A Regional Conservation Plan

For

Atlantic Sturgeon in the U. S. Gulf of Maine

On Behalf of Maine Department of Marine Resources

By

Gail S. Wippelhauser
Maine Department of Marine Resources, Bureau of Science
172 State House Station, Augusta, ME 04539

The project would not have been possible without contributions by:
Jason Bartlett
James Beaudry
Claire Enterline
Nate Gray
Craig King
Josh Noll
Mark Pasterczyk
Jason Valliere
Matt Waterhouse
Skip Zink

Submitted as part of

A Multi-State Collaborative to Develop & Implement a Conservation Program for Three Anadromous Finfish Species of Concern in the Gulf of Maine
NOAA Species of Concern Grant Program Award #NA06NMF4720249A

Atlantic sturgeon GOM Conservation Plan

Introduction

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) once supported a large commercial fishery in the United States. Records of commercial landings from the late 1800s to the late 1900s indicate a severe decline from high catches in 1880 (~1361 mt) and 1890 (~3175 mt) to a low of 22 mt in 1920 (ASMFC 1990; Secor 2002). From the 1920 to the late 1990s, the catch remained below 140 mt. In Maine, exploitation of Atlantic sturgeon began earlier and declined earlier. The first documented fishery was in 1628 at Pejepscot Falls on the Androscoggin River (Wheeler and Wheeler 1878), and by the early 1700s the sturgeon fishery in the Province of Maine employed more than 20 vessels in some years (Atkins 1887). In 1849, harvesters took 160 tons of sturgeon from the Kennebec River for roe and oil, but the fishery was discontinued after 1851 when sturgeon became scare (Atkins 1887). A subsequent fishery in the Kennebec began in 1872, but within five years sturgeon were scarce, and by 1880 the catch was about 150 sturgeon (Atkins 1887). From 1909 to 1981, harvest typically was <2,000 pounds except for 1909-1913, 1933, 1969-1970, 1977, and 1979-1981(Table 1[1]), and three counties accounted for most of the landings. In 1983, Maine closed the tidal waters of the Kennebec and Androscoggin to harvest of sturgeon, and instituted a 72-inch minimum size for other areas. In 1992, the harvest of sturgeon (both species) became illegal in Maine's coastal waters.

Coastwide management of Atlantic sturgeon was initiated in 1988 when the Atlantic States Marine Fisheries Commission (ASMFC) began developing a fisheries management plan (FMP) for the species, and the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) first listed Atlantic sturgeon as a "Species of Concern." In 1990, the ASMFC FMP was officially adopted (ASMFC 1990), and subsequently many of its management recommendations were implemented. In particular, all states either imposed a moratorium on the Atlantic sturgeon fishery in their waters or instituted a 7-foot size limit or a size limit that achieved conservation equivalency. After completing a stock assessment, ASMFC instituted a 40-year moratorium on harvest of Atlantic sturgeon (ASMFC 1998). That same year, Atlantic sturgeon were formally retained on the federal Species of Concern List.

In 2006, Maine, New Hampshire, and Massachusetts received a grant from NMFS (NA06NMF4720249) to conduct research on two species of concern, rainbow smelt and Atlantic sturgeon, and develop a conservation plan for each of them. Studies on Atlantic sturgeon were initiated in 2009, and were conducted only in Maine. In 2012, Atlantic sturgeon were listed under the federal Endangered Species Act (ESA) with the Gulf of Maine (GoM) distinct population segment (DPS) listed as threatened.

In this Conservation Plan we briefly review the basic biology of Atlantic sturgeon, provide detailed information from research on Atlantic sturgeon in the GoM for the period 1977-2001 and 2009-2012, summarize the status of the GoM Atlantic sturgeon, identify threats, and include management recommendations.

---

[1] Data from the Annual Reports of Sea and Shore Fisheries of the State of Maine.

Basic Biology

The Atlantic sturgeon is a long-lived, anadromous species that historically ranged from Hamilton Inlet on the coast of Labrador to the Saint Johns River in Florida (Murawski and Pacheco 1977; Smith and Clugston 1997). Atlantic sturgeon once occupied 38 large river systems in the United States of which 35 supported a spawning population (ASSRT 2007). The species currently is present in 35 rivers, and spawning has been documented in at least 20 (ASSRT 2007).

Atlantic sturgeon populations generally display latitudinal variation in biological characteristics such as growth rate, maturation, and timing of spawning. Fish from more southern river systems tend to grow faster, mature at an earlier age, and undertake spawning migration earlier in the year. Atlantic sturgeon mature between 5 and 19 years of age in South Carolina (Smith et al. 1982), between 11 and 21 years in the Hudson River (Young et al. 1988), and between 22 and 34 years in the St. Lawrence River (Scott and Crossman 1973). Individuals do not spawn every year; the spawning interval for males is 1-5 years (Smith 1985; Collins et al. 2000; Caron et al. 2002) and for 2-5 years for females (Vladykov and Greeley 1963; Van Eenennaam et al. 1996; Stevenson and Secor 1999).

Spawning adults migrate upriver in February and March in southern rivers, April and May in mid-Atlantic rivers, and May and July in Canadian rivers (Murawski and Pacheco 1977; Bain 1997; Smith and Clugston 1997; Caron et al. 2002). Atlantic sturgeon spawn in flowing waters at water temperatures ranging from 13.2-20.5 ºC (Borodin 1925; Huff 1975; Smith 1985), and require solid substrate for the eggs, which are adhesive (Vladykov and Greeley 1963; Huff 1975; Smith 1985).

Information on behavior and ecology of the early life stages is limited. After egg deposition, hatching occurs in approximately 140 h at 18ºC and 94 h at 20ºC (Smith et al. 1980). In the laboratory, Atlantic sturgeon were photonegative and sought cover 5-7 days after hatching, left cover and began swim-up (active vertical migration) and drift behavior (passive migration) on day 8, and continued swimming and drifting until day 19; during this migration period, the free embryos with a yolksac developed into exogenous feeding larvae (Kynard and Horgan 2002).

Juveniles remain in their natal river system for 2-6 years, during which time they experience rapid growth (Bain 1997). In the Hudson River, they are widely distributed throughout the river from July to September, but form an overwintering aggregation in brackish water (Bain 1997). After this period of residency, Atlantic sturgeon ranging from 76-92-cm (Murawski and Pacheco 1977; Smith 1985) may migrate into marine waters, and this transition marks a major change in ecology, growth, and behavior (Bain 1997). Little is known about Atlantic sturgeon in marine waters, except they are often taken as bycatch in commercial fishing gear.

Atlantic sturgeon in the Gulf of Maine (1977-2001)

From 1977 to 2001, the Department of Marine Resources (ME DMR) conducted a series of studies on shortnose sturgeon and Atlantic sturgeon in the Kennebec, Androscoggin, and Sheepscot estuaries in Maine. The 16 years of research conducted over the 24-year period research has been described in detail in Wippelhauser and Squiers (submitted), but information pertinent to Atlantic sturgeon is presented here.

Study area

The study area for 1977-2001 encompassed seven rivers and two connecting passages (Figure 1). Water from the Kennebec and Androscoggin, Maine's second and third largest rivers, respectively, and four small tributaries combine to form Merrymeeting Bay, the largest tidal-freshwater embayment north of Chesapeake Bay. Below the narrow outlet of Merrymeeting Bay, the Kennebec Estuary extends approximately 30 km before entering the Gulf of Maine. The Sheepscot, Maine's eleventh largest river, and the lower Kennebec are connected by the Sasanoa River (oriented NW to SE) and Back River (oriented NE to SW). These passages are narrow to the west, form Hockomock Bay where they cross, and each expands into a large embayment (Montsweag Bay to the north and Knubble Bay to the south) before joining the Sheepscot.

We identified five ecological zones in the study area on the basis of tidal influence, salinity, and geomorphology (Figure 1). The Lower Kennebec Estuary from its mouth at river kilometer (rkm) 0 to Merrymeeting Bay at rkm 30 is narrow and deep with salinity ranging from 0-32‰ depending on location and freshwater discharge (Mayer et al. 1996). The S-B passages (Sasanoa and Back rivers) form a mixing zone between the Lower Kennebec Estuary and the Sheepscot Estuary. Modeled surface salinities during simulated high spring flows (1500 m3/sec) from the Kennebec showed the Lower Kennebec Estuary and S-B passages west of Hockomock Bay were approximately 5‰ while the S-B passages to the east and Sheepscot Estuary were >20‰ (Brooks 2009). Merrymeeting Bay from rkm 30 to rkm 45 is generally <2 m deep at low tide, has extensive intertidal mudflats dominated by Zizania aqutica L. (wild rice), and salinity that rarely exceeds 5‰ (Lichter et al. 2006). The Androscoggin Estuary from rkm 0, which was defined as a line connecting the concrete abutments of an abandoned bridge (Figure 1), to Pejepscot Falls at rkm 8.4 is tidal fresh water. It is shallow today, but historically was navigable by large vessels (Lichter et al. 2006). The lower two-thirds of the Androscoggin Estuary (rkm 0-6) is braided channel, while the upper 0.5 km is characterized by large outcroppings of rock. Brunswick Dam is located at rkm 8.4. The Upper Kennebec Estuary is tidal fresh water from rkm 45 to rkm 74, and has a defined channel for much of its length. The substrate is predominantly sand with scattered outcroppings of rock. In addition to being the upstream limit of the tide, rkm 74 was the location of Edwards Dam, which was constructed in 1837, and removed in 1999.

Methods

Gill net sampling that primarily targeted sturgeon >550-mm total length (TL) was conducted between 1977 and 2000 (Table 2) at 65 stations in the Kennebec, Androscoggin, and Sheepscot estuaries (Figure 1). Nets were deployed as early as April 4 and as late as November 29, but most sampling occurred from May through October (Table 2). The majority of Atlantic sturgeon (87%) were captured with experimental, multifilament, sinking gill nets that were 90-m long, 2.4-m or 1.8-m deep, and consisted of 30-m panels of 152, 178, and 203-mm stretch mesh. Smaller (30-m or 60-m long) sinking and floating gill nets made of 102, 114, 127, 140, or 305-mm stretch mesh also were used depending on the area being fished and the study objectives. All nets were deployed parallel to shore, and surface water temperature was measured with a stem thermometer at the beginning of each set.

If the catch was small and sturgeon were healthy, they were removed from the net, weighed, measured, tagged, and immediately released; if the catch was large or if fish were stressed, they were enumerated and released. Fish were weighed in a sling with a spring scale to the nearest 0.1 kg. Total length and fork length were measured to the nearest mm, and to confirm species mouth width and interorbital width were measured with calipers to the nearest 0.01 mm. To estimate population abundance, unmarked sturgeon were tagged at the base of the dorsal fin with a numbered Carlin tag. Beginning in 1998, each sturgeon also was scanned for the presence of a PIT (Passive Integrated Transponder) tag with an AVID Power Tracker II scanner, and if none was found, an AVID 14-mm PIT tag was injected into the right-side base of the dorsal fin. We also weighed and measured 32 Atlantic sturgeon caught by commercial harvesters in 1980, and checked them for tags.

Size was used to determine life stage (Bain 1997). Size intervals for Atlantic sturgeon were: early juveniles 30 to 490-mm TL, intermediate juveniles 500 to 700-mm TL, late juveniles >700 to 1,490-mm TL, female spawners >1,800-mm FL or >2,000-mm TL, and male spawners >1,350 to 1,900-mm FL or >1,500 to 2,010-mm. TL. Both FL and TL were used for spawning Atlantic sturgeon, because only FL was measured in one sample. Box plots of TL for each species were plotted in JMP version 9.

Catch and catch-per-unit-effort (CPUE) were used to identify seasonal and geographical concentrations of sturgeon. Because fishing time varied and different gills net were used, effort for each sample was calculated by multiplying soak time (h) by net length (m) divided by 90 m. Effort was highly variable among stations, zones, months, and years (Table 2). CPUE was calculated for each sample (CPUE), station (sCPUE), zone-month-year combination (zCPUE), and year (yCPUE), and was defined as the number of sturgeon caught in a 90-m net in one hour (a net-h). Three size classes of sCPUE, based on natural breaks in the data (Jenks), were plotted in ARCGIS 9.

Results

In 16 years, we captured 403 Atlantic sturgeon in 472 gill net sets, equal to 7,146 net-h of effort. Approximately 67% of the Atlantic sturgeon were tagged with a Carlin tag, PIT tag, or both. Sampling mortality was 4.4% for Atlantic sturgeon, and was highest in 1979-1981. Atlantic sturgeon, excluding eight smaller fish, were 555 to 1,981-mm TL (mean=978; SE=15.9; n=337) and weighed 1.0 to 29.5 kg (mean=5.6; SE=0.3; n=270). Median TL was variable for Atlantic sturgeon (Figure 2).

Large catches of Atlantic sturgeon and above average zCPUEs showed similar trends over the study period (Table 3). Concentrations of Atlantic sturgeon occurred most often in the Upper Kennebec Estuary in July (0.02-16.00) , in Merrymeeting Bay from May to November (0.04-0.91), and in the Lower Kennebec Estuary from May to October (0.04-1.16). Concentrations also occurred in the Upper Kennebec Estuary in June 1996 and in the S-B passages in June 1979. Within each zone, the highest catches and sCPUEs occurred at stations between rkm 60 and rkm 65 in the Upper Kennebec Estuary, in the Lower Kennebec Estuary from rkm 17 to rkm 30, and at two stations in the S-B passages (Figure 3).

