IV C. Anadromous Fish Restoration in Massachusetts Bay

Anadromous fishes are an important part of the near-shore fauna along the Massachusetts coast. Seventeen species of anadromous fish reside in our marine and inland waters at various times of year. The potential impact to anadromous fish populations from disruption of the near-shore environment during spawning and migration periods can be high. Siltation resulting from construction activities can smother eggs of anadromous fish that spawn in the upper portion of estuaries (e.g., blueback herring, rainbow smelt, white perch, tomcod) or can block the spawning migration of other anadromous species that are trying to reach the headwaters of rivers draining into the estuaries (e.g., alewives and American shad). The effect of perceived minor insults to the populations can be significant because the anadromous fish resources have already suffered the cumulative effects of years of habitat alteration and disturbance.

MarineFisheries implemented a three-year Anadromous Fish Action Plan to enhance the anadromous fish resources in the embayments and associated watersheds adjacent to the HubLine Project. These are resources that were potentially impacted by the HubLine construction. A 3-part project was proposed which consisted of propagation/stocking, monitoring, construction and repair of anadromous fish passage, and improvements to habitat.

Part 1. Anadromous Fish Passage Enhancements

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Introduction

The objectives of the HubLine Anadromous Fish Passage Enhancement project were to enhance and increase spawning habitat for all anadromous species, but primarily for alosine fishes (alewives, *Alosa pseudoharengus*; blueback herring, *Alosa aestivalis*; and American shad, *Alosa sapidissima*). In 2004, the *MarineFisheries* Anadromous Fish Dynamics and Management Program completed a survey of fish passage along the Massachusetts coast, which identified sites where anadromous fish are impeded or blocked from reaching their spawning grounds. The survey encompassed 215 coastal systems and identified 380 obstructions, mostly nonfunctional dams. Of these dams, 175 have existing fish passage structures of variable condition. Survey results demonstrated that the Commonwealth of Massachusetts has a large investment in coastal fish passage and highlighted the need for significant improvement or new passage in many locations (Reback et al. 2005a; Reback et al. 2005b).

In 2005, using data from the completed fish passage survey, *MarineFisheries* biologists created a prioritized list of construction/repair projects, many of which are located in watersheds associated with the HubLine construction area. Needs for biological monitoring of anadromous fish and spawning habitat improvements in the HubLine region were also identified. Based on the prioritized project list and other identified needs, *MarineFisheries* selected and completed **20 projects** in 13 systems in the HubLine region that (a) ranged from minor to major fishway improvements, (b) created new passage for anadromous fish, (c) evaluated the feasibility for restoring anadromous fish populations, (d) restored or enhanced spawning habitat, and (e) developed innovative technology for assessing river herring passage and run size (Tables IVC1.1 and IVC1.2). Projects were completed in all major tributaries to Boston Harbor, except the Mystic River. The criteria considered for project selection included potential acreage of restored or accessed habitat, historical presence of a fish run, water quality, system hydrology (i.e., flow availability), community support, information gained, and cost effectiveness. Some large potential passage projects in the Boston Harbor region were not considered because costs would have exceeded HubLine funding and/or because of complexities of water management and dam repairs (e.g., improvements at the Charles River Dam, Charles River and the Mystic Lakes Dam, Mystic River). Two Boston Harbor systems,

Table IVC1.1. HubLine anadromous fish passage enhancement and feasibility projects.

System	Town	Obstruction	Work Description
Crane River	Danvers	N/A; instream habitat	Restoration of riffle spawning habitat for smelt; riparian habitat enhancement
Forest River	Salem	Culvert at Coy Pond & instream habitat	Evaluation and enhancement of American eel passage and smelt spawning habitat
Saugus River	Saugus	Lynn Waterways Dam	Installation of eel ramp & monitoring of American eel population
Charles River	Watertown	Bleachery Dam	Dam breach to create fish passage on river's north side
Charles River	Waltham	Moody St. Dam	Fishway repairs and improvement
Charles River	Wellesley; Newton	Finlay Dam	Replacement of fishway baffles
Charles River	Wellesley; Newton	Cordingly Dam	Replacement of fishway baffles
Neponset River	Milton; Mattapan	Walter Baker Dam; Tilestone and Hollingsworth Dam	Supplemental feasibility study for dam removals and contaminant remediation; collaborative project with Riverways, Dept.of Fish and Game
Fore River; Monatiquot River	Braintree	System-wide (five total)	Feasibility study to evaluate river herring passage and restoration
Fore River; Monatiquot River	Braintree	N/A	Installation of USGS staff gage and development of rating curve
Back River	Weymouth	Jackson Square Dam	Removal of accumulated sediment and artificial weir below fishway
Back River	Weymouth	Jackson Square Dam	Streambed enhancement below fishway to accommodate smelt spawning & river herring passage; increased shading
Back River	Weymouth	Iron Hill Dam	Installation of protective grating on fishway & construction of viewing platform (Eagle Scout project)
Weir River	Hingham	Foundry Pond Dam	Restoration of smelt spawning habitat in spillway
Weir River	Hingham	Foundry Pond Dam	Fishway repairs and partial reconstruction
Weir River	Hingham	Foundry Pond Dam	Evaluation of system-wide herring spawning habitat and outmigration options; herring population monitoring; development of water management plan
Bound Brook	Cohasset	Hunters Pond Dam	Feasibility study to evaluate anadromous fish passage improvements and restoration
Indianhead River	Hanover	Elm St. Dam	Fishway reconstruction and baffle replacement
Herring Brook	Pembroke	3rd Mill Ponds Dam	Installation of steeppass fishway and related engineering

Table IVC1.2. Digital video assessment of herring runs at Town Brook, Back, Charles, and Bourne Rivers. The number of time intervals possible, number of intervals counted, average fish per interval, and point estimates of run size are provided.

System	Number of 10 minute intervals possible	Number of 10 minute intervals in which fish were counted	Average number of fish per 10 minute interval	Estimate of run size (number of fish passing upriver)
Town Brook	5040	321	24.97	125,840
Charles River	2016	126	21.44	43,230
Back River	5040	284	13.71	69,052
Bourne River	5040	315	10.34	53,151

the Neponset River and the Fore River, lack fish passage entirely. Consequently, HubLine-funded work in those systems focused on extensive hydraulic modeling and engineering to assess the feasibility and alternatives for fish passage and the potential for anadromous fish restoration.

Summaries of individual HubLine supported fish passage enhancement projects and feasibility studies are provided in the following sections, categorized geographically as North Coastal (adjacent to Boston Harbor and within the HubLine impact area), Boston Harbor, and South Coastal (immediately adjacent to the HubLine impact area). The one major research project, which focused on the development of automated digital video counting technology, is described separately. All HubLine Anadromous Fish Passage Enhancement projects received federal matching funds through the Wallop-Breaux Sport Fish Restoration Program (Massachusetts Division of Marine Fisheries, Diadromous Research and Restoration Grant, F-57R). Two projects also received matching funds from the National Oceanic and Atmospheric Administration (NOAA) Habitat Restoration Partnership and the U.S. Fish and Wildlife Service Fish Habitat Initiative.

Fish Passage Restoration

<u>North Coastal Projects</u>

In the north coastal region, fish passage and instream habitat restoration projects were completed in the Crane River, the Forest River, and the Saugus River. Given the present lack of sustained river herring runs in these north coastal systems, HubLine projects focused on enhancements for American eel (*Anguilla rostrata*) and rainbow smelt (*Osmerus mordax*). River herring were historically present in these north coastal systems; however, the severity of habitat loss over time from industry, development, and water supply needs, as well as the degradation of remaining habitat, eliminated the application of HubLine funds for projects specific to river herring. For example, findings from a collaborative river herring restoration feasibility study led by *MarineFisheries* and the Saugus River Watershed Council concluded that restoring river herring to the Saugus River was infeasible because of watershed modifications from the construction of transportation corridors, and because the constraints of public water supply have reduced river flow and impacted water quality (Gomez and Sullivan 2006). The feasibility study did highlight the possibility for restoring passage for American eels, which in turn led to the successful installation of an eel ramp supported by HubLine funds.

Crane River, Danvers:
The Crane River is a tributary to the Danvers River, which empties into Beverly Harbor. In 1990, *MarineFisheries* identified a stretch of riffle

habitat upstream of a sluiceway at Purchase Street in Danvers as potential spawning habitat for rainbow smelt, but the sluiceway limited access to smelt (Chase 2006). In 1997, the sluiceway was removed, allowing full passage for migrating smelt (Chase 2008a). More recently, *MarineFisheries* has been working to restore smelt to the Crane River through the HubLine supported Rainbow Smelt Propagation program. In conjunction with this effort, Fish Passage Enhancement funds are targeted for enhancements to spawning riffle habitat upstream of the former Purchase Street sluiceway. These enhancements are in the conceptual stage.

Forest River, Salem MA

Although there is little evidence of the presence of diadromous fish in the Forest River system, juvenile American eels were observed during a survey from 1988-1990 (Chase 2006). Coy Pond, a former Town of Marblehead water supply pond, is connected to the tidal portion of the Forest River by a man-made creek referred to here as Leggs Hill Creek. The pond, which flows into the creek through a perched drain pipe, is known to contain American eels, and it supports a recreational fishery for largemouth bass (*Micropterus salmoides*). In 2007, *MarineFisheries*, in collaboration with Salem Sound Coastwatch, evaluated the potential for diadromous fish habitat enhancement in Leggs Hill Creek and for passage improvements to Coy Pond. Based on this HubLine supported evaluation, river herring passage to Coy Pond was deemed infeasible due to low flow and steep gradient. A 15-20m reach of marginal smelt spawning habitat was identified (i.e., low flow and minimal gravel), but intensive management of the invasive strain of the common reed *Phragmites australis* would be necessary to maintain an open channel over the spawning riffle. Improvements to passage for American eel were determined to provide the greatest benefit for diadromous resources. HubLine funds have been designated for an in-stream debris cleanup (tires, barrels, trash, etc.) and an in-channel only *Phragmites* removal to be conducted by Salem Sound Coastwatch. Along with general benefits to the stream environment, the debris cleanup and *Phragmites* removal will improve passage for eels by eliminating artificial blockages in the stream and will improve the existing potential smelt spawning habitat. HubLine funds will also be used to conduct an assessment of eel passage at the perched culvert entering the pond, and if appropriate, implement passage improvements (e.g., modify the slope of the drain pipe or install an eel ramp). These activities are likely to occur in 2009 and/or 2010. Also, if passage enhancements are deemed suitable for this site, developing an estimate of abundance of eels in the pond may be considered prior to any installation/construction. Collecting information on eels currently in the pond would provide *MarineFisheries* the opportunity to assess the success of passage improvements.

Saugus River, Lynn/Saugus:

A recent feasibility study on Saugus River fish passage and hydrology identified American eel passage as a potential restoration option for diadromous fish in the Saugus River (Gomez and Sullivan, 2006). This initial study was funded by the Gulf of Maine Council and conducted by the Saugus River Watershed Council (SRWC) and *Marine Fisheries*. Subsequently, in March 2007, a HubLine supported eel ramp specially designed by Dr. Alex Haro of the USGS Conte Anadromous Fish Research Center, (Turners Falls, MA) was constructed and installed at the Lynn Waterways Dam/Colonial Country Club Dam (Figure IVC1.1). A trap for eels was affixed to the top of the ramp for monitoring purposes. SRWC staff trained by *MarineFisheries* biologists monitored the eel ramp from March 29 to July 2, 2007. Despite operational and high flow problems in April, the eel ramp passed 9082 eels in its first year of operation. In May, two large catches alone, exceeded seasonal passage expectations (Figure IVC1.2; Chase 2008b).

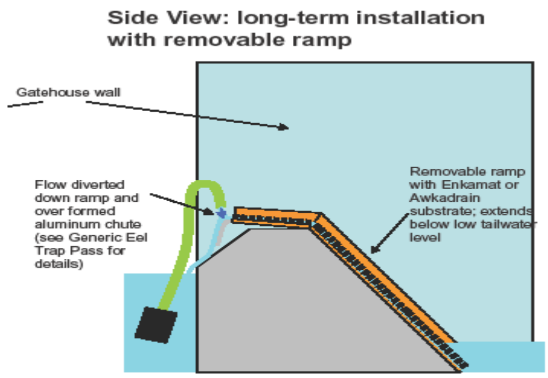
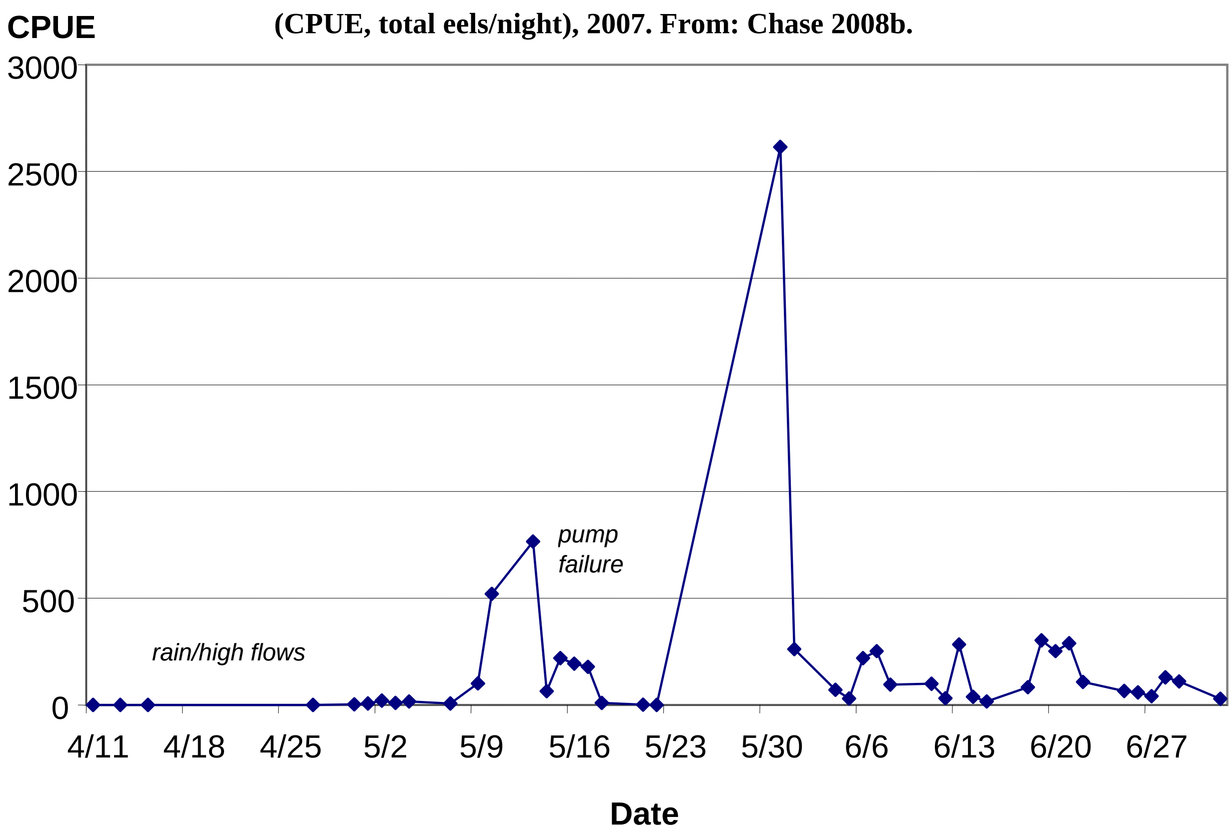


Figure IVC1.1. Eel ramp at the Lynn Waterways Dam/Colonial Country Club Dam, Saugus River, Lynn, MA.

Figure IVC1.2. Saugus River eel ramp catch-per-unit-effort (CPUE, total eels/night), 2007. From: Chase 2008b.



In 2008, approximately 6,500 eels were passed upriver and no operational problems were encountered. In addition to HubLine support for design, installation, and monitoring of the eel ramp, matching funds for this project were received by the Gulf of Maine Council/NOAA Habitat Restoration Partnership.

