The Crooked River: Characteristics, History, and Fisheries Management

Prepared by:

James Pellerin
Assistant Regional Fisheries Biologist
Urban D. Pierce, Jr.
Regional Fisheries Biologist (Retired)

Maine Department of Inland Fisheries and Wildlife

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Foreword

This report was originally initiated in 1983 as a Strategic Fisheries Management Plan for the Crooked River in response to the "Maine Rivers Act" of June 17, 1983, and to formalize and document specific objectives and procedures for managing this important fishery resource. Urban D. Pierce, Jr. drafted the initial report, but never finished due to his retirement from the Maine Department of Inland Fisheries Wildlife (MDIFW). The long and storied history of the Crooked River, its regional importance, extensive data collection efforts, and its significance to the landlocked salmon fishery of Sebago Lake warranted an update and completion of the report.

Portions of the early draft report prepared by Urban Pierce, Jr. are denoted in the table of contents by his initials (UP). Some of these sections are presented largely intact as originally written with only minor edits, whereas other sections have been updated or edited more extensively. Edits, updates, and the remainder of the report were written and compiled by the primary author, James Pellerin.

This report serves to document the extent and quality of the Crooked River's fishery resources, as well as past and present management by the MDIFW. This document also provides a guideline and reference source for the protection and enhancement of this valuable river resource for the future.

Introduction

This document provides an overview of the Crooked River, its fishery, and sets forth a plan for the management of landlocked Atlantic salmon (*Salmo salar*) (also referred to as "salmon") and brook trout (*Salvelinus fontinalis*). The terms "LLS" and "BKT" are used in some tables and graphs for brevity and refer to landlocked Atlantic salmon and brook trout, respectively.

The Crooked River is the single most important spawning and nursery tributary supporting the wild salmon sport fishery in Sebago Lake. The river has the potential to significantly, if not entirely, sustain Sebago Lake's salmon fishery with naturally produced fish. Aside from its importance as a spawning and nursery tributary for wild Sebago Lake salmon, the Crooked River also provides substantial recreational angling opportunity as a high quality riverine salmon fishery.

The Maine Department of Inland Fisheries and Wildlife (MDIFW) has been instrumental in the restoration of spawning runs of salmon and brook trout to the Crooked River since the 1970's. Prior to the early 70's, Sebago Lake salmon had been denied access to nearly all of the spawning and nursery grounds of the Crooked River for nearly 150 years, due to the presence of impassable dams. The obstruction of this major tributary was one of the greatest factors contributing to the decline of wild salmon and brook trout in Sebago Lake. In the late 1960's and early 1970's, two of the three major dams on the lower sections of the river were breached and a fishway was provided at the third. These changes afforded spawning salmonids access to nearly the entire river for the first time in over one and a half centuries. Today, significant numbers of wild salmon and brook trout are again being produced throughout the entire reach of the Crooked River.

There are 25 lakes in the Crooked River drainage, some of which are being actively managed for salmon and brook trout. The largest lake in the drainage is Pleasant Lake (1,077 acres) in Casco and Otisfield. There are also several tributary streams feeding into the main stem of the Crooked River. Most of these tributaries are relatively small, and compared to the main stem of the Crooked River support only limited salmon production. However, they are particularly important for brook trout as spawning and nursery habitat and for thermal refuge. Several of the larger tributaries provide salmon spawning and nursery habitat, but production potential for salmon is dwarfed by the main stem. In addition, the Wade Fish Hatchery and Rearing Station operated by MDIFW are located on Mile Brook, and serves as the major salmon rearing facility for southern Maine.

The first section of this report includes descriptions of the general characteristics of the drainage. Other sections describe the river's history, resources, fish species composition, species abundance, habitat quantity and quality, and the fisheries potential of the river. Based on an assessment of this information, the document then identifies MDIFW's management goals and objectives for the river (the fisheries management plan). Existing and potential problems that could prevent the successful attainment of the goal and objectives are also discussed. Management strategies deemed most appropriate at this time are also explored.

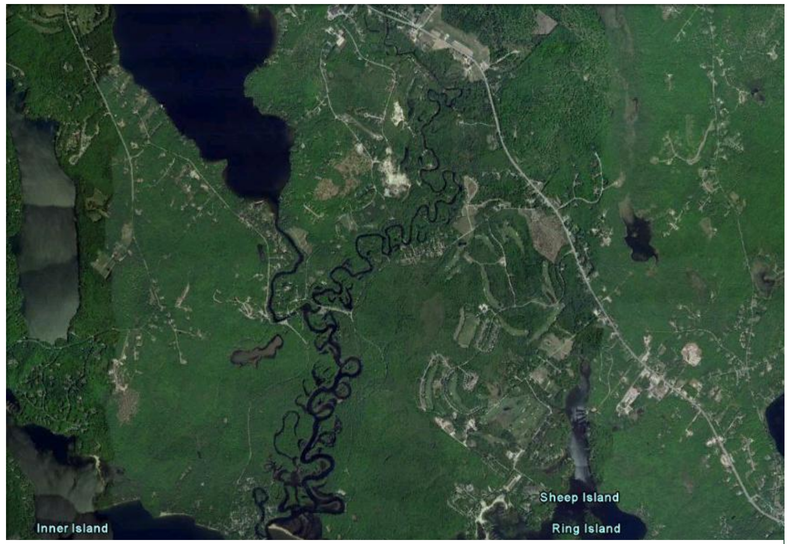
The fisheries management plan section of this document is based on the existing habitat potential of the Crooked River to support wild populations of salmon and brook trout. The management plan is not intended to be so rigid as to preclude changes that may be necessary to better manage this river's resources into the future. For example, we consider the Crooked River to have higher value for its production of wild salmon to Sebago Lake than for the fishing opportunity it provides the angling public, so the rapidly increasing popularity of riverine sport fisheries could necessitate additional fishing restrictions to maintain production goals.

Finally, although presented separately in this document, the management plan for the Crooked River is an integral component of the management plan for Sebago Lake (Brautigam and Pellerin 2008), and key management components in this document may also be incorporated into the lake plan.

Physical Description

General

The Crooked River watershed lies within southwestern Maine in south central Oxford County and in north central Cumberland County. It is bordered by the Androscoggin River watershed to the north and east, and portions of the Presumpscot and Saco River watersheds to the south and west. The Crooked River watershed is a sub-watershed of the Presumpscot River basin and is an indirect tributary to Sebago Lake, which has a surface area of approximately 45.6 mi^2. The Crooked River originates at Songo Pond in Albany and flows in a southerly direction through the townships of Albany, Waterford, Norway, Harrison, Otisfield, Naples, and Casco before it merges with the Songo River, which outlets into Sebago Lake at the Sebago Lake State Park (Photo 1). The mouth of the Crooked River at its confluence with the Songo River near the Songo Locks is approximately twenty miles northwest of Portland, twenty miles southwest of Auburn, and 110 miles north of Boston (USDA 1975). General maps of the Sebago Lake and Crooked River watersheds are presented in Appendices A and B.



Photograph 1. Satellite view of the Crooked River as it enters Sebago Lake, its clearly sinuous path was likely responsible for its name (Google Earth, 2011).

Seasonal and year-round residences are common on most of the lakes and ponds in the watershed. Some seasonal and year-round residential developments also exist at various points along the flood plain of the Crooked River.

Lumbering and land and water recreational uses are the principal enterprises in the drainage. Agriculture is very sparse with a few truck crop farms scattered around the watershed. Much of the historical open land has lain idle and is now reverting back to woodland (USDA 1975). The general development and land use trends reported by the USDA in 1975 have continued to the present and will be discussed in more detail later in the document.

Topography

The topography of the watershed is rolling and mountainous with the river being bordered by a ridge on each side, which forms the watershed divide for most of its approximate sixty-mile length (USDA 1975). The headwater lakes in the Crooked River, including Keewaydin Lake and Songo Pond in the northernmost portions of the basin, lie at elevations of 676 and 651 feet above mean seas level with the surrounding hills and subdued mountains rising another 600 to 1200 feet above them (NERBC 1981). The highest lake elevation in the basin is Mosquito Pond at 950 feet above mean sea level. Elizabeth Mountain near Miles Notch in the

White Mountain National Forest is the highest point of land in the watershed at 2,025 feet above mean sea level (USAD 1975).

The watershed area is part of the New England Upland physiographic region (NERBC 1981). Lakes in the drainage basin are generally connected by short, steep gradient streams that lie in narrow valleys with the relief generally less than 500 feet. At the southern end of the basin near Sebago Lake, the area is a gently undulating plain into which streams have cut gully-like shallow valleys. This area is part of the Seaboard Lowland region and has a relief that is generally less than 150 feet (NERBC 1981).

Songo Pond in Albany Township, considered to be the headwaters of the Crooked River, sits at an elevation of 651 feet above mean sea level. The water surface elevation of the Songo River at the mouth of the Crooked River is controlled by the water levels at Sebago Lake, which USGS topographic maps report as 267 feet above mean sea level. Actual lake water levels have varied over time. Currently (2015) water levels are controlled by a hydroelectric dam on the outlet of Sebago Lake, which is owned and operated by Sappi Fine Paper, formerly S.D. Warren. Lake water levels vary seasonally and are dictated by a lake water level management plan approved by the Department of Environmental Protection and the Federal Energy Regulatory Commission. This plan establishes a range of water levels that vary from 262 to 265.5 feet over the course of a year. Using USGS elevations, the total drop of the main stem river between Songo Pond and the Songo River is 384 feet for a gross slope of 0.17 percent or 7.1 feet per mile. However, there are many sections within the main stem river that have individual gradients exceeding 1.0 percent. Nearly fourteen percent of the total length of the main stem of the Crooked is classified as fast flowing white-water riffle habitat with thirteen and seventy three percent classified either as low gradient run or slow flowing flat-water habitat, respectively.

Bedrock Geology

Most of the Crooked River watershed is located in the Sebago Pluton, which consists of various grades and types of igneous rocks formed in the Carboniferous Period. These igneous rocks are granite compositions with biotite and biotite muscovite granite. The upper portions of the watershed near the townships of Albany, Bethel, and Waterford consist of older Devonian igneous rocks known as tonilite or platonic rock, which has a slightly higher mineral composition than granite. These rocks are often crossed by coarse-grained igneous intrusions of largely granite compositions called pegmatites. Minerals such as feldspar, mica, and beryl crystals are common in the basin pegmatites and in the past have been mined (NERBC 1981). Some of the largest beryl crystals in the world have been mined from the Bumpus Mine in Albany Township. The bedrock is exposed at several locations in the main stem river. All of the bedrock in the watershed exhibits very low buffering capacity and is sensitive to acidification from acid precipitation. For more specific information on the bedrock geology in the Crooked River drainage, refer to the Geologic Bedrock Map of Maine, 1985 (Appendix C).

Surficial Geology

The vast majority of the main stem of the Crooked River flows through deposits of glacial outwash materials of sand and gravel, which were created by melt-water streams in front of the receding late Wisconsin ice margin. Much of the watershed and small segments of the main stem is glacial till, which is a heterogeneous mixture of sand, silt, clay, and stones generally massive in size. Glacial till tends generally to be a blanket deposit that conforms to underlying bedrock topography and is deposited directly by the glacial ice. There are two areas of gravel and sand eskers, which are ridges, formed by melt-water streams flowing in tunnels within or beneath the Wisconsin ice sheet. These eskers are located in the Naples area and in East Stoneham east of Keewaydin Lake. There are also some small areas of ice contact glacial fluvial deposits of sand, gravel, and silt that were deposited by melt water streams adjacent to stagnant glacial ice (Thompson, et.al. 1985). All surficial deposits in the basin also exhibit low buffering ability and are highly sensitive to acidification from acidic precipitation. Alkalinities of all surface waters in the watershed are low reflecting the low buffering capacity of the bedrock and surficial geology present in the drainage. For more information on the surficial geologic deposits in the Crooked River watershed, refer to the Surficial Geologic Map of Maine, 1985 (Appendix D).

Soils

In Cumberland County the soils in the Crooked River basin include generally two associations, which vary according to their parent materials and their climatic and topographic settings. The Windsor or Adams-Hinckley-Deerfield association is found along and immediately adjacent to the main stem river. These soils overlay much of the glacial outwash deposits along the river. Soils in this association tend to be deep, excessively drained to moderately well drained coarse textured materials and found in reliefs that vary from nearly level to steep. The principal limitations of these major soil types are rapid permeability and seasonally high water tables. Because of the rapid permeability, groundwater contamination is a hazard in areas where septic tank systems are used. Also, in the watershed and outlying areas adjacent to the Windsor-Hinkley-Deerfield association is the Hermon-Peru-Paxton association. These soils also tend to be deep, somewhat excessively drained to moderately well drained and contain moderate size textured materials, but may also contain many coarse fragments. These soils are found on large rolling hills that have gently rounded crest with steep lower slopes. Lakes and ponds occupy most of the depressions between the hills, and small organic bogs tend to be numerous (USDA 1974).

In Oxford County the main stem of the Crooked River flows through four of the six soil associations identified in Oxford County, and all six associations occur within the watershed. The Adams-Croghan-Colton association accounts for most of area immediately along the main stem of the Crooked River. The Colonel-Brayton-Skerry association is found around Songo Pond and the upper main stem. The river flows through small areas of the Rumney-Podunk-Medomak and Hermon-Monadnock-Skerry associations along the Waterford/Norway border and near North Waterford, respectively. A summary of the primary characteristics of the main four associations are presented in Table 1 (USDA 1995).

Table 1. Basic characteristics of soil associations of the Crooked River in Oxford county.

Soil Association	Soil Depths	Drainage	Slope	Limitations
Adams-Croghan-Colton	very deep	excessive to moderately well drained	level to steep	droughtiness, rapid permeability, and slope
Colonel-Brayton-Skerry	very deep	moderately well to poorly drained	level to moderately steep	seasonal high water table, surface stones, and a compact substratum
Hermon-Monadnock-Skerry	very deep	excessively to moderately well drained	nearly level to steep	surface stones and boulders, slope
Rumney-Podunk-Medomak	very deep	moderately well to poorly drained	nearly level	flooding, seasonally high water table

Climate

Appendix E shows the mean temperature, precipitation, and snowfall normals for 1971-2000 for the Portland, Bridgton, and Rumford weather stations, which reflect the climatic conditions for the entire Crooked River watershed. More recent data normals (1981-2010) are also noted in the same Appendix, but were not utilized in the remainder of this section due to incomplete data for all sites. The climate for the watershed is characterized by cool to moderately warm summers, fairly cold winters and generally ample rainfall. The Atlantic Ocean has a moderating influence on the local climate more so during the summer than in the winter months. The climate of the inland sections of Cumberland County is described as more continental than maritime (USDA 1974). The mean temperature for the warmest month, July, is 68.7^{o}F for Portland, 67.2^{o}F for Bridgton, and 68.2^{o}F for Rumford, Maine (NOAA 2011). Average temperatures reaching 90 degrees or more usually occur less than 10 days during the summer. The mean temperature for the coldest month, January, is 21.7^{o}F for Portland, 16.5^{o}F for Bridgton, and 17.1^{o}F for Rumford, Maine (NOAA 2011).

The mean annual precipitation for the drainage area varies from 43-45.7 inches per year (NOAA2011). The seasonal distribution is fairly even by season with late summer and early fall being the drier months of the year. Summer rainfall usually amounts to twenty percent or more of the annual total, which is greater than that reported for most of the nation. Mean snowfall amounts are between 66.4-93.5 inches for the watershed. The average seasonal maximum depths on the ground at any time vary considerably from mid-late February. Water content of the snow cover varies from three to as much as eight inches in the upper reaches of the watershed. The total average annual runoff for the watershed varies from 20-24 inches per year (USDA 1975).

The basin lies in the path of the prevailing westerly winds that cross the country and is also exposed to coastal southeasterly and northeasterly storms, some tropical in origin, that travel up the Atlantic coast. These storms are frequently responsible for the major flooding within the drainage.

Drainage & Hydrology

The Crooked River, for most of its length, is by hydrologic definition a third order stream. From approximately the Edes Falls area downstream to its confluence with the Songo River, it is considered a fourth order stream. The watershed centroid length is approximately 61 miles. The total drop in elevation from its origin at Songo Pond to its confluence with the Songo River is 384 feet. The total drainage area of the Crooked River at its outlet is 154 mi^2, and it lies within the Songo River (275 mi^2) and Sebago Lake (440 mi^2) watersheds (Dudley e al, 2001). The Crooked River is the largest tributary to Sebago Lake and contributes nearly 40% of the total surface water inflow into the lake (PWD 2009).

Flows in the Crooked River are for the most part unregulated. The only exceptions are the lake level drawdowns conducted in the fall by some of the lake associations. There are 25 lakes and ponds in the watershed with a total surface area of 2,980 acres. These lakes and ponds range in size from two to 1,077 acres with a mean size of 119 acres (Appendix F). The relatively small number and acreage of the lakes and ponds in the drainage provide only limited storage capacity and have a limited effect on river base flows.

There are approximately 27 direct and at least 29 indirect tributaries discharging into the Crooked River. They total 92.7 stream miles; however, this figure does not include mileage for 7 of the indirect tributaries where stream length information was unavailable (Appendix G). Most of the tributaries are first and second order streams. The only third order stream is Mile Brook located in Casco, which outlets into the Crooked River approximately one mile below Edes Falls.

The Crooked River was gauged at three locations in 1975, 1976, and 1977 by the U.S.G.S. to characterize stream flows. The highest flows recorded for the period were observed in April and the lowest in August. April flow rates averaged 5.9 cubic feet per square mile of drainage area (cfsm) and August flow rates averaged 0.53 cfsm. The annual mean flow rate based on a 150 square mile drainage area was 1.l93 cfsm. The 7Q10 (estimated lowest 7 day flow period expected to occur once every ten years) flow for the river has been estimated to be 0.086 cfsm. Summarized flow data for the Crooked River in Naples is presented in Table 2 (USGS 2009).

As mentioned earlier, most of the main stem river flows over extensive surficial glacial outwash materials. These glacial outwash deposits also contain significant aquifer areas yielding ten to fifty gallons of water per minute. Sections of the main stem just south of Mile Brook, South of Papoose Pond, and in North Waterford contain aquifer areas yielding greater than fifty gallons per minute (MGS 1981). For more details relative to the location, size, and yields of aquifer areas along the Crooked River refer to Sand and Gravel Aquifer Maps # 12, 14, and 15 published by the Maine Geologic Survey, 1981. These aquifer areas represent major recharge areas and contribute to the base flows of the river. These upwelling and seep areas no doubt provide significant cold water refugia areas for brook trout and salmon. Several of the tributaries also provide significant cold water refugia areas for these species during warm periods.

Table 2. USGS monthly mean flow data for the Crooked River in Naples, 1975-2000.

YEAR	Monthly Mean in CFS											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	-	-	-	-	-	168.1	202.5	63.4	82.4	177.8	321.2	-
1976	-	-	-	-	529.9	160.2	197.0	278.9	109.6	289.0	240.4	-
1977	-	-	-	-	205.8	133.2	72.1	59.6	153.6	-	-	-
1995	-	-	-	-	-	-	-	-	-	148.9	546.5	151.6
1996	509.3	773.0	521.9	925.9	531.0	192.7	381.9	100.7	63.9	489.4	278.7	723.3
1997	296.3	265.9	325.1	1,136	501.6	161.0	134.8	77.0	102.6	74.1	376.6	100.1
1998	159.2	200.6	803.4	807.7	442.1	937.6	325.4	68.9	46.1	235.5	187.0	174.1
1999	205.4	254.9	917.2	592.5	195.9	76.5	50.0	42.7	321.7	217.1	247.2	192.1
2000	132.9	124.7	625.6	998.2	409.3	140.7	96.4	73.0	43.1	-	-	-
Mean of monthly Discharge	261	324	639	892	402	246	183	96	115	233	314	268

History

Past Land and Water Use

Land settlement along the Crooked River dates back to the late 1600's with the various land grants made by the Commonwealth of Massachusetts to heirs and survivors of the 1690 expedition against Quebec. Excerpts from various historical accounts sketch the development that took place in these early years and provides a rather colorful historical account of the Crooked River valley. The early history of the first settlers of various towns lying along the Crooked River shows that the river's water resources were very important and strategic to locating near the river. As will be discussed below, "…the Crooked River with its fair flow of water throughout the season was considered a great value from an industrial and manufacturing standpoint…" (Lapham 1886).

"Long wearied by continued French and Indian raids, the Massachusetts Bay Colony in 1690 organized an expedition against Quebec. Each town in the colony was instructed to provide a company of men under the leadership of a prominent citizen" (Dibner 1976).

"Although the 1690 Canada expedition proved to be a fiasco, it resulted in the granting of town-ships to survivors of the expedition or their descendants."

These "Canada towns", as they were called, comprised the largest group of grants during the period from 1730 on. To claim land it was first necessary that the claimants petition the General Court and give evidence that they were survivors, heirs, or representatives of the soldiers who were in the 1690 expedition.

At least thirteen of the original grants were in New Hampshire. In 1740, however, a boundary dispute arose which suspended the further granting of townships in New Hampshire. Some petitioners were even forced to give up lands already granted to them" (Dibner 1976).

"About twenty-five years later, those who had never received a grant once more petitioned the General Court (Massachusetts). The original soldiers were gone, but their heirs were eligible, and there was still much available land in Maine" (Dibner 1976).

Such land grants along the Crooked River included the Raymondtown Grant, which included all of what are now Raymond, Casco, and part of Naples (Dibner 1976). The Otisfield Grant included what are now Otisfield, as well as the greater parts of Harrison and also Naples (HCC 1880). Other grants included the Waterford Grant; the Cummings Purchase that is now known as Norway; and the Oxford grant, which eventually became Albany. The settlers were greatly handicapped because the proprietors lived so far away, so land agents were appointed to act on their behalf (Dibner 1976). "One of these agents was George Pierce of Otis field…" (Dibner 1976).

George Pierce, of Groton, Mass., the first settler of Naples, became an important figure in the settling of the Crooked River valley. His name appears numerous times in connection with the building of several mills along the river.

Lumbering and agriculture were the two most significant enterprises of the early settlers. The river valley was reported to have immense stands of white pine. The settlers also grew their own grain, which included corn, wheat, and rye. William Spurrs writes, "One of the most important things in a new settlement is a saw and gristmill in order to encourage settlers to build houses and to enable them to have their grain ground, also the proprietors on June 3, 1773, voted to lay out a one hundred acre lot for a mill spot and on November 17, 1773 it was "Voted that lot No. 65 (Edes Falls) should be appropriated to the use of a mill it being a suitable place for that purpose." On Wednesday, June 1, 1774 the proprietors met and appointed David Gorham ESQ. and Major Owen Prescott to treat with Mr. George Pierce of Groton who offers to build a mill. There is nothing more in the records concerning Mr. Pierce's saw and gristmill but it is presumed that he built them as agreed.

One report says the mills were carried away by a freshet about 1795, but soon rebuilt. There must have been a time about 1780 that there was no grinding done at Pierce's Mills as the Spurr's who lived at Spurrs Corner used to carry their grist to Captain Dingley's mill at South Casco at a distance of about ten miles, which they probably would not have done if there had been a mill in operation at Pierce's Falls.

After George Pierce moved away and built a brick ended house on the west side of Long Pond about 1797, the mills were abandoned and when his son Oliver after his father died, deeded the mill property to Thomas Edes Jr. December 14, 1827 for $450.00 which deed included lots 57 and 65 excluding 50 acres previously deeded to John McIntosh by George Pierce. There was no mention of any mills, only the house of George Pierce was mentioned, so presumably the mills were rotted down and washed away.

Thomas Edes Jr. or Col. Thomas Edes as he was commonly known, purchased the mill privilege of Oliver Pierce, December 14, 1827 and rebuilt the mills on the east side of the river and operated extensively in lumbering. Wilkinson Edes, brother to Col. Thomas, later owned the mills and built mills on the west bank of the river which he sold to Richard Green May 28, 1861 for $699.00.

Samuel A. and James Whittier bought a privilege on the east bank of Wilkinson Edes, October 27, 1847 for $275.00 with the right to draw 200 square inches of water from the flume of the gristmill from July 1 to November 1.

Robert Edes bought the mills in 1874 and operated them until his death in 1889. He rebuilt the dam with a vast amount of split stone which he hauled a long distance, also rebuilt the mills and made many additions and improvements and furnished employment to as many as 100 hands at one time. After his death the property was sold and operated to some extent by various owners but was finally allowed to go to decay, and at the present (1951) there is no vestige of any mill remaining and only the stonework of the dam remains to show where once was a flourishing business." (Spurr 1950). Edes falls was a compact hamlet consisting of approximately 175 inhabitants during the height of its prosperity (HCC 1880).

The next largest community lying along the Crooked River was Bolsters Mills. "The land on both sides of the Crooked River was part of the town of Otisfield from the time it was incorporated in 1798. The land on the west side became part of the town of Harrison when it was incorporated in 1805. The village of Bolster's Mills was known for many years as "Pinhook". It was later named for Isaac Bolster who built the dam, sawmill, and gristmill here in 1819 and 1820. He was a resident of Paris, and never lived in Bolster's Mills, but his sons Isaac, Jr. and William both settled here in 1821 and 1826, respectively" (Wight 1986). "William Bolster erected the fulling and carding mill in 1870, by E.G. Coy; the place also contains, in Harrison, a grist mill established on the old Bolster mill site, in 1861, by O.G. Cook" (HCC, 1880). The village in addition to the mills also had various shops and stores as well as a tannery that was operated from 1826 to 1876 (HCC 1880). The tannery became one of the town's principal industries during this time (Wight 1986). The original sawmill built in 1819 was operated until 1936 when it was severely damaged by a flood. The flume was washed away and never repaired. A gasoline-powered sawmill was operated at the same site for many years until the buildings were converted into a barn for animals (Wight 1986).

During the times of prosperity at Edes Falls and Bolsters Mills a successful businessman by the name of Worthy C. Barrows, along with his brothers built a sawmill at Carley's Rips in 1846-47. He sold the mill and property to Elijah and Cyrus Scribner in 1851. Cyrus Scribner turned the business over to his two sons, Jesse and Bourdon, who ran a successful lumbering business for many years. Their business expanded to include mills in Norway and Roxbury Maine, as well as in Florida. In 1895, a flood damaged the Scribner's Mill and the brothers returned from Florida to repair it. They stayed in Maine, and also purchased a large tract of land in Hiram belonging to the Hiram Lumber Co., Inc. Bourdon ran the Hiram operation and Jesse continued to operate the mill at Carley's Rips, by now known as Scribner's Mills. Jesse continued some limited mill operations up until 92 years of age (1962), and died in 1970. In 1972, with written consent of Edward Scribner a section of the dam was breached by MDIFW to provide salmon passage. An ice dam took out the footings and collapsed the mill in 1977. Scribner's Mills Preservation, Inc. is currently working to restore the mill and dam operations (SMPI 2009).

There were several other mills located up river from Bolsters Mills in an area of Norway known as "Waterford Three Tiers". Columbus and David Holden of Otisfield and George Pierce of Harrison built mills on the Crooked River in Norway around 1833 (Whitman 1924). These mills were located at Baker's Falls and the small hamlet that developed was known as Holden's mills, which is now known as Sodom. The mills were reported to be very busy, sawing long logs "from two hundred to eight or ten hundred thousand per year, with a shingle machine which manufactures from two to six or eight hundred thousand of shingles annually" (Noyes 1972). These mills burned in November 1844, but were rebuilt and operated for many years by the Holdens (Whitman 1924). The mills also ground pulp, which was hauled by oxen to paper making mills in Mechanic Falls (Holden 1988). A gristmill was also located in the Holden's mill complex.

The Holden's Mills area was also the site of major pulp and long-log drives. It was common for the inhabitants of the area to farm their land in the summer and harvest timber in the winter. Pulp and long-logs were stacked on the banks and driven down the river on the spring high water. The last successful drive occurred in 1928. A drive was attempted in 1929, but low flows in the spring made it impossible (Holden 1988). The log drivers tried to create high flows by damming the river with cofferdams, but were not successful in creating enough flow (Holden 1988). Some logs were driven to Scribner's Mills, but most of the pulp and logs were driven all the way to Sebago Lake where they were rafted to the outlet and then driven down the Presumpscot River to Warren Mills at Saccarappa Falls and Cumberland Mills (Waterford Historical Society, 1879 and 1977). The Holden's mills were abandoned about this time and the buildings and dams deteriorated and no longer exist. Portions of a split stone dam are the only remnants of the Holden enterprises. Joseph Daniels was reported to have built a mill site prior to the Holden's at a location just upstream at the head of the rapids (Holden 1988). However, not much is known about this operation.

The next major enterprising area was located further up-river in North Waterford at Lynch's Mills, now Lynchville. Jonathan Longley built the first sawmill at North Waterford in 1806, after he purchased the site from Major Samuel Warren (Waterford Historical Society, 1879). This sawmill also contained a gristmill. Nathaniel Jewett constructed a fulling mill below the sawmill in 1820 (Waterford Historical Society 1879). In 1833, an additional sawmill was built about a mile below the Longley's mills.

Present Land and Water Use

The Crooked River, being located in southwestern Maine is readily accessible to approximately one half of the total population of the State. Its location in the northern interior portions of Cumberland and southern Oxford counties are the lesser-populated areas of the region. U.S. Census Bureau human population estimates in 2005 for the southwest portion of Maine, that is south and west of the Androscoggin River, was estimated at 617,152 (MSPO 2009). The entire watershed is experiencing increases in growth and development mostly in the form of single-family residences, and some small business operations.

Presently, the largest communities located on or adjacent to the Crooked River include only the villages of Bolsters Mills and North Waterford. Today, several single-family residences and seasonal dwellings dot the shoreline of the river especially adjacent to road crossings and access points. Overall, the shoreline development along the main stem of the Crooked River and much of the watershed is relatively sparse with long stretches of the river corridor totally undeveloped and undisturbed. The undeveloped characteristics of this river offers a unique aesthetic opportunity in southern Maine to enjoy a wilderness type experience for fishing, canoeing, hiking, or hunting.

Land use data for the Crooked River watershed were obtained from the USDA Soil Conservation Service located at the University of Maine in Orono, Maine. The land use data were collected in conjunction with a flood analysis study that was completed for the watershed. The study concluded that the general trend in land use within the watershed would be increased forested land with a trend toward a decrease in the amount of open land and agriculture. These are typical land use trends observed or projected for other watersheds in southern Maine (NERBC 1980, 1981). Although not specific to the Crooked River, a more recent report from Plantiga et al. (1999) estimated that forested land in Maine increased by 377,000 acres between the 1950's and 1990's, while crop and pasture lands decreased by 887,000 acres during the same time period. This change in land use and land cover is largely the result of open lands reverting back to forested areas. However, urbanized or developed land accounts for some of the change with an increase of 66,000 acres from the 1950's to the 1990's (Plantiga et al. 1999). A more relevant analysis of the land use specifically for the Crooked River watershed indicates that in 2001 85.2% of the watershed was forested representing a 4% decline in forested lands since 1990 (PWD 2001). Most of the decrease in forested lands is the result of an increase in urbanized land uses (i.e. residential, commercial, etc.). This analysis also showed an unexpected increase in agricultural lands; however, this anomaly is believed to be an error resulting from a change in the criteria used to categorize agriculture lands in 1990 versus 2001 (Whalen 2011). A summary of the Crooked River land use analysis is presented in Appendix H.

No major industrial complexes are currently located in the watershed. The Crooked River is not considered a "working river" in the sense that no industries or businesses are dependent on its water resources. There are also currently no hydroelectric projects or active mills located anywhere in the entire watershed. The major uses occurring in this watershed at the present time include water storage, drinking water, fishing, swimming, boating and canoeing, camping, hiking, trapping and hunting, lumbering, mineral and gravel mining, and agriculture. The Crooked River is the largest tributary flowing into Sebago Lake, and consequently plays a vital role in terms of water storage and drinking water. Sebago Lake supports the state's largest water utility, the Portland Water District (PWD). The PWD services 200,000 customers in 20 communities (LELT 2011). However, the entire Sebago Lake watershed, including the Crooked and Songo River drainages, is most noted for its various forms of recreation.

Future Land and Water Use

The population for the area south and west of the Androscoggin River is projected to increase up to 716,683 by 2025 (MSPO 2009). This projected increase of almost 100,000 people will place additional demands on the resource in terms of recreational use of the watershed, as well as additional encroachment and development.

The same land use and cover trends described for the past 40 years are expected to continue. Plantiga et al. (1999) projected that forested land would increase by another 400,000 acres between 2000 and 2040, while agricultural/open land would decrease at a slower rate than observed during the prior 40-year period (233,000 acres). On the other hand, a substantial increase in urban land area (56%) was projected by 2050 due to an estimated 16% growth in the population. Most of the urbanized growth is expected to occur in areas located in southern and central Maine.

It is suspected that continued growth and development along the Crooked River watershed will be dominated by low density single-family residences, as well as some limited growth in small businesses. Water use in the watershed is not expected to change dramatically. However, in 2009 Scribner's Mill Preservation, Inc. applied for a permit to rebuild the dam and associated support facilities at the historic Scribner's Mill site. A more detailed review of this project is presented in the "Fish Passage Obstructions" section of this report.

Watershed Protection and Conservation

The Crooked River watershed is predominantly under private ownership; however, some federal and state conversation lands have existed for quite some time. The White Mountain National Forest (WMNF) was established by Presidential proclamation on May 16, 1918. Today the WMNF contains almost 800,000 acres in New Hampshire and western Maine (USFS 2011). The USDA (1975) reported the WMNF included about 27 square miles in the northern part of the Crooked River watershed; however, this value is likely higher today due to more recent land purchases. In 1955, the State of Maine acquired almost 1,300 acres of land for a State Park on Sebago Lake. This parcel includes portions of the lower Songo and Crooked River watersheds. Additionally, in 1991 MDIFW acquired a small 2.5-acre parcel known as the Melvin Lot in Albany.

The remaining known conservation lands in the Crooked River watershed are predominantly conservation easements, which have recently become very popular vehicles for protecting important natural resources. Generally, conservation easements allow the landowner to continue ownership and certain activities (i.e. forestry, agriculture), but prevent or limit future development in perpetuity. These types of easements are beneficial in that they serve to protect the resource at a fraction of the expenses associated with direct purchases. A handful of conservation easements currently exist within the watershed and that number continues to grow as various land trusts, conservation groups, and resource agencies work to protect this unique resource. One of the more significant easements within the Crooked River drainage is the 2002 Jugtown Plains easement held by the Maine Bureau of Parks and Lands, which protects over 3,200 acres in the Towns of Otisfield and Casco including approximately 1.3 miles on the eastern shoreline of the Crooked River. The Western Foot Hills Land Trust currently holds 1,062 acres of easements within the Crooked River watershed, as well as 102 acres of owned property (Dassler 2014). The bulk of these properties are the result of two easements, including the 2007 Hague easement, which protects 460 acres within the watershed and encompasses 1.5 miles along both sides of the river in Waterford, and the 2011 Watkins easement, which protects 690 acres in Harrison including 1.2 miles of shoreline along the Crooked River and 9,906 feet of Russell Brook (WFLT 2012). While these three easements are significant in size and resource values, all conserved lands in the watershed play an important role in protecting the Crooked River drainage.

In the future, local land trusts will play a significant role in acquiring conservation lands in Maine including some within the Crooked River watershed. The Upland Headwater Alliance has assumed a strong stewardship role in the conservation of riparian lands in the river's watershed. LELT (2011) describes the Alliance and its mission as, "a collaboration of area land trusts, protects lands and waters essential to preserving the contiguous ecosystem of our common region. Working with its member trusts and other partners, the Alliance focuses on opportunities across its region that are most effectively addressed through joint action, while maintaining the autonomy of each trust. It encourages public awareness of the natural environment of the region, identifies projects and activities that extend beyond the reach of individual land trusts and other entities, and undertakes action programs to protect land and waterways and promote balance between growth and conservation." Land trusts belonging to the alliance have been very effective in land conservation. As a group, they had secured a total of 9,917 acres of land via fee purchases and conservation easements by 2007 (UHA 2007). The significance of this group to the Crooked River drainage is that they have chosen it as their focus project, called the Crooked River Initiative. As a partner, MDIFW looks forward to working with the group in its efforts to protect this valuable resource and its associated fisheries.

Fishery Management History

Fish Stocking

According to MDIFW's records (Appendix I) the Crooked River has been stocked with several fish species including brook trout, salmon, and on one occasion rainbow trout (*Oncorhyncus mykiss*). Past stocking largely reflects a concerted effort to restore and enhance native salmon and brook trout populations, while striving to balance sometimes competing management needs.

The stocking of rainbow trout fry was a one-time federal stocking that occurred in 1917, before MDIFW was staffed with fisheries biologists. Several decades ago, MDIFW also began stocking rainbow trout experimentally in various waters around the State, but a Department policy was instituted that precluded their stocking in various drainages including the Sebago Lake drainage to protect wild, native salmonid fisheries. A similar revised policy remains in effect today; MDIFW stocks rainbow trout on a limited basis in other waters outside the Sebago Lake drainage to balance public expectation for enhanced fishing while affording protection to Maine's native salmonids.

Brook trout were stocked annually in the Crooked River from 1956-1976. However, the age classes, numbers, and stocking locations were quite variable over the entire time period. The majority of the stockings were legal-sized spring yearling fish that were stocked as a put-and-take fishery to supplement the limited wild brook trout population. By 1977, the MDIFW's regional fisheries staff had made significant strides in enhancing the production of wild salmon, and canceled these brook trout stockings. Stu DeRoche, regional biologist for the area, felt strongly that these stockings were promoting fishing on the river and contributing to additional hooking mortalities and harvest (via misidentification or illegal actions) of juvenile salmon. In the mid to late 1990's, MDIFW was involved in a new initiative to expand put-and-take brook trout fishing opportunities throughout the region, and in 1999 initiated a stocking of catchable brook trout at the popular picnic area known as Twin Bridges on Route 117. This stocking continued until 2009, when it was canceled, because it was deemed inconsistent with the priority management focus on wild salmon and brook trout.

The first stocking of salmon in the Crooked River was 100,000 fry in 1953, which was followed by nine years without salmon stocking. From 1962-1967, relatively large numbers of both spring and fall yearling salmon were stocked in the river, corresponding to a similar stocking program on the lake. At the time, regional biologists were evaluating the combined stocking of spring and fall yearling salmon in the Sebago Lake system. Reportedly, both age classes provided similar returns to Sebago Lake anglers, and the dual stocking program was described as providing a well-balanced, season long fishery (DeRoche 1972). Although the number of wild fish in the fishery was discussed in the report, there was no mention of the contribution of river versus lake-stocked fish to the Sebago Lake fishery.

