amendments

1989 Amendment. Laws 1989, c. 878, § A-29, substituted "the Maine Administrative Procedure Act, Title 5, chapter 375," for "the Maine Administrative Procedures Act, Title 5, section 375,".

[209] Section 8001 et seq. of title 5.

[210] 16 U.S.C.A. § 791a et seq.

APPENDIX B

Revised Procedure to Ensure that State Agency Comments in Federal Hydropower Proceedings are Timely, Coordinated and Consistent

The following replaces the procedure adopted by the Land and Water Resources Council in June 1985. It is designed to ensure that State agency consultations and comments regarding FERC proceedings are timely, well coordinated, and consistent with the Maine Waterway Development and Conservation Act where applicable, with Executive Order No. 13, FY86/87, and with Administration policy as set forth in this document.

FERC licensing is a Federal process which sets forth a defined role for the State. In order to develop an efficient response to this process, procedures and practices need to be carefully structured.

1. FERC Coordinating Committee

The membership of the standing committee of the Land and Water Resources Council, known as the FERC Coordinating Committee, will comprise the following or their designated representatives:

-- Director, State Planning Office (Chairman)
-- Director, Office of Energy Resources
-- Director, Land Use Regulation Commission
-- Chairman, Public Utilities Commission
-- Commissioner, Department of Conservation
-- Commissioner, Department of Environmental Protection
-- Commissioner, Department of Inland Fisheries and Wildlife
-- Commissioner, Department of Marine Resources
-- State Historic Preservation Officer
-- Chairman, Atlantic Sea Run Salmon Commission

The Committee will advise and assist the State Planning Office in fulfilling its functions as lead agency in FERC reviews.

2. Lead Agency

The State Planning Office will be the lead agency in the FERC hydropower process. Its objective will be to expedite the processing of applications, monitor application status and paper flows, coordinate and review agency requests and comments and attempt to resolve disputes between applicants and agencies to assure that state policies will be implemented and the interests of the State well-served.

3. Submission of Consultation Documents and Draft Applications

To implement an efficient, coordinated approach to hydropower licensing, applicants should meet with the State Planning Office to determine the appropriate State agencies for consultation purposes with respect to a particular application. The applicant shall be responsible for distributing consultation documents, drafts and applications to appropriate agencies as determined by the State Planning Office.

4. Comments and Study Requests

A. Designated Agencies

In order to assure efficient use of the State's manpower resources and to avoid overlapping and inconsistent multiple comments or requests, one State agency will be designated to collect, review, consolidate, and synthesize any and all comments and study requests related to a designated subject area and provide to the State Planning Office a single unified comment and study request document. The agency designated below will have the responsibility for providing comments or study requests on the listed topics and for providing coordinated comments or study requests on these topics to the State Planning Office:

- Recreation and Water Use - Department of Conservation
- Fisheries and Wildlife - Department of Inland Fisheries and Wildlife (Marine Resources for Anadromous fisheries)
- Botanical and Aesthetic Resources - State Planning Office
- Water Quality - Department of Environmental Protection
- Land Use and Management (including public lands) - Department of Conservation
- Energy - Office of Energy Resources
- Flood Control - State Planning Office
- Historical; Archeological - State Historic Preservation Office

Where a comment relates to a topic not identified above, it should be submitted directly to the State Planning Office.

Applicants are encouraged to schedule informal meetings with individual agencies and are especially encouraged to meet informally with agencies even before consultation meetings to discuss issues of concern.

B. State Policy

In submitting requests for studies or comments to the State Planning Office, agencies shall work to ensure that such comments and study requests are specific to the project under consideration, that they relate to areas and issues of high State priority and are consistent with State laws and Administration mandates and with Executive Order No. 13 and this procedure, and that they are not unnecessarily burdensome to the applicant.

As part of the consultation comments, the Department of Marine Resources (DMR) or the Department of Inland Fisheries and Wildlife (IF&W), depending on which agency has jurisdiction, shall indicate whether or not it will be requesting the construction, repair, or alteration of fishways in any dam proposed to be licensed or exempted.

C. Procedure

The agency designated to provide the comments or study requests to the State Planning Office shall do so within 60 days of receipt of the initial consultation documents. Failure to submit comments or study requests within this period will be interpreted to mean that the agency wishes to make no comments or to request no studies. Extensions of the comment period may be granted where the applicant requests that an agency delay its comments and the State Planning Office receives timely notification of this request.

The State Planning Office will review the study requests and comments to assure consistency with this policy and to avoid conflicts or overlap. The State Planning Office will provide a final document of requests and comments to applicants within 90 days of the submission of the initial consultation documents and draft application. The State Planning Office will at the same time notify the applicant in writing of those agencies which have waived, or are deemed to have waived, comments or requests.

D. Mediation

If an applicant has any disagreements with agency requests or comments, it may request a joint conference with the State Planning Office and the relevant agency to reach agreement on issues in dispute. Any agreement shall be communicated to the State Planning Office and, in turn, to the applicant in the form or a revised request for studies or comment.

5. FERC Proceedings

A. Status

The State Planning Office shall be responsible for maintaining a record of the status of all hydropower project proceedings pending before FERC. SPO shall also compile and distribute, on a periodic basis, information on the current status of all hydropower project applications before FERC, including their status in State permitting proceedings.

B. Intervention

The State Planning Office shall automatically intervene on the State's behalf in all FERC licensing proceedings for hydropower projects in Maine, and, as appropriate, in selected FERC preliminary permit and license exemption proceedings.

C. Agency Comments

The State Planning Office shall monitor and review all proposed State agency comments to FERC on all licensing, relicensing and exemption applications for consistency with Executive Order No. 13 and this procedure. No later than 15 days prior to any FERC comment deadline, each State agency shall either (a) forward proposed comments to the State Planning Office and to all other agencies involved in the consultation and comment process, or (b) notify the State Planning Office that is has no comments.

The State Planning Office will review all agency comments for consistency and direct the agency to send them to FERC. If SPO finds that comments by agencies are conflicting or inconsistent with State policy, it shall 1) direct the agency whose comments are in question to withhold the transmittal of these comments to FERC, and 2) convene a meeting of the agencies affected to discuss the issues and to mediate a resolution consistent with State policy. Any revised comments which result from such a meeting will be circulated for further comment and within five days forwarded to FERC, if appropriate.

D. Comments Prior to BEP or LURC Decision

State agency comments to FERC or to applicants on hydropower license, relicense and exemption applications, submitted prior to regulatory actions of BEP and LURC, shall recommend no specific terms or conditions upon the federal license or exemption.

This shall not apply to comments submitted by the State Historic Preservation Officer pursuant to the National Historic Preservation Act.

E. Comments Subsequent to BEP or LURC Decision

Comments submitted to FERC subsequent to action by the BEP or LURC shall include a copy of the State decision issued pursuant to the MWDCA where applicable, and of the action on water quality certification pursuant to Section 401 of the Federal Clean Water Act. The written finding of fact shall include a summary of comments submitted by State agencies prior to the decision.

In addition, all comments submitted prior to State permit decisions shall include the following notice to FERC:

> "These comments represent this agency's assessment to date of the proposed project, based on our statutory responsibilities. A decision of the Maine Board of Environmental Protection (or Maine Land Use Regulation Commission) on any application for a State hydropower permit and action by the Board on water quality certification pursuant to Section 401 of the Federal Clean Water Act, and any terms and conditions contained therein, shall represent the sole official position of the State of Maine regarding the subject application."

F. Comments after FERC Comment Deadline

Any comments proposed after FERC's official comment deadline has passed shall first be forwarded to all other agencies on the Committee, and shall be reviewed in accordance with the procedure outlined in Section 5.C, para. 2.

G. Other FERC Proceedings

This coordination procedure shall also apply to State agency review and comment on draft FERC Environmental Impact Statements relating to specific projects, and on proposed FERC regulations.

For any project which falls under LURC jurisdiction, DEP and LURC shall also provide for the coordination of water quality certification proceedings before the BEP under the provisions of Section 401 of the Federal Clean Water Act, to assure consistent action by the two permitting bodies.

H. Public Participation

To provide a means for public participation in the State's role under the FERC hydropower licensing process, the policies and procedures below will be followed by appropriate State agencies unless otherwise precluded by State Law.

1. Upon receipt of consultation documents and FERC hydropower applications for new licenses, SPO will inform the public and interested third parties of each submittal by:

- Distribution of a "Notice of State Agency Review of FERC Hydropower Document" [hereinafter referred to as "the Notice"] to persons and parties who have previously requested to be notified of agency consultation activities generally or for specific hydro projects, and to those listed on a general Hydropower Mailing list maintained by SPO.
- Publication of the Notice in a newspaper of general State circulation.
- Release of the Notice to media of statewide and local circulation.

The Notice will:

- Identify the document under review;
- Indicate where copies may be viewed or obtained;
- Explain how and when comments from the public should be submitted for inclusion in the State commenting process;
- Identify the State review agencies, indicate the topics of concern that each agency is responsible for addressing in comments or study requests, and how each agency may be contacted; and

- Explain how arrangements can be made to be kept informed of consultation meetings and to receive copies of the State comments.

2. Upon receipt of initial consultation documents and FERC applications for relicensing hydropower projects, SPO shall distribute a notification which includes information identical to the notices described in Section 1 above, to those listed on the general hydropower mailing list.

3. SPO and DEP (or LURC, if it has permitting jurisdiction) will each maintain a copy of the consultation document or FERC application for public review at their Augusta offices.

4. Each agency that receives public comments will forward a copy of those comments to SPO and to other appropriate review agencies so that each agency may benefit from this information in preparing comments. Public comments submitted to agencies may be considered in preparation of agency comments. At a minimum, public comments received before the agency commenting deadline will be attached to the State agency comments and forwarded to the applicant by SPO.

APPENDIX C

Standards for Water Quality Classification and Classification of Surface Waters in Kennebec River Basin*

Standards for classification of fresh surface waters

The board shall have four standards for the classification of fresh surface waters which are not classified as great ponds.

1. *Class AA waters*. Class AA shall be the highest classification and shall be applied to waters which are outstanding natural resources and which should be preserved because of their ecological, social, scenic or recreational importance.

   A. Class AA waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection, fishing, recreation in and on the water and navigation and as habitat for fish and other aquatic life. The habitat shall be characterized as free flowing and natural.

   B. The aquatic life, dissolved oxygen and bacteria content of Class AA waters shall be as naturally occurs.

   C. There shall be no direct discharge of pollutants to Class AA waters.

2. *Class A waters*. Class A shall be the second highest classification.

   A. Class A waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life. The habitat shall be characterized as natural.

   B. The dissolved oxygen content of Class A waters shall not be less than 7 parts per million or 75% of saturation, whichever is higher. The aquatic life and bacteria content of Class A waters shall be as naturally occurs.

   C. Direct discharges to these waters licensed after January 1, 1986, shall be permitted only if, in addition to satisfying all the requirements of this article, the discharged effluent will be equal to or better than the existing water quality of the receiving waters. Prior to issuing a discharge license, the board shall require the applicant to objectively

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* This review does not reflect changes in the classification enacted by the Legislature in 1992 regarding hydropower-related impoundments.

demonstrate to the board's satisfaction that the discharge is necessary and that there are no other reasonable alternatives available. Discharges into waters of this classification which were licensed prior to January 1, 1986, shall be allowed to continue only until practical alternatives exist. There shall be no deposits of any material on the banks of these waters in any manner so that transfer of pollutants into the waters is likely.

3. *Class B waters*. Class B shall be the third highest classification.

A. Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life. The habitat shall be characterized as unimpaired.

B. The dissolved oxygen content of Class B waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher, except that for the period from October 1st to May 14th, in order to ensure spawning and egg incubation of indigenous fish species, the 7-day mean dissolved oxygen concentration shall not be less than 9.5 parts per million and the 1-day minimum dissolved oxygen concentration shall not be less than 8.0 parts per million in identified fish spawning areas. Between May 15th and September 30th, the number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 64 per 100 milliliters or an instantaneous level of 427 per 100 milliliters.

C. Discharges to Class B waters shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.

4. *Class C waters*. Class C shall be the fourth highest classification.

A. Class C waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as a habitat for fish and other aquatic life.

B. The dissolved oxygen content of Class C water shall be not less than 5 parts per million or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality if sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes shall be maintained. Between May 15th and September 30th, the number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 142 per 100 milliliters or an instantaneous level of 949 per 100 milliliters. The department shall promulgate rules governing the procedure for designation of spawning areas. Those rules shall include provision for periodic review of designated spawning areas and consultation with affected persons prior to designation of a stretch of water as a spawning area.

C. Discharges to Class C waters may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community.

Standards for classification of lakes and ponds

The board shall have one standard for the classification of great ponds and natural lakes and ponds less than 10 acres in size. Impoundments of rivers that are defined as great ponds pursuant to section 392 shall be classified as GPA or as specifically provided in section 467 and 468.

1. *Class GPA waters*. Class GPA shall be the sole classification of great ponds and natural ponds and lakes less than 10 acres in size.

A. Class GPA waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection, recreation in and on the water, fishing, industrial process and cooling water supply, hydroelectric power generation and navigation and as habitat for fish and other aquatic life. The habitat shall be characterized as natural.

B. Class GPA waters shall be described by their trophic state based on measures of the chlorophyll "a" content, Secchi disk transparency, total phosphorus content and other appropriate criteria. Class GAP waters shall have a stable or decreasing trophic state, subject only to natural fluctuations and shall be free of culturally induced algal blooms which impair their use and enjoyment. The number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 29 per 100 milliliters or an instantaneous level of 194 per 100 milliliters.

C. There shall be no new direct discharge of pollutants into Class GPA waters. Aquatic pesticide treatments or chemical treatments for the purpose of restoring water quality approved by the board shall be exempt from the no-discharge provision. Discharges into these waters which were licensed prior to January 1, 1986, shall be allowed to continue only until practical alternatives exist. No materials may be placed on or removed from the shores or banks of a Class GPA water body in such a manner that materials may fall or be washed into the water or that contaminated drainage therefrom may flow or leach into those waters, except as permitted pursuant to section 391. No change of land use in the watershed of a Class GPA waterbody may, by itself or in combination with other activities, cause water quality degradation which would impair the characteristics and designated uses of downstream GPA waters or cause an increase in the trophic state of those GPA waters.

Standards for classification of estuarine and marine waters

The board shall have three standards for the classification of estuarine and marine waters.

1. *Class SA waters*. Class SA shall be the highest classification and shall be applied to waters which are outstanding natural resources and which should be preserved because of their ecological, social, scenic, economic or recreational importance.

A. Class SA waters shall be of such quality that they are suitable for the designated uses of recreation in and on the water, fishing, aquaculture, propagation and harvesting of shellfish and navigation and as habitat for fish and other estuarine and marine life. The habitat shall be characterized as free-flowing and natural.

B. The estuarine and marine life, dissolved oxygen and bacteria content of Class SA waters shall be as naturally occurs.

C. There shall be no direct discharge of pollutants to Class SA waters.

2. *Class SB waters*. Class SB waters shall be the second highest classification.

A. Class SB waters shall be of such quality that they are suitable for the designated uses of recreation in and on the water, fishing, aquaculture, propagation and harvesting of shellfish, industrial process and cooling water supply, hydroelectric power generation and navigation and as a habitat for fish and other estuarine and marine life. The habitat shall be characterized as unimpaired.

B. The dissolved oxygen content of Class SB waters shall be not less that 85% of saturation. Between May 15th and September 30th, the numbers of enterococcus bacteria of human origin in these waters may not exceed a geometric mean of 8 per 100 milliliters or an instantaneous level of 54 per 100 milliliters. The numbers of total coliform bacteria or other specified indicator organisms in samples representative of the waters in shellfish harvesting areas may not exceed the criteria recommended under the National Shellfish Sanitation Program Manual of Operations, Part I, Sanitation of Shellfish Growing Areas, United States Department of Food and Drug Administration.

C. Discharges to Class SB waters shall not cause adverse impact to estuarine and marine life in that the receiving waters shall be of sufficient quality to support all estuarine and marine species indigenous to the receiving water without detrimental changes in the resident biological community. There shall be no new discharge to Class SB waters which would cause closure of open shellfish areas by the Department of Marine Resources.

3. *Class SC waters*. Class SC waters shall be the third highest classification.

A. Class SC waters shall be of such quality that they are suitable for recreation in and on the water, fishing, aquaculture, propagation and restricted harvesting of shellfish, industrial process and cooling water supply, hydroelectric power generation and navigation and as a habitat for fish and other estuarine and marine life.

B. The dissolved oxygen content of Class SC waters shall be no less than 70% of saturation. Between May 15th and September 30th, the numbers of enterococcus bacteria of human origin in these waters may not exceed a geometric mean of 14 per 100 milliliters or an instantaneous level of 94 per 100 milliliters. The numbers of total coliform bacteria or other specified indicator organisms in samples representative of the waters in restricted shellfish harvesting areas may not exceed the criteria recommended under the National Shellfish Sanitation Program Manual of Operations, Part I, Sanitation of Shellfish Growing Areas, United States Food and Drug Administration.

C. Discharges to Class SC waters may cause some changes to estuarine and marine life provided that the receiving waters are of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community.

1. Kennebec River Basin

A. Kennebec River, main stem

• from Moosehead Lake, including east and west outlets, to a point 1,000 feet below the lake - Class A.

• from a point 1,000 feet below Moosehead Lake to its confluence with Indian Pond - Class AA.

• from Harris Dam to a point located 1,000 feet downstream from Harris Dam - Class A.

• from a point located 1,000 feet downstream from Harris Dam to its confluence with the Dead River - Class AA.

• from its confluence with the Dead River to the Rt. 201A bridge in Anson/Madison except for Wyman Lake - Class A.

• from the Rt. 201A bridge in Anson/Madison to the Fairfield/Skowhegan boundary, including all impoundments - Class B.

• from the Fairfield/Skowhegan boundary to its confluence with Messalonskee Stream - Class C.

• from its confluence with Messalonskee Stream to the Sidney/Augusta boundary - Class B.

• from the Sidney/Augusta boundary to the Father John J. Curran Bridge in Augusta - Class C.

• from the Father John J. Curran Bridge in Augusta to a line drawn across the tidal estuary of the Kennebec River due east of Abagadasset Point - Class C. Further, the Legislature finds that the free-flowing habitat of this river segment provides irreplaceable social and economic benefits and that this use shall be maintained.

• from a line drawn across the tidal estuary of the Kennebec River due east of Abagadasset Point, to a line across the southwesterly area of Merrymeeting Bay formed by an extension of the Brunswick/Bath boundary across the bay in a northwesterly direction to the westerly shore of Merrymeeting Bay and to a line drawn from Chop Point in Woolwich to West Chop Point in Bath - Class B. Further, the Legislature finds that the free-flowing habitat of this river segment provides irreplaceable social and economic benefits and that this use shall be maintained.

B. Carrabassett River Drainage

• Carrabasset River, main stem:

a) above a point located 1.0 mile above the railroad bridge in North Anson - Class A.

b) from a point located 1.0 mile above the railroad bridge in North Anson to its confluence with the Kennebec River - Class B.

• Carrabassett River, tributaries - Class A unless otherwise specified:

a) all tributaries entering the Carrabassett River below the Wire Bridge in New Portland - Class B.

C. Cobbosseecontee Stream Drainage

• Cobbosseecontee Stream, main stem - Class B.

• Cobbosseecontee Stream, tributaries - Class B.

D. Dead River Drainage

• Dead River, main stem:

a) from the Long Falls Dam to a point 5,100 feet below the dam - Class A.

b) from a point 5,000 feet below Long Falls Dam to its confluence with the Kennebec River - Class AA.

• Dead River, tributaries - Class A unless otherwise specified:

a) Black Brook below Dead River Hatchery - Class B.

b) Stratton Brook, Eustis, from the upper Rt. 16/27 bridge to its confluence with Flagstaff Lake - Class B.

c) Spenser Stream- Class B.

E. Messalonskee Stream Drainage

- Messalonskee Stream, main stem:

a) from the outlet of Messalonskee Lake to its confluence with the Kennebec River - Class C.

- Messalonskee Stream, tributaries - Class B.

F. Moose River Drainage

- Moose River, main stem:

a) above its confluence with Number One Brook in Beattie Township - Class A.

b) from its confluence with Number One Brook in Beattie Township to its confluence with Attean Pond - Class AA.

c) from the outlet of Attean Pond to the Rt. 201 bridge in Jackman - class A.

d) from the Rt. 201 bridge in Jackman to its confluence with Long Pond - Class B.

e) from the outlet of Long Pond to its confluence with Moosehead Lake - Class A.

- Moose River, tributaries - Class A.

G. Sandy River Drainage

- Sandy River, main stem:

a) from the outlet of Sandy River Ponds to the Rt. 142 bridge in Phillips - Class AA.

b) from the Rt. 142 bridge in Phillips to its confluence with the Kennebec River - Class B.

- Sandy River, tributaries - Class B unless otherwise specified:

a) all tributaries entering above the Rt. 142 bridge in Phillips - Class A.

b) Wilson Stream, main stem, below the outlet of Wilson Pond - Class C.

H. Sebasticook River Drainage

- Sebasticook River, main stem, including all impoundments:

a) from the confluence of the East Branch and the West Branch to its confluence with the Kennebec River - Class C.

- Sebasticook River, tributaries - Class B unless otherwise specified:

a) Sebasticook River, East Branch main stem, from the outlet of Lake Wassookeag to its confluence with Corundel Lake - Class B.

b) Sebasticook River, East Branch main stem, from the outlet of Corundel Lake to its confluence with the West Branch - Class C.

c) Sebasticook River, West Branch main stem, from the outlet of Great Moose Lake to its confluence with the East Branch, including all impoundments - Class C.

I. Kennebec River, minor tributaries - Class B unless otherwise specified

• all minor tributaries entering above Wyman Dam that are not otherwise classified - Class A.

• all tidal portions of tributaries entering between Edwards Dam and a line drawn across the tidal estuary of the Kennebec River due east of Abagadasset Point - Class C.

• Cold Stream, West Forks Plantation - Class AA.

• Moxie Stream, Moxie Gore, below a point located 1,000 feet downstream of the Moxie Pond dam - Class AA.

• Austin Stream and its tributaries above the highway bridge of Rt. 201 in the Town of Bingham - Class A.

J. Cobbosseecontee Stream, main stem - Class B.

APPENDIX D

Antidegradation Policy
38 MRSA §464, Subchapter 4, Paragraph F

(1) Existing in-stream water uses and the level of water quality necessary to protect those existing uses shall be maintained and protected. Existing in-stream water uses are those uses which have actually occurred on or after November 28, 1975, in or on a water body whether or not the uses are included in the standard for classification of the particular water body.

Determinations of what constitutes an existing in-stream water use on a particular water body shall be made on a case-by-case basis by the Board of Environmental Protection. In making its determination of uses to be protected and maintained, the Board shall consider designated uses for that water body and:

(a) Aquatic, estuarine and marine life present in the water body;

(b) Wildlife that utilize the water body;

(c) Habitat, including significant wetlands, within a water body supporting existing populations of wildlife or aquatic, estuarine or marine life, or plant life that is maintained by the water body;

(d) The use of the water body for recreation in or on the water, fishing, water supply, or commercial activity that depends directly on the preservation of an existing level of water quality. Use of the water body to receive or transport waste water discharges is not considered an existing use for purposes of this antidegradation policy; and

(e) Any other evidence which, for divisions (a), (b), and (C), demonstrates their ecological significance because of their role or importance in the functioning of the ecosystem or their rarity and, for division (d), demonstrates its historical or social significance.

(1A) The board may only issue a waste discharge license pursuant to section 414-A, or approve a water quality certification pursuant to the U.S. Clean Water Act, Section 401, Public Law 92-500, as amended, when the board finds that:

(a) The existing in-stream use involves use of the water body by a population of plant life, wildlife, or aquatic, estuarine or marine life, or as aquatic, estuarine, marine, wildlife, or plant habitat, and the applicant has demonstrated that the proposed activity would not have a significant impact on the existing use. For purposes of this division, significant impact means:

• Impairing the viability of the existing population, including significant impairment to growth and reproduction or an alteration of the habitat which impairs viability of the existing population; or

(b) The existing in-stream use involves use of the water body for recreation in or on the water, fishing, water supply or commercial enterprises that depend directly on the preservation of an existing level of water quality and the applicant has demonstrated that the proposed activity would not result in significant degradation of the existing use.

The board shall determine what constitutes a population of a particular species based upon the degree of geographic and reproductive isolation from other individuals of the same species.

If the board fails to find that the conditions of this subparagraph are met, water quality certification, pursuant to the U.S. Clean Water Act, Section 401, Public Law 92-500, as amended, is denied.

(2) Where high quality waters of the State constitute an outstanding national resource, that water quality shall be maintained and protected. For purposes of this paragraph, the following waters shall be considered outstanding national resources: those water bodies in national and state parks and wildlife refuges; public reserved lands; and those water bodies classified as Class AA and SA waters pursuant to section 465, subsection 1; section 465-B, subsection 1; and listed under sections 467, 468 and 469.

(3) The board may only issue a discharge license pursuant to section 414-A or approve water quality certification pursuant to the U.S. Clean Water Act, Section 401, Public Law 92-500, as amended, if the standards of classification of the water body and the requirements of this paragraph will be met.

(4) Where the actual quality of any classified water exceeds the minimum standards of the next highest classification, that higher water quality shall be maintained and protected. The board shall recommend to the Legislature that that water be reclassified in the next higher classification.

(5) The board may only issue a discharge license pursuant to section 414-A or approve water quality certification pursuant to the U.S. Clean Water Act, Section 401, Public Law 92-500, as amended, which would result in lowering the existing quality of any water body after making a finding, following opportunity for public participation, that the action is necessary to achieve important economic or social benefits to the State and when the action is in conformance with subparagraph (3). That finding must be made following procedures established by rule of the board.

APPENDIX E

Classification of Stream and River Segments in the Kennebec Basin according to the Maine Rivers Study

- "A" Rivers (value greater than state significance)

  -- Lower Kennebec (Bay Point to Augusta)
    -- Dead River (Kennebec River to Flagstaff Lake)
    -- Upper Kennebec (the Forks to Harris dam)
    -- Moxie Stream (Kennebec River to headwaters of Moxie Pond)
    -- Cobboseecontee Stream (Kennebec River to Cobboseecontee Lake)
    -- Moose River (Attean Pond to the Canadian border)
    -- Number Five Bog Stream (Moose River to Schoodic Lake)

- "B" Rivers (value with outstanding statewide significance)

    -- Main stem (Madison to the Forks)
  -- Carrabasset River (Kennebec River to headwaters)
  -- Sandy River (Kennebec River to headwaters)

- "C" Rivers (statewide significance)

  -- Augusta to Madison
  -- Dead River, North Branch (Flagstaff Lake to headwaters of Chain of Ponds)
  -- Dead River, South Branch (Flagstaff Lake to headwaters of Saddleback Lake)
    -- Messalonskee Stream (Kennebec River to Messalonskee Lake)
    -- Carrabassett Stream (Kennebec River to County Line)
    -- Sebasticook River (Kennebec River to headwaters)
  -- Roach River (Moosehead Lake to Seventh Roach Pond)

- "D" Rivers (regional significance)

  -- Indian Pond to Moosehead Lake

APPENDIX F

Acronyms for the Kennebec River Resource Management Plan

ASRSC -- Atlantic Sea-Run Salmon Commission
BPL -- Bureau of Public Lands
BPR -- Bureau of Parks & Recreation
FERC -- Federal Energy Regulatory Commission
CMP -- Central Maine Power Company
DECD -- Department of Economic and Community Development
DEP -- Department of Environmental Protection
DMR -- Department of Marine Resources
FEMA -- Federal Emergency Management Agency
IF&W -- Department of Inland Fisheries & Wildlife
IFIM -- Instream Flow Incremental Methodology
KHDG -- Kennebec Hydro Developers Group
KWPC -- Kennebec Water Power Company
LURC -- Land Use Regulation Commission
MEMA -- Maine Emergency Management Agency
MWDCA -- Maine Waterway Development & Conservation Act
NEPA -- National Environmental Policy Act
NFIP -- National Flood Insurance Program
NKRPC -- North Kennebec Regional Planning Commission
OCP -- Office of Comprehensive Planning
SPO -- State Planning Office
USFWS -- U.S. Fish & Wildlife Service

APPENDIX G

Basis Statement and Summary of Comments

Kennebec River Resources Management Plan

BASIS STATEMENT: The Kennebec River Resources Management Plan responds to the requirements of a Maine statute enacted in 1989 titled "An Act to Ensure Notification and Participation by the Public in Licensing and Relicensing of Hydroelectric Dams and to Further Ensure the Equal Consideration of Fisheries and Recreational Uses in Licensing and Relicensing." This statute, codified at 12 MRSA §407, requires the State Planning Office (SPO) to work with the natural resource agencies of the State to develop a management plan for each watershed in the State with a hydropower project currently or potentially regulated by the Federal government. The Plan responds to the requirements of the Maine statute with respect to the Kennebec River. The Kennebec River Resource Management Plan also serves as the State's "comprehensive plan" for the Kennebec River for purposes of consideration by the Federal Energy Regulatory Commission (FERC) regarding hydroelectric licensing and relicensing within the Kennebec basin.

The Kennebec River Resource Management Plan represents a comprehensive examination of the various resources and beneficial uses of the Kennebec River. The Plan discusses each of these resources and beneficial uses and, consistent with existing State policies, makes certain recommendations that reflect the State's determination of how those resources and beneficial uses should be balanced against one another in various circumstances. The Plan also incorporates and updates existing State policies regarding Kennebec River resources.

Informal hearings were held in October 1991 in Skowhegan and Augusta on an earlier draft of the plan. Formal public hearings were held on the most recent draft of the plan in Bingham on August 26, 1992 and in Augusta on August 27, 1992. The deadline for receipt of public comments was extended from September 25 until November 2, 1992 at the request of representatives of municipalities between Augusta and Waterville.

Many comments on the plan were received during the public hearings and comment period. The comments are summarized below and are followed by SPO's rationale for adopting or declining to adopt proposed changes in the plan. Where consideration of comments resulted in changes to the Plan, this has been noted; otherwise, recommended changes in the Plan were not adopted.

Many comments received were supportive of the Plan in its current form.

A number of comments addressed the process by which the Plan was developed. These comments do not bear directly on the contents of the Plan; as a result, the responses to these comments, while noted, are not reflected in any changes to the Plan itself.

One comment noted that SPO does not have regulatory authority in dam permitting. The SPO agrees with this comment noting that the Plan is not intended to supplant the process by which regulatory decisions regarding the permitting of hydroelectric facilities and storage dams are made.

Some comments stated that the Plan, and the process of its development, represented an attempt to deprive Edwards Manufacturing Company of its right to own and operate its hydroelectric facility and an attempt to impair relicensing of its dam. The Legislature, in enacting 12 MRSA § 407, mandated SPO to develop this, and other, comprehensive plans. The Plan is the result of an objective analysis of relevant data; policy recommendations regarding the most beneficial balancing of resources and uses of the Kennebec River Basin are based on the best professional judgment of natural resource specialists from several State agencies as coordinated by SPO.

One comment was received regarding perceived inconsistencies in the rulemaking process. Rulemaking formally began with the filing of SPO's regulatory agenda with the appropriate standing committees of the Legislature and with the Secretary of State on May 27, 1992. As noted above, informal hearings on an earlier draft of the Plan were held in October of 1991. However, as no regulatory agenda had been filed in 1991 stating SPO's intention to promulgate the Plan as a rule, these informal hearings could not be considered as satisfying the requirements of the Administrative Procedures Act.

One comment asserted that SPO had ignored comments of other State agencies in the development of the Plan. Development of the Plan entailed establishment of consensus among several professional analysts, scientists and policy development specialists for any one of the many complex issues addressed by the Plan. SPO's role in the development of the Plan, as in the development of FERC consultation documents, was to make the final judgment regarding the nature of the consensus derived. In no case did SPO include a policy recommendation in the Plan that was not supported by a majority of the professional staff involved in the decisionmaking process.

Several comments called for timely adoption of the Plan. The timeframe for adoption of the Plan has been a function of : 1) the lengthy analysis required of the many complex issues involved, 2) requirements of the Administrative Procedures Act, and 3) limitations on the resources available to SPO to complete this and other plans. One purpose of the Plan is to provide a basis for State agency comments, recommendations, and permitting decisions related to the licensing and relicensing of hydroelectric facilities. Although originally intended in part to aid State agencies during the FERC consultation process for the ten Kennebec Basin dams whose relicensing application deadlines passed in 1992, the Plan remains relevant for several reasons: 1) five of these dams have refiled applications for water quality certification, proceedings which will be subject to State agency comment over at least the next several months; 2) FERC will consider the Plan as its pursues the lengthy process of relicensing the ten dams mentioned above; 3) First Roach Dam may be required to apply for FERC licensing and therefore be subject to the consultation process; 4) FERC has requested that additional studies be conducted regarding the application for relicensing of the Edwards Dam; as a result, State agencies will be provided with an opportunity to comment on the design and results of requested studies; 5) Flagstaff storage dam began the five-year FERC consultation process in January, 1993; 6) four other dams will begin the consultation process in the next ten years.

Several comments reflected the opinion that the Plan is not a comprehensive river management plan. Some of these comments described the Plan as too heavily focussed on the Edwards Dam. Any perceived focus on the Edwards Dam is a function of the relative impact of the dam on the fisheries resources of the Kennebec River. Due to its location at head of tide, the Edwards Dam has the greatest impact on the fisheries of the river of any dam. As noted in the Plan, anadromous species, including those which will not use fish ladders, are severely impacted by the current dam.

Several comments requested that the same level of detail applied to the analysis of Edwards Dam be applied to the other dams in the Kennebec basin. As noted above, Edwards Dam uniquely affects the basin. Analysis of the balance of uses at other dams in the basin did not warrant the development of policy recommendations such as those applied to Edwards Dam.

One comment was received recommending that the Plan address the cumulative impact of releases of up river lakes and impoundments on the fish habitat of the entire river. The flow of the river is interrupted by a series of impoundments; therefore, each dam's impact on fish habitat is generally limited to its impoundment and to the portion of the river between that dam and the next downstream dam. These impacts are addressed in the licensing and relicensing of individual projects.

One comment noted that the Plan should not be considered a "comprehensive plan" but rather a component of the State's Comprehensive Rivers Management Plan. The legislation enabling the Plan requires that such plans be adopted as components of the State's Comprehensive Rivers Management Plan. FERC refers to such components of the State's Comprehensive Rivers Management Plan as "comprehensive plans;" therefore, the Plan is both a "comprehensive plan" and a component of the State's Comprehensive Rivers Management Plan.

This comment further noted that the Plan should not be described as intended to be used by FERC as the definitive document concerning beneficial uses of the Kennebec River. Although SPO does not see any inconsistency with the legislation enabling the Plan to call it a "definitive document," the Plan has been edited to reflect this request.

A number of comments addressed perceived inconsistencies with various State and federal laws. One reviewer disagreed with the Plan's noted relevancy of Section 404 of the Clean Water Act and the National Environmental Policy Act. Congress has declared that FERC is subject to these laws as they pertain to the examination of threats to wetlands and environmental quality potentially caused by federal actions. Pursuant to NEPA and the Federal Power Act, FERC produces either an Environmental Assessment or an Environmental Impact Statement to support licensing or relicensing.

One comment suggested that the recent Maine Supreme Court decision regarding water quality was overstated. Language from the decision itself has been inserted in the Plan to clarify this point.

One who commented felt that the Plan overstated the jurisdiction of Section 401 of the Clean Water Act by referring to "activities" rather than "discharges." The Supreme Court decision noted in the paragraph above supported the State's position that the application of Section 401 is not limited to projects with discharges.

One comment requested that the chapter in the Plan entitled "Criteria for State Agency Decisionmaking" be expanded to specifically address requirements for receiving water quality certification as part of the process of relicensing dams. The Plan has been so amended.

One comment noted that more effort should be applied to achieving adoption of the Kennebec Hydro Developers' Group (KHDG) Fish Passage Agreement. On October 22, 1993 FERC denied a request for rehearing and let stand staff orders amending project licenses to incorporate the KHDG agreement. This action has been noted in the Plan.

Some comments reflected a concern that the Plan demonstrated a bias against hydroelectric development; that the importance of hydroelectricity to the region and references to State policy that endorses hydropower were not included in the Plan. Similar, although less explicit, comments were received regarding the perception that the Plan was biased towards hydroelectric development; these recommended greater emphasis on wetlands, wildlife habitat, shoreland protection, and recreational opportunities. SPO recognizes that such issues as the perception of bias are difficult, if not impossible, to resolve to the satisfaction of all parties. The benefits of hydropower have been more fully noted in the Plan. The Plan represents a balanced view of the many uses of the Kennebec River.

One comment requested that the Plan incorporate an analysis of the net present value of the power generated by the Kennebec basin's projects over the life of the current and proposed licenses in order to demonstrate the economic benefit provided to licensees. This comment went on to characterize the benefit accruing to owners of hydroelectric facilities as a public subsidy and requested that the Plan require that the public benefits received from each project be commensurate with the financial benefits and power enjoyed by owners of facilities licensed to use the river for power generation. Although hydroelectric facilities generate profits for their owners, the generation of power also provides benefits to residents of the region and the State in terms of providing jobs, indigenous power, taxes, and by other means. The financial benefit to the owners of a hydroelectric facility of operating that facility is not relevant to the balancing of river resources and uses that is required by regulations governing hydroelectric generation.

Two comments questioned the methods used in the Plan to quantify the hydroelectric potential of the Kennebec River. SPO agrees that these methods are inaccurate and has edited the Plan to incorporate a more accurate method, supplied by one reviewer, for estimating hydroelectric potential.

A number of comments addressed the issue of mitigation. One comment opined that mitigation programs are not relevant under the relicensing process, especially with respect to the State role and that pre-project conditions are not appropriate as baselines for the design of mitigation programs. A second comment asserted that applicants should be required to compare pre-project and current environmental conditions as a basis for mitigation requirements and to provide mitigation plans. Mitigation can be a central focus of the consultation process, one in which representatives of State agencies are closely involved. The determination of a baseline against which to measure the requirements for mitigation must be determined on a case-by-case basis. Mitigation plans are required when indicated by the analysis of balance among resources and uses rather than as a general rule.

One comment contested the Plan's reference to the potential significance of First Roach Dam. The State stands by its contention that this dam poses potentially significant hazards to public safety and risks to the environment. The comment also asserted that the First Roach Dam was constructed only for log driving and not for power production. The Plan has been edited to reflect this comment.

Two comments expressed a concern that the Plan would set a precedent for removal of dams other than Edwards. However, the Plan explicitly states that the recommendation of removal of the Edwards Dam is in large part a function of the dam's location at head of tide and that this recommendation for removal is not to be construed as an invitation to seek wholesale removal of the State's hydroelectric facilities.

In a similar vein, one comment noted that the Plan's stated objective to reduce the cumulative impacts of dams on the shad restoration program implied a management strategy that would affect dams other than Edwards. In fact, the objective, as stated in the Plan, is to reduce the cumulative impacts of dams on the shad restoration program by seeking removal of the Edwards Dam. The objective does not imply efforts to remove other dams.

Many comments addressed the Plan's recommendation for removal of the Edwards Dam in Augusta. One who commented made the point that the relatively high cost of power generated by Edwards should not be a factor in assessing the fate of the dam because this high cost could not be anticipated. The price of power generated by the dam is dictated in the terms of the contract between Edwards Manufacturing Co., Inc. and Central Maine Power Company which was signed in the early 1980's. Although power costs have not risen as steeply as predicted at the time this contract was signed, the fact remains that the price of power generated at Edwards, and a number of other generating stations, is much higher than today's avoided cost rate. A second comment noted resentment that property was being submerged in order to generate power that cost much more than replacement power.

Several comments related to the effect of removal of Edwards Dam on the impoundment and the services it provides. One comment addressed a concern that loss of the impoundment would result in reduced black duck habitat; another comment contradicted this conclusion. Open water is more highly valued waterfowl habitat than free flowing waters; however, open water is not typical habitat for black duck which prefer beaver flowages, large wetlands, emergent and wooded wetlands, if distant from populated areas.

Several comments also claimed that there was a lack of assessment of the impact of dam removal on wetlands in the area and the potential for destruction of a 150 year old ecosystem. Although detailed analysis of the impact of dam removal on wetlands necessarily must await further study, initial review of this issue indicates that positive effects, in terms of improved habitat for aquatic species, will outweigh negative effects on those waterfowl and other species which prefer a flatwater resource. One comment expressed an opinion that removal of the dam would not restore the river as proposed because much water would still be impounded above Waterville. It is the location of the Edwards Dam at head of tide that makes its removal of potential significance in the restoration of many of the Kennebec's fisheries.

A number of comments noted concerns regarding changes in the shoreline of the impoundment should the dam be either removed or enlarged. Although relatively few property owners are expected to experience undesirable results as a consequences of dam removal, it is anticipated that some shoreline changes may negatively impact aesthetic values, boat access and the use of dry hydrants, etc. However, the benefit to the residents of the State of allowing the impoundment to revert to a free flowing river outweighs any loss of amenities which may be experienced by shorefront homeowners.

A number of issues raised regarding the removal of Edwards Dam were beyond the scope and intent of the plan. These included the potential flooding of minable gravel deposits, the effect of changes in the impoundment on property values, potential changes in municipal boundary lines that occur at the thread of the river, and possible means of financing dam removal.

Fisheries issues dominated a number of comments regarding the recommendation for removal of Edwards Dam. A number of comments raised concerns regarding the impact on brown trout and smallmouth bass fisheries above the dam if the dam is removed. As stated in the Plan, the restoration of anadromous fisheries to the Kennebec should enhance both the brown trout and sea run brown trout fisheries by providing increased forage for these species. The impact of dam removal on the smallmouth bass fishery is less predictable because this species is adaptable and opportunistic. It is possible that smallmouth bass will continue to produce at the same rate/acre as currently occurs; however, loss of still water habitat will reduce the total landed catch. The smallmouth bass would be expected to continue to support a fishery; however, it will be conducted by wading and from small rather than large boats. The anticipated changes in this fishery would be offset by the benefit resulting from a substantial increase in riverine fishing opportunity upstream from the dam site.

A number of comments pointed out that removal of the Edwards Dam would provide access to the upper river to pest species such as carp and lamprey eels. Lamprey eels occur above the Edwards Dam. They range as far upriver as the dams in Waterville and Winslow. The potential effect of the removal of Edwards Dam on the range of carp was analyzed in 1986 by the Maine Department of Inland Fisheries and Wildlife. The removal of the dam would result on the extension of the range of carp in the mainstem of the Kennebec as far upriver as the next impassable dam in Waterville. Carp prefer sluggish, warm, soft-bottomed, vegetated waters. With the dam removed, little of this habitat would remain and carp would not be expected to do well. The potential risk of introducing carp above Augusta is outweighed by the benefit resulting from a substantial increase in the amount of riverine fishing opportunity in this part of the State. This analysis has been added to the Plan.

One comment stated that fish passage at Edwards would be sufficient to achieve fisheries goals; however, as described in the Plan, a number of anadromous species do not use fishways.

One comment expressed the opinion that the Plan's statement that removal of the Edwards Dam is necessary to promote the Kennebec River's fisheries and recreational resources is too broad. This statement has been modified to say that removal of the dam is necessary to achieve the State's goals for restoration of the Kennebec's fisheries and recreational resources.

One comment asserted that the Plan fails to address the downstream implications of the removal of Edwards Dam. The restoration of several anadromous fisheries that is expected to follow from dam removal will restore large populations of fish to that portion of the Kennebec downstream from the site of Edwards Dam. In addition to supporting a potentially significant sport fishery, these populations will contribute to restoring the Kennebec's estuarine/tidal ecosystem, including Merrymeeting Bay, to a more naturally functioning state. The Plan has been amended to reflect this information.

A number of comments stated that the Plan does not address the potential release of toxic contaminants if the Edwards Dam is removed. An example of contamination resulting from the removal of a dam on the Hudson River was cited. The Plan relies upon the results of sediment toxicity testing carried out upriver of the Edwards Dam and these studies indicate that there is no toxic residue behind the dam (*Expected water quality changes from removal of Edwards Dam, Augusta. 16 February 1992*, and *Addendum 23 February 1992*, Maine Department of Environmental Protection).

One comment expressed the opinion that the Edwards impoundment is needed in order to dilute pollution coming from up river. In fact, the impoundment has the opposite effect because it slows down the flow of water and wastes and can contribute to lower than normal dissolved oxygen.

Several comments addressed the Plan's analysis of the removal of the impact of the removal of Edwards dam on recreational benefits in the area. Some of these comments asserted that such benefits had been overstated; that the Kennebec would only draw fishermen away from other areas rather than generating increased recreation; that the economic benefits of increased recreational activity would not be sufficient to offset the negative effect on Augusta's tax base of dam removal. Other comments asserted that the recreational benefits of dam removal had been understated; that dam removal would boost already significant guiding activity on the river; that the Augusta area could expect to experience the type of economic growth that has followed restoration of shad fisheries in the Connecticut and Delaware Rivers and salmon fisheries in upstate New York. Additional studies will be needed to assess the validity of these comments.

Two comments addressed the role of the power generated at Edwards Dam. The first asserted the need for power from Edwards when Maine Yankee goes off line early next century. According to *The Final Report of the Commission on Comprehensive Energy Planning, Maine State Planning Office, May 1992*, "The goal of Maine energy policy should be to meet the State's energy needs with reliable energy supplies at the lowest possible cost, while at the same time ensuring that our energy production and use is consistent with Maine's goals for a healthy environment and a vibrant economy." This report goes on to state that Maine's energy policy is to promote the continued development of renewable indigenous resources only when it can be ensured "that any reliance on indigenous resources is consistent with state objectives for the proper use and conservation of those resources."

The second comment questioned the need for power generated by Edwards Dam when a large amount of Maine's indigenous power is currently exported out-of-state. Exports of Maine's indigenous power are a function of membership of Central Maine Power and Bangor Hydro Electric Company in the New England Power Pool. Power pooling allows its members to achieve a higher reliability level with less capacity than would be required without a pool and, therefore, at lower cost. Pooling may result in lower fuel costs because load increases draw the lowest cost energy from the pool.

One comment recommended that the negative implications of dam removal should be expanded upon in the Plan. References to potentially negative impacts of dam removal, such as the introduction of carp above Augusta, changes in the shoreline and wetlands in the area of the impoundment, changes in waterfowl habitat, and the loss of a flat water recreational resource, have been added to discussions in the Plan of balancing the advantages and disadvantages of removal of Edwards Dam.

One comment requested that the Plan address the impact of dam removal on shoreland zoning. Significant and permanent changes in the water level of impoundments in the Kennebec basin may alter the shoreland zone as designated by municipalities. As is now noted in the Plan, the effects of such changes would have to be evaluated on a case-by-case basis.

One comment asserted that removal of Edwards Dam would be detrimental to bald eagles which utilize the open water which can be found below the dam in the winter. Eagles are attracted to open water, such as occurs downstream of the Edwards Dam. However, because eagles are very nomadic in Maine during the winter and do not rely on anyone site and because it is likely that, without the dam, open water will occur naturally in the winter at one or more points between Augusta and Waterville, it is anticipated that removal of Edwards Dam will not adversely impact bald eagles.

One comment suggested that restoration of the smelt fishery was unnecessary due to problems in the lobster industry. The proposed restoration of the smelt in the Kennebec River is unrelated to the lobster industry.

One comment noted that the State should focus on cleaning up the river as it is rather than on the removal of Edwards Dam. The State views restoration of habitat as a logical complement to its ongoing efforts to improve water quality in the Kennebec River.

One comment noted that removal of Edwards Dam would allow access to archeological sites. This has been so noted in the Plan.

One comment requested information on the impact of the removal of Edwards Dam on flood control. The Edwards Dam has little effect on flood control for two reasons: 1) The dam is operated in run of river mode with the result that the dam is not used to store water; and 2) at high flows, the effect of the dam is reduced because the water level in the channel below the dam rises to the point that the dam is submerged or nearly submerged.

One comment asserted that the discussion of water quality in the Plan is limited. Additional information on water quality has been added to the Plan.

One comment recommended that the balance among fisheries, recreation and hydropower can best be achieved by looking at the river as a whole rather than forcing this balance at each dam. According to the writer, under this scenario, the best section of the river for a fishery should be managed as a fishery, the best section for whitewater recreation ought to be managed for whitewater recreation, etc. The interconnectedness of the uses of the river prevents basin-wide mitigation from achieving an effective balance of uses. For example, commercial whitewater recreation benefits from the predictability of established dam releases. Similarly, management of a section of river solely for hydropower generation would affect flows necessary to support fisheries and fishing opportunity. Management of a section of river solely for fisheries might require run of river flows, compromising hydropower generation in the area.

A second comment proposed mitigation for necessary losses in fisheries due to power production in the form of enhanced flows for recreation, protection of the river corridor and water quality, and improved access. Mitigation of fishery losses must compensate in kind for those losses; enhanced flows for boating, river corridor protection, etc., would not constitute mitigation for fisheries losses and could even contribute to those losses.

Several comments were received regarding flowsTwo comments called for recreational releases on the Roach River and at East and West Outlet. As a result of the consultation process, the operator of West Outlet has agreed to a continuous release of 120 cfs during the summer recreation season to enhance recreational canoeing. At this time, additional recreational releases in these areas appear to be incompatible with maintenance of fish habitat and fishing opportunity.

One comment recommended that the Plan call for "meaningful public management" of flows and reservoir levels and for improvement of this management to enhance nonpower values. Flows and reservoir levels are managed by KWPC, a private entity, as granted by Legislative charter. The interests of the State and federal governments are represented during the licensing process and may, if necessary, be included in the license as conditions. The State has found that this system of management serves the public interest and that nonpower values do not suffer as a result of this system of management.

One comment recommended that the Plan require applicants to describe hydrologic cycles, species and habitat affected by drawdowns, and wetland losses and to provide plans for mitigation of adverse impacts. Where these issues have been found to be relevant, they are noted in the Plan. While some of these issues are not addressed for each dam site, or for any dam site, it is assumed that they will, if necessary, be addressed on a case-by-case basis during licensing.

One comment asserted that the allowance for flows less than Aquatic Base Flow that is described in the hydropower policies contradicts the goals for inland fisheries. Because the allowance for flows less than Aquatic Base Flow is conditional on maintenance of aquatic organisms, it is not seen as contradicting the goals for inland fisheries

One comment provided updated information on the schedule and rate of releases on the Kennebec and Dead Rivers. The Plan has been amended to include this information.

Two comments addressed the issue of water level fluctuations in impoundments. One comment asserted that the Plan focussed on the disadvantages of fluctuating water levels without describing the benefits of fluctuations. Such fluctuations are beneficial to the generation of hydropower and to the prevention of flood conditions. These benefits have been more fully described in the Plan. A second comment stated that the Plan should call for minimization of fluctuations. The need to protect lives and property against the threat of flooding would make such a policy unwise

One comment was received expressing concerns regarding flooding; it called for additional stream gages and installation of an early warning system. The Plan already recommends additional gages; the recommendation for an early warning system has been added.

One comment recommended that the Plan address the need for greater energy conservation by hydropower licensees. The issue of energy conservation by licensees is beyond the scope of the Plan.

Several comments asserted that the Plan is lacking with regard to discussion of the need for improved access and the impact of access fees. One comment went on to assert that current recreational enhancements are not commensurate with the benefits conferred upon licensees and that licensees should contribute to a recreational enhancement trust for the purpose of purchasing access. State analysis of the balance among resources and uses at the various dams undergoing relicensing did not reveal any required enhancements other than those already called for in the Plan. The issue of fees has been included in the Plan in the form of a recommendation for analysis of fees as an impediment to access.

A number of comments stated that the inland fisheries resources of the Kennebec River had been inadequately described in the Plan. Detailed descriptions of these fisheries have been added to the Plan.

One comment recommended new language for one of the recommendations regarding fisheries restoration. The existing language in the Plan more closely adheres to State policy. One comment asserted that the Plan places too much emphasis on potential fisheries habitat. Achievement of the State's goals for restoration of anadromous fisheries in some cases requires analysis of potential fisheries habitat. One comment recommended reorganizing the subchapter on fisheries; several changes have been made.

One comment recommended that a section on ecological resources be added to the chapter on resources and beneficial uses in the Plan. The current design of the Plan best suits the purposes for which it was intended.

One comment recommended that the Plan should require that applicants for licenses provide a plan for shoreline protection. At this time, the State finds insufficient basis to include this recommendation in the Plan.

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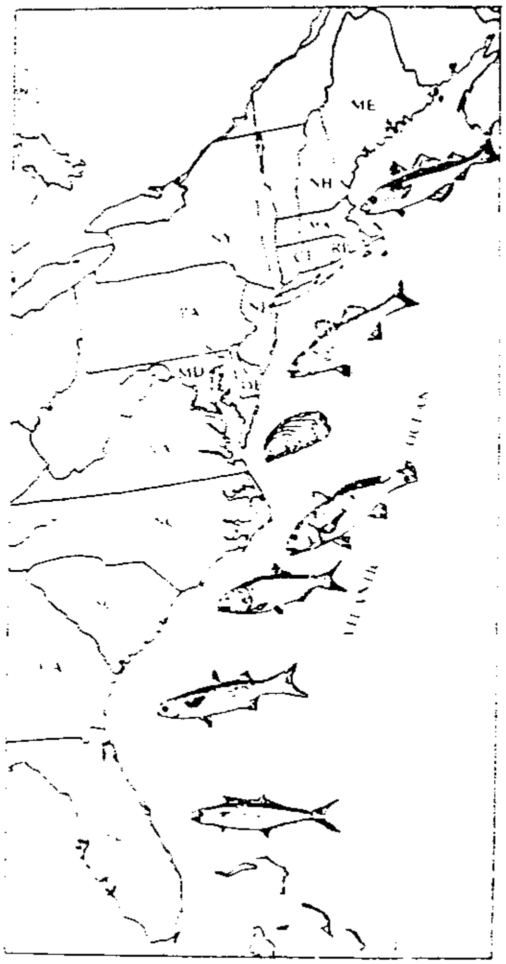
of the

ATLANTIC STATES MARINE FISHERIES COMMISSION



FISHERY MANAGEMENT PLAN FOR AMERICAN SHAD AND RIVER HERRINGS

October 1985

FISHERY MANAGEMENT PLAN FOR THE ANADROMOUS ALOSID STOCKS OF THE EASTERN UNITED STATES: AMERICAN SHAD, HICKORY SHAD, ALEWIFE, AND BLUEBACK HERRING

Phase II in Interstate Management Planning for Migratory Alosids of the Atlantic Coast

Atlantic States Marine Fisheries Commission
1717 Massachusetts Avenue, NW
Washington, D.C. 20036

October, 1985

FOREWORD

This management plan has been prepared by Martin Marietta Environmental Systems under Contract #84-3 and by ASMFC's Shad and River Herring Scientific and Statistical Committee as part of the Interstate Fisheries Management Program administered by the Atlantic States Marine Fisheries Commission. This plan has been reviewed and endorsed by the Interstate Fisheries Management Program's Shad and River Herring Management Board and Shad and River Herring Scientific and Statistical Committee. Funds were provided by Northeast Region, National Marine Fisheries Service, National Oceanic and Atmospheric Administration (NOAA) under an 89-304 anadromous grant. For bibliographic purposes, this document should be cited as follows:

> Atlantic States Marine Fisheries Commission. 1985. Fishery Management Plan for the Anadromous Alosid Stocks of the Eastern United States: American Shad, Hickory Shad, Alewife, and Blueback Herring: Phase II in Interstate Management Planning for Migratory Alosids of the Atlantic Coast. Washington, DC. XVIII + 347 pp.

EXECUTIVE SUMMARY

Preparation of a Fishery Management Plan for the anadromous alosids (American and hickory shad, alewife, blueback herring) of the East Coast of the United States was recommended by the Advisory Committee of the Atlantic States Marine Fisheries Commission (ASMFC) and adopted by the Commission in 1981, in response to the very low current levels of commercial landings of all four species.

As part of the process of developing a Fishery Management Plan for these species, ASMFC established a Shad and River Herring Management Board, with representatives from each of the east coast states in which runs of the species occur and from two federal agencies--the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). The Board subsequently appointed a Scientific and Statistical Committee to direct the development of the management plan. The committee is made up of one representative from each of the coastal states and one representative each from the USFWS and the NMFS. An Action Plan was developed at a Shad and River Herring Management Workshop in Philadelphia, Pennsylvania, 2-3 February 1982, that called for subsequent activity to occur in two phases:

- Phase I - compile available data on the current status and biology of each of the four species and define potential options for management action
- Phase II - develop a management plan, with specification of management actions where appropriate, and identify research needs.

The Phase I report was completed in July 1984. This management plan is based on information compiled in that document and additional data acquired since its publication.

The statement of the goal of this management plan developed by the Board is as follows:

> The goal of this Fisheries Management Plan (FMP) shall be to promote, in a coordinated coastwide manner, the protection and enhancement (including restoration) of shad and river herring stocks occurring on the Atlantic seaboard. This plan was developed because of depletion of stocks from overfishing, loss of habitat (resulting from construction and operation of dams and from pollution), inconsistencies in management actions, and lack of adequate data.

The objectives of the plan are to:

Objective 1 - Regulate exploitation to achieve fishing mortality rates sufficiently low to ensure survival and enhancement of depressed stocks and the continued well-being of stocks exhibiting no perceived decline. A corollary to this objective is minimization of exploitation of a given state's stocks by other states or nations.

Objective 2 - Improve habitat accessibility and quality in a manner consistent with appropriate management actions for nonanadromous fisheries. This objective can be addressed by the following types of management actions:

-- Improve or install passage facilities at dams and other obstacles preventing fish from reaching potential spawning areas

-- Improve water quality in areas where water quality degradation may have affected alosid stocks

-- Ensure that decisions on river flow allocation (e.g., irrigation evaporative loss, out of basin water transport, hydroelectric operations) take into account flow needs for alosid migration, spawning, and nursery usage

-- Ensure that water withdrawal (e.g., cooling flow, drinking water) effects (e.g., impingement and entrainment mortalities, turbine mortalities) do not affect alosid stocks to the extent that they result in stock declines.

Objective 3 - Initiate programs to introduce alosid stocks into waters that historically supported but do not presently support natural spawning migrations, expand existing stock restoration programs, and initiate new programs to enhance depressed stocks.

Objective 4 - Recommend and support research programs that will produce data needed for 1) the development of scientifically rigorous management recommendations relating to sustainable and acceptable yields, 2) the preservation of acceptable stock levels, and 3) optimal utilization of those stocks.

Lack of much needed information resulted in the development of many recommendations dealing with data needs. For this reason, the plan is viewed as a dynamic document. Monitoring of implementation and revision of the recommendations in response to new data will be essential for the plan to be successful. Recommendations of this management plan are as follows:

Regulation of Offshore Harvests

Recommendation 1.1

ASMFC will review, annually, Fishery Management Council decisions and NOAA regulations based on those decisions that relate to the anadromous alosids. Based on any new information or changes in existing status of the stocks, directed fisheries, or fisheries having a potential impact on the alosids, ASMFC shall develop and submit recommendations to the Fishery Management Councils. ASMFC shall retain their position as a voting member on council committees that address anadromous alosid issues (e.g., the Mid-Atlantic Council's Coastal Migratory Species Committee).

Recommendation 1.2

ASMFC will closely monitor the establishment and growth of joint venture and domestic mackerel fisheries in order to evaluate the consequences to river herring stocks of their capture as bycatch. ASMFC will join in the request of the Mid-Atlantic Fishery Management Council for implementation of a data collection plan by NMFS pursuant to Section 303(e) of the MFCMA. Data to be collected pursuant to such a plan should conform to the recommendations set forth in Appendix C of this plan. These data will be evaluated and analyzed to arrive at the recommendations mentioned above.

Regulation of Territorial Sea Harvests

Recommendation 2.1

Each state, in cooperation with NMFS, will monitor and document existing and new FCZ and territorial sea fisheries for anadromous alosids. The extent of participation, amount of harvest, and timing and location of each fishery will be documented; this information will be forwarded to ASMFC for its annual review of fisheries and stock status and for consideration of revision of existing recommendations in this plan. An interstate cooperative coastal shad tagging program will be conducted to determine which stocks are being exploited (see Recommendation 8.3).

Recommendation 2.2

All east coast states will recognize the priority rights of traditional fisheries in internal waters that target resident stocks, while not encouraging new intercept fisheries in territorial sea waters. Of greatest concern are fisheries taking shad along the coast very early in the year, including those occurring in South Carolina, North Carolina, Virginia, Maryland, and Delaware Bay. What appears to be an expanding summer-fall gill net fishery in the Gulf of Maine should also be closely monitored by the New England states. Such fisheries should not be encouraged and, if evidence suggests they pose a threat to any single stock of shad, steps should be taken to prohibit them.

Regulation of Harvests in Internal Water

Recommendation 3.1

Individual states will consider implementing fisheries management actions that would ensure that total exploitation rates for female American shad, hickory shad, and river herring (commercial and recreational) do not exceed levels that threaten the stability of stocks currently at acceptable levels or the enhancement of depressed or newly established stocks. Guidelines for maximum exploitation rates are presented in Table V-1.

Recommendation 3.2

Individual states will initiate studies to document existing fishing mortality rates of all four alosid species and to establish if density dependent catchability exists. Recommended guidelines for design of an acceptable study are presented in Table V-2. States shall obtain at least preliminary data within 2 years of adoption of this plan and provide these data to ASMFC for integration and distribution to interested parties.

Recommendation 3.3

Individual states shall improve records of catch and effort in general, and shall make a special effort to establish the amount of harvest reported as American shad and/or river herring that is actually hickory shad. Examples of steps that could be taken include education of fishermen, modification of reporting forms or mechanisms, and creel/harvest census during critical time periods.

Water Quality

Recommendation 4.1

Resource management agencies in each state shall evaluate their respective state water quality standards and criteria to ensure that those standards and criteria account for the special needs of anadromous alosids. This action should be taken within the normal cyclical process of criteria review that occurs in most states. Steps should be taken within 1 year of implementation of this plan to create a new class of waters (or redefine an existing class) to acknowledge status or potential status as anadromous alosid spawning and nursery areas (analogous to "trout waters"). Primary emphasis should be on locations where sensitive egg and larval stages are found. For those agencies without water quality regulatory authority, protocols and schedules for providing input on water quality regulations to the responsible agency should be identified or created. Waters of existing or potential value as alosid spawning/nursery areas should be identified for the appropriate water quality agency. Agencies in each state shall initiate actions to establish water quality criteria protective of anadromous alosid habitat requirements, but consistent with the management objectives for other species. Suggested values for key parameters are presented in Table V-3.

Recommendation 4.2

Results of ongoing studies dealing with the effects of acid deposition on anadromous alosids will be reviewed by all appropriate agencies and ASMFC as they become available. ASMFC will summarize those findings in a position document on an annual basis. Should those findings support the contention that acid deposition is having a deleterious impact on anadromous alosids, ASMFC shall offer that document as supporting evidence to all organizations and individuals pursuing acid rain controls and/or mitigation measures.

Flow Requirements

Recommendation 5.1

State resource management agencies shall identify or establish protocols that ensure that they have the opportunity to evaluate projects that may affect the flow of streams and rivers supporting or having the potential for supporting runs of anadromous alosids. State resource management agencies shall determine which state agency serves as the primary contact with the Federal Energy Regulatory Commission (FERC), since all applications relating to hydroelectric development are processed by the FERC.

Recommendation 5.2

In reviewing proposed projects that will affect flow regimes, agencies shall ensure that continuous minimum flows and the manner in which the operation of any facility alters flows will not adversely affect anadromous alosids. Guidelines for desirable instream flow variables are presented in Table V-4. State agencies should, if necessary, solicit the advice of the USFWS Instream Flow Group in developing flow recommendations.

Other Habitat Factors

Recommendation 6.1

All state and federal agencies responsible for reviewing impact statements for projects proposed for anadromous alosid spawning and nursery areas shall ensure that those projects will have no impact or only minimal impact on those stocks. Of special concern are natal rivers of newly established stocks or stocks considered depressed or severely depressed (Table V-1).

Recommendation 6.2

ASMFC and federal fisheries agencies shall continue to monitor progress in the development of Bay of Fundy hydroelectric projects. Communications with the Department of State and all interested members of Congress shall be renewed on an annual basis to reiterate opposition to the projects unless it can be demonstrated that no significant mortality to alosids will occur. Continued environmental studies shall be encouraged. Annual status reports based on information obtained from the Canadian government and project developers will be prepared and distributed to Board and Scientific and Statistical Committee members. ASMFC will request from the U.S. Department of State the right to review all environmental impact predictions prepared as part of project development. Factors that influence U.S. purchase of power from these projects should be monitored to determine if actions can be taken to discourage their development.

Restoration of Anadromous Alosids

Recommendation 7.1

All agency personnel participating in anadromous alosid restoration programs should be alert for indications of disease or parasites. At present, no information exists to suggest that transfer of disease or parasites is a problem. However, should a potentially serious problem arise, ASMFC shall develop a disease control and screening program for alosids. Such a program could follow the form of the existing New England Atlantic Salmon Disease Control Program.

Recommendation 7.2

Each state that has not already done so shall evaluate the potential for anadromous alosid restoration within their internal waters. Such an evaluation should include, at a minimum, a listing of waters that currently do not support anadromous alosid stocks but that might if water quality and access were improved or created. Within one year from the date of adoption of this plan, and annually thereafter, each state shall provide to ASMFC this evaluation, a summary description of ongoing restoration efforts, and a statement of anticipated restoration activities for the next five years. ASMFC shall use material from these submittals to prepare an annual summary of coastwide restoration efforts for distribution to agencies, legislators, and all other interested parties.

Recommendation 7.3

ASMFC and all state and federal resource agencies shall support, in every way possible, the preservation and enhancement of federal programs providing funds for the restoration of anadromous fish. Such programs include the Anadromous Fish Act and Wallop-Breaux programs and other federal grant programs that support studies of anadromous alosids, such as Sea Grant and Coastal Zone. It is obvious that most of the very successful anadromous alosid programs that currently exist would not have been initiated if these federal programs were not in place. Implementation of a coastwide alosid restoration plan will not be feasible in the absence of these federal programs. States should also develop additional state funding sources for restoration of anadromous alosids; possibilities include special licenses or stamps.

Recommendation 7.4

All state and federal agencies shall cooperate to further all current or planned anadromous alosid restoration efforts. Because the acquisition of gravid adults for transplanting is essential for most restoration efforts, those agencies having regulatory control over existing healthy runs of all species should be particularly sensitive to the needs of agencies implementing restoration efforts and should provide the maximum cooperation possible. ASMFC's Shad and River Herring Board will serve as a coordinator to resolve any major disputes.

Recommendation 7.5

Because of the important role of turbine mortality in determining the success or failure of many restoration programs, all agencies participating in restoration programs involving hydroelectric projects shall include in those programs plans for turbine mortality and downstream passage studies. The term "fish passage" should consistently be interpreted to include downstream passage in any discussion of restoration activity. Results of ongoing and new studies shall be provided on an annual basis to ASMFC for compilation and for dissemination of data to all appropriate state and federal agencies. A continuous exchange of information on turbine mortality and methods for passing anadromous alosides downstream may lead to new and successful methods for alleviating this problem.

Recommendation 7.6

All resource agencies shall oppose any new hydroelectric projects proposed for drainage systems currently supporting or with potential for supporting anadromous alosid runs unless the developer can demonstrate to the agencies' satisfaction that the project, as proposed, will not have an unacceptable adverse impact on alosid runs. Of particular concern here are small-scale hydroelectric projects existing or proposed for smaller drainage systems supporting river herring runs. Cumulative impacts of several facilities on the same drainage system must also be considered. Major issues are upstream passage of spawning adults and successful downstream passage (i.e., avoidance of turbine mortality) of outmigrating, spawned-out adults and juveniles.

Research Needs

Recommendation 8.1

ASMFC shall serve as a coordinator of research conducted along the east coast dealing with anadromous alosids. ASMFC will prepare a summary compendium of ongoing studies annually. Grant applications and/or proposals for anadromous alosid research programs submitted to federal and/or state agencies should be provided to ASMFC for comment to ensure that the focus of new studies is consistent with management needs identified in this plan.

Recommendation 8.2

In assigning priority for research funding under PL89-43 (Anadromous Fish Conservation Act), NOAA/NMFS and USFWS shall assign high priority to applications for state projects that satisfy data needs identified as having a high priority in this plan (see Table V-12 and V-13).

Recommendation 8.3

ASMFC shall design and coordinate the implementation of an interstate coastal shad tagging research program (see Recommendation 2.1). A tentative study design is presented in Table V-14. The initial interstate effort will focus on participation by South Carolina and North Carolina, or other states where the nature of the fishery makes the study more feasible. ASMFC will be responsible for coordination of the activities of individual states and integration and interpretation of results. Studies that lead to the development of techniques to identify the river of origin of fish taken in mixed stock fisheries (e.g., ocean tagging, extensive within river tagging, innate indicators) should be encouraged in order to enhance the interpretation of findings of this tagging program.

Recommendation 8.4

In establishing new anadromous alosid research programs, state and federal agencies will proceed according to the priorities presented in Table V-13.

Recommendation 8.5

ASMFC shall undertake the compilation and analysis of all data on offshore river herring distribution and harvest available from NOAA (e.g., NMFS research trawl data, observer data, experimental Polish trawl program data). This information should be updated annually, and should be used to develop or revise recommendations to the Fishery Management Councils on regulations needed to protect traditional domestic river herring fisheries.

Citizen Participation

Recommendation 9.1

Individual states are encouraged to establish programs that involve citizens in implementation of this plan. Such involvement would be appropriate as individual state plans are being developed. Participation by user groups and interested citizens may result in the public support required to implement the plan.

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I. INTRODUCTION

Preparation of a Fishery Management Plan for the anadromous alosids of the East Coast of the United States (American and hickory shad, alewife, blueback herring) was recommended to the Atlantic States Marine Fisheries Commission (ASMFC) by its advisory committee, with the recommendation being adopted by the commission in 1981. This action was prompted by the very low current commercial landings of all four species, which was perceived as an indication that management action would be required to restore stocks to their former levels of abundance. The basis for action by the commission was that the four species met five criteria for inclusion in the ASMFC Interstate Fisheries Management Program (ISFMP)(ASMFC 1982):

- The species are valuable to the states and to the nation.
- They are perceived to be in need of management for attainment of optimum yield.
- They are not currently scheduled for management under the Magnuson Fishery Conservation and Management Act (PL 94-265).
- There is reasonable expectation that the plan can be implemented.
- The species are amenable to cost-effective management.

As part of the process of developing a Fishery Management Plan for these species, ASMFC established a Shad and River Herring Management Board which includes representatives from each of the east coast states in which runs of the species currently or formerly occurred: Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, and Virgnia. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are also represented.

The Board subsequently appointed a Scientific and Statistical Committee to direct the development of the management plan. The committee is made up of technical representatives from each of the previously mentioned states and the two federal agencies. An action plan was developed at a shad and river herring management workshop in Philadelphia, Pennsylvania, 2-3 February 1982, which called for subsequent activity to occur in two phases:

- Phase I - compile available data on the current status and biology of each of the four species and define potential management options

- Phase II - develop a management plan with specific management actions, where appropriate, and define research needs.

Martin Marietta Environmental Systems was contracted by ASMFC to develop the management plan. Phase I of the program was completed in July 1984 with the publication of a document entitled, "Current Status and Biological Characteristics of the Anadromous Alosid Stocks of the Eastern United States: American Shad, Hickory Shad, Alewife, and Blueback Herring; Phase I in Interstate Management Planning for Migratory Alosids of the Atlantic Coast." This document, which was made available to the public through the National Technical Information Service (NTIS), is included here as Appendix A, and presents the background information upon which the management plan is based. It is important to note that the status of these four species was evaluated primarily by examining landings data.

The present document constitutes the ASMFC management plan for the four anadromous alosids and, to the extent possible, it conforms to the standards for fishery management plans set by the Magnuson Fisheries Conservation and Management Act of 1976. However, because of the unique nature of these fisheries, this plan differs from the Magnuson Act standards in the following ways:

- Stocks of all four species are at very low levels over portions of their range. Thus, the major short term goal of this plan is to restore or enhance the species rather than to attain an optimum or maximum sustained yield.

- Most exploitation of anadromous alosids occurs in the state of their origin, and interjurisdictional and international conflicts are currently minimal. As a result, the plan focuses on offering biological and economic information of value to individual states in protection and enhancement of their own stocks and promotes coordination among states in all activities dealing with the anadromous alosids.

- Because this plan focuses mainly on restoration, economic issues are not addressed. While the integral role of economics in all fisheries is acknowledged, the depressed state of stocks in many states requires that all efforts currently be directed at biological aspects of management. At a later time, when stocks have been restored to stable and self-supportable levels, management recommendations may be revised to account for economic factors.

- This plan addresses the four species as a group. This approach is possible and desirable because of many similarities in their life history characteristics and current status. Some management objectives included here are applicable to all four species while others are specific to individual species.

- The absence of critical population biology data for all species limits the number of specific quantitative management objectives that could be incorporated into this plan. For this reason, many of the management objectives deal with information needs and acquisition. Thus, this plan is intended to be dynamic in nature; as information gaps are filled management recommendations will be revised and become more specific.

The remainder of this document is presented in four segments:

- The status of the stocks is summarized, based on material presented in detail in Appendix A

- Management problems are identified

- Management goals and objectives are presented

- Recommendations of actions necessary for achievement of management objectives are presented.

All references cited in the text of this plan are listed in the bibliography of Appendix A.

II. CURRENT STATUS OF THE EAST COAST ANADROMOUS ALOSID STOCKS

A. INTRODUCTION

As noted earlier, the Phase I document prepared as part of this management program and appearing here as Appendix A presents a compilation of available data on the current status and biology of the four anadromous alosids of the eastern United States. In this section, the Phase I report is summarized, and in some instances (e.g., catch records) data are updated.

B. SPECIES AND FISHERIES OVERVIEW

The four anadromous alosid species addressed in this plan are the American shad (Alosa sapidissima), hickory shad, (Alosa mediocris), alewife (Alosa pseudoharengus), and blueback herring (Alosa aestivalis). Alewife and blueback herring are addressed jointly as river herring because commercial fishermen do not distinguish between them. Thus, all landings data include only a single category for both species, labeled river herring. Figure I-1 in Appendix A illustrates the four species. Figures I-2 through I-5 in the appendix characterize the general life history of each of the species.

Of the four species, American shad and blueback herring are the two most ubiquitous, spawning from Nova Scotia to Florida. Hickory shad are more southern in distribution, while alewives are more northern. All are anadromous, with their spawning runs occurring from late winter to early summer, depending on species and latitude. Existing data suggest that the river herrings and American shad exhibit extensive seasonal coastal migrations, thus creating possibilities for interstate conflicts in fisheries. Nothing is known of the migratory behavior of hickory shad at sea.

Fisheries for all four species have changed dramatically during the 20th century. In the late 1800s and early 1900s, large, annual catches of all four species were made along the entire coast each spring, with most of the harvest being used for human consumption (Mansueti and Kolb 1953).

Coastwide harvests of all four species have declined markedly since the early 1900s, with the most recent decline occurring during the early 1970s. Tables II-2 and IV-1 of Appendix A present coastwide harvests of American shad and river herring from 1930 to 1984. Landings data for hickory shad (presented in Ch. III of Appendix A) are of questionable value for documenting stock trends. While changes in effort may have contributed to the observed declines in landings, the recent major harvest declines are believed to reflect major declines in stock size. River herring declines are attributable in part to large offshore river herring harvests by foreign fisheries in the late 1960s and early 1970s (Table IV-15 in Appendix A). Causes of declines in American shad and hickory shad are less well defined, as is discussed at length in Appendix A.

In addition to harvest levels changing over the last 50 years, the nature of fisheries, the use of harvest, and the economic value of the species have also changed:

- Shad runs, where abundant, now support extensive sport fisheries that may be of much greater economic value than commercial harvests (e.g., on the Connecticut and Delaware rivers).

- Extensive recreational fisheries which formerly existed in certain locations have essentially disappeared as stocks declined (e.g., American and hickory shad in Maryland).

- Use of commercially harvested river herring has changed from primarily human consumption to primarily pet food, fish meal, and bait.

- Modes of harvest have changed dramatically for American shad (from pound nets and haul seines to gill nets).

- The rate of increase in dollar value for all commercially harvested alosids has consistently been less than the inflation rate (Tables II-8 and II-19 in Appendix A).

Regional contributions to the coastwide stock declines of all species have differed markedly. Greatest harvest declines of both shad and river herring have occurred in the southeastern states and Chesapeake Bay region. Hickory shad stocks, which are more southern in distribution, may have also declined markedly. However, because only landings data are being considered here in evaluating stock status, it is possible that effort and not stock size may have declined in some areas. These observations must also be tempered somewhat by acknowledging the regional differences in fisheries that occur. Very little commercial exploitation of river herring occurs in Delaware, New Jersey, New York, and Connecticut. For this reason, landings data for the mid-Atlantic region do not serve as credible indicators of stock size.

In the case of American shad, the Delaware, Hudson, and Connecticut rivers support the only major shad runs north of the Chesapeake Bay, in contrast to the large number of rivers supporting runs in the Chesapeake and southeast regions. Another factor that confounds trend comparisons between stocks in northern and southern rivers is that the three major northern rivers have each been the focus of some special activity (i.e., restoration, pollution abatement, or fishery closure). Such factors prevent clear rigorous conclusions from being drawn regarding geographical differences in stock trends.

All of the above topics are treated in greater detail in Appendix A. Tables II-2 and IV-1 in Appendix A include American shad and river herring landings data not included in the original version of the Phase I report. Maine river herring landings for 1982 and 1983 declined markedly from earlier years. However, this is attributed to very high spring runnoff in those years (T. Squires, pers. comm.), and the landings decline is not viewed as an indicator of stock decline. In North Carolina, and Virginia, river herring landings in 1982 and 1983 appear to have rebounded substantially from the extremely low harvest taken in 1981. Whether this rebound reflects increased effort or increased stock is not known at this time. Increases in shad landings are also evident in North Carolina and Virginia. Without detailed effort data, no inferences about stock fluctuations can be drawn from these new harvest figures.

C. SOCIOECONOMIC CONTEXT

The nature of existing fisheries may help define management actions that would contribute to stock enhancement. Because all four alosids are anadromous, adult stocks concentrate in inshore areas during the spawning season and are then most vulnerable to exploitation. As a result, fisheries for these species have traditionally been concentrated in the spring and in areas adjacent to or within spawning locations.

Two major exceptions to these generalizations have occurred in the past. Late in the 1950s purse seine fisheries in Massachusetts took substantial amounts of shad and river herring when menhaden stocks declined (p. II-9 of Appendix A). In the late 1960s and early 1970s foreign fisheries began to exploit river herring in coastal waters, with offshore annual harvest eventually exceeding the domestic inshore harvest (p. IV-34 of Appendix A).

In response to the declines in stock abundance that have occurred over the past two decades, fisheries have changed drastically. Thus, the current socioeconomic context for management differs significantly from circumstances in the past. This background can be summarized by category: 1) fisheries conservation zone (FCZ), territorial sea, and Canadian fisheries and 2) internal waters fisheries.

Fisheries Conservation Zone, Territorial Sea, and Canadian Fisheries

- Currently, no domestic fisheries directed at river herring occur in the fisheries conservation zone (FCZ) or in territorial sea waters. Proposals for joint-venture fisheries for mackerel, to be conducted with foreign fleets, may alter this circumstance since such fisheries may take river herring as bycatch.

- Current total allowable landings for foreign fisheries (TALFF) is very low and permits limited bycatch of river herring. No foreign fisheries directed at river herrings exist.

- No foreign offshore fisheries for American shad exist (shad are categorized as a prohibited species within the FCZ). Domestic fisheries exist in offshore areas (>3 miles from shore) and in territorial seas (within 3 miles of shore). Southern territorial sea fisheries for shad yield the highest price per pound for shad along the east coast because they occur early in the season before more northernly runs begin. There are indications that there is increasing coastal/offshore harvest of shad by gillnetters operating along the coast from Maine to South Carolina, although total magnitude of harvest remains low relative to inshore harvests.

- A limited Canadian fishery for American shad occurs in the Bay of Fundy. While not of major significance at present, expansion of this fishery could pose a threat to east coast stocks.

- Additional expansion of FCZ and territorial sea fisheries may depend on market factors.

Internal Waters Fisheries

American Shad

- Most internal waters fisheries occur in or near natal streams.

- Fisheries in natal rivers tend to be traditional in nature with long-time participants, known markets, well defined seasons impacted by timing of the run, and fairly rigid timing of market demand. Primary income for most shad fishermen is from other sources.

- In southern states very substantial "sport" gillnetting occurs; thus harvests are difficult to document.

- Sport fisheries have become prominent in the northeastern and mid-Atlantic regions, to the extent that their economic value exceeds that of concomitant commercial fisheries in those areas. Conversely, in regions where stocks have declined substantially sport fisheries have virtually disappeared (e.g., Maryland runs).

<u>Hickory Shad</u>

- Limited commercial fisheries directed at hickory shad occur in the south, preceding the American shad runs. Most hickory shad harvest, however, is taken as bycatch in the American shad fisheries.

- Hickory shad formerly supported major sport fisheries. However, as stocks decline, these fisheries have also declined.

- Dollar value of hickory shad often differs markedly by state, based on public perception of the desirability of the species (p. III-6 of Appendix A).

<u>River Herring</u>

- Major river herring fisheries in Maine and Massachusetts are operated by local municipalities. Weirs are in place on the home streams, are operated seasonally, and yield harvests that go to traditional markets.

- Very limited river herring fisheries occur in the mid-Atlantic region.

- Fisheries in the Chesapeake Bay and North Carolina are dominated by pound nets. For such fisheries that are specific to river herring to be profitable, large amounts of fish must be harvested. In a sense, the fisheries are self-regulating, since when stocks are low, the fisheries become unprofitable and are not pursued.

- River herring are used primarily as commercial or recreational fishing or crabbing bait, for processing to fish meal, or as pet food. Some markets exist for canned roe, but a minor percentage of total harvest is used for human consumption.

- Substantial sport fisheries exist for river herring (hook and line as well as dip netting). These fisheries are poorly documented but are extensive and of great social importance.

D. SCIENTIFIC CONTEXT

Management actions should ideally be based on detailed knowledge of a species' life history, its population dynamics, and the type, pattern, and magnitude of its exploitation. In the case of the four alosid species addressed here, the depth of knowledge of these factors varies markedly, particularly in the areas of life history and population biology. These limitations will substantially constrain the types of management recommendations that can be developed at this time, which in turn suggests that this plan will have to be regularly reviewed and modified as new information becomes available. The following represents aspects of our knowledge of the species biology of greatest relevance to management recommendations.

Hickory Shad

- Detailed hickory shad studies have been conducted in very few locations, and all have focused on spawning stock age structure and behavior.
- Juveniles are difficult to capture, and little is known of their behavior during emigration.
- Virtually nothing is known about migratory patterns of subadults and nonspawning adults.
- While precise homing to natal streams is assumed, no evidence of homing exists.
- Very little is known of the population dynamics of the species, except that spawning runs are dominated by old repeat spawners to a much greater degree than for the other three alosid species.

River Herring

- Extensive studies of individual runs of alewife and blueback herring have been conducted in states where major fisheries exist, particularly in New England and Virginia.

- In New England states, where major spawning and nursery grounds consist of lakes and ponds, long-term average run size appears to be a function of the amount of spawning/nursery acreage (Gibson 1984, unpublished manuscript).

- In New England runs, fishing mortalities of 80 to 95% do not appear to have a significant impact on spawning success (p. IV-62 of Appendix A).

- In runs occurring in the southeast, some evidence of the dominant year class phenomenon is seen in river herring stocks. (See discussion of Virginia runs on p. IV-22 of Appendix A.) The nature of nursery areas in Virginia differs from that of spawning areas in New England waters, and acreage available for spawning appears to have a lesser impact on stock size than is the case in New England.

- Limited information suggests that river herring stocks undertake extensive coastal migrations, summering in the Gulf of Maine and Bay of Fundy, and wintering in the mid-Atlantic area. Whether regional stocks differ in their extent of migration and whether all stocks intermingle are not known (see pp. IV-37 to IV-46 of Appendix A).

- Patterns of immigration and emmigration of adults and juveniles from spawning areas are well documented.

- The deleterious impact of offshore foreign harvests of Chesapeake Bay and southeastern region river herring stocks suggests that excessive fishing mortality (perhaps of subadult fish) can drastically reduce future recruitment. This observation is not consistent with findings in the New England area.

- Homing of New England stocks is well documented; degree of precision of homing in stocks occurring in tributaries of large estuaries has not been well documented.

American Shad

- Most of the detailed knowledge available concerning American shad population dynamics is for the Connecticut River. Less detailed data are available for other rivers, including the Altamaha, Susquehanna, Delaware, and Hudson.

- In the Connecticut River, with present stock levels, environmental variables (temperature and river flow) appear to exert dominant control on spawning success each year. For shad stocks at very low levels (e.g., Pawcatuck River in Rhode Island) numbers of spawning adults may be the major factor controlling spawning success (Gibson 1984, unpublished manuscript).

- Coastal migration patterns of shad are relatively well documented. All east coast stocks intermingle at sea; they summer in the Gulf of Maine-Bay of Fundy area and overwinter in the mid-Atlantic region. Combined stocks move inshore to the south at the beginning of their spawning migration; individual stocks split from the northerly moving aggregation as they encounter their natal rivers.

- Patterns of immigration and emmigration of adults and juveniles from the spawning areas are well documented.

- Amount of escapement from the fishery is believed to play a major role in assuring the continued stability of a stock. Modeling runs have suggested that for the Connecticut River, harvest rates exceeding 40% of females may endanger stock survival (Crecco 1985, unpublished data).

E. MANAGEMENT CONTEXT

The distinctive characteristics of the fisheries for the anadromous alosids and their life histories define and/or constrain the types of management actions that are feasible and that are likely to lead toward achievement of management objectives. The following topics comprise the context within which management recommendations must be developed. Each is supported by the technical material just discussed and elaborated on in Appendix A.

Homing and Inshore Fisheries

As a generalization, most fisheries for shad and river herring occur in or at the mouths of the spawning streams or rivers. (Individual exceptions occur such as the coastal shad fishery in South Carolina.) It is likely that these fisheries account for the major proportion of adult mortality. The significance to management of the occurrence of homing and the nature of these fisheries is that:

- Drainage systems in general support unique stocks of anadromous alosids.

- Fisheries on these individual drainages constitute a major source of adult mortality.

Offshore and Coastal Migrations and Fisheries

The significance of migration patterns is that:

- Offshore fisheries (foreign or domestic) have potential for affecting runs of all species along the entire east coast.

- Proposed tidal hydroelectric facilities in the Bay of Fundy area pose a serious threat to all east coast river herring and American shad stocks (there is no evidence of hickory shad occurring in the Bay of Fundy).

- Nearshore coastal shad fisheries may affect nonresident shad stocks undertaking their regular seasonal migration.

Population Dynamics

The significance of population dynamics characteristics is that:

- Any management recommendations regarding hickory shad will have virtually no rigorous scientific basis.

- Management recommendations for all runs of American shad may have to draw on information available in very limited geographic areas.

- Habitat management (e.g., improving water quality and access) may have greater impacts on stocks than would harvest restrictions where runs are stable and near maximum carrying capacity.

- Fishing mortalities could have very deleterious effects on stocks that are at low levels, and harvest restrictions may offer the greatest possibility for enhancing recruitment.

Geographic Differences in Stock Status

As was discussed earlier, alosid stocks in the Chesapeake and southeast regions appear to have suffered declines, while those of the mid-Atlantic and New England regions have not. Opportunities for restoration of anadromous runs exist along the entire coast, particularly in areas with large numbers of existing dams. The significance of these points is that:

- Management recommendations should be focused on southern and Chesapeake Bay stocks.
- Restoration could play a major role in enhancing existing stock levels in most regions.

Applicability of Management Options

The life histories of these species and their fisheries determine the potential effectiveness of various management actions.

- Harvest of river herring in the FCZ by U.S. fishermen, either in directed fisheries or as bycatch, is currently unregulated and cannot be regulated unless a management plan is developed by the regional Fishery Management Councils (FMCs).
- Because of the nature of the species' life history, very few year classes make up the segments of American shad and river herring stocks being exploited in coastal and riverine fisheries. Thus, regulations relating to size limits or mesh sizes and designed to prevent growth overfishing will have no impact on these stocks. Stocks where repeat spawning is very substantial may benefit from size or mesh restrictions (e.g., hickory shad).
- Types of regulations that affect the exploitation rate of females will be most effective for controlling recruitment of alosid stocks. Examples of such regulations include lift days, seasons, area restrictions, and gear-type restrictions.

F. REGULATORY FRAMEWORKS

Implementation of any management recommendations included in this plan must be accomplished within existing regulatory frameworks. In the case of the anadromous alosids, the applicable regulatory frameworks are numerous and complex.

Fisheries in the Fisheries Conservation Zone

During periods of ocean residence, all alosid species are vulnerable to fisheries operating in the Fisheries Conservation Zone (3 to 200 nautical miles offshore). Such fisheries fall under the broad management purview of the regional Fishery Management Councils (New England, Mid-Atlantic, and South Atlantic) under authority of the Magnuson Fishery Conservation and Management Act. The councils receive technical/administrative support and advice from the National Oceanic and Atmospheric Administration.

American shad are currently classed as a prohibited species for foreign fisheries within the FCZ. By this classification, none can be legally landed though incidental harvest and overboard disposal are not regulated against. Hickory shad, alewife, and blueback herring are collectively termed "river herring." No fishery management plan (FMP) for anadromous alosids in the FCZ currently exists. The species are mentioned in a Preliminary Management Plan for other species under jurisdiction of the Secretary of Commerce. A total allowable level of foreign fishing (TALFF) for river herring is established as part of the Preliminary Management Plan (PMP) for finfish caught incidentally to foreign trawl fisheries of the Northwest Atlantic. The TALFF is then allocated annually to specific countries by the Department of State based on recommendations from NOAA. Total allocations cannot exceed the TALFF, and for river herring the total landings have generally been well below the TALFF (100 metric tons (mt)) in recent years (1981-1984). No directed fisheries are permitted and all of the TALFF is applied to bycatch. In the absence of an FMP, there exists no regulatory basis for controlling river herring harvests by United States fishermen within the FCZ. Joint-venture fisheries, in which U.S. ships harvest fish which are sold to foreign processing ships, thus fall outside the constraints of the TALFF. Joint venture fisheries must still receive approval of the Councils, however, and receive a permit from NOAA.

State-Managed Fisheries

Fisheries within 3 miles of the coastline and in estuarine and fresh waters fall under the regulatory authority of the individual states. In many drainage systems, interstate management plans have been developed for American shad, as will be discussed below. However, implementation of recommendations in those plans is the responsibility of the individual states, which are not legally bound by those plans.

Regulatory procedures differ substantially among the states. In some the resource management agencies have full regulatory authority, while in others state legislatures retain that authority. Details of regulatory procedures by state are presented in Appendix B. Differing procedures for implementing regulations result in differing amounts of time required for implementation. Time constraints may impact on the feasibility of proposed management actions.

Interstate Agreements

A large number of rivers supporting anadromous alosid runs occur along or cross state boundaries, and interstate compacts or agreements exist for many: Potomac River (Maryland and Virginia); Delaware River (Delaware, New Jersey, Pennsylvania, New York, NMFS, FWS); Connecticut River (Connecticut, Massachusetts, Vermont, New Hampshire, NMFS, FWS), Merrimack River (Massachusetts, New Hampshire, NMFS, FWS); Hudson River (New York, New Jersey, USFWS, NMFS); and the St. Croix River (Maine, Canada).

Fisheries in the Potomac River are regulated by the Potomac River Fisheries Commission (PRFC). The Commission is made up of representatives from Virginia and Maryland and is supported by a technical staff responsible for drafting regulations and monitoring the fisheries. The Commission has to date developed no formal species management plans. Coordination of PRFC regulations with those of Maryland and Virginia is informal, by virtue of the lead resource management personnel from each state being on the Commission. The District of Columbia has recently established a fisheries management program and coordinates their management activities with the PRFC.

Management of Connecticut River anadromous fisheries was initially guided by the Connecticut River Fisheries Policy Committee. The Connecticut River Atlantic Salmon Commission, created by Public Law 98-138 in 1983, has since assumed responsibility for all restoration efforts on the Connecticut River. The commission includes members from Connecticut, Massachusetts, New Hampshire, Vermont, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The focus of management activity has been restoration of American shad and Atlantic salmon. Individual states retain autonomous regulatory authority, except on Atlantic salmon. However, the Commission serves as a forum for coordinating management activities of the individual states.

In the Delaware River drainage, the Delaware Basin Fish and Wildlife Management Cooperative was created to manage the interstate fisheries resources of the basin. Consisting of representatives from New Jersey, Delaware, New York, Pennsylvania, NMFS, and USFWS, the Cooperative developed a comprehensive fishery management plan for American shad in the Delaware. As with the other cooperatives, implementation of the recommendations is the responsibility of the individual states.

The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) was created to guide efforts to restore anadromous fish, particularly American shad, to the Susquehanna River drainage system. The committee includes representatives from Maryland, Pennsylvania, New York, USFWS, the Susquehanna River Basin Commission, and the utilities that operate hydroelectric facilities on the Susquehanna. Because restoration is in its initial phases, all committee activities have dealt with technical matters in contrast to management or regulatory matters. Pennsylvania and Maryland have agreed to keep Susquehanna River shad fisheries closed while a restoration program is proceeding.

A Technical Committee for Fisheries Management of the Merrimack River was formally established on 29 September 1969. This committee was formed to design and implement needed research programs as well as to recommend sound fishery management procedures for the restoration and utilization of anadromous fish species in the Merrimack River basin. The committee consists of representatives from the Massachusetts Division of Fish & Wildlife, the Massachusetts Division of Marine Fisheries, the New Hampshire Fish & Game Department, the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the U.S. Forest Service.

Planning for development of a fisheries management plan for the St. Croix River is currently underway. Tentatively the management committee will include representatives from Canada's Department of Fisheries and Oceans, and from Maine's Atlantic Sea Run Salmon Commission, Department of Inland Fisheries and Wildlife, and Department of Marine Resources. A draft plan is expected to be completed in 1985.

A cooperative agreement between Rhode Island and Connecticut for the management of anadromous fish in the Pawcatuck River is also currently being developed.

III. STATEMENT OF THE PROBLEM

As was described in the introduction, stocks of all four anadromous alosids, considered in aggregate along the entire east coast, have been perceived to have declined substantially over the past two decades. Earlier, even more drastic declines, such as those of the early 1900s (Mansueti and Kolb 1953), were readily attributable to such factors as:

- Construction of large dams across the mainstems of major spawning rivers that prevented access to large portions of historical spawning areas
- Pollution of spawning and nursery areas
- Overfishing due to the methods then allowed, including extending nets across entire rivers, no stream closures, and unlimited harvest.

The more recent declines have been perplexing and frustrating to fisheries managers for a number of reasons:

- No major new dam construction activity has occurred over the past two decades.
- At least modest restrictions on fishing methods and total effort have been in place for many years, both before and after the recent decline (at least for the inshore fisheries).
- While degradation of water quality concomitant with increased development of watersheds has certainly occurred in the last 20 to 30 years, the decline has been gradual, while the major decline in alosid stocks occurred in a relatively brief period in the late 1960s and early 1970s.
- Major declines appear to have occurred in stocks of the southeastern and Cheasapeake Bay regions, while stocks in the mid-Atlantic and New England regions appear to have remained at "acceptable" levels or to have actually increased.
- Concerns about declines in stocks have been based on documented declines in commercial and recreational harvests. While documented declines and relatively anecdotal observations all support inferences of stock declines, little hard data are available to rigorously quantify the declining trends and establish statistical relationships to potential causative factors.

In order to develop management recommendations for these species in the face of such uncertainties, specific problem areas must be defined to the extent that existing information permits. Based on the review and discussion of material presented in the Phase I document (Appendix A), the Scientific and Statistical Committee and Management Board have identified four problem areas relevant to all four of the alosid species addressed here. These problem areas provide the framework within which management recommendations were developed:

- Recruitment overfishing may have occurred for all species, and excessive mortality due to fishing may currently be keeping stocks at depressed levels. Evidence of this is strongest for river herring stocks, for which extremely large offshore harvests of adult and subadult fish were followed immediately by drastic declines in southeastern and Cheasapeake Bay stocks. Relatively high exploitation rates for American shad have been documented in recent years for a number of spawning rivers; excessive exploitation rates could cause major stock declines. At low stock levels, recruitment may be strongly affected by stock size. Thus, high rates of exploitation on stocks at low levels will severely depress recruitment.

- Habitat quality has declined. This generalization is best supported by recent documentation of the decline in water quality of the Chesapeake Bay (EPA 1984), but is confirmed by findings of numerous other studies of river systems along the east coast. The Delaware River situation provides some confirmation of the validity of this problem but from an opposite perspective. Improvements in water quality in the Philadelphia-Camden area of the Delaware River were accompanied by gradual increases in shad stock; however, in some systems (e.g., Ogechee River, Georgia) shad stocks declined drastically with no observed changes in water quality. No substantial decreases in quantity of available habitat can be documented to have occurred in the past two decades. However, changes in river flows due to hydroelectric development and water use may have had impacts on specific stocks.

- American shad stocks from a large number of different river systems may be exposed to intercept fisheries during residence in ocean waters. Rapid expansion of the South Carolina coastal fishery in the last 5 or 6 years may have been supported by exploitation of mixed stocks of fish moving northward as part of their spawning migration pattern. However, no hard evidence of the effect of this fishery on exploitation rates of nonresident stocks is available. Restrictions on stationary gear (the major type used in this fishery) went into effect within the last two years, but apparently had only a limited impact on shad harvest (W. McCord, South Carolina Wildlife and Marine Resources Department, personal communication). Evidence of increased harvests of shad in territorical seas and the FCZ exists for many states along the coast (including Delaware Bay), and all such fisheries are exploiting multiple stocks. These types of fisheries pose potential interstate management problems. The lack of knowledge of the contribution which these fisheries make to total mortality of various stocks, the lack of knowledge as to which stocks are being most affected and the vulnerability of newly restored or depressed stocks to any additional sources of mortality all point to the potential importance of these intercept fisheries.

- <u>Major data deficiencies limit the development of scientifically rigorous management decisions</u>. As has already been discussed, many elements of population biology and life history are poorly documented for the anadromous alosids, especially hickory shad. This lack of knowledge will prevent the development of scientifically rigorous management recommendations. For example, recommendations on sustainable yields will not be possible. The almost total absence of useful data on hickory shad will allow development of only general recommendations for that species. However, the review of existing information does allow us to set research priorities.

IV. STATEMENT OF MANAGEMENT GOAL AND OBJECTIVES

A. MANAGEMENT GOAL

The goal of this management plan is as follows:

> The goal of this Fisheries Management Plan (FMP) shall be to promote, in a coordinated coastwide manner, the protection and enhancement (including restoration) of shad and river herring stocks occurring on the Atlantic seaboard. This plan was developed because of depletion of stocks from overfishing, loss of habitat (resulting from construction and operation of dams and from pollution), inconsistencies in management actions, and lack of adequate data.

This management goal was established at a joint meeting of the Scientific and Statistical Committee and the Management Board, held in Windsor Locks, Connecticut, 18-19 July 1984. The debate leading to establishment of this goal was long and often heated. Two major points of contention were:

- The need or lack of need for numerical goals. This argument centered on the basis for assessing whether the goal was being approached or met. One school of thought was that some numerical goal, such as commercial harvest levels experienced in the early 1960s, should be set as a basis for tracking the success of whatever management actions were implemented. The counter school of thought was that landings were heavily influenced by effort and market factors, thus placing into question the comparability of past and future harvest totals. The consensus was that the primary problem at present was that stocks were extremely low, and that it was premature to set specific numerical goals, especially since the focus of this plan is relatively short term. A number of existing state and interstate restoration plans do have numerical goals.

- Time limits for attainment of goals. This argument was similar to that concerning numerical goals, that is, some benchmark was necessary against which to measure progress. The consensus was that time limits for some objectives should be set, but that a time limit for the attainment of the overall goal was inappropriate.

B. OBJECTIVES

Objectives consistent with the management goal were developed at the July 1984 meeting mentioned above. Draft versions of those objectives were further refined at a meeting of the Shad and River Herring Management Board in Savannah, Georgia, on 1 October 1984. The objectives focus on the statement of the problem in Section III above, and they provide the rationale for the recommended management actions, which follow in Section V.

- <u>Objective 1</u>

  Regulate exploitation to achieve fishing mortality rates sufficiently low to ensure survival and enhancement of depressed stocks and the continued well-being of stocks exhibiting no perceived decline. A corollary to this objective is minimization of exploitation of a given state's stocks by other states or nations.

- <u>Objective 2</u>

  Improve habitat accessibility and quality in a manner consistent with appropriate management actions for nonanadromous fisheries. This objective can be addressed by the following types of management actions:

  -- Improve or install passage facilities at dams and other obstacles preventing fish from reaching potential spawning areas.

  -- Improve water quality in areas where water quality degradation may have affected alosid stocks.

  -- Ensure that decisions on river flow allocation (e.g., irrigation evaporative loss, out of basin water transport, hydroelectric operations) take into account flow needs for alosid migration, spawning, and nursery usage.

  -- Ensure that water withdrawal (e.g., cooling flow, drinking water) effects (e.g., impingement and entrainment mortalities, turbine mortalities) do not affect alosid stocks to the extent that they result in stock declines.

- <u>Objective 3</u>

  Initiate programs to introduce alosid stocks into waters that historically supported but do not presently support natural spawning migrations, expand existing stock restoration programs, and initiate new programs to enhance depressed stocks.

- Objective 4

  Recommend and support research programs that will produce data needed for 1) the development of scientifically rigorous management recommendations relating to sustainable and acceptable yields, 2) the preservation of acceptable stock levels, and 3) optimal utilization of those stocks.

V. MANAGEMENT RECOMMENDATIONS

The management recommendations presented here consist of actions that the Scientific and Statistical Committee and Board feel are necessary to achieve the objectives presented in Section IV. As was stated in earlier portions of this plan, many of these action items will generate data useful for development of additional recommendations. Thus, this plan must be modified on a regular basis if the management goal is to be ultimately met. Most of the following recommendations relate specifically to the objectives presented in Section IV.

A. REGULATION OF EXPLOITATION RATES

Concerns about exploitation fall into three basic categories, as presented in Section III, "Statement of the Problem":

- Exploitation of river herring, specifically, and American shad (if such harvest occurs) in the Fisheries Conservation Zone to the extent that inshore harvests and stock levels are affected

- Establishment or expansion of territorial sea fisheries for American shad (within 3 miles of shore) that exploit nonresident stocks

- Excessive exploitation of all of the alosids within traditional fishing grounds (i.e., internal waters) to the extent that recruitment overfishing is possible or stocks are prevented from increasing to levels supportable by existing habitat.

Specific management recommendations are presented for each of these three categories, following some elaboration of the basis for the concern and for the recommendation.

Exploitation in the Fisheries Conservation Zone

The potential problem of excessive harvest of river herring in the Atlantic Ocean from 3 to 200 miles offshore has very recently become a critical issue. Relevant events of the first several months of 1985 are documented in Appendix C. Applications to the Mid-Atlantic Fisheries Management Council for joint venture fisheries for mackerel prompted the recent activity. River herring are taken as bycatch in mackerel fisheries, and mackerel harvests of the magnitude projected for these fisheries would have resulted in river herring by-catches exceeding the current TALFF of 100 metric tons (mt). ASMFC was invited by the council to provide testimony concerning anticipated recommendations on TALFF at a January 1985 council meeting. Protracted discussion of the issue without its resolution led the council to assign the issue to its Coastal Migratory Species Committee for resolution. ASMFC was again invited to send representatives to the committee meeting to act in an advisory capacity. Minutes of this 5 March 1985 meeting are presented in Appendix C. The major actions resulting from this meeting were:

- Foreign mackerel fisheries were excluded from areas within 20 miles of shore and from a zone south of a line extending east from just north of the mouth of the Chesapeake Bay. TALFF was specified to be less than 1% of mackerel harvest, with no total limit. The intent of these modifications was to exclude foreign fisheries from areas where river herring bycatch was expected to be high, and where the stocks being affected were believed to be those from the Chesapeake and southeastern regions where populations are currently low.

- The committee concluded that they could not impose restrictions on mackerel fisheries prosecuted by American fishermen, whether operating on their own or as joint-venture partners. Thus, no action was recommended by the committee that would decrease the likelihood of large amounts of river herring being taken as bycatch by American fishermen.

- The committee requested ASMFC assistance in developing a list of data that could be recorded by NOAA observers working on offshore vessels and that would contribute to assessing the potential significance of river herring harvests in these expanding fisheries. Data needs were forwarded to the council.

Offshore harvests represent an uncalculated threat to inshore domestic fisheries. The possibility of dramatic changes in the offshore fisheries, with concomitant changes in river herring harvests, confirms the need to monitor this situation and initiate new actions to protect and enhance the river herring stocks as circumstances change. Recent events demonstrate that cooperation among ASMFC, the councils, and NOAA is feasible even in the absence of any formal cooperative agreement. However, under this arrangement, ASMFC remains in only an advisory role and has no formal vote on any managment action. The recommendations that follow are based on the above discussion and material presented in Appendix C.

- Recommendation 1.1

  ASMFC will review, annually, Fishery Management Council decisions and NOAA regulations based on those decisions that relate to the anadromous alosids. Based on any new information or changes in existing status of the stocks, directed fisheries, or fisheries having a potential impact on the alosids, ASMFC shall develop and submit recommendations to the Fishery Management Councils. ASMFC shall retain their position as a voting member on council committees that address anadromous alosid issues (e.g., the Mid-Atlantic Council's Coastal Migratory Species Committee).

- Recommendation 1.2

  ASMFC will closely monitor the establishment and growth of joint venture and domestic mackerel fisheries in order to evaluate the consequences to river herring stocks of their capture as bycatch. ASMFC will join in the request of the Mid-Atlantic Fishery Management Council for implementation of a data collection plan by NMFS pursuant to Section 303(e) of the MFCMA. Data to be collected pursuant to such a plan should conform to the recommendations set forth in Appendix C of this plan. These data will be evaluated and analyzed to arrive at the recommendations mentioned above.

Territorial Sea Fisheries

The issue of territorial sea fisheries relates primarily to American shad at present. While no similar problems appear to exist currently for either hickory shad or river herring, the recommendations below would apply to those species should similar problems arise some time in the future.

During preparation of this plan, potential problems with expanding shad fisheries in the ocean along the Atlantic coast were identified in Maryland, New York, New Jersey, South Carolina, and the Gulf of Maine. The nature of this potential problem is that these fisheries take shad originating in many different river systems along the east coast, as documented by a number of tagging studies (see Appendix A). Fisheries in the Delaware Bay also exploit stocks from many other georgraphic areas. These fisheries are potentially disruptive of traditional fisheries in internal waters.

At this time, these fisheries are rather limited in scope. Should the market situation change, however, expansion could occur and they could impact on some stocks. South Carolina coastal fisheries are also believed to be very wasteful. Weather conditions frequently prevent prompt tending of nets resulting in loss of harvest and often resulting in loss of gear which kills additional fish. Potential problems with these fisheries are exacerbated by the fact that at present it is not possible to distinguish the origin of fish taken in the catch. For this reason, it is not possible to determine which stocks are being most impacted by any of these fisheries.

In 1984, South Carolina promulgated regulations which prohibited the use of stationary gill nets in coastal areas. It was anticipated that these restrictions would effectively eliminate this fishery since stationary gill nets were the primary gear used. However, fishermen have apparently been able to use drift gill nets to continue this fishery. Because of the high market value of shad caught early in the season (when the South Carolina fishery was occurring), it is likely that elimination of that fishery would stimulate establishment of new fisheries, either outside the 3 mile limit or in other states. In addition, numerous anecdotal accounts of increasing offshore (beyond the 3 mile limit) shad gillnetting in many states up and down the coast have been received by Shad and River Herring Scientific and Statistical Committee members. Thus, the status of these fisheries has changed markedly, particularly over the past 18 months, and they remain a serious concern, especially to states initiating restoration programs. Very small, newly established stocks, such as those in the Susquehanna River (Pennsylvania, Maryland) and the Pawcatuck River (Rhode Island) could be seriously impacted if they were to suffer significant non-natal stream fishing mortality.

Based on this and earlier discussion, the following recommendations are presented:

- <u>Recommendation 2.1</u>

  Each state, in cooperation with NMFS, will monitor and document existing and new FCZ and territorial sea fisheries for anadromous alosids. The extent of participation, amount of harvest, and timing and location of each fishery will be documented; this information will be forwarded to ASMFC for its annual review of fisheries and stock status and for consideration of revision of existing recommendations in this plan. An interstate cooperative coastal shad tagging program will be conducted to determine which stocks are being exploited (see Recommendation 8.3).

- Recommendation 2.2

All east coast states will recognize the priority rights of traditional fisheries in internal waters that target resident stocks, while not encouraging new intercept fisheries in territorial sea waters. Of greatest concern are fisheries taking shad along the coast very early in the year, including those occurring in South Carolina, North Carolina, Virginia, Maryland, and the Delaware Bay. What appears to be an expanding summer-fall gill net fishery in the Gulf of Maine should also be closely monitored by the New England states. Such fisheries should not be encouraged and, if evidence suggests they pose a threat to any single stock of shad, steps should be taken to prohibit them.

Controlling Exploitation Rates in Internal Waters

At the current time, and in the future should the above recommendations be implemented, most alosid stocks will experience most of their fishing mortality within waters under regulatory control of the state of their origin. Recommendations presented here represent advice to individual states on how to enhance the status of their own stocks, based on information documented in Appendix A, and in additional data compiled since publication of that report, which will now be discussed.

Appendix D summarizes information from studies in which fishing mortality rates of American shad were measured. Leggett (1976) and Crecco et al. (1985) have established that exploitation rates measured using disc tags have severe biases due to the manner in which the tag increases probability of capture by gill net. Using information presented in Leggett (1976) and included in Appendix D, mortality rates arrived at using disc tags were adjusted. These mortality rates were discussed by the full Scientific and Statistical committee on a number of occasions, and by a Chesapeake Bay-southeastern subcommittee meeting 20-21 February 1985, in Norfolk, Virginia. Examination of these data suggests that at least some shad stocks were experiencing very high exploitation levels prior to their recent declines. However, equally evident are many systems where high rates were recorded while stocks were doing rather well (e.g., James River in 1952). In general, however, adjustment of mortality rates measured using disc tags reveals that what had previously been considered to be very high exploitation rates during periods of stock stability were in reality substantially lower (e.g., Hudson River: reported rate, 65.7%; adjusted rate, 38.7%). In general, exploitation rates during periods when shad stocks were stable were less than 40%.

Additional evidence suggesting that natal river fishing rates have influenced the status of shad stocks includes the following:

- Analysis of historical data for the Connecticut River (Leggett 1976) revealed close relationships between high fishing pressure (50-60% exploitation rate) and subsequent stock declines during the period immediately after World War II. This confirms the role that excessive fishing mortality may play in shad declines and is the strongest case history supporting a 40% natal river fishing rate limit.

- Shad are fast-growing, short-lived fish. The exploited stock consists of only two or three year classes; thus, the species is vulnerable to recruitment overfishing, particularly since spawning success is strongly influenced by environmental conditions. The same type of life history is exhibited by the river herrings. (Northern stocks, however, exhibit extensive repeat spawning, as do hickory shad.) This life history strategy is consistent with those of many marine clupeids for which recruitment failure due to excessive exploitation rates has been documented.

- Gibson (1985, unpublished manuscript) analyzed data from the Pawcatuck River; his regression analyses revealed that 95% of the variation in Pawcatuck River year class strength thus far in that restoration effort can be attributed to the size of the spawning stock; this finding is in strong contrast to results on the Connecticut River, where Crecco (1984) found that parental stock size had only a small effect on year class size. Stock sizes of the Pawcatuck and Connecticut rivers differ from each other by several orders of magnitude. Gibson interprets his results as support for the contention that year class size is most dependent on environmental conditions when spawning stocks are large, and is most dependent on spawning stock size when spawning stocks are low. Restricting harvest when the number of spawners is depleted may enhance recruitment.

Recent population modeling work by Crecco (1985, personal communication) has suggested that the Connecticut River stock of shad could collapse if exploitation rates exceed 40% of the females. These modeling results are consistent with the case history of the Connecticut River stock discussed above (Leggett 1976). The model results are based on multiple runs of the model, each covering a 100-year time period, starting out with populations at their current levels, and incorporating functions reflecting documented relationships between environmental variables and spawning success (Crecco and Savoy 1985, in press) and relationships between fishing mortality and stock size. One key element in the model is that the potential for capture by the commercial fishery increases as stock size decreases with the result that catch per unit effort (CPUE) and total harvests remain steady or decrease only slightly while the stock is actually declining substantially. It will be very important in effecting future modifications of this plan that the existence of such a relationship in other shad and river herring fisheries along the coast be confirmed and quantified.

Integration of all of the above information led the Scientific and Statistical Committee to conclude that restrictions on exploitation rates can contribute to enhancing the status of newly established or currently depressed stocks and help prevent the collapse of stocks currently at acceptable levels. However, the degree of restriction needed will vary with the current status of the stocks.

For the purposes of this document, the committee has defined exploitation rate as the percentage of female fish in the spawning run that are captured in recreational or commercial fisheries during their spawning run in a single year. Implicit in these recommendations is the assumption that nonnatal stream exploitation rates remain constant [<15%, as was found for Connecticut River shad by Leggett (1976)]. Any increase in offshore or coastal exploitation rates would cause the recommended maximum harvest levels to be too high and would call for more restrictive limits. Three levels of maximum exploitation rate within natal rivers were assigned to the various alosid stocks (Table V-1), based on the following definitions of stock status:

	Status	Definition
I	Severely Depleted	Stocks currently at very low levels relative to their status during the 1950s and 1960s.
II	Depleted or Newly Established	Stocks currently substantially below levels which the habitat is known to be able to support. Also applies to newly restored stocks.
III	No Perceived Decline	Stocks which have remained relatively stable over the last 20 years.

The absence of reliable indicators of stock size for most years in most drainage systems for all four species discussed

Table V-1. Recommended maximum exploitation rates for shad and river herring. These recommended values will be modified as new data become available.

Stock and Status	Maximum Exploitation Rate (%)	Specific River or State (for all rivers within a state)
<u>American Shad</u>		
Severly depleted	0	Maryland
Depleted or newly established	25	Virginia, Florida, North Carolina, Rhode Island, Delaware River
No perceived decline	40	Connecticut and Hudson rivers, South Carolina, Georgia[a]
<u>Blueback Herring/Alewife</u>[b]		
Severly depleted	0	Maryland
Depleted or newly established	25	North Carolina, South Carolina, Florida, Virginia

(a) See text on page V-9 concerning Georgia.
(b) Alewife outside of New England.
(c) No information on Georgia or Delaware bluebacks.

Table V-1. Continued

Stock and Status	Maximum Exploitation Rate (%)	Specific River or State (for all rivers within a state)
Blueback Herring/Alewife (Cont'd)		
No perceived decline[c]	40	Connecticut River, Hudson River
New England Alewife		
No perceived decline	Not to exceed current levels	Rhode Island, Connecticut, Massachusetts, New Hampshire, Maine
Hickory Shad		
Severely depleted	0	Maryland
Depleted	25	North Carolina, South Carolina, Georgia, Florida, Virginia

here prevented these categories from being defined quantitatively. Placement of individual stocks into categories was done using trends in landings over the past 20 years and all information available to fisheries biologists working in the respective states. The recommended exploitation values given in Table V-1 will be modified as new data become available.

The recommended exploitation rates for blueback herring presented in Table V-1 are the same as those for American shad because they have similar life history characteristics. Most hickory shad stocks were treated as "depleted," and it is recommended that natal exploitation rates not exceed 25%. The alewife stocks outside New England were pooled with the blueback herring because they often co-occur in the landings. The New England alewife was placed in the "No perceived decline" group, mainly because these are traditional fisheries that have persisted despite high levels of exploitation (60-90%), which is probably a function of the habitats used by those stocks.

While the rationale for a 40% rate for American shad is supported by a large amount of information, the scientific basis for the other specific recommendations is relatively arbitrary. The intention of the committee was to identify rates which by consensus were deemed to be conservative (i.e., that might be more restrictive than necessary.) As additional information is gathered on mortality rates of all these species, particularly in the Chesapeake Bay and southeastern regions, the recommendations will be reassessed.

Exploitation rate data collected in ongoing studies of shad in the Altamaha River, Georgia (Michaels 1984), raise several questions about the appropriateness of 40% as a generally applicable maximum exploitation rate. Data from three years of study revealed female exploitation rates of 47% to 64% (see Appendix D), yet stock abundance has appeared to remain stable. Whether southern stocks may be capable of sustaining higher exploitation rates than more northern stocks (such as those in the Connecticut River) will not be confirmed until longer-term studies are completed. In the absence of proof of such a contention, however, the committee felt that a conservative recommendation was appropriate.

The recommendations on exploitation in internal waters assumes that exploitation in territorial seas and the FCZ remains relatively insignificant. Any substantial change in those fisheries would have an impact on the efficacy of these recommendations. The percentage figures presented in Table V-1 are intended to be acceptable maxima, and are not to be construed as exploitation goals.

The recommendations arising from the above discussion are:

- <u>Recommendation 3.1</u>

  Individual states will consider implementing fisheries management actions that would ensure that total exploitation rates for female American shad, hickory shad, and river herring (commercial and recreational) do not exceed levels that threaten the stability of stocks currently at acceptable levels or the enhancement of depressed or newly established stocks. Guidelines for exploitation rates are presented in Table V-1.

- <u>Recommendation 3.2</u>

  Individual states will initiate studies to document existing fishing mortality rates of all four alosid species and to establish if density dependent catchability exists. Recommended guidelines for design of an acceptable study are presented in Table V-2. States shall obtain at least preliminary data within 2 years of adoption of this plan and provide these data to ASMFC for integration and distribution to interested parties.

- <u>Recommendation 3.3</u>

  Individual states shall improve records of catch and effort in general, and make a special effort to establish the amount of harvest reported as American shad and/or river herring that is actually hickory shad. Examples of steps that could be taken include education of fishermen, modification of reporting forms or mechanisms, and creel/harvest census during critical time periods.

B. IMPROVEMENT OF HABITAT QUALITY

Water Quality

The contribution of degradation in water quality to the observed declines in anadromous alosid stocks has been alluded to in past evaluation of these stocks (Mansuetii and Kolb 1953; Walburg and Nichols 1967) and is discussed in the Phase I report and this document. However, it has never been possible to rigorously quantify the magnitude of this contribution. Only

Table V-2. Suggested guidelines for studies to assess exploitation rates of anadromous alosids[a]

Basic study type	• Tag and recapture
Timing	• Tagging to start near the beginning of the spawning run, and continue through the run; tagging should stop before water temperatures reach levels at which handling mortality becomes significant • Reaction of fish to tagging should be determined (i.e., do most fish move downstream and, if so, how far)
Location	• Ideally, fish for tagging should be captured downstream of the major areas of exploitation
Target sex	• Focus on females if funding constrains the scope of the program
Tag type and tag return program	• Anchor streamer tags (as used by Crecco (Conn) and Michaels (Ga)) • Multilevel reward ($5, $10, $25) plus incentives (e.g., lottery) • Occasional canvass of fishermen, fish houses, and wholesalers

[a]These guidelines are to some extent based on studies currently being done on Connecticut River and Altamaha River American shad. However, they should be equally appropriate for all studies of anadromous alosids, with modifications for the specific location, type, and timing of fisheries in individual drainage systems.

Table V-2. Continued

Number of fish to be tagged	• As many as funding permits (larger numbers of tag returns provide more precise estimates of exploitation) but distributed over the major portion of the run
Capture method	• Hook and line, pound nets (where possible), or drift gill nets. (Mesh sizes used should include those used by commercial fishermen as well as somewhat larger and small meshes to ensure adequate sampling of all age groups.)

on the Delaware River, where water quality problems were dramatically manifested in a "pollution block" in the Philadelphia/Camden area, has pollution abatement resulted in a measurable and large enhancement of an alosid stock, in this case American shad. In most anadromous alosid spawning and nursery areas, water quality declines have been gradual and poorly defined, and it has not been possible to link those declines to changes in alosid stock size. Conversely, in cases where there have been drastic declines in alosid stocks, such as in the Susquehanna River and upper Chesapeake Bay in Maryland, water quality problems have been implicated but not conclusively demonstrated to have been the single or major causative factor.

While cause and effect have not been rigorously demonstrated between water quality changes and alosid stock status, many water quality variables are known to affect the health and well being of all aquatic biota. Documentation of these effects, specifically for the four anadromous alosids, contributes to defining water quality criteria sufficient to protect alosid stocks.

Certain basic water quality parameters have been monitored throughout the east coast in a variety of water types. Such parameters include temperature, dissolved oxygen, conductivity/salinity, pH, and turbidity. The effects of many of these variables on various life stages of the four alosid species have also been studied, although to different degrees depending on species and variable. Available information on these effects is presented in Appendix E with individual tables included for three of the four species. Sources of these data are also included in the Appendix. No information on hickory shad responses to these water quality variables was found.

Some of the information presented in Appendix E was drawn from "A Management Plan for the American Shad (*Alosa sapidissima*) in the Delaware River Basin," prepared by the Delaware Basin Fish and Wildlife Management Cooperative in 1981. Additional guidance on acceptable levels of dissolved oxygen (DO) for shad appears in a document entitled, "Dissolved Oxygen Requirements of a 'Fishable' Delaware River Estuary," prepared for the Delaware River Basin Commission by an ad hoc task force in 1979 and since adopted by resolution of the Cooperative as an official recommendation concerning DO standards. Of all water quality parameters addressed in those documents, acceptable standards were specified only for dissolved oxygen. Additional studies to determine tolerance levels were recommended for the remaining parameters. The Delaware DO guidelines were accepted for this plan as being the desirable levels for protecting and enhancing anadromous alosid stocks.

The Instream Flow and Aquatic Systems Group of the USFWS is presently completing a Delphi assessment to provide information on American shad habitat requirements for use in decision making on instream flow needs. Alosid flow requirements are addressed in detail below. However, a portion of the Delphi process dealt with temperature requirements of all life stages of American shad. Temperature data from that Delphi process provide the basis for temperature criteria presented here.

Other substances that occur in anadromous alosid spawning and nursery areas and are believed to be potentially harmful to aquatic life have been very poorly monitored. These substances include toxic materials such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides). In the literature searches performed to construct the tables in Appendix E, no data were found indicating the concentrations of these substances that cause deleterious effects on any of the alosids. The Delaware Management Plan also provides no specific data on tolerance levels. The absence of such data precludes the development of acceptable water quality criteria for these substances.

The possiblity that acid rain may be a major factor in the decline of many anadromous fishes along the east coast has recently arisen as a major water quality issue. The existing information on tolerance of alosids to low pH is very limited (Appendix E) and insufficient to draw conclusions about the importance of acid rain in alosid declines. However, many studies are currently underway to investigate pH effects (including work sponsored by the Joint NMFS/USFWS Emergency Striped Bass Research Program, and by the Tidewater Fisheries and Power Plant Siting Program divisions of the Maryland Department of Natural Resources). The importance of these studies must be recognized in the recommendations presented in this segment of the plan.

While water quality may have drastic effects on fisheries, in most states the responsibility for water quality regulations and criteria is assigned to an agency different from the one responsible for fisheries management. The following recommendations deal with acceptable water quality criteria and actions necessary to ensure their being addressed in state water quality regulations. Because data on indivdual species are sometimes limited, the specific criteria suggested here are drawn from data for all species and are considered suitable for anadromous alosids in general.

- <u>Recommendation 4.1</u>

  Resource management agencies in each state shall evaluate their respective state water quality standards and criteria to ensure that those standards and criteria account for the special needs of anadromous alosids.

This action should be taken within the normal cyclical process of criteria review that occurs in most states. Steps should be taken within 1 year of implementation of this plan to create a new class of waters (or redefine an existing class) to acknowledge status or potential status as anadromous alosid spawning and nursery areas (analogous to "trout waters"). Primary emphasis should be on locations where sensitive egg and larval stages are found. For those agencies without water quality regulatory authority, protocols and schedules for providing input on water quality regulations to the responsible agency should be identified or created. Waters of existing or potential value as alosid spawning/nursery areas should be identified for the appropriate water quality agency. Agencies in each state shall initiate actions to establish water quality criteria protective of anadromous alosid habitat requirements, but consistent with the management objectives for other species. Suggested values for key parameters are presented in Table V-3.

- Recommendation 4.2

Results of ongoing studies dealing with the effects of acid deposition on anadromous alosids will be reviewed by all appropriate agencies and ASMFC as they become available. ASMFC will summarize those findings in a position document on an annual basis. Should those findings support the contention that acid deposition is having a deleterious impact on anadromous alosids, ASMFC shall offer that document as supporting evidence to all organizations and individuals pursuing acid rain controls and/or mitigation measures.

Flow Requirements

Riverine habitats serve as routes for migration and as spawning and nursery areas for most stocks of the four anadromous alosids. While these species have evolved such that stocks are able to survive natural deviations in river or stream flow (e.g., storm freshets, draughts), regular, unnatural alterations of flow caused by human water use activities can have serious effects on populations. Major problems arise with the creation or refurbishing of hydroelectric facilities. Such projects may deny access to spawning areas (a topic addressed below) but also may alter habitat characteristics such as flow (due to peaking operation and imposition of low flows) and water quality (due to impoundment effects such as decreases in DO and temperature).

Table V-3. Suggested water quality criteria suitable for anadromous alosid spawning and nursery areas

Variable	Time Period and Biological Activity	Value or Range	Goal of Criterion	Source of Information
Dissolved oxygen	Spring and fall (adult and juvenile migration)	Seasonal average not less than 6.5 mg/l; instantaneous minimum 4.0 mg/l	Permit successful movement of fish to and from spawning nursery areas	Delaware River Basin Fish and Wildlife Cooperative (1981)
	Summer (nursery for juveniles)	Not less than 5.0 mg/l at any time	Permit successful growth and survival of juveniles	Delaware River Basin Fish and Wildlife Cooperative (1981)
Suspended sediments	Spring through fall (migration, spawning, nursery activity)	Seasonal average <25 mg/l	Prevent adverse effects of suspended solids on the fish and their habitat	Delaware River Basin Fish and Wildlife Cooperative (1981)
Temperature	Spring (adult migration)	Water body cross-sectional average not to exceed 75°F; ΔT not to exceed 10°F	Ensure that heated water discharges will not block migration	USFWS Delphi (1985)
	Spring (spawning)	Mean daily temperature between 50° and 75°F; ΔT not to exceed 10°F	Ensure that heated or cooled (e.g., dam outflows) discharges will not impair spawning success	USFWS Delphi (1985)

Table V-3. Continued

Variable	Time Period and Biological Activity	Value or Range	Goal of Criterion	Source of Information
Temperature (continued)	Summer (nursery)	Mean daily temperature between 55° and 80°F; ΔT not to exceed 10°F	Ensure that heated or cooled discharges will not impair juvenile growth and survival	USFWS Delphi (1985)
	Fall (juvenile migration)	Water body cross-sectional average not to exceed 70°F (river herring) or 75°F (shad); ΔT not to exceed ± 10°F	Ensure that heated water discharges will not block migration	USFWS Delphi (1985)
pH	Spring (spawning and larval growth)	Instantaneous minimum 6.0 (concomitant aluminum levels must also be considered)	Allow survival and normal development of eggs and larvae	Preliminary laboratory results, MD Department of Natural Resources
Chlorine	Spring (eggs and larvae and juvenile survival)	<0.20 ppm	Allow survival and normal development of eggs and larvae	Morgan and Prince (1977); PSEG (1980)
Toxic compounds (metals, organics)		No available data	Permit successful completion of freshwater segment of life cycle	

Most resource agencies participate in the review of proposed hydroelectric and other water use projects. One frequent element of such reviews is an evaluation of the adequacy of proposed instream flows for protecting aquatic resources. Existing state regulations and/or guidelines regarding hydroelectric projects and stream flows are summarized in Appendix F.

The USFWS participates in the review of nearly all projects that affect stream flows. To facilitate their review of such projects and to provide an objective basis for instream flow decisions, an Instream Flow and Aquatic Systems Group was established within the Division of Biological Services. The function of this group is to develop objective methodologies for defining acceptable flow levels, and to provide assistance to USFWS, state agency personnel, and any other individuals or organizations involved in project reviews. In carrying out this function, this group has established a library of suitability index (SI) curves for various aquatic species for major habitat parameters. Curves for only one of the four anadromous alosids (American shad) have thus far been incorporated into this library. (SI curves are now being completed and will be added to the library in 1985.) Shad SI curves were developed using a Delphi process employing from 10 to 13 shad experts. Habitat characteristics included in this process were current velocity, water depth, substrate, cover, and temperature. Results of this effort offer guidance for selecting acceptable flows at projects where shad may be impacted.

Additional guidance for selecting minimum flows is provided by the requirements of individual states (Appendix F) or other agency divisions. The New England Regional USFWS office has developed guidelines for acceptable minimum flows at projects in the New England States. Their aquatic base flow (ABF) is calculated as the median daily average flow in the low flow month (generally August) for all years of record. The ABF represents the USFWS's minimum flow recommendation unless evidence is provided by the project applicant demonstrating that a lower flow is sufficient to protect aquatic resources.

Decisions on minimum flows are necessarily site specific. The intent of this segment of the plan is to provide general information that can be used by individual agencies to establish flows sufficient to protect anadromous alosid stocks, taking into account site specific factors. Substantial data relating to the flow needed for survival of American shad are available; such data are not available for the other three species. Loesch and Lund (1977) have suggested that blueback spawning sites are characterized by currents stronger than those preferred by alewives. However, no specific required velocities have been established. Recommended flow parameters for those three species are necessarily vague.

The importance of flow to alewife stock success has been reinforced by recent findings in Rhode Island (M. Gibson 1985, personal communication). Draught conditions prevailed during the summer of 1981, and current runs reveal that the contribution of the 1981 year class to 1984 runs is only about half of what would be expected from existing data (i.e., 22% of the run instead of 44%). While flow regulations cannot compensate for such draught conditions in many small waterways, they may prove very beneficial where augmentation of flows is feasible.

- <u>Recommendation 5.1</u>

State resource management agencies shall identify or establish protocols that ensure that they have the opportunity to evaluate projects that may affect the flow of streams and rivers supporting or having the potential for supporting runs of anadromous alosids. State resource management agencies shall determine which state agency serves as the primary contact with the Federal Energy Regulatory Commission (FERC), since all applications relating to hydroelectric development are processed by the FERC.

- <u>Recommendation 5.2</u>

In reviewing proposed projects that will affect flow regimes, agencies shall ensure that continuous minimum flows and the manner in which the operation of any facility alters flows will not adversely affect anadromous alosids. Guidelines for desirable instream flow variables are presented in Table V-4. State agencies should, if necessary, solicit the advice of the USFWS Instream Flow Group in developing flow recommendations.

Other Habitat Factors

Most human activities that affect alosid stocks do so indirectly by changing water quality or flows. However, several types of facilities and operations cause mortality directly. Prominent in this category are facilities using water for cooling purposes (e.g., power plants) or large volume water withdrawals (e.g., drinking water, pumped storage hydroelectric projects, irrigation). Fish mortality is caused by entrainment (i.e., intake and passage through the cooling or water withdrawal system) or impingement (i.e, entrapment on screens used to

Table V-4. General guidelines for selection of instream flows suitable for anadromous alosids; more specific details can be obtained from the indicated sources, particularly the SI curves from the FWS Delphi process.

Specific Guidelines

Species	Activity	Variable	Level	Source
American shad	Spawning/ incubation	Velocity	0.5-3.0 ft/sec	FWS Delphi, 1985
		Depth	2 to 40 ft	
		Substrate	Sand, gravel, cobble	
	Nursery	Velocity	0.2 to 3.0 ft/sec	
		Depth	3 to 40 ft	
	Migration	Velocity	0.5 to 3.0 ft/sec	
		Depth	< 1 ft	
Hickory shad, river herrings		NO DATA AVAILABLE		

General Guidelines

Loar, J.M. and M. J. Sale. 1981. Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development: V. Instream Flow Needs for Fishery Resources. Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 1829. ORNL/TM-7861 ORNL, Oak Ridge, Tennessee 37830.

prevent debris from entering water intake structures). These types of effects are very site specific, and at present no one category poses a significant threat to east coast anadromous stocks. State and federal resource agencies already review environmental impact statements for proposed projects of the type being discussed here. Thus, other than suggesting that such reviews focus on the potential impacts on anadromous alosids, no recommendations relating to this category of habitat factors are necessary.

The single exception to this conclusion is in regard to proposed tidal hydroelectric facilities in the Bay of Fundy (p. 11-66 of Appendix A). All east coast stocks of American shad, and possibly river herring, use the Bay of Fundy as a summer foraging area. As they forage, fish appear to repeatedly move in and out the basins proposed for hydroprojects. Even if mortality due to single passage through a turbine is low, repeated passage will cause high total mortality. Because these projects pose such a great threat to east coast alosid stocks, progress on their development must be closely monitored.

- <u>Recommendation 6.1</u>

All state and federal agencies responsible for reviewing impact statements for projects proposed for anadromous alosid spawning and nursery areas shall ensure that those projects will have no impact or only minimal impact on those stocks. Of special concern are natal rivers of newly established stocks or stocks considered depressed or severely depressed (Table V-1).

- <u>Recommendation 6.2</u>

ASMFC and federal fisheries agencies shall continue to monitor progress in the development of Bay of Fundy hydroelectric projects. Communications with the Department of State and all interested members of Congress shall be renewed on an annual basis to reiterate opposition to the projects unless it can be demonstrated that no significant mortality to alosids will occur. Continued environmental studies shall be encouraged. Annual status reports based on information obtained from the Canadian government and project developers will be prepared and distributed to Board and Scientific and Statistical Committee members. ASMFC will request from the U.S. Department of State the right to review all environmental impact predictions prepared as part of project development. Factors that influence U.S. purchase of power from these projects should be monitored to determine if actions can be taken to discourage their development.

C. RESTORATION OF ANADROMOUS ALOSID STOCKS

For the purposes of this management plan, restoration activities are considered to fall into two categories: restoration of anadromous alosids to habitats that formerly supported stocks but currently do not, and the restoration to former levels of abundance runs currently at very low levels. Recommendations expected to contribute to the restoration of currently depressed stocks include those suggesting restrictions on exploitation rates (recommendations 3.1 and 3.2), those aimed at improving water quality (recommendations 4.1 and 4.2) and those dealing with stream flows (recommendation 5.2).

Most of the information presented in this section of the plan relates to restoration of stocks to currently unoccupied habitats. Opportunities exist for significant increases in total east coast populations of all four alosids should new runs be established in all available waters. Table V-5 presents restoration targets of 28 planned American shad restoration programs, most of which are in various stages of implementation. These programs alone, if successful, would add over 8 million shad to the east coast population (at an average weight of 4 lb, a total of 32 million lb). Current river herring restoration efforts are summarized in Table V-6. Potential numerical increases in river herring stocks are much greater than those for shad. Opportunities for hickory shad restoration are difficult to ascertain because of lack of knowledge of their life history and habitat requirements.

Methods

A number of methods have been used in past or current alosid restoration programs. The major methods are:

- Using hatcheries and stocking larvae and/or juveniles. This approach was used prior to the early 1900s in an attempt to enhance depleted stocks of American shad but was unsuccessful (Mansueti and Kolb 1953). More recent programs (e.g., Pawcatuck, Susquehanna) have employed stocking of shad fry and larvae, but the magnitude of contribution of these fish to future runs has not been well documented; on the Pawcatuck, no significant contribution of stocked fry to subsequent

Table V-5. Current and planned American shad restoration programs in Eastern North America (R. St. Pierre, USFWS).

River and Tributary	State(s) Involved	No. of Dams that Need Passage	Restoration Target (number of fish)
Androscoggin River,	ME	2[a]	135,250
Little Androscoggin	ME	7	89,750
Kennebec River	ME	5	470,000
Sebasticook River	ME	2	155,000
Sandy River	ME	1	100,000
Mainstem-tidal	ME	(Water quality)	750,000
Penobscot River	ME	11	1,500,000
Cocheco River	NH	1	25,000
Lamprey River	NH	2	26,000
Exeter River	NH	1	10,300
Merrimak River[b]	NH/MA	4	1,000,000
Concord River	MA	2	-
Nashua River	NH/MA	4	-
Souhegan River	NH	1	-
Pistcataquog River	NH	1	-
Contoocook River	NH	4	-
Charles River	MA	3	30-40,000
Taunton River	MA	-	25-35,000

[a] One fishway under construction, one to be initiated in 1986.
[b] Direct Fish & Wildlife Service coordination.

Table V-5. Continued

River and Tributary	State(s) Involved	No. of Dams that Need Passage	Restoration Target (number of fish)
Pawcatuck River	RI	-	25-30,000
Wood River	RI	5	-
Hunts River	RI	-	7,000
Thames River	CT	3	350,000
Connecticut River(b)	CT/MA/NH/VT	-	2,000,000
Westfield River	MA	1	-
Raritan River	NJ	9	100,000
Delaware River(b)	DE/NJ/PA/NY	-	-
Schuylkill River	PA	7	300-850,000
Lehigh River	PA	2	165-465,000
Susquehanna River(b)	MD/PA/NY	4	2-3,000,000
James River	VA	5	600,000

Table V-6. Compilation of information on river herring restoration programs (current and planned) along the East Coast

State	Number of Locations or River Systems	Alosid Species	Target Population Level
Maine	3 current 4 in planning	Alewife	46 million (For current and planned programs combined)
New Hampshire	6	Alewife Blueback	.3-.6 million .25-.5 million
Rhode Island	8	Alewife	≈ 2.5 million
Massachusetts	20	Alewife Blueback	? ?
New Jersey	1 Back Creek	Alewife	?
North Carolina	1 Lake Phelps	Blueback	?
Pennsylvania	Susquehanna River	Alewife Blueback	10 million
South Carolina	1 Santee-Cooper (Locks and rediversion canal)	Blueback	6.4 million
Virginia	James River	Alewife Blueback	?

runs was detectable (M. Gibson 1985, personal communication). No restoration programs for river herring or hickory shad have ever utilized hatcheries.

- Transplanting Eggs. This approach has also been commonly used, probably because of its low cost. However, no instance of egg transplants resulting in successful restoration of an anadromous alosid stock has ever been documented. On the Pawcatuck River, some fish were produced from egg transplants, but their numbers were insignificant and insufficient to support restoration.

- Transplanting Adults. This method has proved to be the most successful means of establishing new runs of American shad and river herring. Throughout the New England states, stocking of gravid adult alewife and blueback has resulted in runs returning to the streams receiving the stocked adults. Stocking of adult American shad in various rivers targeted for restoration has resulted in the production of juveniles (which were observed to migrate downstream in the fall) and the return of native adults in 4 or 5 years. The major problems encountered in adult transplant activity are that sources of fish must be found (e.g., a river with a run of substantial size, an agency that will allow fish to be taken, a location at which suitable gear can be used). In addition, transportation and handling difficulties must be overcome (e.g., travel distances cannot be too great, handling stress must be minimized, proper trucks and tanks must be used).

- Recovering Habitat. Anadromous alosids are usually excluded from potentially suitable habitat because of either physical blockage (i.e., dams) or because water quality is such that migration, spawning, and/or normal growth of juveniles is prevented by poor water quality. Steps taken in habitat recovery include the construction of fish passage facilities and/or improvement of water quality (e.g., control of acid mine drainage, elimination of pollutant discharges). In cases where healthy alosid runs already occur in the drainage system, habitat recovery activities provide the opportunity for the existing stocks to exploit new habitat (an example is the Connecticut River, where establishment of fish lifts at Holyoke Dam gave fish access to new segments of the river). Where healthy stocks do not exist, habitat recovery methods must be accompanied by one or more of the three methods already discussed.

Problems

Numerous problems have been encountered in the various restoration programs that have been attempted or are underway. A review of these problems provides a basis for developing recommendations that may improve prospects for successful restoration efforts.

- Most major dams causing migration blockage are owned by public utilities. Because restoration programs are quite expensive, the dam owners usually resist the establishment of such programs.

- FERC authority supercedes that of the states and other agencies with regard to dams on rivers and streams. The only means of forcing recalcitrant utilities to support restoration efforts is through FERC licensing procedures. FERC proceedings are notoriously slow. Thus, efforts to establish many restoration programs have dragged on for many years (e.g., for Susquehanna River restoration, proceedings were initiated in 1978 and are still ongoing).

- State legislation generally does not exist that establishes restoration as a state goal and that provides regulatory backing for many of the steps needed to accomplish restoration.

- Lack of access to habitats may prevent implementation of restoration programs; this problem arises primarily in areas where pond or lake spawning/nursery areas for alewife and blueback are involved.

- Interagency disagreements, and disputes among agencies from the same state, agencies from different states, different federal agencies, and federal and state agencies have frequently arisen in major restoration programs. Often the disputes arise because programs involve the restoration of more than one species and the priorities of the various agencies differ. The disputes often result in inefficiencies and delays in restoration efforts.

- Exploitation of newly established stocks is often difficult to restrict. This problem is particularly accute when dealing with the alosids. Large numbers of fish may be concentrated at a dam during a spawning run, giving the appearance of being very abundant. However, these runs may in fact represent the initial return of native fish extremely important for future growth of the stock; such runs may be only a small fraction of the size of future runs. Regulatory agencies often face political pressure to open fisheries prematurely for the latter reason. Exploitation of these first-generation fish during the early stages of restoration may lead to failure of the effort.

- Turbine mortality of juvenile alosids may represent the biggest unresolved issue for many of the large restoration efforts. Measurement of turbine mortality rates of juvenile alosids is extremely difficult. If turbine mortality rates are high, any restoration effort that does not provide a means for juveniles to successfully bypass turbines during downstream migration will fail. Bypassing of turbines is generally very expensive because of either lost generation (i.e., using spills to get fish over the dam) or the need for installation of screening devices which are very expensive. Utilities are generally very resistant to accommodating downstream passage needs. Mortality of spawned-out adults due to passage through turbines also hinders restoration because it decreases the amount of repeat spawning that may occur. Repeat spawning is particularly important in northern runs.

- Introduction of diseases or parasites has been raised as a potential problem in restoration. These issues have been very prominent in salmonid restoration. However, no known examples of disease or parasite transport have yet been documented in any of the alosid restoration efforts carried out.

Costs and Funding Mechanisms

Major restoration programs are expensive. Installation of passage facilities at dams generally requires extensive construction activity. Biological work, including transplanting adults, monitoring restoration success, and performing related activities add to overall expenses. The Susquehanna River shad restoration program and Rhode Island's alewife and shad restoration activities provide examples of differing program costs.

The Susquehanna shad restoration program will ultimately entail the construction of fish passage facilities at four large dams (one over 100 ft in height). These dams are owned and operated as hydroelectric facilities by electric generation public utilities. Restoration of stocks is being carried out through egg collection, release of hatchery reared larvae and fry, and by adult transplants. Cost estimates for the restoration were developed during FERC proceedings (Docket EL/80-38) and have been summarized by R. St. Pierre, USFWS Susquehanna River Fisheries Coordinator. The costs below are rough estimates for a 10-year demonstration program:

Egg collection, adult transplants, hatchery operations	$ 5 million
Downstream migration and mortality studies (4 dams)	2 million
Downstream bypass and/or screening	2 million
Research, project management, etc.	1 million
Total	$10 million

If the demonstration program is successful and the utilities are ordered to construct permanent fish passage facilities, costs are estimated to be $58 million to $77 million in 1981 dollars. Assuming construction would not be initiated until at least 1995, costs would likely rise to about $100 million, plus additional funds for operating the facilities. The total cost of this program may be on the order of $125 million dollars, nearly all of it borne by the utilities. The projected size of the shad run is 2 million fish annually. In addition to American shad, the program is also designed to provide for the restoration of 10-20 million river herring, some hickory shad, and unestimated numbers of American eel (potentially millions). Benefits of this program would accrue to three states (Maryland, Pennsylvania, New York). The economic value of the recreational and commercial shad fishery alone has been estimated to be between 69 million and 268 million dollars (median of $111.3 million) by K.E. McConnel and I.E. Stran (Direct Testimony, FERC Docket EL80-38; May 1981).

Rhode Island's restoration programs are of a totally different nature. None of the dams involved serve as hydro-electric projects and most are publicly owned. Cost estimates for these programs were provided by M. Gibson, Rhode Island Division of Fish and Wildlife. Since 1968, Denil fishways have been constructed at 9 dams, at a total cost of $410,440. This construction was financed by Anadromous Fisheries Act funds (a 50:50 match with state funds) with anticipated production of between 2 million and 3 million alewives annually. Biological work related to the alewife programs and the shad restoration work on the Pawcatuck River and other coastal rivers has cost about $310,000, supported by Dingell-Johnson funds with a 25:75 state-federal match. Maintenance and field support has cost $85,000, also supported by Dingell-Johnson funds, with a 25:75 state-federal match. Total Rhode Island expenditures to date have been approximately $804,400, with an expectation of an additional 2 million to 3 million alewives and

25 thousand to 30 thousand American shad annually. Alosids have also benefitted from salmon restoration activities and water quality improvement programs.

The Susquehanna River and Rhode Island programs illustrate both the magnitude of costs which will be incurred in expanding existing restoration efforts, and the variety of funding sources which have been employed:

- Utilities. As owners and operators of dams that block migratory passage, utilities may be required to pay all costs involved in restoring anadromous fish to upstream watersheds. However, if the utility does not agree with the resource agencies and commit to implementing restoration efforts, the issue must be resolved by FERC. In FERC proceedings, the feasibility of restoration, its probability of success, and the ultimate benefits to be gained all arise as issues; the resolution of such issues is very difficult. The Electric Power Research Institute (EPRI), which is supported by utilities across the country, has funded a program to review problems with downstream passage of anadromous fish at hydroelectric facilities. Results of this program may be applicable to many restoration programs currently underway.

- Federal Funds. As illustrated in the Rhode Island example, federal funds from various sources have contributed to many successful restoration efforts. Anadromous Fish Act funds have been used for the construction of large numbers of fish passage facilities along the entire east coast. Dingell-Johnson funds have contributed to the biological and support work essential to these programs. It is likely that without these federal funding sources, very few of the restoration efforts would have been initiated. In addition to direct funding, USFWS provides technical assistance in the planning or design of restoration efforts. USFWS staff expertise in the engineering and design of fish passage facilities has contributed to the success of all the major restoration programs.

- State Funds. Sources of funds for fisheries work and the manner in which they are allocated differ markedly among the states. In general, federal programs that offer funds if they are matched by state monies certainly influence allocation of available funds. It is likely that without the impetus provided by Anadromous Fish Act funds, only limited amounts of state funds would have been spent for restoration purposes. Amount of funds allocated to anadromous alosid programs will also vary among states according to the perceived importance of the species (e.g., Maine will spend significantly more on alewife programs than will New Jersey or New York).

Species-Specific Restoration Information

Hickory Shad

There have been no known attempts at restoration of hickory shad. In the absence of any other information, procedures employed for American shad would probably provide the best guidelines for hickory shad restoration efforts.

American Shad

As noted earlier, current American shad restoration programs could add as many as 8 million additional shad to total east coast stocks. This number is based on estimates of the amount of habitat suitable for supporting American shad that will be made accessible. Many estimates of potential run size have used production figures developed for the Connecticut River (2.3 adult spawners per 100 yd^2 of spawning habitat). Parameters used to define potential "spawning habitat" in most cases were site specific; generally, knowledge of historical spawning ranges contributed to making the estimate. Production figures are essential for designing fish passage facilities since capacity is an important design criterion. The following two case studies of American shad restoration programs illustrates many of the points important to consider in undertaking such programs.

The Connecticut River shad restoration program represents a case of "enhancement" of a run in a major drainage basin. A strong run of shad occurred upriver to the base of Holyoke Dam before a fish lift was installed in 1955. The restoration program has allowed this stock to expand into previously unoccupied habitat. The entire history of this restoration effort is presented in detail in an article by Moffitt et al. (1982). Tables V-7 and V-8, from data from that article, document the passage facilities required for this program as well as the annual fish passage totals at the Holyoke fish lift from 1955 to 1984. While the numbers alone suggest that the program has been extremely successful, some of the increase in Holyoke passage may be due to more effective passage facilities, improved water quality, and other factors mentioned by Moffitt et al.

Table V-7. Existing and proposed fish passage facilities in the Connecticut River watershed

Dams				Fishways			
Location	River km	Year constructed	Present height (m)	Existing fishway type	Run size design capacity: salmon	Run size design capacity: shad	Operation date
	Mainstem						
Enfield	110	1880	2	ramp	—	—	1933
Holyoke[a]	139	1849	9	2 lifts with flume	40,000	1,000,000	1955
Turners Falls[b]	198	1798	12	3 ladders, 2 modified Ice Harbor and 1 vertical slot	40,000	850,000	1980
Vernon	228	1909	11	modified Ice Harbor w/ vertical slot ladder	40,000	750,000	1981
Bellows Falls	280	1907	10	vertical slot ladder	40,000	—	1983
Wilder	350	1950	19	split Ice Harbor	20,000	—	1986[c]
	Tributaries						
Leesville (Salmon River)		1918	6	Denil ladder	—	—	1980
Rainbow (Farmington River)		1925	16	vertical slot ladder	5,000	20,000	1976

[a] Three other fishways were built previously at Holyoke in 1873, 1940, 1952 of Brackett design, pool type ladder, and pressure lock, respectively. Shad passed none of these

[b] A previous pool-type ladder was built in 1942, but shad did not pass it

[c] Tentative

Source: Moffit et al. (1982).

Table V-8. Anadromous fish passage recorded at the Holyoke Dam lift since 1955 .

Year	American Shad	River Herring	Atlantic Salmon	Striped Bass
1955	4,900	0	0	0
1956	7,700	0	0	0
1957	8,800	16	1	0
1958	5,700	29	1	0
1959[a]	15,000	20	0	0
1960	15,000	796	2	0
1961	23,000	1,200	0	0
1962	21,000	191	0	0
1963	30,000	32	0	0
1964	35,000	13	0	0
1965	34,000	53	0	0
1966	16,000	54	0	0
1967	19,000	356	0	0
1968	25,000	(b)	0	0
1969	45,000	10,000[c]	0	0
1970	66,000	1,900	0	0
1971	53,000	302	0	0
1972	26,000	188	0	0
1973	25,000	302	0	0
1974	53,000	504	0	0
1975	110,000	1,600	1	0
1976	350,000	4,700	1	0
1977	200,000	33,000	2	0
1978	140,000	38,000	23	0
1979	260,000	40,000	19	0
1980	380,000	198,000	118	103[d]
1981	380,000	420,000	319	139[d]
1982	290,000	590,000	11	510[c]
1983	528,000	454,000	25	231[d]
1984	497,000	483,000	66	346[d]

[a]Passage facility modified.
[b]Not counted.
[c]Estimated.
[d]All immature.

Source: Modified from Moffitt (1982).

(1982). Limited stock augmentation activities relating to anadromous alosids have been conducted as part of this program. Between 1979 and 1983, 800 to 3,300 prespawn shad were transported from Holyoke to above Turner Falls and Vernon Dam to generate runs through new passage facilities at those dams.

The majority of funding for the Connecticut River program has come from the utilities, both for construction of passage facilities and in support of biological programs. However, federal and state funds have also contributed substantially, with sources including Anadromous Fish Act funds, Dingell-Johnson fish restoration funds, USFWS expenditures (directly and via research performed by the Massachusetts Cooperative Fishery Research Unit), and the state resource agencies of Connecticut, Massachusetts, New Hampshire, and Vermont. Total expenditures in the program have been very large, and it is nearly impossible to partition them into funds for alosids versus funds for salmon.

The Pawcatuck River shad program in Rhode Island represents an effort to reestablish shad in a system where they had not occurred in more than 50 years. Two fish passage facilities have been built on the lowermost dams. Denil fishways were constructed at Potter Hill and Bradford Dams in 1968 and 1979, permitting access to 28 river miles of habitat. An average of 1,500 prespawned American shad from the Connecticut River have been transplanted annually to the Pawcatuck River and its tributaries since 1975 (Table V-9). Evidence of successful spawning has been obtained (O'Brien 1977) and first returns of adults were witnessed in 1979. Since then, annual runs of shad have been monitored at a Potter Hill fish trap. Data on sex ratio, age structure, and growth rates have been collected. It cannot be shown from the data collected in this program that cultured juveniles contributed significantly to subsequent adult returns. It also appears that four transplanted females will yield the same number of future recruits as one native female (M. Gibson 1985, unpublished manuscript). These findings support the earlier statements that adult transfer is the best method for stock restoration. It also emphasizes the need to get as many native fish as possible into the spawning grounds even though numbers of first generation fish returning may be very small. Connecticut will soon prohibit capture of shad from it portion of the Pawcatuck to enhance restoration efforts. Costs of the Pawcatuck program were discussed earlier; all were covered by state and federal funds.

River Herring

River herring restoration programs are numerous in the New England states and less common in the mid-Atlantic states

Table V-9. Shad returns, stockings, and environmental data, Pawcatuck River, Rhode Island, 1975-1985

Year	No. of Transplanted Females	No. of Juveniles Cultured	No. of Returning Adults	No. of Females	No. of Age III	No. of Age IV	June Discharge[a]	June Temp.[a]
1975	96	12,500	-	-	-	-	530	19.8
1976	870	40,000	-	-	-	-	233	21.4
1977	734	75,000	-	-	-	-	366	20.0
1978	567	94,000	0	0	0	-	517	20.5
1979	1261	97,000	5	0	0	4	654	19.5
1980	1559	50,000	165	7	9[b]	125	315	20.0
1981	1058	0	882	249	5	101[b]	230	21.0
1982	880	0	645	224	12	41	800	18.0
1983	950	0	491	170	26	173	756	19.1
1984	275	0	1,265	314	74	629	992	20.3
1985[c]	200	0	4,100	1,522	158	1,246	-	-

(a) 1975-1982 U.S. Geological Survey; 1983-1984 Rhode Island Fish and Wildlife data.
(b) These values were adjusted to 12 and 132, respectively, to account for underutilization of juvenile habitat that occurred only in 1977 due to distribution of spawners (Wood River not stocked).
(c) Source: M. Gibson (May 1985, personal communication).

Source: M. Gibson (1985, unpublished manuscript).

and southward (see Table V-6). The majority of the New England programs deal with alewives, since most efforts involve providing access to ponds and lakes, which are preferred spawning/nursery areas for that species.

The Royal River program in Maine is an example of a very successful alewife restoration effort typical of many other New England programs. Table V-10 presents a summary of alewife escapement and stocking in the Royal River system. Fish passage facilities were constructed at two dams, and restoration was initiated by transplanting gravid adults from other systems. Funding has been with state and federal monies. Studies of this run suggest that most recruitment is generated by the small number of fish stocked in Sabbathday Lake (340 acres). Very preliminary calculations suggest that the ratio of returning progeny to number of adults stocked in the lake has been between 87 and 118. A stocking rate of 1.25 fish per acre of lake habitat produced a return of 147 adults per acre (T. Squiers 1985, Maine Department of Marine Resources, personal communication). These figures illustrate why the very high exploitation rates discussed earlier in this plan can be sustained in these New England river herring runs: productivity per spawning adult is very high.

Figure V-1 illustrates the progress of the alewife restoration progam being carried out on the Lamprey River in New Hampshire. The major elements of the program are similar to those of the Royal River program: construction of a fishway at the lowermost dam and a 5-year program of transplanting fish from below the dam to upstream areas. Once substantial numbers of fish began passing through the fishway, trucking of fish was discontinued. Funding for this program came from state and federal sources. Existing data do not permit specific calculations. However, Figure V-1 shows a high number of recruits generated per spawning adult during the initial phase of the program.

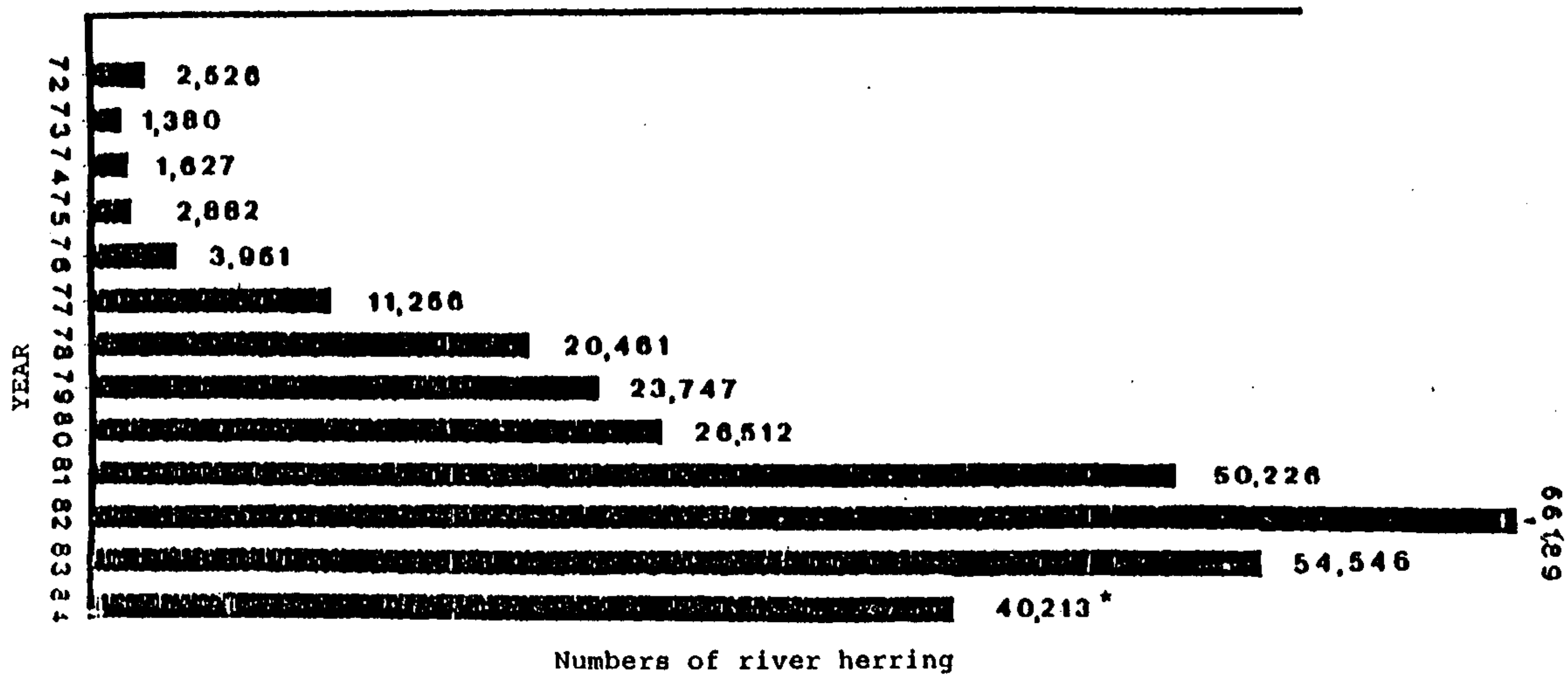
Connecticut River data (see Table V-8) show the magnitude of enhancement of blueback herring stock that resulted from passage of fish over Holyoke dam. The blueback herring is not a primary target species of this program and yet it appears to have benefited markedly from it. Interpretation of these data must, however, be tempered with caveats included in the discussion of the shad program: the increase in numbers can be due in part to improved efficiency of the lifts, redistribution of stock in the river, improved water quality, and other factors.

Table V-10. Alewife run size and stocking in Sabbathday Lake on the Royal River

Year	Total Run at Bridge St. Fishway	Total No. Stocked in Sabbathday Lake
1975	362	
1976	263	
1977	10	425
1978	119	
1979	19	262
1980	2	533
1981	50,000 (est.)	1,280
1982	24,160	582
1983	10,029	493
1984	46,485	527

NOTE: Sabbathday Lake is considered to be the primary spawning and nursery area for this run.

Source: T. Squiers (1985, personal communication).



*Approximately 11,600 river herring were removed from the 1984 run for stocking Lake Winnisquam on the Merrimack River system.

Figure V-1. Annual river herring passage at the Lamprey River fishway in New Hampshire (from J. Greenwood 1984, personal communication)

- Recommendation 7.1

All agency personnel participating in anadromous alosid restoration programs should be alert for indications of disease or parasites. At present, no information exists to suggest that transfer of disease or parasites is a problem. However, should a potentially serious problem arise, ASMFC shall develop a disease control and screening program for alosids. Such a program could follow the form of the existing New England Atlantic Salmon Disease Control Program.

- Recommendation 7.2

Each state that has not already done so shall evaluate the potential which exists for anadromous alosids restoration within their internal waters. Such an evaluation should include, at a minimum, a listing of waters that currently do not support anadromous alosid stocks but that might if water quality and access were improved or created. Within one year from the date of adoption of this plan, and annually thereafter, each state shall provide to ASMFC this evaluation, a summary description of ongoing restoration efforts, and a statement of anticipated restoration activities for the next five years. ASMFC shall use material from these submittals to prepare an annual summary of coastwide restoration efforts for distribution to agencies, legislators, and all other interested parties.

- Recommendation 7.3

ASMFC and all state and federal resource agencies shall support, in every way possible, the preservation and enhancement of federal programs providing funds for the restoration of anadromous fish. Such programs include the Anadromous Fish Act and Wallop-Breaux programs and other federal grant programs that support studies of anadromous alosids, such as Sea Grant and Coastal Zone. It is obvious that most of the very successful anadromous alosid programs that currently exist would not have been initiated if these federal programs were not in place. Implementation of a coastwide alosid restoration plan will not be feasible in the absence of these federal programs. States should also develop additional state funding sources for restoration of anadromous alosids; possiblities include special licenses or stamps.

- <u>Recommendation 7.4</u>

All state and federal agencies shall cooperate to further all current or planned anadromous alosid restoration efforts. Because the acquisition of gravid adults for transplanting is essential for most restoration efforts, those agencies having regulatory control over existing healthy runs of all species should be particularly sensitive to the needs of agencies implementing restoration efforts and should provide the maximum cooperation possible. ASMFC's Shad and River Herring Board will serve as a coordinator to resolve any major disputes.

- <u>Recommendation 7.5</u>

Because of the important role of turbine mortality in determining the success or failure of many restoration programs, all agencies participating in restoration programs involving hydroelectric projects shall include in those programs plans for turbine mortality and downstream passage studies. The term "fish passage" should consistently be interpreted to include downstream passage in any discussion of restoration activity. Results of ongoing and new studies shall be provided on an annual basis to ASMFC for compilation and for dissemination of data to all appropriate state and federal agencies. A continuous exchange of information on turbine mortality and methods for passing anadromous alosids downstream may lead to new and successful methods for alleviating this problem.

- <u>Recommendation 7.6</u>

All resource agencies shall oppose any new hydroelectric projects proposed for drainage systems currently supporting or with potential for supporting anadromous alosid runs unless the developer can demonstrate to the agencies' satisfaction that the project, as proposed, will not have an unacceptable adverse impact on alosid runs. Of particular concern here are small-scale hydroelectric projects existing or proposed for smaller drainage systems supporting river herring runs. Cumulative impacts of several facilities on the same drainage system must also be considered. Major issues are upstream passage of spawning adults and successful downstream passage (i.e., avoidance of turbine mortality) of outmigrating, spawned-out adults and juveniles.

D. RESEARCH AND DATA NEEDS

As has been repeatedly stated throughout this document and the Phase I report, the development of very specific management recommendations for the anadromous alosids has not been possible because of a lack of information on critical aspects of the biology of and fisheries for these four species. During development of this plan, the S&S Committee has identified both data needs (i.e., categories of information that are known to be needed and for which data can be acquired) and research needs (i.e., important areas of interest which are so poorly understood that research is necessary to determine which data are important).

A workshop sponsored by the Hudson River Foundation (HRF), in coordination with the Shad and River Herring Scientific and Statistical Committee, was held in February 1984 to discuss critical data needs for shad research on the Atlantic coast. Participants in that workshop included the S&S committee and outside experts on the American shad from the United States and Canada. Proceedings of the workshop were published by HRF and included a description of shad research projects listed according to priority established by the workshop participants. This list is presented here as Table V-11. As a result of further work of the S&S committee, the priorities of the listed projects were reassessed and a new ranking was developed (Table V-12), reflecting a more narrow focus on topics of particular relevance to this management plan. A Board review of those recommendations resulted in the final priority listing of research needs presented in Table V-13.

The lists presented in Tables V-11, V-12, and V-13 include many types of data needs, each of which can be given a high priority for different but justifiable reasons. Population dynamics of a fish stock control the manner in which that stock will respond to various levels of exploitation, yet little is known of many of such characteristics for all four of the anadromous alosid species. Thus, many of the data needs listed deal with population dynamics characteristics such as stock-recruitment relationships and factors influencing larval survival and spawning success (e.g., Table V-12, items 2 and 3). The relationships among those data needs are illustrated in Figure V-2. The quandry that arises, however, is that while such information is essential for proper management of these species, acquisition of sufficient information to fulfill those data needs will take a substantial number of years. As an example, work serving as the basis for most of what is known about American shad population dynamics was conducted on the Connecticut River for more than 15 years.

While the Scientific and Statistical Committee and Board agreed upon the vital need for population dynamics information,

Table V-11. The priority and title for research projects to identify critical data needs for shad. The approximate cost of each project is presented in parentheses. (From Proceedings of a Workshop on Critical Data Needs for Shad Research on Atlantic Coast of North America, 1984, J. Cooper, ed. Hudson River Foundation, New York, NY. 70 pp.)

PRIORITY	
1	Intensified Ocean Tagging Program. (200K/yr) (600K)
2	Determine Fishing Mortality in Selected Regional Streams. (50K-100K/river) (250K)
3.1	Biotic and Abiotic Mechanisms Affecting the Stock/ Recruitment Relationship. (50K-100K/river)
3.2	Studies of Egg and Larval Survival and Development.
4.1	Discrimination of American Shad Populations by Mitochondrial DNA Analysis. (250K/yr) (750K)
4.2	Parasites of Juvenile American Shad, Blueback Herring, and Alewife, as Biological Tags for Alosid Stock Discriminations. (26K/yr) (65K)
5	Historical Characterization of Socio-economic Development (i.e., Potential Pollutant Sources and Habitat Modification) of Selected Shad Rivers Along the East Coast. (150K-175K)
6	Turbine Mortality Studies. (150K-300K)
7	Energetics of Feeding and Spawning Migrations of Shad on the Atlantic Coast. (100K+)
8	Analyses of American Shad Growth: Circa 1970 versus Circa 1980. (25K/50K)
9	Identification and Quantification of Potential American Shad Spawning and Rearing Habitat Not Presently Utilized and an Analysis of Cost of Recovery. (150K-500K)
10	Development of Standardized Procedures for Developing Juvenile Abundance Indices. (50K/river)

Table V-11. Continued

11	Examination of Early Juvenile Stages of Anadromous Clupeids.
12	An Analysis of Optimum Habitat Utilization of American Shad. (150K-300K)
13	Development of a Long-term Mark or Tag for Juvenile American Shad. (100K-300K)
14	Other proposals

Table V-12. Revised priority listing of shad research projects reflecting Scientific and Statistical Committee views

1. Determination of Fishing Mortality in Selected Regional Streams
2. Studies of Egg and Larval Survival and Development
3. Determination of Biotic and Abiotic Mechanisms Affecting the Stock/Recruitment Relationship
4. Intensified Ocean Tagging Program
5. Turbine Mortality Studies
6. Identification and Quantification of Potential American Shad Spawning and Rearing Habitat Not Presently Utilized and Analysis of Cost of Recovery
7. Discrimination of American Shad Populations by Mitochondrial DNA Analysis
8. Development of a Long-term Mark or Tag for Juvenile American Shad
9. Historical Characterization of Socioeconomic Development (i.e., Potential Pollutant Sources and Habitat Modification) of Selected Shad Rivers Along the East Coast
10. Development of Standardized Procedures for Developing Juvenile Abundance Indices
11. Energetics of Feeding and Spawning Migrations of Shad on the Atlantic Coast
12. An Analysis of Optimum Habitat Utilization of American Shad
13. Analyses of American Shad Growth: Circa 1970 Versus Circa 1980
14. Parasites of Juvenile American Shad, Blueback Herring, and Alewife, as Biological Tags for Alosid Stock Discriminations
15. Examination of Early Juvenile Stages of Anadromous Clupeids

Table V-13. Priority listing of data and information needs for management of the anadromous alosids as established by the Shad and River Management Board (June 1985), focusing only on the research areas of greatest immediate need. Priorities of other research areas are as indicated in Table V-12.

1. Determine the origins of shad being captured in fisheries operating in territorial sea waters of South Carolina, North Carolina, Virgnia, Maryland, Delaware, and New Jersey during winter and early spring (see Table V-14). This information is necessary to determine if these fisheries pose a threat to any East Coast stocks.

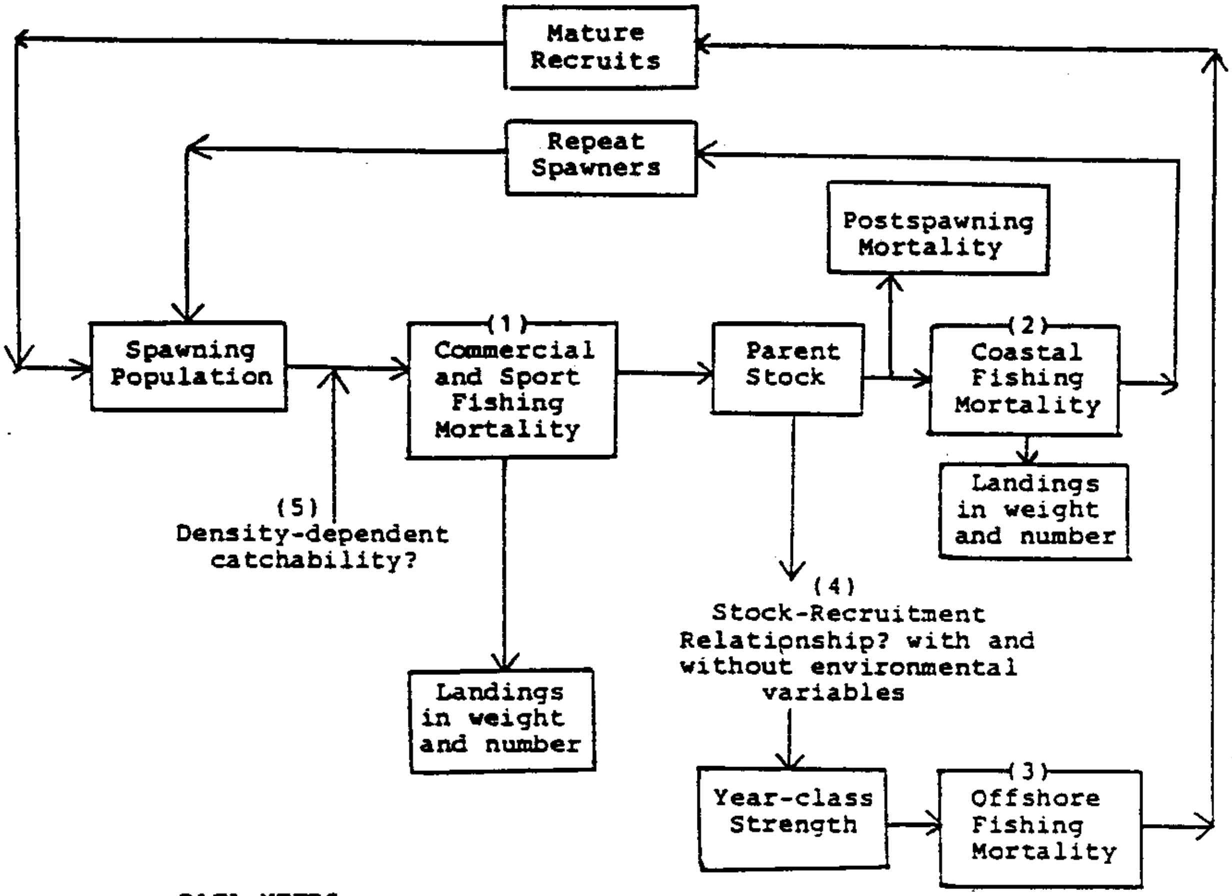
2. Determine annual exploitation rates of all anadromous alosids in each state. These data are needed to determine acceptable rates of exploitation consistent with stock stability and enhancement.

3. Develop a long-term mark or tag for juvenile alosids and/or a method for distinguishing among fish originating in different drainage systems. Such methods would contribute to determining which alosid stocks are being exploited in different fisheries and which are threatened by man's activities in certain areas (e.g., Bay of Fundy tidal hydroelectric facility construction).

4. Evaluate the magnitude of mortality to juvenile alosids caused by passage through hydroelectric turbines and determine optimal techniques for minimizing turbine-related mortality. This information is very important to ensure the success of restoration programs.

5. Develop basic life history information (e.g., population dynamics, migratory behavior, catch and effort data) on hickory shad in states where they are or have been abundant (South Carolina, North Carolina, Virginia, Maryland). These data are necessary for the development of even the most basic management recommendations.

6. Develop and implement programs to establish indices of juvenile alosid abundance in different drainage systems along the East Coast. A juvenile index, if properly calculated and validated, permits regulations to be altered as stock status changes, and can be used in evaluating factors that influence year class success.



DATA NEEDS:

1) Natal Fishing Mortality rate

2) Coastal Fishing Mortality rate

3) Offshore Fishing Mortality rate

4) Stock-recruitment Relationship

5) Density-dependent catchability

Figure V-2. Data needs for anadromous alosids within a population dynamics context it was also evident that certain types of information are needed immediately merely to determine if potential management problems exist and should be addressed. Examples of such information are: a determination of which stocks are being exploited in territorial sea fisheries for American shad in South Carolina; and, a determination of the actual exploitation rates of all of the alosids throughout their range. In many cases, data needed to answer these immediate questions may not contribute substantially to an understanding of the species' population dynamics, but are essential as a basis for making management decisions.

The types of conflicting demands just described led to the changes in priority reflected in the three tables included here. It is evident that as new data are acquired and more knowledge is gained about the species' population dynamics and their fisheries that priorities will be further revised.

Research Needs

- Recommendation 8.1

  ASMFC shall serve as a coordinator of research conducted along the east coast dealing with anadromous alosids. ASMFC will prepare a summary compendium of ongoing studies annually. Grant applications and/or proposals for anadromous alosid research programs submitted to federal and/or state agencies should be provided to ASMFC for comment to ensure that the focus of new studies is consistent with management needs identified in this plan.

- Recommendation 8.2

  In assigning priority for research funding under PL89-43 (Anadromous Fish Conservation Act), NOAA/NMFS and USFWS shall assign high priority to applications for state projects that satisfy data needs identified as having a high priority in this plan (see Tables V-12 and V-13).

- Recommendation 8.3

  ASMFC will design and coordinate the implementation of an interstate coastal shad tagging research program (see Recommendation 2.1). A tentative study design is presented in Table V-14. The initial interstate effort will focus on participation by South Carolina, and North Carolina, or other states where the nature of the fishery makes the study more feasible. ASMFC will be responsible for coordination of the activities of individual states and integration and interpretation of results. Studies that lead to the development of techniques to identify the river of origin of fish taken in mixed stock fisheries (e.g., ocean tagging, extensive within river tagging, innate indicators) should be encouraged in order to enhance the interpretation of findings of this tagging program.

- Recommendation 8.4

In establishing new anadromous alosid research programs, state and federal agencies will proceed according to the priorities presented in Table V-13.

- Recommendation 8.5

ASMFC shall undertake the compilation and analysis of all data on offshore river herring distribution and harvest available from NOAA (e.g., NMFS research trawl data, observer data, experimental Polish trawl program data). This information should be updated annually, and should be used to develop or revise recommendations to the Fishery Management Councils on regulations needed to protect traditional domestic river herring fisheries.

E. CITIZEN INVOLVEMENT

Development of management plans generally includes citizen participation to ensure that user groups are aware of and support recommendations of the plan. For the shad and river herring Fishery Management Plan, no formal citizens committee was established under the auspices of the ASMFC program. The states are encouraged to establish citizen programs of their own.

- Recommendation 9.1

Individual states are encouraged to establish programs that involve citizens in implementation of this plan.

Table V-14. Proposed guidelines for the design of a tagging study to determine which American shad stocks are being exploited in territorial and offshore sea fisheries

Basic Study Type	• Tag and Recapture
Objective	• To determine the home stream origin of shad stocks being exploited in territorial sea and Delaware Bay fisheries
General Methods:	
Timing	• January through April; focus within each state on the time period in which landings are greatest
Tag Type	• Floy streamer or internal anchor tag
Tag Return System	• Multilevel reward ($5, $10, $25) plus incentives (e.g., lottery)
Capture Methods	• Use drift gill nets, use mesh sizes identical to those used in commercial fisheries, fish the same locations as those fisheries
Number of fish to be tagged	• As many as possible within financial constraints

Such involvement would be appropriate as individual state plans are being developed. Participation by user groups and interested citizens may result in public support required to implement the plan.

VI. PLAN IMPLEMENTATION

A number of specific future needs will arise on initial implementation of this plan:

- Most of the recommendations presented here will serve as guidelines for the individual states, and in some aspects this plan serves as a coastwide strategic plan. Implementation would be enhanced if individual states develop state management plans that would essentially serve as the operational plans for implementation.

- A mechanism must be created to allow representatives from all interested state and federal agencies to participate in the monitoring of plan implementation, to assess the impact of this implementation on the stocks and the fisheries, and to initiate corrective action or alternative actions to ensure that there is continued progress in the protection and enhancement of anadromous alosid stocks. Because of the dynamic nature of this plan, the lack of such a mechanism is almost certain to result in eventual failure of the plan.

- No formal structure exists for linking recommendations presented in ASMFC management plans and decisions made concerning harvest of the species of interest in the FCZ. Such a structure would be helpful for coordinating the management activities of the states, the relevant federal agencies, and the Fisheries Management Councils.

- While a number of multistate management groups currently exist (e.g., Delaware Basin, Connecticut Basin) that oversee management of anadromous alosids in their respective areas of jurisdiction, there is no existing institutional structure for integrating and coordinating the ongoing activities of these groups. Thus, actions taken by one could be counterproductive to the efforts of another.

- A number of international issues have been encountered during the development of this plan, and some recommendations presented here specifically address those issues. It is likely that these issues will remain pertinent to the management of the anadromous alosids for an extended period of time. Some mechanism is needed to ensure that resolution of these and other international issues accounts for the interests of all appropriate states and of federal agencies.

The following institutional structures should be maintained to meet the needs just described:

- The Shad and River Herring Board should remain in existence.

- The existing management structure (ASMFC-Scientific and Statistical Committee-Program Manager) should remain in existence to maintain and modify the plan. Their functions would include, for example,

  -- The exchange of new data and information developed in ongoing programs within each state and federal agency

  -- The continued development of standardized data collection and processing procedures (e.g., scale reading, juvenile indices) to enhance the compatability of data being collected along the entire coastal range of each species

  -- Evaluation and analysis of new information, review of existing management recommendations; and the development of annually revised management recommendations to Regional Fishery Management Councils, NOAA, and individual state and interstate consortia, as necessary. This activity would ensure consistency of all management actions directed at the four anadromous alosids throughout their range and over all life stages

  -- Annual reexamination of data needs and priorities to reflect new data and information; the new priority list could then be distributed to all parties conducting research to help ensure that the greatest data needs continue to be met

  -- Serving as a tag program clearinghouse to provide an information center for all alosid tagging studies being conducted on the East Coast.

LIST OF APPENDICES

A. Current Status and Biological Characteristics of the Anadromous Alosid Stocks of the Eastern United States: American Shad, Hickory Shad, Alewife, and Blueback Herring. Phase I in Interstate Management Planning for Migratory Alosids of the Atlantic Coast (Phase I Report; Initially Published July 1984). [Some material presented here is updated from the original report.]

B. Summary of Individual State's Fisheries Regulation Development Process

C. Documentation of Recent Activity Relating to Regulation of Offshore River Herring Harvest

D. Summary of Shad Fishing Mortality Data From the Literature

E. Summary of Information and Literature Sources on Responses of Anadromous Alosids to Specified Water Quality Variables

F. Summary of State Regulations Relating to Instream Flows and Fish Passage

APPENDIX A

PHASE I REPORT

(Tables II-2, III-1, IV-1, and Figures II-1, II-3, II-4, II-5, II-6, IV-1, IV-2, IV-3, IV-4, and IV-5 were updated September 1985.)

CURRENT STATUS AND BIOLOGICAL CHARACTERISTICS OF THE ANADROMOUS ALOSID STOCKS OF THE EASTERN UNITED STATES: AMERICAN SHAD, HICKORY SHAD, ALEWIFE, AND BLUEBACK HERRING

Phase I in Interstate Management Planning for Migratory Alosids of the Atlantic Coast

Prepared for

Interstate Fisheries Management Program
Atlantic States Marine Fisheries Commission
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036

July 1984

FOREWORD

This report has been prepared by Martin Marietta Environmental Systems under Contract #83-3 as part of the Interstate Fisheries Management Program administered by the Atlantic States Marine Fisheries Commission. This report was reviewed and endorsed by the Interstate Fisheries Management Program's Shad and River Herring Management Board and Shad and River Herring Scientific and Statistical Committee. Members of the Scientific and Statistical Committee made major contributions to the report's contents and format. Membership rosters are included as Appendix A to this report. Funds were provided by Northeast Region, National Marine Fisheries Service, National Oceanic and Atmospheric Administration under Cooperative Agreement Number NA-80-FA-H-000-17. For bibliographic purposes, this report should be cited as follows:

Richkus, W.A. and G. DiNardo. 1984. Current status and biological characteristics of the anadromous alosid stocks of the eastern United States: American shad, hickory shad, alewife, and blueback herring. Atlantic States Marine Fisheries Commission, Fisheries Management Report 4, Washington, DC. xix + 225 pp.

EXECUTIVE SUMMARY

Preparation of a Fishery Management Plan for the anadromous alosids (American and hickory shad, alewife, blueback herring) of the East Coast of the United States was recommended by the Advisory Committee of the Atlantic States Marine Fisheries Commission (ASMFC) and adopted by the Commission in 1981, in response to the very low current levels of commercial landings of all four species.

As part of the process of developing a Fishery Management Plan for these species, ASMFC established a Shad and River Herring Management Board, with representatives from each of the east coast states in which runs of the species occur. The Board subsequently appointed a Scientific and Statistical (S&S) Committee to direct the development of the management plan. The committee is made up of one technical representative from each of the coastal states. An Action Plan was developed at a Shad and River Herring Management Workshop in Philadelphia, Pennsylvania, February 2-3, 1982, which called for subsequent activity to occur in two phases:

- Phase I - compile available data on the current status and biology of each of the four species and define potential options for management action
- Phase II - develop a management plan, with specification of management actions where appropriate, and identify research needs.

The present report represents completion of Phase I. American shad, hickory shad, and river herring (alewife and blueback herring) are treated in separate segments of this report. Each segment covers, as appropriate:

- Historical review of the fisheries for the species
- Recent trends in commercial and sport landings - regional basis
- Recent trends in fisheries - state-by-state
- Coastal migration patterns
- Selected life history aspects relevant to management

- Restoration efforts
- Environmental factors influencing stocks
- Management options.

For American shad, pertinent findings are as follows:

- All runs in the Chesapeake Bay and to the south have declined
- The Delaware River run has increased dramatically over the past decade, while Hudson and Connecticut River runs have remained stable
- The predominant gear types for commercial harvesting of American shad are gill nets (stake, anchor, and drift)
- Minimal or no repeat spawning occurs in southern stocks (North Carolina and south), with the percentage of repeat spawners increasing to the north
- All east coast stocks appear to mix at sea, during coastal prespawning migrations, and during foraging periods in the summer in the Gulf of Maine and the Bay of Fundy
- Yearclass size appears to be is set by the time larvae reach the juvenile stage.
- Current studies on the Connecticut River suggest that the numbers of juveniles produced is independent of spawning stock size.
- Restoration efforts that increase spawning habitat may add substantially to the total east coast stock of American shad

For hickory shad, pertinent finding are as follows:

- Landings have decreased in all runs along the east coast
- Spawning runs occur somewhat earlier than those of American shad
- Larger female hickory shad probably suffer the greatest fishing mortality of all segments of the hickory shad population

- Repeat spawners make up the majority of most hickory shad runs.

- Virturally no comprehensive information is available on the life history of hickory shad over a complete life cycle.

For the river herrings (alewife and blueback herring), pertinent findings are as follows:

- Both domestic and offshore landings (foreign) have declined dramatically in the recent decade, with the exception of the state of Maine, where landings have been stable.

- Offshore harvests by foreign fisheries in the late 1960's and early 1970's are strongly implicated in the decline in southern stocks.

- Offshore migrations are not well defined, but appear to be similar to those of American shad

- Spawning habitats appear to differ regionally, with ponds and lakes being used more frequently in New England states by alewives while bluebacks spawn in rivers and streams; to the south, bluebacks use both lakes and rivers as spawning areas.

- Substantial repeat spawning occurs in most runs, yet some runs experiencing extremely high fishing mortalities (80-90%) have remained very stable over extended periods of time.

- Restoration efforts, including the stocking of gravid adults and/or improved access to spawning habitats, have increased stocks dramatically in many drainage systems.

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I. INTRODUCTION

Preparation of a Fishery Management Plan for the anadromous alosids of the East Coast of the United States (American and hickory shad, alewife, blueback herring) was recommended by the Advisory Committee of the Atlantic States Marine Fisheries Commission (ASMFC) and adopted by the Commission in 1981. This action was in response to the very low current levels of commercial landings of all four species, which was perceived as an indication that management action would be required in order to restore stocks to their former levels of abundance. The basis for action by the Commission was that the four species met five criteria for inclusion in the ASMFC Interstate Fisheries Management Program (ISFMP)(ASMFC, 1982):

- Valuable to the states and to the nation
- Perceived to be in need of management for attainment of optimum yield
- Not currently scheduled for management under the Magnuson Fishery Conservation and Management Act (PL 94-265)
- Reasonable expectation of plan implementation
- Cost effective management.

As part of the process of developing a Fishery Management Plan for these species, ASMFC established a Shad and River Herring Management Board. Included on the Board are representatives from each of the east coast states in which runs of the species currently or fomerly occurred: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia and Florida. Both the National Marine Fisheries Service and the U.S. Fish and Wildlife Service also have representatives on the Board. A Board membership list is presented in Appendix A.

The Board subsequently appointed a Scientific and Statistical (S&S) Committee to direct the development of the management plan. The committee is made up of technical representatives from each of the previously mentioned states and the two Federal agencies. A S&S membership list is presented in Appendix A. An Action Plan was developed at a Shad and River Herring Management Workshop in Philadelphia, Pennsylvania, February 2-3, 1982, which called for subsequent activity to occur in two phases:

- Phase I - compile available data on the current status and biology of each of the four species and define potential options for management action
- Phase II - develop a management plan with specification of management actions where appropriate, and define research needs.

Martin Marietta Environmental Center (EC) was contracted by ASMFC in 1982 to carry out Phase I of the Action Plan. The primary sources of material for this report were overview documents prepared for each state by the individual members of the S&S Committee. This material was augmented with information taken from the literature. The present report represents completion of Phase I. It is not intended to be a detailed all-encompassing review of literature on the biology of all four species, since a number of other review documents exist that serve that specific purpose (e.g., Mansuetti and Kolb, 1953; Walburg and Nichols, 1967; Rulifson et al., 1982; Public Service Electric and Gas Company, 1982a, b, c). Instead this report focuses on current fisheries (both commercial and recreational) for each species, recent trends in landings and stock size, and those life history aspects considered most relevant to management action. To a certain extent, sources of data have been "screened", and those of questionable validity or lacking in general applicability have not been included.

American shad, hickory shad, and river herring (alewife and blueback herring) will each be treated in a separate segment of this report. Each segment will have the same organization (where appropriate) as follows:

- Historical review of the fisheries for the species
- Recent trends in commercial and sport landings - regional basis
- Recent trends in fisheries - state-by-state
- Coastal migration patterns
- Selected life history aspects relevant to management
- Restoration efforts
- Environmental factors influencing stocks
- Management options.

A bibliography of data and information sources is included at the end of the report, organized by state. The four species are illustrated in Fig. I-1. General characterizations of the life histories of each species are diagramed in Figs. I-2 to I-5.

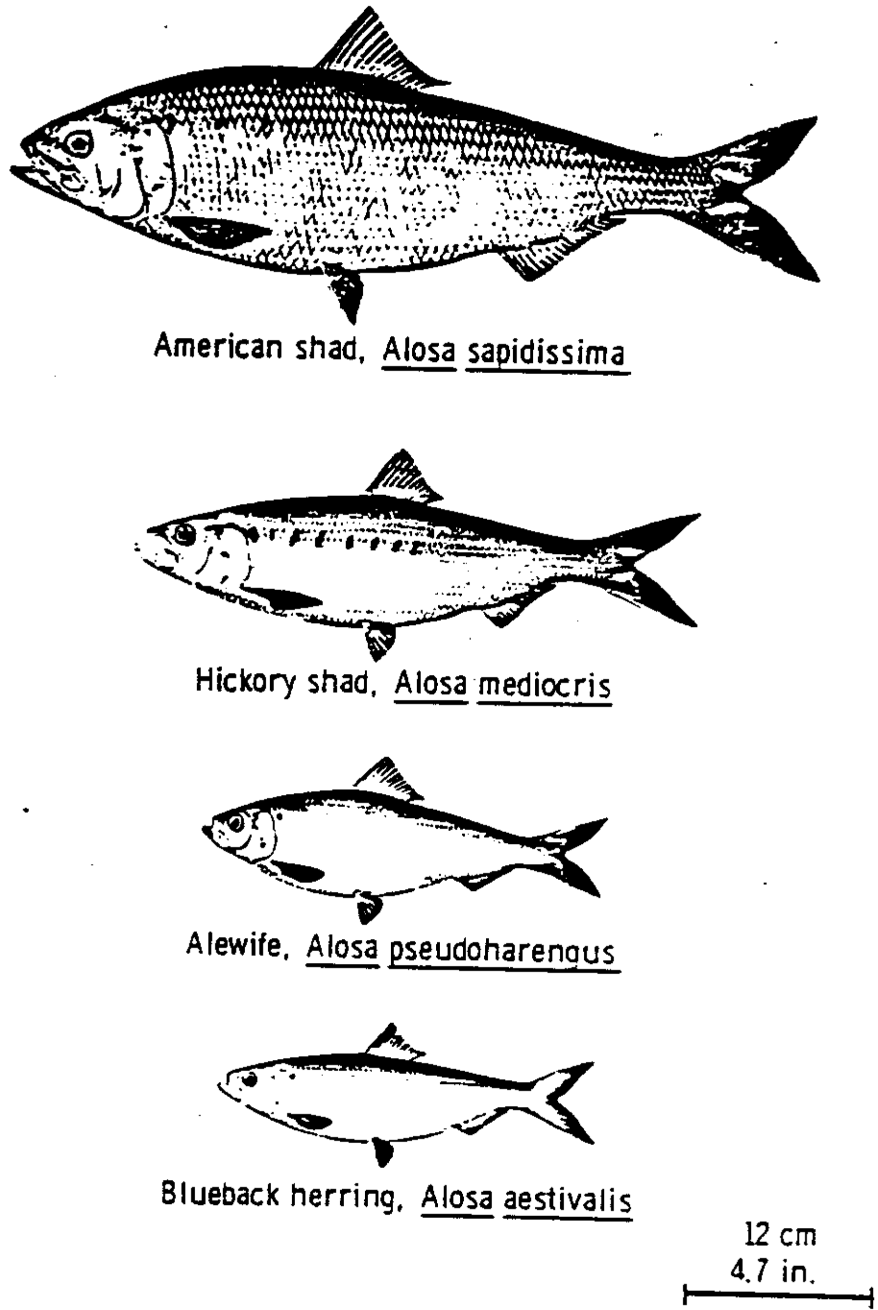


Figure I-1. Illustrations of adults of the four species of east coast anadromous alosids. Drawings are to scale (adapted from Jones, Martin, and Hardy, 1978)

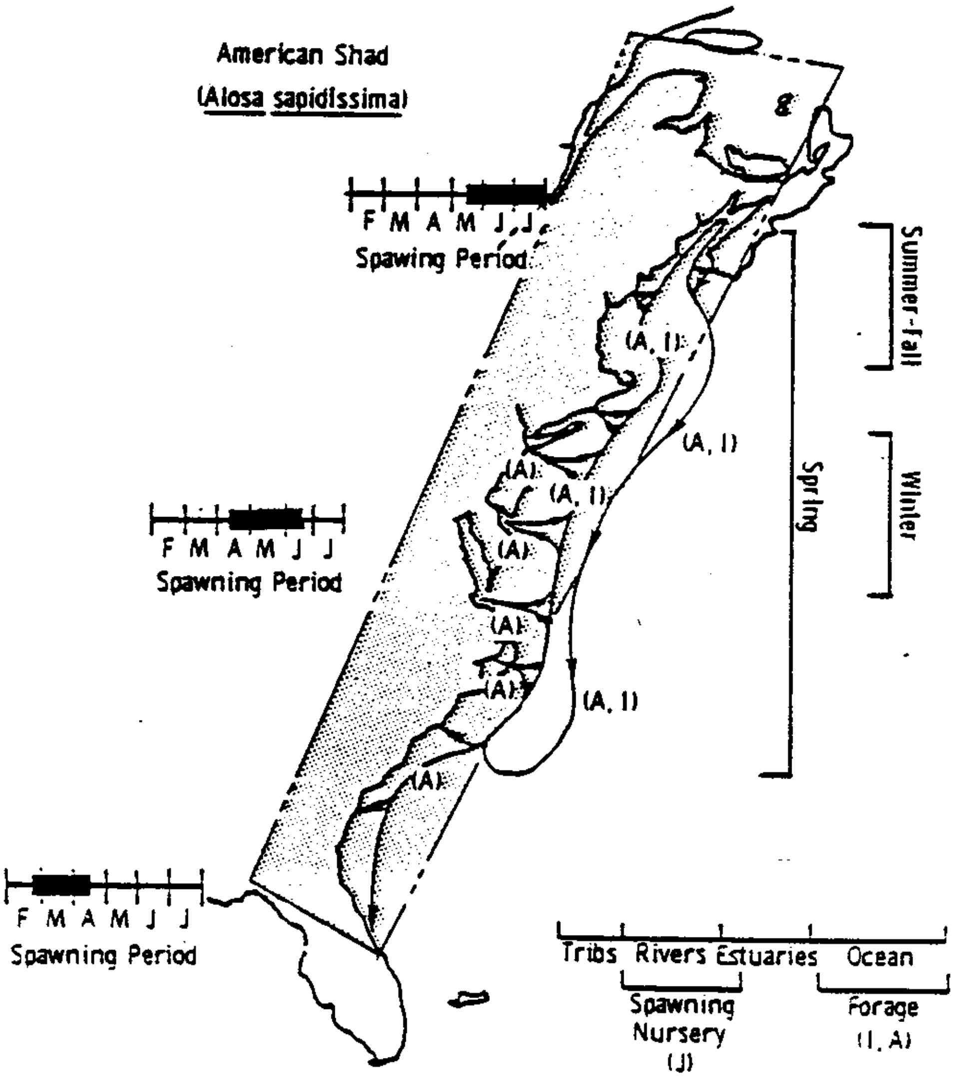


Figure I-2. Diagramatic characterization of the life history of the American shad; A = adult, I = immature, J = juvenile, shaded area represents range of spawning occurrence; bars indicate general seasonal or habitat distribution by life stage. Detailed discussion appears in the text.

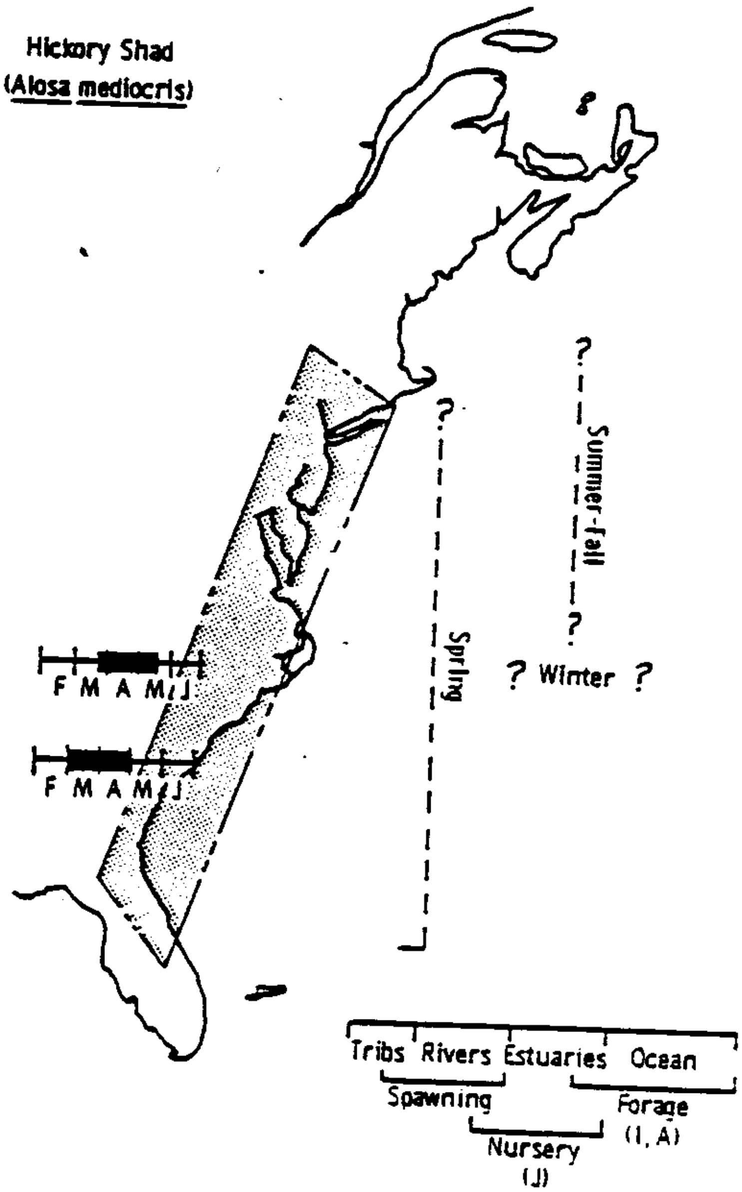


Figure I-3. Diagramatic characterization of the life history of the hickory shad; A = adult, I = immature, J = juvenile, shaded area represents possible range of spawning occurrence; bars indicate general seasonal and habitat distribution by life stage. Detailed discussion appears in the text; dashed lines represent speculation.

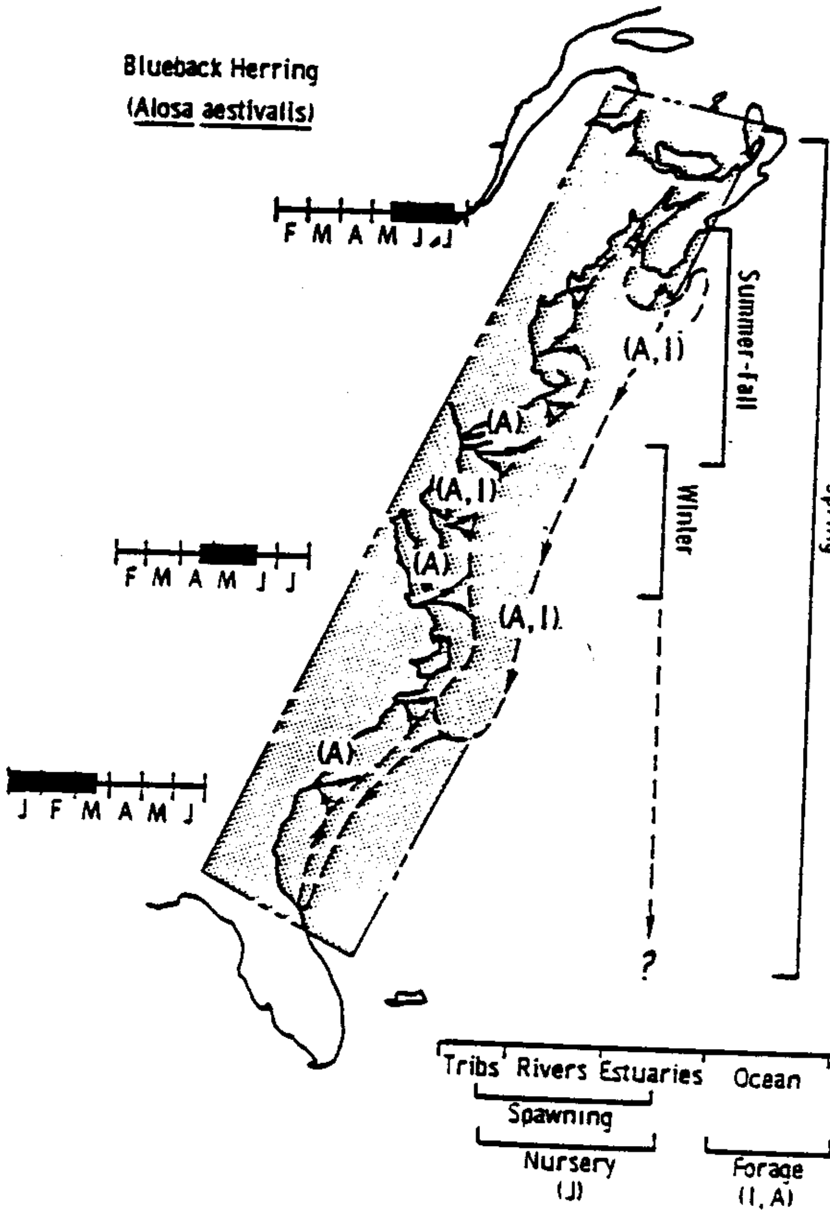


Figure I-4. Diagramatic characterization of the life history of the blueback herring; A = adult, I = immature, J = juvenile; dashed lines represent speculation; shaded area represents range of spawning occurrence; bars indicate general seasonal or habitat distribution of life stage. Detailed discussion appears in the text.

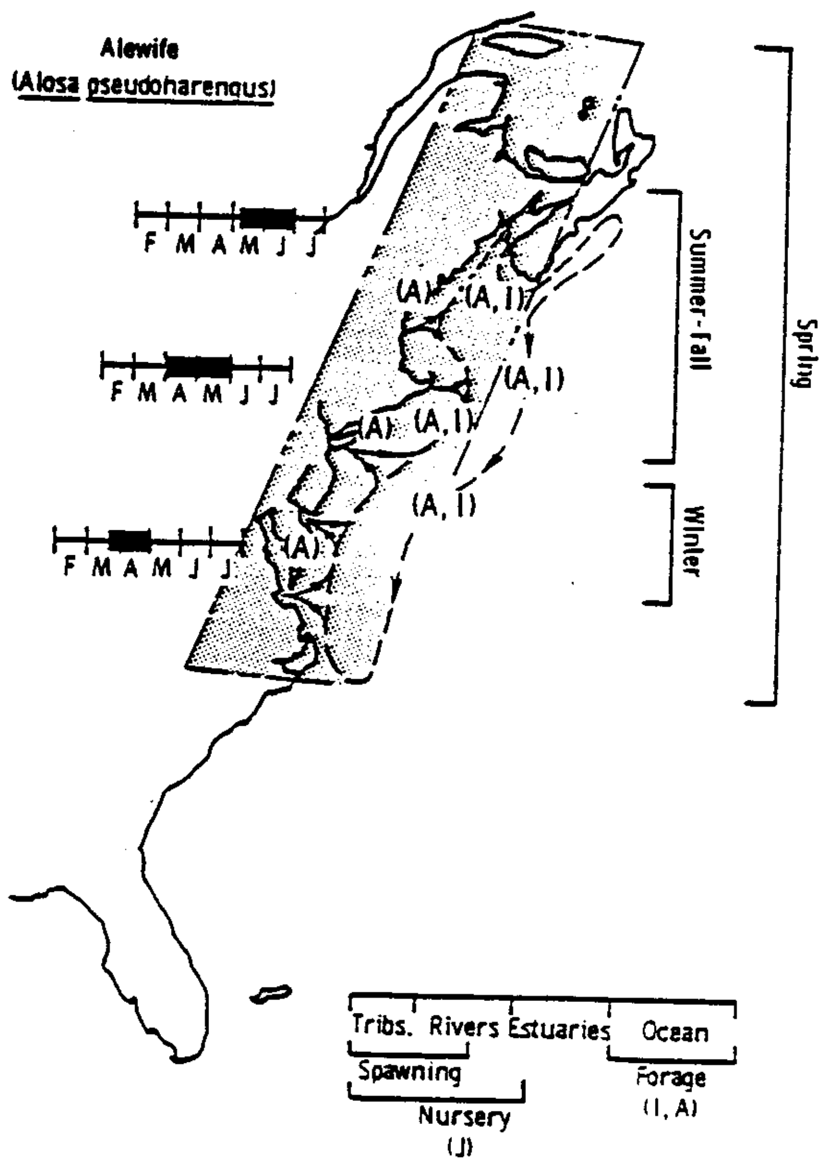


Figure I-5. Diagramatic characterization of the life history of the alewife; A = adult, I = immature, J = juvenile; shaded area represents range of spawning occurrence; bars indicate general seasonal or habitat distribution. Dashed lines represent speculation; detailed discussion appears in the text.

II. American Shad (*Alosa sapidissima*)

A. BACKGROUND AND HISTORICAL TRENDS

Background

American shad spawning runs occur along the east coast of the United States and Canada, from the St. Johns River in Florida to the St. Lawrence River in Canada. Major spawning rivers are listed in Table II-1 (from Walburg and Nichols, 1967).

Historically, the American shad was an extremely important resource species along the east coast of both the United States and Canada, supporting very large commercial fisheries. However, landings of American shad in commercial fisheries have shown long-term declines (Fig. II-1). These historical declines in landings, which have been interpreted as indicators of stock declines, sparked concerns and studies on numerous occasions in the past.

In a very thorough review of information on American shad fisheries, Mansuetti and Kolb (1953) noted that from 1897 to the 1940's, annual harvest of shad declined from 50 million pounds to approximately 11 million pounds. Their assessment of causes of the decline identified several potential major factors, including:

- Pollution of spawning rivers
- Siltation of spawning areas
- Overharvesting
- Dams, by preventing access to spawning areas.

However, they noted that these factors, singly or collectively, could not be made to account completely for the general decline of shad along the Atlantic coast. Mansuetti and Kolb also suggested the existence of some type of natural biological cycle in shad population size, but no evidence was presented to substantiate this view. They also indicated that the prognosis for American shad was poor and envisioned no known means of restoring stocks to their former magnitude.

Table II-1. The original and current limits of shad range in 23 major rivers of the Atlantic coast of the United States (adapted from Walburg and Nichols, 1967).

State	Original limit of shad run: River	Original limit of shad run: Distance of source from coastline	1983 limit of shad run: Locality	1983 limit of shad run: Distance of source from coastline
		Miles		Miles
Florida	St. Johns	375	Lake Washington	250
Georgia	Altamaha	450	Hawkinsville	300
Georgia	Ogeechee	350	Midville	125
Georgia	Savannah	425	Savannah Lock and Dam	180
South Carolina	Edisto	300	Norway	120
South Carolina	Santee: Wateree	350	Santee Dam	65
	Congaree	410	Santee Dam	65
South Carolina	Pee Dee	497	Blewett Falls Dam	242
North Carolina	Cape Fear	290	Lock No. 1	65
North Carolina	Neuse	340	Milburnie	165
North Carolina	Pamlico-Tar	252	Rocky Mount	157
North Carolina	Roanoke	457	Spring Hill	215
Virginia	James	420	Boshers Dam	140
Virginia	Rappahannock	248	Falmouth Falls	155
Maryland	Potomac	400	Little Falls Dam	180
Maryland	Susquehanna	617	Conowingo Dam	205
New York - New Jersey	Delaware East Branch	388	Downsville, N.Y.	360
	West Branch	350	Deposit, N.Y.	350
New York	Hudson	314	Troy, N.Y.	130
Connecticut	Housatonic	202		No shad
Connecticut	Connecticut	174	Bellows Falls	174
Massachusetts	Merrimac	140	Eastman Falls	110
Maine	Kennebec	155		No shad
Maine	Penobscot	255		No shad

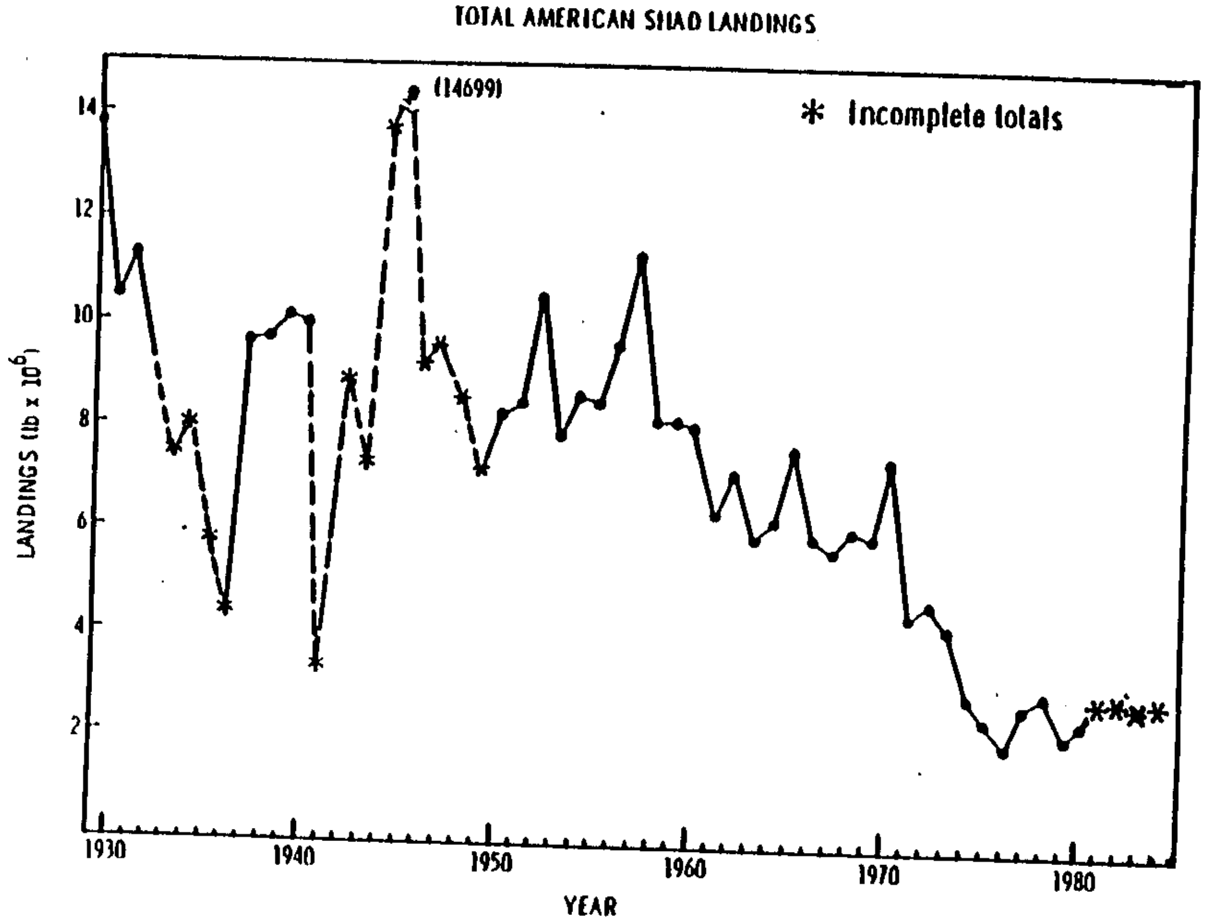


Figure II-1. Reported commercial landings of American shad along the east coast of the United States, 1930 to 1984. Sources of data are listed in Table II-2.

ASMFC recommendations to the United States Fish and Wildlife Service (USFWS) resulted in American shad studies being conducted by USFWS during the 1950's (e.g., Talbot and Sykes, 1957). These efforts were prompted by concern for the status of shad runs at that time, with the goal of establishing the reasons for declines and developing recommendations to reverse declining trends in American shad fisheries. Results of these studies were summarized by Walburg and Nichols (1967). They concluded that many factors had influenced the status of the American shad, but their list of major factors was essentially identical to that of the Mansuetti and Kolb study 14 years earlier:

- Pollution of spawning rivers
- Siltation of spawning areas
- Dams, by preventing access to spawning areas
- Overharvesting.

While Walburg and Nichols presented a more updated view of stock status than Mansuetti and Kolb (1953) they provided no new major insights into the causes of decline. In many respects, the present document represents an updating of the information compiled by Walburg and Nichols in 1967. This updating will begin by examining trends in shad commercial fisheries over the last 20 years on a regional basis; these regional trends will then be examined in more detail on a state-by-state basis.

