**FINAL REPORT**

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

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# Executive Summary

In 2006, the Maine Department of Marine Resources received a 6-year grant from NOAA's Office of Protected Resources to work in collaboration with the Massachusetts Division of Marine Fisheries and New Hampshire Fish and Game Department to document the status of and develop conservation strategies for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), rainbow smelt (*Osmerus mordax)*, and Atlantic salmon (*Salmo salar*) (NA06NMF4720249). At the time, each was federally listed as Species of Concern in the Gulf of Maine – rainbow smelt were listed as a Species of Concern in 2004, Atlantic salmon in 1997, and Atlantic sturgeon in 1988. Since the project began, Atlantic salmon and Atlantic sturgeon have been listed under the federal Endangered Species Act (ESA) in the Gulf of Maine, in 2009 and 2012, respectively. The grant obligations were amended in 2008 to remove Atlantic salmon from this project plan due to budget reductions and impending listing under the ESA. This final report provides first a summary of key elements of the project and also an appendix containing all technical reports, outreach publications, management plans, and other products completed under this grant.

Work on rainbow smelt focused on several objectives:

1) Documenting range contraction and range-wide population declines based on historical data and accounts,
2) Evaluating the status of rainbow smelt populations in the Gulf of Maine region,
3) Developing a population index to track the strength of spawning runs,
4) Assessing a range of potential threats to rainbow smelt populations, and
5) Proposing management actions to help conserve rainbow smelt throughout the Gulf of Maine region.

Work on Atlantic sturgeon focused on:

1) Reviewing the basic biology of Atlantic sturgeon,
2) Compiling detailed information from research on Atlantic sturgeon in the Gulf of Maine for the period 1977-2001 and 2009-2012,
3) Assessing movements with the Kennebec River and Merrymeeting Bay, identifying key habitats in this river and estuary complex, and increasing the sample size for genetic analysis, and
4) Summarizing the status of the Gulf of Maine Atlantic sturgeon, identifying threats, and recommending management actions.

# Objective 1 – Establish an Inter-Agency Species of Concern Technical Advisory Committee

### *Activity 1 – Technical Advisory Committee – Year 1*

The Technical Advisory Committee (TAC) was established in 2007 and includes scientists for all three species originally named under this grant (Atlantic salmon, Atlantic sturgeon, and rainbow smelt). Though work on Atlantic salmon was removed from the project description in 2008, all original TAC members continued to provide guidance and input throughout the project period. These members are:

Maine Department of Marine Resources (ME DMR):

Seth Barker*, Habitat Scientist

Claire Enterline*+, Diadromous Species Scientist (rainbow smelt lead)

John Sowles*+, Ecology Division Director (Retired in 2010 but remained active on TAC)
Joan Trial, Diadromous Species Biologist (Atlantic salmon lead)
Gail Wippelhauser+, Diadromous Species Scientist (Atlantic sturgeon lead)

Maine Department of Inland Fisheries and Wildlife (ME IFW):
Merry Gallagher, Freshwater Fisheries Scientist

New Hampshire Fish and Game Department (NHFG):
Jessica Carloni*, Fisheries Scientist
Douglas Grout, Marine Division Director
Cheri Patterson, Marine Program Supervisor

Massachusetts Division of Marine Fisheries (MA DMF):
Matthew Ayer*, Recreational Fisheries Scientist
Bradford Chase*, Diadromous Species Scientist
Scott Elzey*, Ageing Lab Manager
Christopher Wood*, Project Technician

University of Maine, Gulf of Maine Research Institute (GMRI):
Katherine Mills*, Diadromous Species Scientist (formally with NHFG)

A Subcommittee on Rainbow Smelt (SRS) was also established in 2007 (members of the SRS are listed above with a (*) following their name). A Subcommittee on Atlantic Sturgeon (SAS) was established in 2008 (members of the SAS are listed with a (+) following their name).

Past progress reports have included meeting summaries, and are not included in this final report. All past reports are available at http://www.maine.gov/dmr/smelt/index.htm. The following describes the meeting frequency of each group and major milestones accomplished by each group.

While the full TAC group did not meet regularly, the members were in frequent contact to review field protocols, data analysis techniques, results, reports, and management implications. All reports (including the species conservation plans) were vetted through the entire TAC before release.

The full TAC met at the commencement of the grant in February 2007 to determine specific project tasks, timelines, desired outcomes, and a working plan for utilizing the expertise of each member of the group. An unpublished web link was created to share information between PIs (http://www.maine.gov/dmr/rm/smelt/). This page was recently revised for public consumption, and includes all previous grant reports for this project, as well as methods and field protocols, technical reports, the smelt conservation plan, presentations, and other smelt species information (http://www.maine.gov/dmr/smelt/index.htm).

The full Species of Concern Technical Committee (SOCTAC) met again in January, 2011 following the Fourth North American Workshop on Rainbow Smelt to briefly summarize work to date and discuss future work both under this grant and efforts beyond the grant. The group discussed research that was presented during the workshop, specifically work performed by the Canadian DFO that used various methods (ichthyoplankton sampling, using tiles to collect eggs, adult spawn timing) to identify smelt spawning locations in a large river system (the St. Lawrence River). While we have identified spawning locations in the U. S. Gulf of Maine that occurs in smaller rivers and streams, we have not identified the timing and location of spawning in large rivers (Merrimack, Kennebec, Penobscot, St. Croix rivers). Work towards this end is currently being completed on the

Penobscot River by the NOAA field office as part of a larger project (the Penobscot River Restoration Project) – the group collaborating on this effort to share data, methods, and information. Members of the smelt and sturgeon subgroups briefly described work-to-date, remaining work under the current grant, and questions that would remain unanswered. We identified possible directions for future research and management including restoration projects and assessment, the impacts of sea level rise on smelt and sturgeon spawning habitat, and the effects of warming ocean temperatures on smelt movements and physiology.

The Sub-group on Rainbow Smelt (SRS) met frequently, holding biannual meetings to discuss the upcoming field seasons (late winter meetings) and results and implications (late summer meetings). The group also met in the field each spring to practice new survey techniques (e.g., water velocity monitoring) to ensure all samples were being conducted in a standard way, following the Quality Assurance Program Plan adopted by the group (Chase 2010). Early in the project (October and November 2007 meetings), the group adopted standard field methods to monitor spawning rainbow smelt populations and habitat quality at index sites in Massachusetts, New Hampshire, and Maine. These methods are further described in this report under Objective 2, Activity 3 (Long Term Index Stations). Possible threats to spawning success were identified by the group in 2007 that directed field work 2008-2012 – these included: 1) reduced egg viability due to high periphyton growth, siltation, poor water quality and/or exposure to heavy metals; 2) pathological problems including parasites and long-term disease; 3) reduced fitness due to accumulated toxic contaminants; 4) channelization and flow disruptions. Throughout the grant period, this group worked closely to assist each other with data analysis, reporting, provide guidance when changes in management strategies were made, and to produce both technical documents and outreach materials. Because rainbow smelt are not an inter-state managed species, before this group was established there was no regional rainbow smelt collaboration. This group will continue to work closely together in the future as the Gulf of Maine Rainbow Smelt Committee and will continue regional monitoring and data sharing programs. Major accomplishments of this group to date include:

- A Regional Conservation Plan for Anadromous Rainbow Smelt in the U.S. Gulf of Maine (Enterline *et al.* 2012, Appendix A)
- "Rainbow Smelt: An Imperiled Fish in a Changing World", a six-page informational pamphlet about rainbow smelt biology, population trends, threats, and regional monitoring efforts (Appendix B)
- www.restorerainbowsmelt.com, a central website proving information about rainbow smelt biology, population trends, threats, and regional monitoring efforts
- Revising smelt fishing regulations in Massachusetts and Maine to limit take (Appendix C and D)
- Hosting the Fourth North American Workshop on Rainbow Smelt, and publishing the Extended Abstract Proceedings (Wood *et al.* 2012, Appendix E)
- Quality Assurance Program Plan (QAPP) for Water Quality Measurements Conducted for Diadromous Fish Habitat Monitoring (Chase 2010 , Appendix F)
- Regional fyke net monitoring field protocol (Appendix G)
- Regional standardized ageing methods and equipment (Appendix H)

The Subgroup on Atlantic Sturgeon (SAS) led by Gail Wippelhauser met frequently to discuss efforts to collect and compile information about Atlantic sturgeons' use of the Kennebec River and Merrymeeting Bay area. Early in the granting period, the group reviewed data from past efforts by the ME DMR to locate sturgeon in the area using gill nets. Our efforts focused on compiling these data and using the results to inform telemetry studies. In turn, patterns of movement discerned from the telemetry studies led to habitat mapping using multi-beam technology. After determining that the area was likely supporting spawning by Atlantic sturgeon, the group decided to pursue ichthyoplankton monitoring in the area and documented three genetically confirmed Atlantic sturgeon larvae. Through these efforts, Dr. Wippelhauser produced the first substantial reports describing Atlantic sturgeon use in the Kennebec River and Merrymeeting Bay area. Major accomplishments include:

- A Regional Conservation Plan for Atlantic Sturgeon in the U. S. Gulf of Maine (Appendix I)
- A total of 118 Atlantic sturgeon were caught in the Kennebec River and Merrymeeting Bay area from 2009 to 2012. Of these, 109 were PIT tagged, an acoustic tag was externally attached to 20 caught on spawning grounds, and 20 were implanted with an acoustic tag
- Tissue samples were taken from 64 Atlantic sturgeon, 37 of which were taken from fish on the spawning grounds, 25 from large fish caught in Merrymeeting Bay in August, and two from juveniles caught in Merrymeeting Bay in late fall
- A summary report of 1977-2001 Atlantic sturgeon data from the Kennebec River and Merrymeeting Bay area (Appendix J)
- A manuscript summarizing the movements and habitat use of both shortnose and Atlantic sturgeon in the Kennebec River and Merrymeeting Bay
- Documented overwintering habitat in the Kennebec River using high definition imaging sonar
- Documented likely spawning area in the Kennebec River using telemetry, capture of ripe males at this location, and capture of three genetically confirmed Atlantic sturgeon larvae below this site
- Documented likely spawning area in the Androscoggin River using telemetry and capture of ripe males at this location

This report summarizes the major findings and accomplishments of this project, but does not present in detail all data and analyses completed. A list of all datasets collected as part of this project is included in Appendix K. Datasets are available upon request.

## Objective 2 – Complete a comprehensive GOM inventory for each species

### *Activity 1 – Information Compilation – Year 1*

Information was collected for both rainbow smelt and Atlantic sturgeon from past survey efforts and monitoring efforts not directly associated with this project. When possible, these data were compiled regionally into a single data source and put into a GIS format. Each species' conservation plan describes this information in detail and uses it to inform analyses and management recommendations (Appendix A and Appendix I). The information available for each species is briefly described here.

For rainbow smelt, information about the biology, historical fisheries and habitat use, and fisheries dependent and independent current monitoring efforts was synthesized for the species conservation plan (Appendix A). A thorough literature review was conducted to inform this work and was made publicly available (http://restorerainbowsmelt.com/?page_id=518).

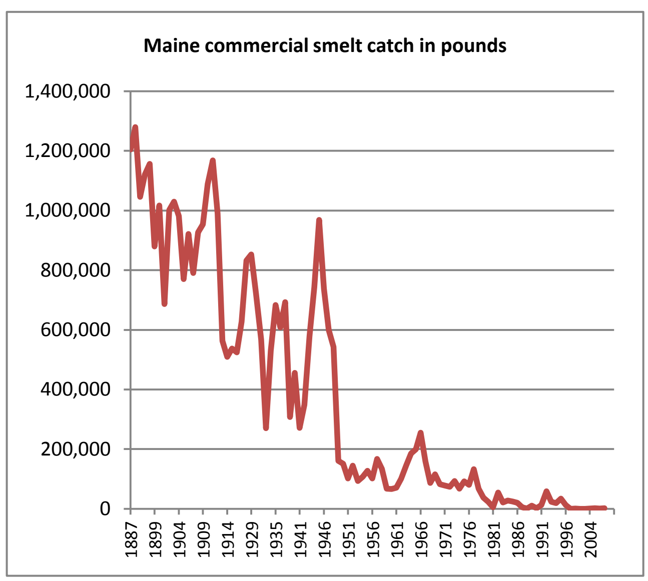


Figure 1. Maine commercial smelt catch in pounds (Squiers *et al.* 1976), and NMFS website).

*Historical Information and Commercial Harvests for Rainbow Smelt*

Historical information regarding smelt harvests, fishing interest, and market demand for smelt throughout the Eastern U.S. was first synthesized into a poster presentation that was presented at the Fourth North American Workshop on Rainbow Smelt (extended abstract in the workshop proceedings, Appendix E), then expanded for the species conservation plan (Appendix A). The earliest accounts are provided by James Smith in 1622, who described smelt as extremely plentiful and a major food source for Native Americans in the spring (*in* Kendall 1926). There is little additional information about early harvests until the mid-1800s, although extensive subsistence and local commercial harvest occurred before this time, based on occasional references and town records. There are some accounts from the Mid-Atlantic region (Virginia, Maryland, and Delaware), but there are no records of harvests in these states. Records and descriptions from the mid-1800s described smelt as extremely abundant from New Jersey to Maine. During this time, food markets developed for smelt in addition to previous uses as fertilizers and livestock feed. By the late 1800s, smelt were an important export product, though many accounts begin to describe concern about decline in abundance during this period, and landings in Maine were already showing a declining trend (Figure 1). The species continued to support important commercial fisheries in New England until the early to mid-1900s, after which landings declined substantially. At this point, commercial effort decreased considerably, due either to regulatory measures (Massachusetts) or fewer commercial fishermen targeting the species (New Hampshire and Maine).

Commercial smelt fishing in Massachusetts is allowed, but has been greatly reduced to a small possession limit (50 fish). Few commercial operations are allowed in New Hampshire and Maine, and landings are recorded on an annual basis. In Maine, the modest amount of commercial fishing allowed in the eastern part of the coast shows a fairly stable trend (these data are confidential and cannot be reported in document for public dissemination).

*Atlantic Sturgeon Commercial Harvests*

Atlantic sturgeon once supported a large commercial fishery in the United States in the 1800s, but landings declined precipitously in the early 1900s. Annual coast-wide harvest in the late 1800s was between ~1000 – 3000 metric tons (mt), however annual harvest had declined to a low of 22 mt in 1920, and remained below 140 mt from 1920 to the late 1990s (ASMFC 1990; Secor 2002). This information was gathered for and is also presented in the species conservation plan (Appendix I).

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). 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 scarce (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). Harvest continued at low levels during the 1900s, with the annual harvest remaining below 2,000 pounds. 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 both Atlantic and shortnose sturgeon became illegal in Maine’s coastal waters.

*Fisheries Dependent Monitoring Information for Rainbow Smelt*

New Hampshire and Maine continue to support large recreational ice-fisheries for rainbow smelt. Both states conduct creel surveys to capture information about the effort and catch of these fisheries, NHFG has conducted winter creel surveys since 1978 on the Lamprey, Oyster/Bellamy and Squamscott rivers as well as Great Bay, and ME DMR conducted surveys 1979-1982 and again beginning in 2009 on the Kennebec River and Merrymeeting Bay. Data from both states surveys were compiled and are presented in the species conservation plan (Appendix A).

Briefly, both datasets show a declining trend in catch per unit effort (CPUE) over the sampling periods. In New Hampshire, the highest annual CPUE for the last ten-year period is half that of the two previous ten year periods (2000-2011, highest annual CPUE = 5.6; 1990-1999 = 10.6; 1980-1989 = 10.3). In Maine, 2009-2011 average CPUE was lower than the previous period (2009-2011 avg. CPUE = 0.48 < 1979-1982 = 0.64), and the recent survey had the lowest CPUE recorded (0.17) during the two time series.

*Fisheries Independent Monitoring Information for Rainbow Smelt*

In addition to the monitoring efforts completed under this grant, other state efforts collect information about rainbow smelt that can be used to better understand the species' population trends, habitat preferences, and annual movements. The three state fisheries agencies perform inshore small-mesh trawl surveys twice a year, in the spring (MA DMF in May, NH/ME in late May and early June) and fall (MA DMF in September, NH/ME in October and early November). The MA DMF has been performing surveys since 1978, while the ME DMR began sampling the New Hampshire and Maine waters in fall 2000. Juvenile abundance monitoring is performed in the Piscataqua River, Great Bay, and Little Harbor estuaries in New Hampshire (since 1997) and in the Kennebec River and Merrymeeting Bay in Maine (since 1979). Lastly, egg deposition monitoring was performed by NHFG from 1978-2007 using methodologies described by Rupp (1965). The data from these monitoring efforts were summarized for the species conservation plan (Appendix A).

*Atlantic Sturgeon Gill Net Monitoring*

From 1977 to 2001, the 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) and information specific to Atlantic sturgeon is detailed in the species conservation plan (Appendix I). Briefly, gill nets of different mesh sizes were deployed parallel to the shore at 65 stations in the Kennebec, Androscoggin, and Sheepscot estuaries as early as April 4 and as late as November 29, but most sampling occurred from May through October. The size and weight of healthy sturgeon were recorded, as well as the number of Atlantic sturgeon caught per net haul. These data were used to identify areas of large aggregates of Atlantic sturgeon that may be important habitat for the fish, and to direct telemetry efforts conducted under this grant.

### ***Activity 2 – Complete Field Inventory – Years 1-2***

*Rainbow Smelt Spawning Locations*

Before the beginning of this grant, the MA DMF performed field surveys at all possible smelt spawning locations on the Gulf of Maine coast of Massachusetts and confirmed current spawning locations (Chase 2006).

During this project, these spawning locations were georeferenced and combined into a regional geospatial database of rainbow smelt spawning locations (Figure 2).

The NHFG performed field fyke net surveys for three weeks in April, 2007 in the six rivers draining into the Great Bay and Piscataqua area: the Winnicut, Squamscott, Lamprey, Oyster, Bellamy, and Salmon Falls rivers. Adult rainbow smelt in spawning condition were caught at each location in sufficient numbers to indicate sizable spawning runs (in the order of hundreds of smelt), except in the Winnicut River where only 9 smelt were caught. The Winnicut River smelt spawning run was of specific concern to NHFG because of documented low smelt returns during the previous 10-15 years. These New Hampshire spawning locations were georeferenced and combined into a regional geospatial database of rainbow smelt spawning locations (Figure 2).

From 2007-2009, biologists with ME DMR worked with Marine Patrol to document coastal rivers and streams currently being used by rainbow smelt for spawning. Marine Patrol officers gave information about the spawning habitat (substrate, possible obstructions), and the strength of the run as characterized by the density of egg mats or number of spawning adults present. We compared the current use and strength of runs to information collected by DMR in the early 1970's and to information compiled in 1984 from DMR and USFW indicating probable smelt spawning sites. Field survey methods were adopted from a 2005 initial effort by ME DMR and the Maine Marine Patrol to update information about current smelt spawning locations. The data collected during this 2005 survey were combined with data collected under this grant in 2007-2009. During this time period, officers visited a total of 279 streams. Combining information collected in 2005, and 2007-2009: 54 (19% of total) historical sites (1970 and/or 1984 data) were not visited and the current level of spawning activity remains unknown; 42 sites (15%) were not listed historically to support spawning, and currently do not support spawning; 35 sites (13%) which historically supported runs do not currently; 14 sites (5%) which historically supported runs currently support smaller runs; 81 sites (29%) currently support limited runs; 53 sites (19%) currently support strong runs (Figure 2). Of the 118 sites that were historically listed as strong runs and checked during 2005, 2007-2009: 49 (42% of checked historical runs) have declined or no longer support runs; 69 (58% of checked historical runs) seem to support runs at the level they did historically. Spawning decline and/or lack of spawning activity was concentrated in southern Maine, lower Casco Bay, the Kennebec River, and the east side of Frenchman's Bay. Limited and strong spawning runs persist in northern Casco Bay, the Medomak, St. Georges, and Penobscot Rivers, and around Pleasant Bay and Cobscook Bay.