Stocking of salmon in the Crooked River ceased for several years, but was resumed in 1974 (two years after fish passage had been established at Scribners and Bolsters Mills). DeRoche (1982) reported that despite the observation of large numbers of adult salmon below the breached dam at Scribners Mills, few had been captured at the Bolsters Mills fish trap from 1972-1974. He suspected spawning salmon had been denied access beyond Scribners Mills for so long that they had lost their homing instinct to spawn in upriver areas beyond the historical barriers. Consequently, spring yearling Sebago-strain salmon were stocked from 1974-1976, and approximately 100 adult salmon from the Jordan River spawning run were transferred to several locations above Bolsters Mills. DeRoche noted significant increases in the number of hatchery and later wild adult salmon at the Bolsters Mills fishtrap after these efforts, which will be presented later in this report.

The last period of salmon stocking in the river occurred in the 1980's in an apparent effort to further develop spawning site fidelity in the upper reaches of the river. The lack of or limited use of these spawning areas are likely due to the same reason noted by DeRoche (1982) - a loss of homing instinct to these areas. In 1980, 147 spawning salmon (Sebago strain) from the Jordan River were transferred to two known spawning areas in the Waterford area (De Roche 1982). Between 1982 and 1988, predominantly fall fingerlings were placed in the headwaters of the main stem, as well as several tributaries including Patte Mill Brook, Swett Brook, Hobbs Brook, and the outlet of McWain Pond.

Other than rainbow trout, most of the salmonids typically raised in our state hatchery system, including salmon, brook trout, lake trout (*Salvelinus namaycush*), brown trout (*Salmo trutta*), and splake (*Salvelinus namaycush X Salvelinus fontinalis*), have historically been or are currently being stocked in various waters within the Crooked River drainage. Of these, the exotic brown trout have been viewed over the years with some degree of concern because if they became established in the Crooked River they would likely compete with native salmon and brook trout. Despite extensive sampling on the Crooked River, only four brown trout have been reported by MDIFW biologists. Furthermore, little natural reproduction of brown trout has been noted in any regional waters, including those with a long history of direct stockings with brown trout.

Fishing Regulations

The Crooked River salmon and brook trout fishery has had a long and varied history of regulations (Appendix J). The following section will review some of the river's regulation history from 1972-2014 with an emphasis on a few of the more important regulation changes. Typically, the length of the open water fishing season on the river has followed general law (April 1 to September 30) with a special extended fall season to provide additional fishing opportunities for adult salmon. Bag and length limits on brook trout were usually general law restrictions - a five fish bag limit and a six inch length limit. On the other hand, bag and length limits on salmon were typically more restrictive than general law. From 1972-1979, five salmon were allowed to be harvested on the Crooked River under general law. However, varying special regulations in the spring and fall during this period of time allowed fewer or no salmon harvest. Over the years bag limits declined from a high of five to a low of none. From 1972-1993, the minimum length limit on salmon harvested in the Crooked River mirrored Sebago Lake's regulations, which varied from 14-17 inches.

Some of the more interesting and significant regulation changes fall under the additional "specials" category in Appendix J, and include the following: no size or bag limit on chain pickerel (*Esox niger*), closing the river to the taking of rainbow smelt (*Osmerus mordax*), and the use of a fly fishing only (FFO) regulation.

- The no size or bag limit on pickerel started in 1975. This regulation likely resulted from predation studies on recently stocked salmon by Warner (1972). In two separate studies Warner reported 29% and 42% of the pickerel examined had consumed juvenile salmon shortly after stocking. This regulation was eliminated in 1986 due to high general law bag limits on pickerel and a lack of effectiveness.

- The Crooked River was first closed to the harvest of spawning smelt in 1976, and remains closed to this day. Although quite controversial due to the popularity of smelt for sport, food, and bait, this regulation was considered an important part of managing the salmon and lake trout fisheries of Sebago Lake. During this time frame salmon lakes around the state were being closed to the harvest of smelt due to their importance as a forage fish for most salmonids, and particularly for salmon (Boucher and Warner 2006).
- The Crooked River had FFO regulations during the extended two week fall fishing season since at least 1972, but by 1982 the section of river from Bolsters Mills downstream to Rte. 11 became FFO for the entire season, and by 1986 the FFO section was extended to approximately 2/3 of the entire river (Rte. 35 in Waterford down to Rte. 11). FFO was extended to the entire river in 2014. The intent of the FFO regulation was and remains primarily to reduce hooking mortality of juvenile and adult salmonids. Warner and Johnson (1978) documented hooking mortality for salmon was much higher for worms (35%) than flies (4%) in a riverine nursery area, and Boucher and Warner (2006) suggested closure of salmon nursery streams to worm fishing may be warranted where juvenile fish production is important to lake and river fisheries.

In addition, a review of the special regulations shows a relatively simple set of regulations and specials from 1972-1978, followed by a seven year period of extremely complicated regulations for the river. Finally in 1986 regulations were revised, and even though they were more restrictive they were much simpler. These simplified base regulations gradually evolved into the current regulations (2014) with the following changes: (1) the addition of an extended fall fishing season (Oct. 1- Oct 15) to provide more angling opportunity for adult salmon; (2) a change from catch-and-release on salmon to a bag limit of 1 salmon at least 26 inches in length, which was a public request to allow the harvest of a trophy fish; and (3) FFO and the other salmon regulations eventually extended to the entire river. Current (2015) regulations on the Crooked River are as follows:

Crooked River, Albany to Casco, etc. (Cumberland and Oxford Counties): S-1 (Closed to taking smelts), S-5 (Fly Fishing Only), S-22 (Daily bag limit on salmon: 1 fish); minimum length limit on salmon: 26 inches.

October 1 – October 15: Fishing allowed as described above from Bolsters Mill Road bridge downstream to Route 11 in Casco. All other fish caught must be released alive at once.

Sport Fisheries: Crooked River

MDIFW does not have angler clerk creel survey data to characterize the river’s salmon and brook trout fisheries. Most of our knowledge of the river’s fisheries comes from anecdotal reports from anglers and wardens. Brook trout fishing in the main stem is largely a spring and fall fishery when water temperatures are cool enough for them to be active within the river. Brook trout may also be found during the warmer summer months wherever coldwater refugia exist such as at the mouths of cooler tributaries, spring seeps, deeper pools, and headwater areas of the main stem. Most of the brook trout caught are relatively small, 6-12 inches in length, although MDIFW has received recent reports of a handful of brook trout in the 15-18 inch range. Spring and summer anglers targeting brook trout are mostly locals, whereas fall fishing for both brook trout and salmon attracts anglers from greater distances.

Although adult salmon occur in the Crooked River year round, salmon fishing is predominantly a spring and fall fishery. A short spring fishery for salmon occurs in the lower river when salmon follow spawning smelt into the lower Songo and Crooked Rivers. Despite the highly desired opportunity to fish for spawning adult salmon in a riverine setting, fishing pressure and success on the river appears to be relatively low compared to similar fisheries around the State. This is probably a result of the "hit or miss" nature of the fishery created by the river's extensive length and numerous holding pools. Anglers may get frustrated fishing the river, as this is a river where it is critical to be in the right place at the right time. The size quality of the adult salmon in the river mirrors the lake fishery with adult fish typically in the 14-24 inch range (Photo 2).

Photograph 2. Successful fisherman holding a Crooked River salmon (Anonymous).

The extensive length of the river and its seasonal fishing opportunities make it difficult to collect information on sport fisheries (i.e. angler use, catch and harvest rates) via direct contact angler surveys. Consequently, the only creel data MDIFW has on the Crooked River fishery are from sources. A summary of voluntary creel data from MDIFW issued personal fishing logbooks and TripTracks℠ (an online fishing logbook system) is presented in Table 3. Although the data are limited, in general it confirms our overall impressions of the fishery. Catch rates (all fish sizes per hr) for both salmon and brook trout appear to be relatively low compared to other

Table 3. A summary of open water creel survey data from Trip Tracks (2004-2007) and voluntary angler books (1999-2009).

Year - Season		Trip Tracks[1] 2004-2007	Voluntary Book[1] 1999-2009
No. anglers surveyed		115	38
No. angler hours		412.2	120.5
Mean Party Size		1.5	1.4
Mean Trip Length		3.5	2.6
No. fish kept	LLS	0 2	2 1
No. fish (and %) released	LLS BKT	36 (100.0) 126 (98.4)	5 (71.4) 10 (90.9)
No. fish caught per angler	LLS BKT	0.31 1.11	0.18 0.29
Hours to catch a fish	LLS BKT	10.6 3.2	60.2 11.0
All/Hour	LLS BKT	0.095 0.311	0.017 0.091
Mean length & size range in inches (No. of fish reported)	LLS BKT	13.5", 5-28" (16) 12.4", 6-19" (43)	15.3", 5-27" (6) 9.2", 4-19.3" (6)

[1]Typical creel survey metrics (i.e. relating to legals and sublegals) could not be utilized due to inaccurate reporting of legals and sublegals by anglers.

Maine rivers. For example, Boucher and Warner (2006) reported an average catch rate of 0.146 legal salmon per hour from 27 creel surveys on six different salmon rivers, 1984-2004. These catch rates are 1.5 times higher than the Crooked River data presented in Table 3, and in reality an even larger disparity between the reported values likely exists due to (1) our data include all salmon caught as opposed to just legal-sizes due to the high Crooked River length limit (26 inches) and the difficulty some anglers may have determining what constitutes a legal sized salmon; and (2) voluntary data are typically biased towards higher catch rates. The size quality of brook trout and salmon reported by anglers appears to be consistent with our perceptions of the fishery, keeping in mind that the reported salmon averages are lowered by the catch of juveniles. A review of the volunteer data from 1999 to 2009 indicate 16 of the 22 salmon (72.7%) were 14 inches or larger, and 15 of the 49 brook trout (30.6%) were 12 inches or larger. The largest salmon and brook trout reported were 28 and 19.3 inches, respectively.

Our initial perception of the Crooked River fishery, particularly for salmon, was that most of the angler use occurs in the fall by anglers targeting pre-spawning adults. Interestingly, only a fraction of the 46 different logbook keepers provided trip information during the fall period (September 1 to October 15). Eighty-six of the 103 fishing trips reported (83.5%) occurred in the spring and summer seasons.

The Crooked River and many of its tributaries provide excellent spawning and juvenile habitat for salmon. Unlike most salmon lakes in the region, salmon production in the Crooked River system contributes a significant number of wild salmon to the Sebago Lake fishery. The percentage of wild salmon in the Sebago fishery has averaged 38.3% (1976-2013), and has ranged from a low of 4.5% (1977) to a high of 62.2% (2013). Figure 1 clearly illustrates a trend of higher contributions of wild salmon in the Sebago Lake fishery, which is not unexpected given the gradual decrease in salmon stocking rates throughout the same time period. However, our data also indicate salmon catch rates have been maintained, which suggests management efforts to improve fish passage and re-establish homing instincts to the upper reaches of the Crooked River were successful.

Other than the Crooked River, no other tributaries provide an appreciable contribution of wild salmon to the lake. Therefore, the true value of the Crooked River is considered greater for its production of wild salmon to Sebago Lake than for the fishing opportunity it provides the angling public. This current management philosophy strongly influences ongoing management efforts.

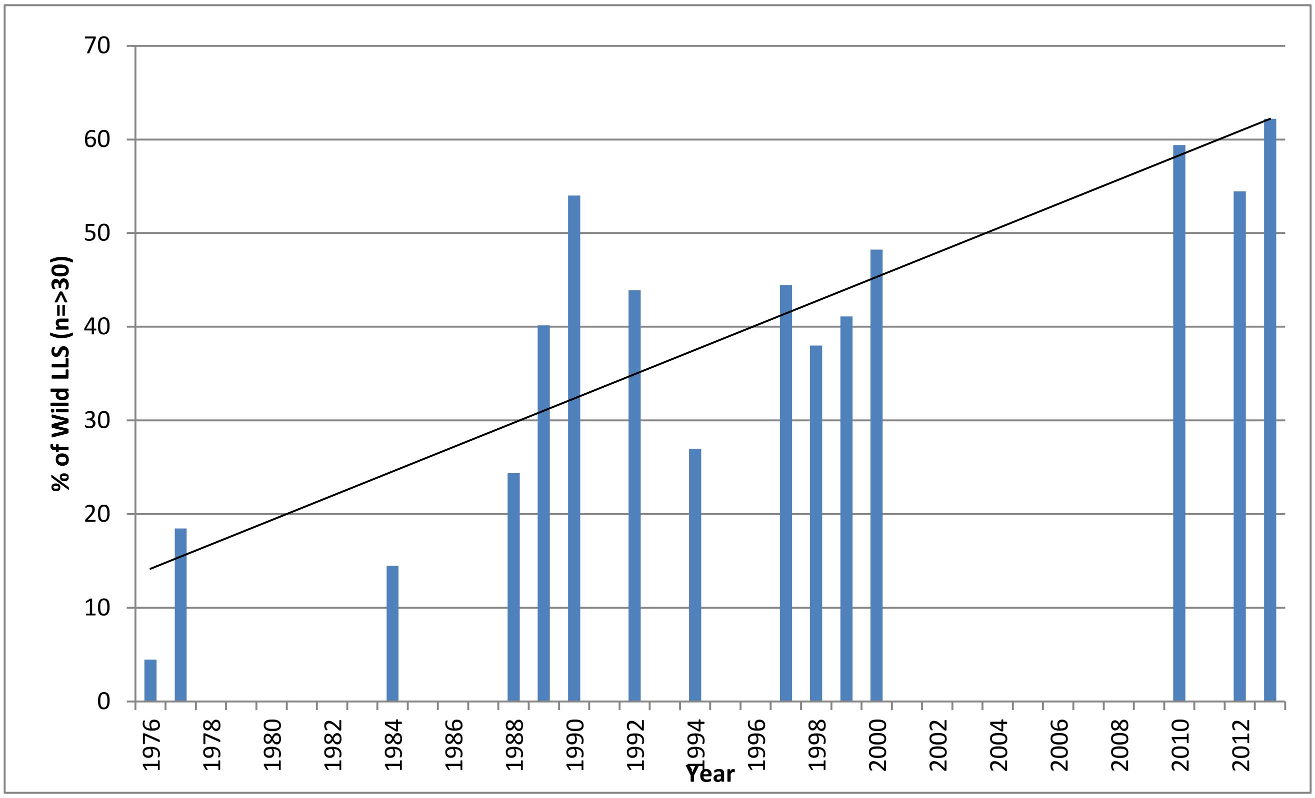


Figure 1. Percentage of wild salmon in the Sebago Lake fishery, 1976-2013.

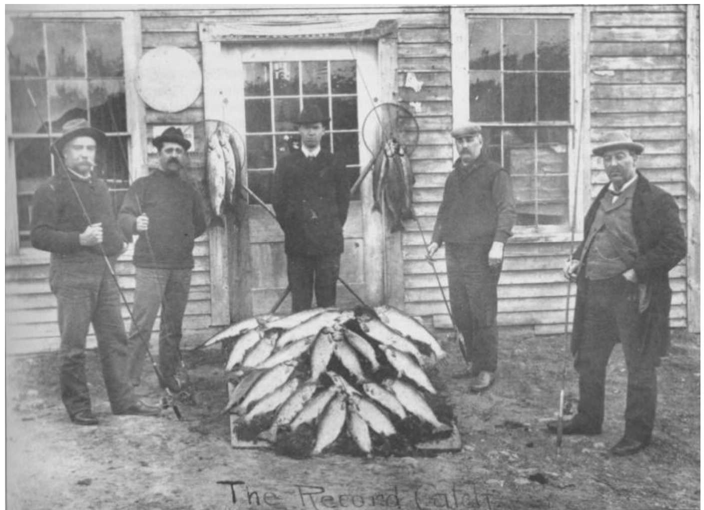
Sport Fisheries: Sebago Lake

The close relationship between the Crooked River and Sebago Lake in regards to salmon warrants a brief history and overview of Sebago Lake and its fisheries. Sebago Lake, located at the outlet of the Crooked River watershed is well known for its excellent recreational sport fisheries for salmon, lake trout, and black bass (*Micropterus spp)*. Brook trout and lake whitefish (*Coregonus clupeaformis*) no longer provide a significant fishery in the lake, likely due to historical changes in species composition.

Sebago Lake is well suited for salmon management. At 30,513 acres, it is the second largest lake in Maine and represents over 56% of the total surface acreage managed for salmon within the Sebago Lake Fisheries Management Region (Region A). The lake is unusually deep with an average and maximum depth of 107 and 316 feet, respectively. Water quality is exceptional, and the lake supports a large volume of cold, oxygenated water. Summer dissolved oxygen levels exceed 5.0 ppm all the way to the bottom, and summer temperatures are suitable for salmonids below 25 feet. The lake also supports a smelt population for forage, which is a pre-requisite for any quality salmon fishery. Like most lakes, the smelt population has periodically experienced large fluctuations in abundance, and has historically exhibited a few relatively long periods of reduced smelt levels.

Sebago Lake and the Crooked River are home to one of only four indigenous salmon populations in the State of Maine, making them both historically and genetically important. All of the other salmon waters in Maine have originated from these four populations, particularly the Sebago and West Grand Lake populations. In addition, salmon from Sebago Lake and other Maine waters have been introduced worldwide to restore and create fisheries for this popular and highly praised sport fish.

The lake's salmon fishery supports a long and renowned history (Photo 3). In 1883 Stanley and Stillwell wrote, "Were the fish better known, this lake (Sebago) would be more visited than dominion waters, and with the same outlay of time and less money, with as great success…" Not long after, anglers from metropolitan areas of New England (i.e. Boston & New York) and even greater distances began traveling by train and coach to fish for salmon at Sebago. In 1907, Edward Blakely caught a 22.5 pound salmon that held the world record slot for many years, and remains the state record for Maine.



Photograph 3. "The Record Catch." An example of the early salmon sport fishery on Sebago (believed to be taken prior to 1900).

While the lake has historically produced many quality salmon over the years, it has also experienced several long-term declines in the quality of its salmon fishing. The first notable decline documented by MDIFW occurred during the 1960's and was largely attributed to the wide spread use of DDT (a pesticide) to control mosquito populations. DDT directly or indirectly impacted Sebago's fish populations, precipitating a significant crash in the lake's salmon and smelt populations. The loss of smelt created a chain reaction that impacted other fisheries reliant on them for forage. Eventually, the use of DDT was banned, and along with several other fishery initiatives, the salmon population made a complete recovery.

The second notable decline in the salmon fishery occurred in 1990, and has largely been attributed to the introduction of lake trout. Over 300,000 lake trout were stocked from 1972-1982; stocking was then discontinued due to evidence of ample natural reproduction. This "naturalized" lake trout population continued to expand as they occupied a new niche in the lake. The salmon and lake trout fisheries peaked in the mid to late 1980s, while the lake trout catch continued to skyrocket between 1988 and 2002. The burgeoning lake trout population overtaxed forage populations in the lake, and also likely contributed to the collapse of several other historical lake fisheries including lake whitefish, white perch (*Morone americana*), and cusk (*Lota lota*).

MDIFW undertook numerous (some still ongoing) initiatives to stem lake trout population growth and create a more stable and balanced lake fishery. These efforts included regulatory, stocking, and other measures. A continual liberalization of lake trout regulations, and progressively reduced salmon stocking rates between 1988 and 2003, where initiated to reduce the number of smelt predators in the lake system. MDIFW has also been involved in several other management initiatives and partnerships to restore the salmon fishery at Sebago Lake including:

- explore/evaluate the use of gillnetting for lake trout removal and the effects on by-catch;
- investigate the potential of lake drawdowns to suppress lake trout spawning;
- explore/evaluate the success of boat electrofishing for lake trout capture during spawning;
- address influence of beaver on salmon spawning;

- investigate/monitor illegal northern pike (*Esox lucius*) introduction and promote removal;
- involvement in annual plankton monitoring (Portland Water District/Sebago Lake Anglers Association;
- work with Southern Maine Community College and Sebago Lake Anglers Association to assess the success of an experimental sea-run smelt egg transfer project;
- collaborate with Windham Rotary's Sebago Lake Ice Fishing Derby as a means of encouraging additional lake trout harvest.

Sebago Lake's smelt population, as well as its salmon fishery, has steadily improved and stabilized since 2001. Recent data analyses also indicate an improvement in overall size quality for lake trout, and a possible decrease in their abundance. Despite these gains, the stability of the system likely remains somewhat fragile and impacts from the illegal introduction of northern pike and landlocked alewives (*Alosa pseudoharengus*) will further complicate fisheries management of the lake. In 2008, MDIFW developed a management plan for Sebago Lake to formalize and build public acceptance of management objectives. In 2013, MDIFW instituted new lake trout regulations that retained liberalized regulations on smaller lake trout, while including a 23-33 inch protective slot limit. While the protective slot seems counterintuitive in terms of reducing lake trout abundance, the intent is to restructure the lake trout population towards larger sizes to promote natural, "top-down" population control via predation from larger lake trout in the system.

The fishery resources of Sebago Lake have not only historical, ecological, and recreational value; they also provide economic value to local and state economies. Over the past two decades (1989-2009), open water angler use of the lake has ranged from 17,427 to 57,898, with an average of 38,132 angler days (n=11). Winter angler use data for the same period ranged from 154 to 9,912 with an average of 3,963 angler days (n=8). A shorter season length and uncertain ice conditions contribute to lower winter use and high variability from year to year. Studies conducted by Boyle (1994) indicate that open water anglers spend $274 annually and fish a total of 15 days, resulting in a per angler trip cost of approximately $20. Applying the consumer price index (USDL 2014) to adjust for inflation generates an approximate cost of $31.57 per angler trip for 2014. Assuming open water and winter anglers spend the same amount of monies per trip, the fishery resources at Sebago Lake contribute an estimated $1.3 million a year to the local and state economies. Additional angler days associated with the Crooked River and the various lakes, ponds, and streams in the watershed also generate revenues, making the appropriative value of watershed's fisheries resources even greater. Thus, the non-appropriative value for all of the various recreational uses of the watershed provides an extremely valuable resource to the State of Maine. The importance of the Sebago Lake fishery and its dependence on the Crooked River for salmon and smelt production further demonstrate the need to manage the Crooked River to provide optimum benefit to the fisheries of the region.

Fish Passage Obstructions

Restoration of a free-flowing system for the Crooked River has always been an important objective of past and current fishery managers. Habitat connectivity between Sebago Lake and this major tributary are invaluable for fish and aquatic organisms requiring different habitats for various life stages, such as spawning habitat, juvenile rearing habitats, and thermal refugia. In addition, an unencumbered stream typically provides better habitat in terms of flow, water quality (e.g. temperature, dissolved oxygen), and provides better transport of materials and organisms. Historical accounts of known manmade obstructions on the Crooked River were discussed under the history section of this document. MDIFW conducted a formal assessment of obstructions to fish migration on the Crooked River as part of a larger statewide study in the mid 1950's. DeRoche (1956, 1961) conducted the survey and reported, "…approximately 80 percent of the suitable spawning and nursery area present in the main Crooked River is being denied spawning salmon because of two dams." A later report of the same conditions after a habitat survey of the river quantified that 88% of the spawning habitat was inaccessible (DeRoche, 1982). A summarized version of DeRoche's obstruction findings are presented below, as are reports of current conditions.

Main Stem Dams

Edes Falls Dam (Photo 4)

Condition 1956/1961: Dam has not been used for many years and its present condition is inoperable for commercial purposes. The dam presents a 4-5 foot drop at the center of the spillway, but at high water levels fish are able to avoid the jump by utilizing the washout in the right side of the dam.

Photograph 4. Remains of Edes Falls Dam around 2005 (MDEP).

Recommendation1956/1961: Remove the remaining spillway structure to allow passage of all fish at all water levels or provide a fishway.

Present Condition: Although many of the original stones are still intact, the center of the dam is largely breached with a 2-3 foot drop during low water levels. Anecdotal reports suggest DeRoche may have manually loosened a few stones sometime in the 1970's in hopes that spring flows would further breach the dam and improve passage. Removal of the remaining 1-2 courses of stones in the center breach would further improve passage, while complete removal would restore the stream to its original hydrology.

Scribner's Mills Dam (Photo 5)

Condition 1956/1961: This dam is operational, and presents salmon with a 7-9 foot high jump over the spillway. The sluiceway likely provides no passage opportunities.

Recommendation1956/1961: Construction of a fishway is required to enable fish to ascend this obstruction.

Photograph 5. Scribner's Mills Dam, 2010 (J. Pellerin).

Present Condition: The sawmill ceased operations in 1962. DeRoche (1972) reported that the dam was made passable to spawning fish in the fall of 1971, whereas DeRoche (1982) and written correspondence in Region A files indicate the dam was partially breached by DeRoche in 1972 with the owner's consent. The mill building subsequently collapsed due to ice dam flows in 1977. The remainder of the "east dam" was removed in 1981 as part of an MDEP permit to build a riverside granite barrier to protect the mill structure, which was to be rebuilt, from ice damage. The "west dam" and sluiceway were still largely intact and remain so to this day. There is some evidence that the historical and remaining structure is causing changes to the local stream morphology.

Over the years, the mill building and many of the associated structures have been restored with the goal of recreating the original sawmill complex for a museum and demonstration purposes. A brief summary of recent events follows:

- Scribner's Mill Preservation, Inc. (SMPI) applied for a Maine Department of Environmental Protection (MDEP) permit to rebuild the dam with a rock ramp type fishway in the location of the "east dam".
- In 2007, the permit was denied by the MDEP. Subsequent appeals to the Board of Environmental Protection and the Supreme Court regarding MDEP's ruling were upheld.
- A revised application for a dam was submitted to MDEP in September of 2009, and later that same fall the Maine Legislature upgraded the entire Crooked River to a Class AA water. Although this classification would preclude the construction of any future dams, the revised application for a dam was submitted to MDEP prior to the effective date of the reclassification.
- In 2014, the permit was denied by the MDEP and no subsequent appeals are anticipated.

Bolsters Mill Dam (Photo 6)

Photograph 6. Remains of Bolsters Mill Dam and natural fish passage structure, 2011 (B. Lewis).

Condition 1956/1961: The dam is no longer operable, but provides an impoundment for the town's people. The dam creates a 4-5 foot jump for migrating fish.

Recommendation 1956/1961: Removal of the dam or provide a fishway.

Present Condition: A fishway was installed at the Bolsters Mill Dam in November 1971 and was first passable to spawning fish in 1972. MDIFW added a fishtrap to the fishway in

1974 to monitor salmon movement and restoration of salmon spawning within the watershed. Operations at the fishtrap and data collection continued up to 1986, when the fishtrap and fishway were replaced with a rock ramp structure. The passage provisions developed at Bolsters Mills were implemented in partnership between MDIFW, the Towns of Otisfield and Harrison, the Bolsters Mills Village Improvement Society (BMVIS), and the dam's owner. The BMVIS wanted to maintain a source of fire protection and aesthetic benefits, while the MDIFW sought improved fish passage. The measures implemented on site maintained some benefits desired by BMVIS, while improving upstream fish passive. In short, the dam modifications were a compromise that eliminated the need for litigation and other proceedings associated with an existing dam. The improvement also removed the costs and oversight required to maintain proper functioning of a traditional fishway, and provided passage for a greater variety of fish size classes over a greater range of flow conditions. Although the implemented modifications did improve general conditions for fish passage, the overall structural integrity and ability to pass fish has deteriorated, including severe erosion of the west bank (this area has since been re-armored) following several significant large flow events. Presently, the site does not adequately pass fish under low and high flow conditions. In the future, MDIFW will investigate the opportunity to improve passage for all life stages of salmon under most flow conditions.

<u>Waterford Dam</u>

<u>Condition 1956/1961:</u> This low log dam previously created a 2-3 foot jump for migrating fish, but had been removed and was passable at the time of survey.

<u>Recommendation 1956/1961:</u> None.

<u>Present Condition:</u> Does not pose a passage issue.

<u>North Waterford Dam (Photo 7)</u>

<u>Condition 1956/1961:</u> This low log dam is not an obstruction at most water levels, and fish are able to utilize the runaround on the right bank.

<u>Recommendation 1956/1961:</u> None.

<u>Present Condition:</u> Does not appear to pose a significant passage issue. However, certain flows may hinder passage of weaker swimming species and younger age classes. In addition, the remaining dam structure is likely affecting local stream morphology. Complete removal would restore the stream to its original hydrology; however, passage concerns identified down river are a higher priority.

Photograph 7. Remainder of North Waterford Dam, 2011 (J. Pellerin).

Tributary Obstructions

Tributary obstructions on the Songo River, Island Pond, McWain Pond (Mills Brook), Keewaydin Lake (Mill Brook), and Virginia Lake were all examined and assessed during the 1956 survey. Spawning and nursery habitat above the lake outlet dams was considered to be minimal and not essential for fishery restoration in the Sebago Lake drainage. On the other hand, it was recommended a fishway or some other provisions be provided for at the Songo Locks so that salmon dropping downstream out of the Long Lake system to spawn were not denied re-access. According to the 1961 revision, an agreement with the State Park Commission guarantees fish passage through this obstruction by opening the gates each fall and allowing free movement of trout and salmon. Management issues and priorities have changed over time, and operational agreements have periodically been modified. Currently, MDIFW requests that gates remain closed until after the salmon spawning season to ensure salmon from Sebago will not be diverted into Long Lake. Furthermore, when the gates are opened draw down releases from Long Lake and the Bay of Naples are encouraged to be completed through the gates and spillway as a measure to reduce the potential for northern pike migratation into Long Lake.

Crooked River Impediment Survey

Fish and aquatic organism passage have become an increasingly important topic among various environmental groups. Recent surveys suggest habitat fragmentation and connectivity issues from improperly constructed stream crossings of transportation infrastructure (i.e. roads, railroads) are widespread, and at times as problematic as low head dams. In 2010, the Casco Bay Estuary Project (CBEP) funded an effort to conduct an impediment survey for the entire Crooked River drainage. This work was undertaken by the Portland Water District (PWD) with assistance from the Sebago Lake Chapter of Trout Unlimited (SLTU). A brief summary of those efforts are presented in Table 4 and were provided by Abbott (2011).

Table 4. Summary of the Crooked River impediment survey, 2010.

Data	Description/Additional Information
Total Data Points: 192	Pre-identified potential barriers within drainage.
I. Total Crossing Sites Surveyed: 96/192 (50%)	
a. Severe Crossing Barriers: 44/96 (46%)	
Perched Inlet: 2/96 (2%)	Severe
Blocked Inlet: 13/96 (14%)	50% or more of opening blocked.
Perched Outlet: 35/96 (36%)	Includes outlets onto cascades.
b. Potential Crossing Barriers: 45/96 (47%)	These are all at stream grade, but lack substrate, have very shallow depths and/or may be partially blocked.
c. No Barrier Crossings: 7/96 = 7%	These all are at stream grade, have sufficient depth and substrate to qualify as the best crossings.
II. Total Surveyed Dam Sites: 11/192 (6%)	These are all impassable, ranging in hydraulic height (spillway height) of 0.3 to 2.3 m.
III. Total Unsurveyed Crossing Sites: 85/192 (44%)	
a. Bridges: 38/85(44%)	Adequate fish passage assumed; quick check if obvious issues then included as surveyed.
b. Inaccessible: 29/85 (34%)	Posted property, excessive distance (i.e. railroad crossings)
c. No Structure or Site Exists: 18/85 (21%)	Abandoned roads/crossings.

Excluding dam structures (most of them are outlet dams on ponds) and inaccessible, unsurveyed structures, a total of 152 stream crossing structures were actually surveyed. Of these, 44 (28.9%) were severe barriers and 45 (29.6%) were potential barriers. Thus, approximately 58.5% of the stream crossing structures in the Crooked River drainage are or may be a barrier to fish and aquatic organism passage. Today, stream crossing structures present similar concerns as historical main-stem dams that were encountered by our predecessors. In the future, MDIFW will review these data in more detail, and work with various organizations to prioritize and remediate problem crossings to improve habitat access for fish in the Crooked River system. In September of 2011, SLTU, MDOT, Caribou Springs, LLC and MDIFW worked collaboratively to modify an impediment located on the lower end of Swett Brook that was identified during this project. In addition, a small dam located upstream of this site was removed in 2013.

Beaver Dams & Other Natural Fish Passage Barriers

Habitat surveys of the Crooked River and its tributaries indicate substantial historical and active beaver activity within the drainage. Despite the co-evolution of beavers and native fish species, many fishery managers believe dams and habitat changes caused by beavers can negatively impact salmonid populations. This view is controversial. Pollack et al. (2003) states, "Although these researchers expressed concern that beaver dams are harmful to trout, no study has ever demonstrated a detrimental population-level effect of dams on salmonids, nor has a study shown that beaver dams are more than a seasonal barrier to fish movement." While these authors provide an excellent review of the subject and make several valid points, population-level or long-term impact studies are rare and the lack of such studies still leaves uncertainty as to the "true" impacts of beaver on salmonid populations.

Photograph 8. Large beaver dam on Mile Brook that was breached by MDIFW in 2004 (Greg Massey).

MDIFW regional fisheries staff maintains that beaver can impact salmonid populations, particularly salmon. Anecdotal observations of population monitoring within the Crooked River drainage by MDIFW staff suggest beaver dams may periodically limit, delay, or prohibit upstream movement of salmon, particularly adults. Cunjak and Therrien (1998 as cited by Pollack 2003) have made similar observations with sea-run Atlantic salmon. Passage issues are typically of a seasonal nature and depend on several factors including dam characteristics (i.e. height, age), site location (i.e. water depth below dam), and water levels during periods of fish movement. On the Crooked River, large beaver dams coupled with low water during the fall spawning run of adult salmon have been a concern for MDIFW fishery biologists. In addition, habitat surveys in the Crooked drainage suggest beavers have created extensive

Photograph 9. Large debris dam on the Crooked River that was breached in 2007 and removed in 2008 (MDIFW Staff).

alterations in stream habitat including changes in substrate, flow velocities, depths, and possibly water temperature that are unlikely to be beneficial to either trout or salmon, and particularly for salmon. Consequently, MDIFW and concerned anglers have breached or removed large beaver dams and other obstructions on occasion prior to the fall spawning run (Photographs 8 and 9). In addition, fishery biologists have advocated for the legal harvest of beavers within the Crooked River drainage to prevent beaver from over populating the stream system.

Public Access

Although MDIFW owns a small undeveloped parcel in Albany, there are currently no known formal public (State or local government) access sites to the Crooked River. Existing road crossings provide most of the available access to the river. The main highways in the watershed include U.S. Route 302 and State Route 11, which cross the river in the southern part of the drainage. State Routes 117 and 37, which cross in the central part, and State Routes 118, 5, and 35, which cross the river in the northern portions of the drainage. There are also dozens of town and private roads that traverse or parallel the river system and allow some form of river access. Access is also available via permissive trespass over private properties. Public access for angling is also allowed on some properties with deeded conservation easements (e.g. Jugtown Plains, Hague).

Two segments of the river are traditionally canoed or kayaked, although both reaches are most readily floated during higher water levels. The trip from East Waterford (State Route 118) to Scribner's Mills is approximately 17 miles long, and features Class I-III rapids, as well as a fair amount of flat water. The trip from Scribner's Mills to Edes Falls is approximately 10 miles consisting of mostly flat water that meanders through woods and fields (DeLorme 1998).

Maine State law dictates that the water and natural resources (wildlife and fisheries) associated with rivers and streams are publicly owned. However, unlike some States where landowners only own to the high-water level, Maine colonial law dictates that the land beneath rivers and streams are owned by the landowner. Consequently, landowners can post their property and prohibit river access by foot. In addition, posting of even a small property at major road crossings can effectively eliminate public use of the resource for miles. This situation is particularly problematic on small to medium-sized waters like the Crooked River that may largely be "unfloatable", and where public use of the resource is largely limited to shoreline and wading activities. While much of the river is currently accessible, these access provisions are tenuous and concerning given the projected increases in development and land postings. Opportunities to provide more formal public access to the river need to be pursued to ensure adequate access for future generations.

Water Quality

MDEP Water Quality Classification

Surface water classification systems are typically used by State and Federal agencies to assist with resource management, to protect water quality for the stated management goal(s), and to provide guidance if standards are not being achieved. The State of Maine has used a water classification system since the 1950's, and it has evolved over time into the present system. The system establishes four classes for freshwater rivers and streams: AA, A, B, and C with each classification having specific allowable uses, and standards (MDEP 2009a). Designated uses and standards for each class are summarized in Table 5.

Table 5. Summary of MDEP classification system for rivers and streams (MDEP, 2009b).

Class	Designated Uses	Dissolved Oxygen Criteria	Bacteria (E.coli) Criteria	Habitat Criteria	Biological Criteria**
AA	Aquatic Life; Drinking Water; Fishing; Recreation	as naturally occurs	as naturally occurs	Free flowing and natural	No direct discharge of pollutants; as naturally occurs
A	Aquatic Life; Drinking Water; Fishing; Recreation; Navigation, Hydropower; Industrial Discharge	7 ppm; 75% saturation	as naturally occurs	Natural	as naturally occurs
B	Aquatic Life; Drinking Water; Fishing; Recreation; Navigation, Hydropower; Industrial Discharge	7 ppm; 75% saturation	64/100 ml (g.m. *) or 236/100 ml (inst.*)	Unimpaired	Discharges 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 to the resident biological community.
C	Aquatic Life; Drinking Water; Fishing; Recreation; Navigation, Hydropower; Industrial Discharge	5 ppm; 60% saturation 6.5 ppm (monthly average) at 22 ° and 24°F	126/100 ml (g.m. *) or 236/100 ml (inst. *)	Habitat for fish and other aquatic life	Discharges 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.
**Numeric bio-criteria in Maine rule Chapter 579, Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams					

Maine statute had classified the Crooked River and its tributaries as follows, "(2) Crooked River and its tributaries, except as otherwise provided, excluding existing impoundments and excluding that area of the river previously impounded at Scribners Mill – Class AA…(4) Mile Brook (Casco) – Class B. [1991, c. 499, §16 (AMD).] (MSL 2009). Consequently, the vast majority of the river, and all but one of its tributaries were designated as Class AA waters. The Class A designated areas presumably cover the small impounded areas related to remnants of the old mill dams, breached dams (Edes Falls), Bolsters Mills, and a specific grand-fathering of the Scribner's site, which is now removed. Mile Brook is an important salmon and brook trout spawning and nursery tributary, but discharges from the Wade Fish Hatchery in Casco have resulted in its B classification.