B. RELEVANCE OF COMMERCIAL LANDINGS DATA TO STOCK ASSESSMENT

Because commercial landings data represent the only long-term records available relating to fish abundance, they serve as the primary basis for discussion of trends in stocks. However, as is widely known and acknowledged by fisheries experts, many factors influence the magnitude of landings beside the basic abundance of the fish being harvested. These include:

- Amount of fishing effort (e.g., number of fishermen, amount of gear used)
- Effects of demand for the species on fishing effort (market factors)

- Environmental conditions, as they may affect fishing effort and/or catchability of the fish (e.g., ice destroying pound nets during a cold winter; high river flow decreasing the efficiency of drift gill nets)

- Market value of roe (female) shad being higher than the market value of buck (male) shad, resulting in discard and non-reporting of buck shad harvest

- Unreliability of catch reporting by fishermen, often to the extent of 100 to 200%, with no constant bias from year-to-year (e.g., Maryland Watermens Association, 1980).

Catch per unit effort (CPUE) is assumed to be proportional to changes in fish stock size. However, a recent Connecticut study (Crecco 1983 in prep) has shown that commercial shad CPUE did not accurately reflect shad stock size. This lack of colinearity between CPUE and stock size was attributed to an inverse relationship between catachability (q) and population size (see Fig. II-2). The catchability coefficient is defined as the percentage of the fish stock removed by a single unit of fishing effort. Such a phenomena could be a market affect, with higher prices at times of low abundance causing fishermen to be more diligent. This phenomenon implies that shad runs can fall to low levels without this being demonstrated in the catch statistics. This is a promising hypothesis to explain how overfishing can cause recruitment failure. The inadequacies of CPUE as an indicator of stock abundance has previously been demonstrated for other fisheries (e.g., Bannerot and Austin, 1983). However, it has been pointed out that the shad fishery in the Connecticut River occurs in relatively confined areas. In an open system, such as the Delaware Bay, fishermen may not have the luxury of modifying the amount or nature of their effort in response to their perception of the size of the run (R. Miller, pers. comm.). Virginia fishermen do tend to be opportunistic in their exploitation of shad (J. Loesch, pers. comm.)

An even more limiting factor in using catch per unit effort as the indicator of American shad stock abundance is that there is essentially an absence of meaningful long-term records of effort along nearly the entire east coast. This absence of effort data currently precludes the use of catch per unit effort as a useful index of stock abundance for examining long-term trends in shad stocks.

Thus, the commercial landings data are the sole means of characterizing stock trends even though it is acknowledged that they only serve as a rough index of stock abundance. For this reason, only severe changes in landings can be considered meaningful in terms of stock changes. Reliable records of recreational harvest are too incomplete and sparse over time to be of use as stock abundance indices.

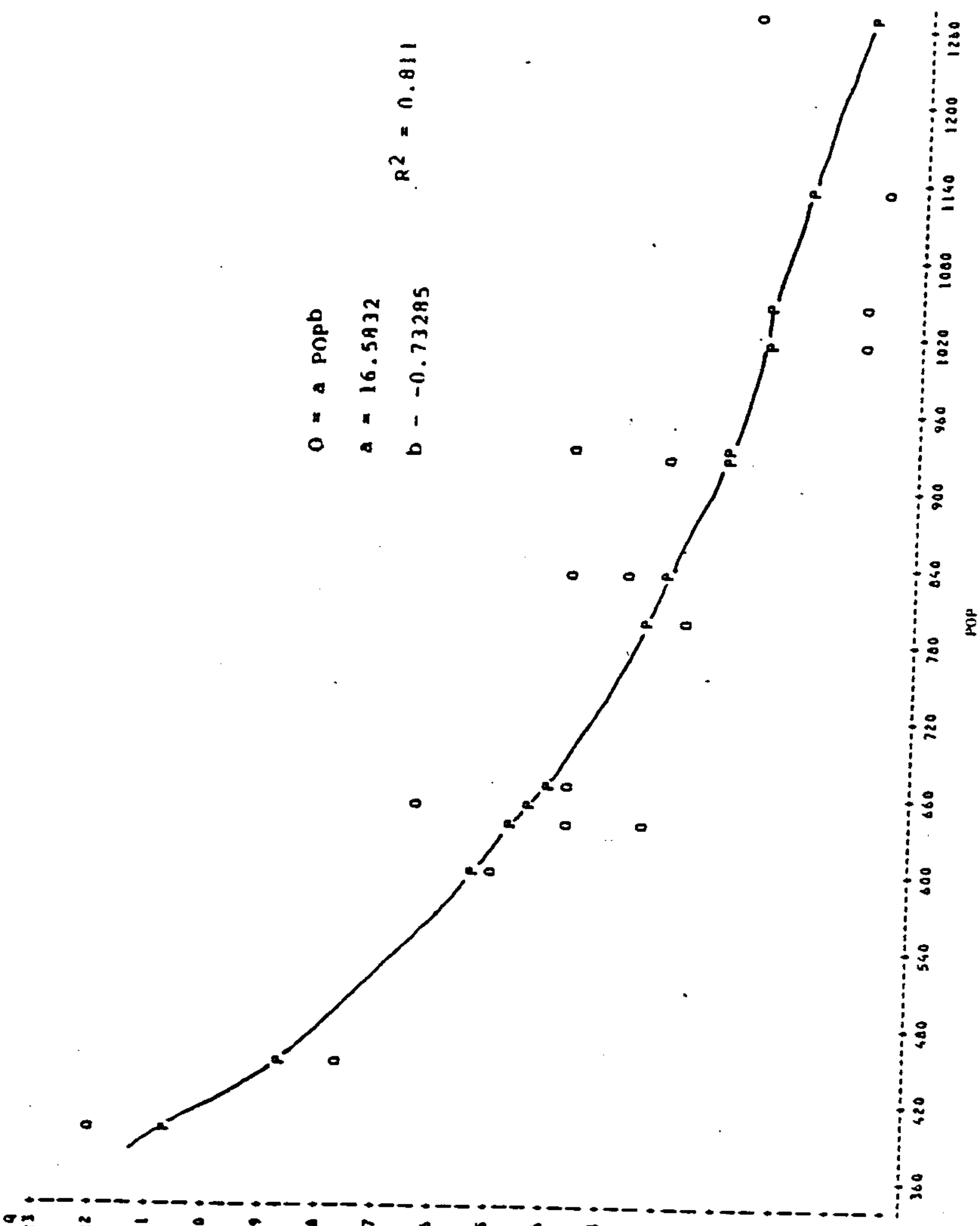


Figure II-2. Relationship between stock size (POP) and catchability (q) for Connecticut River Shad (from Crecco [illegible]

Table II-2. American shad catch (in thousands of pounds) per state and total Atlantic coast for years of available data. Data for 1880-1960 from Walburg & Nichols (1967); 1961-1979 from U.S. Dept. of Commerce Fishery Statistics of the United States (from PSE&G, 1982a); 1980 to present from Boreman (1982) and/or state fisheries agencies; where no number appears information was lacking.

Year	FL	GA	SC	NC	VA	MD	DE	PA	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1880		252	208	3,221	3,172	3,774	1,050	559	750	2,734						18,068
1887		255	366	4,783	3,815	4,041	1,270	1,424	6,495	3,586	337	17	133			29,630
1888		263	433	5,725	7,057	4,868	1,389	1,387	6,523		282	17	260		1,096	33,397
1889		356	577	5,403			1,498	2,753	10,424	4,332	196	17	234		839	
1890		400	563	5,815	7,266	7,128	1,797	2,898	10,623	3,777	120					
1896	1,299	537	672	8,843	11,171	5,541	1,993	2,501	13,910	2,201	261	53	114		1,404	50,499
1897	1,011	788	506	8,963	11,529	5,800	1,621	2,007	13,001	1,884	256					
1901					6,972	3,111	1,368	2,983	14,031	3,432	434				731	
1902	1,819	1,029	434	6,567							480	31	21		849	
1904				3,230	7,420	2,912	951	836	4,338	498	603				1,259	
1908	2,833	1,333	464	3,942	7,314	3,937	870	593	3,004	360	122	4	389		770	25,935
1909					6,030	3,253					122				980	
1915					4,714	1,455					140					
1918	964	101	167	1,657							241					
1920					7,294	1,867					176					
1921					6,909	1,807	87	19	168	116	72					
1923	503	134	184	2,370							46					
1925					6,104	1,260					146					
1927	348	187	182	2,387							120					
1928	691	317	320	3,118							199	6	31	0	110	
1929	701	472	260	1,913	7,977	1,549	94	22	342	364	318	15	92	0	36	13,955
1930	880	275	214	1,172	6,183	998	54	5	224	167	54	4	54	0	89	10,373
1931	621	112	152	883	7,291	1,196	39	7	257	357	75	18	150	0	150	11,336
1932	546	288	123	925	4,848	1,667	16	2	224	401	70	8	46	0	108	9,272
1933					4,817	1,374	22	2	458	352	133	11	63	0	179	
1934	782	232	209	1,274	4,105	885					525					
1935					2,883	800	25	10	818	476	403	6	106	0	13	
1936	282	236	177	1,095	1,615	570					385					
1937	288	193	138	698	3,086	405	20	13	3,340	1,021	303	5	48	0	9	9,647
1938	229	98	59	1,032	3,607	600	14	14	2,492	1,072	427	10	54	0	12	9,720
1939	254	75	42	859	3,559	624	44	11	2,699	1,378	409	28	85	0	8	10,075
1940	344	150	50	801	2,811	446	31	10	3,365	1,382	360	54	95	0	65	9,964
1941	256				2,126	534					438			0	48	
1942	323				2,430	725	14	7	4,826		373	1	33	0	161	
1943	666						24	0	3,348	2,245	553	2	114	0	272	
1944	811				4,665	711	41	0	4,314	2,130	747	4	20	0	441	
1945	842	222	89	912	5,299	617	133	0	2,917	2,850	772	2	29	0	15	14,699
1946	837				3,599	719		0		1,744	1,146	3	10	0	1,107	
1947	625				4,086	868	68	0	1,547	1,267	793	2	52	0	304	
1948	515				3,206	1,004	53	0	1,853	1,393	622	2	34	0	3	
1949	284				2,801	1,083	57	0	1,407	900	471	3	11	0	5	
1950	298	180	73	1,100	3,031	1,443	102	0	1,072	628	264	2	28	0	2	8,223
1951	336	206	96	1,244	3,295	1,554	110	0	682	462	338	6	72	0	76	8,477
1952	203	243	136	1,479	4,007	1,636	65	0	1,402	773	474	5	48	0	50	10,521
1953		214	110	1,188	3,054	1,448	60	0	679	491	360	4	40	0	27	7,799
1954		180	196	1,445	3,169	1,501	55	0	826	707	295	2	9	0	2	8,668
1955	508	158	88	649	3,500	1,464	12	0	1,326	615	210	5	37	0	7	8,599

Table II-2 (Continued)

Year	FL	GA	SC	NC	VA	MD	DE	PA	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1956	376	168	116	773	3,191	2,092	12	0	1,316	704	197	1	724	0	2	9,672
1957	361	247	80	837	2,918	2,356	3	0	1,384	627	329	5	2,214	0	8	11,369
1958	589	319	71	493	2,254	1,900	59	0	964	644	456	2	425	0	10	8,186
1959	540	391	80	419	1,774	1,481	28	0	1,026	672	401	3	1,383	0	2	8,200
1960	511	534	162	702	1,306	1,336	42	0	694	472	421	3	650	0	(1)	8,134
1961	425	404	110	673	1,329	1,815	90	0	633	303	463	4	80	0	0	6,329
1962	760	527	115	765	2,220	1,575	118	0	480	243	456	7	7	0	(1)	7,274
1963	590	331	120	693	2,312	827	100	0	442	202	301	2	22	0	8	5,942
1964	613	134	120	640	2,651	890	150	0	430	141	278	3	39	0	0	6,269
1965	758	376	176	1,069	2,955	1,343	110	0	392	133	352	4	24	0	0	7,692
1966	530	386	119	701	2,431	1,133	56	0	242	81	242	23	12	0	2	5,959
1967	319	334	132	777	2,138	867	26	0	248	113	240	5	509	0	(1)	5,709
1968	531	569	110	842	2,550	958	12	0	241	126	212	2	2	0	2	6,157
1969	390	618	177	719	2,248	1,292	18	0	180	136	190	6	5	0	0	5,987
1970	218	532	148	953	4,112	1,039	13	0	195	106	173	12	1	0	0	7,502
1971	253	420	99	680	1,520	953	8	0	141	73	243	42	0	0	0	4,430
1972	120	344	159	468	2,057	957	9	0	263	103	249	14	1	0	0	4,744
1973	99	239	26	321	2,436	597	8	0	143	157	258	2	1	0	0	4,287
1974	100	162	24	369	1,569	220	8	0	122	164	247	7	3	0	(1)	2,996
1975	33	182	62	241	1,137	184	19	0	122	196	165	6	2	0	35	2,384
1976	28	93	32	167	896	110	36	0	100	186	393	3	0	2	15	2,058
1977	97*	118	80	121	1,469	78		0	198	217	302	1	(1)	3	22	2,706
1978	131	238	105	402	1,235	93	70	0	242	309	266	1	(1)	3	25	3,261
1979	95*	268	197	278	993	18	95	0	149	438*	207	1	3	2	18	2,895
1980	141*	188	271	199	973	23	94	0	293	1,249*	312	2	2	0	28	3,618
1981	170*	196	317	352	499	-	191	0	264	541*	439	33			91	2,625
1982	145*	198	398	412	585	-	350	0	391	383*	373	79			26	3,076
1983	78*	210	331*	444	564	-	233	0	233	448*	447	21			41	2,773
1984	214		492		991	-		0	291	601	199	16			33	
1985	220															

(1) denotes less than 500 lbs

*from A. Kahle, NYSDEC, November 1984.

Table II-2 presents annual landings of American shad by state for the period 1880 through 1983. Sources of the data are primarily NOAA catch records as reported in Fishery Statistics of the United States. Figures II-3 through II-6 represent annual landings aggregated by east coast region, including the New England region (Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut), Middle Atlantic region (New York, New Jersey, Pennsylvania, Delaware), the Chesapeake Bay region (Maryland and Virginia), and the South Atlantic region (North Carolina, South Carolina, Georgia, and Florida).

C. REGIONAL CHARACTERIZATION OF STOCK TRENDS BASED ON COMMERCIAL HARVESTS

The primary focus of these characterizations will be on a period since the last shad stock assessment was made by Walburg and Nichols (1967); i.e., from 1960 to the present. New England landings (Fig. II-3) have remained very stable for the last 20 years. The exception to this fairly stable pattern of landings occurred in the late 1950's and was caused by large reported landings of shad in Massachusetts. These large annual landings have been attributed by Walburg and Nichols to purse seine fisheries being directed at alternative species when Atlantic menhaden stocks declined dramatically. During the remainder of the last 20 years, the stability of New England landings around relatively low levels is almost entirely a function of the Connecticut River landings. The Connecticut River supports the sole major American shad fishery in New England.

Middle Atlantic landings (Fig. II-4) showed a fairly steep decline from the late 1950's to the mid 1960's, followed by a period of relative stability, but with levels remaining low. The current stable level of landings is a function of landings from both the Hudson and the Delaware Rivers, with the Hudson landings dominating.

Chesapeake landings (Fig. II-5) showed relatively large fluctuations in the early 1960's, but no abrupt decline until the early 1970's. That decline was most dramatic in Virginia in terms of total numbers of fish. Maryland landings essentially went to zero, with the subsequent closure of the fishery in 1981.

South Atlantic landings (Fig. II-6) showed a decline in the early 1970's comparable to that exhibited in the Chesapeake region landings. The decline was seen in landings from all the states in the region. There has been some evidence of an increase in the landings beginning in 1978 (Table II-1), although the increase is not dramatic.

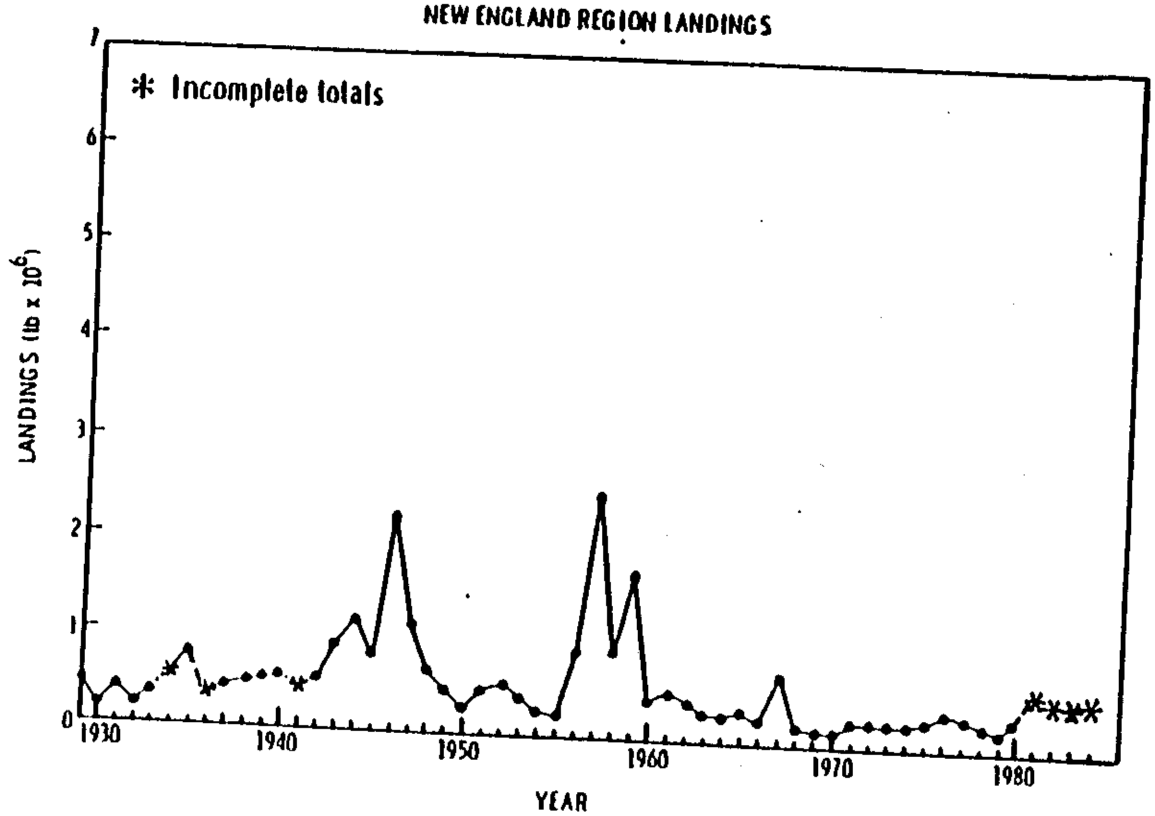


Figure II-3. Reported commercial landings of American shad in the New England region, 1930 to 1984; data sources are listed in Table II-2

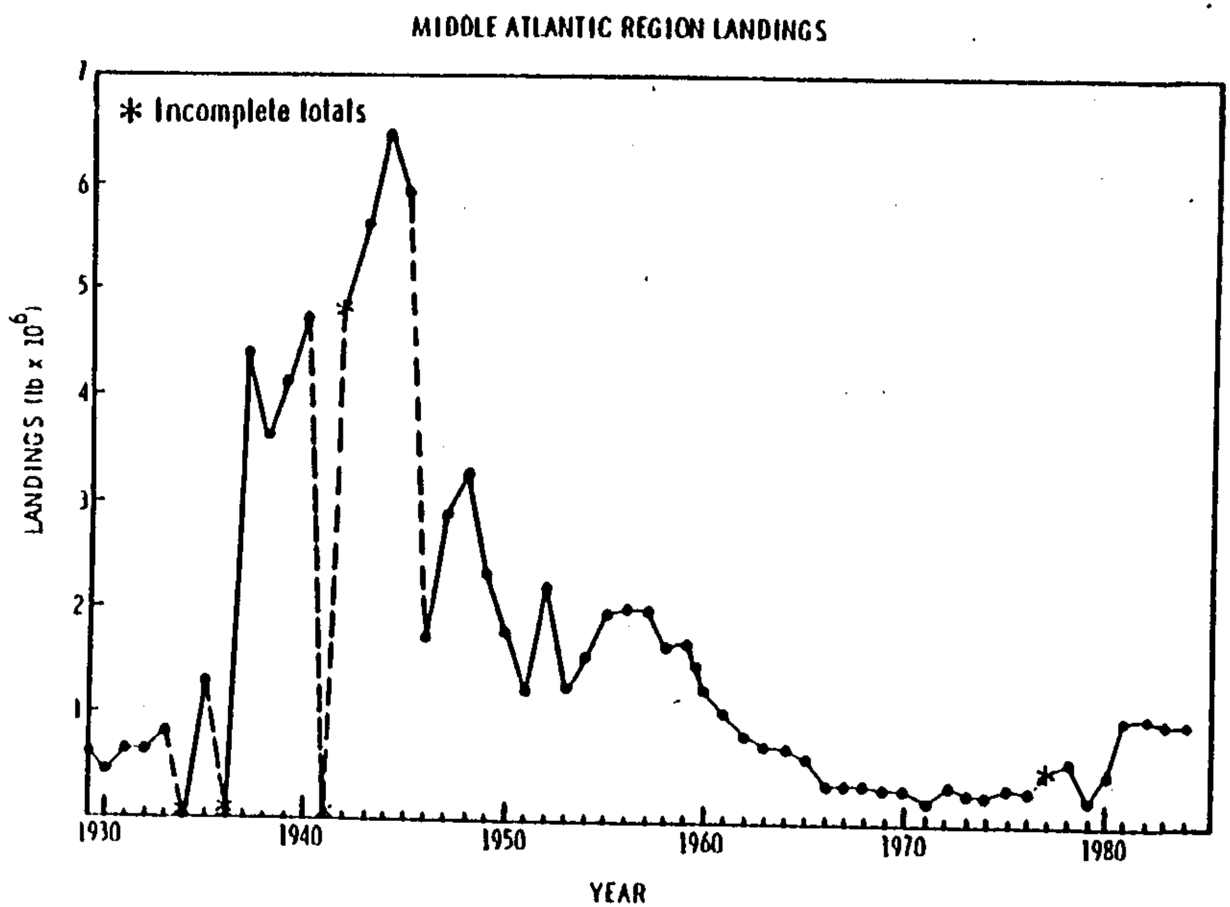


Figure II-4. Reported commercial landings of American shad in the Middle Atlantic region, 1930 to 1984; data sources are listed in Table II-2

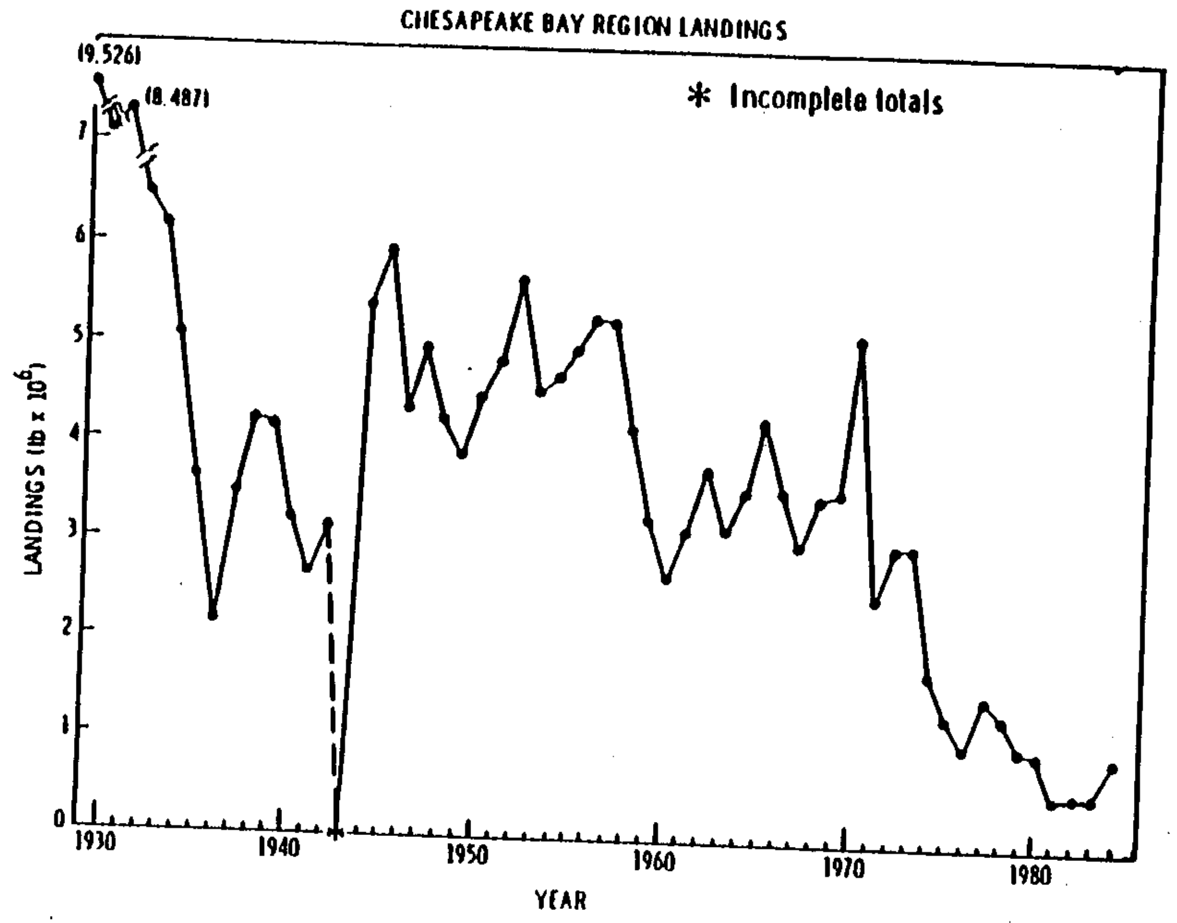


Figure II-5. Reported commercial landings of American shad in the Chesapeake region, 1930 to 1984; data sources are listed in Table II-2

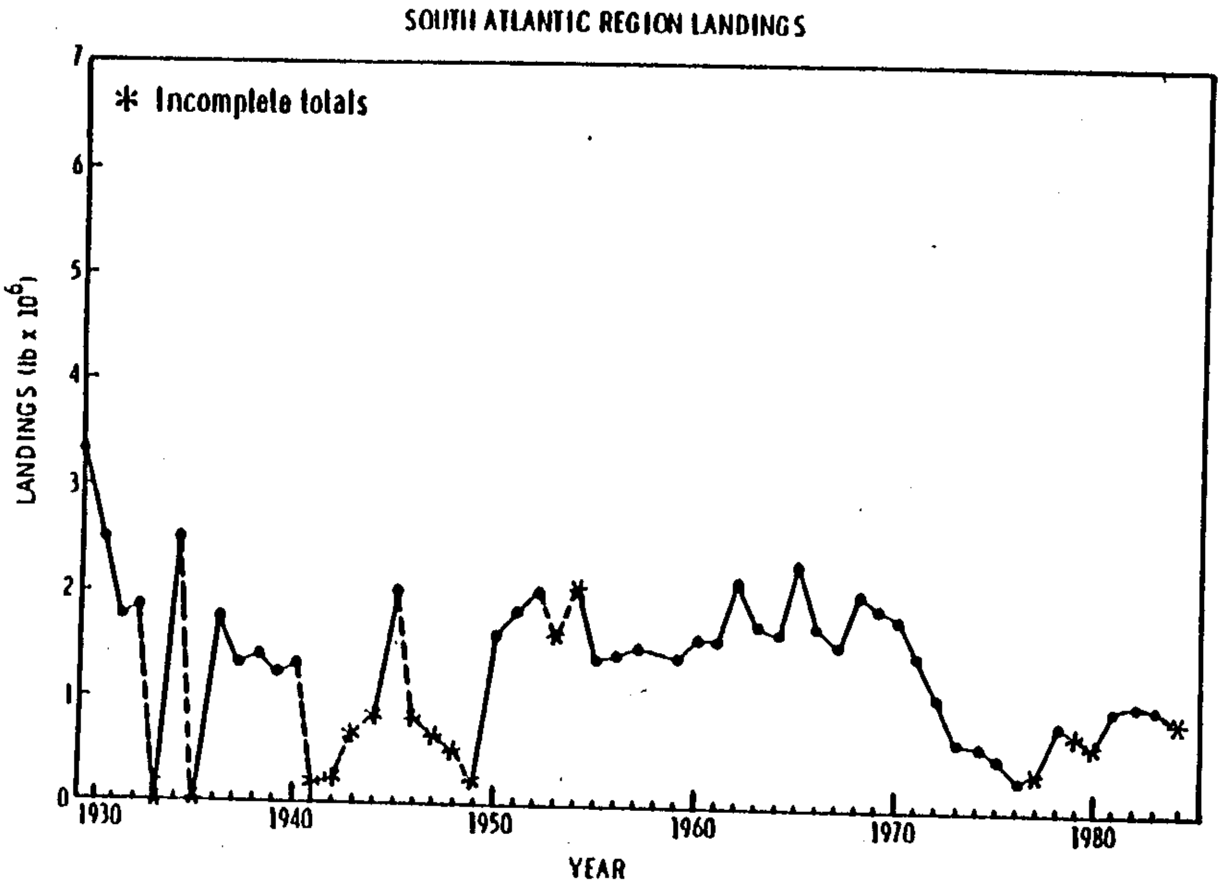


Figure II-6. Reported commercial landings of American shad in the South Atlantic Region, 1930 to 1984; sources of data are listed in Table II-2

Overall, the steep decline in total east coast landings that began in the 1970's (Fig. II-1) is primarily a function of the declines in landings in the Chesapeake and South Atlantic regions. These two regions have in the past contributed the majority of total east coast landings and thus have a disproportionate impact on total landings. The fisheries in different regions differ to a considerable degree, and the quality and quantity of data available differ in similar manners. A more detailed interpretation of the patterns of regional landings just discussed require examination of these fisheries by state and by river system within the state, where appropriate.

D. RECENT TRENDS IN AMERICAN SHAD FISHERIES - STATE-BY-STATE BASIS

Characterization of State Fisheries

Shad fisheries in the New England states of Rhode Island, Massachusetts, New Hampshire, and Maine are primarily undirected. While restoration efforts on a number of New England drainage systems presently are underway, none of these drainages currently supports an active commerical shad fishery. Commercial landings of American shad reported for these states represent fish taken as by-catch in coastal fisheries. Since these are fisheries directed at other species, and because the catch values are relatively small, New England catch data contribute little to an understanding of trends in stocks in this region.

In the state of Connecticut, the Connecticut River fishery comprises nearly all shad landings in the state. As noted in the regional characterizations above, landings have remained relatively stable over the past 20 years. Fishing effort has also remained relatively stable over the same period (V. Crecco, pers. comm.). On the Connecticut River, however, a major restoration program has been under way for a substantial period of time. The major activity in this restoration program has occurred at the Holyoke Dam, and began with the construction of the fish lift at that dam in 1955. This restoration program is discussed in more detail later in this report.

In the mid-Atlantic area, the Hudson and Delaware Rivers have generated nearly all recent shad landings. The Hudson River is the source of nearly all landings in New York state, and contributes a limited amount to landings reported for New Jersey. Klauda et al. (1976) described the declining trend in Hudson River American shad fisheries from the 1940's to 1975. However, landings since the early 1960's have remained relatively stable, though those in the 1970's may have been influenced by a decrease in fishing effort which accompanied publicized concerns about PCB pollution in the Hudson River drainage. PCB concerns may also have influenced marketability. Despite the absence of stock abundance information, the Hudson River stock appears to be relatively healthy, possibly having increased in recent years (Brandt, 1983).

In New Jersey and Delaware, the Delaware River supports the entire commercial fishery. This fishery is located primarily in the tidal waters of the Delaware Bay. As will be discussed later in the report, there is evidence to suggest that the shad fishery at Delaware Bay also takes fish from other river systems. Studies of the Delaware River American shad stock have shown that the stock has increased in size dramatically in recent years, from between 100,000 - 200,000 in the 1970's, to over 500,000 in 1981 (Lupine, 1982). The enhancement of the Delaware River American shad stock is due to the reduction of the duration of the pollution block that has occurred historically in the lower portion of the Delaware River in the Camden-Philadelphia area. In the past, this pollution block has created low dissolved oxygen conditions (<3ppm), which have caused either massive fish kills or prevented fish from moving through the area on their upstream or downstream migrations.

In Maryland waters, which constitute the upper Chesapeake Bay drainage, American shad runs in all major rivers have declined drastically in recent years. These rivers include the Susquehanna, Potomac, and the Nanticoke. These rivers differ considerably in the nature of their drainage systems, both geologically, as well as in terms of pattern and type of human development. The shad runs in all of the drainage systems declined in a pattern consistent with each other beginning in about 1972 (although the decline appeared to begin somewhat earlier in the Nanticoke River)(Carter and Weinrich, 1982). No specific cause for these abrupt declines has been established. All shad fisheries in the state were closed in 1980 and remain closed.

In the state of Virginia, tributaries of the Chesapeake Bay along the western shore support the major American shad runs. Commercial landings in Virginia show a general recent decline (e.g., Kriete and Loesch, 1976), but the characterization of changes in stock sizes based on these data may be compromised to some degree by unknown changes in effort (Atran, Loesch, and Kriete, 1982). Changes in effort, however, are not of sufficient magnitude to serve as the explanation for the precipitous decline in landings over the past decade. The subjective view of researchers in the state of Virginia is that Virginia American shad stocks are now relatively stable at a very low level relative to levels existing in earlier years.

In North Carolina, American shad runs occur in all major coastal drainage systems. A decline in annual landings of about 75% has occurred in the last decade; the causes for this decline are unexplained (Sholar, 1976; Johnson, 1982). The percentage decline in North Carolina landings has been more dramatic than that in Virginia or South Carolina, but has not resulted in stocks reaching the low levels observed in Maryland.

Landings in South Carolina declined to an all-time low in the mid 1970's. However, Crochet et al. (1976) did not observe a significant decline in experimental catch per unit effort of shad between 1974 and 1976. Recent increases of landings (400,000 pounds in 1982) are largely attributable to an increase in the ocean fishery, which currently contributes as much as 75% of total landings. There are indications that this fishery may be exploiting American shad stocks not resident to South Carolina (Ulrich, 1982). Thus, South Carolina shad stocks actually could have declined to the extent observed in other South Atlantic states, without the fisheries landings data showing evidence of the decline.

The shad fishery in Georgia is supported by several river systems. Landings have fluctuated widely over the last decade, but currently tend to be about 50% of the level of landings recorded in the late 1960's and early 1970's. Catch rates in terms of catch per unit effort declined strikingly in the early 1970's (Michaels, 1982). Georgia stocks appear to be relatively stable at low levels, similar to the case in Virginia and South Carolina.

Florida currently supports a very limited shad fishery, possibly because of low stock levels (R. Williams, pers. comm.). Because of the lack of fishing effort, catch data are insufficient to document current status of the stock. Local fisheries personnel believe that Florida stocks may be in a condition similar to that for the majority of the other South Atlantic states - stable at very low levels.

As a general overview of these individual state characterizations, landings data provide evidence to suggest that there has been a broad regional decline in American shad stocks south of the Delaware River, with the greatest declines appearing in the early 1970's. The disparate nature of the rivers supporting runs that have evidenced declines provides no clue as to a potential explanation for the declines. No systematic declines, and in fact some increases, have been observed in shad stocks of the Delaware, Hudson, and Connecticut Rivers. The health of runs in these three major river systems is suggested by all existing information.

The descriptive and relatively subjective characterizations just presented cannot be confirmed on a rigorous analytical basis because of the lack of the adequate population abundance data, the poor quality of most of the landings data, and the quantitiatively undefined market influence on fishing effort. Thus, there are insufficient data available currently to investigate potential hypotheses posed as explanations of the causes of stock declines.

Trends in Gear Usage

Detailed quantitative data on fishing effort directed at American shad are not available. Those "effort" data available, such as are presented in NOAA Fishery Statistics of the United States publications, are generally compilations of information on licensed fishermen or licensed gear. They do not represent the amount and frequency of fishing by the licensees, and thus are not true measures of fishing effort.

Characterizations of the distribution of catch by gear type do, however, provide some indication of how shad fisheries have changed over periods of years. Data on commercial landings as well as gear types used in commercial fisheries compiled in NOAA Fishery Statistics of the United States can be used to characterize trends in gear usage. These records were examined to establish landings of American shad by gear type for each of the states of the east coast (in Delaware, there is no licensing of gear; thus, effort data for that state since 1979 are estimates provided to NOAA by Delaware Division of Fish and Wildlife; R. Miller, pers. comm.).

Walburg and Nichols (1967) provided comparable information for the period prior to 1960. Thus, as a starting point for comparison here, data from Walburg and Nichols are presented in Table II-3. In 1960, various types of gill nets accounted for 63% of the total catch of American shad, with pound nets accounting for 16%. A number of other gear types accounted for the remaining 21% of total landings. In 1965 (Table II-4), gill nets accounted for 66% of landings, pound nets for 26.8%, and other gears for less than 10%. Gill nets continued to account for 66% of landings in 1970 (Table II-5), pound nets for 26.5%, and other gears for the remaining percentage. By 1976 (Table II-6) (the most current data available), gill nets accounted for 80% of total landings, pound nets for 19%, and other gears for approximately 1%.

The trend evident in these data is that gill nets have accounted for an increasingly large percentage of the total harvest of American shad, with gears other than pound nets being used much less frequently. Thus, gill nets have gradually become the gear of preference along the entire east coast, probably because of their ease of use, mobility and catch efficiency. In Virginia, pound net harvest drops to zero when shad stocks are low (J. Loesch, pers. comm.).

Current Status of Fisheries

The current status of state fisheries is summarized in Table II-7. The intent of this table is to provide a generalized characterization of the types and locations of current

Table II-3. American shad catch by state and gear (rounded to lbs x 10^3), Atlantic coast of the United States, 1960 (from Walburg and Nichols, 1967); dashed lines denote no catch reported.

State	Drift gill net	Stake and anchor gill net	Seine	Pound Net	Pyke net	Bow Net	Rod and Reel	Miscel-laneous	Total
Maine	(1)	—	—	—	—	—	—	—	(1)
New Hampshire	—	—	—	—	—	—	—	—	0
Massachusetts	—	8	—	20	—	—	—	631	658
Rhode Island	—	—	—	—	—	—	—	3	3
Connecticut	416	—	4	—	—	—	77	(1)	498
New York	143	127	3	144	—	—	—	—	417
New Jersey	8	567	1	116	—	—	—	1	694
Delaware	2	40	—	—	—	—	—	—	42
Maryland	323	678	10	325	—	—	13	60	1,409
Virginia	308	467	—	598	13	—	—	—	1,386
North Carolina	410	430	36	127	(1)	255	(1)	7	1,266
South Carolina	99	146	(1)	—	—	26	5	6	283
Georgia	513	223	—	—	—	24	8	—	768
Florida	50	163	299	—	—	—	198	—	709
TOTAL	2,274	2,848	354	1,330	13	304	302	709	8,134
% of Total	62.9%		4.4%	16.3%	<1%	3.7%	3.7%	8.7%	

(1) = less than 1,000 lbs.

Table II-4. American shad catch distribution by gear type (rounded to lbs x 10^3), 1965; dashed lines denote no catch reported (from NOAA Fishery Statistics of the United States).

Gear / State	Drift Gill Net	Anchor, set or stake gill net	Haul Seine	Pound Net	Fyke and Hoop Net	Floating Traps	Otter Trawl	Other
Maine	---	---	---	---	---	---	---	---
New Hampshire	---	---	---	---	---	---	---	---
Massachusetts	---	---	---	---	---	---	(1)	---
Rhode Island	---	---	---	---	---	3	1	---
Connecticut	345	5	3	---	---	---	---	---
New York	58	63	2	10	---	---	1	---
New Jersey	51	284	17	25	---	---	11	---
Delaware	9	101	---	---	---	---	---	---
Maryland	282	996	(1)	65	---	---	5	---
Virginia	430	766	28	1625	106	---	---	---
North Carolina	52	620	64	332	---	---	---	---
South Carolina	141	35	---	---	---	---	---	---
Georgia	376	---	---	---	---	---	---	---
Florida	239	202	316	---	---	---	---	---
Total	1,984	3,071	429,200	2,053	106	3	15	4,900
Percent of Total	25.9%	40.0%	5.6%	26.8%	1.4%	<1.0%	<1.0%	<1.0%

(1) = less than 1,000 lbs.

Table II-5. American shad catch distribution by gear type (rounded to lbs x 10^3), 1970; dashed lines denote no catch reported (from NOAA Fishery Statistics of the United States).

Gear / State	Shad Drift Gill Net	Anchor, set or stake gill net	Haul Seine	Pound Net	Fyke and Hoop Net	Floating Traps	Otter Trawl	Other
Maine	---	---	---	---	---	---	---	---
New Hampshire	---	---	---	---	---	---	---	---
Massachusetts	---	---	---	(1)	---	---	(1)	---
Rhode Island	---	---	---	---	---	2	10	---
Connecticut	171	2	---	---	---	---	---	---
New York	47	49	(1)	9	---	---	---	---
New Jersey	8	144	3	19	---	---	21	---
Delaware	---	13	---	---	---	---	---	---
Maryland	168	818	(1)	52	---	---	(1)	(1)
Virginia	851	1399	150	1404	308	---	---	---
North Carolina	47	404	---	502	(1)	---	---	---
South Carolina	83	65	---	---	---	---	---	---
Georgia	532	---	---	---	---	---	---	---
Florida	27	65	127	---	---	---	---	---
Total	1,932	29,600	280	1,988	308	2	32	(1)
Percent of Total	25.8%	39.5%	3.7%	26.5%	4.1%	<1.0%	<1.0%	<1.0%

(1) = less than 1,000 lbs

Table II-6. American shad of catch distribution by gear type (rounded to lbs x 10^3), 1976; dashed lines denote no catch reported (from NOAA Fishery Statistics of the United States).

Gear / State	Drift Gill Net	Anchor, set or stake gill net	Haul Seine	Pound Net	Fyke and Hoop Net	Floating Traps	Otter Trawl	Other
Maine	---	14	---	---	---	---	(1)	---
New Hampshire	---	1	---	---	---	---	---	---
Massachusetts	---	---	---	---	---	---	---	---
Rhode Island	---	---	---	---	---	3	---	---
Connecticut	40	---	---	---	---	---	---	---
New York	12	173	(1)	---	---	---	1	---
New Jersey	22	69	(1)	5	---	---	1	1
Delaware	2	33	---	---	---	---	---	---
Maryland	67	99	---	4	(1)	---	---	---
Virginia	78	546	1	271	---	---	---	---
North Carolina	7	109	6	44	---	---	---	---
South Carolina	9	23	---	---	---	---	---	---
Georgia	16	77	---	---	---	---	---	---
Florida	5	23	---	---	---	---	---	---
Total	193	1167	8	325	(1)	3	2	1
Percent of Total	11.3%	68.5%	<1.0%	19.0%	<1.0%	<1.0%	<1.0%	<1.0%

(1) = less than 1,000 lbs

Table II-7. Characterization of current (1980's) American shad fisheries, by state, developed from material provided by state fisheries agencies in overview documents; quantitative data on recreational fisheries was generally unavailable.

State	Gear type	Type of water fished	Percent of total harvest	Information Source
Rhode Island Massachusetts New Hampshire Maine	multiple gears (by-catch fishery)	coastal waters	100%	Maine Dept. of Marine Resources (1982) New Hampshire Fish and Game Dept. (1982) Massachusetts Div. of Marine Fisheries (1982) Rhode Island Div. of Fish and Wildlife (1982)
Connecticut	drift gill nets	within river (Connecticut River)	100%	Connecticut Dept. of Environmental Protection, Marine Fisheries Office (1982)
	recreational	within rivers	14% (of escapement)	
New York	stake gill nets	lower Hudson River (below RM 45)	100% combined	New York State Dept. of Environmental Conservation (1982)
	drift gill nets	upper Hudson River		
New Jersey	staked, anchored and drift gill nets	coastal waters (Delaware Bay, Raritan and Sandy Hook Bays, lower Hudson River, and coastal areas)	80%	New Jersey Div. of Fish, Game, and Wildlife (1982)
	pound nets	coastal waters	20%	
	recreational	within rivers (Delaware)	10.7% of run	

Table II-7. Continued

State	Gear type	Type of water fished	Percent of total harvest	Information Source
Delaware	anchored and drift gill nets	coastal waters	97%	Delaware Div. of Fish and Wildlife (1982)
	drift gill nets	within rivers (Nanticoke River)	3%	
Maryland	stake and drift gill nets	all waters	100% (when fishery is open)	MD. Dept. of Natural Resources (1982)
Virginia	pound nets	Chesapeake Bay and tributaries	1-4%	Atran, Loesch and Kriete, 1982
	stake and drift gill nets	within rivers	96-99%	
North Carolina	pound nets	coastal waters (Albemarle Sound)	66%	N.C. Dept. of Natural Resources (1982)
	drift gill nets	riverine	10%	
	anchor gill nets	coastal and riverine	20%	
	beach seine	Atlantic Ocean	4%	
South Carolina	drift and set gill nets	inland waters	25%	S.C. Dept. of Wildlife and Marine Resources (1982)
	set gill nets	lower rivers and coastal waters	75%	
	recreational	inland waters	not known	

Table II-7. Continued

State	Gear type	Type of water fished	Percent of total harvest	Information Source
Georgia	drift and set gill nets	inland waters	45% (in Altamaha River)	GA. Dept. of Natural Resources (1982)
	drift and set gill nets	coastal waters	55% (in Altamaha River)	
	recreational		5%	
Florida	anchored gill nets	lower St. Johns River	100%	R. Williams, personal communication
	recreational	Monroe and Harney lakes	8-44% of commercial	Williams and Bruger, 1972

shad fisheries in the individual states and the gear types used. States in which substantial coastal fisheries occur are of particular interest with the prime example being South Carolina. Coastal fisheries and fisheries such as those occurring in the Delaware Bay, have a high probability of harvesting of non-resident stocks.

Recreational fisheries are mentioned on Table II-7, despite the fact that they are poorly documented in most states. Comparisons of recreational harvest to commercial harvest in terms of percentage of total harvest, do not, of course, take into account the relative economic contribution of the respective fisheries. It is well documented that recreational fisheries contribute substantially to the economies of the regions in which shad runs occur (e.g., 1980 National Survey of Fishing, Hunting and Wildlife Associated Recreation, 1982). The magnitudes of recreational harvest in two states, however, are probably suggestive of the impact of fairly intensive recreational fisheries on shad stocks. The two fisheries of interest are those occurring in the Delaware River (New Jersey, New York and Pennsylvania) and in the Connecticut River. As indicated in Table II-7, recreational harvest in the Delaware River accounts for approximately 11% of the run, while the recreational fishery in the Connecticut River takes approximately 14% of the fish escaping the commercial fishery in the lower portion of the river.

Market Factors Influencing Shad Commerical Fisheries

As noted by Mansuetti and Kolb (1953), American shad has historically been considered a highly valuable food fish, particularly in the late 1800's and early 1900's. However, changes in dockside value of commercially harvested American shad over recent decades (i.e. approximately a doubling in value over 30 years, Table II-8), suggest that demand for American shad has declined substantially. The increase in value of shad of about 2 percent per year has been much less than that which would have been anticipated based on the rate of inflation. Many factors may contribute to the relatively low current value of shad, but the major significance of this fact is that the relatively low prices may result in a low commercial effort. As noted previously, fluctuations in effort can influence landings totals, and thus compromise the value of landings data as an indicator of stock abundance.

The relatively low dollar value of American shad may also have significance in terms of the tractability of management of the species. In drainage systems having very traditional fisheries (e.g., the Connecticut River), fishing effort may be relatively insensitive to market fluctuations and value. That is,

Table II-8. Annual average dockside value of American shad (dollars/lb) (From Fishery Statistics of the United States, 1950-1980); dashed lines denote no catch reported.

Year	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	SC	GA	FL
1950	0.03	---	0.06	0.04	0.18	0.17	0.21	---	0.22	0.16	0.16	0.03	0.31	0.31	0.61
1951	0.42	---	0.56	0.03	0.18	0.15	0.23	---	0.22	0.17	0.18	0.24	0.45	0.35	0.16
1952	0.06	---	0.06	0.04	0.14	0.14	0.21	---	0.26	0.14	0.15	0.26	0.30	0.34	0.17
1953	0.04	---	0.02	0.04	0.02	0.14	0.19	---	0.28	0.15	0.17	0.25	0.29	0.36	0.20
1954	0.06	---	0.02	0.06	0.15	0.12	0.15	---	0.13	0.12	0.18	0.18	0.33	0.35	0.15
1955	0.05	---	0.03	0.14	0.14	0.13	0.15	---	0.22	0.14	0.17	0.25	0.31	0.30	0.12
1956	0.06	---	0.01	---	0.14	0.09	0.11	---	0.33	0.12	0.14	0.25	0.35	0.30	0.12
1957	0.06	---	0.01	0.05	0.14	0.10	0.11	---	0.25	0.13	0.17	0.25	0.31	0.30	0.13
1958	0.05	---	0.02	0.03	0.13	0.12	0.45	---	0.10	0.16	0.18	0.25	0.32	0.30	0.11
1959	0.06	---	0.02	0.07	0.13	0.12	0.12	---	0.14	0.12	0.17	0.25	0.32	0.31	0.12
1960	0.07	---	0.17	0.07	0.17	0.16	0.16	---	0.16	0.16	0.17	0.25	0.32	0.33	0.13
1961	---	---	0.01	0.06	0.17	0.15	0.17	---	0.14	0.16	0.17	0.25	0.32	0.23	0.16
1962	0.93	---	0.14	0.14	0.18	0.14	0.15	---	0.13	0.13	0.14	0.25	0.28	0.25	0.10
1963	---	---	0.04	0.06	0.21	0.19	0.20	---	0.13	0.16	0.15	0.24	0.28	0.27	0.11
1964	---	---	0.08	0.05	0.21	0.16	0.13	---	0.13	0.13	0.12	0.20	0.23	0.32	0.10
1965	---	---	0.08	0.10	0.21	0.16	0.10	---	0.15	0.11	0.10	0.20	0.35	0.38	0.11
1966	0.04	---	0.08	0.09	0.21	0.17	0.09	---	0.16	0.12	0.09	0.24	0.28	0.26	---
1967	0.09	---	0.01	0.07	0.19	0.16	0.13	---	0.19	0.15	0.08	---	---	---	0.16
1968	0.02	---	0.09	0.05	0.29	0.18	0.14	---	0.17	0.1	0.06	0.15	0.19	0.24	0.18
1969	---	---	0.08	0.06	0.31	0.15	0.12	---	0.11	0.10	0.07	0.19	0.33	0.30	0.16
1970	---	---	0.09	0.04	0.32	0.12	0.14	---	0.08	0.10	0.08	0.20	0.26	0.26	0.20
1971	---	---	---	0.02	0.28	0.22	0.16	---	0.62	0.13	0.09	0.17	0.40	0.32	0.20
1972	---	---	0.15	0.07	0.30	0.18	0.13	---	0.11	0.12	0.11	0.23	0.28	0.33	0.22
1973	---	---	0.14	0.05	0.28	0.32	0.19	---	0.12	0.18	0.15	0.26	0.46	0.38	0.27
1974	0.14	---	0.10	0.14	0.32	0.27	0.21	---	0.12	0.21	0.15	0.33	0.50	0.39	0.22
1975	0.11	0.10	0.10	0.17	0.35	0.40	0.24	---	0.21	0.24	0.27	0.34	0.60	0.54	0.26
1976	0.07	0.09	---	0.33	0.42	0.32	0.23	---	0.22	0.38	0.32	0.39	0.62	0.61	---
1977							0.27	---	0.21			0.46	0.68	0.71	
1978							0.28		0.28			0.36	0.69	0.66	
1979							0.18		0.16			0.44	0.79		
1980							0.19		0.33			0.44	0.79		
1981							0.25		0.46						
1982							0.30		0.39						
1983							0.33								

fishermen may continue fishing even though economically the return for their investment of time may be limited. In contrast, opportunistic fisheries, such as may occur in waters in the southern states (i.e., South Carolina), may be strongly influenced by market prices. This may be particularly true in the case of fisheries dominated by part-time fishermen interested in obtaining substantial returns for their investment of time.

American shad fisheries may also be substantially influenced by regionally varying, seasonal changes in market value. In order to determine if such a phenomenon occurs, dockside value by month and state for two recent years (1978 and 1979) was compiled from NOAA records (Tables II-9 and II-10). Tables II-11 and II-12 show the monthly shad catch for each state in 1978 and 1979. Value must be placed in perspective to the amount of harvest for the given month. As is evidenced by the data presented in these tables, the value of early southern harvests of shad was consistently higher than the value of shad landed in more northern fisheries. These data support the view that early southern shad are by far the most valuable of all shad landed along the east coast. For example, Table II-10 clearly shows high values for South Carolina and Georgia shad during the period January to March. The high value of these early harvests is due to the market demand existing in the northern states prior to the initiation of the northern runs. These southern fisheries generate fish that are exported to more northern states such as New York (Walburg and Nichols, 1967; Brandt, 1982).

Another aspect of the seasonal nature of the shad fishery is that price fluctuations toward the end of the season due to the lack of market demand may result in curtailment of fishing effort even during periods when harvests and harvest rate could be potentially quite high. Brandt (1983) suggests that the Hudson River fishery, for example, is strongly market limited. He notes that stake and anchor gill net fishermen are highly dependent on purchase of their catch by the Fulton Fish Market. When prices offered by the market drop substantially in the later part of the run, fishermen frequently pull their nets before the run is over. The decline in price may be totally independent of the abundance of the fish. That is, it appears to be a purely seasonal reaction of the market, independent of high or low level of supply. Brandt has also noted that the drift net fishery in the Hudson is one in which effort is frequently a function of immediate demand. That is, a fishermen knowing that he has a specific order for a certain amount of shad will apply the effort necessary to satisfy that specific order.

These market data have a number of implications for the management of commercial American shad fisheries. The relatively low commercial value of shad in the northern areas suggests that an expansion of the shad fisheries in those regions is unlikely. However, this neglects the possibility of new markets

Table II-9. Monthly dockside price per pound for American shad, by state, in 1978; dashed lines denote no catch reported. Blanks denote no data acquired; "shad" represents landings not identified as buck or roe (from NOAA Fishery Statistics of the United States).

State	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Maine	0.10	0.10	0.11	0.1	0.11	0.08	0.09	0.08	0.09	0.05	0.07	0.07
New Hampshire												
Massachusetts	---	---	---	---	---	0.11	---	---	---	---	---	---
Rhode Island	---	---	---	0.26	0.25	---	---	---	0.26	0.25	0.25	---
Connecticut												
New York	---	---	---	0.25	0.21	0.34	0.34	---	---	---	0.10	---
New Jersey	0.25	0.24	0.18	Buck = 0.07 Shad = 0.22	Buck = 0.34 Shad = 0.54	0.66	---	---	---	---	0.17	Buck = 0.31 Shad = 0.31
Delaware												
Maryland	---	---	0.33	0.25	0.28	0.25	---	---	---	---	---	---
Virginia	---	---	0.26	0.12	0.19	0.08	0.25	---	---	---	0.08	0.17
North Carolina	0.45	0.60	0.41	0.27	0.11	0.08	---	---	---	---	0.25	0.25
South Carolina	---	Buck = 0.60 Roe = 0.90 Shad = 0.80	Buck= 0.50 Roe = 0.80 Shad= 0.74	Buck = 0.35 Roe = 0.55 Shad = 0.51	---	---	---	---	---	---	---	---
Georgia	0.62	0.67	0.66	0.35	---	---	---	---	---	---	---	---
Florida												

Table II-10. Monthly dockside price per pound for American shad, by state, in 1979; dashed lines denote no catch reported. Blanks denote no data acquired; "shad" represents landings not identified as buck or roe (from NOAA Fishery Statistics of the United States).

State	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Maine	0.14	0.10	---	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.11
New Hampshire												
Massachusetts	---	---	---	0.07	---	---	---	---	---	0.11	---	---
Rhode Island	---	---	---	0.30	0.15	0.25	---	---	---	---	---	---
Connecticut												
New York	---	---	---	0.40	0.45	0.14	0.18	0.18	---	---	0.22	0.18
New Jersey	0.22	0.32	0.23	0.18	0.18	0.13	0.18	---	---	0.20	0.20	0.22
Delaware												
Maryland	---	---	0.17	0.24	0.34	0.39	---	---	---	---	---	---
Virginia	0.54	0.31	0.25	0.21	0.22	0.12	---	--	0.11	---	0.20	0.22
North Carolina	0.54	0.68	0.43	0.41	0.15	0.16	---	---	---	---	---	0.47
South Carolina	Buck= 0.39 Roe = 0.67	Buck= 0.65 Roe = 0.96 Shad = 0.73	Buck= 0.42 Roe = 0.80	Buck = 0.33 Roe = 0.62	---	---	---	---	---	---	---	---
Georgia	0.91	0.93	0.79	0.48	---	---	---	---	---	---	---	---
Florida												

Table II-11. Monthly American shad catch (lbs) by state - 1978. Dashed lines denote no catch reported, blanks denote no data acquired; "shad" represents landings not identified as buck or roe (from NOAA Fishery Statistics of the United States.

State	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Maine	684	100	45	566	2076	2176	1081	471	275	3135	7215	6687
New Hampshire												
Massachusetts	---	---	---	---	---	76	---	---	---	---	---	---
Rhode Island	---	---	---	133	177	---	---	---	55	620	250	---
Connecticut												
New York	---	---	---	306543	73	1332	198	---	---	---	99	---
New Jersey	183	25	8513	Buck = 4850 Shad = 162697	Buck= 48844 Shad= 8459	Buck= 4697 Shad= 3457	Buck= 74 Shad= 6	---	---	---	Shad= 12	Buck= 95 Shad= 100
Delaware												
Maryland	---	---	5669	38174	19640	820	---	---	---	---	---	---
Virginia	---	---	430708	758068	40340	5066	4	---	---	---	155	700
North Carolina	413	2076	266437	119820	12669	254	---	---	---	---	105	243
South Carolina	---	Buck= 9671 Roe= 34986 Shad= 11455	Buck= 15524 Roe= 44574 Shad= 131534	Buck= 3460 Roe= 10209 Shad= 63302	---	---	---	---	---	---	---	---
Georgia	12032	46449	172860	6601	---	---	---	---	---	---	---	---
Florida	91591	24804	---	---	---	---	---	1054	---	---	---	13593

Table II-12. Monthly American shad catch (lbs) by state - 1979. Dashed lines denote no catch reported; blanks denote no data acquired; "shad" represents landings not identified as buck or roe (from NOAA Fishery Statistics of the United States).

State	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Maine	1470	755	---	2395	2332	780	335	325	970	932	3281	4914
New Hampshire												
Massachusetts	---	---	---	2600	---	---	---	---	---	105	---	---
Rhode Island	---	---	---	340	396	670	---	---	---	---	---	---
Connecticut												
New York	---	---	---	330	288	1321	509	4900	---	---	74	640
New Jersey	Buck= 33 Shad= 6310	40	Buck= 11 Shad= 7240	109058	16874	1341	22	---	---	25	50	7704
Delaware												
Maryland	3	---	8988	31988	5962	47	---	---	---	---	---	---
Virginia	922	88	573789	390067	23607	1434	---	---	4000	---	59	129
North Carolina	2136	19744	198965	51238	4887	454	---	---	---	---	---	646
South Carolina	Buck= 361 Roe= 384	Buck= 11165 Roe= 67354 Shad= 55	Buck= 13060 Roe= 82267	Buck= 2489 Roe= 20061	---	---	---	---	---	---	---	---
Georgia	20489	105428	135447	6514	---	---	---	---	---	---	---	---
Florida												

for American shad coming into existence (e.g., use as pet food). In contrast, the relatively high price for early southern harvests of American shad suggests that the expansion of that fishery could occur. Recent increases in the South Carolina coastal harvests are an indicator of this type of a trend. Increases in these fisheries could also occur as a result of the creation of local early-season markets for the harvests.

If, in fact, the American shad fishery along the east coast of the United States is more in the nature of a traditional fishery than opportunistic fishery for most of the major runs, commercial effort may be relatively unresponsive to changes in stock abundance and price. This would suggest that implementation of any type of radical changes in the commercial fisheries may be resisted by the fishermen. State fisheries personnel have suggested that shad harvests tend to decline whenever a fishery for a more desirable, more valuable species is developed, as is the case with other relatively low value species.

Alternatives to the Use of Commercial Landings Data to Establish Trends in Stock Abundance

As was noted above, commercial landings data represent the primary source of long-term information on stock abundance for American shad. However in a limited number of locations, an alternative indicator of stock abundance is available: an index of juvenile abundance. The advantages of using data of this sort is that they are not influenced by annual changes in effort, inaccurate catch report, market factors, etc. There are, of course, numerous disadvantages to the use of the juvenile abundance index. The primary difficulty with the use of the indices developed for different drainage systems is that standardization of survey designs is unlikely. A standardized design would have to take into account the location of nursery areas and the shift in those areas within drainage system between seasons and in response to numerous environmental variables such as rainfall and temperature. Sampling design would also have to be of sufficient intensity in both time and space to provide a precise and accurate index. Additionally, a sufficient time record of juvenile abundance is needed to verify through correlation with subsequent estimates of adult stock size that the index is an accurate indicator of abundance.

The verification of an index's validity is an extremely difficult procedure, and as a consequence, has only been established in one river system, the Connecticut River. Table II-13 summarizes all of the juvenile index data available for river systems along the east coast. The data set collected in the Connecticut River is the only set satisfying the needs discussed above. Longterm data sets (i.e., greater than 4 years) are also available for rivers in Maryland, Virginia, New Jersey, and New York (for the Hudson River). Less extensive juvenile

Table II-13. Summary of "long-term" (>4 years) juvenile shad survey data currently available on a state-by-state basis

State	Time Period	Drainage System(s)	Comments	Data Sources
Connecticut	1966 to 1972; 1978 to present	Connecticut River	Survey designed to sample American shad; sampling locations and methods consistent; index of juvenile abundance was developed	Connecticut River Shad Study Reports, Connecticut Dept. of Marine Fisheries Office
New York	1973 to 1983	Hudson River	Survey directed primarily at striped bass; sampling locations and methods consistent; no integrated annual index has been developed	Yearclass reports for the multiplant impact study, Hudson River Estuary, Texas Instruments Inc. for Consolidated Edison Company of New York (1974 to 1983)
New Jersey Pennsylvania Delaware New York	1971 to 1975 1979 to present	Delaware River	Survey directed at American shad; sampling locations and methods changed between survey periods; index of juvenile abundance was developed	Delaware River Basin Fish and Wildlife Cooperative (1982) NJ Div. Fish Game and Wildlife (1983)
Maryland	1962 to present	Upper Chesapeake Bay Nanticoke River Choptank River Potomac River	Survey directed primarily at striped bass; sampling locations and methods consistent; all samples averaged for annual index	Maryland Dept. of Natural Resources (1982)
Virginia	1969 to 1975; 1976 to present	James River York River Rappahannock River Potomac River	Survey designs differed before 1975 and after 1976; locations and methods changed; different methods of developing index used.	Virginia Institute of Marine Science (1982)
North Carolina	1971 to present	Albemarle Sound	Consistent sampling design; no integrated index developed	North Carolina Dept. of Natural Resources (1982)

index data are also available for other states, particularly North Carolina.

Figure II-7 illustrates the relative magnitude of juvenile index values from several different drainages in different states. The intent of plotting these index values is to examine if any pattern amongst year-class success (as characterized by juvenile abundance) appears among the regional drainage systems. It is difficult to discern any comparable patterns among river systems from the data presented in that figure. This is primarily due to the lack of synoptic, credible data of sufficient time length. One subjective observation which can be made from the data presented in Figure II-6 is that both the Connecticut and Delaware rivers appear to have had exceptionally good year-classes in 1971.

The basic conclusion from examination of the available juvenile index data is that they are insufficient to rigorously (analytically) contrast trends among populations in the different drainage systems.

E. COASTAL MIGRATION PATTERNS

A knowledge of the coastal migration patterns of the American shad is important in examining various hypotheses proposed to explain the fluctuations in population abundance of East coast shad stocks. Such knowledge permits assessment of factors that may influence shad mortality rates during the portion of their life cycle that they spend at sea. An understanding of coastal migration patterns is also important in deliniating geographical areas in which potential interjurisdictional management problems may occur (that is, identifying locations where non-resident shad stocks are being fished in local fisheries, such as coastal South Carolina).

Coastal migrations must be examined in the context of the general life history pattern of the American shad, which was presented diagramatically in Fig. I-2. American shad are an anadromous species, spawning in freshwater rivers along the east coast in early spring. Juveniles resulting from the spring spawning emigrate from the freshwater nursery areas to the ocean in the fall. The immature shad remain in the ocean in general from 3 to 6 years. Evidence for homing in the American shad is very strong. Older studies supporting homing are summarized by Walburg and Nichols (1967). Of fish tagged in the Connecticut River in recent years, 97% of those recaptured were recaptured in the Connecticut (Crecco, pers. comm.). However, there is evidence of substantial straying of American shad, with the best example being the case of shad stocks on the west coast of the United States. The former U.S. Fish Commission (now NMFS) reported that shad fry were stocked in the Sacramento River system from 1871 through 1880 and subsequently spread

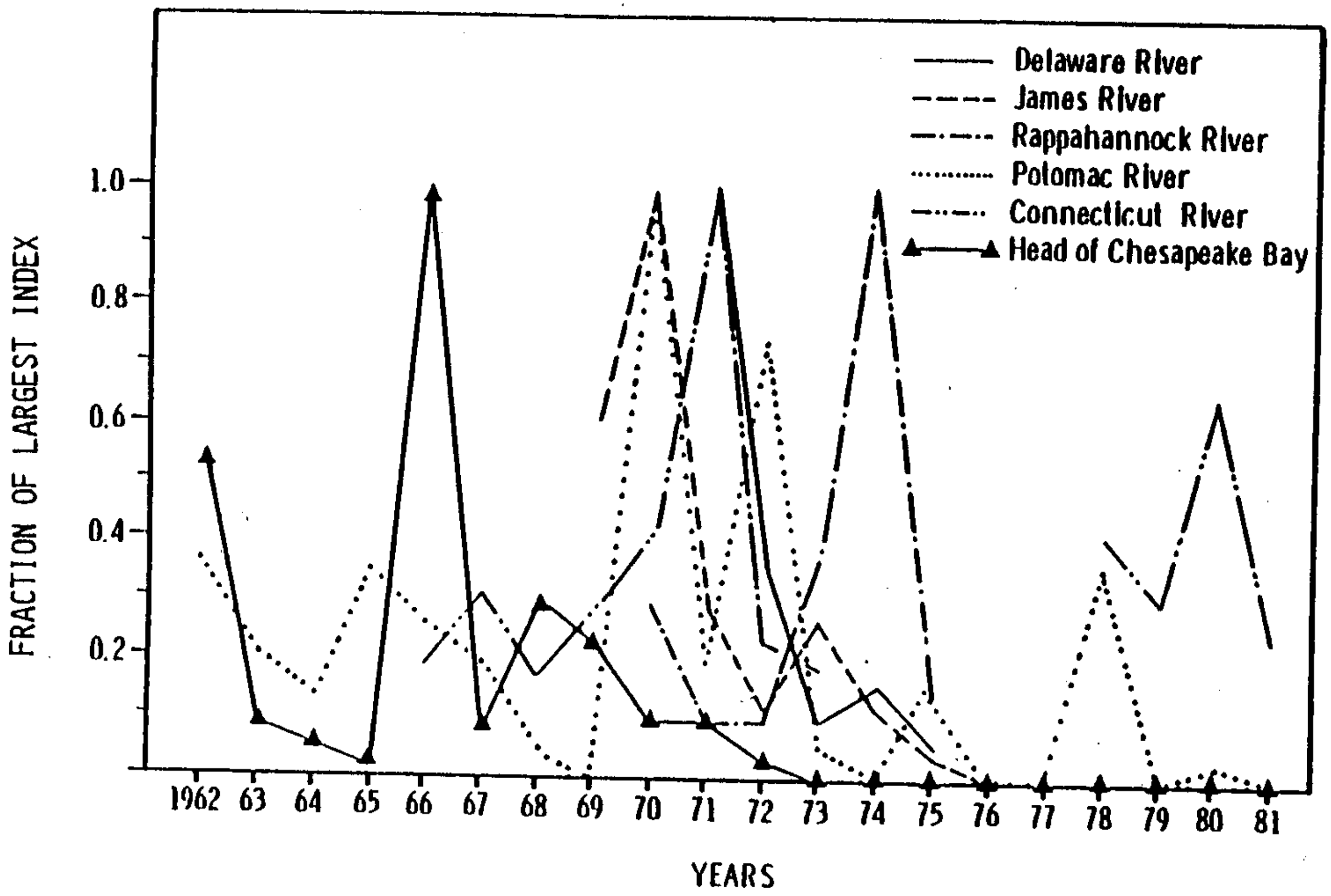


Figure II-7. Comparison of annual American shad juvenile abundance indices for different east coast drainage systems; data for each system are expressed as a percentage of the largest annual index; data sources are listed in Table II-13.

along nearly the entire northwest coast of the United States within 55 years. However, additional stockings in the Columbia River, the Williamette River in Oregon, the Skagit River in Washington and several other Northwest rivers do raise some doubts that all west coast stocks can be attributed to the Sacramento stockings.

It has been suggested (J. Loesch, pers. comm.) that the degree of shad homing may differ depending on the nature of the drainage system. Considerable mixing must occur among shad stocks that utilize the various tributaries in the Chesapeake Bay which could contribute to straying. In contrast, relatively precise homing might be expected in systems such as the Hudson or the Connecticut, where single large rivers exist.

Summary of Findings of Migration Studies

Talbot and Sykes (1958) reported the results of tagging studies conducted from 1938 to 1956. They concluded that, after spawning, adult fish from streams from as far south as Virginia migrate to the Gulf of Maine and remain in that vicinity throughout the summer into fall. In mid-fall, a migration southward begins, with overwintering occurring in the mid-Atlantic area. They concluded that immature fish overwinter in the mid-Atlantic and migrate northward to the Gulf of Maine with the spent adults in the late spring, returning to the mid-Atlantic area in the late fall. Other tagging studies were described by Walburg and Nichols (1967), providing additional support for the concept that the east coast shad stocks overwinter in the mid-Atlantic area.

Leggett and Whitney (1972) refined the description of the migratory pattern of American shad. They suggested that ocean migration patterns were related to water temperatures, and that fish occupied locations where temperatures ranged from 13 to 18°C. Their interpretations of offshore migration patterns was consistent with that of Talbot and Sykes (1958), but augmented with an understanding of the factors influencing that pattern. They also noted the occurrence of fish originating in the Connecticut River (and presumably fish from other central and northern coast stocks) off the North Carolina and Virginia coasts in February and March. In April, the more northern stocks are found in the vicinity of Chesapeake and Delaware Bays. In May and June, fish in prespawning condition from the more northern runs are present in New England and Canadian waters.

Neves and Depres (1979) documented the patterns of American shad catch in National Marine Fisheries Service research vessel bottom trawl surveys. They used these data to refine the description of shad migration patterns presented by Leggett and Whitney. Seasonal distribution of catch are shown in Figs.

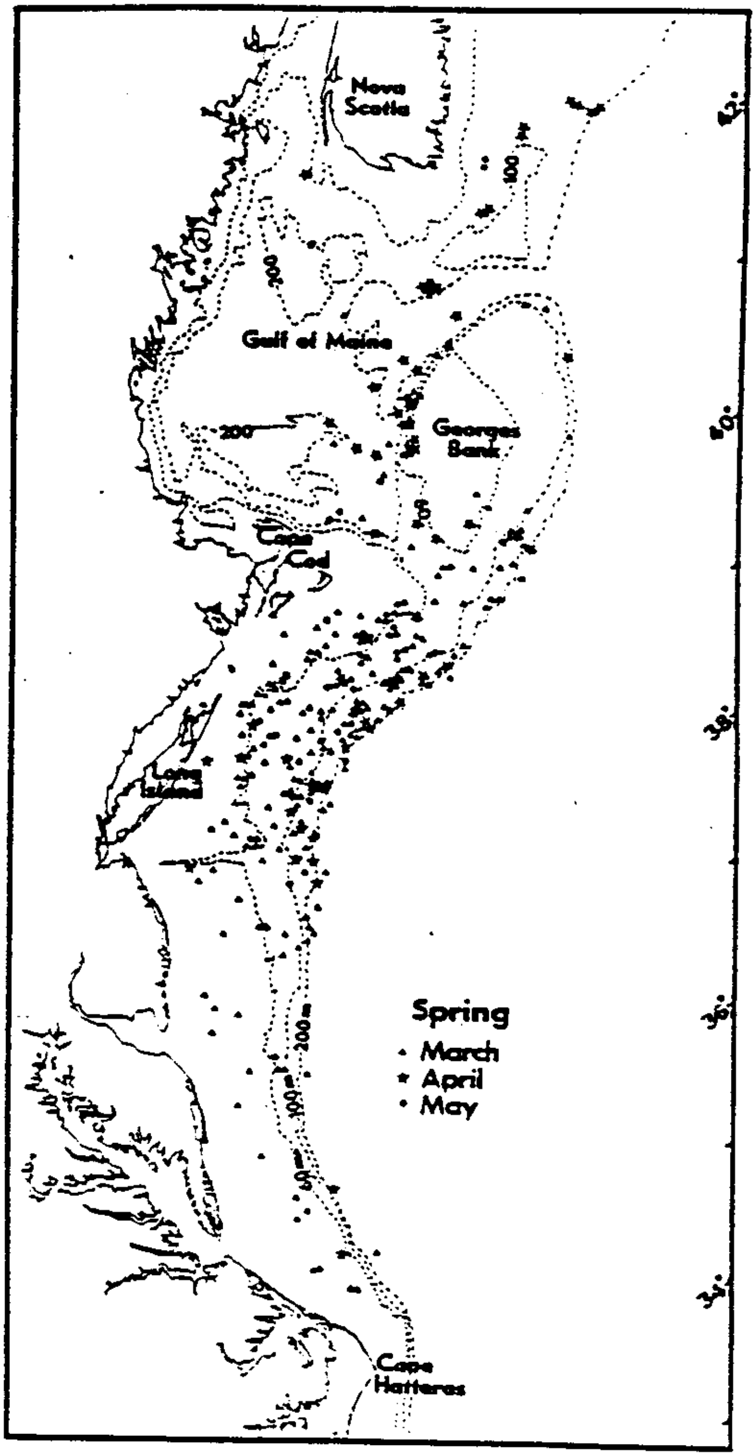


Figure II-8. Location of all American shad catches during spring bottom trawl surveys, 1968-76, Cape Hatteras, N.C., to Nova Scotia (from Neves and Depres, 1979).

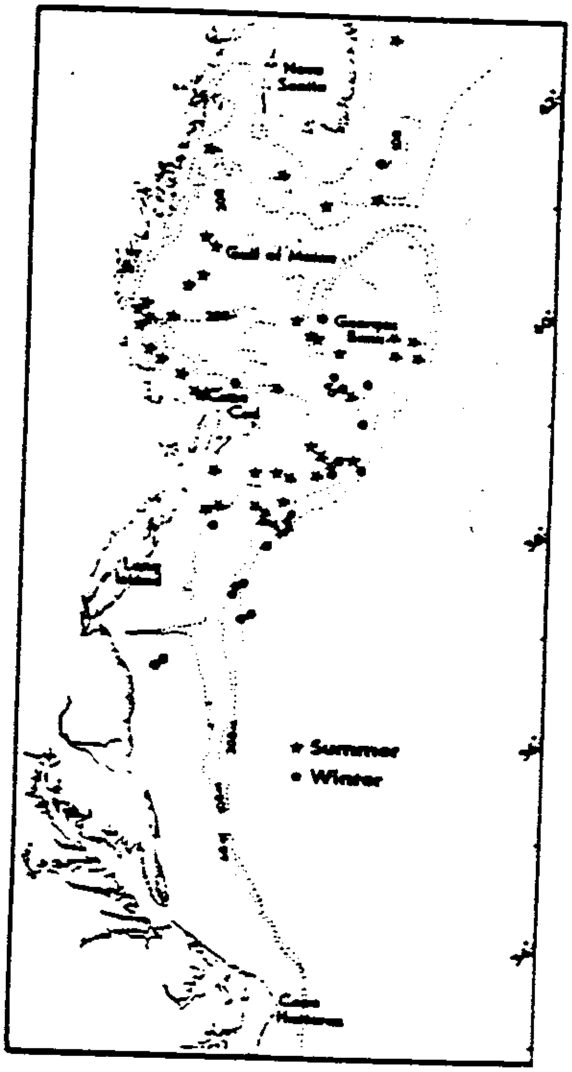


Figure II-9. Location of all American shad catches during summer and winter bottom trawl surveys, 1963-76, Cape Hatteras, N.C., to Nova Scotia (from Neves and Depres, 1979).

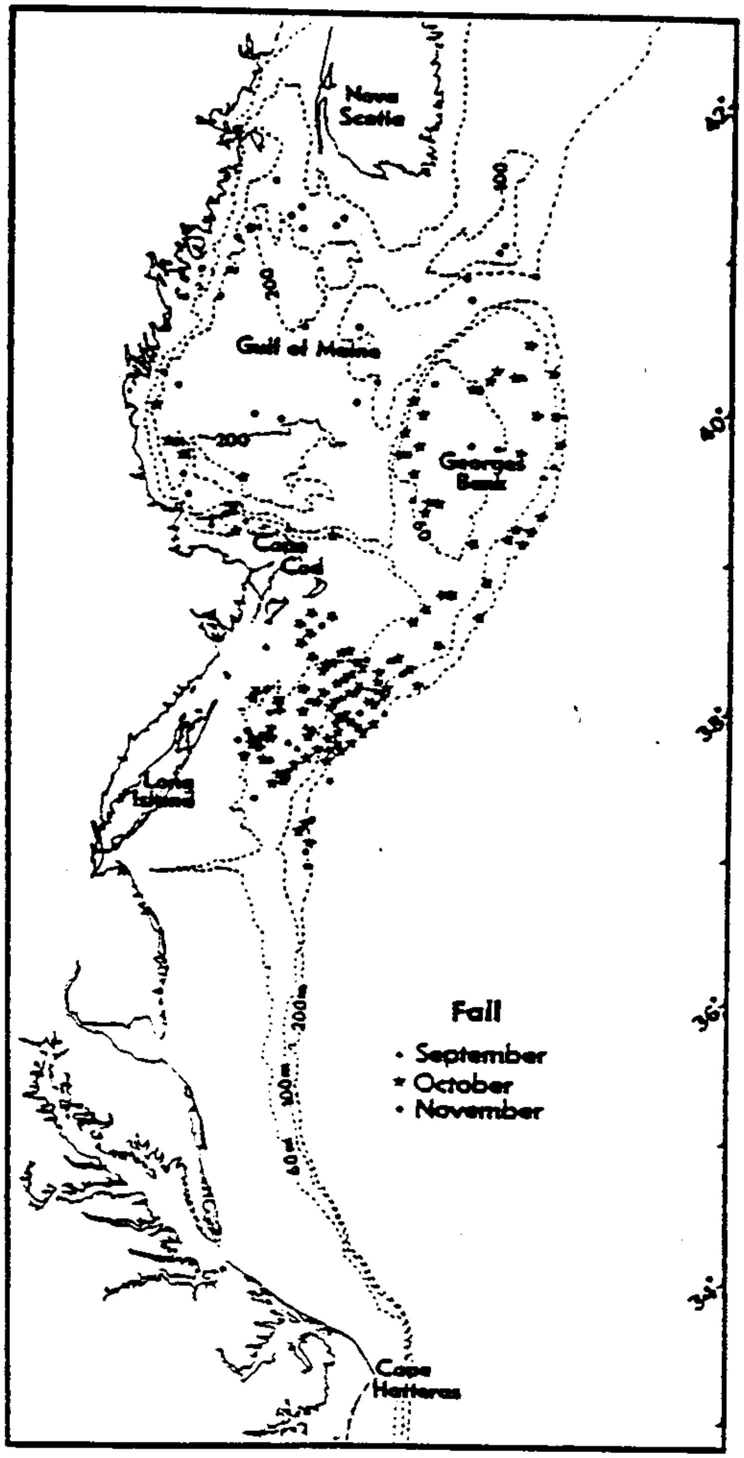


Figure II-10. Location of all American shad catches during autumn bottom trawl surveys, 1963-76, Cape Hatteras, N.C., to Nova Scotia (from Neves and Depres, 1979).

II-8 to II-10. Spring catch data (Fig. II-8) show that shad are widely distributed in the spring, in contrast to the pattern of migration described by Leggett and Whitney. However, Neeves and Depres did not discriminate between sexually mature and immature fish in their paper. Since trawl catches obviously would include both immature and mature fish, the wide spring distribution may reflect some separation of prespawning adults from immatures at this time of year. Neves and Depres also could not determine from the catch data itself whether stocks from all the river systems completly intermingle at all times of the year. However, they did note that adults from all river systems along the east coast are found entering coastal waters as far south as North Carolina in the winter and spring. The authors cite other studies to conclude that a mix of various stocks from the east coast rivers do enter many of the estuaries along the coast in early spring during their northward migration, and that their timing and duration of stay are unknown.

Extensive summer tagging of American shad has been carried out recently in the Bay of Fundy, Canada. Figure II-11 shows locations of recaptures of fish tagged (from Scarratt and Dadswell, 1983). The widespread distribution of recaptures demonstrates that shad from all river systems along the east coast occur in the Bay of Fundy. The data conclusively confirm the seasonal movement patterns hypothesized by Leggett and Whitney and Talbot and Sykes. One other relevant aspect of these data is that, of fish tagged which had a known Canadian home river (i.e., fish which were tagged on their spawning run), five of 52 returns (approximately 10%) came from U.S. coastal waters. This information suggests that Canadian fish contribute to U.S. coastal harvest of American shad. Dadswell also notes the existence of a fall fishery for American shad in the Bay of Fundy which takes adults as well as sexually immature fish. However, this fishery is currently rather limited in extent.

Offshore Harvests

Documentation of offshore American shad harvests is in the form of catch reporting data tabulated by the International Commission for Northwest Atlantic Fisheries (ICNAF) and presented in its annual reports (ICNAF was abolished in 1979 and replaced by the Northwest Atlantic Fisheries Organization (NAFO) which continues to compile fisheries harvest data).

Reported offshore landings of American shad for the recent decade are presented in Table II-14 (from Boreman, 1982). The offshore data are reported by ICNAF reporting zone as well as by country. Data reported by country are a more precise documentation of the harvest actually taken in offshore waters. The data illustrate that reported offshore harvests of American shad are very limited. However, it is known that American shad are frequently misidentified as river herring by foreign as well as

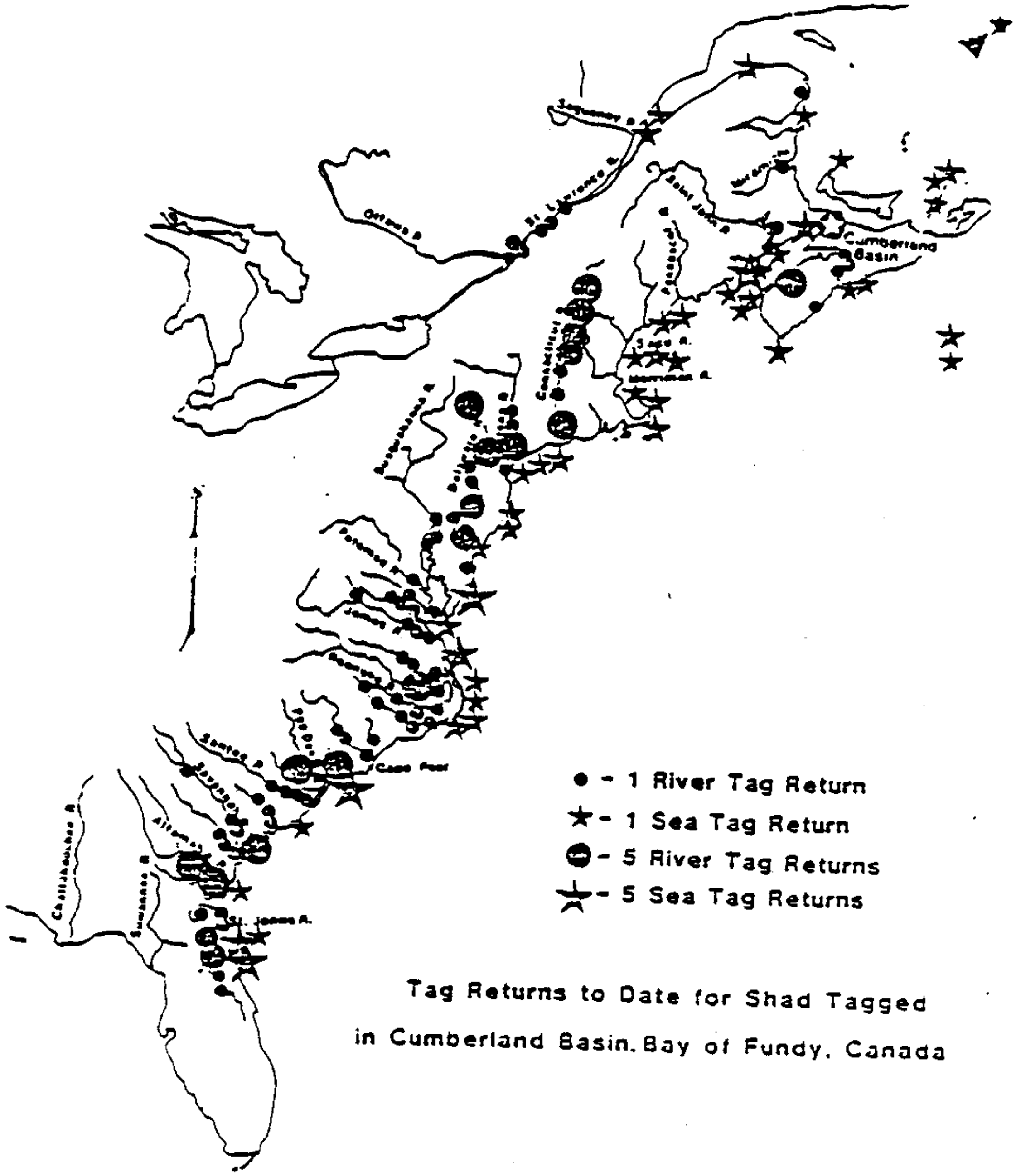


Figure II-11. Locality map for recaptures of shad tagged in Cumberland Basin (from Scarratt and Dadswell, 1983).

Table II-14. Landings of American shad (in thousands of pounds) in ICNAF/NAFO Areas 5 and 6 by Foreign Vessels (from Boreman, 1982)

	Nation				
Year	Bulgaria	E. Germany	Ireland	Japan	Total
1970	0	0	0	0	0
1971	0	0	0	0	0
1972	5	0	0	0	5
1973	0	308	0	0	308
1974	0	0	0	0	0
1975	0	0	1	0	1
1976	0	0	0	5	5
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	0	0	0	0	0
1980	0	0	0	0	0

domestic fishing vessels. Species identification is particularly likely to be poor in the case of immature fish. However, the extent of possibly misidentified harvests is considered by NMFS staff to be minimal. The placement of U.S. observers onboard foreign fishing vessels operating in the U.S. Fishery Conservation Zone in recent years may have decreased the potential for identification errors.

Areas of Potential Interjurisdictional Management Problems

In earlier American shad work initiated by ASMFC (e.g., Talbot and Sykes, 1957, and others), the fisheries for American shad in the 1940's and 50's were characterized as a basis for examining the types of interjurisdictional problems which existed at that time. During those decades, substantial landings of shad were taken in coastal pound nets, particularly in the area of New Jersey and New York (Fischler, 1958; Nichols, 1957). These fisheries took substantial amounts of shad from stocks that were not native to the state in which they were harvested. As an example, 11% of the New York/New Jersey coastal catch was identified as originating in river systems other than the Connecticut and the Hudson. Of the remainder, 76% were Hudson River fish, and 13% were Connecticut River fish (Nichols, 1957). However, there was no detectable relationship between the magnitude of pound net catches in this coastal fishery and the size of shad runs on both the Hudson and the Connecticut Rivers. Whitney (1957) reported the results of a tagging study conducted in the Chesapeake Bay, which suggested that only approximately 3% of Maryland shad stocks were being harvested in pound nets in Virginia waters of the lower Chesapeake Bay. White et al. (1969) reported that 63% of the total harvest in the Delaware Bay is made up of fish from other drainage systems, as far north as Canada. Zarbock (1969) noted that 70% of the recaptures of fish tagged in the Delaware Bay were also taken in other waters. Chittenden (1974) characterized the segments of the Delaware Bay fishery dominated by non-Delaware stocks. Offshore foreign fisheries undoubtedly have the potential to take fish from all east coast coast drainage systems.

These findings are useful for identifying potential interjurisdictional problem areas. However, the reported findings can be influenced by numerous factors, such as the following:

- The composition of the catch in any given area may be a function of the time of the year during which effort is employed (relative to the timing of fish migration) as well as the nature of the gear (e.g., mesh size of gill nets relative to the difference in mean size of different stocks).

- The offshore fisheries (ICNAF/NAFO) use nonselective gear (e.g., large midwater trawls) which probably harvest all size (i.e., age) groups of fish. Thus, such fisheries could influence the at-sea mortality rates for both adults and immature life stages if substantial amounts of American shad were harvested.

- The late summer/early fall fishery for American shad in Canadian waters also takes both immature and mature fish; however, since these efforts are relatively low, it is unlikely that they will have significant effects.

Since all east coast stocks begin their prespawning migrations in southern coastal waters, northern stocks may be exposed to exploitation during much of their northward movement along the coastal United States. This would suggest the potential for higher fishing mortality of more northern stocks than of southern stocks. While immature fish may move with the spawning adults into inshore waters, fisheries are primarily directed at the large, preferably roe shad. This means that selective gear may be used (i.e., large mesh gill nets), with the result that immature fish cannot be detected or harvested.

Implications of Coastal Migration Patterns for Management

Coastal fisheries occurring to the south of South Carolina are unlikely to exploit any of the more northern stocks of American shad, based on the coastal migration pattern data discussed above. In contrast, the spring coastal fisheries from South Carolina northward, the fall fishery in Canadian waters, and the offshore fisheries all may exploit many different stocks of American shad.

The decline in the use of pound nets in coastal waters in the last two decades, particularly in the mid-Atlantic area (New Jersey-New York), reduces the exploitation of non-native stocks in those states. From the information presented above, it would appear that the fisheries in coastal waters of southern states (e.g., North and South Carolina) and in the Delaware Bay have greatest potential for creating interjurisdictional management problems in the case of American shad. The evolution of the southern coastal fisheries in response to high market demand in the early spring could accelerate such problems in the future.

F. SELECTED LIFE HISTORY ASPECTS RELEVANT TO MANAGEMENT

Latitudinal differences in age of maturity

Age of maturity is the age at which a fish first becomes sexually mature. For anadromous alosids, age of maturity differs between sexes. Table II-15 presents data for shad from runs from Florida to Canada. Leggett and Carscadden (1978) concluded that although males from the St. Johns River had a statistically significant lower mean age of maturity than males from all other runs examined (not evident in Table II-15), there was no latitudinal gradient in age of maturity, as is evident in the data presented in Table II-15. However, some degree of variability among river systems is also clear.

The significance of these data on age of maturity to the management of American shad stocks hinges primarily on the fact that all stocks remain at sea for similar periods of time before first returning to spawn. Since the stocks appear to mingle during the major portion of their stay at sea, any ocean or coastal fishery that significantly increases mortality of shad during the coastal migrations may impact on all stocks to a similar degree.

Size at Age

Tables II-16 and II-17 present data on size at age, by sex, for shad taken from five different river systems. All of these data are empirical, determined from actual measurements and scale reading of fish taken in samples, thus avoiding the potential problem of Lee's phenomenon.

Similar data are presented in Figure II-12, from Leggett and Carscaddan (1978). This graph shows the substantial difference in size at age between the more southern stocks and the more northern stocks. The authors attribute difference in growth to the length of juvenile stay in freshwater. However, an examination of other literature suggests that juveniles in the south (i.e., Georgia) leave nursery areas in October and November, as is the case in more northern rivers (Adams, 1970). Thus, the time of initiation of their ocean stay would appear to be similar to that of the juveniles for the more north rivers, suggesting that Leggett and Carscaddan's explanation may not be correct.

Coastal migration data discussed earlier suggests that all east coast stocks utilize the same summer feeding grounds (i.e., Gulf of Maine and Bay of Fundy). If this is the case, all stocks utilized the same resources as forage. Thus, the only

Table II-15. Maximum age and mean age at maturity of American shad from five Atlantic coast populations (from PSEG, 1982a)

River	Maximum Age		Mean Age at Maturity	
	Male	Female	Male	Female
Miramichi, NB[1]	7	7	4.2	4.6
St. John, NB[1]	10	10	4.2	4.5
Connecticut, CT[1]	8	8	4.1	4.8
Delaware, DE[2]				
1963	6	6	4.1	4.9
1964	6	6	4.3	5.2
1965	5	7	4.2	5.2
York, VA[1,2]	6	8	4.2	4.7
St. Johns, FL[1]	5	6	4.1	4.9

1 From Leggett and Carscadden, 1978

2 From Chittenden, 1969

Table II-16. Mean fork length (mm) of female American shad (from PSEG, 1982a)

	Age Group 1	2	3	4	5	6	7	8
St. John R., NB[1]								
$\bar{X}$				430.0	445.4	452.3	464.6	471.0
SD				11.1	17.6	16.2	18.8	29.7
Minimum				410.0	400.0	420.0	420.0	430.0
Maximum				450.0	470.0	480.0	500.0	510.0
n				7	12	20	11	5
Connecticut R., CT[1]								
$\bar{X}$				458.4	474.9	501.1	507.0	524.2
SD				18.2	17.1	21.1	22.5	22.1
Minimum				410.0	410.0	425.0	460.0	475.0
Maximum				495.0	510.0	530.0	540.0	565.0
n				36	176	25	30	24
Delaware R., NJ*[2]								
$\bar{X}$	209.2	321.9	404.4	464.1	511.1	537.8	553.0	558.0
SD	-	-	-	-	-	-	-	
Minimum	-	-	-	-	-	-	-	
Maximum	-	-	-	-	-	-	-	
n	87	87	87	87	59	18	4	
York R., VA[1]								
$\bar{X}$				410.6	431.7	444.8	494.0	458.0
SD				14.7	18.7	39.3	36.9	20.8
Minimum				375.0	390.0	370.0	430.0	440.0
Maximum				440.0	520.0	505.0	567.5	475.0
n				34	101	33	9	2
St. Johns R., FL[1]								
$\bar{X}$			403.0	415.0	441.9	458.2		
SD			19.2	19.1	15.5	8.7		
Minimum			370.0	380.0	420.0	445.0		
Maximum			440.0	475.0	475.0	470.0		
n			13	126	58	6		

*Based on back calculation from scales.

[1] Leggett, 1969.

[2] DBFWMC, 1980.

Table II-17. Mean fork length (mm) of male American shad (from PSEG, 1982a)

	Age Group 1	2	3	4	5	6	7	8
St. John R., NB[1]								
$\bar{X}$				406.3	428.0	436.4	439.4	
SD				16.9	24.9	15.7	15.1	
Minimum				380.0	370.0	400.0	420.0	
Maximum				435.0	460.0	470.0	470.0	
n				8	15	29	18	
Connecticut R., CT[1]								
$\bar{X}$			397.3	432.5	453.0	469.0	480.0	482.8
SD			16.7	21.1	28.0	18.4	23.2	10.4
Minimum			365.0	390.0	345.0	440.0	420.0	460.0
Maximum			450.0	485.0	510.0	525.0	520.0	505.0
n			56	62	54	26	30	28
Delaware R., NJ*[2]								
$\bar{X}$	192.6	306.6	380.3	435.2	466.0	482.0	491.0	
SD	-	-	-	-	-			
Minimum	-	-	-	-	-			
Maximum	-	-	-	-	-			
n	186	186	185	170	26			
York R., VA[1]								
$\bar{X}$			335.0	379.1	398.0	407.2		
SD			-	22.3	19.6	22.4		
Minimum			-	345.0	350.0	375.0		
Maximum			-	435.0	430.0	440.0		
n			1	29	21	5		
St. Johns R., FL[1]								
$\bar{X}$			366.7	385.8	409.0			
SD			19.0	13.8	12.6			
Minimum			295.0	345.0	387.5			
Maximum			395.0	430.0	430.0			
n			56	130	10			

*Based on back calculation from scales.

[1] Leggett, 1969.

[2] DBFWMC, 1980.

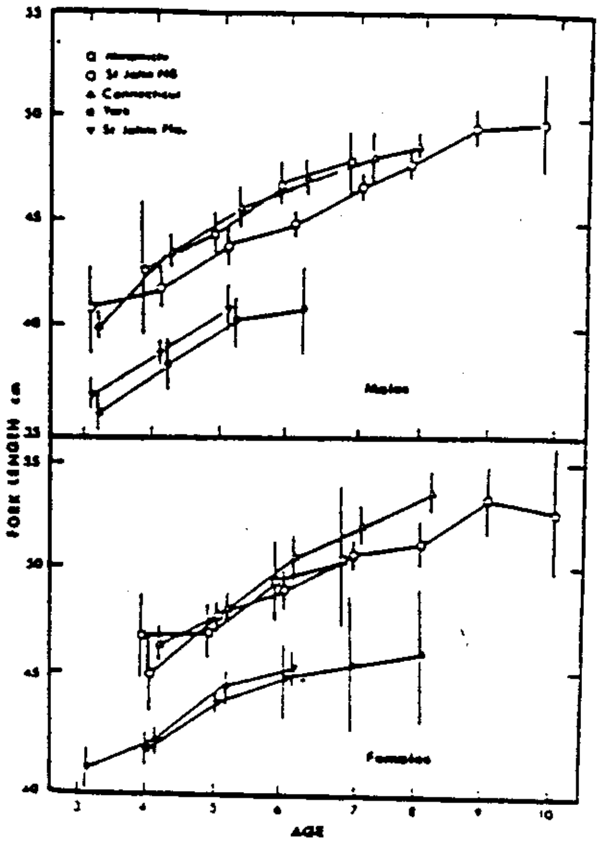


Figure II-12. Size by age of male and female American shad in populations spawning in five Atlantic coast rivers. Vertical bars represent 99% confidence intervals for means (from Leggett and Carscadden, 1978).

apparent explanation for differences in growth between northern and southern stocks is genetic factors relating to evolutionary adaptations of the stocks, as has been discussed by Leggett and Carscaddan (1978).

The significance of size of age data for management purposes is primarily that it may serve as a stock identifier in non-local waters.

Frequency of Repeat Spawning

Data in Table II-18 (from Walburg and Nichols, 1967) reveal the absence of repeat spawning in rivers south of North Carolina, and an increasing occurrence of repeat spawning to the north. Frequency of repeat spawning is strongly influenced by the occurrence of individual large year-classes. During the first year of return of large year-classes the frequency of repeat spawners may be very small primarily because of the large numbers returning from the dominant year-class. Similarly, the return of repeat spawners from a large class in subsequent years may inflate the relative percentage of repeat spawners in a given year. Thus the data summaries presented in Table II-18 must be considered generalizations.

Leggett and Carscaddan (1978) reconfirmed the pattern of frequency of repeat spawning shown in Table II-18 with more recent data. The same pattern is further corroborated by data collected in numerous state studies.

At a scale reading workshop carried out in 1982 in conjunction with a meeting of the Shad and River Herring S&S Committee, questions were raised about individual investigator's discrimination of spawning checks on scales of southern fish. While there is conclusive evidence of the occurrence of very small amounts of repeat spawning in North Carolina, there remains no evidence of repeat spawning from South Carolina to Florida. Existing literature (e.g., Walburg and Nichols, 1967) overwhelmingly supports the view that there is no repeat spawning in the most southern stocks.

The absence of repeat spawners in southern stocks of American shad has considerable significance for the feasibility of various management options in those regions. Similarly, even in runs in the Carolinas, Virginia, and Maryland, where the frequency of repeat spawning is relatively low, limits on the efficacy of harvest on management actions may exist. In cases where the percentage of repeat spawning is minimal, the size of the run in any given year is essentially a function of the spawning success in prior years. In contrast, runs having high percentages of repeat spawners can be enhanced by limiting exploitation in a given year to permit more fish to return as

Table II-18. Age distribution at capture, and number of previous spawnings, for American shad from certain rivers, Atlantic coast of the United States[1] (from Walburg and Nichols, 1967).

[In percent]

Age and spawning group	River									
	St. Johns	Ogeechee	Edisto	Neuse	James	York	Potomac	Delaware	Hudson	Connecticut
Total age (years) at capture:										
2	(2)	---	---	---	---	(2)	---	---	---	---
3	4	2	5	9	12	7	5	1	2	1
4	72	41	16	43	61	55	62	16	23	17
5	22	48	56	34	20	30	28	41	29	42
6	2	9	23	12	7	6	5	30	22	30
7	(2)	---	---	2	(2)	1	(2)	10	14	7
8	---	---	---	---	---	(2)	---	2	6	2
>8	---	---	---	---	---	---	---	---	4	1
Number of times spawned previously[3]:										
0	100	100	100	97	73	76	83	98	49	51
1	---	---	---	3	22	15	15	2	19	31
2	---	---	---	---	5	7	1	---	18	13
3	---	---	---	---	(2)	1	(2)	---	10	4
4	---	---	---	---	---	1	---	---	2	1
5	---	---	---	---	---	---	---	---	2	(1)
>5	---	---	---	---	---	---	---	---	(2)	---

[1] Data for: St. Johns, 1958--Walburg (1960a); Ogeechee, 1954--Sykes (1956); Edisto, 1955--Walburg (1956); Neuse, 1953--Walburg (1957a); James, 1952--Walburg and Sykes (1957); York, 1959--Nichols and Massmann (1963); Potomac, 1952--Walburg and Sykes (1957); Delaware, 1944-45-47-52--Sykes and Lehman (1957); Hudson, 1950-51--Talbot (1954); Connecticut, 1956-59--Walburg (1961).

[2] Less than 0.5 percent.

[3] Determined by counting the number of spawning marks on scales.

repeat spawners in the next year. Harvest restrictions in these circumstances can have a short-term, direct, nonrecruitment-related positive impact on runs in subsequent years. In contrast, size of runs without substantial repeat spawning depends completely on the year-class success of individual runs in the past, and can only be impacted to the extent that increases in run fecundity due to harvest restrictions in any given year result in greater production of progeny.

Mortality Rates

Mortality rates may be partitioned according to life stage:

- Ichthyoplankton
- Juvenile (in freshwater)
- Immature (at sea)
- Adults - fishing mortality; nonfishing spawning run mortality; post-spawning at-sea mortality.

Ichthyoplankton mortality rates tend to be extremely high. Leggett (1977) reported that, on the average, only 0.00083% of American shad eggs produce sexually mature adults. The majority of the mortality occurs from the time of deposition of the egg to the time of juvenile stage. Crecco et al. (1983a) have demonstrated that yearclass size is set at the point in time where larvae reach the juvenile stage, and that larval mortality rates are quite variable from year to year. Survival of larvae (after egg hatch) through juvenile stage may be on the order from 1 to 2% (Public Service Gas and Electric, 1982a).

Juvenile mortality rates have been reviewed in PSEG (1982), and a number of different observed mortality rates for the Connecticut and Delaware rivers are presented in Table II-19. Monthly survival rates of juveniles on the nursery grounds were in the range from 60 to 75%. Crecco et al. (1983a) reported more recent findings of daily mortality rates of juveniles of 1.8 to 2.0% per day. If one assumes an average river residence time for juveniles of three months, the survival of juveniles until outmigration would be on the order of 30% (e.g., 70% of juveniles are lost before reaching the ocean). Longer residence time would reduce this percentage figure even further. Residence times in the Delaware have been reported to be as high as 4-5 months, depending on water temperature (M. Miller, 1982).

Mortality of sexually immature fish at sea has not been documented. Analysis of tagging data collected by Dadswell

Table II-19. Total (= natural) mortality rates for juvenile American shad (from PSEG, 1982)

	Daily Growth Rate	Z_d	Z_m	Monthly Survival (%)	Monthly Mortality (%)
Delaware River (present study)					
100 mm FL	0.0970	0.00964	0.28906	74.9	25.1
150 mm FL	0.1315	0.01306	0.39187	67.8	32.4
200 mm FL	0.1660	0.01649	0.49468	61.0	39.0
Connecticut River (Hints et al., unpubl.)					
1966	-	0.01567	0.470	62.5	37.5
1967	-	0.01613	0.484	61.6	38.4
1968	-	0.00793	0.238	78.8	21.2
1969	-	0.01493	0.448	63.9	36.1
1970	-	0.01173	0.352	70.3	29.7
1971	-	0.01527	0.458	63.3	36.7
1972	-	0.00700	0.210	81.1	18.9
1978	-	0.01493	0.448	63.9	36.1
1979	-	0.01800	0.540	58.3	41.7
Mean:	-	0.01351	0.405	66.7	33.3

Z_d = Daily instantaneous total mortality rate.

Z_m = Monthly instantaneous total mortality rate.

FL = Fork length.

et al 1983) will provide a strong basis for estimating such mortality rates. Based on normal biological processes in fish populations, mortality rates of sexually immature post-juvenile fish would be considerably lower than the mortality rates for the younger life stages.

Adult mortality rates have been estimated a number of different ways, including extensive tagging-recapture studies conducted over periods of years, as well as documentation of passage of individual yearclasses through a fishery by age composition studies over a period of years. All methods of estimation of mortality are subject to alternative interpretations of the data, and thus some older interpretations (e.g., Fredin, 1954) have been reassessed and considered to be in error (e.g., Leggett, 1976; Crecco, 1978). For this reason, compilations of figures from the literature, as are included here, should be considered to be general overviews of mortality rates as opposed to rigid documentation of true mortalities.

Table II-20 presents estimates of fishing mortality rates for a number of different river systems along the east coast. In general, rates may not be as high as presented here. As was already pointed out, some of these values may be suspect because of the manner in which they were derived (e.g., Fredin, 1954). Most recent data (Leggett, 1976; Crecco, 1978) suggest that current commercial fishing mortality rates are generally on the order of 20 to 30%. Fishing mortality rates differ, of course, by sex, since the fishery is directed primarily at larger female (roe) shad, which are more marketable than buck (male) shad. Roe shad fishing mortality rates tend to be approximately double those of buck shad (e.g., Crecco et al, 1982). This figure would of course vary with the amount of effort and specific conditions in any given year. Crecco (1980) has reported a recreational fishing mortality rate of 4 to 10% of the escapement past the commercial fishery on the Connecticut River. Comparable figures for the Delaware River are of 8 to 11% (Table II-21). Table II-22 provides estimates of weight of American shad by age and sex for the Connecticut River. These data permit comparison of numerical harvests reported for recreational fisheries and poundage harvests reported in commercial fisheries.

In addition to fishing mortality, natural mortality adds to the total mortality rate for adult shad. In river systems in which no repeat spawning occurs, of course, total mortality rates are 100%. Thus, it is evident that natural mortality rates are lower in more northern runs with repeat spawning than in southern runs, assuming no major difference in fishing mortality rates. Leggett (1976) assessed annual total mortality rates for Connecticut River shad. He reported annual rates for males and females of 70% and 71%, respectively. Mortality rates were estimated by PSEG (1982) for shad occurring in the Delaware River, and determined to be a 70-80%. However, these values are suspect given the very low percent repeat spawning in that system.

Table II-20. Fishing mortality rates of American shad populations in river systems along the Atlantic coast (adapted from Rulifson et al., 1982)

RIVER SYSTEM	YEAR	MORTALITY(%)	SOURCE(S)
Connecticut River	1941	32.8	Fredin (1954)
	1946	81.9	Fredin (1954)
	1965-1973	22.7	Leggett (1976)
Hudson River	1916	19.8	G.E. Talbot (1954)
	1947	79.0	G.E. Talbot (1954)
Potomac River	1944	41.9	Walburg and Sykes (1957)
	1949	76.0	Walburg and Sykes (1957)
James River	1957	73.0	Walburg and Sykes (1957)
York River	1953	58.3	Nichols and Massmann (1962)
	1958	44.4	Nichols and Massmann (1962)
	1959	55.2	Nichols and Massmann (1962)
Neuse River	1957	65.0	Walburg (1957)
Waccamaw-Pee Dee system	1974	33.9	Crochet et al. (1976)
	1975	29.0	Crochet et al. (1976)
	1976	18.5	Crochet et al. (1976)
Edisto River	1955	20.0	Walburg (1956)
Ogeechee River	1954	66.0	Sykes (1956)
Altamaha River	1967	48.6	Godwin (1968)
	1968	43.3	Godwin (1968)
	1982	52.1	Michaels (pers. comm.) Ga. DNR
	1983	32.3	Michaels (pers. comm.) Ga. DNR
St. Johns River	1960	15.0	Walburg (1960b)

Table II-21. Summary of American shad population estimates and exploitation rate by the sport fishery for the Delaware River, 1979 - 1982.*

Year	Population estimate	Exploitation rate (%)	Estimated number of shad harvested
1979	111,839 ± 32,191	8.0	8,947
1980	181,880 ± 55,058	8.0	14,550
1981	546,215 ± 133,590	8.1	44,243
1982	506,102 ± 176,680	10.7	54,153
1983	249,578 ± 87,342	8.0	19,966

*Prepared by A.J. Lupine, N.J. Division of Fish, Game and Wildlife

Table II-22. Average weight (kg) of American shad by age and sex calculated using von Bertalanffy growth model and observed values (from Crecco, 1978).

Males			Females		
(1) Age	(2) Obs. average weight	(3) Calc. average weight	(4) Age	(5) Obs. average weight	(6) Calc. average weight
II	-	0.572	II	-	0.764
III	0.941	0.902	III	-	1.175
IV	1.269	1.227	IV	1.632	1.606
V	1.534	1.522	V	2.035	2.032
VI	1.793	1.778	VI	2.404	2.435
VII	1.957	1.992	VII	2.926	2.805
VIII	-	2.167	VIII	3.064	3.137
IX	-	2.308	IX	-	3.429
X	-	2.420	X	-	3.683
XI	-	2.508	XI	-	3.901

Annual total mortality rates would appear to be on the order of 70-90% in the northern river systems where repeat spawning occurs.

Mortality rate data just discussed have significant impact on the feasibility of various management actions. The data demonstrate that the major mortality between egg and adult stages occurs during the prejuvenile life stages. In cases where these mortalities are controlled by environmental conditions, as is suggested by Crecco et al. (1983b), management actions aimed at modifying these factors may be infeasible. Restrictions on harvests have the capability solely for altering the portion of total mortality accounted for by fishing. As was noted above, fishing mortality rates due to either commercial fishing alone or in combination with recreational fishing, may account for on the order of 25%-50% of mortality to the spawning stock in a given year. In cases such as the southern runs, where total mortality will be 100%, restrictions on fishing may have limited impact on subsequent run sizes. This topic is discussed in detail under the heading of population dynamics, since the degree of independence between recruitment and spawning size is the determining factor.

Fecundity

Fecundity data had been collected from shad in many of the runs occurring along the east coast. Fecundity, expressed in terms of amount of eggs per female, varies according to the size of the fish but in general ranges between 200,000 and 300,000. Figure II-13 presents data summarized by Leggett and Carscadden (1978). The figure shows that the larger fish (which in northern runs may represent repeat spawners) yield significantly more eggs than the smaller fish. If repeat spawners make up a substantial portion of a run in any given year, they may contribute significantly to total run fecundity. Also, fish in the southern runs have a higher fecundity per unit body weight than do fish in the northern runs. Leggett and Carscaddan interpret this as an evolutionary adaptation of the southern runs; that is, because the fish have the opportunity to spawn only once (because of 100% total mortality), their fecundity per unit body weight is maximized.

The significance of these fecundity data for management is that manipulation of fishing rates may have some effect on the total fecundity of a run in any given year through resultant changes in percentage of repeat spawners. However, whether increasing total run fecundity has a concomitant effect on number of juveniles produced (i.e., on year-class size) is an open question. Data analyzed by Crecco et al. (1983b) suggest that, in fact, yearclass size is almost entirely controlled by environmental factors as opposed to run fecundity at "normal"

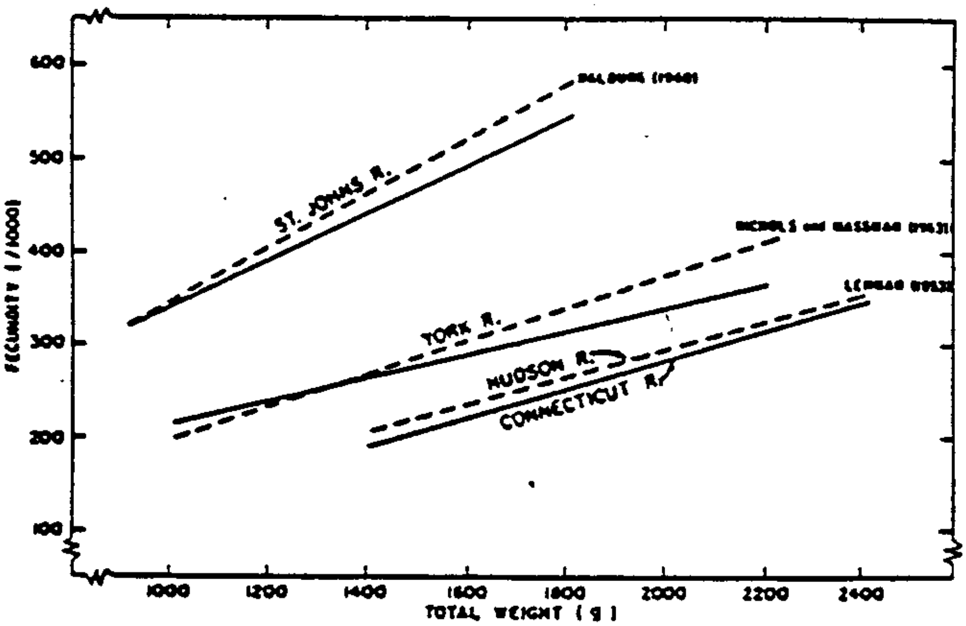


Figure II-13. Relative fecundity of American shad as determined in the referenced study (solid line) and by earlier investigators (dashed line) (from Leggett and Carscadden, 1978).

levels of spawning stock size. This topic is discussed in more detail under the heading of shad population dynamics. Fecundity may become important when run sizes have been depressed to some very low level, termed a threshold level.

Shad Population Dynamics

An understanding of the population dynamics of a species is the most important aspect of fisheries management. Population dynamics represents the integration of many of the individual life history aspects discussed above. Because of the complexity of the factors that control population dynamics, this aspect of any given species life history is in general poorly defined.

Studies reported in the literature in previous years (Talbot, 1954; Walburg, 1963) involved the use of regression analyses to investigate factors that influenced shad stock abundance. Talbot (1954) concluded that escapement (i.e., number of adults escaping the fishery and reaching the spawning grounds) five, four, and one year prior to the year in which stock size was estimated had a significant impact on subsequent year-class size, explaining 85% of the variation in landings in the Hudson River. Walburg (1963) also suggested that adult escapement has a substantial effect on subsequent run size in the Connecticut River. Both these studies suggested that shad exhibit stock-dependent recruitment, i.e., the number of juveniles produced was significantly related to the numbers of adults spawning.

More recent assessments of similar data and reexamination of the premises of the analyses done by both Talbot and Walburg have suggested that there are serious deficiencies in those analyses. Included in these deficiencies are the fact that data were autocorrelated, that the tags used in conducting the studies resulted in biased catch rates for tagged fish, and that there was selectivity in the gears used in documenting the run size. Leggett (1976) and Crecco (1978) both document numerous limitations in the analyses. In the case of the work done by Talbot, the role of run size one year earlier in determining the run size in a given year is of course strongly dependent on escapement simply because at that time, repeat spawners made up 50% of each run. Increased escapement resulted in more repeat spawners the following year, thus generating high correlation.

More recent analyses (e.g., Leggett, 1976, 1977; Crecco et al, 1983b) addressed the same issue of influence of stock stock size on subsequent recruitment to the fisheries in the Connecticut River. Leggett (1976) concluded that at the current time, Connecticut River shad stocks were far below the level of the stock capable of producing maximum yield. He concluded that year-class strength is in part dependent on spawning stock size, but that spawning stock size has much more limited influence than have environmental variables. Crecco (1978) and Crecco et al (1983b) expanded and refined the analyses of Leggett. These results showed that in recent years, stock size has had virtually no influence on the number of recruits returning to the river in subsequent years, and that environmentally-controlled mortality rates in the prejuvenile stage are the dominant factors determining the spawning success of the run in any given year. In essence, the data suggest no significant correlation between parent and progeny numbers.

No other east coast shad runs have been studied to the level of detail of the Connecticut River run. While numerous short-term, life-stage-specific studies have been done in some systems, only recently have relatively complete life history studies been initiated in certain systems (e.g., the Delaware River, the Altamaha River in Georgia). Thus the Connecticut River results must stand as the most detailed examination of population dynamics of American shad. Applicability of the Connecticut River findings to shad runs along the entire east coast must be assessed if those results are to be used as the basis for management decisions for east coast runs.

The significance of these population dynamics findings to the feasibility of management options (at least in the sense of harvest restrictions) is clear. If in fact adult run size has virtually no statistically significant effect on recruitment in subsequent years, restrictions on commercial or recreational harvests will do little to influence subsequent recruitment. The data demonstrate that manipulation of run size will not result in a predictable response in terms of numbers of progeny produced. However, all current researchers acknowledge that at some low population level, the total run fecundity and the total spawning stock size will play an increasingly greater role in determining the number of progeny subsequently produced. Information is not currently available to suggest what this low threshold level will be. Definition of the critical threshold spawning stock size would appear to be one of the major research goals for the future. Management actions involving water quality improvement and increases in habitat availability would, of course, have beneficial impact on stocks, independent of their population dynamics characteristics.

G. RESTORATION PROGRAMS

While restoration of fishery stocks may mean the rehabilitation of existing stocks that are currently at low levels, restoration efforts discussed here will focus on those aimed at establishing new runs to waters which formerly supported runs which were eliminated through either denial of access or through destruction of required habitat. Restoration programs are presently underway along much of the east coast. Existing programs are described in summary in Table II-23. Efforts on major river systems, either in progress or at the startup stage, are being conducted on the Connecticut River and the Susquehanna River. In addition, numerous efforts are being made on much smaller drainage systems listed in Table II-23.

In the majority of these programs, insufficient time has passed to assess success. Returns have been seen in the Pawcatuck River in Rhode Island, but numbers are not up to expectations. Because of the period of time during which the program has been ongoing, the Connecticut River may serve as the best case study of restoration of American shad on the east coast. A detailed discussion of the background and current status of this program is presented by Moffitt et al. (1982). Dam construction on the Connecticut River beginning in the 1700's was responsible for denying American shad access to the majority of the Connecticut River drainage. The lowermost of these dams is the Holyoke facility at South Hadley Falls in Massachusetts. This dam restricted anadromous fish to the lower 140 kilometers of the river. Numerous efforts were made in the early 1900's at reestablishing American shad above both Holyoke and other dams, but all were unsuccessful.

The first facility constructed at the Holyoke Dam for passage of American shad and other anadromous species began operation in 1955. Major improvements were made to the lift in 1976. Numbers of shad passed over the dam have increased from approximately 5,000 in 1955 to over 500,000 in 1983. The facility is designed to accommodate an American shad run of approximately 1 million. The passage data would suggest that the program has been very successful in reestablishing shad to the portion of the Connecticut River above Holyoke Dam. However, recent analyses (Crecco et al, 1983d) have been unable to document a relationship between number of adult shad passed above the Holyoke Dam and sizes of runs 4 and 5 years later. The alternative explanation for increased passage of fish would be increased attractiveness and improved efficiency of the lift facilities and their operations. One possible explanation for lack of demonstrated effectiveness of the restoration effort is high juvenile mortality during downstream passage through the dam turbines (Knapp et al, 1982). All relevant factors are currently under investigation.

Restoration programs serve as extremely valuable management tools because they essentially create new fish for the fishery with no restrictions on current users. However, the success of the restoration has yet to be conclusively demonstrated, and most cost-effective methods of implementation of this type of management approach must be evaluated.

Table II-23. Summary descriptions of current or proposed east coast American shad restoration programs other than the Connecticut River (adapted from material in Atran et al., 1983, and state overview documents).

State	Drainage system	Potential run size	Nature of restoration effort
Maine	Royal, Kennebec, Penobscot, Androscoggin, St. Croix Rivers	Annual harvest of 1.15 million pounds	Improvement in water quality and improved passage facilities
New Hampshire	Lamprey, Exeter and Cocheco Rivers	60,000 adults	Construction of fish passage facility and stocking of gravid adults in 1980-82
Massachusetts	Merrimack, Nemasket, Taunton, and Charles	1,000,000 adults	Construction of fish passage facilities and stocking of gravid adults
Rhode Island	Pawcatuck	Not established	Construction of fish passage facilities and stocking of gravid adults beginning in 1976
New Jersey	Raritan River	Not established	Pollution abatement and stocking of gravid adults.

Table II-23 (continued)

State	Drainage system	Potential run size	Nature of restoration effort
Pennsylvania	Schuylkill River	340,000 to 960,000 fish	Construction of fish passage facilities.
Maryland - Pennsylvania	Susquehanna River	2,000,000 fish	In FERC proceedings. Construction of fish passage at 4 dams requested. Stocking of gravid adults, planting of eggs, and release of hatchery juveniles since 1978.
Virginia	James River	60,000 fish	Construction of fish passage facilities; stocking of gravid adults anticipated.

H. ANTHROPOGENIC EFFECTS - RECENT OR POTENTIAL

The effects of pollution, dam construction, and other man-related environmental alterations on American shad have been documented in several of the earlier review documents (e.g., Walburg and Nichols, 1967; Mansuetti and Kolb, 1953). While these factors may have contributed to historical declines in landings, their role in declines seen in the last 20 years has generally not been clearly delineated. However, in several specific cases, the effects of man-related environmental alterations are known. These cases will be documented here.

Delaware River Pollution Block

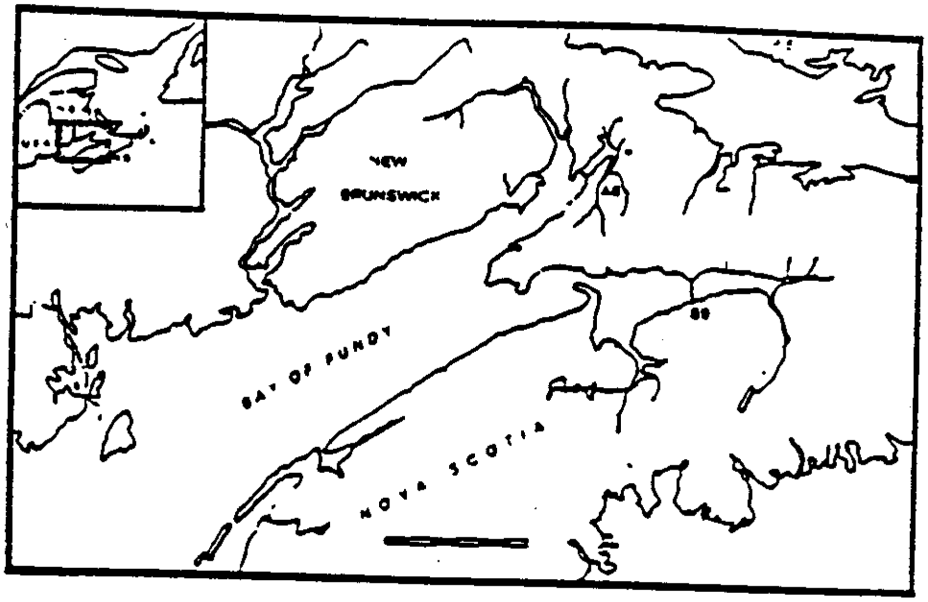
The area of the Delaware River in the vicinity of the cities of Camden, New Jersey, and Philadelphia, Pennsylvania, has a history of pollution problems. This problem is addressed in great detail in a Management Plan for the American Shad in the Delaware River Basin (DBFWMC, 1981). Pollution of the river results in depressed oxygen levels beginning in the spring and extending through the fall. The presence of extremely low dissolved oxygen, frequently reaching anoxia, during periods of spring spawning migration by adults or outmigration by juveniles has in the past served as a constraint on the success of the Delaware River American shad run. Pollution abatement programs over the last 20 years have decreased the organic loading in the Delaware River and contributed to a reduction in the magnitude and the duration of the oxygen block in the Delaware. This has provided an opportunity for more successful spawning runs and downstream emigration of juveniles, resulting in a dramatic increase in the Delaware River shad stock. Despite the success in reducing the duration of the oxygen block, detrimental oxygen levels still occur. Because this oxygen problem occurs in a location which can completely constrain the run (i.e., the pollution block extends across the entire river), any unusual condition, such as extremely low river flow that could aggravate the oxygen block, can have a dramatic impact on individual year-classes. Thus, the Delaware River shad run, despite being very successful within the recent decade, is extremely vulnerable to pollution conditions in one limited segment of the entire drainage system despite the fact that water quality is good upstream as well as downstream of the problem area.

Other Pollution Areas

Water quality conditions have also been considered to have impacted on alosids stocks in North Carolina in the Albemarle Sound area. However, the impact is not as clearly defined as in the case of the Delaware River. Changes in phytoplankton composition have been noted, with the occurrence of blue-green algal blooms and their presence in juvenile alosid guts noted (Johnson, 1982). While these indirect findings suggest a potential pollution effect on alosid stocks, the relationship has not been established rigorously. Similarly, pollution of nearly all estuarine waters along the east coast has certainly increased over the last 20 years, due to industrial, residential, and agricultural development on the watersheds. The general degradation of water quality is a coast-wide problem, although actions to decrease sewage discharges through the construction of sewage plants has actually decreased the levels of sewage nutrients discharged into coastal waters during the past 20 years. This decrease in organic enrichment would benefit the water quality conditions; however, it would not result in a reduction of other types of pollutant discharges into these waters, such as heavy metals, organic compounds, etc. The construction of the Blue Plains sewage treatment plant near Washington, DC, on the Potomac River, had an obvious effect in reducing nuisance algal blooms. The fact that American shad stocks in the Potomac declined during the same period that Blue Plains was reducing nutrient loading poses unresolved questions as to the effect of sewage chlorination and concurrent watershed development on shad stocks.

Bay of Fundy Hydroelectric Projects

Large tidal hydroelectric projects are currently being considered for construction in basins of the Bay of Fundy, Canada (Fig. II-14). These projects have been described in detail by Dadswell et al. (1983) and Gordon and Longhurst (1979). The two individual basins proposed as sites for hydrodevelopment are the Minas and Cumberland Basins. The very large tidal range in these areas, approaching 16 m in specific locations, provides a great potential for generation of electric power through control of water movement in these basins. However, Dadswell et al. (1983) have found that these particular basins are used extensively by American shad as foraging areas during summer months. The extensive tagging studies conducted by Dadswell and his co-workers have shown that fish from all runs along the east coast of the United States enter those specific basins. Dadswell has hypothesized that, in fact, these areas are critical to the success of all east coast shad stocks. Dadswell has also projected that construction of the proposed hydro projects with subsequent passage for American shad through turbines would cause major mortalities to all of the stocks. As described by Scarratt and Dadswell (1983) the situation in these basins is distinct from a circumstance in which the hydroelectric project is on a riverine system. In a river, fish would move through generating turbines only once, while in a tidal project fish may move into and out of



CHARACTERISTICS AND COSTS OF TIDAL POWER SCHEMES

	SITE B9		SITE A8
	1981 New Method	1981 New Method	
1. Total number of powerhouse units	106	128	37
2a Number of Sluices (Shallow)	6	70	—
2b Number of Deep Sluices	44	22	—
3. Number of Spare Units	6	8	2
4. Rated unit output MW	38	38	31
5. Installed Capacity MW	4028	4864	1147
6. Net Plant Capacity MW	3800	4560	1085
7. Net annual energy GWh	11766	14004	3183
8. Capacity Factor (%)	35.4	35.1	33.5
9. Cost Estimate ($x10⁶)			
(a) Total Direct Cost	3524	4011	1153.2
(b) Indirect and interest plus contingency	2493	3019	726.1
(c) Total Capital Cost	6017	7030	1879.3
10. Annual Charge (9c) x .05531	332.8	388.8	103.9
11. Cost of Energy mills/KWh	28.3	27.8	32.6

Figure II-14. Characteristics of tidal hydroelectric facilities proposed for Bay of Fundy estuaries (from Fundy Tidal Power Project Description, 1982).

basin with each tidal cycle. Thus, where turbines cause a relatively small percentage mortality with one passage, the cumulative mortality resulting from repeated passage into and out of the basin would result in substantial mortalities. Also of concern are the potential changes in the basin ecosystem structure. Scarratt and Dadswell (1983) raised the possibility that a reduction of exchange and mixing in these upper basins may reduce biological productivity, resulting in a decline in the forage value of planktonic communities.

Extensive work has been conducted and is continuing in Canada to document the patterns of movement of shad in the basins of the Bay of Fundy and the stock composition of the fish utilizing those areas. A portion of the tag return information was presented earlier in Fig. II-11. As of spring of 1983, nearly 10,000 shad have been tagged and released in the two basins. These tagging studies will not only provide information on the migratory patterns and origin of the stocks using the basins, but will also provide detailed information on mortality rates for all ages of shad. The studies have already shown that the Bay of Fundy is used by all age groups of shad, including both sexually mature and immature fish.

While neither of the proposed major tidal projects is currently in development stage, a prototype, small-scale project will begin operation in 1984 on the Annapolis River estuary in Nova Scotia. Considerable concern has been expressed by American fisheries agencies about the potential for the proposed projects to impact American shad stocks. This concern was conveyed in a letter sent from the Atlantic States Marine Fisheries Commission to all state and federal agencies having responsiblity for fisheries management (see Appendix C). This letter, distributed during the summer of 1983, elicited responses from a number of federal agencies and legislators, as well as a response from the U.S. Department of State. The State Department contacted the Canadian government to express concerns with the project. The Canadian government responded that they were aware of the concerns and that when and if additional development and planning occurred for these projects, fisheries impacts would be one of the major areas investigated. At the current time there is no ongoing development work on the projects. However, considerable predevelopment design and planning have been done and are continuing. Should economic circumstances become more favorable, development could procede rather rapidly. Thus, these projects must be monitored rather closely in order to ensure that the fate of the American shad is fully considered in any development.

I. RELEVANCE AND POTENTIAL VALUE OF ALTERNATIVE MANAGEMENT ACTIONS

Summary of Important Population Biology Aspects

The efficacy of any management action is a function of the life history characteristics of the species being managed. Thus the critical aspects of American shad population biology must be taken into account when considering the potential value of any management action. This summary of these critical aspects is drawn from the material already presented:

- River and coastal fisheries are directed at a very limited number of age classes; ages 4 and 5 make up the majority of American shad harvests along the entire east coast of the United States, with older age classes contributing somewhat more to harvest in northern states.
- Offshore fisheries, and Canadian fisheries in the Bay of Fundy during summer and fall, may take all year-classes, including sexually immature fish.
- All east coast stocks appear to mix at sea during coastal prespawning migrations, and during foraging periods in the summer in the Gulf of Maine and the Bay of Fundy.
- American shad are relatively short-lived, and vary latitudinally from being iteroparous (spawning only once in their lifetime) to semilparous (spawning more than once in their lifetime).
- Certain population characteristics (e.g., size at age, percent repeat spawning) vary latitudinally suggesting that management actions may have to be regionally specific.
- Current data suggest that, for the most part, recruitment may be independent of spawning stock size.
- Restoration efforts opening up new areas of spawning habitat appear to have the potential for adding substantially to the total east coast stock of American shad.

Assessment of the Potential Impact of Various Management Options

Different categories of fishing regulations differ in their ultimate effect on a given population. For example, size limits may influence the fishing mortality rate of specific age classes of fish, whereas gear restrictions may affect all age groups. Thus, in examining the various types of regulatory actions that may be used to manage American shad, it is necessary first to examine the effect on a given stock that certain types of manage-ment actions would have.

One broad category of management action is the implementa-tion of catch restrictions (i.e., the reduction in total harvest of a species). Catch restrictions would have different impacts on American shad stocks depending on which fishery is being re-stricted. In cases where a fishery is in place near the mouth of the spawning drainage system, the restriction on total harvest will increase the escapement of fish. In more northern areas, such an increase in escapement will not only increase the number of fish allowed to spawn in that year but may increase the probability of repeat spawning by those same fish in subse-quent years. The net effect of catch restrictions on river fisheries is to increase the number of fish spawning. However, as discussed in the population dynamics section presented earlier in this report, increasing the number of spawning adults will have an unpredictable impact on subsequent recruitment.

Restriction of offshore harvests and harvests of shad in the summer and fall fisheries in Canadian waters may have its greatest impact in reducing total mortality rates for sexually immature fish, which would make up the majority the impacted populations. However, as was discussed earlier, these fisheries are presently very limited in magnitude. Control of these harvests may represent more of a preventative action than a restorative one.

Restriction of harvest in coastal waters during spawning migrations may impact on the fishing mortality rate for fish of different drainage systems. Based on the migration patterns already described, more northern stocks may be exposed to greater fishing pressure than more southern stocks as they migrate north-ward along the coast. Restrictions on fishing effort in southern waters have the potential for influencing run size of northern stocks.

The magnitude of potential benefits of water quality im-provements may vary considerably by drainage system along the east coast. As was noted earlier in this report, the Delaware River run is vulnerable to seasonal declines in water quality in one specific segment of the entire drainage system. Improve-ments of water quality in that localized area have been extremely effective in enhancing the run in the Delaware. In other areas, such as Albemarle Sound, the more generic nature of water quali-ty problems, with less specific direct linkage to stock condition, makes the efficacy of water quality improvement less clear. Sim-ilar circumstances occur in most of the drainage systems along the coast, except where localized conditions in specific spawning areas or in restricted migratory paths may serve as total con-straints on the success of individual runs.

Restoration programs intuitively would appear to be an attractive management strategy in any portion of the range of American shad on the east coast, since they provide the opportunity to add fish to existing stocks with no detrimental impacts. However, the potential of restoration for contributing significantly has, to date, not been conclusively demonstrated. Success requires the existence of valuable habitat that is currently inaccessible to or unusable by fish, and a high potential for reestablishing runs through normal management actions (e.g., stocking of gravid adults in the spring, hatchery releases of juveniles, water quality improvements).

J. POTENTIAL EFFICACY OF REGULATORY CHANGES

The type of regulatory action that can have an influence on stock dynamics for American shad is, of course, dependent on its population biology characteristics. In contrast to fisheries for such species as cod, very few yearclasses of American shad are exploited (i.e., ages 4 and 5), and the individual fish are not long-lived. In such stocks, unrestricted harvest could result in stock overfishing as opposed to growth overfishing (i.e., instead of reducing the potential biomass harvest by harvesting fish too early in their period of growth, as could be the case for longlived species such as codfish and haddock, overharvesting may reveal itself in subsequent precipitous declines of the spawning stock). These particular aspects of the biology of American shad must be considered in developing a management strategy for the species. Specific regulatory actions must then be selected as the basis for carrying out that management strategy. For example, if it were to be determined that certain sizes, ages, or sexes must be protected, that strategy could be implemented by a number of different types of regulatory action, including the following:

<u>Gear Types</u> - The type of gear employed in a fishery very strongly influences the composition of the harvest taken from a given stock. Certain gears (i.e., gill nets) may be very selective for certain sizes of fish in contrast to other gears (i.e., pound nets), which have equal probability of capture for a broad range of sizes and ages of fish in the vicinity of the gear. Thus, limitations on the type of gear to be employed can be an effective means of altering the exploitation rates for given age, sex, or size category of the species.

<u>Gill Net Mesh Size</u> - Gill nets are an extremely selective gear type. Changes in the legal size of mesh of gill nets have a strong impact on the size frequency of fish captured by those nets. Proper selection of mesh size can result in differential harvest of different

age, size, or sex categories within any given species. In the case of American shad, harvest of mature females could be decreased by requiring smaller mesh size regulations. In addition, the composition of net material (i.e., monofilament vs twine) may have a substantial impact on the overall efficiency of the net; Leggett (1976) has shown that monofilament gill nets are much more efficient than twine gill nets for the capture of American shad. Thus, controls on composition of the nets may be a means of implementing regulated inefficiency in harvest.

Lift Or Closed Periods - Lift periods are those designated times during which fishermen are required to lift their gear (e.g., gill nets, pound nets) from the water to permit increased escapement of fish past the area of fishing. Since the major American shad fisheries occur near the mouth of the spawning rivers, fish that get past this primary location for fishing are almost certain to contribute to total fecundity of the run during that season. In general, lift periods and/or closing of fisheries permit additional escapement in direct proportion to the length of the lift. That is, a lift period of two days per week should, on the average, increase escapement by two-sevenths. However, the relative efficiency of lift periods may vary according to the pattern of the spawning run in a given year and the location of the major gears being used, in relationship to the major migratory routes of the species. In addition, lift periods for fisheries that are situated well into the major spawning areas for the species will not have the same potential value as the lift periods of fisheries situated at the mouths of rivers or along major migratory routes. The precise impact of lift periods on a given run in any given year may be relatively unpredictable.

Seasons - The period of spawning migration of American shad in any given drainage system appears to be strongly controlled by water temperature (Leggett and Whitney, 1972). While seasonal temperature patterns are relatively consistent on a long-term average, the specific temperature conditions in any one year may vary from that average considerably. Regulating the fishing season would help ensure a certain percentage of escapement of a given stock. However, as in the case of lift periods, the actual result of the given season in any given year may be rather unpredictable. Also, in a strongly seasonal fishery such as that for American shad, the use of seasons as a management approach may be inappropriate, since the species are only exploited for a brief period of time.

Locations of Fishing - Restrictions on the areas where fishing is allowed may have a substantial impact on the percentage escapement for a given run. Permitting fishing only near the entrance to a given drainage system ensures that fish passing the fishery will be available for spawning. In contrast, where fishing is permitted on the spawning grounds, the percentage of available stock that may escape the fishery will be much less predictable. Location of fishing may be the type of regulatory action that would make the effects of other types of regulations (such as lift periods) more predictable in total impact on the stock. Thus it may be important as one element of a multi-faceted management action.

Quotas - Quotas are defined as the optimal allowable harvest for a given stock to ensure acceptable subsequent recruitment in the stock. The implementation of the quota system for any given species is dependent on knowledge of the population biology of the species and the existence of a strong quantitative data base for all life stages of the species. In the case of American shad, the data bases necessary for establishing quotas are not available, and the population biology of the species suggests that recruitment, at least under normal conditions, is independent of stock size. In such a case, quotas may be an inappropriate means of manipulating stocks so as to influence subsequent stock size. However, quotas may play a role in allocation of the harvest among user groups where reduction of fishing mortality from all sources is desired.

Recreational Fishing Restrictions - The most common types of limitations placed on recreational fishermen are creel limits and size limits. Size limits in the case of American shad are an inappropriate management action, since they are generally implemented to prevent growth overfishing (i.e., to protect those size classes having the greatest potential for rapid growth before harvest). Size limits would only have an impact in terms of mortality by sex, since buck shad tend to be much smaller than roe shad. Creel limits would serve primarily as a means of allocating harvest among more fishermen, since unless the total number of recreational fishermen were limited, the total recreational harvest would not be controlled. The importance of recreational harvest control may be that in most cases recreational fisheries occur near the actual spawning grounds, in contrast to commercial fisheries which tend to occur near the entrances to the drainage systems.

Innovative Management Strategies

Certain aspects of American shad life history suggest that the optimal approach to management may be one which is flexible and permits alteration of regulations on a year-by-year basis in response to documented changes in spawning success from year-to-year. Crecco's extensive work on the Connecticut River (Crecco et al, 1983a,b) has suggested that the majority of mortality of American shad occurs between the egg and juvenile stage, and that year-class success is set by the time the juvenile stage is reached. Based on this premise, the spawning success of a run in any given year can be established by a detailed juvenile index survey. Fisheries for American shad are known to take mostly virgin fish of ages 4 and 5. Age of maturity by sex is reasonably well documented, as was noted earlier in the report. With a sound data base on relative juvenile abundance from year-to-year and the knowledge of the normal composition of the catch, fisheries management approaches may be outlined which would establish the allowable harvest in any given year based upon the juvenile index 4 and 5 years previously. While the success of such a management approach in terms of subsequent recruitment would not be predictable, it would permit implementation of restrictive regulations in cases where extremely poor spawning success has been documented. This would be a conservative, flexible management approach. It would ensure that fishing mortality would not be an additional source of mortality and stress to a stock already reduced to possibly dangerously low levels.

K. DATA DEFICIENCIES

Relatively little detailed information is available spanning long periods of time on the majority of shad stocks, as is the case with the majority of fisheries along the east coast of the United States. The single exception to this general pattern is the Connecticut River, where long-term data bases are available for almost all aspects of both life history and the fishery for the species. It is evident from the literature generated by the Connecticut River shad programs that the nature of the data being collected on the Connecticut would be the ideal type to be collected in all other major shad runs. Thus, the Connecticut River data base may serve as a benchmark against which to compare data available from the other systems. This comparison points out the major data deficiencies for American shad:

- Accurate catch and effort data - the need for accurate catch and effort data has been frequently stated in the past (Mansuetti and Kolb, 1953; Walburg and Nichols, 1967). This data was viewed as being of value because catch-per-unit effort indices may serve as an index of relative stock size. While accurate total catch data are essential for many different reasons (e.g., establishing economic value of the fishery), the value of accurate effort data has been placed in question by recent studies (e.g., V. Crecco, pers. comm.; Bannerot and Austin, 1983). In addition, the varied nature of the gear types used in fisheries for the species (e.g., stake gill nets, drift gill nets, run-around gill nets, pound nets) increases the complexity of definition of effort units. Thus, improvements in records of effort may be a fruitless activity.

- Long-term juvenile index data - The value of long-term records of relative juvenile abundance in establishing population dynamics characteristics of shad stocks has been demonstrated conclusively in the case of the Connecticut River. In addition, the Maryland juvenile index definitely foretold the decline of stocks in that state. Thus long-term juvenile index data may serve as an extremely valuable tool for establishing flexible management actions in response to the relative spawning success of the stock, as was discussed earlier. However, as was also discussed above, proper juvenile index surveys must take into account the nature of the nursery area of the species, changes in nursery area between years, the representativeness of sampling stations, the efficiency of the sampling gear being used, and all other relevant factors that may influence catch-per-unit sampling effort. If not adequately designed, juvenile surveys may yield misleading data.

- Stock discrimination data - Of particular concern with respect to stock discrimination are those fisheries where multiple stocks may be harvested. This would include fisheries in coastal waters (i.e., South Carolina), in offshore waters, and in Canadian waters. Identification of stocks that are being harvested would permit a clearer definition of total fishing mortality rates for individual stocks. Such data would also provide an objective means of implementing regulations in areas where interjurisdictional problems may arise because of harvest of nonresident stocks.

- Recreational catch data - In many of the major shad runs along the east coast, recreational fisheries are extremely important, both in terms of economic value as well as in potential impact on the stock on the spawning grounds. In general, recreational fisheries are poorly defined. Information on total recreational harvest may permit a clearer definition of management goals, and also may provide a basis for selection of proper regulatory approaches in managing stocks.

- Documentation of offshore harvest - Improved identification of offshore harvests of alosids would contribute to the general documentation of total fishing mortality of stocks of all species. Such information could also be augmented by stock discrimination information developed from samples of offshore harvests.

- Early life stage biological data - Work being conducted on the Connecticut River has strongly suggested that mortality rates from the egg to the juvenile stage are the dominant factors controlling year-class success and recruitment to harvests in future years. Because of the importance of mortality of these life stages for determining the subsequent success of the fishery, additional information should be developed to examine factors influencing these mortality rates. The potential for other factors, such as pollution, to act synergistically or antagonistically to already existing natural factors controlling year-class success should also be assessed.

III. HICKORY SHAD (Alosa mediocris)

A. BACKGROUND

The hickory shad is a more southern species than the cosmopolitan American shad, with spawning populations occurring from Florida northward, probably as far as New York. Older documents (e.g., Hildebrand and Schroeder, 1928; Bigelow and Schroeder, 1953) describe harvests of hickory shad in southern New England. However, they also note frequent misidentification of the species. Overview documents prepared by state fisheries personnel along the east coast report no current hickory shad spawning north of Maryland. In New York state, hickory shad are taken along the eastern shore of Long Island in May and June, but not in the Hudson River American shad fishery; however, this is viewed as an artifact of the fishing gear used in the Hudson being selective for the larger American shad (Brandt, pers. comm.). Hickory shad are smaller than American shad but larger than river herring (Fig. I-1).

As in the case of American shad, landings data represent the only potential long-term record of hickory shad abundance. However, there are a number of factors that make hickory shad commerical landings data of much poorer quality than American shad data. The close similarity in appearance of hickory and American shad frequently results in hickory shad being lumped with American shad in many landings reports. However, in some locations where directed fisheries exist for hickory shad, landings data are species specific. The accuracy of identification of hickory shad may also change with season. Since hickory shad runs begin somewhat earlier than those of American shad, all fish taken early may be identified as hickory shad. Overall, the value of recorded commercial landings of hickory shad as documentation of stock abundance is very questionable.

Reported commercial landings of hickory shad are presented in Table III-1. The data suggest a declining trend in abundance. However, the data limitations just discussed make conclusions about the magnitude and rate of decline difficult to establish. In addition, hickory shad frequently support rather extensive recreational fisheries; however, dependable recreational harvest data do not exist.

Subsequent sections of this chapter of the report are generally organized in the same manner as for the American shad, focusing on the nature of hickory shad fisheries by state, life history aspects relevant to management, and assessment of the efficacy of various management options. However, this report

Table III-1. Reported commercial landings of hickory shad on the east coast of the U.S. (pounds) (NOAA Fishery Statistics of the United States); dashed lines denote no catch reported; blanks denote no data acquired.

DATE	MD	VA	NC	SC	GA	FL	TOTAL
1950					8,000	14,874	22,874
1951					6,000	-	6,000
1952					9,000	-	9,000
1953					6,000	5,725	11,725
1954					0	1,189	1,189
1955					5,000	3,170	8,170
1956			268,082		8,873	21,626	298,581
1957			247,782	6,550	3,330	23,004	280,666
1958			83,985	560	3,119	19,217	106,881
1959	11,300	19,100	99,495	100	4,367	-	134,362
1960	1,874	10,300	180,703	2,586	3,844	-	199,307
1961	15,738	54,000	276,437	923	2,882	-	349,980
1962	6,864	42,100	171,650	791	1,699	-	223,104
1962	4,555	25,600	292,657	750	1,201	-	324,763
1964	14,697	49,542	232,892	1,962	1,030	-	300,123
1965	12,753	34,900	202,000	-	877	-	250,530
1966	8,454	41,265	196,596	-	1,913	-	248,228
1967	7,134	28,400	130,574	-	1,222	-	167,330
1968	6,825	13,830	141,305	-	11,308	-	173,268
1969	19,798	99,765	100,716	1,950	12,295	-	234,524

Table III-1. Continued

DATE	MD	VA	NC	SC	GA	FL	TOTAL
1970	40,132	23,909	61,424	2,600	4,491	-	132,556
1971	11,160	10,490	62,053	-	1,730	-	85,433
1972	22,288	26,803	69,190	3,399	2,515	-	124,195
1973	61,271	55,395	65,973	-	3,456	-	186,095
1974	12,957	41,189	41,725	-	343	-	96,214
1975	15,147	30,908	29,202	2,004	1,294	-	78,555
1976	4,680	3,620	18,716	-	555	-	27,571
1977	984	1,386	22,109	-	1,123	-	25,602
1978	1,394	1,622	20,507	-	2,079	-	25,602
1979	1,895	1,055	31,716	-	445		35,111
1980	2,101		91,501	720	410		94,732
1981	0		81,312	557	377		82,246
1982	0		24,742	676	867		26,285
1983	0		64,669	1,315	2,696		68,680
1984				888	2,862		3,750

segment will differ somewhat from both the American shad and river herring portions for two reasons: 1) the southern range of the hickory shad obviates the need for regional treatment of the fisheries, and 2) the absence of substantial information on many aspects of the life history of the hickory shad limit the depth of treatment.

B. INDIVIDUAL STATE FISHERIES

No commercial landings of hickory shad were reported in Florida after 1959. The occurrence of large harvests in 1956 through 1958, prior to absence of reports, is unexplained (Table III-1). Whether the absence of landings after 1959 was due completely to a decline of the stock or was attributable in part to the lack of landings being reported separately from those of American shad is not known. A very active sport fishery for shad formerly occured on the St. Johns River in Florida, but only about 2.4% of the catch were hickory shad (Walburg, 1960, cited in Rulifson et al., 1982). In recent years, commercially harvested hickory shad have been used primarily as bait in fish and crab traps (Williams et al., 1975).

In Georgia, hickory shad made up approximately 6% of the total shad harvest in 1968, while in 1979 the percentage declined to 0.3% (Michaels, 1982). Higher prices paid for female American shad caused the fishermen to select gill net mesh sizes that are inefficient for hickory shad; therefore, the decline in hickory shad harvest may be incidental to a shift in the direction of effort. For this reason, the fluctuations and/or trends in reported landings cannot be considered to reflect the status of hickory shad stocks. In the absence of specific survey data related to this species, the status of hickory shad in Georgia must be considered to be undefined. Fisheries for hickory shad in Georgia are almost entirely inland. Data collected in 1982 revealed that 90.4% of the hickory shad landed in the Altamaha River were taken in riverine waters, as opposed to the majority of American shad being taken in coastal waters (i.e., sounds and ocean) (Michaels, 1982).

A directed fishery for hickory shad does not exist in South Carolina; reported landings are taken as by-catch in American shad fisheries. Because of the large mesh sizes used in those fisheries, and because the fishery is timed to coincide with the peak of American shad migration, major portions of hickory shad runs may suffer no significant exploitation (Ulrich, 1982).

In North Carolina, there is an early directed fishery for hickory shad, which employs nets of smaller mesh size than those used for American shad and thus of greater efficiency for harvest of hickory shad. However, hickory shad are also harvested in the fishery directed at American shad in most of the major drainage systems in the state. In the American shad fishery, large females make up the majority of hickory shad landings. Most of the harvest is taken in pound and gill nets, but the species has also supported an extensive sport fishery. The North Carolina sport fishery for hickory shad was characterized by Marshall (1976) who reported very low stock levels at that time. Landings of formerly extensive sports fisheries have declined significantly in recent years (Johnson, 1982). Reported commercial landings of hickory shad in North Carolina have been low but stable for the past several years.

As in North Carolina, a limited early fishery directed at hickory shad occurs in Virginia. The emphasis on hickory shad is in effect until American shad runs begin, at which time there is a shift in direction of fishermen's effort. Gill nets account for the majority of hickory shad taken in Virginia (Atran et al., 1982). Active sport fisheries occur in most of the drainage systems having runs, generally in the freshwater tidal areas. Harvests of hickory shad in Virginia declined drastically in 1976 (Table III-1), and are currently stable at a very low level.

Virtually nothing is known of hickory shad stocks in Maryland. Reported commercial landings have declined in recent years, but reporting was probably erratic in the earlier years. For this reason, the magnitude and true extent of a stock decline cannot be assessed from the data. A major sport fishery had occurred in the Upper Chesapeake Bay on Octorraro Creek, a tributary of the Susquehanna River. This fishery declined precipitously in the mid-1970s and has never recovered. The evidence that exists points to a very dramatic decline of hickory shad in Maryland. The hickory shad fishery was closed in 1980 and remains closed.

C. MARKET FACTORS AFFECTING HARVEST

Dockside value of hickory shad (price per pound) by year by state is presented in Table III-2. The accuracy of the data are placed in question, in part, as a result of the mixing of hickory and American shad landings. The prices presented in the table are those specifically for hickory shad; other prices may be in effect when hickory shad are mixed with American shad. The perceived value of hickory shad differs markedly from state to state. In South Carolina and Georgia in recent years, for instance, roe hickory shad command nearly the same price as roe American shad, while in North Carolina the value differs by a factor of four. These types of price differentials would appear to be due to differences in the public and commercial perception of the species, as opposed to any specific difference in the quality of the fish. In addition, the smaller size of hickory shad may contribute to a lower value. Indications

Table III-2. Hickory shad dockside value, by state (rounded to dollars per pound); dashed lines denote no catch reported; blanks denote no data acquired (from NOAA Fishery Statistics of the United States).

YEAR	MD	VA	NC	SC	GA	FL
1950	0.07	0.05	0.05	0.10	0.14	0.04
1951	0.07	0.05	0.07	0.18	0.15	0.04
1952	0.06	0.05	0.04	0.16	0.15	
1953	0.10	0.05	0.04	0.12	0.17	0.03
1954	0.07	0.05	0.05	-	-	0.03
1955	0.08	0.04	0.05	-	0.20	0.03
1956	0.06	0.06	0.06	0.15	0.11	0.04
1957	0.04	0.04	0.06	0.06	0.08	0.05
1958	0.02	0.04	0.06	0.04	0.08	0.03
1959	0.05	0.05	0.06	0.02	0.08	-
1960	0.02	0.03	0.05	0.01	0.08	-
1961	0.06	0.06	0.05	0.06	0.02	-
1962	0.14	0.04	0.05	0.04	0.02	-
1963	0.06	0.04	0.03	0.03	0.04	-
1964	0.07	0.05	0.04	0.03	0.21	-
1965	0.08	0.03	0.04	-	0.09	-
1966	0.05	0.05	0.03	-	0.14	-
1967	0.14	0.07	0.06	-	0.03	-
1968	0.03	0.07	0.04	-	0.09	-
1969	0.10	0.03	0.05	0.15	0.17	-
1970	0.09	0.08	0.05	0.33	0.20	-
1971	0.09	0.09	0.05	-	0.28	-
1972	0.07	0.08	0.06	0.33	0.50	-
1973	0.12	0.13	0.04	-	0.25	-

Table III-2 (continued)

YEAR	MD	VA	NC	SC	GA	FL
1974	0.11	0.11	0.07	-	0.37	-
1975	0.13	0.26	0.06	0.35	0.36	-
1976	0.25	0.30	0.11	-	0.42	-
1977		0.32	0.08	-	0.56	-
1978	0.24	0.44	0.18	-	0.64	-
1979	0.31	0.12	0.16	-	0.70	-
1980						
1981		0.37				

from state fisheries personnel from all of the southern states suggest that there is no directed market for hickory shad, which are sold to the same customers who purchase American shad. A market exists primarily because hickory shad runs precede those of American shad. For this reason, the market factors discussed as influencing American shad landings would have a similar impact on landings of hickory shad.

D. LIFE HISTORY ASPECTS RELEVANT TO MANAGEMENT

General Life History Characterization

Very little is known of the general life history of the hickory shad. The limited amount of detailed information which is available has been developed through studies done in North Carolina (e.g., Mansuetti, 1962; Pate, 1972; Street, 1970; Street, 1969; Street et al., 1975). Older reviews are presented in Hildebrand and Schroeder (1928) and Bigelow and Schroeder (1953). Rulifson et al., (1982) reviewed much existing literature, including much that is anecdotal.

The time of spawning for hickory shad is from March to May in all the southern states, with runs beginning somewhat earlier in the more southern states (Rulifson et al., 1982). Specific locations of spawning areas are generally unknown, except in North Carolina (Marshall, 1976). Spawning occurs in freshwater in extensive segments of the river reach. Juvenile hickory shad are seldom caught, and there is some suggestion that they move downstream at an earlier age than other anadromous alosids. It has been suggested that hickory shad juveniles use estuarine waters as major nursery areas, as opposed to the other alosids that use freshwater nurseries (Pate, 1972; Sholar, 1977).

Oceanic distribution and movement patterns are almost entirely unknown. Lack of sufficient identification of hickory shad in offshore harvests results in no hickory shad being reported in the offshore fisheries. In North Carolina, hickory shad were taken from November to March in a year-round survey program in coastal waters, but they were not taken at other times of the year (Holland and Yelverton, 1973). These data suggest the possibility that hickory shad may move out of the North Carolina area from the beginning of the spawning run through the fall. Bigelow and Shroeder (1953) report occasional large harvests of hickory shad in southern New England in summer and fall. The occurrence of hickory shad in more northern states despite the absence of spawning runs in those states also suggests that hickory shad may undertake the same types of migration as American shad. However, no concrete data are available to document if this is in fact the case.

Age of Maturity and Repeat Spawning

Table III-3 presents age distribution data for samples of hickory shad taken from Florida to North Carolina. A wide age-distribution is evident in all of the runs, with no distinct differences in age of maturity between the sexes. Street et al. (1975) reported that repeat spawners made up approximately 50% of the total run of hickory shad in Albemarle Sound, while in the Neuse River, Pate (1972) found as high as 76% repeat spawning females. The only drainage system in which low repeat-spawning of hickory shad has been reported is the Northeast Cape Fear River, in which only 19% of the males and 9% of the females were found to be repeat spawners (Sholar, 1977). Similarly low values (15%) were found by Fischer (1980) in the same river. In contrast, Street and Adams (1969) reported 70 to 80% repeat spawners in the Altamaha River. In general, repeat spawning is very prominent in runs of hickory shad, as is also suggested by the common occurrence of fish between the ages of 6 and 8.

One caveat that must be considered in examining all hickory shad age and repeat-spawning data is that hickory shad scales are acknowledged by fisheries workers to be among the most difficult alosid scales to read. This difficulty suggests that some available age data may be of questionable accuracy, although the distinction between which data are questionable and which are not cannot be made. Another factor that must be considered in examining age distribution data is that percentage of individual year-classes in samples collected in any one year is strongly influenced by the relative magnitude of that year-class included in the sample. Thus, the most meaningful data are those which aggregate data collected from runs occurring over a period of years.

Size at Age

Table III-4 presents size-at-age data for fish from Florida, South Carolina, and North Carolina. As in the case of other anadromous alosids, females tend to be larger than males. The largest size groups (e.g., fish greater than 350 mm) are about the size of the smallest American shad. This size group, which is composed primarily of older female hickory shad, would be the group most susceptible to harvest as by-catch in American shad fisheries.

Mortality

Very limited data are available on mortality rates for hickory shad. Two values reported in the literature were 82%

Table III-3. Age composition (%) of hickory shad populations in river systems. M = males; F = females; C = sexes combined (From Rulifson et al., 1982)

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	SOURCE(S)
Neuse River										
1977	M		9	39	31	10	6	4	1	Marshall (1977).
	F		1	33	36	19	6	5	1	
1978	M			9	66	22	3	0		Hawkins (1979)
	F			9	64	20	6	1		
Northeast Cape Fear River										
1976	M			29	65	0	6			Sholar (1977b)
	F				45	55				
1978-79	M			52	33	15				Fischer (1980)
	F			10	40	50				
Santee River										
1974	C			21	31	48				Curtis (1974)
St. Johns River										
1971-74	M		12	62	12	12	2			Williams et al. (1975)
	F		2	73	10	13	2			

Table III-4. Size composition (mean fork length in mm) of hickory shad populations in river systems.
M = males; F = females; C = sexes combined
(From Rulifson et al., 1982)

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	SOURCE(S)
Albemarle Sound										
1975	M		289	325	350	371	360	365		Street et al. (1975)
	F		341	341	355	387	384	390		
Pamlico Sound & River										
1976	M		286	297	341	355	395	-		Marshall (1976)
	F		290	324	354	376	413	427		
Neuse River										
1972	M		294	332	346	356	357	369		Page (1972)
	F		311	354	376	395	409	420		
1977	M		294	336	344	356	381	384	397	Marshall (1977)
	F		307	343	357	367	386	415	411	
1978	M			325	343	352	361	-		Hawkins (1979)
	F			338	362	369	403	403		
White Oak River										
1974	M			345	-					Sholar (1975)
	F			-	318					
Northeast Cape Fear River										
1976	M			291	331	-	433			Sholar (1977b)
	F			-	326	349	-			
1978-79	M			300	316	354				Fischer (1980)
	F			308	338	370				
Santee River										
1974	C			411	467	487				Curtis (1974)
St. Johns River										
1971-74	M	-	315	340	358	376	384			Williams et al. (1975)
	F	216	326	352	370	400	420			

total annual mortality in 1977 (Loesch et al., 1977) and 47% in 1978 (Johnson, et al., 1978). These high values would appear to be inconsistent with the high percentage of repeat spawners reported in most hickory shad studies. The overwhelming evidence that repeat spawners make up the majority of hickory shad runs suggest that these mortality values are of questionable validity.

In addition, escapement data also suggest relatively low fishing mortalities. Godwin (1968) reported hickory shad escapement rates in the Altamaha River of 70.2% for females and 87.1% for males.

Other Life History Aspects

All other aspects of the life history of hickory shad are more poorly documented than those aspects just discussed. Any management actions proposed for this species will therefore have to be taken with a very limited biological foundation.

E. MANAGEMENT AND RESTORATION

Because of the lack of detailed information on both fisheries and life history of the species, no actions have been taken by any state directed specifically at hickory shad, except in the case of Maryland, which has closed the hickory shad fisheries. While there have been apparent drastic declines in runs of hickory shad in a number of drainage systems in the southern states, no restoration efforts have been initiated.

F. RELEVANCE AND POTENTIAL VALUE OF VARIOUS MANAGEMENT ACTIONS

Relevant Aspects of Life History and Fisheries

Three major aspects of hickory shad life history are of particular relevance for management of the species:

- Spawning runs are phased somewhat earlier than those of American shad
- Larger roe hickory shad probably suffer the greatest fishing mortality of all segments of the hickory shad population

- A high percentage of repeat spawning of the species suggests that the populations may be dependent on relatively low annual mortalities to remain viable; if this were the case, excessive annual mortality could be detrimental to population stability.

Assessment of the Potential Impact of Various Management Options

Management actions that result in a reduced harvest of hickory shad would have greatest influence on the mortality rates of large, older females. Because fecundity is directly related to body size in most species, restrictions on commercial harvests of hickory shad could substantially increase the total fecundity of a run in any given year, if the run had been exposed to significant fishing mortality in the past. However, the result of increased run fecundity on subsequent recruitment and run size is not known.

Water quality improvements, as was discussed in the case of American shad, might improve the quality of spawning and nursery habitat and/or provide additional suitable habitat for the species. However, no dramatic water quality changes have been documented in any of the systems in which drastic declines in hickory shad appear to have occurred (e.g., comparable to the circumstances in the lower Delaware River). Thus, the role of water quality in influencing the dynamics of hickory shad in the past two decades is undefined.

Restoration of hickory shad runs to drainage systems where access had historically been restricted, would, as in the case of American shad, contribute new fish to existing stocks. However, so little is known about hickory shad that it is difficult to determine areas in which runs may have previously occurred and where they are now absent. Rulifson and Huish (1982) list many streams in the South which are thought to have hickory shad runs but their status is not known. Another factor that may limit the feasibility of restoration may be the lack of available stock for transplanting and a lack of knowledge of proper handling procedures.

G. POTENTIAL EFFICACY OF REGULATORY CHANGES

Seasons

Because hickory shad runs precede those of American shad, regulating seasons for shad fisheries may be an effective means of minimizing fishing mortality rates of large hickory roe shad. However, as was discussed above, the consequence of enhancing run fecundity by minimizing harvest of this particular population segment is unclear.

Gill Net Mesh Sizes

Since hickory shad are taken primarily as by-catch in American shad fisheries, mesh size regulations may have a substantial effect on the fishing mortality rates for the species. Restrictions on the mesh size that would eliminate the use of smaller mesh nets would be certain to decrease fishing mortality rates for hickory shad.

Gear Types

Except for restrictions on gill net mesh sizes, discussed above, little could be done that would differentially affect the harvest of hickory shad as opposed to American shad. This is especially true since so little is known about hickory shad migration patterns and habitat usage. If in fact it were known that hickory shad follow different migratory paths within the drainage systems, limitations on specific types of gear, which selectively fished different types of water, might be a means of controlling the hickory shad harvest.

Lift or Closed Periods

The influence of lift or closed periods during hickory shad runs would have the same impact on hickory shad as was discussed for American shad. That is, the length of a lift within any given period of time (i.e., days per week) would result, on the average, in additional escapement proportional to the relative length of the lift period. Additional escapement would increase total run fecundity.

Catch Quotas and/or Restricted Entry

The almost total lack of information on hickory shad population dynamics, abundance, and general life history essentially eliminates these management approaches as viable options. The data and information bases needed to establish such restrictions do not exist. In addition, the mixing of hickory shad with American shad landings, and the probable misidentification of substantial portions of the total harvest make such a regulatory approach impractical and unenforceable.

H. DATA DEFICIENCIES

Very little is known of hickory shad runs throughout most of their range. Hickory shad are taken incidental to fisheries directed at other species, and even in the case of directed fisheries, only portions of the run are fished intensively. The limited knowledge of life history, in particular the estuarine and coastal migration patterns, suggest that a first step in alleviating data deficiencies should be to undertake life history studies throughout the range of the species. Such information would be vital for the design of studies which would be directed at developing more management-specific data bases, such as:

- Juvenile abundance indices
- Population dynamics characteristics (i.e., mortality rates by life stage)
- Characteristics of spawning, nursery, and foraging habitat.

In addition, the mixing of hickory shad with American shad harvests suggests that although valid catch and effort data might be desirable, acquisition of such information is impractical. The complexity of the fisheries capturing hickory shad suggests that use of catch-per-unit effort-type indices for tracking stock abundance may be impossible. This, in turn, suggests that stocks would have to be monitored using some type of scientific survey approach.

IV. RIVER HERRING: ALEWIFE (*Alosa pseudoharengus*) AND BLUEBACK HERRING (*Alosa aestivalis*)

A. BACKGROUND

The term "river herring," which is applied to both alewife and blueback herring throughout their range along the east coast of the United States, is based on the anadromous nature of both species. It is used generically because in commercial harvest no distinction is made between the two species. As a consequence, all available fisheries data consists of combined harvests of the two species. Thus the use of commercial landings data in assessing trends in abundance of both species requires that they be considered together. In this report, trends in stocks will be discussed in reference to both species together. However, where information is available and appropriate, species-specific material will be presented.

Range

The alewife is the more northern species of the two, being found from Nova Scotia to South Carolina, with the center of distribution skewed towards the northern states (Hildebrand and Schroeder, 1928; Leim and Scott, 1966). Blueback herring have a relatively cosmopolitan distribution along the east coast, occurring from Nova Scotia in the north to Florida in the south (Hildebrand and Schroeder, 1928; Leim and Scott, 1966). However, their center of distribution along the coast is definitely to the south, and they represent the anadromous river herring that occurs in the most southern states.

Historical Trends in Fisheries

Fisheries for river herring have changed dramatically over the last hundred years. In the 1800's and early 1900's, river herring were harvested and salted as food fish, and extremely large harvests were made (Bigelow and Schroeder, 1953). Since that time, both the markets and the nature of gear used in these fisheries have changed drastically. In recent years, the major use of river herring has been for bait (for crab, lobster, and fish), pet food, and reduction to fish meal. Such use varies by geographical region. For example, in Maryland nearly all river herring harvests have been used for crab bait, in Rhode Island nearly all is used for lobster bait, and in Virginia substantial amounts are used for pet food.

Historical records of domestic landings of river herring are presented in Fig. IV-1 and Table IV-1. In addition to domestic landings, substantial offshore landings of river herring were reported by foreign fisheries operating in coastal waters during the late 1960's and early 1970's. The pattern of offshore landings is indicated in Fig. IV-1. Offshore harvests of river herring declined in the mid-1970s concomitant with a decline in the level of foreign fishing effort off the U.S. coast, when the new 200-mile Fishery Conservation Zone was created in the United States.

River herring landings declined abruptly in the beginning of the 1970's. Recent total landings for the entire east coast are the lowest in history. Subsequent portions of this section of the report will follow the format of the American shad segment.

B. RECENT TRENDS IN LANDINGS ON A REGIONAL BASIS

Relevance of Landings Data to Stock Assessment

Factors influencing the relationship of American shad commercial landings to stock size were discussed in section II of this report. Many of those same factors, as well as several others, influence that relationship in the case of river herrings.

- Abundance of the stock
- Amount of fishing effort (e.g., number of nets fished, number of days fished)
- Influence of market factors on the fishing effort (e.g., price per pound at any given time)
- Influence of environmental conditions on effectiveness of effort (e.g., weather conditions, river flow, bottom topography through their effect on the catchability of fish by particular gears)
- Unreliability of catch reports, particularly where harvests per individual may be relatively small; in some states, substantial river herring harvests are made by individual unlicensed fishermen fishing with dip nets, who have no reporting requirement; in cases where fish are harvested for use as bait by the fishermen actually

Table IV-1. River herring catch (in thousands of pounds) per state and total Atlantic coast for years of available data. Data are from U.S. Dept. of Commerce Fishery Statistics of the United States (from PSEG, 1982b), and other sources as noted. Dashed lines denote no catch reported; blanks denote no data acquired.

Year	FL[2]	GA	SC	NC	VA	MD	DE	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1887	-	25	(1)	23,747	4,402	11,062	*	4,085[1]	*	18	1,430	4,130	100	2,526	
1888	-	24	(1)	20,451	6,453	11,512	*	3,881[1]	*	25	1,589	6,292	147	2,836	
1889	-	36	37	19,316	-	-	-	-	-	53	1,307	3,911	140	4,022	
1892	-	-	-	-	-	-	-	-	-	681	1,190	3,651	50	2,276	
1896	-	-	-	-	12,198	17,667	-	-	-	1,001	2,077	5,356	294	3,388	
1897	-	25	2	-	13,690	17,139	-	-	-	-	-	4,779	239	1,249	
1898	-	-	-	-	-	-	-	-	-	868	1,012	2,900	325	3,619	
1902	-	22	-	15,173	-	-	-	-	-	1,663	705	4,517	475	3,341	
1905	-	-	-	-	-	-	-	-	-	1,232	599	4,861	122	3,082	
1908	-	32	-	12,530	37,885	28,805	-	-	-	1,025	288	4,062	121	2,085	
1919	-	-	-	-	-	-	-	-	-	177	270	3,064	0	1,296	
1920	-	-	-	-	16,665	7,072	-	-	-	-	-	-	-	-	
1921	-	-	-	-	18,834	6,505	-	-	-	-	-	-	-	-	
1922	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1923	-	-	0	8,989	-	-	-	-	-	-	-	-	-	-	
1924	-	-	-	-	-	-	-	-	-	116	391	2,593	0	1,583	
1925	-	-	-	-	17,910	7,701	-	-	-	-	-	-	-	-	
1926	-	-	-	-	-	-	*	2,490[1]	*	-	-	-	-	-	
1927	-	-	2	11,911	-	-	-	-	-	-	-	-	-	-	
1928	-	-	2	7,808	-	-	-	-	-	16	161	2,248	0	2,132	
1929	408	-	0	10,768	12,570	5,924	*	1,223[1]	*	9	119	1,386	58	2,821	35,286
1930	366	-	2	9,839	15,387	5,741	*	3,856[1]	*	1	186	1,790	0	2,129	39,297
1931	321	-	0	7,994	17,239	7,827	*	3,615[1]	*	27	127	2,212	0	2,796	42,158
1932	80	-	0	6,584	13,852	7,553	*	2,191[1]	*	19	73	1,164	20	2,296	33,832
1933	148	-	-	-	19,177	6,550	*	1,381[1]	*	15	176	923	0	1,703	40,410
1934	315	-	0	14,897	5,846	5,234	*	-	-	-	-	-	-	-	

Table IV-1. Continued

Year	FL[2]	GA	SC	NC	VA	MD	DE	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1935	224	-	-	-	10,974	4,229	*	555[2]	*	18	55	959	0	3,374	31,652
1936	232	-	0	11,929	8,,609	3,369	-	-	-	-	-	-	-	-	
1937	400	-	0	5,818	15,064	3,819	*	3,819[2]	*	85	218	1,086	0	2,818	33,127
1938	392	-	0	11,219	17,691	5,397	*	5,397[2]	*	28	181	958	0	3,140	44,403
1939	320	-	0	7,714	14,831	4,398	147	35	60	14	23	946	0	2,954	31,442
1940	408	-	0	8,708	11,433	4,679	124	35	62	34	20	879	0	2,260	28,642
1941	412	-	0	-	11,951	5,061	-	-	-	-	-	-	-	-	
1942	416	-	-	-	9,258	3,422	11	58	399	6	200	984	207	2,368	
1943	420	-	-	-	-	-	-	-	-	-	-	-	-	-	
1944	424	-	-	-	17,841	3,504	33	40	10	12	175	2,266	218	2,526	
1945	428	0	0	8,022	14,619	2,584	90	14	261	20	0	988	163	1,358	28,533
1946	419	0	-	-	12,029	3,497	-	-	123	3	217	1,249	-	1,225	
1947	400	0	-	-	22,173	2,746	12	324	89	4	751	633	74	1,499	37,567
1948	386	0	-	-	19,365	3,720	6	171	132	675	317	468	80	1,868	36,474
1949	372	0	-	-	22,003	4,965	26	20	99	1,146	134	502	4	3,281	41,582
1950	358	0	0	6,422	28,702	5,926	47	29	104	1,948	312	270	0	3,166	17,284
1951	514	0	0	12,534	32,604	6,752	37	7	75	490	905	276	0	3,479	57,673
1952	278	0	0	6,511	28,841	4,494	122	1	90	1,061	181	1,905	0	2,783	46,267
1953	0	0	0	13,842	23,976	4,653	104	9	57	340	216	5,535	0	2,443	51,175
1954	51	0	0	12,758	27,930	3,981	76	0	84	973	17	3,020	0	3,296	52,186
1955	57	0	0	12,648	21,843	5,145	1	23	102	890	46	2,621	0	3,779	47,155
1956	77	0	0	12,554	22,107	5,026	1	22	68	79	55	8,922	0	4,588	53,499
1957	30	0	0	11,773	18,758	3,410	8	8	56	63	29	19,027	75	3,969	57,206
1958	127	0	0	14,914	18,361	4,391	0	1	66	10	12	33,815	60	3,095	74,852
1959	16	0	0	14,154	17,447	4,484	0	2	46	8	341	11,618	80	1,631	49,827
1960	26	0	0	12,815	15,464	3,525	3	3	38	20	0	17,651	95	1,412	51,052
1961	2	0	0	11,951	15,526	2,444	(1)	17	34	6	0	20,838	100	1,667	52,585

Table IV-1. Continued

Year	FL[2]	GA	SC	NC	VA	MD	DE	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1962	0	0	0	14,302	25,300	2,378	0	20	38	19	0	8,276	125	1,682	52,140
1963	23	0	0	15,100	26,085	1,466	0	3	32	3	129	11,735	150	1,480	56,206
1964	2	0	0	7,561	26,640	1,314	0	14	37	15	140	5,529	75	1,480	42,807
1965	21	0	2,760	12,826	36,200	2,092	0	22	24	24	210	6,935	125	3,106	64,345
1966	0	0	2,817	12,519	28,535	1,433	0	12	4,188	7	192	6,633	75	1,786	58,197
1967	0	0	2,802	18,486	28,107	2,337	0	9	4	23	186	5,432	65	1,617	59,068
1968	0	0	2,820	15,525	32,319	3,963	0	8	7	33	203	117	41	2,249	57,285
1969	0	0	1,975	19,762	30,446	3,458	0	5	9	11	215	100	38	1,768	57,787
1970	0	0	100	11,521	19,046	2,065	0	8	11	122	144	1,156	31	1,623	35,827
1971	0	0	718	12,722	10,285	2,811	0	10	0	25	53	222	25	1,954	28,825
1972	0	0	297	11,237	10,451	1,690	0	15	(1)	23	34	1,907	24	2,216	27,894
1973	0	0	433	7,926	9,269	2,031	(1)	7	22	14	15	695	22	2,691	23,126
1974	0	0	87	6,210	13,342	1,388	(1)	11	15	17	36	229	0	3,310	24,645
1975	2	0	18	5,952	11,360	718	(1)	9	15	36	41	1,717	0	3,768	23,637
1976	1	0	67	6,402	4,238	126	(1)	11	1	67	34	45	0	3,395	14,387
1977	1	-	282	8,523	1,390	102	(1)	11	0	64	3	30	12	3,374	13,756
1978	-	-	196	6,608	2,127	201	(1)	2	0	61	2	40	11	2,781	12,076
1979	-	-	334	5,119	1,688	1,150	6	7	0	42	6	38	10	2,305	9,690
1980	-	-	661	6,219	1,184	738	(1)	19	1	63	2	5	0	2,645	10,978
1981	-	-	-	4,754	520	151	0	14	65	53	-	5	-	2,327	7,889
1982	-	-	>309	9,438	1,307	590	0	14	229	42	5	25	114	1,390	13,463
1983	-	-	636	5,864	1,838	119	1	2	124	37	6	50	107	1,187	9,871
1984	-	-	625	11,700	972[3]	113		3	4	32	1	90	43	817	
1985	-	-												900	

(1) Denotes less than 500 lbs
1 Regional total from Joseph and Davis, 1965
2 From Boreman, 1982
* Landings aggregated under New Jersey
3 Preliminary

TOTAL RIVER HERRING LANDINGS

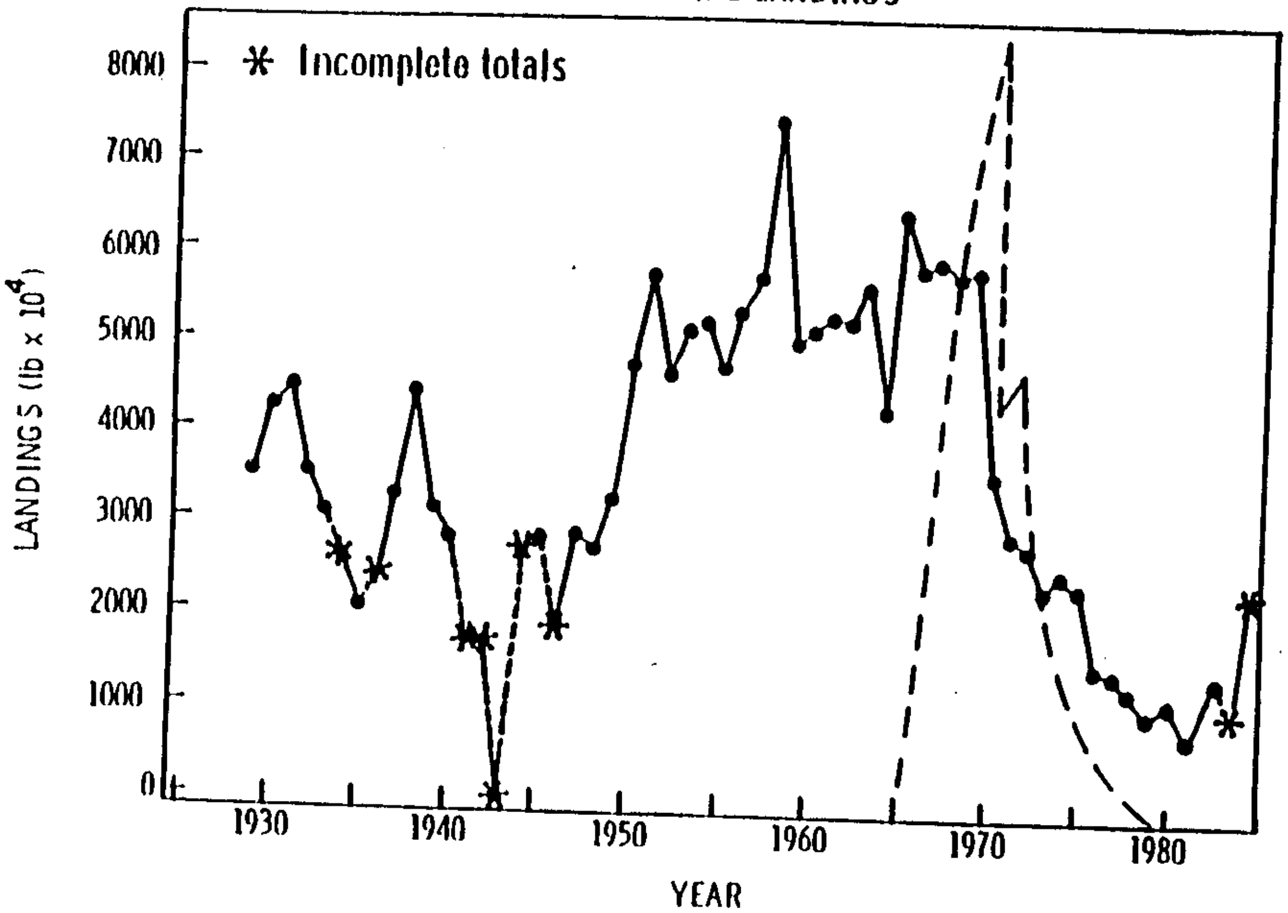


Figure IV-1. Reported commercial landings of river herring (sometimes recorded as "alewife" in landings records) along the east coast of the United States, 1929 to 1984; data are from NOAA Fishery Satistics of the United States and ICNAF. Dashed line represents offshore harvest by foreign fishing vessels.

using the bait (i.e., not involving established dealers or middlemen), harvest reporting may be poor; in Virginia, logbook records recorded for personnel at the Virginia Institute of Marine Science frequently exceeded the totals that eventually were recorded as harvest by the Virginia Marine Resources Commission (J. Loesch, personal communication).

- Unexplained reporting inconsistency up to 1950's; many states having active river herring fisheries reported no harvest during that period of time; thus for many years in the long-term record, total east coast harvest of river herring is not known.

River herring fisheries employ a wide variety of gear types. Quantification of effort for many of these gear types is extremely difficult (e.g., dip net, nondirected gill net). Furthermore, the normalization of the effort of units across all gears is essentially impossible. For these reasons, the use of catch-per-unit-effort (CPUE) as an index for stock abundance along the entire east coast is not possible. Even within individual regions or states, the same factors may make use of CPUE of questionable value.

The nature of the river herring fisheries has changed dramatically over the last 50 years. Whereas in the early 1900's most river herrings were landed for human consumption, only a very small proportion of current landings is used for that purpose. Currently, the amount of fishing effort exerted in river herring fisheries may be strongly influenced by logistics and other factors independent of stock abundance. For example, in fisheries where harvest is sold to dealers for reduction to fish meal, the existence of a single major dealer may determine the existence of the fishery.

There are extensive recreational fisheries for river herring in many areas along the east coast. While some are of the hook and line type (i.e., in the Delaware River), many permit various types of dip nets and seines. The total quantities of fish landed by these recreational netters for personal use may be quite large. All of these landings are unreported, and thus represent a large potential error in recorded river herring harvests.

In Florida, official NOAA landings records record "alewives" as being taken along the west (Gulf) coast in recent years (i.e., since 1972). No river herring runs exist on the west coast of Florida, and the landings recorded as alewives are undoubtedly misidentified.

Overall, river herring landings data may not represent stock abundance very accurately. The data probably are less reliable than American shad data but more reliable than hickory shad data. The many factors influencing river herring reported commercial landings may explain the large degree of variability observed in data on a state-by-state basis (Table IV-1).

Regional Characterization of Fisheries Based on Landings Data

River herring landings in New England are illustrated in Fig. IV-2. The most distinctive characteristic of landings in this region is the series of large landings occurring from the mid-50s to the mid-60's, which can mostly be accounted for by large reported landings in the state of Massachusetts. These may be explained as being a response of menhaden purse seiners switching to river herring as an alternative species when menhaden stocks declined. Purse seine harvests in Massachusetts are discussed later in the report. Landings in the state of Maine, which are the major component of New England landings at other times, have remained relatively stable at a high level for the last two decades. Landings in the remaining states have either declined dramatically (i.e., Rhode Island, New Hampshire) or have remained stable at low levels (Connecticut).

In the middle Atlantic region, landings have been consistently low over the last 40 years (Fig. IV-3). A single anomalous harvest of over 4 million pounds was reported by the State of New York in 1966. This particular record appears to be another case of menhaden fisheries exploiting river herring as an alternative source, based on NOAA records of harvest by gear. Although river herring appear to be abundant in the middle Atlantic region, as will be discussed under individual state discussions below, only limited fisheries exist for them.

River herring landings in the Chesapeake region (Fig. IV-4) have fluctuated as much as 100% over the last 40 to 50 years. However, in the 1970s, they declined to historically low levels and never rebounded. The decline was somewhat more marked in Maryland than in Virginia, with respect to current magnitudes of harvest. However, when viewed from the perspective of the percentage decline from historical levels, Virginia stocks have declined more. Recent harvests are the lowest ever reported for either state, and are the primary reason that total current, east coast landings are extremely low.

Landings in the south Atlantic region have fluctuated widely in the past, and are strongly influenced by changes in effort in different years. Although recent landings are the lowest ever reported, past landings also have been quite low (Figure IV-5).

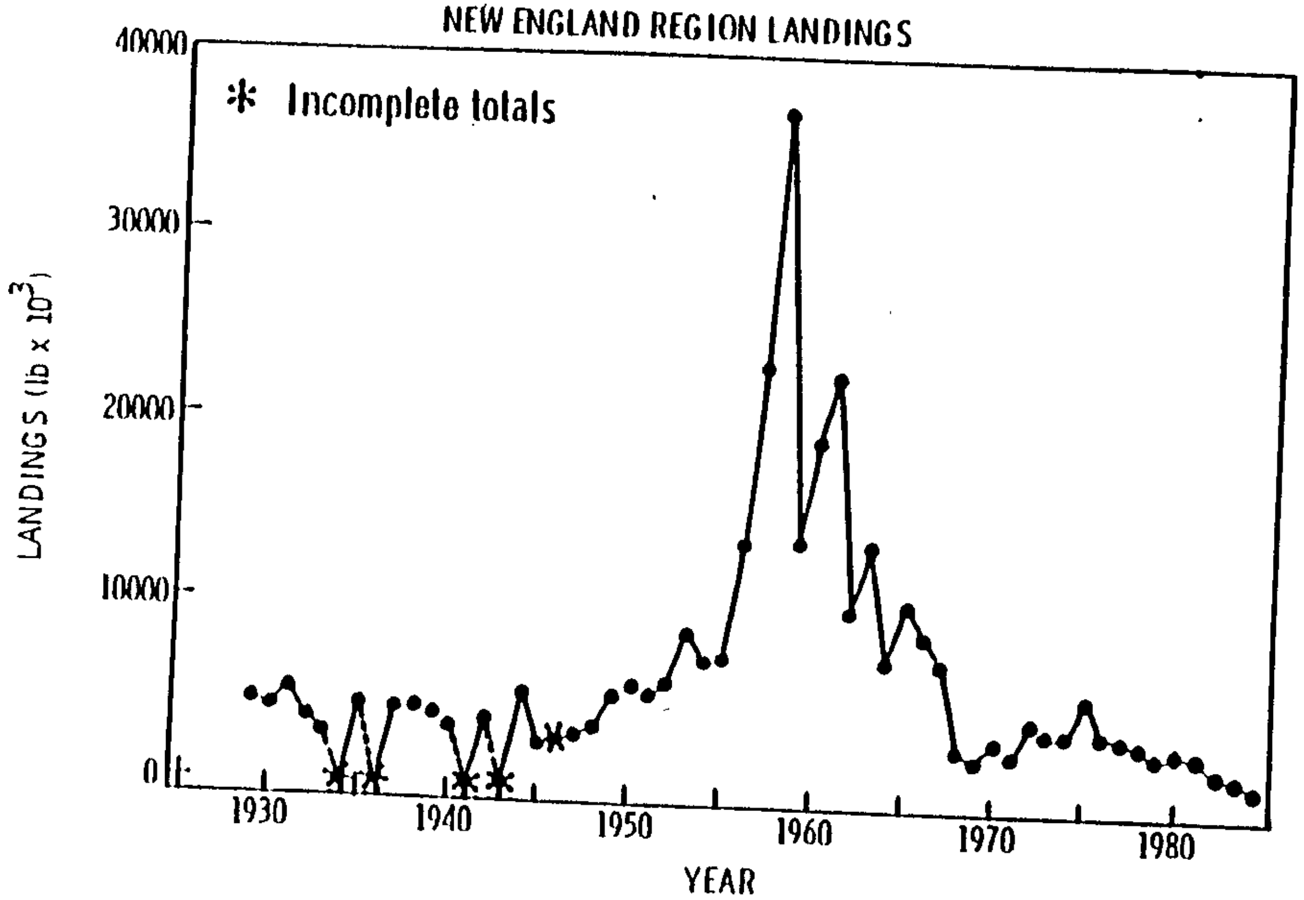


Figure IV-2. Reported commercial harvest of river herring ("alewife") in the New England region, 1929 to 1984; sources of data are noted on Table II-1

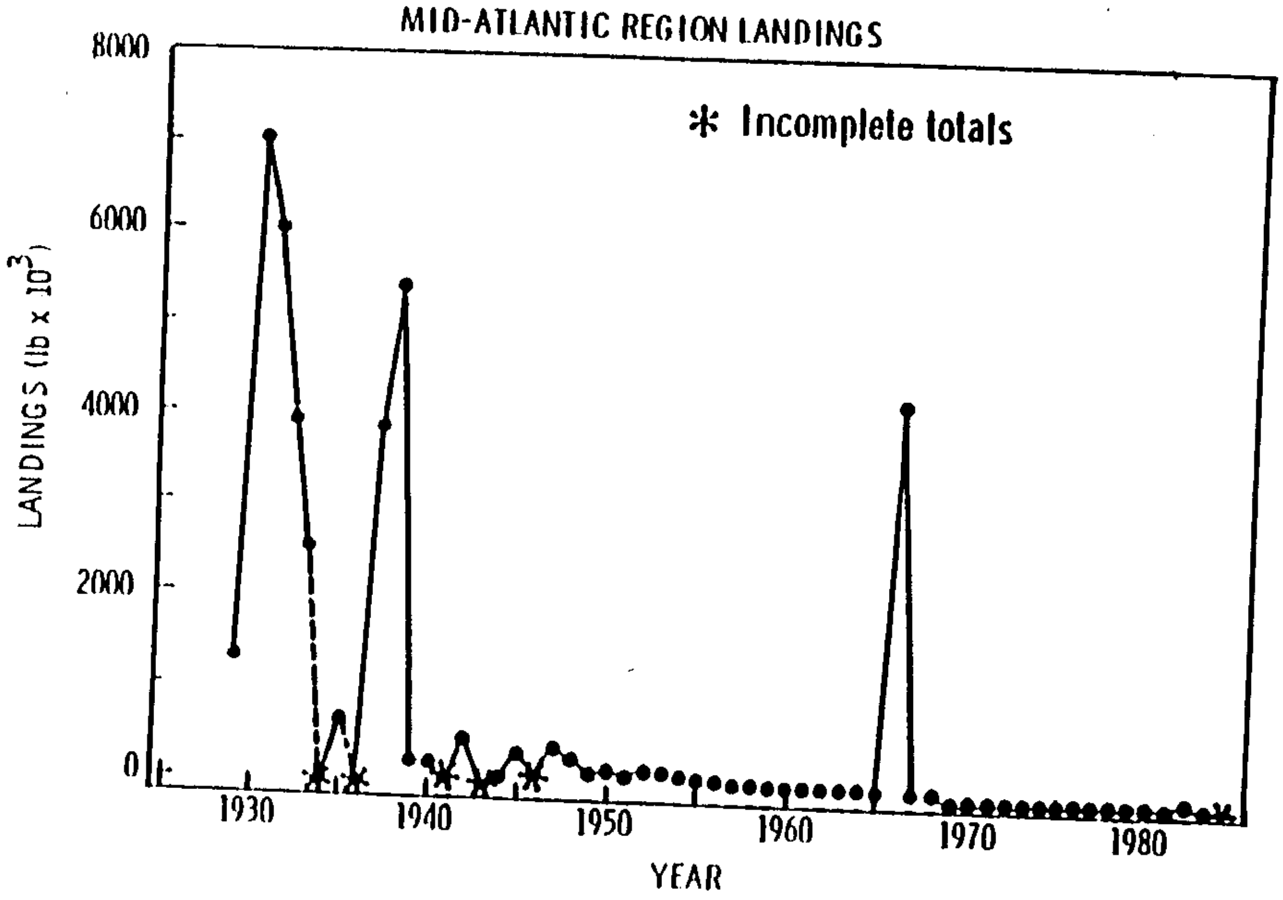


Figure IV-3. Reported commercial harvest of river herring ("alewife") in the Mid-Atlantic Region, 1929 to 1984 (data sources are noted on Table IV-1)

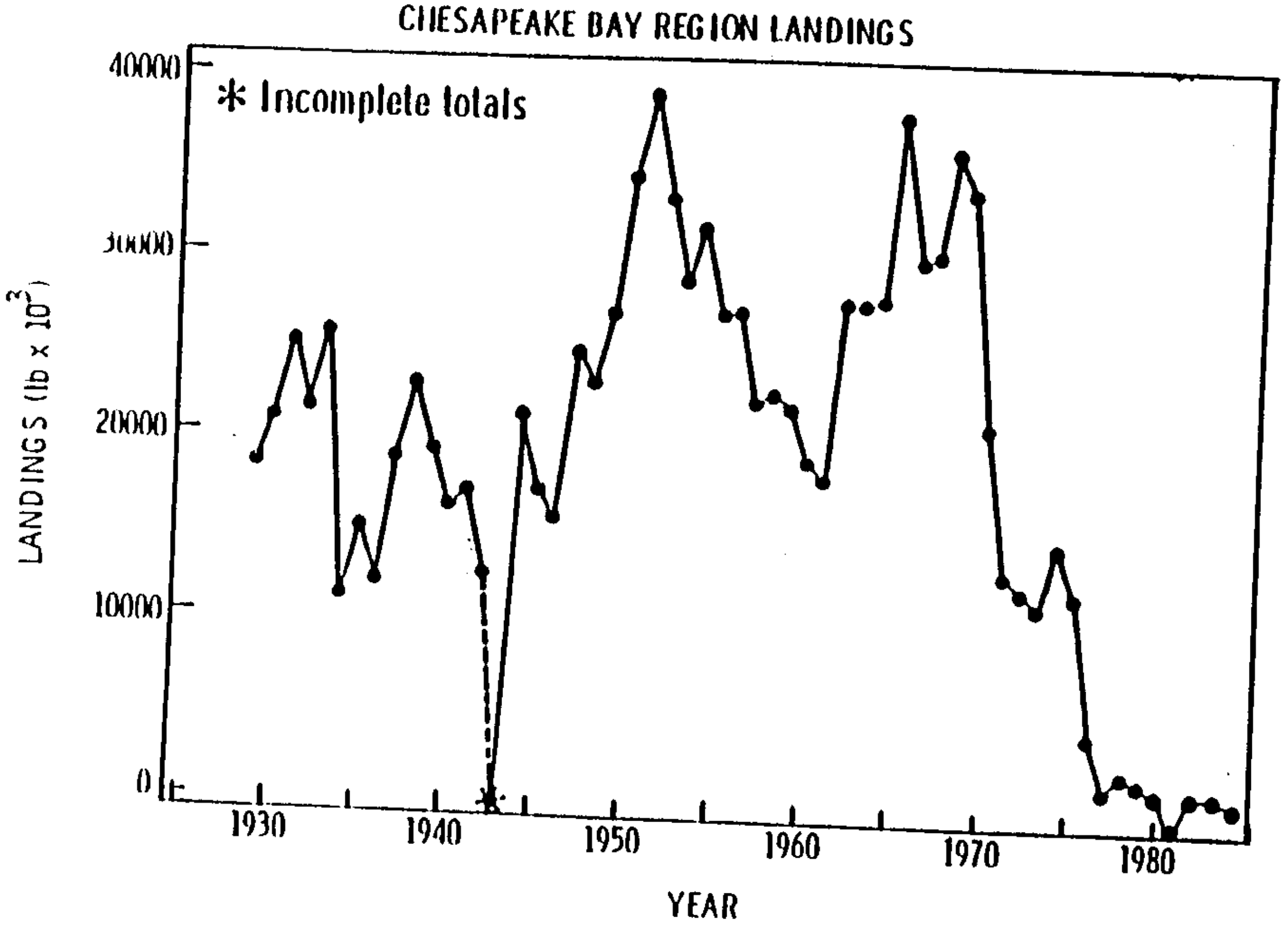


Figure IV-4. Reported commercial harvest of river herring ("alewife") in the Chesapeake Region, 1929 to 1984 (data sources are noted on Table IV-1)

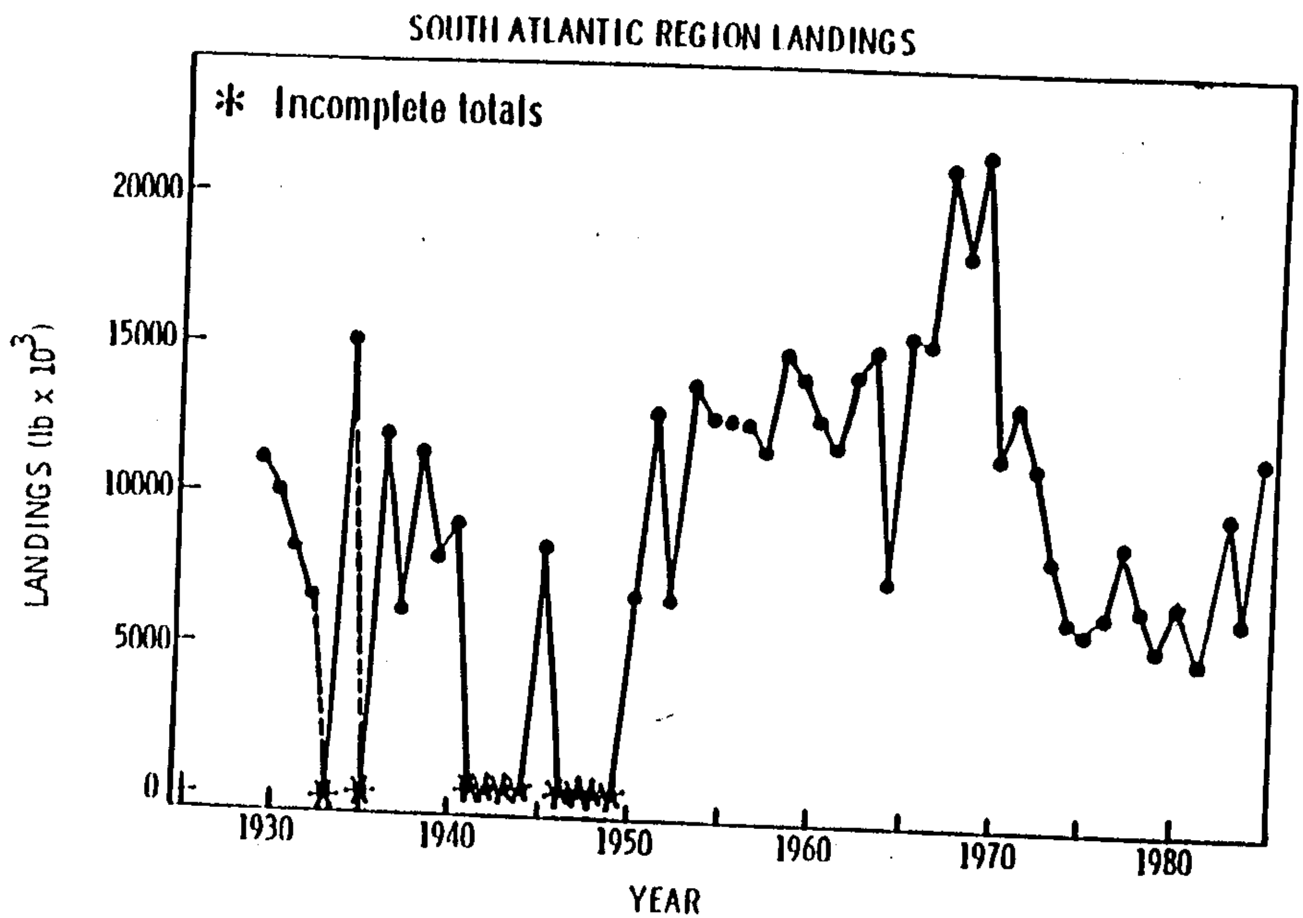


Figure IV-5. Reported commercial harvest of river herring ("alewife") in the South Atlantic region, 1929 to 1984; sources of data are noted on Table IV-1

C. CHARACTERIZATION OF FISHERIES ON A STATE-BY-STATE BASIS

Trend and Gear Usage and Fisheries Characteristics

In order to assess trends in the nature of river herring fisheries on a state-by-state basis, NOAA data were compiled for 1965, 1970, and 1976. The percentage of harvest by various gear types by state over time are illustrated in Tables IV-2, 3, and 4. The types of gear used in river herring fisheries differ substantially by region. Haul seines, dip nets, and weirs predominate in New England, while gill nets, pound nets, haul seines, and fyke nets predominate in the south.

Pound nets have been responsible for the majority of river herring landings in all years, accounting for as high as 86% of east coast landings in 1970. Weirs, used especially in Maine, took a large percentage (24%) of the total catch in 1976. The contribution of gear types other than pound nets and weirs to overall landings has declined substantially over the last decade. In effect, the nature of the fishery has become much less diverse. Note the decreasing contribution of purse seine fisheries in Massachusetts in 1965 and 1970 and their absence in 1976.

Current river herring fisheries on a state-by-state basis are characterized in Table IV-5. As with the species already discussed, these characterizations are meant only as generalized descriptions and were developed from state overview documents.

Characterizations of Fisheries Trends by State

River herring fisheries in Florida are located only on the St. Johns River. In the 1960's, blueback herring were harvested by numerous haul seiners; at present, none are active (R. Williams, pers. comm.). NOAA records indicate that most of the recent harvest has been taken by gill net, but whether the fish are taken as by-catch or in a directed fishery for river herring is not clear. Because of the strong effect of market factors on river herring fisheries, the data do not reveal whether the decline in Florida landings is representative only of stock declines or is affected to a major extent by market factors. No additional data are available to provide further insight to this question. River herring landed in Florida in recent decades have been used primarily as crab and catfish bait.

Georgia has never had a fishery for blueback herring because the types of gears normally used for this species (e.g., pound nets, small mesh gill nets) are not legal in the drainage systems

Table IV-2. Domestic river herring landings (lb x 10^3) by gear type by state, 1965, as reported in NOAA Fishery Statistics of the United States; dashed lines denote no catch reported. *Maine landings, although listed as taken by dip net in NOAA records, are almost entirely taken in river weirs. **Massachusetts landings by purse seine reported in NOAA records cannot be corroborated as being river herring.

State / Gear	Otter Trawl	Floating Traps	Haul Seine	Gill Net	Pound Net	Fyke and Hoop Net	Weirs or Stop Net	Dip Net	Purse Seine	Other
Maine	---	---	---	---	---	---	881	2226*	---	---
New Hampshire	---	---	---	---	---	---	125	---	---	---
Massachusetts	---	---	533	---	4	---	---	66	6332**	---
Rhode Island	---	---	210	---	---	---	---	---	---	---
Connecticut	---	---	17	---	---	---	---	2	---	---
New York	---	---	2	---	---	21	---	---	---	---
New Jersey	---	---	9	---	---	12	---	---	---	---
Delaware	---	---	---	---	---	---	---	---	---	---
Maryland	---	---	6	163	1919	3	---	---	---	---
Virginia	---	---	2660	184	28089	5268	---	---	---	---
North Carolina	---	---	514	3235	---	---	---	---	---	---
South Carolina	---	---	---	---	---	---	---	2760	---	---
Georgia	---	---	---	---	---	---	---	---	---	---
Florida	---	---	3	19	---	---	---	---	---	---
Total	---	---	3953	7025	39090	5304	1006	5054	6332	---
% of Total	---	---	5.8%	10.5%	57.7%	7.5%	1.5%	7.5%	9.3%	---

Table IV-3. Domestic river herring landings (lb x 10^3) by gear type by state, 1970, as reported in NOAA Fishery Statistics of the United States; dashed lines denote no catch reported. *Maine landings, although listed as taken by dip net in NOAA records, are almost entirely taken in river weirs. **Massachusetts landings by purse seine reported in NOAA records cannot be corroborated as being river herring.

State \ Gear	Otter Trawl	Floating Traps	Haul Seine	Gill Net	Pound Net	Fyke and Hoop Net	Weirs or Stop Net	Dip Net	Purse Seine	Other
Maine	---	---	---	---	---	---	---	*1623	---	---
New Hampshire	---	---	---	---	---	---	25	6	---	---
Massachusetts	243	---	100	---	---	---	---	---	**814	---
Rhode Island	18	24	102	---	---	---	---	---	---	---
Connecticut	93	---	14	(1)	---	---	---	15	---	---
New York	2	---	2	5	---	3	---	---	---	---
New Jersey	---	---	4	2	---	(1)	1	---	---	---
Delaware	---	---	---	---	---	---	---	---	---	---
Maryland	---	---	3	213	1846	(1)	---	---	---	2
Virginia	(1)	---	349	29	18069	598	---	---	---	---
North Carolina	---	---	552	32	10873	(1)	---	34	---	---
South Carolina	---	---	---	---	---	---	---	---	---	---
Georgia	---	---	---	---	---	---	---	---	---	---
Florida	---	---	---	---	---	---	---	---	---	---
Total	355	24	1126	280	30788	601	26	1678	814	2
% of Total	1.0%	< 1.0%	3.2%	1.0%	86.3%	1.7%	< 1.0%	4.7%	2.3%	< 1.0%

(1) = less than 1000 lbs

Table IV-4. Domestic river herring landing (lb x 10^3) by gear type by state, 1976 as reported in NOAA Fishery Statistics of the United States; dashed lines denote no catch reported. *Maine landings, although listed as being taken by dip net in NOAA records, are almost entirely taken in river weirs.

Gear / State	Otter Trawl	Floating Traps	Haul Seine	Gill Net	Pound Net	Fyke and Hoop Net	Weirs or Stop Net	Dip Net	Purse Seine	Other
Maine	---	---	---	---	---	---	---	3395*	---	---
New Hampshire	---	---	---	---	---	---	---	---	---	---
Massachusetts	---	---	38	---	---	---	---	6	---	---
Rhode Island	---	3	31	---	---	---	---	---	---	---
Connecticut	---	---	61	4	---	---	---	2	---	1
New York	---	---	---	---	---	---	---	2	---	---
New Jersey	---	---	10	---	---	2	---	---	---	---
Delaware	---	---	---	(1)	---	---	---	---	---	---
Maryland	---	---	3	18	104	(1)	---	---	---	---
Virginia	---	---	(1)	15	4222	---	---	---	---	---
North Carolina	---	---	61	235	6106	---	---	---	---	---
South Carolina	---	---	---	---	---	---	---	67	---	---
Georgia	---	---	---	---	---	---	---	---	---	---
Florida	---	---	(1)	---	---	---	---	---	---	---
Total	---	3	204	273	10433	2	---	3471	---	(1)
Percent of Total	---	< 1%	1.4%	2.0%	72.5%	< 1%	---	24%	---	< 1%

(1) = less than 1000 lbs

Table IV-5. Characterization of current (1980's) river herring fisheries, by state, based on information provided in state overview documents

State	Gear Type	Type of Water Fished	Percent of Harvest	Probable Species Composition	Use of Harvest	Source of Information
Florida	Haul seine Gill net	Inshore Riverine	12% (1976) 88% (1976)	Blueback 100%	Crab and catfish bait	Williams and Grey, 1975; Williams, pers. comm. FL Dept. Nat. Res.
Georgia	No fishery - appropriate gear illegal	—	—	Blueback 100%	—	Michaels, 1982 Georgia Dept. of Nat. Res.
South Carolina	Dip and hoop nets Haul seine Hook and line	Riverine (Cooper River) Riverine (Santee River) Riverine	65% 35% Not reported	Blueback ~ 100% Alewife - trace	Bait Bait Roe consumption	Ulrich, 1982 South Carolina Wildlife & Marine Res. Dept.
North Carolina	Pound nets Gill nets Dip net (recreational)	Estuarine Riverine Riverine	95% ~ 5% Unknown	Blueback 51-95% Alewife 5-49%	Crab bait Crab bait Consumption	Johnson, 1982 Johnson et al. 1980 NC Dept. Nat. Res.
Virginia	Pound nets Dip nets (recreational)	Estuarine Riverine	99% (1976) Unknown	Blueback < 27% Alewife < 30%	Pet food Bait (eel and crab)	Atran, Loesch and Kriete, 1982 Kriete, pers. comm. VIMS.
Maryland	Pound nets Gill nets	Estuarine Estuarine	< 90% < 10%	Blueback - dominant in Susquehanna Alewife - minor	Crab bait - Pet food, roe for human consumption minor	Carter et al., 1982 MD Tidewater Administration
Delaware	Gill nets Hook and line (recreational)	Estuarine Riverine	100% Unknown	Unknown	Crab bait - (80-90%) Human consumption (10-20%)	Miller, 1982 DE Div. of Fish & Wildlife
Pennsylvania	Hook and line	Riverine	Unknown	Unknown	Unknown	R. Hesser, pers. comm.

Table IV-5. Continued

State	Gear Type	Type of Water Fished	Percent of Harvest	Probable Species Composition	Use of Harvest	Source of Information
New Jersey	Haul seine Dip net Hook and line (recreational)	Unknown Riverine (Delaware River)	Unknown (84,000 fish)	Alewife (majority) Blueback (minority)	Unknown Consumption	Lupine, 1982 Zich, 1978 NJ Div. Fish, Game, & Wild-life
New York	Gill nets Haul seines Dip and scap nets (recrea-tional)	Estuarine Estuarine Riverine	Minor Minor Major	Blueback (minority) Alewife (majority)	Consumption	Brandt, 1983 NY Dept. Envir. Con.
Connecticut	Gill nets Dip nets Haul seine	Estuarine Riverine Riverine	Unknown	Blueback (majority) Alewife (minority)	Lobster bait; consumption	Crecco, 1982 CT Dept. Environ. Protection, Marine Fisheries Off.
Rhode Island	Haul seine Bow nets	Estuarine Riverine	Minor Major	Alewife > 90% Blueback < 10%	Lobster bait	Gibson, 1982 RI Fish & Wildlife
Massa-chusetts	Dip net Haul seine	Riverine	Unknown	Alewife (majority) Blueback (minority)	Lobster bait, human con-sumption (minor)	DiCarlo, 1982 MA Div. Mar. Fish.
New Hampshire	Weirs Dip net Gill net	Riverine Riverine Riverine	10% 65% 25%	Alewife (majority)	Lobster bait	Greenwood, 1982 NH Fish & Game Dept.
Maine	River weirs	Riverine	100%	Alewife - 100%	Lobster bait >90% Processing consumption <10%	Flagg and Squiers, 1982 ME Dept. Mar. Res.

inhabited by river herring (Ulrich et al., 1982). Although a number of studies of population biology of river herring in Georgia have been done (e.g., Street, 1969; Godwin and Adams, 1969), the data are insufficient for assessing stock abundance or trends in stock abundance. The current status or recent trends in abundance of Georgia's river herring stocks also cannot be assessed.

South Carolina had no modern fishery for river herring until 1965, when a haul seine fishery was established in the Santee River. Its appearance resulted in a large increase in reported river herring landings in the late 1960's (Table IV-1). However, the magnitude of the landings declined rather rapidly in the 5 to 10 years thereafter. Whether this decline reflected a stock decline or a market effect is not established. A sequence of poor year-classes may have contributed to the decline. Recent landings (late 1970's) appear on the rise. However, substantial data are not available to establish the current status of stocks in most drainage systems.

North Carolina river herring landings declined substantially (approximately 50%) in the early 1970's, then remained stable until an upswing in 1982 (Johnson, 1982). While effort decreased in 1978 and 1979 due to ice removing some pound nets (Johnson et al., 1980), effort between 1972 and 1978 appears to have remained relatively constant. For this reason, the decline in North Carolina landings probably reflects a considerable decline in stocks in the early 70's. This premise is also supported by CPUE data (Table IV-6). The current fishery is dominated by pound nets, and most landings are used as bait.

Although Virginia has consistently had the highest annual landings of river herring of states along the east coast, they began to decline dramatically in the late 1960's, reached a temporary plateau in the early 1970's, and then crashed to very low levels in the late 1970's. Loesch et al., (1979) showed that during this decline, the proportion of blueback herring to alewife increased. These data suggest that the rate of decline in alewife stocks exceeded the rate of decline in blueback herring. The decline in total harvests in the late 1960's has been attributed to offshore overexploitation of river herring stocks by foreign fishing fleets (see Fig. IV-1). Hurricane Agnes, which passed through the region in 1972, is also believed to have affected spawning success in that year as a result of high flows preventing spawning in normal locations and causing displacement of larvae and juveniles from optimal nursey areas. The apparent stock declines suggested by landings data are also reflected in declines in CPUE (Table IV-7). Virginia stocks have not rebounded from these major impacts to date. Current landings in Virginia may also be influenced by market changes. The last fish processing plant which handled river herring in Virginia closed in 1981 (Kriete, pers. comm.), which may have

Table IV-6. River herring catch-and-effort, Albemarle Sound, North Carolina 1971-75. Data are in pounds (lb) and metric tons (mt)(from Street and Davis, 1976).