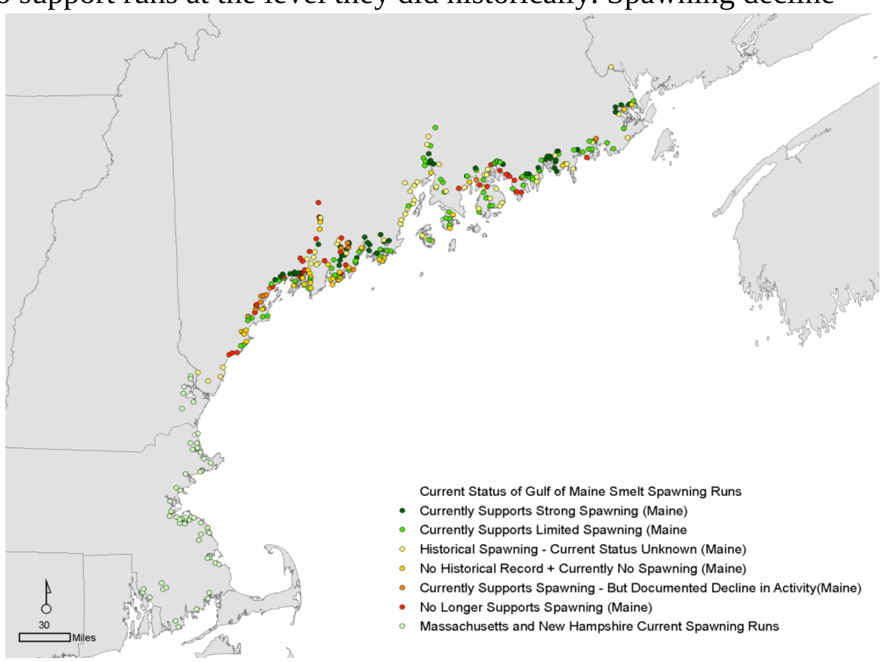


Figure 2. Current status of smelt spawning runs in the U. S. Gulf of Maine and historical sites were the current status remains unknown.

From 2009-2011, the ME DMR collaborated with the Downeast Salmon Federation (DSF) to collect information in Washington County, ME where information about smelt spawning and commercial fishing for smelt has been lacking. The previous surveys conducted by Maine Marine Patrol had focused on spawning activity in smaller streams, however, larger rivers in Washington County may support mainstem spawning populations – the East Machias, Narraguagus, Pleasant, Indian, Harrington, and Chandler rivers all support mainstem commercial fishing operations in the late winter that catch fish in spawning condition. The DSF conducted surveys in the winter and early spring to understand more about the timing and strength of the runs on the Pleasant and Narraguagus Rivers and the population structure of the commercial catch, as well as surveyed smaller streams in the spring to document spawning activity.

*Rainbow Smelt Annual Movements*

Annual movements and habitat use by adult rainbow smelt have been largely assumed based on discrete sampling or patterns in recreational and commercial fishing. Mark and recapture studies have focused on distinct phases of the life cycle, such as movements between spawning areas (Murawski et al. 1980), composition of late and early populations of spawning adults (McKenzie 1964) and winter movements within a river system (Flagg 1983). Larger annual and regional migrations have been synthesized from anecdotal reports by anglers and commercial fishermen. During this project, a thorough literature review was performed that included state agency reports and anecdotal information (e.g., from newspaper articles). Using this information together with information from current state monitoring efforts (near-shore trawl, juvenile abundance, and creel surveys), we synthesized a more complete description of rainbow smelt annual movements that is included in the species conservation plan (Appendix A).

In addition to reviewing the literature and consolidating data from state monitoring efforts, we performed a field study to monitor smelt behavior using telemetry. A sub-sample of smelt caught at the fyke net index stations on the Squamscott and Oyster rivers were tagged with hydroacoustic transmitters (VEMCO V5 and V6) in 2011 (30 smelt tagged) and 2012 (45 smelt tagged). Hydroacoustic receivers were placed in each identified spawning river in Great Bay and the Piscataqua estuary area, and along the Piscataqua River and at the mouth of the river (Figure 3). The data and results will be submitted as part of a Master's Thesis at the University of New Hampshire in Spring 2013 and for journal publication (C. Enterline, unpublished data).

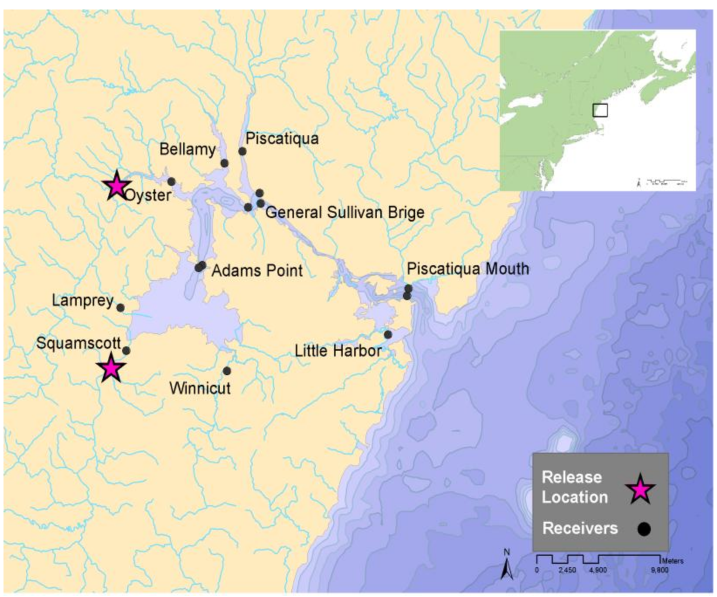


Figure 3. Using hydroacoustic telemetry, spawning and post-spawn smelt were monitored in the Great Bay and Piscataqua embayment, New Hampshire in 2011 and 2012. Smelt were captured, tagged, and released in Squamscott and Oyster rivers. Receivers were placed in all major rivers and to monitor movements into coastal marine waters.

The initial objective of this project was to monitor annual smelt movements including 1) smelt movements during the spawning season and following spawning season, documenting the timing of migration into coastal marine waters, 2) documenting when smelt returned to the embayment in the fall, and 3) smelt movement in the winter under the ice. During 2011, the hydroacoustic receiver array was left in place until December, however, no smelt were detected after June (approximately 3 months after being tagged at the spawning sites). The study was thus refined to answer only the first objective: monitoring smelt movements during the spawning season and post-spawning. In 2012, smelt were monitored from the tagging date (mid to late March) until July.

Preliminary results show that both male and female smelt move between many river systems during the spawning season, both during the night (possibly movement associated with spawning), and during the day, both during low and high tide (possible movement associated with feeding). While some smelt were observed to leave the embayment at the mouth of the Piscataqua River, almost half of the tagged individuals were last detected either in the rivers or within Great Bay. This may be due to mortality or predation. Of the individuals that were observed leaving the embayment, the timing of their movement into coastal waters was fairly consistent – with the last detections in the Piscataqua River occurring in late May or early June, almost four weeks after the last spawning activity was observed at the fyke net index sites.

### *Activity 3 – Long Term Index Stations – Years 1-5*

*Regional Spring Fyke Net Survey to Monitor Spawning Rainbow Smelt*

Earlier research on anadromous smelt populations in the Gulf of Maine has primarily consisted of short-term efforts that monitor smelt size and age structure during spawning runs. These efforts have not produced long-term population indices of abundance for smelt, and presently, no indices exist in New England. This project targeted the spring spawning runs as a source of information on population status. The objective was to produce fishery-independent indices of abundance, with the understanding that only mature smelt participate in the spawning runs. The approach was to record biological data from spawning runs; to conduct analyses on size and age composition, catch-per-unit-effort, and mortality; and to make comparisons as possible among rivers and to previous studies.

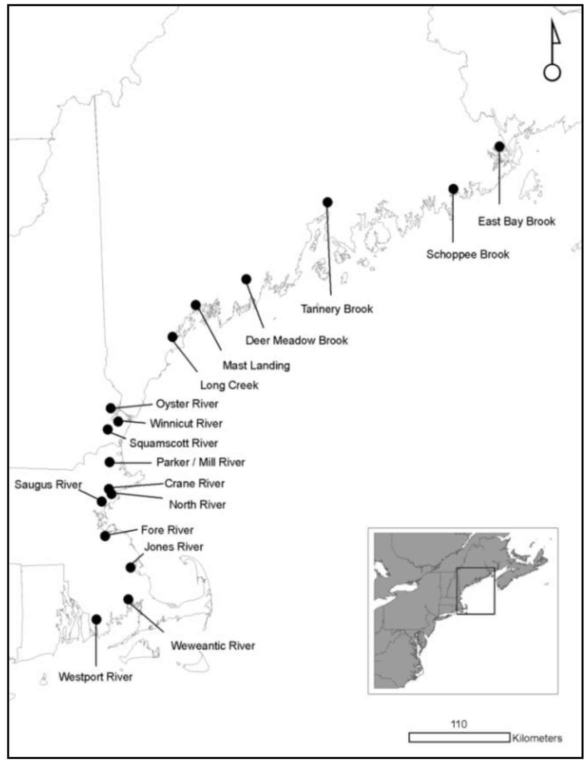


Figure 4. Fyke net monitoring stations in Massachusetts, New Hampshire, and Maine 2008-2012.

As part of this project, fyke net stations were selected at coastal rivers in Maine, New Hampshire, and Massachusetts for monitoring during 2008-2011 (Figure 4, Table 1). After pilot

| | Fyke Net Location | | | | Hydrologic Information | | | Watershed Information | | |
|---|---|---|---|---|---|---|---|---|---|---|
| River | Latitude | Longitude | Town | State | Channel Width (m) | Average Discharge ($m^3/s$) | Average Velocity (m/s) | Watershed (HUC 10) | Drainage Area ($km^2$) | Land Cover (1°/2°) |
| Westport River | 41.6209 | -71.0598 | Westport | MA | 11.3 | - | - | Buzzards Bay | 26.5 | Forest / Agriculture |
| Weweantic River | 41.7662 | -70.7461 | Wareham | MA | 35.7 | - | - | Buzzards Bay | 148.2 | Forest / Agriculture |
| Jones River | 41.9960 | -70.7233 | Kingston | MA | 27.3 | 1.92 | 0.492 | South Coastal Basin | 69.3 | Forest / Wetland |
| Fore River | 42.2225 | -70.9732 | Braintree | MA | 13.7 | 1.92 | 0.623 | Boston Harbor | 74.7 | Development / Forest |
| Saugus River | 42.4680 | -71.0077 | Saugus | MA | 55.4 | - | - | Boston Harbor | 55.8 | Development / Forest |
| North River | 42.5221 | -70.9116 | Salem | MA | 9.1 | 0.49 | 0.454 | North Coastal Basin | 12.6 | Development / Forest |
| Crane River | 42.5566 | -70.9364 | Danvers | MA | 8.2 | 0.17 | 0.497 | North Coastal Basin | 14.0 | Development / Forest |
| Parker River | 42.7505 | -70.9282 | Newbury | MA | 54.8 | - | 0.516 | Plum Island Sound | 66.0 | Forest / Wetland |
| Squamscott River | 42.9824 | -70.9461 | Exeter | NH | 101.0 | 5.65 | 0.384 | Exeter River | 276.9 | Forest / Wetland |
| Winnicut River | 43.0389 | -70.8455 | Greenland | NH | 36.6 | 1.05 | 0.3 | Great Bay | 45.5 | Forest / Wetland |
| Oyster River | 43.1310 | -70.1310 | Durham | NH | 32.9 | - | - | Great Bay | 59.9 | Forest / Development |
| Long Creek | 43.6332 | -70.3133 | S. Portland | ME | 24.3 | - | 0.64 | Fore River | 17.5 | Development / Forest |
| Mast Landing | 43.8587 | -70.0842 | Freeport | ME | 15.2 | - | 0.468 | Casco Bay Basin | 20.7 | Forest / Wetland |
| Deer Meadow Brook | 44.0369 | -69.5874 | Newcastle | ME | 24.9 | - | 0.489 | Sheepscot River | 27.6 | Forest / Wetland |
| Tannery Brook | 44.5706 | -68.7888 | Bucksport | ME | 67.7 | - | 0.402 | Penobscot River and Bay | 13.2 | Forest / Agriculture |
| Schoppee Brook | 44.6627 | -67.5533 | Jonesboro | ME | 16.0 | - | 0.583 | Roques Bluffs Frontal Drainages | 9.3 | Forest / Wetland |
| East Bay Brook | 44.9547 | -67.1041 | Perry | ME | 21.9 | - | 0.217 | Cobscook Bay | 3.0 | Forest / Wetland |

Table 1. Rainbow smelt spawning habitat station locations for water quality monitoring. Drainage areas are GIS calculations set from the location of fyke net placement.

deployments in 2007-2008 to identify suitable stations, eight fyke net stations were monitored in Massachusetts, three stations in New Hampshire and six in Maine. The sampling period in Massachusetts targeted 11 weeks from the first week of March to the third week of May to cover the known smelt spawning period. The sampling duration in New Hampshire and Maine varied due to a later ice-out and spawning season that occurs later with increasing latitude. The stations were chosen for suitability to maintain a fyke net in a known smelt run and to represent a range of run sizes and watershed conditions.

The fyke net was set at mid-channel in the intertidal zone below the downstream limit of smelt egg deposition. The fyke net opening faced downstream, and nets were hauled after overnight sets. This approach was adopted to intercept the spawning movements of smelt that occur at night during the flood tide. Fyke net catches were assumed to be representative of the size and sex composition of the spawning run. With each haul, smelt were counted, sexed, measured (total length) and released. Scales were sampled weekly at some stations for ageing. At most of these stations, we also collected water quality data, periphyton and nutrient samples, light and temperature data, macroinvertebrate community information, and samples from adult smelt for genetic, contaminant load, and pathological analysis. A standardized fyke net monitoring protocol was developed as part of this effort and will be used by each state agency in the future to continue monitoring spawning populations of rainbow smelt at some or all of the index stations sampled during this project (Appendix G).

The species conservation plan (Appendix A) provides a thorough discussion of the results of the fyke net study including differences in seasonality, sex ratios, CPUE, and length at age between the different index sites. Various CPUE metrics were explored with the geometric mean of average weekly catch per haul reported in Table 2. Briefly, the results of this study demonstrated that CPUE varied widely among rivers and years. For the entire region, the two highest overall CPUE (2008-2011 data) were found in Maine (Deer Meadow Brook = 58.07, Schoppee Brook = 37.83), while the two lowest were found in Massachusetts (Westport River = 1.01, North River = 1.37). There was a trend of higher CPUE values at Maine sites than New Hampshire and Massachusetts sites: out of the 17 index sites, four out of the top five highest CPUE were found in Maine (Table 2).

Smelt at the southern stations may experience a faster growth rate in their first year and are reaching a body size that supports maturity sooner than northern runs. Comparing age-at-length among the sites, there is an overall trend of decreasing length-at-age moving northward. Because age-2 males are present with large sample sizes in each run, it is informative to compare the average lengths between sites using this category. The largest length at age (2008-2011 data) was observed in the southern portion of the region (Fore River avg. age-2 male = 184 mm, Table 3), indicating a faster growth rate for this portion. Moving northward, length at age-2 was observed to decline (Mast Landing = 178 mm); however, the smallest length-at-age was observed in the mid-portion of Maine (Deer Meadow Brook avg. age-2 male = 157 mm, Tannery Brook = 142 mm). Sites at the most northeastern portion of the U. S. Gulf of Maine were larger than in mid-Maine, but were significantly smaller than the southern Maine and Massachusetts sites (Schoppee Brook = 163 mm, East Bay Brook = 166 mm).

| Index Site | State | 2008 | 2009 | 2010 | 2011 | 2012 | Overall |
|---|---|---|---|---|---|---|---|
| Weweantic R. | MA | 2.81 | 1.27 | 1.47 | 1.57 | 2.14 | 1.85 |
| Westport R. | MA | 1.00 | 1.00 | 1.00 | 1.02 | 1.00 | 1.00 |
| Jones R. | MA | 9.13 | 5.58 | 7.56 | 5.13 | 17.36 | 8.95 |
| Fore R. | MA | 33.55 | 10.41 | 22.00 | 15.70 | 17.74 | 19.88 |
| Saugus R. | MA | 6.30 | 1.19 | 1.07 | 2.49 | 6.59 | 3.53 |
| North R. | MA | 1.39 | 1.12 | 1.08 | 1.90 | 2.64 | 1.63 |
| Crane R. | MA | 3.03 | 1.97 | 2.12 | 3.39 | 3.44 | 2.79 |
| Parker R. | MA | 7.63 | 2.56 | 1.66 | 2.47 | 3.69 | 3.60 |
| Squamscott R. | NH | 3.45 | 1.44 | 1.08 | 6.26 | 3.05 | 3.06 |
| Winnicut R. | NH | 1.60 | 1.34 | 1.36 | 2.25 | 1.40 | 1.59 |
| Oyster R. | NH | x | x | 5.45 | 5.79 | 5.13 | 5.45 |
| Long Cr. | ME | x | 18.69 | 5.56 | 9.93 | 4.84 | 9.76 |
| Mast Landing | ME | 52.00 | 29.84 | 8.81 | 13.80 | 21.68 | 25.23 |
| Deer Meadow Bk. | ME | 11.11 | 100.82 | 24.86 | 95.46 | 7.37 | 47.93 |
| Tannery Bk. | ME | 15.28 | 28.26 | 41.87 | 14.03 | 5.86 | 21.06 |
| Schoppee Bk. | ME | x | x | 38.42 | 37.25 | 42.90 | 39.52 |
| East Bay R. | ME | 15.48 | 4.42 | 21.66 | 11.86 | x | 13.35 |

Table 2. Catch per unit effort (CPUE) of rainbow smelt at fyke net spawning survey index sites, by annual CPUE and overall CPUE for the entire sampling period, 2008-2011.

Table 3. Mean length at age and proportion at age of anadromous rainbow smelt at regional fyke net index sites 2008-2011. Age keys were applied to length samples for proportion at age.

**Proportion (%) at Age**

| Location | Region | Year | Sex | Length N | Age N | Age-1 | Age-2 | Age-3 | Age-4 | Age-5 | Age-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| East Bay Brook | ME | 2008 | both | 899 | 63 | | 92.2 | 6.7 | | 1.1 | |
| East Bay Brook | ME | 2009 | both | 236 | 68 | 0.8 | 62.3 | 33.9 | 3.0 | | |
| East Bay Brook | ME | 2010 | both | 1387 | 261 | 2.0 | 80.7 | 13.7 | 3.6 | | |
| East Bay Brook | ME | 2011 | both | 1211 | 268 | | 72.0 | 26.7 | 1.2 | 0.1 | |
| Schoppee Brook | ME | 2010 | both | 2034 | 281 | 0.9 | 90.2 | 3.5 | 5.4 | | |
| Schoppee Brook | ME | 2011 | both | 1831 | 245 | 2.2 | 90.7 | 7.1 | | | |
| Tannery Brook | ME | 2008 | both | 2001 | 74 | | 60.0 | 34.2 | 5.8 | | |
| Tannery Brook | ME | 2009 | both | 1778 | 72 | 3.9 | 78.6 | 7.9 | 6.4 | 3.2 | |
| Tannery Brook | ME | 2010 | both | 1892 | 344 | 2.5 | 49.6 | 45.4 | 1.4 | 1.0 | 0.1 |
| Tannery Brook | ME | 2011 | both | 908 | 172 | 6.9 | 36.6 | 48.0 | 8.5 | | |
| Deer Meadow | ME | 2008 | both | 179 | 85 | 5.0 | 77.1 | 17.9 | | | |
| Deer Meadow | ME | 2009 | both | 2016 | 135 | 0 | 90.2 | 5.7 | 3.4 | 0.7 | |
| Deer Meadow | ME | 2010 | both | 1366 | 320 | 2.8 | 26.0 | 64.7 | 5.0 | 1.5 | |
| Deer Meadow | ME | 2011 | both | 1946 | 108 | 1.5 | 83.6 | 6.9 | 6.7 | 0.9 | |
| Mast Landing | ME | 2008 | both | 1620 | 90 | 15.2 | 58.6 | 24.2 | 2.0 | | |
| Mast Landing | ME | 2009 | both | 1106 | 128 | 0.6 | 85.6 | 13.9 | 2.9 | | |
| Mast Landing | ME | 2010 | both | 355 | 268 | 75.5 | 8.7 | 13.8 | 1.7 | 0.3 | |
| Mast Landing | ME | 2011 | both | 1833 | 275 | 44.5 | 53.5 | 0.8 | 1.2 | | |
| Oyster River | NH | 2010 | both | 421 | 185 | 65.8 | 29.0 | 4.5 | 0.7 | | |
| Oyster River | NH | 2011 | both | 401 | 231 | 11.2 | 75.1 | 13.5 | <0.1 | | |
| Fore River | MA | 2008 | both | 1958 | 380 | 51.9 | 41.4 | 6.2 | 0.4 | 0.1 | |
| Fore River | MA | 2009 | both | 846 | 660 | 15.5 | 52.5 | 31.4 | 0.6 | | |
| Fore River | MA | 2010 | both | 1441 | 493 | 89.6 | 7.9 | 2.4 | 0.1 | <0.1 | |
| Fore River | MA | 2011 | both | 1241 | 486 | 48.3 | 48.7 | 2.6 | 0.4 | <0.1 | |

**Mean Length at Age**

| Location | Region | Year | Sex | N | Age-1 | Age-2 | Age-3 | Age-4 | Age-5 | Age-6 |
|---|---|---|---|---|---|---|---|---|---|---|
| East Bay Brook | ME | 2008-11 | M | 322 | 145 | 166 | 197 | 215 | 241 | |
| East Bay Brook | ME | 2008-11 | F | 338 | 155 | 173 | 212 | 238 | 241 | |
| Schoppee Brook | ME | 2010-11 | M | 225 | 146 | 163 | 195 | 204 | | |
| Schoppee Brook | ME | 2010-11 | F | 299 | 152 | 169 | 206 | 234 | | |
| Tannery Brook | ME | 2008-11 | M | 339 | 135 | 142 | 166 | 183 | 190 | |
| Tannery Brook | ME | 2008-11 | F | 322 | 137 | 146 | 178 | 198 | 211 | 215 |
| Deer Meadow | ME | 2008-11 | M | 397 | 138 | 157 | 185 | 209 | 220 | 226 |
| Deer Meadow | ME | 2008-11 | F | 250 | 125 | 160 | 194 | 222 | 208 | |
| Mast Landing | ME | 2008-11 | M | 447 | 132 | 178 | 192 | 211 | | |
| Mast Landing | ME | 2008-11 | F | 312 | 137 | 190 | 209 | 232 | 256 | |
| Oyster River | NH | 2008-11 | M | 344 | 117 | 162 | 179 | 209 | | |
| Oyster River | NH | 2008-11 | F | 60 | 114 | 167 | 180 | | | |
| Fore River | MA | 2008-11 | M | 1113 | 141 | 184 | 202 | 215 | | |
| Fore River | MA | 2008-11 | F | 507 | 142 | 194 | 217 | 249 | 251 | 266 |

Table 4. Anadromous rainbow smelt length data collected at regional fyke net index sites 2008-2011 Sex ratio is the ratio of males to females. Some stations excluded because of low sample size. Smelt of unknown sex are excluded from these statistics.