The MDEP periodically solicits the public to comment on the need for reclassification, which may include either upgrading or downgrading the existing classification if sufficient justification exists to do so. In 2008, the MDIFW was in the midst of reviewing an application by the Scribner's Mills Preservation, Inc. to rebuild a dam on the Crooked River to restore a historical mill operation. The Department was notified of the reclassification process and recognized the importance of upgrading the classification of the Crooked River as a strategy to conserve the river's fisheries. The pending application to rebuild a dam created a heightened level of awareness that interest in reconstructing mill dams could once again jeopardize the river's fisheries. MDIFW advocated for an upgraded classification to AA for the entire river. In the fall of 2009, the Maine Legislature upgraded the entire Crooked River to a Class AA water. Although this classification would preclude the construction of any new dams, the pending 2009 application at the Scribner's site was grandfathered pending a decision at MDEP. As noted earlier, the Scribner's application to rebuild the dam was denied in 2014 and the entire river is now classified as Class AA.

Crooked River biomonitoring has yielded a Class A rating for every sampling event, with the exception of the Naples site in 2005. It should be noted these A ratings do not contradict the AA assignment, as the macroinvertebrate model does not differentiate between the two. Despite these A ratings, the PWD (2007a) reports an increase in macroinvertebrate abundance and a decrease in diversity from the northern to southern portion of the watershed, which typically indicates nutrient enrichment. In addition, the Muddy River and Northwest River watersheds, two other large tributaries to Sebago Lake, have shown no signs of degradation as reflected in the biological community of aquatic insects. A review of the mean Class A modeling probabilities (Table 6) corroborates the PWD's observations, which shows a drop in values from the headwaters downstream. The declining trend in values shown at all sites after 2005 is also concerning.

Table 6. Summary of macroinvertebrate first stage class A modeling probabilities & final classification for the Crooked River.

Year	Albany	Waterford	Harrison	Naples
1989	---	--	---	0.35 (A)
1991	---	0.77 (A)	---	---
2001	---	---	---	0.72 (A)
2003	0.90 (A)	---	0.62 (A)	0.43 (A)
2004	0.95 (A)	0.96 (A)	0.81 (A)	0.78 (A)
2005	0.87 (A)	0.86 (A)	0.84 (A)	0.24 (B)
2006	0.90 (A)	0.88 (A)	0.97 (A)	0.75 (A)
2007	0.97 (A)	0.76 (A)	0.89 (A)	0.67 (A)
2008	0.82 (A)	0.80 (A)	0.90 (A)	0.83 (A)
2009	0.50 (A)	0.39 (A)	0.91 (A)	0.53 (A)
Mean	0.84	0.77	0.84	0.59

In the absence of any unknown illegal dumping activities (PWD received reports of illegal septic service dumping in 2009); nutrient enrichment on the Crooked River is likely the result of nonpoint source pollution within the watershed. Many lake communities within the Crooked River watershed have conducted nonpoint source pollution surveys and related remediation, which is helpful, but does not address the non-lake portions of the watershed. In 2011, the Cumberland County Soil and Water Conservation District, with the help of volunteers, conducted a nonpoint source pollution survey of the Crooked River watershed to identify and prioritize specific problem areas that need to be addressed. Williams (2012) reported on the survey, which identified 164 nonpoint source impact sites with the majority of sites (57%) being associated with State, Town and private roads. It was projected that most of the impact sites could be repaired with minimal to moderate expense. Hopefully, the apparent trends being observed on the river can be stabilized and possibly even reversed.

Temperature

Although many water quality parameters may impact fish populations, three variables typically used to assess fisheries habitat include: temperature, dissolved oxygen, and pH. Temperature is one of the most critical variables when examining a habitat's suitability for fish, particularly for coldwater species like salmon and brook trout. MDIFW has three historical Crooked River datasets with temperature information including: (1) a regional stream database consisting of temperature data collected during fish sampling events (1937-2010); (2) spring-fall daily temperature recordings from monitoring events of the Bolsters fish trap (1974-1986); and (3) spring-fall hourly temperatures at Edes Falls (1999).

The regional stream sampling data has a total of 160 sampling events for temperature with each sampling event different from another by date, time, and/or site. These multiple variations within the dataset make it somewhat difficult to summarize in a meaningful context; however, Table 7 shows the mean, minimum, and maximum temperature values recorded by month and general area of the river. The summer mean monthly river temperature over the entire dataset ranged from a low of 63.1°F in June to a high of 65.7°F

Table 7. Mean, minimum, and maximum temperatures (F°) by month and river reach for stream survey data, 1937-2010.

River Reach	Statistic	Month				
		6	7	8	9	Total
Lower (Scribners - Lake)	N	12	1	10	10	33
	Mean	62.2	68.0	70.0	61.3	64.6
	Minimum	60.8	68.0	63.5	54.3	54.3
	Maximum	66.2	68.0	74.3	72.3	74.3
Middle (Rte 118 - Scribners)	N	20	4	38	9	71
	Mean	64.0	65.3	65.7	63.3	64.9
	Minimum	59.9	62.6	62.6	59.2	59.2
	Maximum	67.1	68.0	71.6	71.8	71.8
Upper (Albany-Rte. 118)	N	12	1	34	9	56
	Mean	62.6	64.4	64.2	59.9	63.3
	Minimum	57.2	64.4	59.0	48.2	48.2
	Maximum	69.8	64.4	71.6	66.2	71.6
N		44	6	82	28	160
Mean		63.1	65.7	65.7	61.5	64.2
Minimum		57.2	62.6	59.0	48.2	48.2
Maximum		69.8	68.0	74.3	72.3	74.3

in July and August with an overall mean of 64.2°F. The mean temperature by river reach revealed a differential temperature increase of 1.6 and 1.3 degrees from the upper to middle and lower reaches, respectively. The higher average temperature in the middle reach was unexpected, but the average temperatures in the lower reach were higher than the middle reach in two of the four summer months. Of the 160 summer sampling events, the temperature exceeded 68°F only 22 times (13.8%), and the highest temperature recorded was 74.3°F. This temperature was taken at the lowermost portion of the river (just above the river's confluence with the Songo River) on August 28, 1937. This dataset was also examined to see if there were any notable warming or cooling trends over the past eight decades, but no noticeable trends were discernable from the data. This could be indicative of no actual change, or more likely, is simply the result of data that are too variable to account for such subtleties.

The Bolsters Mills dataset has a total of 323 sampling events collected between May and November from 1974-1986. Although temperature data are missing for 1982 and specific months within particular years, the Bolsters Mills temperature dataset provides a better picture of annual and monthly variations in water temperature due to the larger sample size and less variation due to sampling site(s). Figure 2 shows a summary graph of the mean monthly temperature by year, a more complete breakdown of the data is provided in Appendix K. Of the six years with complete data, the mean annual water temperature for the period

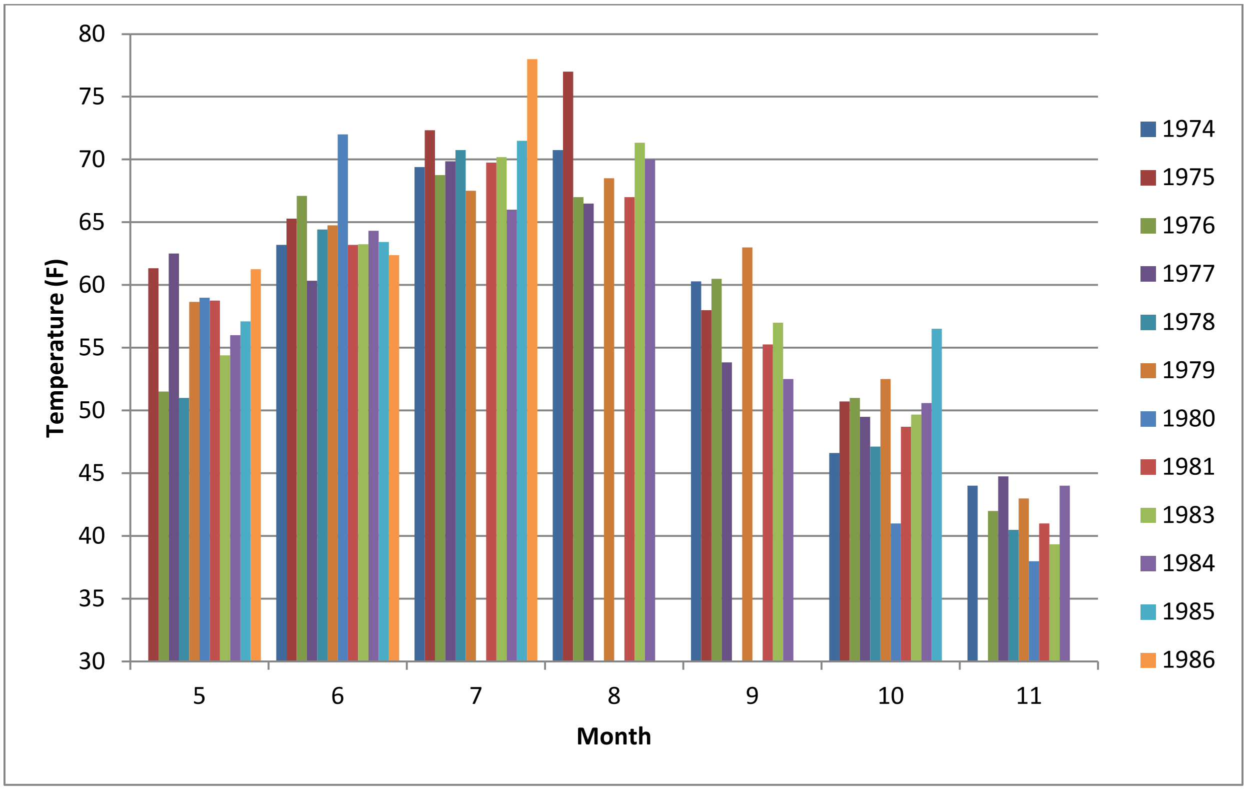


Figure 2. Mean monthly water temperature of the Crooked River at Bolsters Mills by year, 1974-1986.

(May-November) was 58.8°F with a minimum and maximum of 57.2°F and 62.2°F, respectively. The mean annual temperatures for the period indicate minimal variation from year to year, no more than 5.4°F.

The mean monthly river temperature over the entire dataset for the critical summer period (June-September) ranged from a low of 57.6°F in September to a high of 69.8°F in July with an overall mean of 65.3°F. Of the 323 sampling events, the temperature exceeded 68°F sixty times (15.7%), and the highest temperature recorded was 78.1°F. These results are slightly higher than the previously described data, which is likely due to all of the temperature readings coming from a site within the lower river segment.

To understand daily temperature fluctuations on the river (which could not be derived from the other two datasets), hourly temperature recordings were collected in the vicinity of Edes Falls from June 8th to October 12th of 1999 (Figure 3). This dataset depicts a very different picture than the previous temperature datasets, with daily summer temperatures commonly exceeding 68°F. The mean monthly river temperature over the entire dataset for the critical summer period (June-September) ranged from a low of 63.9°F in September to a high of 72.0°F in July with an overall mean of 68.4°F. Of the 3,430 sampling events, the temperature exceeded 68°F 2,133 times (62.2%), and the highest temperature recorded was 79.2°F. While this dataset was expected to reflect the warmest and least suitable conditions for salmonids (given its location low in the river), recorded temperatures were still higher than anticipated. According to the NCDC (1999) the United States was projected to experience its second warmest year on record since 1900, which follows the all-time record of the previous year (1998). In addition, Maine was among 22 other states to experience temperatures rated well above normal for the year. Thus, the 1999 data represents not only a worst case scenario for the river, but also a worst case in relation to historical annual temperature extremes.

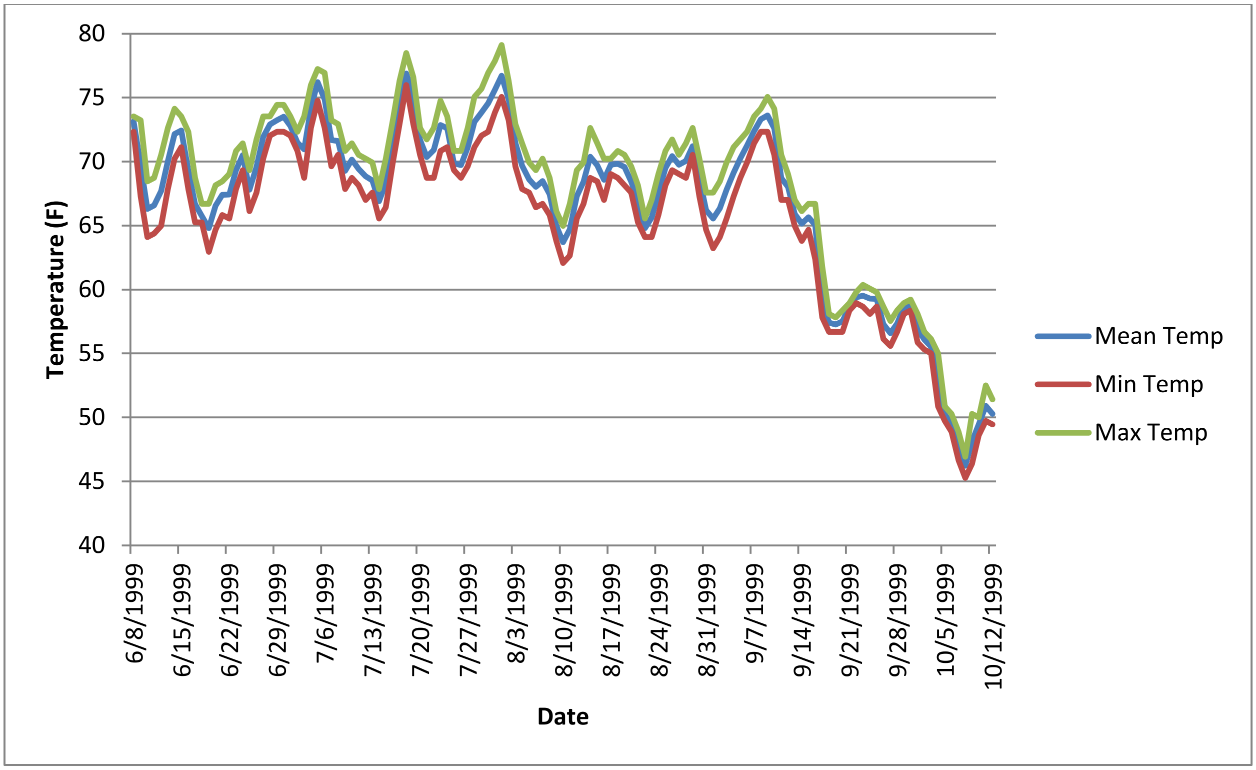


Figure 3. Mean, minimum, and maximum daily temperature (F) recordings for the Crooked River at Edes Falls, June-October 1999.

A summary of temperature preferences and tolerances for Atlantic salmon and brook trout are presented in Table 8. Based on this information, it would appear that the Crooked River is typically within the upper level of the optimum temperature range for production, and is well within the survival tolerance limits for the species.

Although the temperature information presented was developed for the freshwater stages of sea-run Atlantic salmon, it is likely applicable to landlocked salmon. In addition, the salmon in the Crooked River system have evolved over many generations and are likely well adapted to this particular habitat. On the other hand, summer temperatures in the main stem of the Crooked River typically exceed optimum conditions for brook trout, and they probably seek out coldwater refugia (i.e. springs, colder tributaries) during periods of temperature stress.

Table 8. Summary of optimum and lethal temperature ranges reported for Atlantic salmon and brook trout.

Atlantic Salmon (juvenile life stages)		
Description	**Temperature**	**Source**[1]
optimum temperatures for growth & production	59.0-66.2°F	DeCola 1970
upper temperature limit tolerated for short periods	80.6°F	DeCola 1970
upper temperature limit for feeding	72.5°F	Elliot 1991
upper temperature limit for survival	82.0°F	Elliot 1991
upper temperature limit tolerated for short periods	89.6°F	Huntsman (1942)
lethal upper temperature limit under laboratory conditions	89.6°F	Garside (1973)
Brook Trout		
Description	**Temperature**	**Source**
optimum temperatures for growth and survival	51.8-60.8°F	Raleigh (1982)
upper and lower lethal temperature limits	32 and 75.2°F	Raleigh (1982)
[1]As cited by Stanley and Trial (1995)		

Dissolved Oxygen

Although rarely a problem in most Maine river systems, dissolved oxygen is another critical water quality parameter for fish. Elson (1975 as cited by Stanley and Trial 1995) reported that juvenile salmon do not occur in streams where the dissolved oxygen (D.O.) regularly drops below 5 ppm, and successful embryo and larval development requires a minimum D.O. of 6 ppm. Mills (1971 as cited by Raleigh 1982) indicated brook trout require D.O. levels of at least 5 ppm.

The MDIFW's regional stream sampling dataset has a total of 35 dissolved oxygen readings taken at various locations on the river between 1937 and 2010. The mean, minimum, and maximum values are 9.5, 6.0, and 13.0 ppm, respectively. The data, as well as the existence of fisheries for salmon and brook trout indicates that dissolved oxygen levels of the Crooked River are suitable for both species.

pH

In Maine rivers and streams, pH levels are typically suitable for salmonids. However, our geographic location and geologic history increases the vulnerability of our lotic and lentic systems to ongoing acidification from precipitation. Watt et al. (1983) reported that salmon streams in Nova Scotia with mean annual pH levels below 4.7 had lost their salmon runs and those below 5.0 had been impaired. In addition, numerous studies indicate that early stages of salmon development, embryo through post emergent fry, are sensitive to pH levels lower than 5.0 (Peterson 1980, LaCroix 1985). On the other hand, brook trout are very tolerant of low pH levels. Raleigh (1982) states the optimal pH range for brook trout is likely 6.5-8.0 with a tolerance range of 4.0-9.5.

During routine stream sampling events on the Crooked River, 50 pH readings were recorded at various locations between 1937 and 2010. Mean, minimum, and maximum values of the data are 6.5, 6.0, and 7.0, respectively. This data and the existence of fisheries for salmon and brook trout suggest pH levels are adequate for both species. Although available pH values appear suitable, a recent study suggests episodic pH changes, particularly those associated with snowmelt or other large spring and fall rain events may be impacting fish populations. Johnson and Kahl (2005) observed episodic pH events below 5.0 in several of Maine's downeast rivers, and these events likely occur in other Maine river systems. In addition, the bedrock and surficial geology of the Crooked River watershed provides limited buffering capability, and ongoing acidification and its associated leaching of toxic metals (i.e. aluminum) are a potential threat to the fishery resources, particularly salmon.

Other Water Quality Parameters

The USGS has periodically taken a variety of water quality measurements of the Crooked River at its gauging station in Naples, and a review of their records indicates a comprehensive water quality analysis was conducted in 1996 (USGS 2009). An adapted summary of the 1996 water quality data is presented in Appendix L.

The Portland Water District (PWD) also monitors several water quality parameters at various locations on the Crooked River as part of its ongoing efforts to monitor and protect the water quality of Sebago Lake. The PWD (2007, 2009) reported turbidity, total phosphorus, and fecal coliform levels in the Crooked River appeared to be stable and that results were consistent with historical sampling. A summary of the PWD's data is available in Appendices M and N.

MDEP has an extensive statewide biomonitoring program to evaluate whether or not a water body is in attainment of its prescribed water quality classification. In addition, to macroinvertebrate data they commonly collect basic water quality data, which usually consisted of temperature, conductivity and dissolved oxygen. A summary of MDEP water quality sampling data on the Crooked River is provided in Appendix O, and the raw data are available from MDEP (2011).

In general, a review of the above data sources indicates the water quality of the Crooked River is quite good, and capable of meeting all of the designated uses assigned to the river under its current water classification. In addition, the river is certainly suitable for the various life stages of landlocked Atlantic salmon, but summer water temperatures are limiting for brook trout.

Habitat Quantity and Quality

Stream habitat surveys are a relatively low cost, easy-to-use approach that can be tailored to meet a variety of objectives including: the collection of baseline habitat conditions, identification of environmentally stressed stream reaches, documentation and quantification of the habitat and critical habitats (i.e. spawning habitat, nursery habitat), and even used for more intensive habitat based modeling assessments. Over the years, MDIFW has conducted habitat surveys on the Crooked River and several of its tributaries (Photo 10). Data collected include length of habitat types, presence and orientation of tributaries, substrate type, types and quantity of habitat features associated with fish cover, and documenting obstructions to fish passage. The habitat survey protocols conducted within the Crooked River system would largely fall under a meso-scale stream habitat survey (MDIFW Level II), which is more fully described by Gallagher (2007). The remainder of this section summarizes the habitat data collected for the Crooked River system.

Photograph 10. Author surveying Mile Brook (B. Lewis)

Main Stem

During the 1983 and 1984 field seasons MDIFW regional fisheries staff conducted a habitat survey of the entire main stem of the Crooked River from its headwaters in Albany downstream to its confluence with Sebago Lake. The author recently analyzed these historical data, and an overall summary of basic habitat types, dominant substrates, and pool data are presented in Tables 9 and 10.

Habitat data indicate the main stem of the Crooked River is predominantly comprised of pool habitat (73.7%). This may be an over estimate as the river's extensive low gradient, meandering reaches may have made it difficult to differentiate pools from deep, slow run habitat types. If so, run habitat would be underestimated. The fact that only 4,070,184 ft^2 was identified as Class 1-3 pools, which represents only a fraction (33.2%) of the total pool area supports this conclusion. In addition, much of the habitat classified as pools at summer low flows would likely shift to run habitat at moderate to high flows. In any case, the river has ample high to moderate quality adult holding habitat (Class 1 and 2 pools) for salmon, and brook trout where temperatures are not limiting. Fast water habitat in the Crooked is more limited, and consists of relatively short stretches segregated by large reaches of low gradient, meandering pool/run habitat. Riffles provide the majority of preferred habitat for juvenile life stages of salmon (Stanley and Trial 1995), and to a lesser extent brook trout (Raleigh 1982). Appendix P breaks down habitat types by different river reaches, and clearly illustrates that the majority of riffle habitat is located above Edes Falls (95.3%) and Scribners Mills (87.1%). For this reason the MDIFW has historically and continues to focus on providing effective fish passage beyond these points. A more thorough discussion of juvenile salmon production potential will be presented later in this document.

Table 9. Summary of habitat and dominant substrate types in the Crooked River.

Habitat Type	Wetted Area (ft^2)	Percentage of Total Area
Riffle	2,286,200	13.8
Pool	12,241,400	73.7
Run	2,079,000	12.5
Cascade	---	---
Deadwater	---	---
Total	16,606,600[1]	100.0
Substrate Type (Dominant)	**Wetted Area (ft^2)**	**Percentage of Total Area**
Mud	19,160	0.1
Fines	---	---
Sand	12,786,041	77.9
Pea Gravel	---	---
Gravel	813,500	5.0
Cobble	---	---
Rubble	530,085	3.2
Boulder	1,965,400	12.0
Ledge	300,430	1.8
Total	16,414,616[1]	100.0

[1]Substrate and habitat type totals are not equal due to different computational methods (section vs. transect area).

Table 10. Summary of Crooked River pool data by classification.

Pool Class[1]	Number	Wetted Area (ft^2)	Mean Max Depth (ft)
1	389 (70.5%)	3,772,030	7.2
2	90 (16.3%)	273,664	4.7
3	73 (13.2%)	24,485	2.2
Total	552 (100.0%)	4,070,184	6.1

[1]Pool classes described by Gallagher (2007), 1-high quality, 2-moderate quality, 3-low quality

Photograph 11. Typical Boulder/Rubble reach of the Crooked River (MDEP).

Sand is by far the largest dominant substrate type within the Crooked River system (77.9%), which is consistent with the predominant low gradient, slow moving habitat types. A total of nine dominant sand cover types were identified that occurred in conjunction with subdominant substrates ranging from boulder to detritus. As expected, fast water habitats were dominated by various boulder and rubble substrate classes (Photo 11). Rocky substrates ranging from gravel to boulder offer better quality habitats for both brook trout and juvenile salmon (Raleigh 1982, Stanley and Trial 1985). These substrates are relatively limited and widely dispersed throughout the Crooked River. Appendix P shows a breakdown of dominant substrate types by different river reaches, and the majority of the best substrate types for salmonids are located above Edes Falls and Scribners Mills.

Several factors, many of which are not well understood, influence where salmonids actually spawn, so it is difficult to identify and fully quantify spawning habitat in the Crooked River. In addition, the timing of our habitat data collection (summer low flows) was designed for evaluating juvenile production rather than quantifying spawning habitat. Furthermore, potential spawning habitat commonly occurs in small patches that may not have always been reported and mapped. Larger areas of potential spawning habitat were a focus, and as a result potential spawning habitat was likely underestimated. On the other hand, brook trout and salmon prefer gravel substrates for spawning, and our habitat survey data gives us a general sense of the amount of potential spawning habitat and where it occurs. For perspective, 87.1% and 57.2% of the habitat with dominant gravel substrate types are located above Edes Falls and Scribners Mills, respectively. Kondolf and Wolman (1993) determined that in general salmonids can spawn in gravels with a median diameter up to about 10% of their body length. Thus, a typical adult brook trout in the Crooked River could spawn in a median gravel of about 0.5-1.5 inches in diameter, while larger sized salmon could spawn in gravel with a median size up to about 2.5 inches in diameter. Our habitat survey was not detailed enough to determine the quantity of various gravel sizes available for the two species. Consequently, a redd count survey was conducted in 2014, which is discussed later in this report.

Tributaries

In 2007, MDIFW staff reviewed the Crooked River habitat and salmon production data from the early1980's, and expanded habitat data collection efforts to include several of the Crooked River's larger tributaries. To date, MDIFW has conducted habitat surveys on four major tributaries (Mile, Meadow, Swett, and Russell Brooks) including two additional streams (Herrick Brook a tributary to Meadow Brook, and an unnamed tributary to Swett Brook). Appendices P, Q, R, and S summarize the habitat and substrate data for these surveys. Pool data for the larger, more significant pools in these streams were collected, but is not included in this summary. In contrast to the main stem river, adult holding pools for salmon in the tributaries were generally limited and typically of low quality due to size, depth, and cover provided for adult fish.

Mile Brook is approximately 3.9 miles in length and exhibits various habitat types throughout its reach. Upper reaches are dominated by riffle/shallow pool complexes, whereas middle to lower reaches are predominantly run and dead water habitats created by extensive historical and recent beaver activity. Some of the beaver dams are large and may prohibit or at least seasonally restrict fish movement, particularly for adult salmon. The predominant habitat and substrate types were dead water (46.9%) and fines (22.5%) (Appendix Q). The total amount of habitat in Mile Brook (518,851 ft^2) compares to only 3.2% of the entire habitat in the Crooked River. Nonetheless, Mile Brook is considered a relatively important tributary for both salmon and brook trout production due to its reasonably cool summer temperatures and its low proximity in the drainage.

Meadow and Herrick Brooks are 4.6 and 3.7 miles long, respectively, and they are similar to Mile Brook in that upper reaches are dominated by riffle/shallow pool type habitats, whereas middle to lower reaches are predominantly run and dead water habitats created by extensive historical and recent beaver activity. Again, it is suspected that some of the larger dams could, under the right conditions, prohibit or seasonally restrict salmon from fully accessing this potential habitat. Meadow Brook is dominated by dead water habitat (59.6%) and substrate consisting of fines (37.5%), while Herrick Brook is predominant riffle (55.7%) and cobble (38.5%) (Appendix R). The Meadow Brook complex provides 602,701 ft^2 of total habitat, which equates to 3.7% of the entire habitat in the Crooked River.

Swett Brook and its unnamed tributary are approximately 6.3 miles in length. Swett Brook exhibits various habitat types throughout its length, but riffle/minor pool habitat is clearly the dominant habitat type (53.2%) throughout its entire length. The unnamed tributary is essentially all riffle/minor pool habitat (100%). The predominant substrate for Swett Brook and the unnamed tributary are cobble (36.3%) and gravel (61.7%), respectively (Appendix S). Unlike Mile, Meadow, and Herrick Brooks, historical and active beaver impoundments are more limited, but based on a report by (Heinz 2013) some of the beaver dams appear to restrict or adult salmon movement. Habitats in Swett Brook and the unnamed tributary above Hutchinson Pond Road were not surveyed as both road crossings impeded fish passage to varying degrees. In addition, the road crossing on Bisbee Town Road and an old dam site about a mile upstream may preclude movement of adults and/or juveniles at certain flow levels. Sebago TU, CBEP, MDOT, MDIFW, USFWS, and Caribou Springs, LLC secured funding to provide improved passage for the Bisbee Town Road crossing and the dam site in 2011 and 2013, respectively. Although Swett Brook and its tributary up to Hutchinson Pond Road only account for 391,799ft^2 of total habitat (2.4% of the entire habitat in the Crooked River), the habitat is of high quality for salmon and brook trout production. Historical and recent spot electrofishing surveys indicate that wild brook trout and juvenile salmon are distributed throughout its length. In addition, Swett Brook provides important cold water refugia for adult salmon during the summer.

Russell Brook is approximately 2.6 miles in length, excluding areas above the Haskell Hill Road. While the brook is comprised of various habitat types throughout its length, riffle/minor pool type habitat is clearly the dominant habitat type (60.6%). In addition, a rather significant portion of the brook consists of two rather large inactive beaver flowages, which account for the majority of run habitat. Sand is the most dominant substrate (45.2%) (Appendix T). Russell Brook contained 123,880ft^2 of habitat, which is the least of the four tributaries surveyed and it represents only a small fraction (0.7%) of the total habitat area of the Crooked River. Russell Brook has limited habitat potential for juvenile salmon due largely to the large flowage areas within the reach. The best salmon habitat available is located in the lower reach towards the Crooked River, and historical electrofishing data indicates this reach is being utilized by salmon. Brook trout are also present in the brook, and better suited for the available habitat conditions.

Individually these small tributaries appear to provide only limited habitat, but collectively they equal 10% of the habitat area of the entire Crooked River and they play an important role in the overall salmon and brook trout production for the system. In addition, they provide summer temperature refugia and important spawning and rearing habitat for both species, particularly brook trout.

Biological Data - Fish

Fish Species Occurrence and Relative Abundance

To our knowledge, Gerald Cooper completed the first extensive fishery surveys of the Crooked River in 1937. He sampled the river on 58 separate occasions on various dates and locations throughout the year, and documented a total of 14 species of fish (Table 11). From the time of Cooper's surveys until 2014, MDIFW staff sampled the river an additional 143 times and documented six additional fish species within the main stem. Other than brown trout, most of these species were likely present in the system during Cooper's survey, but were either too rare or were not susceptible to his sampling gear. For example, most of Cooper's fish collections were conducted with a seine, which was likely ineffective for species like cusk and American eel (*Anguilla rostrata*). These two species showed up regularly from the 1960's on, when electrofishing became the preferred sampling method. Largemouth bass (*Micropterus salmoides*) and white perch were present in the drainage during Cooper's time, but white perch are likely only transient species and bass numbers were probably much lower than today due to their later introduction into many additional waters in the drainage. Although rarely observed, brown trout showed up later, which is likely the result of expanded stocking programs for the species and their increased presence within the drainage.

Table 11. Species occurrence, relative abundance, and periodicity of fish in the Crooked River, 1937-2014.

Species Observed in Main Stem of the Crooked River			
Common Name	**Abundance**	**1st Observation**	**Comments**
Bridled Shiner	Extirpated?	1937	Only observation
Blacknose Dace	Abundant	1937	
Brown Bullhead	Rare	1937	
Creek Chubsucker	Extirpated?	1937	Only observation
Common Shiner	Abundant	1937	
Fallfish	Common	1937	
Chain Pickerel	Rare	1937	
Pumpkinseed Sunfish	Rare	1937	
Pearl Dace	Extirpated?	1937	Only observation
Smallmouth Bass	Rare	1937	
Yellow Perch	Rare	1937	
White Sucker	Rare	1937	
Brook Trout	Common*	1937	Seasonally, and in headwaters*
Salmon	Abundant	1937	
Later Occurrences within Main Stem			
American Eel	Common	1964	
Cusk	Common*	1965	Lower reaches only*
White Perch	Very Rare	1965	Only observation
Largemouth Bass	Rare	1973	
Brown Trout	Very Rare	1975	2-1975, 1-1980, 1-1985, 1-1996
Creek Chub	Rare	1984	
Other Species Existing within the Drainage, Never Sampled in Main Stem[1]			
Rainbow Smelt	Seasonal (Spring)	1939	Sebago and numerous lakes
Black Crappie	---	1953	Lakes (only 2)
Redbreast Sunfish	---	1954	Lakes (only 2)
Golden Shiner	---	1957	Numerous lakes and tributaries
Landlocked Alewives	---	2004	Pleasant Lake/Sebago Lake
[1]Only confirmed occurrences noted in comments.			

Five additional fish species are known to exist in the drainage, but only one (rainbow smelt) has been documented in the Crooked River (Table 11). Rainbow smelt are seasonal migrants from Sebago Lake, traveling upriver to spawn during the spring. Smelt have been reported to travel as far upstream as Route 11 when the adult population is extremely abundant in Sebago Lake, but more commonly they travel only as far as Route 302 or lower in the river system. Golden shiners (*Notemigonus crysoleucas*) are relatively abundant in the drainage, but surprisingly have never been observed in the Crooked River. In addition, banded killifish (*Fundulus diaphanus*) have been reported in the drainage, but remain unconfirmed within the main stem of the river. Complete listings of known fish species occurrences in lakes and tributaries within the drainage are presented in Appendices U and V.

Based on MDIFW's sampling efforts, the three most abundant species are juvenile salmon, blacknose dace (*Rhinichthys atratuls*), and common shiner (*Luxilus cornutus*). The majority of other fish species known to occur in the Crooked River system are relatively low in abundance. However, it should be noted that our sampling efforts are typically geared towards salmon and often target shallower riffle/run type habitats. Some of the species of lower abundance are likely more common in the slower and deeper moving water habitats within the river.

Electrofishing Data

Electrofishing Data - Abundance of Juvenile Salmon and Brook Trout

As previously stated, wild production of salmon within the Crooked River is an important component of the salmon fishery in Sebago Lake. Consequently, over the years MDIFW staff has expended considerable effort sampling the river's juvenile salmon population. A review of MDIFW's files indicates the main stem of the Crooked River has been electrofished 141 times between 1961 and 2010 with at least 17 different locations. Unfortunately, differences in sampling techniques, electrofishing gear, sites, and distances sampled complicate summarization of the entire historical dataset in a meaningful and comparative context. A thorough review of the electrofishing data indicate three distinct time periods of somewhat consistent sampling methodology with two that can be discussed: (1) 1961-1985 appears to be predominantly single pass electrofishing at multiple sites with a portable generator unit; (2) 1986-1994 no data collection; and (3) 1995-2010 multiple pass electrofishing with a battery powered backpack unit.

In the earlier period (1961-1985), the river was sampled 104 times at up to 9 different sites. The majority of the data were fairly consistently collected at four sites including: below the Edes, Scribners, and Bolsters dam sites, as well as upstream of the Sodom Road crossing. Figure 4 illustrates the historical first-run counts of salmon young of the year (YOY) and parr for these sites during this earlier time period. Data in the figure are presented from downstream to upstream sites, left to right. Although there is significant annual variability in the counts, there are a few interesting observations including: a lack of YOY salmon in the early to mid-1960's, and a lack of YOY salmon at the upper two sites until after the early 1970's.

The lack of YOY in the early 1960's may be related to DDT impacts discussed by Andrews and Everhart (1966). They believed the spraying of DDT around the lake and surrounding watersheds for mosquito control had decimated the smelt population in Sebago and resulted in poor salmon growth, which would have led to fewer spawning adults. They suspected impacts on larval salmon as well. While this may be the case, there still appeared to be parr present during this period. Perhaps parr were dropping into the main stem from unaffected tributaries and were less susceptible to the effects of DDT than larval salmon. The lake fisheries were reportedly beginning a recovery from DDT by the mid-late 1960's.

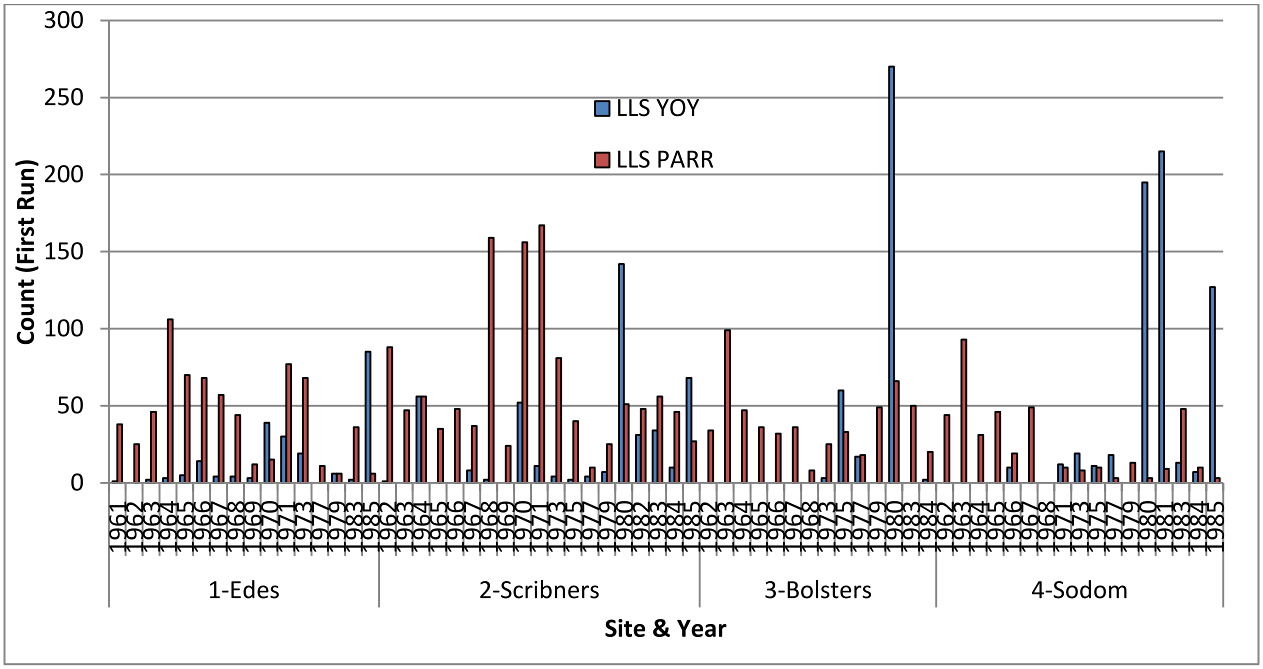


Figure 4. First run counts of salmon YOY and PARR at four selected sites on the Crooked River, 1961-1985.