Season	Total catch (lb)	Total catch (mt)	Pound net catch (lb)	Pound net catch (mt)	Percent of total	Pound net effort	Catch/effort (lb)	Catch/effort (mt)	Other gear (lb)	Other gear (mt)
1971	12,711,200	5,766	12,005,975	5,446	95	645	18,614	8.44	705,225	320
1972	11,237,033	5,097	11,020,023	4,999	98	727	15,158	6.88	217,010	98
1973	7,931,600	3,598	7,613,900	3,454	96	625	12,182	5.53	317,700	144
1974	6,277,671	2,848	5,876,357	2,665	95	653	8,985	4.08	401,314	182
1975	5,903,957	2,678	5,427,072	2,462	92	675	8,040	3.65	476,885	216

Table IV-7. Estimates of the landings of river herring in the Potomac and Rappahannock rivers combined, by spawning check history. Units are thousands of fish and c/f is catch/net/season, by spawning class (from Street and Davis, 1976).

Year, total number, c/f	0	1	2	3	4	5	6	Total & yearly c/f[1]	No. of Pound Nets[2]
1965	17,890	5,573	2,018	973	333	0	0	25,472	146
CPE	122.5	20.6	13.8	6.6	2.3	0	0	174.5	
1966	11,826	7,915	4,258	1,277	495	0	0	27,086	139
CPE	85.1	56.9	29.2	9.2	3.6	0	0	194.9	
1967	15,603	3,964	2,574	594	321	34	23	23,113	127
CPE	122.9	31.2	20.3	4.7	2.5		0.2	182.0	
1968	12,238	3,927	2,759	951	204	65	3	20,147	133
CPE	92.0	29.5	20.7	7.2	1.5	0.5		151.5	
1969	7,336	2,243	886	455	38	4	0	10,962	119
CPE	61.6	18.9	7.5	3.8	0.4		0	92.1	
1970	10,655	2,754	1,593	613	362	14	0	15,991	97
CPE	109.8	28.4	16.4	6.3	3.7	0.2	0	164.9	
1971	2,998	1,470	506	72	22	0	0	5,068	99
	30.3	14.8	5.1	0.7	0.2	0	0	51.2	
1972	3,885	472	502	131	50	5		5,045	105
CPE	36.6	4.5	4.7	1.2	0.5	0.1		47.6	
1973	2,681	817	444	140	33	0	0	4,115	
CPE	27.6	8.4	4.6	1.4	0.4	0	0	42.4	97

[1] Catch per net per season, all ages combined.
[2] In the last half of April, only nets above river mile 10 used.

an impact on harvests in the future. The data in Tables IV-8 to IV-11 indicate contributions of individual alewife and blueback year-classes to total river herring harvests for the period 1968 to 1980 in the Rappahannock and Potomac Rivers. These data illustrate the dominance of a single year-class (1966) of blueback in the Potomac River in contributing to the fishery, and show that year-class success may be extremely variable from year-to-year, independent of the decline over this period of time.

The decline in Maryland river herring landings is of a similar magnitude to that observed in Virginia throughout the 1970's; i.e., essentially one order of magnitude. The decline in Maryland landings is evident in all statistical reporting areas (i.e., drainage systems) in the state (Carter et al., 1982), suggesting that the factors causing the decline are not specific to a particular river system. Although landings in some years may have been influenced by declines in the number of pound nets being fished, the change in effort is not sufficient to explain the declines. As in Virginia, alewife may have declined to a greater extent than blueback herring (Environmental Resources Management, 1980). Maryland stocks may have been affected substantially by both Hurricane Agnes (in 1972) and offshore harvests in the late 1960's and early 1970's.

In Delaware, river herring are taken as by-catch in fisheries directed at other species (e.g., white perch)(Miller, 1982). Landings have been low and variable for a number of years, and probably are not indicative of stock abundance. Both blueback herring and alewife may occur in nearly all accessible freshwater streams in the state. However, no data are available to assess their status or recent trends in stock size.

A similar situation exists in New Jersey, where no directed fisheries occur. All New Jersey landings are by-catch and do not reflect actual abundance of stocks. There is a substantial recreational hook and line fishery for river herring on the Delaware River near Trenton, New Jersey. River herring appear to be very abundant in the Delaware River, and 133 river herring runs in 63 different drainage systems of the state have been documented (Zich, 1978). However, no specific quantitative data are available to address current stock abundance or to define recent trends in abundance.

Historically, river herring have supported a minor commercial fishery in the Hudson River in New York. Commercial sale of river herrings was prohibited from 1976 through 1981 due to PCB pollution, but was permitted again in 1982, thus impacting on the value of commercial landings as stock abundance index. Observations by NYDEC suggest that river herring have increased in abundance in the "Albany Pool" region of the Hudson River in recent years in response to significant improvements in water

Table IV-8. Annual and total year-class contributions (mt) to the Rappahannock River alewife fishery, 1968-1980 (from Atran et al., 1982).

	Year Class												
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	49.79												
1969	44.49	13.21											
1970	47.31	73.36	7.75										
1971	30.62	94.20	57.73	4.48									
1972	18.04	51.10	60.52	54.51	8.82								
1973	1.96	8.00	18.87	39.84	81.20	0.90							
1974		5.40	1.08	18.78	55.90	134.04	0.65						
1975			0.07	0.43	1.16	9.68	59.66	1.23					
1976					0.13	1.71	14.43	25.39	2.15				
1977					0.34	0.17	4.32	41.24	36.16	2.46			
1978							1.83	11.38	54.67	57.03	5.89		
1979								0.28	2.41	14.84	19.89	18.60	
1980										2.49	7.03	12.87	0.88
Yearclass TOTAL	192.21	245.27	146.02	118.04	147.55	146.50	80.89	79.52	95.39	76.82	32.81	31.47	0.88

Table IV-9. Annual and total yearclass contributions (mt) to the Rappahannock River blueback fishery, 1968-1980 (from Atran et al., 1982).

	Year Class												
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	10.68												
1969	90.10	11.39											
1970	14.76	25.48	0.97										
1971	18.19	107.12	72.15	1.01									
1972	8.56	33.17	52.83	37.58									
1973	1.69	8.94	37.34	74.14	118.34	0.97							
1974		1.56	6.00	20.48	46.19	55.97	0.26						
1975				0.52	3.44	19.94	146.82	1.03					
1976					0.07	2.44	26.88	36.05	2.38	0.07			
1977							8.58	107.09	88.06	5.23			
1978						0.38	1.91	78.25	211.10	84.74	4.96		
1979								7.62	42.36	127.51	229.18	16.94	
1980								1.17	6.25	20.32	140.46	26.57	0.59
Yearclass TOTAL	143.98	107.66	169.29	133.73	160.04	79.70	184.45	231.21	350.15	237.87	374.60	43.51	0.59

Table IV-10. Annual and total year-class contributions (mt) to the Potomac River alewife fishery, 1968-1980 (from Atran et al., 1982).

	Year Class												
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	10.93												
1969	97.51	124.05											
1970	38.69	136.99	16.01										
1971	37.55	190.93	115.21										
1972	61.26	169.34	180.59	210.70									
1973	5.44	13.84	21.22	58.88	144.51	6.10							
1974			5.29	8.04	26.51	254.45							
1975				13.44	6.81	62.34	298.17	1.86					
1976					1.47	15.26	72.96	49.97	1.98				
1977						0.04	2.16	16.66	12.56	3.04			
1978								8.41	17.31	20.51	2.16		
1979									1.26	1.39	7.11	1.73	
1980										0.56	14.86	18.15	
TOTAL	251.38	635.15	338.32	291.06	179.30	338.19	373.29	76.90	33.11	25.50	24.13	19.88	

Table IV-11. Annual and total yearclass contributions (mt) to the Potomac River blueback fishery, 1968-1980 (from Atran et al., 1982).

	Year Class												
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	20.03												
1969	646.78	99.65											
1970	492.09	1671.00	23.95										
1971	203.66	1053.98	1000.96	16.24									
1972	74.38	294.52	439.86	576.54	2.56								
1973	2.11	20.61	67.21	151.59	135.26	1.95							
1974		7.06	18.85	51.80	157.71	1068.90							
1975			0.81	37.13	116.23	335.23	1560.10	0.83					
1976				3.54	4.70	98.72	233.70	87.33	4.20				
1977						1.02	31.79	108.67	36.25	1.43			
1978							26.27	157.82	318.41	106.39	1.54		
1979									37.10	79.67	285.31	34.16	
1980									4.22	28.79	213.49	23.72	1.67
Yearclass TOTAL	1439.05	3146.82	1551.64	836.84	416.46	1505.82	1851.86	354.65	400.18	216.28	500.34	57.88	1.67

quality (Brandt, 1983). The observed increase in spawning range and abundance of river herrings suggest that New York stocks are increasing although hard supportive data are not available.

In Connecticut, river herring landings have remained relatively stable over the last 20 years. Distribution of catch among river systems is not known, but the major contributor to the blueback herring harvest probably is the Connecticut River. Alewife runs occur in the majority of the small streams along the coast, but no data are available to assess current status or recent trends in abundance. The view of the state fisheries agency is that stocks are relatively stable (Crecco, 1982).

A large decline in reported river herring harvests in Rhode Island in 1970 resulted from closing a major haul seine fishery at Gilbert Stuart Brook to accomodate the state's need for fish to transplant to other drainage systems for restoration purposes (Gibson, 1982). The substantial decline in harvest that appears in the records after 1976 may have resulted from a reduction in the state's transplanting program, together with a reduction in efforts to provide access to currently inaccessible habitats (Gibson, 1982). Many of the new runs established in the early 1970's declined as a result of these reduced efforts. Current data suggest that stocks in Rhode Island are at very low levels but remain fairly stable. The run at Gilbert Stuart Brook, which has been monitored for the last four years, nearly doubled between 1980 and 1982 to over 80,000 fish, but then declined to 68,000 in 1983.

River herring fisheries in Massachusetts are distinct from fisheries in all the more southern states in that local towns control the fisheries on most of the major drainage systems. Landings in the past 20 years have fluctuated widely from year-to-year (Table IV-1), with 1980 harvests being the lowest ever reported. Recordkeeping by the towns or their designated agents is very poor, and the meaning of the recorded landings data is questionable (DiCarlo, 1982). While the NOAA data suggest a substantial decline in the fishery in recent years, state biologists believe that the stocks have remained relatively stable based on field observations of runs. Recreational harvests by dip netters may be substantial and are also unreported.

New Hampshire implemented new landings records procedures in 1982. A 114,000-pound harvest was recorded for that year, which is dramatically higher than previous years. The very low NOAA values for the previous years probably are extreme underestimates and are not indicative of stock abundance. Recent restoration efforts have been very successful in New Hampshire, with creation of a run of over 50,000 river herring on the Lamprey River. Thus, although data are not available for rigorous documentation, New Hampshire stocks would appear to be increasing (Greenwood, 1982).

River herring landings in Maine have remained remarkably stable when contrasted to landings of other states. For the past 30 years, harvests have fluctuated year-to-year by at most a factor of 2. Although there was a great amount of fishway construction in the 1970's, the new runs were not believed to have substantially contributed to landings through 1976 (Walton, Smith and Sampson, 1976). These authors also noted that landings, in most cases, were a function of what the market will buy rather than the available supply. However, the harvests on the major runs supporting Maine's river herring fisheries have been extremely high (as will be discussed later in the report), and at least for the last 10 years, market factors have probably not had a major impact on reported landings. The absence of substantial declines in Maine river herring harvests in the 1960's, when offshore foreign harvests were greatest, suggests that Maine stocks were not being exploited in those fisheries.

Juvenile Indices as Indicators of Abundance Trends

Extensive scientific studies of river herring have been done in states where the species have supported important fisheries, i.e., North Carolina, Virginia, Maine, Rhode Island, and Maryland. In the remaining states, individual studies have been done, but they tend to be of limited duration or extent and thus of limited value for documenting status or trends in stock abundance.

Juvenile indices are available for several of the states. Maryland's juvenile index data extend back to 1962. These data, categorized by segment of the Chesapeake Bay, are presented in Table IV-12. The data were collected in a consistent manner at the same locations in the fall of each year. Since environmental conditions such as river discharge may vary year-to-year, resulting in shifts in the location of nursery areas and possibly in the time patterns of migration, the value of these juvenile indices as indicators of year-class abundance is probably questionable except in cases of extreme values. With these qualifications, the data can be used to examine some aspects of fluctuations in populations of river herring.

Table IV-13 presents the results of a correlation analysis of alewife and blueback herring juvenile index data within river system as well as between river systems. The data were also analyzed to determine if they supported the conclusion that there were declining trends in year-class abundance over the period of data collection. There was a positive correlation between alewife and blueback herring juvenile indices in the Nanticoke and the Potomac Rivers, but no correlation with data from the Choptank and the head of the Chesapeake Bay. These results are not definitive in establishing whether both

Table IV-12. Alewife and blueback herring juvenile index data for four segments of the Maryland Chesapeake Bay (adapted from Carter, 1982)

Year	Nanticoke River		Choptank River		Potomac River		Head of Bay	
	Alosa aestivalis	Alosa pseudoharengus	Alosa aestivalis	Alosa pseudoharengus	Alosa aestivalis	Alosa pseudeharengus	Alosa aestivalis	Alosa pseudoharengus
1962	6.6	0.5	5.3	2.67	76.8	1.0	56.2	20.4
1963	10.2	2.3	0.4	0.7	0.4	0.4	51.6	6.3
1964	10.2	5.3	0.6	0.3	18.5	19.6	27.2	0.6
1965	20.4	0.5	0.1	0.1	37.3	1.1	10.8	2.7
1966	39.5	0.5	0.8	4.3	23.0	19.6	27.5	15.7
1967	65.7	2.3	22.0	9.8	5.3	0.1	85.1	4.8
1968	19.2	4.5	1.8	4.8	4.5	0.1	79.1	0.3
1969	202.8	0.9	0.8	3.8	2.0	1.1	743.0	10.1
1970	1.8	1.9	15.0	1.4	25.2	5.6	27.3	100.9
1971	3.3	0.5	1.0	1.6	39.6	6.6	16.3	13.7
1972	5.0	3.9	1.5	0.1	13.9	3.6	5.5	1.7
1973	4.3	0.4	0.2	1.2	0.1	0.6	11.8	2.5
1974	8.0	3.4	0.2	0.3	0.1	0.3	0.0	1.1
1975	2.6	0.4	0.7	0.0	107.0	20.7	0.5	13.2
1976	0.2	0.1	0.0	0.5	1.6	0.2	0.4	2.3
1977	0.2	0.1	0.2	0.2	40.5	11.2	0.3	7.3
1978	8.1	0.2	5.0	0.7	100.9	10.0	36.7	3.7
1979	24.6	0.3	18.9	0.6	17.7	2.7	1.0	2.7
1980	3.2	1.0	0.0	0.1	92.2	7.6	0.1	3.2
1981	0.0	0.0	0.1	0.2	0.2	0.4	0.0	3.9
1982	3.0	0.2	0.7	0.4	19.5	1.1	0.1	0.3
20-yr mean	21.8	1.5	3.7	1.7	30.3	5.6	59.03	10.9

Table IV-13. Results of analyses of Maryland river herring juvenile index data; data are presented in Table IV-12.

A. Similarity in pattern of annual relative abundance of each species in the four river systems.

Blueback herring (Friedman's test) $p < 0.005$
(significant similarity among rivers)

Alewife (Friedman's test) $p < 0.25$
(no significant relationship)

B. Similarity in pattern of annual relative abundance of both species within each river system (Spearman Rank Correlation)

Nanticoke River $p < 0.05$
(significant correlation)

Choptank River $p > 0.05$
(no correlation)

Potomac River $p < 0.05$
(significant correlation)

Head of Bay $p > 0.05$
(no correlation)

C. Evidence of time trend in data

Nanticoke River
- Blueback herring $p < 0.01$
- Alewife $p < 0.01$

Choptank River
- Blueback herring $p > 0.25$
- Alewife $p < 0.05$

Potomac River
- Blueback herring $p > 0.50$
- Alewife $p > 0.50$

Head of Bay
- Blueback herring $p < 0.001$
- Alewife $p > 0.25$

species are responding in a similar manner to whatever factors may be determining year-class success. The second set of analyses addressed the question of whether the relative year-class success of each species was similar among four river systems. For the blueback herring, there was a consistent pattern of juvenile index abundance among the four river systems for the time period of data collection. A similar consistent pattern could not be statistically established with alewife. However, as shown in Table IV-12, alewife were much less abundant and the rather sparse data available may contribute to the absence of statistical significance. In the final analyses, the question of whether declining trends could be detected with the juvenile index was addressed. Declining trends in the index for blueback herring were found in the Nanticoke and the head of the bay, while declining trends for alewife were found in the Nanticoke and the Choptank. For the other species-river system combinations, no declining trend could be statistically determined.

The failure of the juvenile index to demonstrate stock declines in view of the dramatic decline in landings suggests inaccuracies in the data. However, the consistency in abundance patterns for blueback herring among the four river systems suggests that factors influencing yearclass success may be operating on broad regional areas as opposed to localized drainage systems.

Juvenile index data have been collected in Virginia for a number of years (Table IV-14). However, the procedures used in early surveys (1972-1977) may have yielded unrepresentative estimates of juvenile abundance based on more recent assessments of survey techniques (J. Loesch, pers. comm.). Sampling was done on a very limited number of dates and in only a few locations and may have yielded inaccurate data. In addition, all sampling was done during daytime, and day-night differences in catch efficiency have been found (Loesch et al, 1982). With these caveats, some assessment can be made of the utility of these data for examining fluctuations in stock abundance.

The data suggest a tendency for both species to respond in a similar manner in terms of annual abundance (e.g., 1973 and 1975 produced large indices in most cases). The relative magnitude of indices for the Potomac River match reasonably well with Maryland's data (Table IV-12). The large 1975 and 1977 year-classes appear in both state's data, as does the poor 1976 year-class. These similarities suggest that both sets may be representative of juvenile abundance. However, as with Maryland's data, no declining trends are evident and thus they do not correspond well to landings data.

Juvenile index data are also available for river herring in Albemarle Sound in North Carolina (Fig. IV-6). These data also do not demonstrate declines. However, since these year-

Table IV-14. Adjusted juvenile alosid catch-per-unit of effort (CPUE) for the indicated rivers, 1972-1978 (from Loesch et al., 1979); * = night-time samples.

Species	Year	Potomac	Rappahannock	Mattaponi	Pamonkey	James
Alewife	1972	3.52	91.60	31.49	10.27	23.85
	1973	3.65	223.41	117.58	32.78	36.67
	1974	6.29	5.30	1.49	8.92	14.69
	1975	4.31	45.16	7.28	48.49	38.42
	1976	1.85	1.24	0	3.50	1.62
	1977	10.66	11.58	0.34	1.63	0.91
	1978*	7.42	14.49	10.03	3.02	3.42
Blueback	1972	193.16	1049.55	174.79	100.37	3936.98
	1973	22.91	3221.82	52.71	626.46	5663.88
	1974	19.46	414.65	60.97	49.75	566.05
	1975	1881.44	4252.23	211.88	1406.09	16238.98
	1976	5.07	140.10	23.80	2.00	79.33
	1977	529.15	894.72	39.10	167.75	241.98
	1978*	284.62	302.78	52.42	187.67	613.84

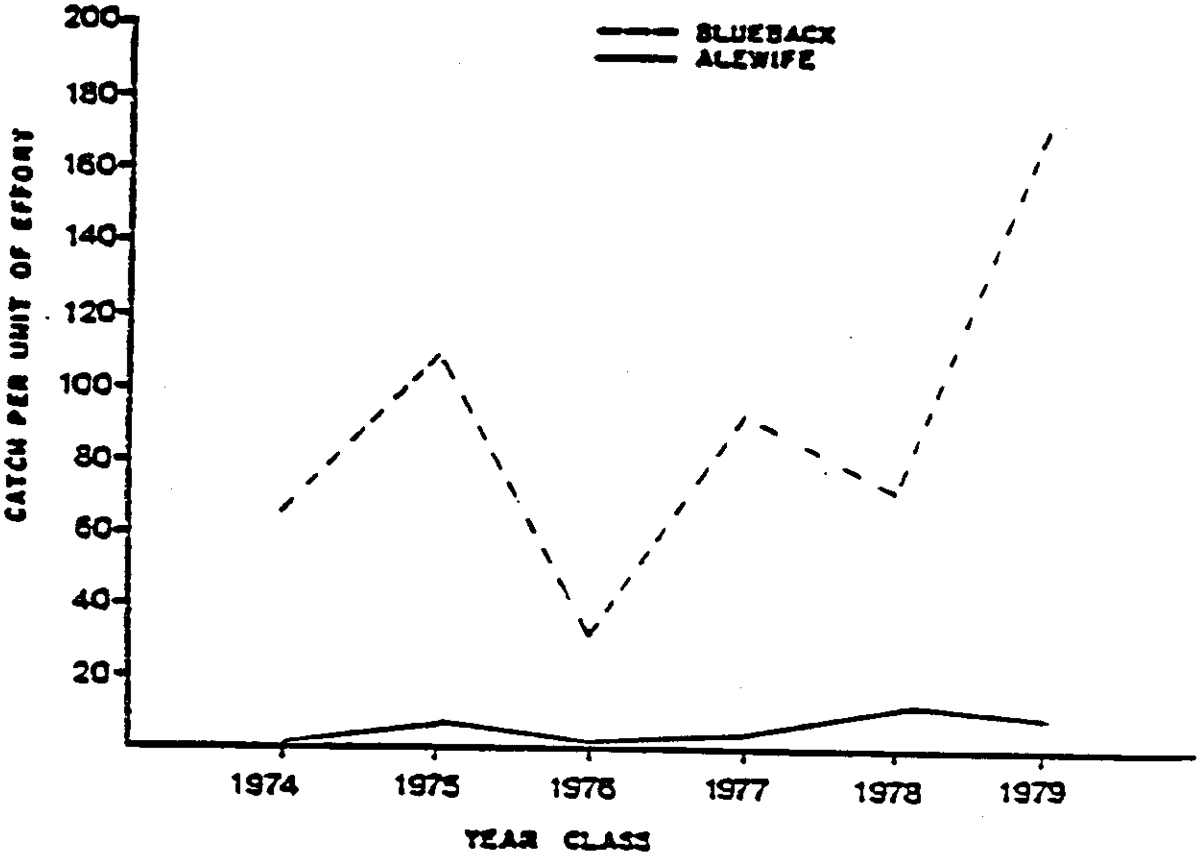


Figure IV-6. Catch-per-unit of effort for blueback herring and alewife year-classes 1974 through 1979 by seine in Albemarle Sound, North Carolina (11 monthly stations)(from Johnson et al., 1980) classes would have entered the fishery from 1978 through 1984, they may accurately predict the current low-level stability of stocks.

Juvenile river herring data were collected in the Hudson River between 1968 and 1982 (Texas Instruments, Inc., 1977-1980). However, integration of the data from different stations and dates to develop annual indices has not been done to date, and thus the data cannot currently be used to examine stock trends.

None of the juvenile index data sets described above have been rigorously verified through correlation with year-class contribution to fisheries in subsequent years. Havey (1973) did report a relationship between numbers of juveniles produced and run size 4 years later for a run in Maine, but this was based on a census of juveniles leaving a pond and not a statistical sampling of that population. Positive correlations between indices and landings four years later of blueback herring were reported for the Rappahannock and Potomac Rivers by Loesch et al. (1979), but there is some question of the validity of those data (Loesch, pers. comm.). The correlation results and descriptive contrasts presented here suggest that the indices may be of value for representing high and low year-class extremes, while having limited utility for representing more average year-classes.

D. COASTAL AND OFFSHORE HARVESTS

Foreign fishing fleets began to exploit offshore river herring stocks in the late 1960's. Peak catch was in 1969, at approximately 80 million pounds (Table IV-15). Catches declined significantly after that date. Street and Davis (1976) concluded that these offshore harvests contributed to overharvest and caused stock declines, particularly in the Chesapeake Bay and South Atlantic stocks. Street and Davis reported that the offshore harvests were composed primarily of fish less than 190 mm in length, which would suggest that they were primarily sexually immature individuals.

Since 1977, the foreign fishery for river herring in the Fishery Conservation Zone (FCZ) of the United States has been managed by the Preliminary Fishery Management Plan (PMP) for the foreign trawl fisheries of the Northwest Atlantic (Boreman, 1982). Allocation of river herring between 1977 and 1980 was 1.1 million pounds annually with some additional allowable by-catch. Since 1981, the allocation has been limited to 100 metric tons, and by-catch regulations have been changed. Current allocations are presented in Table IV-16. When a country's annual allocation for any one species is reached, fishing by that nation's vessels in that part of the FCZ in the northwest Atlantic Ocean must cease and the fishing vessels must leave the

Table IV-15. Reported landings of river herring (lbs x 10^3) in ICNAF/NAFO Areas 5 and 6 by foreign vessels (from Boreman, 1982)

YEAR	BUL	GDR	POL	ROM	SPA	USSR	TOTAL
1964	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0
1967	0	0	0	0	0	14356	14356
1968	0	0	0	0	0	49184	49184
1969	1133	249	0	0	0	78322	79704
1970	1481	419	0	0	0	42083	43983
1971	2291	18538	3101	2015	0	22029	47974
1972	1129	7674	4162	0	0	14756	27721
1973	972	3593	7167	0	0	2348	14080
1974	1704	5862	2399	556	0	1042	11563
1975	1219	4676	137	0	0	1433	7465
1976	564	2778	31	0	0	539	3912
1977	0	152	0	0	0	264	416
1978	0	0	0	0	23	25	48
1979	0	0	4	0	0	24	28
1980	0	0	0	0	4	0	4

Table IV-16. Allocations of river herring by country for foreign fishing within the U.S. Fishery Conservation Zone, 1978-1983

(in metric tons)

	1978	1979	1980	1981	1982	1983
TALFF	500	500	500	100	100	100
ALLOCATIONS						
Bulgaria	—	—	—	5	20	5
Cuba	—	—	25	5	—	—
FRG	—	12	50	—	—	—
GDR	—	10	25	—	—	25
Ireland	—	10	—	—	—	—
Italy	12	13	50	10	10	10
Japan	23	46	50	10	10	10
Mexico	44	40	50	—	—	—
Poland	—	14	50	18	—	—
Portugal	—	—	—	5	5	5
Romania	7	10	10	—	—	—
Spain	52	57	75	10	10	10
USSR	279	197	—	—	—	—
UNALLOCATED	83	91	115	37	45	35

NOTES: River herring for purposes of foreign fishing is defined as alewife, blueback herring, and hickory shad.

TALFF is total allowable level of foreign fishing.

SOURCE: Fisheries of the United States, 1978-1983. USDOC/NOAA/NMFS.

fishing area (G. Mahoney, pers. comm.). Reported offshore landings since 1978 have been consistently low (Table IV-15).

As was discussed in the case of American shad and hickory shad, numerous problems may exist with the ICNAF/NAFO data which serve to document offshore landings. Key among them is the problem with species identification. An additional problem with total ICNAF landings results from inclusion of potentially inaccurate NOAA inshore landings data. This problem can be avoided by examining the ICNAF/NAFO data on a country-by-country basis, since foreign fleets operate only in offshore waters.

Coastal fisheries for river herring are currently minimal in magnitude. Nearly all major river herring harvests are made within individual river systems or at the mouths of those drainage systems.

The totals of current offshore and coastal harvests of river herring are relatively insignificant. Even if current foreign fishery allocations of river herring were taken each year, those landings would comprise less than 2% of total harvest in any given year. However, these fisheries do focus on immature, smaller fish, and a low percentage in terms of total poundage can represent a larger percentage in terms of numbers of individuals. Although the potential for problems with offshore fisheries exists, the problem appears minimal at present.

E. COASTAL MIGRATIONS

A knowledge of coastal migration patterns of river herring is relevant to examination of hypotheses relating to factors influencing mortality and stock trends. Such information is also needed to assess the potential for interjurisdictional conflicts in harvesting the species. Coastal migration must be placed in perspective to the general life history patterns of the two river herring species, summarized in Figs. I-4 and I-5.

Juvenile river herring generally emigrate from freshwater to the ocean in the fall. However, in some instances, it appears that high abundance of juveniles may trigger very early (e.g., summer) emigration of large numbers of small juveniles from the nursery area (e.g., Richkus, 1975). Length of stay of immature fish in the ocean is generally four or five years, dependent on sex. There is some indication that alewives in northern states may remain in inshore waters for one or two years (e.g., Walton, 1981). Spawning runs begin earliest in southern states (December to January in Florida) and latest in the North (May to June in Maine) (Tables IV-17 and IV-18). Homing of fish to their stream of origin is a generally accepted premise, particularly based on numerous successes in creating new runs through stocking of

Table IV-17. Location, month, and water temperature of spawning run of anadromous alewife populations (from PSEG 1982b)

Location	Months of Spawning Runs	Peak Spawning Period	Temperature (°C)	Reference
Tar River, NC	mid-May to mid-April	-	ca. 10-20°C	Frankensteen, 1976
Chowan River, NC	starts early March	by end March	-	Holland and Yelverton, 1973
Lake Mattamuskeet, NC	February through May	March to early April	peak at 12.0-13.1°C	Tyus, 1971, 1974
Maryland streams	late March through April	-	-	Mansueti and Hardy, 1967
Chesapeake Bay tributaries	arrive late March	-	-	Hildebrand and Schroeder, 1928
Chesapeake Bay tributaries	late March through April	-	-	O'Dell, 1975, 1976
Delaware Bay tributaries	early April to mid-May	last half April	-	Smith, 1971
Delaware River, NJ	April through late June	-	-	Anselmini, 1974a,b, IA 1979a,b
New Jersey streams	April, May, June	-	present 10-21.5°C	Zich, 1977
New York streams	early April to early June	-	-	Decker et al., undated
Pausacaco Pond, RI	mid-March to end May	-	run starts 6.7°C; to 21.1°C	Cooper, 1961
Connecticut and Thames rivers, CT	early March to early June	-	-	Marcy, 1969
Bride Lake, CT	early March to June	-	run starts 4-5°C, ends 15-19°C	Kissil, 1974
Bride Lake, CT	early April to early June	mid-May	run starts 5°C	Cianci, 1969
Bride Lake, CT	starts late March or early April	early May to June	-	Kissil, 1969
Parker River, MA	mid-April through end May	early May	peak run ca. 10°C	Mayo, 1974
Massachusetts Bay tributaries	early April to as late as August 20	-	-	Bigelow and Schroeder, 1953
Long Pond, Love Lake, ME	early May to mid-June	-	runs start 10-16.5°C	Havey, 1961, 1968
Maine streams	few until late April or early May	-	-	Bigelow and Schroeder, 1953
Damariscotta Lake, ME	early May to late June	-	-	Libby, 1981

Table IV-17. Continued

Location	Months of Spawning Runs	Peak Spawning Period	Temperature (°C)	Reference
Bay of Fundy tributaries, NS	April through June	-	-	McKenzie, 1932
Margaree River, NS	starts early May, lasts 4-6 weeks	-	-	Scott and Crossman, 1973
Saint John River, NB	early May through late June	-	-	Messieh, 1977
Saint John River, NB	starts March or April	-	-	McKenzie, 1932
Saint John River, NB	earliest good runs in April	-	-	Bigelow and Schroeder, 1953
Maritime Prov. Canada	May through late June	-	-	Gillespie, 1967

Table IV-18. Location, month, and water temperature of spawning runs of blueback herring populations (from PSEG, 1982)

Location	Months of Spawning Runs	Peak Spawning Period	Temperature(°C)	Reference
		Anadromous Blueback Herring		
St. Johns River FL	December, January, February	-	-	McLane, 1955
Georgia Rivers	February, March, April	-	-	Street and Adams, 1969
Santee River SC	Late February through late April	End March to mid-April	13.3-18.5°C	Meador, 1979
Cooper River SC	Early March to early May	Mid-March through early April	6-17°C	Christie, 1978
Tar River NC	Early March to mid-May	-	ca. 10-20°C	Frankensteen, 1973
Chowan River NC	On going in early May	-	-	Holland and Yelverton, 1973
Rappahannock R. VA	March through June	-	-	Davis, 1968
Potomac River VA	Starts last half April to first half May	-	-	Hildebrand, 1963
Susquehanna R. PA	Mid-April to early June	Early May to mid-May	-	Petrimoulx et al., 1980
Chesapeake Bay Tributaries	Lower Bay-early April, upper bay-late April	-	-	Hildebrand and Schroeder, 1928
Chesapeake Bay Tributaries	Last half April through first half May	-	-	Odell, 1974, 1976
Delaware Streams	Late April through mid-June	Last half May	13-24°C	Smith, 1971; Wang and Kernehan, 1979
Delaware River	Late April through June	Late May and early June	-	Anselmini, 1974a,b,c; TI, 1979a,b
New Jersey Streams	April, May, June	-	Present 12.2-24°C	Zich, 1977
Roaring Brook CT	Late April through mid-September	Mid-May through mid-July	Run starts 6.7-8.5°C First spawn at 14°C	Loesch, 1969; Loesch and Lund, 1977
Saint John R. NB	Mid-May to late June	-	-	Messieh, 1977
Canadian Streams	June	-	-	Leim and Scott, 1966

gravid adults in currently unoccupied sites. However, some Bay, with a large estuarine area and numerous tributaries in close proximity, considerable exchange of stocks among river systems may occur (Loesch, pers. comm.).

Coastal Movement Patterns

Very little tagging study data are available for the two species of river herring. There are several explanations for this:

- Most fisheries for the species take large volumes of fish, making detection of small tags unlikely
- These species are not of great economic value in many states, limiting the amount of effort applied in studies.

As a result, tag return information is relatively anecdotal. Brian Jessup (Fisheries and Oceans Canada, pers. comm.) conducted tagging studies in the Bay of Fundy area of Canada and had two tags returned from North Carolina. There have been two tag returns from a small experimental tagging of spent adult river herring on the Orland River in the state of Maine conducted in 1981 and 1982. Of 400 tagged in 1981 and 350 in 1982, one return came from Massachusetts and one from Virginia, both from the 1982 tagging (T. Squiers, pers. comm.). Street (1975) reported that several river herring tagged in North Carolina were taken in the foreign fishery offshore of that state during the summer. These data, while extremely limited, indicate that river herring undertake extensive oceanic migrations, and may in fact carry out the same pattern of migration shown by the American shad.

Neves (1981) described the offshore distribution of alewife and blueback herring based on 10 years of NMFS research vessel trawl survey data. In the spring (Figure IV-7), alewife distributions extend further north than those of blueback herring (Fig. IV-8), which is consistent with the more northern distribution of that species. Summer distributions (Fig. IV-9) also suggest a somewhat more northern center of distribution of alewife. Data for winter and fall are more sparse and less definitive (Figs. IV-9 and IV-10). Alewives appear more widely distributed than blueback herring (Figs. IV-7 and IV-8). Neves hypothesizes that river herring follow a coastal migration pattern similar to that of American shad.

Milstein (1981) reported the occurrence of 1+ aged river herring off of the coast of southern New Jersey in the winter. In Maine, Walton et al. (1976) reported that 1+ fish use inshore than in the case of American shad for extended coastal movement.

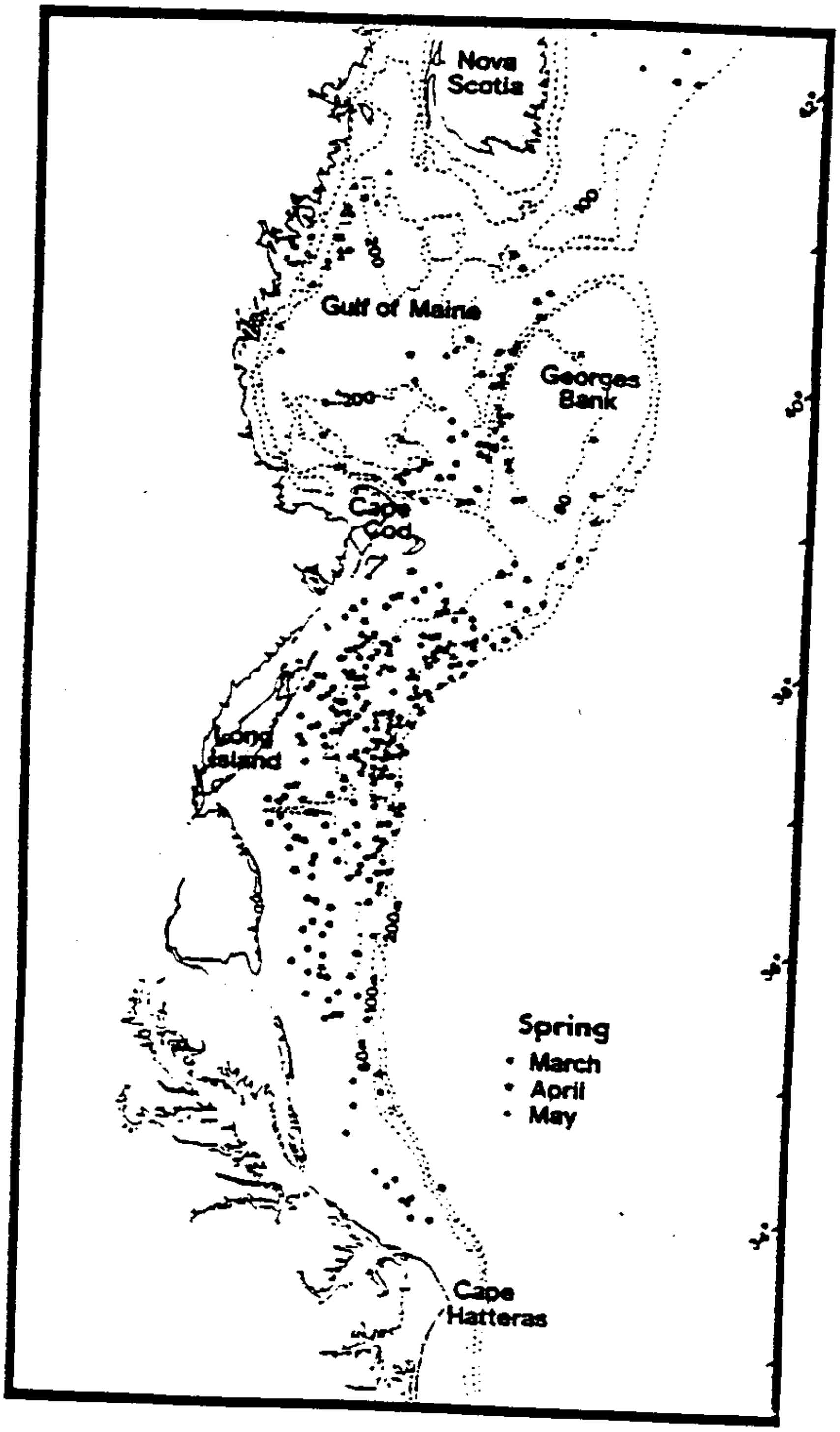


Figure IV-7. Location of alewife catches during spring bottom trawl surveys, 1968-78, Cape Hatteras NC, to Nova Scotia (from Neves, 1981)

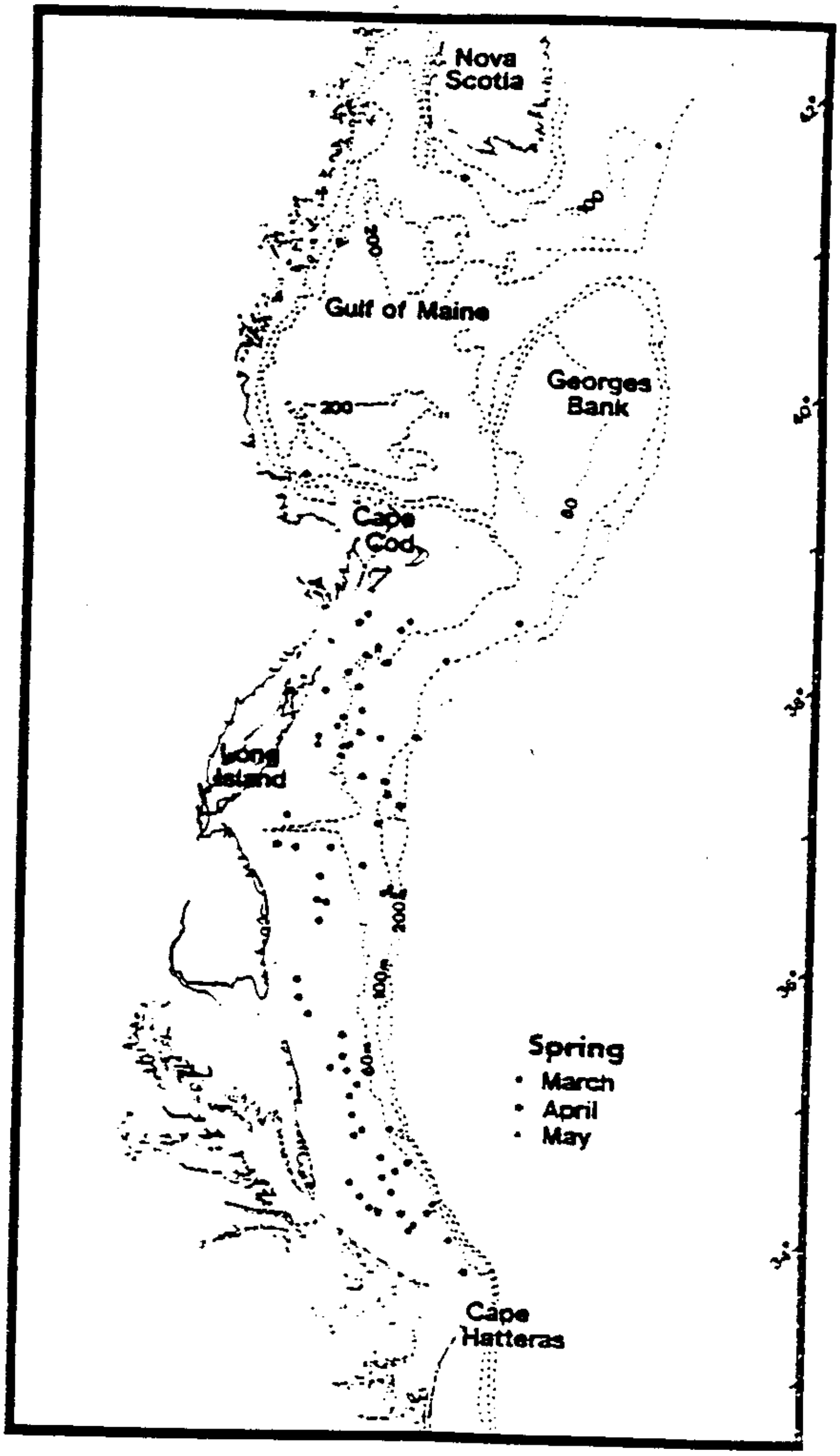


Figure IV-8. Location of blueback herring catches during spring bottom trawl surveys, 1968-78, Cape Hatteras, NC, to Nova Scotia (from Neves, 1981)

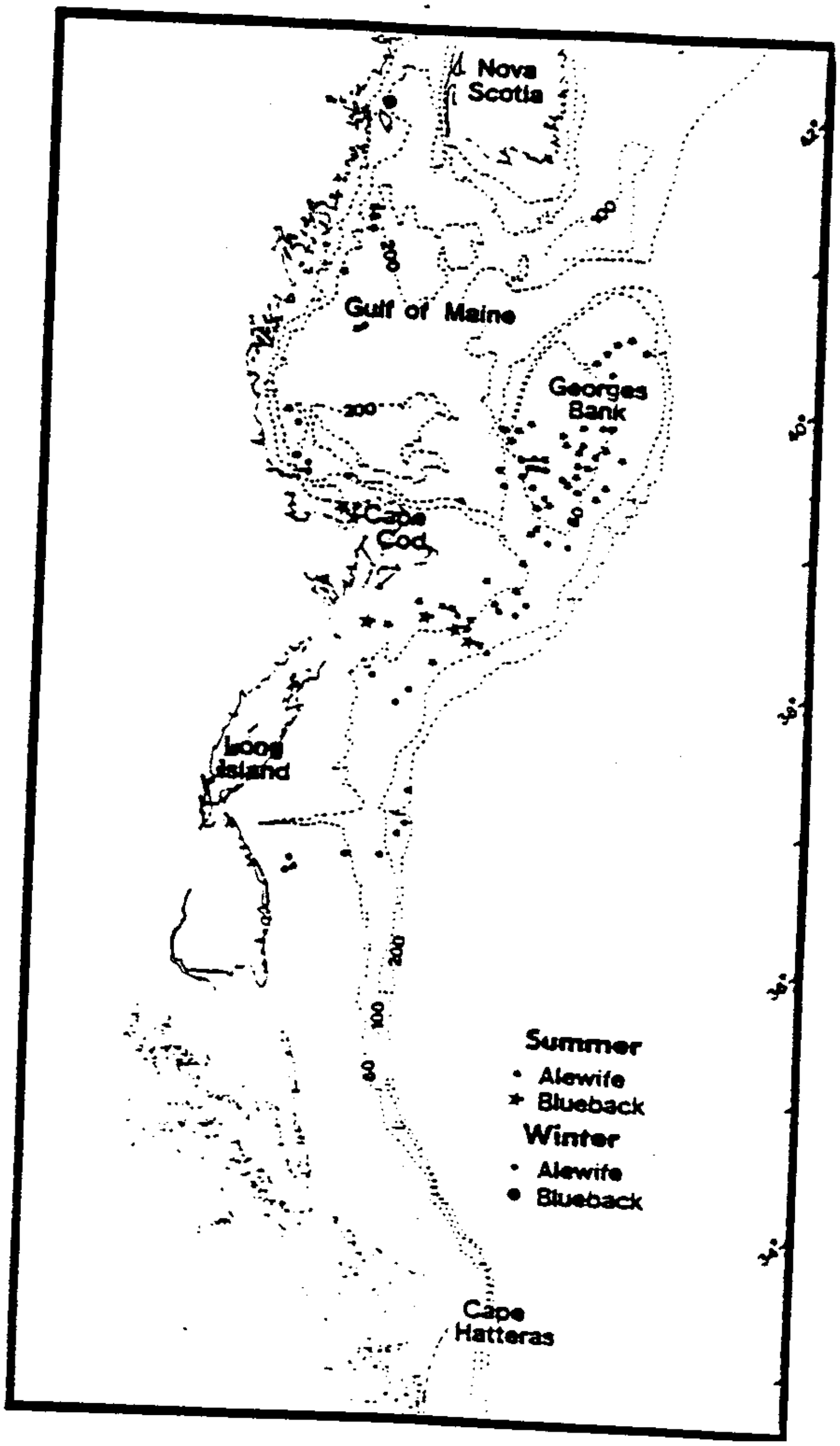


Figure IV-9. Location of catches of alewife and blueback herring during summer and winter bottom trawl surveys, 1963-78, Cape Hatteras, NC, to Nova Scotia (from Neves, 1981)

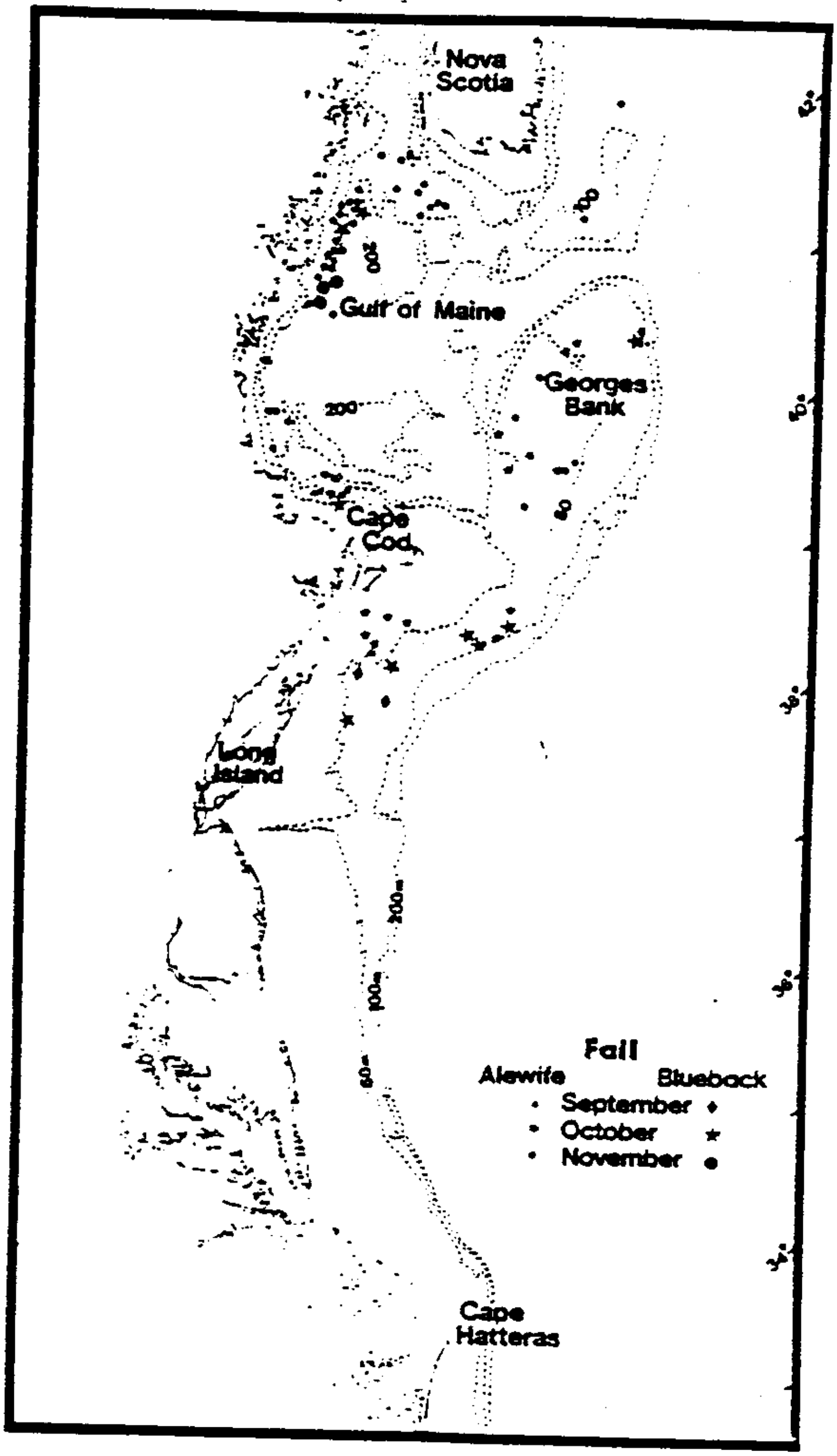


Figure IV-10. Location of catches of alewife and blueback herring during fall bottom trawl surveys, 1963-78, Cape Hatteras, NC, to Nova Scotia (from Neves, 1981)

The offshore harvests by foreign fleets in the late 1960's appeared to impact southern blueback herring stocks while having little apparent effect on northern alewife stocks (see Virginia and Maine discussions above). These findings suggest that coastal river herring stocks do not mingle to the extent that American shad stocks apparently do, at least during the seasons during which foreign harvests were being made. Seasonal changes in location of the foreign fleet during the period when large offshore harvests were being made also suggest a general northward movement of the stocks in summer. The fleet would begin operations off the North Carolina-Virginia coasts in spring and move northward to the Georges Banks area in late summer (H. Johnson, pers. comm.).

In summary, while no data are available to assess the specific coastal migration patterns of individual stocks of river herring from along the east coast of the U.S., the limited data are consistent with an assumption that river herring exhibit a migratory pattern similar to that of American shad. Potential for interjurisdictional conflicts exist where there are active fisheries in coastal waters and the lower portions of major estuaries.

F. MARKET FACTORS INFLUENCING FISHERIES

In the early 1900's, river herring were prized as food fish, primarily because they were amenable to salting for shipment to major urban markets (Williams et al. 1972). With the advent of refrigeration, their use as food fish declined. In more recent years, river herring have been used primarily for bait, pet food, and reduction to fish meal. All these uses have relatively low dollar value and high volume.

Increases in dockside value of landings over the past 30 years appear to reflect the relative low desirability of river herring. Price per pound has risen by only a factor of five over this period, and current value remains very low (3 to 6 cents per pound)(Table IV-19).

Seasonal changes in price do occur, but not with a regional pattern as shown with American shad. NOAA data suggest that early values are high in both Maine and North Carolina. However, the accuracy of the short-term (i.e., monthly) NOAA data is poor. Maine landings are reported for the months of June through October, despite the fact that virtually all harvests are taken in May (Squiers, pers. comm.). Seasonal changes in price per pound would not be expected, since river herring landings are not shipped any extensive distance, but are used locally.

Because of the large-volume nature of commercial river herring fisheries, landings may be significantly influenced by the existence of a small number of major buyers or processing

Table IV-19. Annual average dockside value of river herring (dollars)(from NOAA Fishery Statistics of the United States). Dashed lines denote no catch reported, blanks denote no data acquired.

Year	ME	NH	MA	RI	CO	NY	NJ	PA	DE	MD	VA	NC*	SC	GA	FL
1950	0.01	----	0.12	0.01	0.01	0.03	0.05		0.03	0.02	0.02	0.02	----	----	0.03
1951	0.01	----	0.11	0.01	0.01	0.02	0.04		0.04	0.02	0.01	0.01	----	----	0.02
1952	0.01	----	0.12	0.01	0.01	0.01	0.01		0.06	0.02	0.02	0.01	----	----	0.05
1953	0.01	----	0.02	0.01	0.01	0.04	0.02		0.03	0.02	0.02	0.01	----	----	----
1954	0.01	----	0.01	0.02	0.01	0.04			0.01	0.02	0.01	0.01	----	----	0.04
1955	0.01	----	0.01	0.02	0.01	0.02	0.04		0.05	0.02	0.01	0.01	----	----	0.18
1956	0.01	----	0.01	0.02	0.01	0.03	0.04		0.03	0.02	0.01	0.11	----	----	0.26
1957	0.01	0.01	0.01	0.01	0.02	0.02	0.04		0.04	0.02	0.02	0.01	----	----	0.03
1958	0.01	0.02	0.01	0.01	0.02	0.02	0.04		----	0.02	0.01	0.01	----	----	0.03
1959	0.01	0.01	0.01	0.01	0.01	0.22	0.04		----	0.02	0.01	0.01	----	----	0.03
1960	0.01	0.01	0.01	----	0.01	0.05	0.03		0.02	0.02	0.02	0.01	----	----	0.04
1961	0.02	0.01	0.01	----	0.01	0.93	0.06		0.05	0.01	0.02	0.01	----	----	0.03
1962	0.01	0.01	0.01	----	0.02	0.03	0.05		----	0.01	0.02	0.01	----	----	----
1963	0.02	0.01	0.01	0.02	0.02	0.03	0.04		----	0.02	0.02	0.01	----	----	0.04
1964	0.02	0.01	0.01	0.01	0.01	0.03	0.07		----	0.02	0.02	0.01	----	----	0.02
1965	0.01	0.07	0.12	0.01	0.01	0.04	0.04		----	0.02	0.01	0.10	0.02	----	0.05

Table IV-19. Continued

Year	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	SC	GA	FL
1966	0.02	0.01	0.01	0.02	0.02	0.02	0.04		----	0.02	0.02	0.01	0.02	----	0.03
1967	0.03	0.03	0.01	0.02	0.02	0.05	0.42		----	0.02	0.02	0.02	0.02	----	----
1968	0.02	0.02	0.02	0.02	0.03	0.06	0.04		----	0.02	0.02	0.02	0.02	----	----
1969	0.02	0.03	0.02	0.02	0.03	0.11	0.03		----	0.02	0.02	0.02	0.02	----	----
1970	0.02	0.03	0.01	0.02	0.02	0.09	0.03		----	0.02	0.02	0.02	0.02	----	----
1971	0.02	0.04	0.02	0.04	0.04		0.04		----	0.02	0.02	0.02	0.03	----	----
1972	0.02	0.04	0.02	0.04	0.04	0.06	0.07		----	0.02	0.03	0.02	0.02	----	----
1973	0.03	0.04	0.02	0.07	0.07	0.04	0.04		0.02	0.02	0.03	0.03	0.03	----	----
1974	0.03	----	0.04	0.06	0.06	0.07	0.04		0.03	0.02	0.03	0.04	0.03	----	----
1975	0.04	----	0.01	0.05	0.06	0.07	0.04		0.04	0.02	0.04	0.04	0.06	----	0.15
1976	0.03	----	0.04	0.06	0.04	0.10	0.09		0.04	0.04	0.04	0.05	0.04	----	0.23
1977															

houses. In Virginia, the last processing plant handling river herring closed in 1982 (W. Kriete, pers. comm.), suggesting that landings may decline substantially in the future due to lack of a market.

Several implications of market factors for management of river herring can be drawn from these data. The very low dollar value of these species suggests that fisheries will only persist if large volumes can be harvested. Large relative changes in low prices (i.e., going from 3 to 4 cents per pound), may serve as limited incentive for increases in fishing effort. Existence of a market may be a more important controlling factor on the magnitude of landings than price.

G. SELECTED LIFE HISTORY ASPECTS RELEVANT TO MANAGEMENT

Age of Maturity

Data on age of maturity for male and female blueback herring from several drainage systems along the east coast are presented in Tables IV-20 and IV-21. No latitudinal gradient in age at maturity is evident, although some large differences between river systems are evident. As a generalization, about 80% of females return to spawn by age IV, while data for males are so variable that generalizations cannot be made. The literature frequently allude to males returning at age III (e.g., Hildebrand and Schroeder, 1928).

Comparable data for alewife are presented in Tables IV-22 and IV-23. These data suggest a somewhat higher age of maturity for female alewife than for blueback herring. Male alewife data are more consistent with data for male blueback herring in showing a higher percentage of fish returning at age III than is the case for females. Data from Rhode Island and Maine indicate that mean age and length for males is consistently lower than for females (R.I. Div. of Fish and Wildlife, 1983; Maine Department of Marine Resources, 1983).

These age-of-maturity data suggest no significant difference between the two species: more males return at a somewhat (although not substantially) earlier age than females, and most fish are recruited to spawning runs at least once by age V. Depth of interpretation of such compilations of data is limited because of possible differences in scale-reading procedures followed by different investigators. Such differences were evident during a scale reading workshop held by the Shad and River Herring S and S Committee. However, such age distribution data are sufficient to provide a general overview of the species life history characteristics.

Table IV-20. Cumulative proportion virgin female of blueback herring maturing by age in several Atlantic coast river systems (from PSEG, 1982a)

Reference Location	Street and Adams, 1969 Altamaha, Ogeechee, and Savannah Rivers, GA		Pate, 1973 Albemarle Sound and tributaries, NC		Johnson et al., 1977 Albemarle Sound NC		Johnson et al., 1977 Scuppernong River NC	
Age	n	Proportion	n	Proportion	n	Proportion	n	Proportion
II	4	0.070	-	-	-	-	-	-
III	26	0.510	76	0.284	17	0.037	12	0.080
IV	28	0.980	104	0.672	306	0.695	109	0.807
V	1	1.000	68	0.925	118	0.949	26	0.980
VI	-	-	16	0.985	24	1.000	3	1.000
VII	-	-	4	1.000	-	-	-	-

Reference Location	Johnson et al., 1977 Meherrin River NC		Johnson et al., 1977 Chowan River NC		Johnson et al., 1977 Alligator River NC		Johnson et al., 1977 Edenton Bay NC	
Age	n	Proportion	n	Proportion	n	Proportion	n	Proportion
III	-	-	3	0.021	2	0.067	-	-
IV	63	0.441	111	0.803	23	0.834	-	-
V	59	0.834	28	1.000	5	1.000	1	1.000
VI	21	1.000	-	-	-	-	-	-
VII	-	-	-	-	-	-	-	-

Reference Location	Patrimoulx et al, 1980 Susquehanna River PA		Present Study Delaware River NJ		Loesch, 1969 Poquetanuck and Trading Coves, CT		Marcy, 1969 Connecticut River and Bride Brook, CT	
Age	n	Proportion	n	Proportion	n	Proportion	n	Proportion
III	-	-	-	-	4	0.235	17	0.090
IV	49	0.412	2	0.182	5	0.529	141	0.816
V	66	0.967	6	0.727	8	1.000	31	1.000
VI	4	1.000	1	0.818	-	-	-	-
VII	-	-	2	1.000	-	-	-	-

Reference Location	Scherer, 1972 Connecticut River MA	
Age	n	Proportion
III	7	0.125
IV	40	0.849
V	9	1.000

Table IV-21. Cumulative proportion of virgin male blueback herring maturing by age in several Atlantic coast river systems (from PSEG, 1981a)

Reference Location	Street and Adams, 1969 Altamaha, Ogeechee, and Savannah Rivers, GA		Pate, 1973 Albemarle Sound and tributaries, NC		Johnson et al., 1977 Albemarle Sound NC		Johnson et al., 1977 Scuppernong River NC	
Age	n	Proportion	n	Proportion	n	Proportion	n	Proportion
II	12	0.200	-	-	-	-	-	-
III	41	0.870	112	0.333	50	0.078	33	0.125
IV	7	0.990	154	0.791	453	0.787	192	0.855
V	1	1.000	66	0.987	128	0.987	38	1.000
VI	-	-	4	1.000	8	1.000	-	-

Reference Location	Johnson et al., 1977 Meherrin River NC		Johnson et al., 1977 Chowan River NC		Johnson et al., 1977 Alligator River NC		Johnson et al., 1977 Edenton Bay NC	
Age	n	Proportion	n	Proportion	n	Proportion	n	Proportion
III	4	0.029	12	0.065	1	0.024	-	-
IV	69	0.536	142	0.837	36	0.881	-	-
V	55	0.960	30	1.000	5	1.000	3	0.333
VI	8	1.000	-	-	-	-	5	0.888
VII	-	-	-	-	-	-	1	1.000

Reference Location	Patrimoulx et al, 1980 Susquehanna River PA		Present Study Delaware River NJ		Loesch, 1969 Poquetanuck and Trading Coves, CT		Marcy, 1969 Connecticut River and Bride Brook, CT	
Age	n	Proportion	n	Proportion	n	Proportion	n	Proportion
III	3	0.031	4	0.333	15	0.500	93	0.469
IV	57	0.613	3	0.583	12	0.900	99	0.967
V	38	1.000	3	0.833	3	1.000	7	1.000
VI	-	-	1	0.916	-	-	-	-
VII	-	-	1	1.000	-	-	-	-

Reference Location	Scherer, 1972 Connecticut River MA	
Age	n	Proportion
III	62	0.559
IV	48	0.991
V	1	1.000

Table IV-22. Cumulative proportion of virgin female alewife maturing by age in several Atlantic coast river system (from PSEG, 1982b)

Reference Location	Pate, 1973 Albemarle Sound and tributaries, NC		Johnson et al., 1977 Albemarle Sound, NC		Johnson et al., 1977 Scuppernong River, NC	
Age	n	Proportion	n	Proportion	n	Proportion
III	26	0.132	17	0.046	13	0.104
IV	128	0.782	272	0.787	86	0.792
V	38	0.975	62	0.956	20	0.952
VI	5	1.000	16	1.000	6	1.000

Reference Location	Johnson et al., 1977 Meherrin River, NC		Johnson et al., 1977 Chowan River, NC		Johnson et al., 1977 Alligator River, NC	
Age	n	Proportion	n	Proportion	n	Proportion
IV	27	0.600	58	0.734	4	0.032
V	16	0.956	16	0.937	101	0.840
VI	2	1.000	5	1.000	10	1.000

Reference Location	Johnson et al., 1977 Edenton Bay, NC		Tsimenides, 1970 Rappahannock River, VA		Tsimenides, 1970 Potomac River, VA	
Age	n	Proportion	n	Proportion	n	Proportion
III	-	-	34	0.176	15	0.259
IV	-	-	146	0.933	40	0.948
V	-	-	13	1.000	3	1.000
VI	1	1.000	-	-	-	-

Reference Location	Present study Delaware River, NJ	
Age	n	Proportion
III	4	0.114
IV	17	0.600
V	6	0.771
VI	7	0.971
VII	1	1.000

Table IV-23. Cumulative proportion of virgin male alewife maturing by age in several Atlantic coast river systems (from PSEG, 1982b)

Reference Location	Pate, 1973 Albemarle Sound and tributaries, NC		Johnson et al., 1977 Albemarle Sound, NC		Johnson et al., 1977 Scuppernong River, NC	
Age	n	Proportion	n	Proportion	n	Proportion
II	-	-	2	0.003	-	-
III	81	0.319	97	0.171	59	0.303
IV	136	0.854	387	0.843	111	0.872
V	36	0.995	65	0.956	22	0.985
VI.	1	1.000	5	1.000	3	1.000

Reference Location	Johnson et al., 1977 Meherrin River, NC		Johnson et al., 1977 Chowan River, NC		Johnson et al., 1977 Alligator River, NC	
Age	n	Proportion	n	Proportion	n	Proportion
II	-	-	2	0.015	-	-
III	7	0.084	12	0.105	19	0.133
IV	65	0.867	101	0.859	109	0.895
V	11	1.000	18	0.993	14	0.993
VI	-	-	1	1.000	1	1.000

Reference Location	Johnson et al., 1977 Edenton Bay, NC		Tsimenides, 1970 Rappahannock River, VA		Tsimenides, 1970 Potomac River, VA	
Age	n	Proportion	n	Proportion	n	Proportion
III	-	-	62	0.259	31	0.526
IV	-	-	170	0.971	28	1.000
V	3	0.333	7	1.000	-	-
VI	5	0.889	-	-	-	-
VII	1	1.000	-	-	-	-

Reference Location	Present study Delaware River, NJ	
Age	n	Proportion
III	3	0.176
IV	11	0.823
V	3	1.000

Size at Age

Tables IV-24 and IV-25 present length-at-age data for male and female alewife and blueback herring. Two major points are revealed by these data: females of both species are larger than males, and there is a latitudinal trend in size, with northern fish being of greater size than southern fish. The majority of data presented here are actual measurements of fish at age as opposed to back-calculated lengths at age, thus avoiding the problems of Lee's phenomenon and scale edge resorption.

Juvenile Growth Rates

A compilation of juvenile growth rates for both species is presented in Table IV-26. A regional trend in growth rates is suggested by these data, with substantially higher rates for northern stocks. However, as is discussed below, growth rate may be strongly affected by juvenile density.

Frequency of Repeat Spawning

Spawning history data for blueback herring and alewife are presented in Tables IV-27 and IV-28. As a broad generalization, repeat spawners comprise 30 to 40 percent of all runs. No distinctive latitudinal gradient in percentage repeat spawning is shown in the data presented here, in contrast to the case with American shad. Bulak et al. (1977), reporting only 8% repeat spawners in the Santee-Cooper system in South Carolina, has suggested that a latitudinal gradient does exist. These types of data are heavily influenced by previous fishing mortality, the occurrence of individual dominant year-classes, and the existence of consistent scale-reading biases between individual investigators and geographical regions which cannot be identified. The majority of existing data suggest no latitudinal trend in repeat spawning percentage.

Fecundity

Fecundity estimates for both blueback herring and alewife vary with fish size, with size in turn varying by age and latitude. Data have been collected for fish from many different latitudes along the east coast (e.g., Street, 1969; Frankensten, 1976; Loesch, 1979; Scherer, 1972; Kissil, 1969; Mayo, 1974). In general, fecundity ranges from 100,000 to 200,000 eggs per female for blueback herring, and from 100,000 to 300,000 for alewife. Different methods of estimating fecundity introduce

Table IV-24. Length at age of blueback herring (from PSEG, 1982b)

Data Source	Location	Measurement		AGE III	IV	V	VI	VII	VIII	IX	X	XI
FEMALES												
Street and Adams,[a] 1969	GA	FL (mm)	X̄	244	255	265	276	275	-	-	-	-
			R	-	-	-	-	-	-	-	-	-
Pate, 1973	NC	FL (mm)	X̄	245	252	258	264	268	280	307	-	-
			R	226-275	235-272	236-281	251-281	250-290	280	307	-	-
Frankensteen, 1976	NC	FL (mm)	X̄	-	246.2	254.7	265.0	265.4	-	-	-	-
			R	-	-	-	-	-	-	-	-	-
Beal, 1968[b]	VA	FL (mm)	X̄	-	191	242	230	239	259	262	266	270
			R	-	180-203	217-228	228-245	229-254	256-260	261-262	266-267	270
Petrimoulx et al. 1980	PA	TL (mm)	X̄	-	283	287	307	321	312	-	-	-
			R	-	269-305	250-315	293-328	313-328	312	-	-	-
Marcy, 1969	CT	TL (mm)	X̄	261.3	276.6	291.3	300.9	310.9	-	-	-	-
			R	258-265	255-291	259-321	255-320	289-330	-	-	-	-
Scherer, 1972	MA	TL (mm)	X̄	-	275.7	285.1	304.1	320.1	-	-	-	-
			R	-	266-291	263-315	280-325	312-331	-	-	-	-
MALES												
Street and Adams,[a] 1969	GA	FL (mm)	X̄	234	242	252	264	-	-	-	-	-
			R	-	-	-	-	-	-	-	-	-
Pate, 1973	NC	FL (mm)	X̄	231	241	245	251	258	270	-	-	-
			R	210-247	232-264	221-269	230-283	243-270	270	-	-	-
Frankensteen, 1976	NC	FL (mm)	X̄	-	237.9	244.1	250.5	248.1	-	-	-	-
			R	-	-	-	-	-	-	-	-	-
Beal, 1968[b]	VA	FL (mm)	X̄	-	187	218	232	241	250	256	-	-
			R	-	184-200	218-220	232-240	240-246	250	256	-	-
Petrimoulx et al. 1980	PA	TL (mm)	X̄	254	272	277	301	291	-	-	-	-
			R	236-281	262-296	265-301	283-318	291	-	-	-	-
Marcy, 1969	CT	TL (mm)	X̄	258.0	266.5	279.5	285.8	298.1	-	-	-	-
			R	244-271	248-287	245-297	271-305	275-312	-	-	-	-
Scherer, 1972	MA	TL (mm)	X̄	268.5	267.9	277.8	290.8	306.5	-	-	-	-
			R	244-284	249-292	255-312	273-305	300-313	-	-	-	-

[a] Titles of length-frequency figures in Street and Adams (1969) appear to be in error. Figure 4: hickory shad is actually blueback herring. Lengths herein were derived from this figure.

[b] Beal (1968) apparently counted the freshwater mark as an annulus.

Table IV-25. Length at age of alewife (from PSEG, 1982b)

Reference	Location	Measurement		III	IV	V	VI	VII	VIII	IX
							Males			
Pate, 1973	NC	FL (mm)	$\bar{x}$	236	249	256	259	258	279	-
			R	220-263	226-275	230-279	240-280	255-276	264-281	-
Rideout, 1974	MA	TL (mm)	$\bar{x}$	274.7	298.7	309.4	313.9	319.3	321.2	320.0
			R	250-296	280-316	288-327	297-332	305-335	308-338	320-320
Marcy, 1969	CT	TL (mm)	$\bar{x}$	-	264.6	277.9	289.9	300.7	-	-
			R	-	200-290	257-299	266-306	286-315	-	-
Graham, 1956	Canada	SL (mm)	$\bar{x}$	174.4	175.1	188.6	-	-	-	-
			R	-	-	-	-	-	-	-
							Females			
Pate, 1973	NC	FL (mm)	$\bar{x}$	254	261	270	277	283	287	-
			R	238-276	230-290	239-292	251-298	255-311	264-296	-
Rideout, 1974	MA	TL (mm)	$\bar{x}$	280.4	306.8	318.0	316.8	331.3	333.5	335.2
			R	260-299	282-321	303-332	302-324	315-353	321-352	317-347
Marcy, 1969	CT	TL (mm)	$\bar{x}$	-	283.7	284.0	299.0	307.8	324.8	-
			R	-	266-299	261-302	271-317	287-325	313-339	-
Graham, 1956	Canada	SL (mm)	$\bar{x}$	-	167.3	202.5	248.0	-	-	-
			R	-	-	-	-	-	-	-

Table IV-26.. Growth rates of juvenile blueback herring and alewife.

Species	Data Source	Location	Growth per day
Blueback herring	Loesch (1969)	Connecticut	0.452 mm 0.569 mm 0.657 mm
	Burbidge (1974)	Virginia	0.209 mm
	Michaels (1982)	Georgia	0.208 mm
Alewife	PSE&G (1982)	New Jersey	0.625 mm
	Jimenez (1978)	Massachusetts	0.820-0.996 mm

Table IV-27. Spawning history of anadromous alewife; percentage by age and times spawned (from PSEG, 1982b)

Location (Year)	Reference	Age	Males 0	Males 1	Males 2	Males 3	Males 4	Males 5	Males 6	Males n	Females 0	Females 1	Females 2	Females 3	Females 4	Females 5	Females 6	Females n
Albemarle Sound and Tributaries, NC (1972)	Pate, 1973	III	100.0							81	100.0							36
		IV	79.5	20.5						171	87.7	12.3						146
		V	37.9	43.1	19.0					93	33.6	46.0	20.4					113
		VI	3.7	33.3	31.9	22.2				27	4.7	17.3	61.3	16.7				75
		VII				87.5	12.5			8		5.7	30.0	48.6	14.3			35
		VIII				50.0		50.0		2				50.0	37.5	12.5		8
		Total	66.1	21.9	7.8	3.6	0.5	0.3		382	46.9	31.1	16.9	6.0	2.6	0.3		403
Albemarle Sound, NC (1975-76)	Johnson et al., 1977	II	100.0							2								0
		III	100.0							87	100.0							17
		IV	93.0	7.0						416	96.8	3.2						281
		V	32.0	63.5	4.4					203	33.5	64.3	2.2					103
		VI	11.6	20.9	67.4					43	23.9	19.4	56.7					67
		VII		100.0		100.0				2		8.3	41.7	41.7	8.3			12
		VIII								0			100.0					1
		IX								0			100.0					1
		Total	72.9	22.0	5.0	0.1				753	63.0	35.1	1.8	0.9	0.2			365
Scuppernong River, NC (1975-76)	Johnson et al., 1977	III	100.0							59	100.0							13
		IV	91.0	9.0						122	97.7	2.3						88
		V	61.1	36.1	2.8					36	70.0	30.0						29
		VI	50.0	33.3	16.7					6	60.0	30.0	10.0					10
		VII								0			100.0					1
		Total	87.4	11.4	0.8					223	81.6	9.9	1.4					141
Meherrin River, NC (1975-76)	Johnson et al., 1977	III	100.0							7								0
		IV	98.5	1.5						66	100.0							27
		V	21.6	78.4						51	38.1	59.5	2.4					42
		VI		15.4	84.6					13	20.0	25.0	55.0					20
		VII				100.0				1			33.3	66.7				3
		VIII								0				100.0				3
		IX								0				100.0				1
		Total	60.1	31.2	8.0	0.7				138	49.4	31.6	13.7	5.3				95
Chowan River, NC (1975-76)	Johnson et al., 1977	II	100.0							3								0
		III	100.0							12								0
		IV	95.3	4.7						107	96.7	3.3						60
		V	23.1	71.8	5.1					78	21.3	77.3	1.3					75
		VI	4.8	23.8	71.4					21	17.9	10.7	71.4					28
		VII		100.0						1		14.3	42.9	42.9				7
		Total	61.1	30.1	8.8					222	46.5	37.6	14.1	1.8				170
Alligator River, NC (1975-76)	Johnson et al., 1977	III	100.0							19	100.0							4
		IV	90.1	9.9						111	95.3	4.7						106
		V	36.8	52.6	10.5					38	25.6	69.2	5.1					39
		VI	33.3		66.7					3	11.1	22.2	66.7					9
		Total	79.6	17.7	2.7					171	73.4	21.5	5.1					158
Edenton Bay, NC (1975-76)	Johnson et al., 1977	V	100.0							3								0
		VI	25.0	60.0	15.0					20		100.0						1
		VII	5.3	63.2	26.3	5.3				19			50.0	50.0				4
		VIII								0				100.0				1
		IX								0				50.0	50.0			2
		Total	21.4	57.1	19.0	2.4				42	0.0	12.5	25.0	50.0	12.5			8

Table IV-27. Continued

Location (Year)	Reference	Age	Males 0	1	2	3	4	5	6	N	Females 0	1	2	3	4	5	6	N
			Times Spawned															
Rappahannock River, VA (1963-69)	Tsimenides, 1970	III	25.0			up to four spawns				339	17.6			up to six spawns				103
		IV	71.1							339	75.7							103
		V	3.9							339	6.7							103
		Total								1017								309
Potomac River, VA (1963-69)	Tsimenides, 1970	III	52.6			up to four spawns				59	25.0			up to six spawns				58
		IV	47.4							59	70.0							58
		V								0	5.2							58
		Total								118								174
Delaware River, NJ (1981)	Present Study	III	100.0							3	100.0							4
		IV	86.6	13.4						15	89.5	10.5						19
		V	60.0	40.0						5	60.0	30.0	10.0					10
		VI		33.3	33.3	33.3				3	77.8	11.1		11.1				9
		VII				100.0				1	50.0			50.0				2
		VIII								0				100.0				1
		Total	61.5	30.8	4.0	4.0				27	77.8	13.3	2.2	6.7				45
Connecticut River and Holyoke Brook, CT (1966-67)	Marcy, 1969	III	100.0							-								-
		IV	100.0							-	100.0							-
		V	24.1	75.9						-	37.7	62.3						-
		VI		38.7	61.3					-		74.2	25.8					-
		VII			69.6	30.4				-			82.3	17.7				-
		VIII								-				100.0				-
		Total	(Males + Females = 844 total)															

Table IV-28. Spawning history of blueback herring; percentage by age and times spawned (from PSEG, 1982a)

Location (Year)	Reference	Age	Times Spawned – Males 0	1	2	3	4	5	6	n	Females 0	1	2	3	4	5	6	n
Altamaha, Ogeechee	Street and	II	20.0	-	-	-					7.0	-	-	-				
and Savannah	Adams, 1969	III	67.0	-	-	-					44.0	-	-	-				
Rivers, GA		IV	12.0	-	-	-					47.0	-	-	-				
(1968-69)		V	1.0	-	-	-					2.0	-	-	-				
		Total	32.0	41.0	35.0	8.0					12.0	31.0	17.0	3.0				
Albemarle	Pate, 1973	III	100.0							112	100.0							76
Sound and		IV	61.4	36.6						243	74.3	23.7						140
Tributaries, NC		V	32.8	36.3	30.0					201	31.3	36.4	32.3					217
(1972)		VI	4.7	14.1	61.6	18.0				63	16.5	17.5	47.4	10.6				97
		VII		5.6	5.6	83.3	5.6			18	10.3		22.7	40.9	18.2			22
		VIII					100.0			1					100.0			4
		IX														100.0		1
		Total	50.9	26.5	17.6	4.7	0.3			660	40.1	23.7	21.7	4.8	1.4	0.2		559
Albemarle Sound	Johnson	III	100.0							50	94.4	5.6						18
NC (1975-76)	et al., 1977	IV	99.7	0.3						434	97.5	2.5						316
		V	54.5	44.5	1.3					233	65.4	33.1	1.5					260
		VI	11.8	42.6	44.1	1.5				68	10.5	49.2	38.3					130
		VII		20.0	60.0	20.0				10		13.6	46.7	35.6	2.2			45
		VIII			100.0					1			100.0					1
		IX				100.0				2				100.0				4
		Total	76.2	18.3	4.8	0.5				818	60.1	28.2	8.8	2.8	0.1			776
Scuppernong	Johnson	III	100.0							33	92.3	7.7						13
River, NC	et al., 1977	IV	97.5	2.5						197	94.8	5.2						115
(1975-76)		V	65.5	31.0	3.4					58	51.0	49.0						51
		VI									60.0	40.0						5
		VII												100.0				1
		Total	91.3	8.0	0.7					288	81.1	18.4		0.5				185
Meherrin River,	Johnson	III	100.0							4								
NC (1975-76)	et al., 1977	IV	95.8	4.2						72	100.0							63
		V	59.1	40.9						93	54.1	43.1	3.0					109
		VI	13.3	43.3	41.7	1.7				60	20.4	52.4	27.2					103
		VII		22.2	55.6	22.2				9	.	17.9	43.6	35.9	2.6			39
		VIII			100.0					1			25.0	25.0	50.0			4
		IX				100.0				2				85.7	14.3			7
		Total	56.4	28.6	12.9	2.1				241	44.0	33.2	15.1	6.5	1.2			325
Chowan River,	Johnson	III	100.0							33	100.0							3
NC (1975-76)	et al., 1977	IV	96.6	3.4						147	99.1	0.9						112
		V	43.5	55.1	1.4					69	31.4	55.6	13.3					90
		VI		42.9	57.1					7		54.5	36.4	9.1				11
		VII			100.0					1								
		Total	78.6	19.5	2.3					258	61.7	30.4	7.6	0.5				216
Alligator River	Johnson	III	100.0							1	100.0							3
NC (1975-76)	et al., 1977	IV	94.7	5.3						38	95.8	4.2						24
		V	33.3	66.7						15	31.7	63.7	4.5					22
		VI			100.0					1		100.0						1
		Total	76.4	21.8	1.8					55	60.4	38.8	1.8					50

Table IV-28. Continued

Location (Year)	Reference	Age	Males 0	1	2	3	4	5	6	n	Females 0	1	2	3	4	5	6	n
Edenton Bay (1975-76)	Johnson et al., 1977	V	100.0							3								0
		VI	25.0	60.0	15.0					20		100.0						1
		VII	5.3	63.2	26.3	5.3				19			50.0	50.0				4
		VIII								0				100.0				1
		IX								0				5.0	50.0			2
		Total	21.4	57.1	19.0	2.4				42	0	12.5	25.0	50.0	12.5			8
Susquehanna River, PA (1980)	Petrimoulx et al., 1980	III	100.0							3								0
		IV	96.6	3.4						39	98.0	2.0						50
		V	69.1	25.5	5.5					55	82.5	16.3	1.3					80
		VI	19.0	47.6	33.3					21	10.0	65.0	25.0					40
		VII			100.0					1		40.0	20.0	40.0				5
		VIII								0					100.0			1
		Total	73.6	18.7	7.9					119	67.6	23.9	6.8	1.1	0.6			176
Delaware River, NJ (1981)	Present Study	III	100.0							4								0
		IV	100.0							3	66.7	33.3						3
		V	42.9	42.9	14.3					7	46.2	38.5	15.4					13
		VI	10.0	30.0	30.0	30.0				10	11.1	33.3	44.4	11.1				9
		VII	20.0	20.0	40.0	20.0				5	40.0		20.0	40.0				5
		VIII								0				100.0				2
		IX								0					50.0	50.0		2
		Total	41.4	24.1	20.7	13.8				29	31.6	26.5	20.6	14.7	2.9	2.9		34
Connecticut River and Bride Brook, CT (1966-67)	Marcy, 1969	III	100.0								100.0							
		IV	54.6	44.4							83.3	16.7						
		V		53.4	46.6						2.9	83.8	13.3					
		VI		2.7	56.8	40.5						10.9	82.8	6.3				
		VII			21.4	42.9	35.7						42.6	55.3	2.1			
		Total	(Males and Females = 335 Total)															
Poquetanuck and Trading Coves, CT (1966)	Leasch, 1969	III	100.0							13	100.0							4
		IV	53.1		46.9					23	100.0							5
		V	3.3		96.7					87	16.4	83.6						50
		VI			100.0					23		100.0						29
		VII			100.0					2		100.0						17
		Total	20.0		80.0					150	16.2	83.8						105

unknown biases into the data, and thus various estimates of fecundity in the literature may not be directly comparable. The data demonstrate that both species of river herring have relatively high fecundity, at levels comparable to that for American shad.

Mortality Rates

Mortality and survival rates presented in PSEG (1982b,c) were estimated by using age frequency data presented in the literature (Tables IV-29 and IV-30). Annual mortality rates appear to vary significantly among river systems, ranging from 30 to 90%. No latitudinal gradient is evident, and rates for blueback and alewife appear relatively similar. However, values such as those calculated by PSEG can be strongly influenced by the representativeness of the samples yielding the age data, and by scale-reading procedures.

Despite the great variability in the data, several generalizations can be made. Annual survival rates appear to be highest for ages 4 to 5, and lower but fairly constant for older age groups. As noted above, there is no latitudinal gradient in mortality rates. However, mortality rates can be strongly influenced by fishing pressure, since the fisheries in the different regions of the country vary markedly. Thus, the comparability of mortality estimates for the purpose of drawing conclusions about population biology of the species is inappropriate unless all related factors are accounted for.

Some limited but very precise data are available concerning fishing mortalities of some runs of river herring. Walton (1980) studied several alewife runs in Maine that have supported stable fisheries for many years. He found that fishing mortalities for individual runs ranged from 80 to 95% each year, which exceed nearly all the reported mortality data in literature. However, they are a result of complete monitoring of run size and harvest, and are thus very accurate. DiCarlo (1982) reported exploitation rates of 73 and 80% in 1980 and 81, respectively, in the Herring River in Massachusetts. Both studies were conducted in streams in which the entire alewife run could be diverted into catch facilities. These data demonstrate that fishing mortalities in relatively stable runs in northern states can be extremely high without causing stock declines. In Rhode Island, draught conditions often result in a lack of sufficient outflow from certain drainage systems with dams to permit emmigration by juveniles or spawned-out adults. In such cases, mortalities of 100% occur (M. Gibson, pers. comm.).

Some limited data on juvenile mortality rates are available. Richkus (1974b) reported mortality rates of 75% of juveniles over a 6-week period prior to emigration from a pond in Rhode Island.

Table IV-29. Mean survival and instantaneous mortality of adult male and female alewife (from PSEG, 1982b)

Location	Reference	Males					Females				
		IV-V	V-VI	VI-VII	VII-VIII	VIII-IX	IV-V	V-VI	VI-VII	VII-VIII	VIII-IX
Albemarle Sound and Tributaries, NC	Pate, 1973	0.55	0.28	0.30	0.25	-	0.77	0.66	0.46	0.22	-
Albemarle Sound, NC	Johnson et al, 1977	0.48	0.21	0.04	-	-	0.65	0.36	0.17	0.16	0.50
Scuppernong River, NC	Johnson et al., 1977	0.29	0.16	-	-	-	0.32	0.34	0.10	-	-
Meherrin River, NC	Johnson et al., 1977	0.77	0.25	0.07	-	-	-	0.47	0.15	0.66	0.50
Alligator River, NC	Johnson et al., 1977	0.31	0.07	-	-	-	0.36	0.23	-	-	-
Chowan River, NC	Johnson et al., 1977	0.72	0.26	0.04	-	-	-	0.37	0.25	-	-
Chown River, NC	Holland and Yelverton, 1973	-	0.16	0.66	0.50	-	-	-	-	-	-
Rappahannock River, VA	Tsimenides, 1970	0.76	0.35	0.26	0.08	-	0.77	0.48	0.63	0.18	-
Potomac River, VA	Tsimenides, 1970	0.96	0.65	0.34	-	-	0.67	0.90	0.38	0.31	-
Delaware River, NJ	Present Study	0.41	0.60	0.33	-	-	0.52	0.40	0.25	0.50	-
Parker River, MA	Mayo, 1974	-	-	-	0.27	0.20	-	-	-	-	-
Connecticut River, Ct	Marcy, 1969	-	0.75	0.31	-	-	-	-	0.61	0.10	-
Long Pond, ME	Havey, 1961[a]	0.39	0.19	-	-	-	0.39	0.17	-	-	-
Mean Survival (S)		0.56	0.32	0.26	0.27	-	0.55	0.43	0.33	0.30	-
Instantaneous Total Mortality (Z)		0.5798	1.1394	1.3471	1.3093		0.5978	0.8440	1.1087	1.2040	

[a]Marcy (1969) indicated that Havey counted the freshwater mark as an annulus.

Table IV-30. Estimated mean survival rates of adult male and female blueback herring (from PSEG, 1982a)

Location	Data source	Males IV-V	Males V-VI	Males VI-VII	Males VII-VIII	Males VIII-IX	Females IV-V	Females V-VI	Females VI-VII	Females VII-VIII	Females VIII-IX	Females IX-X
Albemarle Sound and Tributaries, NC	Pate, 1973	0.43	0.41	0.21	0.05	-	-	0.44	0.33	0.05	-	-
Albemarle Sound, NC	Johnson et al., 1977	0.53	0.29	0.15	0.10	-	0.43	0.35	0.22	-	-	-
Scuppernong River, NC	Johnson et al., 1977	0.29	-	-	-	-	0.44	0.10	-	-	-	
Meherrin River, NC	Johnson et al., 1977	-	0.65	0.15	0.11	-	-	0.94	0.30	0.10	-	-
Tar River, NC	Frankensteen, 1976	-	0.34	0.30	-	-	-	0.52	0.16	-	-	-
Alligator River, NC	Johnson et al., 1977	0.39	0.07	-	-	-	0.92	0.09	-	-	-	-
Chowan River, NC	Johnson et al., 1977	0.47	0.10	0.14	-	-	0.70	0.23	0.20	-	-	-
Chowan River, NC	Holland and Yelverton, 1973	-	0.91	0.45	-	-	-	0.33	-	-	-	-
Rappahannock River VA	Beal, 1968[a]	-	-	0.42	0.22	0.17	-	-	0.66	0.21	0.37	0.23
Susquehanna River, PA	Petrimoulx et al., 1980	0.93	0.30	0.05	-	-	-	0.31	0.13	0.20	-	-
Delaware River, NJ	Present Study 1981	-	-	0.50	-	-	-	0.46	0.56	0.40	-	-
Connecticut River, MA	Scherer, 1972	0.40	0.36	0.14	-	-	-	0.28	0.06	-	-	-
Connecticut River, CT	Marcy, 1969	-	0.32	0.37	-	-	-	-	0.74	-	-	-
Thames River, CT	Loesch and Lund, 1977	-	0.26	0.09	-	-	-	0.30	0.59	-	-	-

[a] Beal counted the freshwater mark as an annulus.

As estimated by Loesch and Kreite (1980), daily juvenile mortality rates in Virginia have a mean of 0.03.

The various mortality data just discussed have many different implications for management. The most dramatic data are the fishing mortality rates for runs in Maine and Massachusetts. Those studies reveal that stable and sustained yields can be generated from runs that encounter extremely high fishing mortality rates. The species must have very high reproductive potential for runs to remain viable under those conditions, which in turn suggests that fishing mortality may have a limited impact on subsequent year-class strength. The summary of North Carolina CPUE data presented earlier (Table IV-6) suggests that overharvest and perhaps, more significantly, harvest of sub-adults in offshore waters can reduce stocks to a level at which ready recovery is not possible. In these circumstances, high fishing mortality exerted on the nonreproductive segment of the popuation may, in fact, have had a significant impact on run stability.

Spawning Habitat Characteristics

The nature of habitats used for spawning along the east coast by river herring appears to differ in a regionally distinct way. In the New England states, where alewife make up the majority of river herring stocks, the majority of production comes from spawning in ponds that are accessible to spawning adults. In the mid Atlantic and more southern states, the majority of spawning appears to take place in rivers, small streams, or tidal waters. In North Carolina, swamps appear to be a dominant spawning area. One exception to this general pattern is in the Santee-Cooper system, where blueback utilize impoundments as spawning and nursery grounds. It has been suggested that blueback do not utilize ponds as spawning areas in the north due to competition with alewife (J. Loesch, pers. comm.); however, this observation is not documented in the literature.

Population Dynamics

Havey (1973) reported a strong correlation between the number of juvenile alewives produced and the numbers of adults returning four years later. This suggests that year-class size is set by the time larvae reach the juvenile stage.

The most precise information on the reproductive potential of river herring stocks comes from the results of restoration programs, which will be discussed in the next section of the report. These restoration programs demonstrate the capability for stocks of both blueback herring and alewife in individual drainage systems to increase dramatically when access to previ- ously unexploited spawning and nursery habitats is opened (e.g., Richkus, 1974a), and thus exhibit a high intrinsic rate of increase. Some data from Maine (Walton, 1981) suggest that there is a saturation of such habitats under conditions of high adult spawning stock; that is, at these higher abundances, larger numbers of spawning adults produce fewer juveniles per adult. Such a response might be the case where limited acreage areas are the major nurseries for the stock. However, observa- tions such as those reported by Walton (1981), may not have accounted for the unobserved early migration of large numbers of small juveniles which has been reported to occur under circumstances of very high juvenile density (Richkus, 1974b). The hypothesis posed in this case was that high densities of juveniles cropped zooplankton to very low levels. A lack of forage resulted in early migration of large numbers of juveniles which could then utilize estuarine areas as nursery. Such a phenomenon would yield population dynamics behavior contrary to that hypothesized by Walton. M. Gibson (R.I. Div. of Fish and Wildlife, pers. comm.) has detected a 4.5 year cycle in some alewife runs in Rhode Island, which is consistent with the age of maturity of Rhode Island stocks and a pattern of stock-dependent recruitment, and supports the hypothesis described by Richkus (1974b). A weak relationship between spawning stock size and juvenile production was reported by Havey (1973) for an alewife run in Maine.

In non-pond types of spawning habitats, such as open estuarine tidal freshwater, habitat limits may not be the major controlling factor on river herrings stocks. In such cases, environmental variation may in fact play a major role, as is suggested for American shad. Insufficient data are available for runs of either species of river herring to document the nature of long-term fluctuations in stock abundance or to in- vestigate the factors that would influence those fluctuations.

Ecological Importance

In most drainage systems along the east coast, juvenile river herring represent the major planktivorous species present in the nursery areas during spring and summer. Juvenile alosids have been shown to have a large impact on zooplankton abundance and species composition through predation (Brooks, 1968; Wells, 1970).

Juvenile alosids may also serve as a major forage species for many important game species. As an example, the work being done on blueback herring by Bulak (1977) in the Santee-Cooper River system in South Carolina is, in part, a function of their perceived importance as forage for striped bass. In many New England states (e.g., Rhode Island), gravid adult alewife are planted in ponds inaccessible to spawning runs, to provide juveniles as forage for resident game species, such as large mouth and small mouth bass, and enhanced growth rates of those species have been observed (M. Gibson, pers. comm.).

H. RESTORATION PROGRAMS

Extensive restoration activities have occurred in the New England states in recent decades. These efforts, which are directed primarily at alewives, have involved construction of fish passage facilities at numerous mill dams on small streams as the primary management activity. Gravid spawning adults taken from existing runs are then stocked in the newly accessible ponds, and their progeny serve as the initial spawning run 3 to 5 years later. Less extensive efforts at restoration have been made in the middle and southern mid-Atlantic and southern states. In some cases (i.e., Virginia) the nature of the major spawning in nursery areas (the large riverine and estuarine freshwaters) rule out active restoration efforts such as those occurring in New England. In other states, where restoration in the ponds through establishing fish passage facilities and stocking of adults might be feasible, the species has not been considered of sufficient importance or need to initiate such activities.

Restoration projects initiated in Maine involved the installation of fishways and the stocking of gravid adults. These projects are listed in Table IV-31. Limited data are currently available on the quantitative success of these restoration efforts on the Royal River. An estimated 50,000 fish returned to the Royal River in 1981 four years after the initial stocking of Sabbathday Lake with subsequent runs of 24,160 in 1982 and 10,029 in 1983 (T. Squiers, pers. comm.).

In New Hampshire, restoration efforts have been made on six coastal streams. The most successful of these efforts has been on the Lamprey River, where after nine years a run of over 50,000 fish has been established (Fig. IV-11). A substantial run may have also been established on the Exeter River, with a 1981 run size of over 15,000 fish but a dramatic decline to less than one thousand in 1982 and 1983.

At least 20 streams in Massachusetts are currently being stocked with gravid adult alewives, with a total of 36,000 fish transported in 1981. The intent of this effort is to establish new runs or augment declining runs. From 1971 to 1979, eight new fish passage facilities were constructed. While no data are available to determine quantitative success of these restoration efforts, the first fish passage facility on the Merrimack River at Essex Dam in Lawrence successfully passed alewife and shad in 1983 (DiCarlo, 1982). At the Holyoke Dam fishlift on the Connecticut River, the number of blueback

Table IV-31. Fishway and stream improvement projects in Maine (adapted from Flagg, 1981)

PROJECT NAME	COMPLETION DATE	WATERSHED	LOCATION TOWN	MILES OF STREAMS MADE ACCESSIBLE	ACRES OF LAKES MADE ACCESSIBLE	SPECIES UTILIZING FISHWAYS
Flanders Stream	1969	Flanders Stream	Sullivan	5.1	537	Alewives, brook trout
Winnegance Lake	1970	Kennebec River	Phippsburg	1.3	137	Alewives
Bristol Mills	1971	Pemaquid River	Bristol	7.9	2449	Alewives, brown trout
Chemo Pond	1971	Penobscot River	Bradley	15.0	1146	Alewives, brook trout
Boyden Lake	1972	Little River	Perry	9.3	1702	Alewives
Coleman Pond*	1972	Ducktrap River	Lincolnville	0.2	198	Alewives, brook trout
Bridge Street Dam	1974	Royal River	Yarmouth	0.7	13	Alewives, brook
Elm Street Dam	1981	Royal River	Yarmouth	--	340	trout, brown trout
Pitcher Pond	1974	Ducktrap River	Lincolnville	3.8	473	Alewives, brook trout
West Bay Pond	1974	West Bay Stream	Gouldsboro	4.6	249	Alewives, brook trout
Gardner Lake	1976	East Machias River	East Machias	6.0	5536	Alewives, land-locked salmon, Atlantic salmon
Blackman Stream	1978	Penobscot River	Bradley	Fish passage improvement below Chemo Pond Fishway		
TOTALS				53.7	12,440	

*Indicates removal of old dam. All other projects were Denil fishways constructed over dams.

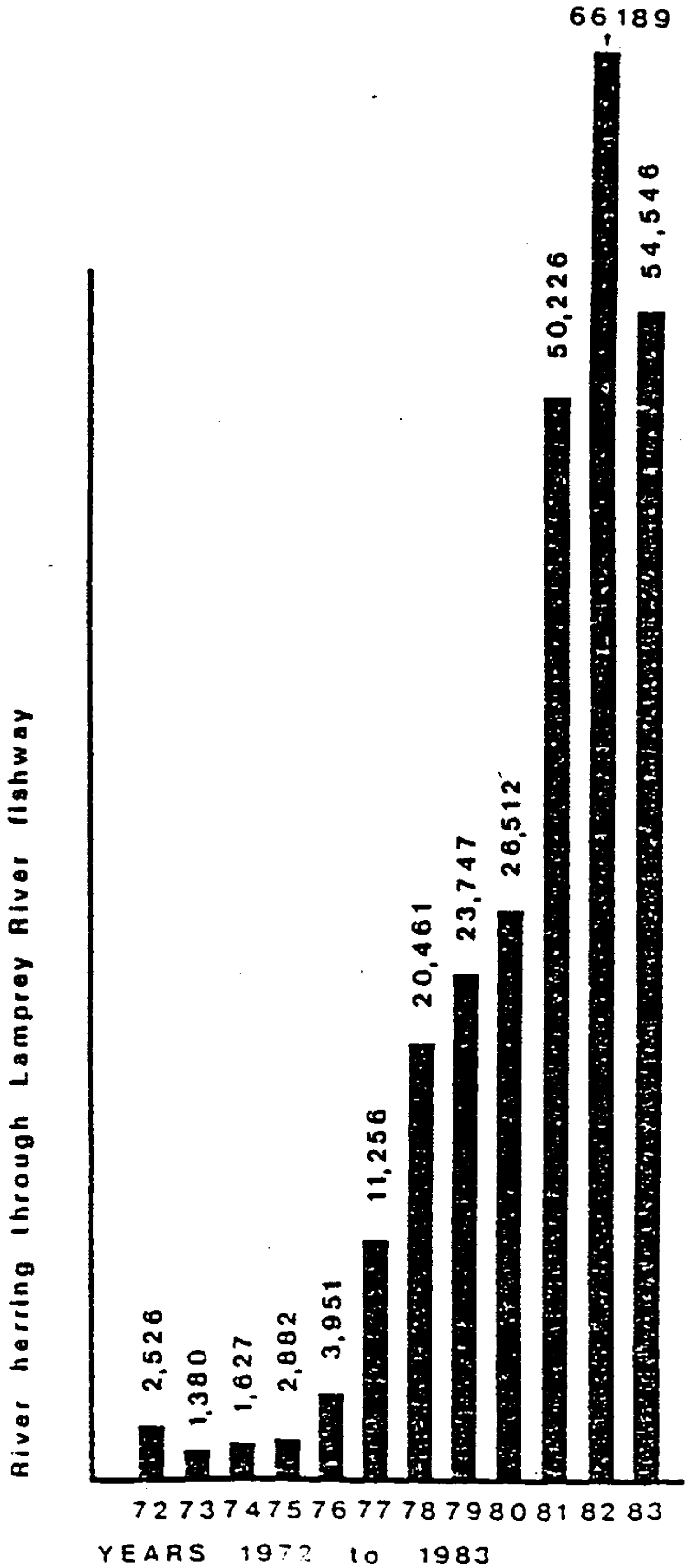


Figure IV-11. Lamprey River alewife run size, 1972 to 1983 (from Greenwood, 1983) herring lifted over the dam increased dramatically between 1974 and 1981 (Table IV-32). These data suggest that restoration has been highly successful in increasing the run size. However, the increase in lift numbers can also have been influenced by the increased efficiency of operation of the fishlift, or by a shift in the distribution of spawning blueback herring in the Connecticut River. Crecco (pers. comm.) found an apparent upstream shift in the center of distribution of larval blueback herring in recent years, which corresponds to the higher numbers of fish being lifted over the dam.

Numerous fishways were constructed in Rhode Island in the late 1960's and early 1970's. Runs were established by stocking gravid adults; the accomplishments of several of those projects are presented in Table IV-33. Several of these runs had become quite extensive in size in the past decade. However, due to a subsequent decrease in restoration efforts and a lack of completion of developing access to major portions of some of the drainage systems, runs have declined in more recent years.

In South Carolina, work is currently underway to preserve the existing blueback herring run in the Santee-Cooper system from any impact caused by the Santee-Cooper Rediversion Project (e.g., Bulak, 1981). Rediversion of substantial flow from one river to the other as a result of this project may alter the distribution of blueback herring stocks in those drainage systems. While not specifically a restoration program, this work involves investigation of fish utilization of the river systems and upstream reservoirs.

In Maryland, surveys of streams supporting anadromous fish runs have been made, and obstructions to migratory passage noted (e.g., Odell et al., 1975). While no current activity relating to removing these obstructions is underway, some future action is anticipated. No explicit river herring restoration efforts are known to exist in the remainder of the states. Potential for restoration has been examined for the Susquehanna (Maryland, Pennsylvania, New York) and James (Virginia) Rivers (e.g., Atran et al., 1983). In many of the east coast states, fish appear to be sufficiently abundant or fisheries are of such a limited extent that extensive restoration efforts are not considered justifiable.

I. ENVIRONMENTAL AND WATER QUALITY EFFECTS ON STOCKS

Major kills of river herring have occurred in various locations along the east coast, some explained and some unexplained. Commonly, large kills have occurred in circumstances of high densities in restricted areas during spawning runs, resulting in excessive oxygen consumption and subsequent asphyxiation.

Table IV-32. Anadromous fish passage recorded at the Holyoke Dam lift since 1955

Year	American shad	Blueback herring	Atlantic salmon	Striped bass
1955	4,900	0	0	0
1956	7,700	0	0	0
1957	8,800	16	1	0
1958	5,700	29	1	0
1959	15,000	20	0	0
1960	15,000	796	2	0
1961	23,000	1,200	0	0
1962	21,000	191	0	0
1963	30,000	32	0	0
1964	35,000	13	0	0
1965	34,000	53	0	0
1966	16,000	54	0	0
1967	19,000	356	0	0
1968	25,000	a	0	0
1969	45,000	10,000b	0	0
1970	66,000	1,900	0	0
1971	53,000	302	0	0
1972	26,000	188	0	0
1973	25,000	302	0	0
1974	53,000	504	0	0
1975	110,000	1,600	1	0
1976	350,000	4,700	1	0
1977	200,000	33,000	2	0
1978	140,000	38,000	23	0
1979	260,000	40,000	19	103c
1980	380,000	198,000	118	139c
1981	380,000	420,000	319	510
1982	290,000	590,000	11	231
1983	528,000	454,000	25	346

a not counted
b estimated
c all immature

Source: Modified from Moffitt, C.M., B. Kynard, and S.G. Rideout. 1982. Fisheries 7(6):2-10.

Table IV-33. Summary of some anadromous fish projects in Rhode Island, 1968-1975 (from data provided by R.I. Division of Fish and Wildlife).

Location	Date	Cost	Information (as of 1983)
Hamilton ladder	1968	$34,000	Alewife run established - 10,000
Peacedale ladder	1969	52,730	Alewife run established - 10,000
Wakefield ladder	1970	38,000	Same as Peacedale.
Bellville ladder	1971	41,000	Same as Peacedale.
Nonquit ladder	1972	26,710	Alewife run 300,000 established; 1,000,000 potential.
Forge Road ladder	1975	39,000	Alewife run of 10,000 established; 150,000 potential.
Bradford ladder	1980	42,000	Alewife run of 50,000 established; 1,000,000 potential.
Potowonut ladder	1982	67,000	Alewife run of 10,000 established; 150,000 potential.

In Maryland, kills of river herring occurred in the Susquehanna River below Conowingo Dam in the 1960's. These kills occurred during the spring spawning run, when turbine output from the dam was shut off in the evening, and fish were trapped at high densities in isolated pools below the dam. Oxygen was reduced to lethal levels and kills occurred (Carter, 1981). In subsequent years, the utility operating the dam has continuously released 5,000 cfs water during the spawning period for anadromous species, and kills have not recurred at those times.

In the Connecticut River, several large kills of blueback herring occurred in the estuarine portion of the river in 1960's and 1970's (Moss et al, 1976). Analyses suggest a number of causative factors (e.g., temperature fluctuations, low dissolved oxygen) though definitive explanations were never arrived at. However, the authors concluded that further deterioration of water quality in the Connecticut River could threaten blueback herring stocks. Occasional kills of river herring have occurred in the Delaware River, associated with the pollution block in the Philadelphia and Camden area. No relationship between these kills and subsequent stock levels has been established. Algal blooms and subsequent oxygen depletion on the tidal Potomac River in Maryland resulted in numerous fish kills in the early 1960's. A number of species, including river herring were involved in those kills (Md. DNR). After construction of the Blue Plains Sewage Treatment Plant, discharge of nutrients in the Potomac was significantly reduced, and algal blooms and related oxygen depletion was decreased. Fish kills have not occurred in recent years. In Virginia, Loesch (1981) documented the elimination of Alosa runs in the Pohick Creek which may have been related to high chlorine levels in sewage discharges into the creek.

On a number of estuarine systems along the east coast, impingement of juvenile alosids at power plant intakes has been recorded. In some cases, impingement rates are quite high for example, Indian Point, on the Hudson River (Texas Instruments, 19771981); and power plants on the Delaware River estuary (DBFWMC, 1981). Total magnitude of impingement mortality along the entire east coast has never been assessed. Individual large kills have occurred at numerous power plant sites, but in general, they represent isolated incidents. Regular impingement rates tend to be relatively low; however, the totals impinged over an entire migratory season might be substantial.

An additional environmental threat that appears to be increasing is the construction of small-scale hydroelectric (SSH) projects on numerous small streams along the northeast coast. SSH projects have been proposed for a variety of locations, such as roadway culverts, existing partially broken dams, old decommissioned projects, etc. Extensive reestablishment of hydroelectric sites on such streams without construction of fish passage facilities could reduce the total availability of river herring spawning habitat. While various documents have been prepared cataloging potential SSH sites in the eastern United States (e.g., USACOE, 1979), no assessment of cumulative effect on anadromous species has been made.

Because river herring runs historically occurred in virtually all small as well as large coastal tributaries, and since pollution of any tributary will have affected the single stock native to that tributary, the current absence of runs where they historically occurred (e.g., Zich, 1977) a posteriori demonstrates adverse effects of water quality degradation. However, the fact that runs occur in many widely dispersed tributaries provides evidence that the total stock of the region can respond to adverse environmental modifications.

Potential development of hydroelectric facilities in the Bay of Fundy was discussed in the American shad segment of this report. Such facilities pose a threat to many river herring stocks, should it be demonstrated that those stocks use the basins of the Bay of Fundy to the same extent as do American shad.

J. POTENTIAL MANAGEMENT OPTIONS

Aspects of River Herring Biology Pertinent to Management

Several aspects of the life history of alewife and blueback herring are particularly relevant to the potential value of different management actions. These include:

- Individual stocks return to their home streams to spawn, but under some circumstances (e.g., possibly in the Chesapeake Bay) there may be some mixing of stocks from tributaries in close proximity.
- Offshore migrations are not well defined; whether a nearshore northward migration of all east coast stocks occurs prior to spawning, as in the case of American shad, is not known.
- Most stocks along the coast exhibit capability for substantial repeat spawning, on the order of 40% of any given run; heavy exploitation of runs can prevent this capability from being expressed (e.g., in some Maine runs where exploitation is 90 to 95% of the run in any given year).

- Latitudinal gradients occur in size and age, but gradients are not strongly evident in other life history characteristics; therefore, no differences in specific management actions by region appear necessary. One latitudinal life history difference is the use of ponds as major spawning nursery habitats in the more northern states by alewives, as opposed to the use of swampy areas and rivers and streams as the predominant spawning area by southern stocks of both alewife and blueback herring.

- Runs of river herring are readily restored through the stocking of gravid adults and the provision of passage facilities over migratory obstacles.

Assessment of Impact on Populations of Various Management Options

Any regulations that would result in a reduction in harvest of river herring will increase the size of the spawning stock in any given year, and similarly will increase the number of fish appearing as repeat spawners in following years. An increase in spawning stock for a given year, however, may not result in increases in year-class strength in that year. The work done in Maine and Massachusetts, showing very high fishing mortalities, suggests that the number of spawners allowed access to the spawning and nursery area may under the existing circumstances have little effect on the number of juveniles produced. Thus catch reductions may not be related directly to subsequent recruitment to future runs.

Excessive exploitation of sexually immature fish while at sea, as occurred in the foreign harvests of river herring in the late 60's and early 70's, appears to have caused declines in the southern and mid-Atlantic river herring stocks. The effects may have been due primarily to the extremely high fishing mortality rate. In such circumstances, catch reductions may have a significant effect on future run sizes.

The limited nature of existing coastal fisheries would suggest that there may be little exploitation of nonresident river herring stocks in any of the east coast states. Because of the locations of pound nets at the mouths of major rivers supporting river herring runs, it is likely that nearly all harvests in that gear are of resident fish. Restrictions on individual state harvests would appear to have primary impact on runs occurring in those states.

On a tributary basis, water quality improvements would appear to be a means of establishing new river herring stocks or enhancing existing low-level stocks. Improvements on small tributary streams along the major drainage systems of the east coast may be a more tractable problem than water quality improvements on the large drainages such as the Delaware or

Hudson Rivers. While improvement of small tributaries may be more tractable, because of their size and the small size of runs using such streams, the net effect on total east coast stock size would be very limited unless a large number of streams were improved.

The comparative ease of restoring river herring populations, which has been demonstrated particularly well in the New England states, suggests that total abundance of river herring could be substantially enhanced if all suitable waters were made available for spawning.

Efficacy of Specific Regulatory Changes

- Gill net mesh sizes - Since most river herring fisheries are not sex-specific, the sex-related size differences would not enter into selection of mesh size by fishermen. In addition, in most fisheries, two year-classes (ages 4 and 5) make up most of the landings, and the size differences between these two age groups is minimal. For those fisheries in which gill nets are a prime gear, mesh size limitations are unlikely to have major impact on stock dynamics, since the degree to which discrimination occurs among sexes and age groups is very limited. Gill net mesh sizes would have greatest impact on limiting total harvest of river herring in mixed species fisheries as opposed to differentially affecting fishing mortality rates for different segments of river herring stock.

- Seasons - Runs of river herring occur within a certain time window during the year, but individual "waves" within that time period are triggered by fluctuations in water temperatures (e.g., Richkus, et al. 1976). Specifying fishing seasons within the spawning period window will have an unpredictable influence on fishing mortality in any given year because climatological conditions will trigger waves in unpredictable patterns. Therefore, it would not appear that setting of seasons for river herrings represents a useful regulatory approach for managing the fisheries, except for altering fishing pressure on one of the two species (since alewife run earlier than blueback herring).

- Gear type - The influence of gear type on river herring harvest is overwhelming. For example, no fishery exists in the state of Georgia because appropriate gears are illegal. Because of the low dollar value of river herring, large volumes must be harvested to establish a viable commercial fishery, and certain gear types are most appropriate for such large volume harvesting (e.g., pound nets, haul seines, and weirs). Restrictions on use of those types of gears would have a substantial effect on the total harvest of river herring.

- Locations of fishing - River herring are most susceptible to exploitation in restricted portions of their migratory routes or at migration barriers (e.g., below dams and fish passage facilities). Fishing mortality can be altered drastically by permitting or restricting exploitation in those areas where potential for harvest is highest. Such regulatory activity, when combined with gear restrictions, has the greatest potential for altering harvest of these species.

- Lift or closed periods - Lift or closed periods would be most appropriate as a regulatory action in locations where the fisheries are located on the restricted portions of migratory routes or on the spawning stream itself. The "wave" nature of the migratory pattern may produce some uncertainty in the total effect of closures from week-to-week or year-to-year. For example, should a two-day per week closure period occur during a "wave," escapement will be extremely high, whereas if the closure occurred during a relatively low migration period, escapement will not be enhanced substantially. On the average, however, it is reasonable to assume that escapement would approximate the same proportion of the run as closure does, for a given time period. Lift periods have been used in the management of river herring since the 1800's in many areas along the east coast.

- Catch quota - Quotas would only be a reasonable regulatory approach if the size of the spawning stock in a given year was predictable, and if the magnitude of desirable escapement was defined. Both of these factors are unlikely to be well defined for river herring fisheries. For this reason, the use of quotas in management would only be valuable as a means of allocation of harvests, in contrast to providing a means for manipulation of subsequent recruitment.

- Restricted entry - In cases where the fisheries are dominated by large-volume harvest gear (e.g., pound nets, haul seines) in a restricted waterway, limiting the number of licensed fishermen may control the total harvest. However, the consequence of restricted entry is dependent on how it impacts on other aspects of the fisheries, such as the amount of gear used and the total effort expended by the individual fishermen. In the majority of river herring fisheries, restricted entry could have substantial impact on total harvests.

K. DATA DEFICIENCIES

While acquisition of accurate catch-and-effort data may be desirable, it may only be feasible to obtain such information for the major components of the fisheries, such as the pound netters, haul seiners and the weir fisheries, where a fairly small number of fishermen are harvesting a major portion of catch. Catch-and-effort data for these fisheries may be useful for establishing an index of stock abundance. However, it is unlikely that accurate harvest data could be acquired for the other users of these individual species, including the sport fishermen, dip netters, and the segment of the user groups taking small amounts on a continuous basis. It would be desirable to establish the magnitude of harvest of these multiple small users. Another factor making acquisition of the latter type of data difficult is the widespread nature of the runs and the occurrence of runs on many small streams.

Long-term juvenile index data would be desirable as an index of stock abundance if it could be demonstrated that the indices collected were acquired in an appropriately designed study program, and if the validity of the indices as representing spawning success was demonstrated by a subsequent correlation with harvests. Difficulties may arise in establishing meaningful juvenile indices due to the widespread nature of river herring runs in many drainage systems. Because fish tend to spawn in large rivers as well as in small tributaries of those rivers, the design of a survey which would provide representative data must be considered carefully. The absence of catch composition data for most runs in prior years has limited the capability for demonstrating correlation between the juvenile index and subsequent harvests.

Information on the coastal migration patterns of river herring and development of techniques that discriminate between different stocks would provide a means of determining where regional stocks may be vulnerable to exploitation when off the spawning grounds. Such information would also provide an indication of the magnitude of fishing mortality experienced by different regional stocks.

Information on the population dynamics of river herring stocks throughout their distribution along the east coast would contribute to an understanding of the influence of spawning stock size on year-class successs. This information is needed to establish desirable escapement rates and thus establish allowable harvest levels. Differences in population biology by latitude or by the nature of spawning habitat (e.g., pond spawners vs tributary spawners) would permit establishment of stock-specific management actions.

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APPENDIX A

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APPENDIX B

Summary of shad fishing laws and regulations

Year	Season	Closed days and areas	Net regulations	Recreational
Georgia				
1983	Jan. 1 through April 31	Two or three day closures, differing by river.	4 1/2 inch stretch mesh. Set nets only in main channel, no longer than 100 feet and not extending over more than half the stream width. Drift nets not longer than 10000 ft.	Must have fresh-water fishing license. Limit is 8 shad/day each fisherman limited to two poles and lines each. Bow nets allowed with minimum mesh.
Rhode Island				
1983	unknown	Pawcatuck and Wood Rivers	Unlawful to net.	Hook and line only, limit is 6 shad/day.
New Jersey				
	November 1 to April 30		AREA 1 Delaware Bay and the Marine portions of its tributaries:	Hook and line and bows. License required.

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
	March 15 to December 15		Haul seine, minimum mesh 2-3/4" stretched; no longer than 70 fathoms. Fyke net, minimum 3" stretched (net and leaders); no longer than 30 fathoms (including leaders).	
	February 1 to May 15		Run around net, minimum mesh 2-3/4" stretched; no longer than 200 fathoms.	
	February 15 to May 15		Shad gill net, (drift, stake, or anchor) minimum mesh 5" stretched.	
	March 1 to December 31		Pound net, minimum mesh 2" stretched.	
	March 1 to December 31		Wire pound net, not to exceed into Delaware Bay more than 300' from MLW mark, or 300' from outside of the flats, which fall bare of MLW.	
	September 1 to May 31		Parallel net, minimum 3-1/2" stretched, may be set only along low tide line parrallel to shore.	

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
		2 p.m. Saturday until midnight Sunday	AREA 2 Delaware River between Penn. and New Jersey below Trenton Falls.	Rod and lines or hand lines must have three or less hooks. All bows acceptable
	Open		seine - none	
	Open		gill net - none	
	July 1 to June 1		eel pot or fyke net, without wings, max. entrance diameter 6" max. outside diameter 30".	
	September 1 to May 31		parallel net or stake net at edge of low water, min. mesh 3-1/2" stretched.	
			Delaware River between Penn. and New Jersey above Trenton Falls.	Maximum of three lines fished at once. All bows acceptable
	Open		seine	

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
	July 1 to June 1		eel pot or fyke net, without wings, max. entrance diameter 6", max. outside diameter 30".	
		2 p.m. Sat. to midnight Sun.	AREA 3 Fresh tidal (portions of tributaries to the Delaware Bay between New Jersey and Delaware.	
	February 1 to June 15		drifting gill net min. mesh 5-1/4" stretched.	
	April 1 to November 30		haul seine min. mesh 2-3/4" stretched, max. length 70' fathoms.	
		2 p.m. Sat. to midnight Sun.	AREA 4 Fresh tidal tributaries to the Delaware River between Penn. and New Jersey.	Hook and line and bows. Licence required.
	March to June 10		seine min. mesh 2-1/2" stretched; drifting gill net min. mesh 5-1/4" stretched.	

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
Delaware				
1982	Feb. 1 to June 10	No fishing from 12:00 noon Sat. to 12:00 midnight Sun. in any Delaware Bay tributary from Blackbird Creek to one-mile south of Mispillion River; Broadkill River - no shad fishing from noon Sat. to sunrise Mon.	Delaware River and Bay: Minimum mesh size 5 1/4 inches stretch Other waters including tributaries of Delaware Bay: Haul seine, fykes, pound nets - minimum mesh 2-inches stretch; gill nets - minimum mesh 3-inches stretch; Maximum length 300-yards in Indian River & Bay, Rehoboth Bay or their tributaries	Tidal waters: Hook and line and spearguns Nontidal waters: Hook and line only; one hook per line
Maryland				
Prior to 1982	Jan. 1 to June 5		None	
1980	Unknown	All Maryland waters except the Potomac River.	None	Closed in all Maryland waters except the Potomac River.
1982	Closed	All Maryland waters	None	Closed

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
Virginia				
1982	Unknown (only on James River)	None	Pound net: minimum mesh 51 mm. Haul seine: maximum length 914 meters; longer than 183 meters minimum mesh 76 mm. Maximum length of fishing structure in Chesapeake Bay 366 meters with minimum of 61 metes between successive structures and 274 meters between adjoining rows of structures. No net set across any river, bay, estuary, creek or inlet longer than one forth the width of the body of water and net shall not be fished more than 1/2 the distance across the channel of water.	Unknown
South Carolina				
1978	Below 40-mile limits: Feb. 1-March 25 Horry County, above 40-mile limit: Feb. 1-May 4	Days - Savannah River: upstream of Interstate 95, Sunday, Monday, and Tuesday closed; downstream of Interstate 95, closed Saturday, Sunday, and Monday	Savannah River: set issuing procedure changed to allow renewal of previously held sets the first 15 days of new licensing year; only 2 sets per household	No creel limit Hook and line season Feb. 1 to May 1. skimbow season Feb. 1 to May 1.

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
	Edisto River, above 40-mile limit: Feb. 1-April 20 Savannah River: Jan. 15-April 15 All other areas, above 40-mile limit: Feb. 1-April 30	Game Zone 5 and 8: 1 hour after official sunset Sunday to Wednesday noon Game Zone 7, Berkeley, and Williamsburg counties: Saturday noon-Monday noon All other areas: Saturday noon-Tuesday noon Areas - Savannah River: fishing prohibited in North Channel of Savannah River downstream from New Savannah Cut and in Back River Cooper River: gill net fishing prohibited in either branch of river or its tributaries from upper "T's" inland Combahee River: closed from US Hwy. 17 seaward Area within the 3 mile limit seaward of Winyah Bay closed to stake and anchor nets	Savannah River: minimum mesh size increased to 4 1/2 inches; maximum mesh size set at 5 1/2 inches stretched mesh Georgetown County: no drift net to exceed 1/2 width of stream between mouth of Waccamaw River and Butler Island Black and Waccamaw Rivers: net length limited to 200 yds. from mouth of either river to 40-mile limit Edisto River: registered sets issued to licensed fishermen with option to renew each licensing year (15 day grace period); no more than two sets per household All streams minimum mesh 5 1/2 inches stretched One half of stream must remain open Minimum of 200 yds. between nets Unlawful for net to remain on bank of stream for more than 3 days after close of season	

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
New York				
1983	March 15 to June 15 in Delaware and Hudson Rivers	"The Plats" in the Hudson River. Others to be established by the Dept. of Environmental Conservation.	Drift gill nets not to exceed 2,000 ft. in length. Other nets not to exceed 1200 ft. in length. Minimum mesh 2-1/2" stretched.	Unknown
		In river estuary no net shall be fixed within 1500 feet of any other licensees net.	Operation of nets is permitted in tidal portions of the Hudson River and tributaries up to the first impassable barrier. Dip nets are also permitted in the Mohawk River upstream of the City of Rome, New York.	
North Carolina				
	None	None (Limited in one small area)	None	None
Connecticut				
1983	April 1 to June 15	Friday sundown to Sunday sundown Thames River: gill net fishing prohibited	Gill net: minimum mesh size 5 inches stretched mesh.	Hook and line 6 fish only daily limit.

Summary of shad fishing laws and regulations (Continued)

Year	Season	Closed days and areas	Net regulations	Recreational
Rhode Island				
1983	None	No shad may be taken from the Pawcatuck and Wood Rivers.	No harvest allowed except by hook and line.	Hook and line only; six fish daily limit
New Hampshire				
1982	None	Fishing permitted upstream (north) of Memorial Bridge in Portsmouth.	Unlawful to net	Hook and line only.

APPENDIX C

ASMFC Letter on Bay of Fundy Hydroproject Concerns

Atlantic States Marine Fisheries Commission
1717 Massachusetts Avenue, N.W.
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July 13, 1983

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EXECUTIVE DIRECTOR
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Hon. Robert A. Jones, Chief
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Dear Bob:

I have been asked to bring to your attention a matter of grave concern to the members of the Atlantic States Marine Fisheries Commission's Interstate Fisheries Management Policy Board. This Board is comprised of administrators of the Atlantic Coast states fisheries agencies and the National Marine Fisheries Service and is dedicated to the management of interjurisdictional marine and anadromous fisheries. Recognizing the value of stocks of American shad and river herring, this organization recently authorized the development of a plan for the interstate management of these species and created a management board and scientific and statistical committee for this purpose.

Recent evidence presented to these bodies of administrators and scientists indicates the potential for a very serious problem that could impact all of the coastal stocks of American shad from Canada to Florida. This evidence, presented at the 1983 Northeast Fish and Wildlife Conference in May of this year by Dr. Michael Dadswell and associates of the Canadian Department of Fisheries and Oceans, shows that American shad from nearly every river system in eastern North America utilize the Bay of Fundy, and in particular the areas known as Minas and Cumberland Basins, as summer feeding grounds. Proposals for the development of tidal power projects within these basins are being considered by Canadian power companies and associated regulatory agencies. It is clear that these projects, when operational, will cause appreciable mortalities among these shad stocks. It has been estimated that repeated passage through turbines at these installations could cause the mutilation of as high as 90% of the shad present. Since it has been demonstrated that up to one third of the total Atlantic Coast shad stocks can be found in these areas during the summer feeding period, severe adverse impact can be expected from the operation of the planned facilities.

In recognition of the importance of these feeding grounds within the Bay of Fundy and the potential hazard that tidal electric generation barriers can represent to shad stocks (and other fishes such as river herring, sturgeon, and striped bass utilizing this area), I wish to express the concerns of the Interstate Fisheries Management Policy Board with these projects. We urge that full consideration be given to the extremely serious ecological damage that such projects could cause. Due consideration must be given to the anticipated economic losses to Atlantic Coast commercial fishermen, and to the full economic ramifications of these projects on the burgeoning sport fisheries these stocks now support. Other issues which should be explored fully by appropriate agencies include the effects of these tidal power projects on migratory waterfowl, and coastal impacts as far south as Boston, Massachusetts caused by permanent changes in normal tidal amplitudes.

We bring this matter to your attention in the hope that you will use whatever influence or authority you may have to assure that adequate consideration is given to this grave situation.

Sincerely

Irwin M. Alperin
Executive Director

/s

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Hon. Kenneth Plumb, Secretary, Federal Energy Reg. Commission
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APPENDIX B

SUMMARY OF INDIVIDUAL STATE'S FISHERIES REGULATION DEVELOPMENT PROCESS

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated problems
Maine	Dept. of Marine Resources	Dept. of Mar. Res.→public hearing→Advisory Council→Commissioner of Mar. Res.→promulgated	Dept. of Mar. Res.: Collects information and drafts proposed regulation. Advisory Council: Composed of 8 members of the commercial fishing industry and 1 member representing recreational fisheries, all appointed by the Governor. Reviews pertinent comments discussed at the public hearing and if acceptable, incorporates them into the proposed regulation. Council advises the Commissioner of Mar. Res. on the nature of the regulation. The advice of the Council is binding on the Commissioner. Commissioner of Mar. Res.: Through advise from the Advisory Council, the Commissioner either approves or disapproves the proposed regulation.	The only mandated time constraint deals with the public hearing process. Announcements for the public hearing (in local newspapers), must be made 30 days prior to the hearing date.	No anticipated problems; the process is very streamlined. After the public hearing, the tasks involving the Advisory Council and the Commissioner of Mar. Res. are completed quickly.
New Hampshire	Fish and Game Dept.	Fisheries Dept.→Director of the Fisheries Dept.→Fish and Game Commission→Public hearing→Joint Legislative Committee on Administrative Rules→promulgated.	Fisheries Dept.: Drafts proposed regulation and submits it to the Director. Director of Fisheries: Reviews proposed regulation; if approved the proposed rule is put on the agenda of the next Fish and Game Commission meeting (at least 2 weeks before scheduled meeting). Fish and Game Commission: Reviews proposed regulation. If approved the proposed regulation is published in the Register and open for public comment. A public hearing can be scheduled 20 days after the proposed regulation appears in the register, however, it is not necessary to have a public hearing. Joint Leg. Com. on Admin. Rules: Approves or disapproves proposed regulation. If approved, the committee has 20 days to file the regulation. If disapproved, the Fish Dept. has 44 days to respond to the committee's decision. The Fish Dept. can either change the regulation or adopt it over the committee's disapproval (in which case the burden of proof would fall on the Fish Dept. to justify the regulation).	Announcement for the public hearing must be made 20 days prior to the hearing date. If Joint Leg. Com. on Admin. Rules approves regulation the maximum time to submit the regulation for adoption is 30 days. If disapproved, the committee has 44 days maximum to present a final ruling. With no problems encountered a proposed regulation can go through the entire system in 3.5 months.	No anticipated problems.

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated problems
Massachusetts	River Herring: Div. of Marine Fish./Local Gov.	Public meetings→Marine Fish. Advisory Commission→Local Gov.→ Promulgated	Public Meeting: Local gov. gets together and petitions the Marine Fish. Advisory Comm. to allow them to institute regulations and manage the local fishery. Marine Fish Advis. Comm.: Reviews local government proposed management plan (regulations included), confers with Div. of Mar. Fish. biologists and approves or disapproves petition (they usually agree). Local Government: Manages local fishery, setting all regulations. Local governments are allowed to change regulations and are not required to inform the Div. of Mar. Fish.	There are no time constraints.	Any new regulations have to be approved by the governing body (typically the local gov.). They would then have to be persuaded to follow the wishes of the Div. of Mar. Fish. If at anytime they do not agree with the proposed or existing regulations they (the regulations) can be dropped.
	American Shad	Inland Fisheries→Public hearing/ Bd. of directors→Secretary of State→promulgated	Inland Fish: drafts proposed regulation. Bd. of Directors: Governor appointed; they review, approve or disapprove the proposed regulation and participate in the public hearing. If accepted, the proposed regulation is submitted to the Secretary of State for promulgation. Sec. of State: Enacts the regulation.	Announcement of the public hearing must occur 30 days prior to the hearing date.	No anticipated problems.
Rhode Island	Div. of Fish & Wildlife	Div. of Fish & Wildlife→ Mar. Fish. Coun.→Public hearing→Mar. Fish. Council→Promulgated	Div. of Fish & Wildlife: Collects pertinent information and drafts proposed regulation. Marine Fish. Coun.: Comprised of citizens appointed by the Governor. Members include representatives of special interest groups (i.e., Comm. and Sport Fisherman, scientists, etc.). Council is a subgroup of the R.I. Coastal Mgt. Council. Council has authority to approve, disapprove, or require modifications to proposed regulation. After the public hearing, the proposed regulation is returned to the Council at which time the public's comments are discussed, and any modifications resulting from the hearing incorporated. If major modifications are required as a result of the public hearing the modified version must again go out for public hearing. If no modifications are made the proposed regulation must be filed within 20 days.	The only mandated time constraints deal with the public hearing process and the pre-promulgation period. Announcements for the public hearing must be made 30 days prior to the hearing date. Filing of the proposed regulation, after final approval must occur within 20 days after acceptance.	No anticipated problems, the process is very streamlined. After the public hearing, the tasks involving the Marine Fish. Council must be completed within 20 days.

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated problems
Connecticut	State Legislature	Bureau of Fish.→Comm. of Env. Prot.→Public Hearing→Bureau of Fish.→Comm. of Env. Prot.→Attorney General→General Assembly Regulations Review Committee→Secretary of State	<u>Bureau of Fish.</u>: Proposes regs; conducts public hearing(s); compiles and addresses public comments; prepares final proposed regs; submits to Comm. Env. Prot. for certification; prepares, and mails to interested parties, notice of availability of final proposed regs; submit to Attorney General, 20 days after mailing of notice; modifies proposed regs based on comments by Attorney General and submits to General Assembly Regulations Review Committee. <u>Commissioner of Environmental Protection</u>: Reviews proposed regs (Dep. Commissioner) issues statement of intent re: proposed regs and schedule of public hearings. Notice must be published in Law Journal 30 days prior to public hearing and in local newspaper not more than 30 nor less than 10 days prior to hearing. Certifies final proposed regulations. <u>Attorney General</u>: Reviews final proposed regs as to form and legal sufficiency. Must comment within 30 days. <u>Regulations Review Committee</u>: Approves final proposed regs. Must act within 60 days or approval automatic. May return regs for cause in which case agency may modify and resubmit or may reject outright in which case agency has recourse to the full General Assembly. <u>Secretary of State</u>: Files final approved regs.	Notice of public hearing must be published in Law Journal 30 days in advance of hearing date. Final proposed regs can not be submitted to Attorney General or Regs Review Committees for at least 30 days after notice of availability of final proposed regs is mailed to interested parties. Attorney General has 30 days for review. Regs Review Committee has 60 days to act or approval is automatic. Regs effective upon filing with Secretary of State or on a later date as may be indicated. Total maximum time 160 days.	No problems anticipated.
New York	Bureau of Fish.	Regional Fishery Managers→Bureau of Fisheries for review→Division Director for review and approval→Regional Fishery Managers for modification and public review→Bureau of Fisheries→Promulgated	<u>Regional Fishery Managers</u>: Draft proposed regulation and submit it to the Bureau of Fish. Upon approval by the Div. Director, incorporate changes into the proposed regulation and discuss the proposed regulation with the public (approximately 3 months). Submit the public's comments, if pertinent, to the Bureau of Fish. for review. <u>Bureau of Fisheries</u>: Contacts Regional Fishery Managers for suggested modifications to existing regulations or for the proposal of new ones. (This usually occurs in Nov.) Reviews the initial draft proposal submitted by the Regional Fish. Man. Reviews the proposed regulation after the public comment period and suggests modifications. <u>Division Director</u>: Reviews proposed regulation. If approved, it is sent back to the Regional Fish. Man. for incorporation of modifications (if needed) and public review. Reviews proposed regulation if public opposition is great.	<u>Regional Fish. Managers</u>: Submit proposed regulations in Nov. <u>Div. Director</u>: Makes 1st review and approval or disapproval by late Dec. <u>Regional Fishery Managers</u>: Contacts public and special interest groups from Jan.-March. <u>Bureau of Fish</u>: Makes final decision by April. Regulation is promulgated in April or May.	No problems are anticipated.

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated problems
New Jersey	Div. of Fish, Game and Wildlife	Fisheries Dept.→Fish and Game Council→Public hearing→promulgated.	Fisheries Dept.: Drafts proposed regulation and submits it to the Fish and Game Council. When needed, incorporates modifications into the proposed regulation. Fish and Game Council: Appointed by the Commissioner or elected to the Council. Reviews proposed regulation, suggests modifications, and if approved passes it on to the public hearing process. If modifications are needed the proposed regulation is sent back to the Fisheries Dept.	Public hearing must be announced 30 days in advance.	No anticipated problems.
Pennsyl-vania	Penn. Fish Commission	Fish. Dept.→Proposed regulation published in agenda of next commission meeting→Public Commission Meeting→Announced in Penn. Bull. as proposed regulations→Public Commission meeting for final adoption→promulgated	Fish Dept.: Submit proposed regulations to Public Commission at their request. Public Commission: Made up of 10 individuals appointed by the governor. Meet four times annually. Meeting are open to the public. Review and suggest modifications to the proposed regulation. If approved, the regulation is published in the Penn. Bull. for public review. The Commission will accept written comments from the public up until their next meeting (usually 3 months), at which time a final decision is rendered. If approved the proposed regulation is promulgated.	Time constraints are governed by the public commission's meeting dates (every 3 months).	No anticipated problems.
Delaware	Div. of Fish and Wildlife	Div. of Fish and Wildlife→Public hearing→Tidal Fish Advisory Council→Promulgated	Div. Fish and Wildlife: Draft proposed regulation. Tidal Fish, Advisory Council: Nominated by Governor and confirmed by Senate according to specifications in state statute. Appointees are usually members of special interest groups (i.e., recreational fishermen, commercial netters, etc.). Review proposed regulation and advise. However, if recommendation is to disapprove the proposed regulation it can still be promulgated.	Announcement of the public hearing must occur 20 days prior to the hearing date in one newspaper with general circulation.	No anticipated problems.

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated* problems
Maryland	Dept. of Natural Resources	Fish. Dept.→Secretary of Natural Resources→Published in MD Register→Public hearing and comment period (45 days after appearing in MD Register)→Published in MD Register for adoption→Enacted as law.	Fish. Dept.: Drafts proposed regulation and submits it to the Secretary of Nat. Res. Secretary of Nat. Res.: Reviews proposed regulation. If approved, it is published in the MD Register at which time the public has 45 days to comment. A public hearing may also held during the 45 day comment period. After the comment period (45 days) the proposed regulation is again published in the MD Register for adoption. However, if modifications to the proposed regulation after the public comment period are great, the modified proposed regulation goes through the public comment period again. The regulation is enacted 10 days after it appears in the MD Register for the second time.	The public comment period must last for 45 days. Total time for a proposed regulation to go through the system is approximately 90 days.	No anticipated problems.
Virginia	Div. of Mar. Res.	Div. of Mar. Res.→Mar. Res. Commission→Div. of Mar. Res. (for drafting of proposed regulation)→promulgated.	Div. of Mar. Res.: Approaches Mar. Res. Comm. about proposed regulation. If approved by the Mar. Res. Comm., the Div. of Mar. Res. must draft the proposed regulation and initiate the public hearing process. Marine Res. Comm.: A 7-man board which reviews the proposed regulation for approval or disapproval. Two or three public hearings are held, the last being in front of the Mar. Res. Comm. at which time they give their final decision. If approved the Commission sets the date at which time the regulation will be enacted. The Mar. Res. Comm. can never adopt an amended form of the regulation that is more stringent than that proposed. Public Hearing Process: Can take 10 to 60 days depending on the immediacy of the matter. If regulation is to have a state wide effect 3 public hearings all held throughout the state the last in front of the Mar. Res. Comm. If the regulation is specific in nature, only 2 hearings are required, the last in front of the Mar. Res. Comm.	The public comment period can last between 10 and 60 days.	No anticipated problems.

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated* problems
North Carolina	Fisheries Dept.	Public → Fisheries Commission → Fish Dept. → Public hearing → promulgated	A proposed regulation can be drafted by either the Fisheries Dept. or the public. __Fisheries Commission__: a 15 member Commission appointed by the Governor. Selection criteria states that one member must be a scientist, one must represent recreational fishermen, one must represent commercial fishermen, and one must represent dealers. This Commission makes the initial decision on whether or not to approve the proposed regulation and pass it on to a public hearing.	Announcement for the public hearing must be made 30 days prior to the hearing date.	If existing regulations are thought to be discriminatory special interest groups may propose modifications.
South Carolina	Legislative Action	__Two possible routes__: A. Dept. of Mar. Fish.→Mar. Adv. Bd.→S.C. Wild. & Mar. Res. Comm.→ Public notice→General Assembly for vote→Promulgated. B. County legislators draft regulations→House or Senate→S.C. Wild. & Mar. Res. Comm.→ Dept. of Mar. Fish.→S.C. Wild. & Mar. Res. Comm.→Public notice→ General Assembly for vote→ Promulgated.	__Dept. of Mar. Fish.__: Draft proposed regulation and submit it to the Mar. Advisory Bd. Review proposed regulation submitted to the S.C. Wild. & Mar. Res. Comm. by the House or Senate. __Mar. Advisory Bd.__: Reviews proposed regulation, makes changes, and if approved submits it to the S.C. Wild. and Mar. Res. Comm. __S.C. Wild. & Mar. Res. Comm.__: Composed of nine members, two of whom are the chairman of the Agricultural and Nat. Res. Committee of the State House of Representatives and the Fish, Game, and Forestry Committee of the Senate. Review proposed regulation and decide whether to release the proposed regulation for voting in the General Assembly. __General Assembly__: Votes on the proposed regulation. __County Legislatures__: Draft proposed regulations and submit it to the House or Senate, depending on which one he is a member of. __House or Senate__: Refers proposed regulation to the S.C. Wild. & Mar. Res. Comm.	There is a 45-day period between the time the public notice is given and the time it can be filed with the General Assembly. The General Assembly is given 90 days within which time it must act. If General Assembly approval or disapproval is not forthcoming during that period (90 days), the regulation goes into effect regardless.	Through pressure for special interest groups, County legislators may attempt to block proposed regulations, or propose modifications to existing regulations.

State	Regulatory authority	Regulatory process (route)	Office responsibility	Regulatory time constraints	Anticipated* problems
Georgia	Dept. of Nat. Res.	Coastal Res. Div.→Commissioner→Public hearing→Commissioner→Bd. of Nat. Res.→Secretary of State→Promulgated.	Coastal Res. Div.: Drafts proposed regulation and submits it to the Commissioner. Commissioner: Reviews proposed regulation, makes modifications, and disapproves or approves the proposed regulation for public hearing. After public hearing all comments and modifications are reviewed by the Commissioner, and if approved sent to the Bd. of Nat. Res. Bd. of Natural Resources: Votes on whether or not to accept proposed regulation. If accepted it is sent to the Secretary of State. Sec. of State: Holds for a filing period of 20 days at which time it is promulgated.	Announcement of the public hearing must occur 30 days prior to the hearing date. Sec. of State holds proposed regulation for a 20-day filing period before it is promulgated.	No anticipated problems.
Florida	Mar. Fish. Comm.	Mar. Fish. Comm.→Public hearing→Mar. Fish. Comm.→Governor's cabinet→promulgated.	Marine Fish. Comm.: Draft proposed regulation. Hold a public hearing on the proposed regulation and incorporate public comments (if pertinent) into the regulation. Pass the proposed regulation to the Governor's cabinet for approval. Governor's Cabinet: Review proposed regulation, make changes, and approve or disapprove the regulation. If disapproved it is sent back to the Mar. Fish. Comm. for modifications. If approved its promulgated	Announcement of the public hearing must occur 30 days prior to the hearing date.	No anticipated problems.

APPENDIX C

DOCUMENTATION OF RECENT ACTIVITY

RELATING TO REGULATION OF

OFFSHORE RIVER HERRING HARVEST

1. Memorandum dated 10 January 1985 from Jim McCallum, ASMFC, to S&S Committee members on joint venture applications to the Mid-Atlantic Council.

2. Position paper by W. Richkus submitted to the Mid-Atlantic Council.

3. Letter from Emory Anderson, NMFS, to John Bryson, Mid-Atlantic Council, dated 8 February 1985, presenting information on the magnitude, timing, and location of river herring bycatch.

4. Letter from John Boreman, NMFS, dated 7 March 1985, presenting information on offshore river herring harvest, 1971-1980.

5. Letter from W. Richkus to Paul Perra, ASMFC, on river herring data which should be acquired by NMFS.

Memorandum

• ATLANTIC STATES MARINE FISHERIES COMMISSION

TO : Shad and River Herring Board and S&S Committee DATE 1/10/85

FROM : Jim McCallum, Council Liaison

SUBJECT: Mid-Atlantic Fishery Management Council Request Regarding River Herring Bycatch in the Atlantic Mackerel TALFF NUMBER M 85-3

The Scientific and Statistical Committee of the Mid-Atlantic Fishery Management Council on November 19, 1984 urged the Council to request an ASMFC recommendation on bycatch of river herring in relation to development of Amendment #2 to the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan (summary attached). At its December 5-6 meeting, the Council agreed to make this request.

The draft FMP amendment reads, in part, "...The foreign river herring fishery is managed through the Trawl Fisheries of the Northwest Atlantic FMP. The Total Allowable Level of Foreign Fishing(TALFF) is 100 mt and is allocated for bycatch in other fisheries, primarily the mackerel fishery... The average river herring bycatch in (the mackerel) fishery for the last three years has been 3% of the mackerel catch. There is some indication that the river herring bycatch increases as the fishery moves closer to shore...

"The river herring TALFF is low because of the condition of the resource...

:...The most likely case is that the (mackerel) fishery will develop initially through joint ventures, probably with related directed foreign fisheries. If the latter situation prevails, if the river herring TALFF remains 100 mt, and if the 3% bycatch relationship continues, there is clearly a problem relative to foreign catches in the development of the U.S. fishery.

"If the only river herring catch by foreign vessels is bycatch in the mackerel fishery, if the foreign catch amounts to 3 mt of river herring for every 100 mt of mackerel, and if the river herring TALFF is 100 mt, then the total allowed foreign mackerel catch cannot exceed 3,333 mt. While this might represent a worst case situation and additional analyses are needed, there is a problem that, if it cannot be solved, at least it must be recognized in the development of the mackerel fishery."

Joint venture applications for the coming fishing year will probably be in the range of 38,000 - 78,000 metric tons. Several possible applications have not been received. Joint venture policy for this and other fisheries has been under discussion for several years in a highly politicized atmosphere. Interest in pursuing large joint ventures in mackerel this year is very high.

The Council and the NMFS will need to make decisions on foreign joint ventures and directed fishing requests in the mackerel fishery early in 1985, and the Council would like to hear from the Commission at its January 16-17 meeting in Easton, Maryland. There will be no opportunity for the Shad and River Herring Board or the SSC to discuss the request as a group before then, so we will not be able to present the Council with a formal recommendation.

M 85-3
1/10/85

After conversations with Bob Jones (Chairman, Shad and River Herring Board), Harrel Johnson (Chairman, Shad and River Herring Scientific and Statistical Committee), and Bill Richkus (Manager, Shad and River Herring Management Program, Martin Marietta) we decided that Bill and Harrel would put together some basic summary information provided by the ASMFC Phase I of the Management Plan for Migratory Alosids of the Atlantic Coast prepared under contract by Martin Marietta Environmental Systems, other draft documents, and any other recent biological information, for distribution to the Council. We will present the information verbally at the Mid-Atlantic Council meeting in Easton, Maryland at 8:00 am, January 17. Several members of the Board and SSC will be present at the Council meeting and the following Striped Bass Stocking Subcommittee, and can be available to answer questions from the Council. Following the Commission presentation, the Council will consider that information during their decision process on the joint venture applications.

A draft of the information to be presented is attached.

Please call me before noon January 15 if you have any questions or additional suggestions.

Thank you.

Enclosure

cc: Ralph W. Abele

SUMMARY MINUTES

SCIENTIFIC & STATISTICAL COMMITTEE (SSC) MEETING

19 November 1984

Philadelphia, PA

There was an SSC Meeting held on 19 November 1984 at the Best Western Airport Inn in Philadelphia, PA. Chairman Hargis convened the meeting at approximately 10:05 a. m. Other Committee members present were Drs. Emory Anderson, Lee Anderson, Austin, Haskin, Holliday, Mr. Surdi, Mr. Wilk and Mr. Hamer. Other attendeees included Mr. Kelfer and Ms. Stevenson, Mid-Atlantic staff, Mr. Marchessault, New England Council staff, Mr. Dave Wallace (United Shellfishermen's Association) and Mr. Steve Devore (American Original).

ATLANTIC MACKEREL, SQUID, AND BUTTERFISH FMP AMENDMENT #2

Mr. Keifer stated that the current Atlantic Mackerel, Squid, and Butterfish FMP lapses in March 1986 and that is was time for the Committee to evaluate the objectives and agree on what problems are to be addressed by Amendment #2. The Committee reviewed a Memo dated 25 September 1984 to the Council's Squid, Mackeral and Butterfish Committee (See Attachment 1) which stated staff's opinions for objectives and problems to be solved by Amendment #2. The Committee offered no changes or additions to the objectives and one addition and minor changes to some of the problems outlined in the Memo. In reference to Problem 2 (C) and due to the apparent problem with the river herring bycatch in the foreign mackerel fishery, particularly when carried out nearshore in conjunction with joint ventures, the Committee urges the Council to ask the Atlantic States Marine Fisheries Commission for its recommendation of bycatch on river herring in relationship to the development of the FMP amendment.

Currently there is a permit requirement for US fishermen (Problem 4 (D)) in the Plan and the staff's question was whether to remove that requirement since it currently yielded no valuable information. The Committee's opinion was not to remove the permit requirement but rather change the word from "Remove" to "Evaluate" to try to obtain better data from the permit. Dr. Holliday felt that the SSC's Data Needs Report needed to be added to the preliminary outline of problems for Squid/Mackerel/Butterfish Amendment #2 and offered the following motion which was seconded by Dr. Lee Anderson and carried unanimously:

> EVALUATE EXISTING PERMITTING AND DATA COLLECTION SYSTEMS RELATIVE TO THE SQUID/MACKEREL/BUTTERFISH DATA NEEDS SPECIFIED IN THE SSC REPORT, EXAMINE HOW THE FMP SHOULD BE CHANGED WHERE NECESSARY TO ATTAIN THESE DATA.

Mr. Keifer stated that there was an opinion expresssed by Council member Stevenson at the Squid, Mackerel, Butterfish Committee Meeting on 23 October 1984 that silver and red hake should possibly be added into Amendment #2 since they are also undeveloped species and have a potential for becoming a target for a directed fishery in the near future. The Committee discussed at great length whether to include the hakes into Amendment #2 and decided that there was no biological facts to support their inclusion at the present time. They unanimously passed the following motion made by Dr. Austin and seconded by Mr. Hamer:

(from Draft Amendment 2 to Mackerel, Squid and Butterfish FMP)

4.2.3. River Herring Bycatch in Foreign Mackerel Fishery.

The foreign river herring fishery is managed through the Trawl Fisheries of the Northwest Atlantic PMP. The TALFF is 100 mt and is allocated for bycatch in other fisheries, primarily the mackerel fishery.

The Council has the preparation of a River Herring FMP on its long range schedule. The Atlantic States Marine Fisheries Commission (ASMFC) is preparing a river herring management plan which may serve as the basis of the Council's FMP.

The most significant (in terms of size of catch) mackerel fishery in the recent past has been the Polish fishery carried out primarily for research purposes. The average river herring bycatch in that fishery for the last three years has been 3% of the mackerel catch. There is some indication that the river herring bycatch increases as the fishery moves closer to shore, although a complete analysis of this in currently under way.

The river herring fishery was an inshore US fishery until the late 1960s when foreign fleets entered the fishery. The US catch averaged 24,800 mt between 1963 and 1969. A downward trend began in 1969, with the 1983 catch 4,100 mt. Data from the NEFC spring and autumn bottom trawl surveys from the Gulf of Maine to northern New Jersey indicate that stock levels have been relatively stable since 1968. Data from the spring bottom trawl surveys between northern New Jersey and Cape Hatteras indicate an increase in river herring biomass since 1975 (USDC, 1984).

The river herring TALFF is low because of the condition of the resource.

While the intent is not to regulate river herring as part of this FMP, the river herring situation poses a significant problem, particularly with regard to the development of the mackerel fishery. If the mackerel fishery develops only with US vessels, the river herring catch will likely increase but it will have no regulatory significance since the PMP does not manage the US fishery. However, the most likely case is that the fishery will develop initially through joint ventures, probably with related directed foreign fisheries. If the latter situation prevails, if the river herring TALFF remains 100 mt, and if the 3% bycatch relationship continues, there is clearly a problem relative to foreign catches in the development of the US fishery.

If the only river herring catch by foreign vessels is bycatch in the mackerel fishery, if the foreign catch amounts to 3 mt of river herring for every 100 mt of mackerel, and if the river herring TALFF is 100 mt, then the total allowed foreign mackerel catch cannot exceed 3,333 mt. While this might represent a worst case situation and additional analyses are needed, there is a problem that, if it cannot be solved, at least it must be recognized in the development of the mackerel fishery.

ASMFC SHAD AND RIVER HERRING SCIENTIFIC AND STATISTICAL COMMITTEE POSITIONS ON RIVER HERRING HARVESTS IN THE U.S. FISHERY CONSERVATION ZONE

Prepared by:

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and

Manager, Shad and River Herring
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Atlantic States Marine Fisheries Commission

January 17, 1985

INTRODUCTION

This document summarizes current opinions and views of the Atlantic States Marine Fisheries Commission's Shad and River Herring Scientific and Statistical Committee on the issue of acceptable levels of offshore river herring* harvests by both foreign and joint-venture fisheries. These views are documented in minutes of committee meetings and in draft documents produced as part of the management program. While they do not constitute final recommendations of the committee, they are strongly indicative of the likely nature of recommendations to be included in the final Interstate Fisheries Management Plan scheduled for completion in October, 1985.

This document was prepared at the request of Jim McCallum, of the Atlantic States Marine Fisheries Commission, and after consultation with Mr. Robert Jones, Chairman of ASMFC's Shad and River Herring Management Board, and Mr. Harrel Johnson, Chairman of ASMFC's Shad and River Herring Scientific and Statistical Committee.

BACKGROUND

Appendix A presents excerpts on offshore river herring harvests from the first document produced in the shad and river herring management program, entitled "Current status and biological characteristics of the anadromous alosid stocks of the eastern United States: American shad, hickory shad, alewife and blueback herring."(a full citation appears in the appendix). Existing information suggests that very large offshore river herring harvests in the late 1960's and early 1970's were in large part responsible for the precipitous declines later observed in river herring stocks in the Chesapeake Bay and southeastern coastal states. River herring stocks in the northeastern and New England states were not similarly affected, suggesting that they were not being over exploited by those same foreign fisheries. Annual river herring landings along the east coast are currently at the lowest level recorded, primarily attributable to extremely low harvests in the Chesapeake Bay and southeastern United States.

*For purposes of the foreign fishing regulations, the term 'river herring' is considered to include alewife, blueback herring, and hickory shad; American shad is considered a prohibited species (50 CFR 611.50()(4)).

COMMITTEE VIEWS AND OPINIONS

Topics to be addressed in the anadromous alosids Interstate Fisheries Management Plan were discussed at Committee meetings which took place July 18-19 and September 17-18, 1984. A draft outline for the management plan was prepared and revised as a result of those meetings. That outline currently is being used in developing a draft management plan (first draft scheduled to be completed in January 1985). In a proposed section of the plan entitled, "Actions necessary for achievement of management objectives," the Committee has included actions aimed at "minimizing to the extent necessary the offshore harvest of alosids." The three specific actions proposed are:

--Provide technical input on a periodic basis for establishing acceptable harvest levels by the Regional Fishery Management Councils and NOAA.

--Recommend to NOAA and the Councils modifications to seasons and/or areas for those fisheries taking alosids as bycatch so as to reduce the bycatch.

--Monitor the establishment and development of joint-venture fisheries which have the potential for or are targeting harvest of alosids; discourage establishment of such fisheries.

These proposed steps make it clear that the Committee has serious concerns about the potential impact of offshore harvests on river herring stocks. In particular, the current depressed state of Chesapeake Bay and southeastern United States stocks may make those stocks particularly sensitive to any increase in fishing mortality, whether inshore or offshore. Information available to the Committee suggested that recent foreign offshore harvests were well below the allowable quotas.* The Committee's intentions are to suggest, at a minimum, that the TALFF remain the same, or, at best, be reduced substantially. Formulation of a specific recommendation on appropriate quotas (TALFF plus joint-venture harvests) is constrained by the paucity of information on population dynamics characteristics of the depressed river herring stocks (in particular, total and fishing mortality rates) and on the geographical origin of stocks

*While the TALFF for river herring was 100 mt annually for 1983 and 1984, amounts allocated to foreign nationals by the Department of State have been less--65 mt for 1983 and 85 mt for 1984. Reported foreign harvests were considerably lower than the amounts allocated, approximately 6 mt in 1983 and 16 mt in 1984; the Northeast Region recommended no change in the level of TALFF for 1985 (G. Mahoney, NMFS, pers. comm.).

being harvested in offshore waters. Acquisition of these data will be a high priority of the Management Plan. In the absence of evidence to the contrary, any reduction in offshore harvest of river herring would appear to be beneficial to the currently depressed stocks.

In addition, it should be noted that incidental harvests of American shad by offshore fisheries are also of great concern to the Committee. Since they are a "prophibited species", harvest is not legal. However, because of sensitivity to handling, any shad caught will be lost even though released. Thus, establishment of any new fisheries should take into account probability of accidental capture of American shad.

APPENDIX A

(Selected excerpts relating to offshore harvests of river herring taken from the document cited below)

CURRENT STATUS AND BIOLOGICAL CHARACTERISTICS OF THE ANADROMOUS ALOSID STOCKS OF THE EASTERN UNITED STATES: AMERICAN SHAD, HICKORY SHAD, ALEWIFE, AND BLUEBACK HERRING

Phase I in Interstate Management Planning for Migratory Alosids of the Atlantic Coast

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July 1984

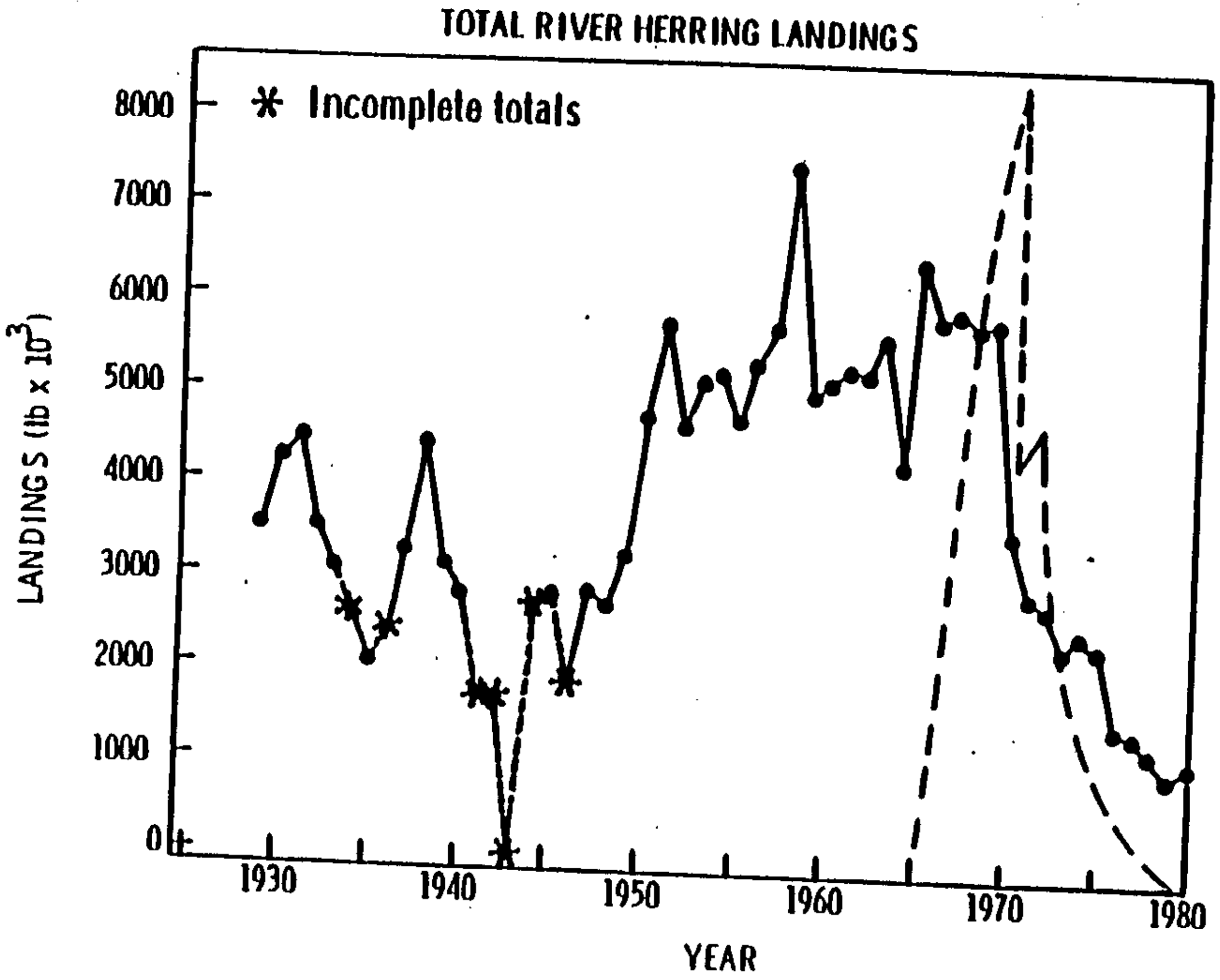

Figure IV-1. Reported commercial landings of river herring (sometimes recorded as "alewife" in landings records) along the east coast of the United States, 1929 to 1980; data are from NOAA Fishery Statistics of the United States and ICNAF. Dashed line represents offshore harvest by foreign fishing vessels.

classes would have entered the fishery from 1978 through 1984, they may accurately predict the current low-level stability of stocks.

Juvenile river herring data were collected in the Hudson River between 1968 and 1982 (Texas Instruments, Inc., 1977-1980). However, integration of the data from different stations and dates to develop annual indices has not been done to date, and thus the data cannot currently be used to examine stock trends.

None of the juvenile index data sets described above have been rigorously verified through correlation with year-class contribution to fisheries in subsequent years. Havey (1973) did report a relationship between numbers of juveniles produced and run size 4 years later for a run in Maine, but this was based on a census of juveniles leaving a pond and not a statistical sampling of that population. Positive correlations between indices and landings four years later of blueback herring were reported for the Rappahannock and Potomac Rivers by Loesch et al. (1979), but there is some question of the validity of those data (Loesch, pers. comm.). The correlation results and descriptive contrasts presented here suggest that the indices may be of value for representing high and low year-class extremes, while having limited utility for representing more average year-classes.

D. COASTAL AND OFFSHORE HARVESTS

Foreign fishing fleets began to exploit offshore river herring stocks in the late 1960's. Peak catch was in 1969, at approximately 80 million pounds (Table IV-15). Catches declined significantly after that date. Street and Davis (1976) concluded that these offshore harvests contributed to overharvest and caused stock declines, particularly in the Chesapeake Bay and South Atlantic stocks. Street and Davis reported that the offshore harvests were composed primarily of fish less than 190 mm in length, which would suggest that they were primarily sexually immature individuals.

Since 1977, the foreign fishery for river herring in the Fishery Conservation Zone (FCZ) of the United States has been managed by the Preliminary Fishery Management Plan (PMP) for the foreign trawl fisheries of the Northwest Atlantic (Boreman, 1982). Allocation of river herring between 1977 and 1980 was 1.1 million pounds annually with some additional allowable by-catch. Since 1981, the allocation has been limited to 100 metric tons, and by-catch regulations have been changed. Current allocations are presented in Table IV-16. When a country's annual allocation for any one species is reached, fishing by that nation's vessels in that part of the FCZ in the northwest Atlantic Ocean must cease and the fishing vessels must leave the

Table IV-15. Reported landings of river herring (lbs x 10^3) in ICNAF/NAFO Areas 5 and 6 by foreign vessels (from Boreman, 1982)

YEAR	BUL	GDR	POL	ROM	SPA	USSR	TOTAL
1964	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0
1967	0	0	0	0	0	14356	14356
1968	0	0	0	0	0	49184	49184
1969	1133	249	0	0	0	78322	79704
1970	1481	419	0	0	0	42083	43983
1971	2291	18538	3101	2015	0	22029	47974
1972	1129	7674	4162	0	0	14756	27721
1973	972	3593	7167	0	0	2348	14080
1974	1704	5862	2399	556	0	1042	11563
1975	1219	4676	137	0	0	1433	7465
1976	564	2778	31	0	0	539	3912
1977	0	152	0	0	0	264	416
1978	0	0	0	0	23	25	48
1979	0	0	4	0	0	24	28
1980	0	0	0	0	4	0	4

Table IV-16. Allocations of river herring by country for foreign fishing within the U.S. Fishery Conservation Zone, 1978-1983

(in metric tons)

	1978	1979	1980	1981	1982	1983
TALFF	500	500	500	100	100	100
ALLOCATIONS						
Bulgaria	—	—	—	5	20	5
Cuba	—	—	25	5	—	—
FRG	—	12	50	—	—	—
GDR	—	10	25	—	—	25
Ireland	—	10	—	—	—	—
Italy	12	13	50	10	10	10
Japan	23	46	50	10	10	10
Mexico	44	40	50	—	—	—
Poland	—	14	50	18	—	—
Portugal	—	—	—	5	5	5
Romania	7	10	10	—	—	—
Spain	52	57	75	10	10	10
USSR	279	197	—	—	—	—
UNALLOCATED	83	91	115	37	45	35

NOTES: River herring for purposes of foreign fishing is defined as alewife, blueback herring, and hickory shad.

TALFF is total allowable level of foreign fishing.

SOURCE: Fisheries of the United States, 1978-1983. USDOC/NOAA/NMFS.

fishing area (G. Mahoney, pers. comm.). Reported offshore landings since 1978 have been consistently low (Table IV-15).

As was discussed in the case of American shad and hickory shad, numerous problems may exist with the ICNAF/NAFO data which serve to document offshore landings. Key among them is the problem with species identification. An additional problem with total ICNAF landings results from inclusion of potentially inaccurate NOAA inshore landings data. This problem can be avoided by examining the ICNAF/NAFO data on a country-by-country basis, since foreign fleets operate only in offshore waters.

Coastal fisheries for river herring are currently minimal in magnitude. Nearly all major river herring harvests are made within individual river systems or at the mouths of those drainage systems.

The totals of current offshore and coastal harvests of river herring are relatively insignificant. Even if current foreign fishery allocations of river herring were taken each year, those landings would comprise less than 2% of total harvest in any given year. However, these fisheries do focus on immature, smaller fish, and a low percentage in terms of total poundage can represent a larger percentage in terms of numbers of individuals. Although the potential for problems with offshore fisheries exists, the problem appears minimal at present.

E. COASTAL MIGRATIONS

A knowledge of coastal migration patterns of river herring is relevant to examination of hypotheses relating to factors influencing mortality and stock trends. Such information is also needed to assess the potential for interjurisdictional conflicts in harvesting the species. Coastal migration must be placed in perspective to the general life history patterns of the two river herring species, summarized in Figs. I-4 and I-5.

Juvenile river herring generally emigrate from freshwater to the ocean in the fall. However, in some instances, it appears that high abundance of juveniles may trigger very early (e.g., summer) emigration of large numbers of small juveniles from the nursery area (e.g., Richkus, 1975). Length of stay of immature fish in the ocean is generally four or five years, dependent on sex. There is some indication that alewives in northern states may remain in inshore waters for one or two years (e.g., Walton, 1981). Spawning runs begin earliest in southern states (December to January in Florida) and latest in the North (May to June in Maine) (Tables IV-17 and IV-18). Homing of fish to their stream of origin is a generally accepted premise, particularly based on numerous successes in creating new runs through stocking of

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

February 8, 1985 F/NEC1:EDA

Mr. John C. Bryson
Executive Director
Mid-Atlantic Fishery Management Council
Room 2115, Federal Building
300 South New Street
Dover, DE 19901-6790

Dear John:

I have taken a look at the data from the US-Polish research fishery for mackerel in an attempt to get some helpful information concerning the by-catch problem in the foreign mackerel fishery. This issue will apparently be considered at the March 5 meeting of the Council's Coastal Migratory Species Committee. Since I will be unable to attend that meeting, I have assembled as much information as possible in this letter and its attachments. Ed Bowman will attend the meeting on behalf of the Center.

River herring, as well as other species, have been taken as by-catch in the directed fisheries for mackerel by Poland beginning in 1981. (Note: Their fishery in 1981 was as a result of an allocation from TALFF; the 1982-84 fisheries were research activities conducted cooperatively with the NEFC.) The text table below summarizes the relevant catch data from each year:

Year	Catch (mt)				River herring / mackerel
	All species	Mackerel	River herring	Other species	
1981	4,078	3,979	11	88	.003
1982	4,887	4,364	206	317	.047
1983	4,638	4,341	93	204	.021
1984	5,838	5,531	222	85	.040

During these four years, the by-catch of river herring has varied from 0.3% to 4.7% of the mackerel catch and has averaged 2.8%.

In an attempt to get some idea as to possible area/time differences in the river herring by-catch, the results from 1984 were examined in detail. (Note: The 1981-83 data were not examined in detail because of the time involved in the analysis. None of the 1981-84 data have been stored on computer files yet, although work has just begun on this in order to facilitate extensive analysis of the entire data base this summer.) For each of the 439 trawl hauls made in 1984 the distance from shore was plotted. Distance from shore varied from 3 to about 80 miles and averaged about 28 miles.

-more-

Catches of both river herring and mackerel were tallied according to where caught (3-19 miles, ≥20 miles, and total), month, and vessel (Table 1). Within the 3-19 mile zone, the average distance from shore for the 161 hauls made there was about 15 miles. Total catches of river herring were much greater in waters less than 20 miles from shore (71%) than in waters 20 miles or greater from shore (29%). The by-catch percentage of river herring for all months and for both vessels was 6.8 in the 3-19 mile zone and 2.0 in the ≥20 mile zone; the overall percentage was 4.0. By-catch percentages varied on a monthly basis, with the highest percentages occurring in March in all areas.

The location of trawl hauls made by the Polish vessels in 1984 is provided in Figures 1 and 2. As indicated, the bulk of the hauls made in the 3-19 mile zone occurred in waters off Delmarva and south, with some off northern New Jersey. River herring by-catch occurred in all areas, however, even in southern New England waters. Of the 58 hauls which caught greater than 1 mt of river herring, 69% were south of the mouth of Chesapeake Bay (37° N).

Of the 5,531 mt of mackerel caught by the Polish fishery in 1984, 42% was from 3-19 miles and 58% was from ≥20 miles (Table 1). The greater portion of the mackerel catch was taken in waters 20 miles or more from shore primarily because 63% of the hauls occurred there. Catch rates for both mackerel and river herring were higher in the 3-19 mile zone (26% higher for mackerel, 326% higher for river herring) (Table 2). On a monthly basis, mackerel as well as river herring catches (Table 1) and catch rates (Table 2) were greatest in March.

In 1984, the total river herring by-catch in the Polish fishery consisted of 83% blueback herring and 17% alewife. Recognizing the likelihood for some incorrect identification of these two species, these percentages must be viewed as only approximate.

The length frequency of river herring measured aboard the Polish vessels in 1984 is as follows:

Fork length (cm)	Number
18	4
19	-
20	-
21	5
22	35
23	129
24	190
25	172
26	157
27	104

-more-

Fork length (cm) (cont'd)	Number
28	57
29	14
30	10
31	3
32	1
33	-
34	-
35	1
Total	882

This length frequency represents adult fish which would be on the verge of moving inshore to spawn.

Even though the greatest river herring by-catch in a directed mackerel fishery is likely to occur inside 20 miles, some will also occur outside 20 miles. Actual levels of by-catch will obviously vary by area and month and also depending on the skill of the individual vessel captains involved in a mackerel fishery. However, regardless of the by-catch percentages one assumes (4%, 2%, 7%), the amount caught is certainly going to exceed the 100-mt level presently on record. Therefore, if a significant increase in the mackerel catch is planned (up to 50,000 mt, for example), whether by US or foreign trawlers, you will have to plan on a significant increase in river herring by-catch (1,000 mt if you assumed a 2% by-catch on 50,000 mt of mackerel).

I hope the above information will be of help. Please contact Ed if you have questions, as I will be away from the office February 18-March 8.

Sincerely,

Emory D. Anderson
Chief, Offshore Fishery
Resources Investigation

Attachments (4)

cc: D. Marshall, NEFMC
S. Testaverde, F/NER72
E. Bowman, F/NEC

Table 1. Catch (kg) of mackerel and river herring in the US-Polish research fishery for mackerel during January-April 1984. Catches and the ratio between river herring and mackerel catches are given by month, vessel, and distance from shore.

Month	3-19 miles			≥ 20 miles			Total		
	Mackerel	River herring	Ratio	Mackerel	River herring	Ratio	Mackerel	River herring	Ratio
				ADMIRAL ARCISZEWSKI					
Jan	337,600	27,830	.082	755,900	5,445	.007	1,093,500	33,275	.030
Feb	128,880	1,830	.014	290,370	2,810	.010	419,250	4,640	.011
Mar	888,050	46,300	.052	416,980	7,960	.019	1,305,030	54,260	.042
Apr	88,840	1,730	.019	611,540	12,360	.020	700,380	14,090	.020
Total	1,443,370	77,690	.054	2,074,790	28,575	.014	3,518,160	106,265	.030
				KNIAZIK					
Jan	242,720	14,415	.059	461,610	240	.001	704,330	14,655	.021
Feb	93,708	-	-	373,251	2,576	.007	466,959	2,576	.006
Mar	554,278	65,639	.118	279,493	32,225	.115	833,771	97,864	.117
Apr	-	-	-	8,200	412	.050	8,200	412	.050
Total	890,706	80,054	.090	1,122,554	35,453	.032	2,013,260	115,507	.057
				TOTAL					
Jan	580,320	42,245	.073	1,217,510	5,685	.005	1,797,830	47,930	.027
Feb	222,588	1,830	.008	663,621	5,386	.008	886,209	7,216	.008
Mar	1,442,328	111,939	.078	696,473	40,185	.058	2,138,801	152,124	.071
Apr	88,840	1,730	.019	619,740	12,772	.021	708,580	14,502	.020
Total	2,334,076	157,744	.068	3,197,344	64,028	.020	5,531,420	221,772	.040

Table 2. Catch per trawl tow (kg) of mackerel and river herring in the US-Polish research fishery for mackerel during January-April 1984. Catch rates and number of tows are given by month, vessel, and distance from shore.

	3-19 miles			≥ 20 miles			Total		
Month	No. tows	Mackerel	River herring	No. tows	Mackerel	River herring	No. tows	Mackerel	River herring
					ADMIRAL ARCISZEWSKI				
Jan	20	16,880	1,392	40	18,898	136	60	18,225	555
Feb	10	12,888	183	19	15,283	148	29	14,457	160
Mar	45	19,734	1,029	27	15,444	295	72	18,125	754
Apr	6	14,807	288	59	10,365	209	65	10,775	217
Total	81	17,819	959	145	14,309	197	226	15,567	470
					KNIAZIK				
Jan	20	12,136	721	49	9,421	5	69	10,208	212
Feb	12	7,809	-	44	8,483	59	56	8,339	46
Mar	48	11,547	1,367	38	7,355	848	86	9,695	1,138
Apr	0	-	-	2	4,100	206	2	4,100	206
Total	80	11,134	1,001	133	8,440	267	213	9,452	542
					TOTAL				
Jan	40	14,508	1,056	89	13,680	64	129	13,937	172
Feb	22	10,118	83	63	10,534	85	85	10,426	85
Mar	93	15,509	1,204	65	10,715	618	158	13,538	963
Apr	6	14,807	288	61	10,160	209	67	10,576	216
Total	161	14,497	980	278	11,501	230	439	12,600	505

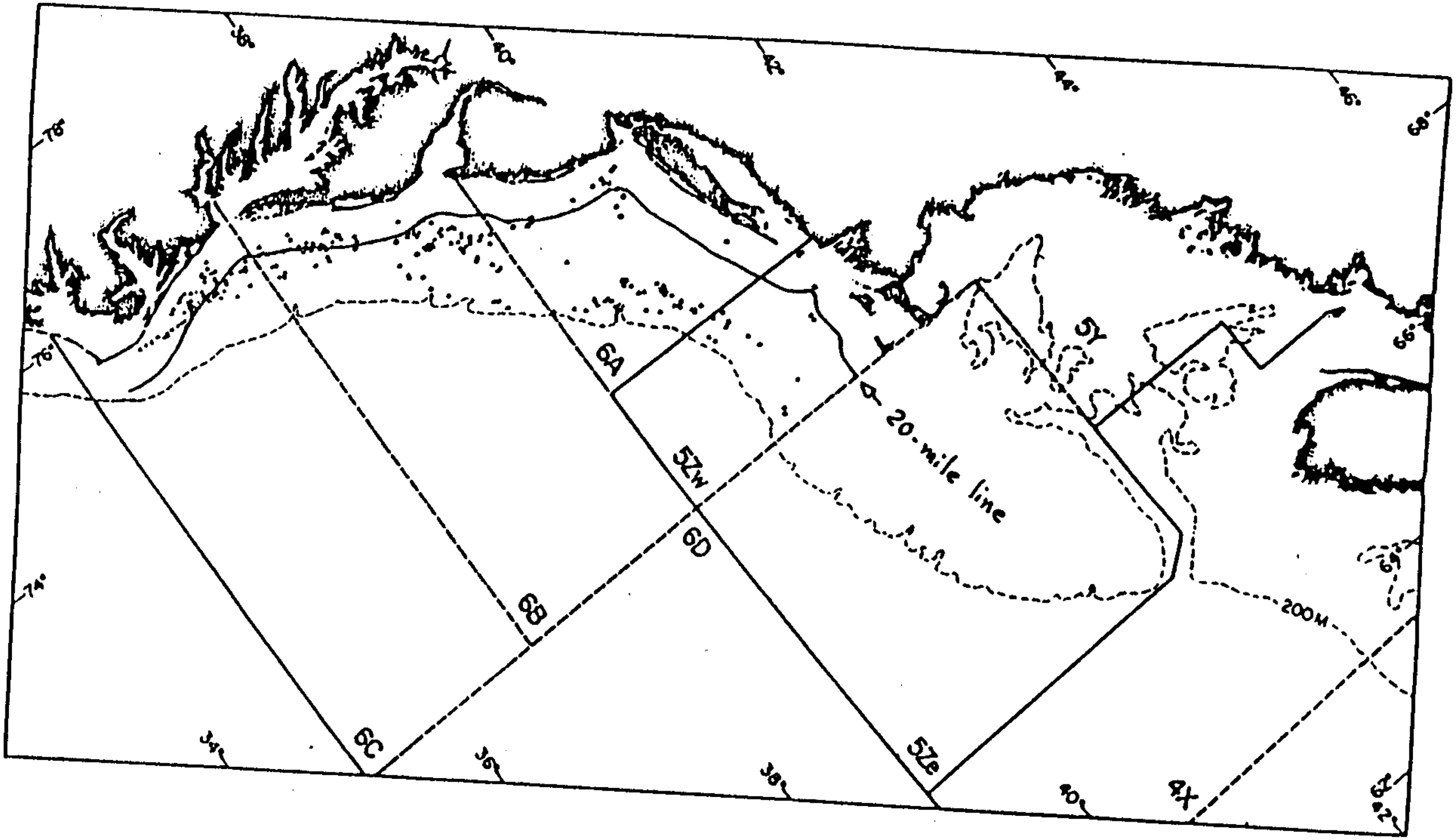

Figure 1. Area of work for the Polish M/T ADMIRAL ARCISZEWSKI Cruise 84-01(I-V) Atlantic Mackerel Research Fishery during 6 January - 30 April 1984. Dots depict location of trawl tows.

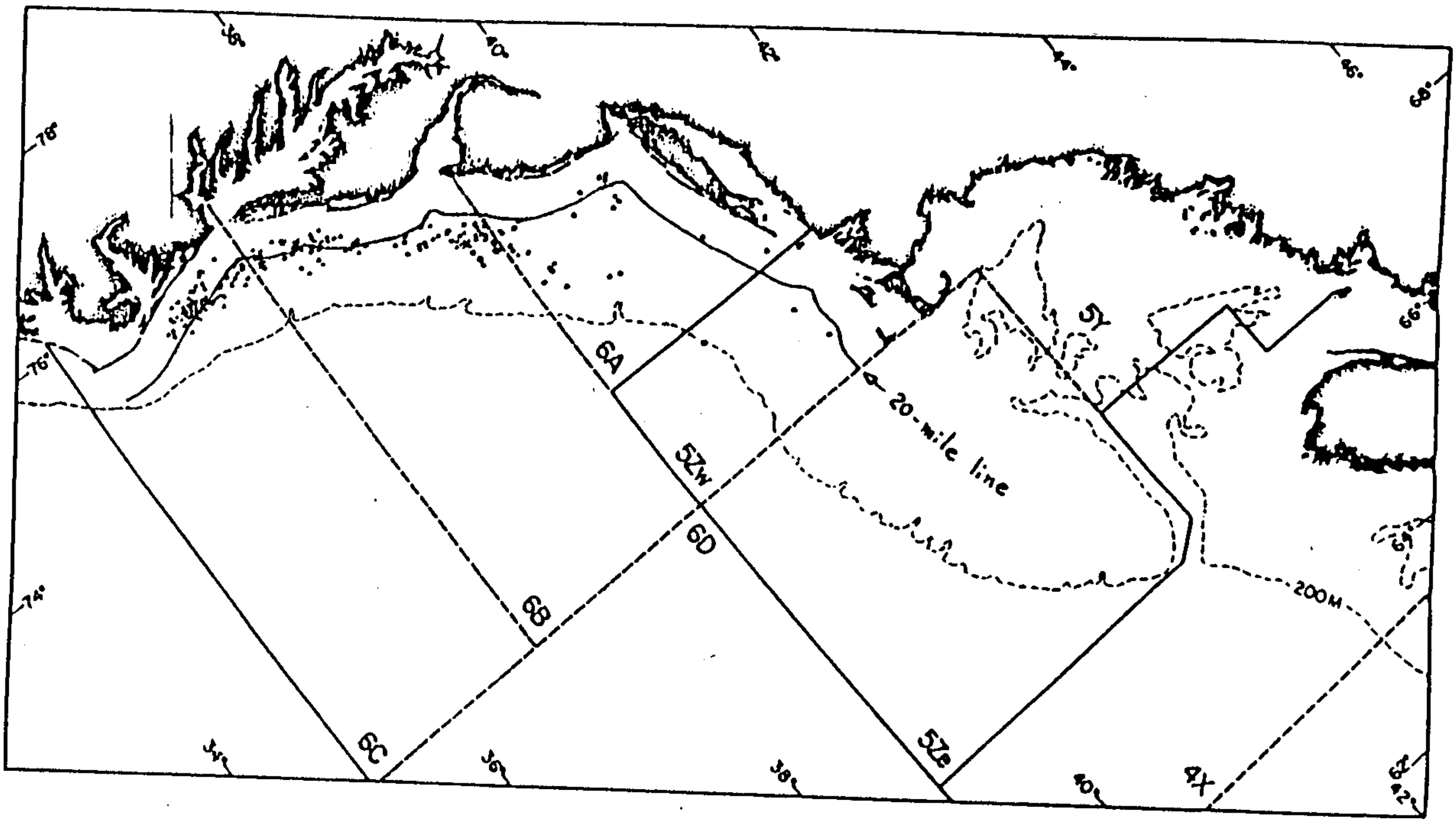

Figure 2. Area of work for the Polish M/T KNIAZIK Cruise 84-01(I-IV) Atlantic Mackerel Research Fishery during 6 January - 4 April 1984. Dots depict location of trawl tows.

NATIONAL MARINE FISHERIES SERVICE

Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

March 7, 1985 F/NEC1:JB

William A. Richkus, Ph.D.
Martin-Marietta Environmental Systems
9200 Rumsey Road
Columbia, Maryland 21045-1934

Dear Bill,

I received your phone message the other day regarding distribution of foreign vessel catch of river herring off the United States during the 1970's. I have been unable to reach you by phone so I have gone ahead and prepared a table of the data that I have regarding the catch by foreign vessels in NAFO Subareas 5 and 6 from 1971 to 1980. This data differs slightly than the data presented in my laboratory reference document because I have found some additional landings that were listed as blueback herring for the years 1973 and 1974. Specifically, in 1973 Bulgaria reported 816,000 lbs of blueback herring landings in addition to 972,000 lbs of river herring landings (which, I presume, are alewife landings), and in 1974 Rumania reported 556,000 lbs of blueback herring landings. I have added the blueback herring landings to the river herring landings. Please let me know if you need additional information.

Sincerely,

John Boreman
Chief, Coastal Fisheries
Resources Investigation

MARTIN MARIETTA ENVIRONMENTAL SYSTEMS

9200 RUMSEY ROAD
COLUMBIA, MARYLAND 21045-1934
(301) 964-9200
FAX #(301) 964-9200, EXT. 350

March 15, 1985

Mr. Paul Perra
Atlantic States Marine Fisheries Commission
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036

Dear Paul::

As you requested, I have assessed river herring and shad data needs with regard to the offshore fisheries. Below is a list of specific types of data which are needed to determine the potential impact of these offshore fisheries on coastal stocks of those species. I have attempted to provide a series of alternative levels of data for each category, going from those data most desirable but labor intensive to those requiring least effort but still being of some value.

1. Recording the presence of adult and/or subadult American shad and hickory shad in the mackerel bycatch (with some indication of relative magnitude of catch).

2. Size frequency distribution of river herring in the bycatch (minimum sample size of about 30 fish of each species - alewife, blueback); second order data - size frequency distribution without speciation; third order data - subjective evaluation of nature of the catch, whether it is mostly adults or subadults or both. These data would not be necessary for each haul, but should be taken from trawls in defined geographical/time segments (perhaps using the NAFO subareas and two week time periods).

3. Collections of scales from fish used for size frequency distributions; these scales could be used by researchers to contribute to stock discrimination.

4. Estimates of magnitude of bycatch of river herring, by haul, including tows taking none or very little

REPORTED COMMERCIAL LANDINGS (000 POUNDS) OF RIVER HERRING BY FOREIGN VESSELS

YEAR	COUNTRY	NAFO SUBAREA						TOTAL
		5Y	5Ze	5Zw	6A	6B	6C	
1971	POLAND	0	2567	534	0	0	0	3101
	ROMANIA	0	44	165	1129	633	44	2015
	USSR	0	858	16154	2309	926	1782	22029
	TOTAL	0	3469	16853	3438	1559	1826	27145
1972	BULGARIA	0	589	218	322	0	0	1129
	GDR	73	1521	847	710	3682	842	7675
	POLAND	2	3201	62	635	225	37	4162
	USSR	93	5185	4963	3772	478	265	14756
	TOTAL	168	10496	6090	5439	4385	1144	27722
1973	BULGARIA	0	509	664	553	62	0	1788
	GDR	0	525	785	930	1270	84	3594
	POLAND	84	2110	4228	602	60	84	7168
	USSR	0	403	181	1484	132	148	2348
	TOTAL	84	3547	5858	3569	1524	316	14898
1974	BULGARIA	0	179	260	1164	101	0	1704
	GDR	0	1446	902	955	2524	35	5862
	POLAND	0	595	895	844	64	0	2398
	ROMANIA	0	0	0	117	342	97	556
	USSR	0	454	64	522	2	0	1042
	TOTAL	0	2674	2121	3602	3033	132	11562
1975	BULGARIA	0	278	238	703	0	0	1219
	GDR	0	2513	298	1049	467	348	4675
	POLAND	0	0	0	82	55	0	137
	USSR	0	1179	0	254	0	0	1433
	TOTAL	0	3970	536	2088	522	348	7464
1976	BULGARIA	0	0	13	317	234	0	564
	GDR	0	37	4	1219	1387	130	2777
	POLAND	0	31	0	0	0	0	31
	USSR	0	340	60	139	0	0	539
	TOTAL	0	408	77	1675	1621	130	[illegible]
1977	GDR	0	0	0	73	57	22	152
	USSR	0	35	154	75	0	0	264
	TOTAL	0	35	154	148	57	22	416
1978	SPAIN	0	4	2	15	2	0	23
	USSR	0	0	18	7	0	0	25
	TOTAL	0	4	20	22	2	0	48
1979	USSR	0	0	9	15	0	0	24
1980	SPAIN	0	2	2	0	0	0	4
	USSR	0	0	0	2	0	0	2
	TOTAL	0	2	2	2	0	0	6
1971-1980		252	24605	31720	19998	12703	3918	93196

(this information contributes to defining areas where bycatch may be minimal); second order data- presence or absence of substantial amounts of river herring in each mackerel tow.

5. It would be nice to obtain tissue samples or otoliths from herring bycatch which could be used in research into stock discrimination studies; however, because no such studies are underway, at least to my knowledge, I would consider this data category to be very low priority.

Those represent the major data needs as far as I can tell. If you have any questions, please give me a call.

Sincerely,

Bill

William A. Richkus, Ph.D.
Manager
Shad and River Herring
Management Program

jvg

c) ASMFC 1999 Amendment 1 to the Fishery Management Plan for Shad & River Herring

Fishery Management Report No. 35
of the

Atlantic States Marine Fisheries Commission

Amendment 1 to the Interstate Fishery Management Plan for Shad & River Herring

April 1999

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Approved by the Atlantic States Marine Fisheries Commission October 1998

This document was prepared in cooperation with the Atlantic States Marine Fisheries Commission=s Shad & River Herring Management Board, Shad & River Herring Technical Committee, Shad & River Herring Plan Development Team, Shad & River Herring Stock Assessment Subcommittee and the Shad & River Herring Advisory Panel.

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Acknowledgements

This fishery management plan was developed through the concerted and dedicated efforts of several individuals, groups, and agencies. The Plan Writer was Carol Markham (Maryland Dept. of Natural Resources). The Plan Development Team was chaired by John Field, ASMFC, and consisted of Kathy Hattala (New York Dept. of Environmental Conservation), Kurt Finsterbusch (University of Maryland), Bonnie Martin (South Carolina Dept. of Natural Resources), Najih Lazar (ASWC), and Richard St. Pierre (USFWS).

Dr. Victor Creeco (Connecticut Department of Environmental Protection) was the chair of the Shad and River Herring Stock Assessment Subcommittee and principal author of the stock assessment of American shad from selected Atlantic coast rivers, without which this plan could not have been initiated. Dr. Crecco was assisted by members of the Shad and River Herring Technical Committee (chaired by Kathy Hattala, New York Dept. of Environmental Conservation (1994-1995) and Dale Weinrich, Maryland Dept. of Natural Resources (1996-1997)). The Plan Development Team is extremely grateful to these individuals for their contributions, expertise, and support during the development of this document.

The Management Board was chaired by Roy Miller (Delaware Dept. of Natural Resources and Environmental Control) in 1995-1996, and Byron Young (New York Dept. of Environmental Conservation) in 1997-1998. While receiving the various drafts of the amendment, the Management Board consulted frequently with the Advisory Panel (chaired by Patricia Jackson, Virginia).

The Plan Development Team is grateful to the many individuals who made contributions to the preparation of Amendment 1. These include the professional and technical staff of the various state and federal agencies involved in the Atlantic States Marine Fisheries Commission who provided the editorial comments and suggestions to the Team. In addition, the Atlantic States Marine Fisheries Commission extends its gratitude to the numerous dedicated conservationists, commercial fishermen, and anglers who have written letters and attended public hearings to express their opinions and ideas about Amendment 1.

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Section 1. INTRODUCTION

1.1 Background Information

Historically, American shad *(Alosa sapidissima),* hickory shad *(Alosa mediocris), alewife (Alosa pseudoharengus),* and blueback herring *(Alosa aestivalis)* (collectively termed alosines) were extremely important resource species and supported very large commercial fisheries along the east coast of both the United States and Canada. Coastwide landings of American shad at the turn of the century were approximately 50 million pounds. However, by 1980, they decreased dramatically to 3.8 million pounds, and by 1993, only 1.5 million pounds were landed. Total landings of river herring varied from 40-65 million pounds from 1950-1970; however, they declined steadily thereafter to less than 12 million pounds by 1980, and by 1996, only 1.4 million pounds were landed. These large declines in commercial landings were perceived as an indication that management action would be required to restore alosine stocks to their former levels of abundance. Therefore, the members of the Atlantic States Marine Fisheries Commission (Commission) recommended the preparation of a cooperative Interstate Fishery Management Plan (Plan) for American Shad and River Herrings. This recommendation was adopted by the Commission in 1981 and the Plan was completed in 1985. A supplement to this American Shad and River Herrings Plan was approved by the Commission in 1988. The document included reports prepared by the Shad and River Herring Stock Assessment Subcommittee, and summaries of material presented at an 1987 Anadromous Alosine Research Workshop. The 1988 supplement also documented changes to management recommendations and research priorities based on new research findings. The 1985 Plan specified recommended management measures, focused primarily on regulating exploitation and enhancing stock restoration efforts. At the time of the 1985 Plan, implementation of its recommendation was at the discretion of the individual states and the Commission did not have direct regulatory authority over individual state fisheries.

The decline in stocks continued, and in 1994, the Plan Review Team and the Management Board determined that the original 1985 Plan was no longer adequate for protecting or restoring the remaining shad and river herring stocks. These declines are possibly due to overharvest by inriver and ocean-intercept fisheries, excessive striped bass predation (Savoy and Crecco 1995), biotic and abiotic environmental changes, and loss of essential spawning and nursery habitat due to water quality degradation and blockages of spawning reaches by dams and other impediments. Although improvement has been seen in a few stocks, alosine populations remain severely depressed.

Depressed stock conditions are unlikely to change under current management because the 1985 Plan does not require any specific management approach or monitoring programs within the management unit, asking only that states provide annual summaries of restoration efforts and ocean fishery activity. Moreover, the Plan does not provide for adaptive management in light of stock growth or declines. In addition, to address the problem of voluntary Plan implementation, the 1993 Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) requires states to adopt management guidelines in approved Commission Plans. In the event that a state does not implement a Commission fishery management plan, the law provides that the U.S. Secretary of Commerce may impose a moratorium in that state=s particular fishery. Under this law, all Commission Plans must include specific measurable standards to improve the status of the stocks and to determine if states comply with these standards. Amendment 1 to the 1985 Plan will provide management guidance, ad required by ACFCMA, by setting specific standards to be met by the states.

Because of the scarcity of reliable data on river herring and hickory shad populations, the ASMFC member states decided to focus Amendment I on American shad regulations and monitoring programs. However, the amendment requires states to initiate fishery-dependent monitoring programs for river herring and hickory shad while recommending continuance of current fishery-independent programs for these species. As data become available for river herring and hickory shad fisheries, states will develop a better understanding of stock status and may take regulatory action at a future date.

1.1.1 Benefits and Implementation

1.1.1.1 Social and Economic Benefits

Restoring populations of American shad would be beneficial because such management action would generally increase the total use and non-use (existence) values of this species in the ASMFC member states and the nation. Increases in consumptive use values could include future allowances for commercial and recreational fishing harvest, while improvements in non-consumptive use values might include increases in ecotourism activities related to the restored American shad stocks (e.g. bird and fish watching at fish passage facilities). Population restoration of American shad might also stabilize harvesting and related commercial markets.

1.1.1.2 Ecological Benefits

American shad play an important ecological role in freshwater, estuarine and marine food chains by preying on some species and serving as prey for others, at all life stages (Facey et al. 1986, MacKenzie et al. 1985, Weiss-Glanz et al.1986). They also historically played a significant role, especially in South Atlantic coastal river systems where the percentage of spawning is low and many of the shad die after spawning, in transferring nutrients from the marine system into the freshwater interior rivers. Durbin et al. (1979) conducted a study of the effects of postpawing alewife on freshwater ecosystems. It was suggested that the potential influence of alosine migrations on the energetics and nutrient dynamics of Atlantic coastal ecosystems is equivalent to effects documented for similar systems in the Pacific Northwest. In additional, Garman (1992) studied the fate and potential significance of postpawning anadromous fish carcasses in the James River, Virginia. He hypothesized that, before recent declines in abundance, the annual input of marine-derived biomass via alosine migrations was an important episodic sources of energy and nutrients for the non-tidal James River.

As predators, American shad consume a variety of invertebrate organism at each life stage and may consume small fishes as adults. As larvae in the Holyoke pool of the Connecticut River, shad consume copepods, midge larvae, midge pupae and small crustaceans (Facey and Van Den Avyle 1986). In the same location, juveniles consumed crustacean zooplankton, midge larvae and pupae, caddis fly larvae and adult insects. Juvenile shad appear to be opportunistic feeders that consume most of their food from the water column, rather than from the bottom or surface. In some areas, however, juvenile shad were clearly selective choosing water fleas (Daphnia) and bosmids over other available prey (MacKenzie et al. 1985). Juveniles in Virginia consumed amphipods, aquatic insects and terrestrial insects. Studies of juveniles from Florida, Georgia and North Carolina also documented insects and crustaceans as primary food items in the diet of juveniles. Once they leave coastal rivers and estuaries and move to the nearshore Atlantic Ocean, the diet of juvenile American shad shifts to include small fishes. Juveniles off the North Carolina coast consumed striped anchovy (Anchoa hepsetus). In the St. Johns River, Florida, juveniles ate bay anchovy (Anchoa mitchelli) and mosquitofish (Gambusia affinis). As adults offshore, shad are believed to be primarily planktivorous, consuming mainly copepods, mysid shrimp, and other zooplanktors. The stomachs of 41 adults caught off the North Carolina coast all contained zooplankton, including amphipods, copepods, isopods, crustaceans and larval decapods. There were fish remains in 39 of the stomachs, however, which indicates that shad are not exclusively planktivorous. Adult shad in the Bay of Fundy consumed copepods and mysid shrimp. It is still unclear whether adult shad eat during the spawning migration. Chittenden (1976) found that the stomachs of most shad captured in freshwater were empty, but a few did contain mayflies. This finding of little or no food is similar to the reports of Hildebrand and Schroeder (1928) and Moss (1946) that adult shad take little or no food while ascending rivers. Chittenden=s (1976) observations suggest, however, that adult shad would opportunistically feed in freshwater if suitably large planktonic forms were readily available.

As prey, American shad are important for other species that are themselves important commercially, recreationally and ecologically. American eels prey on American shad eggs, larvae, and juveniles in freshwater, and striped bass consume juveniles (Facey et al. 1986, Mansueti and Kolb 1953, Walburg and Nichols 1967). Savoy and Crecco (1995) also suggest a direct linkage between increased striped bass predation and the recent dramatic drop in American shad and blueback herring abundance in the Connecticut River. Predation on juvenile American shad by bluefish and other large predators (e.g. weakfish, striped bass) is also perhaps a minor factor that could be delaying the recovery of American shad stocks in the Chesapeake Bay (Klauda et al. 199 1). Once in the ocean, as a schooling species with no dorsal or opercular spines, American shad are undoubtedly preyed upon by many species including sharks, tunas, king mackerel (Scomberomorus regales) and seals and porpoises (Melvin et. al. 1985, Weiss-Glanz et al. 1986).

1.2 Description of the Resource

A comprehensive description of the Atlantic coast stocks of American shad, hickory shad, alewife, and blueback herring can be found in the 1985 Interstate Fishery Management Plan (Plan) for American Shad and River Herrings. This provides the basic information necessary to understand how anadromous alosines relate to their essential habitats, and the significance of the commercial and recreational alosine fisheries to the economy and culture of the Atlantic coast.

1.2.1 American Shad and Hickory Shad Life Histories

American shad and hickory shad are anadromous fish that spend the majority of their life at sea and only enter freshwater in the spring to spawn. Shad are river-specific; that is, each major river along the Atlantic coast appears to have a discrete spawning stock. Shad spawning can occur as early as November in southern states and as late as July in New England and Canada. Depending on geographical location, shad may spawn once and die, or they may survive to make several spawning runs per lifetime. Repeat spawning in hickory shad runs varies among river systems. In American shad, differences occur as shad move north. Most American shad native to rivers south of Cape Fear, North Carolina, die after spawning (Carscadden and Leggett 1975), however, in rivers to the north, the incidence of repeat spawning increases with latitude.

Spawning American shad broadcast a large quantity of eggs into the water column. Fertilized eggs are carried by river currents and hatch within 2-17 days depending on water temperatures (Jones, et. al. 1978). Larvae drift with the current until they mature into juveniles. Juveniles remain in nursery areas, feeding on copepods, other crustaceans, zooplanktors, chironomid larvae, and aquatic and terrestrial insects (Levesque and Reed 1972, Marcy and Jacobson 1976). By late fall, most juvenile shad migrate to nearshore coastal wintering areas. Immature shad will remain in the ocean for three to six years before returning to spawn. Little information is available on the life history of subadult and adult American shad and hickory shad after they emigrate to the sea.

Both American shad and hickory shad are schooling species and highly migratory. After spawning, iteroparous adult American shad return to the sea and migrate northward to their summer feeding grounds in the Gulf of Maine/Bay of Fundy (Dadswell et. al. 1987). Here, they primarily feed on zooplankton and small fishes. Overwintering (winter habitat) occurs along the mid-Atlantic coast, particularly from Maryland to North Carolina. Hickory shad historically spawned in rivers and tributaries along the Atlantic coast from the Bay of Fundy, Canada to the Tomoka River, Florida. Current presence in waters north of Chesapeake Bay is uncertain; however, recent spawning has been documented as far north as the Connecticut River. Studies suggest that hickory shad migrate in a pattern similar to the coastal migrations of American shad, feeding on small fish, squid, fish eggs, small crabs, and pelagic crustaceans.

1.2.2 Alewife and Blueback Herring Life Histories

Alewife and blueback herring (collectively termed river herring because fishermen do not distinguish between them) are relatively small anadromous fish, spending their adult lives at sea, returning only to freshwater areas to spawn in the spring. Alewife spawn in rivers and tributaries from northeastern Newfoundland to South Carolina, but are most abundant in the mid-Atlantic and northeastern states. Blueback herring spawn from Nova Scotia to northern Florida, but are most numerous in warmer waters from Chesapeake Bay south. The onset of spring spawning is related to temperature and thus, varies with latitude. Alewife spawn in a diversity of habitats that includes large rivers, small streams, ponds, and large takes over a range of substrates such as gravel, sand, detritus, and submerged vegetation. Blueback herring prefer to spawn in swift flowing sections of freshwater tributaries, channel sections of fresh and brackish tidal rivers, and Atlantic coastal ponds over gravel and clean sand substrates, especially in northeastern rivers where alewife and blueback herring co-exist. In southeastern rivers where alewife are few, blueback herring exhibit more of a variety in their spawning sites including shallow areas covered with vegetation, in rice fields, in swampy areas, and in small tributaries upstream from the tidal zone. Mature river herring broadcast their eggs and sperm simultaneously into the water column and over the substrate. Immediately after spawning, adults migrate rapidly downstream. Larvae begin to feed externally three to five days after hatching, and transform gradually into the juvenile stage. Juveniles remain in freshwater nursery areas in spring and early summer, feeding mainly on zooplankton. As water temperatures decline in the fall, juvenile move downstream to more saline waters, eventually to the sea. Little information is available on the life history of subadult and adult river herring after they emigrate to the sea as young-of-year or yearlings, and before they mature and return to spawn.

1.2.3 American Shad Stock Assessment Summary

Given the pronounced drop in coastwide shad landings and stock abundance from several Atlantic coast rivers after 1990, a revised stock assessment was clearly warranted to determine the root cause(s) of the recent shad declines along the Atlantic coast. A coast-wide assessment was prepared by Vic Crecco, chair of the Shad Stock Assessment Subcommittee (SAS). This report chose an overfishing definition (F_{30}), reviewed stock trends, and estimated current and historic coastal (Fc) and inriver (F_R) fishing mortality rates on American shad from seven river systems located from Maine rivers in the north to the Altamaha River, Georgia to the south. Trends in total mortality (Z), which include fishing and natural mortalities, were examined for the Pawcatuck River, Rhode Island, upper Chesapeake Bay, Maryland, and tributaries of Albemarle Sound, North Carolina.. Crecco also examined trends in commercial landings for Maine rivers, as well as for North Carolina rivers (Albemarle Sound, Neuse, Panilico, and Cape Fear Rivers) and South Carolina rivers (Waccamaw-Pee Dee, Savannah, Edisto, and Santee Rivers). Crecco examined trends in relative adult stock abundance in the Merrimack River Massachusetts-New Hampshire based on fishway counts and for Virginia rivers based on commercial catch-per-effort (CPUE). A Thompson-Bell yield-per-recruit (YPR) was used to determine the overfishing definition (F_{30}) for each shad stock.

Based on historic trends in commercial CPUE, fishway counts and population estimates, there is evidence of recent and persistent stock declines in three of 12 rivers or systems [Hudson, New York (1992-1996), York and Rappahannock, Virginia (1980-1993)]. Stock declines were evident in the Pawcatuck River, Rhode Island from 1992 to 1994, but stock abundance has risen sharply in the Pawcatuck during 1995 and 1996. Similarly, although shad stock abundance in the Connecticut River has declined to low levels from 1992 to 1995, stock size has risen steadily in 1996 and 1997 to levels approaching the long-term average (800,000 fish). Inriver commercial landings in the Edisto River, South Carolina have declined since 1990, but shad stock abundance in the Edisto exhibited no apparent decline from 1989 to 1996. This strongly suggests that the drop in commercial landings in the Edisto River was largely due to a reduction in fishing effort and not stock abundance. There was no evidence of recent stock declines for seven additional stocks including the Merrimack River, Massachusetts-New Hampshire, the Delaware River, Delaware-New Jersey, Upper Bay tributaries, Maryland, James River, Virginia, Santee River, South Carolina, and the Altamaha River, Georgia. Presumed stock declines inferred solely from declining trends in inriver commercial landings were evident for seven additional stocks including the Neuse, Pamlico, and Cape Fear Rivers, North Carolina, Waccamaw-Pee Dee and Savannah Rivers, South Carolina, for tributaries of Albemarle Sound, North Carolina, as well as for rivers in the state of Maine.

Recent (1992-96) coastal fishing mortality rates (FC) on seven shad stocks (Connecticut, Hudson, Delaware, Upper Bay, Edisto, Santee, and Altamaha Rivers) were relatively low (FC range: 0.02 to 0.24) and well below our overfishing definitions (F_{30} range: 0.39 - 0.48). Average (1992-1996) total fishing mortality rates (FT), which include inriver and coastal fishing mortalities, were below overfishing definitions (F_{30}) for all seven shad stocks for which inriver (FR) and coastal (FC) fishing rates could be estimated. The recent (1994-1997) average FT level (FT=0.45) on Edisto River shad was only slightly below the overfishing definition ($F_{30} = 0.48$) for southern stocks, indicating that fishing mortality rates on Edisto River shad should be monitored closely over the next few years. Based on the analysis, there is no evidence thus far that the coastal intercept fishery has had an adverse impact on these seven shad stocks. In the absence of population data, it is impossible to quantify the impact the ocean-intercept fisheries have on other shad stocks. Like all mixed stock fisheries, small stocks can be at risk under these conditions.

There are no direct fishing mortality estimates on the Pawcatuck River stock. However, total mortality rates declined by about 50% in the Pawcatuck River between 1989 and 1992. Since total mortality estimates have not risen recently and fishing mortality rates on the Pawcatuck shad stock have not increased, the recent (1992-1994) stock decline in the Pawcatuck may not be due to overfishing. The ability to rule out overfishing for the Pawcatuck River stock is tempered somewhat by the fact that no stock origin studies have ever been conducted on the coastal Rhode Island shad landings which, in theory, could easily have overharvested the small (stock size: 1000-2000 fish) Pawcatuck stock. Moreover, total mortality estimates are not available for the Pawcatuck stock after 1992. In order to address potential overfishing in the Pawcatuck, it would be beneficial to estimate fishing mortality directly and to conduct a tagging study on the Rhode Island coastal fishery to determine stock origin.

Relative exploitation rates from the coastal intercept fishery on the York, Rappahannock and James Rivers, Virginia exhibited no apparent trends from 1980 to 1993. This suggests that the coastal intercept harvest was not related to the shad declines in the York and Rappahannock Rivers. The ability to directly link the coastal intercept fishery to stock declines for these rivers is somewhat limited by the lack of CPUE data in 1994, 1995 and 1996, and by the fact that relative exploitation rates cannot be directly compared to our overfishing definition (F_{30}). In addition, it is difficult to assess recent trends in relative exploitation on the Rappahannock or James Rivers origin shad because shad fishing effort declined markedly in these rivers by 1986 as compared to the 1980-85 period. There are no direct estimates of current fishing mortality for seven rivers that have exhibited a recent decline in shad landings. These include shad stocks from Maine rivers, Albemarle Sound, Neuse, Pamlico, and Cape Fear Rivers (North Carolina), and the Waccamaw-Pee Dee and Savannah River (South Carolina). Given the limitations in using landings trends to infer stock trends, there is no way to adequately link inriver and coastal fisheries with presumed stock declines in these rivers. Total mortality estimates have been estimated for shad tributaries of Albemarle Sound between 1980 and 1995. Since these total mortality estimates have varied without trend, there is no indication here that a rise in fishing mortality was related to the decline in commercial shad landings in Albemarle Sound. Shad stock sizes in the Hudson River have declined rather steadily from 1988 to 1996, although current average fishing mortality (mean $F = 0.33$) was still below the estimated overfishing definition($F_{30} = 0.39$). As a result, the Hudson River stock is considered to be fully exploited. Shad stock abundance in the Merrimack River (Massachusetts-New Hampshire), Santee River (South Carolina), Altamaha River (Georgia), Delaware River (Delaware-New Jersey) and upper Bay Rivers (Maryland) have either recently risen to high levels (i.e., Santee, Altamaha and upper Bay stocks) or have remained stable (i.e., Delaware and Merrimack stocks). Current (mean 1992-96) fishing mortality rates (FT) on these stocks have either approached our overfishing definition (F_{30} level) (i.e., as in the case of the Altamaha and Edisto stocks), or were far below the estimated F_{30} level (i.e., as in the case of the upper Bay, Delaware River and Santee River stocks). No fishing mortality estimates are available for the Merrimack River stock.

There is no evidence of recent (1990-96) recruitment failure for any of the eight shad stocks (Maine Rivers, Pawcatuck, Connecticut, Hudson, Delaware, Upper Bay tributaries, Altamaha, and Virginia Rivers) for which a continuous time series of juvenile indices could be examined. This assessment estimated fishing mortality rates for nine shad stocks and general trends in abundance for 13 American shad stocks. The total range of extant American shad populations includes additional populations in small river systems, as well as depleted populations in larger river systems that are actively being restored. Also, much historical habitat is currently void of American shad and may be targeted for restoration in the future. For these stocks, individual states have targeted minimal fishing mortality to protect small stocks and rebuild others. This assessment cannot quantitatively address these systems because of limited biological data, as well as associated uncertainties in stock composition of small populations in fisheries.

1.3 Habitat Considerations

1.3.1 Description of Habitat

Habitats used by all Atlantic anadromous alosine species include spawning sites in coastal rivers and nursery areas, which include primarily freshwater portions of the rivers and their associated bays and estuaries. In addition to the spawning and nursery areas, adult habitats also consist of the nearshore ocean. Adult American shad have also been found to migrate up to 60 miles off the coast (Neves and Depres 1979). These habitats are distributed along the East Coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory alosines may increase or diminish as the size of the population changes.

1.3.1.1 Spawning Habitat

A. American Shad

American shad spawn in rivers throughout the species' range. Historically, the species probably spawned in virtually every accessible river and tributary along the Atlantic coast. However, blockage of spawning rivers by dams and other impediments and degradation of water quality and physical habitat in spawning reaches have severely depleted suitable American shad spawning habitat. American shad migrate from the sea to coastal rivers in the spring and begin spawning when water temperatures range from about 16-19^{0}C. Water temperature is the primary factor that triggers spawning, but photoperiod, current velocity, and turbidity also exert some influence (Leggett and Whitney 1972). American shad can spawn as early as mid-November in Florida to as late as July in some Canadian rivers (MacKensie et al.1985). If possible, adults migrate far upstream and typically spawn in freshwater areas dominated by extensive flats and over sandy or rocky shallows, including the mouths of larger tributary streams (Davis et al. 1970). However, substrate type should be relatively unimportant to successful American shad spawning since the eggs are broadcast into the water column over a range of substrates and most are carried downstream (Mansueti and Kolb 1953; MacKenzie et al. 1985). Only in areas where the eggs settled to the bottom, were covered by silt or sand and then smothered would substrate become a critical habitat problem.

2. Hickory Shad

Historically, hickory shad spawned in rivers and tributaries along the Atlantic coast from the Bay of Fundy, Canada to the Tomoka River, Florida, but now the species= range is uncertain. The most detailed information available on spawning habitat comes from Maryland, Virginia, North Carolina, and Georgia. Hickory shad are anadromous and begin to ascend freshwater streams for spawning in early spring. Spawning can occur between March and early June, depending on latitude, over a water temperature range of 12 to 22^{o}C (Rulifson et. al. 1982). Adult hickory shad appear to spawn in a diversity of physical habitats ranging from backwaters and sloughs, to tributaries, to mainstem portions of large rivers in tidal and non-tidal freshwater areas. Major hickory shad spawning sites in Maryland and Virginia occur in mainstem rivers at the fall line, but some appear to spawn further downstream and also in tributaries. In North Carolina, the freshwater reaches of coastal rivers are the major spawning sites for hickory shad. However, shad have been found in the Neuse River in flooded swamps and sloughs off the channels of tributary creeks and not in the mainstem river. In Georgia, hickory shad apparently spawn in flooded areas off the channel of the Altamaha River, and not in the mainstem of the upper reaches.

3. Alewife and Blueback Herring

Alewife spawn in rivers and tributaries from northeastern Newfoundland to South Carolina, but are most abundant in the mid-Atlantic and northeastern states. At the extreme southern end of their range, alewife begin spawning in late February, but they may not commence spawning until late April or early June at the northern end of their range (Loesch 1987). Blueback herring spawn in rivers and tributaries from Nova Scotia to northern Florida, but are most numerous in warmer waters from Chesapeake Bay south (Scott and Scott 1988). At the extreme southern end of their range, spawning can begin in December or January, but may not commence until June near the northern end of their range and can continue through August (Marcy 1976). Alewife spawn in a diversity of physical habitats that includes large rivers, small streams, ponds, and large lakes over a range of substrates such as gravel, sand detritus, and submerged vegetation. Blueback herring spawning sites include swift flowing sections of freshwater tributaries, channel sections of fresh and brackish tidal rivers, and Atlantic coastal ponds over gravel and clean sand substrates, especially in northeastern rivers where alewife and blueback herring coexist. In southeastern rivers where alewife are few, blueback herring exhibit more of a variety in their spawning sites including: shallow areas covered with vegetation, rice fields, swampy areas, and in small tributaries upstream from the tidal zone. Upstream distribution of adults is a function of habitat suitability and hydrologic conditions permitting access to these sites (Loesch and Lund 1977). Immediately after spawning, surviving adult river herring migrate rapidly downstream.

1.3.1.2 Nursery Habitat

1. American Shad

Nursery habitats for American shad are downstream of spawning grounds because juveniles begin to disperse downstream upon transformation from the larval stage (Chittenden 1969). These nursery habitats usually occur in deep pools away from the shoreline in non-tidal areas, although juveniles occasionally move into shallow water areas (Chittenden 1969). In the Chesapeake Bay system, juveniles are usually found in tidal freshwater reaches of the spawning rivers. Juvenile American shad leave the nursery areas by late fall and may remain in the estuaries and nearshore ocean until they reach one year of age. As young-of-year, they presumably join other schools of young shad in the ocean, where they grow and develop for three to six years before returning to their natal streams to spawn. Subadults appear to migrate farther offshore than sexually mature adults (Neves and Depres 1979).