**MALE**

| State | River | Code | Years | N | Mean | SE | Median | Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|
| MA | Weweantic | WW | 4 | 188 | 151 | 2.01 | 145 | 104 | 238 |
| MA | Jones | JR | 4 | 1249 | 156 | 0.93 | 143 | 106 | 254 |
| MA | Fore | FR | 4 | 4396 | 166 | 0.43 | 157 | 108 | 241 |
| MA | Saugus | SG | 4 | 401 | 162 | 1.30 | 153 | 113 | 240 |
| MA | North | NR | 4 | 79 | 150 | 2.18 | 149 | 118 | 217 |
| MA | Crane | CN | 4 | 262 | 161 | 1.44 | 156 | 121 | 221 |
| MA | Parker | PR | 4 | 1217 | 167 | 0.88 | 156 | 86 | 255 |
| NH | Squamscott | SQ | 2 | 340 | 154 | 1.85 | 159 | 86 | 227 |
| NH | Oyster | OY | 2 | 344 | 149 | 1.74 | 156 | 88 | 225 |
| ME | Long Creek | LC | 4 | 1191 | 169 | 0.41 | 168 | 110 | 228 |
| ME | Mast Landing | ML | 4 | 3099 | 163 | 0.40 | 169 | 105 | 227 |
| ME | Deer Meadow | DM | 4 | 4367 | 166 | 0.33 | 163 | 83 | 241 |
| ME | Tannery Brook | TB | 4 | 4214 | 152 | 0.27 | 152 | 104 | 223 |
| ME | Schoppee | SB | 2 | 2303 | 164 | 0.24 | 163 | 125 | 222 |
| ME | East Bay | EB | 4 | 2368 | 172 | 0.31 | 169 | 136 | 250 |
| **Total** | | | | 26018 | | | | | |

**FEMALE**

| State | River | Code | Sex Ratio | N | Mean | SE | Median | Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|
| MA | Weweantic | WW | 3.4 | 55 | 149 | 4.29 | 139 | 107 | 225 |
| MA | Jones | JR | 2.5 | 492 | 160 | 1.69 | 144 | 100 | 258 |
| MA | Fore | FR | 4.0 | 1090 | 168 | 1.06 | 154 | 111 | 270 |
| MA | Saugus | SG | 7.7 | 52 | 172 | 5.01 | 157 | 129 | 248 |
| MA | North | NR | 3.4 | 23 | 154 | 4.71 | 153 | 113 | 214 |
| MA | Crane | CN | 2.8 | 94 | 169 | 3.31 | 162 | 114 | 257 |
| MA | Parker | PR | 9.5 | 128 | 194 | 3.18 | 204 | 112 | 272 |
| NH | Squamscott | SQ | 3.7 | 93 | 135 | 3.86 | 118 | 86 | 239 |
| NH | Oyster | OY | 5.7 | 60 | 151 | 4.80 | 166 | 88 | 224 |
| ME | Long Creek | LC | 3.3 | 360 | 178 | 0.99 | 176 | 118 | 251 |
| ME | Mast Landing | ML | 2.7 | 1136 | 177 | 0.86 | 180 | 93 | 263 |
| ME | Deer Meadow | DM | 3.6 | 1209 | 165 | 0.71 | 159 | 83 | 258 |
| ME | Tannery Brook | TB | 1.8 | 2366 | 157 | 0.46 | 154 | 108 | 236 |
| ME | Schoppee | SB | 1.5 | 1564 | 174 | 0.53 | 170 | 129 | 256 |
| ME | East Bay | EB | 1.7 | 1389 | 183 | 0.59 | 176 | 122 | 263 |
| **Total** | | | | 10111 | | | | | |

Considering the populations by state, in Massachusetts the age and length data suggest the presence of a truncated age distribution, a sign of stressed populations due to high mortality and potentially poor recruitment. Male smelt in Massachusetts have similar median lengths compared to male smelt in New Hampshire and Maine. However, female smelt in Massachusetts had higher median length than the other states (Table 4); a statistic driven by larger age-2 to age-4 females. Massachusetts stations are dominated by length modes that indicate age-1 and age-2 smelt, with very low presence of smelt older than age-4, indicating reduced survival.

In New Hampshire, two length modes are apparent in both rivers composed of age-1 and age-2 smelt. However, more overlap is seen in these modes than found in Massachusetts smelt age-length data. Few smelt reached age-4 in New Hampshire rivers. For each available age key, age-4 comprised less than 2% of the annual age sample. Growth rates appear to be slower within New Hampshire runs, as age-3 smelt occur at smaller lengths than seen in Massachusetts and no age-2 smelt larger than 19 cm have been sampled.

Median smelt lengths for the Maine stations were slightly larger than at the other states, likely because these runs had a lower proportion of age-1 smelt but higher proportion of age 3+ smelt; however, average length at age was smaller, indicating a slower growth rate compared to sites further south. The Maine smelt runs also averaged higher CPUE rates and showed more balanced age distributions and sex ratios than seen in southern runs. These patterns were most evident in catch data from the easternmost Maine stations. All these observations indicate relatively healthier smelt runs in Maine than in Massachusetts and New Hampshire. The age composition of smelt in Maine's spawning runs contributes to less separation between length modes and an extended age-2+ mode. These features could reflect interesting potential differences in growth rates, maturation, and survival in Maine than at the southern runs.

Each index site contained a smelt population that was male biased (Table 4). Overall, this survey observed an average sex ratio of 4:1. Of the systems sampled, the most heavily male biased were the Parker River, MA, and the Squamscott and Oyster rivers, NH, which all displayed a male to female ratio of greater than 8:1. The lowest male to female ratios (< 2:1) were found in three systems in Maine: Tannery Brook, Schoppee Brook, and the East Bay River. Although spawning runs of most anadromous fishes are male biased, those displaying a substantially higher proportion of males may be indicative of a stressed population. Because the limiting factor for population growth is often the abundance of females, populations dominated by males may be less robust than those containing a higher proportion of females.

However, the skewed sex ratios observed at these fyke net sites may also be due to within-season repeat spawning behavior by male smelt. During the spawning event, multiple males have been observed to attend to one female (Clayton 1976; Hoover 1936; Langlois 1935), a behavior which has been found to increase fertilization success (Purchase et al. 2007). Sampling large groups of smelt during non-breeding seasons has found a balanced sex ratio. Sampling in the Parker River, Massachusetts, found that age-2+ females composed only 11.4% of the sampled population during one spawning survey compared to 47.4% of the winter fishery catch within the same year (Murawski et al. 1980). Fyke net surveys in 2008 at the Mast Landing index site found females comprised only 14.6% of the catch, whereas fall near-shore trawl surveys conducted the following fall in the embayment area below this site an almost even sex ratio (46.2% female) (S. Sherman, ME DMR, pers. comm.).

Further, because mortality rates are calculated by tracking age classes through time they may also be biased when survey methods are re-capturing the same individuals. Previous mortality estimates have been based on total catch during the spawning season. Murawski and Cole (1978) estimated a higher mortality rate for males compared to females in the Parker River, Massachusetts using a frequency at age model based on spawning survey catches. This higher mortality rate may be due to a larger number of age-2 males repeatedly visiting the spawning grounds compared to older males. If this is true, the data would falsely indicate that age-2 males compose a larger proportion of the population. Quantifying the rate of repeat spawning by age and sex allows the frequency at age to be corrected and accurate morality estimates calculated.

To further understand the skewed sex ratio, Maine DMR worked with the USGS Conte Lab to design a Passive Integrated Transponder (PIT) study at Mast Landing, Maine and on the Fore River, Massachusetts. It was one of the largest in-river RFID antenna systems that has ever been designed and the first known project to PIT tag smelt in the country. A subset of smelt caught each week as part of the fyke net survey were tagged internally using 23mm PIT tags (Oregon RFID) and monitored using in-stream continuously running RFID systems. Each smelt receiving a PIT tag was also tagged with a VIE mark in the operculum for the purpose of visual identification upon recapture. Scale samples were taken from all tagged fish to confirm age.

The preliminary results of this study were summarized for the Fourth North American Workshop on Rainbow Smelt Proceedings (Appendix E), and are being synthesized as part of a Master's Thesis for the University of New Hampshire and also for journal submission (C. Enterline, unpublished data). These results show that males do return at a significantly higher rate than females, and that younger males do seem to return at a higher rate than older males (Table 5).

| | Average # of Returns | |
|---|---|---|
| | F | M |
| Age-1 | 1 (n=1) | 2.12 (n=17) |
| Age-2 | 2 (n=1) | 2.03 (n=71) |
| Age-3 | 0 | 1.63 (n=8) |
| Age-4 | 1 (n=2) | 0 |

Table 5. Total number of returns at Mast Landing spawning site 2009-2011 combined. The total number of returns in each sex and age category is shown in parentheses following the average number of returns in each category. Ages are assigned based on length.

Tag retention and mortality studies were completed at Southern Maine Community College (SMCC) and at the Maine DMR fisheries laboratory in West Boothbay Harbor. Preliminary analysis shows a high mortality rate among smelt under 14 cm. Within the first week, the mortality rate was approximately 50% for tagged smelt in both studies. The average size of dead smelt in the first two weeks was ~14.5 cm. A declining mortality rate was observed after week one in both studies, leveling off at ~15% at one month. After week two, the average size of mortalities was ~16 cm. In each study, 30 smelt were also kept as controls. The mortality rate for control fish remained ~4% during a one-month period.

Although fyke nets are demonstrated to be an effective gear for sampling smelt, limited information is available regarding their relative efficiency. Without such information, it is difficult to understand how measures of relative abundance, such as CPUE, relate to actual abundance. To address this information gap, a census fyke net, which bridged the entire channel, was placed in the Fore River, Massachusetts. Sampling the census net targeted overnight sets on a weekly basis at the same time the standard sampling fyke net was deployed immediately downstream. The efficiency of the sampling fyke net was then calculated by comparing the CPUE of the sampling fyke to that of the census fyke.

Between 2009 and 2012, the census fyke was set on 29 separate occasions. Yearly sampling effort ranged from a low of 5 census sets in 2009 and 2010 to a high of 11 census sets in 2012 (Figure 5). Sampling efficiency ranged from 0-100%, with all instances of 100% occurring when no smelt were captured in either the sampling or the census fyke net. When smelt were captured in either net, sampling efficiency averaged 3.8%. This value is smaller than the relative stream channel width sampled by the sampling fyke net, which was approximately 15%. This finding suggests that the sampling net did not collect passing smelt at a rate equal to actual coverage, and that migrating smelt may actively avoid capture in an anchored fyke net. The census fyke net data will be further evaluated in preparation for future publications.

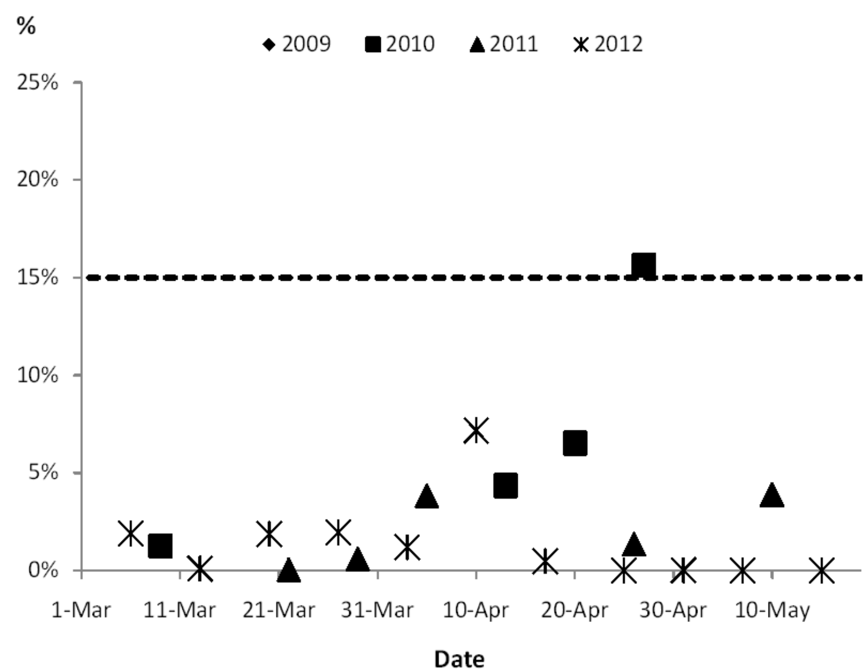


Figure 5 Results of efficiency evaluation of smelt fyke net in the Fore River, MA, 2009-2012. The proportion of smelt caught in the project fyke net compared to the census fyke net catch are displayed.

In addition to collecting information about rainbow smelt during the annual spring fyke net surveys, we also recorded information about other species caught (Tables 6a – 6f). For all vertebrate species, all individuals of bycatch species were counted, and the first 30 individuals captured at each haul measured. For invertebrate species (shrimp, crab, etc.), all individuals caught at each haul were counted. Length information for vertebrate species is available from the state agencies by request.

| | | Crane River | | | | | | Essex River | | | | Fore River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species (common name) | Species (scientific name) | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years |
| alewife | *Alosa pseudoharengus* | | | | 1 | 6 | 7 | 29 | 12 | 114 | 155 | | | | 3 | | 3 |
| Largemouth bass | *Micropterus salmoides* | | | | | | | | 1 | | 1 | | 1 | | | | 1 |
| Smallmouth bass | *Micropterus dolomieui* | | | | | | | | | | | | | | | | |
| Striped bass | *Morone saxatilis* | | | | | | | | | | | | | | | | |
| Bluegill | *Lepomis macrochirus* | | | | 1 | | 1 | 3 | 1 | | 4 | | 1 | 1 | 3 | 5 | 10 |
| Brown bullhead catfish | *Ameiurus nebulosus* | | | 1 | 1 | | 2 | 2 | | 2 | 4 | | 2 | | | | 2 |
| Yellow bullhead catfish | *Ameiurus natalis* | | | | | | | | | | | | | | | | |
| Atlantic cod | *Gadus morhua* | | | | | | | | | | | 1 | 1 | | | 2 | 4 |
| Asian shore crab | *Hemigrapsus sanguineus* | | | | | | | | | | | | | | | 2 | 2 |
| Atlantic mud crab | *Panopeus herbstii* | | | | | | | | | | | | | | | | |
| Atlantic mud crab | *Panopeus herbstii* | | | | | | | | 1 | | 1 | | | | | | |
| Blue crab | *Callinectes sapidus* | | | | | | | | | | | | | | | | |
| Green crab | *Carcinus maenas* | | | | | | | | 1 | 7 | 8 | 12 | 2 | 29 | 1 | 25 | 69 |
| Horseshoe crab | *Limulus polyphemus* | | | | | | | | | | | 1 | | | | | 1 |
| Mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | |
| White-fingered mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | |
| White-tip mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | |
| Black crappie | *Pomoxis nigromaculatus* | | | | | | | 1 | | 1 | 2 | | | 3 | | 2 | 5 |
| Crayfish | *Cambaridae* | | 6 | 3 | | 4 | 13 | | | | | | 1 | 1 | | 1 | 3 |
| Darter | *Etheostoma sp.* | | | | | | | | | | | | | | | | |
| American eel | *Anguilla rostrata* | 3 | | 38 | 14 | 24 | 79 | | 6 | 42 | 48 | 96 | 112 | 121 | 141 | 128 | 598 |
| Summer flounder | *Paralichthys dentatus* | | | | | | | | | | | | | | | | |
| Winter flounder | *Pseudopleuronectes americanus* | | | | | | | | | | | | | | | | |
| Atlantic herring | *Clupea harengus* | | | | | | | | | | | | | | | | |
| Blueback herring | *Alosa aestivalis* | | | | | | | | | | | | | | | | |
| American shad | *Alosa sapidissima* | | | | | | | | | | | | | | | | |
| Hogchoker | *Trinectes maculatus* | | | | | | | | | | | | | | | | |
| Killifish spp. | *Fundulus spp.* | | | | | | | | | 1 | 1 | 3 | | | 2 | | 5 |
| Sea lamprey | *Petromyzon marinus* | | | | | | | | | | | 2 | | | | | 2 |
| American sand lance | *Ammodytes americanus* | | | | | | | | | | | 1 | | | | | 1 |
| Fathead minnow | *Pimephales promelas* | | | | | | | | | | | | | | | | |
| Mummichog | *Fundulus heteroclitus* | 130 | 343 | 1754 | 411 | 3435 | 6073 | 52 | 727 | 3351 | 4130 | 11 | 30 | 5 | 23 | 35 | 104 |
| White perch | *Morone americana* | 2 | | 3 | 1 | | 6 | | 1 | | 1 | 3 | 3 | 2 | 6 | 3 | 17 |
| Yellow perch | *Perca flavescens* | | 12 | 42 | 88 | 15 | 157 | 140 | 1 | 14 | 155 | 4 | | | 42 | 5 | 51 |
| Chain pickerel | *Esox niger* | | | | 1 | | 1 | | 1 | | 1 | | | | | | |
| Redfin pickerel | *Esox americanus* | | | | | | | | | | | | 5 | | | | 5 |
| Pumpkinseed | *Lepomis gibbosus* | | 3 | 3 | 4 | 13 | 23 | | 2 | 1 | 3 | | | | | | |
| Common shiner | *Luxilus cornutus* | | | | 3 | | 3 | | 1 | 8 | 9 | 1 | 2 | 6 | | | 9 |
| Golden shiner | *Notemigonus crysoleucas* | 9 | 9 | 27 | 63 | 1 | 109 | 2 | 1 | 8 | 11 | | | | | | |
| Spottail shiner | *Notropis hudsonius* | | | | | | | | | | | | | | | | |
| Grass shrimp | *Palaemonetes* | 5 | 1 | | 3 | 10 | 19 | | 6 | 21 | 27 | 11 | 38 | 2 | 17 | 118 | 186 |
| Sand shrimp | *Crangon septemspinosa* | 3 | | 19 | 12 | 15 | 49 | | 1 | 78 | 79 | 13 | 14 | | 5 | 47 | 79 |
| Atlantic silverside | *Menidia menidia* | | | | | | | | 1 | 13 | 14 | 2 | | | | | 2 |
| Rainbow smelt | *Osmerus mordax* | 120 | 46 | 68 | 120 | 149 | 503 | 18 | 19 | 44 | 81 | 2454 | 888 | 1826 | 1541 | 1537 | 8246 |
| Fourspine stickleback | *Apeltes quadracus* | 80 | 47 | 417 | 250 | 175 | 969 | | 41 | 82 | 123 | 18 | 46 | 65 | 178 | 70 | 377 |
| Ninespine stickleback | *Pungitius pungitius* | 2 | | 2 | | 1 | 5 | | 5 | 1 | 6 | 1 | | | | | 1 |
| Threespine stickleback | *Gasterosteus aculeatus* | 273 | 2265 | 1984 | 1448 | 1220 | 7190 | 47 | 250 | 761 | 1058 | 17 | 19 | 4 | 13 | 12 | 65 |
| White sucker | *Catostomus commersoni* | | | | | | | | | | | | | | | | |
| Banded sunfish | *Enneacanthus obesus* | 8 | 2 | 70 | 17 | 2 | 99 | | 6 | | 6 | 1 | | 1 | | | 2 |
| Atlantic tomcod | *Microgadus tomcod* | | | 1 | 1 | | 2 | | | 2 | 2 | 16 | 34 | 9 | 19 | 97 | 175 |
| Brook trout | *Salvelinus fontinalis* | | | | | | | 2 | | | 2 | | | | | | |
| Brown trout | *Salmo trutta* | | | | | | | | | 2 | 2 | | | | | | |
| Rainbow trout | *Oncorhynchus mykiss* | | | | | | | | | | | | | | | | |