Boston Harbor Projects

In the Boston Harbor region structural fish passage enhancements and habitat restoration projects were completed in the Charles, Back, and Weir Rivers. Although improvements in all systems will benefit river herring, fishway modifications in the Charles River were made especially in anticipation of returning adult American shad from the HubLine-supported American shad propagation project. In addition, the restoration of critical rainbow smelt spawning habitat downriver of Foundry Pond Dam in the Weir River is slated to occur now that the entrance to the fishway has been reconstructed.

Two HubLine supported feasibility studies were completed in the Boston Harbor region for the Neponset and Fore Rivers, both of which lack fish passage at major impediments. In collaboration with ongoing efforts by the Massachusetts Riverways Program to examine fish passage and contaminant remediation alternatives for the Neponset River, *MarineFisheries* funded a supplemental study covering hydrologic and hydraulic analyses, structural evaluation, sediment analysis and management, and an alternatives analysis. *MarineFisheries* led a feasibility analysis for restoring river herring to the Fore River watershed, specifically to the historic spawning ground at Great Pond in Braintree. Restoration of passage to Great Pond, a public drinking water supply, will require modifications at five structures and the assistance of the TriTown Water Board of Braintree, Randolph and Holbrook to manage limited flow from Great Pond for adult immigration and juvenile emigration. Since the mid-1990s, river herring have been returning to the Fore/Monatiquot River in increasing numbers but have been limited to marginal spawning habitat due to blocked passage.

Charles River, Boston to Waltham:

Evaluation and improvement of fish passage in the Charles River was a primary focus of the Anadromous Fish Passage Enhancement Project, as the success of the concurrent HubLine-funded American Shad Propagation project depends on adequate passage for shad to spawning/rearing habitat. In May 2005, *MarineFisheries* and a U.S. Fish and Wildlife Service fish passage engineer completed an initial examination of fish passage structures in the Charles River from the Charles River Locks in Boston upriver to the Cordingly Dam in Wellesley. Modifications and/or repairs were recommended for six fishways, along with the recommendation for a breach at the Bleachery Dam in Waltham.

In summer and fall of 2005, the *MarineFisheries* fishway construction crew completed functional repairs and modifications to fishways from Watertown to Wellesley/Newton, and created a breach on the north side of the river at Bleachery Dam (Figure IVC1.3). The breach, which was under consideration for a

Figure IVC1.3 Notching of Bleachery Dam.

number of years, created an additional avenue for anadromous fish passage that complements a breach completed on the south side of the river decades ago. Although the "Mother's Day Flood" in May of 2006 damaged the boulder and granite block configuration that provides the proper hydraulics for fish passage through the breach, repairs were made in late summer 2006 by the fishway crew. Fish migrating along the north side of the river are now no longer impeded by the 3.5 ft dam.

To highlight improved passage structures and anadromous fish species in the Charles River, *MarineFisheries* participated in the development of a multi-panel educational kiosk that was installed near the Watertown Dam fishway in

2008. Kiosk project partners included the Massachusetts Department of Conservation and Recreation (DCR), the Corporate Wetlands Restoration Partnership (CWRP), the Charles River Watershed Association (CRWA), Sasaki Associates. *MarineFisheries* staff also led an educational field trip at Watertown Dam in 2008 for the Atrium School (Watertown), focused on anadromous fish resources in the Charles River.

Neponset River, Milton and Mattapan

Fish passage has been impeded by dams in the Neponset River for several centuries, leading to the extirpation of most anadromous fish resources, including a once thriving population of American shad. The first two dams in the Neponset, the Walter Baker Dam (Milton, Dorchester) and the Tileston and Hollingsworth Dam (T&H Dam; Milton, Mattapan) do not have fish passage structures. Today, only rainbow smelt, which spawn at the base of the Walter Baker Dam, and possibly American eel remain. Passage at these sites would open up approximately 17 miles of spawning/rearing habitat for American shad. The Neponset River was initially targeted for American shad fry stocking as part of the HubLine-funded American Shad Propagation Project, but stocking has been delayed until passage provisions are imminent. The long-term success of shad restoration in the Neponset will depend on adequate passage for migrating adults to upriver spawning grounds.

MarineFisheries has been working actively with the Massachusetts Riverways Program (Riverways) for several years to restore ecological function to the Neponset River through establishment of fish passage and remediation of contaminated sediments. In addition to the blockages for fish caused by dams, the Neponset River's industrial past and continued urbanization have resulted in contamination of river bottom sediments by polychlorinated biphenyls (PCBs; Breault et al. 2004). In 2006, Riverways contracted the consulting firm Milone & MacBroom, Inc. (MMI) to complete a final feasibility study to determine the best alternatives for fish passage and river restoration (i.e., remediation of PCB-laden sediments) in the area from the Walter Baker Dam to the Tileston and Hollingsworth Dam. Riverways simultaneously convened a Technical Advisory Committee (TAC) composed of representatives from state and federal agencies (including *MarineFisheries* staff), non-profit organizations, and town government. The TAC reviewed MMI's November 2006 report entitled *Environmental Restoration Report and Environmental Assessment; Neponset River Fish Passage and Habitat Restoration Project; Neponset River Basin*. Based on MMI's findings, the TAC recommended the following preferred alternatives:

> Baker Dam, option 1: Full dam removal with full sediment dredging
>
> Baker Dam, option 2: Full dam removal with containment wall
>
> T & H Dam, option 1: Full dam removal with full sediment dredging
>
> T & H Dam, option 2: Partial dam removal with containment wall

Supplemental analyses were required to further refine recommended restoration and remediation alternatives. Thus, in a joint contract with Riverways, *MarineFisheries* used HubLine funds to support a supplemental feasibility study conducted by MMI and completed in February 2008. This study, *Supplemental Report, Neponset River Fish Passage and Habitat Restoration Project, Neponset River Basin*, included the following critical elements for continuance of the Neponset project: (a) supplemental hydrologic and hydraulic analysis, (b) structural evaluation, (c) supplemental sediment analysis, (d) sediment management, and (e) further discussion of restoration alternatives (Milone and MacBroom 2008). Riverways and *MarineFisheries* sponsored a well-attended public meeting in January 2008 in conjunction with the completion of the supplemental report, and the Neponset project has since shifted toward full public process. Currently, an independently facilitated Citizen's Advisory Committee (CAC) is addressing issues, ideas, and alternatives for the cleanup, restoration, and preservation of the Neponset. The CAC is sponsored by the Department of Conservation and Recreation, the Department of Fish and Game, the

City of Boston's Office of Environmental and Energy Services, the Town of Milton Conservation Commission, the Lower Mills Merchants Association, and the Neponset River Watershed Association. The Neponset River restoration project has progressed significantly during the period of HubLine funding; however, numerous agencies, NGOs, and local citizens are still deliberating on the best restoration alternatives and next steps. Final recommendations from the CAC are expected in spring 2009.

Fore River/Monatiquot River, Braintree (stream gage installation)
The Fore River is a major tributary to Boston Harbor and is known to have one of the largest smelt spawning populations in the state. In recent years thousands of river herring have been observed below natural waterfalls in Braintree, unable to pass upriver to spawning habitat. To better understand the hydrology of this key tributary and in preparation for potential fish passage improvements, *MarineFisheries* entered into a cooperative agreement with the U.S. Geological Survey (USGS) to install a staff gage and develop a rating curve for the Fore River. The gage was installed in August 2005 and the rating curve completed over the late summer low flow period. Based on this initial HubLine-funded work and due to the demonstrated importance of this site, the Fore River was subsequently selected by the Massachusetts Executive Office of Environmental Affairs Streamgaging Initiative (now Executive Office of Energy and Environmental Affairs) for installation of a state of the art real-time stream gage. The new gage (USGS #01105583, Monatiquot River) was one of approximately 30 new gages installed across the state in systems where the growing demand for water is competing with the need to maintain adequate streamflow for aquatic habitat protection. Real-time data from this site can be viewed on the USGS website (http://waterdata.usgs.gov/ma/nwis/rt).

Fore River/Monatiquot River, Braintree (system-wide study to evaluate restoration)
The Fore River Basin is located south of Boston and primarily includes the towns of Braintree, Randolph, Holbrook, Quincy, and Weymouth. The main river draining into the Fore River Bay/Boston Harbor is the Monatiquot River. The Monatiquot River is formed by two main tributaries, the Farm and Cochato Rivers. The Monatiquot River historically contained a large run of alewife that spawned in the large headwater pond called Great Pond, which presently serves as a public water supply; however, successful spawning runs ceased after the construction of dams during the industrial revolution.

There are currently man-made and natural barriers that preclude upstream movement of river herring in the Fore River (Table IVC1.3; Figure IVC1.4). The natural falls referred to here as Rock Falls represents the current upstream extent of river herring migration. There appears to be a historic bypass channel extending around the falls that may have been modified due to the construction of the MBTA railroad and adjacent parking lot. Approximately 50 feet upstream of Rock Falls is the 2 to 3-foot high Ames Pond Dam followed by the Hollingsworth Dam another 560 feet upstream. The Hollingsworth Dam is the first major challenge for restoring river herring. A brick building sits atop the dam, and vertical columns or structural supports extend from the base of the building to the spillway crest. Moving upriver, the next barrier is the Diversion Dam located on Farm River that diverts flow into Richardi Reservoir. Next, Sunset Lake canal connects Sunset Lake to the Farm River at the small Sunset Lake Dam. Finally, the 6.6-foot-high Great Pond Dam is a barrier to passage at Great Pond, the key spawning habitat (180 acres; Table IVC1.3; Figure IVC1.5).

In addition to physical obstructions to anadromous fish passage, river flows on the Farm and Monatiquot Rivers are heavily impacted by water supply withdrawals occurring within the Farm River watershed. Two water supply intakes are located in Great Pond that provide potable water. The two intakes are maintained and operated by the Braintree Water and Sewer Commission (BWSC) and the Randolph/Holbrook Joint Water Board. Only on rare occasions is water spilled below Great Pond Dam; most of the watershed runoff is used for water supply. In addition to water withdrawals in Great Pond, water from the

Farm River can be diverted at the Diversion Dam into Richardi Reservoir for water supply. Water retained in Richardi Reservoir is pumped to either Great Pond or Upper Reservoir to further supplement water supply demands (Figure IVC1.4).

Although river herring were believed to be absent from the Fore River system, *MarineFisheries* and the Fore River Watershed Association (FRWA) observed river herring at the natural falls (referred to here as Rock Falls; Figure IVC1.6) below Hollingsworth Dam in the 1990s. Currently, river herring are spawning in marginal habitat in the main stem Monatiquot River near Route 93. Due to the increasing observations of river herring and the amount of potential spawning habitat further upstream in Great Pond and Sunset Lake, *MarineFisheries* established a partnership with the local community and dam owners to evaluate the feasibility of restoring river herring to the Fore River System. This partnership included *MarineFisheries*, the Town of Braintree, the FRWA, and F.X. Messina Enterprises (Hollingsworth Pond LLC). Shown in Figure IVC1.4 is the proposed migration route for river herring.

Table IVC1.3. Man-made and natural barriers that preclude upstream movement of River Herring in the Fore River, Braintree, MA.

Barrier Location	Ownership	River	Approximate Barrier Height	Alternative(s) to Mitigate Barrier
Natural Falls – referred to as "Rock Falls"	Along shoreline- Hollingsworth Pond, LLC	Monatiquot River	4 feet- steep falls	Resurrect bypass channel around Rock Falls
Ames Pond Dam	Hollingsworth Pond, LLC	Monatiquot River	2-3 feet depending on flow	Lower the sill elevation of dam to mitigate vertical barrier
Hollingsworth Dam	Hollingsworth Pond, LLC	Monatiquot River	12.5 feet	Conventional fishway and dam removal
Richardi Reservoir- Diversion Dam	*Tri-Town Water Board	Farm River	Unknown- although appears to be minor	Based on a site visit does not appear to be a barrier. Slight modifications to stoplog operations may be necessary
Sunset Lake Dam	Town of Braintree	Sunset Lake Canal, Tributary to Farm River	1-2 feet, depending on the number of weirboards	Modifications to weirboards, and potentially install cross vanes below dam to raise water surface elevation
Great Pond Dam	*Tri-Town Water Board	Tributary to Farm River	6.6 feet	Conventional fishway
* The Tri-Town Water Board consists of three towns- Braintree, Holbrook and Randolph				

Figure IVC1.4. Fish passage route and obstructions to Fore River/Monatiquot River system, Braintree, MA.

Figure IVC1.5. Great Pond Dam and Great Pond, key spawning area.

Figure IVC1.6. Natural falls or Rock Falls, Fore River/Monatiquot River system, Braintree, MA.

In January 2008, *MarineFisheries* awarded a HubLine-funded contract to the firm Gomez and Sullivan Engineers, P.C. to complete the feasibility study which included (a) an evaluation of existing river information, (b) hydrologic and hydraulic analysis, (c) scoping design of fish passage options, and (d) recommendations. Concurrent with the contract, *MarineFisheries* staff conducted water quality monitoring at Great Pond and Sunset Lake to determine if water quality conditions are suitable for river herring spawning, incubation and growth. *MarineFisheries* collected information on dissolved oxygen, temperature, specific conductivity, turbidity, and pH. The fundamental questions examined as part of the feasibility study included:

- How much water is withdrawn from the watershed for water supply needs?
- Is there enough water in the basin to support river herring migration?
- Does the drawdown and refill of Great Pond impact the success of spawning?
- Can conventional fish passage be installed at Hollingsworth and Great Pond Dam?
- What are the impacts of removing the Hollingsworth Dam?
- Are water quality conditions in Great Pond and Sunset Lake sufficient to support river herring spawning and growth?
- Is it possible to maintain fishway flows below Great Pond Dam, while preserving water supply needs?
- What are the order of magnitude costs to restore river herring to the basin?

The final report entitled *Feasibility Analysis for Restoring River Herring to the Fore River* (Gomez and Sullivan 2009) is available on the *MarineFisheries* website: (www.mass.gov/dfwele/dmf/programsandprojects/anadrom.htm#anadromous). An evaluation of fish passage options and/or minor modifications was conducted at each dam. Specifically, conventional fish passage options were evaluated at Hollingsworth Dam and Great Pond Dam, while only minor modifications may be necessary at Ames Pond Dam and Sunset Lake Dam to permit fish passage. In addition to conventional fish passage at Hollingsworth Dam, a dam removal alternative was also evaluated.

No decisions on project feasibility or potential fishway structures will be made until the completed feasibility study has been reviewed by project partners. If feasible options for improving fish passage and restoring river herring are demonstrated and suitable spawning habitat is present, funding will be sought for the next stage of plan development, which includes project design, engineering and permitting. Improved fish passage for anadromous species will also benefit the catadromous American eel (*Anguilla rostrata*) which also inhabits the Fore River.

South Coastal Projects

Back River, Weymouth
In collaboration with the Town of Weymouth, *MarineFisheries* completed the first Hubline-funded fish passage enhancement project in January 2005. A swinging grate was installed over the bypass channel near the Back River fishway. The grate will prevent adult river herring and rainbow smelt (*Osmerus mordax*) from entering the bypass channel and assist them in finding the fishway as they move upriver to spawn. The success of the gate will be evaluated by examining herring count data collected annually by the Town of Weymouth.

In the fall of 2005, *MarineFisheries* installed grating over the Iron Hill fishway to prevent poaching of river herring as they migrate to their spawning habitat. Given the severe decline in river herring and the current *MarineFisheries* ban on harvest until 2009, preventing poaching is critical for the protection of this resource. The Iron Hill Dam is the sixth obstruction in this system. After herring ascend the Iron Hill fishway, they must traverse only one additional obstruction before entering their spawning habitat in Whitman's Pond. A viewing platform was also constructed near the fishway to enhance accessibility for biological monitoring and to promote public advocacy. *MarineFisheries* sponsored and assisted a local Eagle Scout working through Senator Robert Hedlund's office to carry out this project.