2. Hickory Shad

Documentation of hickory shad nursery area is difficult because capture of juveniles is rare. Studies suggest that most juveniles leave freshwater and brackish areas in early summer and migrate to estuarine nursery areas (Mansueti 1962). Other studies completed in North Carolina suggest that juveniles migrate directly to saline areas; they do not use the oligohaline portion of the estuary as a nursery area (Pate 1972).

3. Alewife and Blueback Herring

Nursery habitats for alewife and blueback herring occur in non-tidal and tidal freshwater and semi-brackish areas during spring and early summer, moving upstream during periods of decreased flows and encroachment of saline waters. Juvenile alewife and blueback herring begin migrating from their nursery areas as water temperatures decline in the fall. However, in some instances, it appears that a high abundance of juveniles may trigger very early (e.g., summer) emigration of large numbers of small juveniles from the nursery area (Richkus 1975).

1.3.1.3 Adult Resident Habitat and Migratory Routes

1. American Shad

American shad are currently distributed from the Bay of Fundy, Canada southward to the St. Johns River in Florida, and move along the Atlantic coast between summer feeding grounds in the Gulf of Maine and coastal wintering areas mainly off the mid-Atlantic states (Leggett and Whitney 1972). Adult shad migrate to spawning grounds beginning as early as mid-November for southern stocks (Florida) and as late as July in some Canadian rivers (MacKenzie et al. 1985). Those fish return to rivers north of Cape Hatteras usually begin migration later in the spring and follow a route farther seaward into the Mid-Atlantic Bight where water temperatures have risen sufficiently. After spawning is complete, adult and immature shad migrate out of tributaries and rivers and proceed northward along the Atlantic coast to their summer feeding grounds in the Gulf of Maine, Bay of Fundy, the St Lawrence estuary and along the Labrador coast (Dadswell et al. 1987), and remain in that vicinity throughout the summer into fall. In mid-fall, a southward migration begins, with overwintering occurring off Florida, in the mid-Atlantic area, and in the Scotian Shelf-Gulf of Maine (Leggett and Whitney 1972; Dadswell et al. 1987).

B. Hickory Shad

Hickory shad are currently distributed from the Connecticut River to the Tomoka River, Florida. The distribution and movements of adult hickory shad at sea are essentially unknown. Adults have been captured along the southern New England coast during summer and fall. These observations suggest that hickory shad may migrate northward from the mid-Atlantic and southeast Atlantic spawning rivers in a pattern that is similar to the coastal migrations of American shad (Dadswell et al. 1987).

3. Alewife and Blueback Herring

Alewife are currently distributed from northeastern Newfoundland to South Carolina, but are most numerous in the mid-Atlantic and northeastern states. Blueback herring are distributed from Nova Scotia to northern Florida, and are most abundant from the Chesapeake Bay south. However, little information is available concerning the distribution and movements of adult and subadult alewife and blueback herring once they emigrate to the sea. Various studies have determined that alewife and blueback herring are capable of migrating long distances (over 2000 km) in ocean waters of the Atlantic seaboard, and that patterns of river herring migration may be similar to those of American shad (ASMFC 1988).

1.3.2 Present Status of Habitats and Impacts on Fisheries

Fisheries management measures cannot successfully sustain anadromous alosine stocks if the quantity and quality of habitat required by all the species are not available. Harvest of fisheries resources is a major factor impacting population status and dynamics, and is subject to control and manipulation. However, without adequate habitat quantity and quality, the population cannot exist.

Concerns that the declines in anadromous alosine populations are related to habitat degradation has been alluded to in past evaluation of these stocks (Mansueti and Kolb 1953; Walburg and Nichols 1967). However, it has never been possible to rigorously quantify the magnitude of this contribution.

1.3.2.1 Quantity

Little information exists which quantifies the area of existing or historical anadromous alosine habitat. No attempt has been made to quantify the existing area of alosine habitat coastwide.

Nursery areas for anadromous alosines consist of areas in which the larvae, postlarvae, and juveniles grow and mature. These areas include the spawning grounds and areas through which the larvae and postlarvae drift after hatching, as well as the portions of rivers and adjacent estuaries in which they feed, grow, and mature. Juvenile alosines which leave the coastal bays and estuaries prior to reaching adulthood also use the nearshore Atlantic Ocean as a nursery area.

Sub-adult and adult alosine habitat consists of the nearshore Atlantic Ocean from Bay of Fundy, Canada to Florida, inlets which provide access to coastal bays and estuaries, and riverine habitat upstream to the spawning grounds. American shad generally tend to move north to the Gulf of Maine during the summer, and southward and inshore off the Mid-Atlantic states in the winter. Hickory shad are believed to follow a similar migratory pattern to that of American shad. Adult alewife and blueback herring may be capable of migrating along the Atlantic coast, but little information exists on their movements and distribution after they migrate to the ocean. Coastal habitats for adult American shad are depicted in Figures 1-3.

1.3.2.2 Quality

The quality of alosine habitat has been compromised largely by impacts resulting from human activities. Impacts that may have contributed to declines in alosine populations include blockage of spawning rivers by dams and other impediments, pollution of spawning rivers resulting in reduced oxygen levels, elevated levels of heavy metals and toxic contaminants, low pH from acidic deposition, siltation of spawning areas, turbidity, changes in temperature and flow from hydropower or flood control discharge regimes, thermal pollution, and power plant entrainment and impingement. Specific examples of the effects of these impacts on alosine populations can be found in Walburg and Nichols (1967), Mansueti and Kolb (1953), DBFWMC (1981), Johnson (1982), Dadswell et al. (1983), and Gordon and Longhurst (1979).

Recently, stock displacement or enhanced mortality among alosine stocks due to colder than normal ocean water temperatures has also been suggested to explain the recent declines of these stocks. A decline in ocean temperature since 1990 along the Atlantic coast during winter and spring months could have caused a disruption of normal spring migration patterns, resulting in a direct mortality of alosines, or a displacement and/or poor food availability (Jesien et al. 1992).

1.3.2.3 Loss and Degradation

It is generally assumed that anadromous alosine habitat has undergone some degree of loss or degradation; however, few studies exist which quantify impacts in terms of the area of habitat lost or degraded.

1. Water Quality

Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. In most alosine spawning and nursery areas, water quality declines have been gradual and poorly defined, and it has not been possible to link those declines to changes in alosine stock size. In cases where there have been drastic declines in alosine stocks, such as in the Chesapeake Bay in Maryland, water quality problems have been implicated, but not conclusively demonstrated to have been the single or major causative factor.

Toxic materials such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) occur in anadromous alosine spawning and nursery areas and are believed to be potentially harmful to aquatic life, but have been poorly monitored. Similarly, pollution or nearly all estuarine waters along the east coast has certainly increased over the last 30 years, due to industrial, residential, and agricultural development on the watersheds. The general degradation of water quality is a coast-wide problem, although the levels of sewage nutrients discharge into coastal waters during the past 30 years have decreased. This decrease in organic enrichment would benefit water quality conditions; however, it probably would not result in a reduction of other types of pollutant discharges into these waters such as heavy metals and organic compounds.

American shad eggs and larvae have been found to be sensitive to various levels of acid and aluminum (Klauda 1994). American shad stocks that spawn in poorly buffered Eastern Shore Maryland rivers, like the Nanticoke and Choptank, were found to be vulnerable to storm-induced, toxic pulses of low pH and elevated aluminum, and may therefore recover at a much slower rate than well-buffered Western Shore stocks, even if all other anthropogenic stressors are removed. (Klauda 1994) hypothesized that whenever the abundance of an acid-sensitive fish species like American shad is as low as most Maryland stocks are today and annual climatic conditions are less than favorable for good reproduction, even infrequent and temporary episodes of critical or lethal pH and aluminum exposures in the spawning and nursery areas could contribute to significant reductions in egg or larval survival and thereby slow stock recovery.

Riverine areas serve as routes for migration and as spawning and nursery habitats for most alosine stocks. However, alterations of flow caused by human water use activities in these areas can have serious effects on alosine populations. Facilities using water for cooling purposes (e.g., power plants) or large volume water withdrawals (e.g., drinking water, pumped storage hydroelectric projects, irrigation, snow-making) may deny access to spawning and nursery areas and alter habitat characteristics such as flow (due to peaking operation and imposition of low flows) and water quality (due to impoundment effects such as decreases in dissolved oxygen and changes in temperature).

2. Water Use

Impacts of impingement, expressed as reductions in year-class abundance, were calculated for Hudson River American shad in 1974 and 1975. The maximum estimated reductions in year-class abundance were 0.04 in 1974 and 0.06 in 1975. These extremely low impingement impacts on American shad are related to the brief period that this species was concentrated in the vicinity of major power plants during their emigration from the estuary in autumn. It was determined that impingement is probably not a biologically important source of mortality except, perhaps, when added to other, more serious stresses (Barnthouse and Van Winkle 1988).

A large tidal hydroelectric project is currently in use at the mouth of the Annapolis river in portions in the Bay of Fundy, Canada. Dadswell et al. (1983) have found that this particular basin and other surrounding waters are used extensively by American shad from all runs along the east coast of the United States as foraging areas during summer months. Since these are tidal hydroelectric projects, fish may move into and out our the impacted areas with each tidal cycle. Thus, although these turbines cause a relatively small percentage mortality with one passage, the cumulative mortality resulting from repeated tidal passage into and out of these impacted areas would result in substantial mortalities (Scarratt and Dadswell 1983).

In addition, hydroelectric darns exist in several states that only allow one-way passage or no passage of spawning adult American shad. Dams with no passage of fish have substantially reduced the amount of spawning habitat available to spawning American shad and have likely contributed to long-term stock declines. It is also assumed that with darns that allow only one-way passage that most, if not all, adult fish transported above dams are unsuccessful at passing through the hydroelectric stations during outmigration and hence, are lost as returning adults.

1.3.2.4 Current Threats

Potentially serious threats stem from the continued alteration of freshwater flows and discharge patterns to spawning and nursery habitats in rivers and estuaries. Other threats in the form of increased mortality resulting from the placement of additional intakes in spawning and nursery areas will occur, although the impacts may be mitigated to some degree through the use of the best available intake screen technology. Placement of jetties, which disrupt current flow patterns into and out of coastal estuaries and lagoons, may also affect migration patterns or habitat use.

1.3.2.5 Effect on the Ability to Harvest and Market

Impacts which result in mortality over and above that which would occur naturally at any life stage will reduce the size of the population and thereby ultimately reduce the size of the allowable harvest. Such impacts include pollution of spawning rivers, siltation of spawning areas, blockages or other changes in spawning grounds, and overharvesting which could reduce or eliminate reproductive success. Impacts that may not increase mortality, but reduce or eliminate marketability include non-lethal limits of contaminants that may render fish unfit for human consumption, or changes in water quality that may reduce fish condition or appearance to a point where they are unmarketable.

1.3.3 Identification and Distribution of Essential Habitats

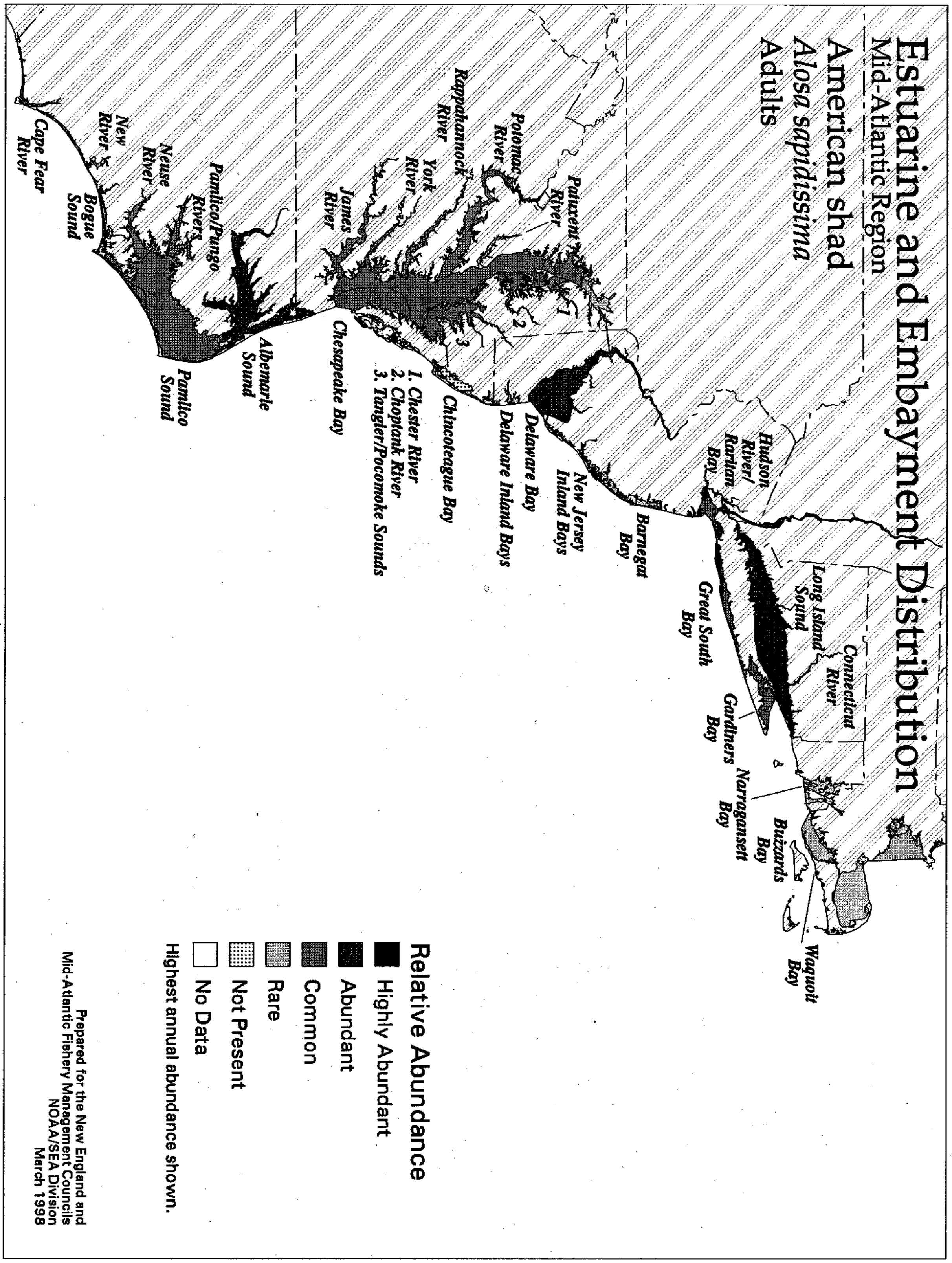
All habitats described above are deemed essential to the sustainability of the four anadromous alosine stocks as they presently exist. These habitats are depicted in Figures 1-3. Due to decreasing stock sizes of all alosine species along the Atlantic coast, it is difficult to determine if adequate spawning, nursery, and adult habitat presently exist to sustain the stocks at recovered levels.

Without a specific goal for restoration of historic or potential alosine habitat, it is difficult to describe all "essential habitat" along the Atlantic coast. States may wish to identify areas targeted for restoration as essential habitat. These additional areas may be necessary for achieving historic alosine production levels in those jurisdictions.

Figure 1. New England Estuarine and Embayment Distribution of Adult American shad.

Figure 2. Mid-Atlantic Estuarine and Embayment Distribution of Adult American shad.

Figure 3. South Atlantic Estuarine and Embayment Distribution of Adult American



shad.

1.4 Description of the Fisheries

American shad, hickory shad, and river herring formerly supported important commercial and recreational fisheries along the entire Atlantic coast. However, all of these fisheries have declined dramatically. Two types of fisheries exploit spring spawning migrations of anadromous alosines: inriver and coastal ocean. Inriver fisheries have been traditionally accepted because they only exploit their stock of origin, whereas ocean fisheries begin earlier in the winter and exploit mixed stocks of different river origins. Although inriver fisheries have traditionally dominated the catch, coastal ocean fisheries have increased in recent years.

Catch statistics for both ocean and inriver alosine fisheries on the Atlantic Coast are compiled by the National Marine Fisheries Service (NMFS) and state agencies for both commercial and recreational fisheries. Information provided below is based on the state reports which are on file with the Commission.

1.4.1 Commercial Fishery

A. American Shad

Historically, American shad supported very large commercial fisheries along the East Coast of both the United States and Canada. Even though total commercial landings (coastal ocean and inriver) of American shad have shown long-term declines, coastal ocean landings of American shad have increased more than four-fold since 1978. In 1980, coastal ocean landings equaled approximately 623,000 pounds; however, by 1989, this number had peaked to 2.1 million pounds and, in 1996, landings were 1.1 million pounds. Ocean harvest contributed about 11 % of total East Coast landings in 1978; however, this contribution increased yearly to approximately 67% by 1996.

The commercial coastal ocean fishery for American shad is primarily gillnet, with exceptions occurring in Rhode Island (floating trap), Connecticut (bottom otter trawl), and New York (pound net and trawl).

Even though only a few states dominate ocean harvest of American shad, the ocean fishery for the species is an important component of the fishery for most East Coast states. From 1980-1996, the majority of commercial coastal harvest was taken in Virginia (24 percent), Delaware (19 percent), New Jersey (18 percent), South Carolina (14 percent) and Maryland (nine percent). All other fisheries were below five percent of the total ocean landings. American shad ocean harvest for states north of New Jersey is from a bycatch fishery, and from New Jersey south, the fishery is directed for American shad. Florida, Georgia, Potomac River Fisheries Commission (PRFC) - District of Columbia, Pennsylvania, and Connecticut do not have coastal ocean fisheries.

American shad landings from commercial inriver fisheries have been steadily decreasing, based on individual state landings records. In 1980, three million pounds of American shad were landed; however, by 1996, this figure had dropped to approximately 594,000 pounds. From 1980-1996, the majority of commercial American shad harvest from inriver fisheries was taken in New York (33 percent), North Carolina (17 percent), Connecticut (15 percent) and Virginia (14 percent). Recently, dramatic declines in landings have occurred even in some of these river systems. In the Connecticut River, 1.6 million American shad were estimated to have returned to the river in 1992. However, as of 1995, this number had dropped dramatically to 304,500. Maine and New Hampshire runs continue to remain at low levels of abundance, and Delaware personnel reported the 1996 adult population estimate of 792,000 fish was well below the 1992 high. American shad inriver fisheries are not allowed in Maine, New Hampshire, Massachusetts, and Rhode Island, and a moratorium on the capture and sale of American shad has existed in Maryland since 1980, and in Virginia, since 1994.

However, some river systems appear to show signs of improvement. Maryland's stocks still remain at historic lows, although the upper Chesapeake Bay 1995 shad run of 336,000 fish represented a 159% increase from the 1994 estimate of 129,500. In addition, Virginia reported excellent runs in the Pamunkey River. Personnel in South Carolina reported the 1995 run of shad up the Santee-Cooper system had greatly improved over the last few years. In general, shad stocks remain depressed with some improvement occurring in rivers such as the Altamaha in Georgia and the Savannah River between South Carolina and Georgia.

B. Hickory shad

Atlantic coast (Maryland to Florida) hickory shad commercial landings (reported by state) are poorly monitored. This is primarily because of mixing with American shad upon landing, poorly understood geographic ranges, and a lack of monitored recreational fishing areas. Report ed commercial hickory shad landings have ranged from a high of 349,980 pounds in 1961 to 95,282 in 1980 to a recent low of 24,114 in 1991. The most recent and complete hickory shad data are for North Carolina, which has historically dominated the commercial fishery. From 1980-1996, North Carolina has accounted for the majority (88%) of the total hickory shad landed from New Jersey to Florida. Hickory shad landings of 125,871 pounds in 1996 were up dramatically from the 11,389 pounds landed in 1990. Hickory shad numbers have been increasing in the last three to four years in the upper Chesapeake Bay and its tributaries, and increases have been evident in both North Carolina and Georgia commercial landings data. However, the lack of accurate commercial harvest data makes it difficult to ascertain the actual status of the stocks.

C. Alewife and Blueback Herring

Total commercial landings of river herring from the Gulf of Maine to Florida were approximately 11 million pounds in 1980. However, total landings decreased to 5.7 million pounds in 1988, and in 1996, they only equaled 1.4 million pounds. Overall, river herring landings data may not accurately represent stock abundance. The many factors influencing river herring-reported commercial landings may explain the large degree of variability observed in data on a state-by-state basis.

River herring commercial inriver landings have been steadily decreasing from a high of 14.1 million pounds in 1985 to 1.4 million pounds in 1996. During the past decade, North Carolina, Virginia, and Maine have accounted for approximately 81 percent of coastwide landings. Inriver herring fisheries are nonexistent in New Hampshire, Rhode Island, New Jersey, and Georgia.

Reliable data on river herring fisheries in the Mid-Atlantic region and Southeast are scarce. Even so, it has been reported that river herring landings from North Carolina increased from approximately 6.2 million pounds in 1980 to 11.6 million pounds in 1985. However, commercial landings have been rapidly decreasing since then, and by 1996 only 529,474 pounds were harvested. A similar situation was seen in Virginia where landings increased to a high of 18.4 million pounds in 1983 and continued to decrease to 141,008 pounds in 1996. Since 1976, Maine has been the major contributor to New England river herring landings. However, these numbers have shown a major downward trend since the early 1970's, and in the past four years, Maine landings have declined dramatically in those rivers which traditionally contributed the majority of the catch.

The river herring fishery was exclusively an U.S. inshore fishery until the late 1960s when distant-water fleets began fishing for river herring off the Mid-Atlantic coast. Commercial ocean harvest of river herring occurs as bycatch in other fisheries of various gear types: gillnet, bottom otter trawl, and menhaden purse seine. From 1980-1996, the majority of the river herring harvest (inriver and ocean) was taken in North Carolina (65 percent), Maine (14 percent), and Virginia (12 percent). Four Atlantic coast states do not have river herring fisheries in ocean waters: Delaware, South Carolina, Georgia, and Florida. Apparently, Georgia is the only state that has no river herring fishery, either inriver or ocean.

1.4.2 Recreational Fishery

It is not known if recreational fisheries exist in the coastal ocean for any of the four alosine species in any state along the Atlantic coast.

A. American Shad

Recreational fisheries for all alosines are poorly documented. It is widely known that American shad do support fairly intensive recreational fisheries in many East Coast rivers; however, very little harvest and catch/effort data exists.

Fisheries occur in the Delaware River (New Jersey, New York and Pennsylvania) and in the Connecticut River, where recreational harvest accounts for approximately more than 10% of total American shad landings. The magnitude of recreational harvest in these two rivers is probably suggestive of the impact of fairly intensive recreational fisheries on American shad stocks. Recreational fishing is growing in popularity in many other river systems along the coast.
A June 1995 angler utilization and economic survey of the American shad fishery in the Delaware River found that anglers caught 83,141 shad and harvested an estimated 16,387 shad

during the 10-week survey period (Miller and Lupine 1996). Although angler effort was apparently reduced during the 1995 season, and the American shad population estimate, determined by the New Jersey Division of Fish, Game, and Wildlife, indicated fewer shad in the river, the catch rate was slightly greater than during the 1986 season. Catch rates varied substantially from lows of 0.04 fish per hour to a high of 0.45 fish per hour.

B. Hickory Shad

Although good recreational catch/effort data does not exist, it is widely known that hickory shad do support substantial recreational fisheries in some East Coast rivers.

C. Alewife and Blueback Herring

There are extensive recreational fisheries for river herring in many rivers along the East Coast. While some are hook and line fisheries (i.e., Delaware River), many states permit various types of dip nets and seines. The total quantity of fish landed by these recreational netters for personal use (i.e., bait and consumption) may be quite large. All of these landings are unreported and thus, represent a large potential error in recorded recreational river herring harvests.

1.4.3 Subsistence Fishing

There are known subsistence fisheries for all alosine species, but the extent of effort and harvest is undocumented.

1.4.4 Non-consumptive Factors

People interested in conservation and wildlife have been known to observe alosine migrations through natural corridors and fish passage facilities. In some regions, this non-consumptive use of the alosine resources is an important part of public education, local heritage and outdoor recreation.

1.4.5 Interactions with other fisheries, species, and other users

Catch of anadromous alosines that occurs in fisheries directed at other species is referred to as bycatch. Bycatch also refers to illegal or unmarketable alosines caught in directed fisheries. Estimates of bycatch are difficult to obtain since few studies have focused specifically on that issue. Bycatch losses contribute to the overall mortality of alosines and are important to consider in the current and future management of these fisheries.

Few data exist on a state-by-state basis for bycatch of any anadromous alosine in other commercial and recreational fisheries. Bycatch in commercial fisheries has occurred in those states with Atlantic mackerel fisheries. Alosines captured in pound nets and gillnets experience high mortality unless the nets are checked often.

The State of Maine, in cooperation with the NMFS, collects landings data from various commercial fisheries in state territorial and the U.S. Exclusive Economic Zone (EEZ) waters. Offshore American shad landings from southwestern Maine (Jeffery=s Ledge) occur as a bycatch to the groundfish gillnet fishery. From 1978-1995, 420,616 pounds of American shad were captured; however, these landings have been declining since 1988.

River herring bycatch does occur in the Atlantic mackerel commercial fishery. This offshore commercial venture involves either a directed U.S. fishery, or a joint venture between U.S. and foreign vessels operating under a quota restriction. For Joint Venture mackerel fisheries operating south of lat. $37^0$30=N, r. herring by catch may not exceed 0.25% of the over-the-side transfers of Atlantic mackerel. However, these fisheries do focus on small, immature fish and a low percentage in terms of total poundage can represent a larger percentage in terms of numbers of individuals. Although the potential for problems with offshore fisheries exists, the problem appears minimal at present.

In addition, bycatch of river herring in Atlantic herring *(Clupea harengus)* fisheries is a potential concern, especially for the recovery of depressed alosine stocks of the Chesapeake Bay and waters further south. A report was completed summarizing the results from 36 sea sampling trips aboard commercial small-mesh trawlers during July through November 1995 in an area that had been previously closed by the NMFS to this type of fishing. This area was opened to small-mesh trawling by the NMFS after extensive analyses that predicted bycatch of regulated species would fall below a five percent threshold, a standard approved by the New England Fishery Management Council to address groundfish conservation. A total of 77 shad (<0.1%), 177 alewife (0.1%), and 3511 blueback herring (1.9%) were captured during the entire sampling.

Recreational bycatch of alosines has not been documented in many states. A hickory shad catch and release experiment was conducted in 1996 by the Maryland Department of Natural Resources (MDNR) in Deer Creek, a tributary to the Susquehanna River. This study showed that no short-term mortality (within 48 hours) was observed from catch and release fly fishing (Lukacovic and Pieper 1996). In addition, a catch and release mortality study of American shad was also completed in the Susquehanna River by MDNR in 1997. Results of this study showed that short-term mortality (within 48 hours) experienced by American shad was less than 1.0%, with all deaths occurring in less than 24 hours. Deaths occurred in fish that bled heavily from hook wounds or suffered damage to the gills (Lukacovic, personal communication).

<u>Protected Species Considerations:</u>

A. Marine Mammals

In October 1995, Commission member states, NMFS and USFWS began discussing ways to improve implementation of the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) in state waters. Historically, these policies have been only minimally implemented and enforced in state waters (0-3 miles). It was agreed that the Commissions Plans describe impacts of state fisheries on certain marine mammals and endangered species (collectively termed "protected species", and recommend ways to minimize these impacts. Section 117 of the MMPA requires that NMFS complete stock assessment reports for all marine mammal stocks within U.S. waters. Each stock assessment report is required to estimate the annual human-caused mortality and serious injury of the stock by source, and for a strategic stock other factors that may be causing a decline or impeding recovery of the stock, including effects on marine mammal habitat and prey and commercial fisheries that interact with the stock.

A strategic stock is defined as a stock: (1) for which the level of direct human-caused mortality exceeds the potential biological removal (PBR) level; (2) which is declining and is likely to be listed under the Endangered Species Act (ESA) within the foreseeable future; or (3) which is listed as a threatened or endangered species under the ESA or as a depleted species under the MMPA.

Section 3(20) of the MMPA defines the term "potential biological removal (PBR) as:

"the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population."

For a strategic stock, Section 118(f) of the MMPA requires NMFS to appoint a Take Reduction Team and this TRT must develop a Take Reduction Plan (TRP) designed to assist in the recovery or to prevent the depletion of the strategic stock which interacts with a commercial fishery.

As a result of draft stock assessment reviews developed under Section 117 of the MMPA, NMFS recognized the need to establish a Team(s) that would focus on reducing the bycatch of coastal bottlenose dolphin, harbor porpoise and humpback whales in several coastal gillnet fisheries of the mid-Atlantic and southeastern United States.

Section 118 (f)(2) of the MMPA states that the immediate goal of a TRP for a strategic stock shall be to reduce, within six months of its implementation, the incidental mortality or serious injury of marine mammals incidentally taken in the course of commercial fishing operations to levels less than the PBR level established for that stock under Section 117.

There are strategic stocks of marine mammals that are taken by gillnets in coastal state waters at the time the American shad fishery occurs. NMFS proposed that the geographic definition for the mid-Atlantic coastal gillnet fishery to be bounded on the east by the 72'30'W. longitudinal line, running south from the southern Long Island shoreline, and on the south by a line drawn from the North Carolina-South Carolina border east to the 72'30' line (61 FR 37035, July 16, 1996). The following are the strategic stocks of marine mammals that are taken by gillnets in coastal state waters at the time mixed stock American shad fisheries occur. There are three strategic stocks that interact with coastal fisheries in state waters on an annual basis: the harbor porpoise, humpback whale, and the coastal migratory stock of bottlenose dolphin.

1. Harbor Porpoise

Harbor porpoise that are found along the eastern United States are considered to be one stock or population. This population was proposed as threatened under the Endangered Species Act (ESA) on January 7, 1993, and the bycatch of the Gulf of Maine population of harbor porpoise (approximately 1300 per year in 1992 and 1993) is significantly greater than the calculated PBR (approximately 400). The distribution of this population extends through at least North Carolina in the winter and early-spring, and then moves northward to the Bay of Fundy/Gulf of Maine in summer.

A total of 124 stranded porpoises have been examined from the Mid-Atlantic states since 1993. Most of the animals taken in state waters are taken in the months of March, April and May, from North Carolina to New Jersey. Fifty percent of those porpoise which stranded in Virginia and North Carolina, and for which a cause of death could be determined, had net marks indicative of gillnet entanglement. Nine porpoise that stranded in Virginia had further indications of mutilation. The timing and location of these stranding data follow the timing and location(s) of the intercept shad fishery as it moves north along the coastline.

2. Humpback Whale

During the past several years there has been a fourfold increase in the number of strandings of humpback whales in the mid-Atlantic region, many with indications of fishing gear entanglement. Between 1989 and 1992, 31 humpback whales stranded from New Jersey through Virginia (Wiley et. al. 1994). Significantly more strandings occurred between Chesapeake Bay and Cape Hatteras, North Carolina. Strandings increased from February through April and 25 percent had scars consistent with net entanglement. Between 1990 and 1996, 10 humpbacks stranded in Virginia. Three of the animals showed evidence of rope abrasion consistent with entanglement.

3. Bottlenose Dolphin

There are at least two stocks of bottlenose dolphin along the eastern coast of the United States: a coastal migratory stock that occurs in coastal waters of the eastern United States; and an offshore stock which is larger and occurs farther offshore than the coastal stock. The coastal bottlenose dolphin stock is designated as depleted under the MMPA as a result of a significant die-off in 1987-1988 that reduced the size of this stock by an estimated 50 percent. At least part of the coastal migratory stock moves north of Cape Hatteras in approximately mid-April and returns south of Cape Hatteras in late October-early November.

Coastal bottlenose dolphin strandings in North Carolina follow the pattern of gillnet fishing effort. Strandings from Cape Hatteras to New Jersey follow the seasonal occurrence of the stock in local waters. Strandings in North Carolina generally occur January through May (peaking in March-May), then again from October through December. This stranding pattern also follows increased fishing effort from Virginia to New Jersey and the seasonal occurrence of bottlenose dolphins in these waters (i.e., late spring through fall from Virginia north). The only known fishery mortalities of this stock occur in state waters. Many of these occur when the shad fishery is in operation in many of these states, as well as other coastal gillnet fisheries. The PBR for this stock (based on stranding data and estimated percentage of these animals taken in gillnet fisheries in state waters) is exceeded by gillnet mortalities each year in North Carolina and northward. Therefore, the estimated bycatch of the coastal stock of bottlenose dolphin in state waters needs to be reduced by greater than 50 percent in order to get below PBR for this stock.

B. Sea Turtles

Sea turtles that occur in U.S. waters are listed as either endangered or threatened under the ESA. Five species occur along the Atlantic coast of the United States; the loggerhead *(Caretta caretta),* Kemp's ridley *(Lepidochelys kempii), green (Chelonia mydas), leatherback (Dermochelys coriacea),* and hawksbill *(Eretmochelys imbricate).*

Shad are harvested primarily with anchored, staked and drift gillnets; however there is also a pound net, trawl, and hook and line component. All of these gear types are documented to impact sea turtles. Because the fishery occurs inshore and in nearshore waters, it is likely to interact with sea turtles depending on the location and season.

<u>Gillnets</u>

Stranded loggerhead and Kemp's ridley sea turtles have been partially or completely entangled in

gilinet material, and are most likely to come in contact with the gear in shallow coastal waters. Green sea turtles are present in small numbers in these areas and could also be taken in this fishery. Leatherbacks are also present especially when warmer waters bring jellyfish, their preferred prey, into coastal areas. Hawksbill sea turtles are only rare visitors to the areas where fishing effort occurs, preferring coral reefs with sponges for forage, so interaction would be limited. However, entanglement in gillnets has been identified as a serious problem for hawksbills in the Caribbean (NMFS and USFWS 1993).

Spring and fall gillnet operations have been strongly implicated in coincident sea turtle stranding events from North Carolina through New Jersey. On average, the highest numbers of interactions occurred in spring, followed by summer and fall. The southern states appear to have had more spring interactions, while the northern states had more summer interactions, probably due to the northern migration of sea turtles in the warmer months.

Netting gear found on stranded turtles varied widely, from 2 - 11.5" (5-29 cm) stretch mesh, and ranged from small, cut pieces of net, to lengths (up to 1200'(365m)) of abandoned net. Net gear was of various materials including nylon, cotton, and propylene, and in various colors including blue, black, and green. Gear type included flounder, sturgeon, and mullet nets, monofilament, twine, gillnets, pound nets, trammel nets, seines, sink nets, and nets attached to anchors, cork floats, and buoys.

<u>Pound Nets</u>

Most of pound net fishery interactions result in live releases and are documented primarily from North Carolina, Virginia, Long Island and Rhode Island. In Chesapeake Bay, Virginia, turtles become entangled in pound nets starting in mid-May with increasing numbers of entanglements until late June. The construction of leaders in pound nets was found to be a significant factor in these entanglements (Musick et. al. 1987). Entanglement was found to be insignificant for small mesh (8-12-inch mesh = small; >12-16-inch mesh = large). Large mesh nets and nets with stringers spaced 16-18 inches apart entangled a large number of turtles. Therefore, the potential to entangle sea turtles in pound nets could be alleviated by decreasing the mesh size in the leaders (Musick et. al. 1987). The pound net component of the shad and river herring fishery for North Carolina occurs in Albemarle Sound that is not frequented by turtles due to the relatively low salinities found there.

Hook and Line

From 1991 through 1995, a total of 112 turtles stranded with fishing hooks associated with some part of its body. Thus, hook and line fishing does impact sea turtles.

Recommendations for Sea Turtle Protection:

1. A conservation plan and application for a section ten ESA incidental take permit should be developed for those states where the fishery occurs when sea turtles are present.

2. Research into gear development/deployment for gillnets should be conducted to minimize the impact on sea turtles.

3. Pound net leaders should be no larger than 12-inch mesh.

4. Public outreach material should be developed to improve awareness of sea turtle entanglement with hooks and monofilament line.

C. Migratory Coastal Birds

An unknown, but possibly significant, number of migratory birds are drowned each year in anchored gillnets in the nearshore marine waters of the mid-Atlantic region during the American shad coastal intercept fishery. Preliminary estimates, based on a study underway by the U.S. Fish and Wildlife Service (USFWS) and incidental mortality data from the Service=s Madison Wildlife Health Laboratory, indicate that many thousands of loons and sea ducks are killed each year. Most of these shad/bird interactions occur during January through March from North Carolina to New Jersey. South Carolina banned anchored gillnets in their coastal fishery because of excessive bird mortalities.

All of the species listed are diving birds which pursue fish underwater or feed on benthic invertebrates. Fish eating birds are especially vulnerable to drowning in gillnets because they pursue prey underwater. Additionally, fish eating birds may be attracted to the vicinity of nets that are anchored for days at a time to feed on forage fish feeding near the nets. All of the birds listed are present along the Atlantic coast from October through April, depending on weather and timing of migration. Double-crested cormorants are present throughout the year but are most abundant in the middle and northern Atlantic states during the summer.

The actual populations of most migratory coastal birds are largely unknown. Except for some diving ducks *(Aythya),* current surveys sample only a small portion of the populations of sea ducks and do not survey for non-game birds such as loons and grebes. The U.S. Migratory Bird Treaty Act prohibits the take and possession of protected migratory birds, except as may be permitted by regulations. Take means to pursue, hunt, shoot, wound, kill, trap, capture or collect. Possession means to detain and control.

A list of protected bird species most likely to interact with American shad fisheries along the Atlantic coast are listed below:

I. Protected birds in nearshore marine coastal waters most likely to interact with American shad gillnets:

Common Loon *(Gavia immer)*
Red-throated Loon *(Gavia stellata)*
Homed Grebe *(Podiceps auritus)*
Red-necked Grebe *(Podiceps grisegena)*
Double-crested Cormorant *(Phalacrocorax auritus)*
Northern Gannet *(Sula bassanus)*
Oldsquaw *(Clangula byemalis)*
Black Scoter *(Melanitta nigra)*
Surf Scoter *(Melanitta perspicillata)*
Red-breasted Merganser *(Mergus serrator)*

II. Protected birds in coastal bays most likely to interact with American shad gillnets and East Coast population status.

Species:	Status:
Common Loon *(Gavia immer)*	Unknown
Red-throated Loon *(Gavia stellata)*	Unknown, 50,000+ winter S. of NJ
Homed Grebe (Podiceps auritus)	Unknown
Red-necked Grebe *(Podiceps grisegena)*	Unknown
Double-crested Cormorant *(Phalacrocorax auritus)*	Abundant and increasing
Redhead *(Aythya americans)*	Depressed but increasing slightly
Canvasback *(Aythya valisineria)*	Slightly increasing
Greater Scaup *(Aythya marila)*	Decreasing
Lesser Scaup *(Aythya affinis)*	Stable
Ring-necked Duck *(Aythya collaris)*	Unknown
Red-breasted Merganser *(Mergus serrator)*	Stable
Common Goldeneye *(Bucephala clangula)*	Stable
Bufflehead *(Bucephala albcola)*	Increasing

Oldsquaw *(Clangula hyemalis)*	Stable
Black Scoter *(Melanitta nigra)*	Probably declining
White-winged Scoter *(Melanittafusca*	Probably declining
Surf Scoter *(Melanitta perspicillata)*	Probably declining
Ruddy Duck *(Oxyurajamaiccasis)*	Stable

C. Shortnose Sturgeon

The shad gillnet fishery has long been know to capture large numbers of sturgeons (Leland 1968), including adult shortnose sturgeon (Collins and Smith 1995). In the southeast, the shad fishery is likely the primary source of injury and direct mortality of shortnose sturgeon (Collins et a1. 1996). Existing data indicate that in the southeastern U.S., this species occurs in the shad gillnet bycatch in every river system that supports both a shad gillnet fishery and a shortnose sturgeon population. In addition to consistent records from the riverine and estuarine segments of the fishery, bycatch of this species has been recorded from the coastal ocean segment of the shad fishery in certain areas (e.g., off Winyah Bay, South Carolina, unpublished data).

The riverine shad gillnet season and the shortnose sturgeon spawning migration normally coincide in the southeastern U.S., resulting in capture of individuals intending to spawn (females apparently spawn only once every 2-3 years). Preliminary data suggest that non-lethal encounters of migrating sturgeon with gillnets may result in fallback (i.e., individuals abort the migration, move back downriver, and presumably resorb their gametes) (unpublished data; personal communication, M. Moser, UNC Wilmington). Thus, in addition to causing injury and direct mortality of spawners, the non-lethal capture of sturgeon in the shad gillnet fishery may cause reduced spawning success and low year class strength.

Recommendation for Shortnose Sturgeon Protection:

A conservation plan and application for a section ten ESA incidental take permit should be developed for those states where the fishery occurs when shortnose sturgeons are present.

1.5 Technical Documentation For New Amendment

In order to reduce the length of Amendment I and restrict its content to major revisions and a minimum of explanatory text, supporting documentation can be found in the 1985 Interstate Fishery Management Plan (Plan) for American Shad and River Herrings. This Plan, along with the 1998 American Shad Stock Assessment Peer Review Report, contain extensive materials that depict essential habitats and provide detailed explanations of the science behind the American shad and river herring management process.

Other supporting documents such as socioeconomic and law enforcement studies may be prepared as needed.

Section 2. AMENDMENT 1 GOAL AND OBJECTIVES

2.1 Amendment 1 Goal and Objectives

Goal: Protect, enhance, and restore east coast migratory spawning stocks of American shad, hickory shad, and river herrings in order to achieve stock restoration and maintain sustainable levels of spawning stock biomass.

Objectives:

1. Prevent overfishing of American shad stocks by constraining fishing mortality below $F_{30.}$

2. Develop definitions of stock restoration, determine appropriate target mortality rates and specify rebuilding schedules for American shad populations within the management unit.

3 . Maintain existing or more conservative regulations for hickory shad and river herring fisheries until new stock assessments suggest changes are necessary. This should keep fishing mortality sufficiently low to ensure survival and enhancement of depressed stocks and the maintenance of stabilized stocks.

4. Promote improvements in degraded or historic alosine habitat throughout the species= range. State and federal managers should consider the following methods to achieve this objective:

   A. Improve or install passage facilities at dams and other obstacles to provide upstream passage to historic spawning areas, or remove these obstacles entirely.

   B. Improve water quality in areas where water quality degradation may have affected alosine stocks.

   C. Evaluate current fish passage facilities for efficiency.

   D. Ensure that decisions on river flow allocation (e.g., irrigation, evaporative loss, out of basin water transport, hydroelectric operations) take into account flow needs for alosine migration, spawning, and nursery usage.

   E. Ensure that water withdrawal (e.g., cooling flow, drinking water) effects (e.g., impingement and entrainment mortalities, turbine mortalities) do not affect alosine stocks to the extent that they result in stock declines.

   F. Evaluate and improve downstream passage for adults and juveniles.

   G. Promote and coordinate alosine stocking programs for:

a) reintroduction to historic spawning area
b) expansion of existing stock restoration programs
c) initiation of new strategies to enhance depressed stocks.

H. Promote cooperative interstate research monitoring and law enforcement.

Establish criteria, standards, and procedures for plan implementation as well as determination of states= compliance with management plan provisions.

2.2 Management Unit

All migratory American shad, hickory shad, and river herring stocks of the east coast of the United States.

Recommendations on management for migratory alosines in the EEZ (3-200 nautical miles offshore) can be found in Section 4.9.

2.3 Definition of Overfishing

For the purposes of this Amendment, a stock of American shad is considered overfished if it exhibits a fishing mortality rate at or above F_{30}. A fishing mortality rate of F_{30} will result in 30% of the maximum spawning potential (biomass per recruit) in the female component of an unfished population.

A conservative overfishing definition of F_{30} was calculated for each of seven studied river systems (Table 1). The overfishing definition mentioned above is not a target for commercial or recreational fisheries to achieve, nor is it suitable for rebuilding depleted stocks. For the purposes of this Amendment, the overfishing definition of F_{30} will serve as a reference point that should not be exceeded in any given year. Target fishing mortality rates for rebuilding or protecting individual stocks shall be developed and monitored by the Technical Committee as data become available and restoration goals are established.

Table 1. Estimates of F_{30} (overfishing mortality rate) for selected stocks of American shad

Connecticut River	[illegible]
Hudson River	0.39
Delaware River	0.43
Upper Chesapeake Bay	0.43
Edisto River	0.48
Santee River	0.48
Altamaha River	0.48

Section 3. ENHANCEMENT AND MONITORING PROGRAM SPECIFICATIONS

This section describes the operational (as opposed to regulatory) procedures for states to follow in implementing Amendment 1. The requirements described below concern both fishery-independent and fishery-dependent monitoring programs as well as stocking and hatchery operations.

In both regulatory and operational considerations, Amendment 1 makes a distinction between producer areas and coastal areas. Producer areas are typically estuaries or river systems in which a discreet population of American shad, hickory shad and/or river herring spawn each spring. Each state shall delineate areas in their jurisdictions where single-stock or inriver fisheries are believed to occur, while differentiating these areas from coastal areas where mixed-stock fisheries occur. States shall report these descriptions when implementing this Amendment under Section 5.1.2.

Newly restored or recolonized producer areas can be designated at the discretion of the Management Board. The term "coastal areas" refers to all other regions within the Management Unit.

3.1 Assessing Annual Recruitment

Annual juvenile recruitment (appearance of juveniles in the ecosystem) of American shad, hickory shad, and river herring is measured in order to assess juvenile production to predict future year-class strength, provide a signal for recruitment failure or major habitat changes, and assessment of hatchery-released larvae. Recruitment is measured by sampling current year juvenile fish abundance in producer areas.

3.1.1 Calculation of Juvenile Abundance Indices

While much data on juvenile alosine abundance in the various river systems exists and CPUE indices are regularly calculated, most of the time series of indices have not been validated against relative abundance of adults in subsequent spawning runs and none have been validated to the same extent as have been striped bass indices. Nonetheless, these indices are still important indicators of juvenile production throughout the management unit.

All juvenile abundance indices, or JAIs, shall be reported as a geometric mean. The method for calculating the geometric mean is described in ASWC (1992) and Crecco (1992). Use of the geometric mean will reduce the probability of a single value unduly influencing management action.

3.1.2 Elements for Measurement and Use of Juvenile Indices

The sampling protocol (stations, sampling intensity and gear type) should be consistent through time for the period for which the index is to be used. For new sampling programs, the following information will be required: details of the sampling design, a description of the analyses performed, and a presentation of the results of those analyses. The Technical Committee shall review any such submittal and either accept or reject it. If rejected, the Committee will provide a written explanation to the sponsor explaining the reasons for the rejection.

Validation is not required for any particular JAI survey. Validation of American shad juvenile indices has been proven difficult and will not be a criteria for accepting or rejecting any given JAI survey.

Indices can be used to guide the management of individual stocks in individual producer areas. The Management Board may require juvenile abundance surveys in new producer areas, or for any other alosine species not currently monitored for juvenile production.

The Technical Committee shall annually examine trends in all required JAI surveys. If any JAI shows recruitment failure (i.e., JAI is lower than 90% of all other values in the dataset) for three consecutive years, then appropriate action should be recommended to the Management Board. The Management Board shall be the final arbiter in all management decisions.

3.1.3 Juvenile Abundance Index Surveys Required

The states that will be required to report an annual juvenile abundance index for American shad are listed in Table 2. When possible, states should report JAIs for other alosine species obtained from the required surveys listed in Table 2. Results of all JAI surveys shall be reported as per Section 5.1.2.2.

3.2 Assessing Adult Population Size and Distribution

Indices of adult spawning stocks are important when determining the efficacy of a particular management approach. Coupled with juvenile abundance indices and fishing mortality estimates, they clarify population dynamics and progress toward restoration goals. Adult stock indices can include mark/recapture studies, enumeration at fish passage facilities, catch-per-unit effort, and measurement of mortality and survival rates.

In addition to examining the adult stock abundance, scientists and managers must also understand how those populations are distributed in mixed-stock fisheries. In the case of American shad, this is particularly important for determining the effects of ocean-intercept fisheries on small, hatchery-supplemented stocks.

3.2.1 Adult Stock Restoration Goals for American Shad

This Amendment is intended to prevent overfishing of alosine populations (including American shad) within the management unit. Although some stocks of American shad are not currently overfished, almost all of them are believed to be at or near historically low levels and far from complete restoration. Nonetheless, definitions of individual stock restoration (e.g. minimum acceptable spawning run size) have not been established by the Technical Committee and approved by the Management Board. This situation has been perpetuated by a poor understanding of actual landings, stock/recruitment relationships and habitat carrying capacity. Therefore, the Technical Committee shall annually review new information obtained by the mandatory monitoring programs in Section 5, and use these data to recommend stock-specific restoration goals and suitable fishing mortality targets to the Management Board. The Management Board shall be the final arbiter in deciding these goals and targets, and may change the regulatory requirements of this Amendment under Section 4.5.

3.2.2 Adult Spawning Stock Surveys Required

States are required to implement the surveys shown in Table 2. Each year, the Technical Committee shall review the results of these surveys and analyze progress made toward any individual stock restoration goals. If restoration milestones for a particular stock are not achieved within five years after they have been established under Section 3.2.1, then the PRT shall recommend to the Management Board appropriate regulatory changes to be implemented under Section 4.5.

States may employ a variety of survey techniques in adult spawning stock surveys in river systems within their jurisdiction. These include gillnet surveys, mark-recapture studies, hydroacoustic surveys, and fish passage CPUES. As part of spawning stock surveys, states are required to take representative samples of adults to determine sex and age composition, repeat spawning (for states north of South Carolina), and size distribution of each stock within their jurisdiction. States must submit proposals to initiate these programs under Section 5.1.2 and changes to required monitoring programs as per Section 4.4.

3.2.3 Mixed Stock Contribution Surveys Required

Each year (beginning in the year 2000), states will be required to take part in a coastwide analysis of mixed stock contribution to ocean landings. The best available technique has been a cooperative coastwide tagging program to determine the origin of fish landed in ocean-intercept fisheries. If states allow a bycatch fishery, they will be required to subsample for tags and/or otoliths (see Section 4. 1). The Technical Committee will recommend the proper methodology or any changes in methodology to the Management Board on an annual basis. The Management Board may institute these changes under Section 4.5.

3.3 Annual Fishing Mortality Target and Measurement

3.3.1 Definition

Total mortality of alosines has essentially two components: natural mortality and fishing mortality. Fishing mortality is the rate at which fish are removed from the population by human activities. These activities include both intentional legal harvest (F_{dir}, or directed fishing mortality) and background or non-harvest activities which include poaching, bycatch, and hook-and-release mortality. Fishing mortality arises from both inriver and ocean fisheries. Non-directed mortality and directed mortality constitute total fishing mortality. Fishing mortality rates are estimated using a variety of fishery-dependent and fishery-independent data. These include catch curve analyses from commercial fisheries and tag/recapture studies. Unfortunately, the linkage between most harvest regulations and F rates is difficult to predict: the success of regulations in attaining target fishing mortality rates is usually determined through retrospective analysis (i.e., examining the previous years results).

It is critical that intensive fishery monitoring be initiated through this Amendment. If fishing mortality rates are too high (i.e., overshooting the target rate), the Management Board can consider imposing more strict regulations coastwide. It should be noted that bycatch of American shad and other alosines in oceanic fisheries, as well as undocumented ocean harvest, could severely bias estimates of total fishing mortality**.**

3.3.2 Biological reference points

Biological reference points (overfishing definitions) were estimated for American shad in seven Atlantic coast rivers including the Connecticut, Hudson, Delaware, upper Chesapeake Bay, Edisto, Santee, and Altamaha systems (Crecco 1998). Although American shad stocks exist in more than 30 river systems within the management unit, only these seven systems generated sufficient data to permit current F estimates.

A conservative overfishing definition of F_{30} was calculated for each of the seven studied river systems (Table 1). F_{30} is t le fishing mortality rate that will result in 30% of the maximum spawning potential (biomz ss per recruit) of an unfished population. The overfishing definition mentioned above is not a target for commercial or recreational fisheries to achieve, nor is it suitable for rebuilding depleted stocks. For the purposes of this Amendment, the overfishing definition of F_{30} will serve as a reference point that shall not be exceeded in any given year. Target fishing mortality rates for rebuilding or protecting individual stocks shall be developed by the states and monitored by the Technical Committee as data become available and restoration goals are established by the states (Section 4).

3.3.3 Requirements for Fishing Mortality Rate Calculation

States that re-open or establish new inriver or ocean bycatch fisheries will have to implement these requirements.

1) Catch composition data will be gathered by those states with inriver commercial fisheries for American shad. Samples shall be representative of location and seasonal distribution of catch, and appropriate biological data shall be collected including size, sex and age composition of landings. Catch composition data will be gathered by those states with coastal commercial fisheries (directed and non-directed) for American shad. Samples shall be representative of

location and seasonal distribution of catch, and appropriate biological data shall be collected including size and sex and age composition of landings.

2) Representative catch and effort data will be gathered by those states with inriver commercial fisheries. Programs should include an evaluation of harvest under-reporting. This reporting element will apply to fisheries for American shad, hickory shad, and river herring.

Representative catch and effort data will be gathered by those states with ocean-intercept commercial fisheries. Programs should include an evaluation of harvest under-reporting.

States are encouraged to gather catch and effort data from inriver subsistence fisheries, including personal consumption and bait harvest.

3) Existing monitoring programs for American shad recreational catch and effort shall be continued every 5 years (see Table 3). New programs to monitor recreational catch and effort in areas not covered by the Marine Recreational Fisheries Statistics Survey (MRFSS) should be developed for anadromous alosines, and NMFS should work to develop ways to differentiate between anadromous alosines in current and future management programs.

States should report any hickory shad incidentally intercepted in creel surveys for American shad.

4) For those river systems listed in Table 2, states must also provide annual estimates of survivorship and/or fishing mortality on American shad using a variety of techniques including catch curve analysis and tagging.

5) The Technical Committee may recommend additional monitoring programs for newly restored or colonized American shad populations as stock status or habitat improvements warrant.

6) Existing programs to monitor catch, effort, mortality, fish passage, migration, and/or stock composition in hickory shad and river herring fisheries shall be continued, and expanded as noted above. Any change to a state's monitoring program for these species must first be reviewed by the Technical Committee and approved the Management Board (see Sections 4.4 and 5)

3.4 Summary of Monitoring Programs

3.4.1 Biological Information

States are mandated to implement the fishery-dependent and independent monitoring programs outlined in Tables 2 and 3. In addition, states are encouraged to continue or augment the monitoring programs for river herring and hickory shad listed in Tables 4-6.

Whenever practical, state harvest and effort reporting requirements will coincide with current and future mandates of the Atlantic Coastal Cooperative Statistics Survey (ACCSP). Data needs not covered by the ACCSP will still be covered by annual reports submitted in conjunction with this FMP.

3.4.2 Social Information

Consumptive use (e.g. commercial fishing activities before closures) and non-consumptive use (e.g. ecotourism activities) surveys focusing on social data should be conducted periodically in a manner consistent with the intent of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) and the ACCSP Implementation Plan.

3.4.3 Economic Information

Consumptive use (e.g. commercial fishing activities before closures) and non-consumptive use (e.g. ecotourism activities) surveys focusing on economic data should be conducted periodically in a manner consistent with the intent of the ACFCMA and the ACCSP implementation Plan.

3.5 Stocking/Restoration

Most ASMFC jurisdictions are actively involved in alosine habitat surveys, identification of stream blockages and fish passage development, management planning, permit review, and stock assessment related to recovery efforts. Although potential exists in many rivers for stock supplementation and re-introductions using adult transplants and cultured fish, few jurisdictions not already involved in these techniques have plans to use them.

Ongoing stocking efforts include:

New England States
Maine conducts active shad restoration programs in many of their river systems. Prespawning adult American shad are stocked in the Androscoggin and Kennebec Rivers, and cultured American shad fry are being stocked in the Kennebec, Medomak, and Saco Rivers. A shad restoration plan is being prepared for the Penobscot River. New Hampshire participates in cooperative American shad passage assessment at major facilities on the Connecticut and Merrimack Rivers. New Hampshire has also been stocking adult American shad from the Connecticut River into various coastal rivers since the 1980s. Massachusetts has been stocking American shad in the Charles, Agawam, and Nemasket Rivers, and the Connecticut River above Vernon Dam. Rhode Island has stocked adult American shad taken from the Holyoke Dam to the Pawcatuck River. Connecticut has long been active in the state-federal cooperative program to restore anadromous fishes to the Connecticut River; however, no stocking of shad currently occurs in Connecticut waters.

Mid-Atlantic States
New York conducts a very limited alosine stocking program; however, further restoration activity in the Hudson River and Long Island tributaries may be planned pending results of ongoing habitat surveys. New Jersey has been stocking adult shad into the Raritan River for several

years; however, a new fish ladder with a viewing window has been in operation at the first darn on this river since 1996. Pennsylvania is not only actively involved in the Susquehanna River shad and herring restoration program, but they have also stocked up to one million cultured Delaware River source shad larvae above the Easton and Glendon dams on the lower Lehigh, and several hundred thousand cultured shad larvae in the Schuylkill River above dams. The most extensive shad stock rebuilding programs occur in the Chesapeake Bay watershed. On the Susquehanna River, New York, Pennsylvania, Maryland, USFWS, and NMFS have worked closely with private utility companies since 1969 to restore alosine populations returning to Conowingo Dam in Maryland. Following several years of shad egg stocking with limited results, Pennsylvania has been able to stock over 145 million larvae and fingerling shad from Delaware, Hudson, and Connecticut stocks into the river. Maryland also has an active culture and stocking program which includes American shad for the upper Bay and the Patuxent, Choptank, and Nanticoke rivers, and hickory shad for the Patuxent and Choptank rivers. Virginia has stocked American shad to the Pamunkey River and James River above Richmond. In addition, for several decades, the Pamunkey Indians had released a total of 22 million larvae into adjacent waters in Virginia. The Potomac River Fisheries Commission stocked 3.2 million shad larvae into the upper Potomac above Little Falls Dam in 1995-1996.

South Atlantic States

North Carolina currently stocks American shad in the Roanoke River. None of the remaining South Atlantic states (South Carolina through Florida) have active alosine restoration programs that involve fish stocking.

3.5.1 Stocking Techniques

Three basic elements of ongoing restoration efforts for anadromous alosines along the Atlantic coast include: (1) control of harvest to allow sufficient spawning escapement; (2) removal of barriers to migration or development of fish passage facilities at dams; and (3) active stock rebuilding, which typically involves fish juvenile or larval) introductions into waters above blockages. Harvest controls may be comprehensive as in state-wide or river-specific fishery closures, or they may be localized as in seasonal or gear restrictions, angler creel limits, or area closures near fishway entrances. Depending on the nature and size of the barrier to migration, the amount of available upstream habitat, and the target population size to be restored, eliminating in-stream obstructions may involve darn removal or breaching, barrier reconfiguration, or construction of fish ladders, lifts, or locks. Although each barrier to migration warrants individual attention from fishery managers and engineers, techniques for providing fish passage are now well established and readily available. Population rebuilding techniques most frequently used include culture and stocking of larvae or juveniles or stocking of pre-spawned adults which have been netted or trapped from nearby or distant waters.

3.5. 1.1 Culture and Marking

Modem American shad culture techniques have been largely developed and refined since the mid-1970s by the Pennsylvania Fish and Boat Commission (PFBC) for the Susquehanna River restoration program. Using eggs stripped and fertilized from spawning adult shad on many east coast rivers (and the Columbia River), PFBC researchers developed or improved incubation and hatching techniques, first feeds and artificial diets, larval rearing densities, flow and water quality requirements, mass-marking using oxytetracycline, and handling and stocking procedures sufficient to produce 10-20 million shad larvae each year. Pennsylvania and Maryland have also refined techniques for rearing and marking fingerling shad in ponds using artificial and natural diets. One of the high costs associated with culture and stocking programs relates to collection and delivery of eggs. Large-scale programs such as those on the Susquehanna and James rivers may require 15-20 million shad eggs to produce ten million fry. Since spawners are not yet sufficiently abundant in rivers undergoing restoration, these eggs are taken and delivered nightly during spawning seasons from neighboring rivers such as the Delaware, Hudson, and Pamunkey. Strip spawning produces 10,000-30,000 eggs per female and viability averages 60-75%. Of those shad that hatch, 90% or more typically survive to stocking.

In the past few years, the Maryland Department of Natural Resources (MDNR) has successfully used tank spawning techniques for shad which were initially developed for striped bass in cooperation with the University of Maryland's Center for Marine Biotechnology. This method involves use of timed-release hormone implants in gravid fish and free-spawning in tanks over a several day period. An air-lift system delivers eggs to collection boxes for incubation on-site or delivery to distant hatcheries. With individual females providing 50,000- 100,000 eggs, high fertilization rates, and very little labor requirement, fewer adult fish are needed and costs are greatly reduced. This technique has also proven effective for hickory shad - but has thus far been unsuccessful with river herring because of the adhesive nature of their eggs.

Cultured shad larvae are typically stocked at seven to 22 days of age and carry one to several fluorescent tags on their otoliths. Marking involves a two-four hour immersion in 200 ppm oxytetracycline antibiotic and can be repeated at three-four day intervals. In addition to allowing discrimination between wild and hatchery fish, use of distinct marks allows for analysis of relative survival or abundance based on egg source, stocking location, time of release or other parameters. Tetracycline marking is 100% effective and the tags appear to stay with the fish throughout their lives. Fish being analyzed for marks must be sacrificed for otolith removal and processing. MDNR has also had success placing binary coded wire tags in fingerling shad.

3.5.1.2 Trap and Transport

Trapping and live transfer of adult shad and river herring has been used by many jurisdictions since the 1960s. These activities may occur within a specific river system, such as taking fish from lifts at downstream hydroelectric projects for stocking above blockages as in the Connecticut and Susquehanna rivers, or they may involve collecting fish with nets or traps in one river for transport and release in another. Examples include shad transfers from Holyoke Dam on the Connecticut to spawning rivers in Maine, New Hampshire, Rhode Island, and eastern Massachusetts, and herring transfers from Conowingo Dam on the Susquehanna to the Patapsco and Patuxent rivers in Maryland. Shad and river herring have also been netted and hauled to upstream or distant spawning waters undergoing restoration (e.g., Hudson River shad to the Susquehanna River; Delaware River shad to the Raritan River). Hauling techniques are well-developed using insulated circular tanks with oxygenation. A properly equipped 1,200 gallon tank can handle 150 adult shad or 1,000 river herring for two-four hour trips with minimal mortality.

3.5.1.3 Evaluation

States with active hatchery programs for American shad or other alosines shall report annually on hatchery contributions (% wild vs. hatchery). States in this category shall submit proposals for these evaluations under Section 5.1.2. 1, and provide annual reports as per Table 10 and Section 5.1.2.2. States should work in cooperation with appropriate federal or regional programs to ensure unique marking in their operations.

3.6 Bycatch Monitoring and Reduction

States and federal agencies shall make every effort to assess the magnitude of alosine bycatch discard mortality (including hook and release mortality) occurring in waters under their jurisdiction. In cases where excessive alosine bycatch is documented, the involved jurisdiction(s) shall make such documentation available immediately to the Technical Committee, Advisory Panel, and Management Board. Any documentation shall include, at a minimum, the following information:

1) location, target species, and season of fishery or fisheries involved;

2) gear and gear specifications used in the fishery (e.g., gillnets, 4.5" mesh size);

3) an estimate of pounds or numbers and size or age of American shad taken per unit of effort in the fishery (e.g., lb. per trip), as well as an estimate of total American shad bycatch in the fishery;

4) an estimate of how long (e.g., years, months, weeks) American shad bycatch has occurred in the fishery.

Where appropriate, NWS and/or USFWS shall assist states with preparing the required report. The Technical Committee and Advisory Panel shall review such information, and prepare reports for the Management Board. After reviewing these reports, the Management Board may recommend remedial steps to be taken by the involved jurisdictions) (i.e., gear restrictions, seasonal/geographic closures, etc.), and may ask the jurisdictions) to continue documenting the problem until it is resolved to the Management Board=s satisfaction.

In general, states shall undertake every effort to reduce or eliminate the loss of American shad from the population due to bycatch discard mortality. When data are available, the Technical Committee shall examine trends in estimated bycatch annually. The Technical Committee will cooperate with the ACCSP to develop a system to collect bycatch data for American shad and other alosine species.

Atlantic Sturgeon Bycatch in Shad and River Herring Fisheries

Atlantic sturgeon have been documented as bycatch in coastal gillnet fisheries for American shad, and Amendment I to the 1990 Interstate Fishery Management Plan for Atlantic Sturgeon (ASMFC, 1998) stipulates that states will annually report on Atlantic sturgeon bycatch to the ASMFC Sturgeon Management Board (Sturgeon Board).

Jurisdictions within this Amendment's management unit shall report any estimates of Atlantic sturgeon bycatch in their shad or river herring fisheries to the Sturgeon Board, regardless of the fishery location. If the Sturgeon Board determines that unacceptable levels of sturgeon bycatch occur in these fisheries, it will stipulate corrective measures for the jurisdictions involved (e.g., area/season closures, gear modification, etc.). If the named jurisdictions do not comply with the conservation measures recommended by the Sturgeon Board, the Sturgeon Board may intervene to close the given shad or river herring fishery under the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) until the bycatch reduction measures are implemented. Please refer to Amendment I to the ASMFC Fisheries Management Plan for Atlantic Sturgeon for more detail.

Table 2. Summary of mandatory fishery independent monitoring programs for American shad.

STATE	SYSTEM	SAMPLING PROGRAM (annual unless otherwise noted)
Maine	Androscoggin & Saco Rivers	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates Recovery of any visibly marked animals
New Hampshire	Lamprey and Exeter Rivers	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates Recovery of any visibly marked animals
Massachusetts	Merrimack River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates Recovery of any visibly marked animals
Rhode Island	Pawcatuck River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates Recovery of any visibly marked animals
Connecticut	Connecticut River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates JAI: Juvenile abundance survey (GM)
New York	Hudson River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and survival estimates JAI: Juvenile abundance index (GM)
	Delaware River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates JAI: Juvenile abundance index (GM)
New Jersey	Delaware River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates JAI: Juvenile abundance index (GM)
Pennsylvania	Susquehanna River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates Recovery of any visibly marked animals JAI: Juvenile abundance index (GM) Hatcherv evaluation
	Lehigh River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates Hatcherv evaluation

Table 2 (cont-d). Summary of mandatory fishery independent monitoring programs for American shad.

Pennsylvania	Delaware River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates JAI: Juvenile abundance_index (GM)
Delaware	Delaware River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates
Maryland	Upper Ches. Bay	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates JAI: Juvenile abundance index (GM) Hatchery evaluation
	Potomac River	JAI: Juvenile abundance index (GM)
D.C.	Potomac River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates
Virginia	James, York, and Rappahannock Rivers	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates JAI: Juvenile abundance index (GM) Hatchery evaluation
North Carolina	Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates
South Carolina	Santee-Cooper system, Edisto River, Winyah Bay and tributaries (Waccwnaw and Pee Dee Rivers), Combahee, Ashepoo, Coosawhatchie, and Savannah Rivers	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates *State may elect to sample these systems on a rotational basis (i.e., one system evaluated per year)
Georgia	Altamaha River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates
Florida	St. Johns River	Annual spawning stock survey and representative sampling for biological data Calculation of mortality and/or survival estimates

Table 3. Mandatory fishery-dependent monitoring programs for American shad.

<table>
<tr><th>STATE</th><th>SYSTEM</th><th>SAMPLING PROGRAM</th></tr>
<tr><td rowspan="2">Maine</td><td>Inriver</td><td>Recreational catch and effort using MRFSS</td></tr>
<tr><td>Atlantic Ocean</td><td>Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Participate in ocean landings stock composition study.</td></tr>
<tr><td>New Hampshire</td><td>Inriver/coastal-</td><td>Recreational catch and effort using MRFSS</td></tr>
<tr><td>Connecticut</td><td>Connecticut River</td><td>Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Biannually monitor recreational landings in CT and MA - age, sex ratio, and fishing effort (hours fished) until annual catch > 1,000 fish</td></tr>
<tr><td rowspan="2">Rhode Island</td><td>Pawcatuck River</td><td>Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Monitor recreational catch and effort every 5 years.</td></tr>
<tr><td>Atlantic Ocean</td><td>Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Participate in Ocean landings stock composition study.</td></tr>
<tr><td rowspan="2">New York</td><td>Hudson River</td><td>Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Monitor recreational landings, catch, and effort every 5 years.</td></tr>
<tr><td>Delaware River</td><td>Monitor recreational landings, catch, and effort every 5 years.
(Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)</td></tr>
<tr><td rowspan="2">New Jersey</td><td>Delaware River and Bay</td><td>Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Monitor recreational landings, catch, and effort every 5 years.
(Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)</td></tr>
<tr><td>Atlantic Ocean</td><td rowspan="2">Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Participate in Ocean landings stock composition study.

Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.

Monitor recreational landings, catch, and effort every 5 years.
(Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)</td></tr>
<tr><td>Delaware</td><td>Delaware River and Bay
(RM 0-75)</td></tr>
</table>

Table 3 (cont=d). Mandatory fishery-dependent monitoring programs for American shad.

Delaware	Nanticoke River Ches. Bay tributatry, upstream portion)	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Monitor recreational landings, catch, and effort every 5 years.
	Atlantic Ocean	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Participate in Ocean landings stock composition study.
Pennsylvania	Delaware River	Monitor recreational landings, catch, and effort every 5 years. (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)
Maryland	Inriver	Monitor recreational landings, catch, and effort every 5 years.
	Atlantic Ocean	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Participate in Ocean landings stock composition study.
Virginia	Inriver	Monitor recreational landings, catch, and effort every 5 years.
	Atlantic Ocean	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Participate in Ocean landings stock composition study.
North Carolina	Albemarle Sound and its tributaries, Tar-Pan-dico, Neuse, and Cape Fear Rivers	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Monitor recreational landings, catch, and effort every 5 years.
	Atlantic Ocean	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Participate in Ocean landings stock composition study.
South Carolina	Santee-Cooper system, Charleston Harbor and its tributaries (Ashley and Cooper Rivers), Edisto River, Santee River, Winyah Bay and its tributaries (Waccwnaw and Pee Dee Rivers)	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Monitor recreational landings, catch, and effort every 5 years. *State may elect to sample these systems on a rotational basis (i.e., one system evaluated per year
	Atlantic Ocean	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Participate in Ocean landings stock composition study.
Georgia	Ogeechee	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. Monitor recreational landings, catch, and effort every 5 years.
Florida	St. Johns River	Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.

		Monitor recreational landings, catch, and effort every 5 years.

Table 4. Summary of recommended fishery-dependent monitoring programs for adult river herring and hickory shad .

State	System	Species	Sampling Program
Maine	All rivers	River herring	Towns must submit an annual harvesting plan and landings to the Department of Marine Resources
New Hampshire	Lamprey, Oyster, Cocheco, Taylor, Exeter Rivers, and Great Bay Estuary	River herring	Mandatory reporting by all Coastal Netters Permittees of catch and effort information. Coastal Netters Permits are required by all fishermen using nets, traps, or weirs in New Hampshire=s open ocean and coastal estuaries
Massachusetts	Over 125 active natal river herring runs	River herring	Some periodic sampling of runs harvested under Local control
Delaware	Delaware River (RM 0-75) Nanticoke River (Ches Bay tributary, upstream portion)	River herring	Mandatory catch reports of the commercial fisheries for landings and effort
Maryland	Nanticoke River	River herring	Monitor annually the commercial pound and fyke net river herring bycatch for catch, effort, sex ratio, length/weight
Virginia	James River, York River system (includes Pamunkey and Mattaponi Rivers), and Rappahannock River	River herring	Monitor the commercial pound net and haul seine fisheries
North Carolina	Albermarle Sound area	River herring	Annually monitor the commercial herring fishery for catch composition age, length, and sex, Annually monitor the catch effort of the Chowan River pound net fishery. Annually monitor Annually monitor the size, age and sex composition of hickory shad
South Carolina	Santee-Cooper system	River herring	Annually monitor the commercial herring fishery for age, length, weight, sex ratio and effort
	Santee River	River herring	A hoop, drop and cast net fishery targeting herring has developed in the Re-diversion canal below St. Stephen Dam since completion of the Re-diversion Project. Landings from this fishery collected by the Freshwater Division.

Table 5. Summary of recommended fishery-independent monitoring programs for adult river herring and hickory shad .

State	System	Species	Sampling Program
Maine	Saco Androscoggin, and St. Croix Rivers	River herring	Estimated number of spawning adults returning to the fishway are made and samples of length, age, and sex are collected
	Kennebec, Anndroscoggin, and Union Rovers	Alewife	Numbers of adults stocked in each lake/impoundment are recorded. Samples are collected for length, age, and sex in the Kennebec and Androscoggin Rivers.
New Hampshire	Lamprey River	River herring	Estimated number of spawning adults returning to fish ladders are made via absolute counts, timed counts, or electronic counting tubes. Samples of 150 lengths by sex are taken three times during the spawning runs (beginning, middle, end). Fifty of the fish from each of the three samples are aged.
	Oyster River	River herring	Estimated number of spawning adults returning to fish ladders are made via absolute counts, timed counts, or electronic counting tubes. Samples of 150 lengths by sex are taken three times during the spawning runs (beginning, middle, end). Fifty of the fish from each of the three samples are aged.
	Cocheco River	River herring	Number of spawning adults returning to fish ladder is counted by hand. Samples of 150 lengths by sex are taken three times during the spawning runs (beginning, middle, end). Fifty of the fish from each of the three samples are aged.
	Exeter River	River herring	Number of spawning adults returning to fish ladder is made via timed counts or absolute counts. Length measurements by sex, and scales for aging are taken in some years on an opportunistic basis.
	Taylor River	River herring	Estimated number of spawning adults returning to fish ladders are made via absolute counts, timed counts, or electronic counting tubes. Length measurement by sex and scales for aging have been taken in some years on an opportunistic basis
Massachusetts	Over 125 active natal river herring runs	River herring	Connecticut River - see Connecticut River Restoration Program annual progress report Merrimack River - See USFWS Anadromous Fish Restoration Program progress report Monument River - Bourne Local Control MR Spring spawning stock survey electronic counters, dip netting, haul seines Programs run annually, expected to continue

Table 5 (cont=d). Summary of recommended fishery-independent monitoring programs for adult river herring and hickory shad .

Connecticut	Connecticut River	Blueback herring	Stock abundance derived from Holyoke fish lift
Rhode Island	Pawcatuck River	Various Alosines	Fishway trap and count at first dam on system since 1979.
Virginia	James River, York River system (includes Pamunkey and Mattaponi Rivers), and Rappahannock River	River herring	Spring spawning stock survey from pound nets
North Carolina	Albemarle Sound and tributaries	River herring and hickory shad	Spawning area assessment work - gillnets of various mesh sizes (not continuous) were set in certain systems for a season (March to May) to capture adults participating in spawning migration. Species, number, length and age data are available for some years.

Table 6. Summary of recommended monitoring programs for juvenile river herring and hickory shad .

State	System	Species	Sampling Program
Maine	Kennebec and Anddroscoggin Rivers	*Alosa* spp.	Annual juvenile Alosine survey
Connecticut	Connecticut River	Blueback herring	Annual geometric mean (catch/seine haul)
Rhode Island	Pawcatuck River	*Alosa* spp.	Juvenile index at 5 stations in estuary, Sept-Oct weekly
New York	Hudson River	*Alosa* spp.	Annual juvenile Alosine survey
Delaware	Delaware River (RM 0-75) Nanticoke River (Ches Bay tributary, upstream portion)	*Alosa* spp.	Annual juvenile fish trawl survey - Delaware River and Bay, April through November Data used to determine year class strength of primarily demersal fishes CPUE, length frequency
New Jersey	Delaware River and Bay	*Alosa* spp.	Striped bass annual JAI seine survey
Pennsylvania	Susquehanna River	*Alosa* spp.	Weekly seining July-Oct (300' x 6' x 3/8") Twice weekly lift net at Holtwood (8' x 8' x 1/2")
Maryland	Chesapeake Bay tributaries	*Alosa* spp.	Striped bass annual JAI seine survey
North Carolina	Albemarle Sound and tributaries	*Alosa* spp.	Annual trawl surveys conducted at set stations, at times year round or seasonal June-October. Three different types of trawls were employed. Trawl sampling dropped due to reduction in force and funds. Annual seine surveys June-October. Number of stations varies, but core station of 11. Data used as relative abundance index of age zero. Arithmetic mean calculated monthly and annually. Mean size data determined monthly and annually.
South Carolina	Santee-Cooper system	River herring and shad	Annual beach seine survey, July-September - number caught per seine haul in Lake Marion Cast netting data from forbay in front of St. Stephen Dam - number caught, length, weight for shad and herring
	Charleston harbor and tributaries (Ashley and Cooper Rivers)	Alosa spp.	Limited Alosine data is available for the lower portions of the Charleston Harbor system from catches made during the conduct of annual shrimp sampling programs. This data is primarily related to time of occurrence, with some size by date information available.

Section 4. MANAGEMENT PROGRAM IMPLEMENTATION

4.1 Commercial fisheries Management Measures

Mandatory reporting on catch and effort in active commercial fisheries for all alosines (American shad, hickory shad, and river herring) will be required as per Section 3.

Whenever practical, state harvest and effort reporting requirements will coincide with current and future mandates of the Atlantic Coastal Cooperative Statistics Survey (ACCSP). Data needs not covered by the ACCSP will still be covered by annual reports submitted in conjunction with the FMP.

A. Ocean-intercept commercial fisheries

Begin a phase-out reduction plan for the commercial ocean-intercept fishery for American shad (outside state-defined producer areas - see beginning of Section 3.1) over a five-year period. States must achieve at least a 40% reduction in effort in the first three years, beginning January 1, 2000. States with directed ocean-intercept fisheries will determine how to achieve this effort reduction and submit proposals as per Sections 5.1.2.1 and 5.1.2.2.

States with non-directed harvest of American shad in ocean fisheries (outside state-defined producer areas - see beginning of Section 3.0) can permit the landing of this shad bycatch, provided that American shad do not constitute more than 5% of the total landings (in pounds) per trip. States permitting the landing of American shad ocean bycatch must annually document that the 5% trip limit is not exceeded, report the extent and nature of the non-directed fisheries, and the total landings of American shad bycatch. In addition, these jurisdictions must subsample all American shad bycatch for size, age, sex distribution as per Section 3.3.3, except as exempted under *de minimis* provisions of Section 4.8.

All jurisdictions shall maintain existing or more conservative regulations for commercial river herring and hickory shad fisheries in ocean waters.

Jurisdictions currently managing under a moratorium in producer areas may shift effort from ocean-intercept fisheries to inriver fisheries, provided that the total mortality for a given exploited stock does not exceed the target mortality (F_{30} or restoration target rate) for that stock**.**

2. Inriver commercial fisheries

States may conduct inriver fisheries for American shad at levels not to exceed F_{30} for the following systems: Connecticut, Hudson, Delaware, Upper Chesapeake Bay, Santee, Edisto, and Altamaha. States with jurisdiction over these systems must submit proposals on how to maintain F at or below F_{30} as per Section 5.1.2. 1. For all other stocks, or any stock of American shad identified for restoration, states must develop and adopt recovery plans as per Section 5.1.2.1 below. States shall not exceed any specified target F suitable for attaining adopted restoration goals.

All jurisdictions shall maintain existing or more conservative regulations for commercial river

herring and hickory shad fisheries, except for expanded monitoring programs outlined in Section 3.3.3.

4.2 Recreational Fisheries Management Measures

All jurisdictions shall not exceed an aggregate 10 fish daily creel limit in recreational fisheries for American shad or hickory shad. For American shad or hickory shad stocks under restoration, states must adopt recreational creel limits consistent with restoration targets. Creel limits should be described in state recovery/fishing plans as per Section 5.1.2. 1.

4.3 Habitat Conservation and Restoration

Shad and river herring stocks along the Atlantic coast are greatly diminished compared to historic levels. Much of this reduction is related to spawning and nursery habitat degradation brought on by effects of human population increase (sewage and stormwater runoff, industrialization), increased erosion, sedimentation and nutrient enrichment associated with agricultural practices, and losses of riparian forests and wetland buffers. All Atlantic coast jurisdictions and several federal agencies routinely review and comment on water development project permits and licenses for activities which adversely affect alosine habitat or interfere with upstream or downstream migrations. Legislation, such as the Clean Water and Clean Air Acts, address these concerns and both water and air quality has shown substantial improvements since the 1960s.

Thousands of kilometers of historic anadromous alosine habitat were lost due to development of dams and other obstructions to migration. These impediments take many forms including large hydroelectric darns on mainstems of rivers, water storage and flood protection projects, small dams erected in tributaries to supply water to historic mills or to meet local water supply or industrial needs, culverts at highway crossings, gauging station weirs, and others. Passage success at these barriers often depends on individual stream flow characteristics during the fish migration season. Shad and river herring may be blocked by a structure only 20-30 centimeters in height above water.

Many state and federal fishery agencies are involved in habitat improvement programs aimed specifically or indirectly at rebuilding stocks of shad and river herring. In most cases, these involve characterizing habitat suitability, defining historic spawning and nursery areas, inventory of blockages to migration, and provision of fish passage facilities. Frequently, these efforts are accompanied by re-stocking above dams to imprint alosines to return and recolonize these waters. Depending on the quality and size of the habitat being restored and the nearness and migratory patterns of suitable source stocks, restoration can occur quickly and at relatively small cost (e.g., adult alewife introduction to a coastal pond), or it can take decades and cost tens of millions of dollars (e.g., large rivers with multiple mainstem dams).

Table 7. Commercial regulations for American shad - Inriver fisheries (as of Jan. 97)

STATE	SYSTEM	SEASON	GEAR LIMITS	Mandatory reporting	Other Restrictions
Maine	All rivers		Hook/Line Only		2 fish per day
New Hampshire	All rivers		Hook/Line Only		2 fish per day
Massachusetts	All rivers		Closed		
Rhode Island	All rivers		Closed		
Connecticut	All rivers	Apr 1 - Jun 15	Multifilament and monofilament gillnets only; monofilament net - nights only	Yes	48hr. escapement period/week
New York	Hudson	Mar 15-Jun 15	Net length: 1200 ft. max Mesh: 3.5 in to 5 in. Not allowed Gear restrictions in defined areas	yes	36hr. escapement period/week - closed area in spawning reach
New Jersey	Delaware River	None	None	None	
	Delaware Bay	Feb 1-Dec 15	Mesh: 5" from Feb 1-Feb 29 Net length 2400 ft.- Feb 1-May 15 1200 ft.-May 16-Dec 15	None	
	Raritan/ Sandy Hooks Bays	Feb 1-Dec 15	Mesh: 5" from Feb 1-Feb 29 Net length 2400 ft.- Feb 1-May 15 1200 ft.-May 16-Dec 15	None	Pound net season: open all year round
New Jersey	Hudson River	Mar 15-Jun 15	Net length: 1200 ft. Mesh 5 in.Gear restrictions in defined areas	yes	36hr. escapement period/week - closed area in spawning reach
Delaware	Delaware River	None	No fixed gillnets (Jan 1-May 31) No Drift gillnet Sat., 1600 hrs Sun. (May 10-Sep 30)	yes	Limited entry on licenses

Table 7 (cont=d). Commercial regulations for American shad - Inriver fisheries (as of Jan. 97).

	Delaware Bay	None	No anchor gillnet- May 10-Sep 30 No drift gillnet Sat., 1600 hrs Sun. May 10-Sep 30	Yes	Limited entry on Licenses
Pennsylvania			Closed		
Maryland			Closed (since 1980)		
PRFC			Closed (Since 1982)		
Virginia			Closed (since 1994)		
North Carolina		Jan 1-Apr 14	Varies by system Mesh Size and net length/yardage restricts Closed areas to gillnetting	Yes; Trip ticket	None
South Carolina		Jan or Feb-Apr (varies by system)	Varies by system Mesh Size: 4.5-5.5 in. Net length limits Closed areas	Yes, from dealers Volunteer from others	Weekly escapement varies by river (72-108hr)
Georgia		Jan 1-Mar 31	Net length limit by gear type Mesh 4.5 in. Minimum restricted area for nets by system		Weekly escapement varies by river (48-120hr)
Florida			Closed		

Table 8. Commercial regulations on American shad - ocean fisheries (as of Jan. 97).

STATE	SEASON	GEAR LIMITS	Mandatory reporting	Other Restrictions
Maine		Hook and Line only		2 fish per day
New Hampshire		NONE		
Massachusetts		Closed		
Rhode Island		NONE		
Connecticut		NONE		
New York		NONE		
New Jersey	Feb 1-Dec15	Mesh: 5" from Feb 1 -Feb 29 Net length: 2400 ft. - Feb 1 -May 15 1200 ft. May 16-Dec 15	NONE	
Pennsylvania		N/A		
Delaware	NONE	Same as inriver No gillnets<0.5 mi offshore form May 10-Nov 30	Yes	Limited entry on licenses
Maryland	Feb 2-Apr 30	NONE	Yes	Limited entry on licenses
PRFC		N/A		
Virginia	NONE	NONE		NONE
North Carolina	Jan 1-Apr 14	NONE	Yes, Trip ticket	Area restrictions
South Carolina	Feb 1-Sat. before Easter or Mar 25	Mesh Size4. Minimum Drift net only Some restricted & closed areas		Weekly escapement: 48 hr
Georgia		Closed		
Florida		Closed		

Table 9. Recreational fishing regulations for American shad - Inriver (as of Jan. 97).

STATE	SEASON	DAILY LIMIT	GEAR LIMIT	Other Restrictions
Maine	NONE	2 fish/day	H&L only	
New Hampshire	NONE	2 fish/day	H&L only	
Massachusetts	NONE	NONE	H&L only, marine waters	
Rhode Island		Catch and release only		
Connecticut	Apr 1-Jun 30	6 fish/day - includes MA water of CT River	H&L only	
New York - Hudson River	Mar 15 - Jun 15	NONE	H&L only	No License required
- Delaware River	NONE	6 fish/day	NONE	
New Jersey - Delaware River	NONE	NONE	NONE	
Pennsylvania - Delaware River	NONE	6 fish/day	H&L only	
- Other systems	NONE	Lehigh: 1 fish/day; Susquehanna: C&R Schuylkill: 6 fish/day	H&L only	
Delaware - Delaware River	NONE	NONE	H&L only	
- Other systems	NONE	NONE	H&L only	≤2 lures/line and 1 hook/lure
Maryland		Closed		
PRFC		Closed		
Virginia		Closed		
North Carolina - Inland - Coastal	NONE Jan 1 - Apr 14	10 fish/day (Aggregate Am. and hickory shad) 10 fish/day (Aggregate Am. and hickory shad)	H&L, License required H&L	License required
South Carolina	NONE	NONE	H&L in most rivers, small nets in others with restrictions	
Georgia	NONE	8 fish/day	H&L only	
Florida	NONE	10 fish aggregate (hickory/American /day	H&L only	License required

4.3.1 Recommendations for Fish Habitat Conservation/Restoration

1. State marine fisheries agencies should identify state permitting and planning agencies that regulate those activities identified in Section 1.3.2 as likely to adversely affect habitat areas of particular concern (H.A.P.Cs) and habitats, either by destruction of habitat or degradation of quality. The marine fisheries agency should work with the relevant permitting or planning agency in each state to develop permit conditions and planning considerations to avoid or mitigate adverse impacts on H.A.P.C.s or other habitats necessary to sustain the species. Standard permit conditions and model policies that contain mitigation techniques should be developed. The development of Memoranda of Understanding (MOUS) with other state agencies are recommended for joint review of projects and planning activities to ensure that habitat protections are adequately incorporated. For example, dredging windows should be established to avoid impacts to susceptible life stages. Dredging windows should be coordinated to ensure practical opportunities for permitted dredging to take place.

2. When it is expected that impacts will occur from an activity described in Section 1.3.2, but probably not above some *de minimum* level, prohibition of the activity may not be warranted, but the marine fisheries agency should request that the appropriate agency consider requiring application of Best Management Practices for the activity.

3. State marine fisheries agencies should coordinate with state water quality agencies and state coastal zone management agencies to ensure that Clean Water Act Section 319 non-point source control plans and Coastal Zone Act Re-authorization Amendment Section 6217 coastal non-point source control plans are developed and implemented so as to minimize adverse impacts of non-point source pollution on the species. In particular, marine fisheries agencies should consider whether areas merit designation as critical coastal areas under state 6217 programs (non-point source pollution control under the Coastal Zone Management Act amendments of 1990) due to water quality impacts to fish habitat, and should provide input to the 6217 lead agencies..

4. State marine fisheries agencies should coordinate with appropriate state agencies to strengthen compliance with National Pollutant Discharge Elimination System (NPDES) or State Pollutant Discharge Elimination System (SPDES) permits.

5. State marine fisheries agencies should work with state coastal zone management agencies to determine whether: 1) additional state policies for habitat protection should be adopted under the state coastal management program; 2) additional federal activities should be added to the state coastal management programs list of activities subject to state consistency review; and 3) the state is fully utilizing the Coastal Zone Management Act federal consistency process for protection of fish habitats.

6. When states have identified habitat restoration as a need, state marine fisheries agencies should coordinate with other agencies to ensure that habitat restoration plans are developed, and funding is actively sought for plan implementation and monitoring.

7. State marine fisheries agencies should coordinate with and provide input to the state water quality agency in development and updating of the Clean Water Act section 303(d) list (priority list of water not meeting state water quality standards). In addition, state marine fisheries agencies should review the adequacy of water quality standards to protect the species of concern and should participate in the triennial review of the state water quality standards.

8. State marine fisheries agencies should review oil spill prevention and response plans for preventing accidental release and recommending prioritized response in H.A.P.C.s.

9. State marine fisheries agencies should work closely with the appropriate Coast Guard District Office in the development, amendment, and implementation of areawide oil spill contingency plans.

10. State marine fisheries agencies should work closely with water quality agencies in the development or revision of river basin plans to identify degraded or threatened resources and recommend preventative, remedial or mitigation measures.

11. State marine fisheries agencies should work with the appropriate agencies to develop contaminated sediment re-mediation plans or active sediment pollution prevention programs for areas with or susceptible to sediment contamination.

12. State marine fisheries agencies should coordinate with appropriate National Estuary Program (NEP) committees to ensure that NEP Comprehensive Coastal Management Plans (CCMPS) identify and implement habitat protection and restoration needs.

Other information regarding habitat restoration and conservation goals, and water quality requirements for American shad can be found in the 1985 Fishery Management Plan for American Shad and River Herrings (ASMFC 1985).

4.4 Alternative State Management Regimes

A state may, with the approval of the Management Board, vary their regulatory specifications contained in Sections 4.2 and 4.3, so long as that state can show to the Boards satisfaction that the target fishing mortality rate or the overfishing definition (see Section 3.3) will not be exceeded.

4.4.1 Management Program Equivalency

Alternative management regimes may also include other indices of their equivalency (e.g., eggs-per-recruit, yield-per-recruit, etc.), in addition to fishing mortality protection.

States shall submit proposals for altering their regulatory program for American shad, hickory shad, or river herring to the Technical Committee and Advisory Panel for review prior to implementing any changes. The Technical Committee and Advisory Panel shall prepare reports on the proposal for the Management Boards. The Management Board shall then accept or reject the changes and establish implementation schedules for any approved changes.

4.5 Adaptive Management

The term "adaptive management" means that fishery managers evaluate the response of a population to the regulatory measures employed and react to resulting changes to ensure that the goal and objectives of a FMP are met. Adaptive management requires that the fishery and population is monitored to an extent sufficient to allow an assessment of how well the plan is performing. Necessary corrections must be made to the management regime if indications are that the population is declining, or that target fishing rates exceed levels desired. If target F is too high or the population is not stable or growing, additional restrictions on harvest must be imposed. If, on the other hand, landings are low and population growth is high, harvests may be increased. Amendment 1 will use this adaptive management approach.

4.5.1 General Procedures

The Management Board may vary the requirements specified in this Amendment as a part of adaptive management in order to achieve the goals and objectives specified in Section 2. Specifically, the Management Board may change target fishing mortality rates, creel limits, seasonal restrictions, commercial fishery quotas and the restoration status of producer areas. Such changes will be instituted to be effective on January 1 or on the first fishing day of the following year, but may be put in place at an alternative time when deemed necessary by the Management Board.

4.5.1.1 Procedural Steps

1. The Plan Review Team (PRT) will continually monitor the status of the fishery and the resource and report on the status to the Management Board on or about May 1. The PRT will consult with the Technical Committee, the Stock Assessment Subcommittee (SAS) and the relevant Advisory Panel, if any, in making such review and report. The report will contain recommendations concerning proposed adaptive management revisions to the management program.

2. The Management Board will review the report of the PRT, and may consult further with the Technical Committee, the SAS or the Advisory Panel. The Management Board may direct the

PRT to prepare an addendum to effectuate any changes it deems necessary. The addendum shall contain a schedule for the states to implement its provisions,

3. The PRT will prepare a draft addendum as directed by the Management Board, and shall distribute it to all states for review and comment. A public hearing will be held in any state that requests one. The PRT will also request comments from federal agencies and the public at large. After a 30-day review period, the PRT will summarize the comments and prepare a final version of the addendum for the Management Board.

D. The Management Board shall review the final version of the addendum prepared by the PRT, and shall also consider the public comments received and the recommendations of the Technical Committee, the SAS and the Advisory Panel; and shall then decide whether to adopt or revise and adopt the addendum.

E. Upon adoption of an addendum implementing adaptive management, states shall prepare plans to carry out the addendum, and submit them to the Management Board for approval, according to the schedule contained in the addendum.

4.5.2 Measures Subject To Change

Management measures that may be modified under this adaptive management framework include changes in regulatory measures such as size limits, possession limits, seasonal closures, and area closures; alteration of EEZ recommendations; creation of Special Management Zones; and modification of individual state commercial and recreational management program requirements.

The Management Board may make changes to the state implementation schedule in accordance with adaptive management provisions. Each jurisdictions= shad and river herring regulations and management program must be approved by the Management Board. States may not implement any regulatory changes concerning shad and river herring, or any management program changes that affect their responsibilities under this Amendment, without first having those changes reviewed by the Technical Committee, Advisory Panel and approved by the Management Board. Also, any jurisdiction using a fishery model is required to submit any changes to its input parameters, including tuning procedures and model formulation, to the Technical Committee for its review and the Technical Committee will report its findings to the Management Board. See Section 4.4, Alternative State Management Regimes, for reporting procedures.

4.6 Emergency Procedures

The Shad and River Herring Management Board may authorize or require emergency action that is not covered by, or is an exception or change to, any provision in Amendment 1. These actions are based on unanticipated changes in the ecosystem, alosine stocks or alosine fisheries that result in significant risks to public health, alosine conservation, or attainment of alosine fishery management objectives. Procedures for implementation are addressed in the ASMFC Interstate Fisheries Management Charter, Section 6(c)(10) (ASMFC 1998).

4.7 Management Institutions

4.7.1 Atlantic States Marine Fisheries Commission and ISFMP Policy Board

The Atlantic States Marine Fisheries Commission (ASMFC) and the Interstate Fisheries Management Program (ISFMP) Policy Board are generally responsible for the oversight and management of the Commission's fisheries management activities. The Commission must approve all fishery management plans and amendments thereto, including this Amendment 1; and must also make all final determinations concerning state compliance or noncompliance. The ISFMP Policy Board reviews recommendations of the various Management Boards and, if it concurs, forwards them on to the Commission for action.

4.7.2 Shad and River Herring Management Board

The Shad and River Herring Management Board is established by the Commission's ISFMP Policy Board and is generally responsible for carrying out all activities under this Amendment. It establishes and oversees the activities of the PRT, the Technical Committee and the SAS; and requests the establishment of the Commissions Shad and River Herring Advisory Panel. Among other things, the Management Board makes changes to the management program under adaptive management, and approves state programs implementing the amendment and alternative state programs under Section 4.4. The Management Board reviews the status of state compliance with the FMP at least annually, and if it determines that a state is out of compliance, reports that determination to the ISFMP Policy Board under the terms of the ISFMP Charter.

4.7.3 Plan Review Team

The Plan Review Team is a small group whose responsibility is to provide all necessary staff support to carry out and document the decisions of the Management Board. This team will be chaired by an ASMFC Shad and River Herring Coordinator. The PRT is directly responsible to the Management Board for providing all of the information and documentation necessary to carry out the Boards decisions.

4.7.4 Technical Committee

The Shad and River Herring Technical Committee will consist of representatives from each jurisdiction and federal agency with an interest in shad and river herring fisheries. Its role is to act as a liaison to the individual state agencies, providing information to the management process and reviewing and making recommendations concerning the management program. The Technical Committee will report to the Management Board, normally through the PRT.

4.7.5 Stock Assessment Subcommittee

The Stock Assessment Subcommittee (SAS) will consist of those scientists with expertise in the assessment of shad and river herring populations. Its role is to assess shad and river herring populations and provide scientific advice concerning the implications of proposed or potential management alternatives, or to respond to other scientific questions of the Management Board.

The SAS will report to the Management Board as well as the Technical Committee.

4.7.6 Advisory Panel

The Shad and River Herring Advisory Panel is established according to the Commission's Advisory Committee Charter. Members of the Advisory Panel are citizens who represent a cross-section of commercial and recreational fishing interests and others who are concerned about shad and river herring conservation and management. The Advisory Panel provides the Management Board with advice directly concerning the Commissions shad and river herring management program. Normally, the Advisory Panels meetings will be held at and in conjunction with selected Management Board meetings.

4.7.7 Secretaries of Commerce and the Interior

Under ACFCMA, if the Commission determines that a state is out of compliance with the FMP it reports that finding to the Secretary of Commerce. The Secretary of Commerce must determine that the measures not taken by the state are necessary for conservation and if such a finding is determined, he/she is then required by the federal law to impose a moratorium on fishing for shad and/or river herring in that states= waters until the state comes back into compliance. In addition, the Commission has accorded NMFS and USFWS voting status on the ISFMP Policy Board and the Shad and River Herring Management Board; and the federal agencies participate on the PRT, the Technical Committee and the SAS.

4.8 *De minimis* status

States that report recreational or commercial landings of American shad that are less than 1% of the coastwide recreational or commercial total are exempted from sub-sampling this catch for biological data, as outlined in Section 3.3.3, paragraph 1.

4.9 Recommendations to Secretaries

<u>Secretary of Interior</u>
ASMFC requests that the Secretary of Interior provide necessary funding to expand the state/federal cooperative tagging program for migratory and mixed stocks of American shad. An enhanced program would greatly improve the current understanding of stock contributions to mixed stock fisheries, annual survivorship, migration, growth rates, and the efficacy of state restoration plans.

In addition, ASMFC recommends that the Secretary of Commerce direct the National Marine Fisheries Service (NMFS) to examine existing databases for information on distribution and habitat use of offshore areas by alosines. In addition, the NMFS should expand at-sea observer programs to further quantify the extent of alosine bycatch in oceanic fisheries. Finally, ASMFC recommends that NMFS expand MRFSS coverage to include riverine or estuarine areas used by anglers to intercept alosines.

Section 5. COMPLIANCE

Under the provisions of ACFCMA, all states (including Washington, D.C. and Potomac River Fisheries Commission (PRFC)) are required to implement the provisions of this Amendment. This section sets forth the specific requirements with which states must comply under the law, and the procedures that will govern the evaluation of compliance.

5.1 Mandatory Compliance Items For States

5.1.1 Regulatory Requirements

A state will be found out of compliance if it's regulatory and management programs for shad and river herring have not been approved by the Management Board.

All state programs must include a regime of restrictions on commercial and recreational fisheries consistent with the requirements of Sections 4.1 and 4.2. Except, a state may propose an alternative management program under Section 4.4, which if approved by the Management Board, may be implemented as an alternative regulatory requirement for compliance under the law.

5.1.1.2 Monitoring Requirements

All state programs must include the mandatory monitoring requirements contained in Section 3.4. 1. States must submit proposals for all intended changes to required monitoring programs that may affect the quality of the data, or the ability of the program to fulfill the needs of the Plan. State proposals for making changes to required monitoring programs will be submitted to the Technical Committee at least two weeks prior to its spring or fall meeting. Proposals must be on a calendar year basis. The Technical Committee will make recommendations to the Management Board concerning whether the proposals are consistent with Amendment 1.

5.1.2 Compliance Schedule

5.1.2.1 Transition to Amendment 1

States must implement this Amendment according to the following schedule:

July 1, 1999: States must submit state recovery/fishing plans (see Table 1) to implement Amendment 1 for approval by the Management Board. Plans, including monitoring programs, must be implemented according to schedule approved by the Management Board.

January 1, 2000: All states must have an approved recovery/fishing plan to implement Amendment 1 in place.

5.1.2.2 Reports On Compliance Submitted to PRT Annually

Each state must submit an annual report concerning its shad and river herring fisheries and management program on or before July I each year, beginning July 1, 1999. The report shall cover: the previous calendar years fishery and management program including activity and results of monitoring, regulations which were in effect and harvest, including estimates of non-harvest losses, following the outline contained in Table 10.

All state programs must include the mandatory monitoring requirements contained in Section 3.4 and Tables 2-3. States must submit proposals for all intended changes to required monitoring programs which may affect the quality of the data, or the ability of the program to fulfill the needs of the fishery management plan. State proposals for making changes to required monitoring programs will be submitted to the Technical Committee at least two weeks prior to its spring or fall meeting. Proposals must be on a calendar year basis. The Technical Committee will make recommendations to the Management Board concerning whether the proposals are consistent with Amendment 1.

In the event that a state realizes it will not be able to fulfill its fishery independent monitoring requirements, it should immediately notify the Commission in writing. The Commission must be notified by the planned commencement date of the monitoring program. The Commission will work with the state to develop a plan to secure funding or plan an alternative program that will satisfy the needs outlined in Amendment 1. If the plan is not implemented 90 days after it has been adopted, the state will be found out of compliance with Amendment 1.

5.2 Procedures for Determining Compliance

Detailed procedures regarding compliance determinations are contained in the ISFMP Charter, Section 7 (ASMFC 1998).

1. The PRT will continually review the status of state implementation, and advise the Management Board at any time that a question arises concerning state compliance. The PRT will review state reports submitted under Section 5.1.2 and prepare a report by October 1 for the Management Board summarizing the status of the resource and the fishery (see Section 4.5. la) and the status of state compliance on a state-by-state basis.

2. Upon review of a report from the PRT, or any time by request from a member of the Management Board, the Management Board will review the status of an individual state=s compliance. If the Management Board finds that a state's approved regulatory and management program fails to meet the requirements of this section, it may recommend that the state be found out of compliance. The recommendation must include a specific list of the state=s deficiencies in implementing and enforcing the Amendment and the actions that the state must take in order to come back into compliance.

3. If the Management Board recommends that a state be found out of compliance as referred to in the preceding paragraph, it shall report that recommendation to the ISFMP Policy Board for further review according to the Commissions Charter for the Interstate Fisheries Management Program.

D. The state that is out of compliance or subject to a recommendation by the Management Board under the preceding subsection may request at any time that the Management Board reevaluate its program. The state shall provide a written statement concerning its actions that justify a reevaluation. The Management Board shall promptly conduct such reevaluation, and if it agrees with the state, shall recommend to the ISFMP Policy Board that the determination of noncompliance be withdrawn. The ISFMP Policy Board and the Commission shall deal with the Management Board's recommendation according to the Commission's Charter for the Interstate Fisheries Management Program..

Table 10. Format required for Annual State Report.

1. Harvest and losses
    A. Commercial fishery
        1. Characterization of fishery (seasons, cap, gears, regulations)

        2. Characterization of directed harvest for all alosines
            a. Landings and method of estimation
            b. Catch composition
                1. Age frequency
                ii Length frequency
                ii Sex ratio
                iv Degree of repeat spawning (estimated from scale data)
            c. Estimation of effort

        3. Characterization of other losses (poaching, bycatch, etc.)
            a. Estimate and method of estimation
            b. Estimate of composition (length and/or age)

    B. Recreational fishery
        1. Characterization of fishery (seasons, cap, regulations)
        2. Characterization of directed harvest
            a. Landings and method of estimation
            b. Catch composition
                i. Age frequency
                ii. Length frequency (legal and sub-legal catch)
            c. Estimation of effort

        3. Characterization of other losses (poaching, hook/release mortality, etc:.)
            a. Estimate and method of estimation
            b. Estimate of composition (length and/or age)

    C. Other losses (fish passage mortality, discarded males, brood stock capture, research losses, etc.)

    D. Table 1. Harvest and losses - including all above estimates in numbers and weight (pounds) of fish and mean weight per fish for each gear type

    E. Protected species I Atlantic sturgeon bycatch estimates

11. Required fishery independent monitoring
    A. Description of requirement as outlined in Amendment 1, Table 2
    B. Brief description of work performed

Table 10 (cont=d). Format required for Annual State Report.

C. Results
  1. Juvenile indices
    a. Index of abundance
    b. Variance

  2. Spawning stock assessment
    a. Length frequency
    b. Age frequency
    c. Sex
    d. Degree of repeat spawning

  3. Annual mortality rate calculation

  4. Hatchery evaluation (%wild vs. hatchery juveniles)

Table 11. Format for state fishing/recovery plans

I.. Inriver or estuarine fisheries

- A. Description of inriver management areas (including geographic boundaries)
- B. Restoration targets for stocks (e.g., spawning run size, population targets, etc.)
- C. Restoration target mortality rate for individual stocks
- D. Timeline for restoration of individual stocks
- E. Management measures to achieve restoration
    1. Commercial quotas, seasons, gear restrictions
    2. Recreational possession limits, seasons
    3. Hatchery programs
    4. Other programs (habitat improvement, fish passage, etc.)

II . Ocean-intercept fisheries

- A. Description of fisheries (season, location, regulations, etc.)
- B. Phase-out plan (five year timeline for effort reduction)
- C. Mixed stock evaluation (i.e., programmatic details for evaluating stock contribution to state ocean landings of American shad).

Section 6. MANAGEMENT RESEARCH NEEDS

States are strongly encouraged to implement the management measures contained in Section 3.4 (stocking/restoration), Section 4.1 (habitat requirements), and Section 6 (research).

6.1 Stock Assessment and Population Dynamics

1) Initiate studies to document fishing mortality rates and to establish if density dependent catchability exists.

2) Improve records of catch and effort, particularly on inland recreational fisheries of American shad, and establish the amount of harvest reported as American shad and/or river herring that is actually hickory shad.

3) Develop standard procedures for developing and validating juvenile abundance indices.

4) Design and implement a coordinated interstate coastal tagging research program.

5) Conduct studies on energetics of feeding and spawning migrations of shad on the Atlantic coast.

6) Analyze American shad growth.

7) Determine and partition annual mortality rates for A major exploited stocks,

8) Ensure that domestic Atlantic mackerel, squid, butterfish fisheries, and joint venture fisheries for Atlantic herring, Atlantic mackerel, and Atlantic menhaden are closely monitored for river herring and immature American shad bycatch and discard.

9) Encourage research on hickory shad.

10) Additional bycatch research and the effects of the shad gillnet fishery on protected species.

6.2 Habitat Information Needs/Recommendations for Future Research

1) Identify and quantify potential American shad spawning and nursery habitat not presently utilized and analyze the cost of recovery within those areas.

2) Define restrictions necessary for implementation of projects in spawning and overwintering areas and develop policies on limiting development projects seasonally or spatially.

3) Conduct historical characterization of socioeconomic development (potential pollutant sources and habitat modification) of selected shad rivers along the East Coast.

4) Document the impact of power plants and other water intakes on larval, postlarval, and juvenile mortality in spawning and nursery areas, and calculate the resultant impact to adult population size.

5) Review studies dealing with the effects of acid deposition on anadromous alosines.

6) Evaluate state water quality standards and criteria to ensure accountability for the special needs of anadromous alosines.

7) Analyze optimum habitat utilization of American shad.

8) Determine the effects of pollution, passage impediments, and other anthropogenic impacts on all life history stages of shad and river herring.

9) Determine utilization/effectiveness of constructed passage devices to evaluate continued use and/or further construction.

10) Determine biotic effects of alosine passage into previously restricted habitats (i.e., lakes, ponds, strearns).

6.3 Stocking

1) Conduct studies of egg and larval survival and development.

2) Determine biotic and abiotic mechanisms affecting the stock/recruitment relationship.

3) Examine early juvenile stages of anadomous alosines.

4) Develop a long-term mark or tag for juvenile American shad.

5) Develop stock ID procedures to permit identification of specific river stocks in mixed-stock intercept fisheries.

6) Conduct research to identify effective methods for restoration stocking programs.

7) Determine biotic effects of alosine stocking on other native species into previously restricted habitats.

6.4 Social and Economic Research Needs

Social data needs might include the following for consumptive and non-consumptive users: demographic information (e.g. age, gender, ethnicity/race, etc.), social structure information (e.g. historical participation, affiliation with NGOS, perceived conflicts, etc.), emic culture information (e.g. occupational motivation, cultural traditions related to resources use), and community information.

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d) ASMFC 2009 Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring

Atlantic States Marine Fisheries Commission

AMENDMENT 2 to the Interstate Fishery Management Plan For SHAD AND RIVER HERRING (River Herring Management)

ASMFC Vision Statement:
Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015.

Approved May 2009

Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring

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This Amendment was prepared under the guidance of the Atlantic States Marine Fisheries Commission's Shad and River Herring Management Board. Technical assistance was provided by the Shad and River Herring Technical Committee, the River Herring Stock Assessment Subcommittee, and the Shad and River Herring Advisory Panel.

Special assistance was provided by the following people: Robert Beal (ASMFC), Stacey Carlson (NMFS), Bryan Chikotas (Pennsylvania Fish and Boat Commission), Matt Cieri (Maine Department of Marine Resources), Tony Jarzynski (Maryland Department of Natural Resources), Amanda Johnson (National Marine Fisheries Service), Toni Kerns (ASMFC), Laura Lee (Virginia Marine Resources Commission), Nichola Meserve (ASMFC), Melissa Paine (ASMFC), Erika Robbins (ASMFC), Jessie Thomas (ASMFC), Brian Watson (Virginia Institute of Marine Science), and Alan Weaver (Virginia Division of Game and Inland Fisheries).

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1. INTRODUCTION

The Atlantic States Marine Fisheries Commission (Commission) is developing an amendment to its Interstate Fishery Management Plan for Shad and River Herring (FMP) under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA). Shad and river herring management authority lies with the coastal states and is coordinated through the Commission. Responsibility for compatible management action in the Exclusive Economic Zone (EEZ) from 3-200 miles from shore lies with the Secretary of Commerce through ACFCMA in the absence of a federal fishery management plan.

PLEASE NOTE: While the FMP is the management document for American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*), **this amendment pertains only to blueback herring and alewife.** The adoption of this amendment would not alter the monitoring requirements or fishery management measures for either American shad or hickory shad.

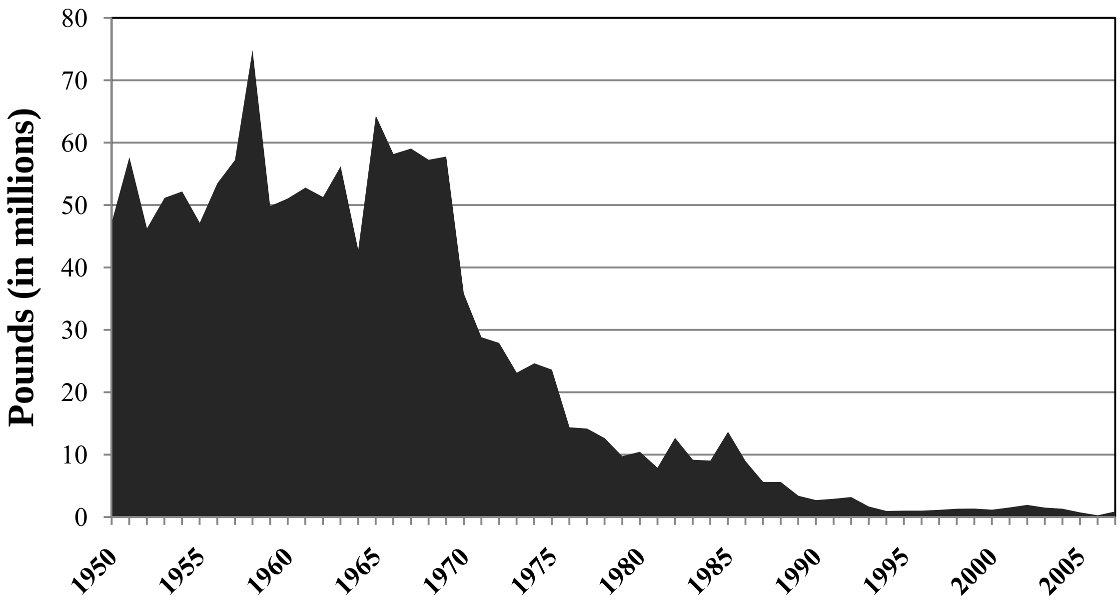
1.1 BACKGROUND INFORMATION

1.1.1 Statement of the Problem

Many populations of blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*), collectively known as *river herring*, have faced anthropogenic threats since colonial times, including fishing (commercial and recreational) and both habitat loss and degradation (e.g., dam construction, siltation, pollution). Stock assessments have identified that many populations of river herring along the Atlantic coast are in decline or are at depressed but stable levels (NC DMF 2006; Crecco and Gibson 1990); however, lack of fishery-dependent and independent data make it difficult to ascertain the status of river herring stocks coastwide. Based on available landings records from the National Marine Fisheries Service (NMFS), commercial landings dropped from 13.7 million pounds in 1985 to under a million pounds in 2007, which represents a difference of 93% (Figure 1; NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

The closure of river herring fisheries by Atlantic coastal states (i.e., Massachusetts, Rhode Island, Connecticut, Virginia and North Carolina) and observed declines in river herring abundance have led to questions about the adequacy of current management of the species to promote healthy fish stocks. Amendment 1 to the FMP states in its objectives that existing regulations for river herring fisheries “should keep fishing mortality sufficiently low to ensure survival and enhancement of depressed stocks and the maintenance of stabilized stocks” (ASMFC 1999); however, questions regarding mortality levels and whether they are low enough to prevent further stock declines have arisen. The Commission and the public have also expressed concern over the lack of monitoring of river herring populations, fisheries and bycatch. This document has been developed to address these questions and concerns.

Figure 1. Total (in-river and ocean) commercial landings (pounds) of river herring for the U.S. Atlantic coast, 1950-2007 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.). Note: Prior to 2000, NMFS landings do not differentiate between alewife and blueback herring and all river herring landings are listed as “alewife” landings.



1.1.2 Benefits of Implementation

Social and Economic Benefits

Maintaining the stability of the overall river herring population will enhance the economic and social benefits attributable to this population in Commission member states and the nation. Economic benefits would include use (e.g., consumptive use values related to commercial and recreational fishing) and non-use values (e.g., existence values) for current and future generations. The alternative state management (“conservation equivalency”) approach for river herring will also be beneficial because it facilitates flexibility for state fishery management agencies to address socioeconomic considerations within their own states while achieving conservation targets. Identifying monitoring requirements and research needs is critical. Considering the socioeconomic aspects of river herring management at the state and regional level should increase the likelihood of implementing or continuing those monitoring and research tasks.

1.1.2.1 Ecological Benefits[1]

During all life stages, river herring contribute greatly to the dynamics of food chains in freshwater, estuarine or marine habitats (Facey *et al*. 1986; MacKenzie *et al*. 1985; Weiss-Glanz *et al*. 1986). While at sea, river herring are prey for many species including sharks, tunas, mackerel and marine mammals, including porpoise and dolphin (ASMFC 1999; Weiss-Glanz *et al*. 1986). In fresh and brackish waters, American eel and striped bass consume both adult and juvenile alosines (Facey *et al*. 1986; Mansueti and Kolb 1953; Savoy and Crecco 1995; Walburg and Nichols 1967). Juvenile herring are high quality prey for largemouth bass (*Micropterus salmoides*); accelerated growth of young bass occurs when herring consumption is high (Yako *et al*. 2000). Tissues taken from predatory fish in tidal freshwaters following the residency of migrating alosines had between 35 and 84 percent of their carbon-biomass derived from marine sources (Garman and Macko 1998; MacAvoy *et al*. 2000). East Coast river herring, particularly populations in the southeast where post-spawning mortality is highest, likely provide nutrients and carbon into riverine systems, similar to nutrient dynamics provided by salmon in the Pacific Northwest (Freeman *et al*. 2003). For example, the James River, Virginia may have received annual biomass input from alosines of 155 kg/ha (138 pounds/acre) before dams blocked migrations above the fall line (Garman 1992).

More than 40 species of birds and mammals congregate to feed on migrating anadromous fish in southeastern Alaska (Willson and Halupka 1995; Willson *et al*. 1998). Similar relationships likely occur between East Coast river herring and birds and mammals (Steven Gephard, Connecticut Department of Environmental Protection, pers. comm.). Fish-eating birds like osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*), prey upon river herring (John W. McCord, South Carolina DNR, pers. comm.) and may have evolved their late winter and spring nesting strategies in response to the availability of food resources supplied by pre and post-spawning alosines. In addition, nutrients released from carcasses of post-spawning alosines can substantially subsidize aquatic food webs by stimulating productivity of bacteria and aquatic vegetation (Kline *et al*. 1993; Richey *et al*. 1975), thereby stimulating the assimilation of marine-derived nutrients into aquatic invertebrates and fish (Bilby *et al*. 1996).

1.2 DESCRIPTION OF THE RESOURCE

A comprehensive description of the Atlantic coast stocks of American shad, hickory shad, alewife, and blueback herring can be found in the 1985 Interstate Fishery Management Plan for Shad and River Herring and in the 2007 American shad stock assessment (ASMFC 2007). This section provides the basic information necessary to understand how anadromous alosines relate to their essential habitats and the significance of the commercial and recreational alosine fisheries to the economy and culture of the Atlantic coast.

[1] This section of the Amendment has been adapted from the South Carolina Department of Natural Resources website (http://www.dnr.sc.gov/cwcs/pdf/Alosid.pdf).

1.2.1 Alewife and Blueback Herring Life Histories

Alewife and blueback herring (collectively known as *river herring*) are anadromous fishes, spending most of their lives in ocean waters, migrating to their natal freshwater areas in the spring months to spawn. Alewife are most abundant in the mid-Atlantic and northeastern states. Blueback herring are found from Nova Scotia to northern Florida and are most abundant in waters from the Chesapeake Bay south (Scott and Scott 1988). Alewife generally spawn earlier than blueback herring in areas where both species occur. Alewife spawn in rivers, creeks, lakes and ponds, over rocks, detritus, submerged aquatic vegetation and sand. Blueback herring generally prefer to spawn over sand or gravel in swift-flowing areas of rivers and tributaries. In more southerly areas where both species exist, blueback herring utilize flooded back swamps, oxbows and stream edges for spawning. For both species, adults return to the ocean after spawning. Juveniles use the rivers and estuaries as nursery areas and migrate to the ocean as water temperatures decline in the fall. River herring reach sexual maturity at 3-6 years of age. Post-spawning mortality is highest in the states south of North Carolina as most populations are considered to be semelparous (i.e., spawn once and die). Little information is available on the life history of river herring once the juveniles emigrate to the ocean and until they return as mature adults to the freshwater areas to spawn.

1.2.2 River Herring Stock Assessment Summaries

1.2.2.1 Stock Assessment of River Herring from Selected Atlantic Coast Rivers – Crecco and Gibson 1990

Crecco and Gibson (1990) conducted the Commission's first assessment of Atlantic coastal river herring stocks. This assessment evaluated the status of six blueback herring stocks and nine alewife stocks between New Brunswick, Canada and North Carolina, USA using long-term commercial catch and effort, age composition, and relative abundance data for juveniles and adults. The assessment developed benchmark estimates of maximum sustained yield (MSY) and of fishing rates (μ) at MSY (μ_{msy}) and at stock collapse (μ_{coll}). Benchmark fishing rates were then compared to recent [prior to 1990] estimates of u. Stocks were considered overfished if the observed u exceeded μ_{msy} and severely overfished if μ exceeded u_{coll}. Stocks were considered fully exploited if u was within 75% of μ_{msy} and partially exploited if μ was less than 75% of μ_{msy}. Models were modified to include both in-river and ocean fishing to allow predictions of effects of change in ocean fishing on benchmark estimates for in-river fisheries in two blueback herring stocks.

To obtain benchmark estimates of MSY and μ, the 1990 assessment combined biomass-per-recruit (B/R) and yield-per-recruit (Y/R) from species specific (stocks combined) Thompson-Bell yield-per-recruit models with stock-specific Shepherd stock recruitment relationships to generate equilibrium spawning stock biomass, recruitment, and yield at a range of instantaneous fishing rates (F). Resulting curves were then used to identify MSY, F at MSY, and F at stock collapse. Instantaneous fishing mortality rates were then converted to estimates of μ_{msy} and μ_{coll} assuming a type I fishery.

Five stocks were determined to be overfished: St. John River alewife and blueback herring, Damariscotta River alewife, Potomac River (VA) alewife, and Chowan River alewife. Four stocks were determined to be experiencing recent stock declines, however, they were not overfished: Potomac River blueback herring, Chowan River blueback herring, Nanticoke River (MD) alewife, and Rappahannock River (VA) alewife (Table 1).

The assessment estimated ocean landings as constituting 20-30% of total river herring landings. This is contrary to Harris and Rulifson's 1989 paper that reports ocean landings from all Atlantic coast states as approximately 3% of total landings between 1978 and 1987. There are potential sources of discrepancy between landings from the coastal river herring fishery and the non-directed ocean fishery: (1) potential high discard mortality; (2) underreporting of total ocean river herring landings or overestimation of in-river landings; (3) computation of weight of ocean landings to numbers of fish could produce erroneous numbers because the ocean fishery harvests both juvenile and adult river herring; and (4) estimation of M too low.

The assessment reported that in all fisheries with depleted or overfished stocks there were significant weir or pound net fisheries. This led to the recommendation that additional conservation measures be adopted to reduce fishing mortality (F). Heavy fishing pressure in Maine, Virginia, and North Carolina were identified in the assessment as being primarily responsible for the continued decline of river herring stocks in the Damariscotta, Rappahannock, and Chowan rivers.

Table 1. Status of several blueback and alewife runs along the Atlantic coast based on data from the 1990 River Herring Stock Assessment. Classifications: *Severely Overfished* (μ exceeds μ_{coll}), *overfished* (μ exceeds μ_{msy}), *fully exploited* (u is within 75% of μ_{msy}), and *partially exploited* (u is less than 75% of μ_{msy}).

River	Species	Status	Stock Condition*
St. John, NB	Alewife	Severely Overfished	Severely Depleted
	Blueback Herring	Overfished	No Trend
Damariscotta, ME	Alewife	Severely Overfished	Severely Depleted
Lamprey, NH	Alewife	Partially Exploited	No Trend
Herring, MA	Alewife/Blueback Herring	Partially Exploited	No Trend
Annaquatucket, RI	Alewife	Partially Exploited	No Trend
Connecticut, CT	Blueback Herring	Partially Exploited	No Trend
Nanticoke, MD	Alewife	Fully Exploited	Severely Depleted
	Blueback Herring	Partially Exploited	No Trend
Potomac, VA	Alewife	Severely Overfished^	Severely Depleted
	Blueback Herring	Fully Exploited	Severely Depleted
Rappahannock, VA	Alewife	Partially Exploited	Severely Depleted
	Blueback Herring	Partially Exploited	No Trend
Chowan, NC	Alewife	Overfished	Severely Depleted
	Blueback Herring	Fully Exploited	Severely Depleted

**Severely depleted* was defined as at least a 50% decline in recent landings or juvenile indices relative to the landings and juvenile indices from the first five years of data.

1.2.2.2 2005 North Carolina Stock Assessment

An updated stock assessment on blueback herring and alewife was conducted in 2005 as part of Amendment 1 to North Carolina's River Herring Fishery Management Plan (NCRHFMP). Historically, river herring have been harvested in many systems in North Carolina; however, the main harvest component has been the Albemarle Sound area, primarily the Chowan River pound net fishery. Based on this information, the 2005 stock assessment update was based on data from the Albemarle Sound area and the Chowan River pound net fishery. Furthermore, blueback herring was used as the indicator species in development of Amendment 1 to the NCRHFMP.

Catch-at-age data from the Chowan River pound net fishery were used to estimate abundance and exploitation rates from 1972-2003. Cohort and annual catch curves provided mortality estimates, while a catch-at-age model incorporating a multinomial error distribution provided estimates of annual recruitment, abundance-at-age and fishing mortality. Bootstraping and log-likelihood profiling were used to evaluate the precision of model estimates (Grist 2005).

Past assessments of river herring stocks assume various levels of natural mortality. Crecco and Gibson (1990) use a value of 1.0 in the first Commission coastwide assessment of river herring stocks. A North Carolina Division of Marine Fisheries (NCDMF) assessment of the Chowan River blueback herring stock by Schaaf (1998) selects a natural mortality value of 0.3. Both the Hoenig (1983) and Pauly (1980) methods of estimating natural mortality yield estimates of 0.51 (Hilborn and Walters 1992) for blueback herring and alewife. The assumed instantaneous rate of natural mortality for the NCDMF 2005 assessment is 0.5 for blueback herring and alewife (Grist, 2005).

Estimated fishing mortality for blueback herring from 1972-1994 was 0.90 and except for 1995 and 1997, fishing mortality ranged from 0.98 in 1998 to 1.91 in 2003, with a corresponding exploitation ranging from 63 to 85%. Alewife estimated fishing mortality from 1972-1994 was 0.98 and except for 1995 and 1997, has ranged from 1.01 in 1998 to 1.86 in 2002, with corresponding exploitation rates ranging from 64 to 85%. The 1972-2003 average fishing mortality rates (based on catch curve analysis) for alewife and blueback herring were 1.27 and 1.17, respectively (Grist 2005).

Chowan River blueback herring and alewife recruitment are based on age-3 fish, considering this is the earliest age the fish are present in the catch. Blueback herring recruitment averaged 28.9 million fish per year from 1972-1985. Recruitment continued to fall, averaging 3.6 million fish since 1986, and declining further to an average of 552,000 fish from 1999-2003. Alewife recruitment averaged 7.5 million fish from 1972-1985, declining to 890,000 fish from 1986-2003. Recruitment averaged 317,000 fish from 1999-2003. Both alewife and blueback herring exhibit extreme variability in recruitment across years and any improvements in recruitment dissipated with high fishing mortality (Grist 2005).

Spawning stock biomass (SSB) estimates were made using mean weight-at-age, the estimated maturity schedule and estimated numbers-at-age from 1972-2003. Trends show a drastic decline for both species of river herring. Blueback herring SSB averaged 4.4 million pounds from 1972-1986, dropping to 1.0 million pounds in 1994 as a response to further declines in recruitment.

Blueback herring SSB reached a record low of 89,678 pounds in 2003. Alewife SSB declined rapidly during the early 1990s, with a record low of 10,862 pounds in 1995. Alewife SSB ranged from 1.1 million pounds to 3.1 million pounds from 1971 to 1988 and declined rapidly in early 1990s. From 1994-1999, alewife SSB averaged 22,953 pounds. The decline in SSB corresponds with historically low recruitment values in the 1990s. A slight increase in alewife SSB has been observed since 2000, however, the 2003 SSB value (92,442 pounds) was only 7.5% of the 1972-2003 SSB average (Grist 2005).

Based on information from the 2005 stock assessment, it was determined that river herring were overfished and overfishing was occurring. North Carolina adopted management measures in Amendment 1 of the NCRHFMP that included a "no-harvest" restriction (commercial and recreational) for river herring, with an annual research set-aside allocation of up to 7,500 pounds that is managed at the North Carolina Division of Marine Fisheries Director's discretion.

1.3 HABITAT CONSIDERATIONS

1.3.1 Alewife Habitat Description

The alewife (*Alosa pseudoharengus*) is an anadromous, highly migratory, euryhaline, pelagic, schooling species. The species spends the majority of its life at sea, returning to freshwater river systems along the Atlantic coast of the United States to spawn (ASMFC 1985). While most alewife are native-anadromous fish, some have been introduced to landlocked systems. Researchers examined two distant anadromous alewife stocks to test whether landlocked stocks were more closely related to St. Croix anadromous stocks or to more geographically distant anadromous stocks. Landlocked alewife were found to be distantly related to all the anadromous stocks tested. A variety of statistical tests confirmed that anadromous and landlocked populations of alewife in the St. Croix are genetically divergent (FST = 0.244). These results implied that very little, if any, interbreeding occurs between the two life history types (Bentzen and Paterson 2006; Willis 2006). Furthermore, significant genetic differences were observed between anadromous alewife populations in the St. Croix and anadromous populations in the LaHave and Gaspereau Rivers, as well as between the two anadromous St. Croix samples (Dennis Stream and Milltown). These results imply homing of alewives to their natal streams and, consequently, at least partial reproductive isolation between spawning runs, even at the level of tributaries within the St. Croix River (Willis 2006).

The historical coastal range of the anadromous alewife was from South Carolina to Labrador, Nova Scotia, and northeastern Newfoundland (Berry 1964; Winters *et al*. 1973; Burgess 1978). However, more recent surveys indicate that they do not currently occur in the southern range beyond North Carolina (Rulifson 1982; Rulifson *et al*. 1994). Alewife from the southernmost portion of the species' range migrate long distances (over 2000 km) in ocean waters of the Atlantic seaboard. Patterns of migration may be similar to those of American shad (*Alosa sapidissima*) (Neves 1981). Although alewife and blueback herring co-occur throughout much of their respective ranges, alewife are typically more abundant than blueback herring in the northern portion of their range (Schmidt *et al*. 2003).

Recent analyses to determine the current status of alewife in the Connecticut, Hudson, and Delaware River systems, suggest that alewife are showing signs of overexploitation (for example, lower mean age, fewer returning spawners, and lower overall abundance) in all of these rivers. However, researchers noted that recently some runs in the northeastern U.S. and Canada have shown increased alewife abundance (Schmidt *et al*. 2003). Furthermore, alewife appeared to be thriving in inland waters, colonizing many freshwater bodies, including all five Great Lakes (Waldman and Limburg 2003).

While this document will focus primarily on the anadromous alewife populations, much of the research on specific environmental requirements of alewife, such as temperature, dissolved oxygen, salinity, and pH, has been conducted on landlocked populations, not anadromous stocks; therefore data should be interpreted with discretion (Klauda *et al*. 1991a).

1.3.1.1 Spawning Habitat

Geographical and Temporal Patterns of Migration

The spring adult alewife migration to spawning grounds in freshwater and brackish water progresses seasonally from south to north, with populations further north returning later in the season as water temperatures rise. Neves (1981) suggested that alewife migrate from offshore waters north of Cape Hatteras, encountering the same thermal barrier as American shad. Alewife then move south along the Atlantic coast for fish homing to southern rivers, while northbound pre-spawning adults continue traveling up the coast (Stone and Jessop 1992). The species spawns in rivers, ponds, and lakes (lacustrine habitat), as far south as North Carolina and as far north as the St. Lawrence River, Canada (Neves 1981; S. Lary, U.S. Fish and Wildlife Service, per. comm.).

Alewife typically spawn from late February to June in the south, and from June through August in the north (Table 2; Marcy 1976b; Neves 1981; Loesch 1987). Spawning is triggered most predictably by a change in the water temperature. Movement upstream may be controlled by water flow, with increased movement occurring during higher flow periods (Collins 1952; Richkus 1974). However, extreme high flows can act as a velocity barrier delaying or preventing upstream migration and access to spawning habitat (S. Lary, U.S. Fish and Wildlife Service, pers. comm.).

Although adult alewife will move upstream at various times of the day, peak migration typically occurs between dawn and noon, and from dusk to midnight (Richkus 1974; Rideout 1974; Richkus and Winn 1979). Researchers have found that high midday movement is restricted to overcast days, and nocturnal movement occurs when water temperatures are abnormally high (Jones *et al*. 1978). Typically, males arrive before females at the mouths of spawning rivers (Cooper 1961; Tyus 1971; Richkus 1974).

Table 2. Reported spawning seasons for alewife along the Atlantic coast of North America.

State or region	Spawning season	Citations
Bay of Fundy tributaries	Late April or early May	Leim and Scott 1996; Dominy 1971
Gulf of St. Lawrence tributaries	Late May or early June	Leim and Scott 1996; Dominy 1971
Maine	Late April to mid-May	Rounsefell and Stringer 1943; Bigelow and Schroeder 1953; Havey 1961; Libby 1981
	Mid-May to mid-June	S. Lary, U.S. Fish and Wildlife Service, pers. comm.
Massachusetts	Early to mid-April	Belding 1921; Bigelow and Schroeder 1953
Mid-Atlantic and southern New England	Late March or early April	Cooper 1961; Kissil 1969; Marcy 1969b; Smith 1971; Saila *et al*. 1972; Richkus 1974; Zich 1978; Wang and Kernehan 1979
Chesapeake Bay region	Mid-March	Jones *et al*. 1978; Loesch 1987
North Carolina	Late February-late March	Holland and Yelverton 1973; Frankensteen 1976

There is strong evidence suggesting that alewife home to their natal rivers to reproduce; however, some individuals have been found to colonize new areas. Alternatively, alewife may reoccupy systems from which they have been extirpated (Havey 1961; Thunberg 1971; Messieh 1977; Loesch 1987). Messieh (1977) found that alewife strayed considerably to adjacent streams in the St. Johns River, Florida, particularly during the pre-spawning period (late winter, early spring), but not during the spawning run. It appears that olfaction is the primary means for homing behavior (Ross and Biagi 1990).

Spawning Location (Ecological)

Alewife select slow-moving sections of rivers or streams to spawn, where the water may be as shallow as 30 cm (Jones *et al*. 1978). The species may also spawn in lakes or ponds, including freshwater coves behind barrier beaches (Smith 1907; Belding 1921; Leim and Scott 1966; Richkus 1974; Colette and Klein-MacPhee 2002). In watersheds where dams are an impediment, spawning may occur in shore-bank eddies or deep pools below the dams (Loesch and Lund 1977). Additionally, in New England and Nova Scotia, alewife spawn in lakes and ponds located within coastal watersheds (Loesch 1987). For this reason, they are typically more abundant than blueback herring in rivers with abundant headwater ponds. In rivers where headwater ponds are absent or scarce, alewife are less abundant in headwater reaches; however, blueback herring utilize the mainstream proper for spawning in those systems (Ross and Biagi 1990). In tributaries of the Rappahannock River, Virginia, upstream areas were found to be more important than downstream areas for spawning alewife (O’Connell and Angermeier 1997). Although earlier studies suggested that alewife ascend further upstream than blueback herring (Hildebrand 1963; Scott and Crossman 1973), Loesch (1987) noted that both species have the ability to ascend rivers far upstream.

Boger (2002) found that river herring within the Rappahannock River watershed spawned in larger, elongated watersheds with greater mean elevation and greater habitat complexity. This researcher suggested that such areas are likely to have more stable base flows that can maintain suitable spawning habitat even during dry years. Additionally, spawning areas had a greater percentage of deciduous forest and developed areas and less grassland areas (Boger 2002).

Temporal Spawning Patterns

Alewife usually spawn 3 to 4 weeks before blueback herring in areas where they co-occur; however, there may be considerable overlap (Loesch 1987) and peak spawning periods may differ by only 2 to 3 weeks (Jones *et al*. 1978). In a tributary of the Rappahannock River, Virginia, O'Connell and Angermeier (1997) found that blueback herring eggs and larvae were more abundant than those of alewife, but alewife used the stream over a longer period of time. The researchers also reported a minor three-day overlap of spawning by these two alosine species. It has been hypothesized that alewife and blueback herring select separate spawning sites in sympatric areas to reduce competition (Loesch 1987). O'Connell and Angermeier (1997) reported that the two species used different spawning habitat due to a temporal, rather than spatial, segregation that minimizes the competition between the two species.

Alewife may spawn throughout the day, however, most spawning occurs at night (Graham 1956). One female fish and up to 25 male fish broadcast eggs and sperm simultaneously just below the surface of the water or over the substrate (Belding 1921; McKenzie 1959; Cooper 1961). Spawning lasts two to three days for each group or "wave" of fish that arrives (Cooper 1961; Kissil 1969; Kissil 1974), with older and larger fish usually spawning first (Belding 1921; Cooper 1961; Libby 1981, 1982). Following spawning, the adult spent fish quickly return downstream (Colette and Klein-MacPhee 2002).

Maturation and Spawning Periodicity

Many alewife are repeat spawners, with some individuals completing seven or eight spawning events in a lifetime (Table 3) (Jessop *et al*. 1983). It is not clear whether there is a clinal trend from south to north for repeat spawning (i.e., more in the north than south) (Klauda *et al*. 1991a), or if there is a typical percent of the annual return population that repeat spawns (i.e., 30 to 40% repeat spawners throughout their range) (Richkus and DiNardo 1984). Furthermore, Kissil (1974) suggested that alewife might spawn more than once in a season.

Table 3. Percentage of repeat spawners for alewife along the Atlantic coast of North America.

State	% Repeat Spawners	Citations
Nova Scotia	60%	O'Neill 1980
Maryland	30-72%	Weinrich *et al*. 1987; Howell *et al*. 1990
Virginia	61%	Joseph and Davis 1965
North Carolina	0.5-15.9%	K. Rawls, North Carolina Division of Marine Fisheries, pers. comm.

Adults will typically spend two to four years at sea before returning to their natal rivers to spawn (Neves 1981). The majority of adults reach sexual maturity at 3, 4, or 5 years of age, although some adults from North Carolina (Richkus and DiNardo 1984) have returned to spawn at age-2 (Jessop *et al*. 1983). The oldest alewife recorded in North Carolina were age-9 (Street *et al*. 1975; Johnson *et al*. 1979); age-10 fish have been caught in New Brunswick (Jessop *et al*. 1983) and Nova Scotia (O'Neill 1980). Additionally, Kissil (1974) found that alewife spawning in Bride Lake, Connecticut, spent three to 82 days on the spawning grounds, while Cooper (1961) reported that most fish left within five days of spawning in Rhode Island.

Spawning Salinity Association

While it is known that alewife can adjust to a wide range of salinities, published data on alewife tolerance ranges are lacking (Klauda *et al*. 1991a). Richkus (1974) found that adults that were transferred from freshwater to saline water (32 ppt), and vice versa, experienced zero mortality. In the north, Leim (1924) studied the life history of American shad and noted that they do not ascend far beyond the tidal influence of the river, yet alewife migrate as far upstream as they can travel. He concluded that alewife may be less dependent on saltwater for development (Leim 1924). Also, unlike American shad, some populations of alewife have become landlocked and are not at all dependent on saltwater (Scott and Crossman 1973).

Spawning Substrate Association

The spawning habitat of alewife can range from sand, gravel, or coarse stone substrates, to submerged vegetation or organic detritus (Edsall 1964; Mansueti and Hardy 1967; Jones *et al*. 1978). Boger (2002) found that river herring spawning areas along the Rappahannock River, Virginia, had substrates that consisted primarily of sand, pebbles, and cobbles (usually associated with higher-gradient streams). In contrast, areas with little or no spawning activity were dominated by organic matter and finer sediments (usually associated with lower-gradient streams and comparatively more agricultural land use) (Boger 2002).

Pardue (1983) evaluated studies of cover component in alewife spawning areas, suggesting that substrate characteristics and associated vegetation were a measure of the ability of a habitat to provide cover to spawning adults, their eggs, and developing larvae. In high flow areas, there is little accumulation of vegetation and detritus, while in low flow areas, detritus and silt accumulate and vegetation has the opportunity to grow (Pardue 1983). Pardue (1983) suggested that substrates with 75% silt (or other soft material containing detritus and vegetation) and sluggish waters are optimal for alewife**.**

Spawning Depth

Water depth in spawning habitat may be a mere 15 cm deep (Bigelow and Schroeder 1953; Rothschild 1962), or as deep as 3 m (Edsall 1964); however, spawning typically occurs at less than 1 m (Murdy *et al*. 1997). Adults may utilize deeper water depths when not spawning in order to avoid high light intensities (Richkus 1974).

Spawning Water Temperature

Adult alewife have been collected in temperatures ranging from 5.7°C to 32°C (Marcy 1976b; Jones *et al*. 1978). Spawning temperatures along the Atlantic coast fall within this broader range (Table 4). There is some discrepancy regarding the minimum spawning temperature for alewife. Although running ripe fish of both sexes have been reported at temperatures as low as 4.2°C in the Chesapeake Bay area (Mansueti and Hardy 1967), some researchers suggest that the minimum spawning temperature for adult alewife is 10.5°C (Cianci 1965; Loesch and Lund 1977). Additionally, lower temperatures may be dangerous for spawning alewife. Otto *et al*. (1976) found that the lower incipient lethal temperature range for adults acclimated at 15.0°C and 21.0°C was between 6°C and 8°C. In this study, no fish survived below 3°C, regardless of acclimation temperature (Otto *et al*. 1976). Furthermore, at temperatures below 4.5°C, normal schooling behavior was significantly reduced for adult alewife from Lake Michigan (Colby 1973).

Table 4. Alewife spawning temperatures for locations along the Atlantic coast of North America.

Location	Temperature (ºC)	Citation
Rhode Island	14.0 – 15.5 (peak)	Jones *et al*. 1978
Lower Connecticut River	7.0 – 10.9	Marcy *et al*. 1976a
Chesapeake Bay	10.5 – 21.6	Jones *et al*. 1978
Patuxent River, MD	11 – 19	J. Mowrer, Morgan State University, unpublished data
Lake Mattamuskeet, NC	13 (peak)	Tyrus 1974

As water temperatures rise, alewife migration eventually slows. Cooper (1961) noted that upstream migration ceased in a Rhode Island stream when temperatures reached 21°C, while Edsall (1970) reported that spawning ceases altogether at 27.8°C. Ultimately, higher temperatures may cause problems for alewife. In fact, Otto *et al*. (1976) found that upper incipient lethal temperatures (temperature at which 50% of the population survives) ranged from 23.5°C to 24.0°C for adults that were acclimated at temperatures of 10°C, 15°C, and 20°C.

Another study reported upper incipient lethal temperatures of 29.8°C and 32.8°C at acclimation temperatures of 16.9°C and 24.5°C, respectively (Stanley and Holzer 1971). In addition, McCauley and Binkowski (1982) reported upper incipient lethal temperatures of 31°C to 34°C after acclimation at 27°C for a northern population of adults.

In general, alewife may prefer cooler water, and northern populations may be more cold tolerant than other migratory anadromous fish (Stone and Jessop 1992). Richkus (1974) showed that the response of migrating adults to a particular hourly temperature was determined by their relationship to a changing baseline temperature, and not on the basis of the absolute value of temperature. Stanley and Colby (1971) found that decreasing temperatures (from 16°C to 3°C at a rate of 2.5°C per day) reduced adult alewife ability to osmoregulate. Adults were also shown to survive temperature decreases of 10°C, regardless of acclimation temperature, if the temperature did not drop below 3°C (Otto *et al*. 1976).

Spawning Dissolved Oxygen Associations

There is little information regarding sensitivities of various life history stages of alewife to dissolved oxygen (Klauda *et al*. 1991a). In one study, adults exposed to dissolved oxygen concentrations ranging from 2.0 to 3.0 mg/L for 16 hours in the laboratory experienced a 33% mortality rate. Alewife were able to withstand dissolved oxygen concentrations as low as 0.5 mg/L for up to 5 minutes, as long as a minimum of 3.0 mg/L was available, thereafter (Dorfman and Westman 1970). Additionally, Jones *et al*. (1988) suggested that the minimum dissolved oxygen concentration for adult alewife is 5.0 mg/L.

Spawning pH Association

Few researchers have reported on pH sensitivity in alewife (Klauda *et al*. 1991a). Byrne (1988) found that the average pH level was 5.0 in several streams in New Jersey where alewife spawning was known to occur. Laboratory tests found that fish from those streams could successfully spawn at a pH as low as 4.5 (Byrne 1988). In another study, adult alewife tolerated a pH range of 6.5 to 7.3 (Collins 1952). When aluminum pulses were administered in the laboratory, critical conditions for spawning could occur during an acidic pulse between pH 5.5 and 6.2, with concomitant concentrations of total monomeric aluminum ranging from 15 to 137 µg/L for a pulse duration of 8 to 96 hours (Klauda 1989). Klauda *et al*. (1991a) suggested a pH range of 5 to 8.5 as suitable for alewife eggs, but no range was provided for spawning.

Spawning Water Velocity/Flow

Increased movement upstream occurs during higher water flows (Collins 1952; Richkus 1974), while spawning typically takes place in quiet, slow-moving waters for alewife (Smith 1907; Belding 1921; Marcy 1976a). Some researchers have noted differential selection of spawning areas in alewife. For example, in Connecticut, alewife choose slower moving waters in Bride Lake (Kissil 1974) and Higganum and Mill creeks, while blueback herring select fast-moving waters in the upper Salmon River and Roaring Brook (Loesch and Lund 1977). In other areas where alewife and blueback herring are forced to spawn in the same vicinity due to blocked passage (Loesch 1987), alewife generally spawn along shorebank eddies or deep pools, whereas, blueback herring will typically select the main stream flow for spawning (Loesch and Lund 1977). In North Carolina, alewife utilize slow moving streams and oxbows (Street *et al*. 2005).

Feeding Behavior

Adult alewife typically do not feed during their upstream spawning run (Bigelow and Schroeder 1953; Colby 1973). Spent fish that have reached brackish waters on their downstream migration will feed voraciously, mostly on mysids (Colette and Klein-MacPhee 2002). While adults may consume their own eggs during the spawning run (Edsall 1964; Carlander 1969), juveniles reportedly feed more actively on them (Colette and Klein-MacPhee 2002).

Competition and Predation

Adult alewife and blueback herring play an important role in the food web and in maintaining the health of the ecosystem. In the inland freshwater and coastal marine environments they provide forage for bass, trout, salmonids, other fish, ospreys, herons, eagles, kingfishers, cormorants, and aquatic fur-bearing mammals (Colby 1973; Royce 1943; Scott and Scott 1988; Loesch 1987; S. Lary, U.S. Fish and Wildlife Service, pers. comm.). In the marine environment, they are eaten by a variety of predators, such as bluefish, weakfish, striped bass, cod, pollock, and silver hake, as well as marine mammals and sea birds. Additionally, alewife are a host to some species of native freshwater mussels, and are essential to upstream movement of mussels through transport of parasitic glochidia. Furthermore, spawning alewife heading upriver give cover to out-migrating Atlantic salmon smolts in the spring (S. Lary, U.S. Fish and Wildlife Service, pers. comm.).

Erkan (2002) notes that predation of alosines has increased dramatically in Rhode Island rivers in recent years, especially by the double-crested cormorant, which often takes advantage of fish staging near the entrance to fishways. Populations of nesting cormorant colonies have increased in size and expanded into new areas. Predation by otters and herons has also increased, but to a lesser extent (D. Erkan, Rhode Island Department of Environmental Management, pers. comm.).

In many coastal communities, the annual alewife run is an integral part of the local culture, and local residents have initiated efforts to protect and restore their cultural link to this fishery, to develop effective management strategies for restoration, to establish self-sustaining harvest levels, and to enhance community education (S. Lary, U.S. Fish and Wildlife Service, pers. comm.).

1.3.1.2 Egg and Larval Habitat

Geographical and Temporal Movement Patterns

Fertilized eggs remain demersal and adhesive for several hours (Mansueti 1956; Jones *et al*. 1978), after which they become pelagic and are transported downstream (Wang and Kernehan 1979). Marcy (1976a) observed eggs more often near the bottom than at the surface in the Connecticut River. Eggs may hatch anywhere from 50 to 360 hours (2 to 15 days) after spawning, depending on water temperature (Fay *et al*. 1983); however, eggs most often hatch within 80 to 95 hours (3 to 5 days) (Edsall 1970).

Within two to five days of hatching, the yolk-sac is absorbed and larvae begin feeding exogenously (Cianci 1965; Jones *et al*. 1978). Post-yolk-sac larvae are positively phototropic (Odell 1934; Cianci 1965). Dovel (1971) observed larvae near or slightly downstream of presumed spawning areas in the Chesapeake Bay, where the water was less than 12 ppt salinity (Dovel 1971). Larvae were also found in or close to observed spawning areas in Nova Scotia rivers in relatively shallow water (2 m) over sandy substrate (O'Neill 1980).

Eggs, Larvae, and Water Velocity/Flow

Sismour (1994) observed a rapid decline in abundance of early preflexion river herring larvae in the Pamunkey River, Virginia, following high river flow in 1989. This observation lead to speculation that high flow leads to increased turbidity, which reduces prey visibility, leading to starvation of larvae (Sismour 1994). Additionally, O'Connell and Angermeier (1997) found that current velocity and dissolved oxygen were the strongest predictors of alewife early egg presence in a Virginia stream. Further north, drought conditions in Rhode Island in the summer of 1981 were strongly suspected of impacting the 1984-year class, which was only half of its expected size (ASMFC 1985). In tributaries of the Chowan system, North Carolina, water flow was related to recruitment of larval river herring (O'Rear 1983).

Egg and Larval Predation

Alewife eggs may be consumed by yellow perch, white perch, spottail shiner, and other alewife (Edsall 1964; Kissil 1969). Alewife larvae are preyed upon by both vertebrate and invertebrate predators (Colby 1973).

1.3.1.3 Juvenile Riverine/Estuarine Habitat

Geographical and Temporal Movement Patterns

In North Carolina, juveniles may spend the summer in the lower ends of rivers where they were spawned (Street *et al*. 1975). In the Chesapeake Bay, juveniles can be found in freshwater tributaries in spring and early summer, but may head upstream in mid-summer when saline waters encroach on their nursery grounds (Warriner *et al*. 1970). Some juveniles in the Chesapeake Bay remain in brackish water through the summer (Murdy *et al*. 1997).

Further north, juveniles in the Hudson River usually remain in freshwater tributaries until June (Schmidt *et al*. 1988). In contrast to the inshore abundance of American shad and blueback herring during the day, juvenile alewife were found to be most abundant in inshore areas at night in the Hudson River (McFadden *et al*. 1978; Dey and Baumann 1978). Hudson River juveniles were observed in shallow portions of the upper and middle estuary in late June and early July, where they remained for several weeks before moving offshore (Schmidt *et al*. 1988). Alewife typically spend three to nine months in their natal rivers before returning to the ocean (Kosa and Mather 2001).

In the summer in the Potomac River, juveniles are abundant near surface waters during the day; however, they shift to mid-water and bottom depths in September, where they remain until they emigrate in November (Warriner *et al*. 1970). Juvenile alewife respond negatively to light and follow diel movement patterns similar to blueback herring. Nevertheless, there appears to be some separation between the alewife and blueback herring as they emigrate from nursery grounds in the fall. The difference occurs most notably at night when alewife can be found more frequently at mid-water depths, while blueback herring are found mostly at the surface (Loesch and Kriete 1980). This behavior may reduce inter-specific competition for food, given that the species' diets are similar (Davis and Cheek 1966; Burbidge 1974; Weaver 1975).

Once water temperatures begin to drop in the late summer through early winter (depending on geographic area), juveniles start heading downstream, initiating their first phase of seaward migration (Pardue 1983; Loesch 1987). Some researchers have found that movement of alewife peaks in the afternoon (Richkus 1975a; Kosa and Mather 2001), while others have found that it peaks at night (Stokesbury and Dadswell 1989). Migration downstream is also prompted by changes in water flow, water levels, precipitation, and light intensity (Cooper 1961; Kissil 1974; Richkus 1975a, 1975b; Pardue 1983). Other researchers have suggested that water flow plays only a minor role in providing migration cues under riverine conditions. Rather, these researchers think that migration timing is triggered by water temperature and moon phases that provide dark nights (i.e., new and quarter moons) (O'Leary and Kynard 1986; Stokesbury and Dadswell 1989). Additionally, Stokesbury and Dadswell (1989) found that alewife remained in the offshore region of the Annapolis estuary, Nova Scotia, for nearly one month before the correct migration cues triggered emigration. Furthermore, large juveniles begin moving downstream before smaller juveniles (Schmidt *et al*. 1988), inhabiting saline waters before they begin their seaward migration (Loesch 1969; Marcy 1976a; Loesch and Kriete 1980).

The influence and magnitude of migration cues on emigrating alewife may vary considerably. Richkus (1975a) observed waves of juvenile alewife leaving systems following environmental changes (e.g., changes in water flow, water levels, precipitation, and light intensity), but the number of fish leaving was unrelated to the level of magnitude of the change. Most fish (60% to 80%) emigrated during a small percentage (approximately 8%) of available days. These waves also lasted two to three days, regardless of the degree of environmental change (Richkus 1975a). Similarly, other researchers have observed that the majority (>80%) of river herring emigrate in waves (Cooper 1961; Huber 1978; Kosa and Mather 2001). Richkus (1975a) also noted that in some instances, high abundances of juvenile alewife might trigger very early (i.e., summer) emigration of large numbers of small juveniles from the nursery area, which is likely a response to a lack of forage. Additionally, juvenile migration of alewife occurs about one month earlier than that of blueback herring (Loesch 1969; Kissil 1974).

Although most juveniles emigrate offshore during their first year, some over-winter in the Chesapeake (Hildebrand 1963) and Delaware bays (Smith 1971). Marcy (1969b) suggested that many juveniles (age-1+) spend their first winter close to the mouth of their natal river due to their presence in the lower portion of the Connecticut River in early spring. Other researchers concur that some juvenile alewife may remain in deep estuarine waters through the winter (Hildebrand and Schroeder 1928). There is some indication that alewife in northern states may remain in inshore waters for one to two years (Walton 1981). Conversely, since juvenile river herring cannot survive water temperatures of 3°C or below (Otto *et al*. 1976), they likely do not over-winter in coastal systems where temperatures are below 3°C (Kosa and Mather 2001).

Juveniles and the Saltwater Interface

Richkus (1974) reported that juvenile alewife that were transferred from freshwater to saline water (32 ppt), and vice versa, experienced zero mortality. Juvenile alewife in the upper Chesapeake Bay were found in salinities ranging from 0 to 8 ppt, but most (82%) were collected from freshwater (Dovel 1971). Furthermore, Pardue (1983) suggested that salinities less than or equal to 5 ppt are optimal for juveniles of this species.

Juvenile Water Temperature Associations

Temperature tolerance range estimates for juvenile alewife vary somewhat between researchers (Table 5). Dovel (1971) found that ninety-eight percent of juvenile alewife in the upper Chesapeake Bay were collected at 25°C.

Table 5. Juvenile alewife temperature tolerances/preferences along the Atlantic coast.

Characterization	Acclimation Temp (°C)	Temp Range (°C)	Location	Citation
Optimal	N/A	15 - 20	Many	Pardue 1983
Suitable	N/A	10 - 28	Many	Klauda *et al*. 1991a
Present	N/A	4 - 27	Upper Chesapeake Bay	Dovel 1971
Present	N/A	13.5 – 29.0	Cape Fear River, NC	Davis and Cheek 1966
Avoidance	26	>34	Delaware River	PSECG 1984
Preferred	15 - 21	17 – 23 (at 4 – 7 ppt)	Delaware River	Meldrim and Gift 1971; PSE&G 1982
Preferred	15 - 18	25.0	Lake Michigan	Otto *et al*. 1976

According to McCauley and Binkowski (1982), the upper lethal temperature for juvenile alewife is approximately 30°C. Concurrently, in Lake Michigan, upper incipient lethal limits (i.e., temperature at which 50% of the population survives) for young-of-the-year alewife acclimated to 10°C, 20°C, and 25°C, was estimated to be slightly less than 26.5°C, 30.3°C, and 32.1°C, respectively (Otto *et al*. 1976). Another study found that juveniles exposed to water at 35°C for 24 hours, after acclimation to water at 18.9 to 20.6°C, had a 20% survival rate (Dorfman and Westman 1970). Moreover, young-of-the-year alewife seem to have critical thermal maxima (CTM) that are 3 to 6°C higher than adults (Otto *et al*. 1976).

Alternatively, when juvenile alewife were subjected to decreasing temperatures (15.6°C down to 2.8°C) over the course of 15 days, they suffered greater than 90% mortality (Colby 1973). In another study, juvenile alewife exposed to 9°C, following acclimation at 20°C in 5.5 ppt salinity, suffered no mortality. However, when the temperature was decreased to 7°C for 96 h, they suffered 27 to 60% mortality (PSE&G 1984). Comparatively, the lower limit at which juvenile river herring are unable to survive is 3°C or less (Otto *et al*. 1976).

Juveniles and Water Velocity/Flow

Water discharge is an important variable influencing relative abundance and emigration of juvenile alewife. Extremely high discharges may adversely affect juvenile emigration, and high or fluctuating discharges may lead to a decrease in the relative abundance of adults and juveniles (Kosa and Mather 2001). Laboratory experiments suggest that juvenile alewife avoid water velocities greater than 10 cm/s, especially in narrow channels (Gordon *et al*. 1992). In large rivers where greater volumes of water can be transported per unit of time without substantial increases in velocity, the effects of discharge may differ (Kosa and Mather 2001).

Kissil (1974) observed juvenile alewife leaving Lake Bride, Connecticut, between June and October; they noted especially high migration occurring during times of heavy water flow. These results are consistent with Cooper's (1961) observations that 98% of juveniles left after periods of heavy rainfall. Huber (1978) also noted that juvenile emigration in the Parker River, Massachusetts, was triggered by an increase in water flow. Furthermore, Jessop (1994) found that the juvenile abundance index (JAI) of alewife decreased with mean river discharge during the summer. Daily instantaneous mortality also increased with mean river discharge from July to August at the Mactaquac Dam headpond on the Saint John River, New Brunswick, Canada (Jessop 1994).

Juvenile Feeding

Juvenile alewife are opportunistic feeders that usually favor seasonally available items (Gregory *et al*. 1983). For example, in the Hamilton Reservoir, Rhode Island, juveniles feed primarily on dipteran midges in July, and cladocerans in August and September (Vigerstad and Colb 1978). Juveniles either select their prey individually or switch to a non-selective filter-feeding mode, which is a behavior utilized more at night (Janssen 1976). Grabe (1996) found that juvenile alewife fed on chironomids, odonates, and other amphipods during the day and early evening hours in the Hudson River. Juveniles have also been observed consuming epiphytic fauna especially at night (Weaver 1975; Grabe 1996). Juveniles may also feed extensively on benthic organisms, including ostracods, chironomid larvae, and oligochaete worms (Watt and Duerden 1974).

The number of zooplankton per liter consumed is assumed to be critical for the survival and growth of juvenile alewife. Pardue (1983) suggests that habitats containing 100 or more zooplankton per liter are optimal. Walton (1987) found that juvenile alewife abundance in Damariscotta Lake, Maine, was controlled by competition for zooplankton, rather than parental stock abundance and recruitment. It has been suggested that clupeids evolved to synchronize the larval stage with the optimal phase of annual plankton production cycles (Blaxter and Hunter

1982). In addition, Morsell and Norden (1968) found that juvenile alewife consume zooplankton until they reach 12 cm TL, and may then switch to increasing amounts of the benthic amphipod Pontoporeia sp. Several researchers (Vigerstad and Colb 1978; O'Neill 1980; Yako 1998) hypothesize that a change in food availability may provide a cue for juvenile anadromous herring to begin emigrating seaward, but no causal link has been established.

Unfortunately, invasive species may threaten food sources for alewife. There is strong evidence that juveniles in the Hudson River have experienced a reduced forage base as a result of zebra mussel colonization (Waldman and Limburg 2003).

Juvenile Competition and Predation

It is often noted throughout the literature that alewife and blueback herring co-exist in the same geographic regions, yet inter-specific competition is often reduced through several mechanisms. For example, juveniles of both species may consume different sizes of prey (Crecco and Blake 1983). Juvenile alewife in the Minas Basin, Nova Scotia, Canada, favor larger benthic prey (particulate-feeding strategy) compared to juvenile blueback herring (filter-feeding strategy) (Stone 1985; Stone and Daborn 1987). In the Cape Fear River, North Carolina, juvenile alewife consume more ostracods, insect eggs, and insect parts than blueback herring (Davis and Cheek 1966).

Alewife also spawn earlier than blueback herring, thereby giving juvenile alewife a relative size advantage over juvenile bluebacks, allowing them a larger selection of prey (Jessop 1990). Differences in juvenile diel feeding activity further reduce competition. One study noted that diurnal feeding by juvenile alewife was bimodal, with peak consumption about one to three hours before sunset and a minor peak occurring about two hours after sunrise (Weaver 1975). In comparison, juvenile blueback herring begin to feed actively at dawn, increasing throughout the day and maximizing at dusk, then diminishing from dusk until dawn (Burbidge 1974).

With regard to predation, juvenile alewife are consumed by American eel, white perch, yellow perch, grass pickerel, largemouth bass, pumpkinseed, shiners, walleye and other fishes, as well as turtles, snakes, birds, and mink (Kissil 1969; Colby 1973; Loesch 1987). In the estuarine waters of Maine, juvenile bluefish prey heavily on alewife (Creaser and Perkins 1994). In Massachusetts's rivers, juvenile alewife are energetically valuable and a key food source for largemouth bass during late summer (Yako *et al*. 2000).

1.3.1.4 Late Stage Juvenile and Adult Marine Habitat

Geographical and Temporal Movement Patterns

Some young-of-the-year alewife over-winter in deep, high salinity areas of the Chesapeake Bay (Hildebrand and Schroeder 1928). Dovel (1971) reported juvenile populations in the upper Chesapeake Bay that did not emigrate until early spring of their second year. Milstein (1981) found that juvenile alewife over-wintered in waters approximately 0.6 to 7.4 km from the shore of New Jersey, at depths of 2.4 to 19.2 m, in what is considered an offshore estuary. This area is warmer with higher salinity than the cooler, lower salinity river-bay estuarine nurseries where alewife reside in fall. The majority of alewife are present in March when bottom temperatures range from 4.4 to 6.5°C and salinity is between 29.0 and 32.0 ppt (Cameron and Pritchard 1963).

Young alewife have been found over-wintering off the North Carolina coast from January to March, concentrated at depths of 20.1 to 36.6 m (Holland and Yelverton 1973; Street *et al*. 1973). However, other sources have noted that juvenile alewife tend to remain near the surface during their first year in saltwater (Bigelow and Schroeder 1953). In Lake Michigan, age-1 fish are usually pelagic, except in spring and fall, where they often occur on the bottom; age-2 fish are typically found on the bottom (Wells 1968).

Information on the life history of young-of-the-year and adult alewife after they emigrate to the sea is sparse (Klauda *et al*. 1991a). Sexual maturity of alewife is reached at a minimum of age-2, but timing may vary regionally. In North Carolina, sexual maturity occurs mostly at age-3. In Connecticut, most males achieve maturity at age-4, and most females at age-5 (Jones *et al*. 1978). It is generally accepted that juveniles join the adult population at sea within the first year of their lives and follow a north-south seasonal migration along the Atlantic coast, similar to that of American shad (Neves 1981). Despite a lack of conclusive evidence, it is thought that alewife are similar to other anadromous clupeids in that they may undergo seasonal migrations within preferred isotherms (Fay *et al*. 1983). In fact, alewife typically migrate in large schools of similar sized fish, and may even form mixed schools with other herring species (Colette and Klein-MacPhee 2002).

During spring, alewife from the Mid-Atlantic Bight move inshore and north of 40° latitude to Nantucket Shoals, Georges Bank, coastal Gulf of Maine, and the inner Bay of Fundy. Commercial catch data indicates that alewife are most frequently caught on Georges Bank and south of Nantucket Shoals (Neves 1981; Rulifson *et al*. 1987). Distribution in the fall is similar to the summer, but alewife concentrate along the northwest perimeter of the Gulf of Maine. In the fall, individuals move offshore and southward to the mid-Atlantic coast between latitude 40°N and 43°N, where they remain until early spring (Neves 1981). It is not known to what extent alewife over-winter in deep water off the continental shelf, but they have rarely been found more than 130 km from the coast (Jones *et al*. 1978).

Alewife also experience diel movement patterns. At sea alewife are more available to bottom trawling gear during the day, suggesting that they follow the diel movement of plankton in the water column and are sensitive to light (Neves 1981). It also seems that feeding and vertical migration are likely controlled by light intensity patterns within thermal preference zones (Richkus and Winn 1979; Neves 1981).

Results from Canadian spring surveys show river herring distributed along the Scotian Gulf, southern Gulf of Maine, and off southwestern Nova Scotia from the Northeast Channel to the central Bay of Fundy; they are found to a lesser degree along the southern edge of Georges Bank and in the canyon between Banquereau and Sable Island Banks (Stone and Jessop 1992). A large component of the over-wintering population on the Scotian Shelf (and possibly some of the U.S. Gulf of Maine population) moves inshore during spring to spawn in Canadian waters. Summer aggregations of river herring in the Bay of Fundy/eastern Gulf of Maine may consist of a mixture of stocks from the entire Atlantic coast, as do similar aggregations of American shad (Dadswell *et al*. 1987). However, based on commercial offshore catches by foreign fleets in the late 1960s, it was believed that coastal river herring stocks did not mingle to the extent that American shad stocks apparently did, at least during the seasons that foreign harvests were made (ASMFC 1985).

Adults and the Saltwater Interface

As noted above, young-of-the-year alewife have been found over-wintering offshore of New Jersey, where salinities range from 29.0 to 32.0 ppt (Milstein 1981). For sub-adults and non-spawning adults that remain in the open ocean, they will reside in full strength seawater. Since alewife may follow a north-south seasonal migration along the Atlantic coast similar to that of American shad (Neves 1981), and pre-spawning adult American shad may detour into estuaries (Neves and Depres 1979), alewife may inhabit more brackish waters during migration.

Depth Associations at Sea

National Marine Fisheries Service catch data found that in offshore areas, alewife were caught most frequently in waters with depths of 56 to 110 m. The vertical position of alewife in the water column may be influenced by zooplankton concentrations (Neves 1981). Zooplankton usually concentrate at depths <100 m in the Gulf of Maine (Bigelow 1926). Stone and Jessop (1992) found that alewife offshore of Nova Scotia, the Bay of Fundy, and the Gulf of Maine, were at depths of 101 to 183 m in the spring; they were in shallower nearshore waters (46 to 82 m) in the summer, and in deeper offshore waters (119 to 192 m) in the fall.

Stone and Jessop (1992) also found differences in depth distribution between smaller fish (sexually immature) and larger fish. Smaller fish occurred in shallow regions (<93 m) during spring and fall, while larger fish were found in deeper areas (≥93 m) throughout the year (Stone and Jessop 1992). Furthermore, Jansen and Brandt (1980) reported that the nocturnal depth distribution of adult landlocked alewife differed by size class, with the smaller fish present at shallower depths.

Interestingly, in coastal waters juvenile alewife are found in deeper water than blueback herring despite their identical diets (Davis and Cheek 1966; Burbidge 1974; Watt and Duerden 1974; Weaver 1975).

Adult Water Temperature Associations

From Cape Hatteras to Nova Scotia, alewife have been caught offshore where surface water temperatures ranged from 2 to 23°C and bottom water temperatures ranged from 3 to 17°C. Catches in this area were most frequent where the average bottom water temperature was between 4 and 7°C (Neves 1981). Stone and Jessop (1992) reported a temperature range of 7 to 11°C for alewife in the northern range off Nova Scotia, the Bay of Fundy, and the Gulf of Maine. The researchers also noted that the presence of a cold (<5°C) intermediate water mass over warmer, deeper waters on the Scotian Shelf, where the largest catches of river herring occurred, may have restricted the extent of vertical migration during the spring. Since few captures were made where bottom temperatures were <5°C, vertical migration may have been confined by a water temperature inversion in this area during the spring (Stone and Jessop 1992).

Alewife may prefer and be better adapted to cooler water than blueback herring (Loesch 1987; Klauda *et al*. 1991a). Northern populations may also exhibit more tolerance to cold temperatures (Stone and Jessop 1992). Additionally, antifreeze activity was found in blood serum from an alewife off Nova Scotia, but not in any captured in Virginia (Duman and DeVries 1974).

Feeding at Sea

At sea, alewife feed largely on particulate zooplankton including euphausiids, calanoid copepods, mysids, hyperiid amphipods, chaetognaths, pteropods, decapod larvae, and salps (Edwards and Bowman 1979; Neves 1981; Vinogradov 1984; Stone and Daborn 1987; Bowman *et al*. 2000). Alewife also consume small fishes, including Atlantic herring, other alewife, eel, sand lance, and cunner (Colette and Klein-MacPhee 2002). They feed either by selectively preying on individuals or non-selectively filter-feeding with gill rakers. Feeding mode depends mostly on prey density, prey size, and water visibility, as well as size of the alewife (Janssen 1976, 1978a, 1978b). In Minas Basin, Bay of Fundy, alewife diets shift from micro-zooplankton in small fish to mysids and amphipods in larger fish. Feeding intensity also decreases with increasing age of fish (Stone 1985).

Alewife generally feed most actively during the day; nighttime predation is usually restricted to larger zooplankton that are easier to detect (Janssen 1978; Janssen and Brandt 1980; Stone and Jessop 1993). In Nova Scotia, alewife feeding peaks at midday during the summer and mid-afternoon during the winter. Alewife also have a higher daily ration in the summer than in the winter (Stone and Jessop 1993). Although direct evidence is lacking, alewife catch in specific areas along Georges Bank, the perimeter of the Gulf of Maine, and south of Nantucket Shoals, may be related to zooplankton abundance (Neves 1981).

Competition and Predation at Sea

Schooling fish such as bluefish, weakfish, and striped bass, prey upon alewife (Bigelow and Schroeder 1953; Ross 1991). Other fish such as dusky shark, spiny dogfish, Atlantic salmon, goosefish, cod, pollock, and silver hake, also prey on alewife (Bowman *et al*. 2000; R. Rountree, University of Massachusetts, unpublished data). Of these species, spiny dogfish appears to have the greatest affinity for alewife (R. Rountree, University of Massachusetts, unpublished data). Also, see Part C of this chapter for additional information.

1.3.1.5 Significant Environmental, Temporal and Spatial Factors Affecting Distribution of Alewife

Table 6. Significant environmental, temporal, and spatial factors affecting distribution of alewife. Please note that, although there may be subtle variations between systems, the following data include a broad range of values that encompass the different systems that occur along the East Coast. Where a specific range is known to exist, it will be noted. For the sub-adult–estuarine/oceanic environment and non-spawning adult–oceanic environment life history phases, the information is provided as a general reference, not as habitat preferences or optima. NIF = No Information Found.

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Spawning Adult	Late February (south) through August (north); slow-moving sections of streams/ponds/ lakes, and shorebank eddies or deep pools, from North Carolina to Labrador & Newfoundland	**Tolerable:** 0.2-3 **Optimal:** NIF **Reported:** Typically spawn in shallower (<1) areas	**Tolerable:** 7-27.8 **Optimal:** 13-20 **Reported:** Broad range; disagreement on minimum temperature for spawning	**Tolerable:** NIF **Optimal:** NIF **Reported:** Migrate as far upstream in freshwater as possible	**Tolerable:** NIF **Optimal:** NIF **Reported:** Usually sand, gravel, cobble, and other coarse stone; some report SAV and detritus	**Tolerable:** NIF **Optimal:** NIF **Reported:** Slow-moving waters	**Tolerable:** >5.0 **Optimal:** NIF **Reported:** Only tolerate low DO for short periods
Egg	Late February (south) through August (north); hatch 50-360 hours after fertilization, but usually within 80-95 hours at spawning site or slightly downstream	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** 10.6-26.7 **Optimal:** 17.2-21.1 **Reported:** Average time to median hatch varies inversely w/temperature	**Tolerable:** NIF **Optimal:** 0-2 **Reported:** Mostly found in freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Usually found in low flow; w/DO, strongest predictor of egg presence	**Tolerable:** ≥5.0 **Optimal:** NIF **Reported:** With velocity, strongest predictor of egg presence
Prolarvae	Hatch in 50 to 360 hours, but usually within 80-95 hours downstream of spawning site	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** 8-31 **Optimal:** 15-24 **Reported:** Variable	**Tolerable:** NIF **Optimal:** 0-3 **Reported:** Mostly found in freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Usually found in low flow	**Tolerable:** ≥5.0 **Optimal:** NIF **Reported:** NIF

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Postlarvae	2 to 5 days downstream of spawning site after prolarvae stage is reached	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** 14-28 **Optimal:** 20-26 **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Larvae grow faster in saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Usually found in low flow	**Tolerable:** ≥5.0 **Optimal:** NIF **Reported:** NIF
Early Juvenile – Riverine	3-9 months in natal rivers after reaching juvenile stage in brackish waters or upstream in freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Absent from near-surface during daylight	**Tolerable:** 10-28 **Optimal:** 15-20 **Reported:** 4-29	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** SAV for protection	**Tolerable:** NIF **Optimal:** NIF **Reported:** Avoid >10cm/s; high migration rates in heavy flow	**Tolerable:** ≥3.6 **Optimal:** NIF **Reported:** NIF
Sub-adult & Non-spawning Adult – Estuarine/ Oceanic	2-5 years after hatching in nearshore estuarine waters or offshore marine waters	**Tolerable:** NIF **Optimal:** 46-192 **Reported:** Zooplankton may influence depth; smaller fish generally in shallower water	**Tolerable:** 2-23 **Optimal:** 4-7 (bottom temp) **Reported:** Northern populations may be more cold tolerant	**Tolerable:** NIF **Optimal:** NIF **Reported:** Brackish to saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

1.3.2 Blueback Herring Habitat Description

Blueback herring (*Alosa aestivalis*) are an anadromous, highly migratory, euryhaline, pelagic, schooling species. Both blueback herring and alewife are often referred to as "river herring," which is a collective term for these two often inter-schooling species (Murdy *et al*. 1997). This term is often used generically in commercial harvests with no distinction between the two species (ASMFC 1985); to further this lumping tendency, landings for both species are reported as alewife (Loesch 1987). Blueback herring spend most of their lives at sea, returning to freshwater only to spawn (Colette and Klein-MacPhee 2002). Their range is commonly cited as spanning from the St. Johns River, Florida (Hildebrand 1963; Williams *et al*. 1975) to Cape Breton, Nova Scotia (Scott and Crossman 1973) and the Miramichi River, New Brunswick (Bigelow and Schroeder 1953; Leim and Scott 1966). However, Williams *et al*. (1975) have reported that blueback herring occur as far south as Tomoka River, a small freshwater tributary of the Halifax River in Florida (a brackish coastal lagoon). Additionally, some landlocked populations occur in the Southeast (Klauda *et al*. 1991a), but landlocking occurs less frequently in blueback herring than in alewife (Schmidt *et al*. 2003).

Blueback herring from the South are capable of migrating extensive distances (over 2000 km) along the Atlantic seaboard, and their patterns of migration may be similar to those of American shad (Neves 1981). This species is most abundant south of the warmer waters of the Chesapeake Bay (Manooch 1988; Scott and Scott 1988), occurring in virtually all tributaries to the Chesapeake Bay, the Delaware River, and in adjacent offshore waters (Jones *et al*. 1978). Although blueback herring and alewife co-occur throughout much of their range, blueback herring are more abundant by one or perhaps two orders of magnitude along the middle and southern parts of their ranges (Schmidt *et al*. 2003).

Several long-term data sets were recently analyzed to determine the current status of blueback herring in large river systems along the East Coast, including the Connecticut, Hudson, and Delaware rivers. Blueback herring show signs of overexploitation in all of these rivers, including reductions in mean age, decreases in percentage of returning spawners, and decreases in abundance. Although researchers did not include smaller drainages in the analysis, they did note that some runs in the northeastern U.S. and Atlantic Canada have observed increased population abundance of blueback herring in recent years (Schmidt *et al*. 2003).

Please note that some of the data presented in this chapter have been derived from studies of landlocked populations and the applicability of environmental requirements is unknown; therefore, they should be interpreted with discretion (Klauda *et al*. 1991a).

1.3.2.1 Spawning Habitat

Geographical and Temporal Patterns of Migration

Adult blueback herring populations in the South return earliest to spawn in freshwater and sometimes brackish waters, with populations further north migrating inland later in the spring when water temperatures have increased. Researchers believe that blueback herring migrate inland from offshore waters north of Cape Hatteras, North Carolina, encountering the same thermal barrier as American shad. Individuals then turn south along the coast if they are homing to South Atlantic rivers (Neves 1981); northbound pre-spawning adults head north along the coast (Stone and Jessop 1992). Adults begin migrations from the offshore region in response to changes in water temperature and light intensity (Pardue 1983). It is assumed that adults return to the rivers in which they were spawned, but some may stray to adjacent streams or colonize new areas; some individuals have even reoccupied systems in which the species was previously extirpated (Messieh 1977; Loesch 1987).

Blueback herring will ascend freshwater far upstream (Massmann 1953; Davis and Cheek 1966; Perlmutter *et al*. 1967; Crecco 1982); their distribution is a function of habitat suitability and hydrological conditions, such as swift flowing water (Loesch and Lund 1977). Earlier hypotheses that blueback herring do not ascend as far upstream as alewife are unfounded (Loesch 1987). In fact, in tributaries of the Rappahannock River, Virginia, upstream areas were found to be more important for blueback herring spawning than downstream areas (O'Connell and Angermeier 1997).

Spawning Location (Ecological)

Generally, blueback herring and alewife attempt to occupy different freshwater spawning areas. However, if blueback herring and alewife are forced to spawn in the same vicinity (i.e., due to blocked passage) (Loesch 1987), some researchers have suggested that the two species occupy separate spawning sites to reduce competition. For example, Loesch and Lund (1977) note that blueback herring typically select the main stream flow for spawning, while neighboring alewife spawn along shorebank eddies or deep pools. In rivers where headwater ponds are absent or poorly developed, alewife may be most abundant farther upstream in headwater reaches, while blueback herring utilize the mainstream proper for spawning (Ross and Biagi 1990). However, in some areas blueback herring are abundant in tributaries and flooded low-lying areas adjacent to main streams (Erkan 2002).

In the allopatric range, where there is no co-occurrence with alewife (south of North Carolina), blueback herring select a greater variety of spawning habitat types (Street 1970; Frankensteen 1976; Christie 1978), including small tributaries upstream from the tidal zone (ASMFC 1999), seasonally flooded rice fields, small densely vegetated streams, cypress swamps, and oxbows, where the substrate is soft and detritus is present (Adams and Street 1969; Godwin and Adams 1969; Adams 1970; Street 1970; Curtis *et al*. 1982; Meador *et al*. 1984). Furthermore, despite the fact that blueback herring generally do not spawn in ponds in their northern range (possibly to reduce competition), they have the ability to do so (Loesch 1987).

Loesch (1987) has reported that blueback herring can adapt their spawning behavior under certain environmental conditions and disperse to new areas if the conditions are suitable. This behavior was demonstrated in the Santee-Cooper System, South Carolina, where hydrological alterations resulting from the creation of a rediversion canal led to changes in spawning site selection in both rivers. In the Cooper River, blueback herring lost access to formerly impounded rice fields along the river, which were important spawning areas. Following the construction of the rediversion canal, there was an increase in the number and length of tributaries along the river that were used as spawning habitat. In the adjacent Santee River, adults dispersed into the rediversion canal itself in favor of their former habitat, which was further upstream (Eversole *et al*. 1994).

Temporal Spawning Trends

Spawning of blueback herring typically commences in the given regions at the following times: 1) Florida – as early as December (McLane 1955); 2) South Carolina (Santee River) – present in February (Bulak and Christie 1981), but spawning begins in early March (Christie 1978; Meador 1982); 3) Chesapeake Bay region - lower tributaries in early April and upper reaches in late April (Hildebrand and Schroeder 1928); 4) Mid-Atlantic region – late April (Smith 1971; Zich 1978; Wang and Kernehan 1979); 5) Susquehanna River - abundance peaks in early to mid-May (R. St. Pierre, U.S. Fish and Wildlife Service, pers. comm.); 6) Connecticut River – present in lower river mid-April, but spawning begins in mid-May (Loesch and Lund 1977); and 7) Saint John River, New Brunswick – present in May (Messieh 1977; Jessop *et al*. 1983), but spawning doesn't commence until June and may run through August (Leim and Scott 1966; Marcy 1976b).

Blueback herring generally spawn 3 to 4 weeks after alewife in areas where they co-occur; however, there may be considerable overlap (Loesch 1987) and peak spawning periods may differ by only 2 to 3 weeks (Hildebrand and Schroeder 1928). In a tributary of the Rappahannock River, Virginia, researchers found that blueback eggs and larvae were more abundant than those of alewife, but that alewife used the stream over a longer period of time. In addition, there was only a three- day overlap of spawning by alewife and blueback herring (O'Connell and Angermeier 1997). Although it has been suggested that alewife and blueback herring select separate spawning sites in sympatric areas to reduce competition (Loesch 1987), O'Connell and Angermeier (1997) did not find that the two species used different spawning habitat in the areas they examined. The researchers suggested that there was a temporal, rather than spatial, segregation that minimized the competition between the two species (O'Connell and Angermeier 1997).

Spawning may occur during the day, but blueback herring spawning activity is normally most prolific from late afternoon (Loesch and Lund 1977) into the night (Johnston and Cheverie 1988). During spawning, a female and two or more males will swim approximately one meter below the surface of the water; subsequently, they will dive to the bottom (Loesch and Lund 1977), simultaneously releasing eggs and sperm over the substrate (Colette and Klein-MacPhee 2002). Spawning typically occurs over an extended period, with groups or "waves" of migrants staying 4 to 5 days before rapidly returning to sea (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Klauda *et al*. 1991a). In a temporal context, the majority of spent adult blueback herring emigrating from the Connecticut River moved through fish passage facilities between 1700 and 2100 hours (Taylor and Kynard 1984).

Maturation and Spawning Periodicity

Blueback herring are repeat spawners at an average rate of 30 to 40% (Richkus and DiNardo 1984). In general, there appears to be an increase in repeat spawning from south to north (Rulifson *et al*. 1982). Researchers have found that approximately 44 to 65% of the blueback herring in Chesapeake Bay tributaries had previously spawned (Joseph and Davis 1965), while 75% of those in Nova Scotia had previously spawned (O'Neill 1980). In the Chowan River, North Carolina, as many as 78% of individuals were first-time spawners (Winslow and Rawls 1992). First spawning occurs when adults are between 3 and 6 years old, but most first-time spawners are age 4 fish (Messieh 1977; Loesch 1987). Joseph and Davis (1965) reported that some blueback herring spawn as many as six times in Virginia.

Jessop (1990) found a stock-recruitment relationship for the spawning stock of river herring and year-class abundance at age 3. Despite these results, most studies have been unable to detect a strong relationship between adult and juvenile abundance of clupeids (Crecco and Savoy 1984; Henderson and Brown 1985; Jessop 1994). Researchers have suggested that although year-class is driven mostly by environmental factors, if the parent stock size falls below a critical level, the size of the spawning stock may become a factor in determining juvenile abundance (Kosa and Mather 2001). To the extent that environmental factors have been linked to year-class abundance, they will be discussed in subsequent sections.

Spawning and the Saltwater Interface

Blueback herring generally spawn in freshwater above the head of tide; brackish and tidal areas are rarely used for spawning by this species (Nichols and Breder 1927; Hildebrand 1963; Fay *et al*. 1983; Murdy *et al*. 1997). Adults, eggs, larvae, and juveniles can tolerate a wide range of salinities, but seem to prefer a more narrow range, depending on life history stage. For example, while spawning may occur in salinities ranging from 0 to 6 ppt, it typically takes place in waters that are less than 1 ppt (Klauda *et al*. 1991a). Boger (2002) presented a modified salinity range for Virginia rivers, suggesting that a suitable salinity range for spawning adults is 0 to 5 ppt. Alternatively, spawning adult blueback herring have been found in brackish ponds at Woods Hole, Massachusetts (Nichols and Breder 1927; Hildebrand 1963).

Spawning Substrate Association

In areas where blueback herring and alewife co-occur (sympatric region), blueback herring prefer to spawn over gravel and clean sand substrates where the water flow is relatively swift, and actively avoid areas with slow-moving or standing water (Bigelow and Welsh 1925; Marcy 1976b; Loesch and Lund 1977; Johnston and Cheverie 1988).

In the allopatric range, there seems to be some variation in blueback herring spawning substrate. Where water flow is more sluggish, there is ample opportunity for detritus and silt to accumulate. Pardue (1983) considered substrates with 75% or more silt and other soft materials (e.g., detritus and vegetation) as optimal for blueback herring spawning because it provides cover for eggs and larvae. However, more recently Boger (2002) found that river herring spawning areas along the Rappahannock River, Virginia, had substrates that consisted primarily of sand, pebbles, and cobbles (usually associated with higher-gradient streams), while areas with little or no spawning were dominated by organic matter and finer sediments (usually associated with lower-gradient streams and comparatively more agricultural land use).

Spawning Depth

During their freshwater migration, blueback herring swim at mid-water depths (compared to deeper water used by American shad) (Witherell 1987). This species is reported to spawn in both shallow (Jones *et al*. 1978) and deep streams (Johnston and Cheverie 1988).

Spawning Water Temperature

O'Connell and Angermeier (1997) found that temperature was the strongest predictor of blueback herring adult and early egg presence in a tributary of the Rappahannock River, Virginia. Blueback herring are reported to spawn at temperatures ranging from a minimum of 13°C (Hawkins 1979; Rulifson *et al*. 1982) to a maximum of 27°C (Loesch 1968). Loesch and Lund (1977) noted that spawning adults were found in the lower Connecticut River in mid-April when water temperatures were as low as 4.7°C, but spawning did not occur until several weeks later when the water temperature had risen. Meador *et al*. (1984) noted that rapid changes in water temperature appeared to be an important factor influencing the timing of spawning. Optimal spawning temperature range is suggested to be 21 to 25°C (Cianci 1969; Marcy 1976b; Klauda *et al*. 1991a) and 20 to 24° C (Pardue 1983). Fish in the laboratory acclimated to 15°C and 29 ppt salinity exhibited a final temperature preference of 22.8°C (Terpin *et al*. 1977).

Spawning Dissolved Oxygen Associations

Adult blueback herring require a minimum of 5.0 mg/L of dissolved oxygen (Jones *et al*. 1978). For example, adults caught in the Cooper and Santee Rivers, South Carolina, were always captured in areas that had a dissolved oxygen concentration of 6 mg/L or higher (Christie *et al*. 1981).

Spawning pH and Aluminum Associations

Adult blueback herring captured in the Santee-Cooper River system, South Carolina, were found within a range of pH 6.0 to 7.5 (Christie and Barwick 1985; Christie *et al*. 1981). Further north, within tributaries of the Delaware River, New Jersey, spawning runs were found within a broader range of pH 4.7 to 7.1 (mean pH 6.2) (Byrne 1988). Based on suggested ranges for eggs (cited in Klauda *et al*. 1991a), Boger (2002) suggested a suitable range of pH 6 to 8, and an optimal range of pH 6.5 to 8 for spawning habitat.

Water Velocity/Flow

In the sympatric range, blueback herring prefer to spawn in large rivers and tributaries where the water flow is relatively swift, actively avoiding areas with slow-moving or standing water (Bigelow and Welsh 1925; Marcy 1976b; Johnston and Cheverie 1988). In such areas, blueback herring will concentrate and spawn in the mainstream flow, while alewife favor shorebank eddies or deep pools for spawning (Loesch and Lund 1977). In Connecticut, blueback herring select the fast-moving waters of the upper Salmon River and Roaring Brook, while alewife are found in the slower-moving waters of Higganum and Mill creeks (Loesch and Lund 1977) and Bride Lake

(Kissil 1974). Researchers suggest that there is differential selection of spawning in these areas (Loesch and Lund 1977).

In the allopatric range, blueback herring favor lentic sites, but may also occupy lotic sites (Loesch 1987; Klauda *et al*. 1991a). Additionally, they may select slower-flowing tributaries and flooded low-lying areas adjacent to main streams with soft substrates and detritus (Street *et al*. 1975; Sholar 1975; 1977; Fischer 1980; Hawkins 1979).

Meador *et al*. (1984) found that high flows (and accompanying low water temperatures) associated with flood control discharges in the Santee River, South Carolina, immediately prior to the spawning season, resulted in lower numbers of blueback herring larvae that year. In the preceding year without flood control discharges, spawning occurred farther upstream (Meador *et al*. 1984). Furthermore, ripe adults were found below the sampling site heading downstream the year that high flows occurred, apparently without having spawned (Bulak and Christie 1981). Concurrently, other studies (Bulak and Curtis 1977; West *et al*. 1988) have found spawning adults moving downstream from spawning areas following a sudden change in water discharge.

In a similar example in the same river system, a rediversion canal and hydroelectric dam with a fish passage facility were constructed between the Cooper River and Santee River, which increased the average flow of the Santee River from 63 m^3/s to 295 m^3/s (Cooke and Leach 2003). Following the rediversion, blueback herring did not concentrate below the dam and few were attracted into the fish lock during periods of zero discharge. Too much water flow also posed a problem, as adults were found concentrating below the dam during periods of discharge, but were unable to locate the entrance to the fish lock due to high turbulence (Chappelear and Cooke 1994). As a result, blueback herring changed migration patterns by abandoning the Santee River, and following the dredged canal to the higher flow of the St. Stephen Dam. Subsequently, access to spawning grounds was increased, which contributed to increases in blueback herring populations (Cook and Leach 2003). Although the importance of in-stream flow requirements has been previously recognized (Crecco and Savoy 1984; ASMFC 1985; Crecco *et al*. 1986; Ross *et al*. 1993), it has usually been with regard to spawning habitat requirements or recruitment potential (Moser and Ross 1994). Cooke and Leach (2003) concluded that the study of, and possible adjustment of, river flow might be an important consideration for restoring alosine habitat.

Feeding Behavior

Adult blueback herring feed during upstream spawning migrations (Rulifson *et al*. 1982; Frankensteen 1976), consuming large and diverse quantities of copepods, cladocerans, ostracods, benthic and terrestrial insects, molluscs, fish eggs, hydrozoans, and stratoblasts (Creed 1985). Sampling of adult blueback herring along the St. Johns River, Florida, found that they also consume vegetation (FWC 1973).

Competition and Predation

Information is lacking that identifies which predator species prey on adult blueback herring during their spawning runs, but it is assumed that they are consumed by other fish, reptiles (e.g., snakes and turtles), birds (e.g., ospreys, eagles, and cormorants), and mammals (e.g., mink) (Loesch 1987; Scott and Scott 1988). Erkan (2002) notes that predation of alosines has increased dramatically in Rhode Island rivers in recent years, especially by the double-crested cormorant, which often takes advantage of fish staging near the entrance to fishways. Populations of nesting cormorant colonies have increased in size and have expanded into areas in which they were not previously observed. Predation by otters and herons has also increased, but to a lesser extent (Erkan 2002).

Several researchers have found evidence of striped bass predation on blueback herring (Trent and Hassler 1966; Manooch 1973; Gardinier and Hoff 1982). A recent study by Savoy and Crecco (2004) strongly supports the hypothesis that striped bass predation in the Connecticut River on adult blueback herring has resulted in a dramatic and unexpected decline in blueback herring abundance since 1992. The researchers further suggest that striped bass prey primarily on spawning adults because their predator avoidance capability may be compromised at that time, due to the strong drive to spawn during upstream migration. Rates of predation on age-0 and 1 alosines were much lower than that of adults (Savoy and Crecco 2004).

1.3.2.2 Egg and Larval Habitat

Geographical and Temporal Movement Patterns

On average, blueback herring eggs are hatched within 38 to 60 hours of fertilization (Adams and Street 1969). Yolk-sac larvae drift passively downstream with the current to slower moving water, where they grow and develop into juveniles (Johnston and Cheverie 1988). Yolk-sac absorption occurs in 2 to 3 days after hatching, and soon thereafter larvae begin to feed exogenously (Cianci 1969). Larvae are sensitive to light, so larval abundance at the surface increases as dusk approaches and reaches a maximum by dawn (Meador 1982).

Water Velocity/Flow

Initially, blueback herring eggs are demersal, but during the water-hardening stage, they are less adhesive and become pelagic (Johnston and Cheverie 1988). In general, blueback herring eggs are buoyant in flowing water, but settle along the bottom in still water (Ross and Biagi 1990).

Water flow rates may have a notable impact on larval populations of blueback herring. For example, year-class size of blueback herring decreased with increasing discharge during May-June from the headpond at the Mactaquac Dam (Saint John River, New Brunswick) (Jessop 1990). Researchers speculated that this was due to a low abundance of phytoplankton and zooplankton that larvae rely on at first feeding; these reductions can result when high discharges occur (Laberge 1975). This effect was not observed for alewife, which spawn 2 to 3 weeks earlier than blueback herring. Sismour (1994) also observed a rapid decline in abundance of early preflexion river herring larvae (includes both alewife and blueback herring) in the Pamunkey River, Virginia, following high river flow in 1989. Similar to Jessop (1990), Sismour (1994) speculated that high flow led to increased turbidity, which reduced prey visibility, leading to starvation of larvae. Furthermore, in tributaries of the Chowan system, North Carolina, water flow was determined to be related to recruitment of larval river herring (O'Rear 1983).

Dixon (1996) found that seasonally high river flow and low water temperature during one season in several Virginia rivers were associated with delayed larval emergence, reduced relative abundance, depressed growth rate, and increased mortality compared with the previous season. It was suggested that high river flow might be a forcing mechanism on another abiotic factor, perhaps turbidity, which directly affects larval growth and survival (Dixon 1996).

Competition and Predation

All life stages of blueback herring, including the egg and larval stages, are important prey for freshwater fishes, birds, amphibians, reptiles, and mammals (Klauda *et al*. 1991a). The ability of blueback herring to feed extensively on rotifers is offered as an explanation for their dominance over American shad in some rivers along the East Coast (Marcy 1976c; Loesch and Kriete 1980).

1.3.2.3 Juvenile Riverine/Estuarine Habitat

Geographical and Temporal Movement Patterns

Recruitment to the juvenile stage for blueback herring begins later in the year than for other alosines because they spawn later and have a shorter growing season (Hildebrand and Schroeder 1928; Schmidt *et al*. 1988). The juvenile stage is reached when fish are about 20 mm TL (Klauda *et al*. 1991a), with growth occurring very rapidly (Colette and Klein-MacPhee 2002).

Massmann (1953), Warriner *et al*. (1970), and Burbidge (1974) have reported that juvenile blueback herring are most abundant upstream of spawning grounds in waters of Virginia. While Burbidge (1974) noted a greater prey density at these locations, he was unsure if fish were actually moving upstream in large numbers, if survival rates upstream were higher compared to survival rates downstream, or if fish were simply moving out of tributaries and oxbows into these areas. Michael Odom (U.S. Fish and Wildlife Service, pers. comm.) has noted that juvenile blueback herring select the pelagic main channel portion of tidal waters of the Potomac River, while American shad juveniles select shallower nearshore flats adjacent to and within submerged aquatic vegetation (SAV) beds. Odom speculates that these two species tend to partition the habitat in this river.

In North Carolina waters, Street *et al*. (1975) found that juveniles typically reside in the lower ends of the rivers in which they were spawned. In Chesapeake Bay tributaries, young-of-the-year blueback herring can be found throughout tidal freshwater nursery areas in spring and early summer; they subsequently head upstream later in the summer when saline waters encroach on their nursery grounds (Warriner *et al*. 1970). Schmidt *et al*. (1988) reasoned that juvenile blueback herring in the Hudson River remained in the vicinity of their natal areas throughout the summer because they were relatively absent downriver until late September.

Nursery areas of the Neuse River, North Carolina, have been characterized as relatively deep, slow-flowing, black waters that drain hardwood swamps (Hawkins 1979). In South Carolina, juvenile blueback herring and American shad were found to co-occur predominantly in deeper, channel habitats of estuarine systems, during fall and winter, while hickory shad selected shallow expanses of sounds and bays. Small crustaceans, favored by blueback herring and American shad, are generally abundant near the bottom in estuarine channels (McCord 2005).

Juvenile blueback herring spend three to –nine months in their natal rivers before returning to the ocean (Kosa and Mather 2001). Observations by Stokesbury and Dadswell (1989) found that blueback herring remained in the offshore region (25 to 30% seawater) of the Annapolis estuary (Nova Scotia) for almost a month before the correct migration cues triggered emigration. Once water temperatures begin to drop in the late summer through early winter (depending on geographic area), juveniles start heading downstream, initiating their first phase of seaward migration (Pardue 1983; Loesch 1987). Migration downstream is also thought by some researchers to be prompted by changes in water flow, water levels, precipitation, and light intensity (Kissil 1974; Pardue 1983). In contrast, other researchers have suggested that water flow plays little role in providing the migration cue under riverine conditions; these researchers think that migration timing is more dependent on water temperature and new to quarter moon phases, which provide dark nights (O'Leary and Kynard 1986; Stokesbury and Dadswell 1989).

In the Connecticut River, juvenile blueback herring were found to move out of river systems rapidly, within a 24-hour period, with peak migration occurring in the early evening at 1800 hours (O'Leary and Kynard 1986). Kosa and Mather (2001) studied juvenile river herring movement from 11 small coastal systems in Massachusetts, and found that most individuals emigrated between 1200 and 1600 hours. Farther north, emigration by juvenile blueback herring in the Annapolis River, Nova Scotia, peaked at night between 1800 and 2300 hours (Stokesbury and Dadswell 1989).

Juvenile blueback herring (age 1+) were found in the lower portion of the Connecticut River in early spring by Marcy (1969b), which led him to speculate that many juveniles likely spend their first winter close to the mouth of the river. To the South, some young-of-the-year may over-winter in deeper, higher salinity areas of the Chesapeake Bay (Hildebrand and Schroeder 1928). In fact, Dovel (1971) reported juvenile populations in the upper Chesapeake Bay that did not emigrate until the early spring of their second year. Juveniles have also been reported over-wintering in the Delaware Bay (Jones *et al*. 1978). Since juvenile river herring do not survive temperatures of 3°C or less (Otto *et al*. 1976), they would not be expected to over-winter in coastal systems where such temperatures persist (Kosa and Mather 2001).

Juveniles and the Saltwater Interface

Juvenile blueback herring are found most often in waters of 0 to 2 ppt prior to fall migration (Jones *et al*. 1988), but are tolerant of much higher salinities early in life. Pardue (1983) concluded that juveniles prefer low salinities in the spring and summer, with an optimal range between 0 and 5 ppt. Chittenden (1972) captured older juveniles in freshwater and subjected them to 28 ppt salinity at 22°C and all but one fish survived (mortality may have been due to handling stress). Furthermore, Klauda *et al*. (1991a) suggested that 0 to 28 ppt was a suitable range for juveniles. Their ability to tolerate salinities as low as 0 ppt, and as high as 28 ppt, allows them to utilize both freshwater and marine nursery areas. However, both Loesch (1968) and Kissil (1968) found that juvenile blueback herring remained in freshwater up to one month longer than juvenile alewife.

In some cases, changes in one environmental factor may impact other environmental factors causing changes in behavior patterns. For example, in the Chowan River, North Carolina, juvenile blueback herring became scarce in sampling areas following drought conditions during the summer of 1981, which resulted in saline waters encroaching farther upriver into nursery areas. Researchers suggested that blueback herring had possibly moved further upstream to freshwater areas to avoid the saltwater intrusion (Winslow *et al*. 1983).

Juvenile Water Temperature Associations

Juvenile blueback herring have a wide range of temperature tolerances (Table 7). Additionally, certain temperatures create cues for the juveniles to begin migration. For example, in the Connecticut River, emigration began when the water temperatures dropped to 21°C in September, peaked at 14 to 15°C, and ended when the temperature dropped to 10°C, in late October and early November (O'Leary and Kynard 1986). Milstein (1981) found juveniles over-wintering in an estuary off the coast of New Jersey where bottom temperatures ranged from 2.0 to 10.0°C. These waters were warmer and had a higher salinity than the cooler, lower salinity estuarine nurseries where the juveniles reside in the fall.

Table 7. Juvenile blueback herring water temperature associations.

Characterization	Temperature Range (°C)	Acclimation Temperature (°C)	Salinity (ppt)	Location	Citation
Present	11.5 – 32.0	N/A		Cape Fear River, NC	Davis and Cheek 1966
Present	6.7 – 32.5	N/A		Connecticut River	Marcy 1976b
Suitable	10 – 30	N/A		Chesapeake Bay	Klauda *et al*. 1991a
Optimal	20 – 30			Many	Pardue 1983
Selection	20 – 22	15 – 20	4 – 6	Delaware River, NJ	Meldrim and Gift 1971
Preference	24 – 28	25 – 26	7 – 8	Laboratory	PSE&G 1978
Avoidance	36	25 – 26	7 – 8	Laboratory	PSE&G 1978
62% Mortality	32 – 33 for 4-6 minutes	19		Laboratory	Marcy and Jacobson 1976
100% Mortality	32 – 33 for 4-6 minutes	22.7		Laboratory	Marcy and Jacobson 1976
100% Mortality	30.5 for 6 minutes	15		Laboratory	PSE&G 1984
100% Mortality	32 for 6 minutes	15	29	Laboratory	Terpin *et al*. 1977
100% Mortality	10	25	6.5 – 7	Laboratory	PSE&G 1978
100% Mortality	0.2	5	8.5 – 10	Laboratory	PSE&G 1978

Juveniles and Water Velocity/Flow

Discharge is an important factor influencing variability in relative abundance and emigration of juvenile river herring across smaller systems. Extremely high discharge may adversely affect juvenile emigration, and high or fluctuating discharge may decrease relative abundance of adult and juvenile blueback herring (Meador *et al*. 1984; West *et al*. 1988; Kosa and Mather 2001). In laboratory experiments, juvenile river herring avoided water velocities greater than 10 cm/s, especially in narrow channels (Gordon *et al*. 1992). However, in large rivers, where greater volumes of water can be transported per unit of time without substantial increases in velocity, the effects of discharge may differ (Kosa and Mather 2001). Jessop (1994) found that the juvenile abundance index (JAI) of blueback herring decreased, and daily instantaneous mortality increased, with mean July-August river discharge from the Mactaquac Dam headpond on the Saint John River, New Brunswick, Canada. Impacts may have been the result of advection from the headpond, or from mortality as a result of reduced phytoplankton and zooplankton prey (Jessop 1994).

Juvenile Feeding

Juvenile blueback herring in nursery areas feed mostly on copepods, cladocerans (Domermuth and Reed 1980), and larval dipterans (Davis and Cheek 1966; Burbidge 1974). In fact, as much as 40% of the juvenile's diet may consist of benthic organisms (Watt and Duerden 1974). Additionally, Burbidge (1974) found that juveniles often select larger items in the James River, Virginia, such as adult copepods, rather than smaller prey, such as *Bosminia* sp., except where there is a high relative abundance of smaller prey. Several researchers (Vigerstad and Colb 1978; O'Neill 1980; Yako 1998) have hypothesized that a change in food availability may provide a cue for juvenile anadromous herring to begin emigrating seaward, but no causal link has been established.

Juvenile blueback herring feed mostly at the surface, below the surface of the water, and to a lesser degree, on benthic prey (Domermuth and Reed 1980; Colette and Klein-MacPhee 2002). Some researchers (Burbidge 1974; Jessop 1990) observed juveniles feeding somewhat at dawn, and increasing feeding throughout the day with a maximum at dusk, then declining overnight. It is suggested that during the day, juveniles will remain within, or near, their zone of preferred light intensity, and feed in a selective mode (Dixon 1996), such as a "particulate" feeding mode (Janssen 1982).

Dixon (1996) noted that the size and age of juvenile blueback herring in the nursery zone increased in the downstream direction. Burbidge (1974) made similar observations that larger juveniles were found in downstream reaches of the James River. Dixon (1996) noted that the relative age distribution and density of juveniles (center of abundance) persisted in the nursery zone throughout the sampling season, which precluded the hypothesis that cohorts move downriver as a function of age and size. Instead, Dixon (1996) referenced Sismour's (1994) theory that as river herring larvae hatch at different times and locations along the river, they will encounter varying concentrations and combinations of potential prey. It is these differences that will affect larval nutrition and survival. In early spring, larvae that are closer to the center of the chlorophyll maxima along the river (which likely support development and expansion of zooplankton assemblages) are more likely to find suitable prey items. Early in the season, sufficient prey in upriver areas may be lacking. As the season progresses and the zooplankton prey field expands to upriver reaches, larvae in these areas may find suitable prey quantities and grow to the juvenile stage (Sismour 1994; Dixon 1996). Pardue (1983) considered habitats that contained 100 or more zooplankton per liter as optimum, which he suggested was critical for survival and growth at this stage. Burbidge (1974) demonstrated a direct relationship between density of zooplankton and distribution and growth of blueback herring. This differential survival rate within the nursery zone over time may account for younger juveniles in upstream reaches (Dixon 1996).

Juvenile Competition and Predation

Many freshwater and marine fishes, birds, amphibians, reptiles, and mammals prey upon young-of-the-year blueback herring. Eels, yellow perch, white perch, and bluefish are among the fish species that prey on blueback herring (Loesch (1987; Juanes *et al*. 1993). Researchers have suggested that excessive predation by striped bass may be contributing to the decline of blueback herring stocks in the Connecticut River (Savoy and Crecco 1995). Furthermore, suitably sized juvenile blueback herring were found to be energetically valuable and potentially a key prey item for largemouth bass in two Massachusetts rivers during the late summer. Although largemouth bass do not consistently consume blueback herring, they are energy-rich prey, which provide the highest growth potential (Yako *et al*. 2000).

It is often noted throughout the literature, that alewife and blueback herring co-exist in the same geographic regions, yet inter-specific competition is often reduced through several mechanisms. For example, juveniles of both species in the Connecticut River consume or select different sizes of prey, leading researchers to conclude that intra-specific competition may be greater than inter-specific competition (Crecco and Blake 1983). This behavior is also evident in the Minas Basin, Nova Scotia, where juvenile blueback herring favor smaller and more planktonic prey (filter feeding strategy) than do juvenile alewife (particulate-feeding strategy) (Stone 1985; Stone and Daborn 1987). In addition, alewife spawn earlier than blueback herring, thereby giving juvenile alewife a relative size advantage over juvenile blueback herring, which allows them access to a larger variety of prey (Jessop 1990).

Furthermore, differences in juvenile diel feeding activity serve to reduce competition. One study noted that diurnal feeding by juvenile alewife is bimodal, with peak consumption about one to three hours before sunset and a minor peak occurring about two hours after sunrise (Weaver 1975). Another study found that juvenile blueback herring begin to feed actively at dawn, with feeding increasing throughout the day and maximizing at dusk, then diminishing from dusk until dawn (Burbidge 1974). Blueback herring are also found closer to the surface at night than alewife that are present at mid-water depths; this behavior may further reduce inter-specific competition for food between the two species (Loesch 1987).

Blueback herring and American shad juveniles also co-occur in shallow nearshore waters during the day, but competition for prey is often reduced by: 1) more opportunistic feeding by American shad; 2) differential selection for cladoceran prey; and 3) higher utilization of copepods by blueback herring (Domermuth and Reed 1980). Juvenile blueback herring are more planktivorous, feeding on copepods, larval dipterans, and cladocerans (Hirschfield *et al*. 1966, Burbidge 1974).

Blueback herring have shown signs of being impacted by invasive species as well. For example, there is strong evidence that juveniles in the Hudson River have experienced a reduced forage base as a result of zebra mussel colonization (Waldman and Limburg 2003).

1.3.2.4 Late Stage Juvenile and Adult Marine Habitat

Geographical and Temporal Patterns at Sea

Juvenile river herring have been found over-wintering in an offshore estuary (Cameron and Pritchard 1963) 0.6 to 7.4 km from the shore of New Jersey, at depths of 2.4 to 19.2 m (Milstein 1981). This estuary is warmer and has a higher salinity than the cooler, lower salinity river-bay estuarine nurseries where river herring reside in the fall. The majority of river herring are present in this offshore estuary during the month of March, when bottom temperatures range from 4.4 to 6.5°C and salinity varies between 29.0 and 32.0 ppt (Cameron and Pritchard 1963). Further south, young blueback herring have been found over-wintering off the North Carolina coast from January to March, concentrated at depths of 5.5 to 18.3 m (Holland and Yelverton 1973; Street *et al*. 1975).

Sexual maturity is reached between ages 3 and 6 for blueback herring**.** Life history information for young-of-the-year and adult blueback herring after they emigrate to the sea, and before they return to freshwater to spawn, is incomplete (Klauda *et al*. 1991a). Researchers assume that most juveniles join the adult population at sea within the first year of their lives, and follow a north-south seasonal migration along the Atlantic coast, similar to that of American shad; changes in temperature likely drive oceanic migration (Neves 1981).

Neves (1981) reported that 16 years of catch data showed that blueback herring were distributed throughout the continental shelf from Cape Hatteras, North Carolina, to Nova Scotia during the spring. Most were found south of Cape Cod, but, unlike alewife, no blueback herring catches were recorded for Georges Bank. During the summer, blueback herring moved north and inshore, but catch records were too infrequent to determine summer occurrence for the species, although several catches were made near Nantucket Shoals and Georges Bank. This species was never collected south of 40° N in the summer. By early fall, the blueback herring were found along Nantucket Shoals, Georges Bank, and the inner Bay of Fundy, but were concentrated mostly along the northwest perimeter of the Gulf of Maine (Neves 1981). In the autumn, they began moving southward and offshore for over-wintering along the mid-Atlantic coast until early spring (Neves 1981; Rulifson *et al*. 1987). Although winter sampling stations were inadequate to define wintering grounds, the few catches that were reported were primarily between latitude 40° N and 43° N. It is unknown to what extent blueback herring over-winter in deep water off the continental shelf of the United States (Neves 1981). This species has been found offshore as far as 200 km (Bigelow and Schroeder 1953; Netzel and Stanek 1966), but they are rarely collected more than 130 km from shore (Jones *et al*. 1978).

Canadian spring survey results also reveal river herring distributed along the Scotian Gulf, southern Gulf of Maine, and off southwestern Nova Scotia from the Northeast Channel to the central Bay of Fundy. They are also found to a lesser degree along the southern edge of Georges Bank and in the canyon between Banquereau and Sable Island Banks. A large component of the over-wintering population on the Scotian Shelf moves inshore during spring to spawn in Canadian waters, but may also include the U.S. Gulf of Maine region (Stone and Jessop 1992).

Salinity Associations at Sea

Adult blueback herring have been collected in salinities ranging from 0 to 35 ppt (Klauda *et al*. 1991a). Chittenden (1972) subjected adults to gradual and abrupt changes in salinity, including direct transfers from fresh to saltwater and vice versa, with no mortality. Non-spawning adults that do not ascend freshwater streams will likely be found mostly in seawater, and possibly brackish estuaries as they make their way up the coast to their summer feeding grounds (Chittenden 1972).

Depth Associations at Sea

The extent to which blueback herring over-winter in deep waters off the continental shelf is unknown. Individuals have been caught most frequently at 27 to 55 m throughout their offshore range. While at sea, blueback herring are more susceptible to bottom trawling gear during the day; this concept led early researchers to conclude that the species is aversive to light and follows the diel movement of plankton in the water column (Neves 1981). In the Gulf of Maine region, zooplankton concentrations are at depths less than 100 m (Bigelow 1926). Since blueback herring are rarely found in waters greater than 100 m in this area, it is speculated that zooplankton influence the depth distribution of blueback herring at sea (Neves 1981). A more recent study of juveniles within the riverine environment (see ***Juvenile depth*** under Part C of this chapter) found that they migrate to the surface within a specific isolume as light intensity changes (Dixon 1996).

Stone and Jessop (1992) found blueback herring offshore of Nova Scotia, the Bay of Fundy, and the Gulf of Maine, at mid-depths of 101 to 183 m in the spring, in shallower nearshore waters of 46 to 82 m in the summer, and in deeper offshore waters of 119 to 192 m in the fall. The researchers also found differences in depth distribution, with smaller fish (sexually immature) occurring in shallow regions (<93 m) during spring and fall, while larger fish occurred in deeper areas (≥93 m) in all seasons (Stone and Jessop 1992). In addition, the semi-pelagic nature of juveniles may provide them with protection from the effects of overfishing (Dadswell 1985).

Temperature Associations at Sea

Although data on offshore temperature associations is limited, researchers speculate that blueback herring are similar to other anadromous clupeids, in that they may undergo seasonal migrations within preferred isotherms (Fay *et al*. 1983). Neves (1981) found that blueback herring were caught in an offshore area where surface water temperatures were between 2 and 20°C and bottom water temperatures ranged from 2 to 16°C; almost all of the fish were caught in water temperatures less than 13°C. Catches were most frequent where bottom temperatures averaged between 4 and 7°C (Neves 1981).

Stone and Jessop (1992) found that the presence of a cold (<5°C) intermediate water mass over warmer, deeper waters on the Scotian Shelf (Hatchey 1942), where the largest catches of river herring occurred, may have restricted the extent of vertical migration during the spring. Since few captures were made where bottom temperatures were less than 5°C during the spring, researchers concluded that vertical migration may be confined by a water temperature inversion in this area (Stone and Jessop 1992).

Feeding at Sea

Blueback herring are size-selective zooplankton feeders (Bigelow and Schroeder 1953), whose diet at sea consists mainly of ctenophores, calanoid copepods, amphipods, mysids and other pelagic shrimps, and small fish (Brooks and Dodson 1965; Neves 1981; Stone 1985; Stone and Daborn 1987; Scott and Scott 1988; Bowman *et al*. 2000). In Minas Basin, Bay of Fundy, smaller blueback herring feed mostly on microzooplankton, while larger fish consume larger prey, including mysids and amphipods; feeding intensity also decreases with increasing age of fish (Stone 1985).