Table 6a. The number of individuals caught are shown for non-target species caught as part of the spring fyke net survey, by year and by site for Massachusetts rivers.

| | | Jones River | | | | | | North River | | | | | | Parker River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species (common name) | Species (scientific name) | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years |
| alewife | *Alosa pseudoharengus* | 7 | | | 3 | 48 | 58 | | | | | | | | | 2 | 2 | 26 | 30 |
| Largemouth bass | *Micropterus salmoides* | | | | | | | | | | | | | | | | | 1 | 1 |
| Smallmouth bass | *Micropterus dolomieui* | | | | | | | | | | | | | | | | | | |
| Striped bass | *Morone saxatilis* | | | | | 1 | 1 | | | | | | | | | | | | |
| Bluegill | *Lepomis macrochirus* | 2 | 1 | 12 | 1 | | 16 | 1 | | 2 | 2 | 34 | 39 | | 1 | 5 | | 10 | 16 |
| Brown bullhead catfish | *Ameiurus nebulosus* | | | | | 1 | 1 | | | | | | | 5 | 24 | 116 | 2 | 10 | 157 |
| Yellow bullhead catfish | *Ameiurus natalis* | | | | | | | | | | 1 | | 1 | 6 | 24 | 28 | 5 | 9 | 72 |
| Atlantic cod | *Gadus morhua* | | | | | | | | | | | | | | | | | | |
| Asian shore crab | *Hemigrapsus sanguineus* | | | | | | | | | | | | | | | | | | |
| Atlantic mud crab | *Panopeus herbstii* | | 7 | 5 | 5 | 1 | 18 | | | | | | | | | | | 1 | 1 |
| Atlantic mud crab | *Panopeus herbstii* | | | | | | | | | | | | | | | | | | |
| Blue crab | *Callinectes sapidus* | | | | | | | | | | | | | | | | | | |
| Green crab | *Carcinus maenas* | | | 1 | | 2 | 3 | | | | | | | | | 3 | 2 | 18 | 23 |
| Horseshoe crab | *Limulus polyphemus* | | | | | | | | | | | | | | | | | | |
| Mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | | | |
| White-fingered mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | 1 | | 1 |
| White-tip mud crab | *Rhithropanopeus harrisii* | 1 | | | 2 | | 3 | | | | | | | | | | | | |
| Black crappie | *Pomoxis nigromaculatus* | | | | | | | | | | | | | | | 3 | | | 3 |
| Crayfish | *Cambaridae* | | | | | | | | | 1 | | | 1 | 2 | 2 | 2 | 3 | 1 | 10 |
| Darter | *Etheostoma sp.* | | | | | | | | | | | | | | | | | | |
| American eel | *Anguilla rostrata* | 17 | 21 | 20 | 7 | 16 | 81 | 35 | 13 | 70 | 57 | 93 | 268 | 14 | 8 | 29 | 36 | 54 | 141 |
| Summer flounder | *Paralichthys dentatus* | | | | | 1 | 1 | | | | | | | | | | | | |
| Winter flounder | *Pseudopleuronectes americanus* | | 1 | 2 | 5 | 2 | 10 | | | | | | | | | | | | |
| Atlantic herring | *Clupea harengus* | 5 | | | 9 | 147 | 161 | | | | | | | | | | | | |
| Blueback herring | *Alosa aestivalis* | | | 1 | | 16 | 17 | | | | | | | 1 | | | | 5 | 6 |
| American shad | *Alosa sapidissima* | | | 1 | | | 1 | | | | | | | | | | | | |
| Hogchoker | *Trinectes maculatus* | | | | | | | | | | | | | | | | | | |
| Killifish spp. | *Fundulus spp.* | | | | | | | | | 1 | | | 1 | | 1 | 1 | | | 2 |
| Sea lamprey | *Petromyzon marinus* | 1 | 2 | | 1 | 1 | 5 | | | | | | | 33 | 9 | 19 | 18 | 23 | 102 |
| American sand lance | *Ammodytes americanus* | | | | | | | | | | | | | | | | | | |
| Fathead minnow | *Pimephales promelas* | | | | | | | | | | | | | | | | | 1 | 1 |
| Mummichog | *Fundulus heteroclitus* | 14 | 15 | | 69 | 137 | 235 | 9932 | 2026 | 775 | 3221 | 4347 | 20301 | 5 | 1 | 1 | 26 | 5 | 38 |
| White perch | *Morone americana* | 19 | 41 | 185 | 34 | 22 | 301 | | | | 2 | | 2 | 7 | 1 | | | 5 | 13 |
| Yellow perch | *Perca flavescens* | 2 | 898 | 5 | 1 | | 906 | 1 | | 11 | | | 12 | 12 | 9 | 9 | 1 | 2 | 33 |
| Chain pickerel | *Esox niger* | | | | | | | | | | | | | | | | | 2 | 2 |
| Redfin pickerel | *Esox americanus* | | | | | 1 | 1 | | | | | | | 1 | 9 | 4 | | 2 | 16 |
| Pumpkinseed | *Lepomis gibbosus* | | | | 1 | | 1 | 7 | 1 | | | 76 | 84 | 3 | 3 | 15 | 4 | 29 | 54 |
| Common shiner | *Luxilus cornutus* | | | | | | | | | | | | | | | | 42 | 10 | 52 |
| Golden shiner | *Notemigonus crysoleucas* | | | | 1 | | 1 | 15 | | | 3 | 24 | 42 | 3 | 7 | 813 | 115 | 15 | 953 |
| Spottail shiner | *Notropis hudsonius* | | | | | | | | | | | | | | | | 4 | | 4 |
| Grass shrimp | *Palaemonetes* | 7 | 8 | 1 | 9 | 13 | 38 | 1 | 4 | 2 | 1 | 2 | 10 | | | | | | |
| Sand shrimp | *Crangon septemspinosa* | 17 | 227 | 1 | 36 | 153 | 434 | 5 | 2 | 2 | 20 | 7 | 36 | | | | | | |
| Atlantic silverside | *Menidia menidia* | 2 | 1 | 2 | 1 | 14 | 20 | 1 | | | | 4 | 5 | | | | | | |
| Rainbow smelt | *Osmerus mordax* | 395 | 326 | 859 | 242 | 1785 | 3607 | 24 | 5 | 2 | 71 | 105 | 207 | 858 | 221 | 109 | 157 | 221 | 1566 |
| Fourspine stickleback | *Apeltes quadracus* | 9 | 59 | 10 | 22 | 20 | 120 | 6 | 2 | 13 | 24 | 24 | 69 | 27 | 80 | 383 | 475 | 357 | 1322 |
| Ninespine stickleback | *Pungitius pungitius* | | | | | | | | | 1 | 1 | 1 | 3 | | | | | | |
| Threespine stickleback | *Gasterosteus aculeatus* | 4 | 39 | 2 | 14 | 79 | 138 | 542 | 209 | 634 | 528 | 271 | 2184 | 11 | 97 | 107 | 218 | 374 | 807 |
| White sucker | *Catostomus commersoni* | | | 1 | | | 1 | | | | | | | 7 | 22 | 48 | 3 | 13 | 93 |
| Banded sunfish | *Enneacanthus obesus* | | | | | | | 4 | | 8 | 21 | 3 | 36 | 7 | 2 | 3 | 7 | 7 | 26 |
| Atlantic tomcod | *Microgadus tomcod* | 3 | 6 | 6 | 2 | 30 | 47 | | | | | | | | | | | | |
| Brook trout | *Salvelinus fontinalis* | | | 2 | | 3 | 5 | | | | | | | | | | | 1 | 1 |
| Brown trout | *Salmo trutta* | | | | | 1 | 1 | | | | | | | | | | | | |
| Rainbow trout | *Oncorhynchus mykiss* | | | | | | | | | | | | | 1 | | | | | 1 |

Table 6b. The number of individuals caught are shown for non-target species caught as part of the spring fyke net survey, by year and by site for Massachusetts rivers.

| | | Saugus River | | | | | | Westport River | | | | | | Weweantic River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species (common name) | Species (scientific name) | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years |
| alewife | *Alosa pseudoharengus* | | | | 10 | 141 | 151 | 38 | 77 | 264 | 119 | 50 | 548 | | 2 | 1 | | | 3 |
| Largemouth bass | *Micropterus salmoides* | | | 1 | | | 1 | | | | | | | | | 1 | | | 1 |
| Smallmouth bass | *Micropterus dolomieui* | | | | | 1 | 1 | | | | | | | | | | | | |
| Striped bass | *Morone saxatilis* | | | | | 2 | 2 | | | 4 | 1 | 1 | 6 | | | | | | |
| Bluegill | *Lepomis macrochirus* | 1 | | 4 | | 3 | 8 | 3 | 6 | 4 | 2 | 1 | 16 | 9 | 13 | 8 | 13 | 18 | 61 |
| Brown bullhead catfish | *Ameiurus nebulosus* | 1 | | 5 | | 1 | 7 | | | 3 | 3 | 15 | 21 | | 2 | 2 | | | 4 |
| Yellow bullhead catfish | *Ameiurus natalis* | | 1 | 1 | | | 2 | | | | | | | | | | | | |
| Atlantic cod | *Gadus morhua* | | | | | | | | | | | | | | | | | | |
| Asian shore crab | *Hemigrapsus sanguineus* | | | | | | | | | | | | | | | | | | |
| Atlantic mud crab | *Panopeus herbstii* | | | | | | | | | | | | | | | | | | |
| Atlantic mud crab | *Panopeus herbstii* | | | | | | | | | | | | | | | | | | |
| Blue crab | *Callinectes sapidus* | | | | | | | | | | | 3 | 3 | | | 17 | | 18 | 35 |
| Green crab | *Carcinus maenas* | | | | | 16 | 16 | | | | | | | | | 2 | | | 2 |
| Horseshoe crab | *Limulus polyphemus* | | | | | | | | | | | | | | | | | | |
| Mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | 1 | | | 1 |
| White-fingered mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | | | |
| White-tip mud crab | *Rhithropanopeus harrisii* | | | | | | | | | | | | | | | | | | |
| Black crappie | *Pomoxis nigromaculatus* | | | 2 | 1 | | 3 | | 2 | | | 4 | 6 | 1 | | | | | 1 |
| Crayfish | *Cambaridae* | 2 | 6 | 1 | 1 | 2 | 12 | | | | | | | | | | | | |
| Darter | *Etheostoma sp.* | | | | | | | | | | | | | | | 5 | | | 5 |
| American eel | *Anguilla rostrata* | 16 | 3 | 20 | 2 | 35 | 76 | 9 | 4 | 4 | 29 | 20 | 66 | 3 | 12 | 27 | 27 | 20 | 89 |
| Summer flounder | *Paralichthys dentatus* | | | | | | | | | | | | | | | | | | |
| Winter flounder | *Pseudopleuronectes americanus* | | | | | | | | | | | | | | | | | | |
| Atlantic herring | *Clupea harengus* | | | | | | | | | | | | | | | | | | |
| Blueback herring | *Alosa aestivalis* | | | | 1 | 71 | 72 | | | | | | | | | | | 1 | 1 |
| American shad | *Alosa sapidissima* | | | | | | | | | | | | | | | | | | |
| Hogchoker | *Trinectes maculatus* | | | | | | | | | | | | | | | 37 | 4 | 108 | 149 |
| Killifish spp. | *Fundulus spp.* | | | | | | | 22 | 5 | 2 | 24 | 1 | 54 | | 16 | 11 | 10 | 12 | 49 |
| Sea lamprey | *Petromyzon marinus* | | | | | | | | | | | | | 11 | 10 | 6 | 22 | 4 | 53 |
| American sand lance | *Ammodytes americanus* | | | | | | | | | | | | | | | | | | |
| Fathead minnow | *Pimephales promelas* | | | | | | | | | | 1 | | 1 | | | | | | |
| Mummichog | *Fundulus heteroclitus* | 254 | 117 | 164 | 168 | 1571 | 2274 | | | | | | | | | 3 | | 2 | 5 |
| White perch | *Morone americana* | 6 | 3 | 5 | 40 | 19 | 73 | 95 | 279 | 60 | 24 | 325 | 783 | 168 | 171 | 4 | 23 | 124 | 490 |
| Yellow perch | *Perca flavescens* | 4 | | 4 | | 2 | 10 | | | 2 | 4 | 19 | 25 | 1 | | | | | 1 |
| Chain pickerel | *Esox niger* | | | | 1 | | 1 | | | | | | | | | | 1 | | 1 |
| Redfin pickerel | *Esox americanus* | 3 | | 1 | | 2 | 6 | | | | | | | | | | 1 | | 1 |
| Pumpkinseed | *Lepomis gibbosus* | | | | 1 | 1 | 2 | 3 | | 2 | 6 | 6 | 17 | | 6 | 4 | 4 | 5 | 19 |
| Common shiner | *Luxilus cornutus* | | | | | | | | | | | | | | | | | | |
| Golden shiner | *Notemigonus crysoleucas* | 4 | 2 | 12 | 1 | 1 | 20 | 27 | 1 | 1 | 12 | 66 | 107 | | 5 | 3 | 5 | 3 | 16 |
| Spottail shiner | *Notropis hudsonius* | | | | | | | | | | | | | | | | | | |
| Grass shrimp | *Palaemonetes* | | | | | | | | | | 2 | | 2 | | | | | | |
| Sand shrimp | *Crangon septemspinosa* | | | | | | | | | | | | | | | | | | |
| Atlantic silverside | *Menidia menidia* | | | | | 17 | 17 | | | | | | | | | | 3 | 12 | 15 |
| Rainbow smelt | *Osmerus mordax* | 376 | 8 | 1 | 68 | 456 | 909 | | | | 1 | | 1 | 176 | 12 | 27 | 30 | 76 | 321 |
| Fourspine stickleback | *Apeltes quadracus* | 106 | 108 | 365 | 79 | 275 | 933 | 7 | 9 | 10 | 11 | 21 | 58 | 2 | 30 | 43 | 40 | 53 | 168 |
| Ninespine stickleback | *Pungitius pungitius* | | 1 | 1 | | | 2 | | | | | | | | | | | | |
| Threespine stickleback | *Gasterosteus aculeatus* | 20 | 581 | 367 | 154 | 126 | 1248 | 17 | 58 | 10 | 68 | | 153 | | 9 | 3 | 3 | 1 | 16 |
| White sucker | *Catostomus commersoni* | 9 | 2 | 44 | 31 | 85 | 171 | | | | | | | | | | | | |
| Banded sunfish | *Enneacanthus obesus* | 2 | 2 | 3 | 1 | 7 | 15 | | | | | | | | | | | | |
| Atlantic tomcod | *Microgadus tomcod* | | | | | | | | | | | | | | | | | 17 | 17 |
| Brook trout | *Salvelinus fontinalis* | | | | | | | 2 | | 1 | 4 | 7 | 14 | | | | | 1 | 1 |
| Brown trout | *Salmo trutta* | 1 | | | | | 1 | | | | | | | | | | | | |
| Rainbow trout | *Oncorhynchus mykiss* | | | | | | | | | | | | | | | | | | |

Table 6c. The number of individuals caught are shown for non-target species caught as part of the spring fyke net survey, by year and by site for Massachusetts rivers.

| | | Oyster River | | | | Squamscott River | | | | | | Winnicut River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species (common name) | Species (scientific name) | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years |
| Alewife | *Alosa pseudoharengus* | 2 | | 1 | 3 | | | | | 7 | 7 | | | | | | |
| Largemouth bass | *Micropterus salmoides* | | | | | | 2 | | | 1 | 3 | | | | | | |
| Bluegill | *Lepomis macrochirus* | 18 | 5 | 6 | 29 | | 11 | | 4 | 11 | 26 | | 4 | 3 | 4 | 2 | 13 |
| Brown bullhead catfish | *Ameiurus nebulosus* | | 1 | | 1 | 6 | 6 | 29 | 22 | 99 | 162 | | 10 | 18 | 4 | 2 | 34 |
| Yellow bullhead catfish | *Ameiurus natalis* | | | | | | | 3 | | | 3 | | | | | | |
| Creek chub | *Semotilus atromaculatus* | | | | | | | 1 | | | 1 | | | 1 | | | 1 |
| Horseshoe crab | *Limulus polyphemus* | 6 | | 14 | 20 | | | | | | | | | | | | |
| Black crappie | *Pomoxis nigromaculatus* | 17 | 9 | 13 | 39 | 2 | 4 | 3 | 1 | 21 | 31 | | | | | | |
| Cunner | *Tautogolabrus adspersus* | | 1 | | 1 | | | | | | | | | | | | |
| Blacknose dace | *Rhinichthys atratulus* | | | | | | | | | | | | | | 1 | | 1 |
| American eel | *Anguilla rostrata* | 46 | 24 | 29 | 99 | 7 | 9 | 20 | 25 | 22 | 83 | 7 | 9 | 7 | 3 | 36 | 62 |
| Fallfish | *Semotilus corporalis* | 2 | | | 2 | 3 | | | | | 3 | 1 | | | | 2 | 3 |
| Smooth Flounder | *Pleuronectes putnami* | 4 | 4 | 24 | 32 | | | | | | | | | 1 | | 25 | 26 |
| Winter flounder | *Pseudopleuronectes americanus* | 13 | 5 | 12 | 30 | | | | | | | | | | | 8 | 8 |
| Atlantic herring | *Clupea harengus* | | | | | | | | | | | | | | | 5 | 5 |
| Blueback herring | *Alosa aestivalis* | | | 1 | 1 | | | | | | | | | | | | |
| River herring spp. | *Alosa* | 15 | 34 | 3 | 52 | | 1 | 6 | 14 | 33 | 54 | | | 13 | 1 | 1 | 15 |
| Banded killifish | *Fundulus diaphanus* | | | | | 1 | | | | | 1 | 32 | | | | 2 | 34 |
| Killifish spp. | *Fundulus spp.* | 24 | 40 | 450 | 514 | 2 | 2 | | 3 | 1 | 8 | 866 | 488 | 13 | 176 | 472 | 2015 |
| Minnow | *Cyprinidae* | | 1 | 1 | 2 | | | | | | | 37 | 4 | | 1 | 4 | 46 |
| Sea lamprey | *Petromyzon marinus* | 7 | 4 | 14 | 25 | 13 | 8 | 2 | 16 | 20 | 59 | | | | 1 | | 1 |
| White perch | *Morone americana* | 39 | 93 | 300 | 432 | 2 | 41 | 105 | 51 | 2847 | 3046 | 41 | 73 | 76 | 205 | 583 | 978 |
| Yellow perch | *Perca flavescens* | 24 | 3 | 2 | 29 | 3 | 152 | 63 | 4 | 4 | 226 | | 5 | 8 | 1 | | 14 |
| Chain pickerel | *Esox niger* | | | | | | 10 | 4 | | 2 | 16 | | 1 | | | | 1 |
| Northen pipefish | *Syngnathus fuscus* | | | | | | | | | | | | | | | 1 | 1 |
| Pumpkinseed sunfish | *Lepomis gibbosus* | 12 | 4 | 13 | 29 | 11 | 2 | 15 | 5 | 12 | 45 | | 10 | 10 | 2 | 46 | 68 |
| Common shiner | *Notropis cornutus* | 9 | | 3 | 12 | 8 | 7 | | 5 | 6 | 26 | 1 | 3 | 4 | 10 | 7 | 25 |
| Golden Shiner | *Notemigonus crysoleucas* | 5 | | 1 | 6 | 12 | 2 | 4 | 15 | 3 | 36 | 3 | 1 | 1 | 6 | 18 | 29 |
| Spottail shiner | *Notropis hudsonius* | | | | | | | | | | | 1 | | | | | 1 |
| Atlantic silverside | *Menidia menidia* | 4 | 5 | 37 | 46 | | | | | | | | 1 | | | 15 | 16 |
| Rainbow smelt | *Osmerus mordax* | 300 | 402 | 240 | 942 | 101 | 151 | 2 | 755 | 469 | 1478 | 14 | 16 | 10 | 34 | 16 | 90 |
| Fourspine stickleback | *Apeltes quadracus* | 48 | 269 | 518 | 835 | 28 | 23 | 3 | 377 | 182 | 613 | 300 | 958 | 866 | 1044 | 2639 | 5807 |
| Ninespine stickleback | *Pungitius pungitius* | 1 | | 8 | 9 | 10 | | | 1 | 3 | 14 | 22 | 154 | 10 | 17 | 40 | 243 |
| Threespine stickleback | *Gasterosteus aculeatus* | 41 | 261 | 523 | 825 | 65 | 74 | | 59 | 23 | 221 | 26 | 143 | 48 | 118 | 257 | 592 |
| White sucker | *Catostomus commersonii* | 1 | | | 1 | 8 | 25 | 4 | 7 | 9 | 53 | 3 | 5 | 3 | 1 | 3 | 15 |
| Banded sunfish | *Enneacanthus obesus* | | | | | | | | | 1 | 1 | | | | | | |
| Redbreast sunfish | *Lepomis auritus* | 3 | | | 3 | | | | | | | | | | | | |
| Atlantic tomcod | *Microgadus tomcod* | 15 | 4 | 162 | 181 | 4 | 2 | | | 18 | 24 | | | 3 | | 15 | 18 |
| Brook trout | *Salvelinus fontinalis* | 2 | | | 2 | | | | | | | | | | | 2 | 2 |
| Rainbow trout | *Oncorhynchus mykiss* | | | | | | | | | | | | 1 | | | | 1 |