The presence of more YOY in the upper reaches of the river beginning in the early 1970's is likely a direct result of the partial restoration of fish passage at Scribner's dam (1971/1972) and Bolsters dam (1972). DeRoche (1982) states, "Electrofishing in the various locations above Bolsters Mills reveals that salmon production is increasing constantly. The 1980 electrofishing results showed that in five study areas, fourteen times more salmon fry were taken than in the previous 15-year period…." A review of the data, along with later data suggests this large spike in production was an anomaly because it occurred in downstream areas as well and was not sustained. A similar spike occurred in 1981 at Sodom Road only and was explained by DeRoche (1982). He indicated that 147 adult salmon were transferred from the Jordan River to known spawning areas in Waterford in the fall of 1980, which likely resulted in the observed increase of salmon fingerlings (YOY) the following year. In general, large spikes of YOY salmon were often not followed by a corresponding spike of parr the following year as one might expect. Parr are known for dispersing great distances, and perhaps they simply spread throughout the river system. The documented presence of parr salmon in the upper river (Bolsters and Sodom) in relatively high numbers before passage was restored was rather unexpected. While there are some anomalies (i.e. a bump in YOY at Sodom in 1971 and the presence of parr upstream, pre-dam removal), it is difficult to fully ascertain what happened during this period of time. For example, there were some unusual stockings and transfers of adult fish above Bolsters Mills reported earlier that are not part of MDIFW's stocking records, as well as some old reports of wild adult salmon periodically being netted and lifted over impediments. In addition, if dam and flume gates were periodically opened, adult and juvenile salmon may have been able to negotiate the obstructions.

Although not shown in Figure 4, various data analyses were performed with the entire dataset, revealing lower first run counts of YOY and parr during the most recent data periods. It is believed this may be a function of a couple factors. First, portable generators were used in the collection of older data and are more effective than newer backpack electrofishing units, particularly in larger river systems like the Crooked River, and may account for higher first run counts. In addition, restoration of fish passage to the entire river would have allowed spawning adults, YOY, and parr to utilize the entire suitable habitat, which would likely decrease the densities of salmon at any given site. While the later suggestion is not obvious from the data presented in figure 4, DeRoche (1972) speculated on the same phenomenon. He reported a substantial decline in juvenile salmon at Scribner's in 1972 (note data is missing from our dataset, but found in an old report - Table 12) and offered two explanations: (1) "…exceptionally high flow in the Crooked River during the 1972 sampling period making it difficult to see and net fish that the electrofishing gear affected…" and (2) "…the Scribner's Mill dam was made passable to spawning adult salmon in the fall of 1971, and it is very likely that fewer than usual salmon spawned in the study area below the dam. This would account for the small number of young of the year salmon found in this section, and if true, annual estimates of young salmon in this section may continue to decrease."

Table 12. Juvenile salmon population estimates reported by DeRoche (1972).

Site	Year	Population Estimate YOY LLS	Population Estimate Parr LLS
Edes Falls	1970	---[1]	66 (26-174)
	1971	150 (51-450)	341 (194-597)
Scribner's Mill	1970	275 (133-571)	375 (282-499)
	1971	116 (32-436)	409 (310-540)
	1972	---[1]	138 (100-191)

[1]Too few fish to compute an estimate. Values in parentheses are confidence limits for the estimates.

The remaining sampling events during this earlier period were at various sites and often conducted with large year gaps or later within the time period, and did not provide additional insights into the status of juvenile salmon in the river.

Electrofishing data for the more recent collection (1995-2010) represents 37 sampling events at 3 different sites. Most of the sampling occurred at downstream (Edes) and upstream (Albany) locations of the river. However, a new sample section representative of the middle reach was added to the annual sampling regime in 2007. Figure 5 shows population estimates of YOY and parr salmon from 1995-2010. No data were collected for Edes in 1997 and the Hague site in 2008 due to high water conditions, and 1995-1996 data for Albany were omitted because a different site within Albany was inadvertently sampled. It is important to note that data collection methods changed during this latter time period, including adding multiple passes of the electroshocker (two in the earlier years, and later increased to three for greater precision), and the use of one or two backpack units depending on the width of the sampled section.

Although there is some variation in the data, it's apparent that the abundance of juvenile salmon in the Crooked River somewhat mirrors the abundance and size quality of the adults in the Sebago Lake fishery. For example, the growth and condition for III+ salmon in Sebago gradually declined to an all-time low in 1995, followed by a rise that peaked in 1998, dropped to another low in 2001, peaked again in 2005, and has shown a slight decline but has remained relatively stable since. Generally, river production increases (Figure 5) mimic the lake trends described above with a lag of 1 to 2 years behind peak periods of lake production. The stable abundance of juveniles in the river after 2006 may reflect a more stable lake population, which has been achieved by stabilizing salmon stocking rates. Interestingly, juvenile salmon abundance appears to have increased despite stable stocking rates in the lake, which may suggest an actual increase in the survival and condition of wild adult salmon. This may be related to declining intraspecific competition resulting from lower stocking rates.

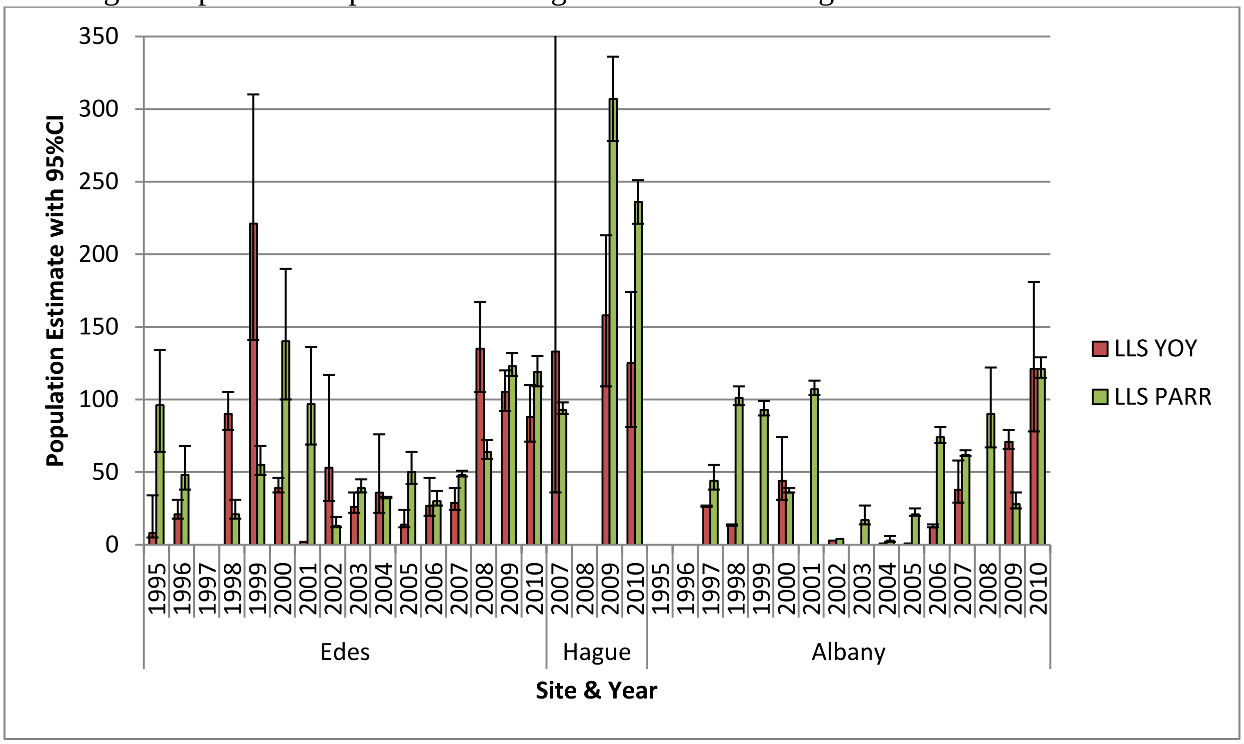


Figure 5. Population estimates of YOY and parr salmon for three sites on the Crooked River, 1995-2010.

It was noted earlier that large beaver dams are suspected of blocking spawning adults. For example, the Albany site has a lot of beaver activity, and we find years where YOY salmon are completely missing from electrofishing samples (i.e. 1999, 2001, and 2008). Missing YOY are more likely an indication of a beaver blockage; parr can probably negotiate dams at some point in the season and will colonize above dams from downstream locations. MDIFW has observed similar instances (missing YOY salmon) on Mile Brook where beaver activity is also common. In one case, we observed consecutive years of no YOY and upon investigation, found a large, active beaver dam low in the stream system.

Valid population estimates and density values were typically unavailable for brook trout due to their low abundance at the time of year salmon were sampled. Thus, Figure 6 simply displays the total number of brook trout by age group, year, and site from electrofishing samples conducted between 1995 and 2010. Brook trout of any age class rarely exceeded more than 10 individuals, regardless of site or year sampled. As noted earlier, brook trout are limited in the main stem of the Crooked River due largely to unfavorable river temperatures, particularly during the late summer period when this stream was typically sampled. Other points of interest regarding brook trout include:

- Specific years appear to be more productive across most or all sites, which is presumably a reflection of wetter and cooler summers.

- An apparent increase in brook trout abundance from downstream to upstream from Edes to Albany. This observation is not unexpected because the river becomes cooler in upstream reaches, and these reaches are in close proximity to a greater abundance of seeps and small tributaries from the more mountainous terrain.
- The Hague Site appears to produce a relatively large number of adult brook trout. Although the habitats are similar between Edes and the Hague site, water temperatures are more favorable for brook trout at the latter. On the other hand, when comparing the Hague and Albany sites, physical habitat is likely the key difference. The Hague site consists of moderately deep riffles and pools that favor adult brook trout, whereas the Albany site has shallower riffles and fewer pools that are more likely to support juvenile trout.

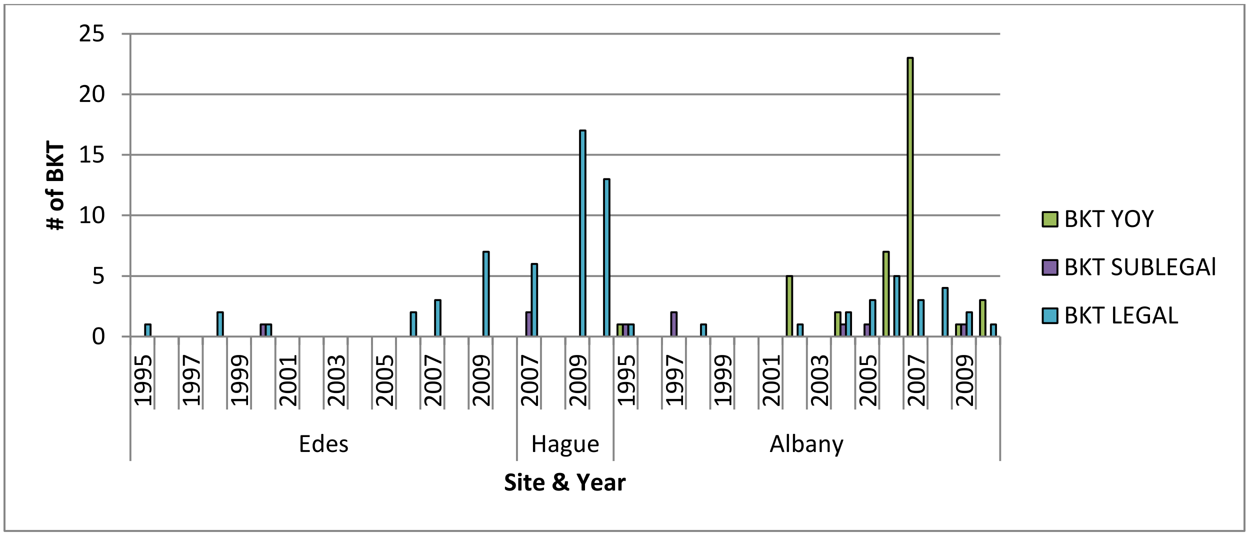


Figure 6. Abundance of brook trout by age group, year, and site, 1995-2010.

<u>Electrofishing Data - Density of Juvenile Salmon and Brook Trout</u>

Expressing density of fish per habitat unit standardizes the data and allows comparisons to be made among different sites or streams. Table 13 summarizes juvenile salmon densities for the Crooked River with comparisons to historical and statewide data. Recent Crooked River data reveal a mean density of 3.6 YOY and 6.3 parr per habitat unit (100 yds^2) across all three sample sites. The density of YOY and parr both appear to increase from the lower river (Edes) to the river's headwaters (Albany). However, the trend is certainly more dramatic for parr. Visual observations of the habitat and the density data suggest the upstream reaches of the Crooked River play a significant role in the overall production of wild salmon.

A review of recent and historical salmon density data for the Crooked River suggests densities were historically higher. As discussed above, this is likely a result of different sampling gear (generator vs. backpack electrofishing units) and the population was no longer confined to the lower reaches of the river by dams. In addition, conditions in Sebago Lake, after their peak in the late 1980's, may have contributed smaller numbers of spawning adult salmon.

Table 13. Juvenile salmon densities for the Crooked River (1995-2010) by site and comparative Maine data.

Crooked River Data, 1995-2010			
Site(s)	**Parameter(s)**	**YOY/HU[1]**	**Parr/HU[1]**
Edes	Average (SE) (n)	2.9 (0.7) (15)	3.2 (0.5) (15)
	Range	0.10 - 10.7	0.6 - 6.8
Hague	Average (SE) (n)	3.4 (0.2) (3)	5.2 (1.60) (3)
	Range	3.1 - 3.9	2.3 - 7.6
Albany	Average (SE) (n)	4.1 (1.7) (14)	9.8 (2.0) (14)
	Range	0 - 20.3	0.5 - 24.1
All	Average (SE) (n)	3.5 (0.8) (32)	6.3 (1.0) (32)
	Range	0 - 20.3	0.5 - 24.1
Other Maine Data for Comparison			
Site(s)	**Parameter(s)**	**YOY/HU[1]**	**Parr/HU[1]**
Crooked River – early 1970's[2] (Scribners & Edes)	Average (SE) (n)	5.6 (1.3) (3)	8.4 (2.1) (5)
	Range	3.3 - 7.8	2.5 - 13.1
Statewide[3]	Average (SE) (n)	21.4 (4.1) (69)	6.2 (0.7) (65)
	Range	0 - 170	0 - 25.0
Western Maine Streams[3]	Average (SE) (n)	31.4 (7.4) (6)	7.0 (2.5) (6)
	Range	7.7 - 48.5	0.4 - 18.1

[1] HU = habitat unit (100yds^2); [2] DeRoche (1972); [3] Boucher and Warner (2006)

Recent parr densities on the Crooked River are similar to statewide and western Maine stream values, but mean YOY densities were up to 5.6 times lower on the Crooked River. YOY on the Crooked River are likely under-represented at our index sites, which offer better parr than YOY habitat. In addition, the two lower index sites are relatively wide and deep, which effects efficacy of sampling due to visibility (small YOY are difficult to observe). Limitations in YOY habitat at the selected index sites are believed to play a larger role than sampling efficacy; this is supported by the findings at Albany where the river is relatively small and shallow.

Electrofishing Data - Growth Parameters of Juvenile Salmon and Brook Trout

Table 14 summarizes general growth parameters of juvenile salmon collected from the Crooked River between 1995 and 2010. Across all sites, YOY and parr salmon averaged 3.4 inches and 5.9 inches, respectively. Boucher and Warner (2006) reported fry lengths between 2.4 and 3.0 inches at the end of their first growing season, and calculated lengths of age II parr averaged 5.9 inches from 17 Maine nursery areas. YOY and parr salmon from the Crooked River appear to exhibit comparable growth to other Maine nursery habitats (Photo 12). Mean weights for YOY and parr salmon across all sites on the Crooked River were 0.25 and 1.16 ounces, respectively. YOY salmon had a mean K-factor of 0.97 and for parr 0.93. No statewide mean weights and K-factors were reported for juvenile salmon in Boucher and Warner (2006).

Photograph 12. Parr salmon from the Albany Site of the Crooked River (MDIFW staff).

Table 14. Summary of mean length, weight, and K-factor of juvenile salmon on the Crooked River, 1995-2010.

Size Group Growth Parameter	Site			
YOY	**Edes**	**Hague**	**Albany**	**All**
Mean Length in in/mm (SE_{mm}) (n)	3.6/91 (0.3) (505)	3.6/92 (1.0) (175)	2.8/72 (0.6) (211)	3.4/87 (0.5) (891)
Mean Weight in oz/g (SEg) (n)	0.28/8 (0.1) (381)	0.28/8 (0.3) (174)	0.11/3 (0.2) (148)	0.25/7 (0.1) (703)
Mean K-factor (SE) (n)	0.98 (0.008) (381)	0.99 (0.010) (174)	0.93 (0.012) (148)	0.97 (0.005) (703)
PARR	**Edes**	**Hague**	**Albany**	**All**
Mean Length in in/mm (SE_{mm}) (n)	6.4/163 (0.6) (718)	6.2/157 (0.7) (566)	4.9/125 (0.5) (642)	5.9/149 (0.5) (1926)
Mean Weight in oz/g (SEg) (n)	1.59/45 (0.3) (709)	1.27/36 (0.7) (563)	0.63/18 (0.4) (642)	1.16/33 (0.4) (1914)
Mean K-factor (SE) (n)	0.99 (0.003) (709)	0.93 (0.004) (563)	0.88 (0.003) (642)	0.93 (0.002) (1914)

In general, salmon growth increases from upstream to downstream in the Crooked River system, which is clearly illustrated by stacked length frequency charts (Figure 7). For example, the break between YOY and parr salmon appears to be around 3.5 inches, 4.5 inches, and 4.9 inches at Albany, Hague, and Edes, respectively. As reported above, our data suggested that water temperature and productivity increased progressively from upper to lower sections of the river, which likely plays a role in the observed size differences. In addition, parr densities decrease as ones moves downstream, which may accommodate better growth from reduced intraspecific competition.

Figure 7 also shows a few larger sized salmon at all sites. These are believed to be older parr that did not emigrate to Sebago Lake as smolts during the typical spring period at age II. Work on Barrows Stream, Maine suggested small, autumn runs of parr salmon may occur when larger year classes were present. In addition, research from 22 Maine lakes indicated that 3% of the salmon spent three years in the stream system as juveniles before emigrating to lake environments (Boucher and Warner, 2006).

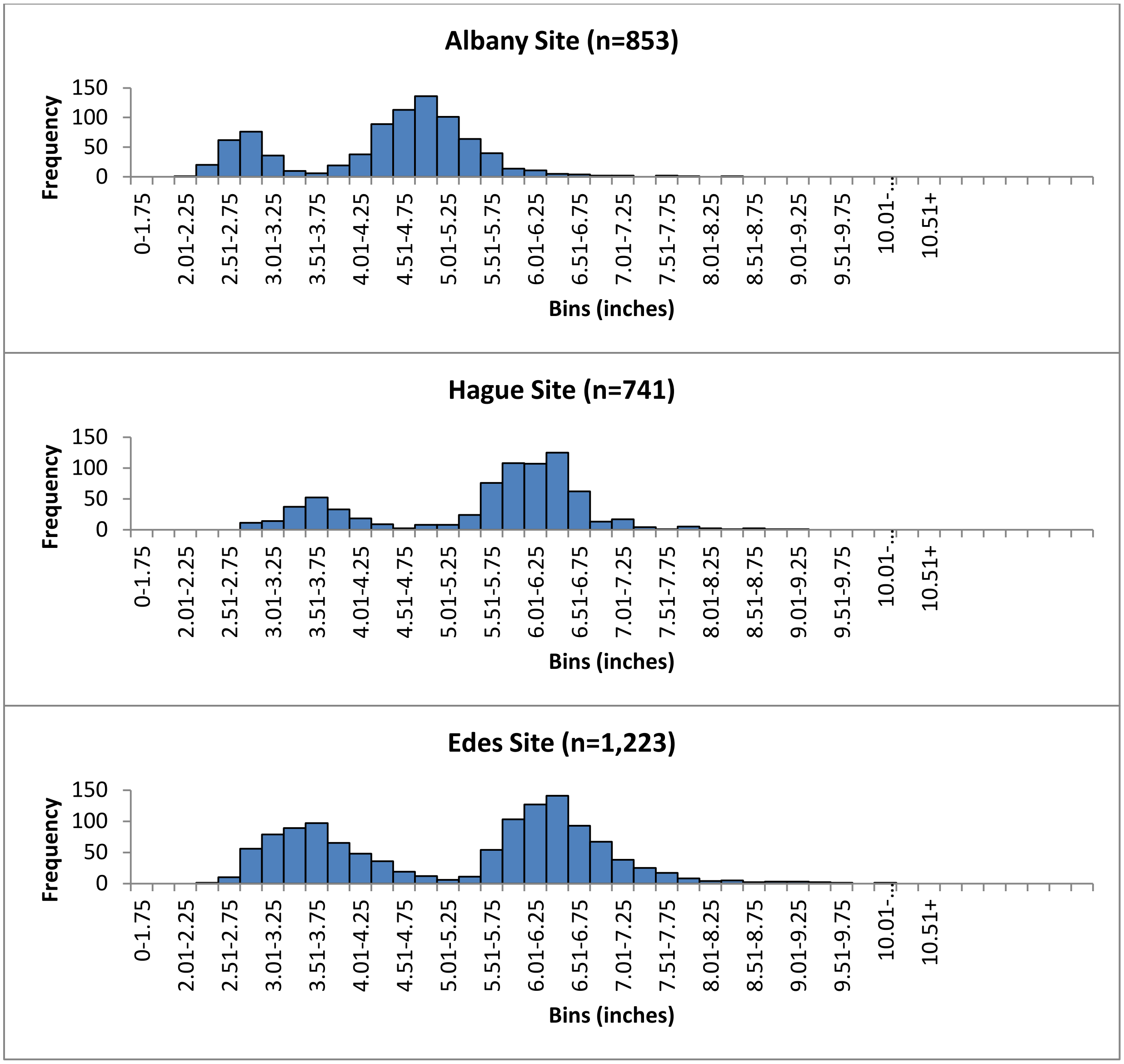


Figure 7. Length frequency charts for juvenile salmon at several Crooked River sites, ordered from downstream to upstream.

Table 15 summarizes general growth parameters of brook trout collected from the Crooked River between 1995 and 2010. Across all sites, YOY, sublegal (<6 inches), and legal (≥6 inches) trout averaged 2.7, 4.8 inches, and 7.7 inches in length, respectively. Mean weights were 0.11, 0.63, and 2.68 ounces for YOY, sublegal, and legal trout, respectively. Observed mean lengths on the Crooked River were very close to those reported by Bonney (2007) for 0+, I+, and II+ trout sampled from streams across the State, whereas mean weights were identical. Condition factors averaged in the low 0.9's for all size groups, although no statewide K-factor comparison was available from Bonney (2007). In general, brook trout from this Crooked River sampling are comprised of relatively young trout. Although a few large brook trout are occasionally reported from the Crooked River, their abundance is relatively low, and the sample is probably representative of the majority of trout in the system. Larger trout would typically not be well represented in this type of sampling due to habitat types sampled and gear limitations.

Table 15. Summary of mean length, weight, and K-factor of brook trout on the Crooked River, 1995-2010.

Size Group Growth Parameter	Site			
YOY[1]	**Edes**	**Hague**	**Albany**	**All**
Mean Length in in/mm (SE_{mm}) (n)	---	---	2.7/68 (1.3) (42)	2.7/68 (1.3) (42)
Mean Weight in oz/g (SEg) (n)	---	---	0.11/3 (0.2) (36)	0.11/3 (0.2) (36)
Mean K-factor (SE) (n)	---	---	0.92 (0.027) (36)	0.92 (0.027) (36)
SUBLEGAL[1]	**Edes**	**Hague**	**Albany**	**All**
Mean Length in in/mm (SE_{mm}) (n)	4.0/102 (-) (1)	4.4/112 (17.5) (2)	5.1/130 (7.5) (6)	4.8/123 (6.8) (9)
Mean Weight in oz/g (SEg) (n)	0.35/10 (-) (1)	0.49/14 (7.0) (2)	0.74/21 (6.0) (3.0)	0.63/18 (2.7) (9)
Mean K-factor (SE) (n)	0.94 (-) (1)	0.91 (0.068) (36)	0.91 (0.031) (6)	0.91 (0.023) (9)
LEGAL[1]	**Edes**	**Hague**	**Albany**	**All**
Mean Length in in/mm (SE_{mm}) (n)	8.1/206 (7.8) (16)	7.5/190 (3.8) (36)	7.8/198 (6.9) (23)	7.7/196 (1.3) (75)
Mean Weight in oz/g (SEg) (n)	3.32/94 (12.0) (16)	2.29/65 (4.4) (36)	2.82/80 (23.0) (9.3)	2.68/76 (0.2) (75)
Mean K-factor (SE) (n)	1.00 (0.021) (16)	0.90 (0.014) (36)	0.95 (0.019) (23)	0.94 (0.027) (75)

[1]Size Groups defined as YOY<=3.6 in, SUBLEGAL=3.7-5.9 in, and LEGAL=>6 in

Bolsters Mills Fish Trap Data

During the fall, adult salmon from Sebago Lake move towards the outlet and into several tributaries for spawning, but the Jordan and Crooked Rivers constitute the most significant runs. MDIFW has an extensive database covering the Jordan River run, while information on the Crooked River run is much more limited. MDIFW's regional fisheries staff operated and maintained a fish trap on the Crooked River at Bolsters Mills for a 13-year period (1974-1986). Typically, data collection began the second week in May and continued until the third week of November. The data from this monitoring program provide a wealth of information on spawning adults, and movements for both salmon and brook trout in the Crooked River system. Although some of the data have been summarized in annual Department reports up to 1981, the remaining data were never formally reported, and movement timing and triggers were not fully explored. This section summarizes all of the Bolsters Mills fish trap data, and provides the primary findings from that data.

Bolsters Mills Data - Total Salmonid Counts

DeRoche (1982) summarized and discussed fish count data from the Boslters Mills trap from 1974 to 1981. A revised summary of the same data with four additional years of data is presented in Table 16. The data presented here differs from DeRoche's earlier report due to several considerations, including: a different size breakdown between juveniles and adult salmon (sizes unspecified by DeRoche), different handling of recaptures, a few suspected minor manual counting errors in the original work, some missing historical data for 1981 in the current table, and a new breakdown of brook trout into sublegal and legal size categories. Despite these differences, most of DeRoche's original findings were consistent with the revised analysis and are summarized as follows:

- Passage at Scribners was obtained in 1972, yet DeRoche reported that wild yearling and adult salmon captured upstream at Bolsters Mills in 1974 and 1975 were likely the result of transfers of spawning adults from the Jordan River, and from the few wild fish that migrated past the Scribner's dam. Despite the existence of passage, this comment stems from observations of adult salmon stacked up below Scribner's dam due to an apparent lack of homing for upstream areas of the river.
- The large increase in adult salmon in 1976 and 1977 resulted from river stockings of 10,000 and 5,000 yearlings in 1974, and 1975, respectively. An additional 10,000 yearling salmon were stocked in 1976, but these fish did not "show up" and no explanations were given by DeRoche.
- Low numbers of juvenile and adult salmon in 1978 and 1980 were reportedly related to a severe drought and an unusually cold fall, respectively.
- The observed increase to 224 wild adults in 1981 was described as a vast improvement and very encouraging. DeRoche reported this was likely the result of improved fish passage at Scribner's and Bolsters, along with efforts to re-establish a population of salmon that would home to the middle and upper reaches of the river.
- Although the labeling of wild/hatchery salmon in the table is accurate, the hatchery portion lacks specific information regarding origin (stocking location); salmon were stocked in both the lake and in the river system. Fish origin is worthy of further discussion due to the unique separation of river and lake-stocked salmon.

  DeRoche (1982) reported, "of the 529 hatchery-reared salmon taken at the Bolsters Mills trap between 1974 and 1981, only 11 (2%) were lake-stocked fish; the remaining 518 salmon were salmon that had been stocked in upriver locations, had migrated downstream into Sebago Lake as smolts, matured in the lake and returned to the Crooked River as spawning adults." Similarly, MDIFW biologists rarely observe wild, unmarked fish in the Jordan River salmon run. Salmon are renowned for their strong homing instinct to spawning areas and stocking sites. DeRoche (1982) discusses homing and salmon movements within the Sebago watershed in greater detail. Wild fish from the Crooked River and lake-stocked fish historically have been (and currently are) largely segregated, which may offer future opportunities for improving the genetic quality of our existing hatchery stock if necessary.
- DeRoche reported small numbers of brook trout were occasionally sampled in the Bolsters Mills trap when river temperatures were favorable, and suggested the large increase in 1974 was the result of upstream river stockings of yearling trout in that same year. However, similar stockings in 1975 and 1976 did not appear to have the same result, particularly in 1975, when only 11 brook trout were observed.

Bolsters Mills data were not collected in 1982 due to State budget problems, but collections resumed from 1983-1986. The catch of wild adult salmon increased to a peak of 433 in 1984, and then gradually began a steady decline until the last year of data collection in 1986. This decline does not represent actual conditions because data collections in 1985 and 1986 were incomplete (4 months) and did not include the fall run (see note 4 in Table 16). A review of monthly catch data suggests these years would likely have had runs of adult, wild salmon in excess of 200 fish. During this same period (1983-1986), there is a noticeable increase in juvenile hatchery salmon caught in the trap, which is likely the result of the resumed stocking of FF and SY salmon directly into the river system from 1982-1987.

Sublegal brook trout were rarely caught in the fish trap during either time period (1974-1981, 1982-1986), but the numbers of legal sized brook trout increased substantially during the later period. According to our stocking records no direct river stockings of brook trout occurred during this time period. However, Sebago Lake received some fairly large stockings of unmarked fall fingerling brook trout during many of these years that may have resulted in additional fish moving into the Crooked River system.

Table 16. Counts of salmon and brook trout captured at the Bolsters Mills fish trap, 1974-1986.

Year	Salmon[1]				Brook Trout[1]	
	Juveniles (<=11.8 in)		Adults (>11.8 in)		Sublegal (<6 in)	Legal =>6 in)
	Hatchery	Wild	Hatchery	Wild		
1974[4]	15	26	3	79	0	66
1975[4]	43	18	34	77	1	11
1976	62	10	99	118	0	30
1977	5	10	202	87	0	20
1978[4]	0	6	16	30 (+1)[2]	0	22
1979	0	4	23	97	0	16
1980[4]	0	1	3	20	0	7
1981	0	0	0	150 (224)[3]	0	4 (8)[3]
1982	---	---	---	---	---	---
1983	204	69 (+1)[2]	6	232	0	51
1984	57	14 (+1)[2]	10	433	0	80
1985[4]	113	22	37	196	0	43 (+2)[2]
1986[4]	237	15	51	167	2	69 (+1)[2]

[1] Recaptures not included in counts
[2] (#) denotes number of fish with no record of a mark
[3] (counts) reported by DeRoche (1982)
[4] 1974 & 1978 - no May data; 1975 - no November data; 1980 – no July, August, September data; 1985 – no July, August, September, or November data; 1986 – no data from August on

Although not shown in the Table 16, two additional salmonid species were collected in the Bolsters Mills Fish Trap - lake trout and brown trout. Twenty one lake trout were captured in 6 of the 13 years the trap was operated. Presumably, these lake trout migrated approximately 25 miles upstream from Sebago Lake. This was an interesting observation, given the relatively small size of the river, the distance traveled, and the numerous fast-water sections that were successfully navigated by a primarily lake-dwelling species. It is unclear what prompted these lake trout to make this journey. In addition, a single juvenile brown trout was collected in the trap in 1985, which is presumed to be a migrant from one of several lake stockings in the drainage.

Lastly, it is important to note that the Bolsters Mills fish trap data do not represent the full extent of the adult salmon run, or that of the other age classes and species. As stated earlier, Bolsters Mills is located approximately 25 miles from the lake. Consequently, 22.5 miles (39%) of the total habitat in the Crooked River occurs below Bolsters Mills. Most of the suitable spawning and nursery habitat in the Crooked River starts around the confluence of Mile Brook, which equates to 15 miles or 25% of the total habitat between Mile Brook and Bolsters Mills, not including tributaries. Therefore, numbers of adult salmon from Sebago Lake reflected above are likely considerably lower than the total run size.

Bolsters Mills – General Timing of Salmonid Movements in the Crooked River

A summary of the total count of salmonids (including recaptures) captured in the Bolsters Mills fish trap by week of the year and month is presented in Figure 8. The graph clearly illustrates salmon were moving during the entire seven month period (May – November) of trap operations. Salmon movement appears to start around the 2nd week of May and almost ceases by the 3rd week of November. Peak salmon movement typically occurs in June and October with week of the year data suggesting that the second week of both months were peak movement times. However, a review of similar plots by year suggests in some years there was also heavy movement in July, and in one year (1981), the peak fall movement shifted to September. These anomalies were likely the result of annual variations in movement triggers (i.e. streamflow, lake/river temperatures). Little movement of salmon occurs between the two peak periods, which coincide with late summer, including all of August and early September. No data are available, but in consideration of the graphed movement patterns and our knowledge of fish behavior, it's likely that there was limited movement of salmon from December to April, when fish occupy their overwintering habitats and adults have returned to the lake.

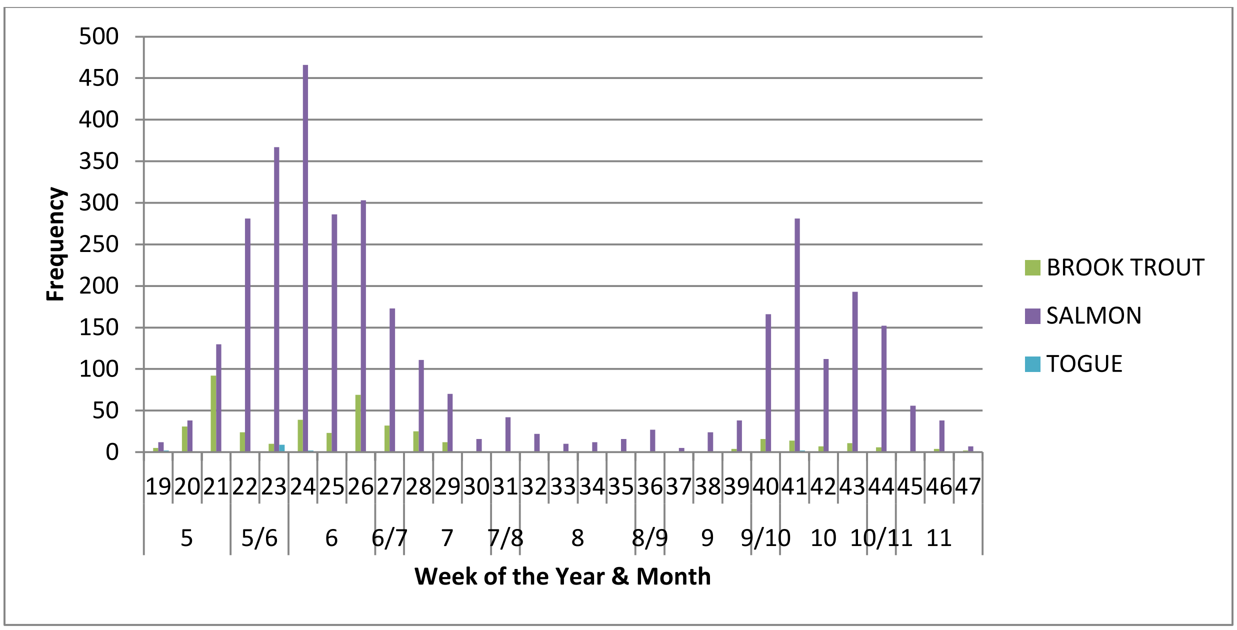


Figure 8. Total count of salmonids caught at the Bolsters Mills fish trap by week of the year, month, and species from 1974-1986.

Brook trout also moved during the entire seven month time period with essentially identical starting and ending points of movement - 2nd week of May through the 3rd week of November. It should be noted that counts of brook trout less than four do not show on the graph due to graph scaling. Peak movement times for brook trout were similar to salmon, except that the spring peak occurred during the last week of May instead of mid-June. In addition, brook trout exhibited a more protracted length of time and a greater degree of limited summer movement, which began around the last week of July and continued until the 2nd and 3rd week of September. This is not unexpected given the relatively warm temperatures of the main stem and the limited tolerance of brook trout to warmer water. Again, the graph and fish behavior suggested little to no movement of brook trout occurred from December to April.

Lake trout were rarely captured in the trap, but 16 of 21 were captured in late May and early June. The remaining five lake trout were caught in October and November. This type of extensive river movement by lake trout is considered uncommon in Maine waters.

Figure 8 provides a general impression of salmonid movements, but it does not clarify when specific age groups of fish were moving. Consequently, a graph of various age groups or size classes by month proves to be quite enlightening (Figure 9). A single YOY salmon was captured in late June of 1974, but is not represented on the graph due to scaling. Juvenile salmon, including YOY, parr, and smolt, appeared to move predominantly in the spring and early summer. For YOY and parr, this movement was likely the result of a resorting and exploration event as fish shuffle from overwintering to summer habitats. Salmon smolts emigrating from the river system to the lake could account for some of this movement. However, the movements of smolts observed on the Crooked River started in May and continued into August with a peak in June, which is surprising because earlier spring movement of salmon smolts has been well documented. Whalen et al. (1999) reported peak movements of sea-run Atlantic salmon smolts in Vermont occurred in early-mid May, while Boucher and Warner (2006) report peak movements of salmon smolts from a northern Maine stream occurred in April and May at water temperatures of 40-45^{o}F. They also discussed a small autumn run occurring in some years, which may explain the small occurrence of smolt-sized fish in October. It appears the smolt run on the Crooked may occur later than typically observed, or this size group may not represent smolts at all. Smolts may have been largely missed during the early spring period (April to mid-May) when the trap was unattended, or they were not vulnerable to upstream capture. If so, it becomes difficult to explain the presence of this size group. They may be large age II or III parr, or sub-adults from a small resident riverine population. However, older-aged parr tend to occur at relatively low rates, particularly on a river system with growth rates observed on the Crooked River, and there is no information to suggest the presence of a resident adult salmon population.