When data from all years were combined, 41 Atlantic sturgeon in spawning condition (ripe males releasing sperm) or >1,350-mm FL or >1,500-mm TL were caught in seven years in the Upper Kennebec Estuary between rkm 52.8 and rkm 74.0 (Figure 3). Sturgeon were caught in 1977-79, 1994, 1996-1997, and 2000 as early as June 13 and as late as July 21. We caught one ripe male at rkm 57.7 on July 21, 1978; five at rkm 74.0 on July 13, 1994; six at rkm 62.6 on June 28 and July 10, 1996; and four at rkm 62.9 and one at rkm 70.2 on July 10-11, 1997. In 1980, commercial harvesters caught 15 ripe males at rkm 58.6 between June 15-29. A single Atlantic sturgeon caught and tagged at rkm 57.7 on July 21, 1978 was recaptured by the commercial harvesters at rkm 58.6 on June 21, 1980.

Early, intermediate, and late stage juvenile Atlantic sturgeon were captured primarily from April through November in Merrymeeting Bay, the Lower Kennebec Estuary and the S-B passage (Figure 4). Just three juveniles were captured in the Upper Kennebec Estuary during the spawning season in June and July.

Discussion

A spawning population of Atlantic sturgeon currently inhabits the Kennebec and Androscoggin estuaries in Maine, and is the only spawning population that has been documented in Maine waters.

Within the Gulf of Maine, spawning Atlantic sturgeon have been documented in just two other rivers (Dadswell 2006; ASSRT 2007), the Saint John River (New Brunswick, Canada) and the Annapolis River (Nova Scotia, Canada). Atlantic sturgeon have endured in the Kennebec, Androscoggin, and Sheepscot estuaries despite past habitat loss from dam construction, sporadic fisheries that likely targeted spawning fish, decades of poor water quality, and habitat degradation. The attributes of the study area, including large volumes of fresh water discharge in spring during spawning, large areas of tidal freshwater habitat for juvenile growth, and large interconnected areas of mesohaline and polyhaline habitat for adult foraging may have allowed Atlantic sturgeon to persist at low levels. Treatment of industrial and municipal wastewater mandated by the Clean Water Act of 1972, which resulted in increased dissolved oxygen levels (Davies et al. 1999), and adoption of a rule in Maine in 1983 that prohibited the catch or possession of sturgeon in the Kennebec undoubtedly improved conditions for the species.

The Atlantic sturgeon population in the Kennebec Estuary is genetically distinct and can be statistically differentiated from other populations along the east coast (Wirgin et al. 2000; Waldeman et al. 2002). The Kennebec sturgeon apparently spawned in tidal freshwater between rkm 58 and rkm 74 from approximately mid-June to mid-July, although they may have entered the river as early as May. The spawning season in Maine was similar to that reported for the St. Lawrence (Hatin et al. 2002), but of shorter duration than in the Hudson River (Bain 1997).

Atlantic sturgeon spawned in the Upper Kennebec Estuary at least one year after removal of Edwards Dam, because fish >1,350-mm FL or >1,500-mm TL were caught on June 29, 2000 at rkm 63.7 Historically they may have spawned farther upstream. Atkins (1887) stated that they spawned primarily between Augusta and Waterville (rkm 74-102), because there was a great decrease in their number after Edwards Dam was built in Augusta. Sturgeon have been sighted above rkm 74 since 1999, and in June 2005 an Atlantic sturgeon was caught at rkm 102 in a gill net set during sampling for American shad (G. S. Wippelhauser, unpublished data). However, during the period from 1977 to 2001, spawning of Atlantic sturgeon above Augusta was not studied.

Atlantic sturgeon from the Kennebec undertake coastal migrations as reported for fish from other river systems. Three of 40 juveniles tagged between 1977 and 1981 were captured to the south. One was captured off Newport, Rhode Island in November after being at large for more than two years, and two were recaptured near Rye, New Hampshire; one had been at large for >2 years and the other for > 4 years. Juvenile Atlantic sturgeon also have been caught sporadically in the Maine-New Hampshire inshore trawl survey. Between 2000 and 2012, 51 Atlantic sturgeon were taken in the trawl survey, 45 of which were caught near the mouth of the Kennebec (Sherman et al. 2003; G. S. Wippelhauser, unpublished data).

Atlantic sturgeon in the Gulf of Maine (2006-2010)

Introduction

Beginning in 2006, researchers at the University of Maine (UMaine: G. Zydlewski, M. Kinnison, J. Zydlewski, S. Fernandez, P. Dionne, and M. Altenritter), ME DMR (G. Wippelhauser), and University of New England (UNE: J. Sulikowski) independently began acoustic telemetry studies of Atlantic sturgeon and shortnose sturgeon in Gulf of Maine (GoM) river systems. The studies had similar objectives: to identify habitat use, document seasonal distribution and abundance, elucidate migration routes, and characterize genetic makeup. Manuscripts are in preparation, but information about Atlantic sturgeon in the Kennebec and Androscoggin systems is presented here.

Study area

The study area, described in detail in Wippelhauser and Squiers (submitted), encompassed the Kennebec River and Estuary, Androscoggin Estuary, Sheepscot Estuary and two passages, the Sasanoa River and Back River, that connect the Kennebec and Sheepscot (Figure 5). The Lower Kennebec Estuary (rkm 0 to rkm 30) is mesohaline to polyhaline, depending on discharge. Merrymeeting Bay (rkm 30 to rkm 45), the Upper Kennebec Estuary (rkm 45-74), and the 8.4-km long Androscoggin Estuary are tidal freshwater; Brunswick Dam is located at the tidal limit of the Androscoggin Estuary. The Kennebec River (rkm 74 to rkm 103) was impounded from 1837 when Edwards Dam was built at rkm 74 until 1999 when the dam was decommissioned and removed; Lockwood Dam is located at rkm 103.

Methods

Acoustic receiver array

An array of 18-20 stationary acoustic receivers (Vemco VR2 in 2007; Vemco VR2W in 2008-2012) was deployed at 16-20 sites in the study area (Figure 5). In most instances the receivers were deployed in narrow reaches of the channel, and a single receiver was able to monitor the entire width of the channel for tagged fish. Receivers typically were deployed in April, and retrieved between October and November, but not all receivers were deployed each year of the study (Table 4). Mobile tracking was conducted occasionally with a portable receiver (Vemco 100) and Vemco directional hydrophone. Receiver locations in the Kennebec Estuary and Kennebec River were identified by river kilometer (rkm) relative to the estuary mouth. Receivers in the Androscoggin were denoted rkm 30 and rkm 31 for graphing purposes, and those in the Sasanoa and Back rivers were identified by a numeral.

Capture and tagging in the Kennebec

Between 2009 and 2012, Atlantic sturgeon were captured at 25 locations between rkm 0 and rkm 75 in the Kennebec Estuary, Kennebec River, and Androscoggin Estuary with multifilament, sinking gill nets that were 30- or 90-m long, 2.4-m or 1.8-m deep, and consisted of a single panel of 305-mm stretch mesh or 30-m panels of 152, 178, and 203-mm stretch mesh. Nets were deployed parallel to shore for 0.6-6.5 h as early as June 9 and as late as November 15. Sturgeon were removed from the gill net and placed in a floating net pen in the river. An individual was removed from the holding pen, weighed in a sling, measured (total length (TL), fork length (FL), interorbital width, and mouth width) and scanned for the presence of a PIT (Passive Integrated Transponder) tag with an AVID Power Tracker II scanner. If no PIT tag was found, an AVID 14-mm PIT tag was injected into the right-side base of the dorsal fin. A small tissue sample was taken from nearly every fish for genetic analysis. A subset of fish captured on known or suspected spawning grounds was fitted with an external acoustic transmitter (Vemco V16-4H) that was attached with wire through holes drilled in two adjacent dorsal scutes; the wire corroded and the tag was shed after the fish entered sea water. A subset of fish captured elsewhere in the river was implanted surgically with an acoustic transmitter (Vemco V16-6L) with a 10-year life. Surgery was performed only on fish that appeared to be in excellent health. The sturgeon was anaesthetized with MS-222 (tricaine methane sulfonate), a 3-4 cm incision was made on one side of the medial ventral line for insertion of the transmitter, and the incision was closed with a single set of individual sutures. The fish was allowed to recover in the floating net pen for approximately 15 min, and was released after it showed clear sign of recovery.

Capture and tagging in the Penobscot

Capture and tagging methods in the Penobscot Estuary have been described in detail in Fernandez et al. (2010) and Dionne (2012). Briefly, shortnose and Atlantic sturgeon were captured in multifilament gill nets fished between rkm 4 and rkm 36 in the Penobscot River from May to November, 2006-2009. Fish were identified to species, weighed, measured, and PIT tagged if not previously tagged. A subset of captured fish were implanted with a coded (Vemco V9P-2L, Vemco V13TP-1L, or V13TP1H) and/or a continuous noncoded (V16-1H) acoustic transmitter (Fernandez et al. 20010; Dionne 2012) designed to transmit a signal for approximately two years.

Ichthyoplankton sampling

To confirm spawning, we attempted to capture sturgeon eggs and larvae with D-nets that were constructed of 800-μ mesh or 1600-μ mesh, had a 1-m diameter opening, and were 4.3-m long. The mouth of the net was attached to a half-circle stainless steel frame 1-m across by 0.5 m high. The net was set on the bottom downstream of spawning fish. Organisms were rinsed from the nets, and immediately preserved in 5% formalin. They were sorted in the laboratory under a dissecting microscope, and sturgeon eggs and larvae were transferred to 75% ethanol for subsequent enumeration and identification according to Jones et al. (1978).

Environmental data

Mean daily discharge for the Androscoggin River was obtained for USGS gauge 01059000, located approximately 27 km above the Brunswick Dam. Similar data for the Kennebec River were obtained for USGS gauge 01049265, located at rkm 87. These data were not adjusted for freshwater entering below the gauge. Beginning in 2009, water temperature was recorded every 8 h at rkm 30, rkm 42, rkm 67, and rkm 102 by a datalogger (HOBO U10-001) in a waterproof container. The temperature logger was attached approximately 1 m from the bottom to a line between a receiver and its anchor. Mean daily temperature was calculated for each datalogger site.

Telemetry data

Receivers were downloaded throughout the deployment period and for a final time when they were retrieved for the year. Data were sorted by transmitter number, date, and time. Fish position in rkm was plotted against date and time for each tagged fish. Transmitters detected for less than a day were excluded from further analysis.

Results

We captured 114 Atlantic sturgeon in the Kennebec and Androscoggin estuaries at 25 sites that were sampled on 79 dates (350 h soak time) between 2007 and 2012. Most sturgeon were PIT tagged (*n=106*), 19 were tagged externally with an acoustic transmitter, and 20 were implanted internally with an acoustic transmitter. Tissue samples were taken from 64 fish, but to date genetic analysis has been conducted only for samples taken from 2009 to 2011.

Spawning areas

Between 2009 and 2011, 39 Atlantic sturgeon >1500-mm TL or in spawning condition (ripe males releasing milt) were caught in June and July in the Upper Kennebec Estuary, Kennebec River, and Androscoggin Estuary. Twenty-seven fish, including five ripe males, were caught in the Upper Kennebec Estuary between rkm 70 and rkm 74 (Table 5; Figure 5). Four fish, including one ripe male, were caught in the Kennebec River at rkm 75, and eight, including one ripe male, were caught in the Androscoggin Estuary at rkm 30 (Table 5; Figure 5). Two of the latter, including the ripe male, had been PIT tagged in the Saco Estuary in 2010; we implanted the male with an acoustic transmitter before discovering the PIT tag.

The 19 Atlantic sturgeon tagged on the spawning grounds either dropped downstream < 1.5 d after being tagged (*n=4*), remained in the area where they were tagged (*n=12*) for 3-25 d, or spent time at two areas (*n=2*) for 1-14 d (Figure 6; Figure 7; Figure 8). Tagged fish were on the spawning ground when freshwater discharge was < 400 cms and water temperature 1 m from the bottom was 19.9-21.8ºC in 2009, 18.5-26.1ºC in 2010, and 18.9-25.6ºC in 2011 (Figure 9, Figure 10, Figure 11). Sturgeon in the Upper Kennebec Estuary typically made repeated trips between rkm 48 and rkm 75 where there were multiple receivers. In 2009, we were unable to fish during the last half of June and first half of July due to high discharge (Figure 9).

Spawning was confirmed in the Kennebec River and Upper Kennebec Estuary by the capture of three Atlantic sturgeon larvae in 2011. We caught two larvae at rkm 75, one (15-mm TL) on July 11 and one (10-mm TL) on July 12. We also caught one larva (15-mm TL) on July 11 at rkm 72. Bottom water temperature was 23-24ºC when the larvae were caught (Figure 11). Species identification of two of the larvae (one was released alive) was confirmed by mitochondrial DNA (Wirgin pers. comm.).