A third Back River project is underway and involves two components which will improve smelt spawning habitat and enhance river herring passage. Smelt spawning below the Jackson Square Dam fishway (Figure IVC1.7) has been impacted by reduced flow caused by an unauthorized stone weir. To restore adequate flow, *MarineFisheries* is working with the Town of Weymouth to breach the weir. In addition, river herring passage has been impacted by the loss of large cobble substrate below the fishway (due to storm/flood events) and the subsequent increase in sediment buildup. *MarineFisheries* proposes to remove the sediment buildup immediately below the fishway and restore the bed of large cobble.

Figure IVC1.7. Jackson Square dam, Back River, Weymouth, MA.

Weir River, Hingham:
Project: Multi-component smelt habitat restoration/river herring restoration evaluation
Status: Underway

The Weir River was once home to the largest smelt population in Massachusetts; however, an emergency dam repair at Foundry Pond Dam eliminated the majority of smelt spawning habitat immediately below the dam, and now smelt are rarely observed in this system. River herring are also rarely observed in the Weir River. Although *MarineFisheries* and the Town of Hingham are very interested in restoring river herring to this system, an evaluation is necessary to determine whether the river has adequate flow and habitat to support herring production. If the river can support a sustainable herring population, juvenile herring out-migration may be negatively impacted by rip-rap at the base of the dam (part of the emergency dam repair). Thus, out-migration options will need to be addressed.

MarineFisheries drafted a multi-component proposal that encompasses the restoration needs for both smelt and river herring. In conjunction with this proposal, *MarineFisheries* is working with the Town of Hingham to develop a springtime water management protocol, as variable releases through the Foundry Pond Dam sluice creates (a) false attraction to poor spawning habitat and egg mortality for smelt and (b) false attraction flow for river herring attempting to move upriver.

For the smelt component of this project, *MarineFisheries* proposes the reconstruction of several islands and deeper swift water channels below the dam to accommodate smelt spawning, and thus restore the habitat to pre-existing/pre-dam repair conditions. The bidding process for this work is underway.

For the river herring component, *MarineFisheries* repaired the base of the fishway. The first step of the fishway had degraded, possibly hindering passage and impacting attraction flow. Next, *MarineFisheries* constructed and installed a trap at the fishway exit to allow the assessment of presence and/or numbers of herring entering the river to spawn and herring were subsequently documented in the river (Figure IVC1.8). The Assistant Conservation Officer for the Town of Hingham has committed to checking this trap daily during the migratory fish season. Based on the results of the monitoring phase, project partners will then determine whether to pursue a feasibility study that will examine the hydrological condition of the river, quantify potential spawning habitat for river herring (current and future, based on the rate of water withdrawals), and evaluate out-migration options for juvenile fish at Foundry Pond Dam (e.g., a notch in the dam). The feasibility study is a critical element to this project, but because it is a long-term objective, it will extend beyond the opportunity for Hubline funding.

Figure IVC1.8. Foundry Pond Dam fishway and monitoring trap, Indianhead River, Hanover.

The Indianhead River, a tributary to the North River, supports a variety of anadromous fish species including river herring, white perch, trout, and most notably—one of the few established populations of American shad in the state. The Elm Street Dam denil style fishway was in need of new wooden baffles and minor structural repair. Specifically, fish passage was impacted at this site because numerous baffles were damaged or missing and because the floor of the fishway was leaking. *MarineFisheries* partnered with the Town of Hanover to replace baffles and *MarineFisheries* anadromous fish staff constructed new baffles and conducted repairs during 2008.

Bound Brook, Cohasset:
Project: Assess fishway efficiency; monitor for presence of river herring; develop water management plan
Status: Under consideration

The objective of this project is to evaluate the feasibility of improving passage for diadromous fish populations in the Bound River system. The target species to benefit from improved passage are river herring (blueback herring -*Alosa aestivalis*, and alewife -*Alosa pseudoharengus*). Restoration of river herring is important to the region because they provide: (1) forage for many species of wildlife, (2) recreational and cultural benefits to citizens who value fish runs for providing food and bait, (3) a sign of a healthy river. Successful passage restoration will also provide benefits to American eel (*Anguilla rostrata*) that seek upstream habitat for foraging, and may improve migratory habitat for freshwater fish and rainbow smelt (*Osmerus mordax*) spawning habitat below Hunters Pond Dam. In addition to improving migratory habitat, the project seeks to evaluate and enhance diadromous fish spawning and nursery habitat.

The Bound Brook watershed (drainage area = 9 mi^2) is located in Cohasset and Scituate in the South Shore Coastal Drainage Area. Bound Brook is formed at the confluence of Aaron River and Herring Brook. Aaron River originates from the Aaron River reservoir (150 acres) that was constructed in 1978, and Herring Brook originates from the natural Lily Pond (50 acres). Bound Brook flows through Hunters Pond (< 2 acres) to meet the tidal waters of The Gulf, a tidal tributary to Cohasset Harbor. Bound Brook has a long history of regulation for hydropower and as a water supply. The presence of Hunters Pond Dam and water management by the Town of Cohasset was recognized as a significant challenge for restoring river herring nearly 100 years ago (Belding 1921). These same concerns have been documented in subsequent surveys by DMF (Reback and DiCarlo 1972; Reback et al. 2005b). A DMF smelt survey identified Hunters Pond Dam as a candidate for dam removal evaluation because of limitations on smelt and herring habitat (Chase 2006).

The Aaron Reservoir and Lily Pond serve as water supplies for Cohasset and both have functional fishways built in the late-1970s. The Hunters Pond Dam has a notched weir-pool fish ladder that was first constructed in 1913 (Belding 1921) and presently provides inefficient passage. Bound Brook does not possess a stream flow gauge station; however, a recent Interbasin Transfer Act (ITA) review included the development of a model to simulate water surface elevations and flow from the two reservoirs and led to release recommendations for maintaining anadromous fish passage (Cox et al. 2006). The permit issued under the ITA in 2004 included requirements for Cohasset to monitor Bound Brook discharge and uphold a minimum release target of 2.2 cfs to support river herring adult immigration and juvenile emigration. Interest in restoring the Bound Brook herring run has increased following the flow management improvements from the ITA process and due to recent observations of river herring at Hunters Pond Dam and Lily Pond by the members of the Gulf Association. This proposal seeks to improve passage and habitat quality for river herring in the Bound Brook system with a focus on the first obstruction at Hunters Pond Dam.

This fish ladder was first built in 1913 and was rebuilt in the same location possibly 40 years ago. The condition of the fish ladder was assessed as "poor/not passable" during the latest fishway survey (Reback et al. 2005b). More recent modifications appeared to have improved the fishway condition, however, the structure is aged and the original design appears inefficient. The project will evaluate the status of the fish ladder and control gate at the mill sluice and make recommendations on dam removal and fish ladder reconstruction options. In addition, the minimum flow targets from the ITA permit should be considered in relation to recently acquired discharge data and the passage improvement options. Any structural improvements will have to be made on the basis that there will be enough flow to support adult spawning migrations and juvenile emigrations. Finally, the water quality of spawning and nursery habitat in Aaron Reservoir, Lily Pond, and Hunters Pond should be evaluated to ensure that suitable conditions exist for successful spawning and juvenile rearing.

Herring Brook, Pembroke:
Project: Fish passage improvement at the Upper Mill Pond Dam
Status: Underway

Herring Brook is the migratory path for river herring to 347 acres of primary spawning and nursery habitat in the North River system, Furnace and Oldham Ponds. Maintaining passage at the Upper Mill Pond Dam is essential for supporting one of the largest river herring spawning runs on the South Shore of Massachusetts (Reback and DiCarlo1972). This Project will benefit the migration requirements for alewives (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American eel (*Anguilla rostrata*), and sea lamprey (*Petromyzon marinus*).

The plan is to reconstruct the dam outlet structure and sluice with concrete forms, replace the wooden fish ladder with three sections of Alaskan steeppass fish ladder, enhance the tailrace of the dam spillway with concrete leads to improve fish attraction, and install a gravity flow American eel ramp in the sluice alongside the fish ladder. Herring run monitoring would be conducted by the Town of Pembroke and local partners.

MarineFisheries funded the development of a scoping design for the outlet structure and fish ladder construction. These plans are available and will guide the development of engineering plans. The Massachusetts Public Access Board (PAB) has agreed to provide engineering plans for the project in 2009. *MarineFisheries* will fund any costs associated with the engineering plans and work with the Town of Pembroke on environmental permitting. The completion of engineering plans is scheduled for September 2009, followed by the bidding for a contract to construct the project during the low water period of the summer 2010. Funding, in addition to that available from HubLine, will be necessary to cover all aspects of the Project.

Research and Monitoring

Boston Harbor Rivers/Region:
Project: Automated digital video technology for counting river herring
Status: Underway

Due to the severe decline in river herring abundance and the current *MarineFisheries* ban on river herring harvest until January 1, 2012, monitoring numbers of herring entering coastal Massachusetts rivers to spawn is critical for the protection and restoration of this resource. *MarineFisheries* has an established herring monitoring program, but it is only implemented in selected streams due to technical or financial limitations to coastwide surveillance. Furthermore, monitoring programs run by community groups and NGOs, although energetic, do not have the scientific rigor needed for science-based management. To improve population assessments for river herring, *MarineFisheries* funded the Massachusetts Cooperative Fish and Wildlife Research Unit, University of Massachusetts-Amherst to develop the technology for an inexpensive and accurate automated digital video system that will count river herring in fishways in coastal Massachusetts streams, and which will produce scientifically defensible data. The Massachusetts Cooperative Fish and Wildlife Research Unit is highly recognized for expertise in anadromous fish biology and ecology, monitoring protocols, and for the development of innovative methodological techniques in fisheries science.

The first step of this project was to develop video technology that can detect distinct images of herring with enough resolution that the images can be recognized and counted individually under a variety of light, turbidity, and turbulence conditions. Accompanying software distinguishes fish images from non-fish images (e.g., bubbles, sticks, leaves). The second step was to develop adequate data storage that encapsulates entire herring runs (e.g., approximately 90 days). Using streaming video, time lapse, or motion detection technology (depending on the situation), images are compressed, stored, and archived using minimal space. The third step was to develop automated image identification procedures/software that summarizes fish counts by hour, day, and season. Data were ground-truthed by and compared to traditional sampling procedures.

In 2006, prior to HubLine funding, the University of Massachusetts scientists conducted a successful pilot study in the Monument River in Bourne, which included live streaming of the herring run over the internet. The project subsequently targeted the Back River in Weymouth, the Charles River in Watertown (with HubLine funds) and ultimately, Town Brook, Plymouth using non-HubLine grants because Plymouth falls outside of the HubLine-impact footprint. The Back River was selected for its large herring run, its reliable local citizen herring counts, and for the variety of power, security, and internet challenges it provides. For comparison, the Charles River was selected because it has a smaller herring run, it harbors a different suite of security and power issues, and because there is substantial community interest in this river. Also, the installation of this video technology in the Charles River greatly benefits the Hubline-funded American shad project, as hatchery-produced adult shad will be monitored as they return to the Charles River to spawn.

University of Massachusetts scientists tested camera equipment types and setups, located and confirmed power and wireless internet sources, and worked on the technical aspects of images produced by above water, underwater, and infrared cameras. *MarineFisheries* staff assisted University of Massachusetts scientists through this process.

Automated systems will allow *MarineFisheries* to record entire herring runs and use powerful statistical software to help answer critical questions about herring run size and composition, run timing, and fish behavior. Remote operation and monitoring of the cameras will allow *MarineFisheries* staff the ability to manage data collection in a number of systems simultaneously.

During the spring 2008 spawning migration, UMASS scientists made point estimates of the number of adult river herring returning to Town Brook, the Charles River, the Back River, and Bourne (Table IVC1.2). Herring were counted during randomly-selected time slots over the duration of each run and sample counts were expanded. More sophisticated analyses and improvements to the system are on-going.

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Part 2. : Rainbow Smelt Culture and Enhancement

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Completion Report – Bradford Chase, Matt Ayer, and Scott Elzey

Introduction

Anadromous rainbow smelt (*Osmerus mordax*) populations have long supported popular recreational and small-scale commercial fisheries in the Gulf of Maine. Smelt are also valued as an important prey for numerous fish and wildlife species. Smelt undergo spring spawning runs where they deposit demersal, adhesive eggs at freshwater riffles near the tidal interface. In many rivers, these locations are also centers of human development where watershed alterations have degraded water and substrate quality. In response to growing concerns over the status of smelt, *MarineFisheries* monitored the spatial occurrence and temporal use of smelt spawning habitat on the Gulf of Maine coast of Massachusetts (Chase 2006). The study also identified influences on smelt spawning success and recommended measures for improving population assessment and restoring populations.

Smelt restoration efforts in New England have primarily involved smelt egg transfers from healthy donor runs to rivers targeted for restoration. Egg transfers occurred in Massachusetts for over 70 years with limited evidence of population enhancement for anadromous smelt runs. During 1995-1997, *MarineFisheries* conducted a smelt egg transfer evaluation in the Crane River, Danvers (Chase et al. 2008). This study demonstrated that a smelt run could be established with egg transfers; however the recruitment gained from the transfers was minor when considering the project cost and effort. The egg transfer study concluded that smelt population restoration could be better achieved by applying growing technologies in laboratory culture (Trencia and Langevin 2003; Ayer et al. 2005) than traditional egg tray transfer methods. Following these experiences and recommendations, proposals were submitted in 2003 for HubLine Restoration funding to develop smelt culture and early life-stage marking techniques, and to NOAA Protected Species Program to develop smelt population indices from fyke net monitoring. Both proposals were approved. The fyke net project was funded by NOAA during 2004/2005 and received supplemental HubLine funding during 2006-2008. The smelt culture project was funded by HubLine for 2005-2008. The two projects were linked throughout the study period as fyke net catches served as the source of mature smelt for laboratory culture and the means to capture hatchery smelt that were previously marked and stocked as larvae.