Table 6d. The number of individuals caught are shown for non-target species caught as part of the spring fyke net survey, by year and by site for New Hampshire rivers.

| Species (common name) | Species (scientific name) | Deer Meadow Brook 2008 | Deer Meadow Brook 2009 | Deer Meadow Brook 2010 | Deer Meadow Brook 2011 | Deer Meadow Brook 2012 | Deer Meadow Brook All Years | East Bay Brook 2008 | East Bay Brook 2009 | East Bay Brook 2010 | East Bay Brook 2011 | East Bay Brook All Years | Long Creek 2009 | Long Creek 2010 | Long Creek 2011 | Long Creek 2012 | Long Creek All Years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alewife | *Alosa pseudoharengus* | 119 | 27 | | 1 | 3 | 150 | | | | | | 5 | 7 | 6 | 2 | 20 |
| Largemouth bass | *Micropterus salmoides* | | | | | | | | | | | | 1 | | | | 1 |
| Brown bullhead catfish | *Ameiurus nebulosus* | | 2 | 1 | | | 3 | | | | | | | | | | |
| Creek chub | *Semotilus atromaculatus* | 17 | 66 | 8 | 14 | 9 | 114 | | | | | | | | | | |
| Atlantic rock crab | *Cancer irroratus* | - | | | | | | - | | | | | - | | | | |
| Green crab | *Carcinus maenas* | 4 | | | | | 4 | | | | | | 68 | 293 | 194 | 234 | 789 |
| crangonidae | *Crangonidae* | | 302 | 1061 | 1 | 1 | 1365 | | | | | | 1310 | 705 | 27 | 4 | 2046 |
| Black crappie | *Pomoxis nigromaculatus* | | | | | | | | | | | | | | | | |
| Crayfish | *Cambaridae* | | | | | | | | | | | | | | | | |
| Cusk | *Brosme brosme* | | | | | | | | | | | | | | | | |
| Blacknose dace | *Rhinichthys atratulus* | 3 | | 17 | | 2 | 22 | | | | | | | | | | |
| American eel | *Anguilla rostrata* | 130 | 30 | 11 | 12 | 48 | 231 | 43 | 19 | 30 | 13 | 105 | 19 | 21 | 3 | 4 | 47 |
| Fallfish | *Semotilus corporalis* | 2 | 1 | | | | 3 | | | | | | | | | | |
| Windowpane flounder | *Scophthalmus aquosus* | 1 | | | | | 1 | | | | | | | | | | |
| Winter flounder | *Pseudopleuronectes americanus* | | | | | | | | | | | | | 2 | | | 2 |
| Banded gunnel | *Pholis gilli* | | | | | | | | | | | | 3 | 9 | 3 | 12 | 27 |
| Rock gunnel | *Pholis gunnellus* | | | | | | | | | | | | | | | | |
| Atlantic red hake | *Urophycis chuss* | | | | | | | | | | | | | | | | |
| Silver hake | *Merluccius bilinearis* | | | | | | | | | | | | | | | | |
| White hake | *Urophycis tenuis* | 1 | | | 19 | | 20 | | | | | | | | | | |
| Atlantic herring | *Clupea harengus* | | | 253 | 50 | | 303 | | | | | | 3 | | | | 3 |
| Blueback herring | *Alosa aestivalis* | | | | | | | | | | | | | | | 4 | 4 |
| River herring spp. | *Alosa* | 57 | 490 | 42 | 10 | 4 | 603 | | | | | | 180 | 289 | 66 | 267 | 802 |
| Banded killifish | *Fundulus diaphanus* | | | | | | | | 1 | | | 1 | | | | | |
| Krill | *Euphausiacea* | 4 | | | | | 4 | | | | | | | | | | |
| Minnow | *Cyprinidae* | 192 | 1539 | 233 | 34 | 110 | 2108 | | | | | | 364 | 328 | 222 | 1176 | 2090 |
| Mummichog | *Fundulus heteroclitus* | | | | | | | | | | | | | | | | |
| Mysidacea | *Mysidacea* | | | | | | | | | | | | | | | | |
| Northern redbelly dace | *Phoxinus eos* | | | | | 8 | 8 | | | | | | | | | | |
| Perch spp. | *Percidae* | 6 | | 3 | 7 | 14 | 30 | | | | 1 | 1 | | | | | |
| White perch | *Morone americana* | | | | | | | | | | | | | 1 | | | 1 |
| Yellow perch | *Perca flavescens* | 1 | | | | | 1 | | | | | | | | | | |
| Chain pickerel | *Esox niger* | | | | | | | | | | | | | | | | |
| Northen pipefish | *Syngnathus fuscus* | | | | | | | | | | | | | | | 2 | 2 |
| Longhorn sculpin | *Myoxocephalus octodecemspinosus* | | | | | | | | | | | | | | | | |
| Sculpins spp. | *Cottidae* | | 2 | | | | 2 | | | | | | | | | | |
| Sea lamprey | *Petromyzon marinus* | 206 | 574 | 45 | 3 | 24 | 852 | | | | | | 5 | 11 | 8 | | 24 |
| Common shiner | *Notropis cornutus* | | | | | 2 | 2 | | | | | | | | | | |
| Golden Shiner | *Notemigonus crysoleucas* | 856 | | | | | 856 | 2 | | | | 2 | | | | 1 | 1 |
| Redfin shiner | *Lythrurus umbratilis* | 48 | 235 | 95 | | 80 | 458 | | | | | | 176 | 39 | 24 | 1313 | 1552 |
| Crangonidae | *Crangon septemspinosa* | | | | | | | | | | | | 2 | | | 60 | 62 |
| Atlantic silverside | *Menidia menidia* | 213 | 7244 | 2777 | 5306 | 382 | 15922 | 1635 | 235 | 1623 | 1569 | 5062 | 1253 | 187 | 409 | 174 | 2023 |
| silversides | *Atherinidae* | | 1 | | | | 1 | | | | | | | | | | |
| Rainbow smelt | *Osmerus mordax* | 3 | 1 | 2 | | | 6 | | | | | | | | | | |
| Stickleback spp. | *Gasterosteidae* | 4 | | | 3 | 4 | 11 | | | | | | 63 | 24 | 4 | 7 | 98 |
| Blackspotted stickleback | *Gasterosteus wheatlandi* | | | 1 | | 25 | 26 | | | | | | 3 | 14 | 8 | 9 | 34 |
| Fourspine stickleback | *Apeltes quadracus* | 22 | 29 | 202 | 11 | 200 | 464 | 111 | 85 | 165 | 30 | 391 | 761 | 1719 | 233 | 687 | 3400 |
| Ninespine stickleback | *Pungitius pungitius* | 17 | 10 | 57 | 11 | | 95 | | | | | | | 1 | | | 1 |
| Threespine stickleback | *Gasterosteus aculeatus* | | | 1 | | 1 | 2 | | | | | | | | | | |
| White sucker | *Catostomus commersonii* | 4 | 14 | | | 4 | 22 | | | | | | | 1 | 1 | | 2 |
| suckers | *Catostomidae* | | | | | | | | | | | | | | | | |
| Pumpkinseed sunfish | *Lepomis gibbosus* | 4 | | | | 2 | 6 | 2 | 2 | | | 4 | 1 | 5 | 7 | 9 | 22 |
| Redbreast sunfish | *Lepomis auritus* | | 1 | | | | 1 | | 2 | | 12 | 14 | | 1 | 1 | | 2 |
| Atlantic tomcod | *Microgadus tomcod* | | | | | | | | | | | | | | | 1 | 1 |
| Brook trout | *Salvelinus fontinalis* | | | | | | | | | | | | | | | 1 | 1 |
| Brown trout | *Salmo trutta* | 1914 | 10568 | 4809 | 5482 | 923 | 23696 | 1793 | 344 | 1818 | 1625 | 5580 | 4217 | 3657 | 1216 | 3967 | 13057 |
| Snapping turtle | *Chelydra serpentina* | | | | | | | | | | | | | | | | |

Table 6e. The number of individuals caught are shown for non-target species caught as part of the spring fyke net survey, by year and by site for Maine rivers.

| | | Mast Landing | | | | | | Schoppee Brook | | | | | Tannery Brook | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species (common name) | Species (scientific name) | 2008 | 2009 | 2010 | 2011 | 2012 | All Years | 2009 | 2010 | 2011 | 2012 | All Years | 2008 | 2009 | 2010 | 2011 | 2012 | All Years |
| Alewife | *Alosa pseudoharengus* | 13 | 36 | 80 | 4 | 5 | 138 | 502 | 7 | | 27 | 34 | | 3 | 2 | 3 | | 8 |
| Largemouth bass | *Micropterus salmoides* | | | | | | | | | | | | 1 | | | | | 1 |
| Brown bullhead catfish | *Ameiurus nebulosus* | | 2 | 2 | | 1 | 5 | 17 | 1 | | 2 | 3 | | | | | | |
| Creek chub | *Semotilus atromaculatus* | 11 | 13 | 1 | 10 | 8 | 43 | 3 | | | | | | 1 | 1 | 6 | | 8 |
| Atlantic rock crab | *Cancer irroratus* | - | | | | | | - | | | | | - | | 1 | | | 1 |
| Green crab | *Carcinus maenas* | | | | | | | | 2 | 2 | 99 | 103 | 53 | 57 | 164 | 92 | 2126 | 2492 |
| crangonidae | *Crangonidae* | | 247 | 434 | 32 | 2 | 715 | 54 | 6 | 2 | | 8 | | 21 | | | | 21 |
| Black crappie | *Pomoxis nigromaculatus* | | | | | | | | | | | | 1 | | | | | 1 |
| Crayfish | *Cambaridae* | | | | | | | | | | | | | 1 | | | | 1 |
| Cusk | *Brosme brosme* | | | | | | | | | | | | 2 | | | | | 2 |
| Blacknose dace | *Rhinichthys atratulus* | 1 | | | 6 | 1 | 8 | 1 | | | | | | | | | | |
| American eel | *Anguilla rostrata* | 13 | 45 | 9 | 20 | 11 | 98 | 197 | 149 | 16 | 334 | 499 | 96 | 124 | 133 | 115 | 55 | 523 |
| Fallfish | *Semotilus corporalis* | | | | | | | | | | | | | | | 2 | | 2 |
| Windowpane flounder | *Scophthalmus aquosus* | 1 | 1 | 2 | | 35 | 39 | 46 | | | | | 14 | 12 | 2 | 6 | 14 | 48 |
| Winter flounder | *Pseudopleuronectes americanus* | | | | | | | | | | | | | | | | | |
| Banded gunnel | *Pholis gilli* | | | | | | | | | | | | 8 | 2 | 8 | 3 | 7 | 28 |
| Rock gunnel | *Pholis gunnellus* | | | | | | | | 1 | | | 1 | | 1 | | | | 1 |
| Atlantic red hake | *Urophycis chuss* | | | | | | | 4 | | | | | | | | | | |
| Silver hake | *Merluccius bilinearis* | | | | | | | | | | | | 1 | 3 | 1 | | | 5 |
| White hake | *Urophycis tenuis* | | | | | | | 5 | | | | | | | | | | |
| Atlantic herring | *Clupea harengus* | | | | | | | | | | | | | | | | | |
| Blueback herring | *Alosa aestivalis* | | | | | 9 | 9 | | | | | | | | | | | |
| River herring spp. | *Alosa* | 1 | 16 | 3 | 2 | 8 | 30 | | | | | | | 1 | | | | 1 |
| Banded killifish | *Fundulus diaphanus* | | | | | | | | | | | | | | | | | |
| Krill | *Euphausiacea* | | | | | | | | | | | | | | | | | |
| Minnow | *Cyprinidae* | 35 | 102 | 7 | 31 | 70 | 245 | 68 | 8 | 2 | 1 | 11 | 39 | 14 | 15 | 35 | 1 | 104 |
| Mummichog | *Fundulus heteroclitus* | | | | | | | | | | | | 13 | | | 1 | | 14 |
| Mysidacea | *Mysidacea* | | | | | | | 2 | | | | | | | | | | |
| Northern redbelly dace | *Phoxinus eos* | | | | | | | | | | | | | | | | 1 | 1 |
| Perch spp. | *Percidae* | 3 | | | 2 | 3 | 8 | | | | | | 1 | | | 5 | | 6 |
| White perch | *Morone americana* | | | | | | | | | | | | 2 | | | | | 2 |
| Yellow perch | *Perca flavescens* | | | | | | | | | | | | | | | | | |
| Chain pickerel | *Esox niger* | | | | | | | 5 | | | | | | | | | | |
| Northen pipefish | *Syngnathus fuscus* | | | | | | | | | | | | | | | | | |
| Longhorn sculpin | *Myoxocephalus octodecemspinosus* | | | | | | | | | | | | 1 | | | | | 1 |
| Sculpins spp. | *Cottidae* | | 5 | | | | 5 | | | | | | | | | | | |
| Sea lamprey | *Petromyzon marinus* | 51 | 39 | 4 | 1 | 10 | 105 | 12 | | 4 | 185 | 189 | 28 | | | 18 | | 46 |
| Common shiner | *Notropis cornutus* | | | | | | | 1 | | | | | | | | | | |
| Golden Shiner | *Notemigonus crysoleucas* | 24 | | | | | 24 | | | | | | 28 | | | | | 28 |
| Redfin shiner | *Lythrurus umbratilis* | 1 | 1 | 3 | | | 5 | 843 | | 2 | 7 | 9 | 1 | 1 | | 9 | | 11 |
| Crangonidae | *Crangon septemspinosa* | | | | | 1 | 1 | | | | | | | | | | | |
| Atlantic silverside | *Menidia menidia* | 4084 | 2220 | 367 | 6192 | 1045 | 13908 | 88 | 3972 | 5495 | 2056 | 11523 | 3357 | 5246 | 3808 | 1030 | 231 | 13672 |
| silversides | *Atherinidae* | | | | | | | | | | | | 1 | | | | | 1 |
| Rainbow smelt | *Osmerus mordax* | | | 12 | 11 | | 23 | | | | | | 4 | | | | | 4 |
| Stickleback spp. | *Gasterosteidae* | 13 | 12 | 13 | 233 | 67 | 338 | | | | | | 25 | 45 | 49 | 99 | | 218 |
| Blackspotted stickleback | *Gasterosteus wheatlandi* | 2 | 6 | 106 | 73 | 66 | 253 | | | | | | 1 | | 5 | 1 | | 7 |
| Fourspine stickleback | *Apeltes quadracus* | 64 | 294 | 394 | 281 | 688 | 1721 | 234 | 102 | 83 | 14 | 199 | 16 | 6 | 4 | 24 | | 50 |
| Ninespine stickleback | *Pungitius pungitius* | 22 | 7 | 29 | 61 | 14 | 133 | 11 | | | | | | 2 | | 3 | | 5 |
| Threespine stickleback | *Gasterosteus aculeatus* | | | | | 17 | 17 | | | | | | | | | | | |
| White sucker | *Catostomus commersonii* | | 1 | | | | 1 | 4 | | | 4 | 4 | | 2 | | 13 | | 15 |
| suckers | *Catostomidae* | | | | | | | 10 | | | | | | | | | | |
| Pumpkinseed sunfish | *Lepomis gibbosus* | | 1 | 5 | 8 | 2283 | 2297 | 5 | 23 | 28 | 19 | 70 | 151 | 182 | 244 | 72 | 394 | 1043 |
| Redbreast sunfish | *Lepomis auritus* | 8 | 2 | 21 | 24 | 1 | 56 | 51 | 15 | 4 | 7 | 26 | | | | | | |
| Atlantic tomcod | *Microgadus tomcod* | 1 | | | | | 1 | | | | | | | | | | | |
| Brook trout | *Salvelinus fontinalis* | | | | | | | | | | | | | | | | | |
| Brown trout | *Salmo trutta* | 4348 | 3050 | 1492 | 6991 | 4345 | 20226 | 2163 | 4286 | 5638 | 2755 | 12679 | 3844 | 5724 | 4437 | 1537 | 2829 | 18371 |
| Snapping turtle | *Chelydra serpentina* | | | | | | | | | | | | | | | | | |

Table 6f. The number of individuals caught are shown for non-target species caught as part of the spring fyke net survey, by year and by site for Maine rivers.

*Monitoring the Winter Smelt Fishery*

NHFG has conducted winter creel surveys since 1978. The survey occurs from ice in to ice out, generally between the months of December and March. Four locations are sampled: the Lamprey, Oyster/Bellamy and Squamscott rivers as well as Great Bay. These surveys are conducted under the Wallop-Breaux Sport Fish Restoration Program and were not conducted under this project. The data from this survey were analyzed for the species conservation to show population trends (Appendix A), and the methods were adopted by ME DMR who began creel surveys under this grant in 2009.

Adopting sampling methods currently used by NHF&G (Sullivan 2009) and methods used in a 1979-1982 study conducted by the ME DMR (Flagg 1983), ME DMR again began conducting creel surveys in 2009 in the Kennebec River and Merrymeeting Bay area (Figure 6). As part of this survey, DMR staff visited participating camps two or three times per week on a rotating basis to collect biological information about the recreational catch. Staff collected biological information from a subset of each angler's catch (up to 100 fish per angler), including length, sex, scale samples for ageing and fin clip samples for genetic sampling. The number of anglers, fishing hours, and the number of fishing lines used was also recorded. The field protocol for this ME DMR survey is included as Appendix L.

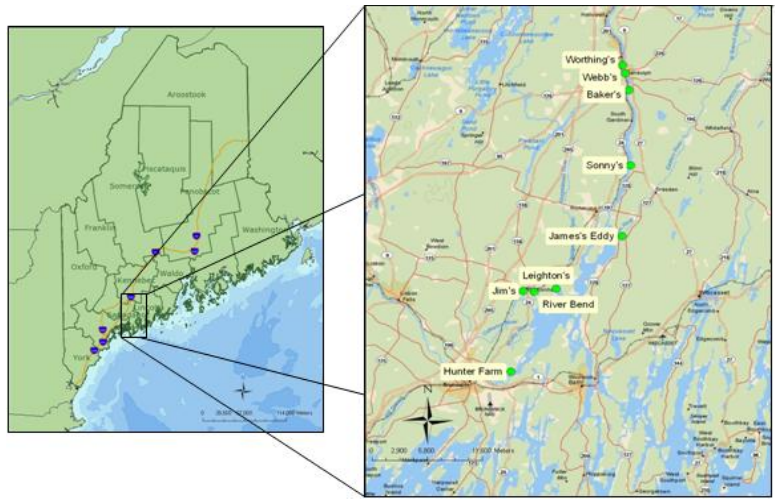


Figure 6. Nine commercial operations set anywhere from 15-100 ice shacks on the Kennebec River and Merrymeeting Bay annually. Anglers fish for rainbow smelt exclusively. ME DMR performs surveys 2-3x week, visiting camps on a rotating schedule. Each camp is visited a minimum of two times each season.

CPUE was calculated as the total number of smelt caught per line-hour of fishing to remain consistent with surveys conducted by ME DMR 1979-1982. The recent survey found a slightly lower CPUE (0.48), compared to the 1979-1982 study CPUE (0.64), however inter-annual variability was significantly larger than the comparison between the two study periods ( Flagg 1983). While annual fluctuations in CPUE occurred in both surveys, the recent survey had the lowest CPUE recorded (0.17) during the two time series.

Catch Card boxes were also posted at each camp for fishermen to voluntarily report information about their total smelt catch and any bycatch; responses varied widely between sites and between years. There were 122 responses in 2009, 6 in 2010, and 37 in 2011 for all camps combined. It is our hope that with continued interaction with anglers and camp owners that the number of responses will increase. Despite the low number of responses in 2010, the Catch Cards still reflected the catch patterns found in creel survey data.

Additionally, the commercial winter fishery and recreational winter fishery in Washington County was sampled for beginning in 2010. The fisheries on the Pleasant and Narraguagus Rivers constitute a large part of the remaining commercial efforts in Maine. We worked with the Downeast Salmon Federation, who is interested in documenting the smelt fishery as one of the oldest fisheries in the country, to sample both the commercial and recreational fisheries.