Two of 30 (7%) Atlantic sturgeon tagged in the Penobscot River between 2007 and 2009 and three of 45 (7%) tagged in the Saco River between 2009 and 2011 were detected in the Upper Kennebec Estuary, Kennebec River, or Androscoggin Estuary in June and July. The sturgeon tagged in the Penobscot were located in the Upper Kennebec Estuary (rkm 58 to 74) between June 15 and July 10, 2010 (Figure 10). In 2011, one sturgeon tagged in the Saco was located in the Upper Kennebec Estuary (rkm 58-74 and rkm 87) between June 18 and July 13, and two sturgeon were located in the Androscoggin Estuary (rkm 30), one from June 7 to July 10 and the other from May 31 to June 22 (Figure 11). None of the Atlantic sturgeon tagged in the Kennebec or Androscoggin have been detected in the Penobscot or Saco to date.

Activity patterns

Tagged fish showed a bimodal pattern of activity. Fish tagged on the spawning ground in the Upper Kennebec Estuary were active from 0100-0200 h and at 1500 h in 2009 and at 0300 h and 1500 h in 2010. Fish tagged on the Androscoggin spawning ground were most active at 0300 h and 1200 h. Fish tagged in Merrymeeting Bay or fish that moved there after spawning in 2011 were detected most often at 2100 h and 1200 h.

Non-spawning habitat

Merrymeeting Bay, the Lower Kennebec Estuary, and one cove located near the mouth of the river were used by post-spawn adults and other life stages of Atlantic sturgeon. Gill net sampling in Merrymeeting Bay from July through September and in Sagadahoc Bay in July produced the greatest catches and highest CPUEs (Table 5). Atlantic sturgeon tagged in the Kennebec appeared in subsequent years as early as May, and some post-spawn adults remained in Merrymeeting Bay or the Lower Kennebec Estuary as late as November.

Twenty (67%) Atlantic sturgeon tagged the Penobscot River between 2007 and 2009 and 16 (35%) tagged in the Saco River migrated into the Kennebec Estuary at least once during the period between 2007 and 2011. These non-spawning fish typically remained in Merrymeeting Bay and the Lower Kennebec Estuary.

Wintering habitat

Some juvenile and later stage Atlantic sturgeon may spend the winter in Merrymeeting Bay at rkm 42 where shortnose sturgeon have been documented to winter (Wippelhauser and Squiers, submitted). In 2011, we captured one juvenile (462-mm TL) Atlantic sturgeon at rkm 42 on November 14. In 2008, an Atlantic sturgeon tagged in the Penobscot was detected at rkm 42 from October 19 through November 12. It was detected the following spring at rkm 34 on April 19, and subsequently moved downstream. In 2009, another Atlantic sturgeon tagged in the Penobscot was detected at rkm 42 between November 2 and December 2 and again on March 13, 2010.

Discussion

Two new spawning areas were confirmed for Atlantic sturgeon in the Gulf of Maine, one in the Androscoggin Estuary below Brunswick Dam, which has always been accessible, and one in the Kennebec River, which only became accessible when Edwards Dam was removed in 1999. Atlantic sturgeon >1500-mm TL were caught in flowing water at each site in June and July when water temperature was 18.9-25.6º, somewhat higher than the range (13.2-20.5 ºC) reported by Borodin (1925), Huff (1975), and Smith (1985). Interestingly, some Atlantic sturgeon tagged in the Saco and Penobscot also spawned in the Kennebec; however, the opposite was not observed. The capture of two Atlantic sturgeon larvae in the Kennebec River, 1 km above the former location of Edwards Dam, and one in the Upper Kennebec Estuary, approximately 1.6 km below the former dam, confirmed spawning in the tidal and newly accessible riverine portions of the Kennebec.

Substrate in the Kennebec River is appropriate for Atlantic sturgeon spawning and nursery habitat. A sediment-characterization survey of the entire Edwards Dam impoundment in 1994 found that coarse sands, gravel, and mixtures of gravel with cobble were the most common sediment types (Stone & Webster 1995). Several years later, the U.S. Geological Survey classified sediment types and mapped their areal extend in the lower Edwards Dam impoundment (rkm 75-87), and reported that approximately 90% of the area consisted of rock, sand, and gravel or combinations of the three substrates (Dudley 1999).

Atlantic sturgeon in the Gulf of Maine – genetic structure

The Atlantic sturgeon population in the Kennebec Estuary is genetically distinct and can be statistically differentiated from other populations along the east coast (Wirgin et al. 2000; Waldeman et al. 2002). Wirgin et al. (2000) sequenced mtDNA from 322 Atlantic sturgeon from 11 river system, 19 of which were from the Kennebec River system. When only young-of-year and spawning adults were included in the analysis, the Kennebec population was most closely associated with St. John and St. Lawrence populations (Wirgin, supplemental data 2006).

More recently, Wirgin et al. (2012) used microsatellite DNA and mitochondrial DNA control region sequence analysis to quantify the stock origin of Atlantic sturgeon caught in Minas Bay in the Bay of Fundy, Canada. As part of the analysis, reference collections were made from nine rivers known to host contemporary spawning populations of Atlantic sturgeon. Tissue samples taken in 2009-2011 from spawning fish in the Kennebec and Androscoggin were included in the analysis. Wirgin et al. (2012) reported that 34-36% of the fish caught in the Minas Basin were fish originating from the Kennebec River (sample size was too small to distinguish the Kennebec from the Androscoggin).

Status

At least six river systems in the GoM historically may have supported spawning populations of Atlantic sturgeon (ASSRT 2007): the Saint John River (New Brunswick, Canada), Annapolis River (Nova Scotia, Canada), St. Croix River (Maine, USA and Nova Scotia, Canada), Penobscot River (Maine, USA), Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers (Maine, USA), and Piscataqua River/Great Bay Estuary System (New Hampshire, USA). However, the ASSRT (2007) concluded that only two extant populations existed in the United States (Kennebec and Penobscot) at the time of the status review. The capture of seven Atlantic sturgeon, including one 1450-mm TL fish, in the Penobscot from 2006 to January 2007 was cited as evidence of an extant population. However, our ongoing telemetry studies have found that Atlantic sturgeon tagged in the Penobscot utilize the Kennebec and Androscoggin, but not the Penobscot, for spawning. In addition, approximately two-thirds of Atlantic sturgeon tagged in the Penobscot spend time in the Lower Kennebec Estuary and Merrymeeting Bay, presumably to forage.

Historically, the Kennebec (Kennebec Estuary, Kennebec River, and Androscoggin Estuary) may have supported approximately 15,000 spawning adults (Kennebec River Resource Management Plan 1993). The current abundance of spawning adults is unknown. However, the finding that Atlantic sturgeon are using concurrently two spawning areas that have always been accessible and a new spawning area that became available 13 years ago is encouraging, and may indicate the population is stable or expanding rather than declining.

Maine may just now be seeing the results of protecting spawning fish, assuming that the age of maturation of Atlantic sturgeon in the GoM is somewhere between that of Hudson River fish (11-21 years) and St. Lawrence fish (22-34 years). The ASSRT (2007) estimated that most extant populations of Atlantic sturgeon have 300 or fewer spawning adults, and the loss of as few as 10 would impede recovery. Prior to 1983, when directed harvest of Atlantic sturgeon in the Kennebec system became illegal, commercial harvesters targeted spawning fish. In 1980, the only year for which we have records, they took 32 fish from the Kennebec. Frequent sightings and increased capture by researchers of Atlantic sturgeon began occurring in the Penobscot River in 2006 and in the Saco River in 2009, 23 and 26 years respectively after the Kennebec commercial fishery was closed. During this interval, water quality, specifically dissolved oxygen, has greatly improved in all Maine's rivers (Davies et al. 1999).

Analysis of ESA listing factors

The present or threatened destruction, modification, or curtailment of habitat or range

Dams

The construction of mainstem dams contributed to the decline of Atlantic sturgeon in Maine. The greatest loss of historic habitat probably occurred in the Kennebec watershed when Edwards Dam was constructed in 1837, which blocked access to 29 km of free-flowing river. Despite this loss, 44 km of tidal freshwater habitat remained available downstream of the dam. In the Penobscot watershed, construction of Bangor Dam, Veazie Dam, and Great Works Dam blocked access to 20 km of historical freshwater habitat, and in summer the amount of tidal freshwater habitat available downstream may be limited to 10-14 km.

Within the Kennebec watershed, 100% of Atlantic sturgeon historical habitat currently is accessible, and we have documented that it is used by Atlantic sturgeon for spawning. Removal of Edwards Dam in 1999 converted the 29-km impoundment to natural lotic habitat, and within months significant changes in water quality, as evidenced by dissolved oxygen and the benthic invertebrate community, were observed (D. Courtemanch, DEP, pers. comm.). Productivity in this reach also appears to have increased. The biomass (not including *Alosa* spp. and *Acipenser* spp.) is three to eight times larger than that in upstream impoundments (Yoder and Kulik 2003).

A similar change is habitat availability is about to occur on the Penobscot River. In 2012, the second mainstem dam (Great Works) was removed, and removal of the first dam (Veazie) is scheduled to begin in the summer of 2013. When Veazie is removed, 100% of historical habitat for Atlantic sturgeon will be accessible. Improved water quality and increased production similar to that seen in the Kennebec is expected to occur.

Water quality

Freshwater habitat available to Atlantic sturgeon is Class A and Class B in the Saco watershed, Class B in the in the Kennebec and Penobscot watersheds, and Class C in the Androscoggin watershed. The classes are defined in Maine statute as:

Class A waters are the second highest classification and must be of such quality that they are suitable for the designated uses of drinking water after disinfection; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as habitat for fish and other aquatic life. The habitat must be characterized as natural. The dissolved oxygen content of Class A waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher. The aquatic life and bacteria content of Class A waters shall be as naturally occurs.

Class B waters are the third highest classification and must be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as habitat for fish and other aquatic life. The habitat must be characterized as unimpaired. The dissolved oxygen content of Class B waters may not be less than 7 parts per million or 75% of saturation, whichever is higher, except that for the period from October 1st to May 14th, in order to ensure spawning and egg incubation of indigenous fish species, the 7-day mean dissolved oxygen concentration may not be less than 9.5 parts per million and the 1-day minimum dissolved oxygen concentration may not be less than 8.0 parts per million in identified fish spawning areas.

Class C waters are the fourth highest classification and must be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as a habitat for fish and other aquatic life. The dissolved oxygen content of Class C water may be not less than 5 parts per million or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes must be maintained. In order to provide additional protection for the growth of indigenous fish, the following standards apply.

- The 30-day average dissolved oxygen criterion of a Class C water is 6.5 parts per million using a temperature of 22 degrees centigrade or the ambient temperature of the water body, whichever is less, if:
- A license or water quality certificate other than a general permit was issued prior to March 16, 2004 for the Class C water and was not based on a 6.5 parts per million 30-day average dissolved oxygen criterion; or

- A discharge or a hydropower project was in existence on March 16, 2005 and required but did not have a license or water quality certificate other than a general permit for the Class C water.
- This criterion for the water body applies to licenses and water quality certificates issued on or after March 16, 2004.
- In Class C waters not governed by subparagraph (1), dissolved oxygen may not be less than 6.5 parts per million as a 30-day average based upon a temperature of 24 degrees centigrade or the ambient temperature of the water body, whichever is less. This criterion for the water body applies to licenses and water quality certificates issued on or after March 16, 2004.

Contaminants

Maine's Surface Water Ambient Toxics (SWAT) monitoring program was established in 1993 to determine the nature, scope, and severity of toxic contamination in the surface waters and fisheries of the State. The authorizing statute states that the program must be designed to comprehensively monitor the lakes, rivers and stream, and marine and estuarine waters of the State on an ongoing basis. In the marine and estuarine modules, blue mussel and clam tissue is analyzed for metals, mercury, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and organochlorinated pesticides.

In 2011 (MDEP 2012), only lead and mercury (but not silver arsenic, cadmium chromium, copper, iron, aluminum, or nickel) in mussel tissue exceeded the National Status and Trends Musselwatch 85th percentile (NST85) at more than half of the sites tested, resulting in an elevated designation. PAH concentrations in clam and mussel tissue did not exceed the NST85. PCB concentrations in mussel tissue exceeded the Maine Center for Disease Control (MCDC) cancer fish tissue action level (FTAL) at two sampling sites (East End Beach, Portland and Crockett Point, Rockland), but PCB concentrations in clams were below this level. Organochlorinated pesticide concentrations in mussel and clam tissue were safely below the MCDC FTAL values.

The study of contaminant levels in Atlantic sturgeon has received little attention. While levels for most metals and PAH in mussels in Maine coastal waters were below the National Status and Trends Musselwatch 85th percentile (NST85), these contaminants bioaccumulate and may be a problem for long-lived species like Atlantic sturgeon. The SWAT report indicated that mussels tend to accumulate more contaminants and accumulate contaminants at higher levels compared to clams. Therefore, it is important to have a better understanding of the diet of Atlantic sturgeon, which have been reported to consume polychaetes, isopods, decapod crustaceans, amphipods, gastropods, and fishes (e.g. sand lance, Ammodytes sp.) as well as bivalves (Vladykov and Greeley 1963; Huff 1975; Scott and Crossman 1973; Johnson et al. 1997; Savoy 2007). Salvaged sturgeon might be a source of tissue samples.