Methods

Smelt Fyke Net

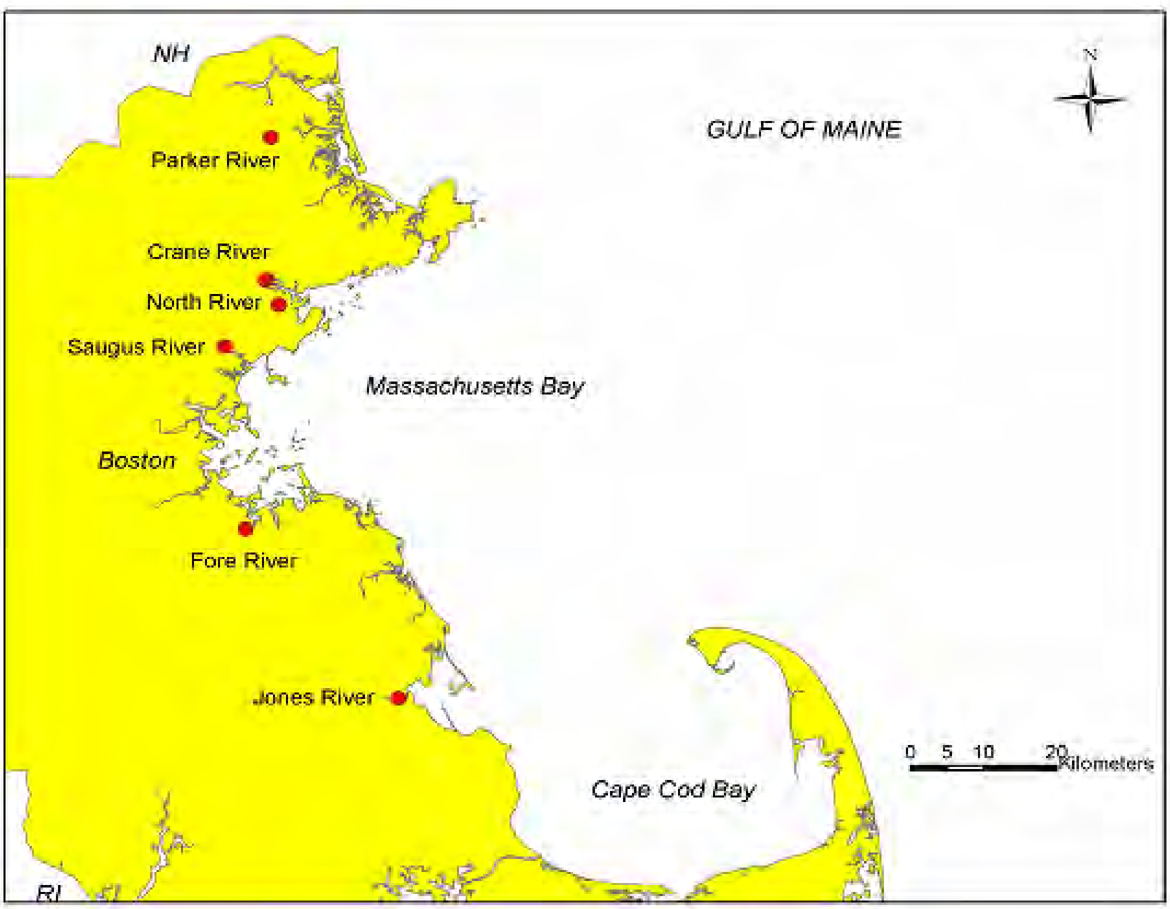
Fyke nets were deployed during spring spawning runs to catch adult smelt and record age structure data and catch-per-unit-effort (CPUE) indices of abundance. Following a pilot season in 2004, a custom fyke net was deployed during 2005-2008 using standardized methods (Appendix IVC2.1). Fyke nets were deployed for an 11 week season that coincided with the smelt spawning run, beginning the first week of March. The nets were set facing downstream in the intertidal zone below the downstream limit of smelt egg deposition. The fyke nets were set on Monday and hauled for three consecutive days and removed from the rivers on Thursday. A modified fyke net was designed with a 4x4 ft. box frame entrance, 4x4 ft. wings, and ¼ inch delta mesh throughout the net (Appendix Figure IVC2.2). Captured fish were counted, measured, and released.

Four stations were selected to serve as long-term, population monitoring stations (Table IVC2.1 and Figure IVC2.1). Random subsamples of smelt were collected weekly at the Fore and Saugus River stations for age sampling and to collect gametes for culture experiments. Smelt larvae hatched from Fore River and Saugus River eggs were marked with oxytetracycline (OTC) and stocked in the Crane River, Danvers. The Crane River and North River of the Danvers River were selected as restoration monitoring stations where captured smelt will be checked for OTC otolith marks.

Table IVC2.1. Smelt fyke net sampling stations and summary river information (discharge = spring ave.).

River	Watershed	Latitude	Longitude	Land Use ($1^o/2^o$)	Drainage Area (km^2)	Discharge (cfs)	Channel Width (m)
Jones River	South Coastal Basin	41^o 59.760'	70^o 43.399'	Residential / Forest	76.7	54.9	18.5
Fore River	Boston Harbor	42^o 13.353'	70^o 58.391'	Urban / Residential	93.5	55.8	16.0
Saugus River	North Coastal Basin	42^o 28.078'	71^o 00.461'	Residential / Urban	124.8	43.2	11.0
North River	North Coastal Basin	42^o 31.328'	70^o 54.696'	Urban / Residential	29.8	24.0	9.0
Crane River	North Coastal Basin	42^o 33.396'	70^o 56.183'	Residential / Urban	14.8	19.1	5.5
Parker River	Parker River	42^o 45.027'	70^o 55.694'	Residential / Forest	156.4	83.2	20.0

Figure IVC2.1. Smelt fyke net sampling stations on the Gulf of Maine coast.



Smelt Culture

Our objectives were to develop culture techniques to achieve high survival of fertilized smelt eggs and reared larvae in a hatchery setting, mark all fertilized eggs with OTC, stock OTC marked larvae in rivers targeted for restoration, and to confirm the persistence of the OTC mark and contributions to spawning runs. Adult smelt were collected from the Fore and Saugus River fyke nets and brought back live to the Annisquam River Marine Fisheries Station in Gloucester, for strip spawning and egg incubation. Smelt were processed the same or next day and the following data were collected: sex, maturity, total length (mm), fork length (mm), weight (g), and scales. Gametes were extracted from mature fish in the laboratory for in-vitro fertilization. Ripe males were patted dry with a paper towel and milt was extracted with plastic pipettes and placed in a dry container on ice. Milt was activated with freshwater and examined under a compound microscope for motility. Ripe females were patted dry with a paper towel and eggs were stripped into sterile and dry polystyrene weigh boats. Total egg weight was recorded for each female and three sub-samples (0.1 g) were removed from the total egg mass and counted to calculate the total number of eggs (eggs/gm). Milt (1 mL) was added to the dry eggs before the addition of 10 mL of freshwater. The mixture was then swirled for three minutes to ensure fertilization. After three minutes, the mixture was poured into a solution of swirling tannic acid (150 mg/L) in a hatching jar (Appendix Figure IVC2.3). The jar was swirled vigorously for 10 minutes before eggs were allowed to settle in the bottom of the jar. The tannic acid solution was replaced with 6-L freshwater following three freshwater rinses. The jars were immersed in a temperature-controlled water bath at 16°C and aeration was added to suspend the developing embryos. Embryos were examined under a dissecting microscope after 24 hours to confirm fertilization.

Just prior to hatching (<24 h), four subsamples of embryos (>100) were removed from each hatching jar and viable and dead embryos were counted to calculate the percent viability for each jar prior to hatch. Newly hatched larvae were immersed in 500 mg/L of buffered OTC. The OTC solution was buffered with dibasic and monobasic sodium phosphate to stabilize the pH of the marking solution between 6.5 and 7.0 while marking larvae. The solution was added to larvae for 6 h in the hatching jars with aeration. After 6 h the marking solution was removed and the jars were refilled with freshwater and aeration was replaced in the jar. Estimates for total eggs spawned were calculated from egg/gm subsamples collected from each female. Confidence intervals (CI, 95%) of egg estimates were calculated for each batch by summing individual fish variances; and for the season by summing variances of all fish sampled. The total eggs incubated for each batch was calculated by subtracting eggs used for subsamples. The subsample data on percent viability were then applied to the total egg estimate for each incubation jar to estimate the total number of larvae released in the Crane River.

The success of smelt hatchery culture prior to this study had been limited by challenges presented by the adhesive properties of smelt eggs and feeding transitions of larval smelt. The innovation of applying tannic acid at the time of fertilization prevented egg adhesion and created opportunities to use traditional hatchery methods for rearing smelt (Ayer et al. 2005). During 2003-2005, we consulted with fisheries biologists and fish culturists at MIT Sea grant, University of New Hampshire and the Quebec Department of Wildlife and Parks to compare experiences related to our goals with smelt culture. Starting in 2005, we attempted to rear samples of smelt larvae in static 38 L aquaria with algae (*Nannochloropsis occulata*) enriched water (greenwater) and rotifers (*B. plicatilis*) and supplied aeration through an airstone. Algae and rotifers were added each day as necessary to the larval culture water. Water quality (temperature, dissolved oxygen, conductivity, ammonia, nitrite, and pH) was monitored twice per week and 50% water changes were also made twice per week.

Results

Smelt Culture

<u>2005 Smelt Culture Summary</u>

A total of 55 females were strip-spawned in seven batches during 2005, resulting in an estimate of 1,337,094 fertilized eggs (± 15,504 eggs, 95%

CI). After removal of subsamples and accounting for mortality, an estimate of 1.1 million larvae was stocked in the Crane River (Table IVC2.2).

Table IVC2.2. Smelt egg stocking summary for HubLine restoration project, 2005-2008.

2005	Batch (No.)	Date	Females (No.)	Incubation Jars (No.)	Egg Total (stripped)	Egg Total (post-sample)	Viability (ave. %)	Larvae Total (Released)
	1	4/1	10		182,738	179,772		148,211
	2	4/7	4		88,698	85,805		70,518
	3	4/13	14		387,371	370,893		306,841
	4	4/14	6		203,785	196,940		162,465
	5	4/25	5		125,271	120,135		99,012
	6	4/26	7		173,519	164,216	86.8	136,300
	7	5/11	9		175,712	166,342	83.0	137,063
	Total		55	NA	1,337,094	1,284,103		1,060,410

2006	Batch (No.)	Date	Females (No.)	Incubation Jars (No.)	Egg Total (stripped)	Egg Total (post-sample)	Viability (ave. %)	Larvae Total (Released)
	1	3/23	5	2	122,931	118,846	70.0	83,752
	2	3/29	25	4	529,867	502,060	76.0	356,494
	3	3/30	5	1	146,221	139,392	57.0	79,453
	4	4/4	17	3	393,753	372,083	47.3	153,593
	5	4/11	17	3	404,703	389,273	60.7	225,977
	6	4/12	2	1	53,622	51,809	93.1	48,234
	7	4/20	6	1	140,688	135,782	64.9	88,122
	8	4/26	3	1	27,978	24,993	93.9	23,468
	9	4/27	13	1	106,543	96,820	51.6	49,959
	10	5/2	16	3	163,652	149,913	84.0	120,549
	Total		109	20	2,089,958	1,980,971		1,229,601

2007	Batch (No.)	Date	Females (No.)	Incubation Jars (No.)	Egg Total (stripped)	Egg Total (post-sample)	Viability (ave. %)	Larvae Total (Released)
	1	3/14	11	3	351,117	339,936	76.3	255,713
	2	3/21	12	4	537,207	527,416	53.2	83,334
	3	3/22	4	1	61,396	58,736	71.9	42,235
	4	3/27	11	2	214,501	208,364	62.0	128,073
	5	3/29	2	1	43,819	43,065	94.8	40,839
	6	4/3	8	2	209,419	204,133	76.1	147,455
	7	4/4	8	1	187,737	180,860	86.9	157,194
	8	4/10	19	4	553,263	537,097	79.4	297,886
	9	4/24	16	3	320,782	309,434	51.6	157,742
	10	5/1	7	2	156,003	150,113	89.4	126,574
	11	5/8	10	2	215,274	207,631	87.7	182,178
	Total		108	25	2,850,518	2,766,785		1,619,223

2008	Batch (No.)	Date	Females (No.)	Incubation Jars (No.)	Egg Total (stripped)	Egg Total (post-sample)	Viability (ave. %)	Larvae Total (Released)
	1	3/14	11	2	292,185	280,239	84.1	236,615
	2	3/19	3	1	70,701	67,288	75.9	51,072
	3	3/25	5	1	90,184	86,150	90.6	78,088
	4	3/26	6	2	176,903	171,650	80.3	134,835
	5	4/1	11	2	263,744	253,232	62.4	151,209
	6	4/8	13	2	404,334	389,689	53.7	209,138
	7	4/10	6	1	191,884	184,746	68.5	126,462
	8	4/15	2	1	17,125	15,238	83.5	12,731
	9	4/17	5	1	136,836	130,482	83.9	109,437
	10	4/22	21	3	267,507	245,584	83.9	201,944
	11	4/23	6	1	95,420	89,102	75.0	66,864
	Total		89	17	2,006,823	1,913,400		1,378,395

Fertilized eggs were maintained at 12 °C in hatching jars, and the average survival of incubated larvae among batches was approximately 83%. During 2005 and 2006, OTC marking was done on eggs marked with 500 mg/l OTC for 24 hours. Between 700-1000 marked larvae from each batch were saved for rearing. Newly hatched larvae responded well initially to rotifers raised on green algae. The rearing experiments were not long-lasting as our static aquaria system suffered ammonia spikes about 10 days after hatch-out. All larvae from the first six batches that were reared in the laboratory died within a month of hatch, presumably due to nitrogen loading. For the 7th batch, we tested subsamples (N = 1000) of larvae in two aquaria with freshwater (same treatment as batch 1-6) and two with 5 ppt salinity. The freshwater tanks suffered the ammonia spike after 10 days and the larvae in the low-salinity tanks survived through a month of feeding on enriched rotifers and lasted for about a month feeding on brine shrimp (*Artemia sp.*) naupplii. All smelt larvae died at about two months, possibly caused by unhatched *Artemia* cysts in their guts.

Smelt eggs from the 6th batch were placed in an experimental streamside incubator in the Crane River that was a modified design of a successful streamside hatchery used in Quebec on the L'Eglise River (Bouchard and Larose 1999; Trencia and Langevin 2003). The hatching jars in the streamside incubator received pumped water from the Crane River and flow exiting the jars carried the positively buoyant larvae out to the river. The eggs were successfully marked with OTC and passively released to the Crane River. However, during incubation, moderate rain elevated turbidity in river water and required daily visits to clean the incubator's filters. The experiences of 2005 led to the decision to concentrate on improving laboratory culture methods. This included developing a recirculating water system, refining rotifer culture in low-salinity water, and improving *Artemia* culture to decapsulate cysts prior to hatching.

2006 Smelt Culture Summary

Smelt hatching and rearing was shifted from a static aquaria system that maintained freshwater in a chiller bath at 12 °C in 2005 to a recirculating water system with 5 ppt salinity water chilled to 13 °C in 2006. The water system temperature was raised in an attempt to decrease the range of hatching time (3-4 days at 12 °C) to reduce the potential for stocking larvae with nearly spent yolk-sacs. The streamside incubator was not deployed in 2006 out of concern for reduced egg survival and increased labor related to stormwater pulses in the urban Crane River. HubLine funds were first used in 2006 to hire a full-time Fisheries Supervisor and seasonal technician to assist the smelt projects.

A total of 109 females were strip-spawned in 10 batches during 2006, resulting in an estimate of 2,089,958 fertilized eggs (± 13,508 eggs, 95% CI). After removal of subsamples and accounting for mortality, an estimate of approximately 1.2 million larvae was stocked in the Crane River (Table IVC2.2). Fertilized eggs were maintained at 13 °C in hatching jars, and the average survival of incubated larvae among batches was 62%. All eggs were marked with 500 mg/l OTC. We reached our pre-season goal of processing two million eggs; however, overall egg survival was reduced in 2006 resulting in only a modest increase in numbers of marked larvae stocked in the Crane River. The reason for the decline in average survival is not certain. Data quality on the assessment of egg viability improved in 2006. A few large batches of eggs appeared to be less than fully ripe at the time of capture and subsequently had lower survival (47-60%).

OTC Marking Experiment. An experiment was conducted to test the hypothesis that OTC marking causes no increase in smelt egg mortality. Eyed smelt eggs (N = 200) were placed in 1-L jars in a 13 °C water bath and exposed to 24-hr treatments of moderate dose OTC (500 mg/l), high dose OTC (1000 mg/l) and a control with no OTC (0 mg/l). Six replicates were run for each treatment. High survival was found for each treatment (85.8% - 0 mg/l; 91.8% - 500 mg/l; and 82.6% - 1000 mg/l). The percentage survival data were arcsine transformed and tested using the student t-test assuming unequal variances ($\alpha = 0.05$). The control treatment was not significantly different from the two OTC doses and the 1000 mg/L OTC treatment did have significantly higher mortality than the 500 mg/L ($P < 0.001$).

The larvae from the OTC experiment were used for continued rearing experiments and to serve as specimens to confirm the persistence of the OTC mark in their otoliths. After two weeks of enriched rotifer rearing in static 38 L aquaria, the larvae were stocked into three 95 L black tanks set in a chilled 1890 L tank connected to a recirculating system with mechanical, ultraviolet and biological filtration. The larvae in these tanks were fed enriched rotifers, followed by enriched *Artemia*, and finally weaned onto a prepared dry diet. The survival of these larvae improved dramatically from the 2005 static system. At the time of this reporting, over one hundred smelt of this 2006 cohort were still alive in the Gloucester laboratory tank system. To the best of our knowledge, this is the first time that rainbow smelt have been reared in a recirculating water system to maturity.