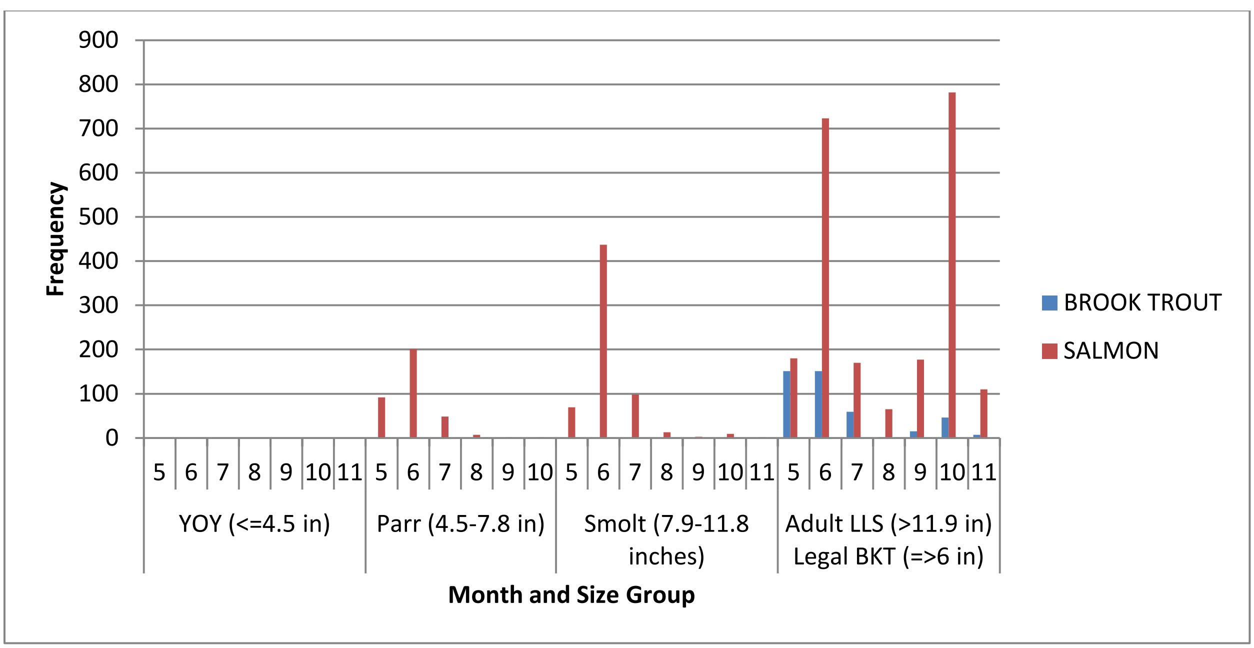


Figure 9. Total count of salmon and brook trout caught at the Bolsters Mills fish trap by month, size/age group, and species from 1974-1986.

Adult salmon were moving throughout the river system from May through November with peak movements in June and October. This pattern of adult salmon movement is similar to that observed in sea-run salmon populations in Maine. CASM (2004) described two distinct periods of spawning migrations for adult sea-run salmon: (1) an early run from May to mid-July and (2) a late run from July through September. MDIFW regional staff has observed adult salmon holding in the Crooked River throughout the summer, which are believed to be predominantly early run fish that have not returned to the lake, rather than river residents. However, given the small lengths (12-14 inches) of a portion of the salmon observed in the Crooked River by MDIFW staff and anglers, confirming or denying the presence of river residence through an age-growth sample may have value in the future.

Juvenile brook trout were rarely captured in the Bolsters Mills trap; during the entire 13 year monitoring period no YOY and only one sublegal brook trout were observed. This was likely due to habitat limitations in the main stem for brook trout, as well as trap design characteristics, which will be discussed in more detail in the following section. Consequently, juvenile brook trout were not depicted in Figure 9, but adult or legal sized brook trout captures are illustrated. Adult brook trout showed considerable movement in May and June, but none during the peak of summer in August. We suspect adult brook trout utilize the main stem of the river for over wintering habitat, then redistribute throughout the drainage in late spring and early summer before main stem temperatures become unsuitable. Brook trout also exhibited some autumn movement, which may be a combination of a limited spawning run and a return to over wintering habitats.

Bolsters Mills – Relationship of Temperature and Flows on Salmonid Movements

Although we have no data for April and the first week of May, it appears that both salmon and brook trout do not begin moving in the spring until water temperatures approach 50°F (Figure 10). Spring movements peaked when water temperatures were between 55-65°F.

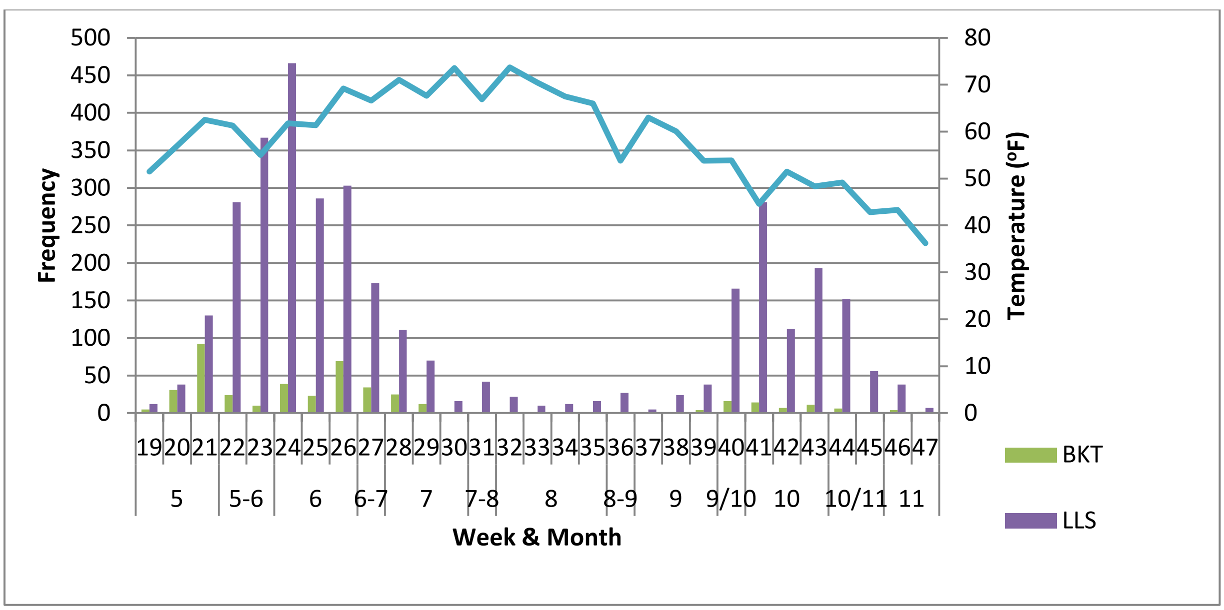


Figure 10. Relationship between salmon and brook trout movement and mean weekly temperature from Bolsters Mills data, 1974-1986.

Summer movement was minimal for both species and slowed as water temperatures approached the high sixties. Water temperature did not appear to be strongly correlated with late summer movements because there was little movement of either species in late summer as temperatures again became favorable. In the fall, fish movement peaked again as water temperature declined from 55-45^{o}F. Movements of each species essentially ceased when water temperatures dropped below 40^{o}F.

Peak movement for all sizes of salmon and brook trout occurred between 60-64^{o}F (Figure 11). Adult salmon moved during the broadest range of temperatures, whereas juvenile salmon moved at a more confined range of temperatures, and there was an absence of movement below 50^{o}F. This was not unexpected because colder temperatures typically occurred in late fall when juvenile salmon showed little movement, as illustrated in Figure 10. The data do not allow us to determine the movement patterns of brook trout other than adults (legal fish), because only three juvenile brook trout were captured during the entire thirteen year period. Peak movement for adult brook trout occurred at slightly warmer temperatures than salmon, 65-69^{o}F. This is largely the result of a secondary peak of brook trout movement that occurred in later June as water temperatures approach 70^{o}F. At this time brook trout were likely seeking coldwater refugia.

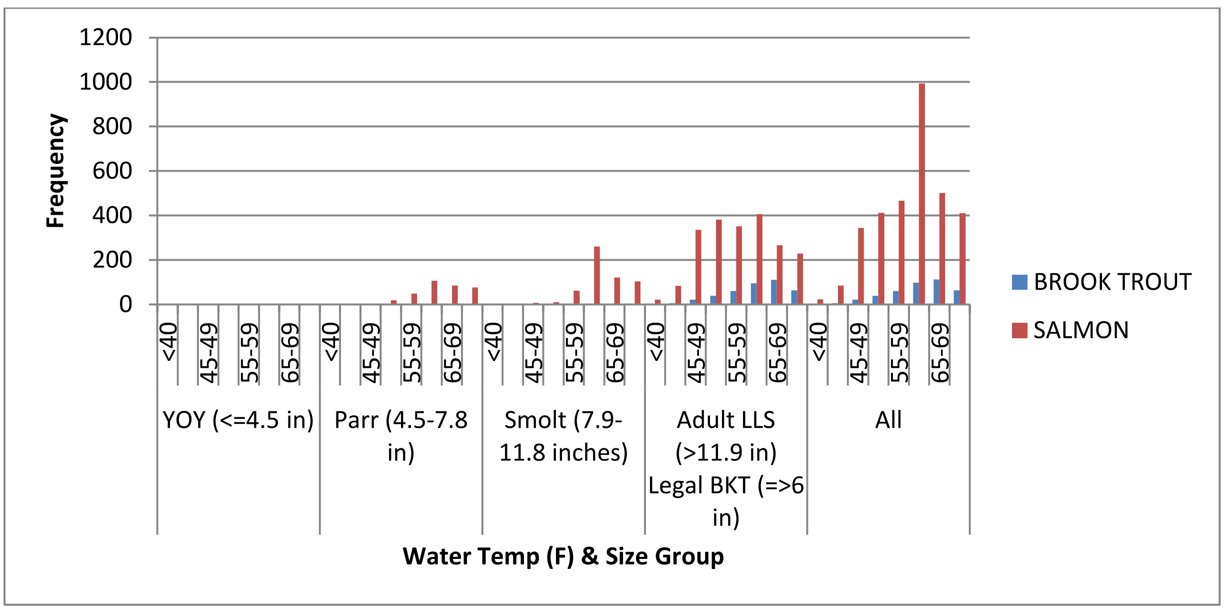


Figure 11. Movement relationship between size groups and water temperature at the Bolsters Mills fish trap, 1974-1986.

A water level gauge was installed at the Bolsters Mills fish trap as an indicator of river flow levels, allowing an examination of possible relationships between flow events and fish movement. Biologists often observe higher catches of spawning salmonids associated with an increase in stream flows. Although annual variation of pooled data blurred the results, it appeared that fish captures (representing movement) were more closely related to high flow events (Figure 12) than to mean or low flows. Based on the available data, fish movements for both species appeared to occur after peak spring flows (April) subsided. As water depths dropped during the summer months and late fall, there was very little movement of either species. In the fall, movements of both salmon and brook trout increased with increasing maximum water depth in the trap. A maximum weekly mean depth of about 22 inches and higher seemed to represent a critical flow level. Water levels above 22 inches in the trap may have stimulated movement, while levels below 22 inches in depth retarded movement.

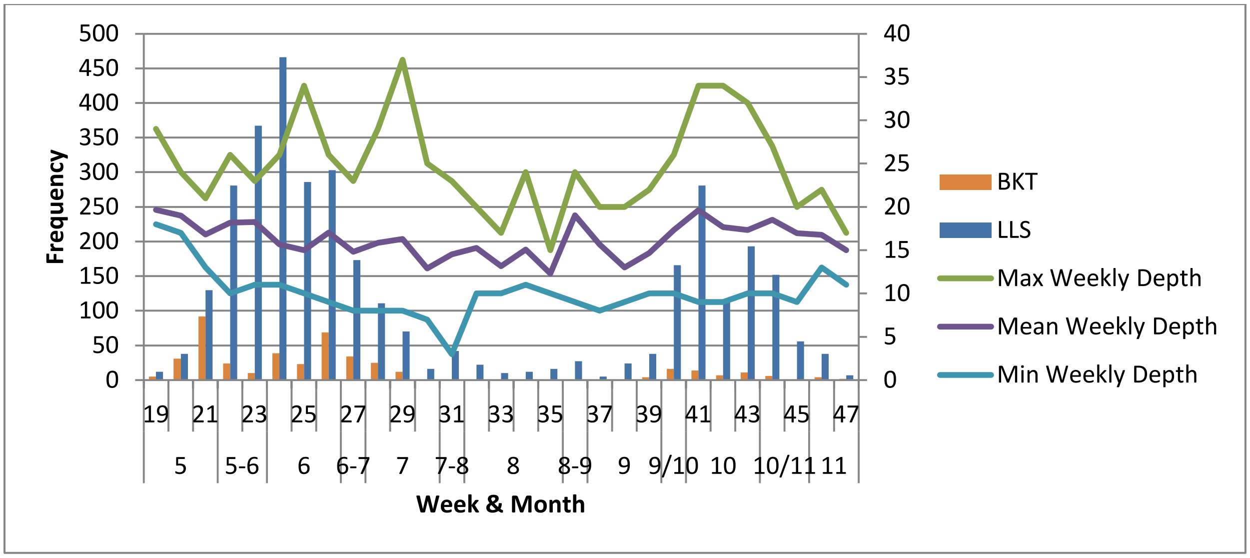


Figure 12. Relationship between salmon and brook trout movement and water depths from Bolsters Mills data, 1974-1986.

A frequency graph of size classes by water depth suggests most salmonid fish movement was largely associated with median flows (depths from 10-24 inches), and that low and high flow events were avoided (Figure 13). However, this interpretation is made cautiously because: (1) the fish ladder and trap design likely had a flow range where it functions best, which would typically be median type flows; and (2) the trap was not tended on a daily basis, so the actual depth in the trap may not accurately reflect the flow event that stimulated fish movement. Figure 13 also suggests larger trout and salmon were able to negotiate a higher range of flows, particularly at the higher flow levels represented by the upper end of the depth scale. This is not surprising because fish swimming performance typically improves with fish length. The lack of juvenile salmon and brook trout caught in the trap was perhaps less a reflection of their abundance, but more a reflection of fishway and trap design, which was designed to monitor the movement of adult salmon. For salmon, juvenile abundance in the river system should have been much higher than that of adults, which may suggest they did not move as much or that the trap design limited their capture (i.e. flow limitations or escapement from the holding pen due to slat spacing). Juvenile brook trout were even less represented than salmon with only three individuals captured over the 13-year period. This was likely a combination of factors, including fishway and trap design, lower abundance of juveniles in the main stem of the river, and more restricted movement patterns.

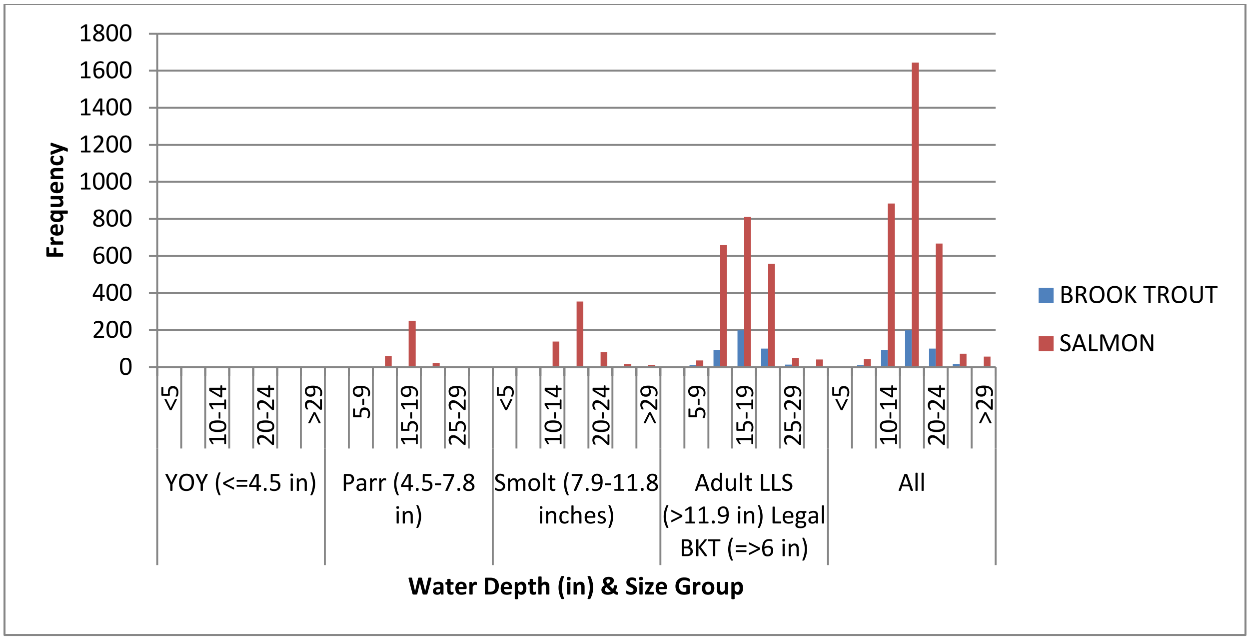


Figure 13. Movement relationship between size groups and water depth at the Bolsters Mills fish trap, 1974-1986.

The preceding discussion provides a general sense of some environmental triggers regarding fish movement on the river, whereas a review of individual annual data may provide a clearer understanding of movement patterns. DeRoche (1982) plotted individual years of data from 1974-1978 and made the following observations regarding fish movement in the Crooked River:

- peak movements "in May and June each year occurred when water temperatures increased from 55-65^{o}F and water height in the trap decreased from over 30 inches to 20 inches and less";
- July-September "increases in fish catches occurred with increases in water temperature (60-70^{o}F), and any rise in water height in the trap";
- he noted an exception to the above statement in late September, "fish activity was stimulated by a drop in water temperatures to the 60's and upper 50's ^{o}F and an increase in water height.";
- and lastly he noted, "During November and December, increases in salmon movement was accompanied by increases in water temperature and water height."

Attempts to graphically demonstrate the movement patterns described by DeRoche across all data years were unsuccessful due to drastic annual variations in temperature, flows, and run sizes. A review of DeRoche's work supports the presence of such patterns, but there were also several unexplained anomalies to the general patterns he described. This suggests additional environmental factors may have been contributing to salmon movement patterns.

<u>Bolsters Mills - Salmonid Growth Parameters</u>

MDIFW's Bolsters Mill dataset contains a large sample of historical length and weight data for salmonids of the Crooked River system. DeRoche (1982) summarized age and growth data for salmon from 1975-1978. However, efforts to replicate his results were unsuccessful due to unknown differences between the data used then and what is available today. In addition, some ages could not be reconciled so we constructed a length frequency chart to categorize individual fish by age group. Table 17 summarizes the Bolsters Mills age and growth data for salmon over the entire 13-year period. A similar, more detailed breakdown by year is presented in Appendix W.

The mean parr length of 7.4 inches was much larger than parr observed during our more recent electrofishing sampling (Table 14), which had a mean length of 5.9 inches. This information further suggests the fish ladder may not have passed smaller sized salmonids, or that the trap grating was too wide to retain smaller individuals and thus biased the size data for smaller age groups, particularly YOY and parr.

Table 17. Summary of salmon growth data by size group from the Bolsters Mill fish trap, 1974-1986[1].

Age Group[2]	Mean Length in in/mm (N)(SD_{mm})	Mean Weight in lb/g (N)(SD_g)	Mean K (N)(SD)
YOY	4.3/110 (1)(-)	---	---
Parr	7.4/188 (326)(10)	0.1/53 (158)(9)	0.79 (158)(0.07)
Smolt	9.1/230 (588)(20)	0.2/103 (283)(38)	0.84 (283)(0.09)
Adult	17.5/445 (2,024)(61)	1.9/867 (1,905)(368)	0.91 (1,905)(0.11)
All	**14.6/373 (2,939)(119)**	**1.6/720 (2,348)(451)**	**0.89 (2,346)(0.11)**

[1]Original dataset was edited to remove salmon with K factors <0.7 or >1.3, which suggests an incorrect length and/or weight. Data without a corresponding length and/or weight were assumed correct and were retained.
[2]Age Groups defined as YOY <=115mm, parr 116-200mm, smolt 201-300mm, and adult>300mm.

Adult-sized salmon (>11.8 in) had a mean length of 17.5 inches. This value is on the larger side for wild adult salmon from Maine waters (age III+ at 14.1 to age VI+ at 17.9 inches), but comparable for younger aged (II-III+) adult fish of hatchery origin as reported by Boucher and Warner (2006). A further breakdown of adult-sized salmon by origin is presented in Table 18. The data indicated that the majority of the adult fish in the sample were of wild origin (78%) and they retained a relatively high mean length of 17.7 inches, while hatchery fish were slightly smaller at 16.9 inches. Boucher and Warner (2006) conducted a similar comparison for wild and stocked salmon from Maine waters with the opposite result; hatchery fish were generally larger than wild fish. The difference in the two data sources was perhaps related to stocking location. The data summarized by Boucher and Warner were for lake-stocked fish, while according to DeRoche (1982) 98% of the hatchery fish caught at the Bolsters Mills fish trap were river-stocked.

Table 18. Comparison of adult wild and hatchery salmon growth data from the Bolsters Mill fish trap, 1974-1986[1].

Origin	Mean Length in in/mm (N)(SD_{mm})	Mean Weight in lb/g (N)(SD_g)	Mean K (N)(SD)
Wild	17.7/450 (1,578) (56)	1.9/881 (1,490) (349)	0.91 (1,490)(0.11)
Hatchery	16.9/429 (444) (72)	1.8/820 (413) (428)	0.91 (428) (0.11)

[1]Original dataset was edited to remove salmon with K factors <0.7 or >1.3, which suggests an incorrect length and/or weight. Data without a corresponding length and/or weight was assumed correct and was retained. Adults defined as salmon > 300mm.

The unusually large mean size of the wild adult salmon from the Crooked River system is an interesting phenomenon. Boucher and Warner (2006) noted that stocked Sebago-strain salmon appeared to be larger than West Grand Lake strain fish, and offered several plausible explanations including: Sebago-strain fish are typically stocked in southern & central Maine lakes, which are subject to high exploitation that may lead to better growth of surviving fish; a longer growing season than western and northern Maine lakes; and possibly even genetics. Recent assessments of paired stockings of both strains into Rangeley and Long Lakes (St.

Agatha) suggested no significant growth differences between the two strains when stocked into the same lakes (Boucher 2008), which does not support the idea that genetics play a role in growth differences. Boucher and Warner's remaining reasons remain plausible explanations for the apparently larger salmon sizes observed from these data.

Over 400 brook trout were captured at the Bolsters Mills Fish Trap from 1974-1986, and Table 19 provides a summary of mean length, weight, and K-factor by size group. Brook trout in the analysis ranged from 5.9 to 20.5 inches in length. Few juvenile brook trout were captured in the trap with no YOY and only a single sublegal brook trout reported. Legal-sized brook trout had a mean length, weight, and K-factor of 9.6 inches, 0.47 lb, and 0.98, respectively. While most of the brook trout were relatively small in size, a limited number were of quality size. For example, twenty brook trout (5%) were 16 inches or longer with the largest being 20.5 inches and weighing 3.5 pounds. We surmise that the number and size quality of brook trout in the Crooked River system has declined since the Bolsters Mills work was conducted due to: (1) discontinuation of brook trout stockings in Sebago Lake, and (2) changes in the species composition in Sebago Lake that are likely detrimental to brook trout survival. Nevertheless, each year a handful of reports are received of some large brook trout being caught from the Crooked River.

Table 19. Summary of growth parameters for brook trout from the Bolsters Mill fish trap, 1974-1986[1].

Size Group	Mean Length in in/mm (N)(SD_{mm})	Mean Weight in lb/g (N)(SD_g)	Mean K (N)(SD)
YOY	---	---	---
Sublegal (< 6 in)	5.9/150 (1)(-)	---	---
Legal (=>6 in)	9.6/245 (398)(63)	0.5/213 (273)(240)	0.98 (273)(0.12)

[1]Original dataset was edited to remove brook trout with K factors <0.7 or >1.3, which suggests an incorrect length and/or weight. Data without a corresponding length and/or weight was assumed correct and was retained.

Crooked River – Trapnetting Data

MDIFW regional staff has periodically attempted to sample the fall spawning run of adult salmon in the lower Crooked River to monitor age, growth, and origin (wild/hatchery). Successfully setting nets at the mouth of and in the Songo River was challenging and ineffective due to site characteristics, river flows, and strong winds. In 2007, MDIFW staff tried a different approach by setting a trapnet backwards (opening facing downstream) with no lead in the main stem river just below the confluence of Mile Brook and the Crooked River where a natural constriction significantly narrows the channel. Although this type of set was labor intensive and required vigilant maintenance (leaf removal), MDIFW captured 61 adult salmon and 1 brook trout. Salmon age and growth data for this sampling event are summarized in Table 20.

Photograph 13. Brian Lewis with wild LLS from the Crooked River, trapnet set visible in background (MDIFW Staff).

Mean length (21.4 inches), weight (3.4 lb), and condition (0.93) of wild salmon in 2007 were excellent, and with the exception of fish being a little leaner, were similar to that of hatchery salmon observed from the same sampling event (Photo 13). Wild adult salmon ranged from age III+ to VII+, while hatchery salmon had a more limited age range of II+ to III+ (excluding two IV+, which were later identified as incorrectly marked salmon). The limited data suggested hatchery salmon had a one-year size advantage over wild fish and consequently are more likely to spawn by age II+ versus age III+ for wild salmon, particularly when growth is good. Age V+ and older comprised 24.5% of the wild salmon catch, compared to (3.8%) for hatchery fish sampled at the Jordan River in the same year 92007). This suggests wild fish exhibited better survival, or that anglers released more wild fish. However, hatchery fish were vulnerable to angling approximately one year earlier than wild fish so comparing hatchery fish from age IV+ and older (22.0%) would be a fairer comparison.

Table 20. Spawning adult salmon age and growth by origin for the Crooked River, 2007.

Age	Data	Mean Length in/mm (n) (SE_{mm})	Mean Weight lb/g (n) (SE_g)	Mean K-factor (n) (SE)
II+	Wild	---	---	---
	Hatchery	20.3/515 (2) (16)	3.1/1390 (2) (10)	1.03 (2) (0.09)
III+	Wild	18.3/466 (11) (8)	2.0/919 (11) (53)	0.90 (11) (0.02)
	Hatchery	21.7/552 (3) (36)	4.3/1950 (3) (409)	1.12 (3) (0.08)
IV+	Wild	21.6/549 (28) (6)	3.5/1578 (28) (55)	0.95 (28) (0.01)
	Hatchery[1]	18.5/470 (2) (24)	2.4/1110 (2) (170)	1.06 (2) (0.00)
V+	Wild	23.3/592 (11) (7)	4.3/1930 (10) (74)	0.94 (10) (0.03)
	Hatchery	---	---	---
VI+	Wild	23.0/584 (1) (-)	3.5/1600 (1) (-)	0.80 (1) (-)
	Hatchery	---	---	---
VII+	Wild	25.7/654 (1) (-)	5.5/2500 (1) (-)	0.89 (1) (-)
	Hatchery	---	---	---
Unaged	Wild[2]	21.9/556 (2) (47)	3.7/1660 (2) (440)	0.94 (2) (0.02)
	Hatchery	---	---	---
All	Wild	21.4/544 (54) (7)	3.4/1528 (53) (60)	0.93 (53) (0.01)
	Hatchery	20.4/518 (7) (21)	3.4/1550 (7) (217)	1.07 (7) (0.04)

[1] the two age IV+ hatchery fish were likely mismarked, based on 2007 Jordan River salmon data they are believed to have been II+
[2] the two un-aged wild fish had unreadable scales

Historical evidence from the Bolsters Mill fish trap suggested very few lake-stocked fish (2%) migrated up the Crooked River. Although the percentage was relatively small (11.5%), 2007 trap net data suggested a higher number of lake-stocked hatchery fish migrate up the Crooked River and likely participate in spawning activities. Considering these new data, in conjunction with the Bolsters Mill data, suggests hatchery salmon may not move as far upstream as wild fish. It's possible that most hatchery salmon home to Mile Brook, which has the same water source (Pleasant Lake) as MDIFW's salmon hatchery in Casco. If so, hatchery salmon may only spawn in the lowermost reaches of the Crooked River and Mile Brook.

Although there is evidence a few salmon smolts remain in Maine river nurseries an additional year or two, most Crooked River salmon smolts drop into the lake as age II fish. Back-calculated lengths show rapid growth from age II to age III, which corresponds to the fish's first season in the lake system (Table 21). Growth is also rapid the following year (age III>IV), but begins to level off beyond this age. Boucher and Warner (2006) reported back-calculated lengths at age for wild salmon from several western Maine waters: age I-3.1 inches; age II-5.5 inches, and age III-9.7 inches. Fish from the Crooked River sample compare similarly for age I and II, but where much larger at age III (14.9 inches). The 2007 data suggest similar stream growth, but lake growth (in Sebago Lake) was exceptional at the time of this sampling event.

Table 21. Back calculated lengths of wild salmon from the Crooked River, 2007.

Annulus	Back-calculated Length		
	N	Mean (in/mm)	SE_{mm}
1	52	2.9/74.1	1.9
2	52	5.3/135.3	4.2
3	52	14.8/376.7	4.1
4	41	19.8/501.7	6.5
5	12	21.1/536.9	9.4
6	2	22.9/582.1	18.5
7	1	25.2/639.8	---

Instream trapnetting was successful and can be a valuable method for future monitoring of adult salmon on the Crooked River, particularly during low-to-moderate flow years. This site and collection method may also support future efforts to maintain the genetic diversity of our hatchery salmon brood by infusing wild-captured stock. Limitations of this site and sampling technique are that it is labor intensive and unfeasible during high flow years, fish are prone to escapement around the wings, and the duration of this spawning run does not allow for a reasonable complete count of the run size. A portable weir system, such as the picket weir being used in the Moosehead Lake Region, or a resistance board weir could be valuable tools for monitoring this population (Obrey 2010, Tobin 1994).

Other Biological Data

Algae

As part of its biological monitoring program, the MDEP has conducted two algae sampling events on the Crooked River. Algal rock scrapings were conducted in the Waterford and Naples sections of the river in 2003 and 2005, respectively. A total of at least 60 algal species (some only identified to a unique genus) were observed from these sampling events, 35 species for Waterford, and 37 for Naples. Although 12 species were common to both sites, the remaining species were different. The dominant algal types at both sites were pennate diatoms, which comprised 74% of the species in Waterford and 70% in Naples. The pennate diatom, *Achnanthidium minutissimu*, exhibited the highest count (cells/cm^2) at both sites. Algal modeling for the Naples site, reflected a MDEP "Class A" designation, as opposed to the assigned "Class AA". A partial summary of the algae data is presented in Appendix X and the entire datasets are available from (MDEP 2011).

Macroinvertebrates

Macroinvertebrate sampling is commonly employed by MDEP's biological monitoring unit to assign and periodically assess river classifications. Macroinvertebrate data is entered into a complex statistical model to produce a "water quality class." The classes (discussed earlier in this document) represent how well the biological community compares to biological communities in natural watersheds. From 1989-2009, 30 macroinvertebrate sampling events were conducted at various sites on the Crooked River (Appendix Y), and a summary of macroinvertebrate genera or species from that sampling is listed in Appendix Z. A total of at least 104 macroinvertebrate species (some only identified to a unique genus) were observed from all sampling events with the midges, caddisflies, and mayflies being the most diverse groups in the order listed. The most abundant species was highly variable by site and year, but was typically a species of caddisfly, mayfly, midge, or black fly.

Potential Salmon Production Modeling

The primary value of the Crooked River from a fisheries management perspective is its potential to contribute wild salmon to the Sebago Lake fishery. Consequently, in the early 1980's Urban Pierce, Jr., Joan Trial, and Owen Fenderson developed a model to predict the salmon production potential of the entire Crooked River based on MDIFW river habitat data and juvenile population densities at select index sites. The original model estimated the number of habitat units (HU=100 yds^2), as well as the river's estimated production potential for both fry (YOY) and parr. The model assumed habitat saturation (30 fry and 15 parr/HU). Habitat suitability index (HSI) values from available mean depth and substrate type data were then adjusted until the number of juvenile salmon/HU equated to that observed from actual sampling of several index sites on the Crooked River as a means to calibrate the model. The actual density values adopted in the original model's development were 11.5 Fry/HU and 5.3 parr/HU. Once the appropriate HSI values were determined they were then applied as follows:

- Fry Habitat Units= fry HSI adjustment value for both mean depth and substrate type*HU
- Parr Habitat Units= parr HSI adjustment value for both mean depth and substrate type*HU
- Fry Production Estimate= (fry HSI adjustment value for both mean depth and substrate type*30)*HU
- Parr Production Estimate= (parr HSI adjustment value for both mean depth and substrate type*15)*HU

Additional explanation and a discussion of the assumptions regarding the model are presented in Appendix AA. A summary of model estimates for the Crooked River and several surveyed tributaries are presented below (Table 22). The modeling allows a rapid determination of the best habitat locations for juvenile salmon, which can be used as a tool for resource protection, as well as a means of defining sampling protocols for the river. Finer scale habitat reviews are also possible, but that discussion is beyond the scope of this report.

A review of the data shows the historical importance of restoring fish passage along the river: 83% of the parr habitat is above Edes Falls Dam, 63% is above Scribner's Mills Dam, and 54% is above Bolsters Mills Dam. The ratio of fry/parr habitat is clearly lower in the Crooked River than in its tributaries, suggesting the main stem of the river is more important for parr production and the tributaries provide important fry nursery habitats. Nonetheless, the main stem Crooked River supports 87% of the fry and 94% of the parr habitat for the entire surveyed watershed.

The original model suggested that the Crooked River system as currently surveyed can produce an estimated 241,587 fry and 102,726 parr. While it is interesting to consider model estimates of both fry and parr, the use of parr values is more meaningful because this older life stage is closer to a smolt, which ultimately contributes to the Sebago Lake fishery. More recent efforts have expanded the modeling to project smolt production by multiplying the parr estimate(s) by a survival rate for the parr-to-smolt life stages. Warner and Havey (1985) found survival of late fall parr to smolt to be 5.1%. While this estimate is reportedly low due to the ability of some smolts to bypass the trapping facilities, it is currently the most relevant figure available from the literature for Maine salmon. Other survival estimates for sea-run Atlantic salmon are discussed in Appendix AA. This survival value, combined with the original production model, yields a predicted production of 5,252 smolts from the Crooked River system, of which 94% are produced from within the main stem of the river. Modeling suggests the four large tributaries Mile, Meadow, Swett, and Russell Brooks contribute 1.1%, 1.9%, 2.5%, and 0.2% of the total smolt production, respectively. Although Mile Brook represents the second smallest salmon production potential, its low proximity in the drainage and our successful sampling of juvenile salmon, suggest it may be the most significant Crooked River tributary for salmon production. Salmon production in the Meadow Brook system is limited due to several factors including: its high position in the drainage; its limited habitat potential, particularly in the mid-lower reaches; and passage issues related to active and inactive beaver dams. Swett Brook has the potential to produce almost as many parr as Mile, Meadow and Russell Brooks

Table 22. Estimated production potential of juvenile salmon from the Crooked River system based on available habitat data.

Area	Fry HU[1]	Parr HU[1]	Estimated Fry Production[2]	Estimated Parr Production[2]	Estimated Smolt Production[3]
Crooked River					
1 - Albany - Rte 35 N. Waterford	972.7	906.9	29,182	13,603	694
2 - N. Waterford - Sodom Rd	1,325.0	1,060.0	39,751	15,901	811
3 – Sodom Rd -Twin Bridges (Rte 117)	1,020.8	805.3	30,624	12,080	616
4 - Twin Bridges - Bolsters Mills	620.0	692.7	18,599	10,391	530
5 - Bolsters Mills - Scribners Mills	467.1	587.3	14,013	8,810	449
6 - Scribners Mills - Edes Falls	1,693.2	1,313.7	50,796	19,706	1,005
7 - Edes Falls - Rte 11	406.9	375.4	12,206	5,631	287
8 - Rte 11- Green Bridge (Songo R)	536.0	729.2	16,081	10,939	558
Subtotal	7,041.7	6,470.7	211,251	97,060	4,950
Mile Brook					
1 - Upstream of Edes Falls Rd	80.4	18.9	2,414	284	14
2 - Edes Falls Rd-Power line	102.6	21.0	3,077	315	16
3 - Powerline-Cooks Mill Rd	48.7	25.2	1,462	378	19
4 - Cooks Mill Rd-Crooked R	25.1	13.0	753	195	10
Subtotal	256.8	78.1	7,706	1,172	60
Meadow Brook					
Meadow Brook	199.3	78.9	5,978	1,185	60
Herrick Brook	237.7	49.8	7,132	746	38
Subtotal	437.0	128.7	13,110	1,931	98
Swett Brook					
Swett Brook	289.0	167.0	8,668	2,499	127
Unnamed Tributary	28.0	4.0	852	64	3
Subtotal	317.0	171.0	9,520	2,563	130
Russell Brook					
Russell Brook	91	17.5	2,731	263	13
Total	**8,143.5**	**6,866**	**244,318**	**102,989**	**5,252**

[1]Habitat units (HU) presented have been adjusted by Habitat Suitability Index (HSI) values for substrate and depth
[2] Density values presented have been adjusted by HSI values for substrate and depth
[3]Estimated smolt production = estimated parr production * 0.051; based on Warner and Havey (1985) survival estimate for the late fall salmon parr to smolt stage

combined. While it is higher in the drainage than any of the other tributaries, the presence of juvenile salmon, adult salmon and redds (Heinz, 2013) indicates Swett Brook is being utilized by salmon for spawning and production. Although there is less beaver activity on Swett Brook than some of the other tributaries, observations by Heinz (2013) suggest beaver dams are restricting passage of adult salmon. Russell Brook was characterized by two large historical beaver flowages with limited production potential for salmon.

The overall smolt estimate (5,252) presented above may be underestimated due to the extremely low survival factor applied and an incomplete inventory of the tributary habitats. It would be valuable to acquire river specific smolt estimates to verify and make adjustments to the existing model.