Tidal power projects

Because of its extremely large tidal fluctuations, there has been renewed interest in producing tidal power in the Gulf of Maine. In the last six years, the Department of Marine Resources has received notices for preliminary permits for 13 tidal power projects, one pump storage project, and two tidal barrage projects that have been proposed for Maine's coastal waters. Applications for preliminary permits in Maine typically have proposed the installation of 50-100 tidal turbines that would be anchored to the bottom. To date, just a single generating unit has been deployed, and is being tested in Cobscook Bay. In addition to projects proposed for Maine, tidal power projects have been proposed for Minas Basin in Canada (Wirgin et al. 2012). Virtually nothing is known about the environmental impacts of these types of turbines (Cada 2007). For large fish like Atlantic sturgeon, the greatest concern if for injury or mortality caused by blades strikes.

Dredging, blasting, pile driving

ME DMR typically recommends ways to reduce impacts of projects on fisheries resources during consultation with private, state, or federal entities. The recommendations may include in-water work windows or sequencing of activities to minimize adverse impacts.

Large projects that involve dredging, blasting, and/or pile driving are not uncommon in the Kennebec River, Kennebec Estuary, and Androscoggin Estuary. In the past, the entity responsible for a project has gone to considerable effort to minimize impacts, typically by conducting studies prior to project initiation, and scheduling construction when it would have the least impacts. For example, a year of study on the shortnose sturgeon spawning habitat in the Androscoggin Estuary in 1993 preceded construction of the Brunswick Bypass to determine if it was in spawning habitat (it wasn't). Prior to the expansion of Bath Iron Works (BIW), an extensive study of water quality and fisheries in the vicinity was conducted from April 1997-June 1998. Furthermore, a telemetry study of shortnose and Atlantic sturgeon distribution in the Lower Kennebec Estuary was conducted in the fall/winter of 1998 and spring of 1999 to inform dredging and blasting schedules.

Overutilization for commercial, recreational, scientific, or educational purposes

Directed catch

Atlantic sturgeon are not protected in Canada, and commercial fisheries still occur for subadults in the Saint John River, New Brunswick where the total allowable catch is approximately 200 adults (Dadswell 2006). Wirgin et al. (2012) reported that 34-36% of the fish caught farther north in the Minas Basin were of Kennebec origin. It is possible that fishery in the Saint John River is taking Kennebec origin fish. Genetic analysis of Atlantic sturgeon taken in the fishery would determine the origin of the fish.

Bycatch

The State of Maine has no active program to monitor bycatch of Atlantic sturgeon in Maine waters. However, we queried the National Marine Fisheries Service Fishery Observer database for the period 1991 through 2012 for Statistical Areas 511, 512, and 513, which encompass Maine's coast. Bycatch was reported only in area 513, the area that extends from the Maine-New Hampshire border east to Muscongus Bay. Within area 513, a total of 1,448 pounds of Atlantic sturgeon or sturgeon bycatch was reported for the years 1991-2012. Bycatch was greatest in 2000, and was relatively high from 1991-1994 (Figure 12). For all years combined, bycatch was greatest in April and November (Figure 12). Sturgeon were taken by sinking fixed or anchored gill net (1,096 pounds) that targeted groundfish (or unknown fish species prior to 1995), purse seine (45 pounds) that targeted Atlantic herring, or otter trawl that targeted Atlantic cod (100 pounds), unknown fish species (70 pounds), or shrimp (137 pounds).

Competition, predation, disease

Harmful algal blooms (HABs) can pose a threat to sturgeon when they consume shellfish exposed to blooms of the dinoflagellate genus *Alexandrium* and the potentially large amounts of neurotoxins accumulated in the shellfish (Fire et al. 2012). These toxic compounds, known as saxitoxins, are responsible for paralytic shellfish poisoning in humans. During the summer of 2009, the coast of Maine experienced a severe *Alexandrium* bloom. On July 10, ME DMR received a call that there were dead sturgeon in Sagadahoc Bay, located immediately to the east of the mouth of the Kennebec. Thirteen shortnose sturgeon and one Atlantic sturgeon were found in the bay. The least decomposed fish, three shortnose sturgeon, were frozen and subsequently necropsied. Saxitoxin-like activity was found in the stomach contents, liver, and gill tissue and fish stomachs contained large number of amethyst gem clams, *Gemma gemma*, (Fire et al. 2012).

Existing regulatory authorities, laws, and policies

Unfortunately, during project and/or permit consultations in the last two years, ME DMR's recommendations often have been ignored. In 2011, dredging below Bath Iron Works was carried out in the summer when both species of sturgeon are known to be in the area. Consultation on construction of a new bridge in Richmond (rkm 45) since April has resulted in no restrictions on pile driving during the upstream migration period for all anadromous species (April 1 – mid July).

Conservation and Management Approaches

Identify critical habitat

The Endangered Species Act (ESA) requires the federal government to designate "critical habitat" for any species it lists under the ESA. "Critical habitat" is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation.

Because the Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers appears to support the only extant population of Atlantic sturgeon within the GoM DPS, the entire complex should be designated as critical habitat. Our studies have demonstrated that the entire complex is used as a migratory corridor, and the Kennebec River , Upper Kennebec Estuary, and Androscoggin Estuary are used for spawning. Laboratory studies indicate downstream migration by young-of-year is limited, so these areas are also likely used as nursery habitat. Our studies also have found that subadults and adults use Merrymeeting Bay, the Lower Kennebec Estuary, and Sasanoa and Back rivers from April though November, probably for foraging. Most recently (gill net sampling on October 24, 2012) we confirmed that juvenile Atlantic sturgeon were located at the same wintering area as shortnose sturgeon in late fall. Two wintering areas have been identified to date, one in Merrymeeting Bay, and one in the Upper Kennebec Estuary.

Concentrations of Atlantic sturgeon have been documented in Sagadahoc Bay, a portion of the Penobscot Estuary in Winterport, and the Saco Estuary. Anecdotal reports indicate Atlantic sturgeon may also be concentrated in Totman Cove, located just west of the mouth of the Kennebec, and in Scarborough Marsh, located near the Saco Estuary. Some or all of these areas should also be designated at critical habitat.

Consultation on tidal power projects

ME DMR will continue to request or recommend intensive fisheries assessment and monitoring of FERC licensed pilot tidal projects. At a minimum the relative seasonal abundance and vertical distribution should be determined for each species in the area, and behavior before and after installation of a turbine unit and multiple units should be examined.

Consultation on dredging, blasting, and construction projects

ME DMR will continue to recommend that dredging, blasting, pile driving and related activities that could impact Atlantic (and shortnose) sturgeon be restricted to the time period between November 1 and April 1 when fish are concentrated in wintering areas or are in marine waters.

Directed catch

ME DMR will continue to participate in development by Canada and the U.S. of a Regional Conservation Strategy for Atlantic Sturgeon in the GoM. Determining the stock composition of Atlantic sturgeon harvested in the St. John River, Canada, is a priority.

Bycatch

ME DMR will continue to participate in the ASMFC Atlantic Sturgeon Technical Committee, which will conduct a new stock assessment for the species, and will continue to investigate ways to reduce bycatch.

Existing regulatory authorities, laws, and policies

Current Maine law makes it unlawful to take, catch, or destroy Atlantic sturgeon and shortnose sturgeon in coastal waters. ME DMR will work with the Maine Department of Inland Fisheries and Wildlife to mirror the regulation in the Kennebec from the coastal water/inland water interface upstream to Lockwood Dam and Benton Falls Dam and in the Penobscot from the coastal water/inland water interface upstream to Milford Dam.

Education and outreach

ME DMR will continue to participate in the ASMFC Atlantic Sturgeon Technical Committee, which will conduct a new stock assessment. Ongoing research will be published in journals widely read by other sturgeon researchers (e.g., Transactions of the American Fisheries Society), and presented at regional and national meetings (e.g., AFS). ME DMR researchers will continue to collaborate with other researchers working in the GoM and to participate in the Atlantic Coast Telemetry (ACT) Network. We will attend outreach events and speak about our work on Maine's rivers. We also will provide data to the SCUTES (Students Collaborating to Undertake tracking Efforts for Sturgeon) program. Finally, ME DMR will post signs at boat launches and popular fishing area describing the status Atlantic sturgeon and describing handling protocols if fish are inadvertently caught.

Research needs

The ASSRT (2007) identified long-term population monitoring, spawning population estimates, population genetics, bycatch and bycatch mortality estimates, identification of spawning and nursery ground, toxic contaminant impacts and thresholds, and develop fish passage devices for sturgeon as important research needs. The list has been refined to address specific research needs for the GoM.

- Estimate the abundance of spawning populations in the Kennebec and Androscoggin systems, possibly using hydroacoustics;
- Determine genetic relatedness between Atlantic sturgeon that spawn in the Kennebec and Androscoggin; determine genetic relatedness between Kennebec and Androscoggin spawners and Atlantic sturgeon caught in the Penobscot and Saco estuaries;
- Identify nursery grounds in the Kennebec and Androscoggin;

- Identify in-river wintering areas for juveniles and sub-adults;
- Identify GoM marine wintering area for adults;
- Determine if spawning occurs in the Penobscot River after removal of Veazie Dam;
- Monitor impacts of pile driving on migratory behavior of Atlantic sturgeon during construction of Richmond Bridge in 2013; and
- Collect tissue samples from salvaged sturgeon for contaminants analysis.

References

Atkins, C.G. 1887. The river fisheries of Maine. Pages 673-728 in: Goode, G.B. 1887. The fisheries and fishing industries of the United States, Section V, Volume 1.

ASMFC (Atlantic States Marine Fisheries Commission). 1990. Interstate fishery management plan for Atlantic sturgeon. Fisheries Management Report No. 17. Atlantic States Marine Fisheries Commission, Washington, D.C. 73 pp.

ASMFC. 1998. Amendment 1 to the Interstate fishery management plan for Atlantic sturgeon. Management Report No. 31. 43 pp.

ASSRT (Atlantic Sturgeon Status Review Team). 2007. Status review of Atlantic sturgeon *Acipenser oxyrinchus oxyrhynchus*). Report to the National Marine Fisheries Service, Northeast Regional Office. February 23, 2007. 174 pages.

Bain, M.B. 1997. Atlantic and shortnose sturgeons of the Hudson River: common and divergent life history attributes. Environmental Biology of Fishes 48: 237-247.

Borodin, N. 1925. Biological observations on the Atlantic sturgeon, *Acipenser sturio*. Transactions of the American Fisheries Society 55: 184-190.

Brooks, D.A. 2009. Circulation and dispersion in a cancellate coast: The river, bays, and estuaries of central Maine. Estuarine, Coastal and Shelf Science 83: 313-325.

Cada, G., J. Ahlgrimm, M. Bahleda, T. Bigford. S. Damiani Stavrakas, D. Hall, . Moursund, and M. sale. 2007. Potential impacts of hydrokinetic and wave energy conversion technologies on aquatic environments. Fisheries 32: 174-181.

Caron, F., D. Hatin, and R. Fortin. 2002. Biological characteristics of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the Saint Lawrence River estuary and the effectiveness of management rules. Journal of Applied Ichthyology 18: 580-585.

Collins, M.R., T.I.J. Smith, and M.L. Moser. 2000. Habitat utilization and biological characteristics of adult Atlantic sturgeon in two South Carolina rivers. Transactions of the American Fisheries Society 129: 982-988.

Dadswell, M.J. 2006. A Review of the Status of Atlantic Sturgeon in Canada, with Comparisons to Populations in the United States and Europe. Fisheries: 218-229.

Davies, S.P., L. Tsomides, J.L. DiFranco, and D.L. Courtemanch. 1999. Biomonitoring retrospective: Fifteen year summary for Maine rivers and streams. State of Maine Department of Environmental Protection, Augusta, ME. 186 pp. http://www.maine.gov/dep/water/monitoring/biomonitoring/biorep2000.htm

Dionne, P.E., G.B.Zydlewski, M.T. Kinnison, J. Zydlewski, and G.S. Wippelhauser. Submitted. Reconsidering residency: Characterization and conservation implications of complex migratory patterns of shortnose sturgeon (*Acipenser* brevirostrum). Canadian Journal of Fisheries and Aquatic Sciences.

Dudley, R.W., 1999, Riverbed-sediment mapping in the Edwards Dam impoundment on the Kennebec River, Maine by use of geophysical techniques: U.S. Geological Survey Open-File Report 99-200, 7 p. Dudley, R.W., 1999, Riverbed-Sediment Mapping in the Edwards Dam Impoundment on the Kennebec River, Maine By Use of Geophysical Techniques: U.S. Geological Survey Open-File Report 99-200, 7 p. http://me.water.usgs.gov/reports/EdwardsBody.pdf

Fernandez, S.J., G.B. Zydlewski, J.D. Zydlewski, G.S. Wippelhauser, and M.T. Kinnison. 2010. Seasonal distribution and movements of shortnose sturgeon and Atlantic sturgeon in the

Penobscot River Estuary, Maine. Transactions of the American Fisheries Society 139: 1436-1449.

Fire, S.E., J. Pruden, D. Couture, Z. Wang, M-Y. D. Bottein, M.L. Hayes, T. Knott, D. Bouchard, A. Lichtenwalner, and G. Wippelhauser. 2012. Saxitoxin exposure in an endangered fish: association of a shortnose sturgeon mortality event with a harmful algal bloom. Marine Ecology Progress Series 460: 145-153.

Hatin, D., R. Fortin, and F. Caron. 2002. Movements and aggregation areas of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the St. Lawrence River estuary, Quebec, Canada. Journal of Applied Ichthyology 18: 586-594.