Comparing data from the Maine DMR 1979-1982 study (Flagg, LN. 1983. *Final Report: Evaluation of Anadromous Fish Resources.* Maine Department of Marine Resources. Project # AFS-21R) to data collected 2009-2012, the current survey has observed a catch per unit effort (CPUE) that is almost half that of the previous survey (1979-82 CPUE = 0.6351, 2009-12 CPUE = 0.3724), however inter-annual variability was significantly larger than the comparison between the two study periods (Table 7). CPUE was calculated as total number of smelt caught per line-hour of fishing. Both surveys observed annual fluctuations in CPUE, but the recent survey saw the lowest CPUE recorded (0.1700).

| Year | Total Catch (no. smelt) | Total Effort (Line-Hours) | CPUE (Smelt per Line-Hour) |
|---|---|---|---|
| 1979 | 452,904 | 576,434 | 0.7857 |
| 1980 | 197,853 | 355,850 | 0.5560 |
| 1981 | 245,189 | 566,780 | 0.4326 |
| 1982 | 405,593 | 550,205 | 0.7372 |
| 2009 | 1353 | 1865 | 0.7308 |
| 2010 | 372 | 2026 | 0.1836 |
| 2011 | 2305 | 4639 | 0.4969 |
| 2012 | 716 | 4213 | 0.1700 |
| 1979-1982 Combined | 1,301,539 | 2,049,269 | 0.6351 |
| 2009-2012 Combined | 4746 | 12743 | 0.3724 |

Table 7. Catch per unit effort (CPUE) was calculated as the total number of smelt caught per year by the total number of line-hours each year.

The mean length differed significantly between males and females within each year 2009-2011 (t-test $p<0.0001<0.05$ in all cases) and between the years for each sex (ANOVA $p<0.0001<0.05$ in all cases). Mean length was significantly higher in 2010 and 2012 compared to 2009 and 2011 (Figure 7); concurrently, CPUE also was lower in 2010 and 2012 (Table 6). Because younger age classes can constitute a larger proportion of the population than older sage classes, this lower CPUE combined with a larger average length in 2010 and 2012 may indicate a problem with a younger age class (poor juvenile survival in the previous year). The mean length decreased in 2011, while the CPUE increased, indicating that the age distribution was more normal in this year (younger age classes were better represented). In most years, the mean sex ratio (M:F) was roughly even (2009 = 1.63; 2010 = 1.54; 2011 = 1.51), although was higher in 2012, when more than twice the number of males were caught compared to females (2012 = 2.19).

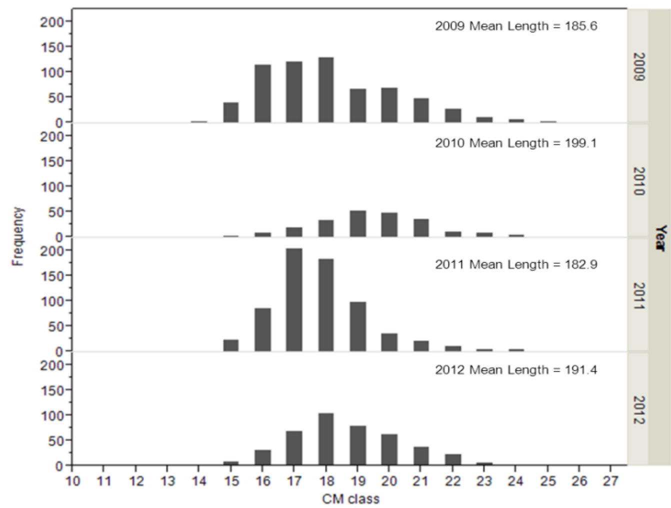


Figure 7. Length frequency by year for smelt sampled during the ME DMR winter creel surveys 2009-2012. The average length in 2010 and 2012 was significantly higher than in 2009 and 2011 (ANOVA and Each Pair t-Test $p < 0.0001$) indicating that younger age classes were underrepresented in 2010 and 2012.

Catch Card boxes are also posted at each camp for fishermen to voluntarily report information about their total smelt catch and any bycatch. Catch Card responses varied widely between sites and between years. We received 125 responses in 2009, 6 in 2010, 41 in 2011, and 27 in 2012 from all camps combined. The low response in 2010 was most likely due to anger about the new required Salt Water Fishing License, which was undergoing state public hearings during the fishing season. It is our hope that with continued conversation with anglers and camp owners that the number of responses will increase. Despite the low number of responses in 2010, the Catch Cards still reflected a sharp decline in catch from 2009 to 2010, and increase again in 2011 (mean reported catch 2009 = 119.9; 2010 = 44.7; 2011 = 131.7; 2012 = 46.7). This trend was also evident in the creel survey data.

We are currently developing age-at-length keys to compare the age composition of the current population to that of the 1979-1982 survey and the NHFG surveys. We will continue to monitor the camps to develop a longer-term dataset to understand more about inter-annual variability and changes in the population.

*Icthyoplankton Survey*

To update information about the timing and location of rainbow smelt and Atlantic sturgeon spawning in the Kennebec, Androscoggin, and Eastern Rivers, we conducted icthyoplankton surveys at four locations in the river complex June – August 2011. Various survey methods were used at each site to understand which methods are most effective at catching larvae, how this may differ between sites, and which methods may be most effective for each species. Three sites were placed directly below the spawning grounds on each river (Kennebec River: GARD; Eastern River: EAST; Androscoggin River: ANDRO). At these three sites, four methods were employed once a week: overnight D-net set; two 20-minute surface plankton tows; two 1-hour stationary plankton net sets; and overnight light trap set. The light traps were made of three clear, plastic jugs and one mesh minnow trap on spaced out on one line with light sticks in each. The fourth site was located downstream of all other sites on the Kennebec River (BATH). Two 20-minute surface plankton tows and two 1-hour stationary plankton net sets were made weekly at this site Because of strong current and high discharge, no overnight sets were made at this site. All stationary plankton nets and D-nets were set on the bottom substrate. All samples were sorted and identified to the species level. The final report for this survey is included in Appendix M.

### ***Activity 4 – Develop a Predictive GIS Habitat Model – Years 1-3***

Changes in land cover in a watershed can affect receiving waters in ways that alter habitat conditions, water quality, and biological communities. Urbanization and agricultural activities contribute to erratic flow levels, warmer water temperatures, channel alterations, sedimentation, chemical and bacterial pollution, and nutrient loading. These physical and chemical changes can secondarily affect anadromous fish spawning success when the impacts from landscape alterations in the watersheds of rivers they use for spawning and rearing. We used regionally standard GIS datasets to compare different watershed characteristic variables to adult rainbow smelt spawning populations. Variables were considered that were available at the same resolution for the entire Gulf of Maine region and that had been shown to affect water quality and/or spawning habitat. These included: watershed size, number of downstream and upstream road crossings, population density, land cover type, and impervious surface cover. The methods used to choose these datasets and extract the data at the appropriate spatial scales were presented at the 2009 Coastal Services Center GeoTools Conference.

Watershed characteristics were then compared to smelt spawning success in three different ways. First, we investigated the relationship between watershed land cover and rainbow smelt spawning habitat use along the coast of Maine using the 2007-2009 Marine Patrol survey data as a response variable. Our ultimate objective was to evaluate whether land cover characteristics can be used to prioritize conservation areas for rainbow smelt. Each spawning site in Maine was given a rank (0-5) depending on the strength of spawning at that run. Using these ranks, we explored the relationship between adult spawning strength and land cover characteristics using cluster analysis and ordered logistic regression. The dominant pattern showed that highly developed watersheds did not support rainbow smelt spawning. Conversely, sites that support higher levels of smelt spawning (ranks 3 and 4) generally had higher forest cover than those ranked lower (ranks 1 and 2). This analysis is only summarized here; a full description of the methods, analysis, and discussion of results was written for the Fourth North American Workshop on Rainbow Smelt proceedings and is included in Appendix E.

| | Correlation with smelt spawning CPUE | |
|---|---|---|
| Land Cover | Watershed Level | Stream Buffer Zone (210m) |
| % developed | **-0.62** | -0.48 |
| % developed open space (parks, golf courses) | -0.47 | -0.32 |
| % forest | **0.60** | **0.60** |
| % wetland | -0.29 | -0.28 |
| % agriculture | -0.06 | 0 |
| number of downstream crossings | -0.46 | -0.46 |

Table 8. Spearman's rank correlation between rainbow smelt spawning CPUE and land cover at two spatial scales. Correlation coefficients in bold type indicate significance at the p = 0.5 level.

Next, we compared watershed characteristics to data collected as part of the fyke net spawning surveys. In this study, we evaluated correlations between rainbow smelt CPUE and the land use in the adjacent watersheds at two spatial scales: (1) the full drainage basin and (2) the 210-meter buffer immediately adjacent to the stream. Correlations between the aggregate mean CPUE of spawning rainbow smelt over 2008-2011 (standardized based on net coverage of the stream width) indicate that weak spawning runs exist in rivers surrounded by urbanized watersheds, while rivers draining forested watersheds support strong smelt spawning populations (Table 8). Interestingly, the negative association between development and CPUE was substantially stronger at the scale of the full drainage basin than when only the riparian buffer zone was considered, possibly because many rivers within urbanized watersheds have extensive riparian wetlands in their buffer zones. The presence of these wetlands at the 210-m scale weakens the influence of urbanization on smelt spawning. Other land cover types and the number of downstream crossings, at either the scale of the watershed or riparian buffer zone, were not significantly correlated to the strength of rainbow smelt spawning populations.

Finally, we considered the relationship between watershed characteristics and water quality, nutrient loading, and periphyton growth at the fyke net index sites. The development of wetlands, agricultural fields, or forested areas replaces porous soils with impervious surfaces, which increases the velocity of water flowing off the land and the supply of suspended sediments, nutrients, and contaminants to adjacent streams. In aquatic ecosystems, these nutrients can promote algal blooms, deplete oxygen, and degrade fish habitat. Correlations between watershed land use (at the watershed and riparian buffer scales) and water quality parameters, nutrient levels, periphyton growth, and heavy metal concentrations were evaluated using Spearman's rank correlation statistic (Table 9). Correlations were similar at full watershed and riparian buffer scales, indicating that land use in the broader watershed exerts a similar influence on water quality as land use immediately adjacent to the receiving stream. Comparing correlations between land cover type, higher percentages of developed areas are associated with higher stream dissolved (available) nitrogen and heavy metals concentrations; conversely, highly forested watersheds are associated with lower concentrations of nitrogen and metals. Because periphyton growth is dependent on available nutrients (like dissolved nitrogen), and because heavy metals can negatively affect embryo development and survival, this pattern suggests that protecting forested areas is important for maintaining water quality conditions that are beneficial to rainbow smelt.

| | **Full watershed** | | | | | **Stream buffer** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | %dev | %devopen | %forest | %wetland | %ag | %dev | %devopen | %forest | %wetland | %ag |
| **Water quality** | | | | | | | | | | |
| conductivity | **0.95** | **0.9** | **-0.83** | -0.16 | -0.12 | **0.94** | **0.92** | **-0.79** | -0.01 | -0.24 |
| DO conc. | **0.67** | **0.65** | -0.38 | -0.18 | -0.19 | **0.51** | **0.56** | -0.34 | -0.05 | -0.2 |
| pH | 0.36 | 0.39 | -0.25 | -0.42 | 0.01 | 0.42 | 0.43 | -0.3 | -0.33 | -0.14 |
| turbidity | 0.32 | 0.47 | -0.22 | -0.14 | -0.04 | 0.28 | **0.51** | -0.12 | -0.21 | -0.18 |
| TP | 0.26 | 0.34 | -0.46 | -0.21 | 0.04 | 0.36 | 0.31 | -0.48 | -0.11 | -0.02 |
| TN | **0.87** | **0.77** | **-0.81** | 0.1 | -0.16 | **0.85** | **0.74** | **-0.74** | 0.24 | -0.19 |
| AFDW | **0.62** | 0.49 | -0.57 | -0.1 | 0.23 | **0.69** | 0.55 | -0.58 | 0.04 | -0.02 |
| alkalinity | **0.83** | **0.77** | **-0.66** | -0.23 | -0.14 | **0.8** | **0.76** | **-0.66** | -0.05 | -0.25 |
| hardness | **0.83** | **0.78** | **-0.7** | -0.24 | -0.11 | **0.88** | **0.88** | **-0.68** | -0.16 | -0.33 |
| | | | | | | | | | | |
| **Metals** | | | | | | | | | | |
| Al | **-0.53** | -0.44 | 0.46 | 0.2 | 0.22 | -0.39 | -0.28 | 0.56 | 0.02 | 0.13 |
| As | **0.54** | 0.45 | -0.44 | 0.13 | 0.22 | **0.61** | **0.57** | -0.4 | 0.15 | -0.04 |
| Ca | **0.83** | **0.75** | **-0.68** | -0.3 | -0.16 | **0.86** | **0.82** | **-0.67** | -0.19 | -0.36 |
| Cu | **0.58** | 0.45 | -0.37 | -0.41 | 0 | 0.42 | 0.35 | -0.41 | -0.25 | -0.09 |
| Fe | 0.26 | 0.43 | -0.32 | 0.22 | 0.42 | 0.19 | 0.41 | -0.3 | 0.24 | 0.34 |
| Mg | **0.86** | **0.84** | **-0.74** | -0.05 | -0.06 | **0.89** | **0.92** | **-0.67** | -0.01 | -0.26 |
| Ni | **0.89** | **0.89** | **-0.74** | -0.21 | -0.04 | **0.81** | **0.83** | **-0.69** | -0.08 | -0.2 |
| Pb | **0.64** | **0.63** | **-0.72** | -0.45 | **-0.81** | **0.81** | 0.59 | **-0.64** | -0.36 | **-0.8** |
| Zn | **0.7** | **0.74** | **-0.87** | -0.29 | -0.35 | **0.74** | **0.71** | **-0.82** | -0.25 | -0.44 |

Table 9. Spearman's rank correlation between water quality metrics and land cover at two spatial scales (e.g., full watershed and riparian buffer zone). Correlation coefficients in bold type indicate significance at the p=0.05 level.

## *Activity 5 – Rainbow Smelt Threat Identification – Years 1-4*

*Spawning Habitat Water Quality, Nutrient Loading, and Periphyton Studies*

Smelt deposit demersal (sinking), adhesive eggs at fast-flowing riffles, where they attach to the substrate or aquatic vegetation. The duration of egg incubation is related to water temperature (McKenzie 1964), and in the Gulf of Maine, eggs hatch 7-21 days after fertilization (Chase et al. 2008, McKenzie 1964). The success of this reproductive strategy depends on suitable water and habitat quality. In many watersheds, the tidal interface is the physical location favored for the development of commerce and community centers. This change in landscape can lead to hydrologic alterations, particularly in urban areas, leaving streams vulnerable to point and non-point source pollutants; nutrient enrichment; and reduced stream flow, shading and riparian buffer.

Changes in spawning habitat may be a major factor in the decline of smelt populations. However, up to this point, the effect to which water quality impairment may be impacting smelt populations in the Gulf of Maine has not been described. With this concern in mind, we developed monitoring programs to assess baseline water and habitat conditions at smelt spawning habitat index sites spanning the entire U. S. Gulf of Maine and explored possible impacts on spawning success resulting from changing habitat conditions.

Five indicators were measured to assess water quality at smelt spawning index sites: basic water chemistry, nutrient concentrations, periphyton growth, heavy metal concentrations, and aquatic macroinvertebrate communities. The sampling was guided by a Quality Assurance Program Plan (QAPP) for monitoring water and habitat quality at smelt spawning habitats in coastal rivers on the Gulf of Maine coast (Chase 2010, Appendix F). The QAPP integrates smelt life history with existing state and federal water quality criteria, with the objective of developing a standardized process to classify the suitability of smelt spawning habitat.

Summary statistics were generated for water quality data by site and then compared to thresholds assembled from existing water quality criteria. The U.S. Environmental Protection Agency (EPA) developed criteria for turbidity, total nitrogen (TN) and total phosphorus (TP) based on the $25^{th}$ percentile of the distribution of observed values in an ecoregion (US EPA 2000). The $25^{th}$ percentile is the value of a given parameter where 25% of all observations are below and 75% are above. The $25^{th}$ percentile was adopted by EPA as the threshold between degraded conditions and minimally impacted locations. Additionally, the Massachusetts Department of Environmental Protection (MassDEP) established Surface Water Quality Standards (SWQS) for temperature, pH and dissolved oxygen (DO) as part of their Clean Water Act waterbody assessment process (MassDEP 2007). These thresholds were selected to protect designated categories of aquatic life, including fish habitat. Stations were classified as *Suitable* (minimally impacted) or *Impaired* for each parameter. Water quality data were also evaluated to explore the potential of establishing new thresholds specifically derived from smelt spawning habitat measurements.

The species conservation plan describes in detail the data and results for the basic water quality parameters, nutrient concentration, periphyton growth, and heavy metal concentrations (Appendix A), and will not be repeated in this section. The laboratory component of the periphyton and sedimentation studies are presented in the journal *Aquatic Sciences* (Wyatt *et al.* 2010), and are presented in the final report from the University of New Hampshire (Appendix N). In addition to the data presented, Yellow Springs Incorporated (YSI) water chemistry sondes were used to measure continuous water quality data (water temperature, dissolved oxygen, specific conductivity, pH and turbidity) at selected index sites. At all field sites were periphyton growth was measured, HOBO continuous loggers were deployed in 2008 and 2009 and canopy covered was measured. These data have not been synthesized but are available from the state agencies by request.

*Biomonitoring*

In the spring of 2010, we monitored the composition of aquatic macroinvertebrate communities at each index site as a measure of overall water quality in each stream. It was our hope to create invertebrate diversity indices for each index site based on overall diversity and weighted by diversity and presence of environmentally sensitive species. The Maine Department of Environmental Protection (ME DEP) uses this method to classify all Maine waters (http://www.maine.gov/dep/water/monitoring/biomonitoring/index.html), and worked with the ME DMR to adopt their methods to our index sites, and share their data analysis techniques. Unfortunately, the results from our macroinvertebrate samples did not conform to the ME DEP classification scheme, and no conclusion could be drawn from the samples. The ME DEP classification scheme compares the proportion of each taxa found at a certain site. Depending on the relative proportion of each taxa, the site is classified on a scale that indicates how pristine the water quality is at that site. Because our sampling was performed at the head of tide at the smelt spawning index site locations, we observed considerably different taxa composition than the ME DEP scheme, and sites were either classified with a lower rank than appropriate based on our other water quality sampling, or no rank was able to be assigned. We had not expected this outcome when adopting the ME DEP methods because we were sampling in the freshwater portions of the streams, however the proximity to tidal waters likely had a larger effect than we initially expected. The final report which includes the data is included in Appendix O.

*Identifying Genetic Stock Structure*

Understanding the genetic structure of a species and the driving factors behind that structure is central to well-designed species management. A species may be comprised of one or more genetic stocks, separated by different spawning areas or physical barriers. Managing a species at too large a scale (i.e., assuming there is only one stock when there are multiple) may lead to the loss of genetic structure and the benefits of local adaptation. Managing at too small a scale (i.e., assuming stocks are isolated within individual rivers when in fact there is some mixing), neglects the important role of gene flow and results in loss of genetic variation (Kovach *et al*., in press).

From 2006-2010, we collected genetic samples at 18 spawning site index stations spanning the U. S. Gulf of Maine to understand if unique genetic stocks existed and the extent of gene flow between spawning populations. All information is presented in the species conservation plan (Appendix A) and was reported by the University of New Hampshire (Appendix N) and in detail by Kovach et al. (in press).

The three most genetically divergent populations were found in Cobscook Bay, Maine, Massachusetts Bay, and Buzzards Bay, Massachussetts. Penobscot Bay and Casco, Maine also showed some differentiation. Gene flow was high between rivers from downeast coastal Maine, the Kennebec River, ME, and Great Bay, NH to northern Massachusetts; all were dominated by the same genetic signal. Midcoast Maine also seemed to be part of this large stock, but also showed distinct signals from Penobscot Bay and Casco Bay (Figure 8).