Naomi Delphin, an intern from Manchester High School, conducted a project to evaluate larval smelt growth and the persistence of OTC marks following the OTC marking experiment. A Zeiss Axiostar microscope with ultraviolet light source was used (40x) to determine the presence of OTC marks on otoliths. Four monthly samples, starting in June 2006, were taken from the three treatments to evaluate growth and the occurrence of the OTC mark in smelt otoliths. For each of the four samples, the OTC mark could not be detected in the control treatment and was detected in the OTC treatments. At the project conclusion (84 days post-hatch) the OTC marks were readily detected for all marked larvae with a stronger mark apparent for the 1000 mg/l dose. A single factor ANOVA and student t-test assuming equal variances were used to determine if significant growth differences occurred among treatments ($\alpha = 0.05$). No significant differences were found for monthly comparisons except for the August sample where the control larvae were significantly larger than the 1000 mg/l treatment larvae ($P = 0.007$).

During September 2006, project staff attended a smelt OTC marking workshop in Hallowell, Maine, sponsored by the Maine Department of Marine Resources. Maine DMR was progressing with smelt marking techniques for a landlocked smelt stocking project and held a workshop to discuss and share methods. At this workshop, concerns were raised over UV autoflorescence occurring in the focus of smelt otoliths, where the OTC mark would be established in embryos. At this point, we considered marking larvae instead of embryos because of the potential that autoflorescence and limited OTC diffusion through the embryo membrane could confound the consistent determination of otolith marks.

In October 2006, we conducted a test of smelt from the spring 2006 OTC marking experiment to detect the presence of the OTC mark at six months post-hatch. In a non-blind test, all marked larvae were confirmed to possess the otolith mark. However, the 500 mg/L treatment larvae at this time had marks that were losing clear distinction. These results and concerns over autoflorescense resulted in the decision to begin OTC marking smelt larvae in 2007. The goal of marking embryos was based on the expected use of the streamside incubator and the efficiency of a single marking dose per egg batch. Marking larvae would require more labor as multiple marking doses would be needed over the duration of hatching. However, the methodologies of larval OTC marking have received wider applications with more demonstrated success than egg marking (Secor et al. 1995).

2007 Smelt Culture Summary

A total of 108 females were strip-spawned in 11 batches during 2007, resulting in an estimate of 2,850,518 fertilized eggs (± 14,996 eggs, 95% CI). After removal of subsamples and accounting for mortality, an estimate of 1.6 million larvae was stocked in the Crane River (Table IVC2.2). Fertilized eggs were maintained at 15 °C in hatching jars, and the average survival of incubated larvae among batches was 75%. Overall, incubation survival improved in 2007. A few batches (#2 and #9) had aeration problems that led to high mortality in individual jars. In the absence of high mortality in these three jars, the average survival would have exceeded 80%. Following a change in marking methods, newly hatched larvae were immersed in 500 mg/l OTC for four hours in hatching jars with aeration supplied. Marked larvae were immediately stocked in the Crane River following the OTC application. Despite raising incubation temperature, the hatching duration remained at 3-4 days. Three OTC marking experiments were conducted in 2007; one on smelt embryos and two on newly hatched smelt larvae.

(1) Smelt Eggs (High Dose). Following the 2006 OTC marking experiment at lower doses we tested the survival of smelt eggs at higher doses. Eyed smelt eggs (N = 100) were placed in 1-L jars in a 15 °C water bath and exposed to 24-hr treatments of 1500 mg/L, 2000 mg/L and a control of 0 mg/L. Six replicates were run for each treatment. High survival was found for each treatment (98.6% - 0 mg/l; 99.6% - 1500 mg/l; and 94.5% - 2000 mg/l). The percentage survival data were arcsine-transformed and tested using the student t-test assuming unequal variances (α = 0.05). Egg survival was not significantly different among treatments. The higher doses of OTC did cause a foamy precipitate to form on the water surface. Although, the foam did not cause mortality rates to differ significantly, the concern was raised that the foam could entrain large numbers of eggs in the larger hatching jars with higher aeration.

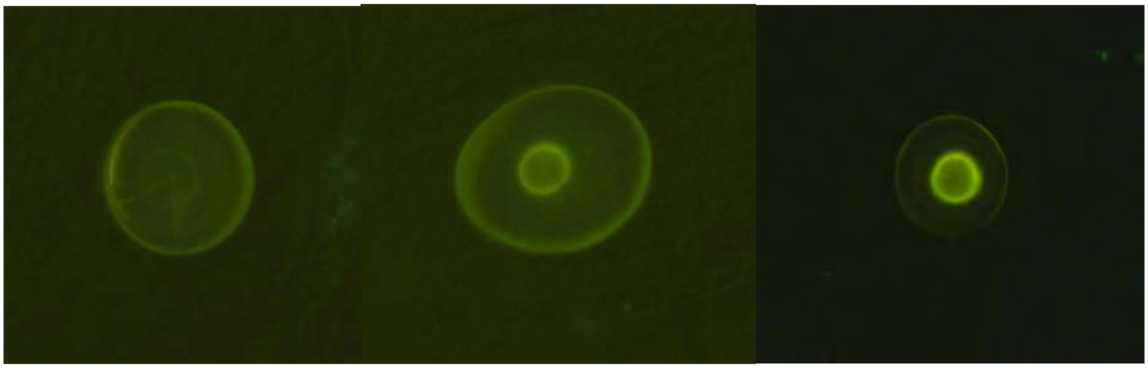
(2) Smelt Larvae (Low Dose). Using the same jars, and water and aeration treatments, the egg OTC marking experiments were repeated with yolk-sac larvae that were 2-3 days post-hatch. Smelt larvae (N = 100) were placed in 1-L jars in a 15 °C water bath and exposed to 4-hr treatments of 250 mg/l, 500 mg/l and a control of 0 mg/l. Six replicates were run for each treatment. High survival was found for each treatment (99.8% - 0 mg/l; 92.3% - 250 mg/l; and 91.2% - 500 mg/l). The percentage survival data were arcsine transformed and tested using the student t-test assuming unequal variances (α = 0.05). Larval survival was not significantly different among treatments.

(3) Smelt Larvae (High Dose). Using the same jars, and water and aeration treatments, the egg OTC marking experiments were repeated with yolk-sac larvae that were 2-3 days post-hatch. Smelt larvae (N = 100) were placed in 1-L jars in a 15 °C water bath and exposed to 4-hr treatments of 750 mg/l, 1000 mg/l and a control of 0 mg/l. Six replicates were run for each treatment. High survival was found for each treatment (98.2% - 0 mg/l; 98.8% - 750 mg/l; and 99.7% - 1000 mg/l). The percentage survival data were arcsine transformed and tested using the student t-test assuming unequal variances (α = 0.05). Larval survival was not significantly different among treatments.

Otolith Analysis. Substantial progress was made in 2007 to develop techniques for processing smelt otoliths and to verify the persistence of OTC in smelt otoliths. The smelt raised from the 2006 OTC marking experiment were checked for OTC marks at >365 days post-hatch during a blind test. The otoliths from the 500 mg/L marked smelt eggs and control smelt could not be distinguished. Otoliths from the 1000 mg/L marked smelt eggs contained a mark that was readily visible in ground otoliths but inconsistently detected in whole otoliths. These results indicate that the OTC mark in smelt marked as eggs, visible at six months, becomes obscured as the otolith grows. The smelt were in good condition and at normal size for age-1 smelt at their one year anniversary; with individuals ranging in length from 110-150 mm TL for all treatments.

Smelt larvae from the 2007 larval marking experiment were inspected during blind tests for the presence of an OTC mark in the otoliths at 14-days (Figure IVC2.2) and six-month post-hatch. At 14-days post-hatch, all marked treatments had a distinct ring present around the focus and no such mark was present in the controls. The six-month OTC check confirmed the mark in all 750 mg/L and 1000 mg/L samples; however, the mark was not detected in any of the 250 mg/L otoliths and the mark was not detected in one of nine otoliths marked at 500 mg/L. It appears that otolith growth had obscured the 250 mg/L mark at six months and reduced detection in 500 mg/L samples from 100% to 90%. The mean total length of smelt larvae was compared at six months using ANOVA with the Tukey Test for multiple comparisons (α = 0.05). Mean larval smelt length ranged from 34 mm (1000 mg/L) to 45 mm (control). The control sample larvae were significantly larger than all other treatments except 750 mg/L which was also significantly larger than the 500 and 1000 mg/L samples. During the winter of 2007/2008, the project purchased and set up a Buehler EcoMet3000 variable speed grinder-polisher and a Buehler Isomet low speed saw for otolith processing. The project also acquired ImagePro6.2 image analysis software to improve our capability to process and analyze smelt scales and otoliths.

Figure IVC2.2. Photographs of OTC mark on smelt otoliths.



0 mg/l OTC 250 mg/l OTC 500 mg/l OTC

2008 Smelt Culture Summary

A total of 89 females were strip-spawned in 11 batches during 2008, resulting in an estimate of 2,006,823 fertilized eggs (± 7,824 eggs, 95% CI). After removal of subsamples and accounting for mortality, an estimate of 1.4 million larvae was stocked in the Crane River (Table IVC2.2). Fertilized eggs were maintained at 16 °C in hatching jars, and the average survival of incubated larvae among batches was 76.5%. Newly hatched larvae were immersed in 500 mg/l OTC for four hours in hatching jars with aeration supplied. Marked larvae were immediately stocked in the Crane River following the OTC application. The number of female smelt sampled and eggs collected declined from 2007, in part due to much lower catches in one of the donor rivers (Saugus River) in 2008 compared to 2006-2007.

The presence of fungal growth on clumped incubating embryos was observed for the first time in 2008. Fungal growth is common at natural smelt spawning habitat when eggs become crowded. The growth seen this season occurred in only a few jars and influenced relatively few eggs and did not appear to change water quality or suppress typical survival rates. The presence of fungus after four seasons of smelt culture was a reminder to maintain quality assurance practices for cleaning culture supplies, handling fish, and incubating procedures.

Otolith Analysis. No additional OTC marking experiments were conducted in 2008. A blind test was conducted one-year post-hatch for the presence of OTC marks in the otoliths of smelt marked as larvae in 2007 with 0, 250, 500, 750, and 1000 mg/L OTC doses. The results were identical to the six-month post-hatch test. Apparently, the 250 mg/L OTC dose is not strong enough to persist in smelt ototliths; and there is some evidence of fading with the 500 mg/L OTC dose, although a high proportion of detection is possible.

All age-1 smelt caught in the Crane and North rivers in 2008 were retained to determine the presence of smelt that were marked with 500 mg/L OTC as larvae and released in the Crane River during 2007. Smelt catches in the Crane River increased sharply from 6 in 2007 to 133 in 2008 with age-1 smelt comprising 56% of the catch. Sixteen percent of these age-1 smelt possessed the OTC mark of smelt stocked in 2007. The North River catches increased modestly from 12 in 2007 to 23 in 2008. Fourteen percent of these age-1 smelt possessed the OTC mark of smelt stocked in 2007. These results provide the first confirmation that our OTC marked larvae stocked in the Crane River survive the emigration to marine waters and a year in marine waters and return to their release location as well as a nearby tributary in the same tidal river system.

Smelt Fyke Net

The smelt fyke net project was developed with funding from NOAA's Protected Resources Division during 2004-2005 (Chase et al. 2006). Following the NOAA pilot project, the fyke net project was adopted as an annual monitoring series by *MarineFisheries* and received supplemental funding from HubLine Restoration funds. Most targeted hauls (N = 33) were successfully completed at the six fyke net stations from 2005-2008 and smelt were caught at each station. Catch data have been processed for species composition and catch-per-unit-effort (catch per haul or CPUE) for the study period and age structure data are complete for 2005-2006. Catches have ranged from few smelt at the restoration stations (present in <30% of hauls and a mean CPUE ≤1.0) to evidence of a relatively strong run in the Fore River (present in 87% of hauls and mean CPUE = 72.3).

A total of 33 fish species were caught at the fyke net stations. Of this total, there were nine diadromous species, 10 estuarine species, and 14 freshwater species. Six species of arthropods were also caught in the nets. Although the project and fyke net were designed to target smelt, the catches also provide useful catch and size data for other diadromous fish that receive little attention in Massachusetts such as Atlantic tomcod, American eel, white perch and lamprey.

Fyke Net Stations

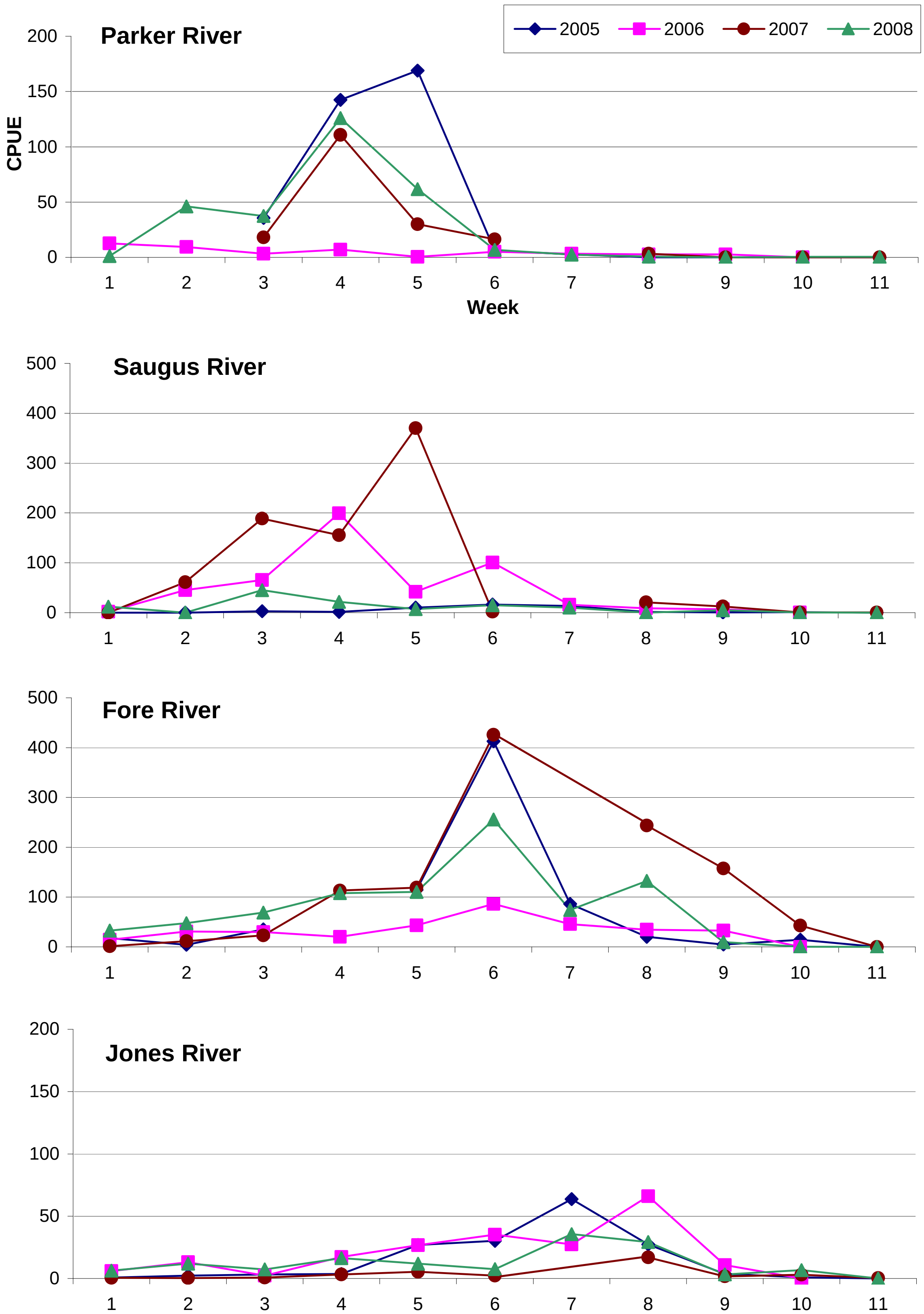
Parker River. The Parker River is located in Newbury and the watershed is the largest among stations and may be the least developed. This station is unique among the six stations by having the shortest smelt spawning run duration and the highest catch rates for sea lamprey. The Parker River mean smelt CPUE was third highest among stations (20.6) (Appendix Table IVC2.4). The Parker River run ended abruptly in late April during each of the monitoring seasons despite being the northernmost station with a delayed ice-out and the coolest water temperature (Figure IVC2.3).