Huff, J.A. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyrinchus* desotoi, in Suwanee River, Florida. Florida Marine Resources Publication 16: 32 pp.

Johnson, J.H., D.S. Dropkin, B.E. Warkentine, J.W. Rachlin, and W.D. Andrews. 1997. Food habitats of Atlantic sturgeon off the central New Jersey coast. Transactions of the American Fisheries Society 126: 166-170.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of fishes of the mid-Atlantic bight: An atlas of eggs, larval, and juvenile stages. Volume 1. Acipenseridae through Ictaluridae. Chesapeake Biological Laboratory, Center for U.S Fish and Wildlife Service, U.S. Department of the Interior.

Kennebec River Resource Management Plan. 1993. Prepared by Natural Resources Policy Division, Maine State Planning Office, Augusta, Maine 04333. 196 pp.

Kynard, B. and M. Horgan. 2002. Ontogenetic behavior and migration of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, and shortnose sturgeon, *A. brevirostrum*, with notes on social behavior. Environmental Biology of Fishes 63: 137-150.

Kynard, B., M. Horgan, and M.Kieffer. 2000. Habitats used by shortnose sturgeon in two Massachusetts rivers, with notes on estuarine Atlantic sturgeon: A hierarchical approach. Transactions of the American Fisheries Society 129: 487-503.

Lichter, J., H. Caron, T.S. Pasakarnis, S.L. Rodgers, T.S. Squiers, Jr., and C.S. Todd. 2006. The ecological collapse and partial recovery of a freshwater tidal ecosystem. Northeast Naturalist 13: 153-178.

Mayer, L.M., D.W. Townsend, N.R. Pettigrew, T.C. Loder, M.W. Wong, D. Kistner-Morris, A.K. Laursen, A.D. Schoudel, C. Conairis, J. Brown, and C. Newell. 1996. The Kennebec, Sheepscot, and Damariscotta river estuaries: seasonal oceanographic data. University of Maine, Department of Oceanography Technical Report No. 9601. 110 pages. University of Maine, Department of Oceanography, 5741 Libby Hall, Orono, ME 04469.

MDEP (Maine Department of Environmental Protection). 2012. Surface Water Ambient Toxics Monitoring Program 2011 Final Report. MDEP, Augusta, ME 04333. 157 pp.

Murawski, S.A. and A. L. Pacheco. 1977. Biological and fisheries data on Atlantic sturgeon (*Acipenser oxyrinchus*). National Marine Fisheries service Technical Series Report 10: 1-69.

Savoy, T. 2007. Prey eaten by Atlantic Sturgeon in Connecticut waters. American Fisheries Society Symposium 56: 157-165.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184: 966 pp.

Secor, D.H. 2002. Atlantic sturgeon fisheries and stock abundances during the late nineteenth century. American Fisheries Society Symposium. 28: 89-98.

Sherman, S.A., V.A. Manfredi, J. Brown, H. Smith, J. Sowles, D.E Grout, D.W. Perkins, Jr., and R. Tetrault. 2003. Final report fall 2001 and spring 2002 Maine-New Hampshire inshore trawl survey. Technical Research Document 03/1. Submitted to NOAA Fisheries-Northeast Region, Cooperative Research Partners Initiative.

Smith, T.I.J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 14(1): 61-72.

Smith, T.I.J., E.K. Dingley, and D.E. Marchette. 1980. Induced spawning behavior and culture of Atlantic sturgeon. Progressive Fish Culturist. 42: 147-151.

Smith, T.I.J. and J.P. Clugston. 1997. Status and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 48: 335-346.

Smith, T.I.J., D.E. Marchette and R.A. Smiley. 1982. Life history, ecology, culture and management of Atlantic sturgeon, *Acipenser oxyrinchus*, Mitchill, in South Carolina. South Carolina Wildlife Marine Resources, Resources Department, Final Report to U.S. Fish and Wildlife Service Project AFS-9. 75 pp.

Stevenson, J.T. and D.H. Secor. 1999. Age determination and growth of Hudson River Atlantic sturgeon, *Acipenser oxyrinchus*. Fishery Bulletin 97: 153-166.

Van Eenennaam, J.P., S. I. Doroshov, G.P. Moberg, J.G. Watson, D.S. Moore, and J. Linares. 1996. Reproductive conditions of the Atlantic sturgeon (*Acipenser oxyrinchus*) in the Hudson River. Estuaries 19: 769-777.

Vladykov, V.D. and J.R. Greeley. 1963. Order Acipenseroidei. Pages 24-60 in: Fishes of the Western North Atlantic. Sears Foundation. Marine Research, Yale University.

Waldeman, J.R., C. Grunwald, J. Stabile, and I. Wirgin. 2002. Impacts of life history and biogeography on the genetic stock structure of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*, Gulf sturgeon *A. oxyrinchus desotoi*, and shortnose sturgeon *A. brevirostrum*. Journal of Applied Ichthyology 18: 509-518.

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

Wippelhauser, G.S. and T.S. Squiers Jr. Submitted. Shortnose sturgeon and Atlantic sturgeon in the Kennebec Estuary, Androscoggin Estuary, and Sheepscot Estuary, Maine

Wirgin, I., J.R. Waldeman, J. Rosko, R. Gross, M.R. Collins, S.G. Rogers, and J. Stabile. 2000. Genetic structure of Atlantic sturgeon populations based on mitochondrial DNA control regions sequences. Transactions of the American Fisheries Society 129: 476-486.

Wirgin, I., L. Maceda, J.R. Waldeman, S. Wehrell, M. Dadswell, and T. King. 2012. Stock origin of migratory Atlantic sturgeon in Minas basin, inner Bay of Fundy, Canada, determined by microsatellite and mitochondrial DNA analysis. Transactions of the American Fisheries Society 141: 1389-1398.

Yoder, C.O. and B.H. Kulik. 2003. An assessment of the Kennebec River fish assemblage: Description of sampling protocols and preliminary data analysis for IBI development.

Young, J.R., T.B. Hoff, W.P. Dey, and G.H. Hoff. 1988. Management recommendations for a Hudson River Atlantic sturgeon fishery based on an age-structured population model. Pp. 353-365. In C.L. Smith, (editor) Fishery Research in the Hudson River. State University of New York Press. Albany.

Table 1. Total harvest of Atlantic sturgeon in Maine and harvest by county, 1909-1981.

Year	Total pounds	York	Cumberland	Sagadahoc	Lincoln	Knox	Penobscot	Hancock	Washington
1909	6,000						6,000		
1910	9,000						9,000		
1911	7,500						7,500		
1912	20,000			12,400			7,600		
1913	8,100	600					7,500		
1914	200						200		
1933	2,308	684	708	749	167				
1935	900		600		300				
1937	1,200		1,200						
1938	500		500						
1940	223								
1942	39		39						
1943	283		283						
1945	406		250			125		31	
1946	324		324						
1947	313		243			70			
1948	228		196					32	
1949	409		370	39					
1950	393		203	190					
1951	528		395	133					
1952	637		509			27		101	
1953	1,165		618	68	55			424	
1954	1,440		1,400					40	
1955	570		526	19				25	
1956	690		580	100		10			
1957	819		779		40				
1958	730		730						
1959	800		522	278					
1961	1,213		947	198		56		12	
1962	611		563		48				
1963	766		478	288					
1964	72		72						
1965	598		496	102					
1966	444		372	72					
1967	1,583		485	1,038	60				
1969	2,783		174	2,543	66				
1970	6,201		585	5,299	317				
1971	856		304	384	144	24			
1972	1,055	252	108	414	244	37			
1973	318	150		126	42				
1974	368		168	78	74	48			
1975	1,424	552	238	500	134				
1976	1,339	485		660	150	44			
1977	4,598	2,692	1,442	452	12				
1978	1,861	1,027	441	54	26			288	25
1979	3,166	822	755	1,130	92	325		42	
1980	3,438	1,499	429	1,272				173	65
1981	3,304	606	794	1,688				216	
	101,703	9,369	19,826	30,274	1,971	766	37,800	1,384	90

Table 2. Total and monthly gill net sampling effort (net-h) in the Upper Kennebec Estuary (UKE), Merrymeeting Bay (MMB), Androscoggin Estuary (AE), Lower Kennebec Estuary (LKE), and Sasanoa and Back river passages (S-B), 1977-2000.

Zone	Year	Total	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
UKE	1977	360.0		24.0	72.0	96.0	48.0	120.0		
	1978	408.0		48.0	120.0	96.0	96.0	48.0		
	1979	112.0		24.0	32.0	56.0				
	1980	120.0		48.0		72.0				
	1981	120.0	40.0	32.0	24.0	24.0				
	1994	7.2				7.2				
	1996	4.4		2.9	1.0	0.5				
	1997	83.5		1.6	1.5	80.4				
	1998	2.4		2.4						
	1999	22.8		22.8						
	2000	2.4			2.4					
MMB	1977	144.0		48.0	48.0		48.0			
	1978	312.0		24.0	56.0	88.0	48.0	48.0	48.0	
	1979	288.0	72.0	96.0	72.0			48.0		
	1980	48.0				48.0				
	1981	88.0			56.0	24.0		8.0		
	1995									
	1996	28.7					0.0		9.0	19.7
	1998	47.4							26.5	20.9
	1999	11.9				4.4	7.5			
	2000	71.0							46.7	24.3
AE	1980	232.0	8.0	168.0	24.0		32.0			
	1981	144.0	88.0	56.0						
	1982	288.0	48.0	192.0	48.0					
	1983	288.0	48.0	192.0	48.0					
	1993	142.9	72.0	70.2	0.7					
	1999	78.3		78.3						
LKE	1977	336.0	72.0	96.0	24.0	24.0	48.0	48.0	24.0	
	1978	72.0			24.0	24.0	24.0			
	1979	336.0		24.0	184.0		56.0	24.0	48.0	
	1980	152.0	48.0		32.0	24.0			48.0	
	1981	200.0			56.0	48.0	48.0	48.0		
	1996	24.4							24.4	
	1997	7.5			0.0	7.5				
	1998	186.5	3.3	34.8	2.1	2.0	13.3	36.1	94.9	
	1999	226.2				33.7	21.8	170.6		
	2000	504.7							416.9	87.7
S-B	1977	240.0		24.0	48.0	24.0	48.0	24.0	24.0	48.0
	1978	336.0		24.0	72.0	96.0	72.0		72.0	
	1979	264.0	24.0	24.0	24.0		72.0	72.0	48.0	
	1980	328.0			104.0	56.0	24.0	48.0	96.0	
	1981	184.0			64.0	48.0	24.0	48.0		
	1996	38.2							30.9	7.3
	1997	0.0			0.0					
	1998	57.4					7.2	27.2	23.0	
	1999	105.1				8.1	8.4	88.6		
	2000	93.0							69.3	23.6

Table 3. Monthly gill net catch of sturgeon from April (A) through November (N) in the Upper Kennebec Estuary (UKE), Merrymeeting Bay (MMB), Androscoggin Estuary (AE), Lower Kennebec Estuary (LKE), and Sasanoa and Back rivers (S-B), 1977-2000. Bold numerals indicate that CPUE was greater than the annual mean, a – denotes no catch, and a blank denotes no effort was expended.

		Number sturgeon caught										Number sturgeon caught							
Zone	Year	A	M	J	J	A	S	O	N	Zone	Year	A	M	J	J	A	S	O	N
UKE	1977		-	-	1	-	-			LKE	1977	-	1	**1**	-	**3**	**3**		
	1978		-	-	**2**	-	-				1978			-	**1**	-			
	1979	-	-	1	-						1979		-	-		-	**16**	-	
	1980		-		-						1980							**9**	
	1981	-	-	-	-						1981			-	-	-	1		
	1994				**7**						1996								
	1996		-	**2**	**8**						1997			-	-				
	1997		-	-	**13**						1998	-	19	1	-	-	**42**	**61**	
	1998		-								1999				4	10	20		
	1999		-								2000							67	12
	2000			8						S-B	1977			-	-	-	-	-	
MMB	1977		-	-		-					1978	-	-	-	-	-		-	
	1978		**2**	-	1	-	**2**	-			1979		-	**1**		-	-	-	
	1979	-	-	-			**8**				1980			-	-	-	-	-	
	1980				**8**						1981			-	-	-	-		
	1981			**2**	**1**		**3**				1996							1	-
	1996					-		1	-		1997			-					
	1998							**15**	1		1998					-	3	-	
	1999				**4**	**3**					1999				3	5	6		
	2000							**11**	**6**		2000							2	1
AE	1980	-	-	-	-														
	1981	-	-																
	1982	-	-	-															
	1983	-	-	-															
	1993	-	-	-															
	1999		-																

Table 4. Location of acoustic telemetry receivers in the Kennebec, Androscoggin, and Sheepscot watersheds, Maine, and the years deployed.