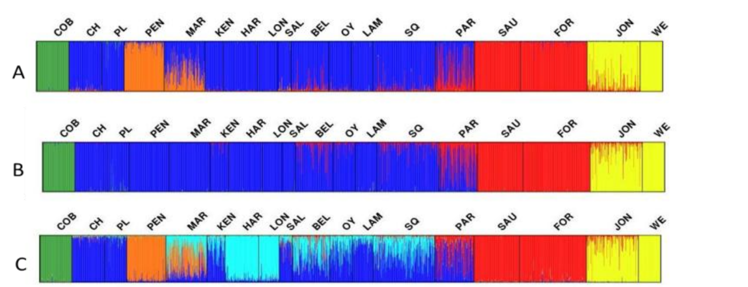


Figure 8. Membership, as identified by STRUCTURE analysis, of rainbow smelt from 18 river systems to (A) K = 5, (B) K = 4, and (C) K = 6 genetically similar clusters. Each line represents the proportional assignment of an individual to the clusters, represented by the different colors. Figure from Kovach, A.I., et al., Identifying the spatial scale of population structure in anadromous rainbow smelt (*Osmerus mordax*). Fish. Res. (2012), http://dx.doi.org/10.1016/j.fishres.2012.07.008

These groupings can assist management decisions on stocking efforts, with the goals of maintaining distinct stocks where possible, while still preserving gene flow to maintain and replenish genetic diversity. Although the study did not find evidence of genetic bottlenecking, genetic variation was significantly reduced in the two most distinct regions: Buzzards Bay (Weweantic River), and Cobscook Bay (East Bay Brook) (Kovach *et al*., in press). The reduced diversity in the Weweantic River is consistent with its location at the southern extent of the species range, where populations can have reduced gene flow and lower spawning population sizes (Schwartz et al. 2003). The reduced variation in Cobscook Bay is more likely due to isolation by circulation patterns. The reduced diversity and distinctive nature of these smelt runs warrant further population monitoring and possibly updated protection measures.

### *Activity 6 – Tasks Unique to Atlantic Sturgeon – Years 1-4*

The Atlantic sturgeon population in the Kennebec Estuary is genetically distinct and can be statistically differentiated from other populations along the U. S. East Coast (Wirgin et al. 2000; Waldeman et al. 2002). 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). 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.

The ME DMR began surveys targeting shortnose sturgeon and Atlantic sturgeon populations in the Kennebec, Androscoggin, and Sheepscot estuaries in 1977-2001 to understand more about their movements within the area and identify important habitat. Surveys were performed using gill net and ichthyoplankton net sampling, Carlin and PIT tagging, and radio and acoustic telemetry. During the current grant, we compiled these data and used the results to inform expanded Atlantic sturgeon telemetry and habitat identification work. This work was summarized by Wippelhauser and Squiers and will be submitted for publication in spring 2013. The species conservation plan (Appendix I) also summarizes the information.

Beginning in 2006, researchers at ME DMR (through this grant project), the University of Maine, and University of New England independently began acoustic telemetry studies of Atlantic sturgeon in three Gulf of Maine river systems: the Penobscot, Kennebec/Androscoggin, and Saco rivers, respectively. The studies had similar objectives: to identify habitat use, seasonal distribution and abundance, and migration routes, and to identify genetic structure within the Gulf of Maine. To this end, ME DMR reinstated the gill net survey in the Kennebec/Androscoggin estuary area and began tagging Atlantic sturgeon with both external (spawning condition fish) and internal (non-spawning condition fish) hydroacoustic transmitters (VEMCO V16). An array of 18-20 stationary acoustic receivers was deployed at 16-20 sites in the study area (Figure 9). 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. Mobile tracking was conducted occasionally with a portable receiver and directional hydrophone.

The species conservation plan (Appendix I) provides a thorough discussion of the methods, results, and implications, and will only be summarized briefly here. We captured 114 Atlantic sturgeon in the Kennebec and Androscoggin estuaries at 25 sites that were sampled on 79 dates 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

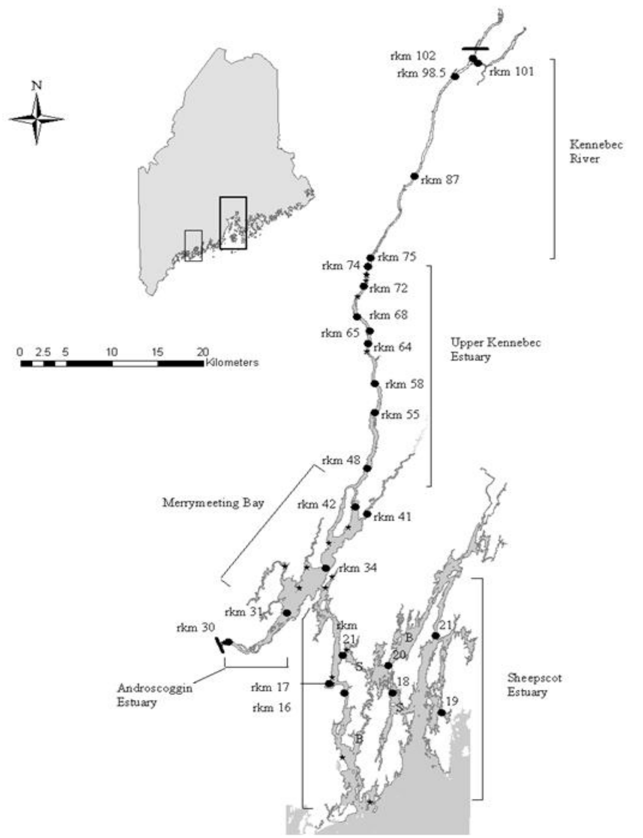


Figure 9. Map of the study area in the Kennebec, Androscoggin, and Sheepscot estuaries, Maine. Receiver locations are indicated black circles. Gill net sampling stations indicated by black stars. Letters indicate the Sasanoa River (S), Back River (B), Hockomock Bay (H), Montsweag Bay (M), and Knubble Bay (K). Dams are indicated by heavy black lines.

conducted only for samples taken from 2009 to 2011. To confirm spawning, we attempted to capture sturgeon eggs and larvae with D-nets. The net was set on the bottom downstream of spawning fish. Two new spawning areas were confirmed for Atlantic sturgeon in the Androscoggin Estuary below Brunswick Dam and one in the Kennebec River, which only became accessible when Edwards Dam was removed in 1999. 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.

Some juvenile and subadult Atlantic sturgeon may remain in the Kennebec during the winter. During late fall gill net sampling, we captured four Atlantic sturgeon while fishing for shortnose sturgeon at a newly identified wintering area in the upper Kennebec Estuary. In December 2012, we used an ROV and an underwater camera to confirm that sidescan sonar targets at the wintering area were sturgeon. While most of the fish appeared to be shortnose sturgeon, it was difficult to distinguish between these and possible small Atlantic sturgeon. To further document the overwintering habitat, we used multibeam sonar to characterize the substrate and topography of the bottom habitat. We found that the area is shallow (5-10m) with sandy bottom.

Tissue samples taken in 2009-2011 from spawning fish in the Kennebec and Androscoggin were included in analysis performed by Wirgin *et al*. (2012) that 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. 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).

## Objective 3 – Establish a fish health monitoring program

### *Activity 1 – Years 1-5*

*Monitoring Fish Health*

Improving understanding of fish health status as well as the abundance, geographic distribution, and vectors of areas of study necessary to support the development and implementation of conservation strategies designed to protect and restore rainbow smelt populations. Pathogens can adversely affect both juveniles and adults in both general and acute ways, including organ failure, energy loss, interruption of hormonal pathways and reproductive weakness.

We characterized pathogen presence in rainbow smelt at fourteen of the fyke net spawning index sites over a two-year period, 2009-2010. The results are discussed briefly here; a full report detailing the results from each index site is included in Appendix P.

Sampling did not detect bacterial pathogens of regulatory concern but did detect endemic parasites that are well documented for similar anadromous species. Parasitological results were typical of wild fish populations, with various trematodes (e.g., black grub), cestodes, nematodes and protozoa observed at all sites. A microsporidian parasite detected in various tissues of many individuals in this study was not identified as to species, but is consistent with *Glugea hertwigi*, which was confirmed at one site: the Fore River, Massachusetts. This parasite has been documented extensively in freshwater smelt can be detrimental to successful spawning because this parasite infests the gonads of smelt (Jimenez et al. 1982, Nsembukya-Katuramu et al. 1981). The observation of large numbers of Philometra spp.-like nematodes in the gonads of the majority of female fish in the study is also consistent with reports of this parasite as an opportunistic pathogen of spawning female fish in other species (Moravec and de Buron 2009).

Virology results revealed a viral agent from adults from Casco Bay, Maine; however, it is difficult to place any significance to this agent at the present time because the virus is not similar to currently catalogued agents (IPNV, IHNV, ISAV, and VHSV have been ruled out by PCR techniques). More analysis on this agent is needed to fully understand the physiological effects it may be having. Fish from a majority of the sites spanning the entire Gulf of Maine region showed evidence of erythrocytic disease, or degradation of red blood cells, leading to anemic effects. This last point may be of specific concern and warrants further investigation to understand the extent of disease and causal factors.

### *Toxic Contaminant Screening*

The ME DMR worked collaboratively with the ME DEP and Maine Bureau of Health to coordinate collecting rainbow smelt to assess concentrations of toxic contaminants and co-planar PCBs. The Maine Bureau of Health used this information when considering an advisory for fish consumption with regard to on smelt caught from the Kennebec River.  The regional Subcommittee on Rainbow Smelt decided to additionally screen smelt from

| | | Average Metal Concentration | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Site Name | Aluminum | Cadmium | Chromium | Copper | Iron | Lead | Mercury | Nickel | Selenium | Zinc |
| MA | Fore River | 3.080 | - | | 2.313 | 11.650 | 0.018 | 251.850 | 0.260 | 0.658 | 31.965 |
| | Jones River | 9.648 | - | 0.605 | 2.730 | 13.825 | 0.023 | 212.350 | 0.540 | 0.568 | 251.350 |
| | North River | 2.320 | - | 8.248 | 1.235 | 82.000 | 0.005 | 267.725 | 0.090 | 0.610 | 30.800 |
| | Parker River | 2.595 | - | 0.000 | 1.408 | 5.625 | 0.012 | 187.150 | - | 0.618 | 36.750 |
| ME | Chandler River | 6.998 | - | 0.490 | 1.660 | 17.800 | 0.146 | 189.550 | 0.208 | 0.765 | 37.300 |
| | Deer Meadow Brook | 4.582 | 0.003 | 0.236 | 1.328 | 12.175 | 0.032 | 218.650 | - | 0.691 | 46.465 |
| | East Bay Brook | 3.343 | - | 0.090 | 1.558 | 11.725 | 0.009 | 155.625 | - | 0.758 | 38.150 |
| | Long Creek | 1.653 | 0.006 | 0.285 | 1.473 | 9.575 | 0.019 | 214.875 | - | 0.725 | 35.500 |
| | Mast Landing | 5.340 | 0.012 | 0.110 | 1.305 | 6.600 | 0.020 | 199.675 | - | 0.658 | 38.300 |
| | Pleasant River | 5.940 | - | 0.503 | 3.735 | 12.300 | 0.021 | 178.900 | 0.568 | 0.673 | 36.425 |
| | Schoppee Brook | 7.590 | 0.006 | 0.598 | 2.823 | 16.600 | 0.026 | 216.825 | 4.715 | 0.608 | 47.775 |
| | Tannery Brook | 4.758 | - | 0.080 | 0.995 | 8.625 | 0.006 | 254.675 | - | 0.635 | 35.475 |
| NH | Squamscott River | 30.590 | 0.012 | 0.190 | 2.742 | 13.592 | 0.032 | 279.342 | 0.275 | 0.692 | 41.018 |
| | Winnicut River | 10.107 | 0.031 | 4.437 | 2.327 | 23.600 | 0.026 | 136.350 | 2.173 | 0.820 | 56.620 |

Table 10. Average metal concentrations are shown by site. Metal concentrations were determined for two batches of ten smelt from each site, one composed of only males, the other of only females. These values show the mean value for both sexes.

13 index sites as well as one river in Maine where smelt are commercially harvested for 209 polychlorinated biphenyl (PCB) congeners, mercury and other metals. The final laboratory reports are included in Appendix Q. The average metal concentration varied between sites (Table 10). Notably, no cadmium was detected in any smelt from Massachusetts, and while silver was tested for, it was not detected in fish from any site.

While it is difficult to discern a pattern between the sites using the metals data solely, comparing total PCB concentrations among sites provides some insight. We considered PCB concentrations by brominated diphenyl ethers (BDE) homologs (di-, tri-, etc.), and total PCB concentrations (pg/g) by weight type (dry, lipid, wet). The average total PCB concentration was found to be highest in smelt from Massachusetts index sites, followed by New Hampshire sites, while concentrations in Maine fish were consistently lower than the other two states (Table 11 and Figure 10). Interestingly, the southern most Maine index site, Long Creek, which is located in a highly developed watershed, also showed the highest PCB concentrations.

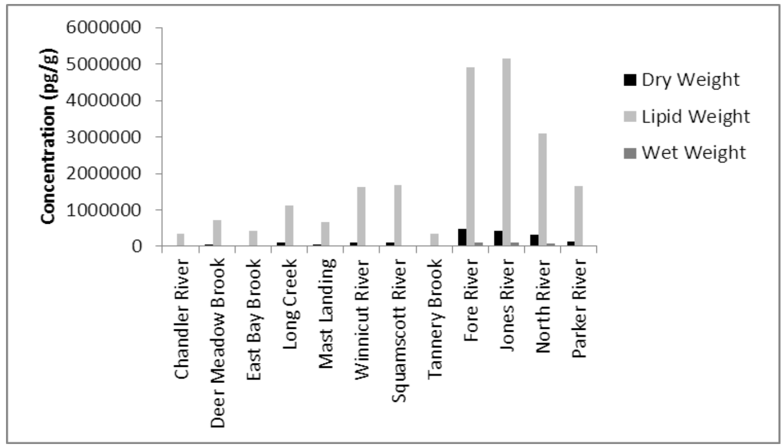


Figure 10. Average PCB concentrations are shown for each site by weight type (dry, lipid, wet) PCB concentrations were determined for two batches of ten smelt from each site, one composed of only males, the other of females. These values show the mean value for both sexes.

**Dry Weight Concentration (pg/g)**

| | ME | | | | | NH | | ME | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BDE Homolog | Chandler River | Deer Meadow Brook | East Bay Brook | Long Creek | Mast Landing | Winnicut River | Squamscott River | Tannery Brook | Fore River | Jones River | North River | Parker River |
| Chlorobiphenyl | 4.11 | 4.40 | 3.90 | 5.64 | 6.03 | 4.42 | 5.53 | 3.61 | 18.55 | 6.43 | 30.68 | 7.76 |
| Di-BDE | 65.80 | 41.64 | 47.03 | 161.23 | 83.90 | 93.92 | 97.50 | 99.13 | 465.26 | 348.63 | 513.25 | 190.26 |
| Tri-BDE | 396.48 | 327.84 | 402.28 | 749.24 | 526.38 | 971.07 | 1212.12 | 429.25 | 4044.26 | 4546.40 | 2879.51 | 2116.96 |
| Tetra-BDE | 3156.78 | 3706.76 | 3036.84 | 8540.18 | 5942.59 | 12309.07 | 13722.00 | 2899.61 | 63736.37 | 61326.94 | 35699.22 | 18483.88 |
| Penta-BDE | 7304.17 | 8997.42 | 7904.46 | 24586.09 | 15424.66 | 33163.80 | 31316.30 | 7518.77 | 152279.75 | 137876.94 | 94641.13 | 32449.97 |
| Hexa-BDE | 5837.19 | 11849.76 | 6911.06 | 23127.79 | 11803.91 | 21175.70 | 26683.48 | 6957.94 | 93866.99 | 97157.19 | 70205.25 | 24529.30 |
| Hepta-BDE | 8352.78 | 21466.53 | 12707.09 | 27922.70 | 17704.45 | 26324.20 | 31485.50 | 9807.48 | 120768.65 | 110217.20 | 81581.05 | 30760.80 |
| Oct-BDE | 1790.33 | 4846.37 | 3074.49 | 5982.19 | 4690.50 | 5515.86 | 6909.01 | 1826.56 | 25750.54 | 18897.53 | 17002.12 | 8096.05 |
| Nona-BDE | 474.10 | 2287.00 | 1085.00 | 2235.00 | 1765.50 | 1725.00 | 2799.00 | 787.10 | 5986.50 | 4324.50 | 3760.50 | 2549.67 |
| Deca-BDE | 130.50 | 1158.67 | 427.50 | 688.00 | 561.50 | 572.00 | 927.00 | 336.50 | 1590.00 | 961.00 | 992.50 | 889.67 |
| Grand Total | 27512.23 | 54686.38 | 35599.65 | 93998.04 | 58509.40 | 101855.04 | 115157.43 | 30665.95 | 468506.85 | 435662.74 | 307305.20 | 120074.31 |

**Lipid Concentration (pg/g)**

| | ME | | | | | NH | | ME | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BDE Homolog | Chandler River | Deer Meadow Brook | East Bay Brook | Long Creek | Mast Landing | Winnicut River | Squamscott River | Tannery Brook | Fore River | Jones River | North River | Parker River |
| Chlorobiphenyl | 50.55 | 62.57 | 47.30 | 69.80 | 73.65 | 70.90 | 79.70 | 43.15 | 201.20 | 74.60 | 339.45 | 106.00 |
| Di-BDE | 802.51 | 570.30 | 565.65 | 1942.10 | 901.65 | 1506.30 | 1404.75 | 1118.47 | 5061.45 | 3843.85 | 5912.20 | 2497.30 |
| Tri-BDE | 4815.60 | 4372.50 | 4610.45 | 8971.55 | 6021.95 | 15577.10 | 17940.35 | 4923.27 | 42821.45 | 51983.00 | 30411.00 | 27456.30 |
| Tetra-BDE | 38061.40 | 48722.93 | 34183.65 | 99998.84 | 68183.70 | 197290.80 | 203689.30 | 33263.92 | 658395.00 | 721979.65 | 353093.20 | 247079.53 |
| Penta-BDE | 88843.97 | 118790.20 | 88469.19 | 285609.80 | 172008.10 | 531697.40 | 464709.10 | 85956.56 | 1579312.2<br>0 | 1612246.45 | 942673.40 | 431919.37 |
| Hexa-BDE | 70768.96 | 158485.63 | 80601.18 | 272715.55 | 134046.60 | 339408.20 | 389742.15 | 81060.71 | 989129.15 | 1156848.15 | 696768.20 | 344243.90 |
| Hepta-BDE | 101714.55 | 287916.33 | 149874.50 | 331379.00 | 201480.50 | 421440.00 | 460276.50 | 115346.90 | 1280833.5<br>0 | 1321100.00 | 837756.00 | 435693.33 |
| Oct-BDE | 21863.45 | 65549.87 | 36897.75 | 73011.55 | 56767.30 | 88328.60 | 99846.65 | 21393.40 | 274850.50 | 222975.40 | 174919.90 | 117109.77 |
| Nona-BDE | 5810.50 | 31120.00 | 13470.00 | 27310.00 | 21630.00 | 27660.00 | 39880.00 | 9343.50 | 64115.00 | 51910.00 | 38670.00 | 36883.33 |
| Deca-BDE | 1595.00 | 16233.33 | 5250.00 | 8395.00 | 6940.00 | 9180.00 | 13300.00 | 4025.00 | 16950.00 | 11300.00 | 10680.00 | 12783.33 |
| Grand Total | 334326.49 | 731823.66 | 413969.67 | 1109403.18 | 668053.45 | 1632159.30 | 1690868.50 | 356474.87 | 4911669.4<br>5 | 5154261.10 | 3091223.35 | 1655772.17 |

**Wet Weight Concentration (pg/g)**

| | ME | | | | | NH | | ME | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BDE Homolog | Chandler River | Deer Meadow Brook | East Bay Brook | Long Creek | Mast Landing | Winnicut River | Squamscott River | Tannery Brook | Fore River | Jones River | North River | Parker River |
| Chlorobiphenyl | 0.90 | 0.89 | 0.91 | 1.28 | 1.30 | 0.93 | 1.14 | 0.75 | 4.09 | 1.38 | 6.89 | 1.62 |
| Di-BDE | 14.52 | 8.42 | 11.02 | 36.66 | 18.11 | 19.86 | 20.09 | 20.74 | 102.66 | 75.99 | 114.60 | 40.32 |
| Tri-BDE | 87.50 | 66.56 | 95.14 | 170.75 | 113.50 | 205.34 | 249.77 | 89.61 | 900.17 | 983.41 | 652.67 | 450.40 |
| Tetra-BDE | 698.73 | 752.70 | 722.34 | 1950.34 | 1281.37 | 2601.17 | 2821.63 | 603.83 | 14267.24 | 13182.01 | 8172.45 | 3890.83 |
| Penta-BDE | 1613.04 | 1828.24 | 1880.78 | 5613.18 | 3323.99 | 7009.53 | 6431.71 | 1569.59 | 34008.08 | 29666.17 | 21627.91 | 6854.03 |
| Hexa-BDE | 1290.66 | 2403.91 | 1630.76 | 5279.31 | 2543.82 | 4476.77 | 5498.37 | 1449.79 | 20883.45 | 20815.37 | 16075.99 | 5071.39 |
| Hepta-BDE | 1841.36 | 4351.20 | 2993.27 | 6365.08 | 3823.79 | 5558.79 | 6477.13 | 2041.12 | 26833.80 | 23587.72 | 18548.04 | 6342.82 |
| Oct-BDE | 394.32 | 982.30 | 721.10 | 1360.18 | 1011.77 | 1164.05 | 1421.88 | 380.19 | 5712.04 | 4058.41 | 3865.37 | 1653.96 |
| Nona-BDE | 104.30 | 463.13 | 252.25 | 509.15 | 380.10 | 364.80 | 577.10 | 163.45 | 1327.15 | 925.80 | 854.85 | 520.33 |
| Deca-BDE | 28.70 | 233.67 | 99.75 | 156.50 | 121.00 | 121.00 | 191.50 | 69.95 | 352.50 | 206.00 | 223.50 | 182.33 |
| Grand Total | 6074.03 | 11091.01 | 8407.31 | 21442.41 | 12618.75 | 21522.23 | 23690.33 | 6389.01 | 104391.16 | 93502.25 | 70142.27 | 25008.03 |

Table 11. Average PCB concentrations are shown for site by BDE homolog and weight type (dry, lipid, wet) PCB concentrations were determined for two batches of ten smelt from each site, one composed of only males, the other of females. These values show the mean value for both sexes.