Around 1994 MDIFW began reducing salmon stocking rates in Sebago Lake in response to declining salmon size quality, which was likely a result of several factors including: a growing wild lake trout population, excessive and unadjusted salmon stocking rates during the 1980's, and a likely increase in wild salmon production. Despite strong public interest to increase salmon stocking rates, MDIFW has continued to stock the lake at a reduced rate. MDIFW's typical guideline for salmon stocking where there is no wild salmon production is 0.33 spring yearling (SY) salmon per acre, which in the case of Sebago Lake equates to 9,590 SY salmon. However, given the presence of an additional competing cold water predator (lake trout), as well as significant contributions from wild salmon, the "typical" stocking rate is necessarily lower. Figure 15 shows the estimated total salmon contribution (wild & stocked) to Sebago Lake from 1999-2011. The graph suggests stocking more than 4,338 hatchery fish would exceed MDIFW's stocking guideline, and this does not take into account the abundant competing lake trout population. A combined annual contribution (wild and stocked) of about 7,000 salmon would likely meet salmon objectives contained in the lake' management plan. Current data from Sebago Lake indicates a relatively high percentage of the salmon caught in the lake are now of wild origin, and modeling of smolt production suggests wild salmon from the Crooked River system may be able to meet the total recruitment needs of the Sebago Lake fishery.

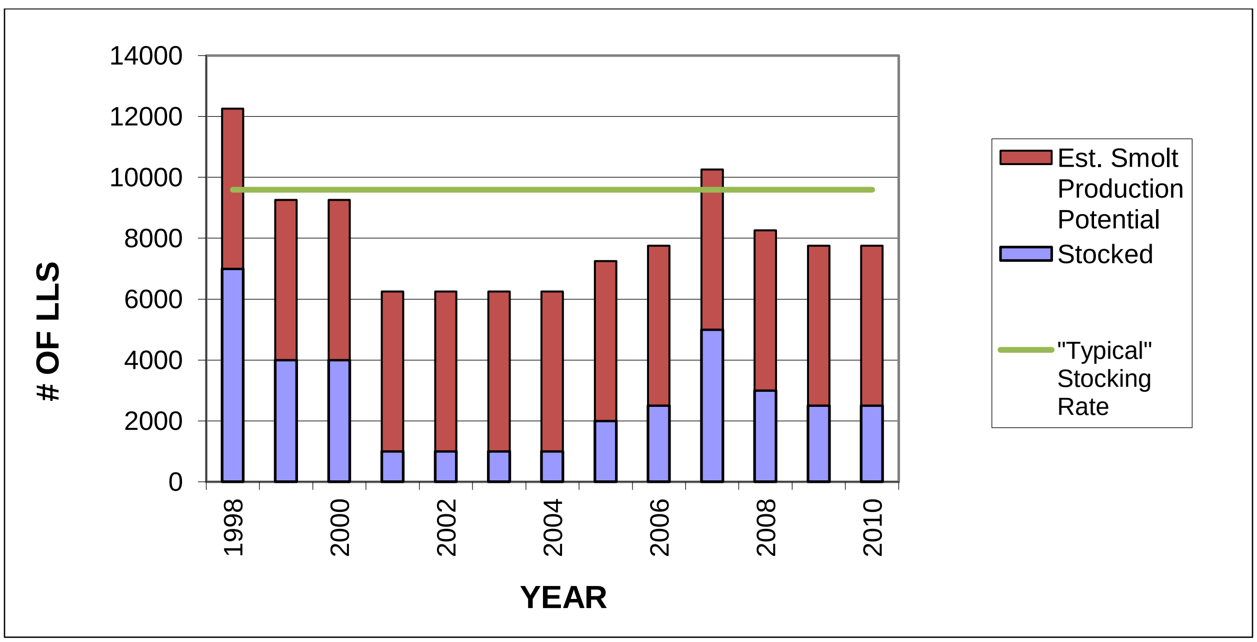


Figure 15. Number of salmon stocked and estimated wild salmon production at Sebago Lake, 1999-2011.

Maintaining and improving the production of wild salmon in Sebago Lake has been a long-term goal for MDIFW, and one that is supported by most anglers. However, managing wild fisheries can also come at a cost because they require more intensive management. For example, wild salmon fisheries may result in excessive abundance and associated growth issues that can be difficult to manage. An over-abundance of wild salmon has occurred on several Maine waters (i.e. Mooselookmeguntic Lake) resulting in unsatisfactory salmon size quality for anglers. In addition, wild fisheries may exhibit more volatility in abundance from year-to-year depending on environmental conditions.

While modeling and projections can be a useful tool, they are subject to many assumptions which may or may not accurately reflect the situation. There are several data gaps in the model projections provided above, including: verify juvenile salmon densities and HSI values for lower quality habitat sections; validate or determine river specific parr-smolt survival; determine actual smolt estimates to confirm and improve modeling results; and assess the value and need for adding additional HSI parameters. Regardless of the actual estimates produced by the model, the primary underlying concepts seem valid:

- The model identifies the relative quality, quantity, and location of habitats within the Crooked River system;
- Hatchery stocking rates in Sebago Lake need to take into account both the togue population and the contribution of wild salmon. Continuous, effective public outreach is necessary to develop public understanding of why historical salmon stocking rates are not beneficial for enhancing the wild salmon population and achieving overall management objectives for the lake and river;
- With adequate production levels, wild salmon from the Crooked River system may be able to fully sustain the Sebago Lake sport fishery.

Crooked River Redd Survey

Although MDIFW has conducted a complete habitat survey of the main stem Crooked River, the survey's design did not allow clear identification of specific locations of salmon spawning habitats, particularly those actually utilized by spawning adults. Salmon spawning sites are critical habitats in terms of production potential, and identifying key spawning locations and their distribution and abundance could play an integral part in the long-term protection of the Crooked River salmon population. In the fall of 2014, MDIFW staff, assisted by Trout Unlimited volunteers, completed a redd inventory on the entire main stem of the Crooked River (Photo 14). A preliminary summary of the survey results is presented in Table 23.

Photograph 14. Classic salmon redd, Crooked River. (J. Pellerin)

A total of 2,107 redds were observed over the 58.1 mile reach of the Crooked River from Songo Pond downstream to its confluence with the Songo River. The data indicate a relatively high percentage of current redd sites are located above historical barriers (Edes – 85.2%, Scribners – 61.1%, Bolsters – 46.9 %), which further validates early and current efforts by the Department to restore and enhance fish passage in the watershed.

Table 23. Summary of Crooked River Redd Survey, 2014.

Summary of Crooked River Redd Counts (2014)				
Section	**Miles**	**Redd Count (%)**	**Redds/Mile**	**Test Pit Count[1]**
Albany-N Waterford	12.3	224[2] (10.6)	19	NA
N Waterford-Sodom	15.7	453 (21.5)	29	146
Sodom-Twin Bridges	3.7	230 (10.9)	62	30
Twin Bridges-Bolsters	4.1	82 (3.9)	20	24
Bolsters-Scribners	2.6	300 (14.2)	115	34
Scribners-Edes	10.1	508 (24.1)	50	47
Edes-Rte 11	2.7	256 (12.2)	95	46
Rte 11-Songo R	6.9	54 (2.6)	8	6
Total	58.1	2,107 (100.0)	36	378
[1] Test pits only counted where they occurred in the presence of one or more redds. [2] Actual counts were 273, adjusted downward 18% for unaccounted test pits within this section.				
Estimated Adult Spawning Population				
2,318 - 4,635[1] adult LLS				
[1] Calculations assume 1-2 redds/female and a F:M sex ratio of 45:55 (Jordan River Data)				

Redd counts have been widely used as a relatively simple and inexpensive method to monitor or estimate the population size of adult spawning salmonids (Johnson et al. 2007). Redd counts in conjunction with a multiplier for redds per female and a sex ratio can be expanded to yield a rough population estimate for the number of spawning adults. An individual female salmonid may dig multiple redds with reports ranging from one to six per female, but there is evidence to suggest that the number of redds/female for Atlantic salmon and steelhead is more likely in the range of 1-2/female (Gautamer et al. 2000 and Duffy 2005 as cited by Johnson et al. 2007 and Christman 2014). Utilizing the redd count data obtained in this survey and the best information available suggest the adult spawning run for the Crooked River in 2014 ranged from approximately 2,300 to 4,600 adult salmon. If the redd count data are adjusted for areas only upstream of Bolsters Mills the estimate of adult salmon would be 1,088 to 2,175. This estimate is considerably higher than actual adult counts from the Bolsters Mills fish trap maintained in the late 70's to early 80's (Table 16), which ranged from 87-433. This latest information suggests there have been significant gains in spawning activity and adult returns to the upper river. This finding is also consistent with observations of more wild salmon in the lake fishery.

Redd count data can overestimate population size via assigning redd counts/female from other salmonid species, over-counting in high use areas, and mistakenly assigning test pits as redds. The first two items are not suspected of being a significant source of error in the 2014 survey, but identifying test pits as redds may be relevant. Test pits were identified as areas of salmon activity that lacked a significant deposit of loose, clean gravel downstream of the forward depression or pit. Future plans to assess the adult salmon population using a portable weir may allow us to better validate the redd data and associated population estimates.

Conclusion

The Crooked River is clearly the most important spawning and nursery tributary supporting the wild salmon sport fishery in Sebago Lake. The Crooked drainage probably has the potential to entirely sustain Sebago Lake's salmon fishery without supplemental stockings. In addition, recent observations of adult salmon indicate the river supports a substantial recreational sport fishery for a high quality, riverine salmon population equal to many others in the State. Since the creation of the fisheries division, each generation of biologists have spent considerable effort trying to understand, improve, and protect this unique resource. It has been rewarding to see the culmination of 6-7 decades of work by various MDIFW biologists unfold into a rather remarkable and successful restoration.

MDIFW and other agencies have collected considerable data on the Crooked River, but many data gaps remain and additional work is needed to better understand and manage this unique resource. The following section outlines a management plan for the river that considers management goals and objectives, data gaps, as well as management problems and strategies. This plan is presented here as a suite of "stand-alone" management guidelines, but it should be considered an adaptable plan that's subject to revision as our knowledge of the resource continues to evolve.

Fishery Management Plan for the Crooked River

Management Goal: Maintain and where possible enhance the production of juvenile wild salmon in the Crooked River, consistent with the Sebago Lake Management Plan to maximize their contribution to the Sebago Lake fishery, while reducing dependence on hatchery salmon.

Prioritized Management Objectives: (1) Maintain and enhance juvenile production of wild salmon; (2) maintain a fishery for adult salmon to the extent it does not jeopardize the production and recruitment of wild salmon to the Sebago Lake fishery; and (3) maintain a secondary fishery for wild brook trout.

Management Problems & Strategies:

Problem 1: Maintaining and improving fish passage of adults and juvenile life stages is critical for meeting our primary management goal for the Crooked River.

Strategies:

- Continue efforts to identify fish barrier issues in the watershed, as well as structures that impact natural stream hydraulics and morphology.
- Present conditions could be further improved for fish passage at several main stem dams including: Edes, Scribners, Bolsters, and Waterford.
- Continue efforts to improve identified passage issues on tributaries, particularly those of greater significance. A good example of this work would be TU's efforts to add weirs to an MDOT bridge structure on Swett Brook, as well as the removal of a small dam on the same stream.
- Some of the larger beaver dams and log jams potentially prohibit, or at least restrict fish movement seasonally. Continue to encourage beaver trapping activities in the Crooked River drainage, and seek volunteer assistance with periodic removal of the larger beaver dams, which may be impacting fish passage, particularly for upstream migrating adults. Any such efforts should be prioritized as follows: main stem Crooked River, Mile Brook, Meadow and Herrick Brooks, Swett Brook, and Russell Brook.

Problem 2: Lack of dependable, effective equipment to monitor the river's wild salmon spawning population. Periodic monitoring of adult salmon in the Crooked River system would provide critical information in support of future management, including: obtaining data on total run size, age and growth, improved understanding of utilization of the Crooked River by hatchery salmon, and the desirability of infusing hatchery stocks with genetic material from wild salmon to maintain high genetic diversity.

Strategies:

- Although a trapnet was moderately effective, a portable weir, perhaps similar to the picket weir being employed by Region E on Moosehead Lake tributaries, or a resistance board weir, could provide accurate, comprehensive information on the Crooked River's salmon population.

Problem 3: Incomplete habitat data for the Crooked River system.

Strategies:

- Continue efforts to survey and map remaining salmon spawning and nursery tributaries in the Crooked River drainage. As time permits, continue to survey remaining larger tributaries. Juvenile salmon were not found at two of the remaining largest tributaries (Hobbs and Smith Brooks) but these brooks were likely sampled far above their confluence with the Crooked River. Consider sampling these streams lower in drainage to determine salmon presence and if salmon are present, conduct a habitat survey of these streams.

Problem 4: Lack of knowledge regarding salmon spawning sites. Salmon spawning sites are critical habitats in terms of production potential. Identifying key locations may play an integral part in the long-term protection of the Crooked River salmon population.

- This issue was largely addressed in the fall of 2014, but a follow-up survey of the major tributaries should also be conducted.

Problem 5: Lack of data may affect the accuracy of the production modeling.

- As time allows, consider making necessary modifications to the model (i.e. increasing salmon/HU).
- Field truth the model, particularly in regards to lower quality habitats.
- Consider verification of model for smaller tributaries by conducting electrofishing surveys in those habitat types.
- Assess smolt production to validate the modeling and to determine the actual current contribution of salmon smolts to the lake fishery.
- A river specific parr-smolt mortality rate would also be valuable and seems to be lacking in the literature for salmon.
- Continue periodic monitoring of index sites as an indicator of juvenile production levels. These surveys no longer need to be conducted on an annual basis; every 4-5 years would be sufficient.

Problem 6: If further assessment suggests river salmon production potential is not being realized due to a lack of spawning adults, then measures to increase wild salmon escapement from the lake fishery should be considered. This effort must be properly timed and consistent with other management needs in the Sebago Lake Management Plan, and it should consider the needs of our salmon hatchery brood program.

Strategies:

- Consider regulations to increase the numbers of wild spawning adults utilizing the Crooked River system. These efforts should not compromise size and growth objectives under the Sebago Lake Management Plan or MDIFW's salmon hatchery brood program.
- DeRoche (1982) reported that the salmon in the Crooked River had lost their ability to home and remained below the Scribner's Dam even after its removal. Stocking efforts above the old dam site were eventually successful in restoring spawning and production in the upper river. "Reseeding" underutilized tributaries may maximize production in nursery streams, particularly if current production is largely the result of strays. Similar stocking efforts could be attempted on the major tributaries with wild fish. However, production potential within the tributaries is limited.

Problem 7: Illegal introductions of invasive fish species, particularly northern pike and landlocked alewives may thwart efforts to maintain and enhance production of wild salmon in the Sebago Lake system as follows:

(1) The Crooked and Songo Rivers provide good spawning habitat for adult pike, and post spawn adult pike could remain in this habitat coincident with smolt outmigration from the Crooked River system. Predation on wild smolts is likely to be heavy, as is additional predation on all age classes in the lake system.

(2) Alewives have been implicated as a plausible cause of Early Mortality Syndrome (EMS) in salmonids including salmon and lake trout (Ketola et al. 2000, Brown and Honeyfield 2006) in several New York lakes. Research suggests alewives are high in the enzyme thiaminase, and consumption creates a maternal thiamine deficiency that impacts offspring survival during early developmental stages. Various effects on adults (decreased swimming abilities, lowered immunity) have also been documented. In contrast, strong lake trout (Kezar Lake, Middle Range Pond) and salmon (Mooselookmeguntic Lake) reproduction has occurred despite the presence of alewives for more than 3 decades. Maine's freshwater ecosystems may have some characteristics that reduce vulnerability to EMS.

Strategies:

- There are no known effective strategies to minimize impacts from these invasive species in lake systems as large as Sebago Lake. Stocking of salmon may successfully maintain the lake fishery, but would not address the potential loss of wild fish from the Crooked River system.
- Where feasible, preclude northern pike migration to other lakes and ponds (i.e., dam/outlet modification, road crossing modifications on some streams) to minimize impacts to the Crooked River and Sebago Lake systems.

<u>Problem 8. The Crooked River has been periodically stocked with salmon of hatchery origin and there is evidence that a small number of spawning adults of hatchery origin utilize the Crooked River system.</u>

Strategies:

- Genetic testing of wild and hatchery stocks would provide insight regarding efforts to conserve the Sebago salmon strain and in maintaining a healthy and compatible hatchery brood stock.
- Acquire funding, discuss appropriate sampling with geneticists, and collect samples for evaluation.
- Efforts to maintain genetic diversity of Sebago Lake's hatchery stock to ensure conservation of the Sebago Lake strain may require comparative genetic testing and diligent proactive brood management strategies.

<u>Problem 9. Observations of adult fish by MDIFW staff and anecdotal reports of anglers suggest there may be a limited river-resident population of salmon.</u>

- Collect a summer sample of adult fish and examine scale growth patterns and age to determine if these adult fish are lake migrants or river residents.

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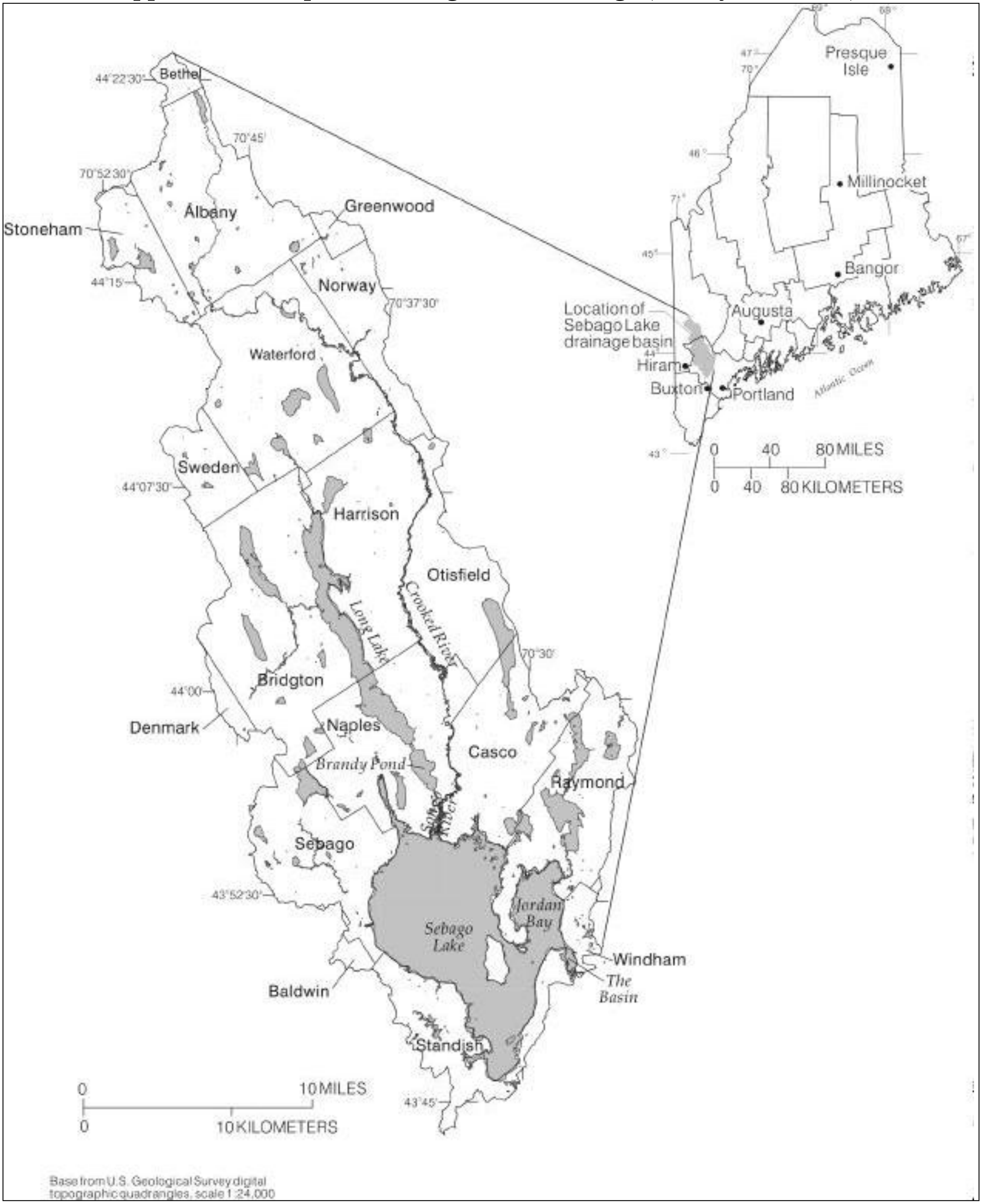
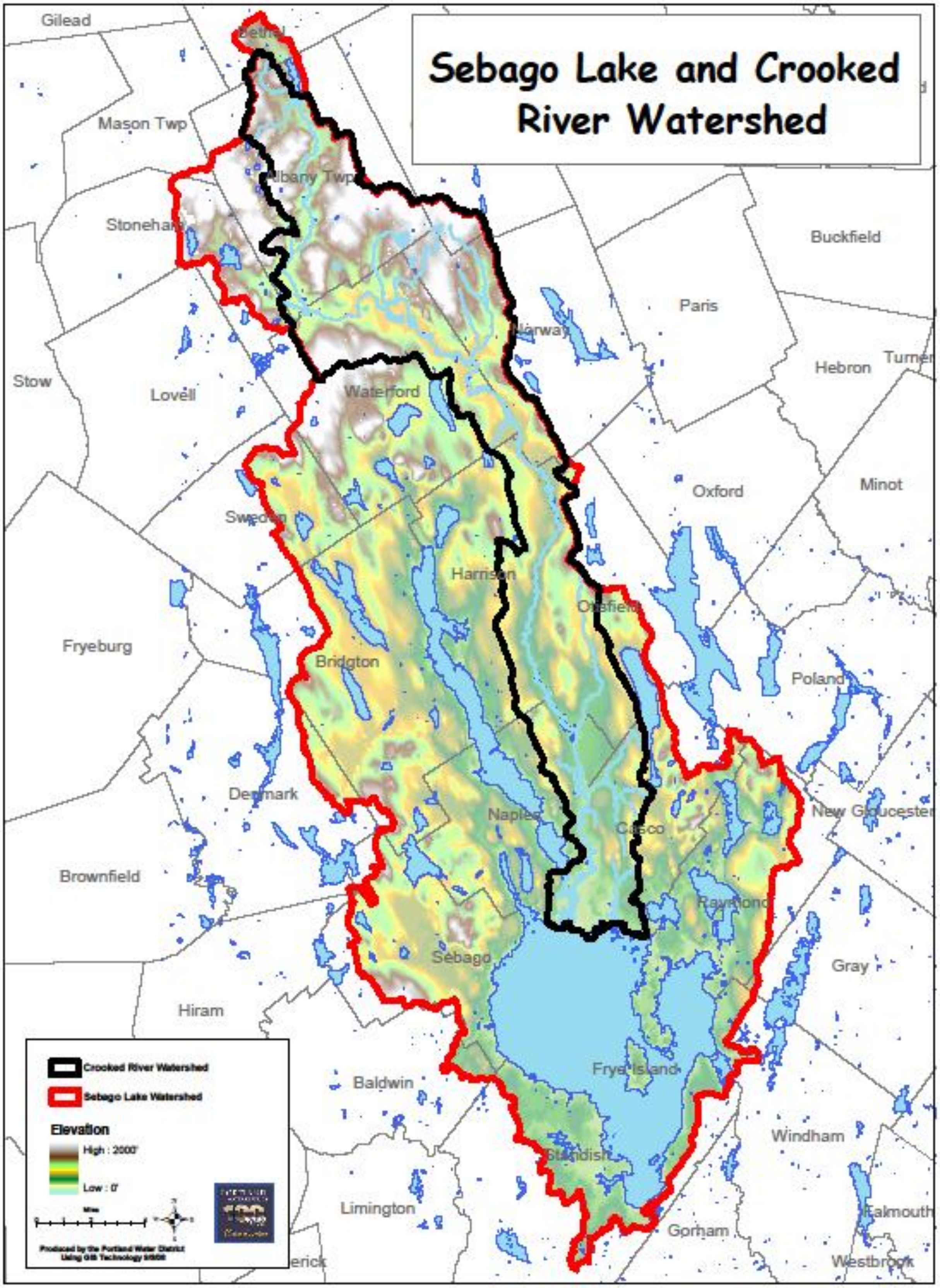
Appendix A. Map of the Sebago Lake drainage (Dudley et al, 2001).



Appendix B. Map of the Sebago Lake and Crooked River watersheds (PWD, 2008).



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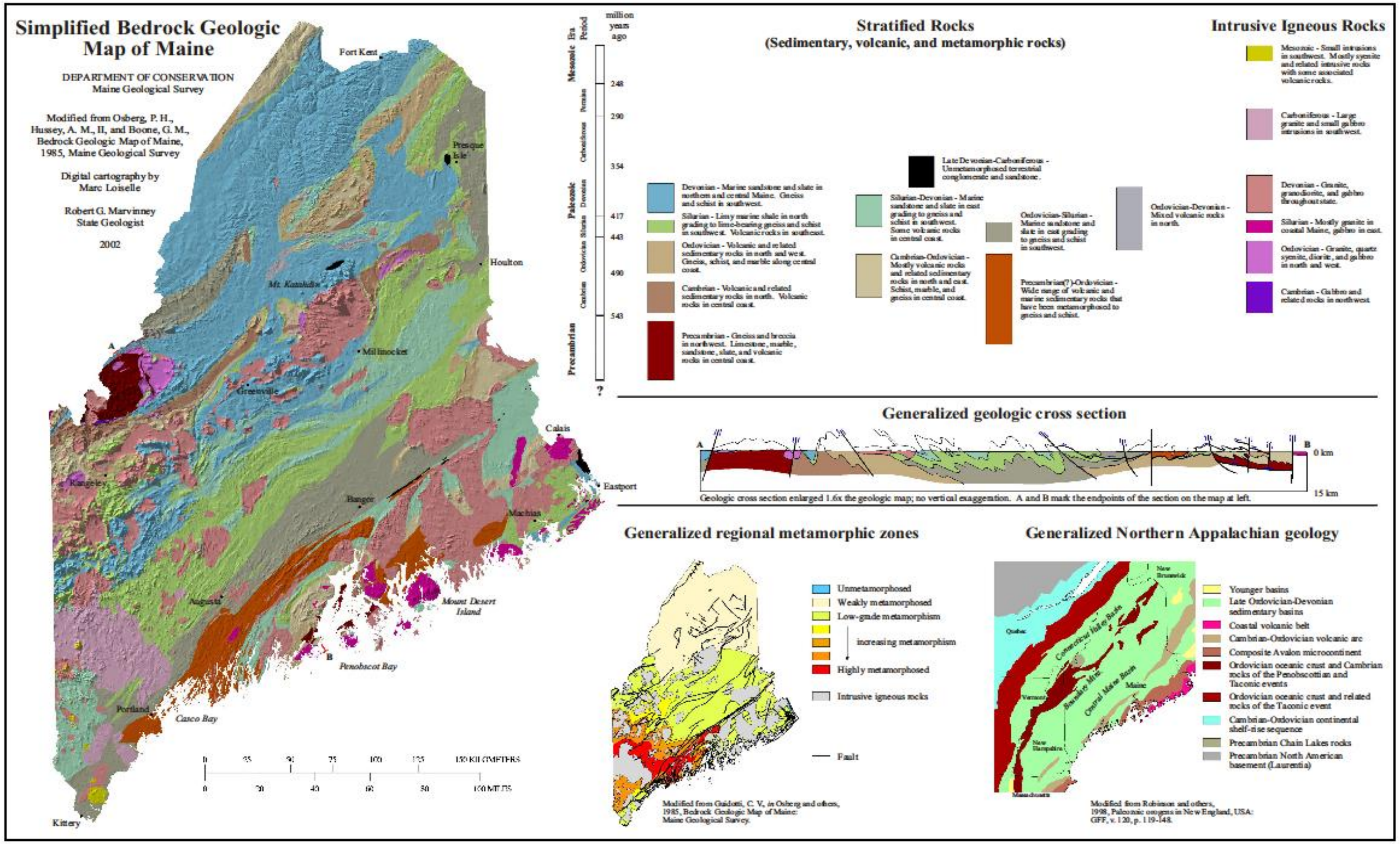
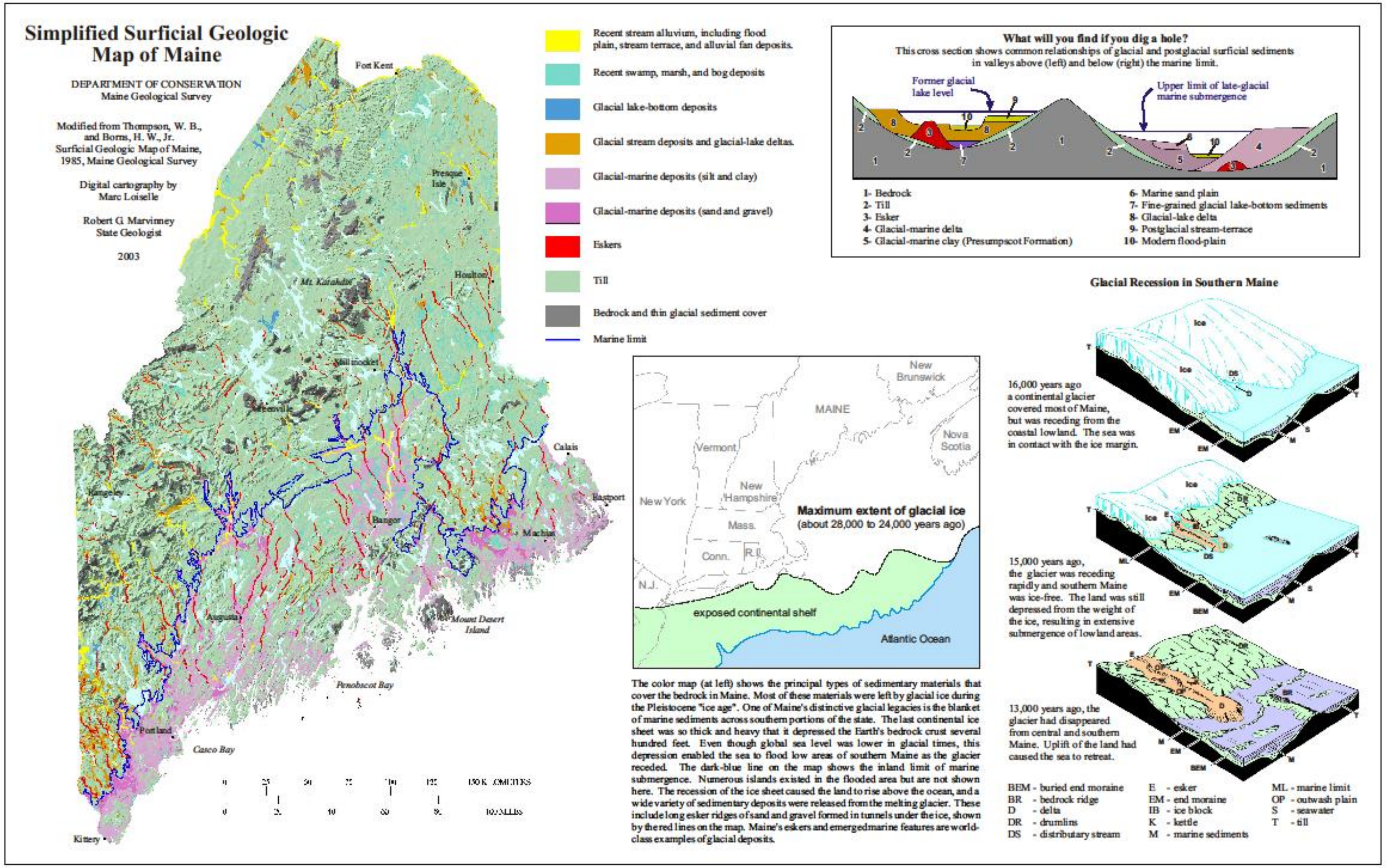
Appendix C. Bedrock geology map.



Appendix D. Surficial geology map.



Appendix E. Climate data for the Crooked River drainage area (NOAA, 2011 and 2014).

Station Name	**Element**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Temperature Normals (^oF)														
Bridgton 3 NW (1971-2000)	Max	28.6	32.4	41.3	52.7	66.2	74.1	78.8	76.7	68.6	57.6	45.0	33.5	54.6
	Mean	16.5	20.0	29.9	41.3	53.7	62.2	67.2	65.1	56.5	45.5	35.4	23.1	43.0
	Min	4.3	7.5	18.4	29.8	41.1	50.2	55.5	53.5	44.4	33.4	25.8	12.7	31.4
Bridgton 3 NW (1981-2010)	Max	27.6	32.0	40.5	53.4	65.9	72.8	77.7	76.1	68.3	57.0	44.9	32.9	54.1
	Mean	16.4	20.1	29.6	41.8	53.6	62.1	67.1	65.4	57.4	45.9	36.0	23.6	43.3
	Min	5.3	8.2	18.7	30.3	41.3	51.3	56.5	54.6	46.5	34.9	27.2	14.3	32.4
Portland Intl AP (1971-2000)	Max	30.9	34.1	42.2	52.8	63.3	72.8	78.8	77.3	68.9	57.9	47.1	36.4	55.2
	Mean	21.7	24.8	33.7	43.7	53.8	62.9	68.7	67.2	58.7	47.7	38.3	27.6	45.7
	Min	12.5	15.6	25.2	34.7	44.2	52.9	58.6	57.2	48.5	37.4	29.5	18.7	36.2
Portland Intl AP (1981-2010)	Max	31.2	34.6	42.1	53.3	63.5	73.2	78.8	77.7	70.0	58.7	48.0	37.3	55.7
	Mean	22.3	25.5	33.5	44.0	53.9	63.4	69.1	68.0	60.1	48.8	39.4	28.8	46.4
	Min	13.4	16.4	24.9	34.7	44.2	53.6	59.4	58.2	50.3	38.9	30.9	20.4	37.1
Rumford 1 SSE (1971-2000)	Max	27.1	31.0	40.1	52.2	66.2	74.5	79.3	77.4	68.9	57.3	43.7	31.8	54.1
	Mean	17.1	20.3	30.2	42.3	54.6	63.3	68.2	66.6	58.0	47.1	36.0	23.2	43.9
	Min	7.0	9.6	20.3	32.3	43.0	52.1	57.1	55.8	47.1	36.8	28.3	14.6	33.7
Precipitation Normals (inches)														
Bridgton 3 NW (1971-2000)		4.25	3.36	4.18	3.99	3.77	4.05	4.03	3.97	3.66	4.61	4.25	3.81	47.93
Portland Intl AP (1971-2000)		4.09	3.14	4.14	4.26	3.82	3.28	3.32	3.05	3.37	4.40	4.72	4.24	45.83
Portland Intl AP (1981-2010)		3.38	3.25	4.24	4.32	4.01	3.79	3.61	3.14	3.69	4.87	4.93	4.02	47.25
Rumford 1 SSE (1971-2000)		3.39	2.31	3.71	3.82	3.94	4.38	3.88	4.25	3.64	3.98	4.24	3.37	44.91
Snowfall Normals (inches)														
Bridgton 3 NW (1971-2000)		22.6	18.7	11.8	5.5	0.1	0	0	0	0	0.3	4.6	16.5	80.1
Portland Intl AP (1971-2000)		20.5	12.8	13.0	3.2	Trace	0	0	0	Trace	0.1	3.2	13.6	66.4
Portland Intl AP (1981-2010)		19.2	12.1	12.7	2.8	0	0	0	0	0	<0.5	1.9	13.2	61.9
Rumford 1 SSE (1971-2000)		21.4	20.2	16.1	6.9	0.4	0	0	0	0	0.8	7.1	20.6	93.5

Source (1971-2000 Normals): Climatography of the US #81
Source (1981-2010 Normals): www.ncdc.noaa.gov

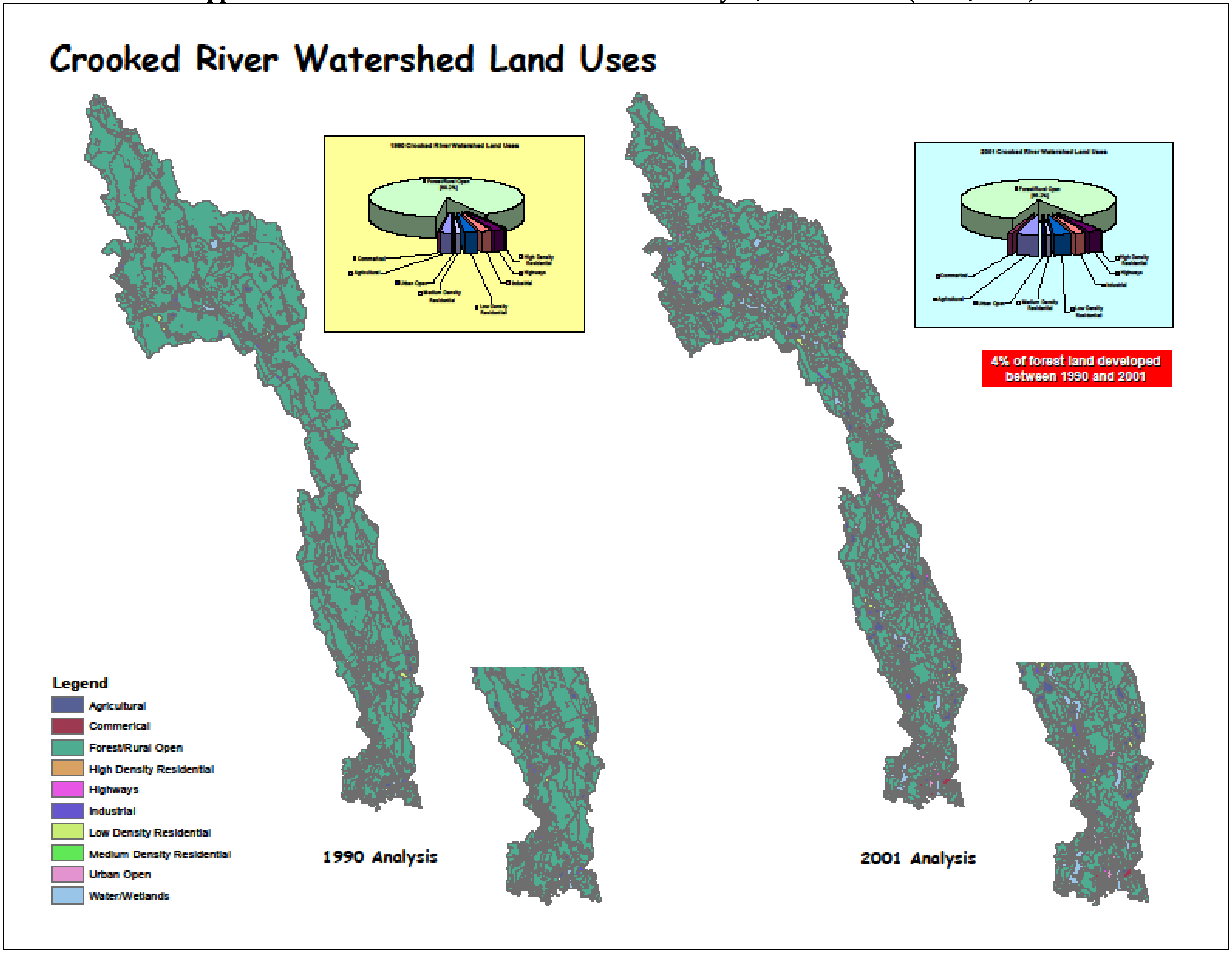
Appendix F. Listing of lakes in the Crooked River drainage and physical information.