	Year deployed					
Receiver	2007	2008	2009	2010	2011	2012
rkm 102	Y	Y	Y	Y	Y	lost
rkm 101			Y			
rkm 99				Y		
rkm 87	Y	Y	Y	Y	Y	lost
rkm 75					Y	Y
rkm 74			Y	Y	Y	
rkm 72	Y	Y	Y	Y	Y	Y
rkm 68	Y	Y	Y	Y	lost	lost
rkm 65	Y	Y	Y	Y	Y	Y
rkm 64			Y	Y	Y	Y
rkm 58	lost		Y	Y	Y	Y
rkm 55	Y	Y	Y	Y	Y	Y
rkm 48	Y	Y	Y	Y	Y	Y
rkm 42	Y	Y	Y	Y	Y	Y
rkm 41	Y	Y	Y	Y	Y	Y
rkm 34	Y	Y	Y	Y	Y	Y
rkm 31	Y	Y	Y	Y		
rkm 30	Y	Y	Y	Y	Y	Y
rkm 21	Y	Y	Y	Y	Y	Y
rkm 17					Y	
rkm 16	Y	Y	Y	lost	Y	Y
18		Y				
19		Y				
20		lost				
21		lost				

Table 5. Date, capture location in the Kennebec and Androscoggin estuaries, and biological characteristics of Atlantic sturgeon tagged with an acoustic transmitter, 2009-2012.

Species	RKM	Date	Acoustic tag	TL (cm)	Sex
Atlantic sturgeon	72	7/20/09	52185	152.0	
Atlantic sturgeon	72	7/21/09	52184	158.0	
Atlantic sturgeon	72	7/21/09	52187	152.0	
Atlantic sturgeon	72	7/22/09	52186	199.0	
Atlantic sturgeon	72	7/22/09	52188	166.0	M
Atlantic sturgeon	70.1	6/17/10	52191	192.0	
Atlantic sturgeon	74	6/24/10	52189	161.0	
Atlantic sturgeon	74	6/25/10	52172	196.0	
Atlantic sturgeon	74	6/25/10		161.0	
Atlantic sturgeon	74	6/25/10		171.0	
Atlantic sturgeon	74	6/25/10		175.0	
Atlantic sturgeon	74	6/25/10	52177	154.0	
Atlantic sturgeon	74	6/25/10	52174		M
Atlantic sturgeon	74	6/25/10	52190	164.0	
Atlantic sturgeon	74	6/25/10	52173	152.0	
Atlantic sturgeon	74	6/25/10	52175	187.0	
Atlantic sturgeon	75	6/16/11	52182		
Atlantic sturgeon	75	6/17/11	52183	169.2	
Atlantic sturgeon	75	6/20/11	52180	184.5	
Atlantic sturgeon	75	6/20/11	52181	188.5	M
Atlantic sturgeon	30	6/21/11		157.2	
Atlantic sturgeon	30	6/21/11	52176	166.6	
Atlantic sturgeon	30	6/21/11	52178	187.2	
Atlantic sturgeon	30	6/21/11	52179	181.4	M
Atlantic sturgeon	30	6/21/11		167.2	
Atlantic sturgeon	30	6/21/11		181.3	
Atlantic sturgeon	30	6/21/11		158.3	
Atlantic sturgeon	30	6/21/11		163.5	
Atlantic sturgeon	72	6/29/11		164.2	
Atlantic sturgeon	72	6/29/11		182.2	
Atlantic sturgeon	72	6/29/11		161.7	
Atlantic sturgeon	72	6/29/11		180.9	
Atlantic sturgeon	72	6/30/11		166.8	
Atlantic sturgeon	72	7/5/11		192.7	M
Atlantic sturgeon	72	7/5/11		166.1	
Atlantic sturgeon	72	7/8/11		170.2	
Atlantic sturgeon	72	7/8/11		176.2	M
Atlantic sturgeon	72	7/11/11		197.4	M
Atlantic sturgeon	72	7/11/11		163.3	

Figure 1. Map of the study area in the Kennebec, Androscoggin, and Sheepscot estuaries, Maine. Distances in river kilometers indicated by lines and adjacent numerals. Gill net sampling stations indicated by black circles. Letters indicate the Sasanoa River (S), Back River (B), Hockomock Bay (H), Montsweag Bay (M), and Knubble Bay (K).

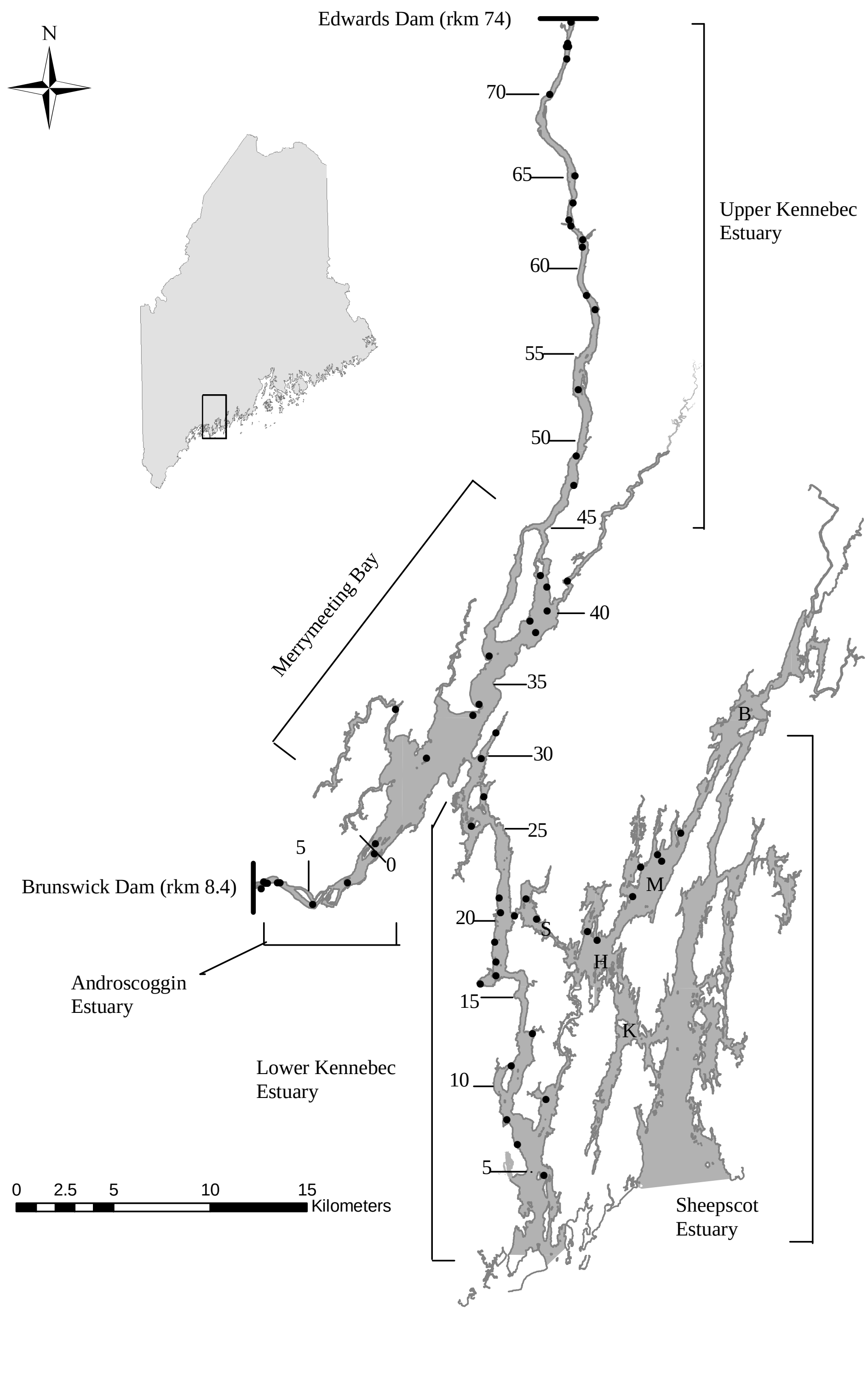

Figure 2. Box plots of total lengths of Atlantic sturgeon (n=337) captured in the Kennebec, Androscoggin, and Sheepscot estuaries, 1977-2000. Box ends = 25th and 75th percentiles of length; line within box=median; error bars [whiskers] = ± 1.5(interquartile range); dots = outliers.

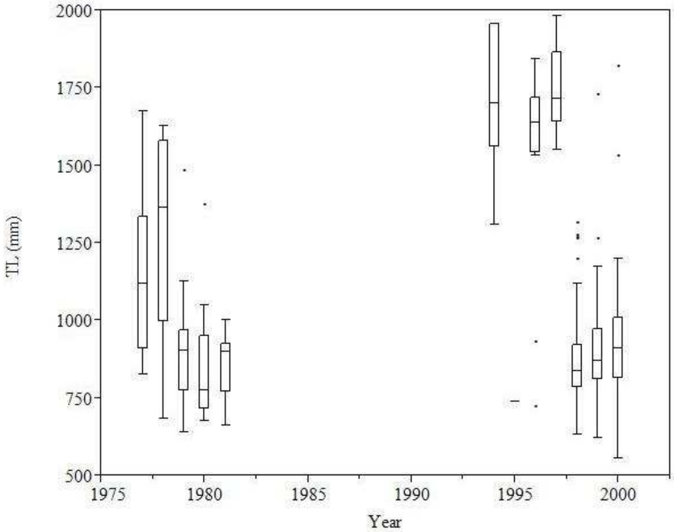

Figure 3. Distribution of Atlantic sturgeon in the Kennebec, Androscoggin, and Sheepscot estuaries, Maine, from 1977-2000. Circle size is mean CPUE for the station (sCPUE); stations with CPUE=0 are not shown. Distances in river kilometers indicated by lines and adjacent numerals. Letters indicate the Sasanoa River (S), Back River (B), Hockomock Bay (H), Montsweag Bay (M), and Knubble Bay (K).

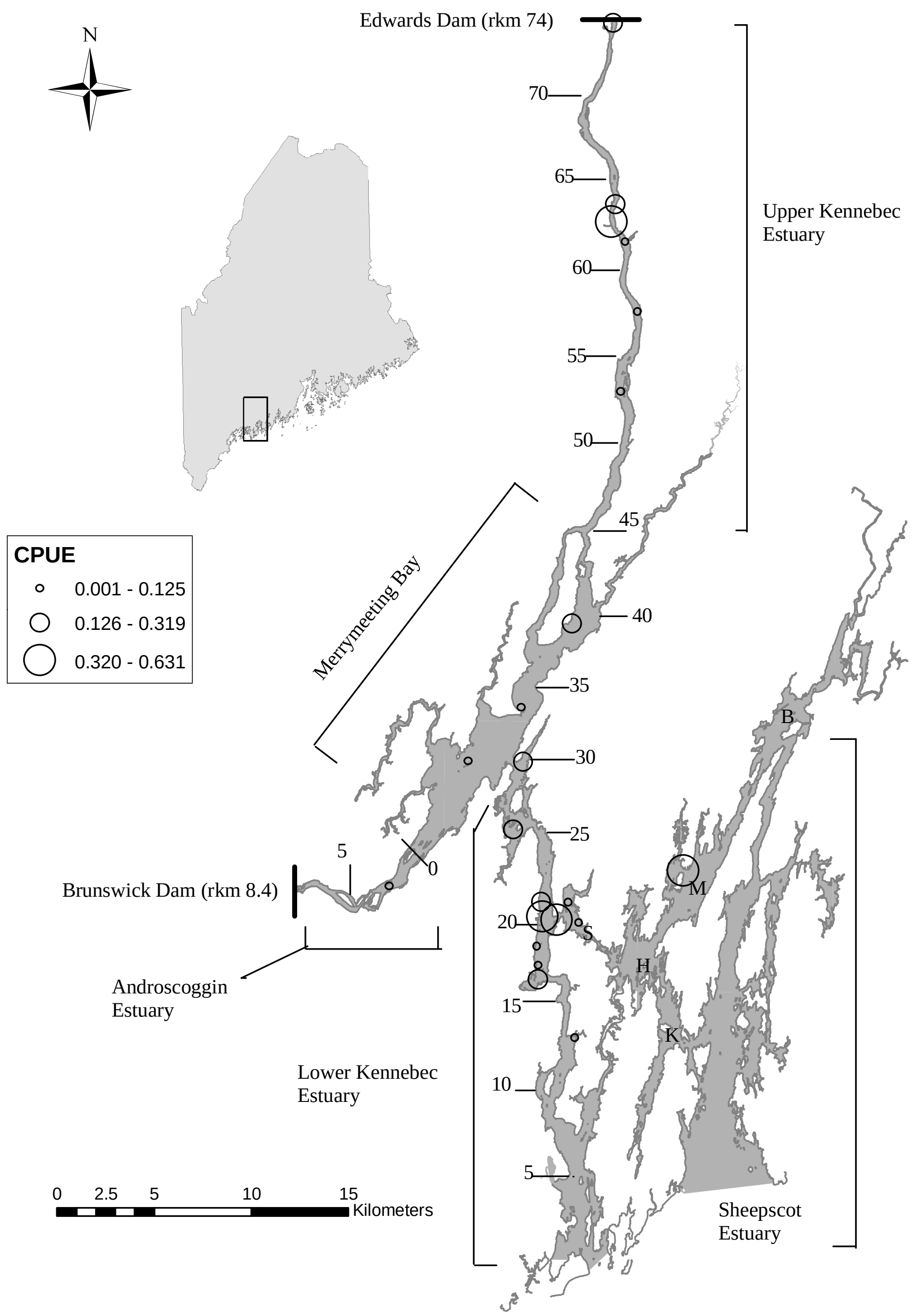

Figure 4. Capture locations (rkm) in the Kennebec Estuary of Atlantic sturgeon measured for total length (TL). Vertical lines delineate approximate TL of life intervals: early juveniles (<500 mm), intermediate juveniles (500-700 mm), late juveniles (700-1490 mm), and adults (>1500 mm). Juvenile stages indicated by X and adults by diamond.