Neves' (1981) analysis of offshore survey results led to the conclusion that blueback herring follow the diel movement of zooplankton while at sea. As discussed above (see Juvenile depth under Part C of this chapter), Dixon's (1996) study in freshwater concluded that juvenile blueback herring followed diel movements in response to light intensity, not prey movement. Although direct evidence is lacking, catches of blueback herring in specific areas along Georges Bank, the perimeter of the Gulf of Maine, and south of Nantucket Shoals may be related to zooplankton abundance (Neves 1981).

Competition and Predation at Sea

Complete information on predation at sea is lacking for blueback herring (Scott and Scott 1988). Fish that are known to prey on blueback herring in the marine environment include spiny dogfish, American eel, cod, Atlantic salmon, silver hake, white hake, and Atlantic halibut, as well as larger schooling species, including bluefish, weakfish, and striped bass (Dadswell 1985; Ross 1991; Bowman *et al*. 2000). Seals, gulls, and terns may also feed on blueback herring in the ocean.

1.3.2.5 *Significant Environmental, Temporal and Spatial Factors Affecting Distribution of Blueback Herring*

Table 8. Significant environmental, temporal, and spatial factors affecting distribution of blueback herring. Please note that, although there may be subtle variations between systems, the following data include a broad range of values that encompass the different systems that occur along the East Coast. Where a specific range is known to exist, it will be noted. For the sub-adult–estuarine/oceanic environment and non-spawning adult–oceanic environment life history phases, the information is provided as a general reference, not as habitat preferences or optima. NIF = No Information Found.

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Spawning Adult	December (Florida) through late August (Nova Scotia) in Atlantic coast rivers from St. Johns River, FL to Nova Scotia **Sympatric range:** Freshwater or brackish water above the head of the tide in fast-moving waters, also brackish ponds **Allopatric range:** Slower-flowing tributaries and flooded low-lying areas adjacent to main streams	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** 13-27 **Optimal:** 20-25 **Reported:** Variable	**Tolerable:** 0-6 **Optimal:** <1 **Reported:** Generally freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Sympatric: gravel, sand; Allopatric: Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Fast flow	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5
Egg	December to August (south to north progression) at spawning site or slightly downstream of spawning site	**Tolerable:** NIF **Optimal:** NIF **Reported:** Usually found at bottom	**Tolerable:** 7-14 **Optimal:** NIF **Reported:** Variable	**Tolerable:** 0-22 **Optimal:** 0-2 **Reported:** Usually freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Larvae	38-60 hours after fertilization downstream of spawning site	**Tolerable:** NIF **Optimal:** NIF **Reported:** Diel movement	**Tolerable:** 13-28 **Optimal:** NIF **Reported:** Variable	**Tolerable:** 0-22 **Optimal:** NIF **Reported:** Usually freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** ≥ 5 **Optimal:** NIF **Reported:** Minimum 5
Early Juvenile – Riverine Environment	3-9 months in natal rivers after reaching juvenile stage upstream or downstream of spawning sites, as far as offshore estuaries	**Tolerable:** NIF **Optimal:** NIF **Reported:** Surface or mid-water (daytime); bottom (nighttime)	**Tolerable:** 11-32 **Optimal:** 20-30 **Reported:** Variable; temp gives migration cues	**Tolerable:** 0-28 **Optimal:** 0-5 (summer) **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** SAV	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 4
Sub-adult & Non-spawning Adult– Estuarine / Oceanic Environment	3-6 years after hatching in nearshore estuarine waters or offshore marine waters	**Tolerable:** NIF **Optimal:** NIF **Reported:** Diel migrations with zooplankton; most frequently caught at 27-55	**Tolerable:** NIF **Optimal:** NIF **Reported:** Probably travel in preferred isotherm like other alosines	**Tolerable:** NIF **Optimal:** NIF **Reported:** Brackish to saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

1.3.3 Overlapping Habitat and Habitat Areas of Particular Concern for Alosines

1.3.3.1 Identification and Distribution of Habitat and Habitat Areas of Particular Concern for Alosines

NOTE: Due to the dearth of information on Habitat Areas of Particular Concern (HAPC) for alosine species, this information is applicable to American shad, hickory shad, alewife, and blueback herring combined. Information about one alosine species may be applicable to other alosine species, and is offered for comparison purposes only. Certainly, more information should be obtained at individual HAPCs for each of the four alosine species.

All habitats described in the preceding chapters (spawning adult, egg, larval, juvenile, sub-adult, and adult resident and migratory) are deemed essential to the sustainability of anadromous alosine stocks, as they presently exist (ASMFC 1999). Klauda *et al*. (1991b) concluded that the critical life history stages for American shad, hickory shad, alewife, and blueback herring, are the egg, prolarva (yolk-sac or pre-feeding larva), post-larva (feeding larva), and early juvenile (through the first month after transformation). Nursery habitat for anadromous alosines consists of areas in which the larvae, post-larvae, and juveniles grow and mature (ASMFC 1999). These areas include spawning grounds and areas through which the larvae and post-larvae drift after hatching, as well as the portions of rivers and estuaries in which they feed, grow, and mature. Juvenile alosines, which leave the coastal bays and estuaries prior to reaching adulthood, also use the nearshore Atlantic Ocean as a nursery area (ASMFC 1999).

Sub-adult and adult habitat for alosines consists of: the nearshore Atlantic Ocean from the Bay of Fundy in Canada to Florida; inlets, which provide access to coastal bays and estuaries; and riverine habitat upstream of the spawning grounds (ASMFC 1999). American shad and river herring have similar seasonal distributions, which may be indicative of similar inshore and offshore migratory patterns (Neves 1981). Although the distribution and movements of hickory shad are essentially unknown after they return to the ocean (Richkus and DiNardo 1984), due to harvest along the southern New England coast in the summer and fall (Bigelow and Schroeder 1953) it is assumed that they also follow a migratory pattern similar to American shad (Dadswell *et al*. 1987).

Critical habitat in North Carolina is defined as, “The fragile estuarine and marine areas that support juvenile and adult populations of economically important seafood species, as well as forage species important in the food chain.” Among these critical habitats are anadromous fish spawning and nursery areas in all coastal fishing waters (NCAC 3I.0101 (20) (NCDEHNR 1997). Although most states have not formally designated essential or critical alosine habitat areas, most states have identified spawning habitat, and some have even identified nursery habitat.

Tables in Section II of each alosine species chapter contain significant environmental, temporal, and spatial factors that affect the distribution of American shad, hickory shad, alewife, and blueback herring. Additional tables found on the included DVD contain confirmed, reported, suspected, or historical state habitat for American shad, hickory shad, alewife, and blueback herring. Alosines spend the majority of their life cycle outside of state waters, and the Commission recognizes that all habitats used by these species are essential to their existence.

1.3.3.2 Present Condition of Riverine Habitats and Habitat Areas of Particular Concern

Fisheries management measures cannot successfully sustain anadromous alosine stocks if the quantity and quality of habitat required by all species are not available. Harvest of fisheries resources is a major factor impacting population status and dynamics, and is subject to control and manipulation. However, without adequate habitat quantity and quality, the population cannot exist (ASMFC 1999).

Habitat Quantity

Thousands of kilometers of historic anadromous alosine habitat have been lost due to development of dams and other obstructions to migration. In the 19th century, organic pollution from factories created zones of hypoxia or anoxia near large cities (Talbot 1954; Chittenden 1969). Gradual loss of spawning and nursery habitat quantity and quality, and overharvesting are thought to be the major causative factors for population declines of American shad, hickory shad, alewife, and blueback herring (ASMFC 1999). Although these threats are considered the major causative factors in the decline of shad and river herring, additional threats are discussed in the Threats chapter.

It is likely that American shad spawned in all rivers and tributaries throughout the species' range on the Atlantic coast prior to dam construction in this country (Colette and Klein-MacPhee 2002). While precise estimates are not possible, it is speculated that at least 130 rivers supported historical runs; now there are fewer than 70 systems that support spawning. Individual spawning runs may have numbered in the hundreds of thousands. It is estimated that runs have been reduced to less than 10% of historic sizes. One recent estimate of river kilometers lost to spawning is 4.36×10^3 compared to the original extent of the runs. This is an increase in available habitat over estimates from earlier years, with losses estimated at 5.28×10^3 in 1898 and 4.49×10^3 in 1960. The increase in available habitat has largely been due to restoration efforts and enforcement of pollutant abatement laws (Limburg *et al*. 2003).

Some states have general characterizations of the degree of habitat loss, but few studies have actually quantified impacts in terms of the area of habitat lost or degraded (ASMFC 1999). It has been noted that dams built during the 1800's and early to mid-1900's on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran *et al*. 1983; CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953). North Carolina characterized river herring habitat loss as "considerable" from wetland drainage, stream channelization, stream blockage, and oxygen-consuming stream effluent (NCDENR 2000).

Some attempts have been made to quantify existing or historical areas of anadromous alosine habitat, including spawning reaches. For example, Maine estimated that the American shad habitat area in the Androscoggin River is 10,217,391 yd^2. In the Kennebec River, Maine, from Augusta to the lower dam in Madison, including the Sebasticook and Sandy rivers, and Seven Mile and Wesserunsett streams, there is an estimated 31,510,241 yd^2 of American shad habitat and 24,606 surface acres of river herring habitat. Lary (1999) identified an estimated 90,868 units (at 100 yd^2 each) of suitable habitat for American shad and 296,858 units (at 100 yd^2 each) for alewife between Jetty and the Hiram Dam along the Saco River, Maine. Above the Bosher's Dam on the James River, Virginia, habitat availability was estimated in terms of the number of spawning fish that the main-stem area could support annually, which was estimated at 1,000,000 shad and 10,000,000 river herring (Weaver *et al*. 2003).

Although many stock sizes of alosine species are decreasing or remain at historically low levels, some stock sizes are increasing. It has not been determined if adequate spawning, nursery, and adult habitat presently exist to sustain stocks at recovered levels (ASMFC 1999).

Habitat Quality

Concern that the decline in anadromous alosine populations is related to habitat degradation has been alluded to in past evaluations of these stocks (Mansueti and Kolb 1953; Walburg and Nichols 1967). This degradation of alosine habitat is largely the result of human activities. However, it has not been possible to rigorously quantify the magnitude of degradation or its contribution to impacting populations (ASMFC 1999).

Of the habitats used by American shad, spawning habitat has been most affected. Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. In most alosine spawning and nursery areas, water quality problems have been gradual and poorly defined; it has not been possible to link those declines to changes in alosine stock size. In cases where there have been drastic declines in alosine stocks, such as in the Chesapeake Bay in Maryland, water quality problems have been implicated, but not conclusively demonstrated to have been the single or major causative factor (ASMFC 1999).

Toxic materials, such as heavy metals and various organic chemicals (i.e., insecticides, solvents, herbicides), occur in anadromous alosine spawning and nursery areas and are believed to be potentially harmful to aquatic life, but have been poorly monitored. Similarly, pollution in nearly all of the estuarine waters along the East Coast has certainly increased over the past 30 years, due to industrial, residential, and agricultural development in the watersheds (ASMFC 1999). Specific challenges that currently exist are identified and discussed in greater detail in the Threats Chapter.

1.3.4 Threats to Alosine Species

NOTE: Due to broad geographic ranges, alosine species are susceptible to varied threats throughout different life stages. The threats identified under this section occur during the freshwater and/or estuarine portion of species life histories.

1.3.4.1 Identification of Threats

THREAT #1: BARRIERS TO UPSTREAM AND DOWNSTREAM MIGRATION

Section 1.1A: Dams and Hydropower Facilities

Issue 1.1A.1: Blocked or restricted upstream access

There has been considerable loss of historic spawning habitat for shad and river herring due to the dams and spillways impeding rivers along the East Coast of the United States. Permanent man-made structures pose an ongoing barrier to fish passage unless fishways are installed or structures are removed. Low-head dams can also pose a problem, as fish are unable to pass over them except when tides or river discharges are exceptionally high (Loesch and Atran 1994). Historically, major dams were often constructed at the site of natural formations conducive to waterpower, such as natural falls. Diversion of water away from rapids at the base of falls can reduce fish habitat, and in some cases cause rivers to run dry at the base for much of the summer (MEOEA 2005).

Many dams have facilities that are designed to provide upstream passage to spawning habitat for migratory species. However, dams without adequate upstream fish passage facilities prevent, or significantly reduce, the numbers of migratory fish that return to available habitat (Quinn 1994). Suboptimal fish passage at a low-head dam on the Neuse River, North Carolina, resulted in limited production of American shad in that system (Beasley and Hightower 2000). Subsequent removal of the dam in 1998 facilitated the return of American shad and striped bass to historic spawning habitats above the dam.

American shad likely spawned in most, if not all, rivers and tributaries in their range prior to dam construction along the Atlantic coast (Colette and Klein-MacPhee 2002). Precise estimates are not possible, but scientists speculate that at least 130 rivers supported historical runs; now there are fewer than 70 spawning systems for American shad. Furthermore, individual spawning runs at one time may have numbered in the hundreds of thousands, but current runs may provide less than 10% of historic spawning habitat (Limburg *et al*. 2003). Dams built from the 19th century through the mid-20th century on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran *et al*. 1983; CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953).

Issue 1.1A.2: Impacts during downstream migration

Another impact of dams on diadromous species migration is their potential to cause mortality to young fish that pass over sluices and spillways during out-migration. Potential effects to fish passing through spillways or sluices may include injury from turbulence, rapid deceleration, terminal velocity, impact against the base of the spillway, scraping against the rough concrete face of the spillbay, and rapid pressure changes (Ferguson 1992; Heisey *et al*. 1996).

Prior to the early 1990s, it was thought that migrating shad and river herring suffered significant mortality going through turbines during downstream passage (Mathur and Heisey 1992). One study estimated that mortality of adult American shad passing through a Kaplan turbine was approximately 21.5% (Bell and Kynard 1985).

Juvenile shad emigrating from rivers have been found to accumulate in larger numbers near the forebay of hydroelectric facilities, where they become entrained in intake flow areas (Martin *et al*. 1994). Relatively high mortality rates were reported (62% to 82%) at a hydroelectric dam for juvenile American shad and blueback herring, depending on the power generation levels tested (Taylor and Kynard 1984). In contrast, Mathur and Heisey (1992) reported a mortality rate of 0% to 3% for juvenile American shad (55 to 140 mm fork length), and 4% for juvenile blueback herring (77 to 105 mm fork length) through Kaplan turbines. Mortality rate increased to 11% in passage through a low-head Francis turbine (Mathur and Heisey 1992). Other studies reported less than 5% mortality when large Kaplan and fixed-blade, mixed-flow turbines were used at a facility along the Susquehanna River (RMC 1991, 1994). At the same site, using small Kaplan and Francis runners, the mortality rate was as high as 22% (NA 2001). At another site, mortality rate was about 15% where higher revolution, Francis-type runners were used (RMC 1992).

Additional studies reported that changes in pressure had a more pronounced effect on juveniles with thinner and weaker tissues as they moved through turbines (Taylor and Kynard 1984). Furthermore, some fish may die later from stress, or become weakened and more susceptible to predation, so losses may not be immediately apparent to researchers (Gloss 1982).

Issue 1.1A.3: Delayed migration

When juvenile alosines delay out-migration, they may concentrate behind dams, making them more susceptible to actively feeding predators. They may also be more vulnerable to anglers that targ*et al*osines as a source of bait. Delayed out-migration can also make juvenile alosines more susceptible to marine predators that they may have avoided if they had followed their natural migration patterns (McCord 2005a). In open rivers, juvenile alosines gradually move seaward in groups that are likely spaced according to the spatial separation of spawning and nursery grounds (Limburg 1996; J. McCord, South Carolina Department of Natural Resources, personal observation).

Issue 1.1A.4: Changes to the river system

In addition to physically impeding fish migration, dams can have other impacts on anadromous fish habitat. Releasing water from dams and impoundments (or reservoirs) may lead to flow alterations, altered sediment transport, disruption of nutrient availability, changes in water quality downstream (including both reduced and increased changes in temperatures), streambank erosion, concentration of sediment and pollutants, changes in species composition, solubilization of iron and manganese and their absorbed or chelated ions, and hydrogen sulfide in hypolimnetic (release of water at low level outlets) releases (Yeager 1995; Erkan 2002). Many dams spill water over the top of the structure where water temperatures are the warmest, which essentially creates a series of warm water ponds rather than a natural stream channel (Erkan 2002). Conversely, water released from deep reservoirs may be poorly oxygenated, below normal seasonal water temperature, or both, thereby causing loss of suitable spawning or nursery habitat in otherwise habitable areas.

Reducing minimum flows can dehydrate otherwise productive habitats causing increased water temperature or reduced dissolved oxygen levels (ASMFC 1985, 1999; USFWS *et al*. 2001).

Pulsing or "hydropeaking" releases typically produce the most substantial environmental alterations (Yeager 1995), including reduced biotic productivity in tailwaters (Cushman 1985).

During low flow periods (typically summer and fall), gases, dissolved oxygen in particular, may be depleted (Yeager 1995). Storing water at hydropower facilities during times of diminished rainfall can also lead to low dissolved oxygen conditions downstream. Such conditions have occurred along the Susquehanna River at the Conowingo Dam, Maryland, from late spring through early fall, and have historically caused large fish kills below the dam (Krauthamer and Richkus 1987).

Disruption of seasonal flow rates in rivers has the potential to impact upstream and downstream migration patterns for adult and juvenile alosines (ASMFC 1985, 1999; Limburg 1996; USFWS *et al*. 2001). Changes to natural flows can also disrupt natural productivity and availability of zooplankton, which is nourishment for larval and early juvenile alosines (Crecco and Savoy 1987; Limburg 1996).

Although most dams that impact diadromous fish are located along the length of rivers, fish can also be affected by hydroelectric projects at the mouths of rivers, such as the large tidal hydroelectric project at the Annapolis River in the Bay of Fundy, Canada. Dadswell *et al*. (1983) found that this particular basin and other surrounding waters are used as foraging areas during summer months by American shad from all runs along the East Coast of the United States. Because the facilities are tidal hydroelectric projects, fish may move into and out of the impacted areas with each tidal cycle. Although turbine mortality is relatively minor with each passage, the repeated passage into and out of these facilities may cumulatively result in substantial overall mortalities (Scarratt and Dadswell 1983).

Issue 1.1A.5: Secondary impacts

Blocked migratory paths can reduce the diadromous species contribution of nutrients and carbon to riparian systems. Riverine habitats and communities may be strongly influenced by migratory fauna that provide a significant source of energy input (Polis *et al*. 1997). Furthermore, many freshwater mussels are dependent upon migratory fishes as hosts for their parasitic larvae (Neves *et al*. 1997; Vaughn and Taylor 1999); loss of upstream habitat for migratory fish is a major cause of mussel population declines (Williams *et al*. 1993; Watters 1996).

It is estimated that the annual biomass contribution of anadromous alosines to the non-tidal James River, Virginia, was 155 kg/ha (assumes 3.6 million fish with 70% post-spawning mortality) in the 1870s, before dams blocked upstream migration (Garman 1992). Based on the estimated 90% reduction in alosine abundance in the Chesapeake Bay over the past 30 years, Garman and Macko (1998) concluded that, "the ecological roles hypothesized for anadromous *Alosa* spp. may now be greatly diminished compared to historical conditions."

Section 1.1B: Avoiding, Minimizing, and Mitigating Impacts of Dams and Hydropower Facilities

Approach 1.1B.1: Removing dams

Not all projects are detrimental to fish populations, so each site should be evaluated separately to determine if fish populations will be (or are being) negatively impacted (Yeager 1995). Wherever practicable, tributary blockages should be removed, dams should be notched, and bypassing dams or installing fish lifts, fish locks, fishways, or navigation locks should be considered. Full dam removal will likely provide the best chance for restoration; however, it is not always practicable to remove large dams along mainstem rivers. Removing dams on smaller, high-order tributaries is more likely to benefit ascending river herring than shad, which spawn in the larger mainstem portions of rivers (Waldman and Limburg 2003).

<u>Example: Successful Dam Removals</u>

Along the large, lower-river tributaries of the Susquehanna River, Pennsylvania, at least 25 dams have either been removed or fitted with fishways, which has provided a total of 350 additional stream kilometers for anadromous fish (St. Pierre 2003). In addition, some dams within the Atlantic sturgeon's range have been removed, including the Treat Falls Dam on the Penobscot River, Maine, and the Enfield Dam on the Connecticut River, Connecticut. In 1999, the Edwards Dam at the head-of-tide on the Kennebec River was removed, which restored 18 miles of Atlantic sturgeon spawning and nursery habitat and resulted in numerous sightings of large Atlantic sturgeon from Augusta to Waterville (Squires 2001).

Unfortunately, many waterways along the Atlantic coast host impoundments constructed during the Industrial Revolution that originally were a source of inexpensive power; many of these structures are no longer in use and should be removed (Erkan 2002).

Approach 1.1B.2: Installing or modifying fish passage facilities

1. For Upstream Passage

a) Fishways

Fish passage facilities, or fishways, allow fish to pass around an impoundment they would otherwise be unable to negotiate. Vertical slot fishways are commonly used to provide upstream access around dam structures. They are designed to draw fish away from the turbulent waters at the base of the dam toward the smooth flowing waters at the entrance of the fishway. Once fish enter the fishway, they negotiate openings, or vertical slots, in the baffle walls. Fish move from pool to pool as they advance up the fishway, using the pools as rest areas (VDGIF 2006).

Another type of fishway is the fish ladder. Fish ladders consist of a series of baffles, or weirs, that interrupt the flow of water through the passage structure. As with vertical slot fishways, a series of ascending pools is created.

A third type of fishway, the Denil fishway, is the most common type in the northeast and reliably passes shad and river herring. In fact, construction of fish ladders in coastal streams of Maine resulted in rapid and noticeable increases in the number of adult alewife returning to these streams (Rounsefell and Stringer 1943).

It is important to note that although fish passage facilities are instrumental in restoring fish to historical habitat, they are not 100% efficient because some percentage of target fish will not find and successfully use the fishway (Weaver *et al*. 2003). At sites where bypass facilities are in place, but are inadequate, efficiency of upstream and downstream fish passage should be improved. Furthermore, passage facilities should be designed specifically for passing target species; some facilities constructed for species such as Atlantic salmon, have proven unsuitable for passing shad (Aprahamian *et al*. 2003).

In 1999, a vertical slot fishway was opened at Bosher's Dam on the James River, Virginia, ending nearly 200 years of blocked access to upstream areas. As a result, 221.4 km of historical spawning habitat on the main stem of the river and 321.9 km on tributaries was restored. By 2001, an increasing trend of relative abundance of American shad in the fall zone was strongly correlated with an increasing trend of American shad passage (Weaver *et al*. 2003). (Note: This increase was dominated by hatchery-raised fish, thus, fish passage may have had little to do with the increased population in this situation; M. Hendricks, Pennsylvania Fish and Boat Commission, pers., comm.)

b) Pipe passes

Pipe passes consist of a pipe below the water level that passes through a barrier. Substrate is provided in the pipe to decrease water velocity and to allow American eel to crawl through the pipe. Although this design creates a direct passage, it is flawed because the pipe often becomes blocked with debris, rendering it ineffective. Pipe passes are most efficient at the outflow of large impoundments that act as a sediment trap for debris so that water entering the pipe is clear of material that might cause a blockage (Solomon and Beach 2004).

c) Locks and lifts

For locks, fish swim into a lock chamber with an open lower gate. The gate periodically closes and the chamber is filled with water, bringing it up to level with the headpond. The upper gate is then opened and the fish swim out. This type of fish passage involves a great deal of engineering and can be expensive. This solution is ideal for very high head situations where conventional passes are impractical (Solomon and Beach 2004).

Alternatively, a fishlift involves a chamber that fish swim into. A steel bucket recessed in the chamber floor is lifted up to or above the head pond level, a gate is opened and the fish are dumped out. Moffitt *et al*. (1982) noted that blueback herring responded quite favorably to improved lift facilities at the Holyoke Dam on the Connecticut River, with passage increasing tremendously. Despite these improvements, stocks have declined considerably in recent years (R. St. Pierre, United States Fish and Wildlife Service, pers. comm.).

2. For Downstream Passage

Fish migrating downstream may pass through turbines, spillage, bypass facilities, or a combination of the three. One comparison between spillways and efficiently operated turbines found that the two systems were comparable in reducing fish mortality (Heisey *et al*. 1996).

Downstream passage of spent adult American shad through large turbines at the Safe Harbor project along the Susquehanna River, Pennsylvania, found that survival rate was 86% (NA and Skalski 1998). Survival rates would likely not be as favorable at facilities that employ smaller, high-speed turbines. Additional measures to help facilitate survival rates include controlled spills during peak migration months (St. Pierre 2003).

At some sites it is not desirable to move fish through turbines, alternatively, they can be moved through a bypass facility. Creating a strong attraction flow helps guide fish to the bypass system and away from the intake flow areas of the turbines (Knights and White 1998; Verdon *et al*. 2003). Additionally, barrier devices can help deter fish away from flow intake areas. Barrier devices used to deter fish include lights, high-frequency sound, air bubble curtains, electrical screens, water jet curtains, and chemicals. Mechanical barrier devices include hanging chains, louvers, angled bars, and screens (Martin *et al*. 1994; Richkus and Whalen 1999; Richkus and Dixon 2003). Submerged strobe lights were found to be quite effective at directing fish away from turbines and through a sluiceway (Martin *et al*. 1994).

Approach 1.1B.3: Operational modifications

Hydroprojects operate more closely to the natural flow patterns of a stream when water moves through them with a fairly constant flow. Consequently, storage-release projects are more likely to alter both daily and seasonal flow patterns (Yeager 1995). Adjusting in-stream flows to more closely reflect natural flow regimes may help increase productivity of alosines, especially during summer to early fall when large, deep reservoirs stratify, and anoxic water releases are possible (McCord 2003).

Power generation can also be reduced, or ceased altogether, during prime downstream migration periods. This option might be cost-effective if migratory behavior coincides with off-peak rate schedules (Gilbert and Wenger 1996). Flows can be re-regulated at dams downstream of the primary dam to stabilize flows further downstream (Cushman 1985). Additionally, some studies have found that the most efficient operating flows for small turbines may not result in the best fish survival rates, but that operation at higher flows may pass fish more safely (Fisher *et al*. 1997).

Where hydrological conditions have been modified, additional measures can be implemented to help mitigate impacts on the river. For example, operational changes can be made to accomplish a number of improvements, such as reducing the upper limit of variability of one or more of the physical or chemical characteristics of the river. For example, incorporating turbine venting into major dams has proven useful for increasing dissolved oxygen concentrations. Alternatively, aerating reservoirs upstream of hydroelectric plants (Mobley and Brock 1996), as well as aerating flows downstream from the plants using labyrinth weirs and infuser weirs have also proven reliable for increasing the dissolved oxygen concentration in the water (Hauser and Brock 1994).

For alosines that migrate downstream during early evening hours, maintaining peak efficiency flows through selected turbines during these hours, as well as employing turbines that reduce mortality, may be effective (St. Pierre 2003).

Approach 1.1B.4: Streambank stabilization

States that have significant problems with streambank erosion have turned to stabilization to help further prevent erosion. Projects should maintain vegetated riparian buffers, making use of native vegetation wherever possible (MEOEA 2005). Habitat modification, including manipulating the cross-sectional geometry of the stream channel, may also serve to mitigate effects (Cushman 1985).

Loesch (1987) found that blueback herring responded favorably to changes in physical and hydrological conditions, becoming re-established and even increasing in abundance once favorable conditions were established or restored.

Approach 1.1B.5: Fish transfers

When populations have been extirpated from their habitat due to dam blockage, it may be necessary to transfer sexually mature pre-spawning adults or hatchery-reared fry and fingerlings above obstructed areas.

Transplanting of fertilized alosine eggs has had limited success; eggs are now collected mostly for use in culture operations. Culture operations have focused primarily on American shad, and to a lesser degree blueback herring, alewife, and hickory shad (Hendricks 2003). Transplanting adult American shad, blueback herring, and alewife has been highly successful. Adult gravid shad can be trapped in the river where they originate, or other rivers, and trucked to upstream sites where they can be expected to spawn in areas that are otherwise not accessible. This may be an effective means for supplementing the river population until fish passage facilities are improved (both in the upstream and downstream direction), or fish passage facilities are constructed where they currently do not exist. As the return populations grow, further modifications may be necessary to accommodate larger runs (St. Pierre 1994).

For example, the release of hatchery-reared American shad in the James River, Virginia, in the mid-1990's, resulted in greater than 40% of hatchery-reared fish spawning several years later. This percentage greatly exceeded the percentage of the hatchery contribution (3 to 8%). If the offspring of hatchery-reared fish survive to reproduce, this should provide a significant boost to this severely depressed population (Olney *et al*. 2003).

At the Conowingo Dam on the Susquehanna River, Pennsylvania, 70 to 85% of the adult American shad returning from 1991 through 1995 were hatchery-reared. By 2003, the hatchery-to-wild ratio had been reversed, and naturally produced adults comprised 40 to 60% of returning fish (St. Pierre 2003).

Additionally, Maryland reported that over 80% of the 142 adults captured in the Patuxent and Choptank rivers in 2000 were of hatchery origin. It appears that shad stock enhancement, through the release of hatchery-reared fish, has proven to be beneficial when accompanied by other management measures including habitat restoration and water quality protection (Hendricks 2003).

Finally, pre-spawning adult American shad were taken from the Connecticut River and transplanted in the Pawcatuck River, Rhode Island, where they had been absent for 100 years. Six years later, in 1985, a population of over 4,000 fish existed (Gibson 1987).

Section 1.2: Road Culverts and Other Sources of Blockage

Issue 1.2A: Road culverts

While dams are the most common obstructions to fish migration, road culverts are also a significant source of blockage. Culverts are popular, low-cost alternatives to bridges when roads must cross small streams and creeks. Although the amount of habitat affected by an individual culvert may be small, the cumulative impact of multiple culverts within a watershed can be substantial (Collier and Odom 1989).

Roads and culverts can also impose significant changes in water quality. Winter runoff in some states includes high concentrations of road salt, while stormwater flows in the summer cause thermal stress and bring high concentrations of other pollutants (MEOEA 2005).

Sampled sites in North Carolina revealed river herring upstream and downstream of bridge crossings, but no herring were found in upstream sections of streams with culverts. Additional study is underway to determine if culverts are the cause for the absence of river herring in these areas (NCDENR 2000). Even structures only 20 to 30 cm above the water can block shad and river herring migration (ASMFC 1999).

Issue 1.2B: Other man-made structures

Additional man-made structures that may obstruct upstream passage include: tidal and amenity barrages; tidal flaps; mill, gauging, amenity, navigation, diversion, and water intake weirs; fish counting structures; and earthen berms (Durkas 1992; Solomon and Beach 2004). The impact of these structures is site-specific and will vary with a number of conditions including head drop, form of the structure, hydrodynamic conditions upstream and downstream, condition of the structure, and presence of edge effects (Solomon and Beach 2004).

Issue 1.2C: Natural barriers

Rivers can also be blocked by non-anthropogenic barriers, such as beaver dams, waterfalls, log piles, and vegetative debris. These blockages may be a hindrance to migration, but they can also be beneficial since they provide adhesion sites for eggs, protective cover, and feeding sites (Klauda *et al*. 1991b). Successful passage at these natural barriers is often dependent on individual stream flow characteristics during the fish migration season.

THREAT #2: WATER WITHDRAWAL FACILITIES

Section 2.1A: Hydropower, Drinking Water, Irrigation, and Snow-making Facilities

Issue 2.1A.1: Impingement and entrainment

Large volume water withdrawals (e.g., drinking water, pumped-storage hydroelectric projects, irrigation, and snow-making), especially at pumped-storage facilities, can drastically alter local current characteristics (e.g., reverse river flow). This can cause delayed movement past the facility, or entrainment where the intakes occur (Layzer and O'Leary 1978). Planktonic eggs and larvae entrained at water withdrawal projects experience high mortality rates due to pressure changes, shear and mechanical stresses, and heat shock (Carlson and McCann 1969; Marcy 1973; Morgan *et al*. 1976). Well-screened facilities are unlikely to cause serious mortality to juveniles; however, large volume withdrawals can entrain significant numbers (Hauck and Edson 1976; Robbins and Mathur 1976).

Impingement of fish can trap them against water filtration screens, leading to asphyxiation, exhaustion, removal from the water for prolonged periods of time, or removal of protective mucous and descaling (DBC 1980).

Studies conducted along the Connecticut River found that larvae and early juveniles of alewife, blueback herring, and American shad suffered 100% mortality when temperatures in the cooling system of a power plant were elevated above 28°C; 80% of the total mortality was caused by mechanical damage and 20% was due to heat shock (Marcy 1976b). Ninety-five percent of the fish near the intake were not captured by the screen, and Marcy (1976b) concluded that it did not seem possible to screen fish larvae effectively. Results from earlier years led Marcy (1976c) to conclude that although mortality rates for eggs and larvae entrained in the intake system were very high, given the high natural mortality rate and the number of eggs produced by one adult shad, the equivalent of only one adult shad was lost during that study year as a result of egg and larval entrainment. Furthermore, there was no evidence that adult shad had changed the location of their spawning areas in the river as a result of plant operation (Marcy 1976c).

Another study of juvenile American shad emigrating from the Hudson River found that impingement at power plants was an inconsequential source of mortality; however, when added to other more serious stresses, it may possibly contribute to increased mortality rates (Barnthouse and Van Winkle 1988).

Issue 2.1A.2: Alteration of stream physical characteristics

Water withdrawals can also alter physical characteristics of streams, including: decreased stream width, depth, and current velocity; altered substrate; and temperature fluctuations (Zale *et al*. 1993). In rivers that are drawn upon for water supply, water is often released downstream during times of decreased river flow (usually summer). Additionally, failure to release water during times of low river flow and higher than normal water temperatures can cause thermal stress, leading to fish mortality. Consequently, water flow disruption can result in less freshwater input to estuaries (Rulifson 1994), which are important nursery areas for many anadromous species.

Cold water releases often decrease the water temperature of the river downstream, which has been shown to cause juvenile American shad to abandon their nursery areas (Chittenden 1969; 1972). At the Cannonsville Reservoir on the West Branch of the Delaware River, cold-water releases from the dam resulted in the elimination of nursery grounds below the dam for American shad (DBC 1980).

Section 2.1B: Avoiding, Minimizing, and Mitigating Impacts of Water Withdrawal Facilities

Approach 2.1B.1: Use of technology and water velocity modification

Impacts resulting from entrainment can be mitigated to some degree through the use of the best available intake screen technology (ASMFC 1999), or through modifying water withdrawal rates or water intake velocities (Lofton 1978; Miller *et al*. 1982). Devices have also been used at hydroelectric projects to deter fish from intake flows, including: electrical screens, air bubble curtains, hanging chains, lights, high-frequency sound, water jet curtains, chemicals, visual keys, or a combination of these approaches (Martin *et al*. 1994). Promoting measures among industry that use reclaimed water, instead of freshwater from natural areas, can help reduce the amount of freshwater needed (FFWCC 2005). Location along the river was also found to be a significant factor affecting impingement rates in the Delaware River (Lofton 1978).

THREAT #3: TOXIC AND THERMAL DISCHARGES

Section 3.1A: Industrial Discharge Contamination

Issue 3.1A.1: Chemical effects on fish

Industrial discharges may contain toxic chemicals, such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) that are harmful to aquatic life (ASMFC 1999). Many contaminants have been identified as having deleterious effects on fish, particularly reproductive impairment (Safe 1990; Longwell *et al*. 1992; Mac and Edsall 1991). Chemicals and heavy metals can be assimilated through the food chain, producing sub-lethal effects such as behavioral and reproductive abnormalities (Matthews *et al*. 1980). In fish, exposure to polychlorinated biphenyls (PCBs) can cause fin erosion, epidermal lesions, blood anemia, altered immune response, and egg mortality (Post 1987; Kennish *et al*. 1992). Furthermore, PCBs are known to have health effects in humans and are considered to be human carcinogens (Budavari *et al*. 1989).

A number of common pollutants have been found to disturb the thyroid gland in fish, which plays a role in the maturation of oocytes. These chemicals include: lindane (organochlorine) (Yadav and Singh 1987); malathion (organophosphorus compound) (Lal and Singh 1987; Singh 1992); endosulfan (organochlorine) (Murty and Devi 1982); 2,3,7,8-PCDD and –PCDF (dioxin and halogenated furane); some PCBs (particularly 2,3,7,8-TCDD *para* and *meta* forms) (Safe 1990); and PAHs (polycyclic aromatic hydrocarbons) (Leatherland and Sunstegard 1977, 1978, 1980).

Steam power plants that use chlorine to prevent bacterial, fungal, and algal growth present a hazard to all aquatic life in the receiving stream, even at low concentrations (Miller *et al*. 1982). Pulp mill effluent and other oxygen-consuming wastes are discharged into a number of streams.

Lack of dissolved oxygen from industrial pollution and sewage discharge can greatly affect abundance of shad and prevent migration upriver or prevent adults from emigrating to sea and returning again to spawn. Everett (1983) found that during times of low water flow when pulp mill effluent comprised a large percentage of the flow, river herring avoided the effluent. Pollution may be diluted in the fall when water flow increases, but fish that reach the polluted waters downriver before the water has flushed the area will typically succumb to suffocation (Miller *et al*. 1982).

Effluent may also pose a greater threat during times of drought. Such conditions were suspected of interfering with the herring migration along the Chowan River, North Carolina, in 1981. In past years, the effluent from the pulp mill had passed prior to the river herring run, but drought conditions caused the effluent to remain in the system longer. Toxic effects were indicated, and researchers suggested that growth and reproduction might have been disrupted as a result of eutrophication and other factors (Winslow *et al*. 1983).

Even thermal effluent from power plants can have a profound effect on fish, causing disruption of schooling behavior, disorientation, and death. Researchers concluded that 30°C was the upper natural temperature limit for juvenile alosines (Marcy *et al*. 1972).

Issue 3.1.2: Sewage effects on fish

Sewage can have direct and indirect effects on anadromous fish. Minimally effective sewage treatment during the 1960s and early 1970s may have been responsible for major phytoplankton and algal blooms in tidal freshwater areas of the Chesapeake Bay, which reduced light penetration (Dixon 1996), and ultimately reduced SAV abundance (Orth *et al*. 1991). Some of Massachusetts' large to mid-sized rivers receive raw sewerage into their waters, and during summer low flows, are composed primarily of sewerage treatment effluent (MEOEA 2005).

Section 3.1B: Avoiding, Minimizing, and Mitigating Impacts of Toxic and Thermal Discharges

Approach 3.1B.1: Proper treatment of facility discharge

Although there has been a general degradation of water quality coastwide, the levels of sewage nutrients discharged into coastal waters during the past 30 years have decreased as a result of the Clean Water Act, passed in 1972. This has led to a decrease in organic enrichment, which has benefited water quality conditions. A reduction of other types of pollutant discharges into these waters, such as heavy metals and organic compounds, would not be expected (ASMFC 1999).

In many northern rivers, such as the Kennebec, Penobscot, Connecticut, Hudson, and Delaware Rivers, dissolved oxygen levels approached zero parts per million in the 1960s and 1970s. Since then, water quality has greatly improved as a result of better point-source treatment of municipal and industrial waste (USFWS-NMFS 1998). In 1974, secondary and tertiary sewage treatment was initiated in the Hudson River, which led to conditions where dissolved oxygen was greater than 60% saturation. There was a return of many fish species to this habitat (Leslie 1988), including a high abundance of juvenile shortnose sturgeon (Carlson and Simpson 1987; Dovel *et al*. 1992).

Additionally, although poor water quality is often identified as a barrier to fish migration, it should be noted that poor water quality can be caused by both point and non-point sources of pollution. In fact, it may be difficult, if not impossible, for water quality standards to be achieved in some regions due to the effects of non-point sources of pollution (Roseboom *et al*. 1982).

The estimated lost spawning habitat for American shad in 1898 was 5.28 x 10^3 river km, and in 1960 it was estimated at 4.49 x 10^3 km. The most recent estimate is now 4.36 x 10^3 river km. This increase in available habitat has been largely attributed to restoration efforts and enforcement of pollutant abatement laws (Limburg *et al*. 2003).

In compliance with the Clean Water Act, proper treatment of large city domestic sewage at treatment plants has dramatically improved the poor water quality conditions that persisted in the Delaware River for many years. Water quality problems were dramatically manifested in a "pollution block," including severely depressed levels of dissolved oxygen in the early 1900s in the Philadelphia/Camden area. There were very few repeat American shad spawners in this river, compared with other mid-Atlantic rivers (Miller *et al*. 1982). The situation had greatly improved by the late 1950s, due to a reduction in point-source pollution entering tidal waters, which led to an increase in dissolved oxygen by the 1980s (Maurice *et al*. 1987). This has led to a large enhancement of the American shad population in this river (Ellis *et al*. 1947; Chittenden 1969; Miller *et al*. 1982).

Similarly, improvements to water quality in the Potomac River in the 1970s led to increased water clarity and subsequently an increase in SAV abundance in 1983 (Dennison *et al*. 1993). In addition, pulp mill effluent was thought to have limited American shad survival in the Roanoke River (Walburg and Nichols 1967), but compliance with water quality standards in recent years has resulted in improved spawning habitat in this system (Hightower and Sparks 2003).

Additional measures to improve habitat include reducing the amount of thermal effluent into rivers and streams, and discharging earlier in the year to reduce impacts to migrating fish (ASMFC 1999).

THREAT #4: CHANNELIZATION AND DREDGING

Section 4.1A: Impacts of Dredging on Fish Habitat

Issue 4.1A.1: Primary environmental impacts of channelization

Channelization has the potential to cause significant environmental impacts (Simpson *et al*. 1982; Brookes 1988), including bank erosion, elevated water velocity, reduced habitat diversity, increased drainage, and poor water quality (Hubbard 1993). Dredging and disposal of spoils along the shoreline can also create spoil banks, which block access to sloughs, pools, adjacent vegetated areas, and backwater swamps (Frankensteen 1976). Dredging may also release contaminants resulting in bioaccumulation, direct toxicity to aquatic organisms, or reduced dissolved oxygen levels (Morton 1977). Furthermore, careless land use practices may lead to erosion, which can lead to high concentrations of suspended solids (turbidity) and substrate (siltation) in the water following normal and intense rainfall events. This can displace larvae and juveniles to less desirable areas downstream and cause osmotic stress (Klauda *et al*. 1991b).

Spoil banks are often unsuitable habitat for fishes. Sand areas are an important nursery habitat to YOY striped bass. This habitat is often lost when dredge disposal material is placed on natural sand bars and/or point bars. The spoil is too unstable to provide good habitat for the food chain. Mesing and Ager (1987) found that electrofishing CPUE for gamefish was significantly greater on natural habitat than on "new (75%)," recent (66%)," or "old (50%)" disposal sites. Old sites that had not been disposed on for 5 to –10 or more years had not recovered to their natural state in terms of relative abundance of gamefish populations. The researchers also found that placement of rock material on degraded sand disposal sites had significantly greater electrofishing CPUE for sportfish than these sites had prior to placement of the rock material (Mesing and Ager 1987).

Draining and filling, or both, of wetlands adjacent to rivers and creeks in which alosines spawn has eliminated spawning areas in North Carolina (NCDENR 2000).

Issue 4.1A.2: Secondary environmental impacts of channelization

Secondary impacts from channel formation include loss of vegetation and debris, which can reduce habitat for invertebrates and result in reduced quantity and diversity of prey for juveniles (Frankensteen 1976). Additionally, stream channelization often leads to altered substrate in the riverbed and increased sedimentation (Hubbard 1993), which in turn can reduce the diversity, density, and species richness of aquatic insects (Chutter 1969; Gammon 1970; Taylor 1977). Suspended sediments can reduce feeding success in larval or juvenile fishes that rely on visual cues for plankton feeding (Kortschal *et al*. 1991). Fish species that rely on benthic invertebrates within sediments may also experience decreased food availability if prey numbers are reduced.

Sediment re-suspension from dredging can also deplete dissolved oxygen, and increase bioavailability of any contaminants that may be bound to the sediments (Clark and Wilber 2000).

Issue 4.1A.3: Impacts of channelization on fish physiology and behavior

Migrating adult river herring have been found to avoid channelized areas with increased water velocities. Several channelized creeks in the Neuse River basin in North Carolina have reduced river herring distribution and spawning areas (Hawkins 1979). Frankensteen (1976) found that the channelization of Grindle Creek, North Carolina removed in-creek vegetation and woody debris, which served as substrate for fertilized eggs.

Channelization can also reduce the amount of pool and riffle habitat (Hubbard 1993), which is an important food-producing area for larvae (Keller 1978; Wesche 1985). American shad postlarvae have been found concentrated in riffle-pool habitat (Ross *et al*. 1993).

Dredging can negatively affect alosine populations by producing suspended sediments (Reine *et al*. 1998), and migrating alosines are known to avoid waters of high sediment load (ASMFC 1985; Reine *et al*. 1998). It is also possible that fish may avoid areas where there is ongoing dredging due to suspended sediment in the water column. This was believed to have been the cause of a diminished return of adult spawning shad in a Rhode Island river, although no causal mechanism could be established (Gibson 1987). Filter-feeding fishes, such as alosines, can be negatively impacted by suspended sediments on gill tissues (Cronin *et al*. 1970). Suspended sediments can clog gills that provide oxygen, resulting in lethal and sub-lethal effects to fish (Sherk *et al*. 1974, 1975).

Nursery areas along the shorelines of the rivers in North Carolina have been affected by dredging and filling, as well as by erection of bulkheads; however, the degree of impact has not been measured. In some areas, juvenile alosines were unable to enter channelized sections of a stream due to high water velocities caused by dredging (ASMFC 2000). Despite findings by Miller *et al*. (1982) that the effects of river dredging on fish populations were insignificant, they suspected that migrating juvenile shad could potentially be impacted by increased suspended solids, lowered dissolved oxygen concentration, and release of toxic materials.

Section 4.1B: Avoiding, Minimizing, and Mitigating Impacts of Channelization

Approach 4.1B.1: Seasonal restrictions and proper material disposal

Dredging restrictions are already in place in many rivers including the Kennebec, Connecticut, Cape Fear, Cooper, and Savannah Rivers (USFWS-NMFS 1998), to help curtail the impacts of dredging to anadromous fish. Seasonal restrictions on dredging in areas where anadromous fish are known to occur should be established until there is irrefutable evidence that dredging does not restrict the movement of fish (Gibson 1987). It is recommended that dredge material be disposed of in the most ecologically beneficial way possible that will prevent harm to existing natural habitats (FFWCC 2005).

THREAT #5: LAND USE CHANGE

The effects of land use and land cover on water quality, stream morphology, and flow regimes are numerous, and may be the most important factors determining quantity and quality of aquatic habitats (Boger 2002). Studies have shown that land use influences dissolved oxygen (Limburg and Schmidt 1990), sediments and turbidity (Basnyat *et al*. 1999; Comeleo *et al*. 1996), water temperature (Hartman *et al*. 1996; Mitchell 1999), pH (Osborne and Wiley 1988; Schofield 1992), nutrients (Basnyat *et al*. 1999; Osborne and Wiley 1988; Peterjohn and Correll 1984), and flow regime (Johnston *et al*. 1990; Webster *et al*. 1992).

Siltation, caused by erosion due to land use practices, can kill submerged aquatic vegetation (SAV). SAV can be adversely affected by suspended sediment concentrations of less than 15 mg/L (Funderburk *et al*. 1991) and by deposition of excessive sediments (Valdes-Murtha and Price 1998). SAV is important because it improves water quality (Rybicki and Hammerschlag 1991), and provides refuge habitat for migratory fish and planktonic prey items (Maldeis 1978; Killgore *et al*. 1989; Monk 1988).

Section 5.1A: Agriculture

Issue 5.1A.1: Sedimentation and irrigation

Decreased water quality from sedimentation became a problem with the advent of land-clearing agriculture in the late 18th century (McBride 2006). Agricultural practices can lead to sedimentation in streams, riparian vegetation loss, influx of nutrients (e.g., inorganic fertilizers and animal wastes), and flow modification (Fajen and Layzer 1993). Agriculture, silviculture, and other land use practices can lead to sedimentation, which reduces the ability of semi-buoyant eggs and adhesive eggs to adhere to substrates (Mansueti 1962).

In addition, excessive nutrient enrichment stimulates heavy growth of phytoplankton that consume large quantities of oxygen when they decay, which can lead to low dissolved oxygen during the growing season (Correll 1987; Tuttle *et al*. 1987). Such conditions can lead to fish kills during hot summer months (Klauda *et al*. 1991b).

Another factor, chemical contamination from agricultural pesticides, has a significant potential to impact stream biota, especially aquatic insects, but is difficult to detect (Ramade *et al*. 1984).

Furthermore, irrigation can cause dewatering of freshwater streams, which can decrease the quantity of both spawning and nursery habitat for anadromous fish. Dewatering can cause reduced water quality as a result of more concentrated pollutants and/or increased water temperature (ASMFC 1985).

Uzee and Angermeier (1993) found that in some Virginia streams, there was an inverse relationship between the proportion of a stream's watershed that was agriculturally developed and the overall tendency of the stream to support river herring runs. In North Carolina, cropland alteration along several creeks and rivers has significantly reduced river herring distribution and spawning areas in the Neuse River basin (Hawkins 1979).

Issue 5.1A.2: Nutrient loading

Atmospheric nitrogen deposition in coastal estuaries of states such as North Carolina, has had an increasingly negative effect on coastal waters, leading to accelerated algal production (or eutrophication) and water quality declines (e.g., hypoxia, toxicity, and fish kills). The primary source of atmospheric nitrogen in these areas comes from livestock operations and their associated nitrogen-rich (ammonia) wastes, and to a lesser degree, urbanization, agriculture, and industrial sources (Paerl *et al*. 1999). Animal production farms have greatly contributed to deteriorating water quality in other areas, including the Savannah, Ogeechee, and Altamaha Rivers (Georgia), and the Chesapeake Bay (USFWS-NMFS 1998; Collins *et al*. 2000; McBride 2006).

From the 1950s to the present, increased nutrient loading has made hypoxic conditions more prevalent (Officer *et al*. 1984; Mackiernan 1987; Jordan *et al*. 1992; Kemp *et al*. 1992; Cooper and Brush 1993; Secor and Gunderson 1998). Hypoxia is most likely caused by eutrophication, due mostly to non-point source pollution (e.g., industrial fertilizers used in agriculture) and point source pollution (e.g., urban sewage).

Section 5.1B: Avoiding, Minimizing, and Mitigating Agricultural Impacts

Approach 5.1B.1: Erosion control and best management practices

Erosion control measures and best management practices (BMPs) can reduce sediment input into streams, which can reduce the impact on aquatic fauna (Lenat 1984; Quinn *et al*. 1992). Agricultural BMPs may include: vegetated buffer strips at the edge of crop fields, conservation tillage, strip cropping, diversion channels and grassed waterways, soil conservation and water quality planning, nutrient management planning, and installing stream bank fencing and forest buffers. Animal waste management includes: manure storage structures, runoff control for barnyards, guttering, and nutrient management (ASMFC 1999). Programs to upgrade wastewater treatment at hog and chicken farms should be promoted (NC WRC 2005). Additionally, restoring natural stream channels and reclaiming floodplains in areas where the channel or shoreline has been altered by agricultural practices can help mitigate impacts (VDGIF 2005).

Section 5.2A: Logging/Forestry

Issue 5.2A.1: Logging

Logging activities can modify hydrologic balances and in-stream flow patterns, create obstructions, modify temperature regimes, and input additional nutrients, sediments, and toxic substances into river systems. Loss of riparian vegetation can result in fewer refuge areas for fish from fallen trees, fewer insects for fish to feed on, and reduced shade along the river, which can lead to increased water temperatures and reduced dissolved oxygen (EDF 2003). Potential threats from deforestation of swamp forests include: siltation from increased erosion and runoff; decreased dissolved oxygen (Lockaby et al. 1997); and disturbance of food-web relationships in adjacent and downstream waterways (Batzer et al. 2005).

In South Carolina, forestry BMPs for bottomland forests are voluntary. When BMPs are not exercised, plant material and disturbed soils may obstruct streams, excessive ruts may force channel-eroded sediments into streams, and partially stagnated waters may become nutrient-rich, which can lead to algal growth. These factors contribute to increased water temperature and reduced dissolved oxygen (McCord 2005b).

Section 5.2B: Avoiding, Minimizing, and Mitigating Logging Impacts

Approach 5.2B.1: Best management practices

Virginia advocates working with private, small foresters to implement forestry BMPs along rivers to reduce the impacts of forestry practices (VDGIF 2005). Florida discourages new bedding on public lands where there is healthy groundcover (FFWCC 2005).

Section 5.3A: Urbanization and Non-Point Source Pollution

Issue 5.3A.1: Pollution impacts on fish and fish habitat

Urbanization can cause elevated concentrations of nutrients, organics, or sediment metals in streams (Wilber and Hunter 1977; Kelly and Hite 1984; Lenat and Crawford 1994). Recent studies conducted in Charleston Harbor, South Carolina, found that crustacean prey of estuarine fishes are directly affected by urbanization and related water quality parameters, including concentrations of a variety of toxicants (especially petroleum-related materials) (EDF 2003). Furthermore, the amount of developed land may influence use of a habitat, but other factors such as size, elevation, and habitat complexity are important as well, and in some cases may outweigh the negative effects of development (Boger 2002). More research is needed on how urbanization affects diadromous fish populations.

One study found that when the percent of land in areas increased to about 10% of the watershed, the number of alewife egg and larvae decreased significantly in tributaries of the Hudson River, New York (Limburg and Schmidt 1990).

Section 5.3B: Avoiding, Minimizing, and Mitigating Impacts of Urbanization and Non-Point Source Pollution

Approach 5.3B.1: Best management practices

Urban BMPs include: erosion and sediment control; stormwater management; septic system maintenance; and forest buffers (ASMFC 1999). Siting stormwater treatment facilities on upland areas is recommended where possible (FFWCC 2005). Wooded buffers and conservation easements should be established along streams to protect critical shoreline areas (ASMFC 1999), and low impact development should be implemented, where practicable (NCWRC 2005).

Since the abundance of SAV is often used as an indirect measure of water quality, and there is a correlation between water quality and alosine abundance, steps should be taken to halt further reduction of underwater sea grasses (especially important in the Chesapeake Bay) (B. Sadzinski, Maryland Department of Natural Resources, pers. comm.).

Regarding cumulative effects on river herring spawning habitat, Boger (2002) suggested that land use and morphology within the entire watershed should be considered, and that the cumulative effects within the entire watershed may be as important as the type of land use within buffer zones. This is an important point to consider when establishing required widths of buffer zones in an effort to balance anthropogenic activities in the watershed and maintain biological integrity of streams (Boger 2002).

THREAT #6: ATMOSPHERIC DEPOSITION

Section 6.1A: Atmospheric Deposition

Issue 6.1A.1: Acid rain and low pH

Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. This occurrence inputs a significant source of pollutants to many water bodies. Pollutants can get from the air into the water through rain and snow, falling particles, and absorption of the gas form of the pollutants into the water. Atmospheric deposition that causes low pH and elevated aluminum (acid rain) can contribute to changes in fish stocks. When pH declines, the normal ionic salt balance of the fish is compromised and fish lose body salts to the surrounding water (Southerland *et al*. 1997).

American shad stocks that spawn in poorly buffered Eastern Shore Maryland rivers, like the Nanticoke and Choptank, were found to be vulnerable to storm-induced, toxic pulses of low pH and elevated aluminum. These stocks, therefore, may recover at a much slower rate than well-buffered Western Shore stocks, even if all other anthropogenic stressors are removed (Klauda 1994; ASMFC 1999). Streams often experience their highest levels of acidity in the spring, when adult shad are returning to spawn (Southerland *et al*. 1997).

There is speculation that recent precipitous declines in American shad populations may partly be due to acid rain (Southerland *et al*. 1997). Fertilized eggs, yolk-sac larvae, and to a lesser degree, young feeding (post yolk-sac) larvae of American shad have the highest probability for exposure to temporary episodes of pH depressions and elevated aluminum levels in, or near, freshwater spawning sites (Klauda 1994). Klauda (1994) suggests that even infrequent and temporary episodes of critical or lethal pH and aluminum exposures in the spawning and nursery areas could contribute to significant reductions in egg or larval survival of American shad and thereby slow stock recovery. High mortalities of hatchery-reared American shad larvae in 2006 and 2007 were thought to be due to pH depression and elevated aluminum (M. Hendricks, Pennsylvania Fish and Boat Commission, pers. comm.). In 2008, treatment of raw hatchery water with limestone sand raised pH from 6.0 to above 7.0, and resulted in high survival and healthy larvae. Juvenile fish are more susceptible to the effects of low pH, which may effectively prevent reproduction (Klauda 1994).

Threats may be seasonal, ongoing, or even sporadic, all of which can have long-term effects on the recovery of stocks. For example, Hurricane Agnes in 1972 is suspected of causing the 1972 year-class failure for American shad, hickory shad, alewife, and blueback herring, as well as altering many spawning habitat areas in the Chesapeake Bay. Almost twenty years later, these impacts were suggested to be contributing to the slow recovery of stocks in this area (Klauda *et al*. 1991b).

Section 6.1B: Avoiding, Minimizing, and Mitigating Impacts of Atmospheric Deposition

Approach 6.1B.1: Reduction of airborne chemicals

Supporting the reduction of airborne chemical releases from power plants, paper mills, and refineries is one way to decrease the levels of toxins in the air that eventually settle into riverine habitat. Incentives can be promoted at the state level and through cooperative interstate agreements (FFWCC 2005).

1.3.4.2 Effects of Habitat Degradation on Harvesting/Marketability

Effects of habitat degradation that result in non-natural mortality can affect the size of the population and ultimately the size of the allowable harvest. Some threats may not increase mortality, but can reduce or eliminate marketability. These threats include non-lethal limits of contaminants that may render fish unfit for human consumption, or changes in water quality that may reduce fish condition or appearance to a point where they are unmarketable (ASMFC 1999).

The following table lists threats that have been identified for shad and river herring habitat. Because the magnitude of an impact may vary locally or regionally, the degree to which each impact may occur is not specified. Instead, the likelihood to which each impact may occur within each geographical area (riverine waters, territorial waters, or EEZ) is provided.

Table 9. Threats identified for shad and river herring. The categories are as follows: Present (P) denotes a threat that has been specifically identified in the literature; No Information Found (NIF) indicates that no information regarding this threat was found within the literature, but there is a possibility that this threat could occur within the specified geographical area; and Not Present (NP) indicates that the threat could not possibly occur within that geographical area (e.g., dam blockage in the EEZ).

THREAT	Riverine Waters	Territorial Waters	EEZ
Chemical			
Acid/aluminum pulses	P	NIF	NIF
Sedimentation	P	NIF	NIF
Suspended particles	P	NIF	NIF
Inorganic inputs	P	P	NIF
Organic chemicals	P	P	NIF
Thermal effluent	P	P	NP
Urban stormwater pollution	P	P	NIF
Sewage/animal waste	P	P	NIF
Non-point source pollution	P	P	NIF
Physical			
Dams/spillways	*P*	NP	NP
Other man-made blockages (e.g., tide gates)	P	P	NP
Non-anthropogenic blockages (e.g., vegetative debris)	P	NP	NP
Culverts	P	NP	NP
Inadequate fishways/fish-lifts	P	NP	NP
Water releases from reservoirs	P	P	NP
Non-hydropower water withdrawal facilities (e.g., irrigation, cooling)	P	P	NP
Channelization	P	NIF	NP
Dredge and fill	P	P	NP
Urban and suburban sprawl	P	NIF	NP
Land-based disturbances (e.g., de-forestation)	P	NIF	NP
Jetties	NP	P	NP
Overharvesting	P	*P*	P
Biological			
Excessive striped bass predation	P	P	NIF
Nuisance/toxic algae	P	NIF	NIF

1.4 DESCRIPTION OF THE FISHERIES

Alewife and blueback herring formerly supported important commercial and recreational fisheries along the entire Atlantic coast; however, all of these fisheries have declined dramatically. Two types of fisheries have exploited spring spawning migrations of alosines: in-river and ocean-intercept. In-river fisheries only exploit the stock native to that system, whereas ocean-intercept fisheries exploit mixed stocks of different river origins.

Catch statistics for both ocean and in-river alosine fisheries on the Atlantic coast are compiled by the National Marine Fisheries Service and state agencies for both commercial and recreational fisheries; however, there are data gaps in these records. It is important to note that harvest from fishers operating in-river or from fisheries that are not federally licensed might not be reported to NMFS. Information provided below is based on state reports, which are on file with the Commission, and data available from NMFS.

1.4.1 Commercial Fishery

River herring have supported one of the oldest documented fisheries in North America (CRASC 2004). During colonial times in-river stocks of anadromous species such as river herring became subject to intensive exploitation as well as habitat degradation related to clear-cutting, damming for mills and wetland conversion to agricultural lands (Purinton *et al.* 2003). For Massachusetts, the decline in coastal alewife fisheries had become so extensive that between 1790 and 1860 regulations were adopted for most Massachusetts rivers to manage in-river alewife fisheries (Belding 1921). In North Carolina, river herring were the most economically important finfish harvested during the late 1880s, but by 1918 the Atlantic menhaden had become more economically viable than river herring (NC DMF 2007).

Uses of harvested river herring have changed from a major local food source for human consumption in the form of smoked, salted and/or pickled fish (e.g., Belding 1921) toward primarily being used for fishmeal, pet food ingredients, and bait for commercial and sport fishing (Fay *et al*. 1983). During the 20th century, river herring supported a small commercial bait industry in the New England states (Purinton *et al.* 2003). These harvests, which were also used for pet food and fishmeal as well as for bait, declined considerably throughout New England between the turn of the 20th century and the 1980s (CRASC 2003). Yet river herring, when available, have become desirable bait species for recreational anglers, as well as remaining a significant bait source for commercial fisheries such as the American lobster (*Homarus americanus*) fishery (e.g., Anonymous n.d.). For example, Schmidt *et al*. (2003) reported that river herring in the Hudson River are used as striped bass (*Morone saxatilis*) bait but noted that smoked herring processed from the spring was still available.

Commercial harvest of river herring in state waters primarily occurs in the late winter and spring, depending upon location. Fishermen use a variety of gear to target river herring, including gillnet, weir, pound net, fish trap, dip net, cast net, fyke net, drop net, lift net, seine, otter trawl and hook-and-line. While most states have or have had commercial fisheries for river herring in the past, some states have recently implemented moratoria on the harvest of river herring, including Massachusetts, Connecticut, Rhode Island and North Carolina. Virginia has implemented complementary regulations for river herring fisheries in river systems that flow into North Carolina. Pennsylvania and the District of Columbia prohibit commercial fisheries within their jurisdiction and have never had commercial river herring fisheries. Although not unlawful, no commercial fishery for river herring has ever existed in Georgia's rivers or coastal waters. In 1994, Florida implemented a net ban in state waters (Adams *et al*. 2000) that effectively eliminated the river herring commercial fishery. Descriptions of other state's commercial fisheries for river herring follow.

In Maine, commercial fisheries for river herring are cooperatively managed by the municipalities that have been granted fishing rights and the Maine Department of Marine Resources (MDMR). Municipal fisheries have a three-day per week, closed period that requires all fishing gear to be opened to allow for free passage upstream or a spawning escapement equivalent. Commercial bait gillnet fishermen operate in coastal waters and may catch river herring, although participation in this fishery is low (27 fishermen in 2007; M. Brown, MDNR, pers. comm.). There are two active fish traps in Maine coastal waters that have an annual combined landings of river herring less than 500 pounds; this fishery is opportunistic and landings are based on seasonal availability.

River herring serve as a significant bait source for commercial fisheries in New Hampshire. New Hampshire Fish and Game Department (NHFGD) requires permits for the harvest of river herring and a license for the sale of the fish. NHFGD prohibits the harvest of river herring on Wednesdays. In New Hampshire waters, there are various restrictions for seines and gillnets (mesh size, length, season, etc.) and other gear and no mobile gear may be used to harvest finfish within the state.

Commercial fisheries for river herring exist within the Hudson River, NY and it tributaries. All commercial take and sale requires a marine permit issued by the New York State Department of Environmental Conservation. Primary gears include gill nets, fished in the main stem Hudson River and scap (lift) or dip nets, which are fished in the smaller tributaries. Other gears used include cast nets, and to a small extent, trap or fyke nets. Fishing season occurs from March 15^{th} through June 15^{th}. Regulations include gear restrictions on net and mesh sizes, as well as area closures along for the main stem river. Permitees are required to fill out an annual report, which includes a descriptions of when / where fishing occurred, along with catch, bycatch and effort expended (amount and type of gear and fishing time). The number of gill net fishers has grown in recent years following the popularity of the Hudson's striped bass fishery; river herring are the primary bait used.

National Marine Fisheries Service reports river herring landings from a variety of commercial fishing operations (primarily otter trawl) off Long Island, NY. Since 2000, all river herring landings, regardless of season, are classified as blueback herring. Any *Alosa spp*. could be in the catch, including alewife (more prevalent in the spring) and hickory shad (more prevalent in the late summer and fall). It is not clear why this single species classification occurs. There are limited fisheries in a few eastern Long Island streams which support small spawning runs of alewives. For ocean waters off of Long Island, a mandatory reporting system exists; however, the accuracy of this reporting has not been verified. Other Long Island gears may encounter river herring as bycatch such as pound net (trap nets), otter trawls, small mesh gill nets and bait seines used for menhaden. The extent of this bycatch is unknown.

River herring are harvested in New Jersey's small-mesh gillnet fishery. The majority of river herring landings from this fishery are categorized as bait. There are likely bait fisheries that operate in New Jersey rivers and creeks where there are large populations of river herring. River herring may also be taken in a variety of other fisheries that operate in New Jersey waters, especially the early spring white perch fishery.

The Delaware commercial fishery for river herring is relatively small, but has produced highly variable landings ranging from 500-36,000 lbs since 1985. All commercial river herring landings come from small-mesh gillnets set for white perch and herring. No specific regulations have been adopted to reduce or restrict commercial landings of river herring; however, there are regulations that apply to the entire commercial fishery that limit commercial fishing effort and have a direct effect on catch. These restrictions include a limited entry license system, limitations on the amount of gear that may be fished, a gillnet season and area restrictions. There is currently proposed legislation that would prohibit the use of any net within 300 feet of any dam and also prohibit the use of any gillnet within the Nanticoke River. These two pieces of legislation would effectively eliminate the commercial fishery for river herring in Delaware.

Maryland's commercial river herring fishery is seasonally restricted, running from 1 January to 5 June, but because most fish have returned to the ocean by June, this law has little, if any, management consequence. Up until 2005, the commercial river herring fishery was a directed fishery employing drift gillnets. Since 2005, the directed fishery reported minimal landings and effort declined. Many commercial gillnet fishermen no longer target river herring. A limited pound net and fyke net bycatch fishery for river herring also exists.

In the Potomac River, the Potomac River Fisheries Commission (PRFC) regulates commercial fishing activity. According to PRFC records, the Potomac river herring fishery has been almost exclusively a pound net fishery since 1964. Pound net fishery effort in the Potomac River has been capped at 100 licenses since 1995.

Virginia's management of fisheries has two regions: (1) those within aquatic reaches affected by the tide are managed by Virginia Marine Resources Commission (VMRC) and (2) those reaches above tidal influence are managed by Virginia Division of Game and Inland Fisheries (VDGIF). Commercial fishing for river herring primarily occurs in areas under VMRC's management. There are restrictions on both length of gear and mesh size for gillnets.

In South Carolina, the river herring commercial fishery is managed with seasons, harvest caps, gear restrictions, weekly lift periods, and licenses. South Carolina's commercial fishery targets adult pre-spawning blueback herring for bait and human consumption, particularly roe. Most fish harvested in the riverine gillnet fishery are consumed locally or sold as bait.

Total commercial landings of river herring from Maine to Florida were approximately 10.5 million pounds in 1980 (NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.). Yet by 1992, total landings decreased to 3.2 million pounds (NMFS, Fisheries Statistics

Division, Silver Spring, MD, pers. comm.). Since 1994, state-reported commercial landings for the East Coast have not exceeded two million pounds. Recent landings by state are presented in Table 10. There are many factors influencing the reported commercial river herring landings that might explain the large degree of variability observed in data on a state-by-state basis.

Table 10. State-reported commercial landings (pounds) of river herring, 2003-2007. †Landings from Maine are from the directed commercial municipal fisheries only; these numbers do not include bait gillnet, bycatch, weir or inland commercial permits, or VTR reports from coastal fisheries. *Under moratorium. ^ Some rivers under moratorium in 2007. ^^ Under moratorium in 2007; landings from research set-asides only.

State	2003	2004	2005	2006	2007
Maine†	969,360	885,582	340,060	1,178,758	740,915
New Hampshire	16,516	9,093	1,514	1,717	1,408
Massachusetts*	-	-	8,952	-	-
Rhode Island*	-	-	-	-	-
Connecticut*	-	-	-	-	-
New York	-	15,200	12,782	9,748	14,354
New Jersey	3,439	4,583	3,247	2,945	223
Pennsylvania	-	-	-	-	-
Delaware	6,371	3,925	3,715	3,355	1,896
Maryland	117,515	60,055	32,255	32,045	54,821
DC	-	-	-	-	-
PRFC	20,132	19,739	8,507	6,819	6,011
Virginia^	209,327	203,273	91,662	48,865	104,923
North Carolina^^	199,716	188,541	250,021	109,243	1,103
South Carolina	129,259	66,735	152,225	82,798	152,558
Georgia	-	-	-	-	-
Florida	-	-	-	-	-
Total	**1,671,635**	**1,456,726**	**904,940**	**1,476,293**	**1,078,212**

There are no consistent regional or U.S. Atlantic time series data of river herring ex-vessel values and related prices. Prior to 2000, NMFS recorded all river herring landings as *alewife* and did not differentiate between the two species (alewife and blueback herring). Consequently, in the following ex-vessel value and price analysis, only data on "alewife" landings and reported total ex-vessel revenues for the Atlantic states during the period 1985-2005 were used. These data were obtained from the Fisheries Statistics Division of the National Marine Fisheries Service.

Using alewife as an overall indicator of recent (1986-2006) river herring ex-vessel value trends, the nominal total (aggregate) ex-vessel value of the U.S. Atlantic coast alewife harvest has ranged from a low of about $123,000 in 2006 to a high of approximately $625,000 in 1986 (Table 11). (Since 1949, the highest nominal total ex-vessel value, ~$1.1 million, reported by NMFS, occurred in 1967.) Annual average nominal, ex-vessel value during the 1987-1996 period, ~$316,000, declined to an average of about $247,000 after 1996. When ex-vessel values are adjusted for inflation using the Consumer Price Index[2], the average total ex-vessel value of alewife landings was about $183,000 coastwide after 1996 (Table 11), only 65% of the total real ex-vessel value for previous period (1987-1996). Since 1987, nominal U.S. Atlantic coast prices per pound for alewife generally increased over time (Figure 2) and peaked at $0.45 per pound in 2006 (Table 11). The U.S. Atlantic real (deflated) price also generally trended upward from 1987, peaking at a ~$0.27 per pound in 2006. With declining landings, the real average real ex-vessel price for alewife during the 1997-2006 period, ~$0.16 per pound, was 45% higher than the ex-vessel price, about $0.11 per pound during the previous 10-year period. Real river herring ex-vessel prices in North Carolina also generally trended upward since 1985, but have not exceeded $0.10 per pound since 1995 (NC DMF 2007).

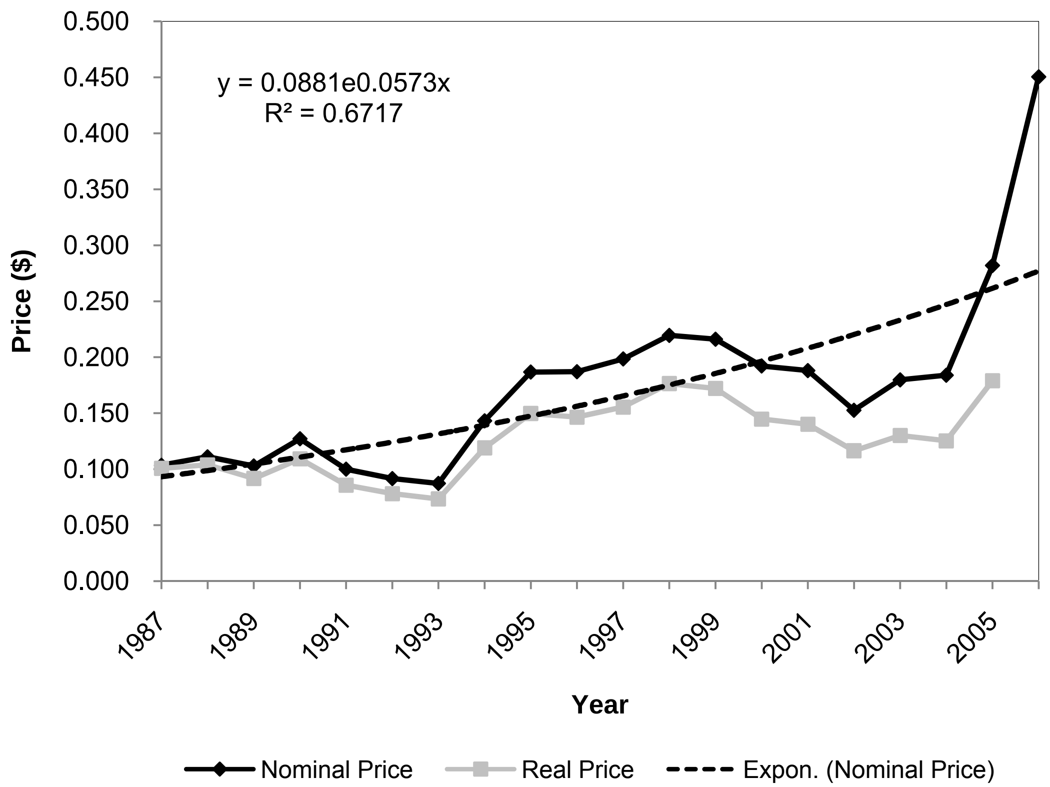
Table 11. Total annual U.S. Atlantic landings, ex-vessel values and prices of the alewife as reported to the National Marine Fisheries Service, 1986-2006 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

Year	Landings (lbs)	Total Ex-vessel Value ($):		Ex-vessel Price, ($/Lb):	
		Nominal	Real^	Nominal	Real^
1987	5,614,390	581,529	565,690	0.104	0.101
1988	5,622,963	625,037	584,693	0.111	0.104
1989	3,413,277	351,407	313,197	0.103	0.092
1990	2,726,369	346,800	298,194	0.127	0.109
1991	2,922,301	292,361	250,954	0.1	0.086
1992	3,213,133	294,672	251,427	0.092	0.078
1993	1,682,532	146,978	123,615	0.087	0.073
1994	970,237	139,071	115,507	0.143	0.119
1995	1,010,874	188,824	151,423	0.187	0.15
1996	1,023,057	191,489	149,952	0.187	0.147
1997	1,160,070	230,280	180,470	0.199	0.156
1998	1,331,720	292,434	235,076	0.22	0.177
1999	1,351,686	292,241	232,861	0.216	0.172
2000	1,171,685	225,212	169,715	0.192	0.145
2001	1,537,171	289,301	215,575	0.188	0.14
2002	1,953,379	298,345	227,571	0.153	0.117
2003	1,499,030	269,612	195,230	0.18	0.13
2004	1,331,878	245,134	167,099	0.184	0.125
2005	732,979	206,683	131,311	0.282	0.179
2006	272,826	122,899	74,620	0.45	0.274
Means: All Years:		**$281,515**	**$231,709**	**$0.18**	**$0.13**
Means: 1987-1996:		**$315,817**	**$280,465**	**$0.124**	**$0.106**
Means: 1997-2006:		**$247,214**	**$182,953**	**$0.226**	**$0.161**

^Total ex-vessel values and prices deflated using the Consumer Price Index.

[2]Given the scope of this analysis, the Consumer Price Index (CPI) was selected for deflating ex-vessel prices out of convenience as well as allowing comparability with other deflated ex-vessel price series. However, as others have noted (e.g., Tomek & Robinson 2003), deflating prices should be approached with caution especially when applying consumer oriented price index series to producer prices.

Figure 2. Real and nominal ex-vessel price ($/lb) for U.S. Atlantic alewife landings, 1986-2006 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).



Schmidt *et al.* (2003) noted that there was no published literature supporting the notion that river herring landings associated with large rivers on the East Coast of North American had been declining "due to the lack of market demand." At least during recent decades, the general increase in annual real alewife ex-vessel prices (Figure 2) is consistent with their observation (i.e., a general decrease or lack of market demand as a major factor contributing to the decline in river herring landings seems very unlikely).

Ex-vessel prices for river herring, like other market commodities, are determined jointly by demand and supply including exogenous factors that impact markets such as harvest constraints or moratoriums. Interacting factors that could be impacting river herring prices besides regulatory constraints on river herring may also include the apparent escalation in market demand for river herring as recreational fishing bait especially for anglers targeting striped bass (e.g., Capone 2007, Volstad *et al*. 2003). For example, retail prices of $3 and $2 for individual live and dead river herring, respectively, have recently been reported for New Jersey bait shops (Geiser 2008) and as high as $5 per fish elsewhere (PFBC 2008).

Recognizing that several factors may affect the level of demand and supply over time, given observed levels of apparent quantities demanded and supplied, an equilibrium price per pound (i.e., an ex-vessel price) can be approximated. Specifically, if it can be shown that a measurable and statistically significant relationship existed between quantities supplied and ex-vessel prices, it is possible to provide some historical insight on how commercial landings have impacted the ex-vessel market segment as well as perhaps forecasting how future prices may be impacted by proposed regulatory actions.

Alewife data (see Table 19) were used to estimate a simple annual ex-vessel price model for characterizing how changes in river herring landings could have recently affected ex-vessel market prices. The following semi-log price model[3] was specified:

$$Real\ Ex\text{-}vessel\ Price_t = \alpha + \beta(ln)Landings_t;$$

where the *Real Ex-vessel Price* is the observed annual (deflated) ex-vessel price per pound for alewife landings in U.S. Atlantic states, *(ln)Landings* is the natural log of the annual amount (poundage) of reported landings, t is time and α and β are parameter coefficients to be estimated for the above model. There are many complicated models or functional forms that could be used to explore the relationship between landings and ex-vessel prices but the choice of this semi-linear form was based on the limitations of the available data and the related need to have a relatively simple price model that is capable of adequately representing the variation in river herring ex-vessel prices associated with different levels of landings. Additionally, since the expected relationship between reported landings and ex-vessel prices is not likely to be linear, a semi-log (non-linear) functional form was selected. The semi-log model was estimated using ordinary least squares (OLS).

The estimated model parameters were the following:

$$Real\ Ex\text{-}vessel\ Price_t = 1.2136 - 0.0756(ln)Landings_t$$

t-Statistics: (8.26) (-7.17)

Durbin-Watson statistic: 1.39

The adjusted R^2 was 0.848 (N=10) and the F-value (51.39) for the equation was significant ($p \leq 0.0001$).

The t-statistic for the alewife landings parameter is statistically significant at the 1% level, and landings are estimated to be negatively (inversely) related to annual alewife ex-vessel price. The estimated model as indicated by the R^2 "explains" about 85% of the ex-vessel price trend variability during 1985-2005. Of course, a more complex demand system is needed to consider other factors (e.g., recreational fishing bait demand, fishery regulatory actions, river herring bait substitutes) that have influenced alewife ex-vessel prices. Regardless, the inverse relationship between prices and landings is consistent with supply-demand relationship over a relatively long time period (i.e., 21 years). Using the estimated coefficient of the landings parameter, *– 0.0756*, and the means of the annual prices and quantities landed, the price flexibility[4], F_P, was estimated

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[3]This simple model is often described as an inverse semi-log demand model but it usually includes more than one explanatory (independent) variable.

[4]It is actually the estimated own-price flexibility coefficient which is predicated on the causality of price changes stemming from quantity changes to the ex-vessel price, instead of the usual price to quantity causality (Tomek & Robinson 2003).

to be approximately *–6.5*. This F_P value suggests that the ex-vessel own-price elasticity of demand for alewife during the years analyzed and perhaps river herring in general is inelastic since the absolute value of F_P coefficient is greater than one (Tomek and Robinson 2003).

This apparent relative flexibility of river herring ex-vessel prices in regard to its own landings at least during the 1985-2005 period may also be symptomatic of market factors that could have historically encouraged harvesters to actually escalate their fishing effort because they perceived an ex-vessel market segment with the potential of offsetting declining harvest quantities with higher ex-vessel prices. Stated another way, river herring harvesters and primary processors in past decades may have perceived a long-term market capable of generating them increasing gross revenues even if quantities harvested were declining (i.e., a relatively flexible ex-vessel price situation). For open access fisheries, flexible prices (i.e., inelastic demand) along with other factors have been implicated in the depletion of various fishery stocks (e.g., Brandt 1999). Consequently, from a historical perspective, total revenue changes at the harvester level associated with declining river herring stocks, including declines independent of commercial fishing effort, such as habitat degradation, may have been partially buffered if river herring prices were generally flexible relative to its own landings.

1.4.2 Recreational Fishery

Recreational fisheries for alosines are often poorly documented, if at all. The National Marine Fisheries Service operates the Marine Recreational Fisheries Statistics Survey (MRFSS) to obtain information on recreational fisheries for marine species. MRFSS does not adequately capture information on anadromous fisheries, including those for alewife and blueback herring. Data collected by MRFSS for recreational alosine fisheries are unreliable due to the current survey design that focuses on active fishing sites along coastal and estuarine areas. Error associated with data on harvest, catch, and effort is often high.

While recreational fisheries for river herring are poorly documented and monitored, it is believed that extensive recreational fisheries exist for river herring in many rivers along the East Coast and in coastal waters. Recreational anglers target river herring mainly for bait (lobster and striped bass) and personal consumption. Moreover, it is apparent that recreational anglers in the Mid-Atlantic and New England states commonly harvest river herring as bait species for targeting striped bass.

Some in-river fisheries operate at the base of spillways where river herring are aggregated while waiting to ascend fish ladders or where upstream progress is retarded by dams. Each state and jurisdiction has different regulations for the recreational harvest of river herring, including licensing requirements, size limits, area closures and gear restrictions. Gears used by recreational anglers to target river herring include: rod and reel, dip net, lift net, gillnet and cast net. Recreational creel limits vary by state, ranging from no limit to 10 fish to one bushel per day. The total quantity of fish landed by these recreational fishers for personal use is unknown. The majority of these landings is unreported and thus, represents a large potential error in recorded recreational river herring harvests. The recreational fisheries for river herring in Massachusetts, Rhode Island, and North Carolina are closed under each state's moratorium.

1.4.3 Subsistence Fishing

There are known subsistence fisheries for alosine fisheries, but the extent of effort and harvest is undocumented. An example of subsistence fisheries for river herring is the Mashpee Wampanoag Indian Tribe on Cape Cod, Massachusetts, which has reported annual harvests ranging between 1,200 and 3,400 fish for the years 2006 through 2008.

1.4.4 Non-Consumptive Factors

People interested in conservation and wildlife have been known to observe alosine migrations through natural corridors and fish passage facilities. In some regions, this non-consumptive use of the alosine resources is an important part of public education, local heritage, ecotourism and outdoor recreation. For example, the Massachusetts Division of Marine Fisheries (MDMF n.d.) prepared a brochure that "provides location and viewing dates for several of our most impressive and accessible river herring runs." Real-time video of spring spawning migrations of alosines are available via online webcams for both the fishway at Bosher's Dam on the James River and Fairmount Dam on the Schuyllkill River (available at: http://www.dgif.virginia.gov/fishing/shadcam/index.asp?pop=3 and http://fairmountwaterworks.com/sony/fishpop.php, respectively). In addition, volunteer involvement in non-consumptive cooperative fishery projects has included activities related to river herring such as the Ipswich River Watershed Association's annual herring counts on the Ipswich River in Massachusetts (Bowling and Morkeski 2002).

1.4.5 Interactions with Other Fisheries, Species and Other Uses

1.4.5.1 Bycatch

Catch of anadromous alosines that occurs in fisheries directed at other species is referred to as bycatch. Bycatch also refers to illegal or unmarketable alosines caught in directed fisheries. Estimates of bycatch are difficult to obtain since few studies have focused specifically on that issue. Bycatch losses contribute to the overall mortality of alosines and are important to consider in the current and future management of these fisheries.

Bycatch of river herring, which includes the harvest of sexually mature and immature fish, occurs in non-directed fisheries that employ small-mesh mobile gear, both at-sea and in-river. Much of this incidental catch is utilized, although it goes undocumented or unreported. The NMFS Sea Sampling (Observer) Program estimated harvest and bycatch from a limited number of Atlantic herring trips taken between 2005 and 2007. Observers documented bycatch of river herring to be 41,458 pounds in 2005, 50,681 pounds in 2006, and 121,246 pounds in 2007 (the 2007 value is preliminary as only observed trips from January to April have been recorded in the Observer Database; NEFMC 2006; Steele 2007). Preliminary analysis indicate in some years, the total bycatch of river herring species in the Atlantic herring fleet alone could be equal to the total landings from the entire in-river directed fishery on the East Coast (Matt Cieri, Maine Department of Marine Resources, pers. comm.). Bycatch of river herring also occurs in inshore and freshwater areas in small-mesh mobile gear, pound nets and anchored gillnets.

1.4.5.2 Protected Species Considerations

Marine Mammals

In October 1995, Commission member states, NMFS and USFWS began discussing ways to improve implementation of the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) in state waters. Historically, these policies have been only minimally implemented and enforced in state waters (0-3 miles). It was agreed that the Commission's plans describe impacts of state fisheries on certain marine mammals and endangered species—collectively termed protected species—and recommend ways to minimize these impacts. Section 117 of the MMPA requires that NMFS and the U.S. Fish and Wildlife Service (USFWS) develop stock assessment reports (Reports) for all marine mammal stocks within U.S. waters or that enter U.S. waters (e.g., stocks for which only the margins of the range extends into U.S. waters or that enter U.S. waters only during anomalous current or temperature shifts). Each Report is required to estimate the annual human-caused mortality and serious injury of the stock, by source, and, for a strategic stock, other factors that may be causing a decline or impeding recovery of the stock, including effects on marine mammal habitat and prey, and commercial fisheries that interact with the stock.

Section 3(20) of the MMPA defines a strategic stock is defined as a stock: (1) for which the level of direct human-caused mortality exceeds the potential biological removal (PBR) level; (2) which is declining and is likely to be listed under the Endangered Species Act (ESA) within the foreseeable future; or (3) which is listed as a threatened or endangered species under the ESA or as a depleted species under the MMPA.

Section 3(20) of the MMPA defines the term *potential biological removal* (PBR) as:

> [T]he maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population.

For strategic stocks interacting with Category I and II fisheries, Section 118(f) of the MMPA requires NMFS to appoint a Take Reduction Team (TRT), which must develop a Take Reduction Plan (TRP) designed to assist in the recovery of or to prevent the depletion of the strategic stock that interacts with a commercial fishery. Section 118(f)(2) of the MMPA states that the immediate goal of a TRP for a strategic stock shall be to reduce, within six months of its implementation, the incidental mortality or serious injury of marine mammals incidentally taken in the course of commercial fishing operations to levels less than the PBR level established for that stock under Section 117.

Upon the completion of draft stock assessment reviews developed under Section 117 of the MMPA, NMFS recognized the need to establish TRTs to reduce serious injury and mortality of coastal bottlenose dolphins, harbor porpoises and large whales in several coastal gillnet fisheries along the Atlantic coast.

There are two strategic stocks of marine mammals that are taken by gillnets in coastal state waters at the time alosine fisheries occur, designated as the Mid-Atlantic gillnet fishery under the MMPA's List of Fishery process. The Mid-Atlantic gillnet fishery operates year-round west of a line drawn at 72° 30' W. long. south to 36° 33.03' N. lat. and east to the eastern edge of the EEZ and north of the North Carolina/South Carolina border, not including waters where Category II and Category III inshore gillnet fisheries operate in bays, estuaries and rivers (72 FR 66048; November 27, 2007). Harbor porpoise and coastal bottlenose dolphins are the strategic stocks of marine mammals that are taken by gillnets in coastal state waters at the time that alosine fisheries occur. Both are known to enter tidal estuaries.

Harbor Porpoise

Harbor porpoises that are found along the eastern United States are considered to be one stock or population: the Gulf of Maine/Bay of Fundy stock. This population is dispersed in the Gulf of Maine and Mid-Atlantic in the winter and spring, and then is more concentrated in the Bay of Fundy/upper Gulf of Maine in the summer. The Harbor Porpoise Take Reduction Plan (HPTRP) became effective in January 1999 and implemented regulations in New England and the Mid-Atlantic to reduce the serious injury and mortality of harbor porpoises in commercial gillnet fisheries. The timing and location of the HPTRP management areas coincide with the temporal and seasonal distribution of harbor porpoises.

In July 1993, the Northeast Fisheries Science Center's Sea Sampling (Observer) program initiated an observer program in the Mid-Atlantic coastal gillnet fishery. From 1995 to 2000, 114 harbor porpoises were observed taken (Waring *et al.* 2002). During that time, observed fishing effort was scattered between New York and North Carolina from the beach to 50 miles from shore. Most of the animals taken in state waters are taken in the months of March, April and May, from North Carolina to New Jersey. After 1995, documented bycatch was observed from December to May. The timing and location of stranding data in Mid-Atlantic States follow the timing and location(s) of the ocean-intercept shad fishery as it moves north along the coastline. It is important to note that the East Coast American shad ocean-intercept fishery closed in 2005.

Annual average estimated harbor porpoise mortality and serious injury from the Mid-Atlantic coastal gillnet fishery between 1995 and 1998, before implementation of the Harbor Porpoise Take Reduction Plan, (63 FR 66464, December 2, 1998), was 358 animals (Waring *et al.* 2002). Subsequently, between 2000 and 2004, the average annual harbor porpoise mortality and serious injury in this fishery was 65 animals (Waring *et al.* 2006). However, NMFS has observed an increase in harbor porpoise takes in commercial gillnet fisheries in recent years, due to a lack of compliance with the HPTRP requirements and takes occurring outside HPTRP management areas. The most recent Report estimates that between 2001 and 2005, the total annual estimated average human-caused mortality was 734 harbor porpoises per year (652 from U.S. fisheries), which is higher than the current PBR of 610 (Waring *et al.* 2007).

NMFS reconvened the Harbor Porpoise Take Reduction Team (HPTRT) in December 2007 to discuss updated harbor porpoise abundance and bycatch information. An additional HPTRT meeting was held in January 2008 via teleconference. The HPTRT made recommendations for modifying the HPTRP to address the recent increases in harbor porpoise takes in both the New England and Mid-Atlantic regions.

Bottlenose Dolphin

There are at least two morphologically and genetically distinct stocks of bottlenose dolphin along the eastern coast of the United States: (1) a coastal migratory stock that occurs in coastal waters from Long Island, New York to as far south as central Florida; and (2) an offshore stock primarily distributed along the outer continental shelf and slope in the Northwest Atlantic Ocean. The coastal morphotype is comprised of a complex mosaic of 7 spatial and temporal management units. Resident estuarine stocks are likely demographically distinct from the coastal management units; however, they are currently included in the coastal management unit definitions (Waring *et al.* 2007). Although the estuarine stocks are currently reported with the management units, abundance, mortality and PBR estimates do not include estuarine stocks. Research continues to further define the coastal stock management units and the degree of movement of estuarine dolphins into nearshore, coastal waters, as the spatial overlap remains unclear.

The coastal bottlenose stock was designated as depleted under the Marine Mammal Protection Act due to a large-scale, natural die-off in 1987-1988. Therefore, the coastal stock is listed as strategic because of this die-off and exceeding PBR from serious injuries and mortalities incidental to commercial fisheries. Because one or more of the management units may be depleted, all of the management units currently retain the depleted status.

Estimated annual mortality previously exceeded PBR in at least one management unit. From 2001-2005, the total estimated average annual fishery-related mortality was 61 dolphins attributed to the Mid-Atlantic gillnet fishery. These takes occurred in the Northern Migratory, Northern North Carolina and Southern North Carolina Management Units during both summer and winter months. From 2001-2005, an annual estimate of at least 5 (CV= 0.53) mortalities occurred in the shark drift gillnet fishery off the coast of Florida, affecting the Central Florida Management Unit. Currently, there are no observer data for other fisheries interacting with the coastal stock. However, stranding data indicate interactions with the Virginia Pound Net Fishery and the Atlantic Blue Crab Trap/Pot Fishery. Therefore, the total average annual mortality estimate is a lower bound of the actual annual human-caused mortality for each coastal management unit (Waring *et al*. 2007).

The Bottlenose Dolphin Take Reduction Team (BDTRT) was convened in 2001, and the Bottlenose Dolphin Take Reduction Plan was implemented in May 26, 2006 (71 FR 24776) to address the serious injuries and mortalities incidental to nine Category I and II fisheries. Estimated fishery mortality currently does not exceed PBR for any of the management units due to recent declines in fishery efforts (Waring *et al*. 2007).

Sea Turtles

Sea turtles that occur in U.S. waters are listed as either endangered or threatened under the ESA. Five species occur along the Atlantic coast of the United States: loggerhead (*Caretta caretta*), Kemps ridley (*Lepidochelys kempii*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*).

Shad and river herring are harvested primarily with anchored, staked and drift gillnets; however, there is also a pound net, trawl, and hook and line component to these fisheries. All of these gear types are documented to impact sea turtles. Because these fisheries occur inshore, it is likely to interact with sea turtles depending on the location and season.

A. Gillnets

Stranded loggerhead and Kemp's ridley sea turtles have been partially or completely entangled in gillnet material, and are most likely to come in contact with the gear in shallow coastal waters. Loggerheads and leatherbacks have been captured in the Mid-Atlantic gillnet fishery. Green sea turtles are present in small numbers in these areas and could also be taken in this fishery. Leatherbacks are also present, especially when warmer waters bring jellyfish, their preferred prey, into coastal areas. Hawksbill sea turtles are only rare visitors to the areas where fishing effort occurs, preferring coral reefs with sponges for forage, so interaction would be limited; however, entanglement in gillnets has been identified as a serious problem for hawksbills in the Caribbean (NMFS and USFWS 1993).

Spring and fall gillnet operations have been strongly implicated in coincident sea turtle stranding events from North Carolina through New Jersey. On average, the highest numbers of interactions occurred in spring, followed by summer and fall. The southern states appear to have had more spring interactions, while the northern states had more summer interactions, probably due to the northern migration of sea turtles in the warmer months.

Netting gear found on stranded turtles varied widely, from 2-11.5-inch (5-29-cm) stretch mesh, and ranged from small, cut pieces of net, to lengths of abandoned net (up to 1200 feet (365 m)). Net gear was of various materials including nylon, cotton, and propylene, and in various colors including blue, black and green. Gear type included flounder, sturgeon, and mullet nets, monofilament, twine, gillnets, pound nets, trammel nets, seines, sink nets, and nets attached to anchors, cork floats and buoys.

B. Pound Nets

Most of pound net fishery interactions result in live releases and are documented primarily from North Carolina, Virginia, Long Island and Rhode Island. In Chesapeake Bay, Virginia, turtles become entangled in pound nets starting in mid-May with increasing numbers of entanglements until late June. The construction of leaders in pound nets was found to be a significant factor in these entanglements (Musick *et al*. 1987). Entanglement was found to be insignificant for small mesh (8-12 inch mesh = small; >12-16 inch mesh = large). Large-mesh nets and nets with stringers spaced 16-18 inches apart entangled a large number of turtles. Therefore, the potential to entangle sea turtles in pound nets could be alleviated by decreasing the mesh size in the leaders (Musick *et al*. 1987). The pound net component of the shad and river herring fishery for North Carolina occurs in Albemarle Sound, which is not frequented by turtles due to the relatively low salinities found there.

C. Hook-and-Line

From 1991 through 1995, a total of 112 stranded turtles had fishing hooks associated with some part of their bodies. Sea turtles have also been caught on recreational hook and line gear. For example, from May 24 to June 21, 2003, five live Kemp's ridleys were reported as being taken by recreational fishermen on the Little Island Fishing Pier near the mouth of the Chesapeake Bay. Many other similar anecdotal reports exist. These animals are typically alive and, while the hooks should be removed whenever possible and when it would not further injure the turtle, NOAA fisheries suspects that the turtles are probably often released without hooks being removed. Thus, hook and line fishing does impact sea turtles.

D. Recommendations for Sea Turtle Protection

1. A conservation plan and application for a Section 10 ESA incidental take permit should be developed for those states where the fishery occurs when sea turtles are present.
2. Research into gear development/deployment for gillnets should be conducted to minimize the impact on sea turtles.
3. Pound net leaders should be no larger than 12-inch mesh.
4. Public outreach material should be developed to improve awareness of sea turtle entanglement with hooks and monofilament line.

Migratory Coastal Birds

An unknown, but possibly significant, number of migratory birds are drowned each year in anchored gillnets in the nearshore marine waters of the mid-Atlantic region. Preliminary estimates, based on a study underway by the U.S. Fish and Wildlife Service and incidental mortality data from the Services Madison Wildlife Health Laboratory, indicate that many thousands of loons and sea ducks are killed each year. Before the ocean-intercept shad fishery closure, most shad/bird interactions occur during January through March from North Carolina to New Jersey. South Carolina banned anchored gillnets in their coastal fishery because of excessive bird mortalities.

All of the species listed in Table 12 are diving birds which pursue fish underwater or feed on benthic invertebrates. Fish eating birds are especially vulnerable to drowning in gillnets because they pursue prey underwater. Additionally, fish eating birds may be attracted to the vicinity of nets that are anchored for days at a time to feed on forage fish feeding near the nets. All of the birds listed are present along the Atlantic coast from October through April, depending on weather and timing of migration. Double-crested cormorants are present throughout the year but are most abundant in the middle and northern Atlantic states during the summer.

The actual populations of most migratory coastal birds are largely unknown. Except for some diving ducks (*Aythya*), current surveys sample only a small portion of the populations of sea ducks and do not survey for non-game birds such as loons and grebes. The U.S. Migratory Bird Treaty Act prohibits the take and possession of protected migratory birds, except as may be permitted by regulations. Take means to pursue, hunt, shoot, wound, kill, trap, capture or collect.

Possession means to detain and control.

A list of protected bird species most likely to interact with shad and river herring fisheries along the Atlantic coast are listed in Table 12 and their status can be found in Table 13.

Table 12. List of protected birds in nearshore marine coastal waters most likely to interact with gillnets.

Common Name	Species Name
Common Loon	*Gavia immer*
Red-throated Loon	*Gavia stellata*
Horned Grebe	*Podiceps auritus*
Red-necked Grebe	*Podiceps grisegena*
Double-crested Cormorant	*Phalacrocorax auritus*
Northern Gannet	*Sula bassanus*
Oldsquaw	*Clangula byemalis*
Black Scoter	*Melanitta nigra*
Surf Scoter	*Melanitta perspicillata*
Red-breasted Merganser	*Mergus serrator*

Table 13. Protected birds in coastal bays most likely to interact with gillnets and their East Coast population status.

Species		Status
Common Name	Species Name	
Common Loon	*Gavia immer*	Unknown
Red-throated Loon	*Gavia stellata*	Unknown, 50,000+ winter south of NJ
Horned Grebe	*Podiceps auritus*	Unknown
Red-necked Grebe	*Podiceps grisegena*	Unknown
Double-crested Cormorant	*Phalacrocorax auritus*	Abundant and increasing
Redhead	*Aythya americana*	Depressed but increasing slightly
Canvasback	*Aythya valisineria*	Slightly increasing
Greater Scaup	*Aythya marila*	Decreasing
Lesser Scaup	*Aythya affinis*	Stable
Ring-necked Duck	*Aythya collaris*	Unknown
Red-breasted Merganser	*Mergus serrator*	Stable
Common Goldeneye	*Bucephala clangula*	Stable
Bufflehead	*Bucephala albcola*	Increasing
Oldsquaw	*Clangula hyemalis*	Stable
Black Scoter	*Melanitta nigra*	Probably declining
White-winged Scoter	*Melanitta fusca*	Probably declining
Surf Scoter	*Melanitta perspicillata*	Probably declining
Ruddy Duck	*Oxyura jamaiccasis*	Stable

Shortnose Sturgeon

The shad gillnet fishery has long been know to capture large numbers of sturgeon (Leland 1968), including adult shortnose sturgeon (Collins and Smith 1995). In the southeast, the shad fishery is likely the primary source of injury and direct mortality of shortnose sturgeon (Collins *et al*. 1996). Existing data indicate that in the southeastern U.S., this species occurs in the shad gillnet bycatch in every river system that supports both a shad gillnet fishery and a shortnose sturgeon population.

The riverine shad gillnet season and the shortnose sturgeon spawning migration normally coincide in the southeastern U.S., resulting in capture of individuals intending to spawn (females apparently spawn only once every 2-3 years). Preliminary data suggest that non-lethal encounters of migrating sturgeon with gillnets may result in fallback (i.e., individuals abort the migration, move back downriver, and presumably resorb their gametes) (unpublished data; pers. comm., M. Moser, UNC Wilmington). Thus, in addition to causing injury and direct mortality of spawners, the non-lethal capture of sturgeon in the shad gillnet fishery may cause reduced spawning success and low year class strength.

A. Recommendation for Shortnose Sturgeon Protection

A conservation plan and application for a Section 10 ESA incidental take permit should be developed for those states where the fishery occurs when shortnose sturgeons are present.

2. AMENDMENT GOALS AND OBJECTIVES

2.1 AMENDMENT 2 GOALS AND OBJECTIVES

Goal: Protect, enhance, and restore East Coast migratory spawning stocks of American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*) in order to achieve stock restoration and maintain sustainable levels of spawning stock biomass.

Objectives of Amendment 2:

1. Prevent further declines in river herring (alewife and blueback herring) abundance.
2. Improve our understanding of bycatch mortality by collecting and analyzing bycatch data.
3. Increase our understanding of river herring fisheries, stock dynamics and population health through fishery-dependent and independent monitoring, in order to allow for evaluation of management performance.

4. Retain existing or more conservative regulations for American shad and hickory shad. Requirements for American shad and hickory shad regulations and monitoring are detailed in Amendment 1 to the Shad and River Herring Fishery Management Plan.
5. Promote improvements in degraded or historic alosine critical habitat throughout the species' range.

2.2 MANAGEMENT UNIT

The management units for alosines species under this Fishery Management Plan include all migratory American shad, hickory shad, alewife and blueback herring stocks of the East Coast of the United States. Landlocked alosine populations are not included in the management unit.

Recommendations on management for migratory alosines in the Exclusive Economic Zone (3-200 nautical miles offshore) can be found in Section 4.9.

2.3 DEFINITION OF OVERFISHING

There are currently no overfishing definitions proposed for river herring stocks.

3. MONITORING PROGRAM SPECIFICATIONS

The collection of quality data is necessary to achieve the goal and objectives of the management program, specifically Objectives 2 and 3. It also enables managers to monitor the performance of management measures by improving stock assessment capabilities. This amendment does not propose changes to the monitoring programs specifications for American shad or hickory shad in previous management documents. Monitoring programs for American shad and hickory shad will remain the same as identified in Amendment 1, Technical Addendum #1 and Addendum I to the Shad and River Herring Fishery Management Plan, unless otherwise modified through future plans.

This section describes the operational (as opposed to regulatory) procedures for states to following implementing Amendment 2. The requirements described below concern both fishery-independent and fishery-dependent monitoring programs as well as stocking and hatchery operations.

States and jurisdictions are required to maintain current monitoring programs and sampling for river herring. States and jurisdictions are also required to implement additional monitoring programs in conjunction with current American shad monitoring programs. Complete monitoring requirements for states and jurisdictions are specified in Tables 15 and 16.

Monitoring of alewife and blueback herring stocks, collectively, must occur on an annual basis. Results of monitoring must be reported annually to the Commission as per Section 7. Requirements for fishery-dependent and independent monitoring are described in Section 3.1 and 3.2.

States and jurisdictions must submit proposals to change their required monitoring programs as per Section 5 of this document. Proposals must be submitted in writing to the Commission along with the annual compliance report. The Technical Committee will review the proposals and prepare recommendations and technical advice to the Management Board. The Management Board will determine final approval for changes to required monitoring programs.

While conducting fishery independent and dependent monitoring programs is vital to the achievement of the goals of Amendment 2, the Commission recognizes the financial investment that such programs require. States and jurisdictions must notify the Commission if they are unable to perform compliance requirements, due to financial reasons, prior to the start of annual monitoring, or as soon as such information becomes available. The Commission will attempt to work with states and jurisdictions to develop a plan to satisfy the needs outlined in Amendment 2. The Management Board has the authority to issue a finding of compliance to states that are unable to complete required monitoring for financial reasons during the annual FMP review.

3.1 FISHERY-INDEPENDENT MONITORING

Annual juvenile recruitment—appearance of juveniles in the ecosystem—of alewife and blueback herring assesses juvenile production, predicts future yearclass strength, and provides a signal for recruitment failure or major habitat changes. Recruitment is measured by sampling current-year juvenile fish abundance in estuaries and river systems with discreet populations of alewife or blueback herring.

3.1.1 Juvenile Abundance Indices

Juvenile abundance indices are important indicators of juvenile production throughout the management unit; however, in many other systems, juvenile production of river herring is not monitored. Results of all juvenile surveys shall be reported to the Commission annually as per Section 7.1.3.

3.1.1.1 Calculation of Juvenile Abundance Indices

All juvenile abundance indices, or JAIs, shall be reported as a geometric mean. The method for calculating the geometric mean is described in ASWC (1992) and Crecco (1992). Use of the geometric mean will reduce the probability of a single value unduly influencing management action.

3.1.1.2 Elements for Measurement and Use of Juvenile Indices

The sampling protocol (stations, sampling intensity and gear type) should be consistent over time for the period that the index is to be used. For new sampling programs, states and jurisdictions must prepare a report for the Commission with the following information: details of the sampling design, a description of the analyses performed, and a presentation of the results of those analyses. The Technical Committee shall review any such submittal and either recommend to the Management Board that it accept or reject the new sampling program. If the recommendation is to reject the new sampling program, the Technical Committee will provide a written explanation to the Management Board explaining the reasons for the recommendation. Validation is not required for any particular JAI survey. Validation of river herring juvenile indices has been proven difficult and will not be a criterion for accepting or rejecting any given JAI survey.

3.1.1.3 Evaluation of Juvenile Abundance Indices

The Technical Committee shall annually examine trends in all required juvenile abundance indices. If any JAI shows recruitment failure (i.e., JAI is lower than 90% of all other values in the dataset) for three consecutive years, then appropriate action should be recommended to the Management Board. The Management Board shall be the final arbiter in all management decisions. The Management Board may require juvenile abundance surveys for newly reestablished river herring runs.

3.1.2 Assessing Adult Population Size

Indices of adult spawning stocks are important when determining the efficacy of a particular management approach. Coupled with juvenile abundance indices and mortality estimates, they clarify population dynamics and progress toward management goals. Adult stock indices can include mark-recapture studies, enumeration at fish passage facilities, catch-per-unit-effort, and measurement of mortality and survival rates.

States and jurisdictions are required to implement adult spawning or population monitoring in the systems listed in Table 15. States and jurisdictions may employ a variety of survey techniques to monitor their adult spawning populations of alewife and blueback herring. These include gillnet surveys, mark-recapture studies, hydroacoustic surveys and fish passage enumeration. As part of spawning stock surveys, states are required to take representative samples of adults to determine sex and age composition, repeat spawning (for states north of South Carolina), and size distribution of each stock and species they are monitoring. When possible, states and jurisdictions should calculate mortality and survival estimates for each species and stock. On fishways where passage is monitored, states should enumerate passage of alewife and blueback herring, and passage inefficiencies should be reported, when possible. Results of all adult spawning population monitoring shall be reported to the Commission annually as per Section 7.1.3.

3.1.3 Hatchery Evaluation

Most Commission jurisdictions are actively involved in alosine habitat surveys, identification of stream blockages and fish passage development, management planning, permit review, and stock assessment related to recovery efforts. Although potential exists in many rivers for stock supplementation and re-introductions using adult transplants and cultured fish, this has occurred only intermittently for river herring species. Hatchery rearing and stocking is much more common for American shad and hickory shad.

3.1.3.1 Stocking and Hatchery Evaluation

States and jurisdictions with active hatchery programs for alosine species shall report annually on hatchery contributions (% wild vs. hatchery). Any state wishing to initiate stocking programs for any alosine must present a program description for Commission review. States should work in cooperation with appropriate federal or regional programs to ensure that marking schemes are coordinated with other sates to prevent conflicts in their operations. Results of all stocking and hatchery activities shall be reported to the Commission annually as per Section 7.1.3.

3.1.3.2 Stocking Techniques

Three basic elements of ongoing restoration efforts for anadromous alosines along the Atlantic coast include: (1) control of harvest to allow sufficient spawning escapement; (2) removal of barriers to migration or development of fish passage facilities at dams; and (3) active stock rebuilding, which typically involves larvae or juvenile fish introductions into waters above blockages. Population rebuilding techniques most frequently used include culture and stocking of larvae or juveniles, or stocking of pre-spawned adults that have been netted or trapped from nearby or distant waters.

Culture and Marking

Techniques for culture and marking of American shad are more widely known and are presented here as a reference for river herring culture and marking. Modern American shad culture techniques have been largely developed and refined since the mid-1970s by the Pennsylvania Fish and Boat Commission (PFBC) for the Susquehanna River restoration program. Using eggs stripped and fertilized from spawning adult shad on many East Coast rivers (and the Columbia River), PFBC researchers developed or improved incubation and hatching techniques, first feeds and artificial diets, larval rearing densities, flow and water quality requirements, mass-marking using oxytetracycline, and handling and stocking procedures sufficient to produce 10-20 million shad larvae each year. Pennsylvania and Maryland have also refined techniques for rearing and marking fingerling shad in ponds using artificial and natural diets. One of the high costs associated with culture and stocking programs relates to collection and delivery of eggs. Large-scale programs such as those on the Susquehanna and James rivers may require 15-20 million shad eggs to produce ten million fry. Since spawners are not yet sufficiently abundant in rivers undergoing restoration, these eggs are taken and delivered nightly during spawning seasons from neighboring rivers such as the Delaware, Hudson and Pamunkey. Strip spawning produces 10,000-30,000 eggs per female and viability averages 60-75%. Of those shad that hatch, 90% or more typically survive to stocking.

The Maryland Department of Natural Resources (MDNR) has successfully used tank-spawning techniques for shad that were initially developed for striped bass in cooperation with the University of Maryland’s Center for Marine Biotechnology. This method involves use of timed-release hormone implants in gravid fish and free-spawning in tanks over a several day period. An airlift system delivers eggs to collection boxes for incubation on-site or delivery to distant hatcheries. With individual females providing 50,000- 100,000 eggs, high fertilization rates and very little labor requirement, fewer adult fish are needed and costs are greatly reduced. This technique has also proven effective for hickory shad, but has thus far been unsuccessful with river herring because of the adhesive nature of their eggs.

Cultured shad larvae are typically stocked at 7-22 days of age and carry one to several fluorescent tags on their otoliths. Marking involves a two-four hour immersion in 200-ppm oxytetracycline antibiotic and can be repeated at three-four day intervals. In addition to allowing discrimination between wild and hatchery fish, use of distinct marks allows for analysis of relative survival or abundance based on egg source, stocking location, time of release or other parameters. Tetracycline marking is 100% effective and the tags appear to stay with the fish throughout their lives. Fish being analyzed for marks must be sacrificed for otolith removal and processing. MDNR has also had success placing binary coded wire tags in fingerling shad.

Trap and Transport

Trapping and live transfer of adult shad and river herring has been used by many jurisdictions since the 1960s. These activities may occur within a specific river system, such as taking fish from lifts at downstream hydroelectric projects for stocking above blockages (e.g., Connecticut and Susquehanna rivers) or they may involve collecting fish with nets or traps in one river for transport and release in another. Examples include shad transfers from Holyoke Dam on the Connecticut River to spawning rivers in Maine, New Hampshire, Rhode Island, and eastern Massachusetts, and herring transfers from Conowingo Dam on the Susquehanna to the Patapsco and Patuxent rivers in Maryland. Shad and river herring have also been netted and hauled to upstream or distant spawning waters undergoing restoration (e.g., Hudson River shad to the Susquehanna River; Delaware River shad to the Raritan River, New Jersey). Well-developed hauling techniques use insulated circular tanks with oxygenation. A properly equipped 1,200-gallon tank can handle 150 adult shad or 1,000 river herring for two-four hour trips with minimal mortality.

3.2 FISHERY-DEPENDENT MONITORING

3.2.1 Commercial Fishery-Dependent Surveys Required

States and jurisdictions are required to monitor the river herring commercial fisheries operating within their state. Each year, the Plan Review Team shall review the results of fishery-dependent monitoring and review progress made to the goals and objectives of Amendment 2. States and jurisdictions may employ a variety of survey techniques in monitoring commercial fisheries in river systems within their management authority. States and jurisdictions are required to report catch (numbers, weight and location) and effort of commercial fisheries for those systems listed in Table 16. Sub-sampling of commercial catches for length, weight, age, sex, repeat spawning (for states north of South Carolina), and species composition must be conducted for the rivers listed in Table 16. Additional sub-sampling is encouraged. Results of all commercial fishery monitoring shall be reported to the Commission annually as per Section 7.1.3.

3.2.2 Recreational Fishery Surveys Required

States and jurisdictions must monitor recreational catch and effort within the rivers listed in Table 16. Techniques used to gather this data may include creel surveys, surveys of license/permit holders, Marine Recreational Fisheries Statistical Survey (MRFSS) / Marine Recreational Information Program (MRIP) and reporting requirements for obtaining/maintaining license or permit. Results of all recreational fishery monitoring shall be reported to the Commission annually as per Section 7.1.3.

3.3 BYCATCH MONITORING AND REDUCTION

Bycatch and discard of river herring in other commercial fisheries can impact river herring populations on a local and coastwide level. River herring interactions with commercial species during specific times and within specific areas may increase bycatch levels. Quantifying current levels of river herring bycatch is essential to determining stock status and implementing effective management programs. Improvements to current monitoring of bycatch and discards are needed to determine the effects on river herring populations and improve management. See Section 6.8 for Recommendations to the Secretaries concerning river herring bycatch in federal waters.

3.4 SUMMARY OF MONITORING PROGRAMS

3.4.1 Biological Information

States and jurisdictions are mandated to implement the fishery-dependent and independent monitoring programs identified for river herring in Section 3.2 and 3.3. In addition, states are required to continue or augment the monitoring programs for American shad and hickory shad. Results of all monitoring shall be reported to the Commission annually as per Section 7.1.3. Whenever practical, state harvest and effort reporting requirements will coincide with current and future mandates of the Atlantic Coastal Cooperative Statistics Survey (ACCSP). Data needs not covered by the ACCSP will still be covered by annual reports submitted in conjunction with this FMP.

Table 14. Summary of monitoring requirements for river herring under Amendment 2. See Tables 15 and 16 for applicable river systems.

Fishery-Independent	Annual spawning stock survey and representative sampling for biological data	
	Calculation of mortality/survival estimates (when available)	
	Juvenile Abundance Index	
	Hatchery evaluation (hatchery vs. wild)--when in place	
	Fishway counts; report inefficiencies (when available)	
Fishery-Dependent	Commercial	Mandatory reporting of catch (numbers, weight, location) and effort. • Sub-samples shall indicate size, age, spawning marks, sex, and species composition of catch (when available)
	Recreational	Monitor recreational catch and effort: • Creel surveys • Survey license/permit holders • MRIP • Reporting requirements for obtaining/maintaining license or permit

Table 15. Summary of mandatory fishery-independent monitoring programs for River Herring.

STATE	SYSTEM	SAMPLING PROGRAM (ANNUAL UNLESS OTHERWISE NOTED)
Maine	Androscoggin, St. Croix & Saco Rivers	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates (excluding St. Croix River) • JAI: Juvenile Abundance Index (GM) (Androscoggin River only) • Hatchery Evaluation
New Hampshire	Exeter, Lamprey, Cocheco, Taylor, Winnicut and Oyster Rivers	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates (Exeter River only)
Massachusetts	Merrimack River	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates
Rhode Island	Pawcatuck, Nonquit, Gilbert-Stuart Rivers and Buckeye Brook	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates (excluding Buckeye Brook) • JAI: Juvenile Abundance Index (GM) (excluding Buckeye Brook)
	Ocean	• Juvenile and Adult trawl survey
	Coastal Ponds and Narragansett Bay	• JAI: Juvenile Abundance Index
Connecticut	Connecticut River	• Annual spawning stock survey and representative sampling for biological data (blueback herring) • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)
New York	Hudson River	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)
	Delaware River (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)
New Jersey	Delaware River (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)

Table 15. Summary of mandatory fishery-independent monitoring programs for River Herring (continued).

STATE	SYSTEM	SAMPLING PROGRAM (ANNUAL UNLESS OTHERWISE NOTED)
Pennsylvania	Susquehanna and Lehigh Rivers	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM) (Susquehanna Only)
	Delaware River (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)
Delaware	Delaware River (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates
	Upper Nanticoke River	• JAI: Juvenile Abundance Index (GM)
Maryland	Upper Chesapeake Bay	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)
D.C.	Potomac River	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile Abundance Index (GM)
Virginia	James, York, and Rappahannock Rivers	• Annual spawning stock survey and representative sampling for biological data (excluding York River) • Calculation of mortality and/or survival estimates • JAI: Juvenile abundance survey (GM)
North Carolina	Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile Abundance Index (GM)
South Carolina	Santee-Cooper system, Eidsto River, Winyah Bay and tributaries (Waccwnaw and Pee Dee Rivers)*	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates * State may elect to sample these systems on a rotational basis (i.e., one system evaluated per year)
Georgia	• There are currently no known river herring populations in Georgia. Should populations be established, the Management Board has the authority to require a fisheries independent monitoring program be implemented.	
Florida	St. Johns River	• Annual spawning stock survey and representative sampling for biological data • Calculation of mortality and/or survival estimates • JAI: Juvenile Abundance Index (GM)

Table 16. Summary of mandatory fishery-dependent monitoring programs for river herring.

STATE	SYSTEM	SAMPLING PROGRAM
Maine	Inriver	• Monitor recreational landings, catch and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
New Hampshire	Inriver	• Monitor recreational landings, catch and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Massachusetts *	Inriver	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Connecticut *	Connecticut River	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Rhode Island *	Pawcatuck River	• Monitor recreational catch and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
New York	Hudson River	• Monitor recreational landings, catch, and effort. • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
	Delaware River	• Monitor recreational landings, catch, and effort (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)
New Jersey	Delaware River and Bay	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)
Delaware	Delaware River and Bay	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)
	Nanticoke River Chesapeake Bay tributary (upstream portion)	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.

* A moratorium is currently in place. Monitoring program listed in Table 16 would be required to re-open of the fishery.

Table 16. Summary of mandatory fishery-dependent monitoring programs for river herring (continued)

STATE	SYSTEM	SAMPLING PROGRAM
Pennsylvania	Delaware River	• Monitor recreational landings, catch, and effort (Cooperative effort between New Jersey, New York, Pennsylvania, and Delaware)
Maryland	Inriver	• Monitor recreational landing, catch, and effort. • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
D.C.	Potomac River	• Monitor recreational landings, catch, and effort
Virginia	Inriver	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
North Carolina*	Albemarle Sound and its tributaties, Tar-Pamlico, Neuse, and Cape Fear Rivers	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
South Carolina	Edisto River, Santee River, Winyah Bay and its tributaries (Waccwnaw and Pee Dee Rivers)	• Monitor recreational landings, catch, and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. * *State may elect to sample these systems on a rotational basis (i.e., one system evaluated per year)
Georgia	• There are currently no known river herring populations in Georgia. Should populations be established, the Management Board has the authority to require a fisheries dependent monitoring program be implemented.	
Florida	St. Johns River	• Monitor recreational landings, catch and effort • Mandatory reporting of catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.

* A moratorium is currently in place. Monitoring program listed in Table 16 would be required to re-open of the fishery.

3.4.2 Social Information

Consumptive use (e.g. commercial fishing activities before closures) and non-consumptive use (e.g. ecotourism activities) surveys focusing on social data should be conducted periodically in a manner consistent with the intent of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) and the ACCSP Implementation Plan.

3.4.3 Economic Information

Consumptive use (e.g. commercial fishing activities before closures) and non-consumptive use (e.g. ecotourism activities) surveys focusing on economic data should be conducted periodically in a manner consistent with the intent of the ACFCMA and the ACCSP implementation Plan.

4. MANAGEMENT PROGRAM IMPLEMENTATION

States and jurisdictions must implement the regulatory program requirements as per Section 7. The Management Board has the ultimate authority to determine the approval of a regulatory program. States and jurisdictions must also submit proposals to change their required regulatory programs as per Section 7.1.2. The Management Board will determine final approval for changes to required regulatory programs.

4.1 COMMERCIAL AND RECREATIONAL FISHERIES MANAGEMENT MEASURES

The Shad and River Herring Management Board approved the following commercial and recreational fishery management measures:

Close Fisheries (Commercial/Recreational) with Exceptions for Systems with a Sustainable Fishery

Systems with a sustainable fishery are defined as those that demonstrate their alewife or blueback herring stock could support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment. In order to maintain a commercial or recreational river herring fishery, states and jurisdictions are required to develop sustainability targets that meet the above definition, which will include specific and practicable criteria for current management and are based on the best available science. Data to substantiate these claims may include, but is not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates. Member states or jurisdictions could potentially develop different sustainability target(s) for river herring based on the unique ecosystem interactions and the available data for a given system. Targets can be applied state-wide or can be river and species specific. Targets for river systems managed by more than one state/jurisdiction should be cooperatively developed. Targets should include a quantifiable means of estimating improvements in populations. As new information becomes available, states should review and update targets in a timely manner.

Examples of proposed sustainability targets could include (but are not limited to):

1. River specific stocks that return spawning stock biomass in excess of spawning habitat saturation (e.g. as determined by *X* number of fish per acre).
2. River specific stocks that return commercially viable numbers of river herring without supplementing brood stock or escapement.
3. River specific river herring catch rates that are not less than a defined percentage of the latest average ten-year catch rate for a number of consecutive years.
4. Stock should contain at least a minimum percentage of repeat spawners.
5. Recruitment of age-*X* fish should be restored to a three-year moving average that is above a defined minimum.

States and jurisdictions must also submit a management plan that describes how the fishery will be conducted and annually monitored in order to show that the sustainability target(s) are being achieved. If a stock is below optimum level the management plan must detail restrictions that will be enacted to allow for an increase in spawning stock abundance and juvenile recruitment. If a stock is at optimum levels, then that level will need to be sustained. The frame of reference for determining the optimum level will vary from system to system, but should be based on an appropriate time scale. States should develop their sustainability targets within this general framework. The Technical Committee is responsible for developing a standard optimum level and timeframe basis.

States and jurisdictions are required to submit sustainability targets and corresponding management plans by January 1, 2010, which will be reviewed by the technical committee. Once a plan is approved by the management board, states and jurisdictions must submit updates on the achievement and maintenance of sustainability targets as part of annual compliance reports, per Section 7.

Fisheries that do not have an approved management plan in place, or are not covered by an approved management plan, by January 1, 2012 will be closed. The Management Board has the final authority to approve management plans for an alewife or blueback herring commercial or recreational fishery on any system under its jurisdiction. Proposals to reopen closed fisheries may be submitted as part of the annual Compliance Report, and will be subject to review by the Plan Development Team, Technical Committee and Management Board.

4.2 HABITAT CONSERVATION AND RESTORATION

River herring stocks along the Atlantic Coast are greatly diminished compared to historic levels. Much of this reduction is related to spawning and nursery habitat degradation brought on by effects of human population increase (sewage and storm water runoff, industrialization, dam construction), increased erosion, sedimentation and nutrient enrichment associated with agricultural practices, and losses of riparian forests and wetland buffers.

Protection, restoration and enhancement of river herring habitat including spawning, nursery, rearing, production, and migration areas, is critical for preventing further declines in river herring abundance, and restoring healthy, self-sustaining river herring populations and their ecological, social, and economic functions and values to the East Coast of the United States.

Each state should identify, categorize and prioritize important existing and historic river herring habitat within its area of jurisdiction.

Periodic monitoring should be designed and implemented to ensure the long-term health and viability of important river herring habitat.

Each state should develop a plan to improve the quality of and restore adequate access to river herring habitat within its area of jurisdiction.

4.2.1 Freshwater Spawning and Larval Rearing Habitat

Barriers that restrict or prevent migration to and/or from currently available and historical freshwater habitat (spawning, nursery, rearing habitat) will reduce juvenile recruitment and limit total production.

Successful upstream and downstream fish passage (safe, timely and effective) past anthropogenic barriers (e.g., *physical* such as dams, weirs, and culverts; and *water quality* such as thermal and chemical discharges, and in-stream flow alterations such as flow regulation and water withdrawal) is essential for adequate access to and utilization of critical freshwater spawning and larval rearing habitat.

Protection and enhancement of freshwater habitat and adjacent riparian interfaces and buffers is important to ensuring the long-term health and viability of river herring spawning and larval habitat, and migratory corridors.

In areas where water resource or shore side development projects are proposed adjacent to identified or potential river herring habitat, state marine fisheries agencies should engage in review of proposed development projects by engaging in licensing and permitting consultation opportunities (e.g., Federal Energy Regulatory Commission hydroelectric project licensing, Section 401 water quality permits, Army Corps of Engineers, Sections 1135(b), 206, 404 permits) in order to assess potential impacts to river herring habitat. The state marine fisheries agencies should then comment on the merits of the development project, and where applicable, propose terms, conditions and prescriptions designed to avoid, minimize and mitigate negative impacts of the development project on critical river herring habitat.

State marine fisheries agencies should also coordinate with state water quality agencies and other governmental entities responsible for developing and implementing river basin and wetland restoration plans and projects, in order to ensure that river herring habitat is identified and adequately protected or enhanced by these plans and projects during their implementation.

State marine fisheries agencies should coordinate with their state inland fisheries agencies to identify important inland freshwater spawning and rearing habitat, and migration corridors. This should be accomplished through site-specific data collection and monitoring. This information should be used to develop comments and recommendations during consultations with permitting agencies regarding potential impacts of a proposed development on river herring production or migration. As an example, construction activities should be avoided during critical migration periods, and seasonal construction restriction for any particular area should be based on site-specific information, and appropriate monitoring to ensure the river herring resource is protected.

States should consider developing plans to protect shore land adjacent to critical river herring production, migration, and staging areas in order to ensure their long-term viability and contribution to the sustainability of the specific population. Protection of river herring habitat or areas of particular concern should be pursued through acquisition, deed restrictions or conservation easements. State fisheries agencies should also work with their state soil and water conservation agencies and agricultural agencies to provide information on these habitats, to be used in their decisions regarding the state's riparian buffer program.

4.2.2 Estuarine Juvenile Rearing and Migration Corridors

The importance of estuaries to river herring as juvenile rearing habitat is not yet fully understood. The impacts of declines in submerged aquatic vegetation beds should be further investigated to determine their importance and juvenile cover and rearing habitat.

The impacts of thermal power generation projects (e.g., nuclear and coal) that withdraw water for cooling (potential entrainment and impingement of fish) and discharge heated water (thermal barriers to migration, habitat degradation) need to be further studied.

The impacts to migrating river herring (both spawning adults and out-migrating juveniles) by proposed in-stream power generation developments such as tidal stream generation that draws energy from currents in much the same way as wind turbines needs to be better understood.

Similar to the situation with riverine areas where water resource or shore side development projects are proposed adjacent to identified or potential river herring habitat or migration corridors, state marine fisheries agencies should engage in review of proposed development projects by engaging in licensing and permitting consultation opportunities in order to assess potential impacts to river herring habitat and comment on the project's merits and mitigation needs.

4.2.3 Coastal Production and Migration Corridors

Potential threats and their level of impact to coastal river herring habitat such as: marine acidification; pharmaceutical, wastewater, pesticide contamination; invasive species; niche displacement; and global climate change are in need of further study.

The impacts to migrating river herring (both spawning adults and migrating juveniles) by proposed wind power generation developments such needs to be better understood.

Similar to the situation with riverine and estuarine areas where water resource or shore side development projects are proposed adjacent to identified or potential river herring habitat or migration corridors, state marine fisheries agencies should engage in review of proposed development projects by taking advantage of licensing and permitting consultation opportunities in order to assess potential impacts to river herring habitat and comment on the project's merits and mitigation needs to protect coastal river herring habitat.

4.2.4 Habitat Restoration, Improvement and Enhancement

States should leverage the existing production capacity of historic, but currently volitionally inaccessible freshwater spawning and larval rearing habitat through a process of trap and transport of excess spawning stock, or planting of aquaculture produced fry and fingerlings. This will help to both increase juvenile recruitment for the population, and will develop a stock of river herring imprinted to that upstream habitat that can take advantage of it once access is restored through barrier removal or installation of fish passage.

The Commission and participating states' and jurisdictions' marine fisheries agencies are encouraged to support fish passage research and development with the goal of improving the efficiency of existing and future installations of fish passage measures and facilities in order to restore desired access to and utilization of critical river herring spawning and juvenile rearing habitat.

The Commission and participating states' and jurisdictions' marine fisheries agencies are encouraged to characterize passage-associated efficiency, mortality, migration delay, and sub-lethal effects for river herring at existing fish passage facilities installed at hydroelectric and other dams. This information should be used to identify and address passage problems at barriers and further the understanding of best available fish passage technology.

States should work to improve and develop safe, timely and effective upstream and downstream fish passage for adults and juveniles at all barriers to river herring migration to and from critical existing and historic spawning, rearing and production habitat.

States should strive to maintain water quality in all suitable habitats for all life stages of river herring in all rivers with existing or potential spawning, juvenile rearing and production habitat.

In rivers with flow regulation (e.g., storage and peak hydroelectric power generation dams), and consumptive water withdrawals (e.g., irrigation, domestic water supply, industrial use) states should strive to maintain in-stream flows at levels that ensure adequate fish passage, water quality and habitat protection for river herring.

State and federal agencies should monitor and report on the amount of freshwater habitat opened through upstream passage projects and any associated changes in emigrating river herring abundance associated with improved habitat access.

4.2.5 Avoidance of Incompatible Activities

Each state should establish seasonal windows of compatibility for activities known or suspected to adversely affect river herring life stages and their habitats (e.g., dredging, filling, aquatic construction) as well as notify the appropriate construction or regulatory agencies in writing.

Projects involving water withdrawal from important habitats (e.g., feeding grounds) should be scrutinized to ensure that adverse impacts resulting from impingement, entrainment or modification of flow, temperature and salinity regimes due to water removal will not adversely impact river herring habitat.

Each state that has human population growth areas within its jurisdiction should develop water use and flow regime guidelines which are protective of river herring habitat and will ensure to the extent possible the long-term health and sustainability of the population.

States should endeavor to ensure that proposed water diversions or withdrawals from river tributaries would not reduce or eliminate river herring habitat.

4.2.6 Fisheries Practices

The use of any fishing gear or practice that is documented to have unacceptable negative impacts on river herring habitat or migration (e.g., habitat damage, bycatch mortality) should be prohibited within the area of that habitat or corridor.

4.2.7 Habitat Recommendations

4.2.7.1 Dams and Other Obstructions

- A focused, coordinated, well supported effort among federal, state and associated interests should be undertaken to address the issue of fish passage development and efficiency. The effort should attempt to develop new technologies and approaches to improve alosine passage efficiency with the premise that existing technology is insufficient to achieve restoration and management goals for several East Coast river systems.
- Where obstruction removal is not feasible, install passage facilities, including fish lifts, fish locks, fishways, navigation locks or notches (low-head dams and culverts). Passage facilities should be designed specifically for passing alosines for optimum efficiency.
- At sites with passage facilities, evaluate the effectiveness of upstream and downstream passage; when passage is inadequate, facilities should be improved.
- To enhance survival at dams during emigration (either post-spawning fish or juveniles), evaluate survival of fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and pass fish via the route with the best survival rate.

- To prevent fish from becoming entrained in intake flow areas of hydropower facilities, construct behavioral barrier devices and re-direct them to safer passage areas.
- Before designing and constructing fish passage systems, determine the behavioral response to major physical factors so that effectiveness can be maximized.
- Conduct studies to determine whether passing migrating adults upstream earlier in the year in some rivers would increase production and larval survival, and opening downstream bypass facilities sooner would reduce mortality of early emigrants (both adult and early-hatched juveniles).
- States should identify and prioritize barriers in need of fish passage based on clear ecological criteria (e.g., amount and quality of habitat upstream of barrier, size, status of affected populations). These prioritizations could apply to a single species, but are likely to be more useful when all diadromous species are evaluated together.
- Where practicable, remove obstructions to upstream and downstream migration.
- Ensure that decisions on river flow allocation (e.g., irrigation, evaporative loss, out of basin water transport, hydroelectric operations) take into account flow needs for alosine migration, spawning and nursery use, and minimize deviation from natural flow regimes.
- Ensure that water withdrawal effects do not impact alosine stocks by impingement/entrainment, and employ intake screens or deterrent devices as needed to prevent egg and larval mortality.
- Alter water intake velocities, if necessary, to reduce mortality to alosines.
- Locate facilities along the river where impingement rates are likely to be lowest.
- To mitigate hydrological changes from dams, consider operational changes such as turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream and adjusting in-stream flows.
- When considering options for restoring alosine habitat, include study of, and possible adjustment to, dam-related altered river flows.
- Evaluate performance of existing fishways and determine features common to effective fishways and those common to ineffective fishways.
- Conduct basic research into alosine migratory behavior as it relates to depth, current velocity, turbulence, entrained air, light, structures, etc.
- Use information from (a) and (b) to conduct computer fluid dynamics (CFD) modeling to develop more effective fishway designs.
- Research technologies (barriers, guidance systems, etc.) for directing emigrating fish to preferred passage routes at dams.
- Document the impact of power plants and other water intakes on larval, postlarval, and juvenile mortality in spawning areas, and calculate the resultant impact to adult population size.

4.2.7.2 Water Quality and Other Contamination

- Non-point and point source pollution should be reduced in spawning and nursery habitat.
- Implement best management practices (BMPs) along rivers and streams, restore wetlands, and utilize stream buffers to control non-point source pollution.
- Implement erosion control measures and BMPs in agricultural, suburban and urban areas to reduce sediment input, toxic materials and nutrients and organics into streams.
- Upgrade wastewater treatment plants and remove biological and organic nutrients from wastewater.
- Reduce the amount of thermal effluent into rivers. On larger rivers, include a thermal zone of passage.
- Provide management options regarding water withdrawal and land use to minimize the impacts of climate change on temperature and flow regimes.
- Discharge earlier in the year to reduce impacts to migrating fish.
- Conduct studies to determine the effects of dredging on alosine habitat and migration; appropriate best management practices, including environmental windows, should be considered whenever navigation dredging or dredged material disposal operations would occur in a given waterway occupied by alosine species.
- Review studies dealing with the effects of acid deposition on anadromous alosines.
- Determine if intermittent episodes of pH depressions and aluminum elevations (caused by acid rain) affect any life stage in freshwater that might lead to reduced reproductive success, especially in poorly buffered river systems.
- Determine if chlorinated sewage effluents are slowing the recovery of depressed shad stocks.

4.2.7.3 Habitat Protection and Restoration

- States should identify and quantify potential shad and river herring spawning and nursery habitat not presently utilized, including a list of areas that would support such habitat if water quality and access were improved or created, and analyze the cost of recovery within those areas. States may wish to identify areas targeted for restoration as essential habitat.
- When states have identified habitat protection or restoration as a need, state marine fisheries agencies should coordinate with other agencies to ensure that habitat restoration plans are developed, and funding is actively sought for plan implementation and monitoring.
- Resource management agencies in each state shall evaluate their respective state water quality standards and criteria to ensure that those standards and criteria account for the special needs of alosines. Primary emphasis should be on locations where sensitive egg and larval stages are found.

- ASMFC should designate important shad and river herring spawning and nursery habitat as Habitat Areas of Particular Concern (HAPCs).
- Any project resulting in elimination of essential habitat (e.g., dredging, filling) should be avoided.

4.2.7.4 Permitting

- All state and federal agencies responsible for reviewing impact statement for projects that may alter anadromous alosine spawning and nursery areas shall ensure that those projects will have no impact or only minimal impact on those stocks. Of special concern are natal rivers of newly established stocks or stocks considered depressed or severely depressed.
- Develop policies for limiting development projects seasonally or spatially in spawning and nursery areas; define, and codify, minimum riparian buffers and other restrictions where necessary.

4.2.7.5 Stock Restoration and Management

- When populations have been extirpated from their habitat, coordinate alosine stocking programs, including: (a) reintroduction to the historic spawning area; (b) expansion of existing stock restoration programs; and (c) initiation of new strategies to enhance depressed stocks.
- When releasing hatchery-reared larvae into river systems for purposes of restoring stocks, synchronize the release with periods of natural prey abundance to minimize mortality and maximize nutritional condition. Determine functional response of predators on larval shad at restoration sites to ascertain appropriate stocking level so that predation is accounted for, and juvenile out-migration goals are met. Also, determine if night stocking will reduce mortality.
- Promote cooperative interstate research monitoring and law enforcement. Establish criteria, standards, and procedures for plan implementation as well as determination of state compliance with management plan provisions.

4.2.7.6 Habitat Change

- Use multi-scale approaches (including GIS) to assess indicators of suitable habitat, using watershed and stream-reach metrics, if possible (it should be noted, that where site-specific data is lacking, it may not be appropriate to assess at this scale).
- Use multi-scale approaches for restoring alosine habitat, including vegetated buffer zones along streams and wetlands, and implementing measures to enhance acid-neutralizing capacity.
- Conduct additional studies on the effects of land use on riverine life stages.
- Examine how deviation from the natural flow regime impacts all alosines. This work should focus on key parameters such as rate of change (increase and decrease), seasonal

peak flow, and seasonal base flow, so that the results can be more easily integrated into a year-round flow management recommendation by state officials.

5. ALTERNATIVE STATE MANAGEMENT REGIMES

Once the Shad and River Herring Management Board approves a management program, states and jurisdictions are required to obtain approval from the Management Board prior to changing their management program in any way that might alter a compliance measure. Changes to management programs that affect measures other than compliance measures must be reported to the Management Board but may be implemented without prior approval. States and jurisdictions submitting alternative proposals must demonstrate the proposed management program will not contribute to overfishing of the resource or inhibit restoration of the resource. The Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board's satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (Section 5.5). All changes in state and jurisdictional plans must be submitted in writing to the Management Board and the Commission either as part of the annual FMP Review process or with the annual compliance report.

5.1 General Procedures

A state may submit a proposal to the Commission for a change to its regulatory program or any mandatory compliance measure under this amendment, including a proposal for *de minimis* status. Such changes shall be submitted to the Chair of the Plan Review Team, who shall then distribute the proposal to the Management Board, Plan Review Team, Technical Committee, Stock Assessment Subcommittee and Advisory Panel, as necessary.

The Plan Review Team is responsible for gathering the comments from the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, and presenting the comments to the Management Board in a timely fashion.

The Shad and River Herring Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board's satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (Section 5.5).

5.2 Management Program Equivalency

The Shad and River Herring Technical Committee, under the direction of the Plan Review Team, will review any alternative management program proposals and provide the Management Board its evaluation of the adequacy of the proposals.

5.3 *De Minimis* Fishery Guidelines

The Commission's Interstate Fisheries Management Program Charter defines *de minimis* as "a situation in which, under the existing condition of the stock and scope of the fishery, conservation and enforcement actions taken by an individual state would be expected to contribute insignificantly to a coastwide conservation program required by a Fishery Management Plan or amendment" (ASMFC 2003).

States that report commercial landings of river herring that are less than 1% of the coastwide commercial total are exempted from sub-sampling commercial and recreational catch for biological data, as outlined in Section 3.2.

States and jurisdictions may petition the Shad and River Herring Management Board at any time for *de minimis* status if their fishery falls below the threshold level. Once *de minimis* status is granted, designated states and jurisdictions must submit annual compliance reports to the Management Board and request *de minimis* status on an annual basis.

5.4 ADAPTIVE MANAGEMENT

The Shad and River Herring Management Board may vary the requirements specified in this amendment as part of adaptive management in order to conserve the American shad, hickory shad, alewife and blueback herring resources. Specifically, the Management Board may change Sections 1.3, 2.3, 3 and 4 (see Section 5.5.2). Such changes will be instituted to be effective on January 1 or the first fishing day of the following year, but may be put in place at an alternative time when deemed necessary by the Management Board.

5.4.1 General Procedures

The Shad and River Herring Plan Review Team will monitor the status of the fishery and the resource and report on that status to the Management Board annually, or as directed to do so by the Management Board. The Plan Development Team will consult with the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, when making such a review and report. The report may contain recommendations for proposed adaptive management revisions to the amendment.

The Management Board will review the Plan Review Team report and may consult further with the Technical Committee, Stock Assessment Subcommittee or the Advisory Panel. The Management Board can direct the Plan Development Team to prepare an addendum to make changes that it deems necessary. The addendum shall contain a schedule for the states and jurisdictions to implement its provisions.

The Plan Development Team will prepare a draft addendum as directed by the Management Board and, upon approval from the Board, shall distribute it for review and comment to all states and jurisdictions with declared interest in the fishery. A public hearing will be held in any state or jurisdiction that requests one. The Plan Development Team will also request public comment from federal agencies and the public at large. After a 30-day review period, the Plan Development Team will summarize the comments and present them to the Management Board.

After considering the comments, the Management Board will direct the Plan Development Team on what to include in the final addendum. The Management Board shall review the final version of the addendum. The Management Board shall then consider whether to adopt or revise and then adopt the addendum.

Upon the adoption of an addendum to implement adaptive management, states and jurisdictions shall prepare plans, when necessary, to implement the addendum and submit those plans to the Management Board for approval, following the schedule contained in the addendum.

5.5.2 Measures Subject to Change

The following measures are subject to change under adaptive management upon approval by the Management Board:

1. Habitat considerations;
2. Overfishing definition;
3. Rebuilding targets and schedules;
4. Fishery-independent monitoring requirements;
5. Fishery-dependent monitoring requirements;
6. Bycatch monitoring and reduction requirements;
7. Reporting requirements;
8. Effort controls;
9. Area closures;
10. Gear restrictions or limitations;
11. Catch controls;
12. Fishing year and/or seasons;
13. Possession limits;
14. Quotas;
15. Bycatch limits and reporting;
16. Observer requirements;
17. Closures;
18. Regulatory measures for the recreational fishery;
19. Recommendations to the Secretaries for complementary actions in federal jurisdictions;
20. *De minimis* specifications;
21. Compliance report due dates; and
22. Any other management measures currently included in the Shad and River Herring Interstate Fishery Management Plan.

5.6 EMERGENCY PROCEDURES

The Shad and River Herring Management Board may authorize or require emergency action that is not covered by, or is an exception or change to, any provision in Amendment 2. Procedures for implementation of emergency action are addressed in the Commission's Interstate Fisheries Management Program Charter, Section Six (c)(10) (ASMFC 2003).

6 MANAGEMENT INSTITUTIONS

The management institutions for shad and River herring shall be subject to the provisions of the ISFMP Charter (ASMFC 2003). The following are not intended to replace any or all of the provisions of the ISFMP Charter. All committee roles and responsibilities are included in detail in the ISFMP Charter and are only summarized here.

6.1 The Commission and the ISFMP Policy Board

The Atlantic States Marine Fisheries Commission and the ISFMP Policy Board are generally responsible for the oversight and management of the Commission's fisheries management activities. The Commission must approve all fishery management plans and amendments, including this Amendment 2, and must also make final determinations concerning state compliance or non-compliance. The ISFMP Policy Board reviews any non-compliance recommendations from the various management boards and sections and, if it concurs, forwards them on to the Commission for action.

6.2 Shad and River Herring Management Board

The Shad and River Herring Management Board is established by the Commission's ISFMP Policy Board and is generally responsible for carrying out all activities under this amendment. It establishes and oversees the activities of the Plan Review Team, Plan Development Team, Technical Committee and Stock Assessment Subcommittee, and requests the establishment of the Commission's Shad and River Herring Advisory Panel. Among other things, the Management Board makes changes to the management program under adaptive management and approves the state and jurisdictional programs implementing the amendment and alternative state programs under Section 4.5. The Management Board reviews the status of state compliance with the FMP at least annually and, if it determines that a state or jurisdiction is out of compliance, reports that determination to the ISFMP Policy Board under the terms of the ISFMP Charter.

6.3 Shad and River Herring Plan Review Team and Plan Development Team

The Shad and River Herring Plan Review Team and Plan Development Team are small groups whose responsibility is to provide all necessary staff support to carry out and document the decisions of the Management Board. Both teams are directly responsible to the Management Board for providing all of the information and documentation necessary to carry out the Board's decisions.

The teams shall be comprised of personnel from state and federal agencies who have scientific or management knowledge of shad and river herring and will be chaired by the Commission's Shad and River Herring FMP Coordinator. The Plan Development Team will be responsible for preparing all documentation necessary for the development of Amendment 2, using the best scientific information available and the most current stock assessment information. Once the Commission adopts Amendment 2, the Plan Review Team will provide annual advice concerning implementation, review, monitoring and enforcement of the amendment.

6.4 Shad and River Herring Technical Committee

The Shad and Rive Herring Technical Committee will consist of representatives from each jurisdiction and federal agency with a declared interest in shad and river herring fisheries. Its role is to act as a liaison to the individual jurisdictions and federal agencies, providing information to the management process and reviewing and making recommendations concerning the management program. The Technical Committee will provide scientific advice to the Management Board, Plan Development Team and Plan Review Team in the development and monitoring of a fishery management plan or amendment.

6.5 Shad and River Herring Stock Assessment Subcommittee

The Shad and River Herring Stock Assessment Subcommittee will consist of scientists with expertise in stock assessment methods or the assessment of shad and river herring populations. Its role is to assess shad and river herring populations and provide scientific advice concerning the implications of proposed or potential management alternatives for the stocks, as well as to respond to other scientific questions from the Management Board, Technical Committee, Plan Development Team or Plan Review Team. The Stock Assessment Subcommittee will report to the Management Board as well as to the Technical Committee.

6.6 Shad and River Herring Advisory Panel

The Shad and River Herring Advisory Panel is established according to the Commission's Advisory Committee Charter. Members of the Advisory Panel are citizens who represent a cross-section of commercial and recreational fishing interests and other who are concerned about shad and river herring conservation and management. The Advisory Panel provides the Management Board with advice directly concerning the Commission's shad and river herring management program.

6.7 Secretaries of Commerce and the Interior

Under the Atlantic Coastal Fisheries Cooperative Management Act, if the Commission determines that a state is out of compliance with the Fishery Management Plan, it reports that finding to the Secretary of Commerce. The Secretary of Commerce must determine that the measures not taken by the state are necessary for conservation and if such a finding is determined, the Secretary is then required by federal law to impose a moratorium on fishing for shad or river herring in that jurisdiction's waters until the state comes back into compliance. In addition, the Commission has accorded the National Marine Fisheries Service and the U.S. Fish and Wildlife Service voting status on the ISFMP Policy Board and the Shad and River Herring

Management Board; the federal agencies participate on the Plan Review Team, Plan Development Team, Technical Committee and Stock Assessment Subcommittee.

6.8 Recommendations to Secretaries

ASMFC recommends that the Secretary of Commerce direct the National Marine Fisheries Service (NMFS) support efforts underway by the New England and Mid-Atlantic Fishery Management Councils to effectively monitor bycatch of river herring in small-mesh fisheries. Additionally, the ASMFC recommends the Secretary of Commerce provide additional resources to support the cooperative efforts between the Commission and the councils to better manage anadromous fisheries. Finally, the ASMFC requests that the Secretary of Commerce take emergency action with regard to implementing the bycatch monitoring measures that have been under discussion at the New England Fishery Management Council to Amendment 4 to the Sea Herring Plan.

7. COMPLIANCE

Full implementation of the provisions in this amendment is necessary for the management program to be equitable, efficient and effective. States and jurisdictions are expected to implement these measures faithfully under state laws. Although the Atlantic States Marine Fisheries Commission does not have authority to directly compel state implementation of these measures, it will continually monitor the effectiveness of state implementation and determine whether states are in compliance with the provisions of this fishery management plan. This section sets forth the specific elements that the Commission will consider in determining state compliance with this fishery management plan and the procedures that govern the evaluation of compliance. Additional details of the procedures are found in the 2003 ASMFC Interstate Fisheries Management Program (ISFMP) Charter. States should be aware that federal law requires their compliance with the provisions of this fishery management plan.

7.1 MANDATORY COMPLIANCE ELEMENTS FOR STATES

A state will be determined out of compliance with the provision of this fishery management plan according to the terms of Section 7 of the ISFMP Charter if:

1. Its regulatory and management programs to implement Sections 3 and 4 have not been approved by the Shad and River Herring Management Board; or
2. It fails to meet any schedule required by Section 7.2, or any addendum prepared under adaptive management (Section 5.4); or
3. It has failed to implement a change to its program when determined necessary by the Shad and River Herring Management Board; or
4. It makes a change to its monitoring programs required under Section 3 or its regulations required under Section 4 without prior approval of the Shad and River Herring Management Board.

7.1.1 Mandatory Elements of State Programs

A state will be found out of compliance if it's regulatory and management programs for shad and river herring have not been approved by the Management Board in section 3 and 4.

All state programs must include a regime of restrictions on commercial and recreational fisheries consistent with the requirements of Section 4. Except, a state may propose an alternative management program under Section 5, which if approved by the Management Board, may be implemented as an alternative regulatory requirement for compliance under the law.

7.1.2 Regulatory Requirements

States may begin to implement Amendment 2 after final approval by the Commission. Each state must submit its required shad and river herring regulatory program to the Commission through Commission staff for approval by the Management Board. During the period between submission of the regulatory plan and the Management Board’s decision to approve or reject it, a state may not adopt a less protective management program than contained in this Amendment or contained in current state law. Once a regulatory program is approved by the Management Board, states may not implement any regulatory changes concerning shad and river herring, nor any management program changes that affect their responsibilities under this Amendment, without first having those changes approved by the Management Board.

7.1.3 Monitoring Requirements

All state programs must include the mandatory monitoring requirements contained in Section 3. States must submit proposals for all intended changes to required monitoring programs that may affect the quality of the data or the ability of the program to fulfill the needs of the fishery management plan. In the event that a state realizes that it will not be able to fulfill its monitoring requirements, it should immediately notify the Commission. The Commission will work with the state to develop a plan to secure funding or plan an alternative program to satisfy the needs outlined in Amendment 2. If the plan is not implemented 90 days after it has been adopted, the state may be found out of compliance with Amendment 2.

7.1.4 Research Requirements

No mandatory research requirements have been identified at this time; however, elements of state plans may be added to address any needs identified during the course of developing Amendment 2.

7.1.5 Law Enforcement Requirements

All state programs must include law enforcement capabilities adequate for successfully implementing the state’s shad and river herring regulations. The adequacy of a state’s enforcement activity will be measured by an annual report to the Commission’s Law Enforcement Committee and the Plan Review Team.

7.1.6 Habitat Requirements

No mandatory habitat requirements have been identified at this time; however, elements of state plans may be added to address any needs identified during the course of developing Amendment 2.

7.2 COMPLIANCE SCHEDULE

States must implement this Amendment according to the following schedule:

January 1, 2010: States and jurisdictions must submit fishery management plans, as detailed in Section 4.1.

January 1, 2012: Fisheries that do not have an approved management plan in place, or are not covered by an approved management plan, by January 1, 2012 will be closed as detailed in section 4.1

Reports on compliance should be submitted to the Commission by each jurisdiction annually, no later than July 1.

7.3 COMPLIANCE REPORT CONTENT

Each state must submit an annual report concerning its shad and river herring fisheries and management program for the previous years. The report shall cover:

1. The previous calendar year's fishery and management program including, activity and results of monitoring, regulations that were in effect, harvest, and estimates of non-harvest losses, following the outline contained in Table 23.
2. The planned management program for the current calendar year, summarizing regulations that will be in effect and monitoring programs that will be performed, and highlighting any changes from the previous year.

Table 17. Required format for annual state compliance reports.

I. HARVEST AND LOSSES
- A. COMMERCIAL FISHERY
  - 1. Characterization of fishery (seasons, cap, gears, regulations)
  - 2. Characterization of directed harvest for all alosines
    - a. Landings and method of estimation
    - b. Catch composition
      - i. Age frequency
      - ii. Length frequency
      - iii. Sex ratio
      - iv. Degree of repeat spawning (estimated from scale data)
    - c. Estimation of effort
  - 3. Characterization of other losses (poaching, bycatch, etc.)
    - a. Estimate and method of estimation
    - b. Estimate of composition (length and/or age)

- B. RECREATIONAL FISHERY
  - 1. Characterization of fishery (seasons, cap, regulations)
  - 2. Characterization of directed harvest
    - a. Landings and method of estimation
    - b. Catch composition
      - i. Age frequency
      - ii. Length frequency (legal and sub-legal catch)
    - c. Estimation of effort
  - 3. Characterization of other losses (poaching, hook/release mortality, etc.)
    - a. Estimate and method of estimation
    - b. Estimate of composition (length and/or age)

- C. OTHER LOSSES (FISH PASSAGE MORTALITY, DISCARDED MALES, BROOD STOCK CAPTURE, RESEARCH LOSSES, ETC.)

- D. TABLE 1. HARVEST AND LOSSES - INCLUDING ALL ABOVE ESTIMATES IN NUMBERS AND WEIGHT (POUNDS) OF FISH AND MEAN WEIGHT PER FISH FOR EACH GEAR TYPE

II. REQUIRED FISHERY INDEPENDENT MONITORING
- A. DESCRIPTION OF REQUIREMENT AS OUTLINED IN AMENDMENT 1, TABLE 2
- B. BRIEF DESCRIPTION OF WORK PERFORMED
- C. RESULTS
  - 1. Juvenile indices
    - a. Index of abundance
    - b. Variance
  - 2. Spawning stock assessment
    - a. Length frequency
    - b. Age frequency
    - c. Sex
    - d. Degree of repeat spawning
  - 3. Annual mortality rate calculation
  - 4. Hatchery evaluation (%wild vs. hatchery)

7.4 PROCEDURES FOR DETERMINING COMPLIANCE

Detailed procedures regarding compliance determinations are contained in the ISFMP Charter, Section Seven.

In brief, all states are responsible for the full and effective implementation and enforcement of fishery management plans in areas subject to their jurisdiction. Written compliance reports as specified in the Plan or Amendment must be submitted annually by each state with a declared interest. Compliance with Amendment 2 will be reviewed at least annually. The Shad and River Herring Management Board, ISFMP Policy Board or the Commission may request the Plan Review Team to conduct a review of Plan implementation and compliance at any time.

The Management Board will review the written findings of the Plan Review Team within 60 days of receipt of a state's compliance report. Should the Management Board recommend to the Policy Board that a state be determined to be out of compliance, a rationale for the recommended noncompliance finding will be included addressing specifically the required measures of Amendment 2 that the state has not implemented or enforced, a statement of how failure to implement or enforce required measures jeopardizes shad and river herring conservation, and the actions a state must take in order to comply with Amendment 2 requirements.

The ISFMP Policy Board will review any recommendation of noncompliance from the Management Board within 30 days. If it concurs in the recommendation, it shall recommend at that time to the Commission that a state be found out of compliance.

The Commission shall consider any noncompliance recommendation from the ISFMP Policy Board within 30 days. Any state that is the subject of a recommendation for a noncompliance finding is given an opportunity to present written and/or oral testimony concerning whether it should be found out of compliance. If the Commission agrees with the recommendation of the ISFMP Policy Board, it may determine that a state is not in compliance with the Amendment 2, and specify the actions the state must take to come into compliance.

Any state that has been determined to be out of compliance may request that the Commission rescind its noncompliance findings, provided the state has revised its shad and river herring conservation measures.

8. MANAGEMENT RESEARCH NEEDS

The following list of research needs have been identified in order to enhance the state or knowledge of the shad and river herring resources, population dynamics, ecology and the various fisheries for alosine species. The Technical Committee, Advisory Panel, and Management Board will review this list annually and an updated prioritized list will be included in the Annual Shad and River Herring FMP Review.

8.1 STOCK ASSESSMENT AND POPULATION DYNAMICS

- Continue to assess current aging techniques for American shad and river herring, using known-age fish, scales, otoliths and spawning marks. Conduct biannual aging workshops to maintain consistency and accuracy in aging fish sampled in state programs.
- Investigate the relation between juvenile production and subsequent yearclass strength for alosine species, with emphasis on the validity of juvenile abundance indices, rates and sources of immature mortality, migratory behavior of juveniles, natural history and ecology of juveniles, and essential nursery habitat in the first few years of life.
- Validate the different values of M for shad stocks through verification of aging techniques and repeat spawning information and develop methods for calculating M.
- Evaluate additional sources of mortality for alosine species, including bait and reduction fisheries.
- Determine which stocks are impacted by mixed stock fisheries (including bycatch fisheries). Methods to be considered could include otolith microchemistry, oxy-tetracycline otolith marking, and/or tagging.
- Evaluate predation by striped bass as a factor of mortality for alosines. Research predation rates and impacts on alosines.
- Quantify fishing mortality (in-river, ocean bycatch, bait fisheries) for major river stocks after ocean closure of directed fisheries.
- Develop comprehensive angler use and harvest survey techniques for use by Atlantic states to assess recreational fisheries for American shad.
- Determine and update biological benchmarks used in assessment modeling (fecundity-at-age, mean weight-at-age for both sexes, partial recruitment vector/maturity schedules) for American shad and river herring stocks in a variety of coastal river systems, including both semelparous and iteroparous stocks.
- Conduct population assessments on river herring—particularly needed in the south.
- Evaluate and ultimately validate large-scale hydroacoustic methods to quantify American shad escapement (spawning run numbers) in major river systems. Identify how shad respond (attract/repelled) by various hydroacoustic signals.

8.2 RESEARCH AND DATA NEEDS

8.2.1 Habitat

- Identify ways to improve fish passage efficiency using hydroacoustics to repel alosines or pheromones or other chemical substances to attract them. Test commercially available acoustic equipment at existing fish passage facility to determine effectiveness. Develop methods to isolate/manufacture pheromones or other alosine attractants.

- Determine the effects of passage impediments on all life history stages of shad and river herring, conduct turbine mortality studies and downstream passage studies.
- Develop and implement techniques to determine shad and herring population targets for tributaries undergoing restoration (dam removals, fishways, supplemental stocking, etc.).
- Characterize tributary habitat quality and quantity for Alosine reintroductions and fish passage development.
- Identify and quantify potential American shad spawning and rearing habitat not presently utilized and conduct an analysis of the cost of recovery.
- Development of appropriate Habitat Suitability Index Models for alosine species in the fishery management plan. Possibly consider expansion of species of importance or go with the most protective criteria for the most susceptible species.
- Determine factors that regulate and potentially limit downstream migration, seawater tolerance, and early ocean survival of juvenile alosines.
- Review studies dealing with the effects of acid deposition on anadromous alosines.
- Determine effects of change in temperature and pH for all life stages.
- Determine optima and tolerance for salinity, dissolved oxygen, pH, substrate, current velocity, depth, temperature, and suspended solids.
- Determine hard limits and range levels for water quality deemed appropriate and defensible for all alosines.
- There has been little research conducted on habitat requirements for hickory shad. Although there are reported ranges of values for some variables, such as temperature or depth, there is no information on tolerances or optima for all life stages. Research on all life stages is necessary to determine habitat requirements.

8.2.2 Life History

- Conduct studies on energetics of feeding and spawning migrations of alosines on the Atlantic coast.
- Conduct studies of egg and larval survival and development.
- Focus research on within-species variation in genetic, reproductive, morphological, and ecological characteristics, given the wide geographic range and variation at the intraspecific level that occurs in alosines.
- Ascertain how abundance and distribution of potential prey affect growth and mortality of early life stages.
- Conduct research on hickory shad migratory behavior. This may explain why hickory shad populations continue to increase while other alosines are in decline.

8.2.3 Stocking and Hatcheries

- Develop effective culture and marking techniques for river herring.
- Refine techniques for hormone induced tank spawning of American shad. Secure adequate eggs for culture programs using native broodstock.

8.2.4 Socioeconomic

- Conduct and evaluate historical characterization of socio-economic development (potential pollutant sources and habitat modification) of selected alosine rivers along the East Coast.
- Collect information from consumptive and non-consumptive users on: demographic information (e.g., age, gender, ethnicity/race), social structure information (e.g., historical participation, affiliation with NGOs, perceived conflicts), other cultural information (e.g., occupational motivation, cultural traditions related to resource's use), and community information.
- In order to improve the management-oriented understanding of historical stock trends and related assessments, the social and economic history of the river herring fisheries should be documented for time periods equivalent to the stock return level sought by the biological standards and this analysis should including documenting market trends, consumer preferences including recreational anglers, the role of product substitutes such as Atlantic herring and menhaden, and the levels of subsistence fisheries as can be obtained.
- Before recommending, re-authorizing and/or implementing stock enhancement programs for a given river system, it is recommended that state agencies or other appropriate management organization conduct *ex-ante* socioeconomic cost and benefit (e.g., estimate non-consumptive and existence values, etc.) analysis of proposed stocking programs.

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10. GLOSSARY

* Definitions taken from: *NOAA Fisheries Glossary*, NOAA Technical Memorandum NMFS-F/SPO-69, October 2005, Revised Edition June 2006.

** Definitions taken from: Stock Assessment Report No. 07-01 (Supplement) of the Atlantic States Marine Fisheries Commission, *American Shad Stock Assessment Report For Peer Review*, August 2007, List of Terms.

All other definitions were developed by the Plan Development Team.

Anadromous*
Fishes that migrate as juveniles from freshwater to saltwater and then return as adults to spawn in freshwater; most Pacific salmon are anadromous.

Area Under the Curve
An estimate of the relative annual abundance of a fish spawning run based on daily fish sample counts over the entire run period. Sample counts can be from fish passage counts at a fishway, or from systematic fishery sampling located downstream of the in-river spawning area, prior to spawning.

Baseline*
A set of reference data sets or analyses used for comparative purposes; it can be based on a reference year or a reference set of (standard) conditions.

Benchmarks**
A particular value of stock size, catch, fishing effort, fishing mortality, and total mortality that may be used as a measurement of stock status or management plan effectiveness. Sometimes these may be referred to as biological reference points.

Biological Reference Points*
1. A biological benchmark against which the abundance of the stock or the fishing mortality rate can be measured in order to determine its status. These reference points can be used as limits or targets, depending on their intended usage;
2. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. These may indicate (a) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or (b) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former are referred to as “target reference points,” and the latter are referred to as “limit reference points” or “thresholds.” Some common examples are $F_{0.1}$, F_{MAX}, and F_{MSY}.

Biomass (B)*
1. Or standing stock. The total weight of a group (or stock) of living organisms (e.g. fish, plankton) or of some defined fraction of it (e.g. spawners) in an area, at a particular time; 2.

Measure of the quantity, usually by weight in pounds or metric tons (2,205 pounds or 1 metric ton), of a stock at a given time.

Bycatch*
Fish other than the primary target species that are caught incidental to the harvest of the primary species. Bycatch may be retained or discarded. Discards may occur for regulatory or economic reasons.

Carrying Capacity*
1. The maximum population of a species that an area or specific ecosystem can support indefinitely without deterioration of the character and quality of the resource;
2. The level of use, at a given level of management, at which a natural or man-made resource can sustain itself over a long period of time. For example, the maximum level of recreational use, in terms of numbers of people and types of activity that can be accommodated before the ecological value of the area declines.

Catch Curve**
An age-based analysis of the catch in a fishery that is used to estimate total mortality of a fish stock. Total mortality is calculated by taking the negative slope of the logarithm of the number of fish caught at successive ages (or with 0, 1, 2... annual spawning marks).

Catch Per Unit (of) Effort (CPUE)*
The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; e.g. number of fish taken per 1,000 hooks per day or weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance. Also called: catch per effort, fishing success, availability.

Catch Rate*
Means sometimes the amount of catch per unit time and sometimes the catch per unit effort.

Cohort*
1. In a stock, a group of fish generated during the same spawning season and born during the same time period;
2. In cold and temperate areas, where fish are long-lived, a cohort corresponds usually to fish born during the same year (a year class). For instance, the 1987 cohort would refer to fish that are age 0 in 1987, age 1 in 1988, and so on. In the tropics, where fish tend to be short lived, cohorts may refer to shorter time intervals (e.g. spring cohort, autumn cohort, monthly cohorts). (see *Year Class*)

Cohort Analysis*
A retrospective analysis of the catches obtained from a given year class at each age (or length interval) over its life in the fishery. Allows estimation of fishing mortality and abundance at each age as well as recruitment. Involves the use of a simplified algorithm based on an approximation that assumes that, in a given time period, all fishing takes place instantaneously in the middle of the time period.

De minimis**
Status obtained by states with minimal fisheries for a certain species and that meet specific provisions described in fishery management plans allowing them to be exempted from specific management requirements of the fishery management plan to the extent that action by the particular States to implement and enforce the plan is not necessary for attainment of the fishery management plan's objectives and the conservation of the fishery.

Depleted Stock*
A stock driven by fishing to very low level of abundance compared to historical levels, with dramatically reduced spawning biomass and reproductive capacity. It requires particularly energetic rebuilding strategies and its recovery time will depend on the present condition, the level of protection, and the environmental conditions.

Directed Fishery*
Fishing that is directed at a certain species or group of species. This applies to both sport and commercial fishing.

Discard*
To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Economic Overfishing*
A level of fish harvesting that is higher than that of economic efficiency; harvesting more fish than necessary to have maximum profits for the fishery.

Economic Value*
The most people are willing to pay to use a given quantity of a good or service; or, the smallest amount people are willing to accept to forego the use of a given quantity of a good or service.

Ecosystem Approach to Fisheries (EAF)*
An approach to fisheries management that strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. The purpose of EAF is to plan, develop, and manage fisheries in a manner that addresses the multiple needs and desires of society, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems.

Ecosystem Approach to Management (EAM)*
Management that is adaptive, is specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives.

Ecosystem Function*
An intrinsic ecosystem characteristic related to the set of conditions and processes whereby an ecosystem maintains its integrity. Ecosystem functions include such processes as decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem-Based Management*
An approach that takes major ecosystem components and services—both structural and functional—into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes. Its goal is to rebuild and sustain populations, species, biological communities, and marine ecosystems at high levels of productivity and biological diversity so as not to jeopardize a wide range of goods and services from marine ecosystems while providing food, revenue, and recreation for humans.

Equilibrium Catch*
The catch (in numbers) taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from the effects of environmental variation) its abundance is not changing from one year to the next.

Equilibrium Yield (EY)*
The yield in weight taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next. Also called: sustainable yield, equivalent sustainable yield.

Escapement*
The number or proportion of fish surviving (escaping from) a given fishery at the end of the fishing season and reaching the spawning grounds. The term is generally used for salmon management.

Exclusive Economic Zone (EEZ)*
The EEZ is the area that extends from the seaward boundaries of the coastal states (3 nautical miles (n.mi.) in most cases, the exceptions are Texas, Puerto Rico and the Gulf coast of Florida at 9 n.mi.) to 200 n.mi. off the U.S. coast. Within this area the United States claims and exercises sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources.

Existence Value*
The economic value of knowing that a resource exists, irrespective of the ability to use the resource now or in the future.9

Exploitable Biomass*
Refers to that portion of a stock's biomass that is available to fishing.

Exploitation**
The annual percentage of the stock removed by fishing either recreationally or commercially.

Exploitation Pattern*
The distribution of fishing mortality over the age composition of the fish population, determined by the type of fishing gear, area and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear; for example, increasing mesh or hook size, or by changing the ratio of harvest by gears exploiting the fish (e.g. gillnet, trawl, hook and line, etc.).

Exploitation Rate*
The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Ex-Vessel*
Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain (at the point of landing) for the catch is an ex-vessel price.

Fecundity*
The potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity usually increases with age and size. The information is used to compute spawning potential.

Fish Passage**
The movement of fish above or below an river obstruction, usually by fish-lifts or fishways.

Fish Passage Efficiency**
The percent of the fish stock captured or passed through an obstruction (i.e., dam) to migration.

Fishery-Dependent*
Data collected directly on a fish or fishery from commercial or sport fishermen and seafood dealers. Common methods include logbooks, trip tickets, port sampling, fishery observers, and phone surveys. (see *Fishery-Independent*)

Fishery-Independent*
Characteristic of information (e.g. stock abundance index) or an activity (e.g. research vessel survey) obtained or undertaken independently of the activity of the fishing sector. Intended to avoid the biases inherent to fishery-related data. (see *Fishery-Dependent*)

Fishery Management Unit (FMU)*
A fishery or a portion of a fishery identified in a fishery management plan (FMP) relevant to the FMP's management objectives. The choice of stocks or species in an FMU depends upon the focus of FMP objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives.

Fishing Mortality (F)*
1. F stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year;
2. A measurement of the rate of removal from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in one year. Instantaneous mortality is that percentage of fish dying at any one time.

F_{30}
The fishing mortality rate that reduces the spawning stock biomass per recruit (SSB/R) to 30% of the amount present in the absence of fishing.

F_{MSY}*
The fishing mortality rate that, if applied constantly, would result in maximum sustainable yield (MSY). Used as a biological reference point, FMSY is the implicit fishing mortality target of many regional and national fishery management authorities and organizations. F_{MSY} can be estimated in two ways: a) from simple biomass aggregated production models; b) from age-structured models that include a stock-recruitment relationship.

F_{MAX}*
1. The level of fishing mortality (rate of removal by fishing) that produces the greatest yield from the fishery;
2. A biological reference point. It is the fishing mortality rate that maximizes equilibrium yield per recruit. FMAX is the F level often used to define growth overfishing. In general, FMAX is different (and higher) than FMSY depending on the stock-recruitment relationship. By definition, FMAX is always higher than $F_{0.1}$.

Index of Abundance*
A relative measure of the abundance of a stock; for example, a time series of catch per unit effort data.

Indicators*
1. A variable, pointer, or index. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and action;
2. Signals of processes, inputs, outputs, effects, results, outcomes, impacts, etc., that enable such phenomena to be judged or measured. Both qualitative and quantitative indicators are needed for management learning, policy review, monitoring, and evaluation;
3. In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions, good or bad.

Instantaneous Rate of Fishing Mortality (F)*
When fishing and natural mortality act concurrently, F is equal to the instantaneous total mortality rate, multiplied by the ratio of fishing deaths to all deaths. Also called: rate of fishing; instantaneous rate of fishing.

Instantaneous Rate of Mortality (Z)*
When fishing and natural mortality act concurrently, the natural logarithm of the survival rate (with sign changed) for deaths due to either natural causes (instantaneous rate of natural mortality, M) or due to fishing mortality (instantaneous rate of fishing mortality, F). The instantaneous rate of total mortality, Z, is the sum of these two rates: $Z = F + M$, also called the coefficient of decrease.

Comment: Usually given on a yearly basis; the figure just described is divided by the fraction of a year represented by the "short interval" in question. This concept is used principally when the size of the vulnerable stock is not changing or is changing only slowly, since among fishes recruitment is not usually associated with stock size in the direct way in which mortality and growth are.

Larvae
Fish developmental stage well differentiated form the later young-of-year and juvenile stages and intervening between the time of hatching and time of transformation or loss of larval character (i.e., fish resembles a young or juvenile individual by absence of a yolk sac, and presence of continuous finfolds and pigmented young-of-year character).

Life Cycle*
Successive series of changes through which an organism passes in the course of its development.

Limit Reference Points*
Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines, limits are referred to as thresholds. In much of the international literature (e.g. United Nations Food and Agricultural Organization, FAO) thresholds are used as buffer points that signal when a limit is being approached.

M
(see Natural Mortality)

Management Objective*
A formally established, more or less quantitative target that is actively sought and provides a direction for management action.

Management Reference Points*
Conventional (agreed values) of indicators of the desirable or undesirable state of a fishery resource of the fishery itself. Reference points could be biological (e.g. expressed in spawning biomass or fishing mortality levels), technical (fishing effort or capacity levels) or economic (employment or revenues levels). They are usually calculated from models in which they may represent critical values.

Management Strategy*
The strategy adopted by the management authority to reach established management goals. In addition to the objectives, it includes choices regarding all or some of the following: access

rights and allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations (e.g. calendar, closed areas, and seasons).

Mature Individuals*
The number of individuals known, estimated, or inferred to be capable of reproduction.

Maturity*
Refers to the ability, on average, of fish of a given age or size to reproduce. Maturity information, in the form of percent mature by age or size, is often used to compute spawning potential.

Maximum Spawning Potential (MSP)*
This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit (SSB/R) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e. %MSP). A stock is considered overfished when the fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock-recruitment data or chosen by analogy using available information on the level required to sustain the stock.

Maximum Sustainable Yield (MSY)*
The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others. Also called: maximum equilibrium catch; maximum sustained yield; sustainable catch.

Minimum Stock Size Threshold (MSST, $B_{threshold}$)*
Another of the status determination criteria (SDC). The greater of (a) 1/2 B_{MSY} , or (b) the minimum stock size at which rebuilding to B_{MSY} will occur within 10 years while fishing at the maximum fishing mortality threshold (MFMT). MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $B_{threshold}$, the stock is overfished.

Moratorium*
A mandatory cessation of fishing activities on a species (e.g. the blue whale), in an area (e.g. a sanctuary), with a particular gear (e.g. large scale driftnets), and for a specified period of time (temporary, definitive, seasonal, or related to reopening criteria).

Mortality*
Measures the rate of death of fish. Mortality occurs at all life stages of the population and tends to decrease with age. Death can be due to several factors such as pollution, starvation, and disease but the main source of death is predation (in unexploited stocks) and fishing (in exploited ones).

Mortality Rate*
The rate at which the numbers in a population decrease with time due to various causes. Mortality rates are critical parameters in determining the effects of harvesting strategies on stocks, yields, revenues, etc. The proportion of the total stock (in numbers) dying each year is called the "annual mortality rate."

Native Species*
A local species that has not been introduced. (see *Introduced Species, Invasive Species*)

Natural Mortality (M)*
1. Deaths of fish from all causes except fishing (e.g. ageing, predation, cannibalism, disease, and perhaps increasingly pollution). It is often expressed as a rate that indicates the percentage of fish dying in a year; e.g. a natural mortality rate of 0.2 implies that approximately 20 percent of the population will die in a year from causes other than fishing;
2. The loss in numbers in a year class from one age group to the subsequent one, due to natural death.

Comment: These many causes of death are usually lumped together for convenience, because they are difficult to separate quantitatively. Sometimes natural mortality is confounded with losses of fish from the stock due to emigration. M has proven very difficult to estimate directly, and is often assumed based on the general life history. The M value is also often assumed to remain constant through time and by age, a very unlikely assumption.

Natural Mortality (M)**
The instantaneous rate at which fish die from all causes other than harvest or other human-induced cause (i.e., turbine mortality). Some sources of natural mortality include predation, spawning mortality, and senescence (old age).

Non-Consumptive Use*
Individuals may use (i.e. observe), yet not consume, certain living ocean resources, like whale watching, sight-seeing, or scuba diving. Additionally, individuals might value the mere existence of living ocean resources without actually observing them.

Non-Point Sources*
Sources of sediment, nutrients, or contaminants that originate from many locations.

Non-Target Species*
Species not specifically targeted as a component of the catch; may be incidentally captured as part of the targeted catch.

Ocean-Intercept Fishery**
A fishery for American shad conducted in state or federal ocean waters targeting the coastal migratory mixed-stock of American shad.

Optimum Yield (OY)*
1. The harvest level for a species that achieves the greatest overall benefits, including economic, social, and biological considerations. Optimum yield (OY) is different from maximum sustainable yield (MSY) in that MSY considers only the biology of the species. The term includes both commercial and sport yields;
2. The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. MSY constitutes a "ceiling" for OY. OY may be lower than MSY, depending on relevant economic, social, or ecological factors. In the case of an overfished fishery, OY should provide for the rebuilding of the stock to
BMSY.

Overexploited*
When stock abundance is too low. The term is used when biomass has been estimated to be below a limit biological reference point that is used as the threshold that defines "overfished conditions."

Overfished*
1. An overfished stock or stock complex "whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding." A stock or stock complex is considered overfished when its population size falls below the minimum stock size threshold (MSST). A rebuilding plan is required for stocks that are deemed overfished;
2. A stock is considered "overfished" when exploited beyond an explicit limit beyond which its abundance is considered 'too low' to ensure safe reproduction. In many fisheries the term is used when biomass has been estimated to be below a limit biological reference point that is used as the signpost defining an "overfished condition." This signpost is often taken as being F_{MSY}, but the usage of the term may not always be consistent. (see *Minimum Stock Size Threshold*)

Comment: The stock may remain overfished (i.e. with a biomass well below the agreed limit) for some time even though fishing pressure might be reduced or suppressed.

Overfishing*
1. According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis." Overfishing is occurring if the maximum fishing mortality threshold (MFMT) is exceeded for 1 year or more;
2. In general, the action of exerting fishing pressure (fishing intensity) beyond the agreed optimum level. A reduction of fishing pressure would, in the medium term, lead to an increase in the total catch. (see *National Standard Guidelines*, *Maximum Fishing Mortality Threshold*, *Maximum Sustainable Yield*)

Comment: For long-lived species, overfishing (i.e. using excessive effort) starts well before the stock becomes overfished. The use of the term "overfishing" may not always be consistent.

Overfishing Limit (OFL)*
Point at which fishing seriously compromised a fishery's continued, sustained productivity. Overfishing limits may be set based on standardized biological criteria established for a particular fishery. Overfishing limits may also incorporate economic and social considerations relevant to a particular fishery.

Oxytetracycline (OTC)**
An antibiotic used to internally mark otoliths of hatchery produced fish.

Predation*
Relationship between two species of animals in which one (the predator) actively hunts and lives off the meat and other body parts of the other (the prey).

Pre-Recruits*
Fish that have not yet reached the recruitment stage (in age or size) to a fishery.

Production*
1. The total output especially of a commodity or an industry;
2. The total living matter (biomass) produced by a stock through growth and recruitment in a given unit of time (e.g. daily, annual production). The "net production" is the net amount of living matter added to the stock during the time period, after deduction of biomass losses through mortality;
3. The total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time.

Production Model*
1. The highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process. Also referred to sometimes as potential yield;
2. Maximum sustainable yield (MSY) or sustainable yield (SY). The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others. (see *Carrying Capacity*, *Maximum Sustainable Yield*, *Sustainable Yield*)

Productivity*
Relates to the birth, growth and death rates of a stock. A highly productive stock is characterized by high birth, growth, and mortality rates, and as a consequence, a high turnover and production to biomass ratios (P/B). Such stocks can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive stocks.

Rebuilding*
1. Implementing management measures that increase a fish stock to its target size1; 2. For a depleted stock, or population, taking action to allow it to grow back to a predefined target level. Stock rebuilding at least back to the level (BMSY) at which a stock could produce maximum sustainable yield (MSY).

Rebuilding Analysis*
An analysis that uses biological information to describe the probability that a stock will rebuild within a given time frame under a particular management regime.

Rebuilding Plan*
1. A document that describes policy measures that will be used to rebuild a fish stock that has been declared overfished;
2. A plan that must be designed to recover stocks to the BMSY level within 10 years when they are overfished (i.e. when biomass [B] < minimum stock size threshold [MSST]). (see *Minimum Stock Size Threshold*)

Recruit*
1. A young fish entering the exploitable stage of its life cycle;
2. A member of "the youngest age group which is considered to belong to the exploitable stock."

Recruitment (R)*
1. The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year;
2. This term is also used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age 2 recruits.

Recruitment Overfishing*
A situation in which the rate of fishing is (or has been) such that annual recruitment to the exploitable stock has become significantly reduced. The situation is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year. If prolonged, recruitment overfishing can lead to stock collapse, particularly under unfavorable environmental conditions.

Recruits*
The numbers of young fish that survive (from birth) to a specific age or grow to a specific size. The specific age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

Reference Level*
A particular level of an indicator (e.g. level of fishing effort, fishing mortality, or stock size) used as a benchmark for assessment and management performance.

Reference Point*
1. A reference point indicates a particular state of a fishery indicator corresponding to a situation considered as desirable (target reference point) or undesirable and requiring immediate action (limit reference point and threshold reference point);
2. An estimated value derived from an agreed scientific procedure and/or model, which corresponds to a specific state of the resource and of the fishery, and that can be used as a guide

for fisheries management. Reference points may be general (applicable to many stocks) or stock-specific;
3. Values of parameters (e.g. B_{MSY}, F_{MSY}, $F_{0.1}$) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability (e.g. MSST) or targets for management (e.g. OY).

Relative Exploitation**
An approach used when catch is known or estimated, but no estimates of abundance are available. For example, it may be calculated as the catch divided by a relative index of abundance. Long-term trends in relative exploitation are can be useful in evaluating the impact of fishing versus other sources of mortality.

Restoration**
In this assessment, this describes the stocking of hatchery produced young-of-year American shad to augment wild cohorts and the transfer of adult American shad to rivers with depleted spawning stocks. Restoration also includes efforts to improve fish passage or remove barriers to migration.

Risk*
1. In general, the possibility of something undesirable happening, of harm or loss. A danger or a hazard. A factor, thing, element, or course involving some uncertain danger;
2. In decision-theory, the degree or probability of a loss; expected loss; average forecasted loss. This terminology is used when enough information is available to formulate probabilities;
3. The probability of adverse effects caused under specified circumstances by an agent in an organism, a population, or an ecological system.

Risk Assessment*
A process of evaluation including the identification of the attendant uncertainties, of the likelihood and severity of an adverse effect(s)/event(s) occurring to man or the environment following exposure under defined conditions to a risk source(s). A risk assessment comprises hazard identification, hazard characterization, exposure assessment, and risk characterization.

Risk Management*
The process of weighing policy alternatives in the light of the result of a risk assessment and other relevant evaluation and, if required, selecting and implementing appropriate control options (which should, where appropriate, include monitoring or surveillance).

River Complex
The freshwater portions of an Atlantic coast river, and its associated tributaries and estuary that encompass the freshwater migration, spawning, and nursery habitat for an American shad stock.
Robustness*
The capacity of a population to persist in the presence of fishing. This depends on the existence of compensatory mechanisms. (see *Reliability*)

Run*
Seasonal migration undertaken by fish, usually as part of their life history; for example, spawning run of salmon, upstream migration of shad. Fishers may refer to increased catches as a "run" of fish, a usage often independent of their migratory behavior.

Run Size**
The magnitude of the upriver spawning migration of American shad.

Semelparous**
Life history strategy in which an organism only spawns once before dying.

Spawning Biomass*
The total weight of all sexually mature fish in the population.

Spawning Ground
The area of suitable spawning habitat associated with a stock.

Spawning Stock*
1. Mature part of a stock responsible for reproduction;
2. Strictly speaking, the part of an overall stock having reached sexual maturity and able to spawn. Often conventionally defined as the number or biomass of all individuals beyond "age at first maturity" or "size at first maturity"; that is, beyond the age or size class in which 50 percent of the individuals are mature.

Spawning Stock Biomass (SSB)*
1. The total weight of all fish (both males and females) in the population that contribute to reproduction. Often conventionally defined as the biomass of all individuals beyond "age at first maturity" or "size at first maturity," i.e. beyond the age or size class in which 50 percent of the individuals are mature;
2. The total biomass of fish of reproductive age during the breeding season of a stock.

Comment: Most often used as a proxy for measuring egg production, the SSB depends on the abundance of the various age classes composing the stock and their past exploitation pattern, rate of growth, fishing and natural mortality rates, onset of sexual maturity, and environmental conditions.

Spawning Stock Biomass**
The total weight of mature fish (often females) in a stock.

Spawning Stock Biomass per Recruit (SSB/R or SBR)*
The expected lifetime contribution to the spawning stock biomass for the average recruit, SSB/R is calculated assuming that fishing mortality is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

Standing Stock*
1. The total weight of a group (or stock) of living organisms (e.g. fish, plankton) or of some defined fraction of it (e.g. spawners), in an area, at a particular time. Example: the spawning biomass of the cod stock on the Georges Bank in 1999;
2. The weight of a fish stock or of some defined portion of it. (see *Abundance*)

Stock*
A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. A fish stock may be treated as a total or a spawning stock. Total stock refers to both juveniles and adults, either in numbers or by weight, while spawning stock refers to the numbers or weight of individuals that are old enough to reproduce.

Comment: In theory, a unit stock is composed of all the individual fish in an area that are part of the same reproductive process. It is self-contained, with no emigration or immigration of individuals from or to the stock. On practical grounds, however, a fraction of the unit stock is considered a "stock" for management purposes (or a management unit), as long as the results of the assessments and management remain close enough to what they would be on the unit stock.

Stock-Recruitment Relationship (SRR)*
The relationship between the level of parental biomass (e.g. spawning stock size) and subsequent recruitment level. Determination of this relationship is useful to analyze the sustainability of alternative harvesting regimes and the level of fishing beyond which stock collapse is likely. The relation is usually blurred by environmental variability and difficult to determine with any accuracy.

Comment: Such a relationship always exists in principle, in that the existence of a parent stock is a prerequisite for the generation of recruitment. However, in many cases there exist regulatory mechanisms such that the number of recruits is not strongly related to the parent stock size over the range of stock sizes observed: this situation is sometimes described as the absence of a stock recruitment relationship, but is more logically described as a special case of a stock-recruitment relationship. Some stock assessment methods incorporate the estimation of such a relationship directly into the model, either explicitly (e.g. some age-structured assessments) or implicitly (most stock production models).

Stock Status**
The agreed perspective of the SASC of the relative level of fish abundance.

Sub-adult**
Juvenile American shad which are part of the ocean migratory mixed stock fish.

Surplus Production*
1. The amount of biomass produced by the stock (through growth and recruitment) over and above that which is required to maintain the total stock biomass at a constant level between consecutive time periods;
2. Production of new biomass by a fishable stock, plus recruits added to it, less what is removed by natural mortality. This is usually estimated as the catch in a given year plus the increase in

stock size (or less the decrease). Also called: natural increase, sustainable yield, and equilibrium catch.

Survival Rate*
Number of fish alive after a specified time interval, divided by the initial number. Usually on a yearly basis.

Survival Ratio*
1. Ratio of recruits to spawners (or parental biomass) in a stock-recruitment analysis. Changes in survival ratios indicate that the productivity of a stock is changing;
2. Number of fish alive after a specified time interval, divided by the initial number. Usually calculated on a yearly basis.

Sustainability*
1. Ability to persist in the long-term. Often used as "short hand" for sustainable development;
2. Characteristic of resources that are managed so that the natural capital stock is non-declining through time, while production opportunities are maintained for the future.

Sustainable Catch (Yield)*
The number (weight) of fish in a stock that can be taken by fishing without reducing the stock biomass from year to year, assuming that environmental conditions remain the same.

Sustainable Fishery
Systems that demonstrate their stocks could support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment.

Sustainable Fishing*
Fishing activities that do not cause or lead to undesirable changes in the biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next.
Comment: Fishing is sustainable when it can be conducted over the long-term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations.

Sustainable Yield*
1. Equilibrium yield;
2. The amount of biomass or the number of units that can be harvested currently in a fishery without compromising the ability of the population/ecosystem to regenerate itself.

Target Reference Point (TRP)*
1. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g. optimum yield, OY). Target reference points should not be exceeded on average;
2. Corresponds to a state of a fishery or a resource that is considered desirable. Management action, whether during a fishery development or a stock rebuilding process, should aim at bringing the fishery system to this level and maintaining it there. In most cases a TRP will be

expressed in a desired level of output for the fishery (e.g. in terms of catch) or of fishing effort or capacity, and will be reflected as an explicit management objective for the fishery.

Target Species*
Those species primarily sought by the fishermen in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species.

Thresholds*
1. Levels of environmental indicators beyond which a system undergoes significant changes; points at which stimuli provoke significant response;
2. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, and then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Total Mortality (Z)*
1. A measurement of the rate of removal of fish from a population by both fishing and natural causes. Total mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in 1 year. Instantaneous mortality is that percentage of fish dying at any one time;
2. The sum of natural (M) and fishing (F) mortality rates.

Turbine Mortality**
American shad mortalities that are caused by fish passing through the turbines of hydroelectric dams during return migrations to the sea.

Unit Stock*
A population of fish grouped together for assessment purposes, which may or may not include all the fish in a stock. (see *Stock*)

Variable*
Anything changeable. A quantity that varies or may vary. Part of a mathematical expression that may assume any value.

Virgin Biomass (B_0)*
The average biomass of a stock that has yet not been fished (in an equilibrium sense). Biomass of an unexploited (or quasi unexploited) stock. Rarely measured. Most often inferred from stock modeling. Used as a reference value to assist the relative health of a stock, monitoring changes in the ratio between current and virgin biomass (B/B_0). It is usually assumed that, in absence of better data, $B = 0.30\ B_0$ is a limit below which a stock should not be driven.

Comment: Virgin Biomass corresponds to a stock's theoretical carrying capacity.

Vulnerability*
A term equivalent to catchability (*q*) but usually applied to separate parts of a stock, for example those of a particular size, or those living in a particular part of the range.

Water Quality*
The chemical, physical, and biological characteristics of water in respect to its suitability for a particular purpose.

Water Quality Criteria*
Specific levels of water quality desired for identified uses, including drinking, recreation, farming, fish production, propagation of other aquatic life, and agricultural and industrial processes.

Watershed*
The areas which supplies water by surface and subsurface flow from rain to a given point in the drainage system.

Year Class*
Fish in a stock born in the same year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on. Occasionally, a stock produces a very small or very large year class that can be pivotal in determining stock abundance in later years. (see *Cohort*)

Yield*
1. The yield curve is the relationship between the expected yield and the level of fishing mortality or (sometimes) fishing effort;
2. Catch in weight. Catch and yield are often used interchangeably. Amount of production per unit area over a given time. A measure of agricultural production.

Yield per Recruit (Y/R or YPR)*
1. A model that estimates yield in terms of weight, but more often as a percentage of the maximum yield, for various combinations of natural mortality, fishing mortality, and time exposed to the fishery;
2. The average expected yield in weight from a single recruit. Y/R is calculated assuming that fishing mortality is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are assumed to be constant.

Yield-per-Recruit Analysis*
Analysis of how growth, natural mortality, and fishing interact to determine the best size of animals at which to start fishing them, and the most appropriate level of fishing mortality. The yield-per-recruit models do not consider the possibility of changes in recruitment (and reproductive capacity) due to change in stock size. They also do not deal with environmental impacts.

Young-of-Year
(see Age 0)

Z
(see Total Mortality)

e) ASMFC 2010 Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring

Atlantic States Marine Fisheries Commission

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management)

ASMFC Vision Statement:
Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

Approved February 2010

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring

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This Amendment was developed through the concerted and dedicated efforts of several individuals, groups and agencies. Guidance was provided by the Atlantic States Marine Fisheries Commission's Shad and River Herring Management Board, chaired by Paul Diodati (Massachusetts Division of Marine Fisheries (2008-2009)) and Malcolm Rhodes (South Carolina (2010 – current). Technical assistance was provided by the Shad and River Herring Technical Committee (chaired by Robert Sadzinski (2008-2009) and Kathryn Hattala (2009 – current)), the American Shad Stock Assessment Subcommittee (chaired by Andrew Kahnle (2004-2007)), and the Shad and River Herring Advisory Panel (chaired by Patricia Jackson (2008) and Byron Young (2009 – current)).

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EXECUTIVE SUMMARY

INTRODUCTION: The Atlantic States Marine Fisheries Commission (ASMFC) developed Amendment 3 to its Interstate Fishery Management Plan (or FMP) for Shad and River Herring under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA 1993). Amendment 3 addresses only management measures for American shad. Management measures for alewife and blueback herring (collectively called river herring) are contained in Amendment 2. Shad and river herring management authority lies with the coastal states and is coordinated through the Commission.

Responsibility for compatible management action in the Exclusive Economic Zone (EEZ) from 3-200 miles from shore lies with the Secretary of Commerce through the ACFCMA in the absence of a federal fishery management plan.

STATEMENT OF THE PROBLEM: In 2007, the American Shad Stock Assessment Subcommittee (SASC) completed an American shad stock assessment report, which was accepted by the Peer Review Panel (PRP) and the Shad and River Herring Management Board in August 2007 (ASMFC 2007). The 2007 American shad stock assessment found that stocks were at all-time lows and did not appear to be recovering to acceptable levels. It identified the primary causes for the continued stock declines as a combination of excessive total mortality, habitat loss and degradation, and migration and habitat access impediments. Although improvement has been seen in a few stocks, many remain severely depressed compared to their historic levels.

Anadromous fish species, such as American shad, are unlike almost all other fish species that are cooperatively managed under ASMFC. Most other ASMFC species are exclusively oceanic and all of their habitat and life cycle needs can be satisfied in the marine environment (although some may utilize coastal shore or estuarine habitat for part of their life). Anadromous fish, as a result of their freshwater and estuarine spawning and nursery requirements, must come into close contact with human populations, and are therefore vulnerable to the many threats and potential sources of injury and mortality associated with human activity in and around rivers and estuaries.

IMPLEMENTATION BENEFITS: Implementation of Amendment 3 and consequent restoration of American shad stocks will produce significant ecological, cultural and economic benefits. Ecologically, American shad and other alosines played important ecological roles in freshwater, estuarine and marine environments during their life cycles. Cultural benefits will arise in part from the revitalization of traditional fisheries and the numerous shad festivals historically held along the east coast each spring during the spawning run. Cultural benefits to Native American tribes will arise through restoration of their traditional fisheries and fishing rights.

DESCRIPTION OF THE RESOURCE AND MANAGEMENT UNIT: The American shad is the largest North American member of the shad and herring family, and historically occurred in all major rivers from Maine through the east coast of Florida. The management units for American shad under this Fishery Management Plan Amendment include all migratory American shad stocks of the Atlantic coast of the United States.

LIFE HISTORY AND HABITAT REQUIREMENTS: American shad are a migratory anadromous fish that spend most of their life at sea along the Atlantic coast and enter freshwater as adults in the spring to spawn. Most young emigrate from their natal rivers during their first year of life. American shad stocks are river-specific; that is, each major tributary along the Atlantic coast appears to have a discrete spawning stock. Habitats used by American shad include adult spawning sites in coastal tributaries and larval and juvenile nursery areas in the freshwater portions of the rivers and their associated bays and estuaries.

GOALS AND OBJECTIVES:
Goal: Protect, enhance, and restore Atlantic coast migratory stocks and critical habitat of American shad in order to achieve levels of spawning stock biomass that are sustainable, can produce a harvestable surplus, and are robust enough to withstand unforeseen threats.

Objectives:
- Maximize the number of juvenile recruits emigrating from freshwater stock complexes.
- Restore and maintain spawning stock biomass and age structure to achieve maximum juvenile recruitment.
- Manage for an optimum yield harvest level that will not compromise Objectives 1 and 2.
- Maximize cost effectiveness to the local, state, and federal governments, and the ASMFC associated with achieving Objectives 1 through 3.

Strategies to Achieve Objectives:
- Quantify and effectively manage sources of bycatch mortality where possible.
- Quantify and effectively manage sources of predation where possible and appropriate.
- Restore and maintain access to historical spawning and nursery habitat (i.e., dam removal and fishway installation).
- Maintain total mortality (Z) of American shad stocks at or below stock assessment benchmarks.
- Ensure that adequate monitoring techniques are implemented to measure migratory success (i.e., upstream and downstream fish passage at barriers).
- Ensure that stock monitoring data are collected and that they are adequate to characterize stock status and stock response to management actions (i.e., develop a sampling program that provides an annual measurable output for spawning stock and juvenile production status)
- Achieve river specific restoration targets for American shad populations as specified in the recent shad assessment or in existing stock specific restoration plans.
- Ensure that the production of hatchery fish is used effectively during restoration efforts.
- Maximize cost effectiveness of data collection to minimize costs to states and jurisdictions through coordinated monitoring, flexibility in monitoring methods, and early vetting of monitoring and management plans.
- Identify interactions between other Commission species management plans (positive or negative) and the objectives stated above.

SUSTAINABLE FISHERY DEFINITION: This document defines a sustainable fishery as "those that demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment*."*

OVERFISHING DEFINITION: Amendment 1 to the American shad and River Herring Fishery Management Plan (ASMFC 1999) refined the definition of overfishing for American shad stocks to be an *instantaneous rate of fishing mortality* rate (F) from directed fisheries that was at or above a benchmark of F_{30}. The most recent stock assessment (ASMFC 2007) concluded that the Amendment 1 definition of overfishing was no longer valid for American shad stocks since they are subjected to several sources of human-induced mortality that includes: directed fishing (F), fish passage mortality at dams, river pollution, and bycatch and discard in indirect fisheries activity. As an interim solution, the recent ASMFC stock assessment (ASMFC 2007) combined all human-induced rates into a single overall human induced rate. Since the components of human-induced mortality (directed fishing, dam-induced, pollution, and bycatch) are difficult or impossible to quantify, ASMFC (2007) did not attempt to develop a benchmark for combined mortality that was analogous to F_{30} for directed fishing alone. Instead, ASMFC (2007) developed benchmark values for *total instantaneous mortality* or Z_{30} (see Table 1). Under this new definition, American shad stocks are affected by a combined human-induced instantaneous mortality rate and by natural mortality (M). Therefore, the total instantaneous mortality (Z) equals human induced mortality plus M. Since the total instantaneous mortality definition combines mortality that are both within and beyond the purview jurisdiction of the Commission, as well as currently unquantified mortality, the Board adopted the use of Z_{30} as a mortality benchmark to help guide management and gauge restoration progress. This amendment did not adopt an overfishing definition, defined as F.

MONITORING PROGRAM SPECIFICATIONS: The collection of adequate fish stock and fishery monitoring data is necessary to achieve the goal and objectives of the American Shad management program. A well designed monitoring program provides measurable outputs that can be used to judge the effectiveness of current management efforts in achieving the desired outcome. This amendment recommends that states increase coordination of data collection on American shad among states with shared water bodies, as well as between freshwater and marine sections of agencies. All available data must be reported in annual compliance reports to ASMFC.

States and jurisdictions will be required to conduct annual fisheries independent and dependent monitoring (See Table 2 and 3). Fisheries independent monitoring includes juvenile abundance, adult stock structure and abundance, and stocking success. Fisheries dependent monitoring includes monitoring of American shad commercial and recreational fisheries. States and jurisdictions may apply to the Management Board for *de minimus* status. Monitoring will be conducted using methods proposed by the state or jurisdiction and subject to Technical Committee review and Board approval.

States and jurisdictions may propose to the Management Board alternative monitoring if they develop a stock specific definition of a sustainable fishery or stock recovery targets, as per Section 6.0, and the proposed alternative monitoring measures progress to the definition or targets. If a states or jurisdiction cannot meet the monitoring requirements, the Commission will work with that state or jurisdiction to develop an acceptable alternative proposal, as per Section 6.0 or Section 7.0, which will be submitted for TC review and Board approval. The Technical Committee is tasked with reviewing and prioritizing the data collection elements in the monitoring program. The review should include a brief explanation of the importance of each element to the stock assessment process.

BYCATCH MONITORING AND REDUCTION: States and jurisdictions will be required to annually monitor bycatch and discard of American shad in fisheries that operate in state waters of rivers and estuaries. States and jurisdictions are required to submit a plan to conduct monitoring of bycatch and discards within the Implementation Plan. Ocean bycatch and discard, however, are coastwide problems that affect shad stocks in all coastal states. This amendment recommends that ocean bycatch and discards be monitored cooperatively by coastal states through the Commission, in cooperation with Fishery Management Councils and NOAA Fisheries.

REGULATORY PROGRAM: The management units for American shad under this Fishery Management Plan Amendment include all migratory American shad stocks of the Atlantic coast of the United States. States and jurisdictions must implement the regulatory program requirements as per Section 7. The Management Board has the ultimate authority to determine the approval of a regulatory program. States and jurisdictions must also submit proposals to change their required regulatory programs as per Section 7.1.2. The Management Board will determine final approval for changes to required regulatory programs.

COMMERCIAL FISHERIES MANAGEMENT MEASURES: States and jurisdictions shall submit a sustainable fisheries management plan for those systems that will remain open to commercial fishing. The request for a fishery will be submitted as part of the Fishing/Recovery Section in the Implementation Plan, as per Section 6.0. States or jurisdictions without an approved plan in place will close the commercial fishery by January 1, 2013.

RECREATIONAL FISHERIES MANAGEMENT MEASURES: States and jurisdictions shall submit a sustainable fisheries management plan for those systems that will remain open to recreational fishing. Catch and release fishing will be permitted on any system. The request for a fishery will be submitted as part of the Fishing/Recovery Section in the Implementation Plan, as per Section 6.0. States or jurisdictions without and approved plan in place will close their recreational fishery (with the exception of catch and release) by January 1, 2013.

HABITAT CONSERVATION AND RESTORATION: American shad stocks along the Atlantic coast are greatly diminished compared to historic levels of the 1880's and early 1900's when landings were near 50 million pounds per year. Much of this reduction has been related to spawning and nursery habitat degradation or blocked access to habitat, resulting from human activity (e.g.; human population increase; sewage and storm water runoff; industrialization; dam construction; increased erosion, sedimentation and nutrient enrichment associated with agricultural practices; and losses of riparian forests and wetland buffers associated with resource extraction and land development). Protection, restoration and enhancement of American shad habitat, including spawning, nursery, rearing, production, and migration areas, are critical objectives necessary for preventing further declines in American shad abundance, and restoring healthy, self-sustaining, robust, and productive American shad stocks to levels that will support the desired ecological, social, and economic functions and values of a restored Atlantic coast American shad population.

THREATS TO AMERICAN SHAD HABITAT: Threats to American shad habitats include the following: barriers to migration; water withdrawals; toxic and thermal wastewater discharge; channelization, dredging and instream construction; inappropriate land uses; atmospheric deposition; climate change; competition and predation by invasive and managed species; fisheries activities; and instream flow regulation.

RECOMMENDATIONS FOR HABITAT RESTORATION, ENHANCEMENT, USE AND PROTECTION: Detailed recommendations are provided to states and jurisdictions for avoiding, reducing or mitigating the impact of the following threats on American shad habitats: dams and other obstructions and water quality and contamination**.** Additional detailed recommendations are provided for habitat protection and restoration; state permitting programs; and American shad stock restoration and management of stocking programs. While this amendment proposes the development of habitat restoration and protection programs, implementation of these programs is not required.

IMPLEMENTATION PLANS: In order to be successful in achieving the stated goal of Amendment 3, states are required to develop Implementation Plans. Implementation Plans will consist of two parts: 1. Review and update of the fishing/recovery plans required under Amendment 1 for the stocks within their jurisdiction; and 2. Habitat plans. Separate Implementation Plans shall be developed for those systems listed in Tables 2 and 3 and which are under the state's or jurisdiction's authority. For states and jurisdictions which share a river or estuary, agencies should include those monitoring programs conducted or planned by the agencies, applicable agency regulations, and habitat and habitat threats applicable to the state or jurisdiction's waters. In shared water bodies where there is a management cooperative, the cooperative or a member state or jurisdiction can be appointed to write the Implementation Plan. States are encouraged to develop plans for any additional systems, as feasible. In some cases, the requirements of this section may be largely met by existing basinwide diadromous fish restoration plans prepared by the federal and state agencies to address the requirements of the Federal Energy Regulatory Commission hydropower licensing requirements.

FISHING/RECOVERY PLAN UPDATES: The updated Fishing/Recovery Plan must include a description of existing and planned monitoring and existing and planned regulatory measures. It may also include a request for commercial and/or recreational fishery, a definition of sustainability, development of benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment), and a proposed timeframe to achieve stated objectives. Monitoring sections of the fishing/recovery plan updates should address the specific monitoring requirements specified in Tables 2 and 3. If states or jurisdictions cannot conduct required monitoring, the plan update should identify required monitoring that cannot be done and provide reasons why it cannot be conducted. It is the intention of this amendment to discuss such problems with implementation prior to plan adoption so that the Commission can work with the state or jurisdiction to obtain secure funding or to develop an alternative. The amendment contains a detailed framework for the Fishing/Recovery Plan updates (see Section 6.1). If a state or jurisdiction chooses to develop a definition of sustainability or stock restoration goals as part of its Fishing/Recovery Plan, it may propose for Management Board review an alternative monitoring plan that measure stock status relative to the definition or goal. Fishing/Recovery Plans are due August 1, 2011.

HABITAT PLANS: The Habitat Plans should include a summary of current and historical spawning and nursery habitat, threats to those habitats, and habitat restoration programs. States and jurisdictions may focus on those threats to habitats within their boundaries that are deemed most significant. A recommended framework for the Habitat Plans is included in the amendment (see Section 6.2). Many of the recommended assessments may have already been conducted by the states as part of their Wildlife Action Plans or Comprehensive Wildlife Conservation Plans. Habitat Plans are due August 1, 2013.

AMENDMENT REVISIONS: Once the American shad Management Board approves a management program, states and jurisdictions are required to obtain approval from the Management Board prior to changing their management program in any way that might alter a compliance measure. Changes to management programs that affect measures other than compliance measures must be reported to the Management Board but may be implemented without prior approval.

ADAPTIVE MANAGEMENT: It is important to note that this amendment provides the Management Board with the ability to re-evaluate and modify the management program very rapidly in response to stock conditions or public input.

COMPLIANCE: Full implementation of the provisions in this amendment is necessary for the management program to be equitable, efficient and effective. States and jurisdictions are expected to implement these measures faithfully under state laws.

MANDATORY COMPLIANCE ELEMENTS FOR STATES: A state or jurisdiction will be determined out of compliance with the provision of this fishery management plan according to the terms of Section 7 of the ISFMP Charter if:

- It's Implementation Plans and annual compliance reports have not been approved by the Shad and River Herring Management Board; or
- It fails to meet any scheduled action required by Section 9.2, or any addendum prepared under adaptive management (Section 7.2); or
- It has failed to implement a change to its program, when determined necessary by the Shad and River Herring Management Board; or
- It makes a change to its monitoring programs required under Section 3 or its regulations required under Section 4 without prior approval of the Shad and River Herring Management Board.

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1. INTRODUCTION

The Atlantic States Marine Fisheries Commission (Commission) was formed by the 15 Atlantic coast states in 1942 in recognition that fish do not adhere to political boundaries. The Commission serves as a deliberative body, coordinating the conservation and management of the states shared near shore fishery resources (marine, shell, and anadromous) for sustainable use. The Commission focuses on responsible stewardship of marine fisheries resources. It serves as a forum for the states to collectively address fisheries issues under the premise that as a group, using a cooperative approach, they can achieve more than they could as individuals. The Commission does not promote a particular state, jurisdiction, or a stakeholder sector.

The Commission's mission is to promote the better utilization of the marine, shell, and anadromous fishery resources of the Atlantic seaboard through the development of a joint program for the promotion and protection of such resources, and by the prevention of physical waste of the fisheries from any cause.

The vision statement of the Commission is: Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015.

The Commission has developed Amendment 3 to its Interstate Fishery Management Plan for Shad and River Herring (ACMFC 1985, 1999, 2000, and 2002), or FMP, under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA 1993). Shad and river herring management authority lies with the coastal states and is coordinated through the Commission. Responsibility for compatible management action in the Exclusive Economic Zone (EEZ) from 3-200 miles from shore lies with the Secretary of Commerce through ACFCMA in the absence of a federal fishery management plan. Further, each federal Fishery Management Council "...shall comment on and make recommendations to the Secretary and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority" (from Magnuson-Stevens Fishery Conservation and Management Act, Section 305, P.L. 104-297, (b) FISH HABITAT (3)(B)).

PLEASE NOTE: While the FMP is the management document for American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*), **the required provisions of Amendment 3 pertain only to American shad.** This amendment does not alter the monitoring requirements or fishery management measures for alewife, blueback herring or hickory shad.

1.1 BACKGROUND INFORMATION

1.1.1 Historical Fishery and Management

Historically, American shad, hickory shad, alewife, and blueback herring (collectively termed alosines) were an extremely important fishery resource and supported very large commercial fisheries along the Atlantic coast of both the United States and Canada. Coastwide landings of American shad at the turn of the century were approximately 50 million pounds. However, by

1980, they decreased dramatically to 3.8 million pounds. Total landings of river herring (alewife and blueback herring) varied from 40-65 million pounds from 1950-1970, then declined steadily thereafter to less than 12 million pounds by 1980. These dramatic declines in commercial landings were perceived as an indication that a coordinated management action would be required to restore alosine stocks to their former levels of abundance. Therefore, in 1981, the members of the Atlantic States Marine Fisheries Commission recommended the preparation of a cooperative Interstate Fishery Management Plan (FMP) for American Shad and River Herrings. The initial FMP was completed in 1985 and recommended management measures that focused primarily on regulating exploitation and enhancing stock restoration efforts. At the time the FMP was completed, the implementation of its recommendations was at the discretion of the individual states, because the Commission did not have direct regulatory authority over individual state fisheries.

A supplement to the FMP was approved by the Commission in 1988. This document included reports prepared by the Shad and River Herring Stock Assessment Subcommittee and summaries of material presented at a 1987 Anadromous Alosine Research Workshop. The 1988 supplement also changed management recommendations and research priorities based on new research findings.

In spite of the efforts to develop and implement the FMP and supplements, alosines stocks continued to decline (Figure 1) and, in 1994, the Plan Review Team and the Management Board determined that the original FMP was no longer adequate for protecting or restoring the remaining shad and river herring stocks. They concluded that the declines may have been the result of overharvest by in-river and ocean-intercept fisheries; excessive striped bass predation (Savoy and Crecco 1995); biotic and abiotic environmental changes; and loss of essential spawning and nursery habitat due to water quality degradation and blockages of spawning reaches by dams and other impediments.

A second coastwide assessment was completed 1998 and Amendment 1 to the FMP was adopted in April 1999. The amendment was revised by addendums in 2000 and 2002. Amendment 1 and the addendums focused on maintaining directed fishing mortality below set benchmarks. These directives have defined ASMFC shad management until the adoption of Amendment 3 in 2010.

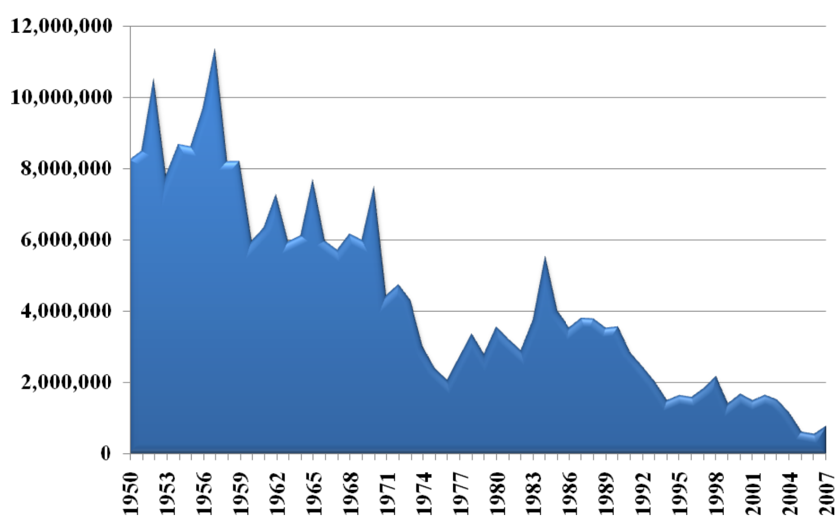

Figure 1. Total (in-river and ocean) commercial landings (pounds) of American shad for the U.S. Atlantic coast, 1950-2008 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

1.1.2 Statement of the Problem

In 2007, the American Shad Stock Assessment Subcommittee (SASC) completed an American shad stock assessment report, which was accepted by the Peer Review Panel (PRP) and the Shad and River Herring Management Board in August 2007 (ASMFC 2007). The 2007 American shad stock assessment found that stocks were at all-time lows and did not appear to be recovering to acceptable levels. It identified the primary causes for the continued stock declines as a combination of excessive total mortality, habitat loss and degradation, and migration and habitat access impediments. Although improvement has been seen in a few stocks, many remain severely depressed compared to their historic levels.

Given these findings, the PRP recommended that current restoration actions need to be reviewed and new directives need to be developed and implemented. The SASC and PRP recommendations included actions to reduce fishing mortality, improve fish passage at mitigation barriers, reduce dam passage mortality and delay, increase larval stocking, and implement habitat restoration actions.

Anadromous fish species, such as American shad, are unlike almost all other fish species that are cooperatively managed under ASMFC. Most other ASMFC species are exclusively oceanic and all of their habitat and life cycle needs can be satisfied in the marine environment (although some may utilize coastal shore or estuarine habitat for part of their life). It has long been assumed that human impact on the ocean environment has been non-existent or minimal. It has also been assumed that the only major human-induced impact on oceanic fish species was from recreational and commercial fishing that resulted in direct mortality. However, anadromous fish, as a result of their freshwater and estuarine spawning and nursery requirements, must come into direct contact with human populations; therefore, they are vulnerable to the many sources of mortality associated with human activity in and around rivers and estuaries.

Extensive populations of anadromous fish species historically existed along the Atlantic coast prior to the Industrial Era. Since that time, non-fishery human-induced threats may have had a significant impact on anadromous fish stocks. Moreover it is likely that American shad stocks and the resulting Atlantic coast population may not reach its full potential until these other threats are adequately addressed.