Crane River. The Crane River is a restoration station in Danvers where all marked larvae from the culture project are stocked. The Crane River is a tributary to the Danvers River estuary and has the smallest watershed, lowest average discharge and lowest species richness (Appendix Table IVC2.5) among stations. It was selected as a restoration station because of the recent introduction of a smelt run following a *MarineFisheries* restoration project (Chase et al. 2008). It was expected that the small size of the river and small existing smelt run would allow the detection of improvements following stocking. Crane River catches have shown signs of improvement in 2008 and 2006 following low catches of only six smelt in 2005 and 2007. Larval smelt stocking began in 2005. The presence of OTC marks in Crane River smelt was confirmed in 2008.

North River. The North River is a tributary to the Danvers River estuary in Salem. The North River was not found to contain a smelt run during the 1980s and 1990s (Chase 2006); however, smelt eggs were found in the North River in 2001 and were presumed to have colonized the river following the stocking project in the nearby Crane River during 1995-1997. The North River has undergone substantial improvements in dry weather water quality due to the reduction of industrial pollution. Yet, the wet weather water quality is likely the worst among stations due to urban stormwater flows. North River smelt catches have been the lowest among all fyke stations and indicate the presence of a small spawning run. The mean CPUE and frequency of occurrence (FOC) of American eel were the second highest among stations (Appendix Table IVC2.6).

Saugus River. The Saugus River station is located at the National Park Service Saugus Iron Works, Saugus. After relatively low catches in 2005, the 2006 CPUE increased 10-fold and doubled again in 2007. The dramatic increase in catches appeared to be driven by a strong 2005 cohort that contributed large numbers of age-1 smelt in 2006 and age-2 smelt in 2007. The large catches in 2006-2007 allowed Saugus smelt samples to contribute to the age-key and gametes for smelt culture. The Saugus River catches have the highest richness of freshwater fish and the highest mean CPUE for white perch among stations (Appendix Table IVC2.7). Similar to the Parker River, the Saugus smelt run peaks early (week 4-5) and few smelt are caught after week 6.

Figure IVC2.3. Average weekly smelt CPUE (smelt/haul) in fyke nets during 11 week season.



Fore River. The Fore River in Braintree has been historically known as one of the largest smelt runs in Massachusetts and was a source of donor eggs for the 1995-1997 Crane River restoration project (Chase et al. 2008). The Fore River is one of only five river systems in Massachusetts with >10,000 m^2 of spawning habitat (along with Parker River, Ipswich River, Neponset River and Jones River – Chase 2006). The Fore River has maintained relatively high smelt catch rates for the study period and is the primary source for age samples and gametes for the culture project. In addition to the highest mean CPUE for smelt, it also has the highest mean CPUE for American eel and Atlantic tomcod (Appendix Table IVC2.8). The spawning season has consistently been the longest among stations with smelt caught during each of the 11 weeks and a distinct peak during week 6 in each season.

Jones River. The Jones River discharges to Cape Cod Bay and is located in Kingston as the southernmost fyke net station. Similar to the Parker River, the watershed is not as developed as the four stations along Massachusetts Bay. The Jones River and the Parker River are the only smelt runs in the study area with previous studies that recorded population data (Lawton et al. 1990; and Murawski and Cole 1978). Work done by *MarineFisheries* during 1979-1981 included run estimates of several million smelt annually. Although the methods differ, a comparison of the two data sets indicates a substantial decline has occurred in the Jones River smelt run. The Jones River catches during 2005-2006 had a high proportion of age-1 smelt and the age-1 males were significantly smaller in length than age-1 males at the other stations (ANOVA, $\alpha = 0.05$). The Jones River smelt CPUE steadily maintained a 3rd or 4th rank annually among stations and has the highest richness of diadromous and estuarine fish species (Appendix Table IVC2.9).

<u>2008 Season</u>

The catch data for the 2008 season are not fully processed at the time of this report. Smelt aging is not complete and the catch data have not been audited. The catch summary data for 2008 are used in Figure IVC2.3- IVC2.4 and Table IVC2.3. Smelt total catch and CPUE in 2008 were within each station's ranges for 2005-2007 with the exception of the Crane River. Crane River smelt catch increased to the highest observed in the four year period. The increase in Crane River catch was driven by the presence of age-1 smelt (56%) of which 16% were confirmed as recaptures of stocked smelt by detecting the OTC otolith mark. Also of note in 2008, was the improvement of smelt catch in the Jones River following very low catches in 2007 and the sharp decline in Saugus River smelt catches. The size composition of the Saugus River catch indicates that the strong 2005 cohort did not contribute large numbers of age-3 smelt to the 2008 run. The cause for increased Jones River catches from 2007 to 2008 is not certain as the 2005, 2006, and 2007 cohorts were well represented in 2008 catches.

<u>Population Indices</u>

The fyke net stations in the Fore, Saugus, Parker, and Jones rivers will be maintained as annual population monitoring stations by *MarineFisheries*. Future efforts will focus on identifying CPUE and age-structure metrics that track population trends. To date, we have evaluated fyke net catch data as nominal CPUE for the 11 week season (Table IVC2.3) and as geometric means for the peak season of weeks 4-9 (Figure IVC2.4). The relative variability of nominal data have been high (CV >100) at most stations for most years. At the Fore River where catch rates are relatively high and consistent, CVs have been the lowest, in the range of 65-115. The Saugus River data exhibited high variability during 2006 and 2007 when large catches occurred. This was caused by a few hauls with very high catches and resulted in high nominal CPUE but low geometric CPUE in those years. Trend analyses will require more seasons of catch data. In the study period, there are cases of significantly higher CPUE that are related to cohort strength (Saugus River – 2006 and Fore River – 2007), and cases of significantly lower CPUE that have no immediate explanation (Parker River – 2006 and Jones River – 2007).

As future analyses are conducted, we will seek metrics that provide trends on run strength and cohort size and environmental influences on recruitment. Because male smelt spawn more than once during the spawning season and the rate of repetitive spawning is unknown, the CPUE data could be biased if the

Figure IVC2.4. Smelt CPUE (catch-per-unit-effort = catch/haul) during peak season (weeks 4-9) of fyke net monitoring. Smelt CPUE data are graphed as geometric mean with back-transformed 95% C.I.

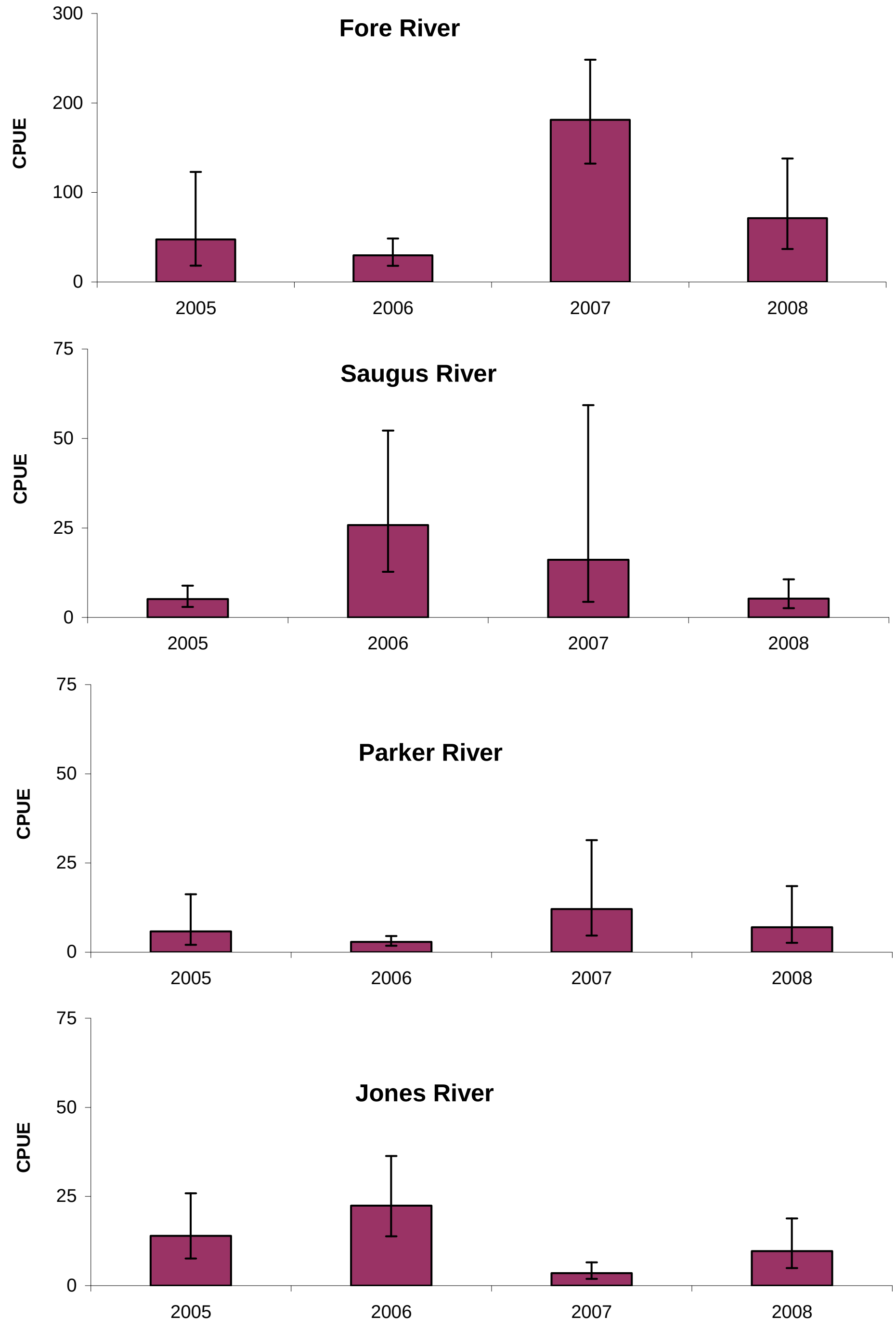


Table IVC2.3. Fyke net smelt catch summary for 2005-2008. Ages for all smelt with length data were allocated using age-length proportions from aged samples. Data from 2007-2008 are not fully processed.

River	Total Catch (No.)	Hauls (No.)	CPUE (smelt/haul)	Length Sample (No.)	Age Sample (No.)	Male (%)	Female (%)	Age-1 (%)	Age-2 (%)	Age-3 (%)	Age-3+ (%)
2005											
Fore	2131	30	71.0	1050	274	0.79	0.21	0.17	0.82	0.01	
Parker	924	26	35.5	482	102	0.86	0.14	0.24	0.74	0.01	0.01
Jones	489	32	15.3	459	0	0.61	0.39	0.49	0.51		
Saugus	141	32	4.4	141	0	0.79	0.21	0.54	0.45	0.01	0.01
Crane	6	22	0.3	6	0	0.83	0.17	0.50	0.50		
North	5	22	0.2	5	0	0.60	0.40	1.00			
2006											
Fore	1015	30	33.8	973	266	0.75	0.25	0.36	0.50	0.14	<0.01
Parker	123	29	4.2	123	0	0.82	0.18	0.33	0.46	0.19	0.02
Jones	614	30	20.5	614	0	0.65	0.35	0.59	0.32	0.09	<0.01
Saugus	1457	30	48.6	1192	184	0.91	0.09	0.65	0.28	0.07	<0.01
Crane	74	26	2.8	74	0	0.84	0.16	0.63	0.34	0.03	
North	43	29	1.5	43	0	0.81	0.19	0.21	0.77	0.02	
2007											
Fore	3435	29	118.4	1835	348	0.76	0.24				
Parker	629	23	27.3	474	0	0.85	0.15				
Jones	103	29	3.6	103	0	0.63	0.37				
Saugus	2433	29	83.9	1080	189	0.93	0.07				
Crane	6	30	0.2	6	0	0.83	0.17				
North	12	30	0.4	12	0	0.67	0.33				
2008											
Fore	2473	32	77.3	1959	372	0.78	0.22				
Parker	850	22	38.6	850	0	0.94	0.06				
Jones	402	33	12.2	402	0	0.61	0.39				
Saugus	376	31	12.1	353	77	0.90	0.10				
Crane	120	35	3.4	120	0	0.80	0.20				
North	24	36	0.7	24	0	0.58	0.42				

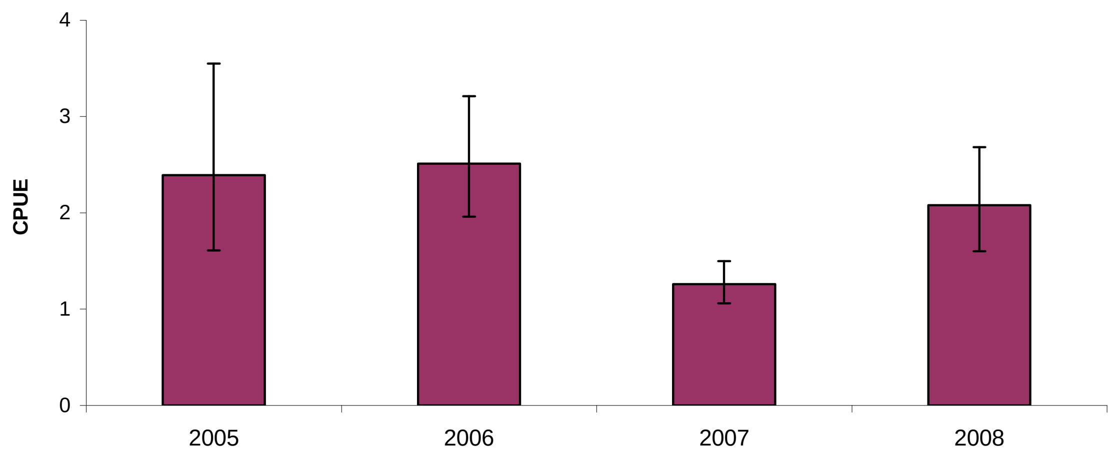
rates differ among rivers and seasons. Secondly, age-1 smelt are considered to be partially recruited to the spawning run with potentially more males entering the rivers at age-1. With these factors in mind, a metric of mature female smelt may prove to be a less biased indicator of run strength. To date, we have processed data for Jones River age-2 females (Figure IVC2.5). The relative variability of nominal CPUE data for age-2 Jones River females actually increased over CPUE data for all Jones River smelt; however, the geometric means showed less separation for the age-2 females. This could reflect less bias in the catch data if the repetitive spawning behavior of males varies with season. The value of sex and cohort-based population metrics will be evaluated with additional seasons of catch data.

Conclusions

Smelt Culture

Approximately 5.3 million marked smelt larvae were stocked into the Crane River during 2005-2008. The analysis of age-1 smelt otoliths from the 2008 catch at the restoration river stations revealed that 16% of the Crane River age-1 smelt and 14% of the North River age-1 smelt were stocked as larvae by this project. Conclusions cannot be reached on the contributions of larvae stocked in 2005 and 2006 because these smelt were marked as eggs and subsequent investigations found that the OTC mark in smelt marked as eggs did not persist in hatchery specimens reared for one year. The smelt larvae stocked in 2007 and 2008 were marked with 500 mg/l OTC as larvae. Our laboratory investigations to date indicate that the OTC mark in smelt marked as larvae is more durable than the egg marking and does not negatively influence egg or larval survival.