WATCODE	WATER NAME	TOWN	ACRES	ELEVATION	AV DEPTH	MAX DEPTH
0361	CROCKER P	ALBANY TWP	10	824	7	13
3210	PROCTOR P	ALBANY TWP	45	577	8	15
3214	WEYMOUTH P	STONEHAM	16	715	9	19
3216	WHITNEY P	STONEHAM	10	590	3	5
3262	SONGO P	ALBANY TWP	224	651	9	25
3264	BROKEN BRIDGE P	ALBANY TWP	20	794	12	25
3266	KNEELAND P	ALBANY TWP	16	589		
3268	PAPOOSE P (LITTLE)	ALBANY TWP	19	550	5	8
3270	CHALK P	ALBANY TWP	25	710	2	4
3272	KEEWAYDIN L	STONEHAM	307	676	17	52
3274	VIRGINIA L	STONEHAM	145	820	10	28
3386	OWL P	CASCO	20	530	8	15
3388	PARKER P	CASCO	166	426	10	19
3414	PAPOOSE P	WATERFORD	64	477	7	15
3418	LONG (MCWAIN) P	WATERFORD	473	537	22	42
3442	DYER ICE P	OTISFIELD	2	635		
3446	PLEASANT L	OTISFIELD	1077	426	29	62
3448	ISLAND P	WATERFORD	166	448	16	48
3488	FURLONG P	ALBANY TWP	17	916	8	20
3490	SPECK P #1 (LITTLE)	NORWAY	4	810		
3492	SPECK P #2 (BIG)	NORWAY	14	855	12	40
3494	HUTCHINSON P	ALBANY TWP	96	915	14	38
6755	ROUND P	ALBANY TWP	14	790	20	29
6761	PATTE MILL P	ALBANY TWP	25	784		
6765	MOSQUITO P	ALBANY TWP	5	950	8	22

Appendix G. Listing of Crooked River tributaries and their associated length (mi.).

STREAMCODE	STREAM NAME	TOWN	MILES
0430310101	MILE B	CASCO/NAPLES	3.9
0430310101.1	BARTLETT B	CASCO	
043031010101	MEADOW B	CASCO	3.1
043031010101	TARKILN B	CASCO	
043031010102	EASTMAN B	OTISFIELD	0.7
043031010103	GREELY B	OTISFIELD	2.0
043031010104	MIDDLE B	OTISFIELD	1.2
043031010105	DYER ICE P OUTLET	OTISFIELD	1.6
043031010106	DOLLY B	OTISFIELD	0.9
0430310101071	OWL P OUTLET		
0430310102	BURGESS B	NAPLES/OTISFIELD	1.7
0430310103	SMITH B	OTISFIELD	2.8
043031010301	COLD B	NAPLES/OTISFIELD	0.9
043031010302	COLLEGE SWAMP B	OTISFIELD	2.8
043031010303	UNNAMED B	OTISFIELD	
04303101030301	UNNAMED B	OTISFIELD	
0430310104	UNNAMED B	HARRISON	1.3
0430310105	DEAD HOLE B	OTISFIELD	0.7
0430310106	RUSSELL B	HARRISON	2.6
0430310107	BIGELOW SWAMP OUTLET	HARRISON	0.6
0430310109	ISLAND P OUTLET	NORWAY/WATERFORD	1.8
043031010901	UNNAMED B	WATERFORD	
0430310110	MEADOW B	NORWAY/WATERFORD	4.6
043031011001	UNNAMED B	NORWAY	2.2
043031011001.1	UNNAMED B	NORWAY	
043031011002	HERRICK B	GREENWOOD/NORWAY	3.7
0430310111	MILLS B	WATERFORD	0.9
0430310112	MCINTYRE B	WATERFORD	1.1
0430310113	HOBBS B	GREENWOOD/NORWAY/WATERFORD	4.4
043031011301	SPECK PONDS OUTLET	NORWAY/WATERFORD	0.5
043031011302	UNNAMED B	GREENWOOD/NORWAY	1.0
043031011303	UNNAMED B	NORWAY	0.6
0430310114	SWETT B	WATERFORD/ALBANY TWP	5.2
043031011401	HUTCHINSON P OUTLET	ALBANY TWP	1.1
0430310115	PAPOOSE P OUTLET	WATERFORD	0.1
0430310116	UNNAMED B	WATERFORD	2.3
0430310117	CHALK P OUTLET	WATERFORD/ALBANY TWP	1.6
0430310118	UNNAMED B	WATERFORD	1.4
0430310119	UNNAMED B	WATERFORD	1.0
0430310120	WARREN B	WATERFORD	2.4
0430310121	MILL B	STONEHAM/WATERFORD/ALBANY TWP	2.9
043031012101	WHITNEY & WEYMOUTH PONDS OUTLET	STONEHAM/ALBANY TWP	0.8
043031012102	MEADOW B	STONEHAM	2.4
0430310121021	UNNAMED B	STONEHAM	0.5
043031012103	BARTLETT B	STONEHAM	1.0
0430310121031	HANNAH B	STONEHAM	1.7
0430310121032	GOODWIN B	STONEHAM	2.1
0430310123	PAPOOSE P (LITTLE) OUTLET	ALBANY TWP	0.2
0430310124	ALBANY B	ALBANY TWP	3.5
0430310125	ANN FLINTS B	ALBANY TWP	1.8
0430310128	BARKERS B	ALBANY TWP	1.8
0430310129	MOSQUITO P OUTLET	ALBANY TWP	0.9
0430310132	PATTE B	ALBANY TWP	3.4
043031013201	WALKER B	ALBANY TWP	3.0
043031013202	NEW ENGLAND B	ALBANY TWP/MASON TWP	1.9
0430310133	UNNAMED B	BETHEL	2.2
TOTAL			92.7

Appendix H. Crooked River watershed land use analysis, 1990 vs. 2001 (PWD, 2001).



Appendix I. Stocking history for the Crooked River.

Date	Town	Site	Species	#Stocked	Age Class	Mark
1/1/1917	Albany	UNKNOWN – FEDERAL STOCKING	RBT	4000	FRY?	UM
1/1/1956	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	400	?	UM
1/1/1957	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	30000	FRY	UM
1/1/1957	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	1500	FRY	UM
1/1/1958	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	900	?	UM
1/1/1959	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	1500	?	UM
4/1/1960	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	1600	SY	UM
4/1/1960	Norway	ANY CROSSING ABOVE EDES FALLS	BKT	500	SY	UM
4/1/1961	Norway	UNKNOWN	BKT	800	SY	UM
4/1/1961	Albany	UNKNOWN	BKT	500	SY	UM
4/1/1962	Albany	UNKNOWN	BKT	1000	SY	UM
4/1/1963	Albany	UNKNOWN	BKT	1300	SY	UM
4/29/1964	Norway	UNKNOWN	BKT	800	SY	UM
4/30/1964	Norway	UNKNOWN	BKT	500	SY	UM
5/1/1964	Norway	UNKNOWN	BKT	500	SY	UM
4/29/1965	Norway	UNKNOWN	BKT	500	SY	UM
5/3/1965	Norway	UNKNOWN	BKT	300	SY	UM
5/20/1965	Norway	UNKNOWN	BKT	500	SY	UM
4/16/1966	Norway	UNKNOWN	BKT	300	SY	UM
5/3/1966	Norway	UNKNOWN	BKT	400	SY	UM
5/18/1966	Norway	UNKNOWN	BKT	400	SY	UM
6/1/1966	Norway	UNKNOWN	BKT	400	SY	UM
5/1/1967	Norway	UNKNOWN	BKT	1000	SY	UM
5/26/1969	Norway	RTE. 118	BKT	400	SY	UM
6/12/1969	Norway	RTE. 118	BKT	350	SY	UM
5/6/1970	Norway	UNKNOWN	BKT	900	SY	UM
6/17/1970	Norway	UNKNOWN	BKT	1440	SY	UM
7/8/1970	Norway	UNKNOWN	BKT	600	SY	UM
8/6/1970	Norway	UNKNOWN	BKT	650	SY	UM
8/6/1970	Norway	UNKNOWN	BKT	325	SY	UM
8/28/1970	Norway	UNKNOWN	BKT	900	SY	UM
9/22/1970	Norway	UNKNOWN	BKT	600	FY	UM
5/8/1971	Norway	UNKNOWN	BKT	1000	SY	UM
6/3/1971	Harrison	BOLSTERS	BKT	1000	SY	UM
6/19/1971	Harrison	UNKNOWN	BKT	498	SY	UM
7/7/1971	Norway	UNKNOWN	BKT	1000	SY	UM
8/19/1971	Norway	UNKNOWN	BKT	900	SY	UM
6/21/1974	Norway	UNKNOWN	BKT	3000	FRY	UM
6/21/1974	Norway	UNKNOWN	BKT	686	SY	UM
5/28/1975	Waterford	UNKNOWN	BKT	500	SY	UM
5/28/1975	Harrison	UNKNOWN	BKT	500	SY	UM
6/19/1975	Waterford	UNKNOWN	BKT	498	SY	UM
6/19/1975	Harrison	UNKNOWN	BKT	498	SY	UM
4/28/1976	Waterford	UNKNOWN	BKT	300	SY	UM
4/28/1976	Norway	UNKNOWN	BKT	400	SY	UM
4/28/1976	Harrison	UNKNOWN	BKT	300	SY	UM
5/18/1976	Norway	UNKNOWN	BKT	400	SY	UM

Appendix I (continued). Stocking History for the Crooked River.

Date	Town	Site	Species	#Stocked	Age Class	Mark
5/18/1976	Harrison	UNKNOWN	BKT	300	SY	UM
5/18/1976	Waterford	UNKNOWN	BKT	300	SY	UM
6/3/1999	Harrison	RTE. 117 TWIN BRIDGES	BKT	400	SY	UM
6/1/2000	Harrison	RTE. 117 TWIN BRIDGES	BKT	300	SY	UM
5/17/2001	Naples	RTE. 117 TWIN BRIDGES	BKT	25	AD	AD
6/7/2001	Harrison	RTE. 117 TWIN BRIDGES	BKT	100	SY	UM
5/9/2003	Otisfield	RTE. 117 TWIN BRIDGES	BKT	125	SY	UM
4/28/2004	Otisfield	RTE. 117 TWIN BRIDGES	BKT	200	SY	UM
4/13/2005	Harrison	RTE. 117 TWIN BRIDGES	BKT	125	SY	UM
4/27/2006	Otisfield	RTE. 117 TWIN BRIDGES	BKT	125	SY	UM
5/7/2007	Otisfield	RTE. 117 TWIN BRIDGES	BKT	125	SY	UM
5/13/2008	Otisfield	RTE. 117 TWIN BRIDGES	BKT	125	SY	UM
1/1/1953	Waterford	ANY CROSSING ABOVE EDES FALLS	LLS	100000	FRY	UM
5/1/1962	Albany	UNKNOWN	LLS	21500	SY	DAD
10/1/1962	Albany	UNKNOWN	LLS	21500	FY	LV
5/1/1963	Albany	UNKNOWN	LLS	21500	SY	RV
10/1/1963	Albany	UNKNOWN	LLS	21500	FY	DLV
5/20/1964	Albany	UNKNOWN	LLS	17500	SY	ANLV
9/1/1964	Albany	UNKNOWN	LLS	17500	FY	RVAD
4/25/1965	Albany	UNKNOWN	LLS	17500	SY	BVDAD
10/1/1965	Albany	UNKNOWN	LLS	17500	FY	DBV
5/9/1966	Albany	UNKNOWN	LLS	17500	SY	DAD
10/4/1966	Albany	UNKNOWN	LLS	17500	FY	RV
4/1/1967	Albany	UNKNOWN	LLS	17500	SY	RVAN
10/1/1967	Albany	UNKNOWN	LLS	17500	FY	LVD
5/28/1974	Otisfield	UNKNOWN	LLS	10000	SY	RV
5/13/1975	Lovell	UNKNOWN	LLS	5000	SY	AD
4/28/1976	Otisfield	UNKNOWN	LLS	5000	SY	UM
5/28/1976	Albany	UNKNOWN	LLS	5000	SY	RPAD
10/4/1982	Waterford	HEADWATERS:MCWAIN, HOBBS,SWETT, PATTY MILL B	LLS	15000	FF	BV
10/19/1983	Norway	NORWAY UPSTRM	LLS	9800	FF	RV
10/12/1984	Norway	NORWAY UPSTRM	LLS	10000	FF	AD
10/10/1985	Albany	ALBANY	LLS	5000	FF	LV
5/21/1986	Albany	UNKNOWN	LLS	1500	SY	LV
10/14/1987	Albany	ALBANY	LLS	5000	FF	BV

Appendix J. Summary of fishing regulations for the Crooked River, 1972-2011.

Period	Season Dates	Bag Limits	Minimum Length	Additional Special Regulations
1972-1974	4/1-9/15; extension to 9/30	5 trout or salmon in the aggregate (or 7.5 pound aggregate weight limit)	LLS 14" BKT 6"	~From confluence with Songo River to first bridge upstream, daily limit 1 salmon from April 1 to May 15. ~Entire Crooked River open to FFO from September 15 to September 30 with daily limit 1 salmon.
1975	4/1-9/15; extension to 9/30	5 trout or salmon in the aggregate (or 7.5 pound aggregate weight limit)	**LLS 17"** BKT 6"	Same as above with the following exceptions/changes (bold): **~ No size or bag on PKL.**
1976-1977	4/1-9/15; extension to 9/30	5 trout or salmon in the aggregate (or 7.5 pound aggregate weight limit)	LLS 17" BKT 6"	Same as above with the following exceptions/changes (bold): ~Entire Crooked River open to FFO from September 15 to September 30 with daily limit 1 salmon **or trout.** **~Closed to the taking of SLT from 4/1-5/31.** **~Fishing legal from the dam at Bolsters Mills except within the fishway.**
1978	4/1-9/15; extension to 9/30	5 trout or salmon in the aggregate (or 7.5 pound aggregate weight limit)	LLS 17" BKT 6"	Same as above with the following exceptions/changes (bold): **~Closed to the taking of smelts except by hook and line.**
1979	4/1-9/15; extension to 9/30	5 trout or salmon in the aggregate (or 7.5 pound aggregate weight limit)	LLS 17" BKT 6"	Complete regulations with changes noted in bold: ~No size or bag limit on pickerel. ~Closed to the taking of smelts except by hook and line; **daily limit 2 quarts.** ~ From confluence with Songo River to first bridge upstream, daily limit 1 salmon from April 1 to May 15. ~**From June 15 to Sept 14 , fishing in the following section is limited to casting with artificial lures only with a daily limit of 2 fish in the aggregate of salmon, brook trout, and togue: (1) from Twin Bridges (Route 117) downstream 400 feet to two red posts; (2) from Bolsters Mills dam downstream 800 feet to two red posts; (3) from Scribners Mills dam downstream 700 feet to two red posts; and (4) from Edes Falls downstream about 600 feet to the steel bridge.** ~Entire Crooked River is open to FFO from September 15 to September 30 with daily limit 1 salmon or trout. ~**No length limit or bag limit on bass from the Twin Bridges at Route 117 (Otisfield) to Route 11 (Casco).** ~Fishing legal from the dam at Bolsters Mills except from the fishway **and trap.**
1980-1981	4/1-9/15; extension to 9/30	**3 salmon, togue, or trout singly or in combination (or 7.5 pound aggregate bag including bass)**	**LLS 16"** BKT 6"	Complete regulations with changes noted in bold: ~No size or bag limit on pickerel. ~**Smelts may be taken by hook and line only.**[1] ~ **From the dam at Bolsters Mills downstream to Route 11 in Casco: fly fishing only, at all times; from June 15-Sept. 15 – daily bag and possession limit on salmon, trout and togue: 2 fish, singly or in combination.** ~ From confluence with Songo River upstream to first bridge, from April 1 to May 15: daily limit on salmon – 1 fish. ~ **From route 117 downstream 400 feet to two red posts: ALO from June 15 to Sept. 15 with daily bag and possession limit on salmon trout and togue 2 fish, singly or in combination.** (Note: same regulations for Bolsters and Edes sections dropped.) ~ From Route 117 downstream to Route 11: no length or bag limit on bass. ~ The entire river, Sept. **16**-30 – FFO; daily bag and possession limit – 1 salmon or 1 trout **or 1 togue.**
1982-1985	4/1-9/15; extension to 9/30	2 LLS 5 BKT (5 fish or 7.5 pound aggregate bag limit)	LLS 16" BKT 6"	Same as above with the following exceptions/changes (bold): ~ **Closed to all fishing within 150 feet of the dam at Bolsters Mills.** **~From 150 feet below the dam at** Bolsters Mills downstream to Route 11 in Casco: FFO, at all times. From June 15-Sept. 15 – daily bag and possession limit on salmon, trout and togue: 2 fish, singly or in combination.
1986-1987	4/1-9/15; extension to 9/30	1 LLS 5 BKT (5 fish or 7.5 pound aggregate bag limit)	LLS 16" BKT 6"	Complete special regulations: ~Closed to the taking of smelts except by hook and line. ~Closed to all fishing within 150 feet of the fishway at Bolsters Mills Dam. ~FFO from Route 11, Casco, Naples, **to Route 35, North Waterford, from April 1 to September 30.**

Appendix J (continued). Summary of fishing regulations for the Crooked River, 1972-2011.

Period	Season Dates	Bag Limits	Minimum Length	Additional Special Regulations
1988-1993	4/1-8/15; 8/16-9/30[2]	1 LLS 5 BKT (5 fish or 7.5 pound aggregate bag limit)	LLS 16" BKT 6"	Complete special regulations: ~Closed to the taking of smelts except by hook and line. ~FFO from Route 11, Casco, Naples, to Route 35, North Waterford, from April 1 to September 30.
1994-1995	4/1-8/15; 8/16-9/30[2]	**No LLS** 5 BKT (5 fish or 7.5 pound aggregate bag limit)	**LLS NA** BKT 6"	Complete special regulations: ~Closed to the taking of smelts. ~From Route 11, Casco, Naples, to Route 35, North Waterford, from April 1 to September 30. FFO, **C&R** for salmon
1996-1999	4/1-8/15; 8/16-9/30[2]	No LLS 5 BKT (5 fish or 7.5 pound aggregate bag limit)	**LLS NA** BKT 6"	Complete special regulations: ~Closed to the taking of smelts. ~From Route 11, Casco, Naples, to Route 35, North Waterford, from April 1 to September 30. FFO, C&R for salmon **~From Bolsters Mill road bridge downstream to Route 11 in Casco: from Oct. 1 – Oct 15, FFO, C&R.**
2000-2013	4/1-8/15; 8/16-9/30[2]	**1 LLS** 5 BKT (5 fish aggregate bag limit)[3]	**LLS 26"** BKT 6"	Complete special regulations: ~Closed to the taking of smelts. ~From Route 11, Casco, Naples, to Route 35, North Waterford, from April 1 to September 30. FFO, Daily bag limit on salmon: 1 fish. Minimum length limit on salmon: 26 inches. ~From Bolsters Mill road bridge downstream to Route 11 in Casco: from Oct. 1 – Oct 15, FFO, Daily bag limit on salmon: 1 fish. Minimum length limit on salmon: 26 inches. **All other fish caught must be released alive at once.**
2014	4/1-8/15; 8/16-9/30[2]	**1 LLS** 5 BKT (5 fish aggregate bag limit)[3]	**LLS 26"** BKT 6"	Complete special regulations: ~Closed to the taking of smelts. ~From Albany to Casco, FFO, Daily bag limit on salmon: 1 fish. Minimum length limit on salmon: 26 inches. ~From Bolsters Mill road bridge downstream to Route 11 in Casco: from Oct. 1 – Oct 15, FFO, Daily bag limit on salmon: 1 fish. Minimum length limit on salmon: 26 inches. **All other fish caught must be released alive at once.**

[1] 2 quart bag limit for SLT became general law.
[2] ALO with a 1 fish bag limit for salmon, trout, or togue.
[3] Aggregate bag limits removed from general law provisions in 2011.
FFO= fly fishing only; C&R= catch and release; ALO=artificial lures only

Appendix K. Temperature (°F) data summary for Bolsters Mills, 1974-1986.

MONTH	Statistic	YEAR												
		1974	1975	1976	1977	1978	1979	1980	1981	1983	1984	1985	1986	Total
5	N		3	2	4	1	3	1	4	5	7	10	8	48
	Mean		61.3	51.5	62.5	51.0	58.7	59.0	58.8	54.4	56.0	57.1	61.3	58.0
	Minimum		59.0	48.0	57.0	51.0	56.0	59.0	55.0	52.0	48.0	46.0	52.0	46.0
	Maximum		65.0	55.0	71.0	51.0	61.0	59.0	65.0	57.0	65.0	64.0	67.0	71.0
6	N	5	7	11	6	7	8	2	5	8	6	7	8	80
	Mean	63.2	65.3	67.1	60.3	64.4	64.8	72.0	63.2	63.3	64.3	63.4	62.4	64.2
	Minimum	59.0	55.0	60.0	57.0	59.0	63.0	70.0	59.0	54.0	59.0	59.0	56.0	54.0
	Maximum	68.0	74.0	74.0	65.0	70.0	68.0	74.0	68.0	72.0	72.0	68.0	66.0	74.0
7	N	5	6	4	7	4	4		4	5	6	4	1	50
	Mean	69.4	72.3	68.8	69.9	70.8	67.5		69.8	70.2	66.0	71.5	78.0	69.8
	Minimum	66.0	68.0	64.0	67.0	68.0	63.0		63.0	64.0	63.0	69.0	78.0	63.0
	Maximum	72.0	75.0	71.0	74.0	75.0	74.0		76.0	75.0	70.0	75.0	78.0	78.0
8	N	4	1	3	2		4		5	3	3			25
	Mean	70.75	77.0	67.0	66.5		68.5		67.0	71.3	70.0			69.1
	Minimum	68.0	77.0	65.0	63.0		61.0		63.0	70.0	66.0			61.0
	Maximum	74.0	77.0	70.0	70.0		77.0		72.0	74.0	72.0			77.0
9	N	7	2	4	6		2		4	2	2			29
	Mean	60.3	58.0	60.5	53.8		63.0		55.3	57.0	52.5			57.6
	Minimum	55.0	56.0	54.0	52.0		54.0		52.0	54.0	48.0			48.0
	Maximum	65.0	60.0	65.0	58.0		72.0		61.0	60.0	57.0			72.0
10	N	5	7	4	10	8	8	2	7	6	10	2		69
	Mean	46.6	50.7	51.0	49.5	47.1	52.5	41.0	48.7	49.7	50.6	56.5		49.6
	Minimum	45.0	45.0	47.0	42.0	43.0	43.0	39.0	45.0	42.0	46.0	55.0		39.0
	Maximum	50.0	54.0	56.0	55.0	50.0	59.0	43.0	52.0	58.0	57.0	58.0		59.0
11	N	2		1	4	4	1	1	3	3	3			22
	Mean	44.0		42.0	44.8	40.5	43.0	38.0	41.0	39.3	44.0			42.0
	Minimum	43.0		42.0	41.0	36.0	43.0	38.0	39.0	36.0	43.0			36.0
	Maximum	45.0		42.0	47.0	45.0	43.0	38.0	43.0	43.0	46.0			47.0
Total N		28	26	29	39	24	30	6	32	32	37	23	17	323
Total Mean		60.3	62.4	62.2	57.2	55.2	60.9	53.8	57.8	58.5	57.5	61.4	62.8	59.3
Total Minimum		43.0	45.0	42.0	41.0	36.0	43.0	38.0	39.0	36.0	43.0	46.0	52.0	36.0
Total Maximum		74.0	77.0	74.0	74.0	75.0	77.0	74.0	76.0	75.0	72.0	75.0	78.0	78.0

Appendix L. Summary of Crooked River water quality data from USGS monitoring in Naples, 1996 (Adapted from USGS, 2009).

Water Quality Parameter	Date	
	5/21/1996	8/15/1996
Temperature ^{o}C	15.5	18.5
Dissolved Oxygen mg/L	9.3	9.3
Dissolved Oxygen % saturation	---	100
pH (field/lab)	6.5/6.5	6.3/6.7
Calculated H-ion	0.00032	0.00051
Specific Conductance uS/cm @ 25^{o}C (field/lab)	43/45	52/54
Alkalinity mg/L as CaC03 (filtered)	5	8
ANC mg/L as CCaCO3 (field/lab)	---/6	9/11
Carbonate mg/L (filtered)	---	0
Bicarbonate mg/L (filtered)	---	10
Carbon dioxide mg/L	3.9	8.7
Total Nitrogen mg/L (unfiltered/filtered)	0.37/0.27	0.38/---
Organic Nitrogen mg/L (unfiltered/filtered)	0.27/0.17	0.26/---
Ammonia mg/L as N (filtered)	0.03	0.04
Ammonia mg/L (filtered)	0.04	0.05
Ammonia + Org-N mg/L as N (filtered)	0.2	<0.2
Ammonia + Org-N mg/L as N	0.3	0.3
Nitrate + Nitrite mg/L as N (filtered)	0.07	0.08
Nitrite mg/L as N (filtered)	<0.01	0.01
Nitrite mg/L (filtered)	---	0.033
Nitrate mg/L as N (filtered)	---	0.07
Nitrate mg/L (filtered)	---	0.31
Phosphorus mg/L as P (filtered/unfiltered)	<0.01/<0.01	<0.01/<0.01
Orthophosphate mg/L as P (filtered)	<0.01	<0.01
Hardness mg/L as CaCo3	9	12
Noncarbonate Hardness mg/L as CaCO3 (filtered)	4	4
Calcium mg/L (filtered)	2.8	3.7
Magnesium mg/L (filtered)	0.53	0.71
Sodium mg/L (filtered)	4.1	4.6
Sodium Adsorption Ratio	0.6	0.6
Sodium Fraction of Cations (%)	48	44
Potassium mg/L (filtered)	0.4	0.6
Chloride mg/L (filtered)	5.8	6.5
Sulfate mg/L (filtered)	2.9	2.8
Flouride mg/L (filtered)	<0.1	<0.1
Silica mg/L as SiO2 (filtered)	5	2.9
Iron ug/L (filtered)	120	230
Maganese ug/L (filtered)	8	9
Residue on Evaporation at 180^{o}C mg/L (filtered)	42	50
Residue - Sum of Constituents mg/L	25	27
Residue Water - dissolved tons/day	64.4	10.9
Residue Water - tons/acre-ft (filtered)	0.06	0.07

Appendix M: Portland Water District data for the Crooked River, 2007 (Adapted from PWD, 2007).

Date	Sample Site	Turbidity (NTU)	Total Phosphorus (ppb)	Fecal Coliform (cfu/100mL)
3/28/07	CR State Park	2.30	---	12
4/25/07	CR State Park	3.90	28.20	5
4/30/07	CR Bolsters Mills	1.80	13.60	10
4/30/07	CR E. Waterford	1.00	17.00	6
4/30/07	CR Hunts Corner	0.80	10.50	10
4/30/07	CR N. Waterford	0.60	10.10	22
4/30/07	CR Old Rte 302 Bridge	1.10	21.70	7
4/30/07	CR Route 35	0.50	10.70	75
4/30/07	CR State Park	1.20	35.50	9
5/15/07	CR State Park	6.20	---	0
6/14/07	CR State Park	1.50	19.30	28
6/19/07	CR Bolsters Mills	1.70	15.70	20
6/19/07	CR E. Waterford	1.60	13.70	27
6/19/07	CR Hunts Corner	1.10	13.90	41
6/19/07	CR N. Waterford	1.60	14.70	
6/19/07	CR Old Rte 302 Bridge	1.00	14.20	21
6/19/07	CR Route 35	1.50	14.40	49
6/19/07	CR State Park	1.50	14.70	15
7/17/07	CR State Park	1.40	---	22
8/9/07	CR Bolsters Mills	1.40	22.70	22
8/9/07	CR E. Waterford	1.50	14.00	62
8/9/07	CR Hunts Corner	1.50	14.80	160
8/9/07	CR N. Waterford	1.40	19.20	52
8/9/07	CR Old Rte 302 Bridge	2.50	18.10	112
8/9/07	CR Route 35	1.70	15.40	58
8/9/07	CR State Park	2.00	16.00	16
8/15/07	CR State Park	1.80	15.30	24
9/25/07	CR State Park	0.50	---	
10/16/07	CR State Park	1.00	16.70	18
10/31/07	CR Bolsters Mills	0.70	13.10	12
10/31/07	CR E. Waterford	0.80	13.70	22
10/31/07	CR Hunts Corner	0.40	13.80	50
10/31/07	CR N. Waterford	0.20	12.70	80
10/31/07	CR Old Rte 302 Bridge	0.40	13.60	9
10/31/07	CR Route 35	0.10	13.70	197
10/31/07	CR State Park	0.70	15.00	10
11/30/07	CR State Park	0.50	---	37

Appendix N: Portland Water District data for the Crooked River, 2009 (Adapted from PWD, 2009).

Date	Sample Site	Turbidity (NTU)	Total Phosphorus (ppb)	Fecal Coliform (cfu/100mL)
3/26/2009	CR State Park	0.92	---	3
4/22/2009	CR State Park	3.50	22.70	24
4/28/2009	CR State Park	1.30	12.00	6
4/28/2009	CR Hunts Corner	0.90	11.10	12
4/28/2009	CR E. Waterford	1.40	12.90	15
4/28/2009	CR Bolsters Mills	1.10	11.90	11
4/28/2009	CR N. Waterford	0.80	8.50	13
4/28/2009	CR Route 35	1.00	9.90	30
4/28/2009	CR Old Rte 302 Bridge	1.80	14.60	8
5/19/2009	CR State Park	1.40	---	20
6/16/2009	CR N. Waterford	1.00	14.00	44
6/16/2009	CR Bolsters Mills	2.50	20.20	81
6/16/2009	CR Route 35	0.70	14.00	96
6/16/2009	CR E. Waterford	1.40	19.70	75
6/16/2009	CR Hunts Corner	1.50	19.60	63
6/16/2009	CR State Park	1.70	22.00	96
6/16/2009	CR Old Rte 302 Bridge	1.50	26.00	84
6/29/2009	CR State Park	3.40	30.60	613
7/7/2009	CR State Park	---	---	66
7/15/2009	CR State Park	1.75	---	41
8/4/2009	CR State Park	1.80	24.80	54
8/4/2009	CR Old Rte 302 Bridge	1.80	28.90	488
8/4/2009	CR Route 35	0.80	16.40	78
8/4/2009	CR N. Waterford	1.10	19.00	93
8/4/2009	CR Bolsters Mills	1.60	24.00	158
8/4/2009	CR E. Waterford	1.40	21.90	210
8/4/2009	CR Hunts Corner	1.10	19.00	126
8/7/2009	CR Old Rte 302 Bridge	---	---	34
8/12/2009	CR State Park	2.00	13.80	59
9/22/2009	CR State Park	1.00	---	15
10/21/2009	CR State Park	0.80	11.10	9
10/29/2009	CR E. Waterford	1.00	---	---
10/29/2009	CR Bolsters Mills	0.80	---	---
10/29/2009	CR State Park	1.00	---	---
10/29/2009	CR Hunts Corner	0.80	---	---
10/29/2009	CR N. Waterford	0.60	---	---
10/29/2009	CR Route 35	0.60	---	---
10/29/2009	CR Old Rte 302 Bridge	0.80	---	---
11/3/2009	CR Old Rte 302 Bridge	---	15.30	6
11/3/2009	CR Hunts Corner	---	12.20	6
11/3/2009	CR Bolsters Mills	---	13.10	11
11/3/2009	CR State Park	---	15.20	10
11/3/2009	CR Route 35	---	11.90	19
11/3/2009	CR N. Waterford	---	10.80	10
11/3/2009	CR E. Waterford	---	13.70	26
11/19/2009	CR State Park	1.39	---	27
12/4/2009	CR State Park	2.50	---	32

Appendix O. Crooked River water quality data via MDEP biomonitoring (MDEP 2011).

Town	Sample Date	Parameter	Value	Units
Naples	6/29/2005	DISSOLVED ORGANIC CARBON	4.5	MG/L
Naples	7/26/2010	DISSOLVED ORGANIC CARBON	6.4	MG/L
Albany	8/20/2003	DISSOLVED OXYGEN	8.2	MG/L
Naples	8/16/2001	DISSOLVED OXYGEN	7.7	MG/L
Naples	6/29/2005	DISSOLVED OXYGEN	8.7	MG/L
Naples	8/3/2005	DISSOLVED OXYGEN	8.57	MG/L
Naples	7/26/2010	DISSOLVED OXYGEN	10.5	MG/L
Waterford	7/10/2003	DISSOLVED OXYGEN	10.4	MG/L
Naples	6/29/2005	NITRATE+NITRITE AS N	0.05	MG/L
Naples	8/3/2005	NITRATE+NITRITE AS N	0.02	MG/L
Naples	7/26/2010	NITRATE+NITRITE AS N	0.01	MG/L
Waterford	7/10/2003	NITRATE+NITRITE AS N	0.02	MG/L
Naples	8/3/2005	PH	6.9	STU
Naples	7/26/2010	PH	6.31	STU
Waterford	7/10/2003	PH	7.12	STU
Waterford	7/10/2003	SILICA	3.3	MG/L
Naples	6/29/2005	SOLUBLE REACTIVE PHOSPHORUS	1	UG/L
Naples	7/26/2010	SOLUBLE REACTIVE PHOSPHORUS	2	UG/L
Waterford	7/10/2003	SOLUBLE REACTIVE PHOSPHORUS	1	UG/L
Albany	8/20/2003	SPECIFIC CONDUCTANCE	35	US/CM
Naples	8/16/2001	SPECIFIC CONDUCTANCE	61.3	US/CM
Naples	6/29/2005	SPECIFIC CONDUCTANCE	50	US/CM
Naples	8/3/2005	SPECIFIC CONDUCTANCE	56.1	US/CM
Naples	7/26/2010	SPECIFIC CONDUCTANCE	34	US/CM
Waterford	7/10/2003	SPECIFIC CONDUCTANCE	47	US/CM
Albany	8/20/2003	TEMPERATURE	18	DEG C
Naples	7/31/1989	TEMPERATURE	21	DEG C
Naples	8/16/2001	TEMPERATURE	21.5	DEG C
Naples	6/29/2005	TEMPERATURE	22.5	DEG C
Naples	8/3/2005	TEMPERATURE	21.8	DEG C
Naples	7/26/2010	TEMPERATURE	22.2	DEG C
Waterford	8/16/1991	TEMPERATURE	21.5	DEG C
Waterford	7/10/2003	TEMPERATURE	21.6	DEG C
Naples	6/29/2005	TOTAL ALKALINITY	8	MG/L
Naples	7/26/2010	TOTAL ALKALINITY	7	MG/L
Waterford	7/10/2003	TOTAL ALKALINITY	9	MG/L
Waterford	7/10/2003	TOTAL DISSOLVED SOLIDS	23	MG/L
Naples	6/29/2005	TOTAL KJELDAHL NITROGEN	0.3	MG/L
Naples	8/3/2005	TOTAL KJELDAHL NITROGEN	0.2	MG/L
Naples	7/26/2010	TOTAL KJELDAHL NITROGEN	0.4	MG/L
Waterford	7/10/2003	TOTAL KJELDAHL NITROGEN	0.2	MG/L
Naples	6/29/2005	TOTAL PHOSPHORUS	0.016	MG/L
Naples	8/3/2005	TOTAL PHOSPHORUS	0.01	MG/L
Naples	7/26/2010	TOTAL PHOSPHORUS	0.018	MG/L

Appendix P. Breakdown of Crooked River habitat and dominant substrate types by river section.

River Section	Habitat Type ft^2			Total
	Riffle	Pool	Run	
Albany-N. Waterford (Rte 35)	544,200	1,370,800	404,200	2,319,200
N. Waterford-Sodom Rd.	347,800	1,760,800	366,000	2,474,600
Sodom Rd.-Twin Bridges	349,800	1,666,600	130,400	2,146,800
Twin Bridges-Bolsters Mills	212,600	1,406,600	141,200	1,760,400
Bolsters Mills-Scribners Mill	537,000	304,400	73,000	914,400
Scribners Mill-Edes Falls	186,800	2,356,000	602,200	3,145,000
Edes Falls-Rte 11	108,000	570,400	189,200	867,600
Rte 11-Songo R (Green Bridge)	0	2,805,800	172,800	2,978,600
Total	2,286,200	12,241,400	2,079,000	16,606,600

River Section	Dominant Substrate ft^2						
	Boulder	Rubble	Gravel	Sand	Muck	Ledge	Total
Albany-N. Waterford (Rte 35)	234,100	116,685	226,905	1,577,360	19,160	85,620	2,259,830
N. Waterford-Sodom Rd.	272,110	28,600	130,200	1,995,230	0	91,750	2,517,890
Sodom Rd.-Twin Bridges	319,670	55,220	44,520	1,657,070	0	72,200	2,148,680
Twin Bridges-Bolsters Mills	373,785	42,060	1,600	1,346,905	0	0	1,764,350
Bolsters Mills-Scribners Mill	248,000	84,500	62,200	450,600	0	16,600	861,900
Scribners Mill-Edes Falls	306,895	110,680	265,500	2,376,406	0	8,460	3,067,941
Edes Falls-Rte 11	180,190	22,700	25,275	608,230	0	25,800	862,195
Rte 11-Songo R (Green Bridge)	30,650	69,640	57,300	2,774,240	0	0	2,931,830
Total	1,965,400	530,085	813,500	12,786,041	19,160	300,430	16,414,616

Appendix Q. Summary of habitat and dominant substrate types in Mile Brook.