1.1.3 Benefits of Amendment 3

1.1.3.1. Social and Economic Benefits

Restoring, enhancing and maintaining the stability and productivity of the Atlantic coast population of American shad will enhance the economic and social benefits for the Commission member states and the nation as a whole. The economic values associated with these benefits would include direct use values (e.g., consumptive use values related to commercial and recreational fishing, and non-consumptive use values such as observing spawning runs), indirect-use values (e.g., contribution to the forage of many other economically important species such as striped bass, and enrichment of freshwater system productivity through transfer of marine derived nutrients), and non-use values (i.e., existence and option values) for current and future generations. For example, an option value might be the value someone places on the potential of future generations having the option of harvesting American shad, which would then be a consumptive use value. The indirect-use values are mainly contributed through the ecological benefits attributed to American shad, which in turn provide ecosystem functions that enhance their numerous direct and non-use economic value.

Although the indirect-use and non-use economic values can be difficult to quantify in dollar terms, it is readily apparent that American shad have supported valuable commercial fisheries along the entire Atlantic coast. However, these fisheries have declined dramatically in recent years. The nominal ex-vessel unit price, which is the price received by the harvesters not adjusted for inflation, for American shad ranged from $0.325 to $1.022 per pound and averaged $0.534 per pound for the years 1980 through 2007. The nominal total (aggregate) ex-vessel value of the U.S. Atlantic coast American shad harvest has ranged from a high of over $2 million in 1984 to a low of about $540,000 in 2006, after the ocean-intercept fishery closure was implemented in all Atlantic coastal states, and it averaged $1.1 million for the years 1980 to 2007. Additionally, the market price paid by the final consumer can be 3 to 10 times or more than the ex-vessel price, yielding an increased economic benefit (i.e., direct use value) well above the price paid to the vessel owner/operator. See Appendix A for a discussion of methodology.

Recreational fisheries for American shad are often poorly documented, if at all. The National Marine Fisheries Service operates the Marine Recreational Fisheries Statistics Survey (MRFSS) to obtain information on recreational fisheries for marine species. MRFSS does not adequately capture information on anadromous fisheries, including those for American shad because the current survey design focuses on active fishing sites along coastal and estuarine areas rather than inland non-tidal waters where most recreational fishing for American shad occurs. However, the seasonal economic impact of shad recreational fisheries may be substantial. A 1986 study of shad anglers fishing on the Delaware River indicated that they collectively spent about $1.6 million during a nine week angling season (PFBC 2008), equivalent to approximately $3 million in 2007. Moreover, the aggregate willingness to pay (economic value) for these shad anglers was estimated to be about $3.2 million or an equivalent $6 million in 2007 (PFBC 2008). Similar recreational fisheries exist in many rivers along the Atlantic coast and each would likely contribute an equivalent economic value.

1.1.3.2. Ecological Benefits

American shad play an important ecological role in freshwater, estuarine, and marine environments during its anadromous life cycle. They influence food chains by preying on some species and serving as prey for others, throughout all life stages (Facey et al. 1986, MacKenzie et al. 1985, Weiss-Glanz et al.1986). During earlier periods of high abundance, American shad also played a significant role in ecosystem nutrient and energy cycling. This was most apparent in South Atlantic coastal river systems, where the percentage of repeat spawning is low and many of the fish die shortly after spawning, thus transferring nutrients and energy derived from the marine system into the freshwater interior rivers. Durbin et al. (1979) conducted a study of the effects of post spawning alewife on freshwater ecosystems. It was suggested that the potential influence of alosine migration on the nutrient and energetic dynamics of Atlantic coast ecosystems is equivalent to effects documented for similar systems in the Pacific Northwest for salmon rivers. Garman (1992) studied the fate and potential significance of post spawning anadromous fish carcasses in the James River, Virginia. He hypothesized that, before recent declines in abundance, the annual input of marine-derived biomass via alosine migrations was an important episodic source of energy and nutrients for the non-tidal James River.

As prey, American shad are important for other species that are themselves important commercially, recreationally and ecologically. American eels prey on American shad eggs, larvae and juveniles in freshwater and striped bass consume juveniles (Facey et al. 1986, Mansueti and Kolb 1953, Walburg and Nichols 1967). Savoy and Crecco (1995) also suggest a direct linkage between increased striped bass predation and the dramatic drop in American shad and blueback herring abundance in the Connecticut River. Predation on juvenile American shad by other large predators (e.g. weakfish, bluefish) is also perhaps a minor factor that could be delaying the recovery of American shad stocks in the Chesapeake Bay (Klauda et al. 1991). Once in the ocean, as a schooling species with no dorsal or opercula spines, American shad are undoubtedly preyed upon by many species including sharks, tunas, king mackerel, seals, and porpoises (Melvin et. al. 1985, Weiss-Glanz et al. 1986). American shad are also a seasonally important prey species for a number of riparian fish, birds, and wildlife species, with the adult spawning American shad arriving in the early spring when other prey may be scarce and the nesting/breeding season is just beginning for many wildlife predators.

1.1.3.3. Cultural Benefits

American shad were and are of cultural significance to Native Americans, European colonists and contemporary Americans who reside near and/or fish in rivers which supported or continue to support spawning runs (Brandywine Conservancy 2005, Day 2006, Groth 1996, McPhee 2002). American shad spawning runs in the spring were an essential element of Native American nutrition. One example is the run in the Penobscot River, Maine, which has been home to the Penobscot Indian Nation for more than 10,000 years. Historic findings of Penobscot fish nets, baskets and spears indicate the sustenance and subsistence significance of fish to the tribe (Day 2006). As noted in Day (2006, page 29), “Federally recognized rights to sustenance fishing rights today remain relatively meaningless for lack of sea-run fish and because resident fish are contaminated.” The same statements regarding the historic significance of the runs and the current meaninglessness of their rights could well be applied to every other Native American tribe along the entire east coast from Maine through Florida.

The cultural significance of American shad and other anadromous species is reflected in the traditions that took root which reflected the significance of sea-run fish in people’s lives (Day 2006). The first-caught salmon of the season from the Penobscot was sent to the President of the United States; families passed fishing traditions through the generations; and fishing clubs for salmon and shad sprang up along the river. The names of the fish are still etched on the inland landscape–for instance, Shad Pond on the Penobscot, where shad can no longer migrate due to downstream dams (Day 2006).

The State of Connecticut General Assembly designated American shad as its State Fish in 2003, the only state to select the species. It was selected because it 1) was a native Connecticut fish; 2) had great historical significance in that it provided food for Native Americans and colonists; 3) it was and is of great commercial value to the state; and 4) because the hardiness of this migratory fish reflects the true Connecticut spirit as reflected in the state's motto: "Qui Transtulit Sustinet" (*He who transplanted still sustains*).

Many communities celebrated and still celebrate the arrival of American (and also hickory) shad by holding festivals to mark the occasion. See Appendix B for a list of current and historic festivals held along the Atlantic coast. These festivals are held during the spring of the year to coincide with the American shad spawning run, and generally entail fishing for, and consumption of, American shad, along with a variety of other activities including running events, arts and crafts shows, music, and many other activities designed to promote social interactions among residents, attract tourists, and benefit the local economy.

Many of the cultural values associated with runs of American shad and other species provide significant incentives for restoration of the runs (Day 2006), as well as for the bolstering of states' economies. Additional benefits include restoration of meaning for Native American and other fishing rights; educational potential of fish bypasses; perpetuation and/or reestablishment of local festivals which are of economic benefit to the residents; and reinvigorating the traditions of fishing for sea-run fish on many East Coast rivers.

The most comprehensive account of the role which American shad has played in the culture of North America since colonization by Europeans is that by John McPhee (McPhee 2002). In *The Founding Fish,* McPhee's research documents the relevance of American shad in seventeenth and eighteenth-century America. He documents George Washington's prowess as a commercial shad fisherman (in 1771, Washington caught 7,760 American shad) and the role of the species in the lives of Henry David Thoreau and John Wilkes Booth. It is clear from his work that American shad have played a significant and largely continuous role in the lives of Americans since European colonization.

1.2 DESCRIPTION OF THE RESOURCE

A comprehensive description of the Atlantic coast stocks of American shad can be found in the 1985 Interstate Fishery Management Plan for Shad and River Herring and in the 2007 American shad stock assessment (ASMFC 2007). This section provides the basic information necessary to understand how anadromous American shad relate to their essential habitats and the significance of the commercial and recreational fisheries to the economy and culture of the Atlantic coast.

1.2.1 American Shad Life History

American shad are an anadromous fish that spend most of their life at sea along the Atlantic coast and enter freshwater as adults in the spring to spawn. American shad stocks are river-specific; that is, each major tributary along the Atlantic coast appears to have a discrete spawning stock. This is because American shad have been documented to have a high fidelity to return, in the spring, to their natal tributary to spawn. Young-of-year fish often migrate downstream to estuaries over the summer. In the fall or subsequent spring, juveniles emigrate from freshwater and estuarine nursery areas and join a mixed-stock, sub-adult coastal migratory population.

After four to six years individuals become sexually mature and migrate to their natal rivers during the spring spawning period that may vary by latitude (see Appendix C for a full description of the American shad life history and habitat requirements). The 2007 American shad stock assessment report identified 86 separate tributaries or potential individual stocks. Of the 86 tributaries identified, only 31 were deemed to have adequate data for a tributary specific stock assessment.

1.2.2 American Shad Stock Assessment Summary

ASMFC, 1988

The first stock assessment was conducted in 1988 (ASMFC 1988) and focused on American shad stocks in 12 Atlantic coast rivers. The Shepherd stock-recruitment model was used to estimate maximum sustainable yield (MSY) and maximum sustainable fishing rate (F_{msy}). They found that MSY was positively correlated to drainage area and that highest F_{msy} occurred in the central part of the species range.

ASMFC, 1998

The second coastwide stock assessment conducted by the ASMFC was completed in 1998 (ASMFC 1998). Generally, assessments were conducted on a river-specific basis, but some grouping of river systems occurred (e.g., Maine rivers were examined collectively, Upper Bay Maryland, Albemarle Sound, and Waccamaw and Pee Dee rivers).

A Thompson-Bell yield-per-recruit (YPR) model was used to derive the overfishing definition (F_{30}) for some shad stocks where possible. F_{30} is that level of fishing mortality that theoretically results in a female spawning stock biomass that is 30% of that possible when only natural mortality acts on the stock. This level of fishing mortality has been shown to be sustainable in other species with similar life history parameters. The assessment examined catch and harvest data, exploitation rates, fish-lift counts, current and historic coastal (Fc) and in-river (Fr) fishing mortality rates, and other indicators of stock status for American shad from selected stocks or river systems located from Maine to the Altamaha River, Georgia, with special attention on recent (1992 to 1996) stock dynamics.

The 1998 assessment concluded that there was evidence of recent (1992-1996) and persistent stock declines in the Hudson and York Rivers and of recent stock increases in the Pawcatuck and Connecticut Rivers. The assessment concluded that the drop in commercial landings in the Edisto River was largely due to a reduction in fishing effort and did not reflect stock abundance. In addition, the assessment reported that there was no evidence of recent stock declines for the Merrimack River, Delaware River, upper Chesapeake Bay tributaries, Rappahannock River, James River, Santee River, and the Altamaha River. Stock declines inferred from declining trends from river-specific commercial landings were evident for the Neuse River, Pamlico River, Cape Fear River, Waccamaw-Pee Dee River, Savannah River, Albemarle Sound tributaries, and rivers in the state of Maine.

Where estimation of recent F rates (1992-1996) was possible, all estimates of total F (Fc + Fr) were below $F_{30,}$ suggesting that these stocks were not overfished. At that time, the assessment also concluded that there was no evidence that the ocean-intercept fishery had an adverse impact on American shad abundance along the Atlantic coast and that there was no evidence of recent (1990-1996) recruitment failure for Maine rivers, Pawcatuck River, Connecticut River, Hudson River, Delaware River, Upper Chesapeake Bay tributaries, Altamaha River and Virginia rivers.

ASMFC, 2007

A coastwide American shad stock assessment was completed and accepted by the Management Board in August 2007. The 2007 stock assessment found that American shad stocks were at all-time lows and did not appear to be recovering. Recent declines of American shad were reported for Maine, New Hampshire, Rhode Island, and Georgia stocks, and for the Hudson (NY), Susquehanna (PA), James (VA), and Edisto (SC) rivers. Low and stable stock abundance was indicated for stocks in Massachusetts, Connecticut, Delaware, a tributary to the upper Chesapeake Bay, the Rappahannock River (VA), and some South Carolina and Florida stocks. Stocks in the Potomac and York Rivers (VA) have shown some signs of recovery in recent years. Data limitations and conflicting data precluded conclusions about status or trends of many of the stocks in North and South Carolina.

The 2007 stock assessment report identified primary causes for stock decline as a combination of overfishing, pollution, and habitat loss due to dam construction. In recent years, coastwide harvests have been 500-900 metric tons (1 – 2 million pounds), nearly two orders of magnitude lower than in the late 19th century. Given these findings, the Peer Review Panel recommended that current restoration actions need to be reviewed and new measures need to be identified and applied. The Peer Review Panel suggested considering a reduction of fishing mortality, enhancement of dam passage and mitigation of dam-related fish mortality, stocking, and habitat restoration.

1.3 HABITAT REQUIREMENTS

American shad utilize coastal tributaries and the associated bays and estuaries for spawning and larval and juvenile nursery habitat. In addition, migratory sub-adult and adult American shad utilize near shore ocean habitats. These habitats are distributed along the Atlantic coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory American shad may increase or diminish as the size of the population changes, habitat quality deteriorates, or habitat access is impaired. For an in-depth description of American shad Habitat Requirements see Appendix C.

As noted in section 1.2.1 the migratory nature of anadromous American shad exposes them to numerous human-induced threats that can result in direct or indirect mortality and reduced juvenile and adult spawning stock recruitment which impact stock status. Some of the most important human-induced threats, from a management perspective, are those leading to freshwater or ocean pollution, habitat degradation or migratory impairment. Individual and cumulative negative impacts to American shad habitat results in reduced stock health, leading to a declining Atlantic coast population. The causes of many human-induced threats are often under some form of regulatory management already, which could be used as a means to avoid, minimize, or reduce the impact of the habitat threats associated with human activities.

1.4 DESCRIPTION OF THE FISHERIES

American shad historically supported important commercial and recreational fisheries along the entire Atlantic coast; however, these fisheries have declined dramatically in recent years. Two types of fisheries exploit spring spawning migrations of American shad: in-river and ocean-intercept. In-river fisheries only exploit the stock native to that system, whereas ocean-intercept fisheries exploit mixed stocks of different river origins. There are some estuarine fisheries (e.g., Delaware Bay, Winyah Bay) that also exploit mixed stocks.

Catch statistics for both ocean and in-river American shad fisheries on the Atlantic coast are compiled by the National Marine Fisheries Service (NMFS) and state agencies for both commercial and recreational fisheries; however, there are data gaps in these records. It is important to note that harvest from fishers operating in-river, or from fisheries that are not federally licensed, might not be reported to NMFS. In addition, bycatch in non-directed fisheries is poorly documented. Information provided below is based on state reports (e.g. annual Compliance Reports) and data available from NMFS.

1.4.1 Commercial Fishery

Since the early 1800s, the American shad supported major commercial fisheries along the Atlantic coast and was one of the most valuable food fish of the U.S. Atlantic coast before World War II (Rulifson et al. 1982). However, American shad, alewives, blueback herring, and other anadromous species were already declining in southern New England by 1870 (Bowen 1970; Moring 1986). Primary causes were impassable dams located on major New England Rivers as well as heavy pollution near towns and mills. For example, the first dam on the Connecticut River was constructed in 1798 at Turners Falls, Massachusetts, which was a 16-foot high structure impassable to all migrating fishes. The estimated U.S. Atlantic coast catch in 1896 was 50 million pounds, but it declined to approximately 10 million pounds per year between 1930 and 1960 (Weiss-Glanz *et al.* 1986) and to about 2 million by 1976.

Historically, aggregated commercial landings (coastal ocean and in-river) of American shad have shown major long-term declines, but coastal ocean landings of American shad did increase more than four-fold after 1978. In 1980, coastal ocean landings equaled approximately 623,000 pounds. By 1989, this number had peaked to 2.1 million pounds, and in 1996 landings were 1.1 million pounds. Ocean harvest contributed about 11 % of total Atlantic coast landings in 1978; this contribution increased yearly to approximately 67% by 1996 as ocean landings increased and in-river landings declined.

The closure of the ocean-intercept fishery in 2005 lowered the coastwide total landings of American shad. Based upon landings data provided in ASMFC Compliance Reports from individual states and jurisdictions, 2007 coastwide landings totaled 824,730 pounds (ASMFC, 2008). Combined landings from North Carolina and South Carolina accounted for 64% of the commercial harvest in 2007. Connecticut, Delaware, New York, New Jersey, and Georgia accounted for 35% of the commercial harvest in 2007. Maine, New Hampshire, Massachusetts, Rhode Island, Pennsylvania, Maryland, the District of Columbia, and Florida reported no directed shad harvest in their state. Shad bycatch landings from ocean waters in 2007 were reported at 4,562 pounds, or about 0.55% of the coastwide commercial harvest. However, it is important to note that only three states—Maine, Massachusetts, and New Jersey – reported landings of ocean bycatch.

An analysis of recent ex-vessel value trends for the commercial American shad fishery can be found in Appendix A. The analysis suggests that in times of generally declining commercial shad landings, market "signals" may have encouraged harvesters to perceive an ex-vessel market segment with the potential of offsetting declining harvest quantities with substantially higher ex-vessel prices. In other words, American shad harvesters in past decades may have continued to fish in response to continued market demand capable of supporting profitable ex-vessel revenues even though catch quantities declined, (i.e., a relatively inelastic own ex-vessel price situation). For open access fisheries, such relatively inelastic demand along with other factors has been implicated in the depletion of various fishery stocks (e.g., Brandt 1999).

1.4.2 Recreational Fishery

Data on recreational fisheries for American shad are limited or are non-existent. The National Marine Fisheries Service operates the Marine Recreational Fisheries Statistics Survey (MRFSS) to obtain information on recreational fisheries for marine species. MRFSS does not adequately capture information on anadromous fisheries, including those for American shad because the current survey design focuses on active fishing sites along coastal and estuarine areas rather than inland non-tidal waters where most recreational fishing for American shad occurs. Error associated with data on harvest, catch, and effort is often high.

Although data are limited, it is readily apparent that substantial shad sport fisheries occur on the Connecticut (CT and MA), the Hudson (NY), the Delaware (NY, PA and NJ), the Susquehanna (MD), the Santee and Cooper (SC), the Savannah (GA), and the St. Johns (FL) Rivers. Limited shad recreational fisheries occur on several other rivers in Massachusetts, Virginia, North Carolina, South Carolina, and Georgia. In 2007, recreational creel limits ranged from zero to 10 fish per day, with the exception of the Santee River (SC), which is permitted to have a 20 fish per day creel limit due to the approval of a conservation equivalency plan in 2000. It is estimated that tens of thousands of shad are caught by hook and line from large Atlantic coast rivers each year by recreational anglers. However, the actual harvest (i.e. catch and removal) may amount to only about 20-40% of total catch due to the prevalence of catch-and-release angling practices.

1.4.3 Tribal Fisheries

There are known tribal fisheries for American shad fisheries (see Section 1.1.3.3), but the extent of effort and harvest is undocumented.

1.4.4 Non-Consumptive Factors

People interested in conservation and wildlife have been known to actively engage in observation of American shad migration during the annual spawning migration as they pass through constricted natural corridors and fish passage facilities. In some regions, this non-consumptive use of the American shad resource is an important part of public education, local heritage, ecotourism, and outdoor recreation. Real-time video of spring spawning migrations of alosines are available via online webcams for both the fishway at Bosher's Dam on the James River and Fairmount Dam on the Schuyllkill River (available at: http://www.dgif.virginia.gov/fishing/shadcam and http:// fairmountwaterworks.com/fishcam.php, respectively). In addition, volunteer involvement in non-consumptive cooperative fishery projects has included activities related to American shad, including the "Shad-In-Schools" educational program and angler group larval shad hatcheries.

Some local governments also sponsor springtime shad festivals and/or related events that include non-fishing activities. According to the American Rivers organization (2008), shad fishing and related tourism along the Susquehanna River generate approximately $30 million annually in economic impacts and "…the estimated values of a restored shad run in Maryland range from $42 million to $178 million."

1.4.5 Interactions with Other Fisheries, Species and Other Uses

For an in-depth description of American shad bycatch, interactions with protected species and interactions with other invasive or managed species see Appendix E.

1.4.5.1 Bycatch

Catch of American shad that occurs in fisheries directed at other species is referred to as bycatch. Bycatch also refers to illegal or unmarketable fish caught in directed fisheries. Estimates of American shad bycatch are difficult to obtain since few studies have focused specifically on that issue. Bycatch losses contribute to the total mortality of American shad, and are important to consider in the current and future management of these fisheries.

Reported shad bycatch landings from ocean waters in 2007 decreased from 2006 levels and were 4,562 pounds, or about 0.55% of the coastwide commercial harvest. It is important to note that only three states—Maine, Massachusetts, and New Jersey—reported landings of ocean bycatch that were used in the calculation of the above statistics. There are concerns that the amount of bycatch that is actually occurring may be much higher than what is reported.

1.4.5.2 Interaction with Protected Species

The management of the American shad populations has the potential to intersect with the management and restoration efforts of a number of protected species. The resulting interactions can potentially have negative impacts for both American shad and the protected species. The protected species can place competitive and predatory pressures on American shad and vice versa. The protected species can also be impacted by regulated fishery activities directed at American shad. The potential for these interactions should be considered during the development of future American shad fishery management plans and actions. Also, the resource agencies responsible for management and restoration of protected species need to be made aware of the potential impacts of their plans and activities on American shad management and restoration efforts.

1.4.5.3 Interaction with Invasive and Other Managed Species

The management of the American shad population has the potential to intersect with the management of a number of invasive (e.g., snakehead fish), and managed species (e.g., commercial and recreational, freshwater and ocean). The resulting interactions are similar to those for protected species and require the same considerations.

2. AMENDMENT 3 GOALS AND OBJECTIVES

Goal: Protect, enhance, and restore Atlantic coast migratory stocks and critical habitat of American shad in order to achieve levels of spawning stock biomass that are sustainable, can produce a harvestable surplus, and are robust enough to withstand unforeseen threats.

Objectives:

- Maximize the number of juvenile recruits emigrating from freshwater stock complexes.
- Restore and maintain spawning stock biomass and age structure to achieve maximum juvenile recruitment.
- Manage for an optimum yield harvest level that will not compromise Objectives 1 and 2.
- Maximize cost effectiveness to the local, state, and federal governments, and the ASMFC associated with achieving Objectives 1 through 3.

Strategies to Achieve Objectives:

- Quantify and effectively manage sources of bycatch mortality where possible.
- Quantify and effectively manage sources of predation where possible and appropriate.
- Restore and maintain access to historical spawning and nursery habitat (i.e., dam removal and fishway installation).
- Maintain total mortality (Z) of American shad stocks at or below stock assessment benchmarks (Table 1).
- Ensure that adequate monitoring techniques are implemented to measure migratory success (i.e., upstream and downstream fish passage at barriers).
- Ensure that stock monitoring data are collected and that they are adequate to characterize stock status and stock response to management actions (i.e., develop a sampling program that provides an annual measurable output for spawning stock and juvenile production status)

- Achieve river specific restoration targets for American shad populations as specified in the recent shad assessment (Table 1) or in stock specific restoration plans.
- Ensure that the production of hatchery fish is used effectively during restoration efforts.
- Maximize cost effectiveness of data collection to minimize costs to states and jurisdictions through coordinated monitoring, flexibility in monitoring methods, and early vetting of monitoring and management plans.
- Identify interactions between other Commission species management plans (positive or negative) and the objectives stated above.

The Commission (2007) developed benchmark mortality rates and restoration targets (abundance) for some individual American shad stocks and for aggregate American shad stocks in selected regions (Table 1). Benchmark mortality rates are not targets, but are rates that should not be exceeded. Restoration targets for abundance indices are targets that should be reached before directed fishing can be initiated.

Table 1. Benchmark mortality rates and restoration targets developed by ASMFC (2007)

Region / River	Mortality		Restoration Targets [c]
	Z (instantaneous)	A (%)[a]	
New England	$Z_{30} = 0.98$	$A_{30} = 0.62$	
Hudson River, NY	$Z_{30} = 0.73$	$A_{30} = 0.51$	
York River, VA	$Z_{30} = 0.85$, Native American fishery $F_{30} = 0.27$	$A_{30} = 0.57$	Gill net monitoring index catch rate [b] = 17.44
Albemarle Sound, NC	$Z_{30} = 1.01$	$A_{30} = 0.63$	
Potomac River			Pound net landings = 31.1 lbs/net-day
James River, VA			Gill net monitoring index catch rate [b] = 6.4
Rappahannock River, VA			Gill net monitoring index catch rate [b] = 1.45
St. John's River, FL			Recreational angling CPUE > 1.0 fish/hour

[a] Total mortality defined as the percent of fish present at the start of the year that die from all causes.
[b] Calculated as area under the curve
[c] States and river basin cooperatives may have stock specific recovery targets that are used, but not included in this amendment.

2.1 MANAGEMENT UNIT

The management units for American shad under this Fishery Management Plan Amendment include all migratory American shad stocks of the Atlantic coast of the United States.

Recommendations on management for migratory American shad in the Exclusive Economic Zone (3-200 nautical miles offshore) can be found in Section 4.10

2.2 DEFINITION OF SUSTAINABLE FISHERY

This document proposes the adoption of a sustainable fisheries definition which is consistent with current coastwide management of river herring (alewife and blueback herring) as described in Amendment 2 to the Shad and River Herring FMP. Amendment 2 defines a sustainable fishery as "those that demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment."

2.3 DEFINITION OF OVERFISHING

The classic definition of overfishing considers overfishing to occur whenever a fish stock is subjected to a level of fishing mortality that jeopardizes the capacity of that stock to produce a maximum yield on a continuing basis. Benchmark fishing mortality is the estimated mortality rate at and above which overfishing occurs.

Amendment 1 to the American shad & River Herring FMP (ASMFC 1999) refined the definition of overfishing for American shad stocks to be an instantaneous rate of fishing mortality rate (F) from directed fisheries that was at or above a benchmark of F_{30}. This benchmark was defined as the *level of directed fishing mortality* that theoretically resulted in a female spawning stock biomass that was 30 % of that in an unfished, "virgin" stock that only experienced natural mortality. Female spawning stock biomass is the total weight of females in all age classes in the spawning population. This definition ignored man-induced mortality from other sources.
The basis for this definition was the assumption that American shad stocks were only affected by F from directed fishing and by instantaneous natural mortality (M) and the total instantaneous mortality (Z), was equal to M plus F. Thus, an unfished stock that only experienced natural mortality would contain the maximum potential female spawning stock biomass. Any fishing on the stock would reduce this biomass to less than maximum. At some point, as the rate of fishing increased, the female spawning stock biomass would be reduced until it contained 30% of the maximum female biomass. The fishing rate that resulted in 30% of the maximum female spawning stock biomass was defined as F_{30}. This overfishing definition was not to be utilized as a target for fisheries to achieve, nor was it believed to be suitable for rebuilding depleted stocks, but was developed to serve as a benchmark that should not be exceeded in any given year. Amendment 1 assumed that fishing rates at or below F_{30} would be sustainable because such rates were documented to be sustainable in other stocks with similar population parameters to American shad. The amendment focused on the female component of the spawning stock because female abundance was considered to be the population factor that most limited reproduction and subsequent recruitment.

2.3.1 Mortality Benchmark

The most recent stock assessment (ASMFC 2007) concluded that the Amendment 1 definition of overfishing that focused only on directed fishing mortality (F) was no longer valid for American shad stocks because shad are affected by several sources of human-induced mortality. These include: directed fishing (F), fish passage mortality at dams, mortality from pollution, and bycatch and discard mortality in indirect fisheries activity. All of these sources of mortality can be substantial, can be controlled, and should therefore be considered when setting a benchmark mortality rate.

As an interim solution, the recent ASMFC stock assessment (ASMFC 2007) combined all human-induced rates into a single overall human induced rate. Since the components of human-induced mortality (e.g., directed fishing, dam-induced, pollution, and bycatch) are difficult or impossible to quantify, ASMFC (2007) did not attempt to develop a benchmark for the combined mortality that was analogous to F_{30} for directed fishing alone. Instead, ASMFC (2007) developed benchmark values for total instantaneous mortality or Z_{30} (Table 1). These benchmark values were defined as the *level of total instantaneous mortality (Z)* that resulted in a female spawning stock biomass that was 30% of the total female spawning stock biomass in a stock that experienced only natural mortality (Z=M). Z can be measured in fish stocks by a variety of methods.

The following explains how the Z_{30} benchmark was developed. American shad stocks are affected by a combined human-induced instantaneous mortality and by natural mortality. A stock that experienced only natural mortality, with no human-induced mortality, would contain the maximum potential female spawning stock biomass. As human-induced mortality from any source increases, female spawning stock biomass decreases. At some point of increased human-induced mortality and thus total mortality, the stock would contain a female spawning stock biomass that was 30% of the maximum. The rate of total mortality that resulted in a female spawning stock biomass that was 30% of the maximum is the Z_{30}. For example, in New England stocks of American shad, a Z that equals 0.98 reduces female spawning stock biomass to 30% of that present when only natural mortality acts on the stocks, assuming a natural mortality (M) of 0.38.

This amendment adopts Z_{30} as a mortality benchmark to help guide management and gauge restoration progress. It does not propose an overfishing definition. Under this mortality benchmark, a stock is considered to experience excessive mortality when the total instantaneous mortality rate (Z) equals or exceeds that at $Z_{30.}$ Excessive mortality is an indication that actions should be considered that reduce total mortality. The priority would be to reduce mortality from inadequate passage at dams and /or bycatch since these losses are avoidable and do not benefit society. Reducing mortality from directed fishing without reducing mortality from other man-induced causes is not encouraged because it transfers fish production from a beneficial use to nonbeneficial uses. Excessive mortality (i.e, at or above Z_{30}) on a stock with no directed fishery would be a warning that bycatch, dam passage mortality, or some other form of human-induced mortality should be addressed. Directed fishing could continue without reduction in stocks where total mortality was below Z_{30}.

American shad stocks of the Atlantic coast exhibit a range of life history attributes because shad stocks spawn in rivers with different morphologic characteristics over a broad latitudinal range. Differences in parameters such as age at maturity, weight at age, and frequency of repeat spawning affect how a stock responds to increased mortality and thus different stocks often have different values of Z_{30}. ASMFC (2007) provided Z_{30} estimates for stocks or aggregate stocks in regions with adequate data. However, many stocks remained without such benchmarks because needed data were lacking or non-existent.

American shad populations may contain multiple year classes in their spawning stocks. Annual total mortality can affect all of these year classes, with older year classes experiencing higher cumulative mortality. Consequently, the spawning stock biomass lost from human-induced factors may be greater than one would intuitively expect from an annual measured rate of mortality.

2.3.2 Future Refinement

Under this amendment, as resources become available, the TC and the SASC will define a more robust benchmark mortality rate definition for American shad stocks. The new definition should embrace the approach proposed by ASMFC (2007) and it should include, or address all sources of human-induced mortality (e.g., directed fishing, bycatch and discards, and losses from dams and other water development projects). These can be combined in a single human-induced rate or partitioned into separate human-induced rates as needed. They should NOT be added to natural mortality when calculating new benchmarks. Further, the TC and SASC should also develop target or rebuilding rates to allow population numbers to grow. These rebuilding targets would require developing a new lower mortality threshold that would increase spawning stock biomass.

3. MONITORING PROGRAM SPECIFICATIONS

The collection of adequate fish stock and fishery monitoring data is necessary to achieve the goal and objectives of the American Shad management program. A well designed monitoring program provides measurable outputs that can be used to judge the effectiveness of current management efforts in achieving the desired outcome. This amendment modifies and adds to some of the monitoring requirements specified in Addendum 1 to Amendment 1 of the Shad and River Herring Fishery Management Plan. All other monitoring requirements remain compliance criteria. Monitoring requirements of Amendment 3 and program specific modifications are summarized in the following sections.

States and jurisdiction specific requirements are listed in Tables 2 and 3 of this amendment. One modification of note involves states and jurisdictions which share a river or an estuary. Under this amendment, such states and jurisdictions are considered to be equally responsible for monitoring of the system. States and jurisdictions that share a resource, but do not conduct a commercial fishery, will be exempt from monitoring the commercial fishery. States and jurisdictions which share a river or estuary may elect which state or jurisdiction will conduct specific monitoring programs for the shared water body. In shared water bodies where there is some sort of management cooperative, such as the Delaware River Basin Fish and Wildlife Management Cooperative, the cooperative may be designated as the responsible party and should report results. States and jurisdictions will supply the Commission with copies of cooperative or interstate agreements when such agreements relieve from or assign states and jurisdictions the responsibility for monitoring activities. A single report summarizing monitoring results from a shared water body is preferred, but not required. Additionally, a second modification in

Amendment 3 is the removal of the recreational monitoring requirement from the Nanticoke River, DE (Table 3) due to the closure of this fishery.

In many states, both the freshwater and the marine sections of state resource agencies collect data on American shad. Often, only those collected by the marine section are provided to ASMFC. This amendment recommends that states and jurisdictions increase coordination of data collection on American shad between freshwater and marine sections of the agency, and that all data be provided to ASMFC through the annual compliance report.

Results of state monitoring will be reported annually to the Commission as per Section 9.3. One important change in Amendment 3 is that, in addition to a written report, all states and jurisdictions will be required to add annual monitoring data to Excel spreadsheets used in the recent ASMFC (2007) stock assessment. The ASMFC, in cooperation with the Technical Committee, will provide states with a template for the spreadsheets. Annual data updates on spreadsheets will be considered part of the compliance reports and will be due at the same time as the written annual compliance reports, unless otherwise determined by the Management Board. This change facilitates an annual summary of stock condition and the development of future benchmark assessments. Excel spreadsheet submittals have proven effective and helpful in other ASMFC species management plans.

Under this amendment, states and jurisdictions will review existing monitoring programs and submit Implementation Plans for existing and planned monitoring as per Section 6.1. States and jurisdictions may propose to the Management Board alternative monitoring if they develop a stock specific definition of a sustainable fishery and the proposed alternative monitoring measures progress toward the definition (See Section 6). Definitions of sustainable fisheries and restoration goals can be index-based or model-based (See Table 1 for examples). This amendment recognizes that sustainable fisheries may operate on stocks that are at lower than maximum abundance. However, such fisheries must not jeopardize long term stock persistence or the achievement of any stock recovery goals. States and jurisdictions may also submit proposals to change their required monitoring programs as per Section 7.1 of this document.). If states or jurisdictions cannot meet the monitoring requirements, they can work with the Commission to develop an acceptable alternative in their Fishing/Recovery plan as stated in Section 6.1. The Shad and River Herring Management Board and Technical Committee will review proposed monitoring programs submitted under Section 6 or 7 to determine if they meet the requirements of Section 3. It is the responsibility of the Technical Committee to prepare recommendations and technical advice for the Management Board. The Management Board will determine final approval for changes to required monitoring programs. Changes to sustainable fisheries definitions, stock recovery targets, and monitoring programs may be submitted for review and approval by the Management Board at any time (See Sections 6 and 7).

The Commission has attempted to minimize monitoring costs in this amendment through coordinated monitoring where possible, flexibility in monitoring methods, and early vetting of monitoring and funding issues through the submission of Implementation Plans (Section 6). Submission of Implementation Plans to the Management Board will facilitate discussion of state problems and allow the Commission to work with the states to explore opportunities to secure funding or develop alternatives.

The Board tasks the Technical Committee to review and prioritize the data collection elements in Tables 2 and 3, as possible. The review should include a brief explanation of the importance of each element to the stock assessment.

3.1 FISHERY-INDEPENDENT MONITORING

States and jurisdictions that are currently required to conduct fisheries independent monitoring will still be required to continue such sampling, unless otherwise noted. This amendment proposes additional annual monitoring for those systems listed in Table 2.

3.1.1 Juvenile Abundance Indices

Annual juvenile recruitment (i.e., appearance of young-of- year or Age-0 fish in the ecosystem) of American shad is measured to assess annual production, to predict future year-class strength, to provide a warning of recruitment failure or major habitat change, and to measure contribution of hatchery-released larvae. Juvenile recruitment is measured by sampling age zero juvenile fish abundance in or downriver of nursery habitat.

All annual juvenile abundance indices, or JAIs, shall be reported as a geometric mean as described by ASMFC (1992) and Crecco (1992), or area under the curve (AUC) as described by ASMFC (2007). Confidence intervals should be provided for geometric means. ASMFC will provide jurisdictions and states with a method to calculate confidence intervals on geometric means. Use of the geometric mean reduces the probability of a single value unduly influencing management action and is most appropriate for sampling that occurs within the nursery area. AUC is most useful when juvenile sampling occurs downriver of nursery areas and fish are sampled during emigration. Abundance of juveniles that emigrate is a function of average daily emigration and days of emigration. A simple geometric mean of catch rates would reflect only the average daily emigration, but not the number of days of such emigration. The AUC approach accounts for both the number of days that juveniles emigrate as well as the daily catch or catch rate and thus is a better measure of annual juvenile out migration when sampling is conducted downstream of the nursery area.

The sampling protocol (stations, sampling intensity and gear type) should be consistent over time for the period the index is to be calculated. Juvenile abundance indices can be biased if fish older than age zero are included. Since age-1 juvenile fish occasionally intermingle with age-zero fish in nursery areas, it is important that sampling programs include a protocol to correctly identify these fish so that they can be eliminated from the catch data prior to summary. Approaches to identifying older fish include length measurements and age estimates from scales or otoliths.

For new sampling programs, states and jurisdictions will document the details of the sampling design and proposed data summary approach. The Technical Committee shall review any proposed programs and either recommend to the Management Board that it accept or reject the new sampling program. If the recommendation is to reject the new sampling program, the Technical Committee will provide a written explanation to the Management Board.

Validation is not required for any particular JAI survey, but it is encouraged. A long time series of data and consistent inter-annual at-sea mortality rates are needed for successful validation, which makes validation of American shad juvenile indices difficult. Validation will not be a criterion for accepting or rejecting any given JAI survey.

3.1.1.1 Juvenile Abundance Index Surveys

States and jurisdictions are required to conduct a JAI survey, as specified in Table 2. States that do not currently conduct juvenile abundance monitoring will develop a program to implement such monitoring. The Management Board may require juvenile abundance surveys for newly reestablished American shad runs.

3.1.1.2 Definition of Juvenile Recruitment Failure

The criteria for judging juvenile recruitment failure should provide for an early warning of emerging problems in production of young from a given stock. The previous definition of juvenile recruitment failure in Amendment 1 (three consecutive JAI values that are lower than 90% of all other values in the river specific data set) is considered inadequate in that it would only flag extreme problems. This amendment institutes a new definition of juvenile recruitment failure, where failure is defined as occurring when three consecutive JAI values are lower than 75% of all other values in the stock specific data series. This definition is identical to that in Section 3.1.1 of Amendment 6 to the Interstate Fishery Management Plan for Atlantic Striped Bass.

3.1.1.3 Evaluation of Juvenile Abundance Indices

The Technical Committee will annually examine trends in all required juvenile abundance indices. If any JAI meets the juvenile recruitment failure trigger, then appropriate action shall be recommended to the Management Board.

3.1.2 Adult Stock Characteristics and Abundance

Annual data on characteristics and abundance of adult spawning stocks are needed to determine efficacy of management approaches. Coupled with juvenile abundance indices and mortality estimates, they clarify population dynamics and progress toward management goals.

States and jurisdictions are required to conduct adult spawning or population monitoring, as specified in Table 2, and may employ a variety of survey techniques to monitor their American shad stock. The objective is to obtain an annual measure of either absolute (population size estimate) or relative abundance. Measures may include mark-recapture studies, enumeration at fish passage facilities, catch-per-unit-effort (CPUE) by appropriate sample gear, or other indices of abundance. As part of spawning stock surveys, states will take representative samples of adults to determine size, sex and age composition and repeat spawning (for states north of South

Carolina) of fish in each stock they are monitoring. When possible, states and jurisdictions north of South Carolina will calculate mortality and survival estimates for each stock.

The recent stock assessment identified several populations where additional fishery independent stock monitoring was warranted. On fishways where passage is measured, passage efficiency will be reported when possible. In cases where passage efficiency is not known, passage numbers cannot be used as indices of stock abundance, because the percent of the population that is passed is unknown and is likely to vary annually. In these cases, it is recommended that states either determine passage efficiencies or develop stock abundance indices downriver of the first barrier.

3.1.2.1. Evaluation of Adult stock characteristics and abundance

The Technical Committee will annually review adult stock characteristics and abundance relative to benchmarks and targets listed in Table 1 or the objectives in state specific fishing/recovery plans and recommend appropriate management actions to the Board if and where appropriate.

3.1.3 Stocking and Hatchery Evaluation

Many Commission jurisdictions augment existing populations or re-introduce populations using fish culture or fish transfer programs. Techniques most frequently used include culture and stocking of larvae or juveniles, and stocking of pre-spawned adults that have been netted or trapped from nearby or distant waters. A detailed summary of current approaches is available through the Commission.

States and jurisdictions with active hatchery programs for American shad will be required to mark all stocked larval and juvenile fish for identification of hatchery products. River and year specific marks are recommended for determining age and year class when fish return as adults. If river and year specific marks are not logistically possible for all stocking programs coastwide, then priorities should be developed through the interstate process. States and jurisdictions with active hatchery programs for American will be required to annually report the number and life stage of stocked fish and estimates of hatchery contribution (percent wild versus hatchery) in the juvenile or adult population. These states or jurisdictions must submit proposals for evaluation under Section 6.0 and annual results as per Section 9.3. Any state wishing to initiate stocking programs for American shad must present a program description including marking and evaluation approach for Commission review. States should work in cooperation with appropriate federal or regional programs to ensure that marking schemes are coordinated with other states to prevent conflicts in operations.

3.2 FISHERY-DEPENDENT MONITORING

States that are currently required to conduct fishery-dependent monitoring will still be required to continue such programs, unless otherwise noted. This amendment requires additional annual fisheries dependent monitoring for those systems listed in Table 3. Monitoring requirements may be fulfilled by data collected by the Atlantic Coastal Cooperative Statistics Program (ACCSP) where appropriate. States and jurisdictions may petition the Management Board for *de minimis* status, which exempts them from fishery dependent monitoring requirements (See section 7.1.3).

3.2.1 Commercial Fishery-Dependent Surveys

States and jurisdictions are required to annually monitor the American shad commercial fisheries operating within their state or jurisdiction by methods developed by the state or jurisdiction and subject to Technical Committee review and Management Board approval. The survey approach should be appropriate to the fisheries monitored and should provide estimates of total catch (numbers or weight and water body), total landings (if different than total catch, numbers or weight, and water body), total effort in the fisheries, and length, weight, age, sex, and repeat spawning composition (for states north of South Carolina) from a subsample of the catch. These data will be reported annually. This requirement may be fulfilled by the commercial component of the ACCSP.

3.2.2 Recreational Fishery Surveys Required

States and jurisdictions are required to conduct annual monitoring and reporting of catch, landings, and effort in the recreational fishery by methods developed by the state or jurisdiction and subject to Technical Committee review and Management Board approval. Techniques used to gather these data may include, but are not limited to, creel surveys, angler logs, surveys of license/permit holders, MRFSS or Marine Recreational Information Program (MRIP) (where appropriate), and reporting requirements for obtaining/maintaining a license or permit. Note that the MRFSS does not survey fisheries above head of tide in coastal rivers where most recreational shad fisheries occur. The future MRIP program may address these deficiencies.

3.3 BYCATCH MONITORING AND REDUCTION

Bycatch and discard of American shad in commercial fisheries may be an important factor inhibiting the recovery of this species and this issue is given special emphasis in Amendment 3. As part of the Implementation Plan, states and jurisdictions are required to submit a plan to monitor bycatch and discards of American shad in fisheries that operate in state waters of rivers and estuaries.

Ocean bycatch and discard are coastwide problems that affect shad stocks in all coastal states. Therefore, this amendment recommends that ocean bycatch and discards be monitored cooperatively by coastal states through the ASMFC, in cooperation with Fishery Management Councils and NOAA Fisheries. The planned bycatch module of the Atlantic Coastal Cooperative Statistics Program may be the best approach to collecting this data.

It is known that many Atlantic coastal American shad stocks migrate to the Gulf of Maine and the Bay of Fundy in summer to feed. In Canadian waters, they are taken in directed fisheries and as bycatch. Size of losses to these sources is not known. The Commission should work with the Department of Fisheries and Oceans Canada to obtain information on American shad losses in the Bay of Fundy and on potential actions that could reduce bycatch.

Responsibility for reporting ocean bycatch should be decided by the Management Board and be based on future arrangements developed to cooperatively monitor ocean fisheries. Responsibility for reporting results of bycatch in river and estuarine fisheries remains with the states and jurisdictions. These results will be reported to the Commission annually as per Section 9.3. This amendment recommends that the Shad and River Herring Management Board coordinate American shad bycatch monitoring with other Commission species management boards to improve collection efficiency and coverage of bycatch data.

In documented cases of high American shad bycatch, the involved jurisdiction(s) shall recommend approaches to reduce such bycatch to the Management Board for review. Options may include gear restrictions and time/area closures.

Table 2 - SUMMARY OF MANDATORY FISHERY-INDEPENDENT MONITORING PROGRAMS FOR AMERICAN SHAD.

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM
Maine	Androscoggin & Saco Rivers	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • Hatchery Evaluation
	Merrymeeting Bay & tributary rivers	• JAI: Juvenile abundance survey (GM)
New Hampshire	Exeter River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM)
	Merrimack River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • JAI: Juvenile abundance survey (GM) • Calculation of mortality and/or survival estimates where possible (Cooperative effort between New Hampshire, Massachusetts, and the USFWS)
Massachusetts	Merrimack River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • JAI: Juvenile abundance survey (GM) • Calculation of mortality and/or survival estimates where possible (Cooperative effort between New Hampshire and Massachusetts, and the USFWS)
	Connecticut River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • JAI: Juvenile abundance survey • Calculation of mortality and/or survival estimates where possible (Cooperative effort between Massachusetts and Connecticut)
Rhode Island	Pawcatuck River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM)
Connecticut	Connecticut River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort between Massachusetts and Connecticut)

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM
New York	Hudson River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM)
	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
New Jersey	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
Pennsylvania	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
	Susquehanna River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort between Pennsylvania and Maryland)
	Lehigh River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • Hatchery Evaluation
Delaware	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
	Nanticoke River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort between Delaware and Maryland)

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM
Maryland	Upper Chesapeake Bay / Susquehanna River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Susquehanna River monitoring is a cooperative effort between Pennsylvania and Maryland)
	Nanticoke River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort between Delaware and Maryland)
	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
District of Columbia	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
Potomac River Fisheries Commission	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
Virginia	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
	James, York, and Rappahannock Rivers	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation
North Carolina	Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • Calculation of mortality and/or survival estimates where possible • Hatchery Evaluation • Juvenile Abundance Index (Albemarle Sound only)

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM
South Carolina	Santee-Cooper system, Edisto River, Winyah Bay and tributaries (Waccamaw and Pee Dee Rivers)*	• Annual spawning stock survey to include passage counts, a relative abundance index, and/or population estimates and representative subsamples that describe size, age, and sex composition of the spawning stock * State may elect to sample these systems on a rotational basis (i.e., one system evaluated per year) • JAI: Juvenile abundance survey (GM)
	Savannah River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM) (Cooperative effort between South Carolina and Georgia)
Georgia	Altamaha and Ogeechee Rivers	• Annual spawning stock survey to include an abundance index or population estimates and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM)
	Savannah River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM) (Cooperative effort between South Carolina and Georgia)
Florida	St. Johns River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM)

Table 3 - SUMMARY OF MANDATORY FISHERY-DEPENDENT MONITORING PROGRAMS FOR AMERICAN SHAD

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM (Bolded sections are proposed under Amendment 3)
ASMFC	Atlantic Ocean (State and Federal waters) – cooperative effort with ALL coastal states and the NOAA Fisheries.	• Coordinate cooperative inter-state effort of ALL coastal states for mandatory reporting or at sea monitoring of bycatch (numbers or weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
All states and jurisdictions	Rivers and estuaries	Mandatory reporting of bycatch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Maine	In-river	• Monitor recreational landings, catch, and effort
New Hampshire	In-river	• Monitor recreational landings, catch, and effort.
Massachusetts	Merrimack River	• Monitor recreational landings, catch, and effort.
	Connecticut River	• Monitor recreational landings, catch, and effort. (Cooperative effort between Massachusetts and Connecticut)
Connecticut	Connecticut River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort. (Cooperative effort between Massachusetts and Connecticut)
Rhode Island	Pawcatuck River	• Monitor recreational landings, catch and effort.
New York	Hudson River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort.
	Delaware River	• Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
New Jersey	Delaware River and Bay	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
Delaware	Delaware River and Bay	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
	Nanticoke River	• None required. Fishery closed.
Pennsylvania	Delaware River	• Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
Maryland	Susquehanna River	• Monitor recreational landings, catch, and effort.
	Potomac River	• Monitor recreational landings, catch, and effort. (Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
District of Columbia	Potomac River	• Monitor recreational landings, catch, and effort. (Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
Potomac River Fisheries Commission	Potomac River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort.

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM (Bolded sections are proposed under Amendment 3)
		(Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
Virginia	York, Rapahhanock, and James Rivers	• Monitor recreational landings, catch, and effort where appropriate
	Potomac River	• Monitor recreational landing, catch, and effort (Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
North Carolina	Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort where appropriate
South Carolina	Edisto River, Santee River, Winyah Bay and its tributaries (Waccamaw and Pee Dee Rivers)	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort where appropriate. • * South Carolina may elect to sample these systems on a rotational basis (i.e., one system evaluated per year)
	Savannah River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort (Cooperative effort between South Carolina and Georgia
Georgia	Altamaha and Ogeechee Rivers	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landing, catch, and effort where appropriate.
	Savannah River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort (Cooperative effort between South Carolina and Georgia)
Florida	St. Johns River	• Monitor recreational landings, catch and effort.

3.4 SUMMARY OF MONITORING PROGRAMS

3.4.1 Biological Information

States and jurisdictions are mandated to implement the fishery-independent and dependent monitoring programs identified for American shad (Tables 2, 3, 4). States and jurisdictions may propose to the Board an alternative monitoring program if designed to measure progress toward restoration objectives or response to a defined sustainable fishery (Section 6). Whenever practical, state harvest and effort reporting requirements will coincide with current and future mandates of the ACCSP. Data needs not covered by the ACCSP will still be covered by annual reports submitted in conjunction with Amendment 3.

3.4.2 Social and Economic Information

Consumptive use (e.g. fishing activities before closures) and non-consumptive use (e.g. ecotourism activities) surveys focusing on social and economic data should be conducted periodically in a manner consistent with the intent of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) and the ACCSP Implementation Plan.

Table 4. Summary of monitoring requirements for American shad

Fishery-Independent	Juvenile Abundance Index	
	Annual spawning stock survey and representative sampling for biological data	
	Calculation of mortality/survival estimates (when available)	
	Hatchery evaluation (hatchery vs. wild)--when in place	
	Fishway counts; report inefficiencies (when available)	
Fishery-Dependent	Commercial	Mandatory reporting of landings (numbers and weight), catch (numbers, weight) and effort. • Sub-samples shall characterize size, age, spawning marks, sex, and species composition of catch (when available)
	Recreational	Monitor recreational by water body of landings, catch and effort: • Creel surveys, or • Survey license/permit holders, or • MRFSS/MRIP, or • Reporting requirements for obtaining/maintaining license or permit, or • Angler logbooks, or • Other
	Bycatch	Require monitoring and reporting of harvest, bycatch and discards of American shad in all fisheries • Bycatch in rivers and estuaries to be monitored and reported by states • Bycatch in at sea and near shore ocean fisheries to be monitored and reported by cooperative interstate and Federal arrangements determined by the Board
		Increase observer coverage and employ portside monitoring
		Coordinate with other FMPs
Annual Summary Report		Annual data summaries to be added to Excel spreadsheets used by ASMFC (2007)

4. REGULATORY PROGRAM

States and jurisdictions must implement the regulatory program requirements as per Section 7. The Management Board has the ultimate authority to determine the approval of a regulatory program. States and jurisdictions must also submit proposals to change their required regulatory programs as per Section 7.1.2. The Management Board will determine final approval for changes to required regulatory programs.

4.1 COMMERCIAL FISHERIES MANAGEMENT MEASURES

The Shad and River Herring Management Board approved the following commercial fishery management measures:

Close Fisheries (Commercial) with Exceptions for Systems with a Sustainable Fishery

Systems with a sustainable fishery are defined as those that demonstrate their American shad stock could support a commercial fishery that will not diminish potential future stock reproduction and recruitment. In order to maintain a commercial American shad fishery, states and jurisdictions are required to submit a request for a fishery as part of the Fishing/Recovery Section of the Implementation Plan (See Section 6.1). The request must include a definition of sustainability, benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment) and a proposed timeframe to achieve stated objectives. The request should also describe how the fishery will be conducted and annually monitored in order to show that the sustainability target(s) are being achieved. Data to substantiate the claim of sustainability include, but are not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates. Sustainability targets can be applied state-wide or can be river and species specific. Targets for river systems managed by more than one state/jurisdiction should be cooperatively developed. Targets should include a quantifiable means of estimating improvements in populations. As new information becomes available, states should review and update targets in a timely manner. The request for a fishery should be submitted to the Shad and River Herring Technical Committee no later than August 1, 2011.

States or jurisdictions without an approved plan in place will close their commercial fishery by January 1, 2013. Proposals to reopen closed fisheries may be submitted as part of the annual Compliance Report, and will be subject to review by the Plan Review Team, Technical Committee and Management Board.

4.2 RECREATIONAL FISHERIES MANAGEMENT MEASURES

The Shad and River Herring Management Board approved the following commercial fishery management measures:

- **Prohibit (Recreational) Harvest and Possession, with Exceptions for Systems with a Sustainable Fishery**
- **Allow States or Jurisdictions to Permit Catch and Release Fishing on any System**

Systems with a sustainable fishery are defined as those that demonstrate their American shad stock could support a recreational fishery that will not diminish potential future stock reproduction and recruitment. In order to maintain a recreational American shad fishery that harvests fish, states and jurisdictions are required to submit a request for a fishery as part of the Fishing/Recovery Section of the Implementation Plan (See Section 6.1). The request must include a definition of sustainability, benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment) and a proposed timeframe to achieve stated objectives. The request should also describe how the fishery will be conducted and annually monitored in order to show that the sustainability target(s) are being achieved. Data to substantiate the claim of sustainability include, but are not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates. Sustainability targets can be applied state-wide or can be river and species specific. Targets for river systems managed by more than one state/jurisdiction should be cooperatively developed. Targets should include a quantifiable means of estimating improvements in populations. As new information becomes available, states should review and update targets in a timely manner. The request for a fishery should be submitted to the Shad and River Herring Technical Committee no later than 1 August 2011. If a state or jurisdiction does not have sufficient data to prove sustainability, the state or jurisdiction is allowed to maintain a catch-and-release recreational fishery.

States or jurisdictions without an approved plan in place will close their recreational fishery (with the exception of catch and release fisheries) by January 1, 2013. Proposals to reopen closed fisheries may be submitted as part of the annual Compliance Report, and will be subject to review by the Plan Review Team, Technical Committee and Management Board.

5. HABITAT CONSERVATION AND RESTORATION

American shad stocks along the Atlantic coast are greatly diminished compared to historic levels of the 1880's and early 1900's when landings were near 50 million pounds per year. Much of this reduction has been related to spawning and nursery habitat degradation, or blocked access to habitat, resulting from human activity (e.g.; human population increase; sewage and storm water runoff; industrialization; dam construction; increased erosion, sedimentation and nutrient enrichment associated with agricultural practices; and losses of riparian forests and wetland buffers associated with resource extraction and land development).

Protection, restoration and enhancement of American shad habitat, including spawning, nursery, rearing, production, and migration areas, are critical objectives necessary for preventing further declines in American shad abundance, and restoring healthy, self-sustaining, robust, and productive American shad stocks to levels that will support the desired ecological, social, and economic functions and values of a restored Atlantic coast American shad population. For more detailed information on Alosine habitat, please refer to Appendix C.

5.1 American shad Habitat

Freshwater Spawning, Egg Development and Larval Rearing Habitat

American shad spawning, egg development, and larval nursery habitat is geographically located in the freshwater portions of Atlantic coast rivers, and their associated tributaries and estuary (river complex). Each of these freshwater aquatic features is under exclusive jurisdiction of the state, states, or jurisdictions within which they are contained. Collectively, these associated freshwater aquatic features spatially define the primary juvenile production unit of a defined American shad stock.

The quality and quantity of habitat within a river complex has a direct bearing upon the juvenile recruitment capacity of the associated stock and ultimately its potential contribution to the Atlantic coast population.

Estuarine Juvenile Rearing and Migration Corridors

The importance of estuaries to American shad as juvenile rearing habitat is not yet fully understood, however evidence suggests that estuaries are important to many American shad stocks. Estuaries are also often important migratory corridors for both spawning adult and emigrating juvenile American shad. Some potential threats in the estuarine environment include degraded juvenile habitat resulting from human-induced impacts, mortality from fisheries, and impediments to migration.

Coastal Production and Migration Corridors

The Atlantic coast ocean environment provides critical migration corridors and production habitat for sub-adult and adult American shad. Potential threats to coastal American shad habitat include: marine acidification; pharmaceutical disposal, wastewater discharge, pesticide contamination; invasive species; niche displacement; and global climate change.

5.2 Potential Threats to American shad Habitat

Barriers to migration – There has likely been considerable loss of production from historic American shad spawning and rearing habitat due to human activities that block access to habitat and/or impact safe, timely and effective fish migration in rivers along the Atlantic coast of the United States.

Water withdrawals - Large volume water withdrawals (e.g., drinking water, pumped-storage hydroelectric projects, irrigation, and snow-making, cooling), especially at pumped-storage facilities, can drastically alter local instream flow characteristics (e.g., reverse river flow). Withdrawals may also alter other physical characteristics of the river channel, including stream width, depth, current velocity, substrate and temperature. This can cause delayed movement past the facility, or impingement or entrainment at intakes causing mortality or injury.

Toxic and thermal wastewater discharge - Industrial and municipal discharges often contain toxic chemicals, such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) that are harmful to aquatic life. Many contaminants have been identified as having deleterious effects on fish, particularly reproductive impairment. Chemicals and heavy metals can be assimilated through the food chain, producing sub-lethal effects such as behavioral and reproductive abnormalities, fin erosion, epidermal lesions, blood anemia, altered immune response, and egg mortality. Thermal discharges can block or impede migration, interfere with egg/larval development, and reduce water quality.

Channelization, dredging, and instream construction - Channelization has the potential to cause significant environmental impacts including bank erosion, elevated water velocity, reduced habitat diversity, increased drainage, and poor water quality. Dredging and disposal of spoils along the shoreline can also create spoil banks, which block access to sloughs, pools, adjacent vegetated areas, and backwater swamps. Dredging may also release contaminants resulting in bioaccumulation, direct toxicity to aquatic organisms, or reduced dissolved oxygen levels. Dredge spoil banks are often unsuitable habitat for fishes. Instream construction may harm habitat, disrupt migration, or result in direct or delayed mortality (e.g., underwater blasting).

Land use - The effects of land use and land cover on water quality, stream morphology, and flow regimes are numerous, and may be one of the most important factors determining quantity and quality of aquatic habitats. Studies have shown that land use influences dissolved oxygen, sedimentation and turbidity, water temperature, pH, nutrients, and flow regime.

Atmospheric deposition - Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. Such deposition is a significant source of pollutants to many water bodies. Pollutants can get from the air into the water through rain and snow, falling particles, and absorption of the gaseous form of the pollutants into the water. Atmospheric deposition that causes low pH and elevated aluminum (acid rain) can contribute to water chemistry changes that result in direct or indirect mortality of young-of-year fish.

Climate change - As climate changes occur, modification of habitat is expected to occur in many aquatic environments. Such modifications could result in changes in large-scale distribution patterns for fish species, and consequent changes in the thermal niche space available. The linkage between fish production and thermal niche space is confounded when the habitat is made unsuitable by a low dissolved oxygen concentration. Annual events that seem related to the seasonal cycle of water temperature might increase in frequency. Temperature plays a dominant role in keying the actual spawning events. Survival of eggs and larvae is often dependent upon the relative timing of egg deposition and environmental vagaries within the spawning period. Predicted temperature changes could be accompanied by rising sea levels with attendant flooding of spawning habitats in estuaries and wetland nursery areas. Rising sea level requires consideration of many coastal processes, including: tidal ranges, storm surges, intrusion of groundwater and surface water, sedimentary processes, and the response by the plant communities of coastal ecosystems to changes in these processes. Resultant impacts are likely to be highly site-specific and to include changes both in temperature and dissolved oxygen structure and other physiographic features.

Competition and predation by invasive and managed species – Several aquatic and terrestrial species pose a potential threat to various life stages of American shad through direct or indirect competition, or predation. The presence and abundance of these species are often the result of human-induced activity (i.e., accidental or intentional introduction, level of population control or management, and propagation).

Fisheries Activities - Some fishing gear or practice may have unacceptable negative impacts on American shad habitat or migration (e.g., habitat damage, bycatch mortality).

Instream Flow Regulation - In rivers with flow regulation (e.g., storage and peaking hydroelectric power generation dams), and consumptive water withdrawals (e.g., irrigation, domestic water supply, industrial use) habitat quality and quantity, fish passage, and water for American shad may be impacted.

5.3 Habitat Utilization

States are encouraged to utilize existing production capacity of historic, but currently inaccessible freshwater spawning and larval rearing habitat through a process of trap and transport of excess spawning stock, or planting of aquaculture produced fry and fingerlings. This will help to both increase juvenile recruitment for the stock, and will develop a stock component imprinted to upstream habitat that can take advantage of it once access is restored through barrier removal or installation of fish passage.

5.4 Fisheries Practices

The use of any fishing gear or practice that is documented to have unacceptable negative impacts on American shad habitat or migration (e.g., habitat damage, bycatch mortality) should be prohibited within the area of that habitat or corridor, as determined by the appropriate jurisdiction(s).

5.5 Habitat Restoration, Enhancement, Utilization, and Protection Recommendations

Dams and Other Obstructions

General Fish Passage

1) States should work in concert with the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) to identify hydropower dams that pose significant impediment to diadromous fish migration, and target them for appropriate recommendations during Federal Energy Regulatory Commission (FERC) relicensing.
2) States should identify and prioritize barriers in need of fish passage based on clear ecological criteria (e.g., amount and quality of habitat upstream of barrier, size, and

status of affected populations). These prioritizations could apply to a single species, but are likely to be more useful when all diadromous species are evaluated together.

3) A focused, coordinated, well supported effort among federal, state, and associated interests should be undertaken to address the issue of fish passage development and efficiency. The effort should attempt to develop new technologies and approaches to improve passage efficiency with the premise that existing technology is insufficient to achieve restoration and management goals for several Atlantic coast river systems.
4) Where obstruction removal is not feasible, install appropriate passage facilities, including fish lifts, fish locks, fishways, navigation locks, or notches (low-head dams and culverts).
5) At sites with passage facilities, evaluate the effectiveness of upstream and downstream passage; when passage is inadequate, facilities should be improved.
6) Facilities for monitoring the effectiveness of the fish passage devices should be incorporated into the design where possible.
7) When designing and constructing fish passage systems, the behavioral response of each species of interest to appropriate site-specific physical factors should be considered.
8) If possible, protection from predation should be provided at the entrance, exit, and throughout the passage.
9) The passage facility should be designed to work under all conditions of head and tail water levels that prevail during periods of migration.
10) Passages are vulnerable to damage by high flows and waterborne debris. Techniques for preventing damage include robust construction, siting facilities where they are least exposed to adverse conditions, and removing the facilities in the winter.
11) Passage facilities should be designed specifically for passing alosines at optimum efficiency.

Upstream Fish Passage

1) American shad must be able to locate and enter the passage facility with little effort and without stress.
2) Where appropriate, improve upstream fish passage effectiveness through operational or structural modifications at impediments to migration.
3) Fish that have ascended the passage facility should be guided/routed to an appropriate area so that they can continue upstream migration, and avoid being swept back downstream below the obstruction.

Downstream Fish Passage

1) To enhance survival at dams during emigration, evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implement measures to pass fish via the route with the best survival rate.

Other Dam Issues

1) Where practicable, remove obstructions to upstream and downstream migration. in lieu of fishway construction.
2) Locate water intakes where impingement/entrainment rates are likely to be lowest, employ intake screens or deterrent devices to prevent egg and larval mortality, and alter water intake velocities to reduce mortalities.
3) To mitigate hydrological changes from dams, consider operational changes such as turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream, and adjusting in-stream flows.
4) Natural river discharge should be taken into account when instream flow alterations are being made to a river (flow regulation) because river flow plays an important role in the migration of diadromous fish.
5) Ensure that decisions on river flow allocation (e.g., irrigation, evaporative loss, out of basin water transport, hydroelectric operations) take into account instream flow needs for American shad migration, spawning, and nursery use, and minimize deviation from natural flow regimes.
6) When considering options for restoring alosine habitat, include study of impacts and possible alteration of dam-related operations to enhance river habitat.

Water Quality and Contamination

1) Maintain water quality and suitable habitat for all life stages of diadromous species in all rivers with populations of American shad.
2) Reduce non-point and point sources of pollution in American shad habitat areas.
3) Implement best management practices (BMPs) along rivers and streams, restore wetlands, and utilize stream buffers to control non-point source pollution.
4) Implement erosion control measures and BMPs in agricultural, suburban, and urban areas to reduce sediment input, toxic materials, and nutrients and organics into streams.
5) Upgrade wastewater treatment plants and remove biological and organic nutrients from wastewater.
6) Reduce the amount of thermal effluent into rivers and require a thermal zone of passage for fish migration and movement.
7) Provide management options regarding water withdrawal and land use to minimize the impacts of climate change on temperature and flow regimes.
8) Discharge earlier in the year to reduce impacts to migrating fish.
9) Conduct studies to determine the effects of dredging on diadromous habitat and migration; appropriate best management practices, including environmental windows, should be considered whenever navigation dredging or dredged material disposal operations would occur in a given waterway occupied by diadromous species.
10) Introduction of new categories of contaminants should be prevented.

Habitat Protection and Restoration

1) States should identify, characterize, and quantify existing spawning and nursery habitat within its jurisdiction.
2) When states have identified habitat protection or restoration as a need, state marine fisheries agencies should coordinate with other agencies to ensure that habitat restoration plans are developed, and funding is actively sought for plan implementation and monitoring.
3) Any activity resulting in elimination of essential habitat (e.g., dredging, filling) should be avoided.
4) States should map substrate for freshwater tidal portions of rivers to determine suitable diadromous fish habitat, and that habitat should be protected and restored as needed.
5) States should notify, in writing, the appropriate federal and state regulatory agencies of the locations of habitats used by diadromous species. Regulatory agencies should be advised of the types of threats to diadromous fish populations, and recommended measures that should be employed to avoid, minimize, or mitigate any threat to current habitat quantity or quality from an activity regulated by that agency.
6) Each state encompassing diadromous fish spawning rivers and/or producer areas should develop water use and flow regime guidelines protective of diadromous spawning and nursery areas.
7) States should identify and quantify potential shad and river herring spawning and nursery habitat not presently utilized, including a list of areas that would support such habitat if water quality and access were improved or created, and analyze the cost of recovery within those areas. States may wish to identify areas targeted for restoration as essential habitat.
8) Resource management agencies in each state should evaluate their respective state water quality standards and criteria to ensure that those standards and criteria account for the special needs of alosines. Primary emphasis should be on locations where sensitive egg and larval stages are found.
9) ASMFC should designate important shad and river herring spawning and nursery habitat as Habitat Areas of Particular Concern (HAPCs).
10) States should endeavor to ensure that proposed water diversions or withdrawals from river tributaries would not reduce or eliminate American shad habitat.

Permitting

1) States should develop policies for limiting development projects seasonally or spatially in spawning and nursery areas; define and codify minimum riparian buffers and other restrictions where necessary.
2) Projects involving water withdrawal (e.g., power plants, irrigation, water supply projects) should be scrutinized to ensure that adverse impacts resulting from impingement, entrainment, and/or modifications of flow and salinity regimes due to water removal will not adversely impact diadromous fish stocks.
3) Each state should establish seasonal windows of compatibility for activities known or suspected to adversely affect freshwater American shad life stages and their habitats (e.g.,

dredging, filling, aquatic construction), and notify the appropriate state and federal regulatory agencies of the recommended windows.

4) State fishery regulatory agencies should develop protocols and schedules for providing input on Federal permits and licenses required by the Clean Water Act, Federal Power Act, and other appropriate vehicles, to ensure that diadromous fish habitats are protected.
5) All state and federal agencies responsible for reviewing impact statements for projects that may alter anadromous alosine spawning and nursery areas should ensure that those projects will have no impact or only minimal impact on those stocks. Of special concern are natal rivers of newly established stocks or stocks considered depressed or severely depressed.

Stock Restoration and Management

1) When populations have been extirpated from their habitat, states should coordinate alosine stocking programs, to restore habitat production including:
    a. Reintroduction to the historic spawning area
    b. Expansion of existing stock restoration programs, and
    c. Initiation of new strategies to enhance depressed stocks.
2) When releasing hatchery-reared larvae into river systems for purposes of restoring stocks, states should synchronize the release with periods of natural prey abundance to minimize mortality and maximize nutritional condition. States should determine functional response of predators on larval shad at restoration sites to ascertain appropriate stocking level so that predation is accounted for, and juvenile out-migration goals are met. Also, states should determine if night stocking will reduce mortality.
3) All stocked larvae and juveniles should be marked. Marking should allow identification of stocked fish by stocked river, age, and year class at the juvenile stage and when fish return to spawn as adults.

Other

1) States should promote cooperative interstate research, monitoring, and law enforcement. Establish criteria, standards, and procedures for plan implementation as well as determination of state compliance with management plan provisions.

2) Diadromous fish may be vulnerable to mortality in hydrokinetic power generation facilities, and such projects should be designed and monitored to eliminate, or minimize, fish mortality.

River-Specific Habitat Recommendations

River-specific habitat recommendations for American shad can be found in:

Atlantic States Marine Fisheries Commission. 2007. American shad stock assessment report for peer review, volumes II and III. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement), Washington, D.C.

6.0 IMPLEMENTATION PLANS

In order to be successful in achieving the stated goal of Amendment 3, states or jurisdictions are required to develop Implementation Plans. Implementation Plans will consist of two parts: 1. Review and update of the Fishing/Recovery Plans required under Amendment 1 for the stocks within their jurisdiction; and 2. Habitat Plans. The updated Fishing/Recovery Plan must include a description of existing and planned monitoring and existing and planned regulatory measures. It may also include, for those states or jurisdictions requesting a fishery, a definition of sustainability, development of benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment), and a proposed timeframe to achieve stated objectives. The habitat plans are new and should include a summary of current and historical spawning and nursery habitat, threats to those habitats, and habitat restoration programs.

Monitoring sections of the Fishing/Recovery Plan updates should address the state or jurisdiction specific monitoring requirements specified in Tables 2 and 3. If states or jurisdictions cannot conduct required monitoring, the plan update should identify required monitoring that cannot be done and reasons why it cannot be conducted. It is the intention of this amendment to discuss identified implementation problems with the state or jurisdiction prior to plan adoption so that the Commission can work with the state or jurisdiction to explore the opportunity to secure adequate funding resources for implementation, or to develop an acceptable alternative that can be implemented with available resources.

If the state or jurisdiction chooses to develop a definition of sustainability and stock restoration goals, it may propose to the Management Board an alternate monitoring plan that measures stock status relative to the definition or goal. If approved by the board, this monitoring program will replace that specified in Tables 2 and 3.

Separate Implementation Plans shall be developed for those systems listed in Tables 2 and 3 and which are under the state or jurisdiction's authority. For states and jurisdictions which share a river or estuary, states should include those monitoring programs conducted or planned by the state, applicable state regulations, and habitat and habitat threats applicable to state waters. In shared water bodies where there is some sort of management cooperative, the cooperative or a member state or jurisdiction can be appointed to write the Implementation Plan. States are encouraged to develop plans for any additional systems, as feasible.

This amendment adopts the below frameworks for the updated Fishing/Recovery Plans and the Habitat Plans. Under this amendment the Technical Committee shall review each plan to ensure that the minimal technical specifications of Amendment 3 are met by the states and jurisdictions. States and jurisdictions are required to submit their Fishing/Recovery Plan to the Commission by August 1, 2011 and their Habitat Plan by August 1, 2013. Submission of these plans to the Management Board is a required action under Amendment 3. These plans are one time submissions under this amendment. They do not replace the annual state compliance reports discussed in Section 8. States without an approved plan for the sustainable fishery are required to close (with the exception of catch and release recreational fisheries) their fisheries by January 1, 2013.

It is understood that the review and update will take considerable time and resources on the part of the states, the federal agencies, and the Commission and its staff to fully develop and implement. It will require leadership and facilitation from the Commission and its staff. It will also require the technical expertise and input from the Plan Review Team, Plan Development Team, and Technical Committee. The federal agencies are strongly encouraged to lend their support and provide assistance in the form of facilitation, planning, technology, and training services.

All plans are to be regularly reviewed, assessed and updated as needed on five-year basis by the state or jurisdiction that prepared them, with a summary report of the review provided to the Board.

6.1 Updated Framework for the Fishing/Recovery Plans

The following is a framework for the updated Fishing/Recovery Plans. The Management Board should task the Technical Committee to review, modify as needed, and approve this framework.

1) **Sustainable Fishery Plan (If proposed)**
    a. Request for fisheries
    b. Definition of sustainability
    c. Summary of current stock status
    d. Benchmark goals and objectives or restoration goals/targets.
    e. Proposed time frame for achievement
    f. Discussion of management measure(s) to be taken if sustainable target is not achieved within indicated timeframe

2) **Stock Monitoring Programs** – Describe the monitoring currently used, or planned, to assess status and characteristics of the spawning stock and of progress toward goals. See requirements of Tables 2 and 3. States and jurisdictions should indicate any required monitoring that cannot be conducted (See Section 6.0).
    a. Fishery Independent
        i. Juvenile abundance indices
        ii. Adult stock monitoring
            1. Relative or absolute abundance
            2. Age, size, sex composition
            3. Total mortality (where possible)
            4. Upriver and downriver passage efficiencies (where possible)
        iii. Hatchery evaluation
            1. Proportion of hatchery fish present in juvenile or adult populations
    b. Fishery Dependent
        i. Commercial Fishery
            1. Total catch, landings, and effort
            2. Age, size, and sex composition of harvested fish
        ii. Recreational fishery
            1. Total catch, landings, and effort or catch per unit effort from a subsample
        iii. Bycatch and discards

3) **Fishery Management Program** – Summarize fisheries regulatory program for:
    a. Commercial fishery
    b. Recreational fishery
    c. Bycatch and discards

6.2. Habitat Plans

The following is the recommended framework for the Habitat Plan. The Management Board should task the Technical Committee to review, modify as needed, and approve this framework. This outline is designed to be an inclusive framework for organizing information on habitat, and threats to that habitat. As such, it is likely that data may not yet be available for some items. In those cases, states and jurisdiction should indicate data status (e.g., not available, being collected, being analyzed, under review).

1) **Habitat Assessment** – Assess the habitat (historic and currently available) and impediments to full utilization of the habitat.
    a. Spawning Habitat
        i. Amount of historical in-river and estuarine spawning habitat (e.g., river kilometers, water surface area (hectares)).
        ii. Amount of currently accessible in-river and estuarine spawning habitat (i.e., habitat accessible to adult fish during the upstream spawning migration).
    b. Rearing Habitat
        i. Amount of historical in-river and estuarine young-of-year rearing habitat (e.g., river kilometers, water surface area (hectares)).
        ii. Amount of currently utilized in-river and estuarine young-of-year rearing habitat (i.e., habitat available to larval stage and young-of-year fish through natural spawning or artificial stocking of hatchery reared juvenile fish).

2) **Threats Assessment** – Inventory and assess the critical threats to habitat quality, quantity, access, and utilization (see - *Appendix C* for a detailed habitat description). For those threats deemed by the state or jurisdiction to be of critical importance to restoration or management of an American shad stock, the state or jurisdiction should develop a threats assessment for inclusion in the Habitat Plan. Examples of potential threats to habitat quality, quantity, and access for American shad stocks include:
    a. Barriers to migration inventory and assessment
        i. Inventory of dams, as feasible, that impact migration and utilization of historic stock (river) specific habitat. Attribute data for each dam should be captured in an electronic database (e.g., spreadsheet) and include: name of dam, purpose of the dam, owner, height, width, length, impoundment size, water storage capacity, location (i.e., river name, state, town, distance from river mouth, geo-reference coordinates), fish passage facilities and measures implemented (i.e., fish passage type, capacity, effectiveness, and operational measure such as directed spill to facilitate downstream passage), and information source (e.g., state dam inventory).

ii. Inventory of other human–induced physical structures (e.g., stream crossing/culverts), as feasible, that impact migration and utilization of historic habitat (data on each structural impediment should include: type, source, and location).
iii. Inventory of altered water quality (e.g., low oxygen zones) and quantity (e.g., regulated minimum flows that impact migration corridors and/or migration cues), as feasible, impediments that impact migration and utilization of historic habitat (data on each water quality and quantity impediment should include: type, source, location, and extent).
iv. Assess barriers to migration in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

b. <u>Water withdrawals inventory and assessment</u>
   i. Inventory of water withdrawals (both permitted and known unpermitted), as feasible, that impact or have the potential to impact (e.g., fish entrainment and impingement, instream habitat alteration, and/or alteration of instream flow) migration and utilization of historic habitat.
   ii. Assess water withdrawals in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

c. <u>Toxic and thermal discharge inventory and assessment</u>
   i. Inventory of toxic and thermal discharge of water, where applicable, that impact or have the potential to impact (e.g., create a barrier, lethal concentration, and/or reduce fitness) migration and utilization of historic habitat.
   ii. Assess toxic and thermal discharge in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

d. <u>Channelization and dredging inventory and assessment</u>
   i. Inventory of channelization and dredging projects, as feasible, that impact or have the potential to impact (e.g., create a barrier, degrade substrate, and/or reduce water quality) migration and utilization of historic habitat.
   ii. Assess stream channelization and dredging in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

e. <u>Land use inventory and assessment</u>
   i. Inventory of land use in the watershed that impact or have the potential to impact (e.g., alter run-off regimes, degrade riparian habitat, increase siltation, reduce water quality and/or diminish riparian buffers) migration and utilization of historic habitat.
   ii. Assess land use in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

f. <u>Atmospheric deposition assessment</u>
   i. Assess atmospheric deposition in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

g. Climate change assessment
    i. Assess potential climate change impacts in the watershed and characterize their impact on American shad migration and utilization of historic habitat.
h. Competition and predation by invasive and managed species assessment
    i. Assess competition and predation by invasive and managed species in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

3) **Habitat Restoration Program** – For threats deemed to be of critical importance to the restoration and management of American shad stocks within its jurisdiction, each state or jurisdiction should develop a program of actions to improve, enhance and/or restore habitat quality and quantity, habitat access, habitat utilization and migration pathways. These programs may include plans to take direct corrective actions within the state or jurisdictions' authority, or to consult with agencies that have management authority over the threat, inform them of the impacts the threat is having on American shad stocks, and recommend potential alternatives or corrective actions to alleviate that threat. Section 5.5 Habitat Restoration, Enhancement, Utilization, and Protection Recommendations should be consulted for potential actions that could be included in the Habitat Restoration Program. While this amendment proposes the development of such programs, the implementation of these programs is not required. Programs could include:

a. Barrier removal and fish passage program – Develop a program to eliminate, minimize, or mitigate impacts from barriers identified in 2 (a) above.
b. Hatchery product supplementation program – Consider the stocking of hatchery reared larvae or juveniles to spawning or rearing habitat that is underutilized due to migration barriers or to new habitat following barrier removal.
c. Water quality improvement program - A program should be developed to address identified impacts of poor water quality to spawning success and juvenile recruitment in 2 (b) and (c) above.
d. Habitat improvement program - A program should be developed to address identified impacts to habitat in 2 (d) and (e) above and to protect quality habitat.
e. Project permit/licensing review program for water withdrawals, toxic and thermal discharge, channelization and dredging, and land use and development, that includes development of recommendations and conditions to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat - A program should be developed to identify, review, assess, and comment or condition permitted/licensed development projects that could impact aquatic habitat or restoration efforts
f. Programs to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat from atmospheric deposition and climate change – Atmospheric deposition and climate change may impact restoration efforts and will need to be addressed through cooperative engagement with the public and regulatory bodies that can influence positive change, or

eliminate/diminish the identified impacts. It is recommended that a program be developed to engage in the public debate and/or regulatory actions in order to attain full consideration of impacts of atmospheric deposition and climate change on American shad habitat and restoration efforts. It is also recommended that the ASMFC should consider developing a plan to engage as a unified body in the atmospheric deposition and climate change debate, and formulate a position statement on future action by regulatory agencies that address the identified impacts.

7. AMENDMENT REVISIONS

7.1 Future Changes to Management Regimes

Once the Shad and River Herring Management Board approves a management program (monitoring, regulatory and habitat), states and jurisdictions are required to obtain approval from the Management Board prior to changing their management program in any way that might alter a compliance measure. Changes to management programs that affect measures other than compliance measures must be reported to the Management Board but may be implemented without prior approval. States and jurisdictions submitting alternative proposals must demonstrate that the proposed management program will not contribute to excessive mortality of the resource or inhibit restoration of the resource. The Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board's satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (Section 7.2). All changes in state and jurisdictional plans must be submitted in writing to the Management Board and the Commission either as part of the annual FMP Review process or with the annual compliance report.

7.1.1 General Procedures

A state may submit a proposal to the Commission for a change to its regulatory program or any mandatory compliance measure under this amendment, including a proposal for *de minimis* status. Such changes shall be submitted to the Chair of the Plan Review Team, who shall then distribute the proposal to the Management Board, Plan Review Team. The Plan Review Team may request additional guidance from the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, as necessary. The Plan Review Team is responsible for gathering the comments, if requested, from the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, and presenting the comments to the Management Board in a timely fashion.

The Shad and River Herring Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board's satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (Section 7.2).

7.1.2 Management Program Equivalency

The Shad and River Herring Technical Committee, under the direction of the Plan Review Team, will review any alternative management program proposals and provide the Management Board its evaluation of the adequacy of the proposals.

7.1.3 *De Minimis* Fishery Guidelines

The Commission's Interstate Fisheries Management Program Charter defines *de minimis* as "a situation in which, under the existing condition of the stock and scope of the fishery, conservation and enforcement actions taken by an individual state would be expected to contribute insignificantly to a coastwide conservation program required by a Fishery Management Plan or amendment" (ASMFC 2003).

States that report commercial landings of American shad that are less than 1% of the coastwide commercial total are exempted from sub-sampling commercial and recreational catch for biological data, as outlined in Section 3.2.

States and jurisdictions may petition the Shad and River Herring Management Board at any time for *de minimis* status if their fishery falls below the threshold level determined by the Board. Once *de minimis* status is granted, designated states and jurisdictions must submit annual compliance reports to the Management Board and request *de minimis* status on an annual basis.

7.2 ADAPTIVE MANAGEMENT

The Shad and River Herring Management Board may vary the requirements specified in this amendment as part of adaptive management in order to conserve American shad resources. Specifically, the Management Board may change state and jurisdiction requirements under Sections 3 and 4 (see Section 7.1.2). Such changes will be instituted to be effective on January 1 or the first fishing day of the following year, but may be put in place at an alternative time when deemed necessary by the Management Board.

7.2.1 General Procedures

The Shad and River Herring Plan Review Team will monitor the status of the fishery and the resource and report on that status to the Management Board annually or when directed to do so by the Management Board. The Plan Review Team will consult with the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, as necessary, when making such a review and report. The report may contain recommendations for proposed adaptive management revisions to the amendment.

The Management Board will review the Plan Review Team report and may consult further with the Technical Committee, Stock Assessment Subcommittee or the Advisory Panel. The Management Board can direct the Plan Development Team to prepare an addendum to make changes that it deems necessary. The addendum shall contain a schedule for the states and jurisdictions to implement its provisions.

The Plan Development Team will prepare a draft addendum as directed by the Management Board and, upon approval from the Board, shall distribute it for review and comment to all states and jurisdictions with declared interest in the fishery. A public hearing will be held in any state or jurisdiction that requests one. After a 30-day review period, the Plan Development Team will summarize the comments and present them to the Management Board.

After considering the comments, the Management Board will direct the Plan Development Team on what to include in the final addendum. The Management Board shall review the final version of the addendum. The Management Board shall then consider whether to adopt or revise and then adopt the addendum.

Upon the adoption of an addendum to implement adaptive management, states and jurisdictions shall prepare plans, when necessary, to implement the addendum and submit those plans to the Management Board for approval, following the schedule contained in the addendum.

7.2.2 Measures Subject to Change

The following measures are subject to change under adaptive management upon approval by the Management Board:

(1) Habitat considerations;
(2) Overfishing definition;
(3) Rebuilding targets and schedules;
(4) Fishery-independent monitoring requirements;
(5) Fishery-dependent monitoring requirements;
(6) Bycatch monitoring and reduction requirements;
(7) Reporting requirements;
(8) Effort controls;
(9) Area closures;
(10) Gear restrictions or limitations;
(11) Catch controls;
(12) Fishing year and/or seasons;
(13) Possession limits;
(14) Quotas;
(15) Bycatch limits and reporting;
(16) Observer requirements;
(17) Closures;
(18) Regulatory measures for the recreational fishery;
(19) Recommendations to the Secretaries for complementary actions in federal jurisdictions;
(20) *De minimis* specifications;
(21) Compliance report due dates; and
(22) Any other management measures currently included in the Shad and River Herring Interstate Fishery Management Plan.

7.3 EMERGENCY PROCEDURES

The Shad and River Herring Management Board may authorize or require emergency action that is not covered by, or is an exception or change to, any provision in Amendment 3. Procedures for implementation of emergency action are addressed in the Commission's Interstate Fisheries Management Program Charter, Section Six (c)(10) (ASMFC 2003).

8. MANAGEMENT INSTITUTIONS

The management institutions for shad and River herring shall be subject to the provisions of the ISFMP Charter (ASMFC 2003). The following are not intended to replace any or all of the provisions of the ISFMP Charter. All committee roles and responsibilities are included in detail in the ISFMP Charter and are only summarized here.

8.1 The Commission and the ISFMP Policy Board

The Atlantic States Marine Fisheries Commission and the ISFMP Policy Board are generally responsible for the oversight and management of the Commission's fisheries management activities. The Commission must approve all fishery management plans and amendments, including this Amendment 3, and must also make final determinations concerning state compliance or non-compliance. The ISFMP Policy Board reviews any non-compliance recommendations from the various management boards and sections and, if it concurs, forwards them on to the Commission for action.

8.2 Shad and River Herring Management Board

The Shad and River Herring Management Board is established by the Commission's ISFMP Policy Board and is generally responsible for carrying out all activities under this amendment. It establishes and oversees the activities of the Plan Review Team, Plan Development Team, Technical Committee and Stock Assessment Subcommittee, and requests the establishment of the Commission's Shad and River Herring Advisory Panel. Among other things, the Management Board makes changes to the management program under adaptive management and approves the state and jurisdictional programs implementing the amendment and alternative state programs under Sections 6 and 7. The Management Board reviews the status of state and jurisdiction compliance with the FMP at least annually and, if it determines that a state or jurisdiction is out of compliance, reports that determination to the ISFMP Policy Board under the terms of the ISFMP Charter.

8.3 Shad and River Herring Plan Review Team and Plan Development Team

The Shad and River Herring Plan Review Team and Plan Development Team are small groups whose responsibility is to provide all necessary staff support to carry out and document the decisions of the Management Board. Both teams are directly responsible to the Management

Board for providing all of the information and documentation necessary to carry out the Board's decisions.

The teams shall be comprised of personnel from state and federal agencies who have scientific or management knowledge of shad and river herring and will be chaired by the Commission's Shad and River Herring FMP Coordinator. The Plan Development Team will be responsible for preparing all documentation necessary for the development of Amendment 3, using the best scientific information available and the most current stock assessment information. Once the Commission adopts Amendment 3, the Plan Review Team will provide annual advice concerning implementation, review, monitoring and enforcement of the amendment.

8.4 Shad and River Herring Technical Committee

The Shad and River Herring Technical Committee will consist of representatives from each state, jurisdiction, and federal agency with a declared interest in shad and river herring fisheries. Its role is to act as a liaison to the individual jurisdictions and federal agencies, providing information to the management process and reviewing and making recommendations concerning the management program. The Technical Committee will provide scientific advice to the Management Board, Plan Development Team and Plan Review Team in the development and monitoring of a fishery management plan or amendment, when requested.

8.5 Shad and River Herring Stock Assessment Subcommittee

The Shad and River Herring Stock Assessment Subcommittee will consist of scientists with expertise in stock assessment methods or the assessment of shad and river herring populations. Its role is to assess shad and river herring populations and provide scientific advice concerning the implications of proposed or potential management alternatives for the stocks, as well as to respond to other scientific questions from the Management Board, Technical Committee, Plan Development Team or Plan Review Team. The Stock Assessment Subcommittee will report to the Management Board as well as to the Technical Committee, when requested.

8.6 Shad and River Herring Advisory Panel

The Shad and River Herring Advisory Panel is established according to the Commission's Advisory Committee Charter. Members of the Advisory Panel are citizens who represent a cross-section of commercial and recreational fishing interests and other who are concerned about shad and river herring conservation and management. The Advisory Panel provides the Management Board with advice directly concerning the Commission's shad and river herring management program.

8.7 Secretaries of Commerce and the Interior

Under the Atlantic Coastal Fisheries Cooperative Management Act, if the Commission determines that a state or jurisdiction is out of compliance with the Fishery Management Plan, it reports that finding to the Secretary of Commerce. The Secretary of Commerce must determine that the measures not taken by the state or jurisdiction are necessary for conservation and if such a finding is determined, the Secretary is then required by federal law to impose a moratorium on fishing for shad or river herring in that jurisdiction's waters until the state comes back into compliance. In addition, the Commission has accorded the National Marine Fisheries Service and the U.S. Fish and Wildlife Service voting status on the ISFMP Policy Board and the Shad and River Herring Management Board; the federal agencies participate on the Plan Review Team, Plan Development Team, Technical Committee and Stock Assessment Subcommittee.

8.8 Recommendations to Secretaries

The ASMFC Shad and River Herring Management Board requests that the Secretary of Commerce direct the National Marine Fisheries Service to collaborate with the ASMFC Board and Technical Committee on shad and river herring bycatch reduction efforts in the New England Fishery Management Council and the Mid-Atlantic Fishery Management Council Fishery Management Plan process. The Commission also recommends the Secretaries of the federal agencies lend their support to states or jurisdictions in the development of the Implementation Plans and provide assistance in the form of facilitation, planning, technology, and training services.

9. COMPLIANCE

Full implementation of the provisions in this amendment is necessary for the management program to be equitable, efficient and effective. States (to include states as well as the District of Columbia and Potomac River Fisheries Commission) are expected to implement these measures faithfully under state laws. Although the Atlantic States Marine Fisheries Commission does not have authority to directly compel state implementation of these measures, it will continually monitor the effectiveness of state implementation and determine whether states are in compliance with the provisions of this amendment. This section sets forth the specific elements that the Commission will consider in determining state compliance with this amendment and the procedures that govern the evaluation of compliance. Additional details of the procedures are found in the 2003 ASMFC Interstate Fisheries Management Program (ISFMP) Charter. States and jurisdictions should be aware that federal law requires their compliance with the provisions of this amendment.

9.1 MANDATORY COMPLIANCE ELEMENTS FOR STATES

A state or jurisdiction will be determined out of compliance with the provision of this fishery management plan according to the terms of Section 7 of the ISFMP Charter if:

1. It's Implementation Plan or its annual compliance reports have not been approved by the Shad and River Herring Management Board; or
2. It fails to meet any scheduled action required by Section 9.2, or any addendum prepared under adaptive management (Section 7.2); or

3. It has failed to implement a change to its monitoring program (Section 3) or its regulations when determined necessary by the Shad and River Herring Management Board; or
4. It makes a change to its monitoring programs required under Section 3 or its regulations required under Section 4 without prior approval of the Shad and River Herring Management Board.

9.1.1 Mandatory Elements of State Programs

A state will be found out of compliance if it's regulatory and management programs for shad and river herring have not been approved by the Management Board in section 3 and 4. A state or jurisdiction may propose an alternative management program under Section 7, which if approved by the Management Board, may be implemented as an alternative regulatory requirement for compliance under the law.

9.1.2 Regulatory Requirements

States and jurisdictions may begin to implement Amendment 3 after final approval by the Commission. Each state and jurisdiction must submit its required shad and river herring regulatory program to the Commission through Commission staff for approval by the Management Board. During the period between submission of the regulatory plan and the Management Board’s decision to approve or reject it, a state or jurisdiction may not adopt a less protective management program than contained in this Amendment or contained in current state law. Once a regulatory program is approved by the Management Board, states and jurisdictions may not implement any regulatory changes concerning shad and river herring, or any management program changes that affect their responsibilities under this Amendment, without first having those changes approved by the Management Board.

9.1.3 Monitoring Requirements

All state and jurisdictional programs must include the mandatory monitoring requirements contained in Section 3 unless the Management Board approves and alternative program as outlined in Section 6.0 and 7.0. States and jurisdictions must submit proposals as part of the Fishing/Recovery Plan for all intended changes to required monitoring programs that may affect the quality of the data or the ability of the program to fulfill the needs of the amendment. In the event that a state or jurisdiction realizes that it will not be able to fulfill its monitoring requirements, it should immediately notify the Commission in writing. The Commission will work with the state or jurisdiction to develop a plan to secure funding or plan an alternative program to satisfy the needs outlined in Amendment 3. If the plan is not implemented 90 days after it has been adopted, the state or jurisdiction may be found out of compliance with Amendment 3.

9.1.4 Research Requirements

No mandatory research requirements have been identified at this time; however, elements of state Implementation Plans may be added to address any needs identified during the course of developing Amendment 3.

9.1.5 Law Enforcement Requirements

All state and jurisdictional programs must include law enforcement capabilities adequate for successfully implementing the state's shad and river herring regulations. The adequacy of a state's enforcement activity will be measured by an annual report to the Commission's Law Enforcement Committee and the Plan Review Team.

9.1.6 Habitat Requirements

No mandatory habitat requirements have been identified at this time; however, elements of state habitat plans (Section 6) may be added to address any needs identified during the course of developing Amendment 3.

9.2 COMPLIANCE SCHEDULE

States and jurisdictions must implement the provisions of this Amendment according to the following schedule:

August 1, 2011 States/jurisdictions must submit their fishing/recovery plan(s), as part of the states/jurisdictions Implementation plan, for review by the Technical Committee and approval by the Management Board

January 1, 2013 States /jurisdictions must implement their approved fishing/ recovery plan(s).

August 1, 2013 States /jurisdictions must submit their habitat plan(s)

Reports on compliance should be submitted to the Commission by each jurisdiction annually, no later than July 1 each year. These reports are separate from the Implementation plans which are one time submissions to the Commission.

9.3 COMPLIANCE REPORT CONTENT

Each state must submit an annual report concerning its shad and river herring fisheries and management program for the previous years. The report shall cover:

1. The previous calendar year's fishery and management program including, activity and results of monitoring, regulations that were in effect, harvest, and estimates of non-harvest losses, following the outline contained in Table 5.
2. All data from monitoring programs must be added to Excel spreadsheets used in the 2007 stock assessment. Updated spreadsheets must be submitted annually as an appendix to the annual report and at the same time as the annual report unless determined otherwise by the Board.
3. The planned management program for the current calendar year, summarizing regulations that will be in effect and monitoring programs that will be performed, and highlighting any changes from the previous year.

Table 5. Required format for annual state compliance reports.

General Format	
Introduction	Summary of the year: highlight any significant changes in monitoring, regulations or harvest.
Request for *de minimis*	If applicable.
Previous year's fishery and management program	Activity and result of fishery-dependent monitoring (provide general results and references to technical documentation) including bycatch monitoring.
	Activity and results of fishery-independent monitoring (provide general results and references to technical documentation).
	Copy of regulations that were in effect, including a reference to the specific compliance criteria as mandated in the FMP.
	Harvest broken down by commercial (gear type where applicable) and recreational fishing, and non-harvest losses, when available.
	Review of progress in implementing habitat recommendations.
Planned management programs for the current calendar year	Summarize regulations that will be in effect (copy of current regulations if different from previous year).
	Summarize monitoring programs that will be performed.
	Highlight any changes from the previous year.

Plan-Specific Requirements				
Harvest and losses	Commercial Fishery	Characterization of the fishery (seasons, caps, gears, regulations).		
		Characterization of directed harvest.	Landings	
			Harvest composition	Age frequency
				Length frequency
				Sex ration
				Degree of repeat spawning (estimated from scales)
			Estimation of Effort	
		Characterization of other losses (poaching, bycatch, etc.).	Estimate and method of estimation	
			Estimate of composition (length and/or age)	
	Recreational Fishery	Characterization of the fishery (seasons, caps, gears, regulations).		
		Characterization of directed harvest.	Landings and method of estimation	
			Estimation of effort or Annual CPUE from a subsample	
		Characterization of other losses (poaching, catch-and-release mortality, etc.)	Estimate and method of estimation	
	Other Losses	Fish passage mortality, discarded males, brood stock capture, research losses, etc.		
	Harvest and Losses Table	Include all above estimates in numbers and weight (pounds) of fish and mean weight per fish for each gear type.		
	Protected Species	Atlantic sturgeon bycatch estimates.		
Required Fishery-Independent Monitoring	Description of requirement as outlined in Section 3.			
	Brief description of work performed.			
	Results	[*To be determined upon final approval of Amendment 3*]		

9.4 PROCEDURES FOR DETERMINING COMPLIANCE

Detailed procedures regarding compliance determinations are contained in the ISFMP Charter, Section Seven.

In brief, all states and jurisdictions are responsible for the full and effective implementation and enforcement of fishery management plans in areas subject to their jurisdiction. Written compliance reports as specified in the Plan or Amendment must be submitted annually by each state with a declared interest. Compliance with Amendment 3 will be reviewed at least annually. The Shad and River Herring Management Board, ISFMP Policy Board or the Commission may request the Plan Review Team to conduct a review of Plan implementation and compliance at any time.

The Management Board will review the written findings of the PRT within 60 days of receipt of a state or jurisdiction's compliance report. Should the Management Board recommend to the Policy Board that a state or jurisdiction be determined to be out of compliance, a rationale for the recommended noncompliance finding will be included addressing specifically the required measures of Amendment 3 that the state or jurisdiction has not implemented or enforced, a statement of how failure to implement or enforce required measures jeopardizes shad and river herring conservation, and the actions a state must take in order to comply with Amendment 3 requirements.

The ISFMP Policy Board will review any recommendation of noncompliance from the Management Board within 30 days. If it concurs in the recommendation, it shall recommend at that time to the Commission that a state or jurisdiction be found out of compliance.

The Commission shall consider any noncompliance recommendation from the ISFMP Policy Board within 30 days. Any state or jurisdiction that is the subject of a recommendation for a noncompliance finding is given an opportunity to present written and/or oral testimony concerning whether it should be found out of compliance. If the Commission agrees with the recommendation of the ISFMP Policy Board, it may determine that a state or jurisdiction is not in compliance with the Amendment 3, and specify the actions the state or jurisdiction must take to come into compliance.

Any state or jurisdiction that has been determined to be out of compliance may request that the Commission rescind its noncompliance findings, provided the state or jurisdiction has revised its shad and river herring conservation measures.

10. MANAGEMENT AND RESEARCH NEEDS

The following list of research needs have been identified in order to enhance the state or knowledge of the shad and river herring resources, population dynamics, ecology and the various fisheries for alosine species. The Technical Committee, Advisory Panel, and Management Board will review this list annually and an updated prioritized list will be included in the Annual Shad and River Herring FMP Review. The below items should be prioritized, from most critical to least critical, by the Technical Committee.

10.1 STOCK ASSESSMENT AND POPULATION DYNAMICS

- Continue to assess current aging techniques for shad and river herring, using known-age fish, scales, otoliths and spawning marks. Known age fish will be available from larval stocking programs that mark each year class. Conduct biannual aging workshops to maintain consistency and accuracy in aging fish sampled in state programs.
- Investigate the relation between juvenile production and subsequent year class strength for alosine species, with emphasis on the validity of juvenile abundance indices, rates and sources of immature mortality, migratory behavior of juveniles, natural history and ecology of juveniles, and essential nursery habitat in the first few years of life.
- Validate estimates of M for American shad stocks.
- Establish management benchmarks for data poor river systems identified within the stock assessment.
- Estimate and evaluate sources of mortality for alosine species from bycatch, and bait and reduction fisheries.
- Determine fishery specific catch, harvest, bycatch, and discard reporting rates.
- Estimate and evaluate river specific mortality from upstream and downstream passage of adults and downriver passage of juveniles past migratory barriers.
- Determine which stocks are impacted by mixed stock fisheries (including bycatch fisheries). Methods to be considered could include otolith microchemistry, oxy-tetracycline otolith marking, and/or tagging.
- Evaluate assumptions critical to in-river tagging programs in Georgia, South Carolina, and Maryland that are used to estimate exploitation rate and population size.
- Develop approaches to estimating relative abundance of spawning stocks in rivers without passage facilities and in rivers with passage facilities with unknown passage efficiencies.
- Evaluate predation by striped bass and other predators as a factor of mortality for alosines. Research predation rates and impacts on alosines.
- Quantify fishing mortality (in-river, ocean bycatch, bait fisheries) for major river stocks after ocean closure of directed fisheries.
- Develop comprehensive and cost effective angler use and harvest survey techniques for use by Atlantic coastal states to assess recreational fisheries for American shad.
- Determine and update biological data inputs used in assessment modeling (fecundity-at-age, mean weight-at-age for both sexes, partial recruitment vector/maturity schedules) for American shad and river herring stocks in a variety of coastal river systems, including both semelparous and iteroparous stocks.
- Evaluate and ultimately validate large-scale hydroacoustic methods to quantify American shad escapement (spawning run numbers) in major river systems. Identify how shad respond (attract/repelled) by various hydroacoustic signals.

10.2 RESEARCH AND DATA NEEDS

10.2.1 Habitat

- Identify ways to improve fish passage efficiency using hydroacoustics to repel alosines from turbine intakes or discharges or pheromones or other chemical substances to attract them to passage entrances. Test commercially available acoustic equipment at existing fish passage facility to determine effectiveness. Develop methods to isolate/manufacture pheromones or other alosine attractants.
- Determine the effects of passage impediments on all life history stages of American shad including turbine mortality and river and barrier specific passage efficiencies. Highest priority would be the lowermost obstruction.
- Develop and implement techniques to determine shad and herring population targets for tributaries undergoing restoration (dam removals, fishways, supplemental stocking, etc.).
- Characterize tributary habitat quality and quantity for Alosine reintroductions and fish passage development.
- Determine impacts to American shad populations from changing ocean environment
- Identify and quantify potential American shad spawning and rearing habitat not presently utilized and conduct an analysis of the cost of recovery.
- Develop appropriate Habitat Suitability Index Models for alosine species in the fishery management plan. Possibly consider expansion of species of importance or go with the most protective criteria for the most susceptible species.
- Determine factors that regulate and potentially limit downstream migration, seawater tolerance, and early ocean survival of juvenile alosines.
- Review studies dealing with the effects of acid deposition on anadromous alosines.
- Determine effects of change in temperature and pH for all life stages.
- Determine optima and tolerance for salinity, dissolved oxygen, pH, substrate, current velocity, depth, temperature, and suspended solids.
- Determine hard limits and range levels for water quality deemed appropriate and defensible for all alosines with emphasis on freshwater migratory, spawning, and nursery areas.
- There has been little research conducted on habitat requirements for hickory shad. Although there are reported ranges of values for some variables, such as temperature or depth, there is no information on tolerances or optima for all life stages. Research on all life stages is necessary to determine habitat requirements.
- Determine impacts of declining submerged aquatic vegetation beds on juvenile cover and rearing habitat.
- Determine impacts of thermal power generation projects (e.g., nuclear and coal) that withdraw water for cooling (potential entrainment and impingement of fish) and discharge heated water (thermal barriers to migration, habitat degradation) on estuarine juvenile rearing and migration corridors.
- Determine impacts to migrating American shad (both spawning adults and out-migrating juveniles and adults) by proposed in-stream power generation developments such as tidal stream generation that draws energy from currents.
- Determine potential threats and their level of impact to coastal American shad habitat from: marine acidification; pharmaceutical, wastewater, pesticide contamination;

invasive species; niche displacement; and global climate change are in need of further study.

- Determine the impacts to migrating American shad (both spawning adults and migrating juveniles) by proposed wind power generation developments in near shore ocean environments.
- Conduct fish passage research and development with the goal of improving the efficiency of existing and future installations of fish passage measures and facilities in order to restore desired access to and utilization of critical American shad spawning and juvenile rearing habitat.
- Conduct studies to determine whether passing migrating adults upstream earlier in the year in some rivers would increase production and larval survival, and opening downstream bypass facilities sooner would reduce mortality of early emigrants (both adult and early-hatched juveniles).
- Conduct studies to determine the effects of dredging on diadromous habitat and migration.

10.2.2 Life History

- Conduct studies on energetics of feeding and spawning migrations of alosines on the Atlantic coast.
- Evaluate impacts of invasive species such as zebra mussels and flathead catfish on larval and juvenile survival.
- Conduct studies of egg and larval survival and development.
- Focus research on within-species variation in genetic, reproductive, morphological, and ecological characteristics, given the wide geographic range and variation at the intraspecific level that occurs in alosines.
- Ascertain how abundance and distribution of potential prey affect growth and mortality of early life stages.
- Conduct research on hickory shad migratory behavior. This may explain why hickory shad populations continue to increase while other alosines are in decline.

10.2.3 Stocking and Hatcheries

- Refine techniques for hormone induced tank spawning of American shad. Secure adequate eggs for culture programs using native broodstock.
- Refine larval marking techniques such that river and year class can be identified when year classes are later recaptured as juveniles or adults.

10.2.4 Socioeconomic

- Conduct and evaluate historical characterization of socio-economic development (potential pollutant sources and habitat modification) of selected alosine rivers along the Atlantic coast.

- Collect information from consumptive and non-consumptive users on: demographic information (e.g., age, gender, ethnicity/race), social structure information (e.g., historical participation, affiliation with NGOs, perceived conflicts), other cultural information (e.g., occupational motivation, cultural traditions related to resource's use), and community information.
- In order to improve the management-oriented understanding of historical stock trends and related assessments, the social and economic history of the river herring fisheries should be documented for time periods equivalent to the stock return level sought by the biological standards and this analysis should including documenting market trends, consumer preferences including recreational anglers, the role of product substitutes such as Atlantic herring and menhaden, and the levels of subsistence fisheries as can be obtained.
- Before recommending, re-authorizing and/or implementing stock enhancement programs for a given river system, it is recommended that state agencies or other appropriate management organization conduct *ex-ante* socioeconomic cost and benefit (e.g., estimate non-consumptive and existence values, etc.) analysis of proposed stocking programs.

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12. GLOSSARY

* Definitions taken from: *NOAA Fisheries Glossary*, NOAA Technical Memorandum NMFS-F/SPO-69, October 2005, Revised Edition June 2006.

** Definitions taken from: Stock Assessment Report No. 07-01 (Supplement) of the Atlantic States Marine Fisheries Commission, *American Shad Stock Assessment Report For Peer Review*, August 2007, List of Terms.

All other definitions were developed by the Plan Development Team.

Anadromous*
Fishes that migrate as juveniles from freshwater to saltwater and then return as adults to spawn in freshwater; most Pacific salmon are anadromous.

Area Under the Curve
An estimate of the relative annual abundance of a fish spawning run based on daily fish sample counts over the entire run period. Sample counts can be from fish passage counts at a fishway, or from systematic fishery sampling located downstream of the in-river spawning area, prior to spawning.

Baseline*
A set of reference data sets or analyses used for comparative purposes; it can be based on a reference year or a reference set of (standard) conditions.

Benchmarks**
A particular value of stock size, catch, fishing effort, fishing mortality, and total mortality that may be used as a measurement of stock status or management plan effectiveness. Sometimes these may be referred to as biological reference points.

Biological Reference Points*
1. A biological benchmark against which the abundance of the stock or the fishing mortality rate can be measured in order to determine its status. These reference points can be used as limits or targets, depending on their intended usage;
2. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. These may indicate (a) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or (b) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former are referred to as "target reference points," and the latter are referred to as "limit reference points" or "thresholds." Some common examples are $F_{0.1}$, F_{MAX}, and F_{MSY}.

Biomass (B)*
1. Or standing stock. The total weight of a group (or stock) of living organisms (e.g. fish, plankton) or of some defined fraction of it (e.g. spawners) in an area, at a particular time; 2. Measure of the quantity, usually by weight in pounds or metric tons (2,205 pounds or 1 metric ton), of a stock at a given time.

Bycatch*
Fish other than the primary target species that are caught incidental to the harvest of the primary species. Bycatch may be retained or discarded. Discards may occur for regulatory or economic reasons.

Carrying Capacity*
1. The maximum population of a species that an area or specific ecosystem can support indefinitely without deterioration of the character and quality of the resource;
2. The level of use, at a given level of management, at which a natural or man-made resource can sustain itself over a long period of time. For example, the maximum level of recreational use, in terms of numbers of people and types of activity that can be accommodated before the ecological value of the area declines.

Catch Curve**
An age-based analysis of the catch in a fishery that is used to estimate total mortality of a fish stock. Total mortality is calculated by taking the negative slope of the logarithm of the number of fish caught at successive ages (or with 0, 1, 2... annual spawning marks).

Catch Per Unit (of) Effort (CPUE)*
The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; e.g. number of fish taken per 1,000 hooks per day or weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance. Also called: catch per effort, fishing success, availability.

Catch Rate*
Means sometimes the amount of catch per unit time and sometimes the catch per unit effort.

Cohort*
1. In a stock, a group of fish generated during the same spawning season and born during the same time period;
2. In cold and temperate areas, where fish are long-lived, a cohort corresponds usually to fish born during the same year (a year class). For instance, the 1987 cohort would refer to fish that are age 0 in 1987, age 1 in 1988, and so on. In the tropics, where fish tend to be short lived, cohorts may refer to shorter time intervals (e.g. spring cohort, autumn cohort, monthly cohorts). (see *Year Class*)

Cohort Analysis*
A retrospective analysis of the catches obtained from a given year class at each age (or length interval) over its life in the fishery. Allows estimation of fishing mortality and abundance at each age as well as recruitment. Involves the use of a simplified algorithm based on an approximation that assumes that, in a given time period, all fishing takes place instantaneously in the middle of the time period.

De minimis**
Status obtained by states with minimal fisheries for a certain species and that meet specific provisions described in fishery management plans allowing them to be exempted from specific management requirements of the fishery management plan to the extent that action by the particular States to implement and enforce the plan is not necessary for attainment of the fishery management plan's objectives and the conservation of the fishery.

Depleted Stock*
A stock driven by fishing to very low level of abundance compared to historical levels, with dramatically reduced spawning biomass and reproductive capacity. It requires particularly energetic rebuilding

strategies and its recovery time will depend on the present condition, the level of protection, and the environmental conditions.

Directed Fishery*
Fishing that is directed at a certain species or group of species. This applies to both sport and commercial fishing.

Discard*
To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Economic Overfishing*
A level of fish harvesting that is higher than that of economic efficiency; harvesting more fish than necessary to have maximum profits for the fishery.

Economic Value*
The most people are willing to pay to use a given quantity of a good or service; or, the smallest amount people are willing to accept to forego the use of a given quantity of a good or service.

Ecosystem Approach to Fisheries (EAF)*
An approach to fisheries management that strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. The purpose of EAF is to plan, develop, and manage fisheries in a manner that addresses the multiple needs and desires of society, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems.

Ecosystem Approach to Management (EAM)*
Management that is adaptive, is specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives.

Ecosystem Function*
An intrinsic ecosystem characteristic related to the set of conditions and processes whereby an ecosystem maintains its integrity. Ecosystem functions include such processes as decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem-Based Management*
An approach that takes major ecosystem components and services—both structural and functional—into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes. Its goal is to rebuild and sustain populations, species, biological communities, and marine ecosystems at high levels of productivity and biological diversity so as not to jeopardize a wide range of goods and services from marine ecosystems while providing food, revenue, and recreation for humans.

Equilibrium Catch*
The catch (in numbers) taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from the effects of environmental variation) its abundance is not changing from one year to the next.

Equilibrium Yield (EY)*
The yield in weight taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next. Also called: sustainable yield, equivalent sustainable yield.

Escapement*
The number or proportion of fish surviving (escaping from) a given fishery at the end of the fishing season and reaching the spawning grounds. The term is generally used for salmon management.

Exclusive Economic Zone (EEZ)*
The EEZ is the area that extends from the seaward boundaries of the coastal states (3 nautical miles (n.mi.) in most cases, the exceptions are Texas, Puerto Rico and the Gulf coast of Florida at 9 n.mi.) to 200 n.mi. off the U.S. coast. Within this area the United States claims and exercises sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources.

Existence Value*
The economic value of knowing that a resource exists, irrespective of the ability to use the resource now or in the future.9

Exploitable Biomass*
Refers to that portion of a stock's biomass that is available to fishing.

Exploitation**
The annual percentage of the stock removed by fishing either recreationally or commercially.

Exploitation Pattern*
The distribution of fishing mortality over the age composition of the fish population, determined by the type of fishing gear, area and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear; for example, increasing mesh or hook size, or by changing the ratio of harvest by gears exploiting the fish (e.g. gillnet, trawl, hook and line, etc.).

Exploitation Rate*
The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Ex-Vessel*
Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain (at the point of landing) for the catch is an ex-vessel price.

Fecundity*
The potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity usually increases with age and size. The information is used to compute spawning potential.

Fish Passage**
The movement of fish above or below an river obstruction, usually by fish-lifts or fishways.

Fish Passage Efficiency**
The percent of the fish stock captured or passed through an obstruction (i.e., dam) to migration.

Fishery-Dependent*
Data collected directly on a fish or fishery from commercial or sport fishermen and seafood dealers. Common methods include logbooks, trip tickets, port sampling, fishery observers, and phone surveys. (see *Fishery-Independent*)

Fishery-Independent*
Characteristic of information (e.g. stock abundance index) or an activity (e.g. research vessel survey) obtained or undertaken independently of the activity of the fishing sector. Intended to avoid the biases inherent to fishery-related data. (see *Fishery-Dependent*)

Fishery Management Unit (FMU)*
A fishery or a portion of a fishery identified in a fishery management plan (FMP) relevant to the FMP's management objectives. The choice of stocks or species in an FMU depends upon the focus of FMP objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives.

Fishing Mortality (F)*
1. F stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year;
2. A measurement of the rate of removal from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in one year. Instantaneous mortality is that percentage of fish dying at any one time.

F_{30}
The fishing mortality rate that reduces the spawning stock biomass per recruit (SSB/R) to 30% of the amount present in the absence of fishing.

F_{MSY}*
The fishing mortality rate that, if applied constantly, would result in maximum sustainable yield (MSY). Used as a biological reference point, FMSY is the implicit fishing mortality target of many regional and national fishery management authorities and organizations. F_{MSY} can be estimated in two ways: a) from simple biomass aggregated production models; b) from age-structured models that include a stock-recruitment relationship.

F_{MAX}*
1. The level of fishing mortality (rate of removal by fishing) that produces the greatest yield from the fishery;
2. A biological reference point. It is the fishing mortality rate that maximizes equilibrium yield per recruit. FMAX is the F level often used to define growth overfishing. In general, FMAX is different (and higher) than FMSY depending on the stock-recruitment relationship. By definition, FMAX is always higher than $F_{0.1}$.

Index of Abundance*
A relative measure of the abundance of a stock; for example, a time series of catch per unit effort data.

Indicators*
1. A variable, pointer, or index. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and action;

2. Signals of processes, inputs, outputs, effects, results, outcomes, impacts, etc., that enable such phenomena to be judged or measured. Both qualitative and quantitative indicators are needed for management learning, policy review, monitoring, and evaluation;
3. In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions, good or bad.

Instantaneous Rate of Fishing Mortality (F)*
When fishing and natural mortality act concurrently, F is equal to the instantaneous total mortality rate, multiplied by the ratio of fishing deaths to all deaths. Also called: rate of fishing; instantaneous rate of fishing.

Instantaneous Rate of Mortality (Z)*
When fishing and natural mortality act concurrently, the natural logarithm of the survival rate (with sign changed) for deaths due to either natural causes (instantaneous rate of natural mortality, M) or due to fishing mortality (instantaneous rate of fishing mortality,
F). The instantaneous rate of total mortality, Z, is the sum of these two rates: $Z = F + M$, also called the coefficient of decrease.

Comment: Usually given on a yearly basis; the figure just described is divided by the fraction of a year represented by the "short interval" in question. This concept is used principally when the size of the vulnerable stock is not changing or is changing only slowly, since among fishes recruitment is not usually associated with stock size in the direct way in which mortality and growth are.

Larvae
Fish developmental stage well differentiated form the later young-of-year and juvenile stages and intervening between the time of hatching and time of transformation or loss of larval character (i.e., fish resembles a young or juvenile individual by absence of a yolk sac, and presence of continuous finfolds and pigmented young-of-year character).

Life Cycle*
Successive series of changes through which an organism passes in the course of its development.

Limit Reference Points*
Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines, limits are referred to as thresholds. In much of the international literature (e.g. United Nations Food and Agricultural Organization, FAO) thresholds are used as buffer points that signal when a limit is being approached.

M
(see Natural Mortality)

Management Objective*
A formally established, more or less quantitative target that is actively sought and provides a direction for management action.

Management Reference Points*
Conventional (agreed values) of indicators of the desirable or undesirable state of a fishery resource of the fishery itself. Reference points could be biological (e.g. expressed in spawning biomass or fishing mortality levels), technical (fishing effort or capacity levels) or economic (employment or revenues levels). They are usually calculated from models in which they may represent critical values.

Management Strategy*
The strategy adopted by the management authority to reach established management goals. In addition to the objectives, it includes choices regarding all or some of the following: access rights and allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations (e.g. calendar, closed areas, and seasons).

Mature Individuals*
The number of individuals known, estimated, or inferred to be capable of reproduction.

Maturity*
Refers to the ability, on average, of fish of a given age or size to reproduce. Maturity information, in the form of percent mature by age or size, is often used to compute spawning potential.

Maximum Spawning Potential (MSP)*
This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit (SSB/R) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e. %MSP). A stock is considered overfished when the fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock-recruitment data or chosen by analogy using available information on the level required to sustain the stock.

Maximum Sustainable Yield (MSY)*
The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others. Also called: maximum equilibrium catch; maximum sustained yield; sustainable catch.

Minimum Stock Size Threshold (MSST, $B_{threshold}$)*
Another of the status determination criteria (SDC). The greater of (a) 1/2 B_{MSY} , or (b) the minimum stock size at which rebuilding to B_{MSY} will occur within 10 years while fishing at the maximum fishing mortality threshold (MFMT). MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $B_{threshold}$, the stock is overfished.

Moratorium*
A mandatory cessation of fishing activities on a species (e.g. the blue whale), in an area (e.g. a sanctuary), with a particular gear (e.g. large scale driftnets), and for a specified period of time (temporary, definitive, seasonal, or related to reopening criteria).

Mortality*
Measures the rate of death of fish. Mortality occurs at all life stages of the population and tends to decrease with age. Death can be due to several factors such as pollution, starvation, and disease but the main source of death is predation (in unexploited stocks) and fishing (in exploited ones).

Mortality Rate*
The rate at which the numbers in a population decrease with time due to various causes. Mortality rates are critical parameters in determining the effects of harvesting strategies on stocks, yields, revenues, etc. The proportion of the total stock (in numbers) dying each year is called the "annual mortality rate."

Native Species*
A local species that has not been introduced. (see *Introduced Species, Invasive Species*)

Natural Mortality (M)*
1. Deaths of fish from all causes except fishing (e.g. ageing, predation, cannibalism, disease, and perhaps increasingly pollution). It is often expressed as a rate that indicates the percentage of fish dying in a year; e.g. a natural mortality rate of 0.2 implies that approximately 20 percent of the population will die in a year from causes other than fishing;
2. The loss in numbers in a year class from one age group to the subsequent one, due to natural death.

Comment: These many causes of death are usually lumped together for convenience, because they are difficult to separate quantitatively. Sometimes natural mortality is confounded with losses of fish from the stock due to emigration. M has proven very difficult to estimate directly, and is often assumed based on the general life history. The M value is also often assumed to remain constant through time and by age, a very unlikely assumption.

Natural Mortality (M)**
The instantaneous rate at which fish die from all causes other than harvest or other human-induced cause (i.e., turbine mortality). Some sources of natural mortality include predation, spawning mortality, and senescence (old age).

Non-Consumptive Use*
Individuals may use (i.e. observe), yet not consume, certain living ocean resources, like whale watching, sight-seeing, or scuba diving. Additionally, individuals might value the mere existence of living ocean resources without actually observing them.

Non-Point Sources*
Sources of sediment, nutrients, or contaminants that originate from many locations.

Non-Target Species*
Species not specifically targeted as a component of the catch; may be incidentally captured as part of the targeted catch.

Ocean-Intercept Fishery**
A fishery for American shad conducted in state or federal ocean waters targeting the coastal migratory mixed-stock of American shad.

Optimum Yield (OY)*
1. The harvest level for a species that achieves the greatest overall benefits, including economic, social, and biological considerations. Optimum yield (OY) is different from maximum sustainable yield (MSY) in that MSY considers only the biology of the species. The term includes both commercial and sport yields;
2. The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. MSY constitutes a "ceiling" for OY. OY may be lower than MSY, depending on relevant economic, social, or ecological factors. In the case of an overfished fishery, OY should provide for the rebuilding of the stock to
BMSY.

Overexploited*
When stock abundance is too low. The term is used when biomass has been estimated to be below a limit biological reference point that is used as the threshold that defines "overfished conditions."

Overfished*
1. An overfished stock or stock complex "whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding." A stock or stock complex is considered overfished when its population size falls below the minimum stock size threshold (MSST). A rebuilding plan is required for stocks that are deemed overfished;
2. A stock is considered "overfished" when exploited beyond an explicit limit beyond which its abundance is considered 'too low' to ensure safe reproduction. In many fisheries the term is used when biomass has been estimated to be below a limit biological reference point that is used as the signpost defining an "overfished condition." This signpost is often taken as being F_{MSY}, but the usage of the term may not always be consistent. (see *Minimum Stock Size Threshold*)

Comment: The stock may remain overfished (i.e. with a biomass well below the agreed limit) for some time even though fishing pressure might be reduced or suppressed.

Overfishing*
1. According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis." Overfishing is occurring if the maximum fishing mortality threshold (MFMT) is exceeded for 1 year or more;
2. In general, the action of exerting fishing pressure (fishing intensity) beyond the agreed optimum level. A reduction of fishing pressure would, in the medium term, lead to an increase in the total catch. (see *National Standard Guidelines*, *Maximum Fishing Mortality Threshold*, *Maximum Sustainable Yield*)

Comment: For long-lived species, overfishing (i.e. using excessive effort) starts well before the stock becomes overfished. The use of the term "overfishing" may not always be consistent.

Overfishing Limit (OFL)*
Point at which fishing seriously compromised a fishery's continued, sustained productivity. Overfishing limits may be set based on standardized biological criteria established for a particular fishery. Overfishing limits may also incorporate economic and social considerations relevant to a particular fishery.

Oxytetracycline (OTC)**
An antibiotic used to internally mark otoliths of hatchery produced fish.

Predation*
Relationship between two species of animals in which one (the predator) actively hunts and lives off the meat and other body parts of the other (the prey).

Pre-Recruits*
Fish that have not yet reached the recruitment stage (in age or size) to a fishery.

Production*
1. The total output especially of a commodity or an industry;
2. The total living matter (biomass) produced by a stock through growth and recruitment in a given unit of time (e.g. daily, annual production). The "net production" is the net amount of living matter added to the stock during the time period, after deduction of biomass losses through mortality;
3. The total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time.

Production Model*

1. The highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process. Also referred to sometimes as potential yield;
2. Maximum sustainable yield (MSY) or sustainable yield (SY). The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others. (see *Carrying Capacity*, *Maximum Sustainable Yield*, *Sustainable Yield*)

Productivity*

Relates to the birth, growth and death rates of a stock. A highly productive stock is characterized by high birth, growth, and mortality rates, and as a consequence, a high turnover and production to biomass ratios (P/B). Such stocks can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive stocks.

Rebuilding*

1. Implementing management measures that increase a fish stock to its target size1; 2. For a depleted stock, or population, taking action to allow it to grow back to a predefined target level. Stock rebuilding at least back to the level (BMSY) at which a stock could produce maximum sustainable yield (MSY).

Rebuilding Analysis*

An analysis that uses biological information to describe the probability that a stock will rebuild within a given time frame under a particular management regime.

Rebuilding Plan*

1. A document that describes policy measures that will be used to rebuild a fish stock that has been declared overfished;
2. A plan that must be designed to recover stocks to the BMSY level within 10 years when they are overfished (i.e. when biomass [B] < minimum stock size threshold [MSST]). (see *Minimum Stock Size Threshold*)

Recruit*

1. A young fish entering the exploitable stage of its life cycle;
2. A member of "the youngest age group which is considered to belong to the exploitable stock."

Recruitment (R)*

1. The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year;
2. This term is also used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age 2 recruits.

Recruitment Overfishing*

A situation in which the rate of fishing is (or has been) such that annual recruitment to the exploitable stock has become significantly reduced. The situation is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year. If prolonged, recruitment overfishing can lead to stock collapse, particularly under unfavorable environmental conditions.

Recruits*
The numbers of young fish that survive (from birth) to a specific age or grow to a specific size. The specific age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

Reference Level*
A particular level of an indicator (e.g. level of fishing effort, fishing mortality, or stock size) used as a benchmark for assessment and management performance.

Reference Point*
1. A reference point indicates a particular state of a fishery indicator corresponding to a situation considered as desirable (target reference point) or undesirable and requiring immediate action (limit reference point and threshold reference point);
2. An estimated value derived from an agreed scientific procedure and/or model, which corresponds to a specific state of the resource and of the fishery, and that can be used as a guide for fisheries management. Reference points may be general (applicable to many stocks) or stock-specific;
3. Values of parameters (e.g. B_{MSY}, F_{MSY}, $F_{0.1}$) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability (e.g. MSST) or targets for management (e.g. OY).

Relative Exploitation**
An approach used when catch is known or estimated, but no estimates of abundance are available. For example, it may be calculated as the catch divided by a relative index of abundance. Long-term trends in relative exploitation are can be useful in evaluating the impact of fishing versus other sources of mortality.

Restoration**
In this assessment, this describes the stocking of hatchery produced young-of-year American shad to augment wild cohorts and the transfer of adult American shad to rivers with depleted spawning stocks. Restoration also includes efforts to improve fish passage or remove barriers to migration.

Risk*
1. In general, the possibility of something undesirable happening, of harm or loss. A danger or a hazard. A factor, thing, element, or course involving some uncertain danger;
2. In decision-theory, the degree or probability of a loss; expected loss; average forecasted loss. This terminology is used when enough information is available to formulate probabilities;
3. The probability of adverse effects caused under specified circumstances by an agent in an organism, a population, or an ecological system.

Risk Assessment*
A process of evaluation including the identification of the attendant uncertainties, of the likelihood and severity of an adverse effect(s)/event(s) occurring to man or the environment following exposure under defined conditions to a risk source(s). A risk assessment comprises hazard identification, hazard characterization, exposure assessment, and risk characterization.

Risk Management*
The process of weighing policy alternatives in the light of the result of a risk assessment and other relevant evaluation and, if required, selecting and implementing appropriate control options (which should, where appropriate, include monitoring or surveillance).

River Complex
The freshwater portions of an Atlantic coast river, and its associated tributaries and estuary that encompass the freshwater migration, spawning, and nursery habitat for an American shad stock.
Robustness*
The capacity of a population to persist in the presence of fishing. This depends on the existence of compensatory mechanisms. (see *Reliability*)

Run*
Seasonal migration undertaken by fish, usually as part of their life history; for example, spawning run of salmon, upstream migration of shad. Fishers may refer to increased catches as a “run” of fish, a usage often independent of their migratory behavior.

Run Size**
The magnitude of the upriver spawning migration of American shad.

Semelparous**
Life history strategy in which an organism only spawns once before dying.

Spawning Biomass*
The total weight of all sexually mature fish in the population.

Spawning Ground
The area of suitable spawning habitat associated with a stock.

Spawning Stock*
1. Mature part of a stock responsible for reproduction;
2. Strictly speaking, the part of an overall stock having reached sexual maturity and able to spawn. Often conventionally defined as the number or biomass of all individuals beyond “age at first maturity” or “size at first maturity”; that is, beyond the age or size class in which 50 percent of the individuals are mature.

Spawning Stock Biomass (SSB)*
1. The total weight of all fish (both males and females) in the population that contribute to reproduction. Often conventionally defined as the biomass of all individuals beyond “age at first maturity” or “size at first maturity,” i.e. beyond the age or size class in which 50 percent of the individuals are mature;
2. The total biomass of fish of reproductive age during the breeding season of a stock.

Comment: Most often used as a proxy for measuring egg production, the SSB depends on the abundance of the various age classes composing the stock and their past exploitation pattern, rate of growth, fishing and natural mortality rates, onset of sexual maturity, and environmental conditions.

Spawning Stock Biomass**
The total weight of mature fish (often females) in a stock.

Spawning Stock Biomass per Recruit (SSB/R or SBR)*
The expected lifetime contribution to the spawning stock biomass for the average recruit, SSB/R is calculated assuming that fishing mortality is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

Standing Stock*
1. The total weight of a group (or stock) of living organisms (e.g. fish, plankton) or of some defined fraction of it (e.g. spawners), in an area, at a particular time. Example: the spawning biomass of the cod stock on the Georges Bank in 1999;
2. The weight of a fish stock or of some defined portion of it. (see *Abundance*)

Stock*
A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. A fish stock may be treated as a total or a spawning stock. Total stock refers to both juveniles and adults, either in numbers or by weight, while spawning stock refers to the numbers or weight of individuals that are old enough to reproduce.

Comment: In theory, a unit stock is composed of all the individual fish in an area that are part of the same reproductive process. It is self-contained, with no emigration or immigration of individuals from or to the stock. On practical grounds, however, a fraction of the unit stock is considered a "stock" for management purposes (or a management unit), as long as the results of the assessments and management remain close enough to what they would be on the unit stock.

Stock-Recruitment Relationship (SRR)*
The relationship between the level of parental biomass (e.g. spawning stock size) and subsequent recruitment level. Determination of this relationship is useful to analyze the sustainability of alternative harvesting regimes and the level of fishing beyond which stock collapse is likely. The relation is usually blurred by environmental variability and difficult to determine with any accuracy.

Comment: Such a relationship always exists in principle, in that the existence of a parent stock is a prerequisite for the generation of recruitment. However, in many cases there exist regulatory mechanisms such that the number of recruits is not strongly related to the parent stock size over the range of stock sizes observed: this situation is sometimes described as the absence of a stock recruitment relationship, but is more logically described as a special case of a stock-recruitment relationship. Some stock assessment methods incorporate the estimation of such a relationship directly into the model, either explicitly (e.g. some age-structured assessments) or implicitly (most stock production models).

Stock Status**
The agreed perspective of the SASC of the relative level of fish abundance.

Sub-adult**
Juvenile American shad which are part of the ocean migratory mixed stock fish.

Surplus Production*
1. The amount of biomass produced by the stock (through growth and recruitment) over and above that which is required to maintain the total stock biomass at a constant level between consecutive time periods;
2. Production of new biomass by a fishable stock, plus recruits added to it, less what is removed by natural mortality. This is usually estimated as the catch in a given year plus the increase in stock size (or less the decrease). Also called: natural increase, sustainable yield, and equilibrium catch.

Survival Rate*
Number of fish alive after a specified time interval, divided by the initial number. Usually on a yearly basis.

Survival Ratio*
1. Ratio of recruits to spawners (or parental biomass) in a stock-recruitment analysis. Changes in survival ratios indicate that the productivity of a stock is changing;
2. Number of fish alive after a specified time interval, divided by the initial number. Usually calculated on a yearly basis.

Sustainability*
1. Ability to persist in the long-term. Often used as "short hand" for sustainable development;
2. Characteristic of resources that are managed so that the natural capital stock is non-declining through time, while production opportunities are maintained for the future.

Sustainable Catch (Yield)*
The number (weight) of fish in a stock that can be taken by fishing without reducing the stock biomass from year to year, assuming that environmental conditions remain the same.

Sustainable Fishery
Systems that demonstrate their stocks could support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment.

Sustainable Fishing*
Fishing activities that do not cause or lead to undesirable changes in the biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next.
Comment: Fishing is sustainable when it can be conducted over the long-term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations.

Sustainable Yield*
1. Equilibrium yield;
2. The amount of biomass or the number of units that can be harvested currently in a fishery without compromising the ability of the population/ecosystem to regenerate itself.

Target Reference Point (TRP)*
1. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g. optimum yield, OY). Target reference points should not be exceeded on average;
2. Corresponds to a state of a fishery or a resource that is considered desirable. Management action, whether during a fishery development or a stock rebuilding process, should aim at bringing the fishery system to this level and maintaining it there. In most cases a TRP will be expressed in a desired level of output for the fishery (e.g. in terms of catch) or of fishing effort or capacity, and will be reflected as an explicit management objective for the fishery.

Target Species*
Those species primarily sought by the fishermen in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species.

Thresholds*
1. Levels of environmental indicators beyond which a system undergoes significant changes; points at which stimuli provoke significant response;
2. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain

point, and then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Total Mortality (Z)*
1. A measurement of the rate of removal of fish from a population by both fishing and natural causes. Total mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in 1 year. Instantaneous mortality is that percentage of fish dying at any one time;
2. The sum of natural (M) and fishing (F) mortality rates.

Turbine Mortality**
American shad mortalities that are caused by fish passing through the turbines of hydroelectric dams during return migrations to the sea.

Unit Stock*
A population of fish grouped together for assessment purposes, which may or may not include all the fish in a stock. (see *Stock*)

Variable*
Anything changeable. A quantity that varies or may vary. Part of a mathematical expression that may assume any value.

Virgin Biomass (B_0)*
The average biomass of a stock that has yet not been fished (in an equilibrium sense). Biomass of an unexploited (or quasi unexploited) stock. Rarely measured. Most often inferred from stock modeling. Used as a reference value to assist the relative health of a stock, monitoring changes in the ratio between current and virgin biomass (B/B_0). It is usually assumed that, in absence of better data, $B = 0.30\ B_0$ is a limit below which a stock should not be driven.

Comment: Virgin Biomass corresponds to a stock's theoretical carrying capacity.

Vulnerability*
A term equivalent to catchability (*q*) but usually applied to separate parts of a stock, for example those of a particular size, or those living in a particular part of the range.

Water Quality*
The chemical, physical, and biological characteristics of water in respect to its suitability for a particular purpose.

Water Quality Criteria*
Specific levels of water quality desired for identified uses, including drinking, recreation, farming, fish production, propagation of other aquatic life, and agricultural and industrial processes.

Watershed*
The areas which supplies water by surface and subsurface flow from rain to a given point in the drainage system.

Year Class*
Fish in a stock born in the same year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on. Occasionally, a stock produces a

very small or very large year class that can be pivotal in determining stock abundance in later years. (see *Cohort*)

Yield*

1. The yield curve is the relationship between the expected yield and the level of fishing mortality or (sometimes) fishing effort;
2. Catch in weight. Catch and yield are often used interchangeably. Amount of production per unit area over a given time. A measure of agricultural production.

Yield per Recruit (Y/R or YPR)*

1. A model that estimates yield in terms of weight, but more often as a percentage of the maximum yield, for various combinations of natural mortality, fishing mortality, and time exposed to the fishery;
2. The average expected yield in weight from a single recruit. Y/R is calculated assuming that fishing mortality is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are assumed to be constant.

Yield-per-Recruit Analysis*

Analysis of how growth, natural mortality, and fishing interact to determine the best size of animals at which to start fishing them, and the most appropriate level of fishing mortality. The yield-per-recruit models do not consider the possibility of changes in recruitment (and reproductive capacity) due to change in stock size. They also do not deal with environmental impacts.

Young-of-Year

(see Age 0)

Z

(see Total Mortality)

Appendix A – Economic Trends

An analysis of ex-vessel value trends for American shad landings, 1980 through 2007.
Raymond Rhodes, College of Charleston, Charleston, SC

Ex-vessel values reported with all U.S. Atlantic American shad landings during the 1980-2007 were used as an overall indicator of recent shad ex-vessel value trends (Table 1). The nominal total (aggregate) ex-vessel value of the U.S. Atlantic coast American shad harvest has ranged from a low of about $540,000 in 2006, after the ocean-intercept fishery closure was implemented in 2005 by all Atlantic states, to a high of over $2 million in 1984 (Table 1)**.** This 1984 value was also highest nominal total ex-vessel value reported since 1949 and associated with modest resurgences of shad landings previously described during the 1980's. Annual average nominal, ex-vessel value during the 1980-1993 period, ~$1.5 million, declined to an average of about $969,000 after 1993 (Table 1). Moreover, when shad total ex-vessel values are adjusted for inflation using the Producer Price Index[1], the average total ex-vessel value of American shad landings was only about $730,000 coastwide after 1993 (Table 1), only 52% of the total real ex-vessel value for previous period (1980-1993). Since 1980, nominal U.S. Atlantic coast dockside prices per pound for American shad have generally varied over time (Figure 2) but it did increase substantially after 2004 and peaked at $1.02 per pound in 2005 (Table 1), the first year of the ocean-intercept fishery closure. In contrast, the U.S. Atlantic real (deflated) price peaked in 1994 at a ~$0.77 per pound. The average real ex-vessel price for American shad during the 1993-2007 period, ~$0.53 per pound, was only about 26% higher than the average real ex-vessel price, $0.42 per pound, during the previous 14-year period despite declining stocks and related state various imposed moratoriums during the 1990's.

American shad data (see Table 1) were used to estimate a simple annual ex-vessel price model for characterizing how changes in American shad landings could have recently affected ex-vessel market prices. The following semi-log price model[2] was specified:

$$\textit{Real Ex-vessel Price}_t = \alpha + \beta(\ln)\textit{Landings}_t;$$

where the *Real Ex-vessel Price* is the observed annual (deflated) ex-vessel price per pound for American shad landings in U.S. Atlantic states, *(ln)Landings* is the natural log of the annual amount (poundage) of reported landings, *t* is time and α and β are parameter coefficients to be estimated for the above model. There are many complicated models or functional forms that could be used to explore the relationship between landings and ex-vessel prices but the choice of this semi-linear form was based on the limitations of the available data and the related need to have a relatively simple price model that is capable of adequately representing the variation in American shad ex-vessel prices associated with different levels of landings. Additionally, since the expected relationship between reported landings and ex-vessel prices is not likely to be linear, a semi-log (non-linear) functional form was selected. The semi-log model was estimated using ordinary least squares (OLS).

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[1]Given the scope of this analysis, the Producer Price Index was selected for deflating ex-vessel prices out of convenience. Regardless, deflating prices should be approached with caution especially when applying consumer oriented price index series to producer prices (Tomek & Robinson 2003).
[2]This simple model is often described as an inverse semi-log demand model; however, it usually includes more than one explanatory (independent) variable.

The estimated model parameters were the following:

$$\begin{aligned}&\textit{Real Ex-vessel Price}_t = 2.201 - 0.118(\ln)\textit{Landings}_t\\&\textit{t-Statistics:} \quad (5.280)\ (-4.140)\\&\textit{Durbin-Watson statistic:} \quad 0.854\end{aligned}$$

The adjusted R^2 was 0.374 (N=28) and the F-value (17.144) for the equation was significant ($p \leq 0.0001$).

The t-statistic for the American shad landings parameter is statistically significant at the 1% level, and landings are estimated to be negatively (inversely) related to annual American shad ex-vessel price. The estimated model as indicated by the R^2 "explains" only about 37% of the ex-vessel price trend variability during the 1980-2007 period. Of course, a more complex supply-demand system is definitely needed to consider many other factors (e.g., fishery regulatory actions, American shad substitutes, regional market structure changes, etc.) that may have influenced American shad ex-vessel prices. Regardless, the inverse relationship between prices and landings is consistent with supply-demand relationship over a relatively long time period (i.e., 21 years). Using the estimated coefficient of the landings parameter, *– 0.118*, and the means of the annual prices and quantities landed, the price flexibility[3], F_P, was estimated to be approximately *–3.6*. While recognizing the limitations of this simple price trend analysis, the calculated F_P value suggests that the ex-vessel own-price elasticity of demand for American shad during the years analyzed and perhaps American shad in general is inelastic since the absolute value of F_P coefficient is greater than one (Tomek and Robinson 2003).

This apparent relative flexibility of If American shad ex-vessel prices were relatively flexible in regard to its own landings during the 1980-2007 period, this may have also been symptomatic of a market that could have historically encouraged harvesters to actually escalate their fishing effort because they perceived an ex-vessel market segment with the potential of offsetting declining harvest quantities with higher ex-vessel prices. For open access fisheries, flexible prices (i.e., relatively inelastic demand) along with other factors have been implicated in the depletion of various fishery stocks (e.g., Brandt 1999). Consequently, from a historical perspective, total revenue changes at the harvester level associated with declining American shad stocks, including declines independent of commercial fishing effort, such as habitat degradation, may have been partially buffered if American shad prices were generally flexible relative to its own landings.

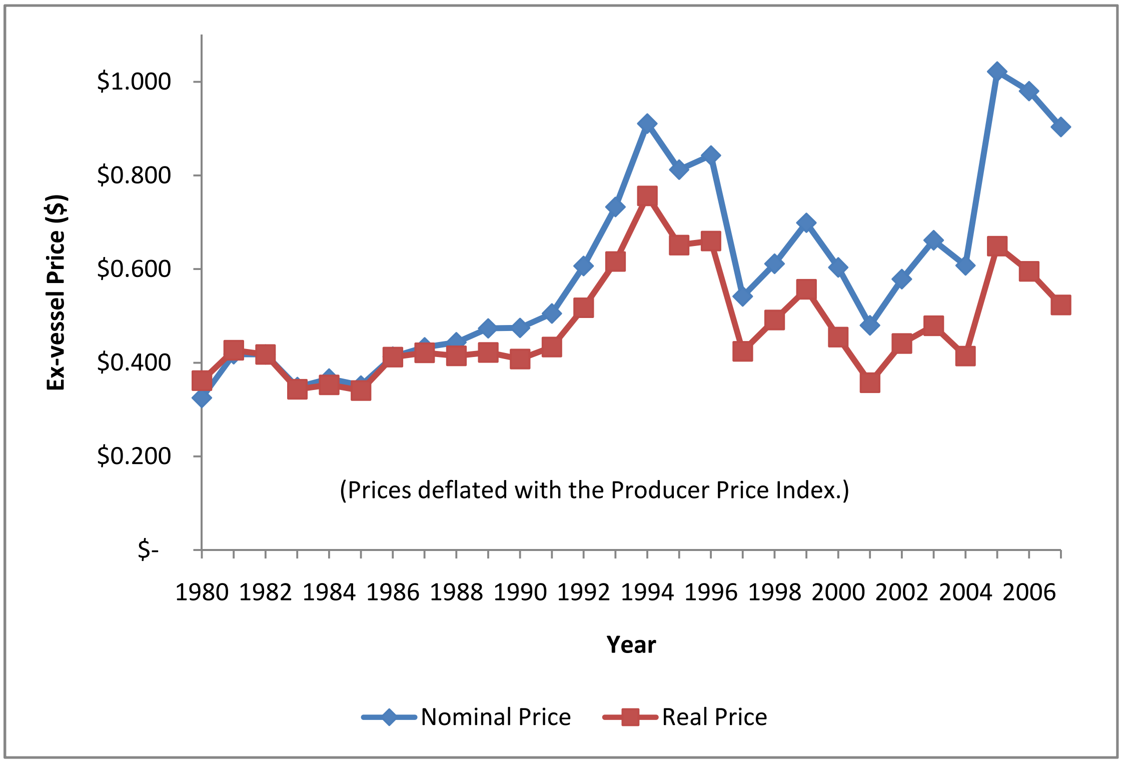
[3]It is actually the estimated own-price flexibility coefficient which is predicated on the causality of price changes stemming from quantity changes to the ex-vessel price, instead of the usual price to quantity causality (Tomek & Robinson 2003).

Table 1. Total annual U.S. Atlantic landings, ex-vessel values and prices of the American shad as reported to the National Marine Fisheries Service, 1980-2007 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

	Landings	Total Ex-vessel Value ($):		Ex-vessel Price ($/lb):	
Year	(Lbs)	Nominal	Real[a]	Nominal	Real
1980	3,558,690	1,156,135	1,287,455	0.325	0.362
1981	3,207,067	1,341,312	1,368,686	0.418	0.427
1982	2,891,200	1,207,413	1,207,413	0.418	0.418
1983	3,753,052	1,305,500	1,288,746	0.348	0.343
1984	5,549,458	2,030,236	1,957,797	0.366	0.353
1985	3,994,868	1,403,789	1,360,261	0.351	0.341
1986	3,526,570	1,455,594	1,452,689	0.413	0.412
1987	3,801,049	1,646,246	1,601,407	0.433	0.421
1988	3,781,141	1,676,451	1,568,242	0.443	0.415
1989	3,521,651	1,666,895	1,485,646	0.473	0.422
1990	3,559,078	1,688,504	1,451,852	0.474	0.408
1991	2,829,719	1,429,109	1,226,703	0.505	0.434
1992	2,435,435	1,476,891	1,260,146	0.606	0.517
1993	2,015,913	1,476,996	1,242,217	0.733	0.616
1994	1,494,092	1,360,658	1,130,115	0.911	0.756
1995	1,637,349	1,329,852	1,066,441	0.812	0.651
1996	1,582,837	1,333,969	1,044,612	0.843	0.660
1997	1,833,467	992,832	778,082	0.542	0.424
1998	2,175,395	1,329,858	1,069,018	0.611	0.491
1999	1,406,080	982,818	783,122	0.699	0.557
2000	1,675,359	1,011,091	761,937	0.604	0.455
2001	1,490,404	714,801	532,639	0.480	0.357
2002	1,643,238	950,372	724,921	0.578	0.441
2003	1,509,898	998,804	723,247	0.662	0.479
2004	1,136,520	690,619	470,770	0.608	0.414
2005	609,592	622,779	395,666	1.022	0.649
2006	550,664	539,755	327,720	0.980	0.595
2007	776,316	701,408	406,378	0.904	0.523
Means, All Years:		**$ 1,151,690**	**$ 535,249**	**$ 0.534**	**$ 0.477**
Means, 1980-1993:		**$ 1,497,219**	**$ 1,411,376**	**$ 0.450**	**$ 0.421**
Means, 1994-2007:		**$ 968,544**	**$ 729,619**	**$ 0.732**	**$ 0.532**

[a]Total ex-vessel values and prices deflated with the Producer Price Index.

Figure 1. Real and nominal ex-vessel price ($/lb) for U.S. Atlantic American shad landings, 1980-2007 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).



Appendix B - Historic and current festivals, races and tournaments held in celebration of American shad spawning migrations

The following is a preliminary list of historic and current American shad festivals. This list is not comprehensive and is subject to update and modification. If you have any information of the status of listed events, or know of additional events not included, please contact Kate Taylor, Shad and River Herring FMP Coordinator, at ktaylor@asmfc.org.

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Great American Shad Run	Manchester, NH	Unknown	June 18, 2000	Unknown
Connecticut River Museum Shad Festival	Essex, CT	Connecticut River Museum;	May 14, 2005 May 20, 2006 May 19, 2007	Unknown
Connecticut River Shad Bake [www.essexrotary.com/fundraisers/CT-Shad-Bake-Picnic/index.html]	Essex, CT	Essex Elementary School; Essex Rotary Club	June 6, 2009	51st annual, Active
Planked Shad Supper	Old Saybrook, CT	Connecticut Freemasons, Siloam Lodge #32	2005	Active?
Shad Derby Festival [www.windsorshadderby.org/events]	Windsor, CT	Shad Fest Bureau, Windsor Jaycees, Chamber of Commerce, Rod and Gun Club, others	May 2-4, 2009	Begun 1954, Active
Holyoke Gas and Electric Shad Derby [www.hged.com/html/shadderby.html]	Holyoke, MA	Holyoke Gas and Electric Company	May 10-18, 2008 May 2009	Begun 2003, Active
Shad Bake and Native American Technology Day [www.naihrv.org/]	Albany, NY	Corning Preserve; Native American Institute of the Hudson River Valley	May 11, 2008 May 16, 2009	Active
Shad Festival	Beacon, NY	Unknown	May , 1987	Believed to be inactive since 1993
Hudson Day	Bronx, NY	Unknown	June 14, 1987	Unknown

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Hudson River Shad Festival [www.midhudsonnews.com/Catskill.htm]	Catskill, NY	The Catskill Point; Hudson River Foundation	May 21, 2005 May 21, 2009	Active
Annual Shad Bake and Country Barbecue [www.clctrust.org/Shad]	Chatham, NY	Columbia Land Conservancy	May 29, 2005	Active; but shad dropped from title for 2009
Riverlovers Shadfest [www.riverlovers.org/shadfest.htm]	Croton-on-Hudson, NY	Croton Point Park; Westchester County Parks, Riverlovers, Inc.	May 16, 2004 May 20, 2007 May 18, 2008 May 17, 2009	Active
Riverkeeper Shad Festival [www.riverkeeper.org]	Garrison, NY	Historic Boscobel Mansion; Boscobel Restoration	May 15, 2005 May 18, 2008	20^{th} anniversary event will occur in 2010
Rondout Shad Festival [www.hrmm.org/museum/festival.htm]	Kingston, NY	Rondout; Hudson River Maritime Museum	May 12, 2007 May 10, 2008	Unknown
Drums Along the Hudson: a Native American Festival and Shad Fest [www.drumsalongthehudson.org/]	Manhattan, NY	Inwood Hill Park; New York City Department of Parks and Recreation, Lotus Music and Dance, WABC-TV, New York City Department of Cultural Affairs	April 30, 2006 May 3, 2008 May 17, 2009	Active; but shad dropped from title for 2009
Shad Festival	Montrose, NY	George's Island Park; Ferry Sloops, Inc.	May, 1987 May 16, 1993	Unknown
Shad Festival	North Tarrytown, NY	?; Hudson River Foundation	May, 1987	Unknown
Nyack Shad Festival, aka Riverfest	Nyack, NY	Nyack Waterfront Park; Hudson River Foundation, Clearwater, Friends of the Nyacks	May 14, 2005 May 5, 2007	Unknown
Hudson River Festival and Shad Bake	Sparkill, NY	St. Charles A.M.E. Zion Church	April 30, 1994 April 30, 2005	Unknown
Shad Festival	Yonkers, NY	John Fitzgerald Kennedy Marina; Ferry Sloops, Inc.	April 25, 1993	Unknown

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Annual Shad Bake	Edgewater, NJ	Veterans' Field; Farrell Huber American Legion Hall Post	June 6, 1987	Unknown
Shad Fest 2009 [bestofnj.com/2009/04/03/shad-fest-saturday-april-25-sunday-april-26-lambertville/]	Lambertville, NJ	multiple venues, multiple sponsors, including Lewis Island; Delaware River Basin Commission	April 26-27, 2008 April 25-26, 2009	Active
Hooked on the Hudson [www.stripedbassderby.com/HOH/]	Fort Lee, NJ	Ross Dock Recreation Area; Palisades Interstate Park Commission, Hudson River Fishermen's Association, others	May, 1987 May 6, 2001 April 25, 2009	Active; but no mention of shad in 2009
Bethlehem Shad Festival [mgfx.com/fishing/assocs/drsfa/shadfest.htm]	Bethlehem, PA	18th Century Industrial Area; Delaware River Shad Fishermen's Association	May 5, 1996 May 10, 1997	Begun 1978; Unknown
Fishtown Shad Festival [www.fishtownshadfest.org]	Fishtown, PA	Penn Treaty Park; Fishtown Area Business Association	April 25, 2009	Begun 2009, Active
Shad Run 5K [www.fishtownshadfest.org/2009_02_01_archive.html]	Fishtown, PA	Penn Treaty Park, Delaware Avenue; Fishtown Beer Runners, others	April 25, 2009	Active
Forks of the Delaware Shad Fishing Tournament and Festival [shadtournament.com/]	Easton, PA	Scott Park; City of Easton	April 25-May 9, 2009	Begun 1983, Active
Nanticoke River Shad Festival [www.nanticokeriver.org/shad%20fest%2009.html]	Vienna, MD	Vienna Waterfront; Chesapeake Bay Foundation, Nanticoke Watershed Alliance, City of Vienna, others	April 25, 2009	Begun 1995, Active
National Casting Call (shad fishing) RSVP REQUIRED, SEE WEB SITE [www.nationalcastingcall.com/]	District of Columbia	Fletcher's Cove; American Fly Fishing Trade Association, National Fish Habitat Action Plan, Association of Fish and Wildlife Agencies, U.S. Fish and Wildlife Service, many others (see web site)	April 27, 2009	Active
Annual Shad Planking [www.shadplanking.com/2009_planking_info.html]	Wakefield, VA	Wakefield Sportsmens Club; Wakefield Ruritan Club	April 15, 2009	61st annual, Active

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Grifton Shad Festival (includes both species but primarily hickory) [www.grifton.com/shadfest.html]	Grifton, NC	Town Common Area and other venues, Town of Grifton	April 14-19, 2009	Begun 1969, 35th annual, Active
Cape Fear River Shad Festival [http://thingstodo.msn.com/riegelwood-nc/events/show/86706795-cape-fear-river-shad-festival]	Riegelwood, NC	Lock and Dam #1; Lower Bladen-Columbus Historical Society	April 11, 2009	Active

Appendix C – Alosine Habitat

Greene, K. E., J. L. Zimmerman, R. W. Laney, and J. C. Thomas-Blate. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series No. 9, Washington, D.C.

American shad Habitat Description

Habitats used by all Atlantic anadromous alosine species include spawning sites in coastal rivers and nursery areas, which include primarily freshwater portions of the rivers and their associated bays and estuaries. In addition to the spawning and nursery areas, adult habitats also consist of the nearshore ocean. Adult American shad have also been found to migrate up to 60 miles off the coast (Neves and Depres 1979). These habitats are distributed along the East Coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory alosines may increase or diminish as the size of the population changes.

Spawning Habitat

Geographical and Temporal Patterns of Migration

The existing Atlantic coast stocks of American shad have a geographic range that currently extends from the St. Johns River, Florida, to the St. Lawrence River, Canada (see above for historic range). Scientists estimate that this species once ascended at least 130 rivers along the Atlantic coast to spawn, but today fewer than 70 systems have runs (Limburg et al. 2003). Most American shad return to their natal rivers and tributaries to spawn (Fredin 1954; Talbot 1954; Hill 1959; Nichols 1966; Carscadden and Leggett 1975), although on average, 3% stray to non-natal river systems (Mansueti and Kolb 1953; Williams and Daborn 1984; Melvin et al. 1985). In fact, Hendricks et al. (2002) demonstrated that hatchery-reared American shad homed to a specific tributary within the Delaware River system several years after stocking, and also preferred the side of the tributary influenced by the plume of their natal river.

The degree of homing by American shad may depend on the nature of the drainage system. If so, mixing of stocks and consequent straying would more likely occur in large and diversified estuarine systems, such as the Chesapeake Bay, while more precise homing could be expected in systems that have a single large river, such as the Hudson River (Richkus and DiNardo 1984).

Timing	Month	Location	Citation
Begin	December	St. Johns River, FL	Williams and Bruger 1972
Peak	January	St. Johns River, FL	Leggett 1976
Begin	mid-January	GA and SC	Walburg and Nichols 1967; Leggett and Whitney 1972
Begin	mid-February	NC and VA	Walburg and Nichols 1967; Leggett and Whitney 1972
Peak	March	NC and VA	Walburg and Nichols 1967; Leggett and Whitney 1972
Peak	April	Potomac River	Walburg and Nichols 1967; Leggett and Whitney 1972
Peak	early May	Delaware River	Walburg and Nichols 1967; Leggett and Whitney 1972
Range	March-June	Hudson & Connecticut rivers	Walburg and Nichols 1967; Leggett and Whitney 1972
Range	June-August	Androscoggin River, Maine	Brown and Sleeper 2004
End	July-August	Canadian rivers	MacKenzie et al. 1985; Scott and Scott 1988

Table 1. American shad temporal spawning trends along the Atlantic coast of North America

American shad spring spawning migrations begin in the south and move gradually north as the season progresses and water temperatures increase (Table 1; Walburg 1960). Spawning runs typically last 2-3 months, but may vary depending on weather conditions (Limburg et al. 2003). The diel timing of migration may not vary greatly from region to region. In the James River, Virginia, spawning adults ascended mostly between 0900 and 1600 hours (Weaver et al. 2003). Arnold (2000) reported similar results in the Lehigh River, Pennsylvania, where American shad passed primarily between 0900 and 1400 hours.

American shad show varied preferences for migration distance upstream depending on the river system. There does not seem to be a minimum distance from brackish waters at which spawning occurs (Leim 1924; Massmann 1952), but upstream and mid-river segments appear to be favored (Massmann 1952; Bilkovic et al. 2002). It is not unusual for American shad to travel 25 to 100 miles upstream to spawn; some populations historically migrated over 300 miles upstream (Stevenson 1899; Walburg and Nichols 1967). In the 18th and 19th centuries, American shad runs were reported as far inland as 451 miles along the Great Pee Dee and Yadkin rivers in North Carolina (Smith 1907) and over 500 miles in the Susquehanna River (Stevenson 1899).
Male American shad arrive at riverine spawning grounds before females (Leim 1924). Females release their eggs close to the water surface to be fertilized by one or several males. Diel patterns of egg release depend upon water turbidity and light intensity. In clear open water, eggs are released and fertilized after sunset (Leim 1924; Whitney 1961), with peak spawning around midnight (Massmann 1952; Miller et al. 1971; 1975). In turbid waters (or on overcast days; Miller et al. 1982), eggs are released and fertilized during the day (Chittenden 1976a). For example, in the Pamunkey River, Virginia, spawning has been observed throughout the day, which may be due to relatively turbid waters damping light intensity (Massmann 1952). These

findings support the hypothesis of Miller et al. (1982) that daily spawning is regulated by light intensity.

Another interesting aspect of American shad migration is the regional difference in spawning periodicity. American shad that spawn north of Cape Hatteras are iteroparous (repeat spawners), while almost all American shad spawning south of Cape Hatteras are semelparous (die after one spawning season). This may be due to the fact that south of North Carolina the physiological limits of American shad are stretched during long oceanic migrations; higher southern water temperatures may also have an effect (Leggett 1969). Moreover, Leggett and Carscadden (1978) suggest that southern stocks produce more eggs per unit of body weight than northern populations to compensate for not spawning repeatedly.

Location	% of repeat spawners	Citations
Neuse River, NC	3	Leggett and Carscadden 1978
York River, VA	24	Leggett and Carscadden 1978
Connecticut River	63	Leggett and Carscadden 1978
Saint John River, Canada	73	Colette and Klein-MacPhee 2002

Table 2. Percentage of repeat spawners for American shad along the Atlantic coast of North America

Studies show the percentage of iteroparous adult American shad increases northward along the Atlantic coast (Table 2). However, the percentage of repeat spawners may fluctuate over time within the same river due to pollution, fishing pressure, land-use change, or other factors (Limburg et al. 2003). Furthermore, almost 59% of American shad in the St. Lawrence River did not spawn every year following the onset of maturation, skipping one or more seasons (Provost 1987). Additionally, some fish spawn up to five times before they die (Carscadden and Leggett 1975).

Members of this species exhibit asynchronous ovarian development and batch spawning. In addition, American shad spawn repeatedly as they move upriver (Glebe and Leggett 1981a), which some researchers think may be a function of their high fecundity (Colette and Klein-MacPhee 2002). Estimates of egg production for the York River, Virginia, are 20,000 to 70,000 eggs per kg somatic weight spawned every four days (Olney et al. 2001).

However, some researchers believe that fecundity in American shad may be indeterminate, and that previous annual or lifetime fecundity estimates may not be accurate (Olney et al. 2001). Researchers examining batch fecundity of semelparous American shad in the St. Johns River, Florida, and iteroparous individuals in the York and Connecticut rivers in Virginia and Connecticut, respectively, found no statistically significant differences in batch fecundity among the populations. Until spawning frequency, duration, and batch size throughout the spawning season are known, lifetime fecundity for various stocks cannot be determined and previous methods to determine fecundity throughout the coastal range will be inadequate (Olney and McBride 2003). Nevertheless, the habitat productivity potential estimate used in Maine is 2.3 shad per 100 square yards of water surface area (Brown and Sleeper 2004).

It is interesting to note that Olney et al. (2001) found that approximately 70 percent of post-spawning American shad females leaving the York River had only partially spent ovaries, which suggests that the maximum reproduction level of most females in the river system each year is not achieved. Researchers hypothesize that these females utilize partially spent ovaries by reabsorbing unspawned, yoked oocytes to supplement somatic energy sources as they return to the ocean. These fish likely have a greater potential for surviving multiple spawning events than individuals that are fully spent and have no such energy reserves (Olney et al. 2001). Even with energy reserves, spent adults are usually very emaciated and return to sea soon after spawning (Chittenden 1976b), sometimes feeding before reaching saltwater (Atkins 1887).

Layzer (1974) found that American shad selected discrete spawning sites in the Connecticut River and remained there for most of the season despite the large area available for spawning. Sometimes spawners forego areas with highly suitable habitats that are further downstream, suggesting that there are other variables that influence habitat choice (Bilkovic 2000). Ross et al. (1993) suggest that choice of spawning habitat may be unrelated to physical variables, but rather may reflect a selective pressure such as fewer egg predators in selected habitats.

Spawning Salinity Association

Adult American shad may spend two to three days in estuarine waters prior to upriver migration (Dodson et al. 1972; Leggett 1976). Leim (1924) observed spawning by American shad in brackish waters, but other researchers believe that spawning occurs only in freshwater (Massman 1952; MacKenzie et al. 1985). Spawning typically occurs in tidal and non-tidal freshwater regions of rivers and tributaries (Chittenden 1976a). While in the Hudson River, American shad ascend beyond the saltwater interface and go as far upstream as they can travel (Schmidt et al. 1988), eggs are typically deposited slightly above the range of tide in the Shubenacadie River, Canada (Leim 1924). In many rivers, adult spawners historically migrated beyond tidal freshwater areas, but they can no longer reach these areas due to dam blockages (Mansueti and Kolb 1953).

Interestingly, American shad tolerate a wide range of salinities during early developmental stages (Chittenden 1969) and adult years (Dodson et al. 1972), even though their eggs are normally deposited in freshwater (Weiss-Glanz 1986). Additionally, Limburg and Ross (1995) concluded that a preference for upriver spawning sites may be genetically fixed, but its advantage or significance was not related to salt intolerance of eggs and larvae.

Leggett and O'Boyle (1976) conducted an experiment to see if American shad require a period of acclimation to freshwater. The researchers determined that fish transferred from seawater to freshwater, with a 6°C temperature increase over a 2.5-hour period, experienced physiologic stress and a 54% mortality rate five hours later. Furthermore, adults did not survive transfers from saltwater (27 ppt) to freshwater with a 14°C temperature increase. Mortality rates varied from 0 to 40% for transfers from waters with salinities ranging from 13 to 25 ppt to freshwater and temperature increases up to 6°C. However, adult American shad may be better adapted to transfers from freshwater to saltwater. They tolerated transfers from freshwater to 24 ppt and temperature increases of up to 9°C (Leggett and O'Boyle 1976).

Spawning Substrate Association

Spawning often occurs far upstream or in river channels dominated by flats of sand, silt, muck, gravel, or boulders (Mansueti and Kolb 1953; Walburg 1960; Walburg and Nichols 1967; Leggett 1976; Jones et al. 1978). The importance of substrate type to American shad spawning behavior is still debated. Bilkovic et al. (2002) concluded that substrate type was not predictive of spawning and nursery habitat in two Virginia rivers that were surveyed. Similarly, Krauthamer and Richkus (1987) do not consider substrate type to be an important factor at the spawning site since eggs are released into the water column.

However, eggs are semi-buoyant and may eventually sink to the bottom. Thus, areas predominated by sand and gravel may enhance survival because there is sufficient water velocity to remove particles and prevent suffocation if eggs settle to the bottom (Walburg and Nichols 1967). Furthermore, Layzer (1974) noted that survival rates of shad eggs were highest where gravel and rubble substrates were present. Likewise, Hightower and Sparks (2003) hypothesize that larger substrates are important for American shad reproduction, based on observations of spawning in the Roanoke River, North Carolina. Other researchers have also observed American shad spawning primarily over sandy bottoms free of mud and silt (Williams and Bruger 1972).

Spawning Depth

Depth is not considered a critical habitat parameter for American shad in spawning habitat (Weiss-Glanz et al. 1986), although Witherell and Kynard (1990) observed adult American shad in the lower half of the water column during the upstream migration. Once they reach preferred spawning areas, adults have been found at river depths ranging from 0.45 to 10 m (Mansueti and Kolb 1953; Walburg and Nichols 1967). However, depths less than 4 m are generally considered ideal (Bilkovic 2000).

Ross et al. (1993) observed that the greatest level of spawning occurred where the water depth was less than 1 m in the Delaware River. Other studies suggest that adults select river areas that are less than 10 ft deep (3.3 m) or have broad flats (Mansueti and Kolb 1953; Leggett 1976; Kuzmeskus 1977). Adults may reside in slow, deep pools during the day, and in the evening move to shallower water where riffle-pools may be present to spawn (Chittenden 1969; Layzer 1974). During the spawning event, females and males can be found close to the surface for the release and fertilization of eggs (Medcof 1957).

Stier and Crance (1985) suggest that for all life history stages, including spawning, egg incubation, larvae, and juveniles, the optimum depth range is between 1.5 and 6.1 m. Depths less than 0.46 m (for spawning adults, larvae, and juveniles) and 0.15 m (for egg incubation), and depths greater than 15.24 (for all life history stages) are considered unsuitable (Stier and Crance 1985). However, recent studies on optimal habitat for spawning events have found that these areas may be defined more narrowly than indicated by studies focused primarily on egg collection. For example, sites deeper than 2 m in the Neuse River, North Carolina, were used less extensively than expected for spawning based on depth availability within the spawning grounds and over the entire river (Beasley and Hightower 2000; Bowman and Hightower 2001).

Spawning Water Temperature

Spawning for American shad may occur across a broad range of temperatures (Table 3). Water temperature is the primary factor that triggers spawning, but photoperiod, water flow and velocity, and turbidity also exert some influence (Leggett and Whitney 1972). Based on the temperature range reported by Leggett and Whitney (1972), Parker (1990) suggests that pre-spawning adults tolerate higher temperatures as they undergo physiological changes and become sexually ripe.

Most spawning occurs in waters with temperatures between 12-21°C (Walburg and Nichols 1967; Leggett and Whitney 1972). Generally, water temperatures below 12°C cause total or partial cessation of spawning (Leim 1924). However, Jones et al. (1978) reported American shad moving into natal rivers when water temperatures were 4° C or lower. Additionally, Marcy (1976) found that peak spawning temperatures varied from year to year. For example, peak spawning temperatures in the Connecticut River were 22°C and 14.8°C in 1968 and 1969, respectively (Marcy 1976).

Other factors, such as the pace of gonadal and egg development may also be related to water temperature. Mansueti and Kolb (1953) found that shad ovaries developed more slowly at 12.8°C than at 20 to 25°C. In theory, eggs may develop slowly at first then mature rapidly with higher temperatures (DBC 1980).

Activity	**Temperature (°C)**	**Location**	**Citation**
Migration	5 - 23	Throughout range	Walburg and Nichols 1967
Migration (peak)	8.6 - 19.9 (16 - 19)	North Carolina	Leggett and Whitney 1972
Peak migration	16.5 - 21.5	Southern rivers	Leggett 1976
Spawning	8 - 26	Throughout range	Walburg and Nichols 1967; Stier and Crance 1985
Optimum spawning	14 - 20	Throughout range	Stier and Crance 1985
Optimum spawning	14 – 24.5	Throughout range	Ross et al. 1993

Table 3. American shad migration and spawning temperatures for the Atlantic coast

Dissolved oxygen associations

American shad require well-oxygenated waters in all habitats throughout their life history (MacKenzie et al. 1985). Jessop (1975) found that migrating adults require minimum dissolved oxygen (DO) levels between 4 and 5 mg/L in the headwaters of the Saint John River, New Brunswick. Dissolved oxygen levels below 3.5 mg/L have been shown to have sub-lethal effects on American shad (Chittenden 1973a); levels less than 3.0 mg/L completely inhibit upstream migration in the Delaware River (Miller et al. 1982). Additionally, dissolved oxygen levels less than 2.0 mg/L cause a high incidence of mortality (Tagatz 1961; Chittenden 1969), and below 0.6 mg/L cause 100% mortality (Chittenden 1969). Although minimum daily dissolved oxygen concentrations of 2.5 to 3.0 mg/L should be sufficient to allow American shad to migrate through polluted areas, Chittenden (1973a) recommends that suitable spawning areas have a minimum of

4.0 mg/L. Miller et al. (1982) propose even higher minimum concentrations, suggesting that anything below 5.0 mg/L should be considered potentially hazardous to adult and juvenile American shad.

Spawning water velocity/flow

Water velocity (m/sec) is an important parameter for determining American shad spawning habitat (Stier and Crance 1985). Walburg (1960) found that spawning and egg incubation most often occurred where water velocity was 0.3 to 0.9 m/s. In support, Stier and Crance (1985) suggested that this was the optimum range for spawning areas. Ross et al. (1993) observed that American shad spawning activity was highest in areas where water velocity ranged from 0.0 to 0.7 m/s; this suggested that there was no lower suitability limit during this stage and that the upper limit should be modified. However, Bilkovic (2000) determined that the optimum water velocity range for eggs and larvae was 0.3 to 0.7 m/s, and hypothesized that some minimum velocity was required. A minimum velocity is needed in order to prevent siltation and ensure that conditions conducive to spawning and egg incubation occur (Williams and Bruger 1972; Bilkovic 2000).

Appropriate water velocity at the entrance of a fishway is also important for American shad migrating upstream to spawning areas. Researchers found that water velocities of 0.6 to 0.9 m/s at the entrance to a pool-and-weir fishway was needed to attract American shad to the structure (Walburg and Nichols 1967). The Conowingo Dam fish lift on the Susquehanna River uses entrance velocities of 2 to 3 m/s to attract American shad to the lift (R. St. Pierre, U.S. Fish and Wildlife Service, personal communication). At other sites, such as the Holyoke Dam in Massachusetts, American shad have trouble locating fishway entrances among turbulent discharges and avoid the area; thus, too much water velocity and/or turbulence may actually deter this species (Barry and Kynard 1986).

Ross et al. (1993) noted that habitat selection among spawning adult American shad favored relatively shallow (0.5 to 1.5 m) mid-river runs with moderate to high current velocity (0.3-0.7 m/s). To a lesser degree, adults also were located in channels (deeper, greater current velocities, little if any SAV) and SAV shallows (inshore, high densities of SAV, low current velocities). The researchers found adults seemed to avoid pools (wide river segment, deep, low current velocities) and riffle pools (immediately downstream of riffles, deep water, variable current velocity and direction) that contained both deep and slow water. This avoidance of pools and riffle pools may be explained by the fact that the preferred run habitat contained both swift and shallow water characteristics. Channels and SAV shallows may be either swift or shallow; these characteristics may lead to higher survivability of newly spawned eggs compared to deep pool habitat (Ross et al. 1993). Similarly, Bilkovic et al. (2002) found the greatest level of spawning activity in runs.

Water velocity may also contribute in some way to weight loss and mortality during the annual spawning migration, especially for male American shad. Males typically migrate upstream earlier in the season when water velocities are greater, thus expending more energy than females (Glebe and Leggett 1973; DBC 1980).

In addition, areas with high water flows provide a cue for spawning American shad (Orth and White 1993). In 1985, a rediversion canal and hydroelectric dam constructed between the Cooper River and Santee River, South Carolina, increased the average flow of the Santee River from 63 m^3/s to 295 m^3/s. (Cooke and Leach 2003). The increased river flow and access to spawning grounds through the fish passage facility have contributed to increases in American shad populations. Although the importance of instream flow requirements has been previously recognized with regard to spawning habitat requirements or recruitment potential (Crecco and Savoy 1984; ASMFC 1985; Crecco et al. 1986; Ross et al. 1993; Moser and Ross 1994), Cooke and Leach (2003) suggested that river flow might be an important consideration for restoring alosine habitat.

Water flow may have additional importance for American shad populations in the future. Although Summers and Rose (1987) did not detect direct relationships between stock size and river flow or water temperature, they found that spawning stock size, river flow rate, and temperature were important predictors of future American shad population sizes. These researchers suggested that future studies incorporate a combination of environmental variables, rather than a single environmental variable, to determine what stimuli affect stock size.

Suspended solids

Adults appear to be quite tolerant of turbid water conditions. In the Shuebenacadie River, Nova Scotia, suspended solid concentrations as high as 1000 mg/L did not deter migrating adults (Leim 1924). Furthermore, Auld and Schubel (1978) found that suspended solid concentrations of 1000 mg/L did not significantly affect hatching success of eggs.

Feeding

Early research suggested that adult American shad did not feed in freshwater during upstream migration or after spawning (Hatton 1940; Moss 1946; Nichols 1959) because the most available food source in the freshwater community was too small to be retained by adult gillrakers (Walburg and Nichols 1967). Atkinson (1951) suggested that American shad stopped feeding due to the physical separation from suitable food sources rather than a behavioral or physiological reduction in feeding.

More recent studies of feeding habits of American shad in the York River, Virginia, found that individuals did, in fact, feed as they migrated from the oceanic to coastal waters (Chittenden 1969, 1976b; Walters and Olney 2003). Walters and Olney (2003) compared stomach fullness of migrating American shad with individuals in the ocean and estuary, and found that as American shad moved from oceanic waters to coastal and estuarine waters their diet composition changed from oceanic copepods, such as *Calanus finmarchicus*, to other copepods, such as *C. typicus* and *Acartia* spp. (Walters and Olney 2003). The estuarine mysid shrimp *Neomysis americana* became an important component, replacing euphausids in spent and partially spent adults. Minor amounts of other crustaceans were also found in spent American shad stomachs including cumaceans, sevenspine bay shrimp (*Crangon septemspinosa*), and gammarid amphipods, as well as woody and green plant debris that had little or no nutritional value (Walters and Olney 2003). This finding suggested that these fish fed if there was suitable prey available (Atkinson 1951).

The ability to feed during migration and after spawning may be an important factor in decreasing post-spawning mortality of American shad (Walters and Olney 2003). Migration requires significant energetic expenditures and causes weight loss (Glebe and Leggett 1981a; 1981b); the resumption of feeding likely represents a return to natural feeding patterns, which allows the fish to begin regaining lost energy reserves (Walter and Olney 2003). Finally, the ability to survive spawning has been correlated with the degree of energy lost (Glebe and Leggett 1981b; Bernatchez and Dodson 1987). Therefore, American shad that feed actively before and after spawning may have a higher likelihood of repeat spawning. Additionally, individuals whose spawning grounds are in closer proximity to estuarine food sources (and do not expend as much energy as those that have to travel farther), and emigrating fish that have partially spent ovaries that can be reabsorbed for energy (Olney et al. 2001), may have a higher frequency of repeat spawning and lower energy expenditures (Walter and Olney 2003).

Competition and predation

Early studies found that seals and humans preyed upon adult American shad (Scott and Crossman 1973), but the species appeared to have few other predators (Scott and Scott 1988). Erkan (2002) found that predation of alosines has increased in Rhode Island rivers, noting that the Double-crested Cormorant often takes advantage of American shad staging near fishway entrances. Predation by otters and herons has also increased, but to a lesser extent (D. Erkan, Rhode Island Division of Fish and Wildlife, personal communication). A recent study strongly supports the hypothesis that striped bass predation on adult American shad in the Connecticut River has resulted in a dramatic and unexpected decline in American shad abundance since 1992 (Savoy and Crecco 2004). Researchers further suggest that striped bass prey primarily on spawning adults because their predator avoidance capability may be compromised at that time, due to a strong drive to spawn during upstream migration. Rates of predation on ages 0 and 1 alosines was also much lower (Savoy and Crecco 2004).

In south Atlantic coastal rivers where the percentage of repeat spawning is low or non-existent, adult American shad that die after spawning may contribute significant nutrient input from the marine system into freshwater interior rivers (ASMFC 1999). Garman (1992) hypothesized that before recent declines in abundance, the annual input of marine-derived biomass of post-spawning alosines was an important seasonal source of energy and nutrients for the non-tidal James River.

Egg and Larval Habitat

Geographical and temporal movement patterns

American shad eggs and larvae have been found at, or downstream of, spawning locations. Upstream areas typically have extensive woody debris where important larval and juvenile American shad prey items reside, and spawning there may ensure that eggs develop within favorable habitats (Bilkovic et al. 2002).

Once American shad eggs are released into the water column, they are initially semi-buoyant or demersal. Survival of eggs is dependent on several factors, including current velocity, dissolved oxygen, water temperature, suspended sediments, pollution, and predation (Krauthamer and Richkus 1987; Bailey and Houde 1989). Whitworth and Bennett (1970) monitored American shad eggs after they were broadcast and found that they traveled a distance of 5 to 35 m downstream before they sank or became lodged on the bottom. Other researchers reported similar observations (Barker 1965; Carlson 1968; Chittenden 1969).

Laboratory experiments suggested that sinking rates for American shad eggs were around 0.5 to 0.7 m/min (1.6 to 2.4 ft/min), with newly spawned eggs sinking at a quicker rate, although hydrodynamic and tidal effects were not accounted for in the experiments (Massmann 1952; Chittenden 1969). Other factors, such as amount of woody debris, influence how far eggs travel and may prevent eggs from settling far from the spawning site (Bilkovic 2000). Once eggs sink to the bottom, they are swept under rocks and boulders and are kept in place by eddy currents. In addition, eggs may become dislodged and swept downstream to nearby pools (DBC 1980).

American shad yolk-sac larvae may not use inshore habitat as extensively as post-yolk-sac larvae (Limburg 1996). One early study (Mitchell 1925, cited by Crecco et al. 1983) found that yolk-sac larvae were near the bottom and swam to shore as the yolk-sac reabsorbed. Metzger et al. (1992) also found yolk-sac larvae mostly in offshore areas along the bottom, while post yolk-sac larvae were more concentrated in quiet areas near shorelines (Cave 1978; Metzger et al. 1992). Yolk-sac larvae are typically found deeper in the water column than post-larvae, due to their semi-buoyant nature and aversion to light. Post-larvae, in contrast, are more abundant in surface waters, especially downstream of spawning sites (Marcy 1976).

Yolk-sac larvae exhaust their food supply within 4 to 7 days of hatching (Walburg and Nichols 1967), usually when they are approximately 10 to 12 mm total length (TL) (Marcy 1972). Survival is affected by water temperature, water flow, food production and density, and predation (State of Maryland 1985; Bailey and Houde 1989; Limburg 1996). Larvae may drift passively into brackish water shortly after hatching occurs, or can remain in freshwater for the remainder of the summer (State of Maine 1982); often they aggregate in eddies and backwaters (Stier and Crance 1985). Ross et al. (1993) reported that American shad larvae frequent riffle pools where water depth is moderate and velocity and direction vary. Alternatively, larvae in the Mattaponi and Pamunkey rivers, Virginia, were dispersed from the upper through the downriver areas. Unlike the presence of eggs, which can be predicted in most cases using physical habitat and shoreline/land use ratings, distinct habitat associations could not be discerned for larval distributions. This may be due to the fact that larvae were carried further downstream than eggs, dispersing them into more variable habitats (Bilkovic et al. 2002).

Eggs, larvae, and the saltwater interface

Although American shad eggs are generally deposited in freshwater, it is unknown whether they hatch in freshwater, brackish water, or in both (Weiss-Glanz 1986). Early attempts to acclimate larval shad to seawater resulted in high mortality rates (Milner 1876). Leim (1924) purported that successful development of embryos and larvae occurs under low salinity conditions. In the Shubenacadie River, Canada, eggs and larvae were most often observed in areas with a salinity of 0 ppt (range 0 to 7.6 ppt). Additionally, while larvae may tolerate salinities as high as 15 ppt, these conditions often result in death. Leim (1924) also found that temperature may influence salinity sensitivities, with lower temperatures (i.e., 12°C) resulting in more abnormalities at 15 and 22.5 ppt than higher temperatures (i.e., 17°C).

In another study, Limburg and Ross (1995) found that salinities of 10 to 20% were favorable for post-yolk sac American shad larvae, and concluded that estuarine salinities neither depressed growth rates nor elevated mortality rates of larval American shad compared with freshwater conditions. These researchers concluded that other ecological factors may play a greater role in influencing spawning site selection by American shad than the physiological effects of salinity.

Egg and larval substrate association

Areas with sand or gravel substrates may be better for egg and larval survival because they allow sufficient water velocity to remove silt or sand that can suffocate eggs (Walburg and Nichols 1967). Additionally, survival rates of American shad eggs have been found to be highest among gravel and rubble substrates (Layzer 1974). According to Krauthamer and Richkus (1987), bottom composition is not a critical factor in the selection of spawning locations for American shad. After American shad eggs are fertilized, they either sink to the bottom where they become lodged under rocks and boulders, or they are swept by currents to nearby pools (Chittenden 1969). Bilkovic (2000) concluded that substrate type was not a good predictor of spawning and nursery habitat in rivers.

Egg and larval depth

Eggs are slightly heavier than water, but may be buoyed by prevailing currents and tides. Most eggs settle at, or near, the bottom of the river during the water-hardening stage (Leim 1924; Jones et al. 1978). In the Connecticut River, American shad eggs are distributed almost uniformly between the surface and the bottom of the river. Larvae are more than twice as abundant in surface waters, and are even more abundant in the water column as they move downstream (Marcy 1976).

Walburg and Nichols (1967) found 49% of American shad eggs in waters shallower than 3.3 m (10 ft), 30% in water 3.7 to 6.7 m (11 to 20 ft), and 21% in water 7 to 10 m (21 to 30 ft). Similarly, Massman (1952) reported that five times more eggs per hour were collected at depths ranging from 1.5 to 6.1 m (4.9 to 20.0 ft), than in deeper waters of the Pamunkey and Mattaponi rivers. In the same river systems, Bilkovic et al. (2002) found eggs at depths of 0.9 to 5.0 m, and larvae at 1 to 10 m.

Egg and larval water temperature

Rate of development of shad eggs is correlated with water temperature (Table 4; Mansueti and Kolb 1953). According to Limburg (1996), within the temperature range of 11 to 27°C, the time it takes for eggs to develop can be expressed as:

$$\log_e(EDT) = 8.9 - 2.484 \times \log_e(T)$$

where EDT is egg development time in days and T is temperature in degrees Celsius.

Days	Temperature	Reference
15.5	12° C	Leim 1924
17	12° C	Ryder 1887
7	17° C	Leim 1924
3	24° C	MacKenzie et al. 1985
2	27° C	Rice 1878

Table 4. American shad egg development time at various temperatures

Estimates of near-surface water temperatures suitable for development and survival of American shad eggs range from 8 to 30°C (Walburg and Nichols 1967; Bradford et al. 1968; Stier and Crance 1985; Ross et al. 1993). Leim (1924) suggests that optimal conditions for American shad egg development occur in the dark at 17°C and 7.5 ppt salinity.

Characterization	Temperature (°C)	Citation
Suitable	10 - 27	Bradford et al. 1968
Suitable	13.0 - 26.2	Ross et al. 1993
Suitable	10 - 30	Stier and Crance 1985
Optimal	15.5 - 26.5	Leim 1924
Optimal	15 - 25	Stier and Crance 1985

Table 5. American shad larval temperature tolerance ranges

Water temperatures above 27°C can cause abnormalities or a total cessation of larval American shad development (Bradford et al. 1968). Few larvae have been found living in temperatures above 28°C (Table 5; Marcy 1971; 1973), and no viable larvae develop from eggs incubated above 29°C (Bradford et al. 1968). Ross et al. (1993) recommend that further sampling be conducted for post-larval stages at temperatures greater than or equal to 27°C to confirm upper optimal temperature preferences. In this study, the researchers found no reduction in density of larvae at the upper thermal limit (26 to 27°C) in areas sampled along the Delaware River (Ross et al. 1993).

Laboratory experiments have shown that American shad eggs can tolerate extreme temperature changes as long as the exposure is of relatively short duration (Klauda et al. 1991). Temperature increases after acclimation at various temperatures produced variable results; however, some eggs were found to withstand temperatures of 30.5°C for 30 minutes and 35.2°C for 5 minutes (Schubel and Koo 1976). Furthermore, sensitivity to temperature change decreases as eggs mature (Koo et al. 1976).

Shoubridge (1977) analyzed temperature regimes in several coastal rivers throughout the range of American shad, and found that as latitude increases: 1) the duration of the temperature optima for egg and larval development decreases, and 2) the variability of the temperature regime increases. Based on Shoubridge's work, Leggett and Carscadden (1978) suggest that variation in American shad egg and larval survival, year-class strength, and recruitment also increases with latitude.

Crecco and Savoy (1984) found that low water temperatures (with high rainfall and river flow) were significantly correlated with low American shad juvenile abundance during the month of

June in the Connecticut River, while high water temperatures (with low river flow and rainfall) were significantly correlated with high juvenile abundance. In addition, depressed water temperatures can retard the onset and duration of American shad spawning (Leggett and Whitney 1972), larval growth rate (Murai et al. 1979), and the production of riverine zooplankton (Chandler 1937; Beach 1960).

Egg and larval dissolved oxygen associations

Miller et al. (1982) concluded that the minimum dissolved oxygen level for both eggs and larvae of American shad is approximately 5 mg/L. This is the value that Bilkovic (2000) assigned for optimum conditions for survival, growth, and development of American shad.

Although specific tolerance or optima data for eggs and larvae is limited, there are studies that note the presence or absence of eggs and larvae under certain dissolved oxygen conditions (Bilkovic et al. 2002). In the Neuse River, North Carolina, American shad eggs were collected in waters with dissolved oxygen levels ranging from 6 to 10 mg/L (Hawkins 1979). Marcy (1976) did not find any American shad eggs in waters of the Connecticut River where dissolved oxygen concentrations were less than 5 mg/L. Bilkovic (2000) found variations in dissolved oxygen concentrations for eggs (10.5 mg/L), yolk-sac larvae (9.0 mg/L), and post-larvae (8.1 mg/L) in the Mattaponi and Pamunkey rivers.

Marcy (1976) determined that the dissolved oxygen LC_{50} values (i.e., concentration that causes 50% mortality) for American shad eggs in the Connecticut River were between 2.0 and 2.5 mg/L. In the Columbia River, the LC_{50} was close to 3.5 mg/L for eggs and at least 4.0 mg/L for a high percentage of hatched eggs and healthy larvae; less than 1.0 mg/L dissolved oxygen resulted in total mortality (Bradford et al. 1968). Klauda et al. (1991) concluded that a good hatch with a high percentage of normal larvae required dissolved oxygen levels during egg incubation of at least 4.0 mg/L, based on observations by both Maurice et al. (1987) and Chittenden (1973a). Finally, it is worth noting that cleanup of the Delaware River has had a measurably positive effect on increasing dissolved oxygen concentrations in that system (Maurice et al. 1987).

Egg and larval pH and aluminum associations

Level	pH	Citation
Tolerance- egg	5.5 - 9.5	Bradford et al. 1968
Tolerance- egg	6.0 – 7.5	Klauda 1994
Tolerance- egg	6.5 - 8.5	Bilkovic et al. 2002
LD_{50}- egg	5.5	Klauda 1994
Mortality- egg	<5.2	Bradford et al. 1968
Tolerance- larvae	6.7 – 9.9	Klauda 1994
Tolerance- larvae	6.5 - 9.3	Bilkovic et al. 2002
Optimal- larvae	>7.0	Leach and Houde 1999
Tolerance- both	6.0 - 9.0	Leim 1924

Table 6. American shad egg and larval environmental pH tolerance ranges

A number of researchers have examined the effects of pH on American shad eggs and larvae (Table 6). Klauda (1994) hypothesized that even infrequent and temporary episodes of critical or lethal pH and aluminum exposures in spawning and nursery areas could contribute to significant reductions in egg or larval survival and slow stock recovery. Similarly, Leach and Houde (1999) noted that sudden drops in pH levels, such as those associated with rainfall, could cause sudden mortalities for American shad larvae.

In a laboratory study, Klauda (1994) subjected eggs, yolk-sac larvae, and post-larvae to an array of acid and aluminum conditions; larvae appeared to be more sensitive to acid and aluminum pulses than eggs. When eggs were subjected to aluminum pulses, critical conditions were met at pH 5.7 (with 50 or 200 µg/L Al) and pH 6.5 (with 100 µg/L Al) for 96-hour treatments. The least severe treatment that resulted in critical conditions for 1 to 3 day old yolk-sac larvae was a 24 h exposure to pH 6.1 with 92 µg/L Al. The least severe treatment that resulted in a lethal condition for yolk-sac larvae was a 24 h exposure to pH 5.5 with 214 µg/L Al. Furthermore, post-larvae (6 to 16 days old) were found to be more sensitive to acid and aluminum pulses than both eggs and yolk-sac larvae. Critical conditions occurred at pH 5.2 (with 46 µg/L Al) and pH 6.2 (with 54 or 79 µg/L Al) for 8 hours, and lethal conditions occurred at pH 5.2 (with 63 µg/L Al) for 16 hours (Klauda 1994).

Egg and larval water velocity/flow

Several studies report water velocity preferences for larval American shad, with 0 to 1.0 m/s the most commonly reported range (Walburg 1960; Walburg and Nichols 1967; Stier and Crance 1985; Bilkovic et al. 2002). Kuzmeskus (1977) found freshly spawned eggs in areas with water velocity rates between 0.095 and 1.32 m/s. Williams and Bruger (1972) noted that increased siltation may result if water velocities are less than 0.3 m/s, causing increased egg mortality from suffocation and bacterial infection.

Freshwater discharge can influence both eggs and larvae of American shad. Increased river flow can carry eggs from favorable nursery habitat to unfavorable areas that reduce their chance for survival. Lower flows may result in favorable hydrodynamic, thermal, and feeding conditions (Crecco and Savoy 1987a; Limburg 1996). Larval and juvenile American shad may select eddies and backwater areas where water flow is reduced (Crecco and Savoy 1987b). Limburg (1996) found that high spring river discharges coupled with low temperatures and low food availability contributed to high larval mortality in the Hudson River. Larvae that hatched after May, when the highest discharges occurred, had a higher survival rate (Limburg 1996). Furthermore, year-class strength and river flow showed a significant negative correlation in studies conducted on the Connecticut River (Marcy 1976). Larval survival rates have also been negatively correlated with increased river flow in June, but positively correlated with June river temperatures (Savoy and Crecco 1988).

Although hydrographic turbulence may affect larval American shad survival rates, the precise mechanisms of this influence are uncertain because daily river flow and rainfall levels are nonlinear, time-dependent processes that may act singularly or in combination with other factors, such as temperature and turbidity (Sharp 1980). Decreased temperatures can affect larval growth rates (Murai et al. 1979) and riverine zooplankton production that American shad may require for nourishment (Chandler 1937; Beach 1960). Turbulence can also cause turbidity, which may compromise the ability of larval fish to see their prey (Theilacker and Dorsey 1980). Increased turbidity may also affect the food web. Turbidity can cause reduced photosynthesis by phytoplankton, which in turn may lead to elimination of the cladocerans and copepods that American shad feed upon (Chandler 1937; Hynes 1970; Crecco and Blake 1983; Johnson and Dropkin 1995).

Suspended solids

American shad eggs are less vulnerable to the effects of suspended solids than larvae. For example, Auld and Schubel (1978) found that suspended solid concentrations of up to 1000 mg/L did not significantly reduce hatching success, while larvae exposed to concentrations of 100 mg/L, or greater, had significantly reduced survival rates.

Feeding Behavior

Predation and starvation are considered the primary causes of mortality among larval fish of many marine species (May 1974; Hunter 1981). Newly hatched American shad larvae must begin feeding within 5 days, or they will die from malnutrition (Wiggins et al. 1984). Furthermore, older larvae have significantly reduced survival rates if they are deprived of food for as little as 2 days (Johnson and Dropkin 1995). Researchers have also found that larvae fed at intermediate prey densities of 500 L^{-1} survived as well as those fed at high prey densities, and significantly higher than starved larvae, which indicates that some minimal level of feeding in riverine reaches can increase survival (Johnson and Dropkin 1995).

Crecco et al. (1983) suggest that larval American shad survival rates are related to spring and summer zooplankton densities. Additionally, despite larval American shad abundance being highest during May, Limburg (1996) determined that year-class was established by cohorts hatched after June 1 due to more favorable conditions, including warmer temperatures, lower flow rates, and higher zooplankton densities.

Once the yolk-sac is absorbed, American shad larvae consume zooplankton, copepods, immature insects, and adult aquatic and terrestrial insects (Leim 1924; Mitchell 1925; Maxfield 1953; Crecco and Blake 1983; Facey and Van Den Avyle 1986). Several researchers have noted varying levels of selectivity for copepods and cladocerans (Crecco and Blake 1983; Johnson and Dropkin 1995), but zooplankton and chironomids generally comprise the bulk of larval diets (Maxfield 1953; Levesque and Reed 1972). Larval American shad feeding occurs most actively in late afternoon or early evening, usually peaking between 1200 h and 2000 h (Johnson and Dropkin 1995); feeding is least intensive near dawn (Massman 1963; Grabe 1996). Larval American shad are opportunistic feeders, shifting their diet depending on availability, river location, and their size (Leim 1924; Maxfield 1953; Walburg 1956; Levesque and Reed 1972; Marcy 1976).

Researchers have also attempted to determine if the patchiness of planktonic prey has any effect on cohort survival. Letcher and Rice (1997) found that increasing levels of patchiness enhances survival when productivity or average prey density is low, but will reduce cohort survival when productivity is high. Thus, except when average prey densities of plankton are particularly high, prey patchiness may be a requirement for survival of fish larvae (Letcher and Rice 1997).

Competition and predation

American shad eggs and larvae are preyed upon primarily by American eels (*Anguilla rostrata*) and striped bass (*Morone saxatilis*) (Mansueti and Kolb 1953; Walburg and Nichols 1967; Facey et al. 1986), although they may be preyed upon by any fish that is large enough to consume them (McPhee 2002). According to Johnson and Ringler (1998), American shad larvae that were stocked in the Susquehanna River, Pennsylvania, experienced the lowest percentage mortality at releases of 400,000 to 700,00 larvae. A high rate of larval mortality at releases up to 400,000 may have been due to depensatory mechanisms, and releases above 700,000 may have resulted in increased predator aggregation at the site. Although some individual predators consumed up to 900 American shad larvae, mortality of larvae at the stocking site was usually less than 2% (an insignificant source of mortality) (Johnson and Ringler 1998).

Contaminants

Bradford et al. (1968) found that the lethal dose (LD_{50}) of sulfates for American shad eggs is >1000 mg/L at 15.5° C. The LD_{50} of iron for eggs is greater than 40 mg/L between pH 5.5 and 7.2 (Bradford et al. 1968). American shad eggs that are exposed to zinc and lead concentrations of 0.03 and 0.01 mg/L experience high mortality rates within 36 hours (Meade 1976). In addition, when water hardness is low (i.e., 12 mg/L), the toxicity of the zinc and lead are intensified (Klauda et al. 1991).

Juvenile Riverine/Estuarine Habitat

Geographical and temporal movement patterns

American shad larvae are transformed into juveniles 3 to 5 weeks after hatching at around 28 mm total length (TL) (Jones et al. 1978; Crecco and Blake 1983; Klauda et al. 1991; McCormick et al. 1996); they disperse at, or downstream of, the spawning grounds, where they spend their first summer in the lower portion of the same river. While most young American shad use freshwater nursery reaches (McCormick et al. 1996), it is thought that their early ability to hypo-osmoregulate allows them to utilize brackish nursery areas during years of high juvenile abundance (Crecco et al. 1983). Juveniles are typically 7 to 15 cm in length before they leave the river and enter the ocean (Talbot and Sykes 1958). For example, in the Hudson River, juvenile American shad and blueback herring were found inshore during the day, while alewives predominated inshore at night (McFadden et al. 1978; Dey and Baumann 1978). Additionally, American shad juveniles use the headpond of the Annapolis River, Nova Scotia, as a nursery area, which has surface water salinities of 25 to 30%; they were observed remaining in the offshore region of the estuary for almost a month before the correct cues triggered emigration (Stokesbury and Dadswell 1989). Farther south, O'Donnell (2000) found that juvenile American shad in the Connecticut River began their seaward emigration at approximately 80 days post-hatch.

In addition, juvenile American shad may demonstrate temporal and latitudinal migration trends. It seems that juveniles in northern rivers emigrate seaward first, and those from southern rivers emigrate progressively later in the year (Leggett 1977a). For example, downstream emigration peaks at night (i.e., at 1800-2300 hours) (O'Leary and Kynard 1986; Stokesbury and Dadswell 1989) in September and October in the Connecticut River, late October in the Hudson River (Schmidt et al. 1988), and late October through late November in the Upper Delaware River and Chesapeake Bay (Krauthamer and Richkus 1987) and the Cape Fear River, North Carolina (Fischer 1980). Interestingly, some researchers (Chittenden 1969; Limburg 1996; O'Donnell 2000) found evidence that juvenile emigration was already underway by mid-summer, indicating that movement may be triggered by cues other than declining fall temperatures.

The combination of factors that trigger juvenile American shad emigration is uncertain, but some researchers suggest that decreased water temperatures, reduced water flow, or a combination of both during autumn appear to be key factors (Sykes and Lehman 1957; Walburg and Nichols 1967; Moss 1970). In the Susquehanna River, an increase in river flow from October through November may actually help push juveniles downstream (R. St. Pierre, U.S. Fish and Wildlife Service, personal communication). Miller et al. (1973) suggest that water temperature is more important than all other factors, because it directly affects the juvenile American shad. The lower lethal temperature limit that triggers the final movement of juveniles from fresh water is approximately 4 to 6°C (Chittenden 1969; Marcy 1976). In addition, Zydlewski and McCormick (1997a) observed changes in osmoregulatory physiology in migrating juvenile American shad, and concluded that these changes were part of a suite of physiological alterations that occur at the time of migration. While these changes are strongly affected by temperature, researchers suggest that other environmental and/or ontogenetic factors may have an influence on timing of migration (Zydlewski and McCormick 1997a).

Another migration theory deals with the age and growth of juvenile American shad. Limburg (1996) suggested that at the population level, temperature may provide the stimulus for fish to emigrate, or it may be a gradual process that is cued by size of fish, with early cohorts leaving first. Several researchers (Chittenden 1969; Miller et al. 1973; Limburg 1996; O'Donnell 2000) have observed younger, smaller young-of-the-year American shad in upstream reaches, while older and larger individuals within the same age cohorts are found downstream earlier in the season. This apparent behavior has lead researchers to hypothesize that as American shad grow and age, they move downstream (Chittenden 1969; Miller et al. 1973; Limburg 1996; O'Donnell 2000). Similarly, both Chittenden (1969) and Marcy (1976) suggest that factors associated with size appear to initiate the earlier stages of seaward emigration.

In contrast, Stokesbury and Dadswell (1989) suggest that size at emigration may not be the important factor that triggers migration, but that environmental stress may reach a point where seaward movement is necessary regardless of a critical size. O'Leary and Kynard (1986) and Stokesbury and Dadswell (1989) found that American shad movement typically occurred during quarter to new moon periods when water temperatures dropped below 19°C and 12°C, respectively. In these cases, decreasing water temperatures and the new moon phase, which provided dark nights, were considered to be more important in providing cues for emigration than increased river flow.

Following downstream migration in late fall, juvenile American shad may spend their first year near the mouths of streams, in estuaries, or in other nearshore waters (Hildebrand 1963; Colette and Klein-MacPhee 2002), or they may move to deeper, higher salinity areas, such as in portions of the lower Chesapeake Bay (Table 7; Hildebrand and Schroeder 1928). In their southern range, some juveniles may stay in the river for up to one full year (Williams and Bruger 1972). In South Carolina, juvenile American shad were found predominantly in deeper, channel habitats of estuarine systems, during fall and winter. Small crustaceans preyed upon by American shad are generally abundant near the bottom in these areas (McCord 2003).

Habitat Type	Location	Citation
sound	Long Island	Savoy 1993
offshore estuary	New Jersey	Milstein 1981; Cameron and Pritchard 1963
brackish/ freshwater	Potomac River	Hammer 1942
estuary	Neuse River, NC	Holland and Yelverton 1973

Table 7. Overwintering habitats for juvenile American shad along the Atlantic coast

Juveniles and the saltwater interface

Early studies of juvenile American shad describe a variety of responses to changes in salinity. When accompanied by temperature changes, juveniles generally adapt to abrupt transfers from freshwater to saltwater, but high mortality results when transferred from saltwater to freshwater (Tagatz 1961). For example, Tagatz (1961) observed 60% mortality for juveniles in isothermal transfers (21°C) from freshwater to 30 ppt saltwater; however, no individuals survived transfers from freshwater (21.1°C) to 33 ppt saltwater (7.2 to 12.8°C). Freshwater transfers to 15 ppt in association with a temperature decrease less than 4°C also resulted in high mortalities (30 to 50%). Conversely, at temperature increases greater than 14°C, all juvenile American shad survived abrupt transfers from saltwater (15 ppt and 33 ppt) to freshwater (Tagatz 1961).

In another study, Chittenden (1973b) observed 0% mortality in isothermal transfers (17°C) from freshwater or 5 ppt to 32 ppt seawater. Additionally, juveniles transferred from 30 ppt seawater to freshwater suffered 100% mortality, but no mortalities resulted when they were transferred from 5 ppt to freshwater. In general, American shad are considered to be capable of surviving a wide range of salinities at early life stages, especially if salinity changes are gradual (Chittenden 1969).

Experiments conducted on American shad and other anadromous fish (Rounsefell and Everhart 1953; Houston 1957; Tagatz 1961; Zydlewski and McCormick 1997a, 1997b) have demonstrated that most fish undergo physiological changes before emigrating to saltwater. This ability to adapt to changes in salinity occurs at the onset of metamorphosis for American shad, between 26 and 45 days post-hatch. Zydlewski and McCormick (1997b) noted that the ability to osmoregulate in full-strength seawater is an important factor that limits American shad early life history stages to freshwater and low-salinity estuaries. The researchers suggested that a decrease and subsequent loss of hyper-osmoregulatory ability may serve as a proximate cue for juveniles to begin their downstream migration (Zydlewski and McCormick 1997b).

Juvenile substrate association

Although juvenile American shad are often most abundant where boulder, cobble, gravel, and sand are present (Walburg and Nichols 1967; Odom 1997), substrate type is not considered to be a critical factor in nursery areas (Krauthamer and Richkus 1987). Ross et al. (1997) found no overall effect of habitat type on juvenile American shad relative abundance in the upper Delaware River, indicating that juveniles use a wide variety of habitat types to their advantage in many nursery areas. These researchers suggest that in contrast to earlier life stages and spawning adults, pre-migratory juveniles may be habitat generalists; however, a positive relationship was found between abundance of juvenile American shad and percent of SAV cover in SAV habitats only. In addition, Odom (1997) found that juvenile American shad favored riffle/run habitat in the James River, especially areas with extensive beds of water stargrass (*Heteranthera dubia*). These areas provided flow-boundary feeding stations where juveniles could feed on drifting macroinvertebrates while reducing their energy costs (Odom 1997).

Estuarine productivity is linked to freshwater detrital nutrient input to the estuary (Biggs and Flemer 1972; Hobbie et al. 1973; Saila 1973; Day et al.1975) and detritus production in the salt marsh (Teal 1962; Odum and Heald 1973; Reimhold et al. 1973; Stevenson et al. 1975). Based on the assumption that the amount of submerged and emergent vegetation will be a qualitative estimate of the estuary's secondary productivity, and therefore, food availability (zooplankton) to juvenile American shad, Stier and Crance (1985) suggest that estuarine habitat with 50% or more vegetation coverage is optimal.

It is important to note that, although no link has been made between the presence of SAV and abundance of alosines, there seems to be a general agreement that there is a correlation between water quality and alosine abundance (B. Sadzinski, Maryland Department of Natural Resources, personal communication). Abundance of SAV is often used as an indirect measure of water quality, with factors such as available light (Livingston et al. 1998), salinity, temperature, water depth, tidal range, grazers, suitable sediment quality, sediment nutrients, wave action, current velocity, and chemical contaminants controlling the distribution of underwater grasses (Koch 2001). Maryland has made it a priority to increase the amount of SAV within the Chesapeake Bay watershed in order to improve water quality. According to B. Sadzinski (Maryland Department of Natural Resources, personal communication), if SAV in a given area increases, this can be used as an indicator of improved water quality, which in turn, will likely benefit alosine species.

Juvenile depth

Juveniles have been observed at depths ranging from 0.9 to 4.9 m in the Connecticut River (Marcy 1976); however, abundance is related to the distance upstream and not to depth (MacKenzie et al. 1985). In the Connecticut River, juveniles were caught primarily at the bottom during the day (87%) and all were caught at the surface at night (Marcy 1976). Chittenden (1969) observed juveniles in the Delaware River most often in deeper, non-tidal pools away from the shoreline during daylight hours; after sunset juveniles scattered and were found at all depths (Miller et al. 1973).

Although data was sparse for depth optima for juveniles, Stier and Crance (1985) developed a suitability index based on input provided by research scientists. They suggest that for all life history stages, including juveniles, the optimum range for river depth is between 1.5 and 6.1 m. Depths less than 0.46 m and greater than 15.24 m are unsuitable habitat according to the model.

Juvenile water temperature associations

Juvenile American shad demonstrate some variability in temperature tolerances and preferences among river systems (Table 8). Leim (1924) found that juveniles captured in the Shubenacadie River, Canada, were usually found where temperatures tended to be the highest compared to other regions of the river. Additionally, temperature appears to have a significant impact on growth of juvenile American shad. Limburg (1996) found that juveniles in the laboratory had higher initial growth rates at 28.5°C than individuals reared at lower temperatures. O'Donnell (2000) concluded that it may be advantageous for eggs to hatch later in the year because temperatures are higher and growth rates are faster; however, competition and predation rates are also higher.

Characterization	Temperature (°C)	Location	Citation
Optimal range	15.5 - 23.9	N/A	Crance 1985
Optimal range	10 - 25	N/A	Stier and Crance 1985
Range	10 - 30	Connecticut River	Marcy et al. 1972
Critical maximum	34 - 35	Neuse River, NC	Horton and Bridges 1973
Maximum tolerance	35	N/A	Stier and Crance 1985
Minimum preference	8	N/A	MacKenzie et al. 1985
Minimum tolerance	3	N/A	Stier and Crance 1985
Minimum tolerance	31.6	N/A	Ecological Analysts Inc. 1978
Begin migration	19	Connecticut River	Leggett 1976; O'Leary and Kynard 1986
Begin migration	23 - 26	Connecticut River	Marcy 1976
Begin migration	18.3	Connecticut River	Watson 1970
Peak migration	16	Connecticut River	Leggett and Whitney 1972; O'Leary and Kynard 1986
Peak migration	15.1	North Carolina	Neves and Depres 1979; Boreman 1981
End migration	8.3	Delaware River	Chittenden and Westman 1967
End migration	8.3	Chesapeake Bay	Chesapeake Bay Program 1988

Table 8. Temperature tolerances, preferences, and cues for juvenile American shad

Juvenile American shad do not appear to be as tolerant to temperature changes as eggs of the same species. In fact, juveniles are sensitive to water temperature changes, and actively avoid temperature extremes, if possible. Laboratory tests suggest that juveniles can tolerate temperature increases between 1° and 4°C above ambient temperature, but beyond that they will avoid changes if given a choice (Moss 1970). For example, juveniles acclimated to 25° C suffered a 100% mortality rate when the temperature was decreased to 15°C. There was also a 100% mortality rate for juveniles acclimated to 15°C and then subjected to temperatures less than 5°C. Finally, no survival was reported for juveniles acclimated to 5°C and then exposed to 1°C (PSE&G 1982).

Juvenile dissolved oxygen associations

Minimum dissolved oxygen values have a more adverse effect upon fish than average dissolved oxygen values; therefore, minimum dissolved oxygen criteria have been recommended. Dissolved oxygen concentrations less than 5.0 mg/L are considered sub-lethal to juvenile American shad (Miller et al. 1982). As with spawning areas, Bilkovic (2000) assigned a value of greater than 5.0 mg/L dissolved oxygen as optimal for nursery areas.

Seemingly healthy juvenile American shad have been collected in the Hudson River, New York, where dissolved oxygen concentrations were 4 to 5 mg/L (Burdick 1954). Similarly, in headponds above hydroelectric dams on the St. John River, New Brunswick, dissolved oxygen must be at least 4 to 5 mg/L for migrating juveniles to pass through (Jessop 1975). In the Delaware River, dissolved oxygen concentrations less than 3.0 mg/L blocked juvenile migration, and concentrations below 2.0 mg/L were lethal. Emigrating juveniles have historically arrived at the upper tidal section of the Delaware River by mid-October, but do not continue further seaward movement until November or December, when the pollution/low oxygen conditions dissipate (Miller et al. 1982).

Under laboratory conditions, juvenile American shad did not lose equilibrium until dissolved oxygen decreased to 2.5 to 3.5 mg/L (Chittenden 1969, 1973a). Juveniles have been reported to survive brief exposure to dissolved oxygen concentrations of as little as 0.5 mg/L, but survived only if greater than 3 mg/L was available immediately thereafter (Dorfman and Westman 1970).

Juvenile pH associations

Areas that are poorly buffered (low alkalinity) and subject to episodic or chronic acidification may provide less suitable nursery habitat than areas that have higher alkalinities and are less subject to episodic or chronic acidification (Klauda et al. 1991). Once juvenile American shad move downstream to brackish areas with a higher buffering capacity, they may be less impacted by changes in pH (Klauda 1989).

Juvenile water velocity/flow

Ideal water velocity rates are thought to range between 0.06 to 0.75 m/s for the juvenile non-migratory stage of American shad (Klauda et al. 1991). The rate of water velocity is also critical for fish migrating downstream that pass over spillways (MacKenzie et al. 1985). Furthermore, it has been suggested that water flow may serve to orient emigrating juveniles in the downstream direction. Studies conducted on American shad in the St. Johns River, Florida, led researchers to speculate that the lack of water flow as a result of low water levels could result in the inability of juveniles to find their way downstream (Williams and Bruger 1972).

Juveniles and suspended solids

Ross et al. (1997) suggest that optimal turbidity values for premigratory American shad juveniles in tributaries is between 0.75 and 2.2 NTU. While preliminary, these results could be cautiously applied to other river systems, but consideration should be given to the range and diversity of habitat types in the river system under study before applying the models.

Juvenile feeding

Juvenile American shad begin feeding in freshwater and continue into the estuarine environment. They favor zooplankton over phytoplankton (Maxfield 1953; Walburg 1956), and in general, have a wider selection of prey taxa than larvae due to their increased size and the estuaries' higher diversity. Long, closely-spaced gill rakers enable juveniles to effectively filter plankton from the water column during respiratory movements (Leim 1924). Juvenile American shad are opportunistic feeders, whose freshwater diet includes copepods, crustacean zooplankton, cladocerans, aquatic insect larvae, and adult aquatic and terrestrial insects (Leim 1924; Maxfield 1953; Massmann 1963; Levesque and Reed 1972; Marcy 1976). After juveniles leave coastal rivers and estuaries for nearshore waters, they may prey on some fish, such as smelt, sand lance, silver hake, bay anchovy, striped anchovy, and mosquitofish (Leidy 1868; Bowman et al. 2000).

Although juveniles obtain most of their food from the water column (ASMFC 1999), many of the crustaceans that juveniles prey upon are benthic (Krauthamer and Richkus 1987). Leim (1924) speculated that although American shad obtain a minor amount of food near the bottom of the water column, they do not pick it off the bottom, but rather capture items as they are carried up into the water column a short distance by tidal currents (including mollusks).

Walburg (1956) found that juvenile American shad fed primarily on suitable organisms that were readily available. In contrast, Ross et al. (1997) found that juveniles in SAV habitat fed principally on chironomids, while those feeding in tributaries consumed terrestrial insects almost exclusively, despite the fact that insects were less available than other food sources. Researchers did not attribute the differences to developmental limitations, but concluded that there were true feeding differences between habitats. Other studies have noted different selection of organisms along the same river, but at different locations, such as above a dam (Levesque and Reed 1972) or downstream of a dam (Domermuth and Reed 1980).