Figure IVC2.5. Smelt CPUE (catch-per-unit-effort = catch/haul) for age-2 females at the Jones River, 2005-2008. Smelt CPUE data are graphed as geometric mean with back-transformed 95% CI.



The total numbers of smelt caught at the restoration stations during 2005-2008 and proportion of stocked smelt in the 2008 catch are relatively low. The catch data imply that both smelt runs have relatively few adult smelt running into these small tidal rivers. The fyke net catch data for the Crane and North River show inconsistent catches during the four seasons. Despite a narrow channel, only six smelt were caught in the Crane River during 2005 (no stocking influence possible) and 2007 (two potential cohorts of stocked smelt). The catch in 2008 was nearly twice as much as seen the previous three seasons in the Crane River. With continued sampling and larval stocking in 2009 we should gain a better assessment of the contribution of stocking to subsequent smelt runs and the overall utility of these methods for smelt population restoration.

The smelt culture project has made significant contributions to our understanding of smelt culture and restoration. We believe these efforts mark the first time rainbow smelt have been reared on a dry diet and to maturity in closed-loop hatchery system. This success came through substantial trial-and-error and innovation. The recapture of OTC-marked rainbow smelt in the Crane River is also a novel achievement that will hopefully develop into a restoration tool that can be applied in other river systems.

Smelt Fyke Net

The smelt fyke net project successfully maintained fyke nets at six stations during 2005-2008. A high percentage of targeted sets were successful and smelt were found to be present at each station within a wide range of mean CPUE. Also, the stations displayed unique population signals of spawning run seasonality, age composition, and size at age. The fyke net catch data is showing promise for tracking age composition and cohort strength. The 2005-2008 catches confirm concerns over declining smelt populations when compared to catch data from studies conducted in the 1970s in the Jones and Parker Rivers. The fyke net catch data also contributed information on other species of diadromous fish that are poorly documented in Massachusetts. The FOC and size composition data are unique for American eel, white perch, Atlantic tomcod and sea lamprey in coastal rivers of Massachusetts. Additional seasons of sampling and analysis are needed to determine if unbiased indices of relative abundance can discern annual smelt population trends.

Acknowledgements

The smelt culture and fyke net projects have received constant support from the Sportfish Restoration Act during precursor projects and throughout 2005-2008. NOAA's Protected Resources Division funded the pilot project during 2005-2006 that developed the ongoing fyke net study. HubLine Restoration Funds funded all smelt culture efforts during 2006-2008 and assisted the associated fyke net project during 2007-2008. We had the good fortune to hire superb technicians each season. We thank the following technicians for all their dedication during cold and wet days in the field: Kate Taylor, Kevin MacGowan, Carolyn Woodhead, Sarah Turner, and Katie L' Heureux. Our motto was "somebody has got to get wet" and everybody did. We thank Jon Gilmartin and Brian Castonguay for their carpentry and plumbing skills that built the hatchery. We appreciate the assistance with smelt aging and marking from Karina Broomstein as an American Fisheries Society Hutton Scholar and Naomi Delphin as an intern from Manchester High School.

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Part 3. American Shad Propagation

Staff: Project Supervisor: Kristen H. Ferry
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Completion Report: Kristen H. Ferry

Introduction

American shad (*Alosa sapidissima*), the largest members of the Clupeidae or herring family (up to 7-8 lbs and 30 inches in length), were once an important component of the anadromous fish fauna in Massachusetts, especially in larger rivers such as the Connecticut, Merrimack, Neponset, and Charles Rivers. Shad were also present in a few smaller systems including the Palmer and Indianhead Rivers. As anadromous fish, American shad spend the majority of their lives in the ocean, but adults (beginning at age three to five years) must return to freshwater to spawn. In Massachusetts, adult shad migrate into their natal rivers to spawn each spring, primarily during May and June. Newly born juveniles remain in freshwater riverine nursery habitat until late summer and fall, when they migrate to the ocean to feed and grow for the next several years. Due to differences in water temperature and other environmental cues, the timing of adult upriver migration and juvenile outmigration varies throughout the range of American shad from Florida to Newfoundland.

Historically, American shad were important to commercial and recreational fisheries in Massachusetts, but over the last century, shad were extirpated or reduced to unsustainable populations in all Massachusetts rivers where they occurred. The decline of shad was likely due to the construction of dams/obstructions which blocked spawning migrations, water pollution on the spawning grounds, and over-fishing. Developing impacts today may include changes in land and water use patterns (i.e., urbanization) that result in habitat loss, non point source pollution, and heightened water withdrawals from key spawning rivers. Other concerns include climate change, predation, and bycatch in other fisheries. Currently, American shad are in severe decline Atlantic coast wide.

The objectives of the of the *MarineFisheries* HubLine funded American Shad Propagation Project were to (a) begin to restore sustainable populations of American shad to the Charles River and secondarily the Neponset River, and to (b) create local sportfisheries in those systems. Project design included the development of a shad culture and stocking program in conjunction with fish passage improvements to the Charles and Neponset Rivers. Since the mid-1990s, the technology for artificial production of American shad has improved, and the propagation and stocking of shad fry in tributaries to the Chesapeake Bay and the Delaware River have resulted in successful enhancement of shad populations (Hendricks 1995; Hendricks 2006). Regionally, a smaller scale fry stocking program in Maine is beginning to exhibit positive results (*Pers. Comm*., Nate Gray, Maine Department of Marine Resources). Thus, the *MarineFisheries* shad propagation project was modeled after these successful programs.

To achieve the restoration objectives *MarineFisheries* and the U.S. Fish and Wildlife Service (USFWS), Central New England Fisheries Resource Office (CNEFRO) entered into a formal five year Cooperative Agreement for American shad propagation in April 2006. This agreement provided for the development of a shad culture program at the Nashua National Fish Hatchery, Nashua, NH and the North Attleboro National Fish Hatchery, North Attleboro, MA, and two regional Atlantic salmon hatcheries. The production commitment for this agreement was nine million shad fry for the Charles River, at three million per year; however, both *MarineFisheries* and the CNEFRO are committed to the long-term collaborative effort of restoring American shad to the Commonwealth, including the Merrimack River, the donor broodstock system for this project. In addition to HubLine funding, the CNEFRO received internal USFWS funds to help retrofit the Nashua and North Attleboro National Fish Hatcheries for shad production and to hire additional hatchery staff dedicated to the project. *MarineFisheries* successfully secured match funding for the Shad Propagation Project for current and future years through the federal Wallop-Breaux Sport Fish Restoration Program (F-57R).

Target Systems

Charles River

The 80 mile long Charles River flows through 23 metro-Boston communities and changes 350 ft in elevation from source to sea. The watershed area is approximately 308 square miles. Of the twenty documented dams on the Charles, six between Boston Harbor and Wellesley/Newton provide passage for anadromous fish via fishways or breach. Currently, anadromous fish cannot pass beyond the Metropolitan Circular Dam at river mile 20, Wellesley/Newton. Historical records of American shad in the Charles River date back to 1633, when Puritan settlers in Watertown constructed an extensive weir for their harvest. In 1634 William Wood described the harvest of 100,000 shad from the Charles in two consecutive tides near Watertown (Wood 1634).

The Charles River was the primary target for HubLine-funded American shad restoration due to (a) the availability of spawning/rearing habitat, (b) the availability of functioning fishways suitable for shad passage, and (c) the historical significance of shad in this system. The Charles River is estimated to support a population of 30,000 adult shad, and recent water quality improvements coupled with fish passage improvements have enhanced the opportunity for successful restoration. In preparation for the shad propagation project, *MarineFisheries* completed HubLine funded repairs to fishways at Watertown Dam, Watertown and Moody Street Dam, Waltham in summer and fall of 2005. New baffles were constructed and replaced for the denil style fishways at Finlay and Cordingly Dams in Newton/Wellesley. Most notably, a breach to the north side of the 3.5 ft high Bleachery Dam, Waltham was completed in September 2005 (Figure IVC3.1). This breach, under consideration for a number of years, created an additional avenue for anadromous fish passage that complements a breach completed on the south side of the river decades ago.

Neponset River

The secondary target for American shad restoration was the 29 mile long Neponset River, which serves as the southern border to the City of Boston as it flows through four prominent neighborhoods. This system, whose watershed area is approximately 120 square miles, was likely home to a once thriving shad population. Unfortunately, dams have impeded fish passage in the Neponset for 350 years, leading to extirpation of most anadromous fish resources. The first two dams on the Neponset, the Walter Baker Dam and the Tileston and Hollingsworth Dam do not have fish passage structures. Today, only rainbow smelt (*Osmerus mordax*), which spawn at the base of the Walter Baker Dam, and possibly American eel (*Anguilla rostrata*) remain. In addition to the dams, the Neponset River's industrial past and continued urbanization have resulted in contaminated water and bottom sediments. Joint efforts between *MarineFisheries* and the Massachusetts Riverways Program are currently underway to remove or provide passage at these dams and remove or contain PCB contaminated sediments (Ferry 2007). In conjunction with the shad restoration project, *MarineFisheries* also used HubLine monies to fund the most recent Neponset River Supplemental Feasibility Study to further examine restoration alternatives. Dam removal or partial dam removal, the preferred options at the Walter Baker and Tileston and Hollingsworth sites would open up approximately 17 miles of spawning/rearing habitat for American shad.

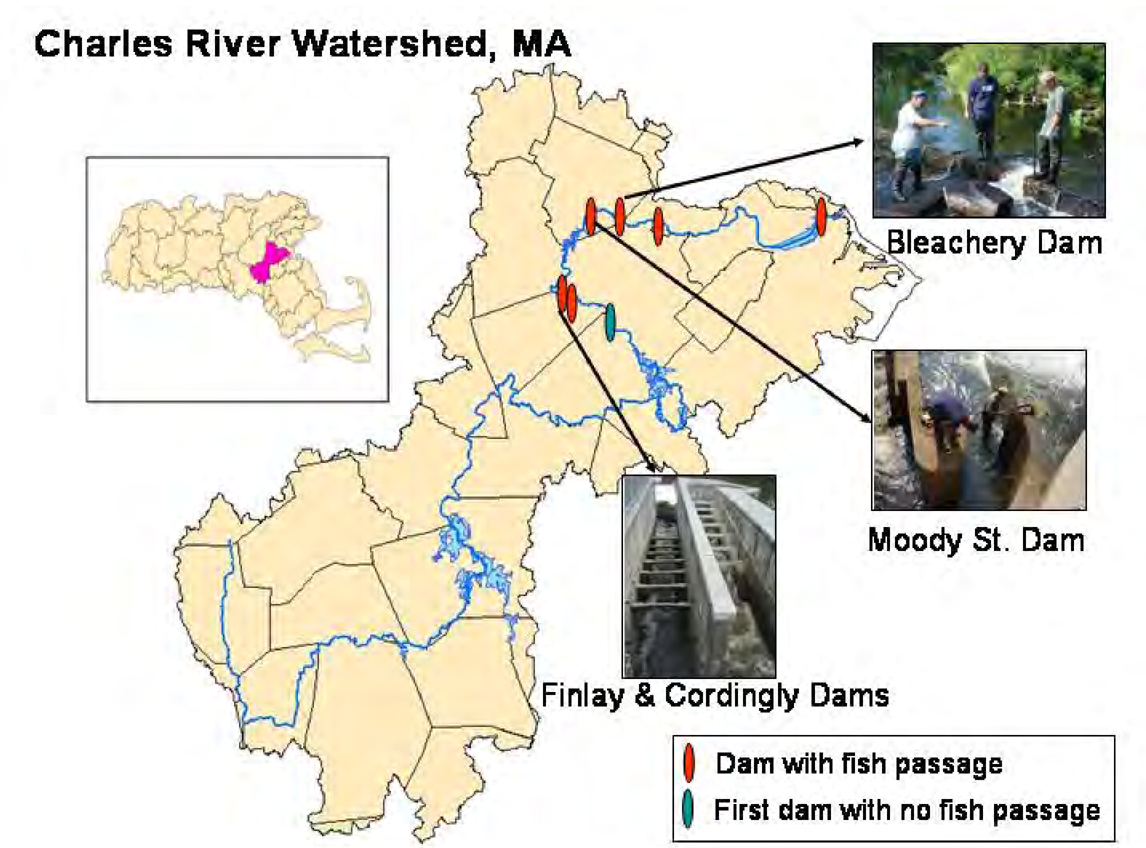

Figure IVC3.1. Charles River watershed showing locations of functioning fishways and first obstruction. Fry were stocked in the Charles River at the Woerd Avenue launch ramp, Waltham, between Moody St. dam and Finlay Dam in Newton.

Although much progress was made on the Neponset River project during the period of HubLine funding, numerous agencies, NGOs, and local citizens are still deliberating on the best restoration alternatives for this system. Currently, an independently facilitated Citizen's Advisory Committee (CAC) is addressing issues, ideas, and alternatives for the cleanup, restoration, and preservation of the Neponset. The CAC is sponsored by the Department of Conservation and Recreation, the Department of Fish and Game, the City of Boston Office of Environmental and Energy Services, the Town of Milton Conservation Commission, the Lower Mills Merchants Association, and the Neponset River Watershed Association.

As fish passage was not projected to be realized during the HubLine period, *MarineFisheries* opted to delay enhancement to the Neponset River and allocate all American shad fry production to the Charles River. *MarineFisheries* will initiate shad enhancement in the Neponset, as the habitat restoration process moves forward.

Methods

Broodstock shad for the HubLine American shad propagation project were obtained from the Merrimack River, at Essex Dam in Lawrence, MA. The Merrimack was chosen because of its proximity to the Charles River and because until recently the shad population appeared to be rebounding, with passage numbers at Essex Dam surpassing 76,000 in 2001. The increase in shad numbers was likely due to improved water quality and the construction of more efficient fish passage structures at hydropower facilities, including mechanical fish lifts at Essex Dam and Pawtucket Dam in Lowell, MA. In addition to the *MarineFisheries* project, American shad from the Merrimack River are also used to support restoration programs in Maine and New Hampshire through the Merrimack River Anadromous Fish Restoration Program.

Between 2005 and 2008, the Merrimack River experienced a number of extreme high flow events during the upstream anadromous fish passage season, April to July. Unfortunately, these events severely impacted fish passage operations at the Essex Dam fish lift, where USFWS hatchery staff planned to acquire broodstock shad for the HubLine project. In 2005, a series of significant rain events in June and subsequent high water conditions forced the closure of the fish lift at the time of peak shad passage. Only 6,500 American shad were passed upriver, roughly 10% of the previous five year average. In 2006, the historic Mother's Day Flood in May damaged the fish lift, resulting in a suspension of operations for the majority of the fish passage season. Heavy rains (approx. 15 inches in 48 hours) brought the average Merrimack River flow (4,500 to 10,000 cfs during May and June) to a near record 106,000 cfs. Just over 1200 fish were passed. Broodstock shad were obtained primarily via boat electrofishing below Essex Dam once tailrace waters receded to safe levels in late June 2006, causing a far later than anticipated start to fry production. High water events were less severe in 2007 and 2008, but caused either a delayed start to fish passage or shutdowns during the passage season; broodstock shad were successfully obtained from the fish lift. Enel North America, the licensed operator of the Essex Dam hydropower facility, is currently installing a multi-million dollar inflatable crest gate system that will replace wooden flashboards, help mitigate the effects of moderate high water events, and improve fish passage during those events. Although numbers of American shad passed at Essex Dam increased in 2007 and 2008, the American shad stock assessment completed by the Atlantic States Marine Fisheries Commission in 2007 indicated that shad populations are continuing to decline Atlantic coast wide.