Mile Brook		
Habitat Type	**Wetted Area (ft^2)**	**Percentage of Total Area**
Riffle	161,446	31.1
Pool[1]	23,240	4.5
Run	82,065	15.8
Cascade	8,800	1.7
Deadwater	243,300	46.9
Total	518,851[2]	100.0
Substrate Type (Dominant)	**Wetted Area (ft^2)**	**Percentage of Total Area**
Mud	95,430	20.2
Fines	106,218	22.5
Sand	95,781	20.3
Pea Gravel	9,655	2.0
Gravel	89,180	18.8
Cobble	74,097	15.7
Rubble	2,300	0.5
Boulder	162	0
Ledge	0	0
Total	472,823[2]	100

[1] Only large/significant pools (adult LLS holding pools) were differentiated from riffle/pool type habitats.
[2]Substrate Type and Habitat Type Totals not equal due to different computational methods (section vs. transect area).

Appendix R. Summary of habitat and dominant substrate types in Meadow & Herrick Brooks.

Meadow Brook			Herrick Brook		
Habitat Type	**Wetted Area (ft^2)**	**Percentage of Total Area**	**Habitat Type**	**Wetted Area (ft^2)**	**Percentage of Total Area**
Riffle	101,250	29.7	Riffle	145,768	55.7
Pool[1]	32,336	9.5	Pool[1]	17,400	6.6
Run	4,150	1.2	Run	42,557	16.3
Cascade	0	0	Cascade	6,800	2.6
Deadwater	203,220	59.6	Deadwater	49,220	18.8
Total	340,956[2]	100	Total	261,745[2]	100
Substrate Type (Dominant)	**Wetted Area (ft^2)**	**Percentage of Total Area**	**Substrate Type (Dominant)**	**Wetted Area (ft^2)**	**Percentage of Total Area**
Mud	0	0	Mud	0	0
Clay	8,907	2.6	Clay	405	0.2
Fines	127,122.5	37.5	Fines	21,130	7.9
Sand	54,702.5	16.1	Sand	52,884	19.8
Pea Gravel	9,895	2.9	Pea Gravel	20,540	7.7
Gravel	39,184	11.5	Gravel	54,115.5	20.3
Cobble	83,566.5	24.6	Cobble	102,770	38.5
Rubble	15,134	4.5	Rubble	4,567.5	1.7
Boulder	277.5	0.1	Boulder	1,929	0.7
Ledge	634	0.2	Ledge	8,364.5	3.2
Total	339,423[2]	100	Total	266,705.5[2]	100

[1] Only large/significant pools (adult LLS holding pools) were differentiated from riffle/pool type habitats.
[2] Substrate Type and Habitat Type Totals not equal due to different computational methods (section vs. transect area).

Appendix S. Summary of habitat and dominant substrate types in Swett Brook & Unnamed Tributary.

Swett Brook[3]			Unnamed Tibutary[3]		
Habitat Type	**Wetted Area (ft^2)**	**Percentage of Total Area**	**Habitat Type**	**Wetted Area (ft^2)**	**Percentage of Total Area**
Riffle	194,784	53.2	Riffle	25,872	100
Pool[1]	48,755	13.3	Pool[1]	0	0
Run	59,200	16.2	Run	0	0
Cascade	6,400	1.7	Cascade	0	0
Rapids	5,000	1.4	Rapids	0	0
Deadwater	51,788	14.2	Deadwater	0	0
Total	365,927[2]	100	Total	25,872[2]	100
Substrate Type (Dominant)	**Wetted Area (ft^2)**	**Percentage of Total Area**	**Substrate Type (Dominant)**	**Wetted Area (ft^2)**	**Percentage of Total Area**
Mud	0	0	Mud	0	0
Clay	0	0	Clay	0	0
Fines	7,020	1.9	Fines	0	0
Sand	99,302	27.1	Sand	0	0
Pea Gravel	41,484	11.3	Pea Gravel	0	0
Gravel	39,858.5	10.9	Gravel	16,400	61.7
Cobble	132,827	36.3	Cobble	9,457	35.6
Rubble	33,332.5	9.1	Rubble	0	0
Boulder	5,818.5	1.6	Boulder	0	0
Ledge	6,735	1.8	Ledge	715	2.7
Total	366,377.5[2]	100	Total	26,572[2]	100

[1] Only large/significant pools (adult LLS holding pools) were differentiated from riffle/pool type habitats.
[2] Substrate Type and Habitat Type Totals not equal due to different computational methods (section vs. transect area).
[3] Stream areas above Hutchinson Pond Road not surveyed due to likely fish barriers at road crossings.

Appendix T. Summary of habitat and dominant substrate types in Russell Brook.

Russell Brook[3]		
Habitat Type	**Wetted Area (sqft)**	**Percentage of Total Area**
Riffle	75,090	60.6
Pool[1]	965	0.8
Run	45,935	37.1
Cascade	0	0
Rapids	0	0
Deadwater	1,890	1.5
Total	123,880[2]	100
Substrate Type (Dominant)	**Wetted Area (sqft)**	**Percentage of Total Area**
Subterranean	270	0.2
Fines	2,235	1.8
Sand	55,087.5	45.2
Pea Gravel	850	0.7
Gravel	19,005	15.6
Cobble	28,062.5	23.0
Rubble	16,377.5	13.4
Total	121,887.5[2]	100 (99.9)

[1] Only large/significant pools (adult LLS holding pools) were differentiated from riffle/pool type habitats.
[2]Substrate Type and Habitat Type Totals not equal due to different computational methods (section vs. transect area).
[3]Stream areas above Haskell Hill Rd not surveyed due to likely fish barriers at road crossings.

Appendix U. Known fish species occurrence in lakes within the Crooked River drainage, 2007.

WATCODE	WATER NAME	TOWN	PRINCIPAL FISHERIES[1]	OCCURRENCE of OTHER FISH SPECIES	SPECIES REPORTED/UNCONFIRMED
0361	CROCKER P	ALBANY TWP	BKT	GLS	
3210	PROCTOR P	ALBANY TWP	SMB	GLS, FHM, PKL, PKS	BLC, BUL, EEL, FLF, LMB, WHP, WHS
3214	WEYMOUTH P	STONEHAM	PKL		
3216	WHITNEY P	STONEHAM	PKL	GLS, PKS	
3262	SONGO P	ALBANY TWP	BKT, LLS, SMB, PKL	CMS, GLS, LMB, PKS, SLT, WHS, YLP	BUL, EEL, WHP
3264	BROKEN BRIDGE P	ALBANY TWP	BKT	GLS	
3266	KNEELAND P	ALBANY TWP			GLS, PKL
3268	PAPOOSE P (LITTLE)	ALBANY TWP		BUL, CCS, GLS, LMB, PKL, PKS, YLP	
3270	CHALK P	ALBANY TWP		PKL	
3272	KEEWAYDIN L	STONEHAM	BKT, LLS	BUL, EEL, GLS, FLF, LMB, SMB, PKL, PKS, , SLT, WHP, WHS, YLP	BLC
3274	VIRGINIA L	STONEHAM	BKT, LMB, PKL, WHP	BLC, BUL, CMS, EEL, GLS, FLF, PKS, SLT, WHS, YLP	
3386	OWL P	CASCO	PKL	GLS, PKS, WHS, YLP	BLC
3388	PARKER P	CASCO	BKT, LMB, PKL, SMB, WHP	BLC, BUL, CSK, EEL, GLS, LLS, PKS, WHS, YLP	BKF
3414	PAPOOSE P	WATERFORD	BLC, PKL, SMB, WHP	BUL, CCS, CMS, FLF, GLS, LLS, PKS, WHS, YLP	EEL, LMB
3418	LONG (MCWAIN) P	WATERFORD	SMB, PKL	BUL, FLF, PKS, RBS, SLT, WHS, YLP	CMS, EEL, GLS, LMB
3442	DYER ICE P	OTISFIELD			
3446	PLEASANT L	OTISFIELD	CSK, LLS, LMB, SMB, WHP	BUL, EEL, GLS, LKT, LLA, PKS, SLT, WHS, YLP	BKF
3448	ISLAND P	WATERFORD	BKT, LMB, SMB, PKL	BUL, MIN, PKS, RBS, SLT, WHS, YLP	EEL
3488	FURLONG P	ALBANY TWP	PKL	GLS	
3490	SPECK P #1 (LITTLE)	NORWAY		PKL	
3492	SPECK P #2 (BIG)	NORWAY	BKT		
3494	HUTCHINSON P	ALBANY TWP	BKT, BNT, LMB, PKL, SMB	BUL, YLP	EEL, MIN, SLT
6755	ROUND P	ALBANY TWP	BKT	BUL, GLS, PKL	BND
6761	PATTE MILL P	ALBANY TWP		PKL, PKS	BUL, GLS
6765	MOSQUITO P	ALBANY TWP	BKT		

[1]Principal fishery defined as species commonly targeted by anglers fishing the particular water.

Appendix V. Known fish species occurrence in Crooked River tributaries, 2005.

STREAMCODE	STREAM NAME	TOWN	PRINCIPAL FISHERY[1]	FISH SPECIES OCCURRENCE	COMMENTS
0430310101	MILE B	CASCO/NAPLES	BKT	BND, BUL, CMS, CSK, EEL, FLF, GLS, LLS, LMB, PKL, PKS	
0430310101.1	BARTLETT B	CASCO	BKT	BND, FLF, WHS	
043031010101	MEADOW B	CASCO	BKT	BND, EEL, PKL, WHS	
043031010101	TARKILN B	CASCO	BKT		
043031010102	EASTMAN B	OTISFIELD			NOT SAMPLED
043031010103	GREELY B	OTISFIELD	BKT		
043031010104	MIDDLE B	OTISFIELD			DRY CHANNEL
043031010105	DYER ICE P OUTLET	OTISFIELD			NO FISH
043031010106	DOLLY B	OTISFIELD		BND, CCB, WHS	
0430310101071	OWL P OUTLET			BUL, WHS	
0430310102	BURGESS B	NAPLES/OTISFIELD	BKT		
0430310103	SMITH B	OTISFIELD		CMS, PKS	BKT LIKELY
043031010301	COLD B	NAPLES/OTISFIELD			NOT SAMPLED, BKT LIKELY
043031010302	COLLEGE SWAMP B	OTISFIELD	BKT	BND, WHS	
043031010303	UNNAMED B	OTISFIELD		BKT, BND	
04303101030301	UNNAMED B	OTISFIELD		BND	
0430310104	UNNAMED B	HARRISON			NOT SAMPLED
0430310105	DEAD HOLE B	OTISFIELD	BKT		
0430310106	RUSSELL B	HARRISON		BKT, BND, CMS, FLF, LLS	
0430310107	BIGELOW SWAMP OUTLET	HARRISON		BKT, BND, WHS	
0430310109	ISLAND P OUTLET	NORWAY/WATERFORD		BKT, BND, CCB, FLF, LMB, WHS	
043031010901	UNNAMED B	WATERFORD		BKT	
0430310110	MEADOW B	NORWAY/WATERFORD		BKT, BND, CCB, CMS, LLS, WHS	
043031011001	UNNAMED B	NORWAY	BKT	BND, CCB	
043031011001.1	UNNAMED B	NORWAY		BKT, CCB	
043031011002	HERRICK B	GREENWOOD/NORWAY	BKT	BND, CCB, LLS, LMB, WHS	
0430310111	MILLS B	WATERFORD			NOT SAMPLED
0430310112	MCINTYRE B	WATERFORD			NOT SAMPLED
0430310113	HOBBS B	GREENWOOD/NORWAY/WATERFORD		BKT, BND, CCB, WHS	
043031011301	SPECK PONDS OUTLET	NORWAY/WATERFORD			DRY CHANNEL
043031011302	UNNAMED B	GREENWOOD/NORWAY			NOT SAMPLED
043031011303	UNNAMED B	NORWAY	BKT	BND	
0430310114	SWETT B	WATERFORD/ALBANY TWP		BKT, BND, BNT, CCB, LLS, WHS	
043031011401	HUTCHINSON P OUTLET	ALBANY TWP		BND, BNT, CCB, LMB, SMB	

Appendix V (continued). Known fish species occurrence in Crooked River tributaries, 2005.

STREAMCODE	STREAM NAME	TOWN	PRINCIPAL FISHERY[1]	FISH SPECIES OCCURRENCE	COMMENTS
0430310115	PAPOOSE P OUTLET	WATERFORD			NOT SAMPLED
0430310116	UNNAMED B	WATERFORD			NOT SAMPLED
0430310117	CHALK P OUTLET	WATERFORD/ALBANY TWP	BKT	BND	
0430310118	UNNAMED B	WATERFORD			NOT SAMPLED
0430310119	UNNAMED B	WATERFORD			NOT SAMPLED
0430310120	WARREN B	WATERFORD			NOT SAMPLED
0430310121	MILL B	STONEHAM/WATERFORD/ALBANY TWP		BKT	
043031012101	WHITNEY & WEYMOUTH PONDS OUTLET	STONEHAM/ALBANY TWP			NOT SAMPLED
043031012102	MEADOW B	STONEHAM			NOT SAMPLED
0430310121021	UNNAMED B	STONEHAM			NOT SAMPLED
043031012103	BARTLETT B	STONEHAM			NOT SAMPLED
0430310121031	HANNAH B	STONEHAM			NOT SAMPLED
0430310121032	GOODWIN B	STONEHAM			NOT SAMPLED
0430310123	PAPOOSE P (LITTLE) OUTLET	ALBANY TWP			NOT SAMPLED
0430310124	ALBANY B	ALBANY TWP			NOT SAMPLED
0430310125	ANN FLINTS B	ALBANY TWP	BKT	BND, CCB	
0430310128	BARKERS B	ALBANY TWP	BKT		
0430310129	MOSQUITO P OUTLET	ALBANY TWP			DRY CHANNEL
0430310132	PATTE B	ALBANY TWP	BKT	BND, BUL, FLF, GLS, LLS, YLP, WHS	
043031013201	WALKER B	ALBANY TWP		BKT, BND	
043031013202	NEW ENGLAND B	ALBANY TWP/MASON TWP	BKT		
0430310133	UNNAMED B	BETHEL	BKT	BUL, LMB, YLP, WHS	

[1]Noted as a principal fishery if legal sized trout were present, may not be actively fished.

Appendix W. LLS Age & growth data for the Bolsters Mill Fish trap on the Crooked River, 1974-1986.[1]

Year	Age Group[2]	Mean Length in in/mm (N)(SD_{mm})	Mean Weight in lbs/g (N)(SD_g)	Mean K (N)(SD)
1974	YOY	4.3/110 (1)()	---	---
	Parr	7.4/187 (19)(7.4)	---	---
	Smolt	9.4/240 (25)(19)	---	---
	Adult	15.3/389 (68)(45)	1.22/555(34)(286)	0.81 (34)(0.08)
	All	**12.6/319 (113)(95)**	**1.22/555(34)(286)**	**0.81 (34)(0.08)**
1975	Parr	7.4/189(9)(5)	---	---
	Smolt	9.6/245(53)(27)	0.40/180(3)(17)	1.1 (3)(0.11)
	Adult	13.7/349(76)(33)	1.00/455(41)(110)	0.90 (41)(0.14)
	(blank)	---	0.50/227(1)()	---
	All	**11.8/299(138)(65)**	**0.95/432(45)(130)**	**0.92 (44)(0.14)**
1976	Parr	7.5/190(21)(7)	0.12/53(10)(6)	0.82 (10)(0.05)
	Smolt	8.9/225(33)(20)	0.24/110(10)(65)	0.85 (10)(0.20)
	Adult	14.3/361(166)(21)	0.96/434(165)(79)	0.92 (165)(0.13)
	All	**12.8/324(220)(68)**	**0.87/396(185)(134)**	**0.91 (185)(0.13)**
1977	Parr	7.6/192(2)(2)	0.18/80(1)(-)	1.17 (1)(-)
	Smolt	10.0/254(10)(27)	0.35/157(9)(55)	0.90 (9)(0.15)
	Adult	16.1/408(277)(26)	1.40/617(277)(147)	0.89 (277)(0.11)
	All	**15.7/401(289)(42)**	**1.32/601(287)(168)**	**0.90 (287)(0.11)**
1978	Smolt	10.4/265(6)(21)	0.37/169(6)(49)	0.90 (6)(0.11)
	Adult	18.9/480(47)(42)	2.31/1047(47)(254)	0.93 (47)(0.10)
	All	**18.0/456(53)(80)**	**2.09/947(53)(369)**	**0.92 (53)(0.10)**
1979	Smolt	10.4/264(3)(48)	0.45/203(3)(116)	0.99 (3)(0.18)
	Adult	20.4/518(120)(50)	2.94/1335(120)(381)	0.93 (120)(0.07)
	All	**20.2/512(123)(63)**	**2.88/1307(123)(416)**	**0.93 (123)(0.08)**
1980	Smolt	9.4/239(1)(-)	0.25/115(1)(-)	0.84 (1)(-)
	Adult	20.1/510(23)(65)	2.85/1294(23)(510)	0.92 (23)(0.08)
	All	**19.6/499(24)(84)**	**2.74/1245(24)(554)**	**0.92 (24)(0.08)**
1981	Adult	18.6/472(145)(48)	2.49/1131(145)(375)	1.05 (145)(0.12)
	All	**18.6/472(145)(48)**	**2.49/1131(145)(375)**	**1.05 (145)(0.12)**
1983	Parr	7.4/188(142)(11)	0.11/52(126)(8)	0.77 (126)(0.05)
	Smolt	8.5/217(125)(18)	0.17/79(100)(19)	0.78 (100)(0.04)
	Adult	17.0/432(227)(43)	1.49/677(195)(187)	0.82 (195)(0.08)
	(blank)	---	1.27/575(1)(-)	---
	All	**12.1/307(494)(120)**	**0.77/348(422)(331)**	**0.80 (421)(0.07)**
1984	Parr	7.4/188(16)(11)	0.12/53(12)(8)	0.78 (12)(0.07)
	Smolt	8.8/224(46)(15)	0.20/90(46)(24)	0.79 (46)(0.09)
	Adult	17.8/453(434)(38)	1.94/879(433)(237)	0.92 (433)(0.08)
	All	**16.7/423(496)(87)**	**1.73/785(491)(341)**	**0.91 (491)(0.09)**
1985	Parr	7.4/189(98)(9)	---	---
	Smolt	8.5/216(39)(12)	---	---
	Adult	19.5/495(223)(49)	2.51/1141(213)(355)	0.92 (213)(0.09)
	All	**15/381(360)(151)**	**2.51/1141(213)(355)**	**0.92 (213)(0.09)**
1986	Parr	7.4/188(19)(10)	0.14/62(9)(11)	0.95 (9)(0.07)
	Smolt	9.2/234(247)(14)	0.26/117(105)(23)	0.90 (105)(0.06)
	Adult	19.0/482(218)(37)	2.22/1007(212)(272)	0.88 (212)(0.08)
	All	**13.5/344(484)(128)**	**1.53/694(326)(481)**	**0.89 (326)(0.07)**
All Years	**All Age Classes**	**14.7/373(2,939)(119)**	**1.59/720(2,348)(451)**	**0.89 (2,346)(0.11)**

[1]Original dataset was edited to remove LLS with K factors <0.7 or >1.3, which suggested an incorrect length and/or weight. Data without a corresponding length and/or weight was assumed correct and was retained.
[2]YOY <=115mm (4.5 in), Parr 116-200mm (4.6-7.8 in), Smolt 201-300mm (7.9-11.8 in), Adult>300mm (11.8 in)

Appendix X. Summary of algae data for the Crooked River (MDEP 2011).

Waterford (7/10/2003)			Naples (6/29/2005)		
Algae Type	**Genus species**	**Value (cells/cm^2)**	**Algae Type**	**Genus species**	**Value (cells/cm^2)**
COLONIAL GREEN	Ankistrodesmus falcatus	5,131	CENTRIC DIATOM	Aulacoseira alpigena	427
COLONIAL GREEN	Pediastrum tetras	3,421	COCCOID & COLONIAL CYANOBACT	Chamaesiphon incrustans	1,211
COLONIAL GREEN	Scenedesmus ecornis	1,710	DESMID	Closterium moniliferum	606
CYANOBACTERIA	Undeter. bg filament 1-2µm	6,414	DESMID	Euastrum pulchellum	606
DESMID	Closterium	428	FILAMENTOUS CYANOBACTERIA	Homoeothrix janthina	43,601
DESMID	Closterium dianae var. brevius	428	FILAMENTOUS CYANOBACTERIA	Lyngbya	10,900
FILAMENTOUS GREEN	Bulbochaete	12,400	FILAMENTOUS CYANOBACTERIA	Phormidium minnesotense	16,956
FILAMENTOUS GREEN	Mougeotia 30-40µm	855	FILAMENTOUS CYANOBACTERIA	Phormidium sp. 3 d7um	49,657
FILAMENTOUS GREEN	Zygnema	8,124	FILAMENTOUS GREEN	Stigeoclonium lubricum	8,478
PENNATE DIATOM	Achnanthidium minutissimum	92,498	PENNATE DIATOM	Achnanthes reimeri	4,269
PENNATE DIATOM	Brachysira brebissonii	2,529	PENNATE DIATOM	Achnanthidium deflexum	854
PENNATE DIATOM	Brachysira microcephala	4,336	PENNATE DIATOM	Achnanthidium minutissimum	212,185
PENNATE DIATOM	Craticula submolesta	723	PENNATE DIATOM	Achnanthidium rivulare	855
PENNATE DIATOM	Cymbella gracilis	723	PENNATE DIATOM	Brachysira brebissonii	427
PENNATE DIATOM	Encyonema silesiacum	361	PENNATE DIATOM	Brachysira vitrea	2,562
PENNATE DIATOM	Encyonopsis microcephala	723	PENNATE DIATOM	Cymbella gracilis	1,281
PENNATE DIATOM	Eucocconeis laevis	361	PENNATE DIATOM	Diatoma moniliformis	854
PENNATE DIATOM	Eunotia arcus var. bidens	723	PENNATE DIATOM	Encyonema silesiacum	854
PENNATE DIATOM	Eunotia exigua	723	PENNATE DIATOM	Encyonopsis microcephala	854
PENNATE DIATOM	Eunotia implicata	361	PENNATE DIATOM	Eunotia exigua	427
PENNATE DIATOM	Eunotia incisa	4,336	PENNATE DIATOM	Eunotia minor	1,281
PENNATE DIATOM	Eunotia pectinalis	47,333	PENNATE DIATOM	Eunotia pectinalis var. undulata	1,281
PENNATE DIATOM	Fragilaria capucina var. gracilis	17,343	PENNATE DIATOM	Eunotia soleirolii	2,562
PENNATE DIATOM	Fragilaria vaucheriae	1,084	PENNATE DIATOM	Fragilaria capucina	854
PENNATE DIATOM	Frustulia crassinervia	2,891	PENNATE DIATOM	Fragilaria capucina var. gracilis	5,550
PENNATE DIATOM	Gomphonema	723	PENNATE DIATOM	Fragilaria famelica	1,281
PENNATE DIATOM	Gomphonema acuminatum	723	PENNATE DIATOM	Fragilaria vaucheriae	5,123
PENNATE DIATOM	Gomphonema apuncto	2,168	PENNATE DIATOM	Frustulia crassinervia	427
PENNATE DIATOM	Gomphonema parvulum	7,226	PENNATE DIATOM	Gomphonema parvulum	8,112
PENNATE DIATOM	Gomphonema truncatum	723	PENNATE DIATOM	Navicula cryptotenella	427
PENNATE DIATOM	Navicula cryptocephala	723	PENNATE DIATOM	Navicula gregaria	854
PENNATE DIATOM	Navicula cryptotenella	2,529	PENNATE DIATOM	Navicula utermoehlii	427
PENNATE DIATOM	Navicula gregaria	361	PENNATE DIATOM	Nitzschia acidoclinata	854
PENNATE DIATOM	Synedra rumpens	6,504	PENNATE DIATOM	Pinnularia obscura	854
PENNATE DIATOM	Synedra ulna	15,537	PENNATE DIATOM	Planothidium stewartii	427
PENNATE DIATOM	Tabellaria flocculosa	2,529	RED	Audouinella	59,952
UNICELLULAR GREEN	Tetraedron minimum	855	RED	Batrachospermum	14,534

Appendix Y. Summary of MDEP/PWD biological monitoring on the Crooked River (MDEP, 2011).

Town	Sample Type	Sample ID	Sample Date	Statutory Class	Attained Class	Report Available	Data Type(s)
Naples	Macroinvertebrate	1216	9/19/2001	AA	Yes	No	MI SW PC SWS
Naples	Macroinvertebrate	SA-237-2005	6/29/2005	AA	n/a	No	SW PC SWS
Naples	Macroinvertebrate	SA-237-2005 (395)	6/29/2005	AA	n/a	No	AL PC
Naples	Macroinvertebrate	SA-237-2005VB	8/3/2005	AA	n/a	No	SW PC
Naples	Macroinvertebrate	SA-237-2010	7/26/2010	AA	n/a	No	SW PC SWS
Naples	Macroinvertebrate	SA-237-2010 (988)	7/26/2010	AA	n/a	No	PC
Naples	Macroinvertebrate	264	8/28/1989	AA	Yes	No	MI SW PC SWS
Naples	Macroinvertebrate	1358	9/17/2003	AA	Yes	No	MI PC SWS
Naples	Macroinvertebrate	1307	9/13/2004	AA	Yes	No	MI PC SWS
Naples	Macroinvertebrate	1624	9/13/2005	AA	No	No	MI PC SWS
Naples	Macroinvertebrate	1760	9/28/2006	AA	Yes	No	MI PC SWS
Naples	Macroinvertebrate	1766	9/26/2007	AA	Yes	No	MI PC SWS
Naples	Macroinvertebrate	1983	9/24/2008	AA	Yes	Yes	MI PC
Harrison	Macroinvertebrate	1360	9/17/2003	AA	Yes	No	MI PC SWS
Harrison	Macroinvertebrate	1304	9/13/2004	AA	Yes	No	MI SW PC SWS
Harrison	Macroinvertebrate	1622	9/13/2005	AA	Yes	No	MI PC SWS
Harrison	Macroinvertebrate	1759	9/26/2006	AA	Yes	No	MI PC SWS
Harrison	Macroinvertebrate	1765	9/26/2007	AA	Yes	No	MI PC SWS
Harrison	Macroinvertebrate	1982	9/25/2008	AA	Yes	Yes	MI PC
Waterford	Algae	SA-673-2003	7/10/2003	AA	n/a	No	SW PC SWS
Waterford	Algae	SA-673-2003 (212)	7/10/2003	AA	n/a	No	AL PC
Waterford	Macroinvertebrate	336	9/16/1991	AA	Yes	No	MI SW PC SWS
Waterford	Macroinvertebrate	1306	9/13/2004	AA	Yes	No	MI PC SWS
Waterford	Macroinvertebrate	1623	9/13/2005	AA	Yes	No	MI PC SWS
Waterford	Macroinvertebrate	1758	9/26/2006	AA	Yes	No	MI PC SWS
Waterford	Macroinvertebrate	1764	9/26/2007	AA	Yes	No	MI PC SWS
Waterford	Macroinvertebrate	1981	9/25/2008	AA	Yes	Yes	MI PC
Albany	Macroinvertebrate	1359	9/17/2003	AA	Yes	No	MI SW PC SWS
Albany	Macroinvertebrate	1308	9/13/2004	AA	Yes	No	MI PC SWS
Albany	Macroinvertebrate	1625	9/13/2005	AA	Yes	No	MI PC SWS
Albany	Macroinvertebrate	1757	9/26/2006	AA	Yes	No	MI PC SWS
Albany	Macroinvertebrate	1763	9/26/2007	AA	Yes	No	MI PC SWS
Albany	Macroinvertebrate	1980	9/25/2008	AA	Yes	Yes	MI PC

MI - Macroinvertebrate; SW – Surface Water (i.e. temperature, DO); PC – Physical Characteristics (i.e. depth, wetted width); SWS – Surface Water Substrates (i.e. % of substrate types); AL – Algae

Appendix Z. List of macroinvertebrates known to occur in the Crooked River (MDEP, 2011).

AMPHIPOD	**FLY: CRANE**	**MAYFLY (con.)**
Hyalella azteca	Antocha	Heptageniidae
BEETLE	Hexatoma	Isonychia
Optioservus	Tipula	Leptophlebiidae
Optioservus ovalis	**FLY: MIDGE**	Leucrocuta
Oulimnius latiusculus	Chironomidae	Maccaffertium
Promoresia tardella	Cricotopus	Maccaffertium luteum
Stenelmis	Cricotopus bicinctus	Maccaffertium modestum
Stenelmis crenata	Cricotopus trifascia	Paraleptophlebia
CADDISFLY	Eukiefferiella	Plauditus
Agapetus	Eukiefferiella brehmi group	Procloeon
Brachycentrus appalachia	Eukiefferiella brevicalcar group	Serratella (Teloganopsis) deficiens
Brachycentrus numerosus	Eukiefferiella devonica group	Serratella serratoides
Ceraclea	Eukiefferiella tirolensis	**RIBBON WORM**
Cernotina	Larsia	Prostoma
Cheumatopsyche	Micropsectra	**STONEFLY**
Chimarra	Microtendipes rydalensis group	Acroneuria
Dolophilodes	Nanocladius	Acroneuria abnormis
Glossosoma	Nanocladius branchicolus	Acroneuria lycorias
Hydropsyche	Nanocladius downesi	Capniidae
Hydropsyche depravata complex	Nilotanypus fimbriatus	Isoperla
Hydropsyche morosa	Orthocladius	Paracapnia angulata
Hydropsyche scalaris group	Orthocladius carlatus	Paragnetina immarginata
Hydropsyche sparna	Orthocladius mallochi	Paragnetina media
Hydropsychidae	Paracricotopus	Perlidae
Hydroptila	Parametriocnemus	Perlodidae
Lepidostoma	Pentaneura inconspicua	Pteronarcys dorsata
Micrasema	Polypedilum aviceps	Taeniopteryx
Micrasema wataga	Potthastia longimana	**WORM**
Neureclipsis	Psectrocladius	Lumbriculus variegatus
Oecetis persimilis	Rheocricotopus robacki	Nais
Oxyethira	Rheocricotopus tuberculatus	Nais behningi
Polycentropus	Rheopelopia acra group	Nais communis
Psilotreta indecisa	Rheotanytarsus	Stylaria lacustris
Rhyacophila	Thienemanniella xena	
Rhyacophila fuscula	Tvetenia	
DOBSONFLY	Tvetenia paucunca	
Nigronia serricornis	Tvetenia vitracies	
DRAGONFLY/DAMSEFLY	**FLY: WATERSNIPE**	
Boyeria vinosa	Atherix	
Calopterygidae	**MAYFLY**	
Gomphidae	Acerpenna	
Ophiogomphus	Acerpenna macdunnoughi	
FLY: AQUATIC DANCE	Acerpenna pygmaea	
Hemerodromia	Baetidae	
FLY: BLACK	Baetis	
Simulium	Baetis flavistriga	
Simulium fibrinflatum	Baetis pluto	
Simulium jenningsi	Epeorus	
Simulium jenningsi complex	Ephemerella	
Simulium tuberosum	Ephemerellidae	
Simulium venustum/verecundum complex	Eurylophella	

Appendix AA. Crooked River – Description of HSI Habitat Based Modeling for Predicting Juvenile Salmon Production in the Crooked River, Maine

I. General Model Details:

- Data are expressed as number of salmon per habitat unit (HU); 1 HU = 100 yds^2 or 900 ft^2
- River section = section of river between two habitat transects (typically 200-400')
- Stream Area = specified stream reach in original program identified as follows:
  - Albany: sections LE 396; Patte Dam downstream to Rte 35 in N Waterford
  - N Waterford: sections 397-681; Rte 35 in N. Waterford downstream to Rte 118
  - Sodom: sections 682-885; Rte 118 downstream to Twin Bridges (~ 2,800' upstream of TB @ powerline)
  - Twin Bridges: sections 886-1014; Twin Bridges downstream to Bolsters (~ 2,400' upstream of Bolsters)
  - Bolsters: sections 1015-1064; Bolsters downstream to Scribners (~ 5,300' upstream of Scribners)
  - Scribners: sections 1065-1346; Scribners downstream to Edes Falls Dam
  - Edes Falls: sections 1347-1423; Edes Falls Dam downstream to Rte 11
  - Below Rte 11: sections 1424-1607; Rte 11 downstream to Green Bridge
  - Note: Some of the original stream areas noted above in the program appear to have been defined by nearby utility crossings rather than the specified road or dam site. In addition, sections breaks did not always fall right on the specified start/stop location. Table 1 clarifies the start and stop points for the program, and what the actual map start and stop points should be for the specified sites.

Table 1. Comparison of start and stop points for program and actual area descriptions.

Stream Area	Program Section		Maps Section		Difference in ending (transects)
	Start	Stop	Start	Stop	
Albany – Patte Dam to Rte 35	0	396	0	396	0
N. Waterford – Rte 35 to Sodom Rd	397	681	397	681	0
Sodom – Sodom Rd to Rte 117	682	885	682	910	25
Twin Bridges – Rte 117 to Bolsters	886	1014	911	1024 + 100 ft	10.5
Bolsters – Bolsters to Scribners	1015	1064	1025 - 100 ft	1088	24
Scribners – Scribners to Edes	1065	1346	1089	1361 + 100 ft	15.5
Edes Falls – Edes to Rte 11	1347	1423	1362 - 100 ft	1423	0
Below Rte. 11 – Rte 11 to green bridge @ Songo	1424	1607	1424	1607	0

Note: Some of the original stream areas appear to have been defined by utility crossings rather than area specified road or dam sites (885, 1064, and 1346 = powerline; 1014=pipeline)

II. General Model Description:

- Model computes the square area for each section of the river.
- Model then assigns an HSI type quality rating for each river section, similar to HSI assignments discussed by Stanley and Trial (1995). The model developed by Pierce, Fenderson, and Trial computes an HSI rating for YOY and parr salmon based on available habitat data, substrate type and water depth. In addition, after field truthing specific adjustments were made to the model to reflect actual Crooked River density data at the time of development. These adjustments differ from the model later developed by Stanley and Trial (1995).
- Model then calculates a mean of HSI adjustments weighted by section area for each stream mile and stream area (i.e. Sodom, Edes Falls); figures a total area based on section and substrate area, which is used to determine habitat units.
- HUs are then adjusted for each life stage based on HSI ratings.

- Juvenile salmon densities are also calculated for each life stage (see section on assumptions)

III. Assumptions:

- Program only accounts for depth and substrate; other habitat and environmental factors (i.e. temperature, seasonal flows, # of spawning adults, etc.) likely have an impact on actual habitat units and densities of each life stage. Nonetheless, model predictions come fairly close to the average parr density values reported for Atlantic salmon, salmon statewide, and salmon on the Crooked River (see below).
- Model assumes a maximum/optimum density of 30 YOY and 15 parr/HU (HSI = 1.0) and then makes adjustments based on habitat suitability for each life stage.
- Based on the model, the average YOY and parr densities predicted for the 8 stream areas of the Crooked River were 11.5 and 5.3/HU, respectively. Predicted densities at specific locations vary depending on HSI value assignments and HUs for the area.

IV. YOY/Parr Density References:

- Baum (1997) reported that as "a rule of thumb" Maine Rivers typically produce 19 YOY and 6 parr Atlantic salmon per habitat unit (based on 100 m^2). Adjusting for HU from metric to English units results in 15.9 YOY and 5.0 parr/HU. He also concluded that Maine Rivers typically yield parr densities of 5-10/metric habitat unit, which equates to 4.2-8.4 parr/HU.
- Havey (1974) reported salmon YOY densities of 9.7 ± 2.9/HU at Barrows Stream with 10 years of data, 1960-1971.
- AuClair (1982) evaluated 12 Moosehead Lake tributaries and found a range of 5.7-14.7 parr/HU with an average value of 7.7 parr/HU.
- Warner and Havey (1985) reported a mean salmon parr density of 5.8/HU ± 1.0, which included data from 12 Maine streams and 34 samples.
- Boucher and Warner (2006) reported a mean LLS YOY density of 21.4/HU ± 4.1 (20 Maine streams & 69 samples) and a parr density of 6.7/HU ± 0.7 (14 Maine streams & 65 samples).
- Observed salmon parr densities for the Crooked River ranged from 0.5-15.6/HU for our two index sites (Edes Falls and Albany) with an average of 2.7 YOY/HU and 5.4 parr/HU, 1998-2006.
- Pellerin and Pierce (2011) reviewed the Crooked River data from 1995-2010 and concluded mean YOY and parr densities of 3.6/HU ± 0.8 and 6.3/HU ± 1, respectively. YOY and/or parr densities on the Crooked River have varied from as low as 0/HU to as high as 24.1/HU at specific sample sites.

V. Conclusions:

- Model predications appear to be fairly representative of observed average parr densities for the Crooked; however, observed densities may vary highly from year-to-year depending upon various factors (i.e. number of spawning adults, seasonal flows, temperatures, etc.
- The adjustments used in the original model based on 11.5 YOY and 5.3 parr/HU may need to be tweaked, as observed parr densities seem to be increasing.
- Model appears to overestimate parr densities at lower reaches and under estimate upstream reaches, but again the overall average appears to be reasonable.
- Model appears to overestimate YOY densities; however, it is more likely that YOY are underrepresented due to habitat suitability at specific index sites and efficacy of sampling.

VI. Estimating Smolt Production

- Being able the quantify an estimated number of smolts entering Sebago Lake from the Crooked River system each year is the true value of this modeling exercise from a fisheries perspective.
- Baum (1997) reported the parr to smolt survival rate for Atlantic salmon in Maine rivers ranged from 35-55%, but Kocik et al. (1998) reported survival on the Narraguagas River to be less than 30%.
- Meister (1962) determined a survival rate of 8.9% from mid-summer parr to smolt stage for Atlantic salmon.
- Warner and Havey (1985) found survival of late fall parr to smolt to be 5.1%, which was based on four years of salmon monitoring of Barrows Stream. This estimate was reportedly low due to the ability for some smolts to bypass the trapping facilities.
- Conclusion: Survival estimate of 5.1% may be low, but is based on the best available data for salmon.
- The resulting estimate of total parr production is adjusted by a survival estimate (0.051) for the parr to smolt stage.

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