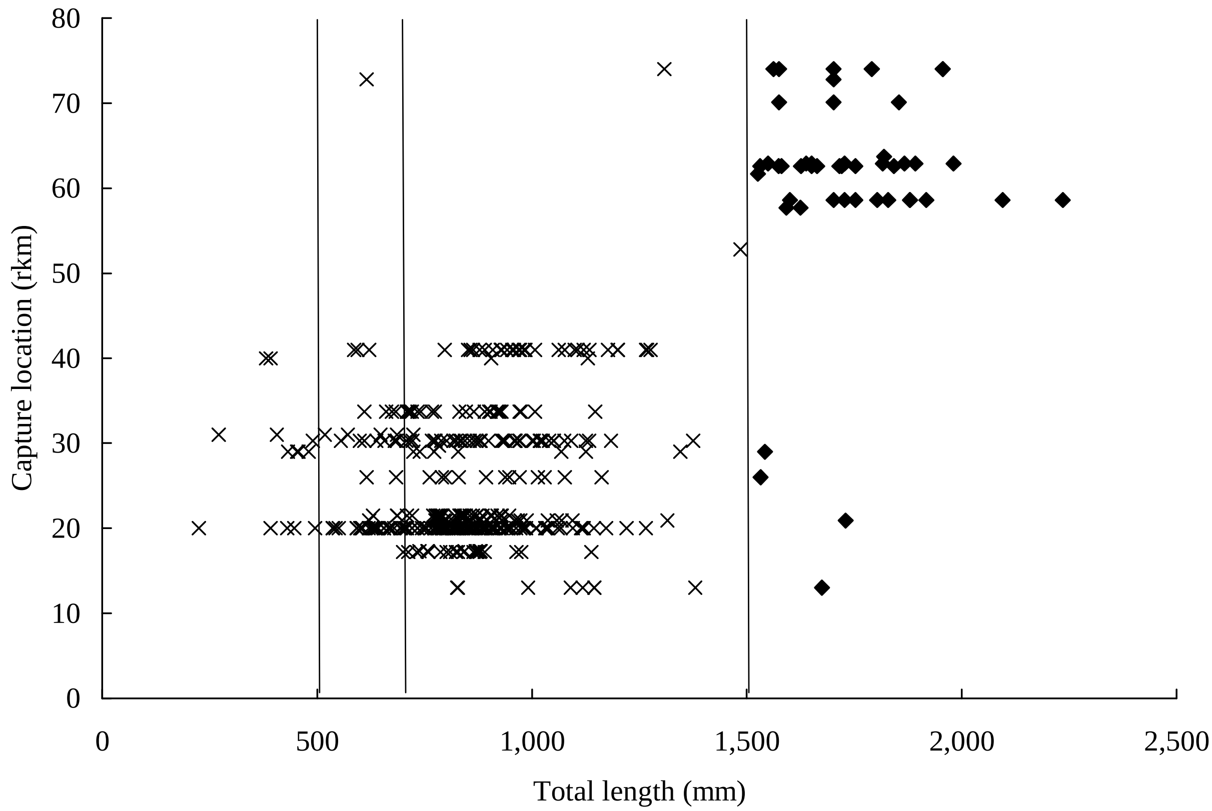

Figure 5. Map of the study area in the Kennebec, Androscoggin, and Sheepscot estuaries, Maine. Receiver locations are indicated black circles. Gill net sampling stations indicated by black stars. Letters indicate the Sasanoa River (S), Back River (B), Hockomock Bay (H), Montsweag Bay (M), and Knubble Bay (K). Dams are indicated by heavy black lines.

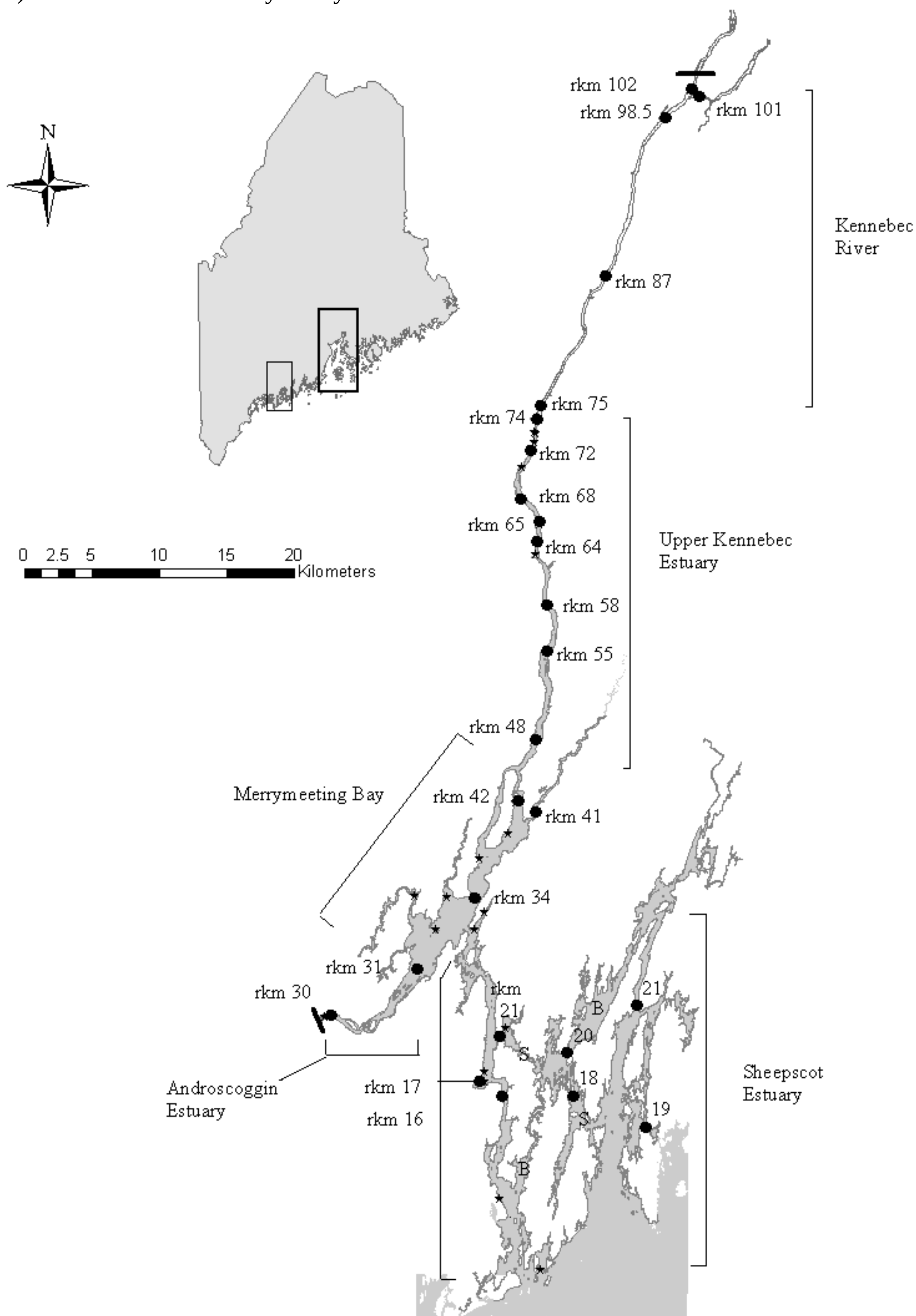

Figure 6. Movements of five Atlantic sturgeon caught and tagged at a known spawning area in the Upper Kennebec Estuary in 2009. Symbols indicate date and location of each detection.

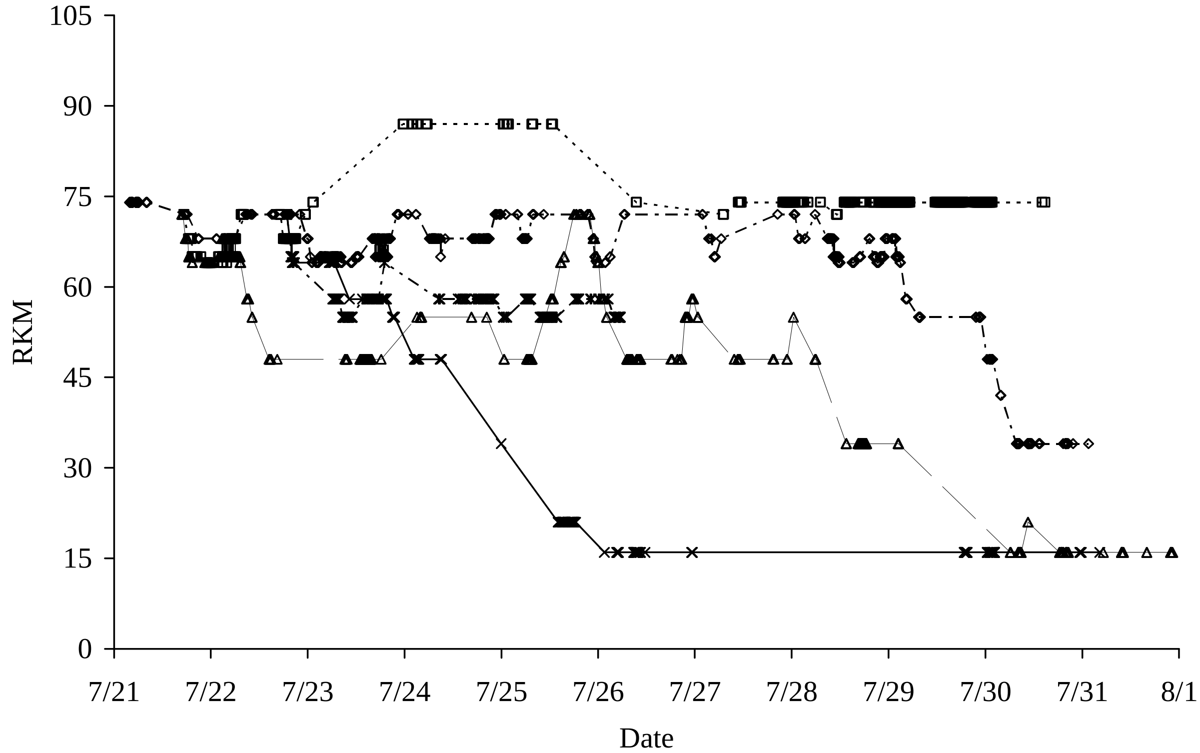

Figure 7. Movements of seven Atlantic sturgeon caught and tagged at a known spawning area in the Upper Kennebec Estuary in 2010. Symbols indicate date and location of each detection.

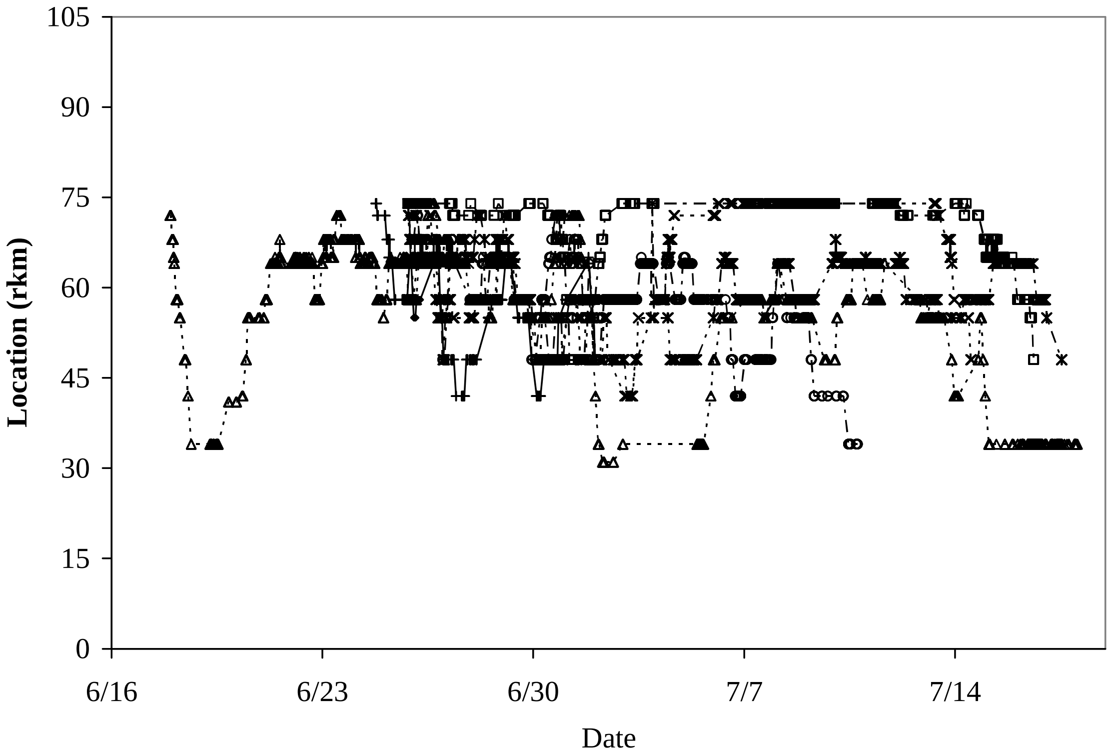

Figure 8. Movements of three Atlantic sturgeon caught and tagged at a newly identified spawning area in the Kennebec River and three caught and tagged at a newly identified spawning area in the Androscoggin estuary in 2011. Symbols indicate date and location of each detection.