Despite coincident high flow events in the Merrimack River that limited broodstock availability, the HubLine American Shad Propagation Project successfully produced and stocked shad fry in the Charles River between 2005 and 2008. Beginning in June 2005, limited pilot production was conducted at Essex Dam and at the North Attleboro National Fish Hatchery. The goals of the pilot work were to (a) construct test facilities, (b) evaluate reproductive condition of captive broodstock, (c) test and evaluate tank spawning and rearing techniques, and (d) adjust water quality and flows in the hatchery to suit shad production. To address these goals, 50 adult shad were collected from the Essex Dam fish lift, injected with a Luteinizing-Releasing Hormone analogue and Salmon Gonadotropin Releasing Hormone, and held in spawning tanks on the dam (Figure IVC3.2). The goal was to spawn broodstock onsite and transfer live eggs to the Nashua and North Attleboro hatcheries for rearing instead of transporting adult shad which can experience high mortality. Live eggs and larvae were produced and transferred to the North Attleboro hatchery for experimental rearing, however, riverside spawning at the Essex Dam was abandoned in subsequent years due to increased water temperatures and high turbidity in the tanks, and security and construction complexities at the privately owned hydroelectric facility. All shad broodstock were transferred to the Nashua National Fish Hatchery for spawning during 2006-2008 (also the North Attleboro National Fish Hatchery in 2008). Prior to annual spawning operations, a sample of adult American shad were obtained at the Essex Dam fish lift, Merrimack River and sent to the USFWS lab in Lamar, Pennsylvania for fish health certification.

Pilot production goals were met, and at the end of the trials, broodstock shad and eggs/larvae were sacrificed. Federal law prohibits the release of hormone-injected fish into the wild, and stocking the minimal number of shad fry produced was not economically reasonable. Following the trials, infrastructure modifications were completed at the Nashua National Fish Hatchery in preparation for full production, including the installation of fiberglass spawning tanks and heating units to accommodate thermal conditions suitable for shad.

Figure IVC3.2. Hormone injection of American shad broodstock, Essex Dam, Merrimack River, Massachusetts.

Both hormone-induced spawning and volitional spawning (no hormones) were tested; however, hormones were generally used to encourage more rapid tank spawning. This decision was made mainly due to space-time constraints, as volitional spawning typically requires fish to be held in large capacity hatchery tanks for several weeks before spawning occurs naturally. American shad are sensitive fish, often suffering high in-hatchery mortality. Thus, volitional spawning can impose additional challenges on hatchery staff. Strip spawning, a method in which eggs and sperm are physically removed or "stripped" from adult shad for use in fry production, was not considered for this project due to the large number of sacrificial fish necessary to obtain adequate eggs and sperm.

Egg incubation and rearing of larvae took place at the USFWS hatcheries in Nashua and North Attleboro. Larvae were raised for a minimum of 7-10 days before release as fry into the upper Charles River. Prior to release, all fry were immersed in an oxy-tetracycline bath to mark their otoliths (ear bones). Otolith marking allows identification and quantification of hatchery-origin shad in 3-4 years when these fish reach maturity and return to spawn. Because marked shad fry surviving to maturity have shown high fidelity to natal rivers (Hendricks et al. 2002), *MarineFisheries* expects a proportion of shad stocked into the Charles River to return to these systems as adults when they will be sampled and examined for marked otoliths.

Fry were stocked in the Charles River at the Woerd Avenue boat launch ramp, Waltham, the impounded habitat between Moody St. dam and Finlay Dam in Newton (Figure IVC3.1). Although shad can move great distances upriver to spawn in unimpeded systems, we chose to stock the fry in an area that they could feasibly return to as adults. The intent was to lessen mortality on outmigrating juveniles by stocking them above a minimal number of dams to provide adequate nursery area, while encouraging retention until fall. To exit a system with impediments, juvenile shad must either traverse the crest of the dam landing in the spillway or exit downriver through the fishway. In higher flow events, it is more likely that juveniles would be washed over the dam crest, increasing the possibility of mortality. Thus the decision was a tradeoff between where shad should be stocked based on life history and where it is feasible in an impacted system.

Following stocking of fry, continuous water quality data, including temperature, pH, dissolved oxygen, conductivity, and turbidity were recorded by a YSI 6920 Sonde downriver of the stocking site (river km 22). To estimate juvenile survival and to help establish recruitment indices, sampling for hatchery-origin juveniles began several weeks following annual stockings, was conducted throughout the river below the stocking site, and continued through fall. Several methods for monitoring juveniles were assessed, including seining, drop netting (e.g., in dam bays), and electrofishing; however, electrofishing by boat was selected as the most efficient method for detecting the presence/absence of juvenile shad over a wide river area and for identifying habitat utilized (Figure IVC3.3).

Results and Discussion

Production

Based on the pilot work completed in 2005, full production began in 2006. Between 2006 and 2008, the total number of broodstock shad used annually for fry production ranged from 773 – 1155, including in-hatchery mortalities and fish released alive to the Merrimack (Table IVC3.1).

Figure IVC3.3. Electrofishing for American shad (left). Close-up of electro-shocking apparatus (right).

Table IVC3.1. American shad fry production by year and hatchery. Number of broodstock shad includes both males and females and hatchery mortalities. Fry were released into the Charles River in Waltham. ND refers to no data available.

Year	Hatchery	No. Broodstock Shad	No. Eggs Produced	Percent Viability of Eggs (%)	No. Fry Hatched	Percent Fry Survival (%)	Total Released
2006	Nashua NFH	911	4,342,376	50.7	2,149,906	83.0	1,785,622
2007	Nashua NFH	1,155	3,801,201	19.7	747,369	89.4	668,048*
2008	Nashua NFH	619 **	2,144,859	34.7	744,183	78.4	583,642
2008	North Attleboro NFH	154	1,807,498	36.0	ND	ND	610,442

*Several thousand fry were retained and sent to the New England Aquarium for exhibit.

**Although 619 total broodstock were obtained for spawning, 202 fish were released live back to the Merrimack following nearly one month in the hatchery without spawning. Thus, 417 shad (including hatchery mortalities) were used for active spawning.

Broodstock reproductive condition varied across years, influencing the number of fish used for spawning. In June 2006, shad collected for spawning in the tailrace of Essex Dam were very ripe, producing the highest percentage of viable eggs among years following hormone injection. The flood-induced failure of fish passage in 2006 (i.e., damaged fish lift) combined with high June Merrimack River temperatures forced migrating shad to congregate in warm tailrace waters, possibly enhancing reproductive condition in this localized area. Merrimack River flow was high at the commencement of the 2007 run and water temperature was cooler compared to 2006. Broodstock shad collected during the same June time period were far less ripe, and in-hatchery mortality was higher following hormone injection. Egg viability was also greatly reduced, as hormone-treated fish consistently released unripe eggs throughout the production season. Due to increased broodstock mortality, hatchery staff had difficulty maintaining the 2:1 male to female ratio typically recommended for American shad production.

In an effort to increase egg viability and reduce in-hatchery mortality of adults, volitional spawning was attempted. Adult broodstock were obtained from the Essex Dam fish lift, Merrimack River, in May and June 2008, and transported to the Nashua National Fish Hatchery and the North Attleboro National Fish Hatchery. Although the fish at the Nashua Hatchery exhibited good survival, they failed to spawn after nearly a month in the hatchery. Given the narrow time window for shad production and the limited tank capacity for broodstock, these shad were released back to the Merrimack River in mid June 2008, upriver of the Essex Dam. Replacement broodstock were obtained at the fish lift, treated with hormone, and successfully spawned. The fewer broodstock held at North Attleboro spawned successfully without hormones; however, these fish were obtained late in the run. All hormone-treated broodstock shad were dispatched following spawning and used for agency and university biological sampling when possible.

In 2006, 4.3 million eggs were produced, and average egg viability was 50.7% (Table IVC3.1). Fry survival from hatch to stock was 86.9%. All 1,785,622 stocked fry were immersed in an oxytetracycline bath (OTC) to mark their otoliths prior to release. Although the production goal for 2006 was three million fry, the production achieved in that year was exceptional, given the severe delay in broodstock collection due to the historic flood levels.

Of the 3.8 million eggs produced in 2007, only 747,369 fry were hatched (19.7% viability; Table IVC3.1). This low viability was likely linked to the hormone induction of apparent unripe broodstock. Similar to 2006 results, 2007 fry survival from hatch to stock was 87%. The 660,000 fry stocked in the Charles River were immersed in an oxytetracycline bath to mark their otoliths prior to release. Although the long term goal is to use a consistent otolith mark (one day or multiple day mark combination), due to limited rearing tank capacity at the Nashua hatchery, day-of-mark varied slightly among stocked fry.

In 2008, a total 3.9 million eggs were produced by the two hatcheries (average 35% viability, Table IVC3.1). The number of oxytetracycline-treated fry released was 1.2 million.

Evaluation

In September 2006, hatchery origin juveniles were detected during an electrofishing monitoring survey in the Charles River, Waltham (Figure IVC3.4). The total length of the OTC juvenile samples ranged from 75-130mm. Hatchery origin was confirmed by the presence of an OTC mark on otoliths examined under a fluorescent microscope (Figure IVC3.5).

Two electrofishing surveys for juvenile shad were conducted in fall 2007 by USFWS and *MarineFisheries* staff. On September 25, the first survey was conducted from the stocking site at the Woerd Avenue Boat Launch, Waltham, downriver to the Moody Street Dam, Waltham. American shad and river herring were observed in large schools during this survey. A sample of 10 juvenile shad ranging in total length from 96 – 160mm was retained for the identification of marked otoliths. Hatchery origin was confirmed by the presence of an oxytetracycline mark on nine of the ten fish subsampled. Otoliths for one

Figure IVC3.4. Hatchery origin juvenile American shad sampled in a September 2006 electrofishing survey in the Charles River, Waltham, MA.

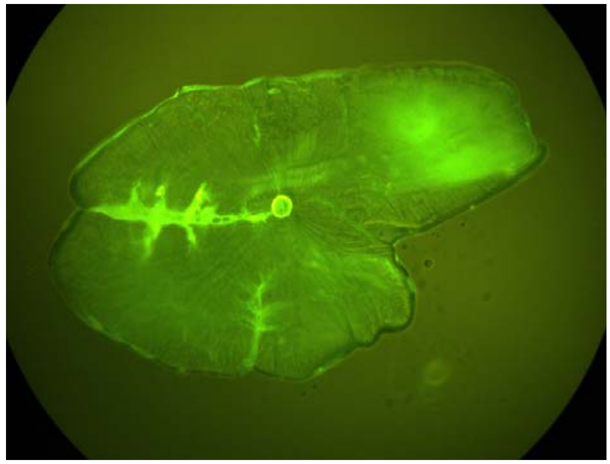

Figure IVC3.5. Oxytetracycline mark on juvenile American shad otolith from the Charles River, Waltham, MA (bright ring in center of image).

fish were broken during extraction and were unreadable. Marks were identified using a fluorescent
microscope and state-of-the-art image analysis system.

Two electrofishing surveys for juvenile shad were conducted in fall 2007 by USFWS and *MarineFisheries* staff. On September 25, the first survey was conducted from the stocking site at the Woerd Avenue Boat Launch, Waltham, downriver to the Moody Street Dam, Waltham. American shad and river herring were observed in large schools during this survey. A sample of 10 juvenile shad ranging in total length from 96 – 160mm was retained for the identification of marked otoliths. Hatchery origin was confirmed by the presence of an oxytetracycline mark on nine of the ten fish subsampled. Otoliths for one fish were broken during extraction and were unreadable. Marks were identified using a fluorescent microscope and state-of-the-art image analysis system.

On October 2, 2007, a second survey was conducted from the Daly Field Boat Launch, Brighton downriver to the Museum of Science, Boston. No American shad were observed; however, numerous schools of juvenile river herring were observed near the Beacon Street and Arsenal Street Bridges, Brighton. During September and October 2007, coastal Massachusetts experienced a drought. Charles River flow was low and no spill was occurring over the Moody Street Dam.

In fall, 2008, 41 juvenile shad were collected, ranging in size from 75-107mm total length. The samples exhibited 100% OTC-mark retention.

American shad passage was much improved in 2008, with over 26,000 shad passing through the lift facility (Figure IVC3.6). River herring passage was poor due to the late opening of the lift. Delayed opening was a result of high river flow from increased snow pack melt in New Hampshire.

Starting in 2009, any adults returning to the Charles River will be captured on video at the Watertown Dam. Adult shad will be sampled and examined for marked otoliths. A successful restoration will be indicated in future years by the presence of a greater number of naturally-spawned individuals as compared to hatchery-spawned individuals.

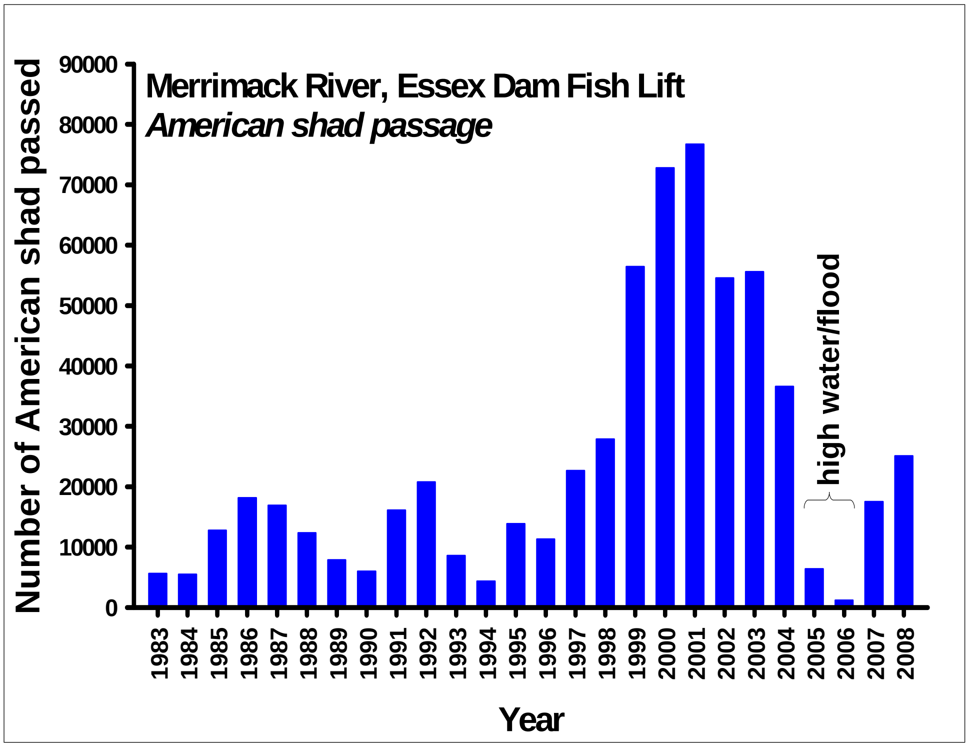

Figure IVC3.6. Number of American shad passed at the Essex Dam Fish Lift, Merrimack River, Massachusetts, 1983-2008.

MarineFisheries considers Charles River American shad an important fishery resource of the Commonwealth and is committed to achieving a successful restoration. As with all juvenile anadromous fish stocking programs, the shad fry stocked in the Charles River will contend with obstacles including predation, unsuitable flow, downriver passage, availability of forage species (i.e. the zooplankton community), and habitat alterations including unsuitable temperature in the zone of passage habitat. However, every effort will be made to facilitate the success of this Project including achievement of target production goals. In the event that production goals are not met during the funding period, our partner, USFWS, is committed to fulfilling this obligation to the benefit of the Commonwealth.

Outreach

Outreach was an important part of the HubLine Shad Restoration Project. A lecture on the Charles River shad restoration program was presented to the Boston area chapter of Trout Unlimited and another presentation was co-authored with the USFWS about this Shad restoration project for an annual Northeast Fish and Wildlife Conference.

Shad fry, produced by this Project, were provided to the New England Aquarium for an educational exhibit. Project personnel, USFWS, and the fish curator of the New England Aquarium developed educational signage for the HubLine American shad juvenile display.

Staff also participated in the development of a multi-panel educational kiosk installed near the Watertown Dam fishway. Kiosk project partners include *MarineFisheries*, the Department of Conservation and Recreation, the Corporate Wetlands Restoration Partnership, the Charles River Watershed Association, and Sasaki Associates.

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