Our goal was to collect information about contaminant concentrations found in smelt representing a wide geographic region and located in a range of watershed types. We did not explore the physiological effects that contaminant accumulation may be causing in smelt. This is a topic for further research. The data collected by this effort can provide information about the range of concentrations that may be observed in wild populations.

## Objective 4 – Develop a set of conservation and restoration strategies

### *Activity 1 – Years 1-5*

*Develop Regional Conservation Plans*

Data collected as part of this project were analyzed and pertinent results were synthesized for the conservation plans for both rainbow smelt and Atlantic sturgeon. These conservation plans summarize historical information for each species, present relevant data that have management implications, and present both state and regional management recommendations. This Atlantic sturgeon conservation plan is included as Appendix I, and the smelt conservation plan is included as Appendix A. The species' conservation plans were presented to the directors of each state agency for approval and were accepted. The Atlantic sturgeon conservation plan will be available through ME DMR and will also be distributed to the regional management councils. The rainbow smelt conservation plan was printed in a limited quantity and distributed to regional agencies and organizations (e.g. NMFW Northeast Regional Office, Piscatiqua River Estuary Partnership, Wells National Estuarine Research Reserve, USFWS regional offices) at the January 2013 Diadromous Species Restoration Research Network meeting. Each state agency still retains a small number of copies to distribute by request, and will also hold copies at each agency's research library. The rainbow smelt conservation plan is also available online through the regional website (restorerainbowsmelt.com), and on the ME DMR website (http://www.maine.gov/dmr/smelt/index.htm).

Each state will work towards implementing all recommendations. For Atlantic sturgeon, the following points were recommended:

1. Identify and designate critical habitat in the Kennebec, Androscoggin, and Sheepscot rivers
2. Consultation with Maine DMR on tidal power projects
3. Consultation with Maine DMR on dredging, blasting, and construction projects
4. Continue working with Canada to understand the impacts of Canadian directed catch
5. Continue to monitor and report bycatch to the Atlantic States Marine Fisheries Commission
6. Review existing regulatory authorities, laws and policies

Regional recommendations for rainbow smelt management are as follows:

1. Continue existing monitoring programs, including fyke net monitoring, near-shore trawl surveys, winter creel surveys, and juvenile abundance surveys
2. Restore historical or degraded habitat
3. Assess sustainability of current smelt fisheries and change management if necessary
4. Expand research to estimate population size and assess the potential impacts of ecosystem and climate changes
5. Implement stocking of marked larvae, with continued monitoring and genetic considerations

Each state also developed specific recommendations. For Massachusetts, these include:

1. Apply the information gained from the present study and recent smelt habitat improvement projects to identify potential restoration sites and design smelt spawning habitat improvements that meet the life history requirements of smelt. Projects that can remove barriers and extend habitat connectivity for smelt and other diadromous fish should be prioritized

2. Continue monitoring smelt fyke net stations from the present study that have been identified as having promise to support long-term indices of abundance (i.e., Weweantic River, Jones River, Fore River and Parker River). Improve and maintain data collection at fyke net stations to support future development of biological population benchmarks
3. Develop water quality criteria that relate to designated uses within the Massachusetts Wetlands Protection Action order to protect the specific habitats of anadromous fish, including smelt spawning habitat
4. Conduct a smelt habitat survey of the Buzzards Bay region of Massachusetts that was not mapped during the previous Gulf of Maine survey in Massachusetts
5. Develop a state smelt conservation plan similar those completed for Maine (1976) and New Hampshire (1981)

For New Hampshire these include:

1. Continue monitoring efforts in place including: winter creel survey, juvenile abundance seine survey, spring spawning run fyke net sampling
2. Improve water quality and support New Hampshire Department of Environmental Services in developing nutrient criteria for Great Bay Estuary
3. Identify habitat restoration projects to enhance smelt spawning conditions.
4. Continue to support dam removal projects to connect smelt to historical spawning habitats
5. Conduct a smelt spawning habitat assessment of coastal areas in New Hampshire.

For Maine these include:

1. Continuing monitoring of smelt populations through fyke net sampling, creel surveys, the inshore trawl survey, and the juvenile abundance survey
2. Developing a mark-recapture study to estimate the current extraction rate of recreational ice fishing on the Kennebec River and Merrymeeting Bay and other rivers and embayments that support recreational ice fishing
3. Restoring stream connectivity and access to historical spawning grounds with monitoring to assess pre- and post-construction conditions and smelt populations
4. Assessing threats to smelt habitat and evaluating connections between degraded habitat and local smelt population decline
5. Stocking rainbow smelt larvae marked with oxytetracycline into historical smelt spawning streams that maintain good habitat, while maintaining the genetic structure as identified by this project and annually monitoring stocking success.

All recommendations are described in further detail with support from recent surveys in the species' conservation plans (Appendix I, and Appendix A).

## Objective 5 – Approval and Implementation

### *Activity 1 – Years 3-5*

Before the inception of this grant project few management, restoration, or research discussions focused on, or even considered rainbow smelt. Some work had been completed in Massachusetts that catalogued the current status of smelt in that state, and creel survey and egg deposition surveys in New Hampshire had monitored the relative smelt population abundance in Great Bay, but no regional efforts had been initiated. Through this project, we have begun long-term regionally standardized monitoring efforts that have already generated enough data to inform policy and management decisions and direct future research, we have updated information about the population status, and most importantly the work has brought the species into focus for restoration efforts.

*Regulation Revisions*

Massachusetts and Maine completed the process of revising regulations for rainbow smelt to limit take and gear type to protect existing stocks. In Massachusetts, a regulation that limits recreational and commercial take to 50 fish per day went into effect October 30, 2009 (Appendix C). In Maine, a regulation was passed by the Marine Resources Advisory Council that extends the current limit of two quarts per day during the spawning season (March 15-June 30), limits gear to dip net and hook-and-line during the spawning season, and hook-and-line only for the remainder of the year for the majority of the state. The regulation also prohibits walking in streams while fishing for smelt to protect the egg beds. Commercial harvest of smelt on the Penobscot River has been closed, and the length of the commercial harvest season in Downeast Maine has been shortened. The new regulation in Maine went into effect December 21, 2009 (Appendix D). The regulations are included in Appendix L and M.

*Policy and Management*

The results from this project have informed policy and management decisions. Projects to restore spawning habitat and access to habitat have been completed in each state and more projects continue to begin. In New Hampshire, the Winnicut River Dam was removed in 2009. Though the dam removal was funded through another project, the dam removal restores smelt spawning habitat and the site will continue to be monitored using field protocols developed as part of this project. In Massachusetts, protecting and restoring smelt habitat are now stated management strategies. To this end, MA DMF has completed smelt habitat restoration projects in the Crane River, Danvers, Weir River, Hingham and Shute Brook, Saugus, and is working the Massachusetts Department of Environmental Protection and other state agencies on stream daylighting projects that will restore smelt habitat in Town Brook, Quincy, and Smelt Brook, Weymouth.

The results of this project have also informed policy decisions. In Maine, the ME DMR used the results of data collected during the project to inform a policy decision to deny a request to open upper Casco Bay to commercial gill-netting for smelts. Based on mortality estimates calculated from data collected during the fyke net survey work at an upper Casco Bay spawning site and the presence/absence survey conducted state-wide, and the regional findings that smelt populations are depleted compared to historical levels, Maine DMR policy makers decided that no new commercial fisheries for smelt should be opened at this time.

Results from this project will inform the identification of critical habitat and development of a species recovery plan for Atlantic sturgeon for the Gulf of Maine DPS by the NMFS and the USFWS. Results from this project also will be used by the Atlantic States Marine Fisheries Commission (ASMFC) to conduct a stock assessment for the species. Gail Wippelhauser represents Maine on the ASMFC Atlantic Sturgeon Technical Committee, and will be working with the Stock Assessment Subcommittee. In 2011, Gail Wippelhauser attended the Sturgeon Workshop, sponsored by the NMFS, to consider management, research, and permitting issues.

*Population Restoration through Stocking Larvae*

The MA DMF developed smelt restoration and re-population strategies based on stocking oxytetracycline (OTC) marked yolk-sac larvae into to historic smelt spawning habitat. MA DMF stocked OTC marked larvae in the Crane River 2007-2011; because this river is also a fyke net survey site, MA DMF has been able to collect adults at this site and take a sub-sample to examine the otoliths for recaptures of stocked fish. Each year since the program began in 2007, a proportion or the sub-sampled fish do show the OTC mark, and the CPUE at this fyke net survey does continue to increase, indicating that the stocking may be helping to increase this local population. Because of the apparent success of the stocking in the Crane River, MA DMF ceased stocking that location after the 2011 season and began stocking the Essex River, a larger river where the spawning population has also drastically declined but the habitat has recently been improved. This project is discussed in more detail in Ayer *et al*., 2012, *Laboratory marking of anadromous rainbow smelt embryos and larvae and the implications for restoration* (in Wood *et al.* 2012, Appendix E), and was presented at the 2010 American Fisheries Society meeting.

Adopting methods perfected the MA DMF, Maine DMR began a program with the North Haven Community School to stock OTC marked smelt larvae at a North Haven stream that supported spawning populations up to 30 years ago. The smelt runs on the island began to decline in the 1980's and have since become extirpated, although the habitat remains unaltered and in good condition. We worked with the school to collect adult rainbow smelt as part of the ME DMR fyke net survey, strip spawn these adults at the North Haven Community School, rear the eggs in the school lab to larvae, and mark the larvae with oxytetracycline hydrochloride (OTC) a mild antibiotic which leaves a permanent mark of the otoliths of each fish. These larvae were released in a stream that will be re-sampled annually to measure the success of stocking and indirect effects on the rest of the ecosystem. A sub-sample of any future catch will be taken and the otoliths examined to confirm the success of the larvae stocking program. Maine DMR will continue this project in the future.

*Hosting the Fourth North American Workshop on Rainbow Smelt*

In an effort to convene a larger body of stakeholders to share information about rainbow smelt, the Subcommittee on Rainbow Smelt hosted the Fourth North American Workshop on Rainbow Smelt in Portland, Maine on January 24-25, 2011. The workshop was the largest of the four smelt workshops hosted (over 85 participants), and had the widest range of participants both geographically and disciplines. The three previous workshops were held in Halifax, NS (2007), and Québec (2003 and 1999). Participants in the 2011 workshop included fisheries managers and researchers from other states, including Connecticut, Rhode Island, and Michigan, from Canadian provinces, from our own states who have not been directly involved in this project, and from the universities who are conducting research on rainbow smelt or may be interested in the implications of our research. The two-day workshop culminated in a panel discussion representing the majority of the range of the rainbow smelt: Canadian St. Lawrence and freshwater, Canadian maritime, Gulf of Maine, inland regions of Maine, and the Great Lakes. The proceedings from this workshop were published as part of the Massachusetts Division of Marine Fisheries Technical Report series (Appendix E, Wood *et al*. 2012).

*Distributing Information to Public Audiences*

As part of the amendment submitted to NMFS in June 2008, we committed to an enhanced version of the Annual Report to highlight progress and findings that would be distributed to environmental organizations, local governments, and environmental educators. Working with a graphic designer, we developed a reader friendly pamphlet to communicate to a wide range of groups including federal, state, and local managers, non-profit organizations, sports fishery groups, and interested people from the public. The pamphlet provides information about smelt biology and the species status, highlights why rainbow smelt is a species of concern, gives an overview of threats to the species, identifies what local governments and individual people can do to support the species, and describes state agency efforts to monitor and manage the species (Appendix B). The content of this pamphlet was adapted into a webpage that would be geared towards managers, researchers, and interested people. The website can be found at http://restorerainbowsmelt.com.

*Collaborations*

Through this project, we have formed collaborations with researchers, stakeholder groups, and other state and federal agencies based on work to protect and restore smelt populations and habitat. The ME DMR has been working with a multi-agency committee (including NMFS, Maine Departments of Transportation, Inland Fisheries and Wildlife, Environmental Protection, Conservation, the Atlantic Salmon Federation, and the Nature Conservancy) to develop a web-based tool to prioritize road-stream crossing connectivity projects based on important fish habitat. Maine DMR has been advising the committee on rainbow smelt habitat and specific sites of decline or extirpation. The MA DMF has been working with the Massachusetts Division of Transportation on a similar project to prioritize road-stream crossing projects, and to restore habitat quality and access to spawning habitat for rainbow smelt.

Working with the Downeast Salmon Federation, the ME DMR employed the predictive GIS model to estimate the likelihood of rainbow smelt spawning returning to two rivers in Downeast Maine in the event that tide gates are removed that have obstructed passage for many years. The watershed characteristics were calculated for the two watersheds in question and compared to values for the index sites, and it was predicted that each would support spawning if the tide gates were removed. A handout summarizing this analysis was created for public hearings and was included in a previous progress report.

As a result of discussions at the Fourth North American Workshop on Rainbow Smelt, Maine DMR worked with the Wells National Estuarine Research Reserve to develop sampling methods to identify spawning habitat in the Wells and Rachel Carson Reserves in southern Maine and to confirm the current status of spawning in rivers within the reserves.

Long Creek in South Portland, Maine has been identified as a US EPA Clean Water Act 303(d) impaired waterbody and a priority project for the Maine Department of Environmental Protection and the South Portland Water District. Maine DMR is collaborating with these agencies to gather information about water chemistry, nutrient concentrations, biomass growth, fish diversity, and rainbow smelt spawning in the creek. Maine DMR began sampling in the creek in spring of 2009. The data gathered will be used as a baseline to measure changes in water quality and habitat use as Best Management Practices are implemented in the watershed. Maine DMR will also provide reports that will advise future restoration projects in the watershed.

Through this project, we also have formed collaborations with researchers and other state and federal agencies based on work to protect and restore Atlantic sturgeon populations and habitat. The ME DMR has been collaborating with sturgeon researchers in Maine (University of Maine, University of New England) and the Gulf of Maine (U.S. Geological Survey). We are active participants in the Atlantic Cooperative Telemetry (ACT) network, which improves our ability to understand the coastal movements of Atlantic sturgeon.

*Education and Outreach*

Maine partners have established a working relationship with Southern Maine Community College (SMCC) and Bowdoin College in an effort to provide both an opportunity for students to get hands-on field work experience, and information about the Gulf of Maine anadromous fish populations. SMCC students helped set up and monitor a PIT tag retention study, and project partners have presented the project for marine biology classes. Maine partners presented the winter sampling project for Bowdoin College students, and mentored two students who completed their senior research project on rainbow smelt. With guidance from Maine DMR, students designed a winter sampling project on the Abbagadassett River in Merrymeeting Bay to collect biological information and scale samples. Maine DMR staff trained the students to mount and age scales and develop age-length keys. The students set a fyke net loaned by Maine DMR in the Abbagadassett River to study rainbow smelt spawning in the spring. Maine DMR staff gave guidance for sampling techniques and data interpretation.

To increase awareness of the project in New Hampshire, Jessica Fischer at the New Hampshire Department of Fish and Game wrote an article describing declining rainbow smelt populations that was published in the July/August edition of the New Hampshire Wildlife Journal. The article was included in a previous progress report.

The Maine DMR worked with Maine SEAGrant to create a poster providing information about smelt and our research at the fyke net survey site Tannery Brook in Bucksport, Maine. The poster was placed in an information kiosk located in downtown Bucksport on a public walkway, directly adjacent to Tannery Brook. The Maine DMR also worked with the Downeast Salmon Federation (DSF) to construct two community kiosks and post posters, pamphlets, and other information at these kiosks. One kiosk is on the Pleasant River in downtown Columbia Falls at the site of major spawning grounds and commercial effort. The other is at Redmon’s Brook in Harrington, Maine, also a major spawning site. DSF recently acquired the land around Redmon’s Brook and is keeping the land in conservation to support rainbow smelt spawning habitat.

*Presentations*

Partners in all three states have presented information about this project at many different venues.

- October, 2008 – Brad Chase (MA DMF) *The threat of eutrophication on anadromous fish spawning and nursery habitat.* New England Estuarine Research Society, Fall Meeting, Block Island, RI. Present smelt habitat monitoring process under SOC project QAPP.

- July, 2009 – Brad Chase (MA DMF), Coastal Environmental Sensing Network Conference at the University of Massachusetts, Boston. *Environmental influences on diadromous fish migrations.* Linked environmental and water quality data to CPUE using the smelt fyke index stations.

- August, 2009 – Claire Enterline (ME DMR), Maine Department of Environmental Protection, W. Boothbay Harbor, ME. *Rainbow Smelt: A Declining Species on the East Coast of the United States.* Summary of water quality information being gathered as part of the regional fyke net survey.

- October, 2009 – Katherine Mills (NHFG) and Claire Enterline (ME DMR), Piscataqua River Estuary Partership State of the Estuaries Conference, Somersville, NH. *A Multi-State Collaborative to Develop and Implement a Conservation Program for Rainbow Smelt.* Description of the SOC project, monitoring, analyses, and objectives. (http://www.prep.unh.edu/resources/09sote/www_sote_shows/Mills&Enterline.pdf)

- February, 2010 - Katherine Mills (NHFG), Portsmouth Community Radio. Discussed the status of rainbow smelt and associated conservation efforts and the specific research aspects of this project.

- April, 2010 -- Brad Chase (MA DMF). *Water Quality Monitoring of Diadromous Fish Spawning and Nursery Habitat.* Northeast Fish and Wildlife Conference, Needham, MA. Present smelt spawning habitat monitoring process and results under SOC project QAPP.

- June, 2010 - Katherine Mills (NHFG). *Protecting a threatened coastal fish species through collaborative regional research and planning*. Coastal Society's 22nd Biannual Conference in Wilmington, NC. The abstract and will be published in the Conference proceedings, and was included in a previous progress report.

- September, 2010 – Matthew Ayer (MA DMF). *Laboratory marking of anadromous rainbow smelt embryos and larvae and the implications for restoration*. American Fisheries Society Annual Meeting, Pittsburgh, PA. Discussed methods using oxytetracycline to mark smelt embryos that are released as part of stock enhancement in Massachusetts.

- September, 2010 – Claire Enterline (ME DMR). *Improving methods to accurately age rainbow smelt* (Osmerus mordax). American Fisheries Society Annual Meeting, Pittsburgh, PA. Discussed regionally standardized methods to collect, clean, and age rainbow smelt scales. http://www.maine.gov/dmr/smelt/documents/scaleaging.pdf

- November, 2010 – Claire Enterline (ME DMR). *A Multi-State Collaborative to Develop and Implement a Conservation Program for Rainbow Smelt.* Diadromous Species Restoration Research Network meeting. Summarized the purpose of this project and preliminary results.

- January, 2011 – Brad Chase (MA DMF). *Rainbow smelt (Osmerus mordax) spawning population monitoring on the Gulf of Maine coast of New England*. Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Brad Chase (MA DMF). Water quality and habitat assessment of rainbow smelt (*Osmerus mordax*) spawning locations in rivers on the Gulf of Maine coast. Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Katherine Mills (UMaine). *Relationships between watershed conditions and rainbow smelt spawning populations in Maine, USA.* Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Claire Enterline (ME DMR). *Monitoring within-season spawning behavior by rainbow smelt Osmerus mordax using passive integrated transponder (PIT) systems.* Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Matt Ayer (MA DMF). *Laboratory marking of anadromous rainbow smelt embryos and larvae and the implications for restoration.* Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Chris Wood (MA DMF). *A historical view of anadromous rainbow smelt populations and fisheries in the eastern United States.* Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Claire Enterline (ME DMR). *Out on the ice – sampling Maine's recreational winter smelt fishery on the Kennebec River and Merrymeeting Bay.* Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- January, 2011 – Claire Enterline (ME DMR). *Improving methods to accurately age rainbow smelt* (Osmerus mordax). Fourth North American Workshop on Rainbow Smelt. Extended abstract in Appendix E.

- February, 2011 – Jessica Fischer (NHFG). *A Multi-State Collaborative to Develop and Implement a Conservation Program for Rainbow Smelt.* New Hampshire Fish and Game Commission. Summarized the purpose of this project and preliminary results.

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