Feeding of juvenile American shad may also differ along a stream gradient. In waters of Virginia, Massman (1963) found that juvenile American shad upstream consume more food than juveniles that remain downstream near their spawning grounds. The upstream sections of the river have a higher shoreline to open water ratio that may provide a more abundant source of terrestrial insects, a favored prey item (Massman 1963; Levesque and Reed 1972), while the downstream sections contain more autochthonously-derived prey. In contrast, the lower reach of the Hudson River appears to be more productive (as a function of primary productivity and respiration rates) than upper and middle reaches (Sirois and Fredrick 1978; Howarth et al. 1992). This greater productivity may lead to higher fish production in the lower estuary, as well as a higher relative condition of downriver juvenile American shad earlier in the season, compared to upriver and midriver fish (Limburg 1994).

Juvenile American shad also demonstrate diel feeding patterns. Johnson and Dropkin (1995) found that juveniles increase feeding intensity as the day progresses, achieving a maximum feeding rate at 2000 h. Similarly, juveniles in the Mattaponi and Pamunkey rivers in Virginia, feed during the day with stomachs reaching maximum fullness by early evening (Massman 1963).

In addition, at least one non-native species has proven to have an impact on young-of-the-year American shad. In the Hudson River, there is strong evidence that zebra mussel colonization has reduced the planktonic forage base of the species (Waldman and Limburg 2003).

Juvenile competition and predation

Juveniles in freshwater may be preyed upon by American eel, bluefish, weakfish, striped bass, birds, and aquatic mammals (Mansueti and Kolb 1953; Walburg and Nichols 1967; Facey et al. 1986).

With regard to inter-species competition, differences among alosine species in terms of distribution, diel activity patterns, and feeding habits are evident in many systems, and are likely mechanisms that may reduce competition between juveniles of the different species (Schmidt et al. 1988). For example, several researchers have noted that larger American shad (Chittenden 1969; Marcy 1976; Schmidt et al. 1988) and alewife (Loesch et al. 1982; Schmidt et al. 1988) move downstream first, which helps to segregate size classes of the two species.

Secondly, there is the idea of diel, inshore-offshore segregation. Both American shad and blueback herring juveniles occur in shallow nearshore waters during the day. However, competition for prey between American shad and blueback herring is often reduced by: 1) more opportunistic feeding by American shad, 2) differential selection for cladoceran prey, and 3) higher utilization of copepods by blueback herring (Domermuth and Reed 1980). American shad feed most often in the upper water column, the air-water interface (Loesch et al. 1982), and even leap from the water (Massman 1963), feeding on *Chironomidae* larvae, *Formicidae*, and *Cladocera*; they are highly selective for terrestrial insects (Davis and Cheek 1966; Levesque and Reed 1972). Juvenile bluebacks are more planktivorous, feeding on copepods, larval dipterans, and *Cladocera* (Hirschfield et al. 1966), but not the same cladoceran families that alewife feed upon (Domermuth and Reed 1980).

Juveniles and contaminants

Tagatz (1961) found that the 48 h lethal concentrations (LC_{50}) for juvenile American shad range from 2,417 to 91,167 mg/L for gasoline, No. 2 diesel fuel, and bunker oil. The effects of gasoline and diesel fuel are exacerbated when the dissolved oxygen concentration is simultaneously reduced. Gasoline concentrations of 68 mg/L at 21 to 23°C resulted in a lethal time (LT_{50}) of 50 minutes for juveniles when dissolved oxygen was reduced to 2.6 to 3.2 mg/L. Additionally, juveniles that were exposed to 84 mg/L of diesel fuel at 21 to 23°C with dissolved oxygen between 1.9 and 3.1 mg/L experienced an LT_{50} of 270 minutes (Tagatz 1961).

Late Stage Juvenile and Adult Marine Habitat

Geographical and temporal patterns at sea

American shad typically live 5 to 7 years (Leggett 1969) and remain in the ocean for 2 to 6 years before becoming sexually mature, at which point they return to their natal rivers to spawn (Talbot and Sykes 1958; Walburg and Nichols 1967). Both sexes begin to mature at 2 years, with males maturing on average in 4.3 years and females maturing on average in 4.6 years. Fish north of Cape Hatteras are iteroparous and will return to rivers to spawn when temperatures are suitable (Leggett 1969).

Results from 50 years of tagging indicate that discrete, widely separated aggregations of juvenile and adult American shad occur at sea (Talbot and Sykes 1958; Leggett 1977a, 1977b; Dadswell et al. 1987; Melvin et al. 1992). These aggregations are a heterogeneous mixture of individuals from many river systems (Dadswell et al. 1987); it is unknown if American shad from all river systems along the east coast intermingle throughout the entire year (Neves and Depres 1979). Populations that return to rivers to spawn are a relatively homogeneous group (Dadswell et al. 1987), and fish from all river systems can be found entering coastal waters as far south as North Carolina in the winter and spring (Neves and Depres 1979).

Dadswell et al. (1987) presented the following seasonal movement timeline for American shad:

1) *January & February* –found offshore from Florida to Nova Scotia; spawning inshore from Florida to South Carolina;
2) *March & April* –moving onshore and northward from the Mid-Atlantic Bight to Nova Scotia; spawning from North Carolina to the Bay of Fundy;
3) *Late June* – concentrated in the inner Bay of Fundy, inner Gulf of St. Lawrence, Gulf of Maine, and off Newfoundland and Labrador; spawning fish are still upstream from Delaware River to St. Lawrence River;
4) *Autumn* –American shad leaving the St. Lawrence estuary are captured across the southern Gulf of St. Lawrence, while fish leaving the Bay of Fundy are found from Maine to Long Island; some individuals already migrated as far south as Georgia and Florida.

Through an analysis of tag returns, occurrence records, and trawl survey data, Dadswell et al. (1987) found that there are three primary offshore areas where aggregations of American shad overwinter: 1) off the Scotian Shelf/Bay of Fundy, 2) in the Mid-Atlantic Bight, and 3) off the Florida coast. It appears that the majority of American shad that overwinter along the Scotian Shelf spawn in rivers in Canada and New England (Vladykov 1936; Melvin et al. 1985). Fish aggregations that overwinter off the mid-Atlantic coast (from Maryland to North Carolina) are comprised of populations that spawn in rivers from Georgia to Quebec (Talbot and Sykes 1958; Miller et al. 1982; Dadswell et al. 1987).

The regional composition of American shad aggregations overwintering off the Florida coast is unknown. Leggett (1977a) proposed the following estimates for timing and origin of southern migrations for overwintering off Florida based on migration rates and an average departure date of October 1 from the Gulf of Maine/Bay of Fundy region: Rhode Island/Long Island coast in mid-to-late October, off Delaware Bay in early November, and off the coast of North Carolina, Georgia, and Florida in early December. Additionally, early migration studies of American shad found that during mild winters, small aggregations sometimes enter the sounds of North Carolina during November and December, but disappear if the weather becomes cold (Talbot and Sykes 1958).

Most American shad populations that overwinter off the mid-Atlantic coast (between 36° to 40°N) migrate shoreward in the winter and early spring. Pre-spawning adults homing to rivers in the south Atlantic migrate shoreward north of Cape Hatteras, North Carolina, then head south along the coast to their natal rivers. The proximity of the Gulf Stream to North Carolina provides a narrow migration corridor at Cape Hatteras through which individuals may maintain travel in the preferred temperature range of 3 to 15°C. Although pre-spawning adults are not required to follow a coastal route to North Atlantic rivers because temperatures in the Mid-Atlantic Bight are generally well within a tolerable range in the spring, tag returns indicate that most individuals likely enter coastal waters in the lower mid-Atlantic region, and then migrate north along the coast (Dadswell et al. 1987).

South of Cape Cod, pre-spawning American shad migrate close to shore (Leggett and Whitney 1972), but north of that point the migration corridor is less clear (Dadswell et al. 1987). Pre-spawning adults may detour into estuaries during their coastal migration; however, the timing and duration of the stay is unknown (Neves and Depres 1979). Although poorly documented, immature American shad (age 1+) may also enter estuaries and accompany adults to the spawning grounds, more than 150 km upstream (Limburg 1995, 1998). Additionally, non-spawning adults have been recorded in brackish estuaries (Hildebrand 1963; Gabriel et al. 1976). Dadswell et al. (1987) found three primary offshore summer aggregations of American shad: 1) Bay of Fundy/Gulf of Maine, 2) St. Lawrence estuary, and 3) off the coast of Newfound and Labrador. Neves and Depres (1979) also found distinct summer aggregations on Georges Bank and south of Nantucket Shoals. Furthermore, American shad from all river systems, including those from south Atlantic rivers, have been collected at the Gulf of Maine feeding grounds during the summer (Neves and Depres 1979). While individuals from north Atlantic rivers are most abundant in the Bay of Fundy in the early summer, the appearance of American shad from the southern range does not peak until mid-summer (Melvin 1984; Dadswell et al. 1987). These migrating groups are a mixture of juveniles, immature sub-adults, and spent and resting adults that originate from rivers along the entire East Coast (Dadswell et al. 1983). Since there are very few repeat spawners in the southern range, the majority (76%) of American shad that migrate to the Bay of Fundy from areas south of Cape Lookout, North Carolina, are juveniles (Melvin et al. 1992).

American shad enter the Bay of Fundy in early summer and move throughout the inner Bay of Fundy for four months in a counterclockwise direction with the residual current (Dadswell et al. 1987). As water temperatures decline in the fall, American shad begin moving through the Gulf of Maine, and continue to their offshore wintering grounds. This species has been captured in late fall and winter 80 to 95 km offshore of eastern Nova Scotia (Vladykov 1936), 65 to 80 km off the coast of Maine, 40 to 145 km off southern New England, and 175 km from the nearest land of southern Georges Bank (Colette and Klein-MacPhee 2002; Dadswell et al. 1987).

Salinity associations at sea

During their residence in the open ocean, American shad sub-adults and adults will live in seawater that is approximately 33 ppt. During coastal migration periods, pre-spawning adults may detour into estuaries where water is more brackish, but the timing and duration of the stay is unknown (Neves and Depres 1979).

Depth associations at sea

While it is known that adult American shad move offshore to deeper waters during the fall and early winter, information regarding preferred depths is lacking. American shad have been found throughout a broad depth range in the ocean, from surface waters to depths of 340 m (Walburg and Nichols 1967; Facey and Van Den Avyle 1986). Alternatively, catch data analyses showed that this species has been caught at depths ranging from surface waters to 220 m (Walburg and Nichols 1967), but are most commonly found at intermediate depths of 50 to 100 m (Neves and Depres 1979). Seasonal migrations are thought to occur mainly in surface waters (Neves and Depres 1979).

The summer and autumn months are a time of active feeding for American shad, and analyzing stomach contents has served as a means to infer distribution in the water column. Studies by Neves and Depres (1979) suggested that American shad follow diel movements of zooplankton, staying near the bottom during the day and dispersing in the water column at night. Other researchers (Dadswell et al. 1983) have suggested that light intensity may control depth selection by American shad. For example, American shad swim much higher in the water column in the turbid waters of Cumberland Basin, Bay of Fundy, than they do in clear coastal waters, where they are found in deeper water. Both areas are within the same surface light intensity range (Dadswell et al. 1983).

Temperature associations at sea

Early studies by Leggett and Whitney (1972) found that American shad move along the coast via a "migrational corridor" where water temperatures are between 13 and 18°C. Neves and Depres (1979) later modified the near-bottom temperature range from 3 to 15°C, with a preferred range of 7 to 13°C. These researchers also hypothesized that seasonal movements are broadly controlled by climate, and that American shad follow paths along migration corridors or oceanic paths of "preferred" isotherms. Melvin et al. (1985) and Dadswell et al. (1987) revised this theory with data indicating movement of American shad across thermal barriers. It was determined that American shad remain for extended periods in temperatures outside their "preferred" range; this species migrates rapidly between regions regardless of currents and temperatures (Melvin et al. 1985; Dadswell et al. 1987). For example, Dadswell et al. (1987) documented non-reproductive American shad migrating from wintering grounds in the Mid-Atlantic Bight through the Gulf of Maine in May-June, where a constant sub-surface temperature of 6°C prevails, to reach the Bay of Fundy by mid-summer.

Temperature change and some aspect of seasonality (i.e., day length) may initiate migratory behavior, but timing of the behavior by different individuals may be influenced by intrinsic (genetic) factors and life history stage of the individual. Chance may also play a small role in determining which direction a fish will travel, at least within a confined coastal region. Dadswell et al. (1987) concluded that extrinsic factors related to ocean climate, seasonality, and currents may provide cues for portions of non-goal-oriented migration, while intrinsic cues and bi-coordinate navigation appear to be important during goal-oriented migration.

Suspended solid associations at sea

Due to extreme turbidity, the American shad preference zone for light intensity in summer and fall in the Bay of Fundy is limited to surface waters (2 to 10 m). Although this makes the fish more susceptible to fishing gear that operates near surface waters, these waters are highly productive sources of zooplankton. Sight-oriented planktivores may be at a disadvantage in these turbid waters, but American shad, which can use a filter-feeding mechanism, may have a competitive advantage (Dadswell et al. 1983).

Feeding at sea

While offshore, American shad are primarily planktivorous, feeding on the most readily available organisms, such as copepods, mysid shrimps, ostracods, amphipods, isopods, euphausids, larval barnacles, jellyfish, small fish, and fish eggs (Willey 1923; Leim 1924; Maxfield 1953; Massmann 1963; Levesque and Reed 1972; Marcy 1976). Themelis (1986) found that in the Bay of Fundy, American shad mostly consume planktonic and epibenthic crustaceans. Differences in dominant prey items may be attributed to changing availability of zooplankton assemblages and the size of the American shad. Juveniles feed more extensively on copepods than adults and a smaller proportion of their diet is composed of large prey items such as euphausids and mysids (Themelis 1986). In earlier studies, Leim (1924) reported similar observations, with copepods decreasing in importance in the diets of American shad over 400 mm in length. Detritus has also been found in the stomachs of American shad, but it probably provides little nutritional value and is simply ingested during the course of feeding (Themelis 1986).

The Bay of Fundy is regarded as the primary summer feeding grounds for American shad, however, the entire bay does not provide optimal feeding conditions for adults. For example, although both adult and juvenile American shad feed readily in the oceanic lower Bay of Fundy, only juveniles feed to a large extent within the turbid and estuarine waters of the upper bay. This is attributed to the juvenile's ability to successfully filter smaller prey items that dominate the upper bay (Themelis 1982).

Competition and predation at sea

Once in the ocean, American shad are undoubtedly preyed upon by many species including sharks, tunas, king mackerel, bluefish, striped bass, Atlantic salmon, seals, porpoises, other marine mammals, and seabirds, given their schooling nature and lack of dorsal or opercular spines (Melvin et al. 1985; Weiss-Glanz et al. 1986).

Current laboratory research by Plachta and Popper (2003) has found that American shad can detect ultrasonic signals to at least 180 kHz, which is within the range that echolocating harbour porpoises and bottlenose dolphins use to track alosines. In this laboratory environment, American shad have been observed modifying their behavior in response to echolocation beams, such as turning slowly away from the sound source, forming very compact groups, and displaying a quick "panic" response. Although behavior in a natural environment may be different from that observed in experimental tanks, this study suggests that American shad may have evolved a mechanism to make themselves less "conspicuous" or less easily preyed upon by echolocating odontocetes (Plachta and Popper 2003).

1.3.1.5 Significant Environmental, Temporal and Spatial Factors Affecting Distribution of American shad

Table 9 Significant environmental, temporal, and spatial factors affecting distribution of American shad. Please note that, although there may be subtle variations between systems, the following data include a broad range of values that encompass the different systems that occur along the East Coast. Where a specific range is known to exist, it will be noted. For the sub-adult–estuarine/oceanic environment and non-spawning adult–oceanic environment life history phases, the information is provided as a general reference, not as habitat preferences or optima. NIF = No Information Found.

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Spawning Adult	Mid-November-August (south to north progression) in natal rivers and tributaries from St. Johns River, Florida to St. Lawrence River, Canada	**Tolerable:** 0.46-15.24 **Optimal:** 1.5-6.1 **Reported:** Variable	**Tolerable:** 8-26 **Optimal:** 14-24.5 **Reported:** Varies across range and may vary between years	**Tolerable:** NIF **Optimal:** NIF **Reported:** Mostly freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Sand, silt, gravel, boulder	**Tolerable:** NIF **Optimal:** 0.3-0.9 **Reported:** Avoid pools but prefer slow flow; velocity is an important factor	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 4
Egg	Mid-November-August (south to north progression) at spawning areas or slightly downstream	**Tolerable:** NIF **Optimal:** NIF **Reported:** Settle at bottom in shallow water	**Tolerable:** 8-30 **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Gravel, rubble, and sand have highest survival	**Tolerable:** NIF **Optimal:** 0.3-0.9 **Reported:** Low flow	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5
Larvae	2-17 days after fertilization depending on temperature, downstream of spawning areas	**Tolerable:** 0.46-15.24 **Optimal:** 1.5-6.1 **Reported:** Surface and water column	**Tolerable:** 10-30 **Optimal:** 15-25 **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** 0.3-0.9 **Reported:** Low flow	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Early Juvenile – Riverine Environment	3-5 weeks after hatching Downstream of spawning areas as far as brackish waters	**Tolerable:** 0.46-15.24 **Optimal:** 1.5-6.1 **Reported:** Variable	**Tolerable:** 3-35 **Optimal:** 10-25 **Reported:** Variable; growth higher at higher temps	**Tolerable:** 0-30 **Optimal:** NIF **Reported:** Gradual change well tolerated	**Tolerable:** NIF **Optimal:** Possibly areas w/50%+ SAV **Reported:** Boulder, cobble, gravel, sand, SAV	**Tolerable:** NIF **Optimal:** 0.1-0.8 **Reported:** Moderate needed for migration	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5
Subadult & Non-spawning Adult – Estuarine / Oceanic Environment	2-6 years after hatching; 1) Overwinter offshore of Florida, the Mid-Atlantic Bight, and Nova Scotia 2) Spring – migration route is unknown 3) Late June – inner Bay of Fundy, inner Gulf of St. Lawrence, Gulf of Maine, and Newfoundland and Labrador 4) Autumn – moving offshore	**Tolerable:** Surface waters to 340 m **Optimal:** 50-100 m **Reported:** Variable; possible diel migrations with zooplankton	**Tolerable:** Variable **Optimal:** 7-13 **Reported:** Generally travel in preferred isotherm	**Tolerable:** NIF **Optimal:** NIF **Reported:** Brackish to saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

Appendix D - Overlapping Habitat and Habitat Areas of Particular Concern for Alosines

Identification and Distribution of Habitat and Habitat Areas of Particular Concern for Alosines

NOTE: Due to the dearth of information on Habitat Areas of Particular Concern (HAPC) for alosine species, this information is applicable to American shad, hickory shad, alewife, and blueback herring combined. Information about one alosine species may be applicable to other alosine species, and is offered for comparison purposes only. Certainly, more information should be obtained at individual HAPCs for each of the four alosine species.

All habitats described in the preceding chapters (spawning adult, egg, larval, juvenile, sub-adult, and adult resident and migratory) are deemed essential to the sustainability of anadromous alosine stocks, as they presently exist (ASMFC 1999). Klauda *et al*. (1991b) concluded that the critical life history stages for American shad, hickory shad, alewife, and blueback herring, are the egg, prolarva (yolk-sac or pre-feeding larva), post-larva (feeding larva), and early juvenile (through the first month after transformation). Nursery habitat for anadromous alosines consists of areas in which the larvae, post-larvae, and juveniles grow and mature (ASMFC 1999). These areas include spawning grounds and areas through which the larvae and post-larvae drift after hatching, as well as the portions of rivers and estuaries in which they feed, grow, and mature. Juvenile alosines, which leave the coastal bays and estuaries prior to reaching adulthood, also use the nearshore Atlantic Ocean as a nursery area (ASMFC 1999).

Sub-adult and adult habitat for alosines consists of: the nearshore Atlantic Ocean from the Bay of Fundy in Canada to Florida; inlets, which provide access to coastal bays and estuaries; and riverine habitat upstream of the spawning grounds (ASMFC 1999). American shad and river herring have similar seasonal distributions, which may be indicative of similar inshore and offshore migratory patterns (Neves 1981). Although the distribution and movements of hickory shad are essentially unknown after they return to the ocean (Richkus and DiNardo 1984), due to harvest along the southern New England coast in the summer and fall (Bigelow and Schroeder 1953) it is assumed that they also follow a migratory pattern similar to American shad (Dadswell *et al*. 1987).

Critical habitat in North Carolina is defined as, "The fragile estuarine and marine areas that support juvenile and adult populations of economically important seafood species, as well as forage species important in the food chain." Among these critical habitats are anadromous fish spawning and nursery areas in all coastal fishing waters (NCAC 3I.0101 (20) (NCDEHNR 1997). Although most states have not formally designated essential or critical alosine habitat areas, most states have identified spawning habitat, and some have even identified nursery habitat.

Tables in Section II of each alosine species chapter contain significant environmental, temporal, and spatial factors that affect the distribution of American shad, hickory shad, alewife, and blueback herring. Additional tables found on the included DVD contain confirmed, reported, suspected, or historical state habitat for American shad, hickory shad, alewife, and blueback herring. Alosines spend the majority of their life cycle outside of state waters, and the Commission recognizes that all habitats used by these species are essential to their existence.

Present Condition of Riverine Habitats and Habitat Areas of Particular Concern

Fisheries management measures cannot successfully sustain anadromous alosine stocks if the quantity and quality of habitat required by all species are not available. Harvest of fisheries resources is a major factor impacting population status and dynamics, and is subject to control and manipulation. However, without adequate habitat quantity and quality, the population cannot exist (ASMFC 1999).

Habitat Quantity

Thousands of kilometers of historic anadromous alosine habitat have been lost due to development of dams and other obstructions to migration. In the 19th century, organic pollution from factories created zones of hypoxia or anoxia near large cities (Talbot 1954; Chittenden 1969). Gradual loss of spawning and nursery habitat quantity and quality, and overharvesting are thought to be the major causative factors for population declines of American shad, hickory shad, alewife, and blueback herring (ASMFC 1999). Although these threats are considered the major causative factors in the decline of shad and river herring, additional threats are discussed in the Threats chapter.

It is likely that American shad spawned in all rivers and tributaries throughout the species' range on the Atlantic coast prior to dam construction in this country (Colette and Klein-MacPhee 2002). While precise estimates are not possible, it is speculated that at least 130 rivers supported historical runs; now there are fewer than 70 systems that support spawning. Individual spawning runs may have numbered in the hundreds of thousands. It is estimated that runs have been reduced to less than 10% of historic sizes. One recent estimate of river kilometers lost to spawning is 4.36×10^3 compared to the original extent of the runs. This is an increase in available habitat over estimates from earlier years, with losses estimated at 5.28×10^3 in 1898 and 4.49×10^3 in 1960. The increase in available habitat has largely been due to restoration efforts and enforcement of pollutant abatement laws (Limburg *et al*. 2003).

Some states have general characterizations of the degree of habitat loss, but few studies have actually quantified impacts in terms of the area of habitat lost or degraded (ASMFC 1999). It has been noted that dams built during the 1800's and early to mid-1900's on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran *et al*. 1983; CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953). North Carolina characterized river herring habitat loss as "considerable" from wetland drainage, stream channelization, stream blockage, and oxygen-consuming stream effluent (NCDENR 2000).

Some attempts have been made to quantify existing or historical areas of anadromous alosine habitat, including spawning reaches. For example, Maine estimated that the American shad habitat area in the Androscoggin River is 10,217,391 yd^2. In the Kennebec River, Maine, from Augusta to the lower dam in Madison, including the Sebasticook and Sandy rivers, and Seven Mile and Wesserunsett streams, there is an estimated 31,510,241 yd^2 of American shad habitat and 24,606 surface acres of river herring habitat. Lary (1999) identified an estimated 90,868 units (at 100 yd^2 each) of suitable habitat for American shad and 296,858 units (at 100 yd^2 each) for alewife between Jetty and the Hiram Dam along the Saco River, Maine. Above the Bosher's Dam on the James River, Virginia, habitat availability was estimated in terms of the number of spawning fish that the main-stem area could support annually, which was estimated at 1,000,000 shad and 10,000,000 river herring (Weaver *et al*. 2003).

Although many stock sizes of alosine species are decreasing or remain at historically low levels, some stock sizes are increasing. It has not been determined if adequate spawning, nursery, and adult habitat presently exist to sustain stocks at recovered levels (ASMFC 1999).

Habitat Quality

Concern that the decline in anadromous alosine populations is related to habitat degradation has been alluded to in past evaluations of these stocks (Mansueti and Kolb 1953; Walburg and Nichols 1967). This degradation of alosine habitat is largely the result of human activities. However, it has not been possible to rigorously quantify the magnitude of degradation or its contribution to impacting populations (ASMFC 1999).

Of the habitats used by American shad, spawning habitat has been most affected. Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. In most alosine spawning and nursery areas, water quality problems have been gradual and poorly defined; it has not been possible to link those declines to changes in alosine stock size. In cases where there have been drastic declines in alosine stocks, such as in the Chesapeake Bay in Maryland, water quality problems have been implicated, but not conclusively demonstrated to have been the single or major causative factor (ASMFC 1999).

Toxic materials, such as heavy metals and various organic chemicals (i.e., insecticides, solvents, herbicides), occur in anadromous alosine spawning and nursery areas and are believed to be potentially harmful to aquatic life, but have been poorly monitored. Similarly, pollution in nearly all of the estuarine waters along the East Coast has certainly increased over the past 30 years, due to industrial, residential, and agricultural development in the watersheds (ASMFC 1999). Specific challenges that currently exist are identified and discussed in greater detail in the Threats Chapter.

Threats to Alosine Species

NOTE: Due to broad geographic ranges, alosine species are susceptible to varied threats throughout different life stages. The threats identified under this section occur during the freshwater and/or estuarine portion of species life histories.

Identification of Threats

THREAT #1: BARRIERS TO UPSTREAM AND DOWNSTREAM MIGRATION

Section 1.1A: Dams and Hydropower Facilities

Issue 1.1A.1: Blocked or restricted upstream access

There has been considerable loss of historic spawning habitat for shad and river herring due to the dams and spillways impeding rivers along the East Coast of the United States. Permanent man-made structures pose an ongoing barrier to fish passage unless fishways are installed or structures are removed. Low-head dams can also pose a problem, as fish are unable to pass over them except when tides or river discharges are exceptionally high (Loesch and Atran 1994). Historically, major dams were often constructed at the site of natural formations conducive to waterpower, such as natural falls. Diversion of water away from rapids at the base of falls can reduce fish habitat, and in some cases cause rivers to run dry at the base for much of the summer (MEOEA 2005).

Many dams have facilities that are designed to provide upstream passage to spawning habitat for migratory species. However, dams without adequate upstream fish passage facilities prevent, or significantly reduce, the numbers of migratory fish that return to available habitat (Quinn 1994). Suboptimal fish passage at a low-head dam on the Neuse River, North Carolina, resulted in limited production of American shad in that system (Beasley and Hightower 2000). Subsequent removal of the dam in 1998 facilitated the return of American shad and striped bass to historic spawning habitats above the dam.

American shad likely spawned in most, if not all, rivers and tributaries in their range prior to dam construction along the Atlantic coast (Colette and Klein-MacPhee 2002). Precise estimates are not possible, but scientists speculate that at least 130 rivers supported historical runs; now there are fewer than 70 spawning systems for American shad. Furthermore, individual spawning runs at one time may have numbered in the hundreds of thousands, but current runs may provide less than 10% of historic spawning habitat (Limburg *et al*. 2003). Dams built from the 19th century through the mid-20th century on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran *et al*. 1983; CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953).

Issue 1.1A.2: Impacts during downstream migration

Another impact of dams on diadromous species migration is their potential to cause mortality to young fish that pass over sluices and spillways during out-migration. Potential effects to fish passing through spillways or sluices may include injury from turbulence, rapid deceleration, terminal velocity, impact against the base of the spillway, scraping against the rough concrete face of the spillbay, and rapid pressure changes (Ferguson 1992; Heisey *et al*. 1996).

Prior to the early 1990s, it was thought that migrating shad and river herring suffered significant mortality going through turbines during downstream passage (Mathur and Heisey 1992). One study estimated that mortality of adult American shad passing through a Kaplan turbine was approximately 21.5% (Bell and Kynard 1985).

Juvenile shad emigrating from rivers have been found to accumulate in larger numbers near the forebay of hydroelectric facilities, where they become entrained in intake flow areas (Martin *et al*. 1994). Relatively high mortality rates were reported (62% to 82%) at a hydroelectric dam for juvenile American shad and blueback herring, depending on the power generation levels tested (Taylor and Kynard 1984). In contrast, Mathur and Heisey (1992) reported a mortality rate of 0% to 3% for juvenile American shad (55 to 140 mm fork length), and 4% for juvenile blueback herring (77 to 105 mm fork length) through Kaplan turbines. Mortality rate increased to 11% in passage through a low-head Francis turbine (Mathur and Heisey 1992). Other studies reported less than 5% mortality when large Kaplan and fixed-blade, mixed-flow turbines were used at a facility along the Susquehanna River (RMC 1991, 1994). At the same site, using small Kaplan and Francis runners, the mortality rate was as high as 22% (NA 2001). At another site, mortality rate was about 15% where higher revolution, Francis-type runners were used (RMC 1992).

Additional studies reported that changes in pressure had a more pronounced effect on juveniles with thinner and weaker tissues as they moved through turbines (Taylor and Kynard 1984). Furthermore, some fish may die later from stress, or become weakened and more susceptible to predation, so losses may not be immediately apparent to researchers (Gloss 1982).

Issue 1.1A.3: Delayed migration

When juvenile alosines delay out-migration, they may concentrate behind dams, making them more susceptible to actively feeding predators. They may also be more vulnerable to anglers that targ*et al*osines as a source of bait. Delayed out-migration can also make juvenile alosines more susceptible to marine predators that they may have avoided if they had followed their natural migration patterns (McCord 2005a). In open rivers, juvenile alosines gradually move seaward in groups that are likely spaced according to the spatial separation of spawning and nursery grounds (Limburg 1996; J. McCord, South Carolina Department of Natural Resources, personal observation).

Issue 1.1A.4: Changes to the river system

In addition to physically impeding fish migration, dams can have other impacts on anadromous fish habitat. Releasing water from dams and impoundments (or reservoirs) may lead to flow alterations, altered sediment transport, disruption of nutrient availability, changes in water quality downstream (including both reduced and increased changes in temperatures), streambank erosion, concentration of sediment and pollutants, changes in species composition, solubilization of iron and manganese and their absorbed or chelated ions, and hydrogen sulfide in hypolimnetic (release of water at low level outlets) releases (Yeager 1995; Erkan 2002). Many dams spill water over the top of the structure where water temperatures are the warmest, which essentially creates a series of warm water ponds rather than a natural stream channel (Erkan 2002). Conversely, water released from deep reservoirs may be poorly oxygenated, below normal seasonal water temperature, or both, thereby causing loss of suitable spawning or nursery habitat in otherwise habitable areas.

Reducing minimum flows can dehydrate otherwise productive habitats causing increased water temperature or reduced dissolved oxygen levels (ASMFC 1985, 1999; USFWS *et al*. 2001).

Pulsing or "hydropeaking" releases typically produce the most substantial environmental alterations (Yeager 1995), including reduced biotic productivity in tailwaters (Cushman 1985).

During low flow periods (typically summer and fall), gases, dissolved oxygen in particular, may be depleted (Yeager 1995). Storing water at hydropower facilities during times of diminished rainfall can also lead to low dissolved oxygen conditions downstream. Such conditions have occurred along the Susquehanna River at the Conowingo Dam, Maryland, from late spring through early fall, and have historically caused large fish kills below the dam (Krauthamer and Richkus 1987).

Disruption of seasonal flow rates in rivers has the potential to impact upstream and downstream migration patterns for adult and juvenile alosines (ASMFC 1985, 1999; Limburg 1996; USFWS *et al*. 2001). Changes to natural flows can also disrupt natural productivity and availability of zooplankton, which is nourishment for larval and early juvenile alosines (Crecco and Savoy 1987; Limburg 1996).

Although most dams that impact diadromous fish are located along the length of rivers, fish can also be affected by hydroelectric projects at the mouths of rivers, such as the large tidal hydroelectric project at the Annapolis River in the Bay of Fundy, Canada. Dadswell *et al*. (1983) found that this particular basin and other surrounding waters are used as foraging areas during summer months by American shad from all runs along the East Coast of the United States. Because the facilities are tidal hydroelectric projects, fish may move into and out of the impacted areas with each tidal cycle. Although turbine mortality is relatively minor with each passage, the repeated passage into and out of these facilities may cumulatively result in substantial overall mortalities (Scarratt and Dadswell 1983).

Issue 1.1A.5: Secondary impacts

Blocked migratory paths can reduce the diadromous species contribution of nutrients and carbon to riparian systems. Riverine habitats and communities may be strongly influenced by migratory fauna that provide a significant source of energy input (Polis *et al*. 1997). Furthermore, many freshwater mussels are dependent upon migratory fishes as hosts for their parasitic larvae (Neves *et al*. 1997; Vaughn and Taylor 1999); loss of upstream habitat for migratory fish is a major cause of mussel population declines (Williams *et al*. 1993; Watters 1996).

It is estimated that the annual biomass contribution of anadromous alosines to the non-tidal James River, Virginia, was 155 kg/ha (assumes 3.6 million fish with 70% post-spawning mortality) in the 1870s, before dams blocked upstream migration (Garman 1992). Based on the estimated 90% reduction in alosine abundance in the Chesapeake Bay over the past 30 years, Garman and Macko (1998) concluded that, "the ecological roles hypothesized for anadromous *Alosa* spp. may now be greatly diminished compared to historical conditions."

Section 1.1B: Avoiding, Minimizing, and Mitigating Impacts of Dams and Hydropower Facilities

Approach 1.1B.1: Removing dams

Not all projects are detrimental to fish populations, so each site should be evaluated separately to determine if fish populations will be (or are being) negatively impacted (Yeager 1995). Wherever practicable, tributary blockages should be removed, dams should be notched, and bypassing dams or installing fish lifts, fish locks, fishways, or navigation locks should be considered. Full dam removal will likely provide the best chance for restoration; however, it is not always practicable to remove large dams along mainstem rivers. Removing dams on smaller, high-order tributaries is more likely to benefit ascending river herring than shad, which spawn in the larger mainstem portions of rivers (Waldman and Limburg 2003).

<u>Example: Successful Dam Removals</u>

Along the large, lower-river tributaries of the Susquehanna River, Pennsylvania, at least 25 dams have either been removed or fitted with fishways, which has provided a total of 350 additional stream kilometers for anadromous fish (St. Pierre 2003). In addition, some dams within the Atlantic sturgeon's range have been removed, including the Treat Falls Dam on the Penobscot River, Maine, and the Enfield Dam on the Connecticut River, Connecticut. In 1999, the Edwards Dam at the head-of-tide on the Kennebec River was removed, which restored 18 miles of Atlantic sturgeon spawning and nursery habitat and resulted in numerous sightings of large Atlantic sturgeon from Augusta to Waterville (Squires 2001).

Unfortunately, many waterways along the Atlantic coast host impoundments constructed during the Industrial Revolution that originally were a source of inexpensive power; many of these structures are no longer in use and should be removed (Erkan 2002).

Approach 1.1B.2: Installing or modifying fish passage facilities

1. For Upstream Passage

a) Fishways

Fish passage facilities, or fishways, allow fish to pass around an impoundment they would otherwise be unable to negotiate. Vertical slot fishways are commonly used to provide upstream access around dam structures. They are designed to draw fish away from the turbulent waters at the base of the dam toward the smooth flowing waters at the entrance of the fishway. Once fish enter the fishway, they negotiate openings, or vertical slots, in the baffle walls. Fish move from pool to pool as they advance up the fishway, using the pools as rest areas (VDGIF 2006).

Another type of fishway is the fish ladder. Fish ladders consist of a series of baffles, or weirs, that interrupt the flow of water through the passage structure. As with vertical slot fishways, a series of ascending pools is created.

A third type of fishway, the Denil fishway, is the most common type in the northeast and reliably passes shad and river herring. In fact, construction of fish ladders in coastal streams of Maine resulted in rapid and noticeable increases in the number of adult alewife returning to these streams (Rounsefell and Stringer 1943).

It is important to note that although fish passage facilities are instrumental in restoring fish to historical habitat, they are not 100% efficient because some percentage of target fish will not find and successfully use the fishway (Weaver *et al*. 2003). At sites where bypass facilities are in place, but are inadequate, efficiency of upstream and downstream fish passage should be improved. Furthermore, passage facilities should be designed specifically for passing target species; some facilities constructed for species such as Atlantic salmon, have proven unsuitable for passing shad (Aprahamian *et al*. 2003).

In 1999, a vertical slot fishway was opened at Bosher's Dam on the James River, Virginia, ending nearly 200 years of blocked access to upstream areas. As a result, 221.4 km of historical spawning habitat on the main stem of the river and 321.9 km on tributaries was restored. By 2001, an increasing trend of relative abundance of American shad in the fall zone was strongly correlated with an increasing trend of American shad passage (Weaver *et al*. 2003). (Note: This increase was dominated by hatchery-raised fish, thus, fish passage may have had little to do with the increased population in this situation; M. Hendricks, Pennsylvania Fish and Boat Commission, pers., comm.)

b) Pipe passes

Pipe passes consist of a pipe below the water level that passes through a barrier. Substrate is provided in the pipe to decrease water velocity and to allow American eel to crawl through the pipe. Although this design creates a direct passage, it is flawed because the pipe often becomes blocked with debris, rendering it ineffective. Pipe passes are most efficient at the outflow of large impoundments that act as a sediment trap for debris so that water entering the pipe is clear of material that might cause a blockage (Solomon and Beach 2004).

c) Locks and lifts

For locks, fish swim into a lock chamber with an open lower gate. The gate periodically closes and the chamber is filled with water, bringing it up to level with the headpond. The upper gate is then opened and the fish swim out. This type of fish passage involves a great deal of engineering and can be expensive. This solution is ideal for very high head situations where conventional passes are impractical (Solomon and Beach 2004).

Alternatively, a fishlift involves a chamber that fish swim into. A steel bucket recessed in the chamber floor is lifted up to or above the head pond level, a gate is opened and the fish are dumped out. Moffitt *et al*. (1982) noted that blueback herring responded quite favorably to improved lift facilities at the Holyoke Dam on the Connecticut River, with passage increasing tremendously. Despite these improvements, stocks have declined considerably in recent years (R. St. Pierre, United States Fish and Wildlife Service, pers. comm.).

2. For Downstream Passage

Fish migrating downstream may pass through turbines, spillage, bypass facilities, or a combination of the three. One comparison between spillways and efficiently operated turbines found that the two systems were comparable in reducing fish mortality (Heisey *et al*. 1996).

Downstream passage of spent adult American shad through large turbines at the Safe Harbor project along the Susquehanna River, Pennsylvania, found that survival rate was 86% (NA and Skalski 1998). Survival rates would likely not be as favorable at facilities that employ smaller, high-speed turbines. Additional measures to help facilitate survival rates include controlled spills during peak migration months (St. Pierre 2003).

At some sites it is not desirable to move fish through turbines, alternatively, they can be moved through a bypass facility. Creating a strong attraction flow helps guide fish to the bypass system and away from the intake flow areas of the turbines (Knights and White 1998; Verdon *et al*. 2003). Additionally, barrier devices can help deter fish away from flow intake areas. Barrier devices used to deter fish include lights, high-frequency sound, air bubble curtains, electrical screens, water jet curtains, and chemicals. Mechanical barrier devices include hanging chains, louvers, angled bars, and screens (Martin *et al*. 1994; Richkus and Whalen 1999; Richkus and Dixon 2003). Submerged strobe lights were found to be quite effective at directing fish away from turbines and through a sluiceway (Martin *et al*. 1994).

Approach 1.1B.3: Operational modifications

Hydroprojects operate more closely to the natural flow patterns of a stream when water moves through them with a fairly constant flow. Consequently, storage-release projects are more likely to alter both daily and seasonal flow patterns (Yeager 1995). Adjusting in-stream flows to more closely reflect natural flow regimes may help increase productivity of alosines, especially during summer to early fall when large, deep reservoirs stratify, and anoxic water releases are possible (McCord 2003).

Power generation can also be reduced, or ceased altogether, during prime downstream migration periods. This option might be cost-effective if migratory behavior coincides with off-peak rate schedules (Gilbert and Wenger 1996). Flows can be re-regulated at dams downstream of the primary dam to stabilize flows further downstream (Cushman 1985). Additionally, some studies have found that the most efficient operating flows for small turbines may not result in the best fish survival rates, but that operation at higher flows may pass fish more safely (Fisher *et al*. 1997).

Where hydrological conditions have been modified, additional measures can be implemented to help mitigate impacts on the river. For example, operational changes can be made to accomplish a number of improvements, such as reducing the upper limit of variability of one or more of the physical or chemical characteristics of the river. For example, incorporating turbine venting into major dams has proven useful for increasing dissolved oxygen concentrations. Alternatively, aerating reservoirs upstream of hydroelectric plants (Mobley and Brock 1996), as well as aerating flows downstream from the plants using labyrinth weirs and infuser weirs have also proven reliable for increasing the dissolved oxygen concentration in the water (Hauser and Brock 1994).

For alosines that migrate downstream during early evening hours, maintaining peak efficiency flows through selected turbines during these hours, as well as employing turbines that reduce mortality, may be effective (St. Pierre 2003).

Approach 1.1B.4: Streambank stabilization

States that have significant problems with streambank erosion have turned to stabilization to help further prevent erosion. Projects should maintain vegetated riparian buffers, making use of native vegetation wherever possible (MEOEA 2005). Habitat modification, including manipulating the cross-sectional geometry of the stream channel, may also serve to mitigate effects (Cushman 1985).

Loesch (1987) found that blueback herring responded favorably to changes in physical and hydrological conditions, becoming re-established and even increasing in abundance once favorable conditions were established or restored.

Approach 1.1B.5: Fish transfers

When populations have been extirpated from their habitat due to dam blockage, it may be necessary to transfer sexually mature pre-spawning adults or hatchery-reared fry and fingerlings above obstructed areas.

Transplanting of fertilized alosine eggs has had limited success; eggs are now collected mostly for use in culture operations. Culture operations have focused primarily on American shad, and to a lesser degree blueback herring, alewife, and hickory shad (Hendricks 2003). Transplanting adult American shad, blueback herring, and alewife has been highly successful. Adult gravid shad can be trapped in the river where they originate, or other rivers, and trucked to upstream sites where they can be expected to spawn in areas that are otherwise not accessible. This may be an effective means for supplementing the river population until fish passage facilities are improved (both in the upstream and downstream direction), or fish passage facilities are constructed where they currently do not exist. As the return populations grow, further modifications may be necessary to accommodate larger runs (St. Pierre 1994).

For example, the release of hatchery-reared American shad in the James River, Virginia, in the mid-1990's, resulted in greater than 40% of hatchery-reared fish spawning several years later. This percentage greatly exceeded the percentage of the hatchery contribution (3 to 8%). If the offspring of hatchery-reared fish survive to reproduce, this should provide a significant boost to this severely depressed population (Olney *et al*. 2003).

At the Conowingo Dam on the Susquehanna River, Pennsylvania, 70 to 85% of the adult American shad returning from 1991 through 1995 were hatchery-reared. By 2003, the hatchery-to-wild ratio had been reversed, and naturally produced adults comprised 40 to 60% of returning fish (St. Pierre 2003).

Additionally, Maryland reported that over 80% of the 142 adults captured in the Patuxent and Choptank rivers in 2000 were of hatchery origin. It appears that shad stock enhancement, through the release of hatchery-reared fish, has proven to be beneficial when accompanied by other management measures including habitat restoration and water quality protection (Hendricks 2003).

Finally, pre-spawning adult American shad were taken from the Connecticut River and transplanted in the Pawcatuck River, Rhode Island, where they had been absent for 100 years. Six years later, in 1985, a population of over 4,000 fish existed (Gibson 1987).

Section 1.2: Road Culverts and Other Sources of Blockage

Issue 1.2A: Road culverts

While dams are the most common obstructions to fish migration, road culverts are also a significant source of blockage. Culverts are popular, low-cost alternatives to bridges when roads must cross small streams and creeks. Although the amount of habitat affected by an individual culvert may be small, the cumulative impact of multiple culverts within a watershed can be substantial (Collier and Odom 1989).

Roads and culverts can also impose significant changes in water quality. Winter runoff in some states includes high concentrations of road salt, while stormwater flows in the summer cause thermal stress and bring high concentrations of other pollutants (MEOEA 2005).

Sampled sites in North Carolina revealed river herring upstream and downstream of bridge crossings, but no herring were found in upstream sections of streams with culverts. Additional study is underway to determine if culverts are the cause for the absence of river herring in these areas (NCDENR 2000). Even structures only 20 to 30 cm above the water can block shad and river herring migration (ASMFC 1999).

Issue 1.2B: Other man-made structures

Additional man-made structures that may obstruct upstream passage include: tidal and amenity barrages; tidal flaps; mill, gauging, amenity, navigation, diversion, and water intake weirs; fish counting structures; and earthen berms (Durkas 1992; Solomon and Beach 2004). The impact of these structures is site-specific and will vary with a number of conditions including head drop, form of the structure, hydrodynamic conditions upstream and downstream, condition of the structure, and presence of edge effects (Solomon and Beach 2004).

Issue 1.2C: Natural barriers

Rivers can also be blocked by non-anthropogenic barriers, such as beaver dams, waterfalls, log piles, and vegetative debris. These blockages may be a hindrance to migration, but they can also be beneficial since they provide adhesion sites for eggs, protective cover, and feeding sites (Klauda *et al*. 1991b). Successful passage at these natural barriers is often dependent on individual stream flow characteristics during the fish migration season.

THREAT #2: WATER WITHDRAWAL FACILITIES

Section 2.1A: Hydropower, Drinking Water, Irrigation, and Snow-making Facilities

Issue 2.1A.1: Impingement and entrainment

Large volume water withdrawals (e.g., drinking water, pumped-storage hydroelectric projects, irrigation, and snow-making), especially at pumped-storage facilities, can drastically alter local current characteristics (e.g., reverse river flow). This can cause delayed movement past the facility, or entrainment where the intakes occur (Layzer and O'Leary 1978). Planktonic eggs and larvae entrained at water withdrawal projects experience high mortality rates due to pressure changes, shear and mechanical stresses, and heat shock (Carlson and McCann 1969; Marcy 1973; Morgan *et al*. 1976). Well-screened facilities are unlikely to cause serious mortality to juveniles; however, large volume withdrawals can entrain significant numbers (Hauck and Edson 1976; Robbins and Mathur 1976).

Impingement of fish can trap them against water filtration screens, leading to asphyxiation, exhaustion, removal from the water for prolonged periods of time, or removal of protective mucous and descaling (DBC 1980).

Studies conducted along the Connecticut River found that larvae and early juveniles of alewife, blueback herring, and American shad suffered 100% mortality when temperatures in the cooling system of a power plant were elevated above 28°C; 80% of the total mortality was caused by mechanical damage and 20% was due to heat shock (Marcy 1976b). Ninety-five percent of the fish near the intake were not captured by the screen, and Marcy (1976b) concluded that it did not seem possible to screen fish larvae effectively. Results from earlier years led Marcy (1976c) to conclude that although mortality rates for eggs and larvae entrained in the intake system were very high, given the high natural mortality rate and the number of eggs produced by one adult shad, the equivalent of only one adult shad was lost during that study year as a result of egg and larval entrainment. Furthermore, there was no evidence that adult shad had changed the location of their spawning areas in the river as a result of plant operation (Marcy 1976c).

Another study of juvenile American shad emigrating from the Hudson River found that impingement at power plants was an inconsequential source of mortality; however, when added to other more serious stresses, it may possibly contribute to increased mortality rates (Barnthouse and Van Winkle 1988).

Issue 2.1A.2: Alteration of stream physical characteristics

Water withdrawals can also alter physical characteristics of streams, including: decreased stream width, depth, and current velocity; altered substrate; and temperature fluctuations (Zale *et al*. 1993). In rivers that are drawn upon for water supply, water is often released downstream during times of decreased river flow (usually summer). Additionally, failure to release water during times of low river flow and higher than normal water temperatures can cause thermal stress, leading to fish mortality. Consequently, water flow disruption can result in less freshwater input to estuaries (Rulifson 1994), which are important nursery areas for many anadromous species.

Cold water releases often decrease the water temperature of the river downstream, which has been shown to cause juvenile American shad to abandon their nursery areas (Chittenden 1969; 1972). At the Cannonsville Reservoir on the West Branch of the Delaware River, cold-water releases from the dam resulted in the elimination of nursery grounds below the dam for American shad (DBC 1980).

Section 2.1B: Avoiding, Minimizing, and Mitigating Impacts of Water Withdrawal Facilities

Approach 2.1B.1: Use of technology and water velocity modification

Impacts resulting from entrainment can be mitigated to some degree through the use of the best available intake screen technology (ASMFC 1999), or through modifying water withdrawal rates or water intake velocities (Lofton 1978; Miller *et al*. 1982). Devices have also been used at hydroelectric projects to deter fish from intake flows, including: electrical screens, air bubble curtains, hanging chains, lights, high-frequency sound, water jet curtains, chemicals, visual keys, or a combination of these approaches (Martin *et al*. 1994). Promoting measures among industry that use reclaimed water, instead of freshwater from natural areas, can help reduce the amount of freshwater needed (FFWCC 2005). Location along the river was also found to be a significant factor affecting impingement rates in the Delaware River (Lofton 1978).

THREAT #3: TOXIC AND THERMAL DISCHARGES

Section 3.1A: Industrial Discharge Contamination

Issue 3.1A.1: Chemical effects on fish

Industrial discharges may contain toxic chemicals, such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) that are harmful to aquatic life (ASMFC 1999). Many contaminants have been identified as having deleterious effects on fish, particularly reproductive impairment (Safe 1990; Longwell *et al*. 1992; Mac and Edsall 1991). Chemicals and heavy metals can be assimilated through the food chain, producing sub-lethal effects such as behavioral and reproductive abnormalities (Matthews *et al*. 1980). In fish, exposure to polychlorinated biphenyls (PCBs) can cause fin erosion, epidermal lesions, blood anemia, altered immune response, and egg mortality (Post 1987;

Kennish *et al*. 1992). Furthermore, PCBs are known to have health effects in humans and are considered to be human carcinogens (Budavari *et al*. 1989).

A number of common pollutants have been found to disturb the thyroid gland in fish, which plays a role in the maturation of oocytes. These chemicals include: lindane (organochlorine) (Yadav and Singh 1987); malathion (organophosphorus compound) (Lal and Singh 1987; Singh 1992); endosulfan (organochlorine) (Murty and Devi 1982); 2,3,7,8-PCDD and –PCDF (dioxin and halogenated furane); some PCBs (particularly 2,3,7,8-TCDD *para* and *meta* forms) (Safe 1990); and PAHs (polycyclic aromatic hydrocarbons) (Leatherland and Sunstegard 1977, 1978, 1980).

Steam power plants that use chlorine to prevent bacterial, fungal, and algal growth present a hazard to all aquatic life in the receiving stream, even at low concentrations (Miller *et al*. 1982). Pulp mill effluent and other oxygen-consuming wastes are discharged into a number of streams.

Lack of dissolved oxygen from industrial pollution and sewage discharge can greatly affect abundance of shad and prevent migration upriver or prevent adults from emigrating to sea and returning again to spawn. Everett (1983) found that during times of low water flow when pulp mill effluent comprised a large percentage of the flow, river herring avoided the effluent. Pollution may be diluted in the fall when water flow increases, but fish that reach the polluted waters downriver before the water has flushed the area will typically succumb to suffocation (Miller *et al*. 1982).

Effluent may also pose a greater threat during times of drought. Such conditions were suspected of interfering with the herring migration along the Chowan River, North Carolina, in 1981. In past years, the effluent from the pulp mill had passed prior to the river herring run, but drought conditions caused the effluent to remain in the system longer. Toxic effects were indicated, and researchers suggested that growth and reproduction might have been disrupted as a result of eutrophication and other factors (Winslow *et al*. 1983).

Even thermal effluent from power plants can have a profound effect on fish, causing disruption of schooling behavior, disorientation, and death. Researchers concluded that 30°C was the upper natural temperature limit for juvenile alosines (Marcy *et al*. 1972).

Issue 3.1.2: Sewage effects on fish

Sewage can have direct and indirect effects on anadromous fish. Minimally effective sewage treatment during the 1960s and early 1970s may have been responsible for major phytoplankton and algal blooms in tidal freshwater areas of the Chesapeake Bay, which reduced light penetration (Dixon 1996), and ultimately reduced SAV abundance (Orth *et al*. 1991). Some of Massachusetts' large to mid-sized rivers receive raw sewerage into their waters, and during summer low flows, are composed primarily of sewerage treatment effluent (MEOEA 2005).

Section 3.1B: Avoiding, Minimizing, and Mitigating Impacts of Toxic and Thermal Discharges

Approach 3.1B.1: Proper treatment of facility discharge

Although there has been a general degradation of water quality coastwide, the levels of sewage nutrients discharged into coastal waters during the past 30 years have decreased as a result of the Clean Water Act, passed in 1972. This has led to a decrease in organic enrichment, which has benefited water quality conditions. A reduction of other types of pollutant discharges into these waters, such as heavy metals and organic compounds, would not be expected (ASMFC 1999).

In many northern rivers, such as the Kennebec, Penobscot, Connecticut, Hudson, and Delaware Rivers, dissolved oxygen levels approached zero parts per million in the 1960s and 1970s. Since then, water quality has greatly improved as a result of better point-source treatment of municipal and industrial waste (USFWS-NMFS 1998). In 1974, secondary and tertiary sewage treatment was initiated in the Hudson River, which led to conditions where dissolved oxygen was greater than 60% saturation. There was a return of many fish species to this habitat (Leslie 1988), including a high abundance of juvenile shortnose sturgeon (Carlson and Simpson 1987; Dovel *et al*. 1992).

Additionally, although poor water quality is often identified as a barrier to fish migration, it should be noted that poor water quality can be caused by both point and non-point sources of pollution. In fact, it may be difficult, if not impossible, for water quality standards to be achieved in some regions due to the effects of non-point sources of pollution (Roseboom *et al*. 1982).

The estimated lost spawning habitat for American shad in 1898 was 5.28×10^3 river km, and in 1960 it was estimated at 4.49×10^3 km. The most recent estimate is now 4.36×10^3 river km. This increase in available habitat has been largely attributed to restoration efforts and enforcement of pollutant abatement laws (Limburg *et al*. 2003).

In compliance with the Clean Water Act, proper treatment of large city domestic sewage at treatment plants has dramatically improved the poor water quality conditions that persisted in the Delaware River for many years. Water quality problems were dramatically manifested in a "pollution block," including severely depressed levels of dissolved oxygen in the early 1900s in the Philadelphia/Camden area. There were very few repeat American shad spawners in this river, compared with other mid-Atlantic rivers (Miller *et al*. 1982). The situation had greatly improved by the late 1950s, due to a reduction in point-source pollution entering tidal waters, which led to an increase in dissolved oxygen by the 1980s (Maurice *et al*. 1987). This has led to a large enhancement of the American shad population in this river (Ellis *et al*. 1947; Chittenden 1969; Miller *et al*. 1982).

Similarly, improvements to water quality in the Potomac River in the 1970s led to increased water clarity and subsequently an increase in SAV abundance in 1983 (Dennison *et al*. 1993). In addition, pulp mill effluent was thought to have limited American shad survival in the Roanoke River (Walburg and Nichols 1967), but compliance with water quality standards in recent years has resulted in improved spawning habitat in this system (Hightower and Sparks 2003). Additional measures to improve habitat include reducing the amount of thermal effluent into rivers and streams, and discharging earlier in the year to reduce impacts to migrating fish (ASMFC 1999).

THREAT #4: CHANNELIZATION AND DREDGING

Section 4.1A: Impacts of Dredging on Fish Habitat

Issue 4.1A.1: Primary environmental impacts of channelization

Channelization has the potential to cause significant environmental impacts (Simpson *et al*. 1982; Brookes 1988), including bank erosion, elevated water velocity, reduced habitat diversity, increased drainage, and poor water quality (Hubbard 1993). Dredging and disposal of spoils along the shoreline can also create spoil banks, which block access to sloughs, pools, adjacent vegetated areas, and backwater swamps (Frankensteen 1976). Dredging may also release contaminants resulting in bioaccumulation, direct toxicity to aquatic organisms, or reduced dissolved oxygen levels (Morton 1977). Furthermore, careless land use practices may lead to erosion, which can lead to high concentrations of suspended solids (turbidity) and substrate (siltation) in the water following normal and intense rainfall events. This can displace larvae and juveniles to less desirable areas downstream and cause osmotic stress (Klauda *et al*. 1991b).

Spoil banks are often unsuitable habitat for fishes. Sand areas are an important nursery habitat to YOY striped bass. This habitat is often lost when dredge disposal material is placed on natural sand bars and/or point bars. The spoil is too unstable to provide good habitat for the food chain. Mesing and Ager (1987) found that electrofishing CPUE for gamefish was significantly greater on natural habitat than on "new (75%)," recent (66%)," or "old (50%)" disposal sites. Old sites that had not been disposed on for 5 to –10 or more years had not recovered to their natural state in terms of relative abundance of gamefish populations. The researchers also found that placement of rock material on degraded sand disposal sites had significantly greater electrofishing CPUE for sportfish than these sites had prior to placement of the rock material (Mesing and Ager 1987).

Draining and filling, or both, of wetlands adjacent to rivers and creeks in which alosines spawn has eliminated spawning areas in North Carolina (NCDENR 2000).

Issue 4.1A.2: Secondary environmental impacts of channelization

Secondary impacts from channel formation include loss of vegetation and debris, which can reduce habitat for invertebrates and result in reduced quantity and diversity of prey for juveniles (Frankensteen 1976). Additionally, stream channelization often leads to altered substrate in the riverbed and increased sedimentation (Hubbard 1993), which in turn can reduce the diversity, density, and species richness of aquatic insects (Chutter 1969; Gammon 1970; Taylor 1977). Suspended sediments can reduce feeding success in larval or juvenile fishes that rely on visual cues for plankton feeding (Kortschal *et al*. 1991). Fish species that rely on benthic invertebrates within sediments may also experience decreased food availability if prey numbers are reduced. Sediment re-suspension from dredging can also deplete dissolved oxygen, and increase bioavailability of any contaminants that may be bound to the sediments (Clark and Wilber 2000).

Issue 4.1A.3: Impacts of channelization on fish physiology and behavior

Migrating adult river herring have been found to avoid channelized areas with increased water velocities. Several channelized creeks in the Neuse River basin in North Carolina have reduced river herring distribution and spawning areas (Hawkins 1979). Frankensteen (1976) found that the channelization of Grindle Creek, North Carolina removed in-creek vegetation and woody debris, which served as substrate for fertilized eggs.

Channelization can also reduce the amount of pool and riffle habitat (Hubbard 1993), which is an important food-producing area for larvae (Keller 1978; Wesche 1985). American shad postlarvae have been found concentrated in riffle-pool habitat (Ross *et al*. 1993).

Dredging can negatively affect alosine populations by producing suspended sediments (Reine *et al*. 1998), and migrating alosines are known to avoid waters of high sediment load (ASMFC 1985; Reine *et al*. 1998). It is also possible that fish may avoid areas where there is ongoing dredging due to suspended sediment in the water column. This was believed to have been the cause of a diminished return of adult spawning shad in a Rhode Island river, although no causal mechanism could be established (Gibson 1987). Filter-feeding fishes, such as alosines, can be negatively impacted by suspended sediments on gill tissues (Cronin *et al*. 1970). Suspended sediments can clog gills that provide oxygen, resulting in lethal and sub-lethal effects to fish (Sherk *et al*. 1974, 1975).

Nursery areas along the shorelines of the rivers in North Carolina have been affected by dredging and filling, as well as by erection of bulkheads; however, the degree of impact has not been measured. In some areas, juvenile alosines were unable to enter channelized sections of a stream due to high water velocities caused by dredging (ASMFC 2000). Despite findings by Miller *et al*. (1982) that the effects of river dredging on fish populations were insignificant, they suspected that migrating juvenile shad could potentially be impacted by increased suspended solids, lowered dissolved oxygen concentration, and release of toxic materials.

Section 4.1B: Avoiding, Minimizing, and Mitigating Impacts of Channelization

Approach 4.1B.1: Seasonal restrictions and proper material disposal

Dredging restrictions are already in place in many rivers including the Kennebec, Connecticut, Cape Fear, Cooper, and Savannah Rivers (USFWS-NMFS 1998), to help curtail the impacts of dredging to anadromous fish. Seasonal restrictions on dredging in areas where anadromous fish are known to occur should be established until there is irrefutable evidence that dredging does not restrict the movement of fish (Gibson 1987). It is recommended that dredge material be disposed of in the most ecologically beneficial way possible that will prevent harm to existing natural habitats (FFWCC 2005).

THREAT #5: LAND USE CHANGE

The effects of land use and land cover on water quality, stream morphology, and flow regimes are numerous, and may be the most important factors determining quantity and quality of aquatic habitats (Boger 2002). Studies have shown that land use influences dissolved oxygen (Limburg and Schmidt 1990), sediments and turbidity (Basnyat *et al*. 1999; Comeleo *et al*. 1996), water temperature (Hartman *et al*. 1996; Mitchell 1999), pH (Osborne and Wiley 1988; Schofield 1992), nutrients (Basnyat *et al*. 1999; Osborne and Wiley 1988; Peterjohn and Correll 1984), and flow regime (Johnston *et al*. 1990; Webster *et al*. 1992).

Siltation, caused by erosion due to land use practices, can kill submerged aquatic vegetation (SAV). SAV can be adversely affected by suspended sediment concentrations of less than 15 mg/L (Funderburk *et al*. 1991) and by deposition of excessive sediments (Valdes-Murtha and Price 1998). SAV is important because it improves water quality (Rybicki and Hammerschlag 1991), and provides refuge habitat for migratory fish and planktonic prey items (Maldeis 1978; Killgore *et al*. 1989; Monk 1988).

Section 5.1A: Agriculture

Issue 5.1A.1: Sedimentation and irrigation

Decreased water quality from sedimentation became a problem with the advent of land-clearing agriculture in the late 18th century (McBride 2006). Agricultural practices can lead to sedimentation in streams, riparian vegetation loss, influx of nutrients (e.g., inorganic fertilizers and animal wastes), and flow modification (Fajen and Layzer 1993). Agriculture, silviculture, and other land use practices can lead to sedimentation, which reduces the ability of semi-buoyant eggs and adhesive eggs to adhere to substrates (Mansueti 1962).

In addition, excessive nutrient enrichment stimulates heavy growth of phytoplankton that consume large quantities of oxygen when they decay, which can lead to low dissolved oxygen during the growing season (Correll 1987; Tuttle *et al*. 1987). Such conditions can lead to fish kills during hot summer months (Klauda *et al*. 1991b).

Another factor, chemical contamination from agricultural pesticides, has a significant potential to impact stream biota, especially aquatic insects, but is difficult to detect (Ramade *et al*. 1984).

Furthermore, irrigation can cause dewatering of freshwater streams, which can decrease the quantity of both spawning and nursery habitat for anadromous fish. Dewatering can cause reduced water quality as a result of more concentrated pollutants and/or increased water temperature (ASMFC 1985).

Uzee and Angermeier (1993) found that in some Virginia streams, there was an inverse relationship between the proportion of a stream's watershed that was agriculturally developed and the overall tendency of the stream to support river herring runs. In North Carolina, cropland alteration along several creeks and rivers has significantly reduced river herring distribution and spawning areas in the Neuse River basin (Hawkins 1979).

Issue 5.1A.2: Nutrient loading

Atmospheric nitrogen deposition in coastal estuaries of states such as North Carolina, has had an increasingly negative effect on coastal waters, leading to accelerated algal production (or eutrophication) and water quality declines (e.g., hypoxia, toxicity, and fish kills). The primary source of atmospheric nitrogen in these areas comes from livestock operations and their associated nitrogen-rich (ammonia) wastes, and to a lesser degree, urbanization, agriculture, and industrial sources (Paerl *et al*. 1999). Animal production farms have greatly contributed to deteriorating water quality in other areas, including the Savannah, Ogeechee, and Altamaha Rivers (Georgia), and the Chesapeake Bay (USFWS-NMFS 1998; Collins *et al*. 2000; McBride 2006).

From the 1950s to the present, increased nutrient loading has made hypoxic conditions more prevalent (Officer *et al*. 1984; Mackiernan 1987; Jordan *et al*. 1992; Kemp *et al*. 1992; Cooper and Brush 1993; Secor and Gunderson 1998). Hypoxia is most likely caused by eutrophication, due mostly to non-point source pollution (e.g., industrial fertilizers used in agriculture) and point source pollution (e.g., urban sewage).

Section 5.1B: Avoiding, Minimizing, and Mitigating Agricultural Impacts

Approach 5.1B.1: Erosion control and best management practices

Erosion control measures and best management practices (BMPs) can reduce sediment input into streams, which can reduce the impact on aquatic fauna (Lenat 1984; Quinn *et al*. 1992). Agricultural BMPs may include: vegetated buffer strips at the edge of crop fields, conservation tillage, strip cropping, diversion channels and grassed waterways, soil conservation and water quality planning, nutrient management planning, and installing stream bank fencing and forest buffers. Animal waste management includes: manure storage structures, runoff control for barnyards, guttering, and nutrient management (ASMFC 1999). Programs to upgrade wastewater treatment at hog and chicken farms should be promoted (NC WRC 2005). Additionally, restoring natural stream channels and reclaiming floodplains in areas where the channel or shoreline has been altered by agricultural practices can help mitigate impacts (VDGIF 2005).

Section 5.2A: Logging/Forestry

Issue 5.2A.1: Logging

Logging activities can modify hydrologic balances and in-stream flow patterns, create obstructions, modify temperature regimes, and input additional nutrients, sediments, and toxic substances into river systems. Loss of riparian vegetation can result in fewer refuge areas for fish from fallen trees, fewer insects for fish to feed on, and reduced shade along the river, which can lead to increased water temperatures and reduced dissolved oxygen (EDF 2003). Potential threats from deforestation of swamp forests include: siltation from increased erosion and runoff; decreased dissolved oxygen (Lockaby et al. 1997); and disturbance of food-web relationships in adjacent and downstream waterways (Batzer et al. 2005).

In South Carolina, forestry BMPs for bottomland forests are voluntary. When BMPs are not exercised, plant material and disturbed soils may obstruct streams, excessive ruts may force channel-eroded sediments into streams, and partially stagnated waters may become nutrient-rich, which can lead to algal growth. These factors contribute to increased water temperature and reduced dissolved oxygen (McCord 2005b).

Section 5.2B: Avoiding, Minimizing, and Mitigating Logging Impacts

Approach 5.2B.1: Best management practices

Virginia advocates working with private, small foresters to implement forestry BMPs along rivers to reduce the impacts of forestry practices (VDGIF 2005). Florida discourages new bedding on public lands where there is healthy groundcover (FFWCC 2005).

Section 5.3A: Urbanization and Non-Point Source Pollution

Issue 5.3A.1: Pollution impacts on fish and fish habitat

Urbanization can cause elevated concentrations of nutrients, organics, or sediment metals in streams (Wilber and Hunter 1977; Kelly and Hite 1984; Lenat and Crawford 1994). Recent studies conducted in Charleston Harbor, South Carolina, found that crustacean prey of estuarine fishes are directly affected by urbanization and related water quality parameters, including concentrations of a variety of toxicants (especially petroleum-related materials) (EDF 2003). Furthermore, the amount of developed land may influence use of a habitat, but other factors such as size, elevation, and habitat complexity are important as well, and in some cases may outweigh the negative effects of development (Boger 2002). More research is needed on how urbanization affects diadromous fish populations.

One study found that when the percent of land in areas increased to about 10% of the watershed, the number of alewife egg and larvae decreased significantly in tributaries of the Hudson River, New York (Limburg and Schmidt 1990).

Section 5.3B: Avoiding, Minimizing, and Mitigating Impacts of Urbanization and Non-Point Source Pollution

Approach 5.3B.1: Best management practices

Urban BMPs include: erosion and sediment control; stormwater management; septic system maintenance; and forest buffers (ASMFC 1999). Siting stormwater treatment facilities on upland areas is recommended where possible (FFWCC 2005). Wooded buffers and conservation easements should be established along streams to protect critical shoreline areas (ASMFC 1999), and low impact development should be implemented, where practicable (NCWRC 2005).

Since the abundance of SAV is often used as an indirect measure of water quality, and there is a correlation between water quality and alosine abundance, steps should be taken to halt further reduction of underwater sea grasses (especially important in the Chesapeake Bay) (B. Sadzinski, Maryland Department of Natural Resources, pers. comm.).

Regarding cumulative effects on river herring spawning habitat, Boger (2002) suggested that land use and morphology within the entire watershed should be considered, and that the cumulative effects within the entire watershed may be as important as the type of land use within buffer zones. This is an important point to consider when establishing required widths of buffer zones in an effort to balance anthropogenic activities in the watershed and maintain biological integrity of streams (Boger 2002).

THREAT #6: ATMOSPHERIC DEPOSITION

Section 6.1A: Atmospheric Deposition

Issue 6.1A.1: Acid rain and low pH

Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. This occurrence inputs a significant source of pollutants to many water bodies. Pollutants can get from the air into the water through rain and snow, falling particles, and absorption of the gas form of the pollutants into the water. Atmospheric deposition that causes low pH and elevated aluminum (acid rain) can contribute to changes in fish stocks. When pH declines, the normal ionic salt balance of the fish is compromised and fish lose body salts to the surrounding water (Southerland *et al*. 1997).

American shad stocks that spawn in poorly buffered Eastern Shore Maryland rivers, like the Nanticoke and Choptank, were found to be vulnerable to storm-induced, toxic pulses of low pH and elevated aluminum. These stocks, therefore, may recover at a much slower rate than well-buffered Western Shore stocks, even if all other anthropogenic stressors are removed (Klauda 1994; ASMFC 1999). Streams often experience their highest levels of acidity in the spring, when adult shad are returning to spawn (Southerland *et al*. 1997).

There is speculation that recent precipitous declines in American shad populations may partly be due to acid rain (Southerland *et al*. 1997). Fertilized eggs, yolk-sac larvae, and to a lesser degree, young feeding (post yolk-sac) larvae of American shad have the highest probability for exposure to temporary episodes of pH depressions and elevated aluminum levels in, or near, freshwater spawning sites (Klauda 1994). Klauda (1994) suggests that even infrequent and temporary episodes of critical or lethal pH and aluminum exposures in the spawning and nursery areas could contribute to significant reductions in egg or larval survival of American shad and thereby slow stock recovery. High mortalities of hatchery-reared American shad larvae in 2006 and 2007 were thought to be due to pH depression and elevated aluminum (M. Hendricks, Pennsylvania Fish and Boat Commission, pers. comm.). In 2008, treatment of raw hatchery water with limestone sand raised pH from 6.0 to above 7.0, and resulted in high survival and healthy larvae. Juvenile fish are more susceptible to the effects of low pH, which may effectively prevent reproduction (Klauda 1994).

Threats may be seasonal, ongoing, or even sporadic, all of which can have long-term effects on the recovery of stocks. For example, Hurricane Agnes in 1972 is suspected of causing the 1972 year-class failure for American shad, hickory shad, alewife, and blueback herring, as well as altering many spawning habitat areas in the Chesapeake Bay. Almost twenty years later, these impacts were suggested to be contributing to the slow recovery of stocks in this area (Klauda *et al*. 1991b).

Section 6.1B: Avoiding, Minimizing, and Mitigating Impacts of Atmospheric Deposition

Approach 6.1B.1: Reduction of airborne chemicals

Supporting the reduction of airborne chemical releases from power plants, paper mills, and refineries is one way to decrease the levels of toxins in the air that eventually settle into riverine habitat. Incentives can be promoted at the state level and through cooperative interstate agreements (FFWCC 2005).

Effects of Habitat Degradation on Harvesting/Marketability

Effects of habitat degradation that result in non-natural mortality can affect the size of the population and ultimately the size of the allowable harvest. Some threats may not increase mortality, but can reduce or eliminate marketability. These threats include non-lethal limits of contaminants that may render fish unfit for human consumption, or changes in water quality that may reduce fish condition or appearance to a point where they are unmarketable (ASMFC 1999).

The following table lists threats that have been identified for shad and river herring habitat. Because the magnitude of an impact may vary locally or regionally, the degree to which each impact may occur is not specified. Instead, the likelihood to which each impact may occur within each geographical area (riverine waters, territorial waters, or EEZ) is provided.

Table 1. Threats identified for shad and river herring. The categories are as follows: Present (P) denotes a threat that has been specifically identified in the literature; No Information Found (NIF) indicates that no information regarding this threat was found within the literature, but there is a possibility that this threat could occur within the specified geographical area; and Not Present (NP) indicates that the threat could not possibly occur within that geographical area (e.g., dam blockage in the EEZ).

THREAT	Riverine Waters	Territorial Waters	EEZ
Chemical			
Acid/aluminum pulses	P	NIF	NIF
Sedimentation	P	NIF	NIF
Suspended particles	P	NIF	NIF
Inorganic inputs	P	P	NIF
Organic chemicals	P	P	NIF
Thermal effluent	P	P	NP
Urban stormwater pollution	P	P	NIF
Sewage/animal waste	P	P	NIF
Non-point source pollution	P	P	NIF
Physical			
Dams/spillways	*P*	NP	NP
Other man-made blockages (e.g., tide gates)	P	P	NP
Non-anthropogenic blockages (e.g., vegetative debris)	P	NP	NP
Culverts	P	NP	NP
Inadequate fishways/fish-lifts	P	NP	NP
Water releases from reservoirs	P	P	NP
Non-hydropower water withdrawal facilities (e.g., irrigation, cooling)	P	P	NP
Channelization	P	NIF	NP
Dredge and fill	P	P	NP
Urban and suburban sprawl	P	NIF	NP
Land-based disturbances (e.g., de-forestation)	P	NIF	NP
Jetties	NP	P	NP
Overharvesting	P	*P*	P
Biological			
Excessive striped bass predation	P	P	NIF
Nuisance/toxic algae	P	NIF	NIF

Appendix E - Protected Species Considerations

Marine Mammals

In October 1995, Commission member states, NMFS and USFWS began discussing ways to improve implementation of the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) in state waters. Historically, these policies have been only minimally implemented and enforced in state waters (0-3 miles). It was agreed that the Commission's plans describe impacts of state fisheries on certain marine mammals and endangered species—collectively termed protected species—and recommend ways to minimize these impacts. Section 117 of the MMPA requires that NMFS and the U.S. Fisher and Wildlife Service (USFWS) develop stock assessment reports (Reports) for all marine mammal stocks within U.S. waters or that enter U.S. waters (e.g., stocks for which only the margins of the range extends into U.S. waters or that enter U.S. waters only during anomalous current or temperature shifts). Each Report is required to estimate the annual human-caused mortality and serious injury of the stock, by source, and, for a strategic stock, other factors that may be causing a decline or impeding recovery of the stock, including effects on marine mammal habitat and prey, and commercial fisheries that interact with the stock.

Section 3(20) of the MMPA defines a strategic stock as a stock: (1) for which the level of direct human-caused mortality exceeds the potential biological removal (PBR) level; (2) which is declining and is likely to be listed under the Endangered Species Act (ESA) within the foreseeable future; or (3) which is listed as a threatened or endangered species under the ESA or as a depleted species under the MMPA.

Section 3(20) of the MMPA defines the term *potential biological removal* (PBR) as:

> [T]he maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population.

For strategic stocks interacting with Category I and II fisheries, Section 118(f) of the MMPA requires NMFS to appoint a Take Reduction Team (TRT), which must develop a Take Reduction Plan (TRP) designed to assist in the recovery of or to prevent the depletion of the strategic stock that interacts with a commercial fishery. Section 118(f)(2) of the MMPA states that the immediate goal of a TRP for a strategic stock shall be to reduce, within six months of its implementation, the incidental mortality or serious injury of marine mammals incidentally taken in the course of commercial fishing operations to levels less than the PBR level established for that stock under Section 117.

Upon the completion of draft stock assessment reviews developed under Section 117 of the MMPA, NMFS recognized the need to establish TRTs to reduce serious injury and mortality of coastal bottlenose dolphins, harbor porpoises and large whales in several coastal gillnet fisheries along the Atlantic coast.

Harbor Porpise and coastal bottlenose dolphin are taken by gillnets in coastal state waters at the time alosine fisheries occur, designated as the Mid-Atlantic gillnet fishery under the MMPA's List of Fishery process. The Mid-Atlantic gillnet fishery operates year-round west of a line drawn at 72° 30' W. long. south to 36° 33.03' N. lat. and east to the eastern edge of the EEZ and north of the North Carolina/South Carolina border, not including waters where Category II and Category III inshore gillnet fisheries operate in bays, estuaries and rivers (72 FR 66048; November 27, 2007). Both Harbor Porpoise and bottlenose dolphins are known to enter tidal estuaries.

Harbor Porpoise

Harbor porpoises that are found along the eastern United States are considered to be one stock or population: the Gulf of Maine/Bay of Fundy stock. This population is dispersed in the Gulf of Maine and Mid-Atlantic in the winter and spring, and then is more concentrated in the Bay of Fundy/upper Gulf of Maine in the summer. The Harbor Porpoise Take Reduction Plan (HPTRP) became effective in January 1999 and implemented regulations in New England and the Mid-Atlantic to reduce the serious injury and mortality of harbor porpoises in commercial gillnet fisheries. The timing and location of the HPTRP management areas coincide with the temporal and seasonal distribution of harbor porpoises.

In July 1993, the Northeast Fisheries Science Center's Sea Sampling (Observer) program initiated an observer program in the Mid-Atlantic coastal gillnet fishery. From 1995 to 2000, 114 harbor porpoises were observed taken (Waring *et al.* 2002). During that time, observed fishing effort was scattered between New York and North Carolina from the beach to 50 miles from shore. Most of the animals taken in state waters are taken in the months of March, April and May, from North Carolina to New Jersey. After 1995, documented bycatch was observed from December to May. The timing and location of stranding data in Mid-Atlantic States follow the timing and location(s) of the ocean-intercept shad fishery as it moves north along the coastline. It is important to note that the East Coast American shad ocean-intercept fishery closed in 2005.

Annual average estimated harbor porpoise mortality and serious injury from the Mid-Atlantic coastal gillnet fishery between 1995 and 1998, before implementation of the Harbor Porpoise Take Reduction Plan, (63 FR 66464, December 2, 1998), was 358 animals (Waring *et al.* 2002). Subsequently, between 2000 and 2004, the average annual harbor porpoise mortality and serious injury in this fishery was 65 animals (Waring *et al.* 2006). However, NMFS has observed an increase in harbor porpoise takes in commercial gillnet fisheries in recent years, due to a lack of compliance with the HPTRP requirements and takes occurring outside HPTRP management areas. The most recent Report estimates that between 2001 and 2005, the total annual estimated average human-caused mortality was 734 harbor porpoises per year (652 from U.S. fisheries), which is higher than the current PBR of 610 (Waring *et al.* 2007).

NMFS reconvened the Harbor Porpoise Take Reduction Team (HPTRT) in December 2007 to discuss updated harbor porpoise abundance and bycatch information. An additional HPTRT meeting was held in January 2008 via teleconference. The HPTRT made recommendations for modifying the HPTRP to address the recent increases in harbor porpoise takes in both the New England and Mid-Atlantic regions.

Bottlenose Dolphin

There are at least two morphologically and genetically distinct stocks of bottlenose dolphin along the eastern coast of the United States: (1) a coastal migratory stock that occurs in coastal waters from Long Island, New York to as far south as central Florida; and (2) an offshore stock primarily distributed along the outer continental shelf and slope in the Northwest Atlantic Ocean. The coastal morphotype is comprised of a complex mosaic of 7 spatial and temporal management units. Resident estuarine stocks are likely demographically distinct from the coastal management units; however, they are currently included in the coastal management unit definitions (Waring *et al.* 2007). Although the estuarine stocks are currently reported with the management units, abundance, mortality and PBR estimates do not include estuarine stocks. Research continues to further define the coastal stock management units and the degree of movement of estuarine dolphins into nearshore, coastal waters, as the spatial overlap remains unclear.

The coastal bottlenose stock was designated as depleted under the Marine Mammal Protection Act due to a large-scale, natural die-off in 1987-1988. Therefore, the coastal stock is listed as strategic because of this die-off and exceeding PBR from serious injuries and mortalities incidental to commercial fisheries. Because one or more of the management units may be depleted, all of the management units currently retain the depleted status.

Estimated annual mortality previously exceeded PBR in at least one management unit. From 2001-2005, the total estimated average annual fishery-related mortality was 61 dolphins attributed to the Mid-Atlantic gillnet fishery. These takes occurred in the Northern Migratory, Northern North Carolina and Southern North Carolina Management Units during both summer and winter months. From 2001-2005, an annual estimate of at least 5 (CV= 0.53) mortalities occurred in the shark drift gillnet fishery off the coast of Florida, affecting the Central Florida Management Unit. Currently, there are no observer data for other fisheries interacting with the coastal stock. However, stranding data indicate interactions with the Virginia Pound Net Fishery and the Atlantic Blue Crab Trap/Pot Fishery. Therefore, the total average annual mortality estimate is a lower bound of the actual annual human-caused mortality for each coastal management unit (Waring *et al*. 2007).

The Bottlenose Dolphin Take Reduction Team (BDTRT) was convened in 2001, and the Bottlenose Dolphin Take Reduction Plan was implemented in May 26, 2006 (71 FR 24776) to address the serious injuries and mortalities incidental to nine Category I and II fisheries. Estimated fishery mortality currently does not exceed PBR for any of the management units due to recent declines in fishery efforts (Waring *et al*. 2007).

Sea Turtles

Sea turtles that occur in U.S. waters are listed as either endangered or threatened under the ESA. Five species occur along the Atlantic coast of the United States: loggerhead (*Caretta caretta*), Kemps ridley (*Lepidochelys kempii*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*).

Shad and river herring are harvested primarily with anchored, staked and drift gillnets; however, there is also a pound net, trawl, and hook and line component to these fisheries. All of these gear types are documented to impact sea turtles. Because these fisheries occur inshore, it is likely to interact with sea turtles depending on the location and season.

A. Gillnets

Stranded loggerhead and Kemp's ridley sea turtles have been partially or completely entangled in gillnet material, and are most likely to come in contact with the gear in shallow coastal waters. Loggerheads and leatherbacks have been captured in the Mid-Atlantic gillnet fishery. Green sea turtles are present in small numbers in these areas and could also be taken in this fishery. Leatherbacks are also present, especially when warmer waters bring jellyfish, their preferred prey, into coastal areas. Hawksbill sea turtles are only rare visitors to the areas where fishing effort occurs, preferring coral reefs with sponges for forage, so interaction would be limited; however, entanglement in gillnets has been identified as a serious problem for hawksbills in the Caribbean (NMFS and USFWS 1993).

Spring and fall gillnet operations have been strongly implicated in coincident sea turtle stranding events from North Carolina through New Jersey. On average, the highest numbers of interactions occurred in spring, followed by summer and fall. The southern states appear to have had more spring interactions, while the northern states had more summer interactions, probably due to the northern migration of sea turtles in the warmer months.

Netting gear found on stranded turtles varied widely, from 2-11.5-inch (5-29-cm) stretch mesh, and ranged from small, cut pieces of net, to lengths of abandoned net (up to 1200 feet (365 m)). Net gear was of various materials including nylon, cotton, and propylene, and in various colors including blue, black and green. Gear type included flounder, sturgeon, and mullet nets, monofilament, twine, gillnets, pound nets, trammel nets, seines, sink nets, and nets attached to anchors, cork floats and buoys.

B. Pound Nets

Most of pound net fishery interactions result in live releases and are documented primarily from North Carolina, Virginia, Long Island and Rhode Island. In Chesapeake Bay, Virginia, turtles become entangled in pound nets starting in mid-May with increasing numbers of entanglements until late June. The construction of leaders in pound nets was found to be a significant factor in these entanglements (Musick *et al*. 1987). Entanglement was found to be insignificant for small mesh (8-12 inch mesh = small; >12-16 inch mesh = large). Large-mesh nets and nets with stringers spaced 16-18 inches apart entangled a large number of turtles. Therefore, the potential to entangle sea turtles in pound nets could be alleviated by decreasing the mesh size in the leaders (Musick *et al*. 1987). The pound net component of the shad and river herring fishery for North Carolina occurs in Albemarle Sound, which is not frequented by turtles due to the relatively low salinities found there.,

C. Hook-and-Line

From 1991 through 1995, a total of 112 stranded turtles had fishing hooks associated with some part of their bodies. Sea turtles have also been caught on recreational hook and line gear. For example, from May 24 to June 21, 2003, five live Kemp's ridleys were reported as being taken by recreational fishermen on the Little Island Fishing Pier near the mouth of the Chesapeake Bay. Many other similar anecdotal reports exist. These animals are typically alive and, while the hooks should be removed whenever possible and when it would not further injure the turtle, NOAA fisheries suspects that the turtles are probably often released without hooks being removed. It is unlikely that hook and line fishing for shad impact sea turtles because most shad angling occurs in inland waters not frequented by seaturtles.

D. Recommendations for Sea Turtle Protection

1. A conservation plan and application for a Section 10 ESA incidental take permit should be developed for those states where the fishery occurs when sea turtles are present.
2. Research into gear development/deployment for gillnets should be conducted to minimize the impact on sea turtles.
3. Pound net leaders should be no larger than 12-inch mesh.
4. Public outreach material should be developed to improve awareness of sea turtle entanglement with hooks and monofilament line.

Migratory Coastal Birds

An unknown, but possibly significant, number of migratory birds are drowned each year in anchored gillnets in the nearshore marine waters of the mid-Atlantic region. Preliminary estimates, based on a study underway by the U.S. Fish and Wildlife Service and incidental mortality data from the Services Madison Wildlife Health Laboratory, indicate that many thousands of loons and sea ducks are killed each year. Before the ocean-intercept shad fishery closure, most shad/bird interactions occur during January through March from North Carolina to New Jersey. South Carolina banned anchored gillnets in their coastal fishery because of excessive bird mortalities.

All of the species listed in Table 2 are diving birds which pursue fish underwater or feed on benthic invertebrates. Fish eating birds are especially vulnerable to drowning in gillnets because they pursue prey underwater. Additionally, fish eating birds may be attracted to the vicinity of nets that are anchored for days at a time to feed on forage fish feeding near the nets. All of the birds listed are present along the Atlantic coast from October through April, depending on weather and timing of migration. Double-crested cormorants are present throughout the year but are most abundant in the middle and northern Atlantic states during the summer.

The actual populations of most migratory coastal birds are largely unknown. Except for some diving ducks (*Aythya*), current surveys sample only a small portion of the populations of sea ducks and do not survey for non-game birds such as loons and grebes. The U.S. Migratory Bird Treaty Act prohibits the take and possession of protected migratory birds, except as may be permitted by regulations. Take means to pursue, hunt, shoot, wound, kill, trap, capture or collect. Possession means to detain and control.

A list of protected bird species most likely to interact with shad herring fisheries along the Atlantic coast are listed in Table 2 and their status can be found in Table 3.

Table 1 List of protected birds in nearshore marine coastal waters most likely to interact with gillnets.

Common Name	Species Name
Common Loon	*Gavia immer*
Red-throated Loon	*Gavia stellata*
Horned Grebe	*Podiceps auritus*
Red-necked Grebe	*Podiceps grisegena*
Double-crested Cormorant	*Phalacrocorax auritus*
Northern Gannet	*Sula bassanus*
Oldsquaw	*Clangula byemalis*
Black Scoter	*Melanitta nigra*
Surf Scoter	*Melanitta perspicillata*
Red-breasted Merganser	*Mergus serrator*

Table 2. Protected birds in coastal bays most likely to interact with gillnets and their East Coast population status.

Species		Status
Common Name	**Species Name**	
Common Loon	*Gavia immer*	Unknown
Red-throated Loon	*Gavia stellata*	Unknown, 50,000+ winter south of NJ
Horned Grebe	*Podiceps auritus*	Unknown
Red-necked Grebe	*Podiceps grisegena*	Unknown
Double-crested Cormorant	*Phalacrocorax auritus*	Abundant and increasing
Redhead	*Aythya americana*	Depressed but increasing slightly
Canvasback	*Aythya valisineria*	Slightly increasing
Greater Scaup	*Aythya marila*	Decreasing
Lesser Scaup	*Aythya affinis*	Stable
Ring-necked Duck	*Aythya collaris*	Unknown
Red-breasted Merganser	*Mergus serrator*	Stable
Common Goldeneye	*Bucephala clangula*	Stable
Bufflehead	*Bucephala albcola*	Increasing
Oldsquaw	*Clangula hyemalis*	Stable
Black Scoter	*Melanitta nigra*	Probably declining
White-winged Scoter	*Melanitta fusca*	Probably declining
Surf Scoter	*Melanitta perspicillata*	Probably declining
Ruddy Duck	*Oxyura jamaiccasis*	Stable

Shortnose Sturgeon

The shad gillnet fishery has long been known to capture large numbers of sturgeon (Leland 1968), including adult shortnose sturgeon (Collins and Smith 1995). In the southeast, the shad fishery is likely the primary source of injury and direct mortality of shortnose sturgeon (Collins *et al*. 1996). Existing data indicate that in the southeastern U.S., this species occurs in the shad gillnet bycatch in every river system that supports both a shad gillnet fishery and a shortnose sturgeon population.

The riverine shad gillnet season and the shortnose sturgeon spawning migration normally coincide in the southeastern U.S., resulting in capture of individuals intending to spawn (females apparently spawn only once every 2-3 years). Preliminary data suggest that non-lethal encounters of migrating sturgeon with gillnets may result in fallback (i.e., individuals abort the migration, move back downriver, and presumably resorb their gametes) (unpublished data; pers. comm., M. Moser, UNC Wilmington). Thus, in addition to causing injury and direct mortality of spawners, the non-lethal capture of sturgeon in the shad gillnet fishery may cause reduced spawning success and low year class strength.

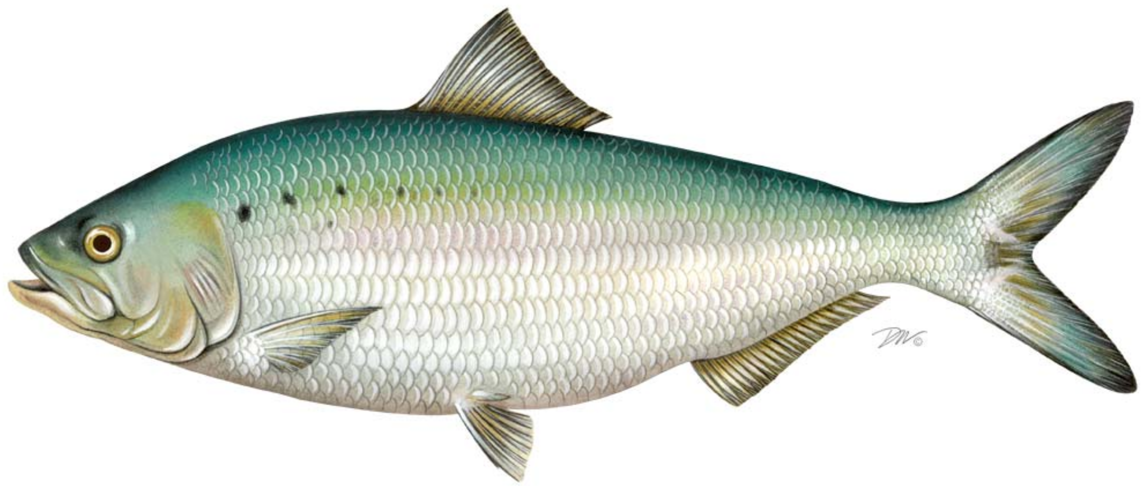
A. Recommendation for Shortnose Sturgeon Protection

A conservation plan and application for a Section 10 ESA incidental take permit should be developed for those states where the fishery occurs when shortnose sturgeons are present and shortnose sturgeon are a documented bycatch..

f) Maine Department of Marine Resources (MDMR) 2014 American Shad Habitat Plan

Maine Department of Marine Resources

American Shad Habitat Plan



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Submitted to the Atlantic States Marine Fisheries Commission as a requirement of Amendment 3 to the Interstate Management Plan for Shad and River Herring

Approved February 6, 2014

Maine Department of Marine Resources

American Shad Habitat Plan

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September 16, 2013

Submitted to the Atlantic States Marine Fisheries Commission as a requirement of the Amendment 3 to the Interstate Management Plan for Shad and River Herring

Report Overview

This report will provide river-specific information for the major known American shad spawning and young-of-year rivers: the Saco, Androscoggin, Kennebec (and Sebasticook), and Penobscot rivers. Information about general threats, data availability, current work and recommended actions are summarized in the first section.

State-Wide Information

Amount of Habitat

State-wide, there are twenty-three identified American shad rivers with over 2545 river kilometers of potential habitat. Currently only 1611 river kilometers are known to be open to American shad passage, while over 810 river kilometers of historical habitat are currently inaccessible (Figure 1, Table 1). Of the habitat that is accessible, a large portion on many rivers is above dams with fishways that may provide only limited accessibility. It is assumed that the mapped habitat represents both adult and juvenile use. American shad are documented as regular catches in recreational fishing reports from the Sheepscot, Mousam, Presumpscot, Saco and Kennebec rivers and Scarborough Marsh, but there are few reports from other rivers. The population sizes are unknown.

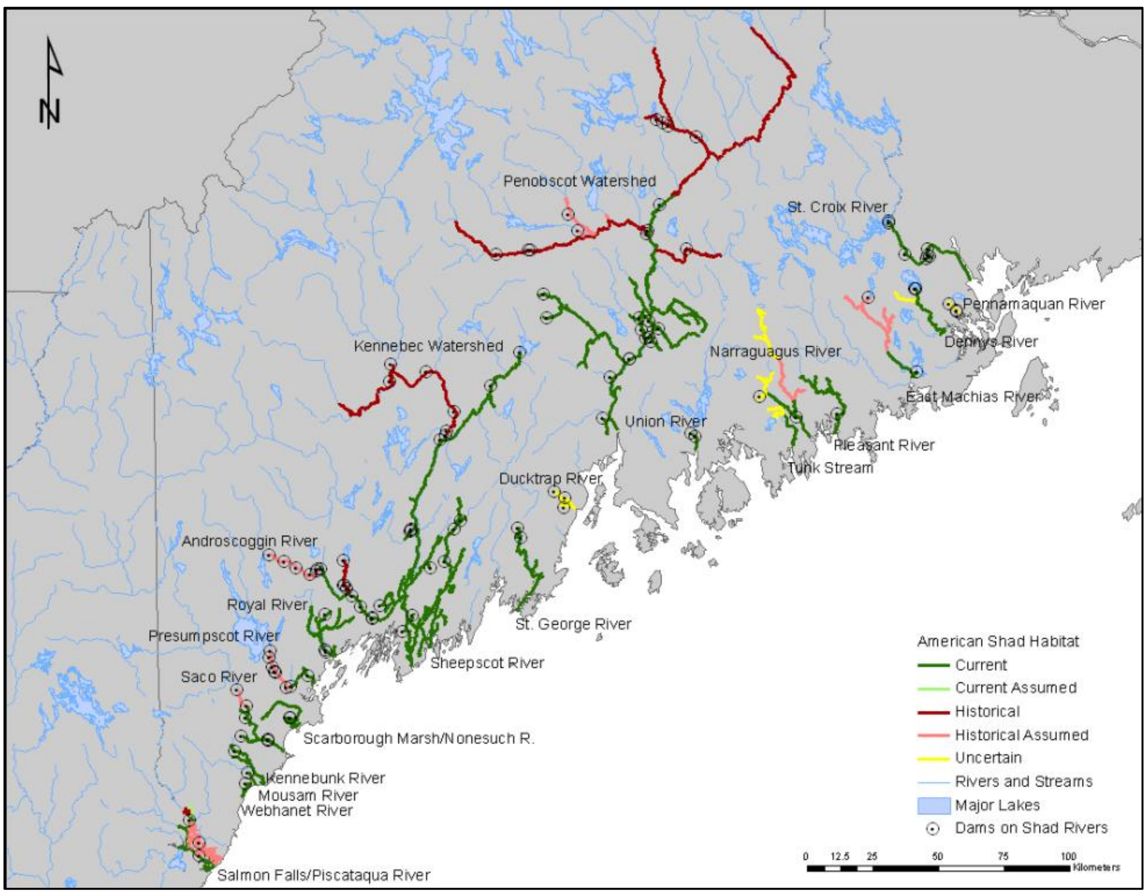

Figure 1. American shad habitat in Maine waters as identified by a USFWS mapping effort (USFWS 1983). Dams and impoundments on shad rivers are also shown.

Major Threats

Barriers to migration are the primary impediments to American shad habitat and successful spawning within Maine state waters. Out of 24 shad rivers in Maine, 18 have a mainstem dam that likely limits shad passage upstream. Of these, five have no capacity for fish passage (Table 2).

Even when fish passage is installed at these dams, the use of habitat upstream of dams is thought to be much lower than the use of areas below the dam. In 2011, video monitoring below Brunswick Fishway on the Androscoggin River documented over 16,000 American shad below the dam, while no shad were passed at the top of vertical slot fishway (J. Lichter, Bowdoin College, pers. comm). Fish passage efficiency for American shad has not been documented at the other sites in Maine, however other studies have described the potential for shad passage.

Table 1. Amount of American shad habitat (river kilometers) in Maine waters (USFWS 1983). Rivers are listed in order of descending habitat kilometers.

River/Watershed	Current (though may be limited)	Current Assumed	Historical	Historical Assumed	Uncertain	Total
Penobscot Watershed	399.6		354.0	32.7		786.3
Kennebec Watershed	300.4		107.2			407.6
Salmon Falls/Piscataqua River	59.8	8.1	8.9	108.1		184.9
Sheepscot River	178.8					178.8
Narraguagus River	38.9			35.6	60.4	134.9
Royal River	106.2					106.2
Androscoggin River	48.3		17.4	34.8		100.5
Saco River	49.1			50.6		99.7
East Machias River	18.8			67.0		85.7
Pleasant River	72.1					72.1
Scarborough Marsh/Nonesuch R.	70.4					70.4
St. George River	65.5					65.5
St. Croix River	61.8					61.8
Kennebunk River	47.0					47.0
Dennys River	34.8				10.7	45.5
Presumpscot River	22.0			22.2		44.2
Tunk Stream	20.2				16.8	37.1
Ducktrap River					22.8	22.8
Webhanet River	8.9					8.9
Union River	7.9					7.9
Pennamaquan River					7.6	7.6
Mousam River	6.3					6.3
Little River	5.5					5.5
Grand Total	**1622.3**	**8.1**	**487.5**	**351.0**	**118.2**	**2587.2**

The majority of the dams with fish passage on shad rivers in Maine have Denil fishways. Denil fishways seem to have high potential for passage (Slatick and Basham 1985, Haro *et al.* 1999), however, the ability of shad to locate the fishway opening in a large mainstem dam may be low, especially when there is a large spillway. Thus, the potential for shad passage above a mainstem dam with a Denil fishway is generally moderate.

Other mainstem dams in Maine have fishlifts. The potential for these locations to pass American shad is thought to be low to moderate. As discussed above, the ability of shad to locate the fishlift entrance is likely hindered by attraction flows from large spillways. Further, in all Maine dams with fishlifts there is evidence that shad remain in holding areas above the fishlift but do not exit the headpond, as evidenced by a large proportion of "passed" shad found only when the facilities are periodically de-watered, and only few shad passed during normal operations (Maine DMR ASMFC Compliance 2011 Report).

Table 2. The first mainstem dams on American shad rivers in Maine with fish passage and dam ownership information listed.

River/Watershed	Distance to first mainstem dam (km)	First Mainstem Dam Name	Fish Passage Type	Shad Passage Potential	Dam Ownership	FERC License	FERC License Renewal
Salmon Falls/ Piscataqua River	26.8	South Berwick Dam	Denil	Moderate	Consolidated Hydro New Hampshire, Inc	Yes	11/30/2037
Salmon Falls/ Piscataqua River	26.6	Great Works Pond Dam	None	None	Great Works Hyrdo Co.	No	
Webhanet River	None						
Little River	3.3	Skinners Mill Dam	None	None	Not listed	No	
Mousam River	6.8	Kessler Dam	None	None	Kennebunk Light and Power District	Yes (3 dams)	3/31/22
Kennebunk River	27.9	Days Mill	None	None	Private	No	
Saco River	9.3	Cataract Project	Fish Lift, Denil, 2 fish locks	Low to Moderate	Brookfield Renewable Energy	Yes (4 dams)	11/30/29
Scarborough Marsh/ Nonesuch R.	None						
Presumpscot River	12.6	Cumberland Mills	Denil Fishway	Moderate	S. D. Warren	No	
Royal River	4.9	Bridge Street Dam	Denil Fishway	Low	Town of Falmouth	No	
Androscoggin River	48.2	Brunswick Project	Vertical slot	Low (Documented)	Brookfield Renewable Energy	Yes	2/28/29
Kennebec River	140.8	Lockwood Project	Fish Lift	Low	Brookfield Renewable Energy	Yes	10/31/36
Sebasticook River	173.6	Benton Falls	Fish Lift	Moderate	Essex Hydro Associates	Yes	2/28/34
Sheepscot River	44.0	Head Tide Dam	Slots	Moderate	Town of Alna	No	
St. George River	48.3	Sennebec Pond Dam	Rock Ramp	High	Sennebec Lake Assoc.	No	
Ducktrap River	17.9	Dickey Mill Dam	None	None	Not listed	No	
Penobscot Watershed	68.5	Milford Dam	Fish Lift	Low to Moderate	Bangor Hydro Electric Co.	Yes	4/1/38
Union River	7.3	Ellsworth Dam	Denil,Trap and Truck	Not Passed Upstream	Black Bear Hydro	Yes	12/31/18 (consulting)
Tunk Stream	None						
Narraguagus River	10.6	Cherryfield Dam	Denil Fishway	Moderate	Town of Cherryfield	No	
Pleasant River	None						
East Machias River	None						
Dennys River	None						
Pennamaquan River	2.9	Pembroke Cottage Dam	Denil Fishway	Moderate	Private	No	
St. Croix River	30.8	Milltown Power Station Dam	Denil Fishway	Moderate	New Brunswick Electric Co.	No	

Water quality. While poor water quality due to point source pollution from tanneries, paper mill companies, and other manufacturing may have negatively impacted adult spawners, developing embryos, and young-of-year in the early to mid-twentieth century, improvements were made as a result of the Clean Water Act after 1970. As a result, it is not thought that poor water quality remains a threat in most known spawning/rearing locations. Basic water quality parameters (temperature, dissolved oxygen, turbidity, pH) are well above the tolerances for American shad, *when they are taken*. It should be noted that only temperature is taken on a daily basis at most fishways in Maine whether DMR or power-company operated,. Moreover, there are no current studies in Maine to determine whether existing levels of toxic contaminants (heavy metals, PCBs) may be negatively affecting shad populations.

The Maine Department of Environmental Protection (DEP) administers regular water quality testing of Maine's waters. The State has four classes for freshwater rivers, three classes for marine and estuarine waters, and one class for lakes and ponds. A close comparison of the standards will show that there are few differences between the uses or the qualities of the various classes. All classifications attain the minimum fishable-swimmable standards established in the federal Clean Water Act, and most support the same set of designated uses with some modest variations in their description. More information about the classification schema can be found at: http://www.maine.gov/dep/water/monitoring/classification/

The Maine DEP determines the water quality classification of freshwater areas through the Biological Monitoring Program. This program assesses the health of rivers, streams, and wetlands by evaluating the composition of resident aquatic benthic macroinvertebrate and algal communities. The DEP develops standards for each river, stream and wetland using these methods, testing important sites on a rotating basis. Smaller waterways may be tested infrequently. More information can be found at:
http://www.maine.gov/dep/water/monitoring/biomonitoring/index.html

Marine water quality is assessed by multiple organizations and the information compiled by the Maine DEP for Clean Water Act reports that are due every other year to the EPA. The DEP utilizes data for assessments in marine waters from its own environmental and toxics monitoring programs including the Surface Water Ambient Toxics and the Gulf of Maine Council on the Marine Environment's Gulfwatch project, and to a large extent from a variety of governmental agencies, academic institutions, non-profit organizations and municipalities, such as the Maine Healthy Beaches program, Maine Department of Marine Resources, New Hampshire Department of Environmental Services, University of Maine, BioDiversity Research Institute, Casco Bay Estuary Partnership, Kennebec Estuary Land Trust, Marine Environmental Research Institute, Mount Desert Island Biological Laboratory, Town of Rockport Conservation Commission, and the Wells National Estuarine Research Reserve. Additionally, a number of volunteer monitoring groups monitor Maine's estuarine and coastal waters. The DEP currently accepts data from organizations with approved Quality Assurance Project Plans (QAPPs) whose monitoring programs and analytical labs enable collection and processing of quality data, and from selected organization with DEP-approved sampling plans. Biannual reports can be found at:
http://www.maine.gov/dep/water/monitoring/305b/index.htm

Channelization and dredging occur in Maine waters, though are not thought to be a significant threat to American shad habitat. Channelization and dredging typically occur beyond the mouths of rivers in association with beach restoration (southern Maine) or shipping lanes (Kennebec River, Bath Iron Works). Before any channelization or dredging project commences, it must first be reviewed by all relevant agencies (including Maine DMR, Maine DEP, USFWS, and NOAA) which provide comments concerning species interaction.

Invasive species. Concerning the threat from competition and predation, a growing number of invasive white catfish, carp (*Cyprinus carpio*), and Northern pike have been documented in Maine. These species are found in American shad spawning areas, but the impact on shad populations has not been documented.

Statewide Available Data

In 1982, the US Fish and Wildlife Service (USFWS) compiled habitat information for many diadromous species to create a snapshot of the current and historic distribution in Maine that is available from the USFWS Northeast Regional Office's data website (USFWS 2013). The purpose of this project was to identify, based on the best available information, the current and historic geographic distribution of 12 diadromous (sea-run) fish species in Maine (alewife, American eel, American shad, Atlantic salmon, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, sea run brook trout, shortnose sturgeon, striped bass).

To begin this process, available digital data depicting current and historic extent of each species was presented on a series of paper maps. These maps were distributed throughout the state and reviewed by fisheries biologists, including representatives from government agencies, non-government organizations and private individuals. Reviewers edited the maps on the basis of their personal knowledge, institutional knowledge and review of existing data and documents, both published and unpublished. These maps were then collated and coded in a networked hydrography dataset (the most detailed available National Hydrography Dataset[NHD]) resulting in one GIS layer (a line Feature Class) for each fish species. Each Feature Class shows the user the current and historic extent of the species and the sources used to delineate that extent. The Feature Class can be used alone but is most useful when joined back to the NHD as an event table, thus making additional data available (e.g. feature names, flow, etc.). The 'AmericanShad' feature class specifically identifies the current and historic distribution of American shad in Maine (USFWS 1982).

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, FERC

Other Organizations

Dam ownership for first mainstem dams is listed in Table 2.

Current Action and Progress

During all Federal Energy Regulatory Commission (FERC) relicensing processes, the Maine DMR in collaboration with federal agencies advocates for fish passage that will allow the best accommodation for all diadromous fish passage, including American shad passage. In addition to FERC processes, the Maine DMR also provides comments on most fish passage projects in the state – where there is a project on identified shad river, we provide comments and work with public and private landowners to install fish passage, or upgrade existing passage, to allow for all maximum passage potential for all diadromous species, including American shad.

Regarding monitoring projects, other than three on-going activities (fishway monitoring on the major rivers, juvenile beach seine and in-river trawl surveys, recreational fishing surveys), there are few efforts focused on American shad in Maine waters. There are a few river-specific projects that are discussed in the sections below, including video monitoring at Brunswick fishway. There are, however, no efforts to ground-truth the assumed current spawning habitat, and currently no fishway efficiency studies that focus on shad passage.

Larval stocking. American shad fry were raised at the Waldoboro hatchery from 1992 to 2008 using eggs collected from adults from the Kennebec, Connecticut, Androscoggin, Merrimack, Saco, and Sebasticook Rivers. The program ended in 2008 due to a lack of funding. Larval American shad that were reared in the hatchery were 'marked' by immersion in an oxytetracycline (OTC) bath before being released. Receiving locations included multiple sites on the Androscoggin, Kennebec, and Sebasticook Rivers (both below and above dams), as well as at the presumed spawning locations on the Medomak River and on the Saco River in tidal water. The hatchery closed in 2009 with no plans to reopen the hatchery due to funding and current management of American shad along the East Coast.

Adult American shad otoliths are collected from mortalities at fish passage facilities, from juveniles collected during the beach seine surveys, and from some anglers who voluntarily submitted samples. The Maine DMR inshore trawl survey also began collecting otoliths from a sub-sample of American shad in fall 2012. We are currently fine-tuning our instrumentation and methods to correctly identify OTC marked otoliths. While we have not directly measured the success of the stocking program, juvenile abundance in the Kennebec/Androscoggin complex does seem to have increased concurrent to larval stocking (Figure 2).

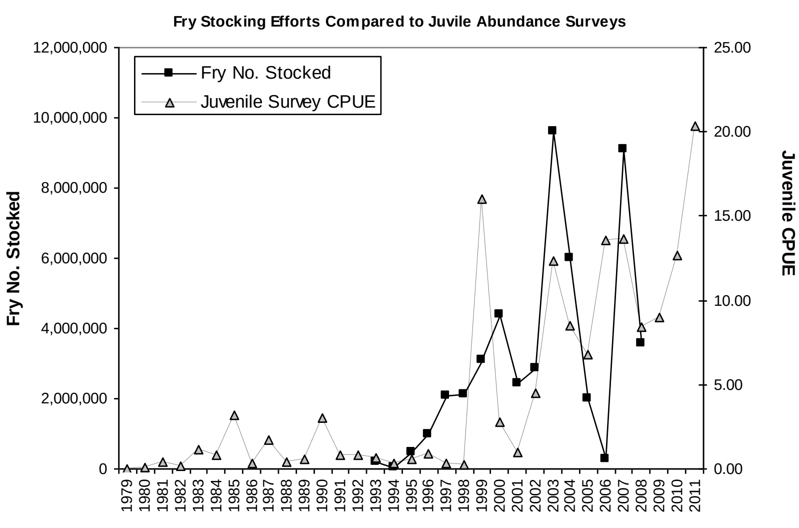

Figure 2. Juvenile abundance compared to fry stocking efforts.

Juvenile Abundance Surveys. In 1979, MDMR established the Juvenile Alosine Survey for the Kennebec/Androscoggin estuary to monitor the abundance of juvenile alosines at 14 permanent sampling sites. Four sites are on the upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one each on the Cathance, Abagadasset, and Eastern rivers. These sites are in the tidal freshwater portion of the estuary. Since 1994, Maine DMR added six additional sites in the lower salinity-stratified portion of the Kennebec River.

Over the entire sampling period (1979-2012), the overall highest average catch per unit effort (CPUE) for juvenile American shad was found in the Abagadasset River (11.46 shad per haul), followed by the upper Kennebec River (9.02). Merrymeeting Bay (4.99), the Cathance (3.83), Eastern (2.87), and the lower Kennebec rivers (2.09) all have lower but consistent CPUE values. The Androscoggin River consistently has low catches of shad or years where no shad are caught (0.51 shad per haul; Table 3). The strength of these data in identifying successful spawning areas is limited because sampling in performed after the spawning event, and juvenile shad may have become dispersed from their natal location by passive larval drift. These data may provide some insight into juvenile shad habitat.

Recommended Action(s)

- Remove mainstem hydropower dams or install effective fish passage
- Ground-truth assumed current spawning habitat state-wide
- Conduct population estimates for Saco, Androscoggin, Kennebec/Sebasticook, and Penobscot rivers
- Map young-of-year habitat based on existing beach seine and in-river trawl surveys in the Kennebec River/Merrymeeting Bay estuary complex and Penobscot River
- Conduct fishway efficiency studies that focus on shad passage at existing fishways
- Determine locations beyond those regularly monitored where American shad passage may be limited by human-made obstructions
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) at known spawning grounds during May-July

Table 3. American shad catch per unit effort in eight survey locations in the Kennebec River/Merrymeeting Bay estuary complex. Survey design was altered in 1994 when 6 stations were added to the survey sites.

Juvenile American Shad Catch per Unit Effort by River Segment								
Year	Upper Kennebec River	Merrymeeting Bay	Androscoggin River	Cathance River	Abagadasset River	Eastern River	Mid Kennebec River	Lower Kennebec River
1979	0.16	0.00	0.00	0.00		0.00		0.00
1980	0.00	0.36	0.29	0.00		0.00		0.00
1981	1.08	0.85	0.29	0.50		0.00	0.17	0.00
1982	0.00	0.33	0.17	0.00		0.00	0.63	0.00
1983	0.15	0.20	2.18	3.00		0.00		
1984	0.90	0.46	0.00	2.00		0.67		
1985	0.69	1.53	0.40	6.50		7.00		
1986	0.10	0.15	0.08	1.00		0.50		
1987	0.15	8.05	0.17	1.25	0.50	0.00		
1988	0.11	1.36	0.00	0.00	0.33	0.51		
1989	1.25	0.29	1.29	0.48	0.00	0.00		
1990	3.50	2.46	0.83	6.83	0.33	4.20		
1991	1.21	0.00	0.00	0.67	1.67	1.17		
1992	0.10	0.67	0.67	3.67	0.00	0.00		
1993	0.00	0.29	3.63	0.00	0.00	0.00		
1994	0.00	0.35	1.00	0.00	0.17	0.50		
1995	0.21	0.39	1.89	0.17	0.60	0.33		
1996	4.15	0.25	0.00	0.20	0.33	0.50		
1997	0.00	0.88	0.80	0.00	0.40	0.00		
1998	0.00	1.67	0.00	0.00	0.00	0.00		
1999	0.00	20.46	0.00	42.67	33.00	0.00		
2000	15.14	0.33	0.14	0.33	0.33	1.33		1.58
2001	0.57	3.14	2.57	0.43	0.00	0.20		0.05
2002	1.96	2.18	0.18	1.86	22.86	2.43		0.19
2003	74.13	3.63	0.00	2.17	0.67	5.33		0.42
2004	48.21	6.67	0.00	0.67	3.00	0.50		0.39
2005	24.96	3.42	0.06	2.83	10.00	2.40		3.72
2006	38.79	25.30	0.00	0.67	16.50	8.33		5.44
2007	33.38	24.13	0.00	0.67	19.00	16.83		1.40
2008	3.95	12.88	0.00	3.00	34.17	3.67		1.38
2009	4.29	16.38	0.20	4.17	31.67	5.17		1.27
2010	45.63	8.25	0.39	11.00	15.33	7.17		1.03
2011	0.63	11.25	0.00	25.33	94.17	9.17		1.73
2012	1.30	11.17	0.06	8.00	13.00	19.67		16.86
Average	9.02	4.99	0.51	3.83	11.46	2.87	0.40	2.09

Saco River

Amount of Habitat

There are currently 49.1 river kilometers of accessible shad habitat in the Saco River (though accessibility to habitat above dams with fish passage is limited), with another 50.6 river kilometers of assumed historical habitat (Table 1). Spawning and juvenile habitat have not been identified. Although no studies have documented shad spawning areas in the Saco River, it is thought that the majority of spawning occurs below the Cataract Project mainstem dams. Habitat above this area is mapped as accessible habitat because shad passage is possible at the Skelton Dam fishlift and interim trap and truck operations to move shad past the project's fish locks (see discussion below). The river portion listed as inaccessible (historical assumed) is above the Bar Mills, which currently has no fish passage facility (Figure 3).

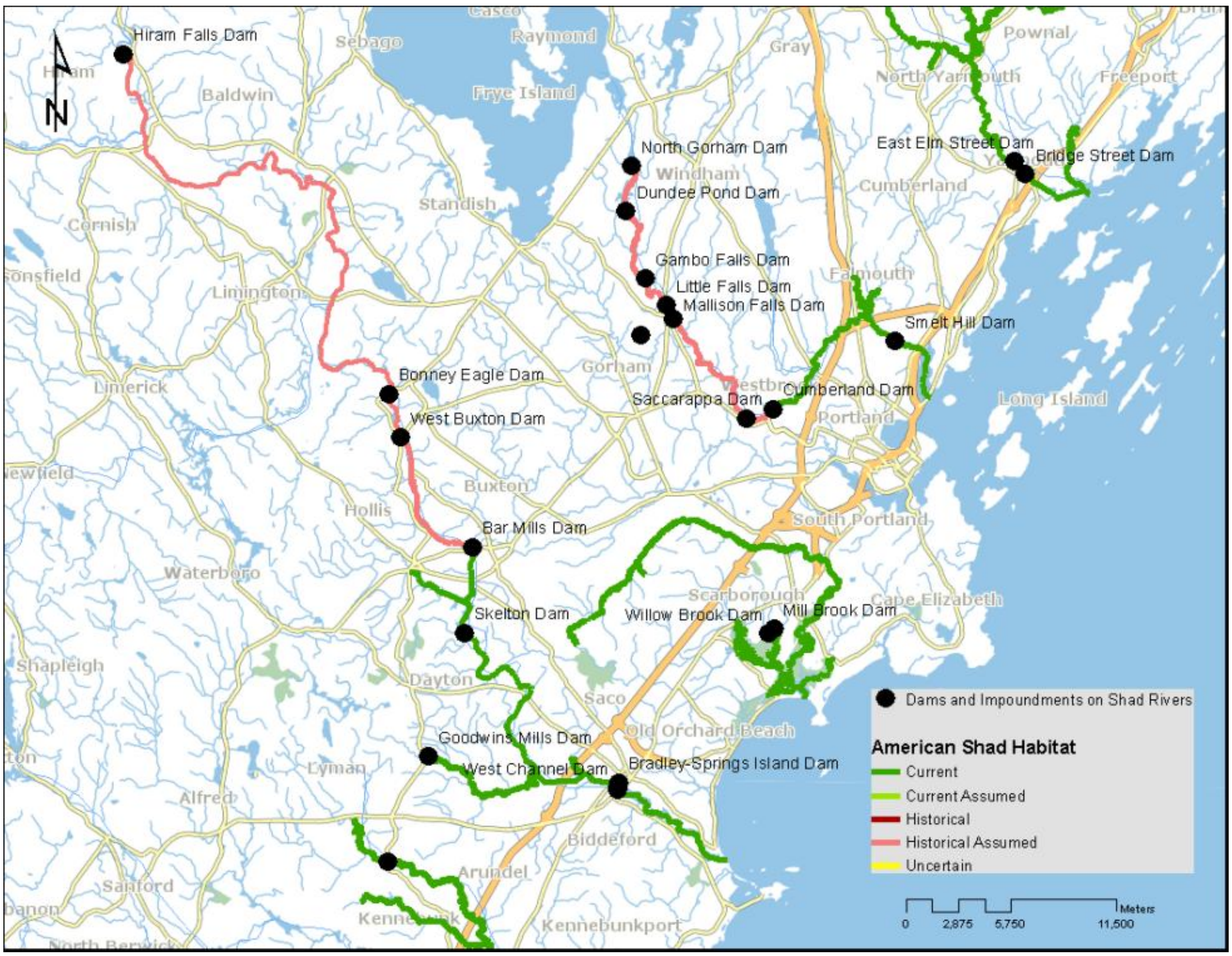

Figure 3. Saco River American shad habitat. Historical habitat is above dams with no fish passage. The Scarborough Marsh and Nonesuch River shad habitat is also shown in full in the middle-right of the figure.

Available Data

- Adult American shad counts, Brookfield Renewable Energy
- Video monitoring of shad behavior downstream on the Cataract Project, Brookfield Renewable Energy
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration

The majority of shad passage on the Saco River occurs at the East Channel fishlift of the Cataract Project. The project is licensed by the Federal Energy Regulatory Commission (FERC No. 2528) and is owned by Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light). The project includes the Cataract (East Channel) Dam and East Channel fishlift and an integral intake powerhouse containing a single turbine generator on the northeastern side of Factory Island in the City of Saco; and the West Channel dam and Denil fishway in the cities of Saco and Biddeford (Figure 3).

The impoundment formed by these dams extends upriver in the cities of Biddeford and Saco about 0.3 mile to another set of dams at Spring Island referred to as Bradbury and Spring Island dams. The impoundment formed by these dams extends upriver approximately 9.3 miles through the cities of Biddeford and Saco and the towns of Dayton and Buxton to Brookfield Renewable Energy's Skelton Project (Figure 3). A 90-foot high fish lift was constructed at the Skelton Project and first became operational in the fall of 2001.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light)

Other Organizations

Saco River Salmon Club

Current Action and Progress

Monitoring and Passage. In 2012, the Cataract fishways were operated by personnel from Nextera Energy Resources Hydro Operations division. These fishways were built to pass anadromous target species (Atlantic salmon, American shad, and river herring) as part of resource agency plans to restore these species to the Saco River, and have operated for 19 years. Although fishway construction was completed in the spring of 1993, the fishways were not completely operational until June 2, 1993 (East Channel) and June 25, 1993 (West Channel).

An underwater camera connected to a television monitor and VCR was first used in 1995 to gather information on fish behavior within the lower flume of the East Channel fishlift. The camera documented that shad exhibit a fallback behavior in and around the East Channel lower flume V gate crowder. On occasion, shad would swim upstream through the V gate crowder into the hopper area, then within minutes (and sometimes seconds) swim back downstream through the V gates and out of the lower flume into the tailrace. Also, on many occasions, shad were reluctant to pass through the V gate crowder in the fishing position (see 1995 Cataract fishway study report Sections 3 and 4 for detailed information on camera study and results). Since 1996, the underwater video camera, combined with keeping the V gate crowder wide open, was a very important technique that increased East Channel fishway efficiency. Fishway personnel observed that by keeping the V gate crowder open, shad moved readily into the trapping area. Utilizing the underwater camera, fishway personnel could observe shad as they passed through the wide open V gate crowder, then close the crowder and trap before the shad had a chance to fall back. This technique will continue in 2013.

A 2007 settlement agreement provides a schedule for fish passage at the remaining dams owned by FPL Energy (Table 4), a schedule for effectiveness testing, and a schedule for improvements at the Spring Island or Bradbury dam so American shad can pass.

Table 4. Schedule for fish passage implementation at Saco River dams.

Dam Name	Upstream anadromous passage
Cataract - East Channel, West Channel	fishlift, Denil
Cataract - Springs Island, Bradbury	fishlocks
Skelton	fishlift
Bar Mills	5/1/2016
West Buxton	5/1/2019
Bonny Eagle	5/1/2022
Hiram	5/1/2025

In 2012, NextEra biologists counted a total of 6,404 American shad (6,221 passing the East Channel Dam, and 183 passing the West Channel Dam, Figure 4). In addition to the 6,221 American shad successfully passing through the Cataract East Channel fishway, a total of 68 shad mortalities were noted. This represents a total fishway mortality of 1.2 %, which is similar to past years: 1995 (3.5%), 1996 (4.8%), 1997 (2.7%), 1998 (3.5%), 1999 (2.6%), 2000 (2.7%), 2001 (2.4%), 2002 (2.8%), 2003 (2.5%), 2004 (3.0%), 2005 (2.6%), 2006 (2.8%), 2007 (3.0%), 2008 (2.9%), 2009 (4.8%), 2010(1.9%), 2011 (2.1%). The majority of the American shad captured at the East Channel fishlift were transported to the Diamond Riverside Boat Ramp stocking location (approximately half mile upstream of the fishway), while the remaining shad were allowed to freely swim through the fishway into the Cataract impoundment.

At the Skelton Project during the 2012 season, 47 shad were lifted. It is assumed that many of the American shad that were not lifted at the Skelton fishway spawned below the project, as post-spawned American shad and juvenile American shad are routinely observed at the downstream Cataract Project. Also, the 9.3 miles between the Skelton Project and the Cataract Project provides potential spawning habitat for approximately 25,000 adult American shad.

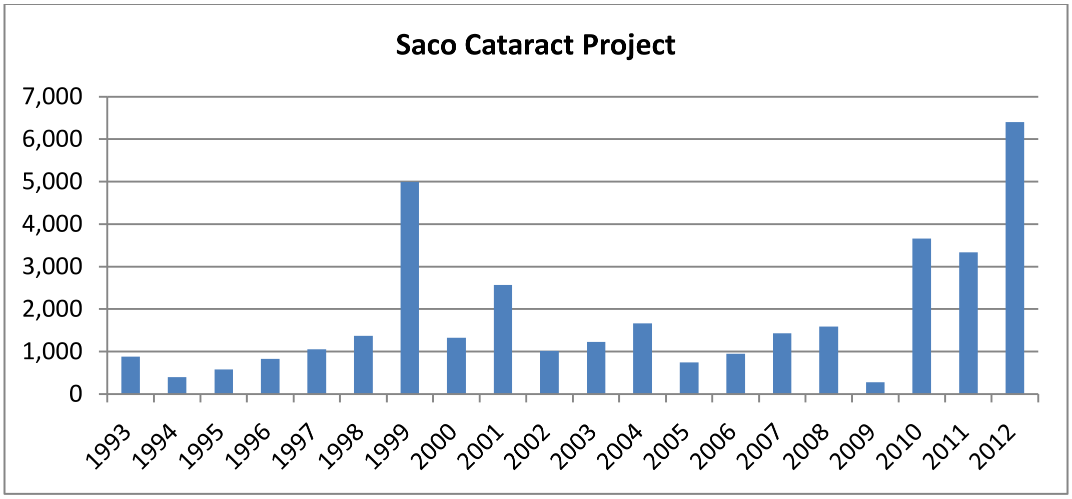

Figure 4. American shad passage at the Cataract Project from 1993 to 2012.

Goals and Recommended Actions

- Continue DMR consultations on proposed operational change to improve shad passage at fish locks
- Ground-truth spawning habitat both below Cataract Project and identify other spawning areas upstream
- Estimate mortality for adult shad passing the Cataract Project
- Conduct downstream efficiency and mortality studies
- In addition to video monitoring at the Cataract Project, document upstream efficiency at this location and at the Skelton Project
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season

The timeline and associated costs of these recommended actions has not been determined.

Androscoggin River

Amount of Habitat

The Androscoggin River contains 100.5 river kilometers of potential American shad habitat. Of this, 48.3 river kilometers are accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining habitat is inaccessible due to obstructed fish passage (Figure 5, Table 1). While passage above the Brunswick Dam is considered possible because the vertical-slot fishway allows some shad passage, actual passage by American shad has been documented to be very low (Figure 6), and the majority of habitat use has been documented in the small portion of river below the dam.

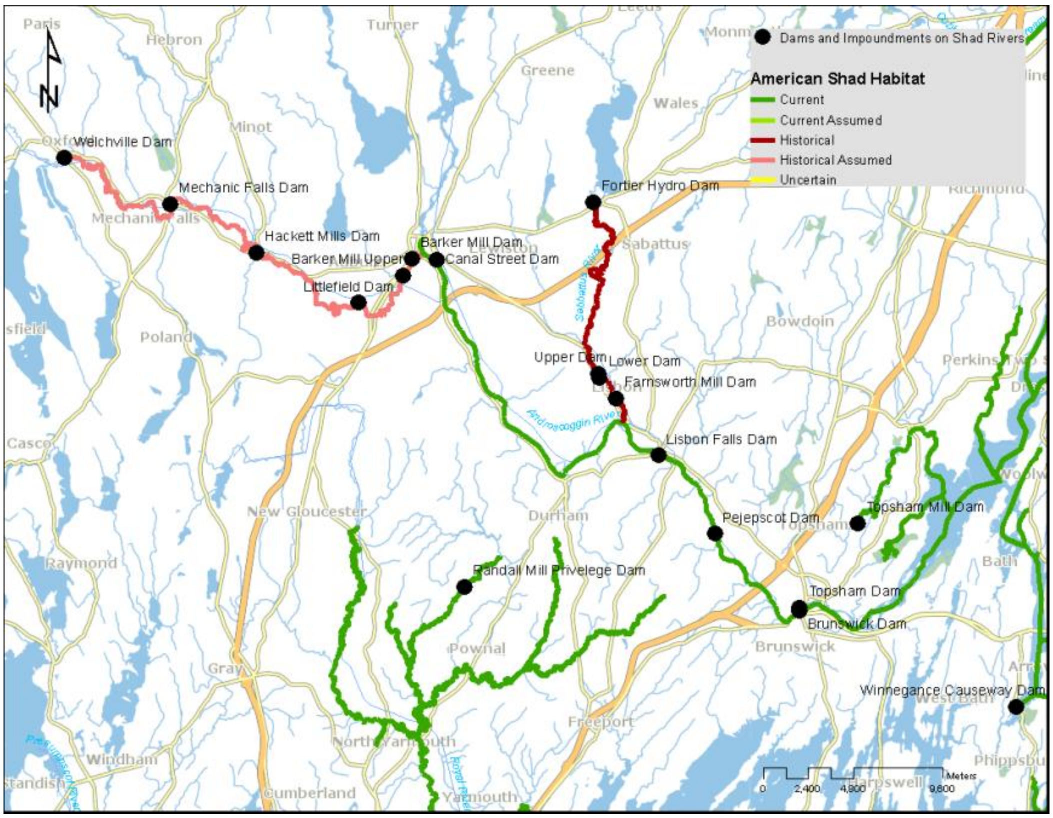

Figure 5. Androscoggin River American shad habitat. Historical habitat is above dams with no fish passage. The upper portion of the Royal River also is shown at the bottom of the figure.

Available Data

- Adult American shad counts, Maine DMR
- Juvenile Abundance, Maine DMR
- Video monitoring of shad behavior downstream of Brunswick Fishway, Bowdoin College
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Past water quality (no longer considered to be a threat)
- Invasive species (possible, not studied)

American shad historically spawned in the Androscoggin River from Merrymeeting Bay to Lewiston Falls, and in the Little Androscoggin River from its confluence with the Androscoggin to Biscoe Falls. However, construction in 1807 a low-head dam at the head-of-tide on the Androscoggin River caused the abundant American shad run to decline sharply.

<u>Barriers to migration.</u> In 1980 the U.S. Fish and Wildlife Service developed conceptual drawings for a vertical slot fishway for the Brunswick Project, which is located at the head-of-tide on the Androscoggin River. The fishway was designed to pass 85,000 American shad and 1,000,000 alewives annually. The upstream passage facility was one of the first vertical slot fishways designed to pass American shad on the east coast, and was a scaled-down version of a fishway located on the Columbia River. Redevelopment of the Brunswick Project and construction of the fishway was completed in 1983. The completed fishway was 570 feet long, and consisted of 42 individual pools with a one-foot drop between each. Downstream passage consisted of a 12-inch pipe located between two turbine intakes. When the Federal Energy Regulatory Commission issued a license for the Brunswick Project in 1979, it did not require efficiency studies for the upstream and downstream passage facilities.

Maine DMR initiated an anadromous fish restoration program in the Androscoggin River after fish passage was installed the Brunswick Project dam, and just prior to the installation of passage in 1987 and 1988 at the next two upstream projects. Between 1985 and 2008, a total of 7,882 prespawn American shad from in-state (Cathance and Androscoggin rivers) and out-of-state (Merrimack and Connecticut rivers) sources were stocked into spawning habitat below Lewiston Falls. In addition, approximately 5.6 million shad fry were stocked into these waters between 1999 and 2008.

Currently the factor limiting successful American shad restoration to the Androscoggin is the lack of effective passage at the Brunswick Project. Neither the Brunswick vertical slot fishway nor a similar one at the Rainbow Dam on the Farmington River, CT, has proven to be successful at passing American shad. Visual observations, underwater videography, and radio telemetry studies conducted at the Brunswick Project by Maine DMR in cooperation with the U.S. Fish and Wildlife Service have shown that American shad swim past the fishway entrance repeatedly, but rarely enter it. The few shad that enter the fishway rarely ascend beyond the corner pool, and in 27 years of operation only 219 American shad have used the fishway.

In February 2011, NextEra Energy, owner of the Brunswick Project, agreed to conduct an experiment to determine whether upstream passage of American shad could be improved by increasing the amount of attraction water at the fishway (see Video Monitoring below).

<u>Past water quality.</u> After dams confined American shad to the tidal portion of the river, severe water pollution virtually eliminated the population. American shad that continued to reproduce in the six-mile stretch of river below Brunswick supported significant commercial fisheries until the

late 1920's. By the early 1930s, severe water pollution from upstream industries and municipalities had caused declines in many fish species. Water pollution abatement efforts that began in the early 1970s resulted in the dramatic improvement of water quality in the Androscoggin River.

Invasive species. White catfish, carp (*Cyprinus carpio*), and Northern pike populations are known to be increasing in the lower Androscoggin River, in the portion where American shad spawning occurs and where juvenile shad are found. The effect of these invasive species on shad populations is not known, however white catfish are known to eat fish eggs of native species.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light)

Other Organizations

Bowdoin College, University of Maine, Bates College, University of Southern Maine, Androscoggin River Alliance, Friends of Merrymeeting Bay

Current Action and Progress

Juvenile Abundance Surveys. See description in State-Wide Information above.

Monitoring and Passage. Fisheries personnel monitor American shad during their spawning migration at the Brunswick Fishway on the Androscoggin River. Shad are counted and passed upstream as they are encountered at the top of the fishway, after the shad have volitionally passed the 42 pools of the fishway. Biological sampling (length, weight, sex, and scale sample) is not performed on live American shad because the run levels continue to be extremely low, and any handling may cause mortality. Sampling is performed on American shad that have experienced fish passage mortality. Passage of American shad has remained low – only 11 were passed in 2012, and only 289 total passed in all years of the data series (Figure 6).

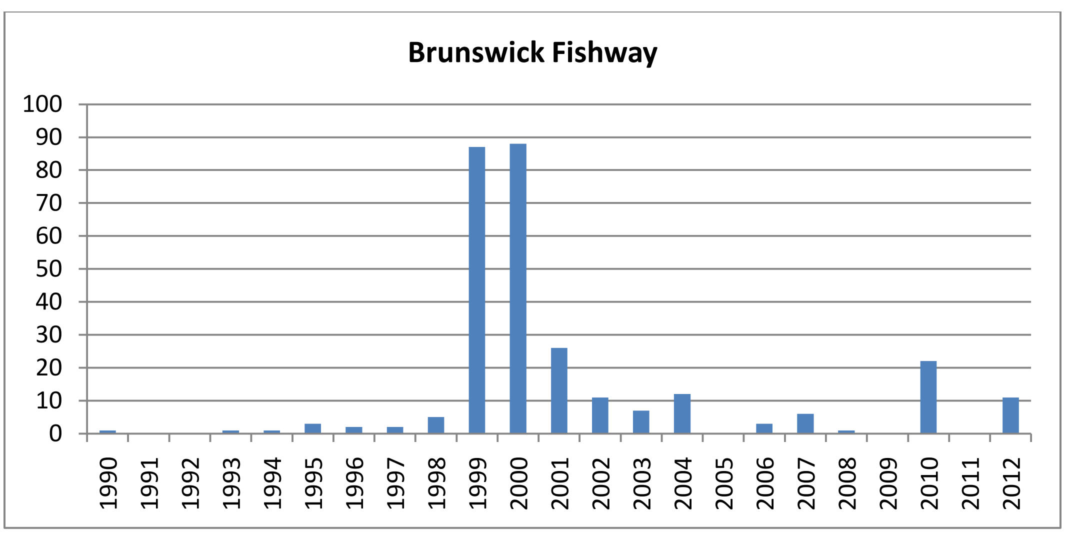

Figure 6. American shad passed above the Brunswick fishway from 1990 to 2012.

Video monitoring. In 2011 and again in 2013, John Lichter of Bowdoin-Bates-USM research group along with his summer research students, Bob Richter of Brookfield Renewable Power, Neil Ward of the Androscoggin River Alliance, and Gail Wippelhauser of the Maine DMR collaborated on an experiment to determine whether upstream passage of spawning American shad at Brunswick Fishway could be improved by increasing the attraction flow at the fishway entrance. Two current inducers were installed adjacent to the fishway entrance. The presence and behavior of American shad was monitored with two underwater cameras, one located in the river about 40 m feet downstream of the fishway entrance to confirm the presence of shad in the river, and a second one placed adjacent to the fishway entrance. Digital video recorders, computers, and software were installed in the fish ladder control room. Salmonsoft@ software was used to record video images when a fish crossed in front of each of the cameras.

In 2011, inducers were turned on and off over alternating two-hour periods. Approximately 16,558 American shad were counted at the lower camera, although previous telemetry studies have shown that an individual may swim past this part of the river multiple times per day. The fish were active primarily during the day for a period of 5-6 h, beginning 1-2 hours before high slack water and continuing for 3-4 hours into the ebb tide. A total of 91 American shad were seen at the entrance of the fishway. More fish were seen at the entrance in the afternoon than in the morning, and more fish were seen when the current inducers were turned on (54) than when the inducers were off (37). However, the current inducers were more effective in the morning than in the afternoon. In 2013, two current inducers were installed adjacent to the fishway entrance and were alternately turned off for 24 hours (attraction water of 100 cfs) then on for 24 hours (attraction water of 180 cfs) with the change occurring at noon every day. Approximately 500 of the nearly 25,000 shad viewed at the lower camera made it to the entrance of the fish ladder. To date, we have only completed roughly 2/3rds of the 2013 video data analysis. Equipment damage related to flooding prevented the study in 2012.

Because it is not clear how many of the 16,000-25,000+ shad viewed at the lower camera circled around the far side of the river after failing to find the fish ladder and were subsequently recounted in the lower camera, we are planning a study that will determine shad movement patterns in the tailrace of the dam for 2014. In any case, there appears to be some number of thousands of shad trying to navigate past the Brunswick Hydroelectric facility each year. Previous work with Michael Brown of the Maine DMR and John Lichter, Bowdoin College, showed that shad will spawn in the tidal waters of the lower Androscoggin if they cannot pass the dam.

Goals and Recommended Actions

- Conduct population estimates for adults spawning in the lower Androscoggin River
- Map young-of-year habitat based on existing beach seine surveys
- Continue fishway efficiency studies at Brunswick Fishway that document poor passage by adult American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Study impact of invasive species populations on shad populations

The timeline and associated costs of these recommended actions has not been determined.

Kennebec and Sebasticook Rivers

Amount of Habitat

The Kennebec watershed contains 407.6 river kilometers of potential American shad habitat. Of this, 300.4 river kilometers are currently accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining 107.2 river kilometers are inaccessible due to obstructed fish passage (Table 1).

The watershed contains two major spawning areas, the mainstem Kennebec River below Lockwood Dam and the the Sebasticook River below Benton Falls Dam (Figure 7). While passage above these is considered possible because both dams have fishlifts, actual passage by American shad has been documented to be very low (Figure 8), and the majority of spawning is thought to occur below the first mainstem dams.

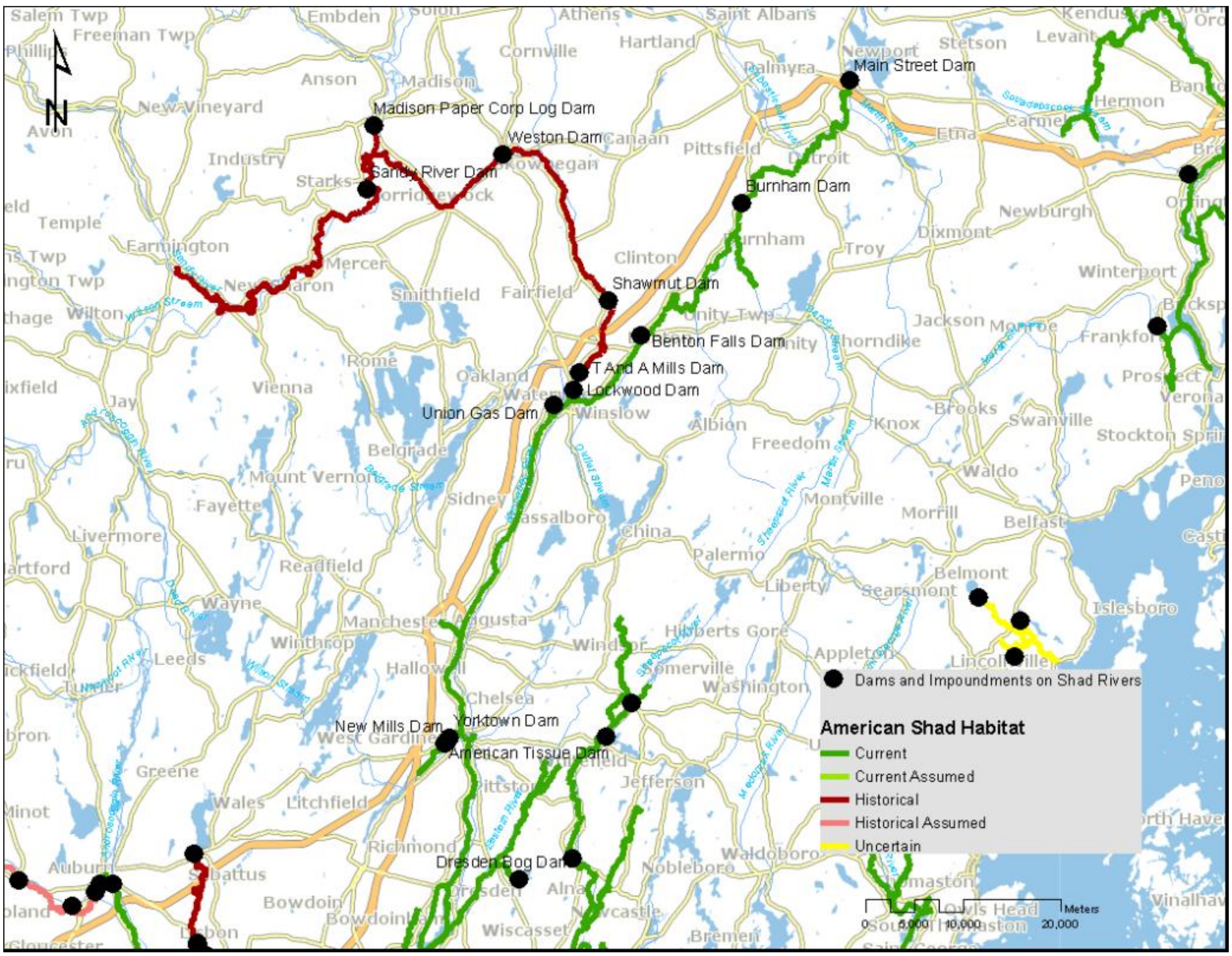

Figure 7. American shad habitat in the Kennebec and Sebasticook rivers. Historical habitat is above dams with no fish passage. The upper portion of the Sheepscot River also is shown at the bottom of the figure, in close proximity to the lower Kennebec River.

Available Data

- Adult American shad counts, Maine DMR
- Juvenile Abundance, Maine DMR
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Past water quality (no longer considered to be a threat)
- Invasive species (possible, not studied)

Barriers to migration. The Kennebec River Restoration Program was initiated following the development of a Strategic Plan in 1985, an Operational Plan in 1986, and the signing of an Agreement in 1986 between the Maine DMR and the Kennebec Hydro Developers Group (KHDG). This Agreement provided a delay in fish passage requirements at seven hydropower facilities above Augusta in exchange for funds to initiate the restoration by means of trap-and-truck of river herring and American shad to selected upriver spawning and nursery habitat. In 1998, a new Agreement between state and federal fisheries agencies and the members of the KHDG was signed. The new Agreement provided for the removal of Edwards Dam, included new timetables or triggers for fish passage at the seven hydropower facilities above Augusta, and provided additional funds to continue the restoration by trap-and-truck. In 2006, the Kennebec River Restoration Program entered a new phase when upstream anadromous fish passage became operational at the Benton Falls, Burnham, and Lockwood hydropower projects (Figure 7).

Upstream passage at the Burnham and Benton Falls was required to be operational one year following the installation of permanent or temporary upstream fish passage at Fort Halifax and following installation of permanent upstream fish passage at four upriver non-hydro dams. These projects included the implementation of interim upstream passage measures at Fort Halifax dam and the construction of fishways at the Pleasant Pond dam in Stetson, the Plymouth Pond dam in Plymouth, the Sebasticook Lake outlet dam in Newport and the removal of the Guilford dam in Newport. Passage at the Benton Falls Dam was established in 2006 by way of a fishlift. The top of the lift contains a watered holding area leading to a large fish excluder, a gate with vertical bars spaces 2” apart to prevent larger fish from passing in an effort to minimize invasive species passage. All American shad passing Benton Falls must be manually passed upstream over this excluder grate. A fishlift also provides passage at the Burham Dam, however no upstream excluder panel prevents free passage of shad once they pass the fishlift.

The Lower Kennebec River Comprehensive Hydropower Settlement Accord requires that the Licensee install a trap, lift, and transfer facility at the project’s powerhouses at Lockwood Dam. These facilities were operational in 2006. American shad that reach the top of the fishlift are passed upstream, however the next dam 1.9 river kilometers upstream has no fish passage capabilities.

The potential for these locations to pass American shad is thought to be low to moderate. The ability of shad to locate the fishlift entrance is likely hindered by attraction flows from large spillways. Further, at Benton Falls Dam there is evidence that shad remain in holding areas undetected, as evidenced by a large proportion of "passed" shad found only when the facilities are periodically de-watered, and only few shad passed during normal operations (Maine DMR ASMFC Compliance 2011 Report). However, this effect may be a result of flow differentials between the downstream portion of the dam and the headpond. Shad may remain in the portion between the fishlift and the headpond for longer periods of time because the flow is much lower than the tailraces, and use this time for resting.

Past water quality. Water pollution from upstream industries and municipalities in the early to mid-20th century had significant impacts on water quality in the Kennebec watershed and was thought to cause declines in many fish species populations. Water pollution abatement efforts that began in the early 1970s resulted in the dramatic improvement of water quality in the Kennebec and Sebasticook rivers. While water quality has drastically improved over the past forty years, high levels of PCBs and some toxic contaminants are still found in many resident fish species.

Invasive species. White catfish and carp (*Cyprinus carpio*) populations are known to be increasing in the Kennebec and Sebasticook rivers, in the portion where American shad spawning occurs and where juvenile shad are found. The effect of these invasive species on shad populations is not known, however white catfish are known to eat fish eggs of native species.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light), KEI (USA) Power Management Inc., Benton Falls Associates (Essex Hydro Associates), Kennebec Hydro Developers Group

Other Organizations

Friends of Merrymeeting Bay, Kennebec Estuary Land Trust, Sportsman's Alliance of Maine

Current Action and Progress

Juvenile Abundance Surveys. See description in State-Wide Information above.

Monitoring and Passage. Fisheries personnel monitor American shad during their spawning migration at the Lockwood Dam on the Kennebec River and the Benton Falls Dam on the Sebasticook River. Shad are counted and passed upstream as they are encountered at the top of the fishway, after the shad have volitionally entered the fishlift. Biological sampling (length, weight, sex, and scale sample) is not performed on live American shad because the run levels continue to be extremely low, and any handling may cause mortality. Sampling is performed on American shad that have experienced fish passage mortality. Passage of American shad has remained low – only 5 were passed in 2012 at the Lockwood Dam, and only 39 total since the fishlift at Lockwood was operational. Passage at Benton Falls Dam may be increasing: in 2012 163 shad were passed (Figure 8).

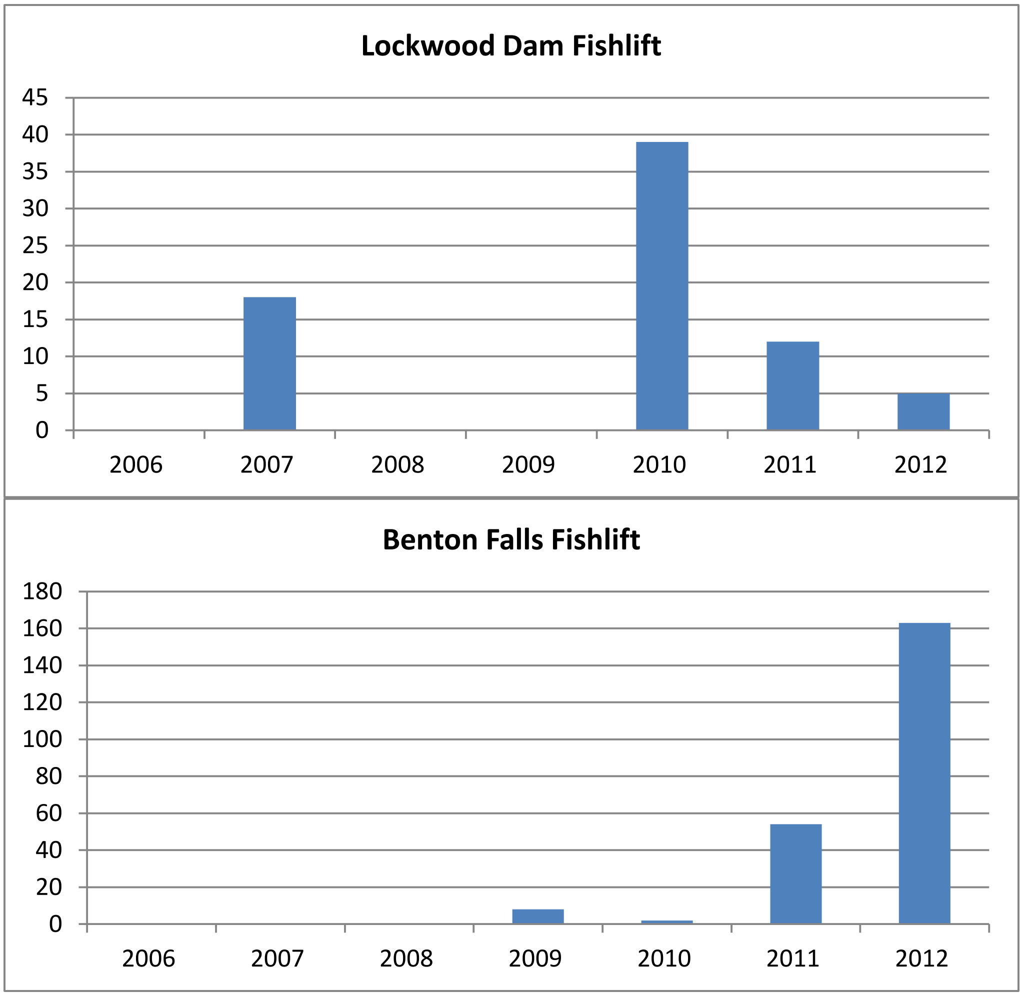

Figure 8. American shad passage at two counting locations in the Kennebec watershed. Fish passage was not operational before 2006.

Goals and Recommended Actions

- Ground-truth spawning habitat in the mainstem Kennebec and Sebasticook rivers
- Conduct population estimates for spawning adults
- Map young-of-year habitat based on existing beach seine surveys
- Develop fishway efficiency studies at Benton Falls and Lockwood fishlifts
- Conduct downstream passage studies at Benton Falls for both adult and juvenile American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Study impact of invasive species populations on shad populations

The timeline and associated costs of these recommended actions has not been determined.

Penobscot River

Amount of Habitat

The Penobscot watershed contains 786.3 river kilometers of potential American shad habitat. Of this, only 399.6 river kilometers are currently accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining 386.7 river kilometers are inaccessible due to obstructed fish passage (Table 1).

Though few adult shad have been captured at the lower mainstem dams as part of fishway operations, recent summer trawl surveys conducted in the lower portion of the river have captured juvenile American shad (Lipsky and Saunders 2013). In 2004, 12 juvenile American shad were electrofished downstream of the Veazie Dam but none were captured during extensive upriver sampling (mainstem Penobscot from Veazie to the confluence of the East and West Branch in East Millinocket, the West Branch Penobscot to the outlet of Seboomook Lake, the East Branch Penobscot to Grindstone Falls, the Piscataquis River, the Stillwater River, Passadumkeag Stream, Pushaw Stream, and Millinocket Stream) (Yoder et al. 2004).

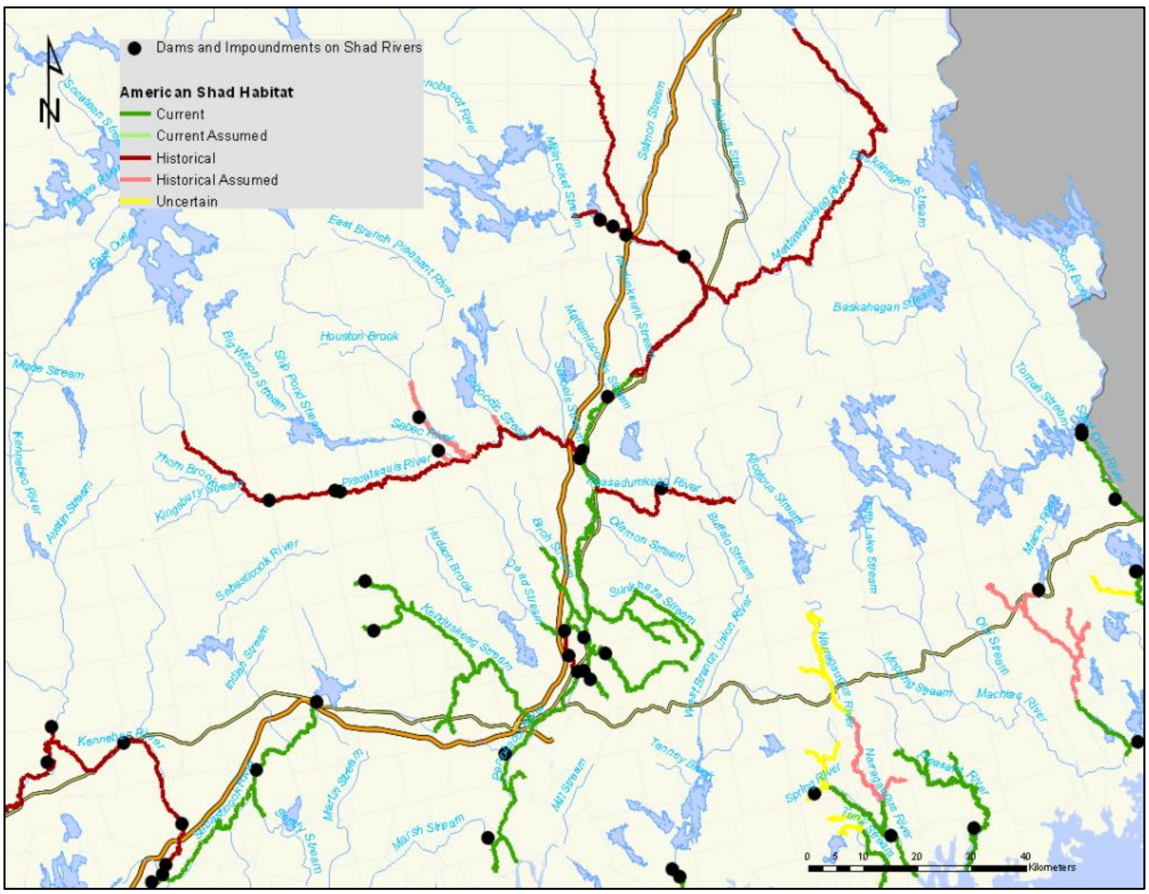

Figure 9. American shad habitat in Penobscot watershed. Historical habitat is above dams with no fish passage. The upper portion of the Kennebec River River also is shown at the bottom left the figure, and the Narraguagus, Pleasant, and East Machias rivers appear in the bottom right.

Available Data

- Adult American shad counts, Maine DMR
- Fish community survey data, NOAA
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Possible water quality

Barriers to migration. Until recently, mainstem dams in the lower portion of the Penobscot River have limited fish passage by all species, and reduced the amount of spawning habitat for American shad by more than half of the potential area. In 2004, the Lower Penobscot River Settlement Accord was signed, a multi-party agreement which laid the framework for the Penobscot River Restoration Project (PRRP). Through this project, the Penobscot Trust purchased the Veazie, Great Works, and Howland Dams in 2010 with the goal of dam removal or fish passage at each location. Five major projects are part of this effort to improve migratory fish passage and habitat in the lower Penobscot River:

- Removal of Great Works Dam in 2012
- Upgrade of Old Town Fuel & Fiber water intake in 2012 to reduce fish interaction
- Removal of Veazie Dam in 2013
- Installation of a fishlift at Milford Dam in 2013; and
- Decommissioning and construction of a bypass at Howland Dam

Before these projects were completed, limited access was available to American shad by way of upstream passage at the Veazie Dam, and two Denil fishways at the Great Works Dam.

Water quality. In the early 20th century, severe water pollution from upstream industries and municipalities had had a significant impact on fish populations. Water pollution improvement efforts that began in the early 1970s resulted in the dramatic improvement of water quality, however many paper mills and other industry still operate on the river. While the PRRP has addressed some known issues with water intake, others may exist.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Black Bear Hydro Partners, LLC, Penobscot River Restoration Trust, PPL Corporation

Other Organizations

Penobscot Indian Nation, American Rivers, Atlantic Salmon Federation, Maine Audubon, Natural Resources Council of Maine, and Trout Unlimited

Current Action and Progress

Barrier removal and passage facilities. Recent work has opened habitat in the lower portion of the Penobscot River through removal of the Great Works and Veazie dams, and upcoming installation of a fishlift at Milford Dam and bypass at the Howland Dam. The result of these projects on American shad will likely not been seen for a few years.

Before the Veazie Dam was removed, few American shad were provided upstream passage at the fish trap installed at that dam – since 1978, fewer than twenty adult spawning shad were passed. It is likely that the majority of shad in the Penobscot River remained below the dam, and any spawning occurred in the mainstem.

Fish community surveys. NOAA Northeast Fishery Science Center (NEFSC) Maine Field Station has conducted fish community monitoring since 2010 in the Penobscot Estuary. The survey has relied on a combination of fixed (seine and fyke) and mobile (trawl) capture gear combined with mobile hydroacoustics to describe relative abundance and species composition in the estuary. Sampling has generally occurred from April through October at weekly to monthly intervals depending on the year, season and gear. Twelve seine sites are distributed from 10 to 40 kilometers downstream of head-tide, four fyke sites at 12 and 25 kilometers downstream of head-tide and trawls from 15 to 55 kilometers downstream of head-tide. A total of 67 species have been identified including 10 diadromous, 27 freshwater and 30 marine life histories. Most dominant in the surveys by number are the clupeids namely *Clupea harengus* with *Alosa* species most common in percent occurrence. The survey has been successful in establishing systematic methods of sampling and has provided a platform for several researchers interested in estuary species such as: *Salmo salar*, *Fundulus heteroclitus*, *Osmerus mordax*, *Microgadus tomcod*, *Alosa pseudoharengus*, *Alosa aestivalis*, and *Alosa sapidissima*.

One of the objectives of the Penobscot Estuary survey was to describe temporal and spatial distributions of diadromous species including American shad. It is believed the Penobscot has a remnant population of American shad through anecdotal reports from anglers and infrequent occurrence at the Veazie Dam fishway trap operated by the Maine DMR. Seine surveys conducted in collaboration with the Maine DMR in 2010 - 2012, confirmed presence of young-of-year (YOY) American shad in the estuary and 2011-2013 trawl surveys have confirmed presence of age- 1 juveniles. Lipsky and Saunders (2013) summarized YOY distribution in the Penobscot and determined that due to salinity intolerance, the YOY are likely the result of natural reproduction from the Penobscot rather than larval drift from other spawning locations.

Seine and fyke catch data have shown that most (40% of total) YOY shad are captured in September but are present from July through November. Captures were most common (45% of total) in the tidal freshwater reaches of the estuary, 8-15 kilometers below head of tide. However, captures did occur in higher salinity (10-20 ppt) areas over 45 kilometers from head of tide. Trawl data suggests some age- 1 American shad utilize the Penobscot estuary in their second summer for rearing. Trawls in 2011 to 2013 have captured 750 individuals between 9 and 27 cm total length. For the trawl, most captures occur at the high turbidity, salinity mixing zone 20 to 30 kilometers downstream of head tide.

Goals and Recommended Actions

- Ground-truth spawning habitat in the lower Penobscot River once the PRRP current objectives are complete
- Conduct population estimates for spawning adults
- Map young-of-year habitat based on existing beach seine surveys
- Develop fishway efficiency studies at Milford fishlift after sufficient time has passed for shad populations that may have spawned below the Great Works Dam have "found" their way upstream (part of current FERC license)
- Conduct downstream passage studies at Milford fishlift for both adult and juvenile American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Continued work to open habitat further upstream

Timeline

Current summer trawl surveys have documents American shad juveniles in the Penobscot River, however, with the large-scale changes occurring under the PRRP, dedicated work towards identifying spawning habitat and performing fish passage efficiency studies may be more productive after sufficient time has passed to allow fish populations to respond. Under the assumption that the PRRP work will be complete by 2016, it is suggested that the above recommendations be implemented in 2020, with the exception of water chemistry sampling which should be implemented at the Milford fishlift when it is operational. Adult shad counts and fish community surveys should continue annually.

Associated Costs

To accomplish the goals of the PRRP, it is estimated that ~$55 million is needed (Penobscot Restoration Trust 2013).

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g) MDMR 2020 Maine Sustainable Fisheries Management Plan for American Shad

MAINE DEPARTMENT OF MARINE RESOURCES

Maine Sustainable Fisheries Management Plan for American Shad

Maine Department of Marine Resources
32 Blossom lane
Augusta, Maine 04333

Approved August 4, 2020

1. Introduction

American shad (*Alosa sapidissima*) are managed in state waters by the Atlantic States Marine Fisheries Commission (ASMFC). In 2010 the Atlantic States Marine Fisheries Commission Shad and River Herring Management Board passed Amendment 3 to the American Shad and River Herring Management Plan. Amendment 3 was developed to address continued concerns over declining populations of American shad coastwide. Amendment 3 closed all commercial and recreational fishing for American shad along the East Coast starting in January 2013 unless individual states developed an ASMFC approved sustainable fisheries management plan for American shad. States without an approved sustainable fisheries management plan were limited to catch and release fishing for American shad.

2. Regulatory History

Historically, American shad were abundant in Maine's large coastal rivers and streams. American shad were an important food source for indigenous people and an important economic resource for European settlers. As shad fisheries continued to develop state fisheries managers utilized several regulatory processes to manage Maine's commercial and recreational American shad fisheries. Most of these regulations applied to the directed commercial American shad fisheries in the Kennebec, Androscoggin, and Merrymeeting Bay areas of the state from the late 1800s through the 1940s. Several of the smaller coastal rivers had additional river-specific harvest regulations. Maine regulated the directed fishing effort for American shad through mesh size and lead length restrictions for commercial shad operations that utilized gill nets and weirs. Later, closed seasons allowed additional escapement for spawning fish to migrate upstream to spawning areas. By the end of the 1940s, the effects of pollution, dam construction, and overfishing depleted many of the coastal river fisheries to the point where it became economically infeasible to continue commercial fishing operations. Commercial catches of American shad after the 1940s resulted principally from herring and groundfish fishing operations in nearshore and offshore locations in the Gulf of Maine.

3. Current Regulations

Effective May 19, 1998, the Maine Department of Marine Resources (MDMR) closed all state waters to commercial fishing for American shad. Although Hickory shad may be present in Maine's coastal waters during the spring, summer, or fall, confirmed catches of hickory shad in the commercial sector, recreational fishery, or state sponsored semi-annual trawl surveys conducted in Maine and New Hampshire have not occurred in several years. Since mandatory reporting requirements began in 1996, only one commercial trip in Maine, during the 1999 fishing season, reported catching two hickory shad.

In May 1998, the State of Maine established a two fish per day recreational limit for American shad in state waters. Gear restrictions limit anglers to a single hook and line while fishing American shad. This regulation has remained in effect since May 1998.

4. Status of the Stocks

Statewide there are 23 identified American shad rivers with over 2,545 river kilometers of potential habitat. Currently, only 1,611 river kilometers are known to be open for upstream passage for American shad, while over 810 river kilometers of historical habitat are currently inaccessible (Figure 1; Table 1). Of the habitat that is accessible, a large proportion of the habitat on many rivers is above dams with fishways that may provide only limited accessibility. It is assumed that the mapped habitat supports both adult and juvenile life stages of American shad. Adult shad numbers are increasing in Maine because of the extensive restoration on the main stems of Maine's largest rivers (Table 2). However, returns are low compared to historic numbers that once supported large commercial fisheries.

Prior to the year 1998, main stem dams without adequate upstream passage, pollution, and habitat loss virtually eliminated American shad from most Maine rivers. After the collapse of American shad populations in Maine and prior to the restoration projects started in 1984, American shad were most often caught in Maine's inland waters as incidentally catches by recreational anglers fishing for Atlantic salmon.

The occurrence of American shad in Maine rivers became more prevalent with the development of a restoration plan which utilized trap and truck of prespawn fish from other states. Development of a hatchery to propagate native and captive shad from other states for release into Maine rivers contributed to an expanding native shad population. These restoration efforts were supported through continued installation of upstream and downstream fish passage and dam removals on Maine's largest rivers.

Today recreational fishing for American shad in Maine is not widespread and is restricted to river stretches below existing main stem dams. Six rivers in Maine support most of the recreational fishing for American shad Currently, American shad are documented as catches in qualitative fishing reports from anglers fishing in the Androscoggin, Saco, Mousam, Kennebec, Penobscot and Narraguagus rivers, but there are few reports from other rivers. The population sizes in these rivers is currently unknown other than the counts provided at dams which provide upstream fish passage.

The Mousam, Saco, Androscoggin, Kennebec, Penobscot and Narraguagus rivers range in size from small coastal streams to large complex river systems. The Kennebec and Saco rivers are the most productive recreational fishing spots for American shad. These rivers, except for the Narraguagus and upper section of the Kennebec and Penobscot rivers, are covered by the NOAA MRIP survey. Data provided by NOAA for the period 1996 – 2018 confirm state fisheries biologists observations that the proportion of recreational anglers fishing for American shad is low and harvest of American shad is almost nonexistent. (Tables 3 & 4; Figure 2)

Statewide Landings

Commercial fishing for American shad is currently prohibited in the state of Maine. Historically, commercial shad fisheries were an important source of food and employment in the lower portions of the larger river systems throughout coastal Maine. Like many of Maine's coastal rivers, pollution and construction of dams without fish passage, or fishways that provided ineffective upstream fish passage, reduced shad populations to the point where commercial fishing was no longer viable.

Since Maine prohibited commercial fishing for American shad in May 1998, commercial landings of American shad occurred principally as bycatch in the groundfish gill net fishery in federal waters off the coast of Maine. With changes in the groundfish fishery, landings of American shad in Maine ports have been close to zero.

Passage

Barriers to migration are the primary impediments to American shad habitat and successful spawning within Maine state waters. Of 23 rivers known to have historical or known populations of American shad, 18 rivers have a mainstem dam that limits upstream passage of American shad. Of these, five have no capacity for fish passage. Taylor 1951, documented the decline of several American shad populations in Maine's largest rivers. He identified dams as one of the major reasons for population declines and dams still remain a major threat to American shad today.

Even though fish passage may be installed at these dams, or others, the use of habitat upstream is thought to be much lower than the use of habitats below these dams. In 2011, video monitoring below the Brunswick fishway on the Androscoggin River documented over 16,000 American shad below the dam, while no shad were passed at the top of vertical slot fishway (J. Lichter, Bowdoin College, pers. comm). Similar observations have been made at several dams, including those with the newest fish passage technology.

The majority of the dams with fish passage on shad rivers in Maine utilize fish lifts or Denil fishways. Denil fishways seem to have high potential for passage (Slatick and Basham 1985, Haro *et al.* 1999), however, the ability of shad to locate the fishway entrance in a large mainstem dam can be low, especially when combined with a large spillway and spill unassociated with designed attraction flows. Most newly constructed fish passage facilities on mainstem rivers in Maine utilize fish lifts. The potential for these facilities to pass American shad is thought to be low to moderate dependent on placement and operation. As discussed above, the ability of shad to locate the fish lift entrance is likely affected by attraction flows from areas adjacent to the fishway along large spillways. At some Maine dams that utilize fish lifts there is evidence that shad may remain in holding areas below the fish lift and do not enter the headpond, as evidenced by shad found when the facilities are periodically dewatered.

Management History

Fisheries managers used a number of regulatory processes to manage American shad fisheries in Maine (gear, season, catch limits). Many of these regulations applied to the commercial American shad fisheries in the Kennebec, Androscoggin, and Merrymeeting Bay Complex from the late 1800s through the 1940s. Several of the smaller coastal rivers had additional river-specific harvest regulations. Closed seasons allowed additional escapement of spawning shad as shad populations declined. By the end of the 1940s, the effects of pollution and over fishing depleted many of the coastal river fisheries to the point where it became economically infeasible to continue commercial fishing operations. Generally, commercial shad catches after the 1940s were bycatch resulting from Atlantic herring and groundfish fishing operations in offshore fishing locations.

During the period 1940 through the mid-1980s the State of Maine passively managed American shad populations on most river systems. Management began to change on some river systems as water quality improved and fish passage became a standard in the relicensing of hydropower projects operating in Maine. With the anticipation of improved water quality and upstream passage the State initiated a more active management approach. These management actions included the trap and transfer of adult American shad from in-state and out-of-state sources and, for the first time, included the production of hatchery products for release into river systems considered for restoration.

Restoration Efforts

In addition to providing upstream and downstream passage and dam removals on several of Maine's rivers the state implemented active restoration strategies to recover American shad. The Department of Marine Resources began adult stocking and hatchery programs to restore American shad to the state of Maine prior to the anticipated removal of Edwards Dam in Augusta and in conjunction with the newly created fishway at the Brunswick hydropower dam on the Androscoggin River.

Adult stocking

Active shad restoration in Maine began in 1985 by stocking prespawn adult American shad into the Androscoggin River. For the first two years of this stocking program adult shad were captured in the Cathance River (ME) and the Merrimack River (MA) and released into the Androscoggin River. Beginning in 1988 adult shad from the Connecticut River (Holyoke fish lift), the Merrimack River (Lowell, MA) and native shad returning to the Androscoggin were released into the Androscoggin River above the Brunswick dam. Adult shad were actively stocked from out of state sources for all years except 1998, 2000, 2001, 2005, 2006. The adult shad stocking program ended in 2009 due to limited funding and the availability of American shad broodstock from other states. Due to cost and the status of American shad runs coastwide the adult transfer program is not expected to resume.

American shad restoration began on the Kennebec River in 1987 by stocking a small number of prespawn adult shad obtained from Maine rivers. Between 1988 and 1997, adult shad were taken from the Connecticut River at the Holyoke lift and released into the Kennebec River above Augusta.
Stocking adult shad directly into the rivers targeted for restoration occurred for 15 years. In 2009, the MDMR decided to discontinue the direct stocking of adult shad into the river systems and relied on the culture and release of marked hatchery larvae (Table 5)

Larval stocking

American shad larvae were raised at the Waldoboro hatchery from 1992 to 2008 using eggs collected from adults from the Kennebec, Connecticut, Androscoggin, Merrimack, Saco, and Sebasticook rivers. Beginning in 1993, shad eggs from Connecticut River adults were transported to the Waldobo Shad Hatchery in Waldoboro, ME, cultured up to 21 days, and released as larvae into the Kennebec or Sebasticook rivers (a tributary to the Kennebec River). Beginning in 1998, adult shad from the Connecticut and Merrimack rivers were transported to the Waldoboro Hatchery for use as broodstock in a tank-spawning system.

Larval American shad reared in the hatchery were 'marked' by immersion in an oxytetracycline (OTC) bath before being released. Receiving locations included multiple sites on the Androscoggin, Kennebec, and Sebasticook rivers (both below and above dams), as well as at the presumed spawning locations on the Medomak River and on the Saco River in tidal water below the dam. The hatchery closed in 2009 with no plans to reopen the hatchery due to funding, availability of broodstock and current management of American shad along the East Coast.

To assess the success of the hatchery program adult American shad otoliths were collected from mortalities at fish passage facilities, from juveniles collected during beach seine surveys, and from some anglers who voluntarily submitted samples. The Maine DMR inshore trawl survey also began collecting otoliths from a subsample of American shad during the fall of 2012. While it is difficult to directly measured the success of the stocking program statewide, juvenile abundance in the Kennebec/Androscoggin complex did increase concurrent with larval stocking.

Current Action and Progress

During the Federal Energy Regulatory Commission (FERC) relicensing process, the Maine Department of Marine Resources, in collaboration with federal agencies, advocates for fish passage infrastructure and operations that provide the best accommodation for all diadromous fish passage, including American shad. In addition to the FERC process, the Maine DMR also provides comments on all construction projects in the state where there may be an interaction with an identified shad resource. The Department provides comments and works with public and private landowners to install fish passage or upgrade existing passage to allow for maximum passage potential for all diadromous species, including American shad.

There are four ongoing annual monitoring projects that collect data on American shad in Maine waters. These projects collect data from a number of different habitats and life stages of American shad. The projects include fishway monitoring on major rivers, a juvenile beach seine survey, the Maine-New Hampshire trawl survey and the recreational fishing (MRIP) survey. Three of these projects provide fisheries independent data. Fisheries dependent data sources are limited to the MRIP survey conducted in conjunction with the federal agencies. There are few additional fisheries dependent data sources available other than historical landings records for coastal and offshore fisheries, historical tag return data and recreational fisheries data collected through the MRIP survey. The coverage and numbers of American shad sampled by the MRIP survey are highly variable and based on low numbers of American shad sampled by the survey (Tables 3&4)

1. **Fishery-Dependent Data Sources**

Statewide

Early commercial landings remained relatively stable at around 445,000 kg from 1887 to 1911 (Figure 3). The origin of the fish captured in the commercial fishery is unknown. Research studies indicate that the American shad most likely originated from several different rivers. Catches rose to a peak of 1,495,066 kg in 1912, dropped to mean of 51,400 kg in 1928 through 1933, and remained very low through 1940. Landings then increased to a high of 502,044 kg in 1945 and remained at a relatively low level from 1948 through 1976. Since 1978, landings have ranged from a high of 41,096 kg in 1981 to a low of 8.1 kg in 2002. From 1978 to 1990, landings averaged 14,369 kg. Since the directed fishery closed in 1998, annual landings have been less than 200 kg. Ocean bycatch has decreased due to increases in the minimum gill net mesh size allowed in the groundfish gill net fishery (16.5 cm stretch mesh). Since 1950, commercial catches in gill nets generally exceeded those in other gears. However, there is now no directed commercial fishery for shad in Maine waters and any American shad captured are bycatch resulting while conducting commercial fisheries for other species.

To estimate the number of shad native to Maine rivers and their contribution to the fishery Flagg *et al*. (1976) used a combination of harvest change following dam construction and drainage area historically available for shad spawning to estimate potential historical spawning stock size. According to Atkins (1889), the completion of the Edwards dam in Augusta in 1837 resulted in a 50 percent decline in the shad catch of the lower Kennebec. Therefore, the 8,268 square kilometers of the upper Kennebec previously accessible to shad apparently produced 50 percent of the commercial harvest. During the 12-year period from 1903 to 1914, the lower Kennebec yielded an average annual harvest of 308,370 kg. This then equaled the harvest produced from 8,268 square kilometers of accessible drainage area in the upper Kennebec. Excluding the New Hampshire portion of the Androscoggin and Saco River drainages, the total land area of Maine that drains into Maine coastal waters approximates 64,200 square kilometers. Historically, approximately 33,280 square kilometers of this drainage was accessible to American shad. Based on historical harvest from the Kennebec, this would have generated a potential yield of 1,215,000 kg of Maine-produced fish. If we assume a harvest of 30 to 80 percent of the total run that is characteristic of commercial shad fisheries in southern New England areas, the total Maine historical run size would have ranged from 1,518,750 kg to 4,050,000 kg. Assuming a mean weight of 1.8 kg, the total historical population would have been 850,000 to 2,250,000 adult fish (Flagg *et al.* 1976).

Merrymeeting Bay Complex

Fishery dependent data for the Merrymeeting Bay Complex is limited to historical data. It is likely that a combination of overfishing, pollution and habitat loss from dam construction beginning in colonial period through the early 1800s contributed to the disappearance and dramatic declines of shad stocks in the state of Maine (Flagg *et al*. 1976). The commercial fishery for American shad closed in 1998 and the recreational bag limit of 2 fish caught by hook and line was established during the same year. The state of Maine does not conduct a recreational creel survey or survey bycatch in commercial fisheries for other species. Historical commercial landings data are available from the coastal and offshore fisheries that targeted American shad or retained this species as bycatch in commercial fisheries targeting other species.

2. **Fishery-Independent Data Sources**

Statewide

Statewide fisheries independent data are predominantly limited to trap or lift counts and the Maine-New Hampshire Trawl Survey (Table 2). Other than the biological data collected during the trawl survey there are few instances where biological data are collected from American shad. The Department does not collect biological data due to concerns for low numbers returning to trap and lift facilities statewide. Biological data collect is limited to mortalities that result from passage and transport activities.

Merrymeeting Bay Complex

Maine DMR initiated sampling of age-0 American shad in 1979 at 14 sites in the Merrymeeting Bay Complex (Figure 4). There are four sites on the lower tidal Kennebec River, three on the lower Androscoggin River, four on Merrymeeting Bay, and one each on the Eastern, Cathance, and Abagadasett rivers. Eight sites were added to the Kennebec River above the former Edwards dam in 2000 (Figure 5). Site 8A was abandoned because a recent bridge construction project altered the river at that sampling site.

Field crews sample sites once every two weeks between July 1 and October 1 each year. Collections are made with a beach seine within three hours of low water. From 1979 through 1982, the net was 9 m long, 1.8 m deep, and constructed with 3.2 mm stretched nylon mesh. Starting in 1983, the seine was constructed of 6.4 mm stretch nylon mesh and measured 17 m long, and 1.8 m deep with a 1.8 m x 1.8 m bag at its center. Although a bag was added, and the method of seining was modified, the area sampled remained the same.

During sampling, field staff holds one end of the seine stationary at the land-water interface and the boat operator tows the other end perpendicular to shore. When the net is fully extended, the distal end is towed in an arc upriver and pulled ashore. The net samples an area of approximately 220 square meters. Field personnel sort and process all samples at the sample location. Field staff count and measure all alosines. Fifty individuals of each species, other than alosines, are measured. Dividing the number of individuals caught by the number of seine hauls gives the catch-per-unit-effort (CPUE) index. The State does not collect juvenile index data from other river systems where shad spawning exists.

Maine DMR staff believes that age-0 shad move freely among sites in the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasett rivers, and Merrymeeting Bay. For this reason, data from these sites were combined and single arithmetic and geometric mean calculated each year (Table 6). Separate means were calculated for the sites above the site of the former Edwards dam on the upper Kennebec River (Table 7).

The annual geometric means for collections of age-0 American shad in the Merrymeeting Bay Complex were relatively high in the 1980s, low during the 1990s and increased until 2010 (Figure 6). Since 2010 the geometric mean has decreased within Merrymeeting Bay except for the years 2013, 2014 and 2017. The geometric means of the catch per haul at the upper Kennebec sites were high for the period 2004 through 2008 (Figure 10). For the period 2009 to 2018 the JAI index decreased significantly. Since 2012 the number of sampling trips had also declined to fewer than thirty-two seine hauls per season, partly due to low water levels and the ability of sample crews to access sample locations on the river.

To assess the effects of dam removal, larval stocking, and assumed increase in population size based on trap counts, comparisons were made to better understand these relationships. The relationship between the relative abundance of age zero American shad lagged by five and six years was calculated for the period 1984 to 2018. The numbers of larvae stocked were also compered to changes in the Merrymeeting Bay JAI Index for the period 1992 through 2008 as well as the contribution of larval stocking to the number of the zero aged American shad captured during the JAI survey. The number of OTC marked hatchery larvae stocked in the Kennebec River was compared to the percent of OTC marked juveniles recovered during the JAI survey. Results indicated that there was a positive relationship between the number of larvae stocked and the number of juveniles captured during the survey.

Maine-New Hampshire Trawl Survey

The Maine-New Hampshire Inshore Groundfish Trawl Survey is a fisheries independent assessment of fisheries resources inside the coastal waters of Maine and New Hampshire. Its purpose is to fill a significant information gap that effects efficient management of Maine's fisheries resources. The survey is designed to provide biological, environmental and timing data on a number of commercial and non-commercial fish species found in the coastal waters during the spring and fall of each year. When the survey originally began in the fall of 2000 the focus was to assess groundfish abundance. Over the course of the survey the focus changed to include all commercial and noncommercial species.

Survey staff sample 120 stations stratified among five sections along the Maine coast each spring and fall (Figure 8). The survey counts and weighs all shad caught at each of the 120 sample stations. The coast is divided into five areas based on geologic, oceanographic, geographic and biologic factors. Each area is divided into four depth strata; 5-20, 21-35, 36-55, and 55+ fathoms. Stations are located randomly to reflect representative conditions within each of the strata.

Gear consists of a modified shrimp net with 2-inch mesh in the wings and a 1/4 inch mesh liner in the cod end. Foot rope and head ropes are 57' and 70' respectively, with 6-inch rubber cookies. The gear was designed to be very light on the bottom to minimize habitat disruption. The survey subsamples the shad catch and measures individual fork length to the nearest centimeter.

The highest catch rates of older juvenile American shad in coastal ocean waters generally occurred in Regions 1 and 2 along the westernmost coast of Maine. These regions bracket the mouths of the Saco and Kennebec rivers. The highest arithmetic mean catches per trawl tended to occur most often during the fall rather than the spring, most likely due to the numbers of juveniles leaving the river systems (Tables 8&9). For six of the last seven years the spring survey captured higher mean numbers per trawl and were generally more consistent than the mean catches during the fall trawl survey (Figures 9). The percent occurrence of American shad captured for all tows conducted during the spring and fall survey time series indicate that an increasing number of tows capture American shad (Figure 10). Captured American shad were 7 to 48 cm FL (Table 10). Mean lengths tended to be 15 to 20 cm. Age-length curves developed for American shad of the Hudson River suggest that these fish were one and two years old (Stira 1976). The trawl survey data indicate a general increase and length and weight of American shad captured since the beginning of the survey. Numbers captured during the spring survey were generally higher during the fall survey, but the stratified means were below 20 fish for both surveys (Figures 11 & 12).

Proposed fisheries to stay open

This plan proposes to maintain a statewide 2 fish creel limit for American shad. The 2 fish recreational limit with existing gear restrictions has been in effect since May 19, 1998.

Sustainability Targets

A. Definition

A sustainable American shad fishery will not diminish future stock reproduction and recruitment of American shad in Maine.

B. Methods for Monitoring Stock

The Maine Department of Marine Resources proposes to use run count data (Figure 13) in conjunction with JAI data for the Merrymeeting Bay Complex (Figure 14). Both datasets are fisheries independent and cover the main production areas in the state and provides upstream passage counts statewide.

Fishery Independent Data

The JAI time series exists for the period 1979 through 2019 and tracks the abundance of juvenile American shad at several fixed survey stations throughout Merrymeeting Bay and the six rivers that enter the freshwater tidal estuary. The 25-percentile will be used in conjunction with run counts to make decisions to modify existing management strategies or implement rule changes to the existing creel limit.

Trap counts of American shad passed upstream will be used as an additional metric to assess the number American shad above the first main stem dam with a fishway. The 25-percentile of the aggregate number of shad counted at the first main stem dam with a fishway and counting station will be used in conjunction with the JAI survey time series. The fish passage count metric will be used as a secondary metric because of the amount of spawning habitat below some mainstem dams and the efficiency of fishways to pass American shad upstream.

Timeframe

The proposed benchmarks will be implemented as soon as they are reviewed by the American Shad and River Herring Technical Committee and approved by the Management Board.

Proposed Regulation Modifications to Support Targets

No changes are proposed to the existing recreational or commercial fish rules in effect as of May 1998, which prohibits commercial fishing for American shad and established a 2-fish recreational creel limit.

Enforcement

The Maine Marine Patrol and Maine Warden Service share enforcement authority regarding American shad within their respective jurisdictions. The Maine Department of Marine Resources coordinates with regional field offices to collaborate on enforcement issues regarding American shad.

C. Adaptive Management

Evaluation Schedule

Run count and JAI survey data will be reviewed annually and added to their respective time series to provide updated annual metric values. The 25-percentile management triggers are fixed at the values in the table American Shad Management Triggers. The management triggers will be updated every five years when the states review and update American Shad SFMPs. Annual metric values will be available for review in the annual Shad and River Herring Compliance Report submitted to the Shad and River Herring Technical Committee by July 1 of each year.

Consequence or Control Rules

If for three consecutive years either the JAI Survey or one or more of the trap counts are below the 25-percentile the American shad harvest will be reduced to one fish or an American shad fishing season will be instituted to reduce effort to equate to a one fish bag limit.

If for three consecutive years, the JAI survey and one or more of the trap counts are below the 25-percentile the American shad fishery will close and be open only for catch and release fishing.

American Shad Management Triggers

Index	25-Percentile
JAI Series (1984 - 2018)	0.23
Mean Fishway Counts (1990 - 2018)	372
Total Fishway Counts (1990 - 2018)	791.5

Potential Future Benchmarks

The American shad assessment may provide some additional direction for additional methods to monitor and assess American shad on a statewide level. As American shad populations increase biological sampling may allow the Department to collect and age scales for estimation of mortality or other indices reviewed and approved by the SARC or the Technical Committee.

Tables

Table 1. Amount of American shad habitat (river kilometers) in Maine waters (USFWS 1983). Rivers are listed in order of descending habitat kilometers.

River/Watershed	Current (though may be limited)	Current Assumed	Historical	Historical Assumed	Uncertain	Total
Penobscot Watershed	399.6		354.0	32.7		786.3
Kennebec Watershed	300.4		107.2			407.6
Salmon Falls/Piscataqua River	59.8	8.1	8.9	108.1		184.9
Sheepscot River	178.8					178.8
Narraguagus River	38.9			35.6	60.4	134.9
Royal River	106.2					106.2
Androscoggin River	48.3		17.4	34.8		100.5
Saco River	49.1			50.6		99.7
East Machias River	18.8			67.0		85.7
Pleasant River	72.1					72.1
Scarborough Marsh/Nonesuch R.	70.4					70.4
St. George River	65.5					65.5
St. Croix River	61.8					61.8
Kennebunk River	47.0					47.0
Dennys River	34.8				10.7	45.5
Presumpscot River	22.0			22.2		44.2
Tunk Stream	20.2				16.8	37.1
Ducktrap River					22.8	22.8
Webhanet River	8.9					8.9
Union River	7.9					7.9
Pennamaquan River					7.6	7.6
Mousam River	6.3					6.3
Little River	5.5					5.5
Grand Total	**1622.3**	**8.1**	**487.5**	**351.0**	**118.2**	**2587.2**

Table 2. Upstream passage of American over the lowermost dam on the Androscoggin, Saco, Kennebec, Sebasticook and Penobscot rivers 1981 – 2018.

	American Shad				
Year	**Androscoggin**	**Saco**	**Kennebec**	**Sebasticook**	**Penobscot**
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990	1				
1991	0				
1992	0				
1993	1	882			
1994	1	399			
1995	3	580			
1996	2	837			
1997	2	1,104			
1998	5	1,374			
1999	87	4,994			
2000	88	1,323			
2001	26	2,570			
2002	11	1,014			
2003	7	1,227			
2004	12	1,627			
2005	0	744			
2006	3	883	0		
2007	6	1,428	18		
2008	1	1,491	0		
2009	0	278	0	8	
2010	22	3,663	39	2	
2011	0	3,338	12	54	
2012	11	6,419	5	163	
2013	14	6,171	0	114	
2014	0	2,580	1	26	809
2015	58	6,171	26	47	1,806
2016	1,096	16,926	830	18	7,862
2017	1	3,727	213	64	3,868
2018	32	4,107	437	26	3,958
Min	**0**	**278**	**0**	**2**	**809**
Max	**1,096**	**16,926**	**830**	**163**	**7,862**
Ave	**51**	**2,918**	**122**	**52**	**3,661**
Total	**1,490**	**75,857**	**1,581**	**522**	**18,303**

Table 3. Query of MRIP data collected from Maine waters 1996 – 2018.

Year	Interviews	Anglers that Caught Shad	Total Shad Catch	Harvest
1996	1,146	2	3	0
1997	1,185	0	0	0
1998	1,528	2	2	1
1999	1,688	2	2	1
2000	1,539	2	2	1
2001	2,347	3	4	0
2002	2,002	1	1	0
2003	1,601	1	1	0
2004	1,369	2	3	0
2005	1,350	0	0	0
2006	1,292	3	6	1
2007	1,788	4	5	0
2008	1,510	5	12	1
2009	1,383	6	43	2
2010	1,440	7	11	0
2011	1,495	6	34	0
2012	1,569	6	50	0
2013	1,277	2	3	0
2014	1,770	4	6	4
2015	1,395	16	69	7
2016	1,549	28	90	10
2017	1,695	8	31	2
2018	1,444	7	17	3

Table 4. Expanded American shad catch, harvest and percent standard error (PSE) for Maine waters.

Year	Total Catch	Catch PSE	Total Harvest	Harvest PSE
1987	84,458	58.4	84,458	58.4
1992	1,149	70.7	574	100
1996	1,170	77.1	0	-
1998	461	70.5	231	99.5
1999	1,065	74.2	701	100
2000	1,137	70.7	552	100
2001	1,661	59	0	-
2002	438	100	0	-
2003	1,367	100	0	-
2004	1,545	100	0	-
2005	1,244	100	0	-
2006	8,566	74.8	1,428	100
2007	4,480	84	0	-
2008	4,812	66.9	303	98.2
2009	19,095	59.3	843	72.9
2010	9,423	66.2	0	-
2011	4,295	60.6	0	-
2012	17,620	67	0	-
2013	945	93	0	-
2014	779	97.6	779	97.6
2015	779	97.6	779	97.6
2016	8,870	52.2	1,740	88.1
2017	1,974	64.6	261	98.1
2018	45,146	83.2	4,108	90.8

Table 5. Number of American shad larvae raised at the Waldoboro Hatchery and stocked in Maine Rivers, 1992-2018.

Year	Saco River	Medomak River	Androscoggin River	Main Stem Kennebec River	Sebasticook River	Kennebec River System
1992	0	230000	0	0	0	0
1993	0	61000	0	194400	0	194400
1994	0	30460	0	58800	0	58800
1995	0	318290	0	479612	0	479612
1996	0	327495	0	339319	320000	659319
1997	414201	208240	0	1615603	474313	2089916
1998	408575	269043	0	1381723	744163	2125886
1999	151774	17626	316967	1944712	839500	2784212
2000	259090	145900	522000	3374325	500004	3874329
2001	313560	213	308556	1496454	618879	2115333
2002	0	11143	295725	1571856	1013852	2585708
2003	0	0	1269842	5989358	1857184	7846542
2004	0	0	538613	4548947	382217	4931164
2005	0	0	96551	1105343	0	1105343
2006	0	0	0	262,131	0	262,131
2007	0	0	0	9,082,178	0	9,082,178
2008	0	0	712,286	1,396,689	288,507	1,685,196
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
Total	**1,547,200**	**1,619,410**	**4,060,540**	**34,841,450**	**7,038,619**	**41,880,069**

Table 6. Mean catch-per-unit-effort of age-0 American shad from the Merrymeeting Bay complex in Maine. The complex includes Merrymeeting Bay and the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasett rivers.

	Sample	Total	Arithmetic		Geometric	
Year	**Size**	**Catch**	**Mean**	**SE**	**Mean**	**SE**
1979	45	10	0.22	0.13	0.10	0.06
1980	57	9	0.16			
1981	58	29	0.50			
1982	59	9	0.15			
1983	53	42	0.79			
1984	45	32	0.71	0.33	0.29	0.09
1985	42	77	1.83	0.68	0.68	0.13
1986	62	32	0.52	0.21	0.22	0.06
1987	60	136	2.27	0.87	0.63	0.12
1988	100	1,377	13.77	8.88	0.52	0.11
1989	92	72	0.78	0.32	0.23	0.07
1990	98	211	2.15	0.69	0.51	0.09
1991	88	64	0.73	0.28	0.25	0.06
1992	79	62	0.78	0.31	0.26	0.07
1993	76	80	1.05	0.75	0.10	0.06
1994	93	24	0.26	0.13	0.09	0.04
1995	110	55	0.50	0.20	0.16	0.05
1996	89	111	1.25	0.92	0.21	0.06
1997	110	37	0.34	0.20	0.09	0.04
1998	112	40	0.36	0.28	0.06	0.04
1999	108	1,059	9.81	4.45	0.51	0.15
2000	111	398	3.59	2.25	0.29	0.08
2001	129	234	1.81	0.70	0.20	0.05
2002	127	316	2.49	1.23	0.45	0.07
2003	114	680	5.96	7.63	0.94	0.12
2004	105	1,356	12.91	7.09	1.02	0.13
2005	112	879	7.85	2.78	1.07	0.12
2006	120	2,148	17.90	6.66	1.75	0.14
2007	119	1,642	13.80	3.06	1.98	0.15
2008	104	680	6.54	1.56	1.59	0.13
2009	111	783	7.05	1.48	1.63	0.13
2010	114	1,547	13.57	4.15	1.66	0.14
2011	117	1,113	9.51	4.02	1.30	0.12
2012	118	1,135	9.62	5.05	1.21	0.12
2013	120	2,131	17.76	6.48	1.95	0.15
2014	120	1,300	10.83	2.91	1.53	0.13
2015	112	446	4.16	1.38	0.96	0.10
2016	116	297	2.56	0.60	0.83	0.09
2017	110	721	6.55	2.26	1.29	0.12
2018	120	237	2.07	0.56	0.59	0.08

Table 7. Mean catch per unit effort of age zero American shad from the Kennebec River above the former site of the Edwards Dam.

			Arithmetic		Geometric	
Year	Sample size	Total catch	Mean	SD	Mean	SD
2000	76	437	5.75	40.84	0.32	0.91
2001	63	1379	21.89	80.19	1.01	1.60
2002	64	1974	30.84	210.24	0.64	1.35
2003	46	702	15.26	55.21	0.73	1.49
2004	42	648	15.43	54.79	1.43	1.58
2005	41	3701	90.27	341.29	1.06	1.96
2006	48	4041	85.98	196.18	3.68	2.44
2007	50	9599	191.98	544.83	4.47	2.60
2008	10	668	66.8	104.92	7.51	2.14
2009	8	10	1.25	3.54	0.35	0.85
2010	21	681	32.43	126.02	1.8	1.91
2011	24	1901	79.21	159.98	4.44	2.41
2012	40	103	2.58	15.8	0.17	0.75
2013	0	0	-	-	-	-
2014	0	0	-	-	-	-
2015	32	85	2.66	9.89	0.37	0.96
2016	8	6	0.75	1.75	0.36	0.65
2017	8	0	-	-	-	-
2018	28	0	-	-	-	-

Table 8. Arithmetic mean and variation of number of American shad taken per tow in the spring survey in the near shore ocean waters of Maine

SPRING

	Number			plus/minus 2 SE		Weight			plus/minus 2 SE	
	mean	**SE**	**CV**	**Upper**	**Lower**	**mean**	**SE**	**CV**	**Upper**	**Lower**
2001	1.16	0.37	0.76	1.90	0.42	0.04	0.01	0.67	0.06	0.02
2002	3.05	0.50	0.39	4.05	2.05	0.15	0.03	0.48	0.21	0.08
2003	1.62	0.34	0.38	2.29	0.94	0.05	0.01	0.39	0.07	0.03
2004	0.45	0.11	0.46	0.67	0.24	0.02	0.00	0.53	0.02	0.01
2005	1.67	0.29	0.31	2.26	1.09	0.06	0.01	0.34	0.09	0.03
2006	8.72	1.59	0.39	11.91	5.54	0.32	0.06	0.40	0.44	0.20
2007	2.41	0.30	0.28	3.00	1.81	0.11	0.01	0.30	0.14	0.08
2008	0.98	0.35	0.78	1.68	0.29	0.03	0.01	0.51	0.05	0.02
2009	1.24	0.17	0.31	1.58	0.90	0.04	0.01	0.32	0.05	0.03
2010	1.31	0.25	0.43	1.81	0.80	0.05	0.01	0.43	0.07	0.03
2011	3.24	0.60	0.41	4.44	2.04	0.14	0.03	0.43	0.20	0.08
2012	3.06	0.34	0.26	3.75	2.38	0.21	0.02	0.29	0.26	0.16
2013	2.36	0.45	0.43	3.26	1.46	0.16	0.04	0.57	0.24	0.08
2014	1.53	0.37	0.57	2.26	0.80	0.08	0.02	0.63	0.13	0.04
2015	3.38	1.46	1.06	6.29	0.46	0.13	0.05	0.96	0.23	0.03
2016	3.26	0.66	0.49	4.58	1.95	0.13	0.03	0.59	0.20	0.07
2017	3.01	0.38	0.31	3.76	2.26	0.13	0.02	0.34	0.16	0.09
2018	3.07	0.60	0.49	4.28	1.87	0.10	0.02	0.50	0.14	0.06

Table 9. Arithmetic mean and variation of number of American shad taken per tow in the fall survey in the near shore ocean waters of Maine.

FALL	Number			plus/minus 2 SE		Weight			plus/minus 2 SE	
	Mean	SE	CV	Upper	Lower	mean	SE	CV	Upper	Lower
2000	0.56	0.18	0.75	0.92	0.20	0.04	0.01	0.79	0.07	0.01
2001	0.06	0.04	1.37	0.14	-0.01	0.01	0.00	1.30	0.02	0.00
2002	1.33	0.54	0.81	2.42	0.24	0.03	0.01	0.68	0.05	0.01
2003	5.45	4.52	1.43	14.49	-3.58	0.16	0.09	1.00	0.34	-0.02
2004	1.08	0.46	0.81	1.99	0.17	0.08	0.03	0.65	0.14	0.02
2005	2.81	0.37	0.21	3.56	2.06	0.25	0.03	0.18	0.31	0.20
2006	1.14	0.54	0.94	2.21	0.07	0.09	0.02	0.51	0.14	0.04
2007	13.15	7.26	1.11	27.68	-1.38	0.53	0.16	0.67	0.84	0.21
2008	1.78	0.43	0.47	2.63	0.93	0.20	0.05	0.46	0.29	0.11
2009	2.91	1.60	1.22	6.11	-0.28	0.39	0.21	1.17	0.80	-0.02
2010	1.10	0.51	0.93	2.13	0.08	0.07	0.02	0.67	0.12	0.02
2011	12.10	10.92	1.81	33.95	-9.75	0.29	0.09	0.63	0.47	0.11
2012	1.81	0.76	0.86	3.33	0.28	0.24	0.10	0.83	0.44	0.04
2013	2.33	0.69	0.71	3.70	0.96	0.37	0.09	0.57	0.54	0.19
2014	1.26	0.37	0.64	2.01	0.51	0.16	0.05	0.64	0.26	0.07
2015	16.33	10.67	1.31	37.67	-5.02	0.99	0.31	0.69	1.61	0.36
2016	2.22	0.59	0.57	3.39	1.05	0.29	0.06	0.51	0.42	0.16
2017	2.38	0.65	0.70	3.69	1.08	0.28	0.06	0.61	0.41	0.15
2018	1.67	0.40	0.52	2.48	0.86	0.20	0.04	0.47	0.28	0.11

Table 10. Fork length (cm) of American shad collected by bottom trawl in near-shore ocean waters of Maine.

Year	Season	Min	Max
2000	Fall	9	29
2001	Spring	12	26
	Fall	19	28
2002	Spring	12	28
	Fall	8	22
2003	Spring	10	19
	Fall	10	31
2004	Spring	11	24
	Fall	8	35
2005	Spring	12	24
	Fall	9	24
2006	Spring	9	25
	Fall	9	29
2007	Spring	7	30
	Fall	8	34
2008	Spring	10	28
	Fall	14	30
2009	Spring	11	25
	Fall	11	40
2010	Spring	9	22
	Fall	10	30
2011	Spring	9	28
	Fall	7	44
2012	Spring	8	39
	Fall	9	34
2013	Spring	10	30
	Fall	16	37
2014	Spring	12	47
	Fall	10	44
2015	Spring	12	42
	Fall	9	40
2016	Spring	8	48
	Fall	11	39
2017	Spring	10	43
	Fall	10	41
2018	Spring	12	26
	Fall	7	39

Figures

Figure 1. American shad habitat in Maine waters.

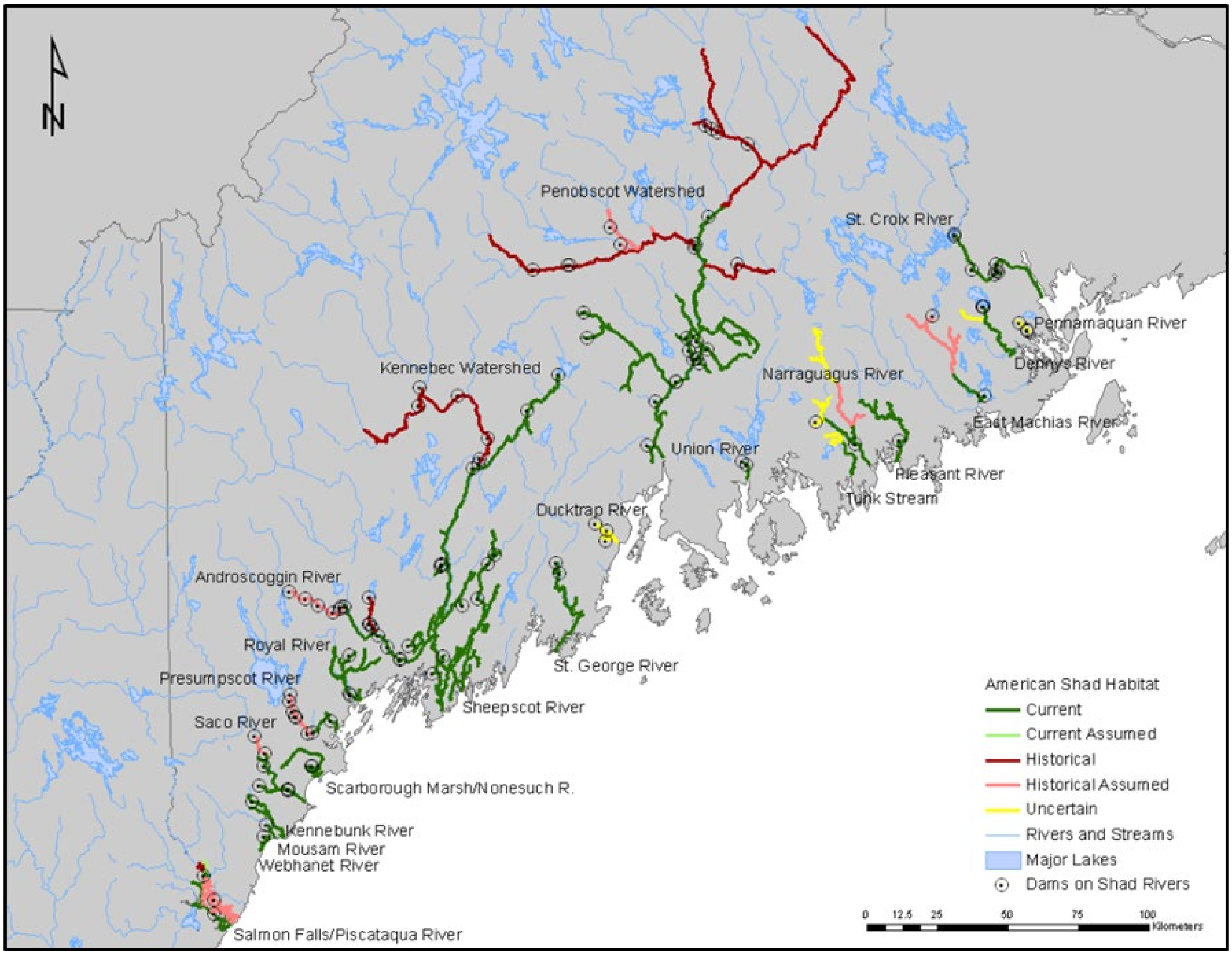


Figure 2. American shad caught and harvested based on unexpanded MRIP survey data 1996 – 2018.

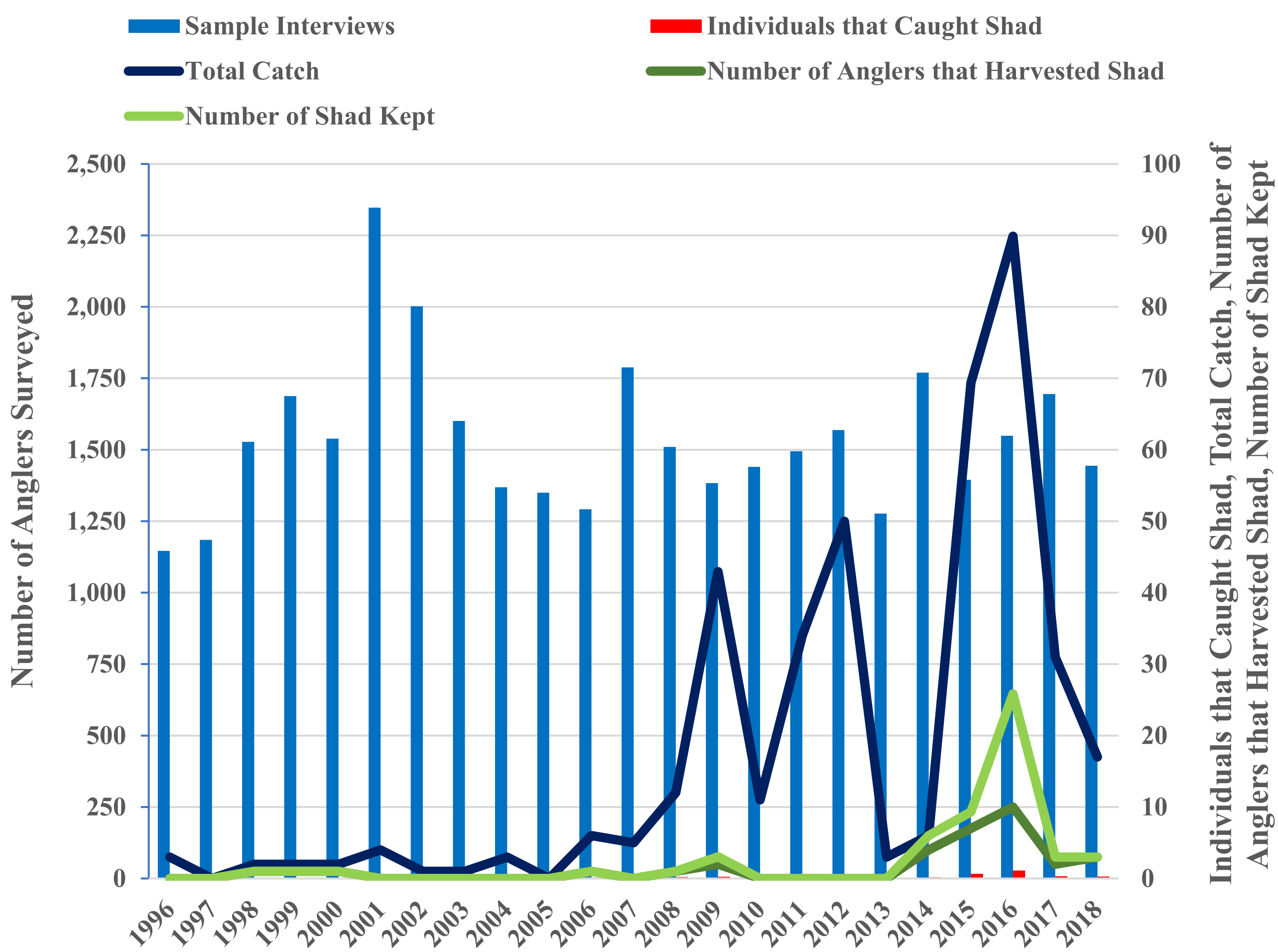


Figure 3. Commercial American shad landings for the State of Maine, 1887-2018.

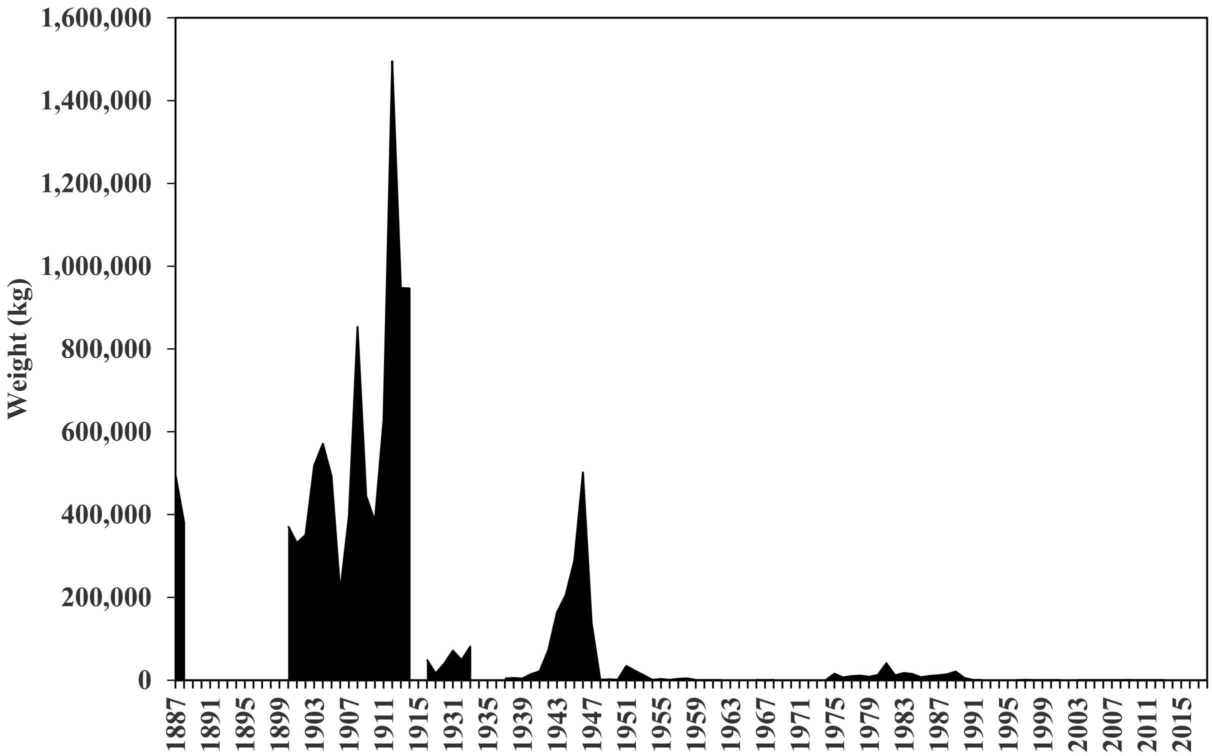


Figure 4. Juvenile alosine surveys sites in the Kennebec and Androscoggin estuary complex.

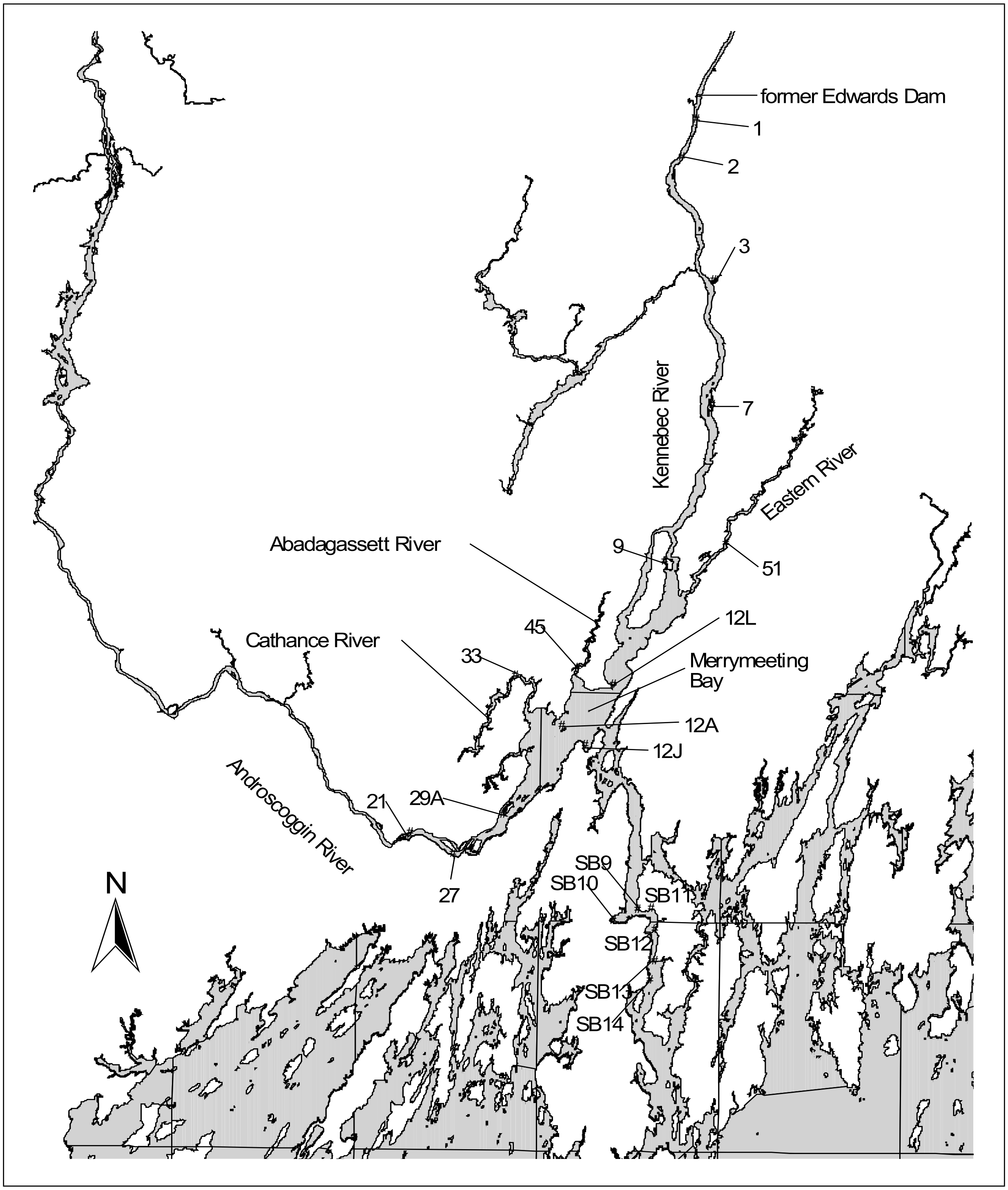


Figure 5. Beach seine sites in the non-tidal sections of the Kennebec River above the former Edwards Dam.