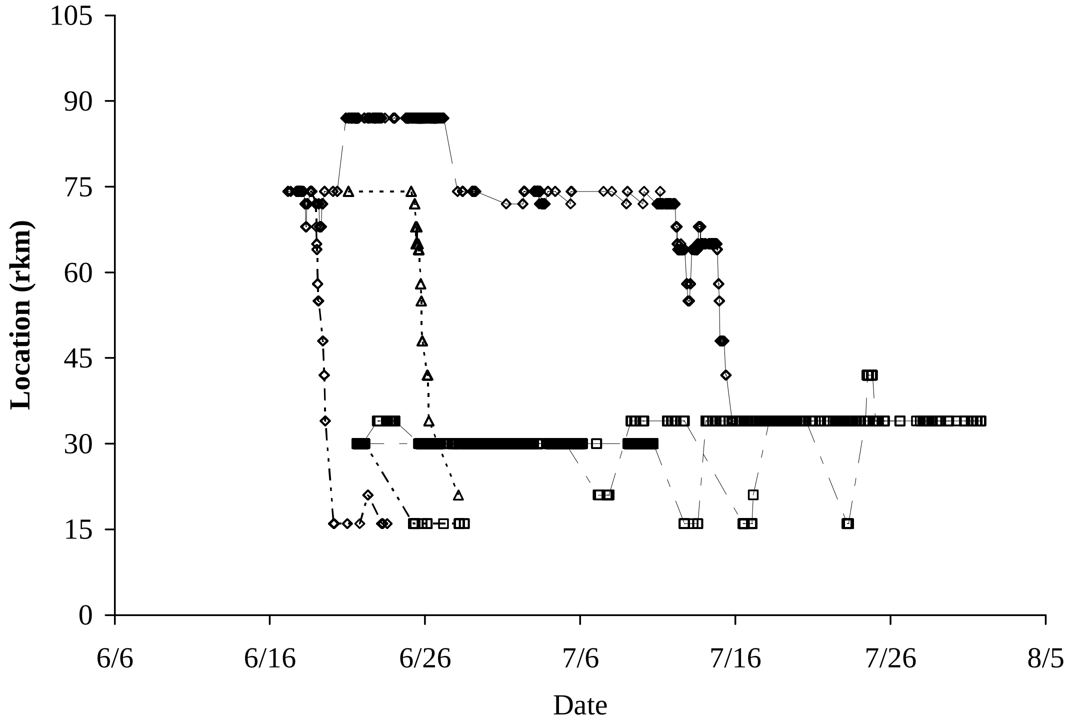

Figure 9. Freshwater discharge in the Kennebec River (solid line) and bottom water temperature at rkm 68 (triangles) in 2009. Horizontal double-headed arrow indicates when four Atlantic sturgeon caught and tagged by ME DMR (DMR) in 2009 were detected in the Upper Kennebec Estuary (UKE).

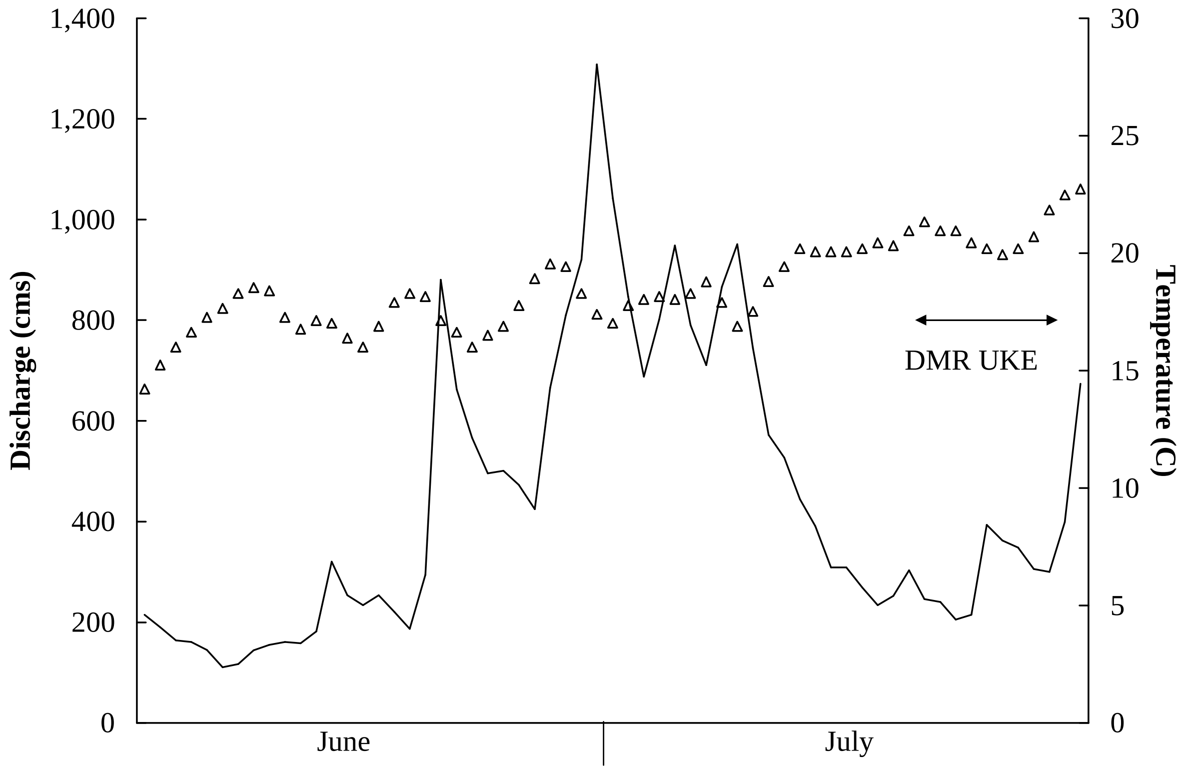

Figure 10. Freshwater discharge in the Kennebec River (solid line) and bottom water temperature at rkm 68 (triangles) in 2010. Solid double-headed arrow indicates when seven Atlantic sturgeon caught and tagged by ME DMR (DMR) n the Kennebec River were detected in the Upper Kennebec Estuary (UKE). Dashed double-headed arrow indicates when two Atlantic sturgeon caught and tagged by the University of Maine (UM) in the Penobscot, one in 2008 and one in 2009, were detected in the UKE.

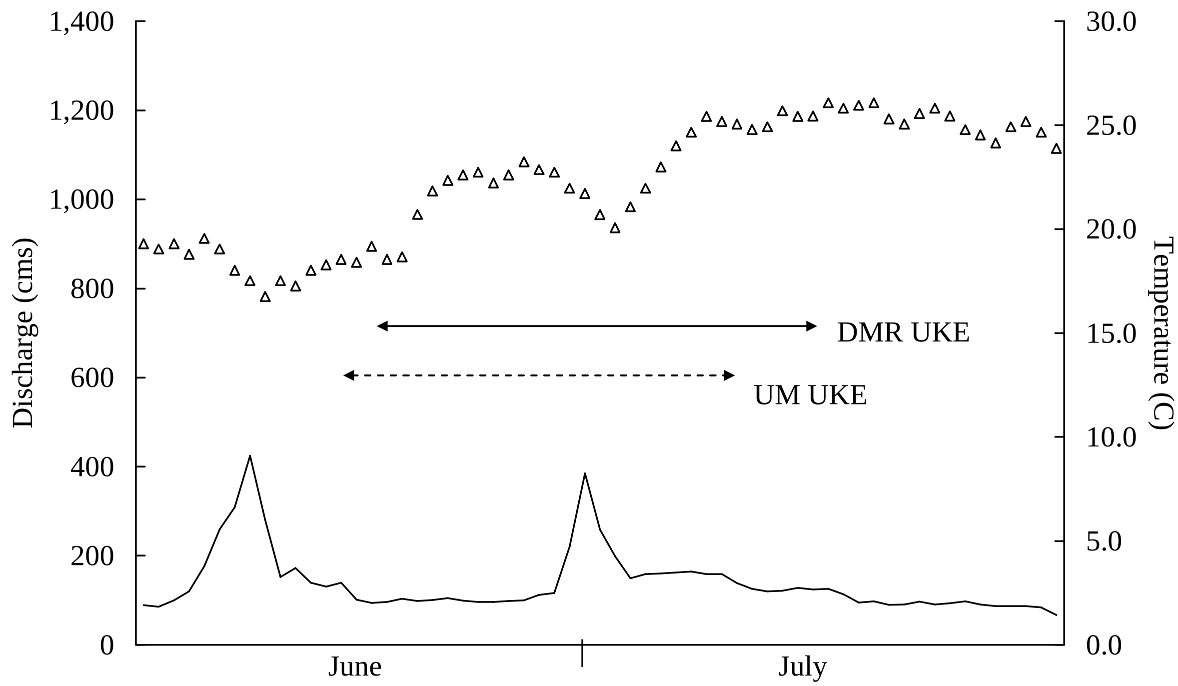

Figure 11. Freshwater discharge in the Kennebec River (solid line) and Androscoggin River (dotted line), and bottom water temperature at rkm 102 (diamond) and rkm 30 (cross) in 2011. Solid double-headed arrow indicates when three Atlantic sturgeon caught and tagged by ME DMR (DMR) in the Kennebec in 2011 were detected at the spawning area at in the Upper Kennebec Estuary (UKE); one of the fish also migrated moved upstream to the Kennebec River (DMR KR). Dashed double-headed arrow indicates when three Atlantic sturgeon caught and tagged by UM DMR in the Androscoggin Estuary (AE) in 2011 and three caught and tagged by the University of New England (UNE) in the Saco were detected in the AE. Stars indicate when Atlantic sturgeon larvae were caught in the KR and UKE .

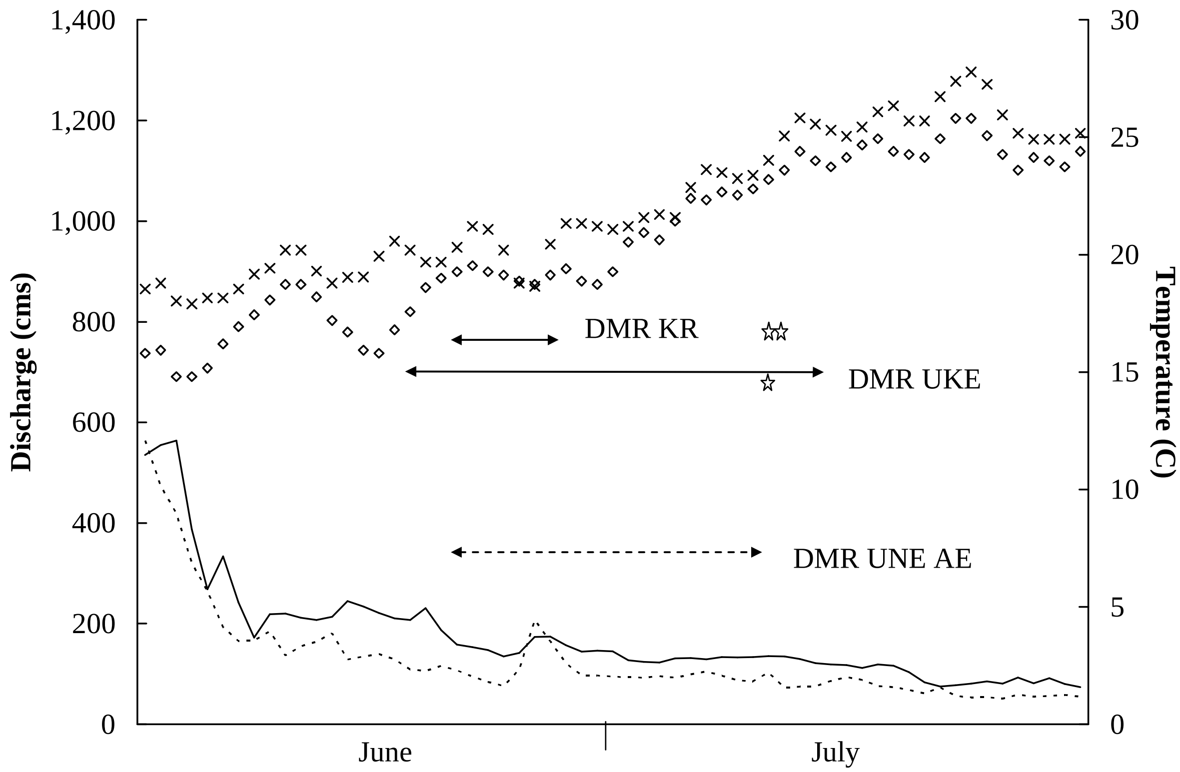

Figure 12. Total bycatch by year (top panel) and month (bottom panel) of Atlantic sturgeon or sturgeon from the National Marine Fisheries Service Fishery Observer database in areas 511, 512, and 513 (GoM) for the period 1991-2010.