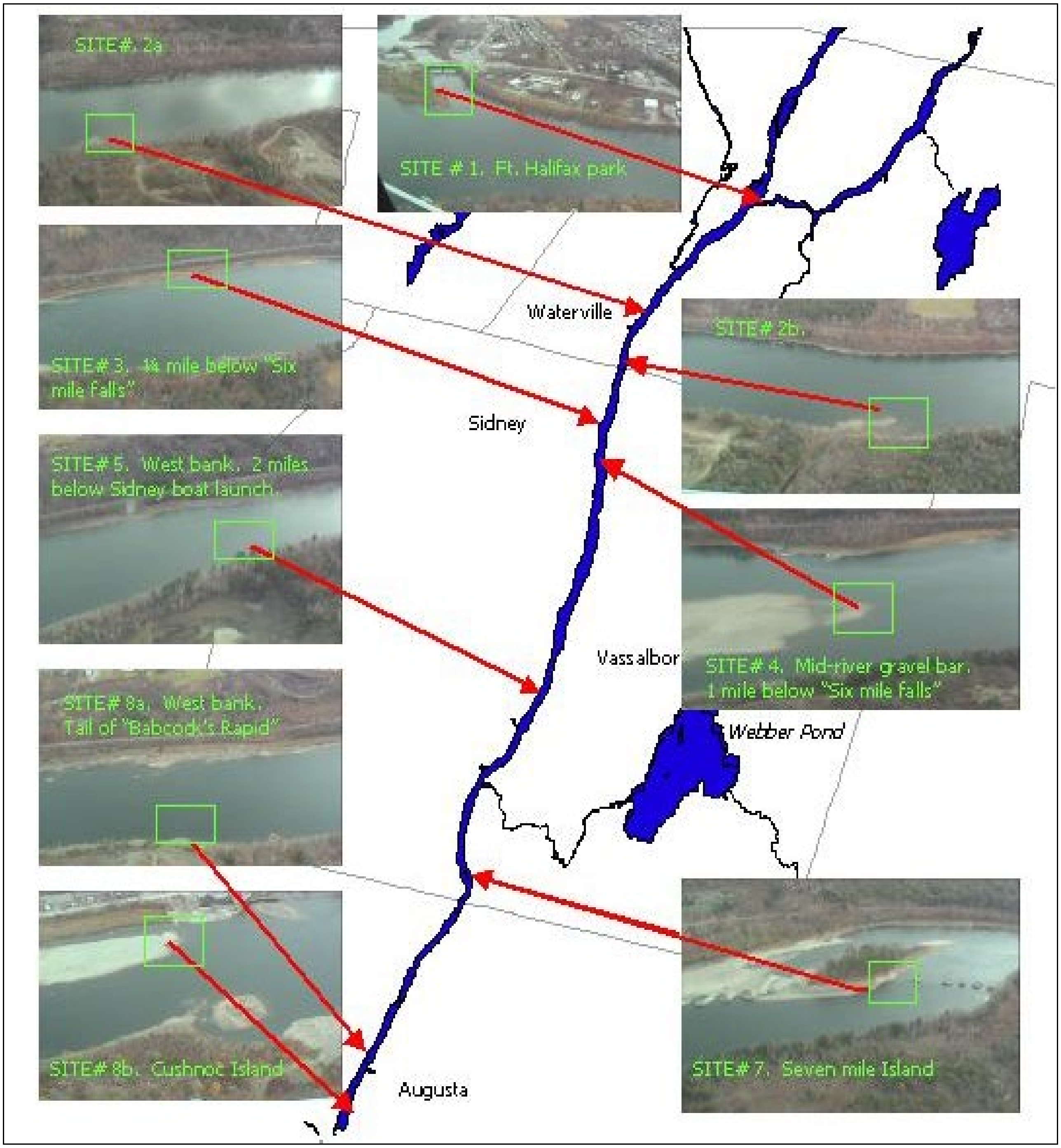


Figure 6. Geometric mean catch-per-seine-haul of age-0 American shad at sites in Merrymeeting Bay and the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasett rivers.

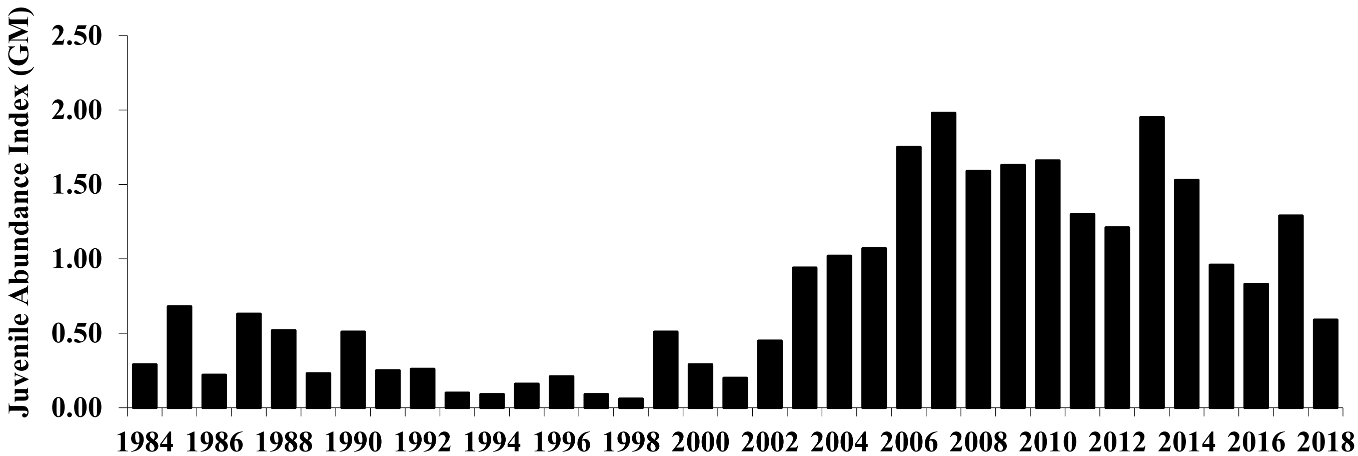


Figure 7. Geometric mean catch-per-seine-haul of age-0 American shad sites in the upper Kennebec River, Maine.

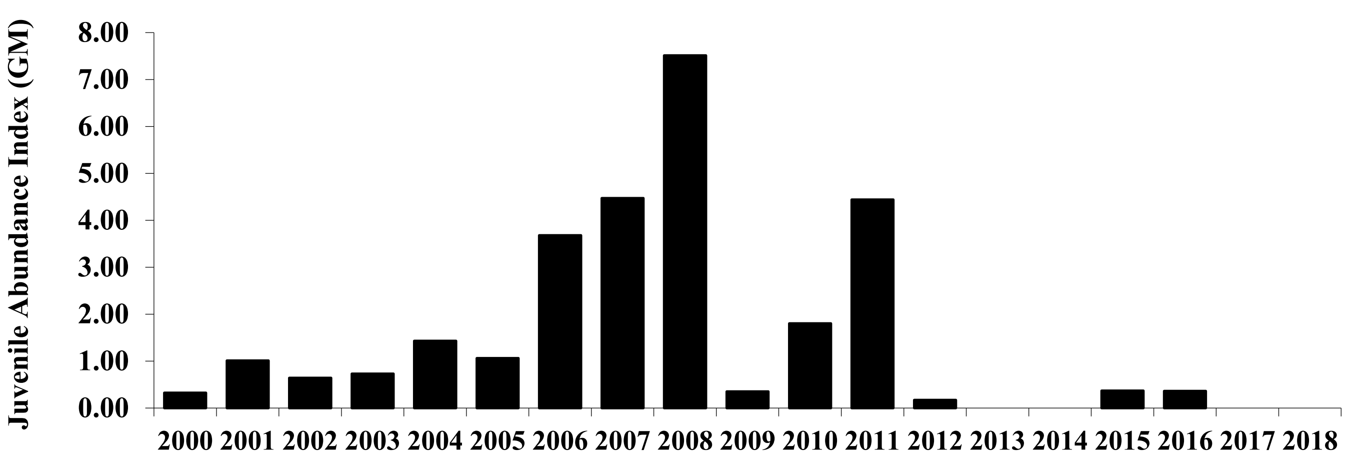


Figure 8. Ocean trawl sampling regions on the coast of Maine and New Hampshire.

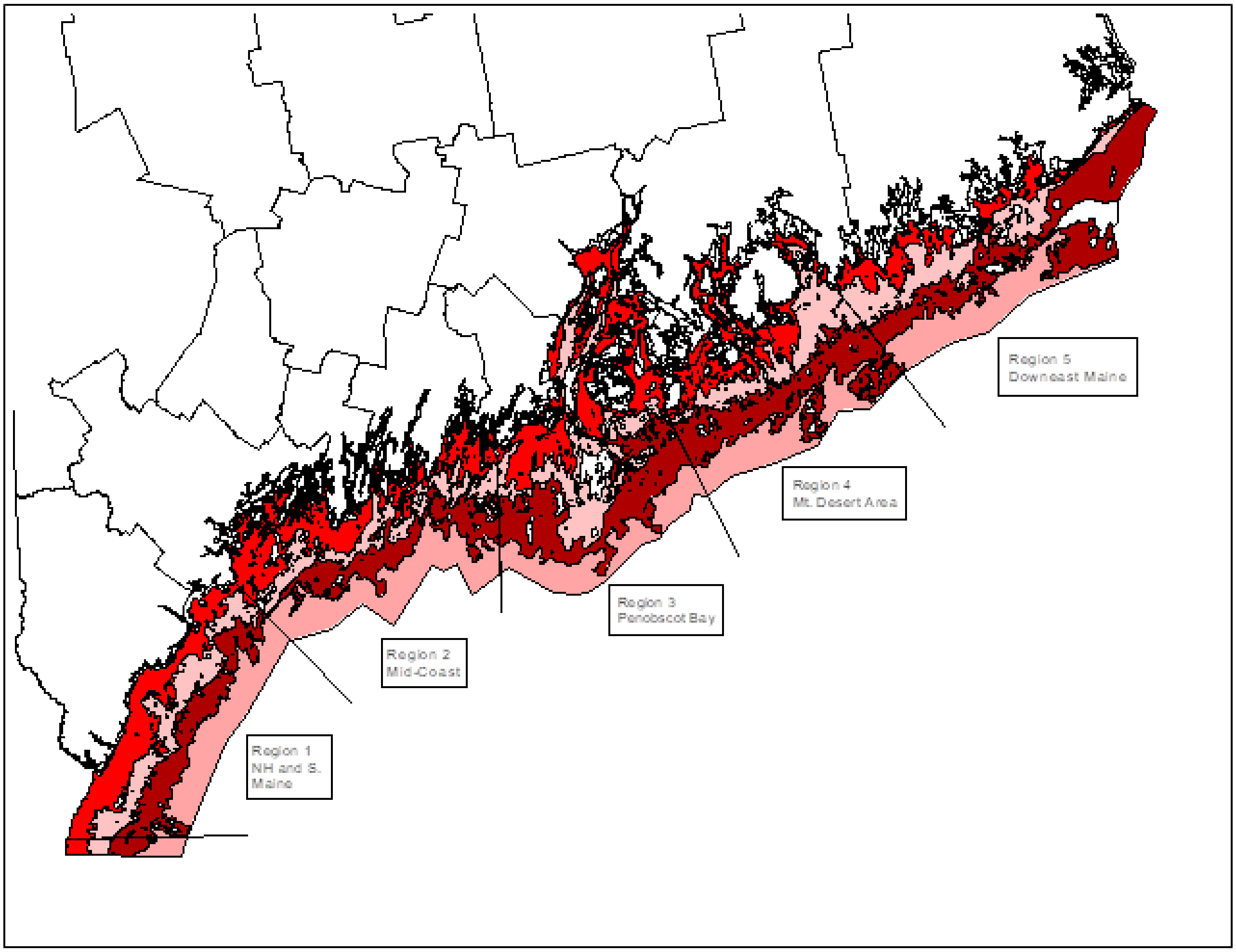


Figure 9. Catch-per-trawl of juvenile American shad taken in near shore ocean waters of Maine.

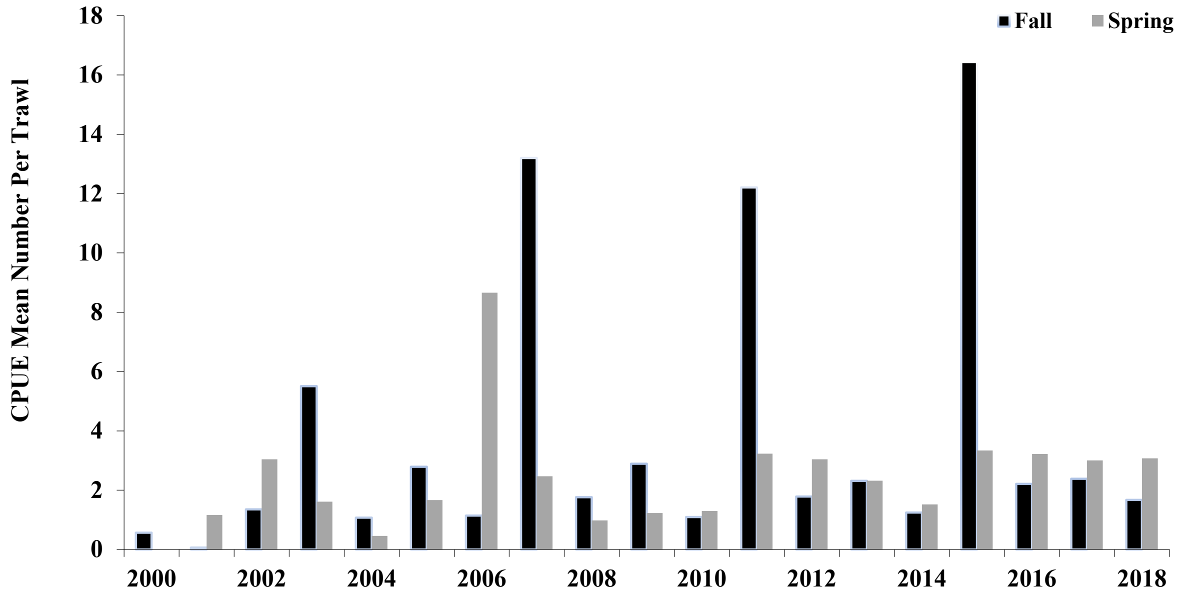


Figure 10. Percent occurrence of American shad captured for all tows conducted during the spring and fall trawl survey.

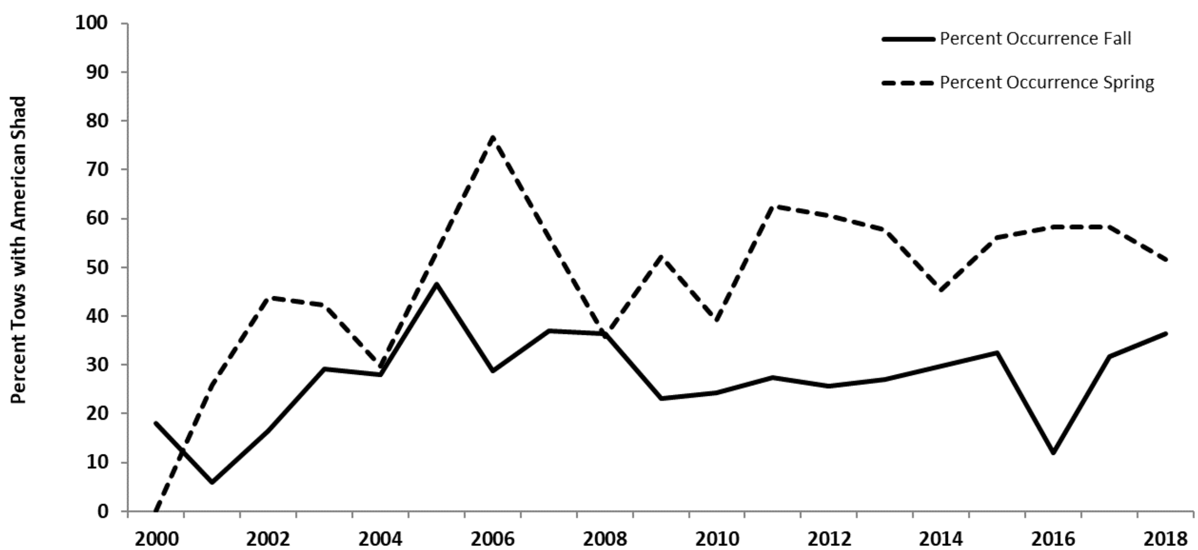


Figure 11.Stratified mean number and weight of American shad caught per tow during the spring trawl survey along the Maine coast.

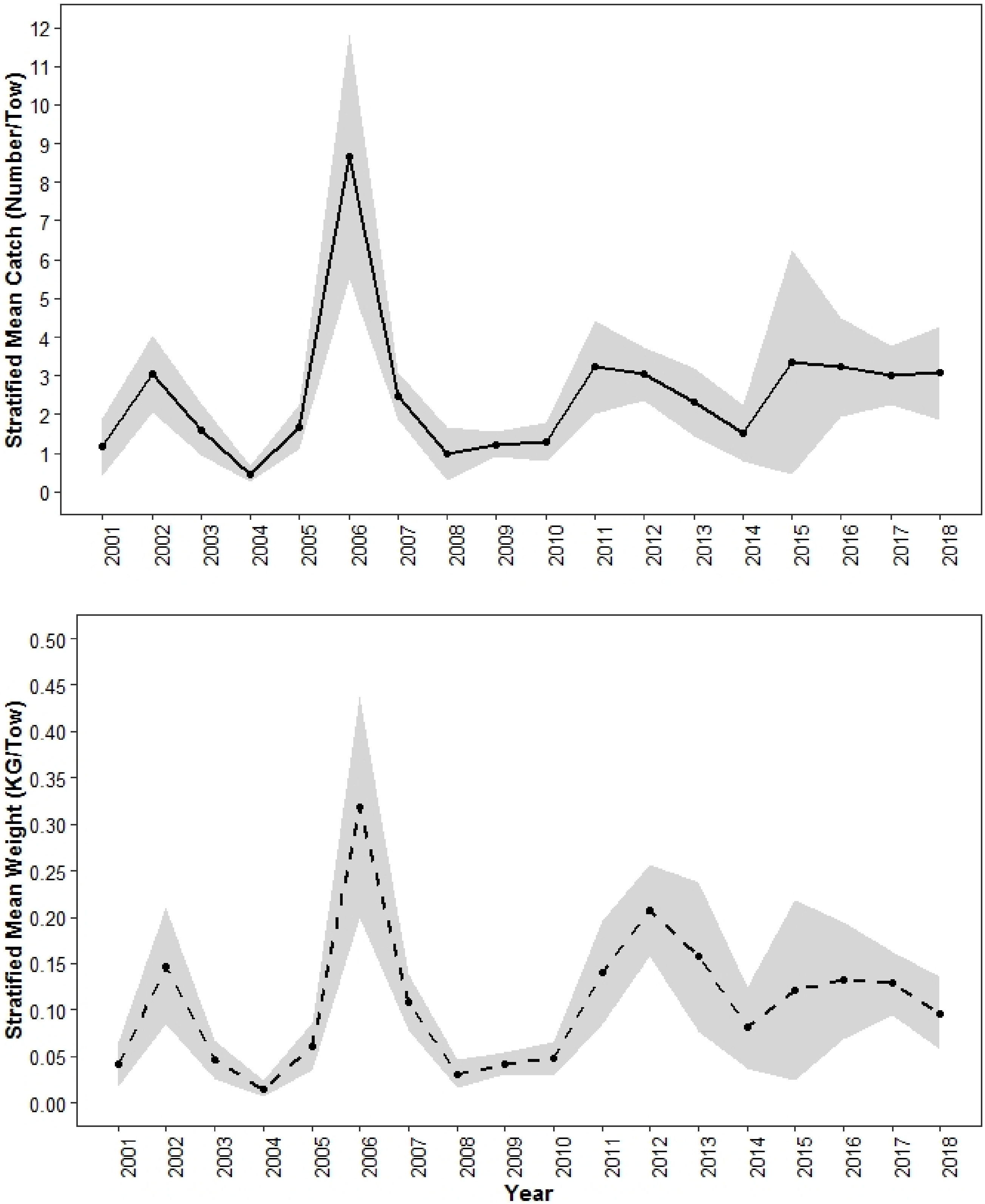
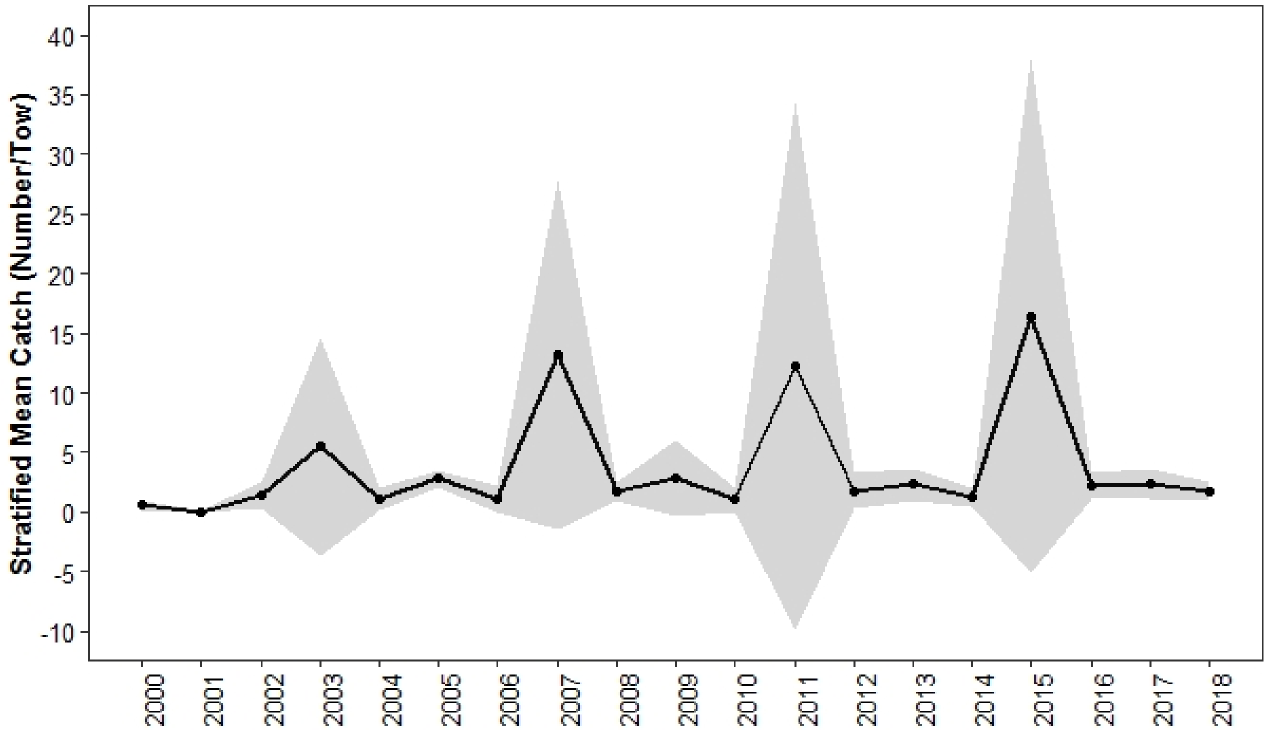


Figure 12. Stratified mean number and weight of American shad caught per tow during the fall trawl survey along the Maine coast.



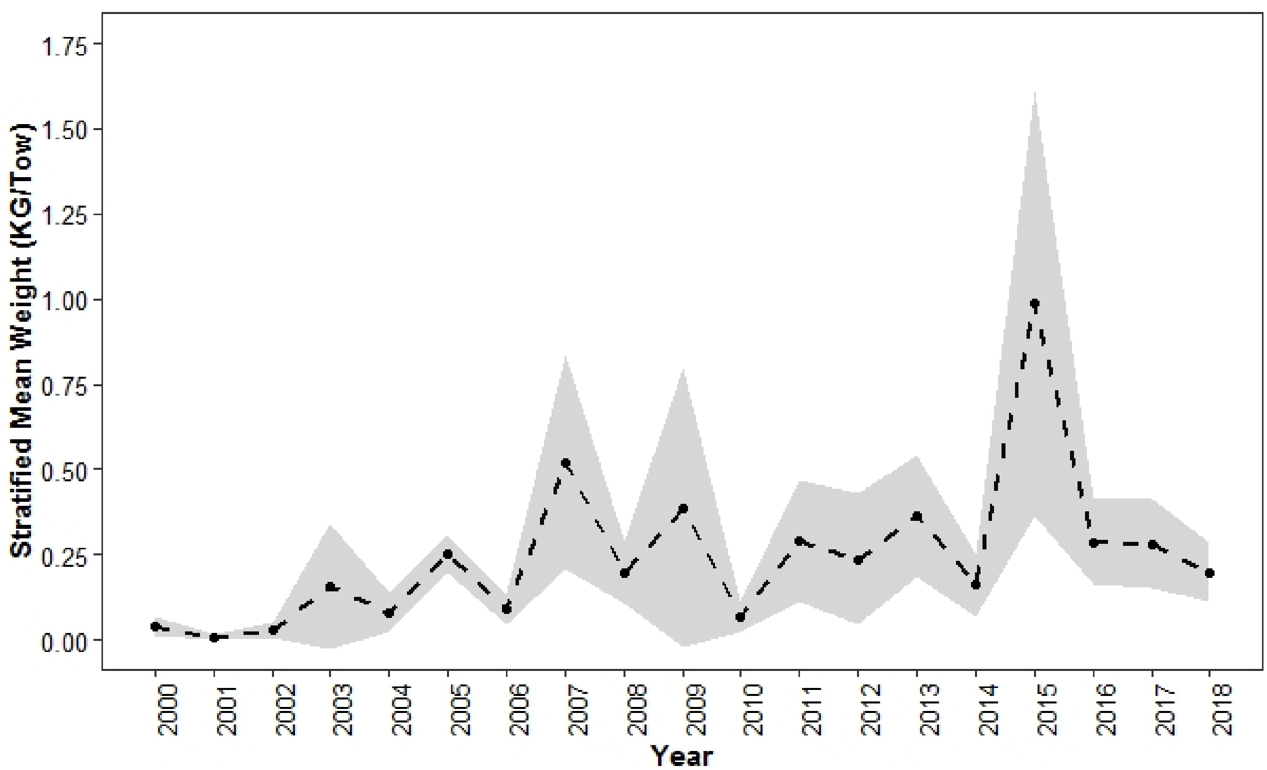


Figure 13. Cumulative upstream passage counts of American shad on all Maine rivers with counting capability.

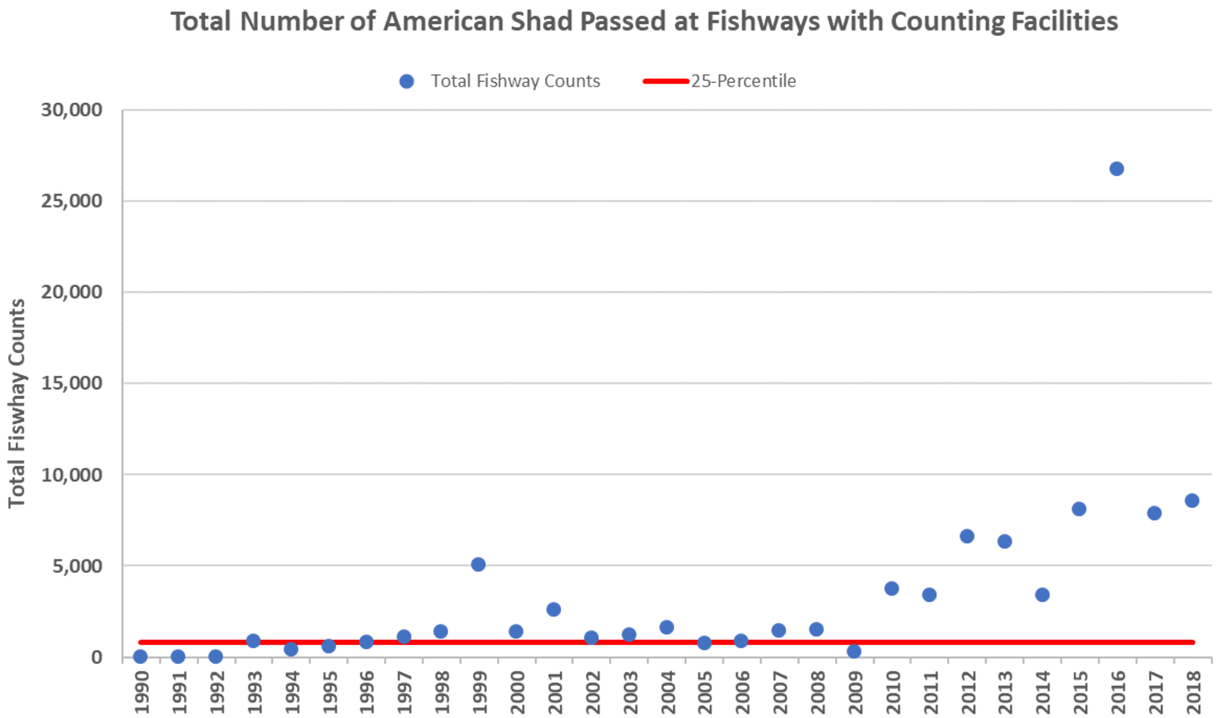
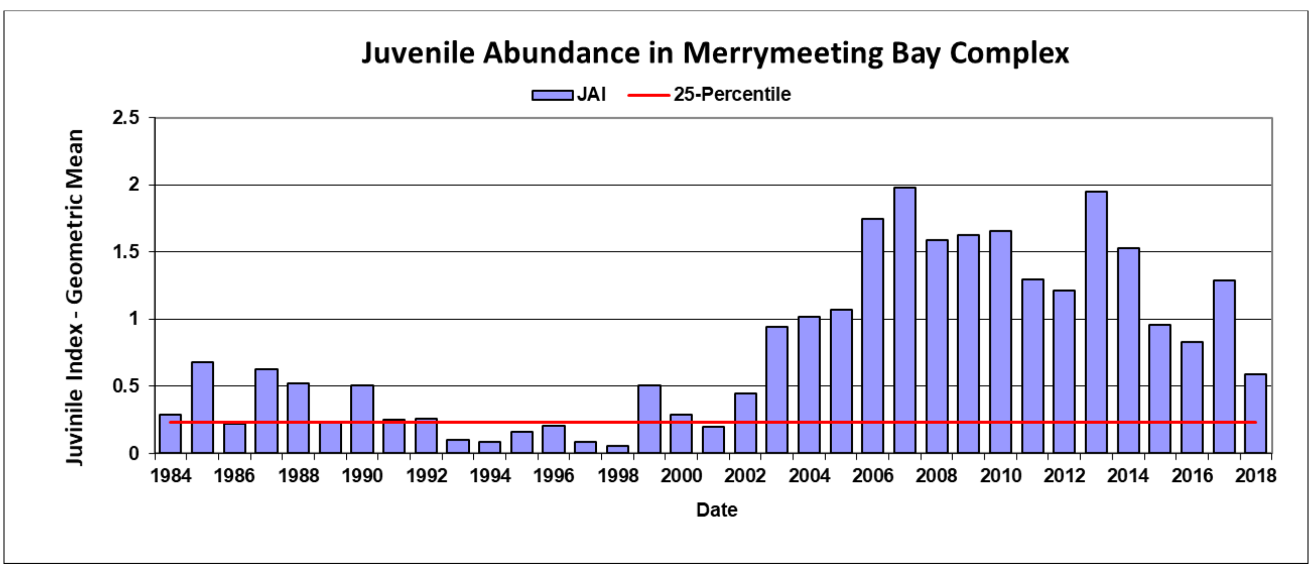


Figure 14. American shad JAI survey in Merrymeeting Bay 1984 – 2018.



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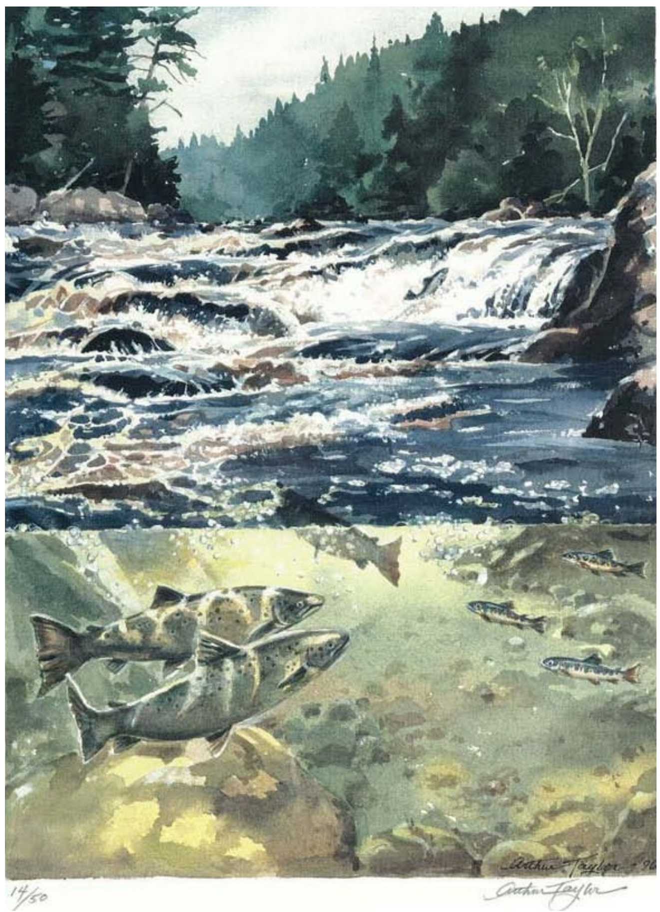
h) 2019 Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (*Salmo salar*)

Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (*Salmo salar*)

FINAL PLAN FOR THE 2009 ESA LISTING



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

U.S. Department of Interior
Fish and Wildlife Service
Ecological Services and Fisheries

Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (*Salmo salar*)

Approved: ______________________________
Regional Director, Northeast Region
U.S. Fish and Wildlife Service
Hadley, Massachusetts

Date: 1/31/19

Approved: Chris Oliver
Assistant Administrator for Fisheries
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Silver Spring, Maryland

Date: 12/17/18

PREFACE

This recovery plan has been developed pursuant to the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) (ESA). The recovery plan is accompanied by a Website that contains supplemental scientific assessments and supporting information (www.Atlanticsalmonrestoration.org). Recovery plans are subject to public review; comments received during the review period were considered during preparation of the final plan. The supplemental information was accessible for informational purposes but was not provided for formal public review.

The ESA establishes policies and procedures for identifying, listing, and protecting species of fish, wildlife, and plants that are endangered or threatened with extinction. The purposes of the ESA are "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species." The ESA definition of "species" includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature. Defined in the ESA, an endangered species is any species that is in danger of extinction throughout all or a significant portion of its range whereas a threatened species is any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The Gulf of Maine (GOM) distinct population segment (DPS) of Atlantic salmon was originally listed as endangered in December 2000 (65 FR 69459, November 17, 2000) by NOAA's National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) and encompassed salmon populations in small river systems along the Maine coast. Subsequently, new data led to expansion of the GOM DPS to include, in addition to the coastal rivers, populations in larger river systems covering a more extensive geographic area. Jointly, NMFS and the USFWS published the final rule for the expanded DPS in June 2009 (74 FR 29344, June 19, 2009).

The Secretaries of the Department of the Interior and the Department of Commerce are responsible for administering ESA provisions as they apply to GOM DPS of Atlantic salmon. Management authority for endangered and threatened species under the Departments' jurisdictions has been delegated to the USFWS and NMFS. These agencies, collectively referred to as the Services, share Federal jurisdiction for GOM Atlantic salmon, with USFWS having lead responsibility primarily for activities in freshwater and NMFS having lead responsibility for activities in the estuary and marine environments and for dams.

To help identify and guide recovery needs for listed species, section 4(f) of the ESA directs the Secretaries to develop and implement recovery plans for listed species. A recovery plan must include to the maximum extent practicable: (1) a description of site-specific management actions necessary to conserve the species; (2) objective, measurable criteria that, when met, will allow the species to be removed from the endangered and threatened species list; and (3) estimates of the time and funding required to achieve the plan's goals.

This recovery plan specifically addresses the planning requirements of the ESA for the GOM DPS of Atlantic salmon listed in 2009. It presents a recovery strategy based on the biological and ecological needs of the species as well as current threats and conservation accomplishments that affect its long-term viability. This recovery document wholly supersedes the recovery plan approved in 2005 for the DPS listed in 2000 (NMFS and USFWS, 2005). Because it addresses the 2009 expanded DPS, this plan is the initial recovery plan for the currently listed entity.

DISCLAIMER

Recovery plans delineate such reasonable actions believed to be necessary, based upon the best scientific, commercial data available, for the conservation and survival of listed species. The USFWS in cooperation with, and with major contributions from, NMFS prepared this recovery plan for the GOM DPS of Atlantic salmon (*Salmo salar*).

Recovery plans do not necessarily represent the views or the official position or approval of any individuals or agencies other than the USFWS and NMFS. Recovery plans are neither regulatory nor decision documents; rather, they are technical advisory documents that provide recommendations to achieve stated recovery objectives. Objectives will be attained and funds expended contingent on appropriations, priorities, and other budgetary constraints. Nothing in this plan should be construed as a requirement that any Federal agency obligate or pay funds in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and completion of recovery actions.

Literature citations should read as follows:

U.S. Fish and Wildlife Service and NMFS. 2018. Recovery plan for the Gulf of Maine Distinct Population Segment of Atlantic salmon (*Salmo salar*). 74 pp.

Review copies of this recovery plan can be downloaded via the Internet at:

http://www.fws.gov/northeast/EcologicalServices/recovery.html

or

https://www.greateratlantic.fisheries.noaa.gov/protected/atlsalmon/

Copies will also be provided upon request to the U.S. Fish and Wildlife Service, Maine Fish and Wildlife Service Complex, 306 Hatchery Road, East Orland Maine 04431; telephone 207-902-1567.

GUIDE TO THE PLAN

This document represents a departure from the 2005 recovery plan for the GOM DPS of Atlantic salmon as it does not include detailed supplementary information. Rather, the plan focuses on the statutory requirements of the ESA, which are to identify, to the maximum extent practicable, recovery criteria, recovery actions, and time and cost estimates. More in-depth scientific information and analyses, as well as activities that address the site-specific recovery actions, are contained in other documents made available on the Atlantic Salmon Restoration Website (see box 1 below). Although the material on the Website is not part of the recovery plan itself, hyperlinks to specific Web pages are included throughout this document. Note also that technical and management terms are defined in the glossary to the Atlantic salmon recovery plan companion document.

The major sections of the plan include:

Part I. **Introduction**, which describes the listed entity and governance structure for recovery and summarizes the threats and conservation measures that affect the current status of the DPS

Part II. **Recovery Strategy**, which lays out the long-term guiding principles for the criteria and actions that comprise the GOM DPS recovery program

Part III. **Recovery Goals, Objectives, and Criteria**

Part IV. **Recovery Actions**, describing the long-term actions needed to meet recovery criteria and general implementation responsibilities

Part V. **Time and Cost Estimates** for achieving the ESA delisting goal

CHANGES FROM THE 2005 RECOVERY PLAN

- This recovery plan addresses the expanded range of the GOM DPS of Atlantic salmon described in the 2009 listing rule (74 FR 29344, June 19, 2009).
- This plan reflects a new recovery planning approach (termed the Recovery Planning and Implementation, or RPI) being adopted by the USFWS. RPI plans focus on the statutory elements of recovery criteria, recovery actions, and time and cost estimates.
- Details about biology and threats, and other supporting documentation can be accessed at the Atlantic Salmon Recovery Plan Companion Document.
- A long-term implementation strategy and site-specific recovery actions at a Salmon Habitat Recovery Unit (SHRU) scale are identified in this plan, while management activities that implement recovery actions in the short term can be found in SHRU-level workplans posted on the Atlantic Salmon Restoration Website.

Box 1.

ACKNOWLEDGMENTS

The primary intent of this recovery plan is to provide recovery goals and objectives toward which all stakeholders can cooperatively work. This plan builds on the significant body of published work and expert knowledge regarding Atlantic salmon and other diadromous species.

Many individuals have contributed to the development of this plan. Writing team members Dan Kircheis, Peter Lamothe, and Mary Parkin, have worked from a draft authored by Antonio Bentivoglio. In addition, the following individuals have made substantial contributions to the plan: Alex Abbott, Bill Archambault, William Ardren, Ernie Atkinson, Mike Bailey, Meredith Bartron, Dave Bean, Colby Bruchs, Steve Coghlan, Mary Colligan, Scott Craig, Paul Christman, Oliver Cox, Julie Crocker, Kim Damon-Randall, Serena Doose, Rob Dudley, Kayla Easler, Stewart Fefer, Jaime Geiger, Anna Harris, Clayton Hawkes, Chris Holbrook, Bob Houston, Ted Koch, John Kocik, Steve Koenig, Ben Letcher, Trent Liebech, Greg Mackey, Wende Mahaney, Mark McCollough, Steve McCormick, Mike Millard, Martin Miller, Slade Moore, Katrina Mueller, Lori Nordstrom, Paul Phifer, Peter Ruksznis, Paul Santavy, Rory Saunders, Fred Seavey, Tim Sheehan, Steve Shepard, Randy Spencer, John Sweka, Joan Trial, Tara Trinko Lake, Jed Wright, Laury Zicari and Joe Zydlewski.

Special thanks go to Ruth Taylor and Ed Baum for providing the copyrights for the use of Arthur Taylor's "Coming Home" painting as the cover art for this recovery plan.

This plan is dedicated to the treasured memory of Jed Wright, Melissa Laser, Clem Fay, Joris Naiman, and Barbara Arter and their outstanding contributions to Atlantic salmon recovery in Maine. The accomplishments of Melissa and Clem have been noted in previous documents and are an inspiration for current and future conservation efforts needed to recover this endangered species. Here, we would like to elaborate on those more recently lost, Joris, Barbara and Jed.

Joris Naiman was the Department of Interior Solicitor who spent countless hours reviewing both the original Atlantic salmon recovery plan and, for as long as he could sustain his energy, this plan. He cared greatly that we, as Federal servants, adhere to both the letter and the spirit of the ESA. Although his intellect was his defining feature, he had a sense of adventure that included flying helicopters. Joris never hesitated to point out flaws in logic or to delve deeply into the meaning of how we proposed to recover salmon in the GOM DPS. He was a major force in ensuring the integrity of recovery plans, a legacy that we hope we have carried forward in this plan.

Barbara Arter was a conservationist and avid fly fisher who worked tirelessly as a volunteer, teacher, and consultant to advocate and promote the conservation of natural resources in Maine. She was never afraid to ask the tough questions, and always with a smile. As a conservation planner, she was diligent and thorough in her investigations. She made significant contributions to the Atlantic salmon program in writing watershed management plans; facilitating project oriented workshops and meetings, and, more recently, serving as the Science Information Coordinator for the Diadromous Species Research and Restoration Network. Barbara's determination, insights, abilities, personality, and laughter will be greatly missed by all those fortunate enough to have worked with her.

Jed Wright was the Project Leader for the USFWS Gulf of Maine Coastal Program Office in Falmouth, Maine. Jed began his career with the USFWS mapping Atlantic salmon habitat in the rivers of Downeast Maine. Jed evolved to become a leader in improving aquatic connectivity throughout the state and New England. Jed's passion for conservation and his patience and quiet leadership were a motivating force for all who knew and worked closely with him. Jed worked closely with a multitude of partners including the Nature Conservancy, the Audubon Society, many land trust and conservation groups as well as state and federal government agencies. Jed will be greatly missed by all who had the honor and pleasure to have worked with him.

EXECUTIVE SUMMARY

After originally listing the Gulf of Maine (GOM) distinct population segment (DPS) of Atlantic salmon as endangered in December 2000 and publishing a recovery plan in November 2005, the USFWS and NMFS conducted a second status review and listed an expanded GOM DPS on June 19, 2009. The expanded DPS encompasses all anadromous Atlantic salmon in a freshwater range covering the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River and includes all associated conservation hatchery populations used to supplement these natural populations. Concurrent with the new listing, NMFS identified and designated critical habitat within the range of the expanded GOM DPS. This recovery plan pertains to the expanded DPS and accounts for new information.

RECOVERY PLANNING APPROACH: The plan adopts a planning approach recently endorsed by the USFWS and, for this plan, NMFS. The new approach, termed Recovery Planning and Implementation (RPI), focuses on the three statutory requirements in the ESA, including site-specific recovery actions; objective, measurable criteria for delisting; and time and cost estimates to achieve recovery and intermediate steps. It also provides relevant background information for understanding the proposed recovery program, including a summary of the governance structure, threats, conservation measures, and recovery strategy for the DPS. Other relevant data and analyses are available on the Atlantic Salmon Recovery Plan Companion Document. Links to specific web pages are included throughout this plan.

RECOVERY UNITS: The critical habitat rule (74 FR 29300, June 19, 2009) delineates recovery units for the expanded DPS. These units, designated as Salmon Habitat Recovery Units (SHRUs)[1], respond to life history needs and the environmental variation associated with freshwater habitats. The SHRUs encompass the full range of the DPS, including:

- Merrymeeting Bay, which covers the Androscoggin and Kennebec, and extends east to include the Sheepscot, Pemaquid, Medomak, and St. George watersheds;

- Penobscot Bay, which covers the entire Penobscot basin and extends west to and includes the Ducktrap watershed; and,

- Downeast, including all coastal watersheds from the Union River east to the Dennys River.

THREATS TO THE DPS: This plan is based in large part upon an updated threats analysis for the expanded GOM DPS. The 2009 listing rule called particular attention to three major threats to Atlantic salmon: dams, inadequacy of regulatory mechanisms related to dams, and low marine survival. The rule also identified a number of secondary stressors, including activities or actions that pertain to habitat quality and accessibility, commercial and recreational fisheries, disease and predation, inadequacy of regulatory mechanisms related to water withdrawal and water quality,

[1] Recovery units also assist with the implementation of Section 7 consultations under the ESA. However, each Section 7 consultation must assess the effects of an action to the recovery unit and the entire listed entity.

aquaculture, artificial propagation, climate change, competition, and depleted diadromous fish communities. Collectively, these stressors constitute a fourth major threat. Since the 2009 listing, our understanding of threats to the DPS has continued to grow. New and emerging threats, all of which constitute significant impediments to recovery, include road stream crossings that impede fish passage, international intercept fisheries, and new information about the effects of climate change. It is important to note that, as recovery proceeds, information and the level of concern about various threats will continue to evolve.

RECOVERY STRATEGY: This recovery plan is based on two premises: first, that recovery actions must focus on rivers and estuaries located in the GOM DPS until we better understand threats in the marine environment, and second, that survival of Atlantic salmon in the DPS will be dependent on conservation hatcheries through much of the recovery process. In addition, the scientific foundation for this plan includes conservation biology principles regarding population viability, our understanding of freshwater habitat viability, and threats abatement needs. These principles are summarized within the viability framework of resiliency, representation, and redundancy.

The recovery strategy also incorporates adaptive management, phasing of recovery actions, a geographic framework based upon the three SHRUs, and a collaborative approach that focuses on full inclusion of partners in implementing recovery actions. This recovery plan includes a table that generally identifies the priority, timing, and involved parties for the various actions, but it is important to recognize that decisions made about recovery activities will be formulated in SHRU-level work plans.

RECOVERY GOAL: The overall goal of this recovery plan is to remove the GOM DPS of Atlantic salmon from the Federal List of Endangered and Threatened Wildlife. The interim goal is to reclassify the DPS from endangered to threatened status.

RECOVERY OBJECTIVES AND CRITERIA: The objectives and criteria in this plan address biological recovery needs and abatement of threats, as summarized below.[2]

> **Reclassification Objectives –** Maintain sustainable, naturally reared populations with access to sufficient suitable habitat in at least two of the three SHRUs, and ensure that management options for marine survival are better understood. In addition, reduce or eliminate those threats that, either individually or in combination, pose a risk of imminent extinction to the DPS.
>
> **Delisting Objectives –** Maintain self-sustaining, wild populations with access to sufficient suitable habitat in each SHRU, and ensure that necessary management options for marine survival are in place. In addition, reduce or eliminate all threats that, either individually or in combination, pose a risk of endangerment to the DPS.

Biological Criteria for Reclassification – Reclassification of the GOM DPS from endangered to threatened will be considered when all of the following biological criteria are met:

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[2] The biological recovery criteria for the GOM DPS of Atlantic salmon were established in the 2009 critical habitat final rule (NOAA 2009).

1. ***Abundance:*** The DPS has total annual returns of at least 1,500 adults originating from wild origin, or hatchery stocked eggs, fry or parr spawning in the wild, with at least 2 of the 3 SHRUs having a minimum annual escapement of 500 naturally reared adults.

2. ***Productivity:*** Among the SHRUs that have met or exceeded the abundance criterion, the population has a positive mean growth rate greater than 1.0 in the 10-year (two-generation) period preceding reclassification.

3.. ***Habitat:*** In each of the SHRUs where the abundance and productivity criterion have been met, there is a minimum of 7,500 units of accessible and suitable spawning and rearing habitats capable of supporting the offspring of 1,500 naturally reared adults.

Biological Criteria for Delisting - Delisting of the GOM DPS will be considered when all of the following criteria are met:

1. ***Abundance*:** The DPS has a self-sustaining annual escapement of at least 2,000 wild origin adults in each SHRU, for a DPS-wide total of at least 6,000 wild adults.

2. ***Productivity:*** Each SHRU has a positive mean population growth rate of greater than 1.0 in the 10-year (two-generation) period preceding delisting. *In addition,* at the time of delisting, the DPS demonstrates self-sustaining persistence, whereby the total wild population in each SHRU has less than a 50-percent probability of falling below 500 adult wild spawners in the next 15 years based on population viability analysis (PVA) projections.

3. ***Habitat:*** Sufficient suitable spawning and rearing habitat for the offspring of the 6,000 wild adults is accessible and distributed throughout the designated Atlantic salmon critical habitat, with at least 30,000 accessible and suitable Habitat Units in each SHRU, located according to the known migratory patterns of returning wild adult salmon. This will require both habitat protection and restoration at significant levels.

Threats Abatement Criteria: Threats to GOM DPS identified both in the 2009 listing rule and since then, must be diminished prior to reclassification and, to a greater extent, delisting. Therefore, this plan includes criteria specific to reducing threats to the survival and recovery of the species. In this Plan we identify a number of primary threats as well as a number of secondary stressors, that in their combination constitute a primary threat. In order to delist the GOM DPS of Atlantic salmon, each individual primary threat must be sufficiently abated according to stated criteria in section III. The Services also recognize that primary threats may change over time. The Services will develop an implementation strategy to address the secondary stressors in a manner that allows for a sufficient reduction in extinction risk as the recovery process advances. To facilitate this strategy, the adaptive management and collaborative aspects of the Recovery Strategy will come into play. Monitoring and relevant research will be critical in determining to what extent secondary stressors must be resolved in association with abatement of the threats.

Numerous criteria for abating the threats and the stressors are detailed in the body of the recovery plan.

RECOVERY ACTIONS: This recovery plan focuses on the site-specific actions necessary to recover the GOM DPS of Atlantic salmon. These actions address both survival and recovery needs and are site-specific to the extent practicable as required by section 4(f)(1)(B)(i) of the ESA. In this plan, the SHRU often represents the site in which the actions are scaled to. In some circumstances, recovery actions encompass the entire DPS or are not geographically based (e.g. genetic studies and other research). Scaling site-specific actions to the SHRU takes into account both the multi-faceted, interdisciplinary nature of recovery actions and long timeframe needed to reach reclassification and delisting objectives; thus, the SHRU constitutes the geographic scale in which the Services will measure recovery progress and carry out adaptive management. Using a finer scale than the SHRU to identify site-specific actions is not practicable because there are a number of different pathways and scenarios that could allow for salmon recovery to happen. Every dam removal or every restoration project will affect the population differently based on its position within the watershed, the level of impact that the activity is actually having on the population to begin with, and its relationship to other threats within the watershed. Therefore, being more prescriptive by using a finer scale than the SHRU-level regarding what projects need to happen would be too inflexible and mask viable options given the wide range of possible pathways and different combinations of restoration actions that could allow for recovery to occur. SHRU-level workplans provide the basis for determining activities within the SHRU that should be implemented in order to complete the plan's SHRU specific recovery actions. Although these workplans link back to this recovery plan, they are not considered part of the plan itself. The eight categories of recovery actions include:

- **Habitat Connectivity**, intended to enhance connectivity between the ocean and freshwater habitats important for salmon recovery;
- **Freshwater Conservation**, intended to increase adult spawners through the freshwater production of smolts;
- **Marine and Estuary**, intended to increase survival in these habitats by increasing understanding of these salmon ecosystems and identifying the location and timing of constraints to the marine productivity of salmon in support of management actions to improve survival;
- **Outreach, Education, and Engagement**, intended to collaborate with partners and engage interested parties in recovery efforts for the GOM DPS;
- **Federal/Tribal Coordination**, intended to ensure federal agencies and associated programs continue to recognize and uphold federal Tribal Trust responsibilities;
- **Conservation Hatchery**, intended to provide demographic support and maintain genetic diversity appropriate for the purpose of recovering Atlantic salmon in the Gulf of Maine DPS;
- **Genetic Diversity**, intended to maintain the genetic diversity and promote increased fitness of Atlantic salmon populations over time;
- **Funding Program Actions,** intended to identify funding programs that support State, local and NGO conservation efforts that benefit Atlantic salmon recovery

ESTIMATED TIME TO RECOVERY: The Services project a 75-year timeframe to achieve delisting of the GOM DPS of Atlantic salmon. This accounts for approximately 15 generations of salmon and assumes an estimated upper limit for resource investment into implementation of recovery actions. It is difficult to estimate a time and cost for reclassification because of uncertainties associated with the current significant threats to the species, especially marine survival, and impacts of climate change. The earliest possible time scenario would be 10 years based on the current reclassification criteria.

ESTIMATED COST OF RECOVERY: The implementation plan includes actions that are funded or partially funded under the Services baseline budget (based on fiscal year 2017 budget allocations), and actions that are necessary for Atlantic salmon recovery but are currently not funded under our current budget. The baseline budget of the USFWS and NMFS is approximately $8.6 million per year. This largely includes funding to support the State of Maine's management of Atlantic salmon through Maine Department of Marine Resources, population assessments, genetic analysis, and implementation of the ESA including Section 7 and Section 10, and hatchery operations. The estimated cost of implementing recovery actions not covered by the Services baseline budget is estimated at approximately $24 million per year. These costs include actions such as fishway installations, dam removals, replacing undersized culverts, among other activities. The cost of implementing recovery actions will change over time as recovery actions are completed, new actions are identified, and as new technologies and management approaches are adopted. As such estimating the final cost of recovery over 75 years is highly speculative although we present one possible scenario in Part V of the recovery plan.

ASSESSMENT OF RECOVERY PRIORITY: The USFWS and NMFS have adopted separate Recovery Priority systems to prioritize recovery planning and implementation. The recovery priority for each agency is reassessed at least biannually, as part of the agency's biennial reports to congress on recovering threatened and endangered species under the ESA. The USFWS and NMFS will revisit these priority determinations on a biannual basis and will work to ensure that these determinations are based on a consideration of the best available information and are coordinated to the maximum extent practicable, with any differences identified and explained.

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PART I. INTRODUCTION

A. Listed Entity and Recovery Units

1. Gulf of Maine Distinct Population Segment of Atlantic Salmon

Atlantic salmon populations in the United States have been grouped into the Long Island Sound, Central New England, and Gulf of Maine (GOM) population segments (figure 1) (Fay, et al., 2006). Under the Endangered Species Act (ESA), a distinct population segment of a vertebrate species is treated as a species for listing and recovery purposes if it meets the qualifying criteria defined by the joint Distinct Population Segment (DPS) policy of 1996 (61 FR 4722, February 7, 1996). This policy lays out three criteria, all of which must be met before a population segment can be listed as a DPS. These criteria include the discreteness of the population segment in relation to the remainder of the species to which it belongs, the significance of the population segment to the species to which it belongs, and the population segment's conservation status in relation to the ESA's standards for listing as endangered or threatened.

Figure 1. **Freshwater range of Atlantic salmon in the United States represented by three distinct population segments. Only the Gulf of Maine Distinct Population Segment currently support wild populations**

All native Atlantic salmon populations in the Long Island Sound and Central New England population segments have been extirpated. As of 2014, non-native Atlantic salmon were still present in the Central New England and Long Island Sound population segments as an artifact of a reintroduction program that existed in the Connecticut and Merrimack Rivers from 1967 to 2012. In 2013, the USFWS discontinued the federally supported programs to rebuild these stocks. However, Atlantic salmon persist in some rivers in the Long Island Sound and Central New England DPS as a result of state supported efforts to maintain Atlantic salmon presence in some rivers. These include the State of Connecticut's Atlantic Salmon Legacy program that supports a small stocking program in the Connecticut River, and the Saco River Salmon Club's hatchery program supported by the State of Maine's Department of Marine Resources (DMR) that continues to maintain a small stocking program in the Saco River. The Atlantic salmon used to support these programs are not part of the listed entity and therefore, are not protected under the ESA. Only the GOM population segment supports native wild salmon populations, all of which are at extremely low population size, leading to the designation of this population segment as a DPS.

The GOM DPS of Atlantic salmon was first listed by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service

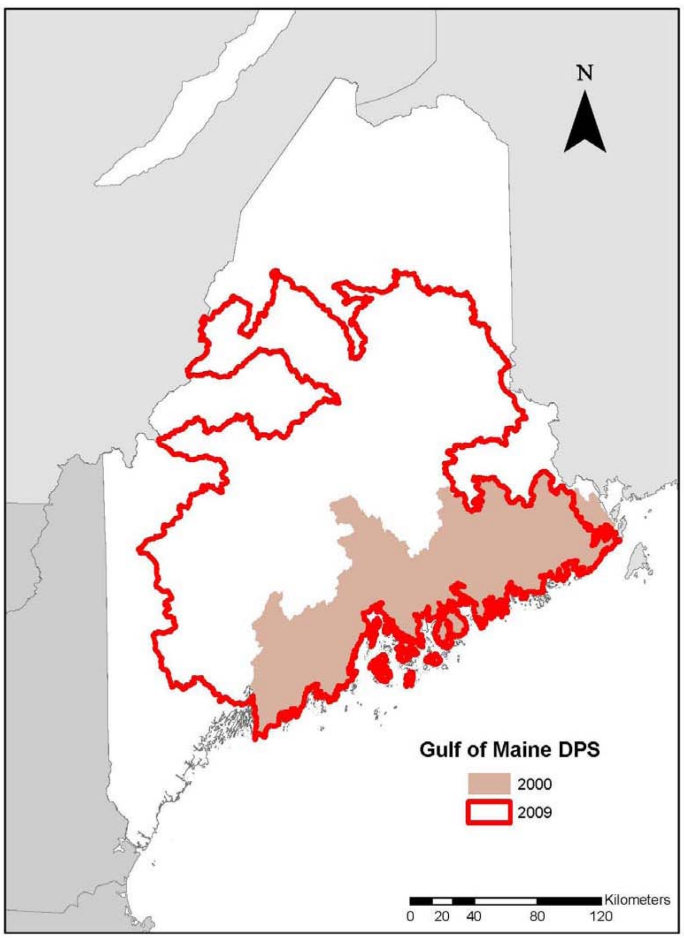

Figure 2. Geographic range of the GOM DPS as defined in the 2000 and 2009 listing rules.

(NMFS) (collectively referred to as the Services) as endangered in 2000 (65 FR 69459, November 17, 2000). The 2000 GOM DPS included all naturally reproducing remnant populations of Atlantic salmon from the Kennebec River downstream of the former Edwards Dam site, northward to the mouth of the St. Croix River. At the time of the 2000 listing, however, there were uncertainties associated with biological and genetic relationships of Atlantic salmon inhabiting the Androscoggin River, Kennebec River, and Penobscot River to wild Atlantic salmon populations (Figure 2).

A subsequent status review (Fay et al., 2006) recommended that the GOM DPS be expanded to incorporate all naturally reproducing anadromous Atlantic salmon having a freshwater range in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River, including all associated conservation hatchery populations used to supplement these natural populations. The marine range, which remained unchanged, extends from the GOM throughout the Northwest Atlantic Ocean to the coast of Greenland. The Services jointly listed this expanded GOM DPS as endangered on June 19, 2009 (74 FR 29300, June 19, 2009).

2. Atlantic Salmon Recovery Units

In considering recovery needs for the GOM DPS at the time of the 2009 listing, we identified the geographic and population-level factors that would buffer the DPS from adverse demographic and environmental events. This included the fundamental need to ensure that Atlantic salmon are well distributed across their GOM range to accommodate metapopulation dynamics. To address life history characteristics as well as demographic and environmental variation, a geographic framework represented by three SHRUs within the DPS was established (Figure 3; also see NMFS 2009, Appendix A).

Figure 3. **Salmon Habitat Recovery Units (SHRU's) within the GOM DPS**

The three SHRUs delineated for the GOM Atlantic salmon DPS are the:

- Merrymeeting Bay SHRU – Incorporates two large basins, the Androscoggin and Kennebec, and extends east to include the Sheepscot, Pemaquid, Medomak, and St. George watersheds;

- Penobscot Bay SHRU – Includes the entire Penobscot basin and extends west to include the Ducktrap watershed; and,

- Downeast Coastal SHRU – Includes all coastal watersheds from the Union River east to the Dennys River.

The Services will use the recovery units to organize geographically based recovery actions, as well as to assist with the appropriate implementation of Section 7 consultations under the ESA. In doing the latter, the Services will assess the effects of an action on the recovery unit and the entire range of the listed entity.

B. Overview of Recovery Governance and Coordination

1. Recovery Governance Structure

Recovery of the GOM DPS requires coordination of numerous conservation planning and management efforts across the entire DPS. An effective governance structure is key to charting a comprehensive long-term recovery program that facilitates interagency and intergovernmental cooperation along with the strategic involvement of a full range of partners and interested parties. The National Research Council (2004) also undertook a review of Atlantic salmon in Maine and recommended that recovery planning for the species adopt a systematic, structured approach to making management decisions, focused on understanding critical uncertainties and on developing strategies that address key sources of ecological risk. In 2004 and 2005, the agencies collaborated to develop joint priorities with the goal of providing an internal and external focus to agency efforts on behalf of Atlantic salmon. The three focus areas were as follows: (1) investigate possible causes and magnitude of early marine survival; (2) operate and evaluate conservation hatchery programs for the DPS and Penobscot River; and (3) Habitat.

The USFWS, NMFS, Maine DMR, and the Penobscot Indian Nation (PIN) share a stewardship interest and governmental responsibility for recovering Atlantic salmon. Collectively the agencies developed a governance structure to facilitate coordination and decision making among these entities and address the recommendations made by the National Research Council.

The current governance structure, which is subject to change, includes an Action Team for each major recovery program element, an Atlantic Salmon Policy Board, and an Atlantic Salmon Management Board. The Action Teams develop implementation plans, review and recommend changes in or approval of project proposals, identify and resolve areas of policy or scientific disagreement, and coordinate to implement and monitor recovery actions. The Policy Board guides broad policy direction, annually reaffirms program priorities, and commits resources for recovery implementation. The Management Board provides updates on potential and real changes to resource commitments and resolves differences of priorities among Action Teams.

The GOM DPS of Atlantic salmon cannot be recovered without broader participation. The governance structure is intended not only to guide recovery efforts among the government entities but to engage other partners in the salmon recovery program, including governmental agencies, nongovernmental organizations (NGOs), commercial and recreational interests, and the general public. Types of recovery actions that NGOs and other partners have implemented to date include dam removals, passage inventories and improvements at road stream crossings, hatchery production of fry, fry stocking, parr stocking, and land conservation and protection. Collaboration, local initiatives, public involvement and support, monitoring, and adaptive management will continue to be essential to this recovery effort.

The recovery governance structure has several stated purposes, including:

- Ensuring that recovery of the GOM DPS is achieved in a manner that is transparent and easily understood in terms of roles and responsibilities of the government entities;
- Ensuring that the best available science is being integrated into recovery;
- Ensuring that resources are made available to implement recommended actions in any given funding cycle;
- Resolving disputes and ensure continuity of operations throughout the operational year;
- Ensuring effective communication among the agencies and the various organizational levels within the agencies;
- Ensuring effective communication among the agencies and their partners in recovery, including NGOs, commercial and recreational interests and the general public;
- Ensuring that the trust responsibilities of the Federal agencies to federally recognized Tribes are appropriately exercised; and,
- Ensuring that those proposals requesting agency resources are vetted and determined to be consistent with agency policies and available resources.

Atlantic salmon recovery is also guided by multi-agency, issue-specific documents, interagency agreements, and international cooperative efforts. The value of these guidance documents is in no way diminished by completion of a recovery plan, and they will continue to provide important technical guidance for recovery actions.

Given our Federal trust responsibilities with regard to Tribal consultation, we provide more detail below on coordination with Maine tribes relative to Atlantic salmon recovery.

2. Tribal Coordination and Collaboration

In Maine, the Wabanaki people represent four tribes: the Passamaquoddy Tribe in Washington County, the Penobscot Indian Nation based at Indian Island on the Penobscot River, the Houlton Band of Maliseets in Northern Maine, and the Aroostook Band of Micmacs, also in Northern Maine. Atlantic salmon and the suite of diadromous fish indigenous to Maine's rivers, streams, lakes, and ponds are of great cultural importance to these Tribes for religious/cultural ceremonies, subsistence, and commerce, all of which have been negatively affected by the decline of Atlantic salmon. Up through 1988[3], the Penobscot Indian Nation harvested Atlantic salmon for sustenance. Since then, however, the Tribe has voluntarily abstained from harvesting Atlantic salmon out of concern for the health of the species. The Passamaquoddy Tribe and Penobscot Indian Nation also hold lands containing habitat that is critical to the survival and recovery of Atlantic salmon. As a result, the working relationship between the Services, the State of Maine, and the Tribes is crucial to the recovery of Atlantic salmon.

The Penobscot Indian Nation, along with the Services and Maine DMR, are co-participants in the management of Atlantic salmon. The Penobscot Indian Nation has member participation on Atlantic salmon Action Teams, the Atlantic salmon Policy Board, and the Atlantic salmon Management Board. Beyond the Management Board, the Services are committed to working with all Tribes in Maine in managing Atlantic salmon while finding ways to best achieve the fisheries needs of the Tribes.

Both Federal agencies have policies and guidance that establishes meaningful procedures for the collaboration and coordination with tribal officials. Detailed information on these procedures can be found at: Department of Commerce Policies and U.S. Fish and Wildlife Service Policies .

[3] Two salmon were harvested for ceremonial purposes in 1988 by Tribal members; see 50 CFR 29344.

C. Threats to Species Viability

1. Threats Identified at Time of Listing

This section summarizes the primary and secondary stressors—described according to the ESA's five listing factors in the box below—upon which the 2009 rule for the Atlantic salmon GOM DPS was based (74 FR 29344, June 19, 2009), and which continue to affect its survival and recovery.

FIVE LISTING FACTORS UNDER THE ESA (§4(a)(1))

A species is listed when it is determined to be endangered or threatened because of any of the following factors:

(A) The present or threatened destruction, modification, or curtailment of its habitat or range;
(B) Overutilization for commercial, recreational, scientific, or educational purposes;
(C) Disease or predation;
(D) The inadequacy of existing regulatory mechanisms; and
(E) Other natural or manmade factors affecting its survival.

These factors must also be evaluated when reclassifying or delisting any listed species.

Box 2.

The 2009 listing rule highlighted three threats as the most significant factors in the decline of Atlantic salmon in Maine as well as a number of secondary stressors that collectively constitute a significant threat to the continued existence of the GOM DPS of Atlantic salmon. The threats and stressors as they relate to each of the five listing factors are summarized below. See Chapter 6 of The Companion Document for a more detailed description of the threats.

Significant threats associated with listing factor A (habitat loss or degradation)

Dams

The direct, indirect, and delayed mortality associated with dams and the ecological effects of dams are a significant threat to the recovery of the GOM DPS of Atlantic salmon. Dams significantly impede migration pathways and can result in direct, indirect or delayed mortality of Atlantic salmon adults, smolts and kelts. Mortality can occur in electricity-generating dams if salmon travel over the spillway, through a downstream fish passage facility or through power-generating turbines. Indirect or delayed mortality can occur when fish are injured or disoriented by the dams and become more vulnerable to predators. Lack of flow cues at dam reservoirs can also increase predation because of the increased time salmon spend in the impoundment.

Dams have a number of additional negative ecological effects on Atlantic salmon. Dams create impoundments that inundate the natural stream and river habitat and cause sediment deposition that can cover important rearing and spawning habitat. Impoundments create large pools of water in which water temperatures can increase above preferred Atlantic salmon temperature levels. These impoundments and associated habitat changes can become preferred habitat for warm water exotic species that prey on juvenile Atlantic salmon. Impoundments can cause migratory delays, which, in turn, can reduce a salmon's tolerance to salinity, thereby increasing estuarine mortality (McCormick et al., 1998). For additional information, see Fay et al. (2006), and Appendix 8 in Fay et al. (2006), and the 2009 GOM DPS Atlantic salmon listing rule (74 FR 29344, June 19, 2009).

Secondary stressors associated with factor A

Habitat Complexity

Some forest, agricultural, and other land use practices have reduced habitat complexity within the range of the GOM DPS of Atlantic salmon. Reduced habitat complexity acts as a stressor on the GOM DPS by reducing spaces for hiding from predators and increasing water temperature. Large wood and boulders are currently lacking from many rivers because of historical timber harvest practices. When present, large wood and boulders create and maintain a diverse variety of habitat types. Large trees were harvested from riparian areas; this reduced the supply of large wood to channels. In addition, any large wood and boulders that were in river channels were often removed in order to facilitate log drives. Historical forestry and agricultural practices were likely the cause of currently altered channel characteristics, such as width-to-depth ratios (i.e., channels are wider and shallower today than they were historically). Channels with large width-to-depth ratios tend to experience more rapid water temperature fluctuations, which are stressful for salmon, particularly in the summer when temperatures are warmer.

Water Quantity

Direct water withdrawals and groundwater withdrawals for crop irrigation and commercial and public use can directly impact Atlantic salmon habitat by depleting stream flow. Reduced stream flow can reduce the quantity of habitat, increase water temperature, and reduce dissolved oxygen. The cumulative effects of individual water withdrawal impacts on Maine rivers is poorly understood; however, it is known that adequate water supply and quality is essential to all life stages and life history behaviors of Atlantic salmon, including adult migration, spawning, fry emergence, and smolt emigration.

Water Quality

Maine's water quality classification system provides for different water quality standards for different classes of water. These standards were not developed specifically for Atlantic salmon, and the lower quality standard classes may not provide high enough water quality to protect all life stages of Atlantic salmon. See Chapter 6 of The Companion Document for a more detailed description of the threats associated with factor A.

Significant threats associated with listing factor B (Overutilization)

No significant threats were identified at the time of listing that are associated with factor B.

Secondary stressors associated with factor B

Fish Harvest

Intercept fisheries, by-catch in recreational fisheries, and poaching result in direct mortality or cause stress, thus reducing reproductive success and survival of Atlantic salmon. Although international commercial harvest has been highly restricted since 2002, this issue has reemerged as a growing concern (see New and Emerging Threats below). Recreational angling of many freshwater species occurs throughout the range of the GOM DPS, and the potential exists for the incidental capture and misidentification of both juvenile and adult Atlantic salmon. Direct or indirect mortality may result even in fish that are caught and released as a result of injury or stress.

Significant threats associated with listing factor C (disease or predation)

No significant threats were identified at the time of listing that are associated with factor C.

Secondary stressors associated with factor C

Disease Outbreaks

Disease outbreaks, whether occurring in the natural or hatchery environment, have the potential to cause negative population-wide effects. Atlantic salmon are susceptible to numerous bacterial, viral, and fungal diseases. Parasites can also affect salmon. Federally managed conservation hatcheries adhere to rigorous disease prevention protocols and management regulations designed to: prevent the introduction of pathogens into the natural and hatchery environments; prevent and control, as necessary, disease outbreaks in hatchery populations; and, prevent the inadvertent spread of pathogens between facilities and river systems.

Predation

The impact of predation on the GOM DPS is important because of the imbalance between the low numbers of adults returning to spawn and the increase in population sizes of both native and nonnative predators. Increased numbers of predators combined with decreased abundance of alternative prey have likely increased predation mortality on juvenile Atlantic salmon, especially at the smolt life stage.

Significant threats associated with listing factor D (Inadequacy of regulatory mechanisms)

Inadequate regulatory mechanisms related to dams

Atlantic salmon require access to suitable habitat to complete their life history. As described under Factor A, dams within the range of the GOM DPS impede access to much of the suitable habitat that was historically available.

Hydroelectric dams in the GOM DPS are licensed by FERC under the Federal Power Act (FPA). As of 2018, there are 36 FERC dams in the Merrymeeting Bay SHRU. Eleven of these are in designated critical habitat, and two of those have FERC exemptions. Of the 11 dams in designated critical habitat, four of the dams have swim through fishways and one of the dams has a trap-and-truck facility. There are 25 FERC dams in the Penobscot SHRU. Eight FERC dams are located in designated critical habitat, of which three have FERC exemptions. Of the eight dams in designated critical habitat, five of the dams have swim through fishways, and one has a trap-and-truck facility. In the Downeast Coastal SHRU there are three FERC dams. All three dams are in designated critical habitat. Of the three dams, there are no swim through fishways and one trap-and-truck facility.

FERC exemptions are intended for projects that should have minimal environmental impacts. Exemption orders are subject to mandatory fish and wildlife conditions by fish and wildlife agencies under section 30 of the FPA. However, exemptions have no statutory maximum term, and include no mechanism to require reevaluation of the exempted project's environmental impacts should environmental conditions or circumstances change.

Current FERC licenses for many dams contain a reservation provision under FPA section 18 (16 U.S.C. 797) that could allow fishways to be prescribed by the Services (16 U.S.C. 811) outside of the relicensing process. Exercise of this authority requires administrative proceedings before the FERC that requires initiation by either NMFS or USFWS. The FERC maintains that, for the remainder of the projects whose licenses do not contain reserve authority, reopening these licenses may be dependent upon the success of a petition to the FERC to exercise its own reserve authority. The Services' section 18 authorities under the FPA are limited to prescribing a facility for fish passage (such as a fish ladder), operation and maintenance of the facility, and any other conditions necessary to ensure effective passage. Habitat degradation and ecological impacts caused by these dams cannot be addressed by the Services' prescriptive authority under section 18 of the FPA, but may be under FPA section 10(j) (16 U.S.C. 803) recommendations.

NMFS has completed consultation pursuant to section 7 of the ESA on a number of the hydroelectric dams; typically, consultation has been triggered as a result of a relicensing proceeding or by the licensee's request for a license amendment to incorporate measures to minimize or monitor effects on Atlantic salmon (referred to as a Species Protection Plan). Section 7(a)(2) of the ESA requires every Federal agency to insure that any action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any listed species or results in the destruction or adverse modification of critical habitat. Section 9 of the ESA prohibits take of listed species. If take is occurring at a facility, FERC and/or the applicant needs to initiate the process under section 7 or 10 of the ESA to obtain an exemption from the section 9 prohibitions, which would be conditioned on implementation of measures to minimize, monitor and report incidental take. NMFS is currently engaging these Licensees to develop Species Protection Plans for these dams.

The majority of dams within the GOM DPS do not generate electricity, and therefore do not require either a FERC license or a Maine Department of Environmental Protection (MDEP) water quality certification. These dams are typically small and historically were used for a variety of purposes, including flood control, log drives, mill working, storage, recreation, and processing water. Most of these facilities do not have fish passage, and many of them are not in use. Before salmon were listed, lack of fish passage and other impacts to salmon could be addressed only through State law, as noted previously. Overall, the inadequacy of existing regulatory mechanisms relating to dams is a significant threat to the GOM DPS.

Secondary stressors associated with factor D

No secondary stressors were identified at the time of listing that are associated with factor D.

Significant threats associated with listing factor E (other factors)

Marine survival

Despite significant reductions in commercial intercept fisheries, rates of marine survival of GOM DPS Atlantic salmon are very low. Factors other than fisheries that effect marine survival include factors like climate variability, shifting foodweb dynamics, and climate change. Marine survival is indexed by smolt return rates; a smolt return rate is the ratio of the number of adult returns produced by a smolt cohort to the number of outmigrating smolts (number of naturally reared smolts and/or the number of stocked hatchery smolts). It should be noted that by using this method marine survival incorporates a significant amount of mortality that may originate in the freshwater or estuarine system from dam-associated direct, indirect, or delayed mortality (see Factor A). Regardless of the metric, far fewer adult Atlantic salmon return to Maine rivers than is sustainable. See "Threats Associated with Factor E" in Chapter 6 of the Companion Document for more on the impact of low marine survival on the DPS.

Secondary stressors associated with factor E

Depleted Diadromous Communities

Damming rivers, thus preventing migration to spawning grounds, was a major factor in the decline of Atlantic salmon and much of the co-evolved suite of diadromous fish (e.g., alewife and blueback herring). Many co-evolved diadromous species have experienced dramatic declines throughout their ranges and current abundance indices are fractions of historical levels. The dramatic decline in diadromous species has negative impacts on Atlantic salmon populations, including through depletion of an alternative food source for predators of salmon, reductions in food available for juvenile and adult salmon, nutrient cycling, and habitat conditioning. These impacts may be contributing to decreased survival in lower river and estuarine areas.

Artificial Propagation

The conservation hatchery programs at Craig Brook and Green Lake National Fish Hatcheries (CBNFH and GLNFH) are vital to preserving and stabilizing individual and composite genetic stocks until freshwater and marine conditions improve. Without hatchery production, the likelihood of imminent extinction would be very high, and it is also important to know that hatchery salmon are protected as part of the GOM DPS. Nonetheless, inherent risks associated with the broodstock and stocking program for the DPS include domestication and loss of genetic variability, along with the potential for catastrophic loss due to the limited number of hatcheries maintaining GOM DPS Atlantic salmon. To mitigate these risks, a broodstock management plan has been implemented with the goal of maintaining genetic diversity throughout the hatchery management process, including estimating genetic diversity for each captive broodstock (Bartron, et al., 2006).

Aquaculture

Concerns about the effects of Atlantic salmon aquaculture on wild Atlantic salmon stocks, including the GOM DPS, continue, including the risk of exposing native salmon to serious salmon pathogens and genetic and ecological risks. Although recent advances in containment and marking of aquaculture fish offer more control over the potential for negative impacts, they do not eliminate the risk that aquaculture fish pose to wild Atlantic salmon. More information on conservation measures that have been taken to address the threat of aquaculture can be found on in chapter 6 under Threats Associated with Factor E of the Companion Document.

Competition

Prior to 1800, the resident riverine fish communities in Maine were made up of native species. Today, Atlantic salmon coexist with a diverse array of nonnative resident fishes, including brown trout, largemouth bass, smallmouth bass, and northern pike. The range expansion of these nonnative species is of particular concern, because they often require similar resources and can exclude salmon from preferred habitats, reduce food availability, and increase predation.

2. New and Emerging Significant Threats to the Species

In addition to the threats identified at the time of listing, new information on road stream crossings, the West Greenland intercept fishery in the North Atlantic, and climate change is causing growing concern about their effects on Atlantic salmon in the GOM DPS. Therefore, this recovery plan has identified these as significant threats affecting the GOM DPS. For more information on New and Emerging Threats see Chapter 7 of the Companion Document.

Road stream crossings (Factor A)

Together with dams, lack of access to suitable freshwater habitat due to road stream crossings has become a major concern with regard to recovery of the GOM DPS of Atlantic salmon. The amount of accessible freshwater habitat is a fraction of historical levels; this was initially caused by building dams and later by road stream crossings that created barriers to upstream migration. Fish passage barriers continue to prevent fish from reaching essential spawning and rearing habitat. Undersized culverts create hydraulic barriers that sever habitat connectivity within the range of the GOM DPS. Improperly placed and undersized culverts create fish passage barriers through perched outlets, increased water velocities, or insufficient water flow and depth within the culvert. Poorly placed or designed road stream crossings reduce access to habitat necessary for Atlantic salmon spawning and rearing and alter stream processes including transport of sediment and materials. These barriers also impair ecological complexity and increase the salmon's vulnerability to higher rates of extinction from demographic, environmental, and genetic stochasticity. More information on the threat of road/stream crossings can be found in Chapter 7 of the Companion Document.

Intercept fisheries in the North Atlantic (Factor B)

Commercial fisheries for Atlantic salmon within the United States have been closed since 1947; however, small but significant fisheries continue within the species' migratory corridor off the coast of Canada and Greenland. To effectively engage in issues requiring international collaboration, the United States is a party to the North Atlantic Salmon Conservation Organization (NASCO) and International Conference for the Exploration of the Seas (ICES). The United States is a signatory to the "Convention for the Conservation of Salmon in the North Atlantic Ocean" which entered into force in October 1983, creating NASCO to ensure that the burden of Atlantic salmon conservation was shared by both States of Origin and Distant Water Countries. Intercept fisheries (adult fish captured in nets while in transit to or from their feeding grounds in the North Atlantic or on their feeding grounds in the North Atlantic) have posed a significant challenge to recovery of the GOM DPS. Among distance water fisheries, the West Greenland fishery intercepts the greatest number of U.S. origin fish. Other fisheries where U.S. origin fish are harvested include the St. Pierre and Miquelon fishery located off the coast of Newfoundland, and a subsistence fishery that occurs in Labrador, Canada. More information on the threat of the Intercept Fisheries in the North Atlantic can be found in Chapter 7 of the Companion Document.

Climate change (Factor E)

At the time of listing in 2009, there was reasonable certainty that climate change was affecting Atlantic salmon in the GOM DPS (e.g., National Research Council, 2004; Fay et al. 2006), but there was uncertainty about how and to what extent. Since listing, new and emerging science has led to a better understanding of climate change effects and its impact on salmon. Recent information indicates that climate change is having significant impacts on the habitats that Atlantic salmon depend on and, in turn, is affecting the overall survival and recovery of Atlantic salmon (Mills et al. 2013, Renkawitz, 2015).

Briefly, climate change can affect all aspects of the salmon's life history by altering habitat features through increases in sea surface temperatures. Global averaged temperature combined with land and ocean surface temperatures show a warming trend. Although these temperature changes seem subtle, they are associated with changes in the seasonal cycles of phytoplankton, zooplankton, and fish populations in the marine environment (Greene and Pershing 2007). Subtle increases in global temperature are also associated with changes in freshwater hydrologic regimes; and alterations in the timing and frequency of river ice flows (Dudley & Hodgkins 2002). All of these factors influence environmental cues that stimulate Atlantic salmon migration, spawning, and feeding activities. As this is now considered to be an emerging threat to the viability of the DPS, new information and analyses will be made available in Chapter 7 of the Companion Document as it becomes available.

D. Historical and Contemporary Conservation Measures

Atlantic salmon conservation and restoration efforts have been underway for more than 150 years. The earliest efforts to restore and improve anadromous fish runs in New England rivers were driven by depletion of stocks through non-sustainable commercial fisheries, coupled with habitat loss due to impassable dams. Pollution was also considered a factor in fish population declines.

Starting in the late 1800s artificial propagation and fish culture programs were established first at CBNFH and later at GLNFH. These programs have allowed Atlantic salmon to survive during times that many of Maine's rivers were not suitable for salmon survival; they also allowed for maintenance of an economically important commercial fishery into the early 1900s and a recreational fishery through the early 1990s. The hatchery programs are now essential in preserving the genetic integrity of the last remaining Atlantic salmon populations in the United States.

Efforts to restore river habitats in order to support Atlantic salmon started with the recognition that dams without fish passage were a major threat to the species. A number of Federal laws were then enacted that contributed to Atlantic salmon conservation, including the Water Pollution Control Act of 1948, which subsequently became the Clean Water Act of 1972 (CWA), and the Anadromous Fish Conservation Act of 1965. The Clean Water Act significantly curtailed pollution that had once caused rivers and streams in Maine to be toxic to both humans and fish, while the Anadromous Fish Conservation Act provided resources to install fishways on most of the mainstem dams in the Penobscot River and remove or breach defunct dams in the Narraguagus, Machias, and Sheepscot Rivers. By all indications, these efforts were working to restore salmon, as Atlantic salmon returns began increasing starting in the early 1970s. Through the mid-1980s, between 2,000 and 3,000 adult returns were consistently being documented annually on the Penobscot River.

In 1983, the State of Maine adopted its first prioritized, biologically based, statewide restoration and management plan for Atlantic salmon (Baum 1997). This plan was directed at building and maintaining a viable run of Atlantic salmon and a fishery in the seven remaining rivers that contained wild Atlantic salmon. Unfortunately, shortly thereafter Atlantic salmon marine survival rates crashed, leading to precipitous declines in GOM salmon populations.

In the 1990s, the salmon program shifted away from a recreational fishery program to a stock preservation program that including genetics studies, habitat surveys and biological monitoring to further understand why populations were declining. During this time, federal hatcheries transitioned to a program aimed at preserving remaining river-specific natural genetic diversity. Other management and science efforts also shifted towards more active conservation, including closing a commercial export fishery in Greenland that was believed to be central to the decline, and assessing freshwater habitats.

Following the 2000 federal listing of Atlantic salmon as endangered and the development of the first Atlantic salmon recovery plan (2005), emphasis was placed on making major improvements to the conservation hatchery and stocking programs, and expanding habitat conservation efforts. Conservation efforts were directed toward concerns with aquaculture, protecting accessible freshwater habitats by reducing threats from water and land use practices, and identifying impacts associated with water quality.

Although efforts to improve water quality and access to freshwater habitats have been underway for many decades (e.g., Edwards dam removal (1999), Clean Water Act enacted in 1972), there was an emphasis shift in the mid-2000s that focused restoration efforts on restoring habitat connectivity. This included improving connectivity by locating and removing culvert barriers, removing dams when possible, and installing fishways when dam removal was not feasible. These efforts were exemplified by the removal of two mainstem hydroelectric projects and construction of a bypass at a third project on the Penobscot River. In addition, the Services and hydro developers in the GOM DPS have worked together to craft plans for fish passage at many of the remaining hydro facilities. Downstream and upstream fish passage improvement projects and fish passage studies are now underway at many hydro projects within the designated critical habitat area for Atlantic salmon.

The conservation efforts of the past century, largely driven by regulatory measures, have afforded important conservation benefits to the GOM DPS and the entire suite of diadromous fish that coexist alongside Atlantic salmon. Without these efforts, salmon, along with many other diadromous species, would likely have been extirpated from Maine's rivers and streams decades ago. Examples of conservation successes since Atlantic salmon were first listed in 2000 include:

1. Conservation successes addressing the threat of Dams

Numerous dams have been removed and many new fishways have been constructed since Atlantic salmon were first listed as an endangered species in 2000. The most comprehensive efforts to improve fish passage encompassed the work of the Penobscot River Restoration Project, the State of Maine's 2009 Operation Plan for the Restoration of the Penobscot River (MDMR and MDIFW, 2009), and designation of the Penobscot Habitat Focus Area by NMFS. Part of these efforts included a negotiation process involving the Penobscot Indian Nation, industry representatives, the State of Maine, NGOs and federal partners that resulted in a Settlement Agreement. These efforts lead to the removal of Veazie (2013) and Greatworks Dam (2012), the two lowermost mainstem dams on the Penobscot river; and the removal of, or improvement of fish passage at numerous other small dams in the Penobscot watershed. In addition, a state of the art fishway was constructed at the Milford Dam (2012) which is now the lower most dam in the Penobscot. Most of these projects were supported by funds made available through programs that target the conservation of threatened and endangered species, such as money allocated to States through Section 6 of the ESA. Furthermore, Section 7 consultation was carried out to assess the effects of the dam removals and project modifications. Monitoring requirements were implemented and are authorized under Section 7 and Section 10 of the ESA. We continue to use these tools to monitor and ensure the effectiveness of these projects in achieving their conservation goals of reconnecting Maine's rivers and restoring sea-run fish communities.

Although Atlantic salmon have been slow to respond to in-river improvements, largely because of continued threats they face while at sea, the other sea-run species have responded significantly. River herring that were once constrained to the lower 30 miles of the Penobscot River have now been observed more than 130 miles upstream from sea. Before the dams were removed, annual returns of river herring numbered near or below 2,000. Since the dams were removed, and with the support of stocking efforts, the numbers of river herring and American shad passing upstream of the Milford Dam has increased significantly. The dam removals also allowed for the expansion of the range of American shad and ESA listed shortnose sturgeon. Both were once constrained to below the lowermost dam on the Penobscot River. In 2016, shortnose sturgeon were observed using their historic habitat upstream of the Veazie and Greatworks dams for the first time in over

100 years. Furthermore, more than 7,000 American shad were observed passing through the fishway at the Milford dam and some were seen in the river up to 70 miles upstream from the sea. Given the observance of shad in the Penobscot, anglers are once again seeking out American shad as a viable sport fish in the Penobscot River.

There has also been significant conservation successes in the Kennebec River watershed. The Kennebec River Diadromous Fish Restoration Project was initiated in 1986 when the Maine Department of Marine Resources (MDMR) signed a settlement agreement with the Kennebec Hydro-Developers Group (KHDG). A second settlement agreement signed in 1998 by state and federal fisheries resource agencies, non-governmental organizations, and the KHDG resulted in the removal of Edwards Dam in Augusta to provide fish passage for all diadromous fish species, instituted schedules or triggers for fish passage at the seven KHDG dams, and provided additional funding for the stocking program. From 1837 to 1999 the Edwards Dam in Augusta prevented any upstream fish passage. Removal of Edwards dam restored full access to historical spawning habitat for species like Atlantic sturgeon, shortnose sturgeon, and rainbow smelt, but not for species including alewife, American shad and Atlantic salmon that migrated much further up the river (MDMR, 2007). With the removal of Edwards Dam, the first dam on the Mainstem is now the Lockwood Dam in Waterville. In 2006, a fish lift was constructed with the ability to trap and truck Atlantic upstream of three dams that continued to block access to the Sandy River. The Sandy River contains high quality, abundant Atlantic salmon spawning and nursery habitat.

The Sebasticook River, a tributary to the Kennebec, enters the mainstem on the east bank at Waterville just below the Lockwood dam. Historically the Sebasticook supported large runs of diadromous fish. Particularly, American shad, blueback herring and alewives (MDMR 2007). Until the year 2000, the Fort Halifax, Benton, and Burnham dams blocked passage of diadromous fish into most of the Sebasticook River (MDMR 2007). Though the removal of the Edwards dam in Augusta allowed fish passage as far up as far as Lockwood on the Kennebec River, the Fort Halifax dam on the Sebasticook River prevented passage of all diadromous fish into the Sebasticook. In 2000, a fish pump was installed capable of pumping alewives (though not effective at passing other diadromous fish) over the dam (Gail Wippelhauser, e-mail communications, January 2008). By 2006, fish passage was enhanced at the Benton and Burnham dams allowing free passage of alewives once above Fort Halifax throughout the mainstem of the Sebasticook River as far up as Sebasticook Lake. In 2008, the Fort Halifax dam was completely removed such that the first dam on the Sebasticook River is now at Benton Falls.

Because of efforts like this, Maine is one of only a few states along the east coast where populations of river herring are actually growing. Although Atlantic salmon continue to be a critically endangered species, the actions and protections afforded to salmon through the ESA and the perseverance and motivation of the NGO community, has afforded considerable conservation benefit to some of Maine’s most economically and ecologically important fisheries resources. Restoration of the searun fish, such as alewife and American shad, help restore the ecosystems upon which Atlantic salmon depend by restoring the flow of marine nutrients into freshwater ecosystems (Guyette 2012, Guyette, Loftin et al. 2014), and likely provides a predation buffer to emigrating smolts (Saunders et al. 2006). Furthermore, with these efforts, Maine’s sea run fisheries continue to represent a long standing and essential part of Maine’s culture and economy.

For more information on conservation efforts see Chapter 8 of the Companion Document.

2. Conservation successes addressing the threat of Aquaculture

The overall threat that aquaculture poses to GOM DPS Atlantic salmon has decreased substantially over the past decade; impacts associated with aquaculture to the GOM DPS are less than they were historically. This decrease in potential aquaculture impacts is demonstrated by:

a. There are fewer aquaculture salmon along the Maine coast. Current aquaculture stocking levels are 1,984,000 farmed salmon down from 4,511,000 farmed salmon in 2000.

b. As a result of gear type and pen material improvements, Containment Management System plans, and other requirements, the number of escaped farmed salmon documented in GOM DPS rivers has dropped significantly.

c. All Maine aquaculture salmon are currently from North American stocks. This reduces the impacts of gene introgression on the GOM DPS.

d. As a result of mandatory permit requirements and voluntary programs, Maine salmon aquaculture facilities have improved disease and parasite prevention and control measures to the point that we do not anticipate a major threat from the transfer of disease or parasites to GOM DPS salmon.

PART II. RECOVERY STRATEGY

The following recovery strategy recognizes that the continued survival of the GOM DPS of Atlantic salmon currently relies on the conservation hatchery programs. Reliance on the hatchery programs is expected to continue until freshwater ecosystem function has been improved, connectivity has been adequately restored, and marine survival rates improve to the point where wild salmon are returning to spawn at sustainable levels. Therefore, the primary drivers of ongoing and future recovery efforts are the need to reduce uncertainty and the ability to address those factors most likely to allow increased numbers of wild salmon to return to their spawning habitat each year. Each element of this strategy is discussed below.

A. Foundation

1. Conservation Frameworks

The central aim of recovery of the GOM DPS is for the population to have a low risk of extinction in the foreseeable future due to threats from environmental variation, demographic variation, or changes in genetic diversity. The foundational principles for achieving this aim are based on Shaffer and Stein's (2000) "3-Rs" principles and McElhaney et al.'s (2000) principles regarding viable salmon populations (VSPs). The "3-Rs" framework identifies resilience (population health), redundancy (distribution), and representation (genetic and niche diversity) as the basic indicators of species viability. In general, the more resilient, redundant, and representative a species is, the more likely it is to persist over time, even under changing environmental conditions. The VSP framework, originally used to determine the conservation status of Pacific salmonids, is now recognized as a tool that can be applied to evaluating the viability of additional salmonid and non-salmonid species.

2. Conservation Assessments

In addition to these conservation frameworks, recovery of the GOM DPS is predicated on the assessment results for three fundamental aspects of Atlantic salmon conservation: population viability, habitat availability, and abatement of threats to the species. Although each of these aspects pertains to the range-wide status of the species, the near- to mid-term recovery focus is on assessing and managing for viability in the freshwater environment, as we know what is needed to restore freshwater habitats. Although survival of emigrating Atlantic smolts and adults while at sea is the biggest drivers of Atlantic salmon population trends in the GOM DPS, the maximum potential abundance of the salmon is directly proportional to the quantity and quality of freshwater habitats that are available for spawning and juvenile rearing. Further, barriers that block or impede salmon passage and threats that reduce the quality and quantity of habitat decrease the potential abundance of salmon–an abundance that is needed to support a sufficiently large, geographically distributed population that is resilient to environmental perturbations such as poor marine conditions, drought, and extreme temperatures.

Population Viability

Preventing extinction will require substantial increases in the abundance, productivity, and distribution of naturally reared Atlantic salmon in GOM DPS rivers as addressed by both the 3-Rs and VSP frameworks. Increased abundance and productivity will improve the resilience of each population in the DPS, while maintaining a wide distribution of Atlantic salmon across the range of the DPS. Increased abundance and productivity will ensure that the metapopulation (A collection of spatially divided subpopulations that experience a certain degree of gene flow among them) characteristics of Atlantic salmon are retained and provide redundancy and representation of populations across the range. Atlantic salmon have strong homing characteristics that allow local breeding populations to become well-adapted to a particular environment. At the same time, limited straying (i.e., spawning in their non-natal river) does occur among salmon populations; this helps maintain population diversity through exchange of some genes between populations and allows for population expansion and recolonization of extirpated populations. Accommodating these life history characteristics and distributional needs should provide protection from demographic and environmental variation.

Assessment of both population-level and rangewide extinction risks provides the foundation for setting recovery thresholds with respect to abundance, productivity, and distribution. This assessment requires analysis of the various factors that influence viability. Overall analysis results indicate that a minimum of 2,000 adult wild salmon must return to spawn in each SHRU to achieve rangewide population viability (NMFS 2009 (Appendix A)).

The USFWS hatchery program is critical to maintaining genetic diversity and effective population size while populations are low (see Phased Approach below). It is also important, however, to recognize that hatchery management is subject to funding availability. Hatchery funding contingencies could lead to changes in the recovery strategy for the DPS in the future. For more information on population viability, see Chapter 10 of the Companion Document.

Freshwater Habitat Availability

The life history of the Atlantic salmon requires a high degree of access between freshwater, estuarine, and marine environments, and sufficiently suitable natural habitats must be available to support wild populations. Habitat access is categorized as: (1) Habitat with No Access, (2) Habitat with Impeded Access, (3) Habitat that is Accessible, and (4) Habitat that is Fully Accessible. These categories are fully defined in section F, below.

To ensure the long-term sustainability of wild populations, there must be sufficient access to suitable habitat to support spawning and juvenile rearing. Ultimately, returning adults will dictate the actual amount of habitat needed, but the minimum amount of suitable habitat that must be accessible to returning adults is considered to be 30,000 Habitat Units per SHRU to delist the DPS (NMFS 2009 (Appendix C)).

This estimate is tied to the 2,000 adult wild spawners in each SHRU needed to ensure the long-term viability of the GOM DPS. Suitable freshwater habitat is assessed at the hydrological unit code (HUC) level 10 and is based on observations of physical and biological features that salmon most often select (*https://water.usgs.gov/GIS/huc.html*). Although the habitat quality assessment provides reasonable predictability of where the best habitats are for the spawning and rearing of Atlantic salmon, they do not represent verifiable evidence of the productivity of a HUC 10 watershed. Not until areas that are currently impeded or inaccessible allow for uninterrupted migration will we be able to fully assess the productive potential of a particular habitat area for Atlantic salmon. Likewise, the optimal composition and spatial distribution of this habitat throughout each SHRU is uncertain as tools to identify and characterize habitat productivity at fine resolution across entire watersheds are currently limited. These limitations will be addressed through adaptive management approaches.

Threats Abatement

Recovery criteria correspond to the five factors upon which determinations to list, reclassify, and delist a species are based. Although not every identified threat needs to be completely eliminated to remove a species from the federal endangered species list, current and foreseeable threats must be abated to the point where a recovered species is unlikely to become in danger of extinction again within the foreseeable future.

Because of the high level of uncertainty regarding threats and management options in the marine environment, this recovery strategy places a primary focus on abating threats in the freshwater environment and increasing our understanding of threats to marine survival. As we learn more about opportunities to improve marine survival, the recovery strategy, and recovery criteria based on the strategy, will expand accordingly to address those threats.

B. Adaptive Strategy

Recovery strategies are predicated on maximizing the likelihood of recovery success. To accomplish this, the strategy must address many sources of uncertainty. Assumptions must be made about future conditions, including environmental conditions, threats, funding availability, partner interest, and the species' response to management actions. To maintain the maximum likelihood of recovery success over time, the recovery strategy may need to be revised should any of these assumptions prove to be incorrect. Adaptive management, that is, adjusting management as management results and other events become better understood, provides a systematic means of addressing uncertainties and is an important approach for any recovery strategy. In addition to being a guiding principle for the overall recovery strategy, recovery actions that can benefit from a formal adaptive management process are specified in Part IV of this plan.

C. Phased Approach

Given the unavoidable complexity and uncertainties associated with recovery of the GOM DPS, as well as inevitable funding constraints, this recovery strategy adopts a stepwise approach that outlines a pathway towards recovery through four phases. The recovery actions outlined in Part

IV of this plan will be linked to each phase to demonstrate their role in the overall recovery effort. Since the 2000 listing of Atlantic salmon populations, a number of recovery actions have already been addressed; consequently, the actions in phase 1 are largely complete, and the overall recovery effort has generally entered phase 2.

Phases of recovery:

Phase 1: Includes identifying the threats to the species and characterizing the habitat needs of the species necessary for their recovery.

Phase 2: Focuses on ensuring the persistence of the GOM DPS through the use of the conservation hatcheries while abating imminent threats to the continued existence of the DPS. By the end of this phase, reclassification from endangered to threatened should be possible (see Part III).

Recovery actions associated with Phase 2 are geared toward creating the necessary foundation for establishment and protection of sufficiently resilient wild populations to withstand foreseeable long-term stresses, and toward providing Atlantic salmon with access to suitable habitat throughout their life cycle. Given our current level of understanding, Phase 2 focuses on freshwater habitat used by Atlantic salmon for spawning, rearing, and upstream and downstream migration; it also emphasizes research on threats within the marine environment.

Phase 3: Focuses on increasing the abundance, distribution, and productivity of naturally reared Atlantic salmon. This phase involves transitioning from dependence on the conservation hatcheries to wild smolt production and ensuring that mechanisms are in place to address continuing threats to the species in both the freshwater and ocean environments. We recognize that this is a long-term endeavor that will also need to address the information gaps associated with marine survival and, with this information in hand, identify appropriate management actions. At the end of Phase 3, delisting should be possible (see Part III).

Phase 4: Focuses on ensuring the Gulf of Maine Distinct Population of Atlantic salmon is comprised of a self-sustaining wild population geographically distributed across connected habitats throughout the range, with minimal dependence on human intervention to complete its natural life cycle. This will require that mechanisms are in place that prevent or abate the foreseeable threats to the long-term survival of the species and will involve post delisting monitoring to show that recovery is being sustained.

D. Geographic Framework

Recovery of the GOM DPS is contingent on a wide range of research and management actions over an extended period of time. In this recovery plan the three SHRU's (*see* NMFS, 2009 (Appendix A)) represent the geographic framework to organize recovery actions and ensure that they are implemented as effectively as possible. These SHRUs (Downeast, Penobscot, and Merrymeeting Bay) provide a framework for articulating spatial distribution objectives and ensuring that viable populations are established across the major geographic regions within the DPS, and that threats are addressed effectively across the DPS.

E. Coordination and Collaboration

Federal agencies, state agencies, tribes, industries, conservation organizations, private citizens, and other groups have been working toward restoring Atlantic salmon populations in Maine for over 100 years; many of these groups continue to provide support to salmon recovery throughout the DPS. In addition to NMFS and USFWS, Maine DMR, and the PIN, key recovery collaborators, as of early 2018, include: American Rivers; Appalachian Mountain Club; Atlantic Salmon Federation; Downeast Lakes Land Trust; Downeast Salmon Federation; Ducks Unlimited; Environmental Protection Agency; Fisheries Improvement Network; Forest Products Council; Forest Society of Maine; Keeping Maine’s Forests; Maine Audubon; Maine Coast Heritage Trust; Maine Department of Environmental Protection; Maine Department of Inland Fisheries and Wildlife; Maine Department of Transportation; Maine Forest Service; Maine Rivers; Maine Tree Foundation; Natural Resources Conservation Service; Natural Resources Council of Maine; Penobscot River Restoration Trust; Project SHARE; The Nature Conservancy; Trout Unlimited; University of Maine Cooperative Extension Service; USGS; University of Maine; and the ACOE, among many others.

To promote continued, strategic coordination among the wide array of partners to salmon recovery in Maine, the following approach to recovery implementation has been devised.

1. DPS-wide Recovery Implementation Strategy

This plan lays out site-specific recovery actions, at various scales, that should lead to the achievement of rangewide recovery objectives as measured by the recovery criteria. Often times research projects are not geographically based, but the results may apply to specific geographic areas or rangewide. The geographic scale at that site-specific actions are described is the SHRU. Using this scale is appropriate to monitor recovery progress and apply adaptive management strategies. Using a finer scale than the SHRU to identify site-specific actions is not practicable because there are a number of different pathways and scenarios that could allow for salmon recovery to happen. Every dam removal or every restoration project will affect the population differently based on its position within the watershed, the level of impact that the activity is actually having on the population to begin with, and its relationship to other threats within the watershed. Subsequently, being more prescriptive than the SHRU on what projects need to happen would be too inflexible and mask viable options given the wide range of possible pathways and different combinations of restoration actions that could allow for recovery to occur. SHRU-level workplans, described in the next section, provide the basis for determining activities that should be implemented in the short term for each of the plan’s recovery actions.

2. SHRU-level Workplans

The SHRU-level workplans for each SHRU provides guidance on activities that upon their implementation will help address recovery actions in the recovery plan. Although these workplans link back to this recovery plan, they are not considered part of the plan itself. The workplans identify activities that, within each SHRU and ultimately on a DPS-wide basis, will contribute to a coordinated recovery effort aimed at meeting the recovery criteria laid out in Part III. Some activities may be unique to a particular SHRU, while others may apply to all three SHRUs but at differing priorities or levels of effort.

We anticipate that the SHRU-level workplans will change over time as a function of adaptive management and identification of newly identified opportunities or threats. Regular discussions about the workplans, involving partners and the interested public, will be held to ensure that recommended activities are responsive to ongoing and emerging needs and opportunities. The SHRU-level workplans can be found on the Atlantic Salmon Recovery Plan Website (Click here).

F. Definitions Pertaining to Recovery Criteria and Actions

For ease of reference, we are providing the following definitions for concepts and terms contained in Part III, Recovery Criteria, and Part IV, Recovery Actions. Further discussion of these concepts is presented in the 2009 critical habitat rule.

1. Habitat Accessibility Categories

Habitat with No Access: Habitat above a barrier (dam or road stream crossing) that has no fish passage.

Habitat with Impeded Access: Habitat above a barrier that temporarily blocks or impairs a salmon's natural ability to pass (e.g., a culvert or dam with a fishway with limited function).

Habitat that is Accessible: At a minimum, the habitat must allow for movement of parr that seek out suitable habitats for feeding and sheltering, downstream movements of smolts during the spring migration, and upstream and downstream movement of adults that seek out habitats for spawning and resting. To meet this standard, habitat must be either: (1) Accessible above a dam with upstream and downstream passage that does not preclude recovery, or (2) accessible above road stream crossings set at the correct elevation using the Stream Simulation methodology.

Habitat that is Fully Accessible: Habitat where there is no artificial barrier between it and the ocean.[4]

[4] The Services may categorize some bridges with natural stream channels and bottomless culverts as fully accessible if the area beneath the bridge has a gradient, stream width, floodplain, and configuration similar to the existing natural channel upstream or downstream of the crossing.

2. Critical Habitat Features

Certain recovery criteria reference critical habitat features. Section 3 of the ESA defines critical habitat, in part, as specific areas within the geographical area occupied by the species supporting those physical and biological features that are essential for the conservation of the species and that may require special management considerations or protection. Federal agencies are required to consult with the Services on actions they carry out, fund, or authorize to ensure that their actions will not destroy or adversely modify critical habitat. ESA Section 7 consultation is required for any Federal action that may affect designated critical habitat. The necessary physical and biological features constituting critical habitat are described in detail in the final critical habitat designation (74 FR 29300, June 19, 2009). These include seven habitat features essential to spawning and rearing and six habitat features essential to migration, as defined below:

Spawning and rearing

1. Deep, oxygenated pools and cover (e.g., boulders, woody debris, vegetation) near freshwater spawning sites necessary to support adult migrants during the summer while they await spawning in the fall.

2. Freshwater spawning sites that contain clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support spawning activity, egg incubation, and larval development.

3. Freshwater spawning and rearing sites with clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support emergence, territorial development, and feeding activities of Atlantic salmon fry.

4. Freshwater rearing sites with space to accommodate growth and survival of Atlantic salmon parr.

5. Freshwater rearing sites with a combination of river, stream, and lake habitats that accommodate Atlantic salmon parrs' ability to occupy many niches and maximize parr production.

6. Freshwater rearing sites with cool, oxygenated water to support growth and survival of Atlantic salmon parr.

7. Freshwater rearing sites with diverse food resources to support growth and survival of Atlantic salmon parr.

Migration

1. Freshwater and estuary migratory sites free of physical and biological barriers that delay or prevent access for adult salmon seeking spawning grounds needed to support recovered populations.

2. Freshwater and estuary migration sites with pool, lake, and instream habitat that provide cool, oxygenated water, and cover items (e.g., boulders, woody debris, vegetation) to serve as temporary holding and resting areas during upstream migration of adult salmon.

3. Freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation.

4. Freshwater and estuary migration sites free of physical and biological barriers that delay or prevent emigration of smolts to the marine environment.

5. Freshwater and estuary migration sites with sufficiently cool water temperatures and water flows that coincide with diurnal cues to stimulate smolt migration.

6. Freshwater migration sites with water chemistry needed to support seawater adaptation of smolts.

PART III. RECOVERY GOALS, OBJECTIVES, AND CRITERIA

The following goals, objectives, and criteria set standards for ascertaining when recovery progress has been made under the ESA. These standards refer to the definitions of endangered and threatened under section 3 of the ESA: endangered means that a species is *in danger of extinction throughout all or a significant portion of its range*, whereas a threatened species is *likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range*.

Recovery goals, objectives, and criteria guide the recovery program toward accomplishments that bring the species closer to the definition of threatened and, ultimately, to the point where neither definition applies and listing is no longer warranted. The criteria in recovery plans can be changed based on new information and insights. The five-factor analysis under ESA section 4(a)(1) is the statutory process for making reclassification and delisting determinations. Any changes to this document could require a plan revision which is subject to the public review and comment period provisions under ESA section 4(f)(4).

G. Recovery Goals

The ultimate goal of this recovery program is to improve the long-term population viability of the GOM DPS of Atlantic salmon to the point where it no longer requires the protections of the ESA and can be removed from the Federal List of Endangered and Threatened Wildlife. The intermediate goal is to reclassify the DPS from endangered to threatened by improving conditions to the point where it is no longer in danger of extinction but, in the absence of continued ESA protections, would likely revert to an endangered species in the foreseeable future.

H. Recovery Objectives

1. Reclassification Objectives

- Maintain a sustainable, naturally reared population in at least two of the three SHRUs and ensure access to sufficient suitable habitat in these SHRUs for these populations.

- Ensure that management options, if any, for marine survival are better understood.

- Reduce or eliminate those threats that either, individually or in combination endanger the DPS.

2. Delisting Objectives

- Maintain self-sustaining, wild populations in each SHRU, and ensure access to sufficient suitable habitat in each SHRU for these populations.
- Ensure that necessary and available management options for marine survival are in place.
- Reduce or eliminate those threats that either, individually or in combination threaten the DPS.

I. Recovery Criteria

In accordance with section 4(f) of the ESA, this section presents criteria for identifying when the reclassification and delisting objectives for the GOM DPS have been achieved. The starting point for these criteria is the preliminary delisting criteria that were described in detail in the 2009 critical habitat rule (74 FR 29300, June 19, 2009). Both biological and threats-abatement criteria are provided to address recovery objectives. Atlantic salmon abundance and productivity criteria cannot be met without addressing low marine survival and mortality from dams.

These criteria reflect the achievement of recovery through the strategy described in the Part II, Recovery Strategy, of this plan. In particular, the biological criteria address fulfillment of the resiliency, redundancy, and representation components of DPS viability as indicated below. The threats-abatement criteria are included to ensure that viability is achieved through the recovery process and maintained after the DPS is delisted. The recovery criteria may be subject to revision if there are changes in the conditions that salmon live or if new information becomes available. Any revision to the criteria would trigger a public notice and an opportunity for public comment. Please note that, for ease of reference, terms regarding habitat access or critical habitat features in the following criteria are defined in Part II, section F, above.

1. Biological Criteria[5]

Reclassification Criteria:

Reclassification of the GOM DPS from endangered to threatened will be considered when all of the following biological criteria are met:

1a. Abundance (Resilience): The DPS has total annual returns of at least 1,500 adults originating from wild origin, or hatchery stocked eggs, fry or parr spawning in the wild, with at least 2 of the 3 SHRUs having a minimum annual escapement of 500 naturally reared adults.

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[5] The criteria for both reclassification and delisting address *only* the conditions needed to achieve a probability of long-term viability such that ESA protections are no longer warranted. The abundance criteria for DPS salmon do not take into account additional numbers of fish to support either recreational or sustenance fishing. Establishment of harvestable levels of salmon would necessarily be above and beyond these recovery criteria.

1b. ***Productivity (resilience):*** Among the SHRU's that have met or exceeded the abundance criterion, the population has a positive mean growth rate greater than 1 in the 10-year (two-generation) period preceding reclassification.

1c. ***Habitat (redundancy and representation):*** In each of the SHRUs where the abundance and productivity criterion have been met, there is a minimum of 7,500 units of accessible and suitable spawning and rearing habitats capable of supporting the offspring of 1,500 naturally reared adults.

Delisting Criteria:

Delisting of the GOM DPS will be considered when all of the following criteria are met:

1d. ***Abundance (Resilience)*****:** The DPS has a self-sustaining annual escapement of at least 2,000 wild origin adults in each SHRU, for a DPS-wide total of at least 6,000 wild adults.

1e. ***Productivity (Resilience):*** Each SHRU has a positive mean growth rate of greater than 1.0 in the 10-year (two-generation) period preceding delisting. *And* at the time of delisting, the DPS demonstrates self-sustaining persistence, whereby the total wild population in each SHRU has less than a 50-percent probability of falling below 500 adult wild spawners in the next 15 years based on population viability analysis (PVA) projections.

1f. ***Habitat (Redundancy and Representation):*** Sufficient suitable spawning and rearing habitat for the offspring of the 6,000 wild adults is accessible and distributed throughout the designated Atlantic salmon critical habitat, with at least 30,000 accessible and suitable Habitat Units in each SHRU, located according to the known migratory patterns of returning wild adult salmon. This will require both habitat protection and restoration at significant levels.

2. Threats-abatement Criteria

The criteria in this section describe how the five listing factors (see box 2, page 6) will be addressed to determine whether a species warrants the protections of the ESA. The criteria focus first on primary threats to the DPS (including ongoing threats identified in the 2009 listing rule, as well as emerging threats). These criteria are followed by criteria for threats considered to be secondary on an individual basis but which, in combination, constitute a major threat.

Reclassification Criteria:

The following threats-abatement criteria must be met to the extent necessary to support a GOM DPS of Atlantic salmon that is no longer in danger of extinction. Completion of the recovery actions needed to meet these criteria will signal the end of phase two of the recovery process for the DPS as described in the Recovery Strategy section of this plan.

2a. ***Dams and road stream crossings (factor A):*** A combination of dam removals, passage improvements at dams, passable road crossing structures, and removal or redesign of any other instream barriers to fish passage provides salmon access to sufficient habitat needed to achieve the habitat criterion for reclassification (see Biological Criterion 1d, above).

2b. ***Regulatory mechanisms for dams (factor D):*** FERC licenses for hydroelectric dams in designated Atlantic salmon critical habitat have been amended, or otherwise include, requirements to protect upstream and downstream migrating Atlantic salmon and minimize effects to habitat.

2c. ***Climate change (factor E):*** A water quality monitoring program is established to track climate change trends and effects on: (a) freshwater, estuarine, and marine habitats, and (b) salmon health. This program includes adaptive management strategies to mitigate or protect salmon from any harmful effects associated with climate change. In addition, freshwater areas that have greater resilience to climate change are identified, quantified, and incorporated into recovery goals and actions.

2d. ***Low marine survival (factor E):*** In combination with the climate change monitoring program, a program for identifying and quantifying additional anthropogenic threats in the marine environment is designed and implemented, and adaptive management strategies for mitigating the harmful effects of these threats, when possible, are developed. These factors include, but are not necessarily limited to, intercept fisheries and aquaculture management.

2e. ***Loss of genetic diversity (factor E):*** Extant DPS family groups and genetic diversity are maintained at levels needed to support Biological Criteria 1a, 1b, and 1c, above, through adaptive hatchery practices and stock management strategies.

Delisting Criteria

The following threats-based criteria must be met to the extent necessary to support a recovered GOM DPS of Atlantic salmon. Completion of the recovery actions needed to meet these criteria will signal the end of phase 3 of the recovery process for the DPS as described in the Recovery Strategy section of this plan.

Delisting criteria addressing primary threats:

2f. ***Dams (factor A):*** Upstream and downstream passage at dams deemed essential to the conservation of Atlantic salmon are improved by dam removal and/or through operational or structural changes. Dam removals and structural changes must provide access to spawning and nursery habitats (freshwater habitat that is categorized as accessible or fully accessible habitat (See section “F” of this recovery plan) will be counted toward meeting this recovery criterion), reduce direct and indirect mortality of upstream and downstream migrating salmon, and provide for properly functioning critical habitat features.

2g. ***Road stream crossings (factor A):*** Upstream and downstream passage at culverts deemed essential to the conservation of Atlantic salmon are improved through culvert removal or through culvert installation or replacement. Culvert removals or improvements must provide access to spawning and nursery habitats (freshwater habitat that is categorized as accessible or fully accessible habitat will be counted toward meeting this recovery criterion), reduces degradation of surrounding habitat features, and provides for properly functioning critical habitat features.

2h. ***Regulatory mechanisms for dams (factor D):*** Regulatory mechanisms for hydroelectric and non-hydroelectric dams are in place and effectively enforced to maintain accessible and fully accessible upstream and downstream passage, water quality conditions that support a recovered population, and properly functioning critical habitat features.

2i. ***Marine survival (factor E):*** Marine survival is at a level that supports a recovered population, factors that influence marine survival (including intercept fisheries) are identified and quantified, management measures that maintain marine survival are implemented, and an adaptive management strategy that incorporates marine survival models into Atlantic salmon management plans and regulatory mechanisms is implemented.

2j. ***Climate change (factor E):*** Recognizing a high degree of uncertainty, climate-induced threats to Atlantic salmon in both their freshwater and marine environments are addressed to meet the following conditions:

- Sufficient data, data collection tools, and predictive models are in place to allow for accurate forecasting of climate conditions as they relate to Atlantic salmon survival in freshwater and marine environments; and
- Robust predictive models and appropriate actions are incorporated into Atlantic salmon management and regulatory mechanisms.
- Climate resilient habitats are identified and incorporated into management measures

Delisting criteria addressing secondary threats:

This category of threats includes multiple stressors that, *in combination*, rise to the level of a significant extinction risk to DPS salmon. Within this category, tradeoffs can be made in terms of how different stressors are addressed; in other words, not every criterion for secondary threats has to be met to consider delisting. As progress is achieved in addressing these threats, and as a better understanding is gained of how addressing these threats contributes to achievement of the biological criteria, the extent to which these threats must be addressed to support a recovered GOM DPS of Atlantic salmon can be better described.

2k. ***Instream flow conditions (factor A):*** Instream flow in designated critical habitat is managed according to conditions that are well suited for Atlantic salmon spawning, incubation, rearing, and migration.

2l. ***Water quality (factor A):*** Water quality, including water temperature, in designated critical habitat is managed according to conditions that are best suited to support Atlantic salmon spawning, incubation, rearing, and migration.

2m. ***Habitat complexity (factor A):*** Riparian areas are managed to promote diverse and complex habitat features suitable for Atlantic salmon habitat through appropriate forest and land management practices, including managing riparian zones that promote large wood.

2n. ***Overutilization (factor B):*** Utilization of GOM DPS Atlantic salmon for commercial, recreational, scientific, and educational purposes, and utilization related to bycatch and poaching, are managed by meeting the following conditions:

- Monitoring programs and management plans are in place and implemented; and
- NASCO participation ensures adequate management of intercept fisheries that impact United States-origin GOM DPS Atlantic salmon.

2o. ***Disease (factor C):*** Bacterial, viral, and fungal disease risks are managed by all hatcheries and other facilities by implementing rigorous disease prevention and management measures and protocols that incorporate the most up-to-date science and information by all hatcheries and other facilities.

2p. ***Predation (factor C):*** Plans for the management of species that prey on Atlantic salmon support a recovered GOM DPS of Atlantic salmon and are implemented.

2q. ***Regulatory mechanisms related to water withdrawals (factor D):*** Regulatory mechanisms that ensure maintenance of natural variations in flows and water levels are enforced.

2r. ***Regulatory mechanisms related to water quality (factor D):*** Regulatory mechanisms that protect water quality necessary to support Atlantic salmon spawning, rearing, and migration needs are enforced.

2s. ***Regulatory mechanisms related to illegal utilization (factor D):*** Regulatory mechanisms that control illegal utilization of GOM DPS Atlantic salmon are enforced.

2t. ***Regulatory mechanisms related to predation and competition (factor D):*** Regulatory mechanisms that prohibit the illegal stocking and introduction of any species that prey on, or compete with, Atlantic salmon are enforced.

2u. ***Artificial propagation (factor E):*** Atlantic salmon hatchery, broodstock, and stocking management plans are implemented to reduce the risks of domestication and loss of genetic diversity of the GOM DPS of Atlantic salmon.

2v. ***Aquaculture (factor E):*** Programs and management plans are implemented to ensure that aquaculture practices adequately reduce interactions of aquaculture fish with wild populations of Atlantic salmon.

2w. ***Depleted diadromous fish communities (factor E):*** Co-evolved diadromous species are restored to the extent necessary to provide the resources and ecosystem functions needed for a recovered GOM DPS of Atlantic salmon.

2x. ***Competition by nonnative species (factor E):*** Develop and implement plans for the stocking, introduction, and management of nonindigenous species that compete with Atlantic salmon to ensure they support a recovered GOM DPS of Atlantic salmon

D. Evaluating Recovery Progress

The USFWS and our partners monitor progress towards recovery through the Environmental Conservation Online System (ECOS), a gateway Website that provides access to data systems in the USFWS and other government data sources (see: *http://ecos.fws.gov/ecp/*). This central point of access assists USFWS and NMFS personnel in managing data and information, and it provides public access to information from numerous USFWS databases. NMFS and partners monitor recovery progress through the Recovery Action Mapping Tool (RAMT), a Website database that tracks recovery action status and related projects (https://www.webapps.nwfsc.noaa.gov/wcr/). The Services review, at least once every five years, all listed species to determine if the species should be reclassified or removed from the ESA list. This review involves evaluation of the Factors (A-E) and, where a recovery plan exist, progress in achieving the recovery criteria.

PART IV. RECOVERY ACTIONS

As explained in Part II, this recovery plan focuses on the statutory requirements of the ESA, including site-specific recovery actions. The geographic scale at which most actions are described is the SHRU. Some actions encompass all SHRU's, whereas a number of actions are specific to the marine environment and cannot be described at the SHRU scale. The SHRUs were developed to describe the appropriate spatial scale necessary to support a recovered population and thus we believe this is the appropriate scale at which to monitor recovery progress and apply adaptive management strategies. Geographically based activities that can be implemented in the short term will be determined through SHRU-level workplans that will be updated as new implementation ideas, new opportunities, and additional information become available. Although these workplans will link back to the following recovery actions, they are not considered part of the recovery plan itself.

A. Recovery Actions

Connectivity Actions (C): The Goal of connectivity actions are to enhance connectivity between the ocean and freshwater habitats important for salmon recovery.

C1.0 Identify and Prioritize Barriers to Atlantic Salmon.
This action should ensure that the most productive areas are well connected to each other and to the GOM, and that restoration projects are prioritized based on their biological merits. The prioritization must provide a clear and transparent way of assessing the relative biological value of individual restoration opportunities. Ways that this action will be completed are:

> **C1.1** Identify and prioritize fish passage barriers in the Merrymeeting Bay SHRU necessary for the survival and recovery of Atlantic salmon.
>
> **C1.2** Identify and prioritize fish passage barriers in the Downeast Coastal SHRU necessary for the survival and recovery of Atlantic salmon.
>
> **C1.3** Identify and prioritize fish passage barriers in the Penobscot SHRU necessary for the survival and recovery of Atlantic salmon.

C2.0 Remove Dams to Ensure Access to Habitats Necessary for Atlantic Salmon Recovery.
One of the most significant threats to Atlantic salmon are dams. Dams block or significantly impede a salmon's ability to access freshwater habitats essential for spawning and juvenile rearing. Dams, especially dams with turbines, can delay, injure or kill a significant number of downstream migrating smolts as they are heading to the ocean. Dams can kill (directly or indirectly) post-spawned adults (kelts) as they attempt to return to the ocean, preventing their ability to spawn again. Dam removal offers the highest likelihood of addressing these threats. Dam removals will need to be accomplished through partnerships and collaboration among all stakeholders. Ways that this action will be completed are:

C2.1 Remove non-regulated dams in the Merrymeeting Bay SHRU as appropriate, and according to the barrier prioritizations.

C2.2 Remove non-regulated dams in the Penobscot Bay SHRU as appropriate, and according to the barrier prioritizations.

C2.3 Remove non-regulated dams in the Downeast Coastal SHRU as appropriate, and according to the barrier prioritizations.

C2.4 When feasible, remove hydro-electric dams that afford significant conservation benefit to Atlantic salmon and the ecosystems that they depend on.

C3.0 Improve Fish Passage at Dams to Ensure Access to Habitats Necessary for Atlantic Salmon Recovery. In some instances, removal of fish passage barriers (particularly dams) is not possible. However, traditional engineered fishways and nature-like fishways (rock ramps, nature-like bypasses, etc.) may be installed to partially ameliorate the effects of a given barrier. If properly designed, these fishways can provide sufficient protection to Atlantic salmon and their ecosystems. Ways that this action will be completed are:

C3.1 Install fishways at non-FERC licensed dams in the Merrymeeting Bay SHRU as appropriate, and according to the prioritizations.

C3.2 Install fishways at non-FERC licensed dams in the Penobscot Bay SHRU as appropriate, and according to the prioritizations.

C3.3 Install fishways at non-FERC licensed dams in the Downeast Coastal SHRU as appropriate, and according to the prioritizations.

C3.4 Install fishways at FERC licensed dams in the Merrymeeting Bay SHRU as appropriate, and according to the prioritizations.

C3.5 Install fishways at FERC licensed dams in the Penobscot Bay SHRU as appropriate, and according to the prioritizations.

C3.6 Install fishways at FERC licensed dams in the Downeast Coastal SHRU as appropriate, and according to the prioritizations.

C4.0 Improve Fish Passage at Road Crossings. Culverts and other road crossings can block the migration of salmon and other migratory fish, particularly in headwater areas where culverts are ubiquitous across the landscape. Headwater habitats can serve as spawning and nursery habitats and are often important areas for temporary or long-term feeding and thermal refuge by Atlantic salmon parr. The effects of known passage barriers can be ameliorated by culvert removal (often through road de-commissioning), culvert replacement (i.e., resizing to 1.2 bank-full width or greater), or bridge construction. Ways that this action will be completed include:

C4.1 Complete tier 1 road stream crossings according to the Maine DOT's Programmatic consultation for transportation projects (USFWS 2017) in the Merrymeeting Bay SHRU.

C4.2 Complete tier 1 road stream crossings according to the Maine DOT's Programmatic consultation for transportation projects (USFWS 2017) in the Penobscot Bay SHRU.

C4.3 Complete tier 1 road stream crossings according to the Maine DOT's Programmatic consultation for transportation projects (USFWS 2017) in the Downeast Coastal SHRU.

C4.4 Complete tier 2 road stream crossings according to the Programmatic consultation for transportation projects (USFWS 2017) in the Merrymeeting Bay SRHU.

C4.5 Complete tier 2 road stream crossings according to the Programmatic consultation for transportation projects (USFWS 2017) in the Penobscot Bay SHRU.

C4.6 Complete tier 2 road stream crossings according to the Programmatic consultation for transportation projects (USFWS 2017) in the Downeast Coastal SHRU.

C4.7 Install culverts and bridges that allow for unimpeded passage of all life stages of Atlantic salmon along municipally owned roads.

C4.8 Install culverts and bridges that allow for unimpeded passage of all life stages of Atlantic salmon along privately owned roads.

C5.0 Implement Connectivity Projects that Ensure Access to the Co-Evolved Suite of Diadromous Fish that are Part of the Ecosystem that Atlantic Salmon Depend On. Atlantic salmon evolved in the presence of eleven other native sea-run species of fish including alewives, blueback herring, and sea lamprey. The life histories of these species share many similarities likely to take advantage of the ecological services that the other species provide. These services likely include buffering from predation, serving as sources of food and nutrients, and habitat conditioning such as what lamprey do when they excavate redds for spawning. Therefore, removing barriers that block the passage of the co-evolved suite of sea-run species is necessary to restore the ecosystems upon which salmon depend on. Ways that this action will be completed include:

C5.1 Identify and prioritize fish passage barriers across all SHRU's that maximize opportunities for the co-evolved suite of diadromous fish that are part of the ecosystem that salmon depend on.

C5.2 Remove dams across all SHRU's according to the prioritization that maximize opportunities for the co-evolved suite of diadromous fish that are part of the ecosystem that salmon depend on.

C5.3 Install fishways at dams across all SHRU's according to the prioritization that maximize opportunities for the co-evolved suite of diadromous fish that are part of the ecosystem that salmon depend on.

C6.0 Employ Science, Assessment and Monitoring of Barriers to Fish Passage. Conducting feasibility analysis, engineering studies, pre-and post-passage effectiveness and survival studies, and post restoration monitoring is essential in implementing and completing successful connectivity projects. Many of these studies are necessary components to inform the prioritization actions in C1.0. The level of assessments and monitoring is site specific and can vary considerably from project to project. Ways that this action will be completed include:

> **C6.1** Use the best available methods, including fish tagging and marking, to perform fish passage barrier assessments throughout the GOM DPS as necessary.
>
> **C6.2** Determine the feasibility of connectivity projects that afford direct benefits to Atlantic salmon.
>
> **C6.3** Conduct engineering studies for potential fish passage improvement projects that provide direct benefits to Atlantic salmon.
>
> **C6.4** Determine the feasibility of connectivity projects that primarily benefit the co-evolved suite of sea-run fish that Atlantic salmon depend on.
>
> **C6.5** Conduct engineering studies for potential fish passage improvement projects that primarily benefits the suite of sea-run fish that Atlantic salmon depend on.
>
> **C6.6** As needed conduct pre- and post- barrier removal and fish passage improvement monitoring using up-to-date methods.
>
> **C6.7** Establish Atlantic salmon passage efficiency targets that support the survival and recovery of the GOM DPS.
>
> **C6.8** Establish downstream and upstream Atlantic salmon passage design criteria for road stream crossings.

C7.0 Permit, Monitor and Enforce Regulations Related to Barriers to Fish Passage. A variety of local, state, and federal regulations must be complied with during restoration project implementation. This requires application to a variety of regulatory agencies for permits to conduct the project as well as post construction compliance monitoring. Ways that this action will be completed include:

> **C7.1** Complete ESA section 7 programmatic consultations with action agencies on road stream crossing improvement projects that effect Atlantic salmon.
>
> **C7.2** Prioritize regulatory mechanisms that maintain and promote connectivity within designated critical habitat.
>
> **C7.3** Conduct compliance monitoring of fish passage efficiency target and carry out enforcement actions when necessary.

C7.4 Carry out consultation pursuant to section 7 of the ESA on authorizations, funding or permits for potential fish passage improvement projects.

<u>Freshwater Actions (F):</u> The goal of freshwater actions is to increase adult spawners by increasing the numbers of smolts in freshwater.

F1.0 Evaluate Distribution and Abundance of Naturally-Reared Atlantic Salmon and Hatchery Products. Methodical and scientifically defensible population monitoring implemented to determine trends in abundance of all life-stages of Atlantic salmon and to evaluate the effects of recovery actions is necessary. Ways that this action will be completed include:

F1.1 Enumerate smolt populations to assess freshwater productivity and hatchery product survival in all SHRUs.

F1.2 Monitor and assess instream young-of-year and parr to evaluate freshwater productivity, early lifestage survival from egg to smolt, and hatchery product fitness and survival in all SHRUs.

F1.3 Conduct redd counts to estimate adult Atlantic salmon escapement and assess natural re-colonization within the range of the GOM DPS.

F1.4 Enumerate returns of adult Atlantic salmon captured at fish trapping facilities within the range of the GOM DPS.

F2.0 Implement Stocking Programs For Vacant Habitat Targeted at Preventing Extinction of Locally Adapted Stocks and Increasing Their Abundance and Distribution. This action will implement stock enhancement strategies focused on maximizing fitness and maintaining genetic diversity of the GOM DPS of Atlantic salmon. Ways that this action will be completed include:

F2.1 Prevent extinction of locally adapted stocks in all SHRUs by using diverse stocking strategies that protect and promote increased fitness and genetic diversity.

F2.2 Increase resiliency of all locally adapted stocks across the DPS by identifying and utilizing vacant habitats, including climate resilient habitats where they exist to create redundant populations.

F2.3 Develop and implement a stock reintroduction plans for vacant suitable habitats in all SHRUs.

F3.0 Identify, Maintain, Protect and Restore Priority Freshwater Habitats for Atlantic salmon. These efforts aim to conserve and restore properly functioning freshwater ecosystems that support biological requirements of all lifestages of Atlantic salmon. Ways that this action will be completed include:

F3.1 Establish and implement a water temperature monitoring protocol in all SHRUs to support efforts to identify climate vulnerable and climate resilient habitats.

F3.2 Inventory and prioritize freshwater habitats that provide the best opportunity for salmon recovery, including climate resilient habitats, in all SHRUs.

F3.3 Protect and maintain freshwater and riparian habitats according to prioritization in all SHRUs.

F3.4. Develop watershed restoration action plans for all SHRUs that identifies appropriate site specific actions necessary to restore ecological processes that promote and sustain properly functioning stream channels.

F3.5 Restore freshwater and riparian habitats according to the restoration action plans described in action F3.4.

F3.6 Conduct a detailed climate change risk analysis for all locally adapted salmon populations in the DPS to help prioritize actions and develop new ones that are necessary to support climate resilient populations.

F3.7 Review and if needed, revisit critical habitat designation to ensure that there is sufficient climate resilient habitats into the foreseeable future necessary to allow for Atlantic salmon survival and recovery.

F4.0 Implement Methods to Minimize Predation Pressures and Angling Pressure on Atlantic Salmon. Maximize survival of Atlantic salmon by reducing predatory and/or competitive interactions of other avian, mammalian, and/or piscine species and finding ways to minimize capture of Atlantic salmon by anglers. Ways that this action will be completed include:

F4.1 Identify, and when possible, remove derelict manmade structures that increase foraging opportunities for avian and mammalian predators on Atlantic salmon in all SHRUs.

F4.2 Identify and implement measures to minimize localized avian predation on hatchery-origin Atlantic salmon smolts in all SHRUs.

F4.3 Evaluate effects of mammalian predation on adult Atlantic salmon in all SHRUs, and if needed, implement measures to minimize predation.

F4.4 Identify and implement measures to avoid or minimize the spread of non-native species that prey on, or compete with Atlantic salmon in all SHRUs.

F4.5 Identify and implement measures to minimize competition with or predation on Atlantic salmon by non-native species in all SHRUs.

F4.6 Identify and reduce incidental catch of Atlantic salmon by regulatory area closure and/or angler education.

F5.0 Minimize Escapes and the Effects of Escaped Aquaculture Atlantic salmon on Local Populations. Protect locally adapted Atlantic salmon stocks from negative breeding and/or competitive interaction with commercially-reared salmon. Ways that this action will be completed include:

F5.1 Where capture facilities exist, monitor for and collect genetic samples of adult returns suspect of being from aquaculture origin.

F5.2 Develop and implement a contingency plan for capturing and culling escaped aquaculture origin Atlantic salmon within rivers without capture facilities.

F5.3 Ensure Federal and State permit include requirements for containment management plans to minimize escapes and the risks from escapes, and for such plans to be monitored for effectiveness.

F5.4 Ensure, when necessary, that Federal and State permits include requirements for the use of North American strain Atlantic salmon at aquaculture sites where escapes have the potential to interact with wild fish.

F5.6 Ensure, when necessary, Federal and State permit include requirements for reporting escapes of farmed Atlantic salmon.

F5.7 Continue international efforts to coordinate escape reporting and permit requirements to minimize interactions of farmed salmon with wild salmon.

F6.0 Avoid and Minimize the Effects of Pollution, Water Use and Other Activities on Atlantic salmon and Their Habitats. Reduce the impact of agriculture, aquaculture, residential or commercial use on water levels and/or water quality. Ways that this action will be completed include:

F6.1 Review and update the State of Maine water quality standards to ensure they are protective of all lifestages of Atlantic salmon.

F6.2 Monitor waste-water and storm water discharge and associated pollutants to ensure that effects to Atlantic salmon and their habitat are minimized.

F6.3 Install streamflow gauges or use other appropriate methods to monitor the effects of water withdrawal and implement measures to avoid and minimize effects of water withdrawals to all life stages of Atlantic salmon.

Marine and Estuary Actions (M): The goal of marine and estuary actions is to increase Atlantic salmon survival through increased ecosystem understanding and identification of spatial and temporal constraints to salmon marine productivity to inform and support management actions that improve survival.

M1.0 Continue Ongoing International Negotiations and Partnerships to Ensure U.S. Interests in Atlantic Salmon Conservation are Understood and Considered: Given the majority of U.S. salmon time at sea is in Canadian, Greenland, or international waters, partnerships and research networks are key to research and cost-savings. This includes fulfilling the U.S. role in international science-based management. Ways that this action will be completed include:

> **M1.1** Maintain an active U.S. management role at the North Atlantic Salmon Conservation Organization (NASCO) to improve at-sea distant water survival of Atlantic salmon through reduction of fishing mortality and evaluation of drivers of natural mortality at sea.
>
> **M1.2** Pursue opportunities outside NASCO to minimize the impact of intercept fisheries in Canada, St. Pierre et Miquelon, and Greenland on U.S. Atlantic salmon.
>
> **M1.3** Continue to participate in collaborative research initiatives through the International Atlantic Salmon Research Board, Canada Atlantic Salmon Research Joint Venture, Ocean Tracking Network, and U.S. Animal Tracking Network to strengthen knowledge and expertise while leveraging resources to study salmon seascapes and ecosystems (research).

M2.0 Continue Ongoing Research and Monitoring to Further Understand the Ecological Conditions that Allow Atlantic Salmon to Succeed in the Estuary and Marine Environment and the Factors that Impede Their Survival: Continued research and monitoring of Atlantic salmon in the estuary and marine environment is essential in understanding the conditions that salmon need to survive. This includes understanding salmon's interactions with other species, and changing foodweb dynamics that could have cascading effects that affect many commercially, and ecologically important species beyond salmon. Ways that this action will be completed include:

> **M2.1** Study marine prey base shifts to understand prey production dynamics, energy budgets, and distribution to inform management of forage to minimize impacts of climate change.
>
> **M2.2** Expand upon pilot studies (2012-2018) of the ecological role of co-evolved diadromous species.
>
> **M2.3** Seek opportunities to enhance resiliency of Atlantic salmon to changing conditions in the estuary and marine environment. Managing for resilience includes: (a) examining interactions of salmon with predators and parasites; (b) conducting smolt, post-smolt, and adult tracking studies to further investigate migration ecology; and (c) continue evaluation of existing marine related data for correlations at U.S., North American, and North Atlantic scales to better characterize the impact of oceanographic changes.

M3.0 Reduce Effects of Human Activities on Migratory Smolts/Post-Smolts in Estuary, Coastal, and Northeast Shelf Domestic Waters: The purpose of this action is to fulfill responsibilities under the ESA and the Atlantic salmon Fisheries Management Plan issued under the Magnuson-Stevens Fisheries Conservation and Management Act. The way that this action will be completed is:

> **M3.1** In response to project proposals, evaluate the effects of human activities on Atlantic salmon and their habitats in the estuary and marine environment using Section 7 and Section 10 of the ESA and propose measures, as appropriate, to minimize such effects.

<u>Outreach and Education Actions (O):</u> The goal of the outreach and education actions are to collaborate with partners and engage interested parties in recovery efforts for the GOM DPS.

O1.0 Inform Stakeholders and the Public of Sea-Run Fish Resources in Maine and the Importance of Protecting and Restoring the Ecosystems Upon Which They Depend. Help the target audience understand the role they play in salmon recovery and make more informed decisions about how their actions may affect the ecosystems that salmon depend on. Ways that this action will be completed include:

> **O1.1** Collaborate on preparation of outreach materials.
>
> **O1.2** Develop and maintain a website where information about all sea run fish, including their biology, ecology, and conservation, can be accessed.
>
> **O1.3** Participate in key outreach events with representatives from the full range of sea run fish restoration partners.
>
> **O1.4** Continue existing outreach programs in coordination with partners.

O2.0 Fulfill the Conservation Goals of the ESA by Engaging with Stakeholders and the Public to Guide the Implementation of Actions Necessary for the Recovery of Atlantic salmon. The purpose of this action is to promote conservation efforts that benefit Atlantic salmon and the ecosystems they depend on. Ways that this action will be completed include:

> **O2.1** Conduct Atlantic salmon framework meetings as a means for the agencies, stakeholders and the public to engage in dialogue on Atlantic salmon recovery efforts.
>
> **O2.2** Continue with the Atlantic salmon ecosystem forum as a means to learn of new science and management efforts that pertain to the restoration of Atlantic salmon and the ecosystems that they depend on.
>
> **O2.3** Work with federal agencies to find opportunities where they can use their authorities to further the conservation of Atlantic salmon as directed under Section 7(a)(1) of the ESA.
>
> **O2.4** Involve interested parties in the development and updating of SHRU-level workplans.

O3.0 Provide Training and Opportunities for Stakeholders to Increase Capacity in Implementing Recovery Efforts. The purpose of this action is to educate and ensure that the Endangered Species Act and its regulatory measures are clearly understood, articulated, and carried out by entities that directly affect recovery of Atlantic salmon and their ecosystems. Ways that this action will be completed include:

> **O3.1** Provide training on approaches to habitat restoration including road crossing and Section 6 funding resources.
>
> **O3.2** Conduct workshops and trainings on ESA requirements.
>
> **O3.3** Increase the number of received proposals to federal funding opportunities that support salmon recovery efforts by increased communication and outreach to stakeholders.

Federal/Tribal Coordination (T): The goal of Federal/Tribal Coordination is to ensure that federal agencies and associated programs continue to recognize and uphold Tribal Trust Responsibilities.

T1.0 Continue Federal/Tribal Engagement and Coordination: The federal trust responsibility, which originates from the unique, historical relationship between the United States and Indian tribes, consists of the highest moral and legal obligations that the federal government must meet to ensure the protection of tribal and individual Indian lands, assets and resources as well as treaty and similarly recognized rights. Through government-to-government consultation, defined as Consultation, the Federal government recognizes and distinguishes the views and policies of Federally-recognized American Indian and Alaska Native tribal governments from those of the general public and considers those views in the context of the responsibilities of Federally-recognized tribes to their people and tribal members (NOAA 13175 Policy). Agencies will carry out their obligations by committing to and completing these actions.

> **T1.1** Strengthen the government-to-government relationship with tribal nations and fulfill federal trust obligations.
>
> **T1.2** Ensure continued tribal representation in the co-management of Atlantic salmon.

Conservation Hatchery Actions (H): The goal of hatchery actions is to implement hatchery practices that maintain fitness and genetic diversity of the GOM DPS of Atlantic salmon.

H1.0 Implement Methods Necessary to Maintain and Promote Genetic Diversity of Salmon Populations in the Hatcheries: The purpose of this action is to implement hatchery practices that are necessary to protect and preserve the remaining genetic diversity that constitutes the GOM DPS of Atlantic salmon; ensure the continued existence of the species so that recovery in the wild can occur; and increase distribution and abundance as recovery efforts improve access and productivity of freshwater habitats. Ways in which this action will be completed include:

H1.1 Conduct annual fish health, disease, and biosecurity activities related to conservation hatcheries annual activities.

H1.2 Capture, collect and maintain captive, domestic, and sea run broodstock as necessary to preserve and maximize the genetic diversity of the GOM DPS and enhance, to the extent possible, the effective population size of the GOM DPS.

H1.3 Produce Atlantic salmon to be stocked as eggs and fry to increase freshwater selection and representation of locally adapted stocks, and minimize the loss of family groups during parr broodstock collections.

H1.4 Produce Atlantic salmon to be stocked as parr and smolts to increase marine selection and representation of locally adapted stocks, and minimize the loss of family groups during sea run adult broodstock collections.

H1.5 Investigate and implement alternative hatchery practices that increase survival of hatchery product in the wild and promote resilience to climate variability.

H1.6 Identify and implement hatchery practices that minimize the effects of domestication on remaining wild stocks of Atlantic salmon (examples might include selective breeding and marking programs).

H1.7 As necessary and appropriate for salmon recovery, develop broodstock programs in watersheds that currently do not have locally adapted breeding populations within the GOM DPS (e.g. Kennebec and Androscoggin rivers).

H2.0 Provide Hatchery Product Necessary to Support Science, Research and Assessments that are Needed to Evaluate Recovery Efforts and Assess Threats to the Continued Survival of the Species. Science and assessment is needed to further understand the threats that impede Atlantic salmon recovery as well as to evaluate the effectiveness of recovery efforts. In many circumstances, the use of Atlantic salmon is necessary to effectively carry out these actions. Ways in which this action will be implemented include:

H2.1 Identify by life stage, the numbers of GOM DPS origin Atlantic salmon that can be allocated to support survival studies at FERC dams, and other research and assessment efforts without compromising the hatcheries efforts to prevent extinction of the species and support recovery efforts.

H2.2 As appropriate and within the scope of H2.1, provide eggs to support research, threat assessments and recovery efforts for Atlantic salmon. This could include programs at private hatcheries, industry partners or academic institutions.

H2.3 As appropriate and within the scope of H2.1, produce Atlantic salmon to support upstream and downstream fish passage studies at hydroelectric and other fish passage structures/barriers within the GOM DPS.

Genetics Actions (G): The Goal of the Genetics actions are to maintain the genetic diversity and promote fitness of Atlantic salmon populations over time.

G1.0 Annually Characterize all Atlantic salmon Collected for use as Broodstock for Origin Determination and Genetic Variation. Genetic monitoring and analyses is a necessary component of managing Atlantic salmon in the conservation hatcheries. Genetic analyses allow for tracking of survival of Atlantic salmon eggs and fry stocked into rivers of origin, preventing the mating of siblings during spawning of hatchery salmon and maximizing overall diversity of hatchery brood stock. The ways that this action will be completed include:

> **G1.1** As needed, genetically screen Atlantic salmon that are suspected to originate from aquaculture escapes.
>
> **G1.2** Prioritize and implement ongoing genetic data analysis needs with respect to management goals and with the potential of considering new techniques and approaches.
>
> **G1.3** Manage data resulting from production, stocking, and genetic evaluation to facilitate program assessment and monitoring.
>
> **G1.5** Use genetic analyses to inform and improve best hatchery management practices.

G2.0 Use Genetic Data to Evaluate and Inform Recovery. Genetic information can be used to evaluate the health of wild populations and guide management to optimize diversity, fitness and resiliency of the GOM DPS. The ways this action will be completed include:

> **G2.1** Genetically analyze and evaluate management practices relating to DPS recovery.
>
> **G2.2** Use genetic analyses to guide efforts to increase distribution and abundance of locally adapted stocks among vacant habitats in the DPS.

Funding Programs (FP): The goal of these actions is to identify funding programs that support State, local and NGO conservation efforts that benefit Atlantic salmon recovery.

FP1.0: Provide Funds through Federal Grant Programs that Support Recovery Efforts for Atlantic Salmon: Various funding programs, some of which have been appropriated through Congress, support conservation and restoration efforts that benefit Atlantic salmon, and are not covered under the agencies' baseline budget. Ways that this action can be completed include:

> **FP1.1** Funding through NMFS and U.S. Fish and Wildlife ESA Section 6 programs that supports State and Tribal sponsored programs that benefit threatened and endangered species.
>
> **FP1.2** Funding through NMFS's Habitat Restoration Centers' Coastal and Marine Habitat Restoration Grants for projects that promote productive and sustainable fisheries, improve

the recovery and conservation of protected resources, and promote healthy ecosystems and resilient communities through the restoration of coastal habitats.

FP1.3 Funding through NMFS's Habitat Blue Print in support of restoration efforts on the Penobscot River.

FP1.4 Funding to support actions identified in SHRU-specific restoration work plans.

FP1.5 Provide funding, as available, for efforts that promote salmon conservation by minimizing interactions between Atlantic salmon and non-native fish.

B. Action Implementation

The following DPS-wide implementation table provides: the listing factor(s) that the action addresses (see Box 2 in section D, Threats to Species Viability), the action priority (see Box 3), the recovery phase(s) (see Part II), cost basis, estimated cost/year, estimated 5-year costs, cost rationale and responsible parties.

Actions where the costs are described as "baseline" are actions that can be completed under the existing baseline budget for NMFS, Maine DMR and the USFWS. The majority of these costs cover hatchery operations, fulfilling our obligations in implementing the ESA including Section 7 and Section 10, and active monitoring and assessment of population status and trends. Implementation of recovery actions covered under the baseline budget are based on Fiscal Year 2017 expenditures and inflation-based increases to cover increases in labor and operational costs including building leases and utilities. The FY 2017 budget dedicated to Atlantic salmon restoration among NMFS, Maine DMR Cooperative Agreement for Atlantic salmon programs, and the USFWS includes:

Greater Atlantic Regional Fisheries Office and NMFS Headquarters Offices……..$2,800,000.00
Northeast Fisheries Science Center: .. ………………………………………….. $2,257,000.00
Maine DMR Cooperative Agreement:...………………………………………………$877,000.00
U.S. Fish and Wildlife Service Hatchery Program:………………...…………………$2,000,000.00
U.S. Fish and Wildlife Service Ecological Services:………………...………………..$700,000.00
Total Atlantic salmon program budget (FY-2017):…………………...…...……...$8,634,000.00

Actions where the costs are described as "Calculated" or "Professional Judgement" represent recovery actions that are not currently funded under the baseline budget, and subsequently will require additional resources to implement. Actions where the costs are described as "N/A" represent actions where the estimated cost for implementation is currently unknown as more information is needed to make a reasonable estimate of cost.

Action priority numbers and recovery phases are closely aligned. Recovery phases are, however, based additionally on operational considerations such as feasibility and the need to complete one action in order to begin implementing another. For instance, despite the need to maintain adequate marine survival rates to prevent extinction, research on marine survival needs to be well underway or completed before effective management actions can commence; in this case, some Priority 1 actions may not be included in Recovery phase 1.

RECOVERY ACTION PRIORITY NUMBERS

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other negative impact short of extinction,

Priority 3: All other actions necessary to provide for the full recovery of the species.

Box 3.

Note that the timeframes and costs take the entire recovery period into account and thus provide the information needed for Part IV of this plan. It should also be noted that each recovery action either addresses one or more of the five listing factors *or* is directly related to arresting and reversing declining population trends in order to meet the biological recovery criteria in Part III of the plan.

For those recovery actions that are geographically based, the actions in this table will tier down to SHRU-level workplans that describe activities with a 5-year horizon. Regularly scheduled SHRU-level meetings will be held to identify potential projects and report on past accomplishments.

Table 1. **GOM DPS of Atlantic salmon DPS-wide recovery implementation table**

Action #	Action	Listing Factor	Priority	Phase	Cost Basis (Baseline, Calculated, Expert Opinion, N/A)	Estimated cost/year	Estimated cost between FY 19 and FY 23	Cost Rationale	Partners
CONNECTIVITY ACTIONS									
C1.0	**Identify and Prioritize Barriers to Atlantic salmon**								
C1.1	Identify and prioritize fish passage barriers in the Merrymeeting Bay SHRU necessary for the survival and recovery of Atlantic salmon	A	1	2	Baseline + expert opinion	$20,000.00	$100,000.00		NMFS, USFWS, Maine DMR, NGO's
C1.2	Identify and prioritize fish passage barriers in the Downeast Coastal SHRU necessary for the survival and recovery of Atlantic salmon	A	1	2	Baseline + expert opinion	$20,000.00	$100,000.00		NMFS, USFWS, Maine DMR, NGO's
C1.3	Identify and prioritize fish passage barriers in the Penobscot SHRU necessary for the survival and recovery of Atlantic salmon	A	1	2	Baseline	_	_	Prioritization is near completion for the Penobscot SHRU	NMFS, USFWS, Maine DMR, NGO's
C2.0	**Remove dams to ensure access to habitats necessary for Atlantic salmon Recovery**								
C2.1	Remove non-regulated dams in the Merrymeeting Bay SHRU as appropriate, and according to the barrier prioritizations	A	1	2	Calculated	$100,000.00	$500,000.00	Assumes an estimated $250,000/dam removal and an average of 2 removals every 5 years	Dam owners, NGO's, USFWS, NMFS

C2.2	Remove non-regulated dams in the Penobscot Bay SHRU as appropriate, and according to the barrier prioritizations	A	1	2	Calculated	$100,000.00	$500,000.00	Assumes an estimated $250,000/dam removal and an average of 2 removals every 5 years	Dam owners, NGO's, USFWS, NMFS, Tribes
C2.3	Remove non-regulated dams in the Downeast Coastal SHRU as appropriate, and according to the barrier prioritizations	A	1	2	Calculated	$50,000.00	$250,000.00	Assumes an estimated $250,000/dam removal and an average of 1 removal every 5 years	Dam owners, NGO's, USFWS, NMFS
C2.4	When feasible, remove hydro-electric dams that afford significant conservation benefit to Atlantic salmon and the ecosystems that they depend on.	A	1	2	N/A	_	_	Any removal would likely be done outside of the regulatory authority of the ESA through a negotiation process with the hydro industry and conservation partners. Subsequently the number of removals and the associated cost would likely vary considerably depending on the terms of an agreement.	Dam owners, NGO's, USFWS, NMFS
C3.0	**Improve Fish Passage at Dams to ensure access to habitats necessary for Atlantic salmon recovery**								
C3.1	Install fishways at non-FERC licensed dams in the Merrymeeting Bay SHRU as appropriate, and according to the prioritizations	A	2	2	Calculated	$100,000.00	$500,000.00	Assumes an estimated $250,000/fishway and an Average of 2 fishways every 5 years	Dam owners, NGO's, USFWS, NMFS
C3.2	Install fishways at non-FERC licensed dams in the Penobscot Bay SHRU as appropriate, and according to the prioritizations	A	2	2	Calculated	$100,000.00	$500,000.00	Assumes an estimated $250,000/fishway and an Average of 2 fishways every 5 years	Dam owners, NGO's, USFWS, NMFS, Tribes
C3.3	Install fishways at non-FERC licensed dams in the Downeast Coastal SHRU as appropriate, and according to the prioritizations	A	2	2	Calculated	$50,000.00	$250,000.00	Assumes an estimated $250,000/fishway and an Average of 1 fishways every 5 years	Dam owners, NGO's, USFWS, NMFS

C3.4	Install fishways at FERC licensed dams in the Merrymeeting Bay SHRU as appropriate, and according to the prioritizations	A	2	2	Calculated	$13,000,000.00	$65,000,000.00	Assumes 5 fish passage facilities at an estimated $13 million each at FERC licensed dams constructed before 2023.	Dam owners, USFWS, NMFS
C3.5	Install fishways at FERC licensed dams in the Penobscot Bay SHRU as appropriate, and according to the prioritizations	A	2	2	Calculated	N/A	N/A	Assumes no new fish passage facilities at FERC licensed dams constructed before 2023.	Dam owners, USFWS, NMFS
C3.6	Install fishways at FERC licensed dams in the Downeast Coastal SHRU as appropriate, and according to the prioritizations	A	2	2	Calculated	N/A	N/A	Assumes no new fish passage facilities at FERC licensed dams constructed before 2023.	Dam owners, USFWS, NMFS
C4.0	**Improve Fish Passage at Road Crossings**								
C4.1	Complete tier 1 road stream crossings according to the Maine DOT's Programmatic consultation for transportation projects (USFWS 2017) in the Merrymeeting Bay SRHU	A	2	2	Calculated	$80,262.00	$401,310.00	Assumes an average cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	MEDOT, Federal Highways
C4.2	Complete tier 1 road stream crossings according to the Maine DOT's Programmatic consultation for transportation projects (USFWS 2017) in the Penobscot Bay SHRU	A	2	2	Calculated	$80,262.00	$401,310.00	Assumes an average cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	MEDOT, Federal Highways
C4.3	Complete tier 1 road stream crossings according to the Maine DOT's Programmatic consultation for transportation projects (USFWS 2017) in the Downeast Coastal SHRU	A	2	2	Calculated	$68,796.00	$343,980.00	Assumes an average cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	MEDOT, Federal Highways

C4.4	Complete tier 2 road stream crossings according to the Programmatic consultation for transportation projects (USFWS 2017) in the Merrymeeting Bay SRHU	A	2	3	Calculated	$57,330.00	$286,650.00	Assumes an average cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	MEDOT, Federal Highways
C4.5	Complete tier 2 road stream crossings according to the Programmatic consultation for transportation projects (USFWS 2017) in the Penobscot Bay SHRU	A	2	3	Calculated	$57,330.00	$286,650.00	Assumes an average cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	MEDOT, Federal Highways
C4.6	Complete tier 2 road stream crossings according to the Programmatic consultation for transportation projects (USFWS 2017) in the Downeast Coastal SHRU	A	2	3	Calculated	$57,330.00	$286,650.00	Assumes an average cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	MEDOT, Federal Highways
C4.7	Install culverts and bridges that allow for unimpeded passage of all life stages of Atlantic salmon along municipally owned roads	A	2	2, 3	Calculated	$171,990.00	$859,950.00	Assumes 15 municipally owned culverts/year at an estimated cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	Municipalities, Tribal Governments, FEMA, USDA-NRCS, NGO's
C4.8	Install culverts and bridges that allow for unimpeded passage of all life stages of Atlantic salmon along privately owned roads	A	2	2, 3	Calculated	$171,990.00	$859,950.00	Assumes 15 municipally owned culverts/year at an estimated cost of $11,466/project over and above existing installation standards to ensure protections to Atlantic salmon	USDA-NRCS, Private Landowners, NGO's
C5.0	**Implement connectivity projects that ensure access to the co-evolved suite of diadromous fish that are part of the ecosystem that Atlantic salmon depend on**								

C5.1	Identify and prioritize fish passage barriers that maximize opportunities for the co-evolved suite of diadromous fish that are part of the ecosystem that salmon depend on	A	2	2, 3	Baseline	—	—	—	NMFS, USFWS, Maine DMR, NGO's, Tribes
C5.2	Remove dams according to the prioritization that maximize opportunities for the co-evolved suite of diadromous fish that are part of the ecosystem that salmon depend on	A	2	2, 3	Calculated	$100,000.00	$500,000.00	Assumes an estimated $250,000/dam removal; Avg of 2 removals every 5 years	Dam owners, NGO's, Maine DMR, USFWS, NMFS, Tribes
C5.3	Install fishways at dams according to the prioritization that maximize opportunities for the co-evolved suite of diadromous fish that are part of the ecosystem that salmon depend on	A	2	2, 3	Calculated	$150,000.00	$750,000.00	Assumes an estimated $250,000/fishway; Avg of 3 fishways every 5 years	Dam owners, NGO's, Maine DMR, USFWS, NMFS, Tribes
C6.0	**Science, Assessment and monitoring of barriers to fish passage**								
C6.1	Use the best available methods, including fish tagging and marking, to perform fish passage barrier assessments throughout the GOM DPS as necessary.	A	2	2	Calculated	$500,000.00	$2,500,000.00	Estimate assumes $125,000 per study averaging 4 studies per year.	Dam owners, Academia, USFWS, NMFS
C6.2	Determine the feasibility of connectivity projects that afford direct benefits to Atlantic salmon.	A	2	2	Calculated	$30,000.00	$150,000.00	assumes 3 feasibility studies every 5 years on dams that afford direct benefits to Atlantic salmon	Dam owners, NGO's, USFWS, NMFS

C6.3	Conduct engineering design and permitting for potential fish passage improvement projects that provide direct benefits to Atlantic salmon	A	2	2	Calculated	$30,000.00	$150,000.00	assumes 3 engineering and designs every 5 years on dams that afford direct benefits to Atlantic salmon	Dam owners, NGO's, USFWS, NMFS
C6.4	Determine the feasibility of connectivity projects that primarily benefit the co-evolved suite of sea-run fish the Atlantic salmon depend on	A	2	2	Calculated	$30,000.00	$150,000.00	assumes 3 feasibility studies every 5 years on dams that primarily benefit the co-evolved suite of searun fish that Atlantic salmon depend on	Dam owners, NGO's, USFWS, NMFS
C6.5	Conduct engineering design and permitting for potential fish passage improvement projects that primarily benefits the suite of searun fish that Atlantic salmon depend on	A	2	2	Calculated	$30,000.00	$150,000.00	assumes 3 engineering designs and permitting every 5 years on dams that primarily benefit the co-evolved suite of searun fish that Atlantic salmon depend on	Dam owners, NGO's, USFWS, NMFS
C6.6	As needed conduct pre- and post- barrier removal and fish passage improvement monitoring using up-to-date methods.	A	2	2	Baseline+ $200,000 calculated	$40,000.00	$200,000.00	_	Dam owners, NGO's, Academia, Maine DMR, USFWS, NMFS
C6.7	Establish Atlantic salmon passage efficiency targets that do not "jeopardize the continued existence" of the GOM DPS.	A, D	1	1	Baseline	$150,000.00	$750,000.00	_	NMFS
C6.8	Establish downstream and upstream Atlantic salmon passage design criteria for road stream crossings.	A	1	1	Baseline	_	_	_	USFWS
C7.0	**Permit, monitor and Enforce regulations related to barriers to fish passage**								

C7.1	Complete ESA section 7 programmatic consultations with action agencies on road stream crossing improvement projects that effect Atlantic salmon	A	1	1	Baseline	_	_	_	MEDOT, ACOE, FEMA, USFWS, NMFS
C7.2	Prioritize regulatory mechanisms that maintain and promote connectivity within designated critical habitat.	A, D	1	1	Baseline	_	_	_	NMFS, USFWS
C7.3	Conduct compliance monitoring of fish passage efficiency targets and carry out enforcement actions when necessary.	A, D	1	2, 3	Baseline	_	_	_	NMFS, USFWS
C7.4	Carry out consultation pursuant to Section 7 of the ESA on authorizations, funding or permits for potential fish passage improvement projects	A	1	2, 3	Baseline	_	_	_	NMFS, USFWS

FRESHWATER ACTIONS									
F1.0	**Evaluate distribution and abundance of naturally-reared Atlantic salmon and hatchery products**								
F1.1	Enumerate smolt populations to assess freshwater productivity, hatchery product survival.	A	1	ALL	Baseline	_	_	_	Maine DMR

F1.2	Monitor and assess instream young-of-year and parr to evaluate freshwater productivity, early lifestage survival from egg to smolt, and hatchery product fitness and survival in all SHRUs	A	1	ALL	Baseline	_	_	_	Maine DMR
F1.3	Conduct redd counts to estimate adult Atlantic salmon escapement and assess natural re-colonization within the range of the GOM DPS	A	1	ALL	Baseline	_	_	_	Maine DMR
F1.4	Enumerate returns of adult Atlantic salmon captured at fish trapping facilities within the range of the GOM DPS	A	1	ALL	Baseline	_	_	_	Maine DMR
F2.0	**Implement stocking programs for vacant habitat targeted at preventing extinction of locally adapted stocks and increasing their abundance and distribution**								
F2.1	Prevent extinction of locally adapted stocks in all SHRUs by using diverse stocking strategies that protect and promote increased fitness and genetic diversity	A, E	1	2	Baseline	_	_	_	Maine DMR, USFWS
F2.2	Increase resiliency of all locally adapted stocks across the DPS by identifying and utilizing vacant habitats, including climate resilient habitats where they exist to create redundant populations	A, E	1	2	Baseline	_	_	_	Maine DMR, USFWS
F2.3	Develop and implement a stock reintroduction plans for vacant habitats in all SHRUs	A, E	2	2	Baseline	_	_	_	Maine DMR, USFWS

F3.0	**Identify, maintain, protect and restore priority freshwater habitats for Atlantic salmon**								
F3.1	Establish and implement a water temperature monitoring protocol in all SHRUs to support efforts to identify climate vulnerable and climate resilient habitats	A	1	1	Baseline	—	—	—	USFWS, Maine DMR, NMFS, NGO's
F3.2	Inventory and prioritize freshwater habitats that provide the best opportunity for salmon recovery, including climate resilient habitats, in all SHRUs	A	1	1	Baseline	—	—	—	Maine DMR, USFWS
F3.3	Protect and maintain freshwater and riparian habitats according to prioritization in all SHRUs	A	1	2	Calculated	$5,000,000.00	$25,000,000.00	Estimate's assumes $5 million annual investment of roughly 45,000 acres/year that would provide some conservation benefit to salmon. This figure is estimated based on land acquisition efforts for the purpose of conservation made by the Lands for Maine's future program. This figure does not directly factor in restoration of freshwater habitats but it assumes that some fraction of the $5 million dollar investment would be used for these purposes if it were deemed appropriate.	Lands For Maine's Future, Maine DMR, USFWS, NMFS, NGOs,
F3.4	Develop watershed restoration action plans for all SHRUs that identifies appropriate site specific actions necessary to restore ecological processes that promote and sustain properly functioning stream channels	A	2	2	Baseline	—	—	—	Maine DMR, USFWS, NMFS, Tribes, NGO's

F3.5	Restore freshwater and riparian habitats according to the restoration action plans described in action F3.5	A	2	2	Expert Opinion	$50,000	$250,000.00	_	Maine DMR, USFWS, NMFS, Tribes, NGO's
F3.6	Conduct a detailed climate change risk analysis for all locally adapted salmon populations in the DPS to help prioritize actions and develop new ones that are necessary to support climate resilient populations	A, E	1	1	Expert Opinion	$150,000.00	_	_	Maine DMR, USFWS, NMFS, Tribes, NGO's, Acadamia
F3.7	Review and if needed, revisit critical habitat designation to ensure that there is sufficient climate resilient habitats into the foreseeable future necessary to allow for survival and recovery	A, E	2	1	Baseline	_	_	_	NMFS, USFWS
F4.0	**Implement methods to minimize predation pressures and angling pressures on Atlantic salmon**								
F4.1	Identify, and when possible, remove derelict manmade structures that increase foraging opportunities for avian and mammalian predators on Atlantic salmon in all SHRUs	C	3	2	expert opinion	$10,000.00	$50,000	_	Maine DMR, NGO's
F4.2	Identify and implement measures to minimize localized avian predation on hatchery-origin Atlantic salmon smolts in all SHRUs	C	3	2	expert opinion	$10,000.00	$50,000.00	_	USFWS, NMFS, Maine DMR, NGOs

F4.3	Evaluate impact of mammalian predation on adult Atlantic salmon in all SHRUs, and implement, if needed measures to minimize predation	C	3	3	N/A	_	_	_	USFWS, NMFS, Maine DMR, Acadamia
F4.4	Identify and implement measures to avoid or minimize the spread of non-native species that prey on, or compete with Atlantic salmon in all SHRUs	C	1	2	Expert opinion	$20,000.00	$100,000.00	_	Maine DMR, Maine DIFW, Acadamia
F4.5	Identify and implement measures to minimize competition with or predation on Atlantic salmon by non-native species in all SHRUs	C	2	2	Expert opinion	$10,000.00	$50,000.00	_	Maine DMR, Maine DIFW, Acadamia
F4.6	Identify and reduce incidental bycatch of Atlantic salmon by regulatory area closure and/or angler education	B, C	2	1	Expert opinion	$30,000.00	$150,000.00	_	Maine DMR, Maine DIFW, NGO's
F5.0	**Minimize escapes and the effects of escaped aquaculture Atlantic salmon on local populations**								
F5.1	Where capture facilities exist, monitor for and collect genetic samples of adult returns suspect of being from aquaculture origin	C	1	ALL	Expert Opinion	$50,000.00	$250,000.00	Cost estimates based on resource needs from previous escapes	Maine DMR, USFWS, NMFS
F5.2	Develop and implement a contingency plan for capturing and culling escaped aquaculture origin Atlantic salmon within rivers without capture facilities	C	1	ALL	expert opinion	$50,000.00	$250,000.00	Cost estimates based on resource needs from previous escapes	Maine DMR, USFWS, NMFS, Commercial Aquaculture

F5.3	Ensure when necessary, that Federal and State permit include requirements for containment management plans to minimize escapes and the risks from escapes, and for such plans to be monitored for effectiveness	C	1	ALL	Baseline	—	—	—	Maine DMR, Commercial Aquaculture, NMFS
F5.4	Ensure when necessary, that Federal and State permits include requirements for the use of North American strain Atlantic salmon at aquaculture sites where the potential for escapes have the potential tomay interact with wild fish.	C	1	ALL	Baseline	—	—	—	Maine DMR, Commercial Aquaculture, NMFS
F5.6	Ensure when necessary, that Federal and State permit include requirements for reporting escapes of farmed Atlantic salmon	C	1	ALL	Baseline	—	—	—	Maine DMR, Commercial Aquaculture, NMFS
F5.7	Continue international efforts to coordinate escape reporting and permit requirements to minimize interactions of farmed salmon with wild salmon	C	1	ALL	Baseline	—	—	—	NMFS, Dept. of Fisheries and Oceans - Canada.
F6.0	**Avoid and minimize the effects of pollution, water use and other activities on Atlantic salmon and their habitats**								
F6.1	Review and update the State of Maine water quality standards to ensure they are protective of all lifestages of Atlantic salmon	A	2	ALL	Baseline	—	—	—	Maine DEP, Maine DMR
F6.2	Monitor waste-water and storm water discharge and associated pollutants to ensure that effects to Atlantic salmon and their habitats are minimized	A	2	ALL	Baseline	—	—	—	Maine DEP, Maine DMR

F6.3	Install streamflow gauges or use other appropriate methods to monitor the effects of water withdrawal and implement measures to avoid and minimize effects of water withdrawals on all life stages of Atlantic salmon	A, E	2	ALL	Expert Opinion	$234,000.00	$450,000.00	Install 3 gauges/SHRU at $20,000/gauge and annual maintenance of $6,000	Maine DMR, USGS

MARINE AND ESTUARY ACTIONS									
M1.0	**Continue ongoing international negotiations and partnerships to ensure U.S. interests in Atlantic salmon conservation are understood and considered**								
M1.1	Maintain an active U.S. role at NASCO to improve at-sea distant water survival of Atlantic salmon through reduction of fishing mortality and evaluation of drivers of natural mortality at sea.	B, E	1	2	Baseline	—	—	ongoing with 3% annual increase in cost	State Department, NASCO, NMFS, Atlantic Salmon Federation
M1.2	Pursue opportunities outside NASCO to minimize the impact of intercept fisheries in Canada, St. Pierre et Miquelon, and Greenland on U.S. Atlantic salmon.	B	2	1	Baseline	—	—	ongoing with 3% annual increase in cost	Atlantic Salmon Federation, Department of Fisheries and Oceans Canada, State Department, NMFS

M1.3	Continue to participate in collaborative research initiatives through the International Atlantic Salmon Research Board, Canada Atlantic Salmon Research Joint Venture, Ocean Tracking Network, and U.S. Animal Tracking Network to strengthen knowledge and expertise while leveraging resources to study salmon seascapes and ecosystems (research).	B, E	1	1	Baseline	_	$475,000.00	Ongoing with 5% annual increase in cost. Due to increased costs, additional resources ($95 K annually) would be needed for this element in FY2021, or reduction is scope.	Atlantic Salmon Federation, Department of Fisheries and Oceans Canada, BOEM, Navy, NMFS
M2.0	**Continue ongoing research and monitoring to further understand the ecological conditions that allow Atlantic salmon to succeed in the estuary and marine environment and the factors that impede their survival**								
M2.1	Study marine prey base shifts to understand prey production dynamics, energy budgets, and distribution to inform management of forage to minimize impacts of climate change.	E	1	1	Baseline	_	_	ongoing with 5% annual increase in cost	Department of Fisheries and Oceans Canada and Greenland Institute of Natural Resources, Academia, NMFS
M2.2	Expand upon pilot studies (2012-2018) of the ecological role of co-evolved diadromous species.	C, E	3	1	Calculated	$145,000.00	$802,000.00	contractor with boat, seasonal technician, and supplies & equipment, 5% annual increase in cost	NGO's, Academia, NMFS

M2.3	Seek opportunities to enhance resiliency of Atlantic salmon to changing conditions in the estuary and marine environment. Managing for resilience includes: (a) examining interactions of salmon with predators and parasites; (b) conducting smolt. Post-smolt, and adult tracking studies to further investigate migration ecology; and (c) continue evaluation of existing marine related data for correlations at U.S., North American, and North Atlantic scales to better characterize the impact of oceanographic changes.	C, E	1	1	Calculated	$160,000.00	$884,000.00	2-3 year post-docs with research and analysis budgets with 5% annual increase in cost	Department of Fisheries and Oceans Canada, BOEM, Navy, Academia, NMFS
M3.0	**Reduce effects of human activities on migratory smolts/posts-molts in estuary, coastal, and Northeast Shelf domestic waters**								
M3.1	Evaluate the effects of human activities that affect Atlantic salmon and their habitats in the estuary and marine environment using Section 7 and Section 10 of the ESA and propose measures, as appropriate, to minimize such effects.	D	2	1	Baseline	—	—	ongoing with 5% annual increase in cost	Maine DMR, Atlantic Salmon Federation, Department of Fisheries and Oceans Canada, BOEM, Navy, NMFS

Outreach and Education Actions									
O1.0	**Inform stakeholders and the public of sea-run fish resources in Maine and the importance of protecting and restoring the ecosystems upon which they depend.**								
O1.1	Collaborate on preparation of outreach materials.	A	2	2	Baseline	_	_	_	USFWS, Sea Grant, NGO's, NMFS, Maine DMR, Tribal Partners
O1.2	Develop and maintain a website where basic information about all sea run fish, including their biology, ecology, and conservation, can be accessed.	A	2	2	Baseline	_	_	_	NMFS
O1.3	Participate in key outreach events with representatives from the full range of sea run fish restoration partners.	A	2	2	Baseline	_	_	_	USFWS, Sea Grant, NGO's, NMFS, Maine DMR, Tribal Partners
O1.4	Continue existing outreach programs in coordination with partners.	A	2	2	Baseline	_	_	_	USFWS, Sea Grant, NGO's, NMFS, Maine DMR, Tribal Partners
O2.0	**Fulfill the conservation goals of the ESA by engaging with stakeholders and the public to guide the implementation of actions necessary for the recovery of Atlantic salmon**								
O2.1	Conduct Atlantic salmon framework meetings as a means for the agencies, stakeholders and the public to engage in dialogue on Atlantic salmon recovery efforts	A	2	2	Baseline	_	_	_	USFWS, NMFS, Maine DMR, Tribal Partners

O2.2	Continue with the Atlantic salmon ecosystem forum as a means to learn of new science and management efforts that pertain to the restoration of Atlantic salmon and the ecosystems that they depend on	A	2	2	Baseline	_	_	_	NMFS
O2.3	Work with federal agencies to find opportunities where they can use their authorities to further the conservation of Atlantic salmon as directed under Section 7(a)(1) of the ESA.	A	2	2	Baseline	_	_	_	USFWS, NMFS, ACOE, FERC, USDA/NRCS, Federal Highways
O2.4	Involve interested parties in the development and updating of SHRU-level workplans	A	2	2	Baseline	_	_	_	USFWS, NMFS, Maine DMR, NGO's, Tribal Partners
O3.0	**Provide training and opportunities for stakeholders to increase capacity in implementing recovery efforts**								
O3.1	Provide training on approaches to habitat restoration including road crossing and Section 6 funding resources	A	2	2	Baseline	_	_	_	USFWS, NMFS
O3.2	Conduct workshops and trainings on ESA requirements	A	2	2	Baseline	_	_	_	USFWS, NMFS
O3.3	Increase the number of received proposals to federal funding opportunities that support salmon recovery efforts by increased communication and outreach to stakeholders.	A	2	2	Baseline	_	_	_	USFWS, NMFS

FEDERAL/TRIBAL COORDINATION ACTIONS									
T1.0	**Continued Federal/Tribal Engagement and Coordination**								
T1.1	Strengthen the government-to-government relationship with tribal nations and fulfill federal trust obligations.	A, B, D	1	1-4	Baseline	—	—	—	NMFS, USFWS, Tribes
T1.2	Ensure continued tribal representation in the co-management of Atlantic salmon.	A, B, D	1	1-4	Baseline	—	—	—	NMFS, USFWS, Tribes

CONSERVATION HATCHERY ACTIONS									
H1.0	**Implement methods necessary to maintain and promote genetic diversity of salmon populations in the hatcheries**								
H1.1	Conduct Annual Fish Health, Disease, and Biosecurity Activities related to conservation hatcheries annual activities.	C	1	2	Baseline	—	—	—	USFWS
H1.2	Capture, collect and maintain captive, domestic, and sea run broodstock as necessary to preserve and maximize the genetic diversity of the GOM DPS and enhance, to the extent possible, the effective population size of the GOM DPS.	A, E	1	2	Baseline	—	—	—	USFWS, Maine DMR

H1.3	Produce Atlantic salmon to be stocked as eggs and fry to increase freshwater selection and representation of locally adapted stocks, and minimize the loss of family groups during parr broodstock collections.	A, E	1	2	Baseline	—	—	—	USFWS, Maine DMR
H1.4	Produce Atlantic salmon to be stocked as parr and smolts to increase marine selection and representation of locally adapted stocks, and minimize the loss of family groups during sea run adult broodstock collections.	A, E	1	2	Baseline	—	—	—	USFWS, Maine DMR
H1.5	Investigate and implement alternative hatchery practices that increase survival of hatchery product in the wild and promote resilience to climate variability.	A, E	2	2	Baseline	—	—	—	USFWS, NMFS, Maine DMR
H1.6	Identify and implement hatchery practices that minimize the effects of domestication on remaining wild stocks of Atlantic salmon (examples might include selective breeding and marking programs).	A, E	2	2	Baseline	—	—	—	USFWS, Maine DMR
H1.7	As necessary and appropriate for salmon recovery, develop broodstock programs in watersheds that currently do not have locally adapted breeding populations within the GOM DPS (e.g. Kennebec and Androscoggin rivers).	A, E	2	2	Baseline	—	—	—	USFWS, NMFS, Maine DMR

H2.0	**Provide hatchery product necessary to support science, research and assessments that are needed to evaluate recovery efforts and assess threats to the continued survival of the species**								
H2.1	Identify by life stage, the numbers of GOM DPS origin Atlantic salmon that can be allocated to support survival studies at FERC dams, and other research and assessment efforts without compromising the hatcheries efforts to prevent extinction of the species and support recovery efforts.	A	2	2	Baseline	_	_	_	USFWS
H2.2	As appropriate and within the scope of H2.1, provide eggs to support research, threat assessments and recovery efforts for Atlantic salmon. This could include programs at private hatcheries, industry partners or academic institutions.	A, D	2	2	Baseline	_	_	_	USFWS, NMFS, Maine DMR, Academia
H2.3	As appropriate and within the scope of H2.1, produce Atlantic salmon to support upstream and downstream fish passage studies at hydroelectric and other fish passage structures/barriers within the GOM DPS.	A	2	2	Baseline	_	_	_	USFWS, NMFS, Maine DMR

GENETICS ACTIONS									
G1.0	**Annually characterize all Atlantic salmon collected for use as broodstock for origin determination and genetic variation**								
G1.1	As needed, genetically screen Atlantic salmon that are suspected to originate from aquaculture escapes	A, B, D	1	2	Baseline	_	_	_	USFWS, MDMR
G1.2	Prioritize and implement ongoing genetic data analysis needs with respect to management goals and with the potential of considering new techniques and approaches.	D	1	2	Baseline + Calculated	$75,000	$375,000.00	Calculated cost would allow for new techniques and analysis	USFWS
G1.3	Manage data resulting from production, stocking, and genetic evaluation to facilitate program assessment and monitoring.	D	1	2	Baseline	_	_	_	USFWS
G1.4	Use genetic analyses to inform and improve best hatchery management practices.	D	1	2	Baseline	_	_	_	USFWS
G.20	**Use of genetic data to evaluate and inform recovery**								
G.21	Genetically analyze and evaluate management practices relating to DPS recovery.	D	1	2	Calculated	$50,000	$ 250,000.00	Assumes supplies and salaries to do up to 1500 samples per year	USFWS, NMFS, MDMR
G2.2	Use genetic analyses to guide efforts to increase distribution and abundance of locally adapted stocks among vacant habitats in the DPS	A, D	1	2	Calculated	$50,000	$250,000.00	Assumes supplies and salaries to do up to 1500 samples per year	USFWS, NMFS, MDMR

FUNDING PROGRAM ACTIONS									
FP1.0	**Provide funds through federal grant programs that support recovery efforts for Atlantic salmon.**								
FP1.1	Continue to provide funding through NMFS and U.S. Fish and Wildlife ESA Section 6 programs that supports State and Tribal sponsored programs that benefit threatened and endangered species	A	2	2, 3	Expert Opinion	$500,000.00	$2,500,000.00	Based on best professional estimate of average funding demand on an annual basis	NMFS, USFWS
FP1.2	Continue to provide funding through NMFS's Habitat Restoration Centers' Coastal and Marine Habitat Restoration Grants for projects that promote productive and sustainable fisheries, improve the recovery and conservation of protected resources, and promote healthy ecosystems and resilient communities through the restoration of coastal habitats	A	2	2, 3	Expert Opinion	$1,500,000.00	$7,500,000.00	Based on best professional estimate of average funding demand on an annual basis	NMFS
FP1.3	Continue to provide funding through NMFS's Habitat Blue Print in support of restoration efforts on the Penobscot River	A	2	2, 3	Expert Opinion	$200,000.00	$1,000,000.00	Based on best professional estimate of average funding demand on an annual basis	NMFS
FP1.4	Provide funding to support actions identified in SHRU-specific restoration work plans	A	2	2, 3	Expert Opinion	$200,000.00	$1,000,000.00	Based on best professional estimate of average funding demand on an annual basis	Maine DMR, USFWS, NMFS
FP1.5	Provide funding, as available, for efforts that promote salmon conservation by minimizing interactions between Atlantic salmon and non-native fish.	A	2	2,3	Expert Opinion	$500,000.00	$ 2,500,000.00	Based on best professional estimate of average funding demand on an annual basis	Maine DMR, Maine IF&W, USFWS

PART V. TIME AND COST ESTIMATES

J. Time to Delisting

Recovery of the GOM DPS of Atlantic salmon is projected to take 75 years. This accounts for approximately 15 generations of salmon and is based on an assumed upper limit of available resources for implementation of recovery actions. It should be noted that both this time estimate and the cost estimate below are unavoidably speculative, given the uncertainties surrounding recovery of this DPS.

Estimating the time and cost for reclassification is equally difficult. The earliest possible time to reclassification is estimated to be 10 years (approximately two generations of salmon).

K. Cost of Recovery

Incremental costs of recovery are calculated at 5-year intervals. We estimate annual baseline costs that support staff, hatchery operations, fulfilling our obligations in implementing the ESA including Section 7 and Section 10, and active monitoring and assessment of population status and trends as approximately $8.6 million/year. We have estimated that the annual costs of implementing recovery actions over and above those actions covered under the baseline budget at $24 million per year, or approximately $120,000,000.00 over the next 5 years (2019 - 2023). Beyond five years, our ability to estimate costs become considerably more uncertain. One possibility we may be able to assume is that most of the cost of implementing recovery actions that address the significant threats to the species (dams, climate change, road crossings, marine survival and the West Greenland Fishery) will likely be borne over the next 15 -years as they are our highest priority actions that require our most immediate attention. Under this scenario, the estimated cost to address the high priority actions over 15 years in conjunction with the baseline costs would be in the range of $446 million. We may also be able to assume that the baseline cost of $8.6 million/year (discounting inflationary costs) may continue until populations become less dependent on hatcheries whereby the need for hatchery support and hatchery assessments would decrease. If we assume a $3 million decrease in program budgets after 25 years, the estimated annual baseline cost would decrease to approximately $5.6 million per year. Based on all these assumptions the estimated total cost of recovery may be in the order of $858 million over the 75-year timeframe needed to achieve recovery.

We should also note that many of the most costly actions such as removing dams, installing fishways, and infrastructure improvements at road crossings will also afford direct benefits to many other species including commercially important alewives and American eel, and recreationally important species such as American shad. Some actions, such as infrastructure improvements at road crossings using stream simulation design that ensure fish passage for Atlantic salmon and other fish, has been shown to afford substantial societal and economic benefit relative to the initial investment at these crossings, by significantly increasing structural resilience to storm events (Gillespie et al. 2014). Other ancillary benefits of implementing recovery actions would also include improvements in water quality and flow in salmon rivers, enhanced understanding of sustainable management for numerous freshwater and marine resources that are part of the ecosystems that salmon live, and additional reduction in environmental stressors that affect salmon and the surrounding ecosystems that salmon depend on. We emphasize that this cost estimate involves a high degree of uncertainty about the actual trajectory of the recovery program over the long term. It is, therefore, highly subject to change and should not be used with any intent other than meeting our legal requirement to provide the public with our best understanding of the general level of effort and expense to achieve the plan's goal of recovering the Atlantic salmon GOM DPS.

L. Assessing Recovery Priority

The USFWS and NMFS have adopted separate processes for identify Recovery Priority. Both agencies use the recovery priority numbers to prioritize recovery planning and implementation. The recovery priority for each agency is reassessed at least biannually, as part of the agency's biennial reports to congress on recovering threatened and endangered species under the ESA

The USFWS and NMFS will use their processes to determine recovery priority for Atlantic salmon and will work collaboratively to ensure that any differences are clearly identified and explained. Both agencies will revisit these priority determinations on a biannual basis. This assessment, will inform prioritizing implementation of the actions outlined in this recovery plan.

Additionally, as part of the implementation of the ESA, we are obligated to carry out reviews of the status of the DPS every 5 years. NMFS and FWS follow joint guidance on the development of 5-year reviews. The 5-year review gathers current information on a species and determines whether recovery plan criteria have been met. NMFS announced initiation of a 5-year review of the status of Atlantic salmon in 2018. We expect that review will be published in 2019. In the 5-year review, we can determine whether the species should:

1. Be removed from the ESA
2. Be changed in status from an endangered species to a threatened species
3. Or, Maintain the species' current classification status

Any recommendation to reclassify or delist Atlantic salmon would have to proceed through a formal rule making process.

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APPENDIX: LIST OF POSTED SUPPORTING MATERIALS

- Companion Document
- Statement of Cooperation
- Consultation and Coordination with Indian Tribal Governments (EO 13175)
- Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar) (DRAFT). 2016
- Atlantic Salmon Recovery Framework
- Recovery Proposals Review and Approval Process
- Craig Brook and Green Lake National Fish Hatcheries Websites
- East Machias Aquatic Resource Center Website
- Final Atlantic Salmon Recovery Plan **2005**
- 2009 critical habitat rule
- 2009 Final Listing Rule
- SHRU-level workplans
- 2008 Strategic Plan for the Restoration of Diadromous Fish in the Penobscot River
- 2006 Broodstock Management Plan
- U.S. Forest Service Stream Simulation Methodology
- U.S. Atlantic salmon Assessment Committee Reports
- National Research Council's "Atlantic Salmon in Maine"

i) MDMR 1986 Strategic and Operational Plan for the Restoration of Shad and Alewives to the Kennebec River: Foreword

STRATEGIC PLAN

AND

OPERATIONAL PLAN

FOR THE RESTORATION OF

SHAD AND ALEWIVES

TO THE KENNEBEC RIVER ABOVE AUGUSTA

Prepared By:

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May, 1985
Revised August, 1986

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FOREWORD

The following two documents outline the Department of Marine Resources' Plan for the restoration of shad and alewives to their historical habitat in the Kennebec River above Augusta. This plan is dependent of the installation of a collection/ sorting/ trapping/ trucking/ passage facility at the Edwards Dam (FERC # 2389).

The Strategic Plan contains pertinent information concerning the Department's Goals and Objectives. The amount and location of spawning and nursery areas for shad and alewives are identified in Tables 1 and 2, along with the potential shad and alewife production within discrete areas of the watershed. The location of various dams, condition, height, and use are also documented.

The Operational Plan provides detail on how the Department of Marine Resources intends to implement Phase I of the Strategic Plan for the period 1986 through 1998. Also included is a "Fish Passage Action Plan" which lists the dams and dates for which fish passage will be necessary in order to implement restoration of shad and alewives.

A number of dam owners on the Kennebec River have formed the Kennebec Hydro Developer's Group (KHDG) to facilitate anadromous fish restoration in the basin. The attached agreement between the State of Maine and KHDG specifies the manner in which the anadromous fish restoration program will be implemented. This plan and agreement constitutes the basis for anadromous fish restoration in the Kennebec basin above Augusta and supercedes the previous restoration plan filed with the FERC in response to the Hydro Kennebec application, FERC #2322.

Spencer Apollonio

SPENCER APOLLONIO, COMMISSIONER
Maine Department of Marine Resources

j) MDMR 1986 Strategic and Operational Plan for the Restoration of Shad and Alewives to the Kennebec River Above Augusta

STRATEGIC PLAN

AND

OPERATIONAL PLAN

FOR THE RESTORATION OF

SHAD AND ALEWIVES

TO THE KENNEBEC RIVER ABOVE AUGUSTA

Prepared By:

Thomas S. Squiers, Jr.
Malcolm Smith
Department of Marine Resources
May, 1985
Revised August, 1986

Partially funded by U.S. Department of Commerce, National Marine Fisheries Service
P.L. 89-304 Anadromous Fish Act
Project: ME: AFC-23

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Spencer Apollonio

SPENCER APOLLONIO, COMMISSIONER
Maine Department of Marine Resources

k) 1986 Atlantic Salmon Management in the Kennebec River: A Status Report and Interim Management Plan

ATLANTIC SALMON MANAGEMENT IN THE KENNEBEC RIVER:

A status report and interim management plan

by

Kenneth F. Beland
Fishery Biologist
Atlantic Sea-Run Salmon Commission

April, 1986

FOREWORD

The following document outlines the Atlantic Sea-Run Salmon Commission's interim plan for Atlantic salmon restoration to the Kennebec River above Augusta. This plan is dependent upon the provision of fish passage to waters above the Edwards Dam (FERC #2389).

This document is not intended to stand alone as a management plan, but rather, is intended to supplement existing fisheries management plans prepared by the Maine Department of Inland Fisheries and Wildlife and Department of Marine Resources. It is the Commission's intention to develop a more comprehensive long-term plan for restoration of Atlantic salmon to the Kennebec drainage in the near future.

A number of dam owners on the Kennebec River have formed the Kennebec Hydro Developer Group (KHDG) to coordinate fish passage needs with anadromous fish restoration plans for the Kennebec. It is anticipated that ongoing planning and consultation between KHDG and the State fishery agencies will produce a joint fish passage development plan and anadromous fish restoration program that will facilitate the restoration of salmon, shad, and alewives to the Kennebec River drainage.

G. H. Manuel, Chairman
Atlantic Sea-Run Salmon Commission

Spencer Apollonio, Commissioner

Harlow Floyd, Commissioner

Atlantic Salmon Management in the Kennebec River: A Status Report and Interim Management Plan

April, 1986

Kenneth F. Beland
Fishery Biologist
Atlantic Sea-Run Salmon Commission

In their 1969 report on fishery management in the Kennebec River drainage, Foye et al. briefly described the history of the Atlantic salmon resource of the Kennebec River. They also presented data on the quantity and location of Atlantic salmon nursery habitat within the Kennebec watershed. At the time of that report, water pollution and impassable dams precluded the initiation of an Atlantic salmon restoration program for the Kennebec. This report is intended as an interim Atlantic salmon management supplement to the 1969 report, based upon current conditions in the Kennebec drainage.

Since 1969, water quality in the Kennebec River and its tributaries has improved considerably, as a result of improvements in the treatment of municipal and industrial wastewaters. Water pollution no longer precludes the restoration of Atlantic salmon in the Kennebec. Department of Environmental Protection water quality data have been summarized and are presented in Appendix A.

The Atlantic Sea-Run Salmon Commission's Strategic Plan for Atlantic salmon management targets the Kennebec River and the Group "C" rivers for Atlantic salmon restoration when resources for that project can be made available for the Kennebec without detracting from existing management and restoration programs, the Group "A" and Group "B" rivers, as outlined in that document.

The Kennebec River currently has a small population of Atlantic salmon below the Augusta dam, composed of hatchery strays from other rivers, as well as wild fish originating from tributaries below Augusta. The salmon runs in the Kennebec below Augusta are of uncertain magnitude, but are believed to number less than 200 adults in most years. Those salmon present in the Kennebec support a small fishery located below the Augusta dam. Atlantic salmon captures for the years 1973-1984 in the Kennebec River are presented in Table 1.

Self-sustaining Atlantic salmon populations co-exist with other coldwater and warmwater fisheries on several other Maine river systems. It is the Atlantic Sea-Run Salmon Commission's belief that an Atlantic salmon population and fishery can exist in the Kennebec watershed without jeopardizing existing fisheries.

Achieving the Atlantic Sea-Run Salmon Commission's long-term restoration goal for the Kennebec River is dependent upon the availability of adequate fish passage to areas of suitable habitat. As the first obstacle encountered by anadromous fish upon their return to the river, passage at the Augusta dam is critical to future salmon restoration efforts on the Kennebec River. The Augusta dam is not the only site requiring fish passage in order to begin salmon restoration on the Kennebec River. Although a minor amount of salmon nursery area exists between Augusta and Waterville in tributaries, most of the salmon rearing area in the Kennebec lies upstream from other impassable dams. Salmon habitat in the Kennebec and its tributaries below Madison is presented in Table 2.

Interim Atlantic salmon passage on the Kennebec River is needed until such time as significant numbers of hatchery salmon are committed to the Kennebec salmon restoration and a long-term fish passage program is adopted. The interim passage program for upstream fish passage will involve trapping at Augusta and transport of salmon to selected upstream areas, in a manner that makes use of their reproductive potential. Long-term fish passage needs involve upstream and downstream fish passage facilities at dams above Augusta.

The distribution of Atlantic salmon spawning and nursery habitat in the Kennebec River and tributaries below Madison is shown in Table 2. The data presented for the Winslow-Shawmut reach are based upon the FERC license application by Scott Paper Company for the Winston dam (Hydro-Kennebec Project), and only include nursery habitat located within the project area. The available data indicate that over 33,000 production units (100 square yards per unit) of suitable nursery area is present in the Kennebec watershed downstream of the Madison dam. Approximately one-half of that total (17,304 units) is located in the Sandy River sub-drainage. Other significant tributary habitat areas are Wesserunsett Stream and the Sebasticook River (Table 2).

Until hatchery fish surplus to present program needs could be made available for the Kennebec, salmon restoration would depend upon utilization of the reproductive potential of those salmon that presently return to the Kennebec. Such a passive restoration strategy would result in a slow increase in stock size in the Kennebec, but is dependent upon the provision of adequate upstream and downstream fish passage to assure that the existing spawning potential of the Kennebec River is used wisely. If an interim trap and transport program for Atlantic salmon is implemented for the Kennebec River, it is anticipated that salmon will be released into habitat areas above Augusta in a manner consistent with habitat capabilities. The first stage of such a program includes trib utaries to the Kennebec downstream of Waterville, which includes the Sebasticook River sub-drainage. It is estimated that approximately 250 adult salmon are required for full habitat utilization in this part of the drainage. Any salmon in excess of 250 would be available for transport to areas upstream of Waterville, and will be distributed according to the habitat requirement for each area.

As noted in Appendix A, portions of the Sebasticook River are presently considered marginal for salmonid fishes, due to water quality problems. Should any part of this drainage prove unsuitable for Atlantic salmon at such time as fish passage above Augusta is available, the allocation of salmon to that drainage would be modified accordingly.

Expanding the habitat availability and distribution of adult salmon in the Kennebec would greatly enhance the sport fishing potential of that river for Atlantic salmon. In the Kennebec River, Atlantic salmon fishing is presently limited to waters below the Augusta dam. Providing passage to areas upstream of the Edwards Dam will make sport fishing opportunity available in other portions of the watershed.

Sport fisheries in Maine rivers with self-sustaining populations currently harvest between 10 and 30 percent of the returning adult salmon, with the remaining fish making up the spawning escapement.

As Atlantic salmon restoration efforts on the Kennebec River expand, the Commission will probably adopt regulations that allow sport fishing opportunity to increase while severely restricting the harvest of large Atlantic salmon. Similar regulations have already been enacted on the Penobscot and St. Croix Rivers, with the objective of enhancing spawning escapement.

The Atlantic Sea-Run Salmon Commission will be preparing a comprehensive salmon management plan for the Kennebec River. As an interim measure, transport of salmon captured at Augusta or other suitable sites to upstream habitat areas in a sequential fashion will be an acceptable alternative to permanent fishways. As part of the development of long-term Atlantic salmon restoration plans for the Kennebec River drainage, the Commission will be working with the Department of Marine Resources and dam owners to develop a comprehensive program of upstream and downstream fish passage development for the benefit of anadromous fish restoration.

Table 1. Documented Atlantic Salmon Returns, Kennebec River, 1973-1984

Year	# Salmon	Comments
1973	30	Found dead below Augusta dam; 15 tagged hatchery strays, 14 untagged hatchery strays, 1 wild origin
1975	2	Caught by anglers; tagged hatchery strays
1976	2	Netted below Augusta; hatchery strays
1979	20+	6 caught by anglers; 2 wild, 4 hatchery strays; 14 seined or netted, some strays, others uncertain; several reported released by anglers
1980	4+	Caught by anglers; 2 hatchery strays, 2 unknown; others re-leased by anglers
1981	14	5 caught & kept by anglers; 3 hatchery strays, 2 of unknown origin; 9 others released by anglers
1982	24	21 caught & kept by anglers, unknown origin; 3 released by anglers
1983	18	12 caught & kept by anglers, unknown origin; 6 released by anglers
1984	1	Caught illegally in Bond Brook

Table 2. Atlantic Salmon Nursery Habitat, Kennebec River & tributaries below Madison

River Section	Nursery Habitat ($100\ yd^2$ units)	Minimum Spawning Escapement Requirements[1]
Below Augusta		
Bond Brook	176	12
Togus Stream	958	56
	1,134	68
Augusta-Waterville		
Sevenmile Brook	141	8
Sebasticook River		
Winslow-Burnham	3,300	196
above Burnham	879	52
	4,320	256
Waterville-Skowhegan		
Wesserunsett Stream	4,576	272
Martin Stream	642	38
Carrabassett Stream	432	26
Main Stem below Shawmut[2]	840	174
Main Stem above Shawmut	2,915	50
	9,405	560
Skowhegan-Madison		
Sandy River	17,304	1,028
Main Stem[2]	1,170	70
	18,474	1,098
Total Below Madison	33,362	1,982

[1] Spawning escapement requirements based upon 220 eggs per $100\ yd^2$ production unit, 50% females, 9 lbs. average, 7,400 eggs per female

[2] This figure is believed to underestimate the available habitat in this river reach

l) 1986 Appendix A Summary of Water Quality in the Kennebec River Basin

APPENDIX A

SUMMARY OF WATER QUALITY IN THE KENNEBEC RIVER BASIN

Prepared for the Atlantic Sea-Run Salmon Commission

by John Sowles; Maine Department of Environmental Protection

January, 1986

At the request of the Atlantic Sea-Run Salmon Commission, this water quality summary focuses on the Kennebec mainstem, Carrabassett River, Sandy River, Wesserunsett Stream, and Sebasticook River. Based on historical evidence showing that oxygen levels during winter did not present a problem to fish, even before 1978, field data were collected only between May and October. Occasionally some information is available on inorganic and organic compounds. Water quality in the Kennebec River Basin has improved dramatically since 1978 when most of the major discharges were treated for biochemical oxygen demand (B.O.D.) wastes. Data collected during the summers of 1983, 1984, and 1985 indicate that dissolved oxygen levels in most of the drainage exceed 80% saturation and 7.0 mg/l during the hottest days of summer. Exceptions do occur, however, which in some instances could limit use of particular stretches of water by salmonids.

The Carrabassett River and its tributaries contain high levels of oxygen (90% saturation). With the exception of Stanley Stream in Kingfield, dissolved oxygen was never observed to fall below 7.0 mg/l and exceeded $22^{o}C$ only on very warm days in the slower and wider portions. Stanley Stream in Kingfield is now in the process of being cleaned up as the Town constructs sewage treatment facilities. This should remove the only serious source of B.O.D. containing wastes from Carrabassett. In the headwaters, development, road building, and forest clearing has the potential of affecting water quality in the Carrabassett. For example, turbidity and siltation in the river increases sharply during heavy run-off events. While no obvious biological affects have been noted, the overall biological impact is not yet known.

The mainstem of the Sandy River has no known significant water quality problems based on samples collected from eight mainstem sites. Dissolved oxygen remained above the 75% saturation level throughout the season and biological monitoring indicated water quality was sufficient to support aquatic life indigenous to the Sandy River. Four tributaries, however, have depressed levels of oxygen considered marginal for salmonids. Cascade Brook, Farmington and Wilson Stream, North Chesterville have oxygen concentrations as low as 5.2 mg/l and 61% saturation. Little Norridgewock Stream, Chesterville has oxygen concentrations as low as 4.5 mg/l and 51% saturation. An unnamed stream in New Sharon which drains a now closed out oxidation lagoon is virtually anoxic during low flow and high temperatures. Minimum concentrations typically occur in late summer. These tributaries, however, do not significantly influence water quality in the mainstem of the Sandy River due to their small flow relative to that of the Sandy River. With the exception of these four tributaries, water quality in the Sandy River drainage is sufficient to support salmonid populations.

Water quality in Wesserunsett Stream was sampled only at one spot, near its confluence with the Kennebec River in Skowhegan. Dissolved oxygen was consistently above 80% saturation and temperatures did not exceed 24°C.

The Sebasticook River and its East Branch continue to have serious water quality problems. Between Newport and Clinton, summertime dissolved oxygen frequently falls below 5.0 mg/l and at times is less than 1.0 mg/l at Detroit. Even at Winslow, dissolved oxygen is as low as 5.7 mg/l or

65% saturation. During the rest of the year dissolved oxygen in the East Branch is considerably higher although it has been observed to be as low as 8.1 mg/l on occasion outside the summer months. The segment below Newport should improve markedly in 1986 when the town connects to its new treatment plant. An unknown influence on water quality below Newport is the effect of the Sebasticook Lake restoration project which involves a late summer drawdown. The water released is typically rich in nutrients due to algae. Since algae are also a source of B.O.D., night time oxygen levels below Newport may continue to experience a depression. The actual amount of the depression can not yet be predicted due to the overwhelming masking effect of Newport's presently untreated wastes. Above Sebasticook Lake, between Corinna and the lake, fish kills recently have been frequent. Benthic invertebrate analysis of that portion of the river reveals a very serious chronic toxicity problem. The segment below Corinna is now under study with toxicity tests being conducted to locate the source of the problem. No prognosis for this stretch can be made. Several tributaries to the East Branch Sebasticook also have poor water quality. Stetson Stream, Martin Stream, Carleton Stream and Mill Stream all experience low (less than 60%) dissolved oxygen levels in the summer.

The West Branch Sebasticook has no known problems even with a tannery in its headwaters. Toxicity tests using Daphnia pulex and Ceriodaphnia reticulata and dissolved oxygen levels support the concept that water quality is sufficient to support salmonids.

m） 1985 Lower Kennebec Inland Fisheries Overview

Appendix B

LOWER KENNEBEC RIVER

INLAND FISHERIES MANAGEMENT OVERVIEW

Prepared by:
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Department of Inland Fisheries and Wildlife
July 1985

LOWER KENNEBEC RIVER

INLAND FISHERIES MANAGEMENT OVERVIEW

July, 1985

During the mid 1960's, studies were undertaken by biologists of the Maine Department of Inland Fisheries and Game, (now the Maine Department of Inland Fisheries and Wildlife) to provide the Department with information on the river's inland and anadromous fishery resources. These studies led to the publication of Fish Management in the Kennebec River. This publication addressed potentials within the drainage for a variety of sport and commercial species, taking into account problems facing the Department in developing and realizing the full potentials for fish management in the drainage.

Fortunately, water quality in the main stem of the river and many of its tributaries has noticeably improved through the efforts of the Maine Department of Environmental Protection with cooperation from industries and municipalities. Water degradation from wood bark deposits associated with log driving has also been greatly reduced with the termination of log driving in the Kennebec. Water quality in the Kennebec River above the Edwards Dam in Augusta is presently suitable for the management of several species of inland and anadromous fish. Dissolved oxygen levels in the main stem and its principal tributaries are now adequate to support fish life. Oxygen levels of 5 p.p.m. or higher now occur during periods of warm weather and low flow, a noticeable improvement since the 1960's.

Restoration of anadromous fish in the drainage will require fish passage facilities at the Edwards Dam in Augusta. If not properly controlled, passage of undesirable fish, such as the carp and lamprey eel would be allowed through these facilities into the upper sections of the drainage. Since the extension of the range of these and other undesirable species such as the northern pike, calico bass, and largemouth bass into upper section of the drainage would adversely affect ongoing inland fisheries management programs, trapping and sorting facilities should be required at strategic fish passage facilities developed on the main stem of the Kennebec River. As a temporary measure, it will be necessary to capture anadromous fish at the Edwards Dam in Augusta and truck them to selected sections of the drainage, pending construction of additional fish passage and sorting facilities at upstream dams. The current upriver limits of several species of fish which could adversely impact ongoing inland fisheries management programs are shown in Figure 1.

Certain of the lakes and ponds of the Kennebec River that lie within the area proposed for restoration of anadromous fishes support a wide variety of gamefish species including landlocked salmon, brook trout, brown trout, and lake trout, among others. Introductions of anadromous alewives into the waters listed in Table 1 should be postponed until the impact of such introductions on existing inland fisheries is better understood. The interaction of anadromous alewives with salmonids, smelts, and other inland fish will be assessed through a cooperative research project sponsored by the Maine Department of Marine Resources and the Maine Inland Fisheries and Wildlife Department. Based upon the results of these studies a cooperative decision will be made regarding future alewife introductions into the listed waters.

Alewives may also interact with freshwater gamefish to the advantage of the latter. For example, in riverine situations, where smelts usually are not a significant part of the diet of coldwater gamefish, young alewives might provide forage for river dwelling salmonids. For instance, the Department of Inland Fisheries and Wildlife has recently initiated an experimental brown trout program in the lower reaches of the Kennebec River between Augusta and Skowehgan (see Appendix I). The initial phase of the project, which began with the first stocking of browns in the spring of 1983, is designed to determine if browns can survive in the river and provide fishing for a minimum of two angling seasons. Since the long term goal of this project is to provide a brown trout sport fishery with a catch rate of 0.20 trout per angler day and an average size of 1.5 pounds per fish, it is obvious that a good growth rate is essential to the program's success. Young alewives, migrating from upriver lake systems, will be available as forage for browns that occupy the river. In fact, juvenile alewives might be the most abundant forage in the lower Kennebec from late July into October and it is hoped that they will enhance brown trout growth.

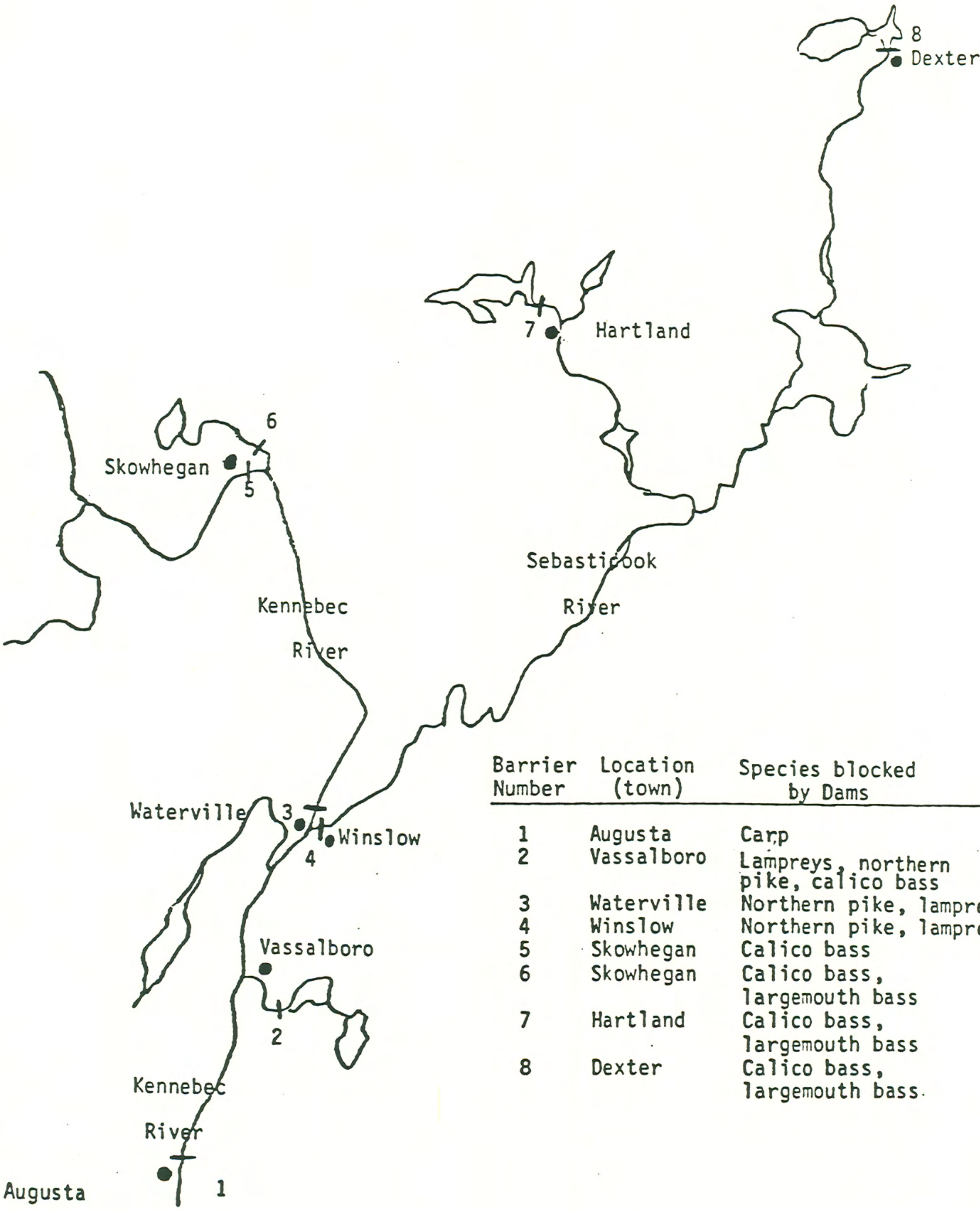
If the precautions noted above are carefully followed, the restoration of anadromous fishes to the Kennebec River should play an important role in maximizing the river's sport fishery potential.

TABLE 1.

WATERS IN WHICH PLANTINGS OF ANADROMOUS ALEWIVES ARE TO BE POSTPONED

WATER	LOCATION
NORCROSS POND	CHESTERVILLE
WILSON LAKE	WILTON
VARNUM POND	WILTON, TEMPLE
CLEARWATER LAKE	INDUSTRY, FARMINGTON
PORTER LAKE	STRONG, NEW VINEYARD
SPECTACLE POND	VASSALBORO, AUGUSTA
CHINA LAKE	CHINA, VASSALBORO
GREAT MOOSE POND	HARTLAND, HARMONY
WASSOOKEAG LAKE	DEXTER
BELGRADE CHAIN OF LAKES (ABOVE DAM IN OAKLAND)	BELGRADE, OAKLAND, ROME SMITHFIELD, SIDNEY, ETC.
LAKES OF COBBOSSEE STREAM DRAINAGE (ABOVE PLEASANT POND IN LITCHFIELD)	LITCHFIELD, MONMOUTH, MANCHESTER, WINTHROP, ETC.
BIG INDIAN POND	ST. ALBANS

Figure 1. Barriers to fish migration which restrict the range of Northern pike, calico bass (black crappie), largemouth bass, carp, and lamprey eels in the Kennebec River and its tributaries.



Barrier Number	Location (town)	Species blocked by Dams
1	Augusta	Carp
2	Vassalboro	Lampreys, northern pike, calico bass
3	Waterville	Northern pike, lampreys
4	Winslow	Northern pike, lampreys
5	Skowhegan	Calico bass
6	Skowhegan	Calico bass, largemouth bass
7	Hartland	Calico bass, largemouth bass
8	Dexter	Calico bass, largemouth bass.