Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-18

A Survey of Anadromous Fish Passage in Coastal Massachusetts

Part 4. Boston Harbor, North Shore and Merrimack River

P. D. Brady, K. E. Reback, K. D. McLaughlin, and C. G. Milliken

Massachusetts Division of Marine Fisheries
Department of Fisheries, Wildlife and Environmental Law Enforcement
Executive Office of Environmental Affairs
Commonwealth of Massachusetts

January 2005

Massachusetts Division of Marine Fisheries
Technical Report TR-18

A Survey of Anadromous Fish Passage in Coastal Massachusetts
Part 4. Boston Harbor, North Shore and Merrimack River

Phillips D. Brady, Kenneth E. Reback, Katherine D. McLauglin, and Cheryl G. Milliken

Massachusetts Division of Marine Fisheries
Southshore Field Station
Pocasset, MA

January 2005

Massachusetts Division of Marine Fisheries
Paul Diodati, Director
Department of Fisheries, Wildlife and Environmental Law Enforcement
Dave Peters, Commissioner
Executive Office of Environmental Affairs
Ellen Roy Herzfelder, Secretary
Commonwealth of Massachusetts

TABLE OF CONTENTS

Part 4: Boston Harbor, North Shore, and Merrimack River Watersheds

Acknowledgements

The authors wish to thank the following people for their assistance in carrying out this survey and for sharing their knowledge of the anadromous fish resources of the Commonwealth:
Brian Creedon, Tracy Curley, Jack Dixon, George Funnell, Steve Kennedy, Paul Montague, Don St. Pierre, Ken Sprankle and Dave Watling.

The following Division of Marine Fisheries personnel were invaluable in the preparation of this report: Brad Chase, Rusty Iwanowicz and Greg Skomal. Special thanks to Edward Clark, who participated in much of the field work. We also wish to recognize Tracy Pugh for her work in data compilation and editing.

This work was funded in part by a grant from the Massachusetts Watershed Initiative.

ABSTRACT

Anadromous fish species such as alewife, blueback herring, rainbow smelt, American shad, and white perch are important members of the coastal and freshwater fish faunas of Massachusetts. Providing passage through numerous man-made blockages allowing for the spawning migration of these fishes is essential to maintaining healthy populations. Information on blockages (primarily dams) and fish passage structures (fishways) has not been updated since the early 1970s. In order to update this information, a survey was conducted by the Massachusetts Division of Marine Fisheries during 2001-2002. The purpose was to provide information on the present state of fish passage in Massachusetts coastal streams and rivers and to provide guidance for future restoration efforts. The results of this survey are presented in this report.

All rivers and streams flowing into Massachusetts' coastal waters were examined. The presence of anadromous species in a system was determined from a variety of sources including past Division surveys, regional biologists, harbormasters, and local herring and shellfish wardens. If alewives or blueback herring were not specifically identified, the generic term river herring was used in the species present listing.

Most rivers and streams were surveyed from mouth to headwaters. General physical characteristics of the water bodies and data of specific importance to anadromous fish were noted. All obstructions and fishways were photographed and their locations were recorded using handheld GPS units. Site specific details were documented for the first impassable obstruction and its impoundment area to assist in the evaluation of future alterations or fish passage possibilities. On some streams, information was gathered on additional impassable obstructions as well. River obstruction type, construction material, and structural and hydraulic heights were recorded. When a fishway was present, the type of design, dimensions, construction materials, and number of baffles, pools and weirs were recorded. Fishways were rated based on their condition and function. Condition (poor, fair, good or excellent) described the physical structure and referred to the level of deterioration of the ladder. Function (not passable, inefficient passage, or passable) described how well the structure passed fish. A brief description of the state of fish passage and the potential for further improvements were provided for each river and stream.

The survey included 215 coastal streams. Along these streams, 493 lakes, ponds or reservoirs and 380 obstructions to migratory fish passage were documented. The majority of the obstructions are man-made dams that in many cases have long ceased to perform the functions for which they were originally constructed. About 68% of the dams are six feet or under in height and only 3% were 24 feet tall or greater. The survey identified 175 existing fish passage structures and more than 100 active river herring runs. Weir pool and notched weir pool fishways were by far the most common designs employed in Massachusetts followed by the denil ladder, stream baffles, Alaskan Steeppass, combination designs, vertical slot and fish lifts. About 46% of the existing fishways were judged to be in deteriorated condition and 50% were judged to function inadequately.

The survey clearly demonstrates that Massachusetts has a large investment in fish passage along our coastal rivers and streams. The survey and associated recommendations identify numerous projects that should be undertaken over the next several years. These projects include the maintenance, repair, and re-design of failing or inefficient existing fishways, and the construction of new fishways to provide access to additional spawning grounds. The information provided by this survey will guide the planning and implementation of future infrastructure work by the Massachusetts Division of Marine Fisheries necessary for the management and improvement of Massachusetts' anadromous fish populations.

This report is Part 4 in a four part series that covers the coast of Massachusetts. The information provided in this report covers the watersheds within Boston Harbor, the North Shore, and the Merrimack River. The other parts in the series are: Part 1 – Southeastern Massachusetts; Part 2 – Cape Cod and the Islands; Part 3 – South Shore.

INTRODUCTION

Anadromous fishes in Massachusetts coastal waters have undergone a striking decline in abundance over the past 400 years. The combined effects of impassable dams, gross pollution, water diversion and overfishing had drastically reduced or eliminated anadromous fish populations. Twentieth century efforts at restoring depleted stocks through focused care and management led to a significant recovery in the Commonwealth. Today more than 100 coastal rivers and streams are the sites of active herring runs.

During the fall of 1967, the Massachusetts Division of Marine Fisheries (DMF) began a survey of coastal streams to determine the existence of anadromous fish resources and the potential for restoration and enhancement. The results of that survey, published as a Federal Aid completion report in 1972, have served as the basis for anadromous fish management in Massachusetts since that time. The recommendations that resulted from the survey have provided a work plan for DMF's anadromous fish project over the last 30 years. In the three decades since the completion of the survey, numerous changes have taken place. Some fishways have deteriorated or their designs have become obsolete. Dams have failed, eliminating spawning or nursery habitats. Impoundments have degraded due to eutrophication, and water withdrawals have raised fish passage issues. Other changes have been positive. Many fishways have been constructed, replaced, or repaired and designs have improved dramatically. Stocking programs have resulted in new populations and the restoration of others. Water quality has improved in many systems. Most of the recommendations made in the 1972 report have been successfully carried out.

Because of these changed conditions, continued effective management of coastal anadromous fish resources in Massachusetts required a new survey and report that would generate an updated set of recommendations. This document presents the results of a new anadromous fishway survey conducted in 2001 and 2002. The information and recommendations presented are intended to form the basis of an action plan for future DMF anadromous fish work. Recommendations are presented and prioritized for each watershed to enable the DMF to better execute its statutory mandate to develop and manage the anadromous fish resources of the Commonwealth.

This is the final report in a four part series that covers the coast of Massachusetts. Findings from the watersheds of Boston Harbor, the Merrimack River, and the North Shore of Massachusetts are presented in this report. The first report in the series is comprised of the Southeastern portion of Massachusetts, including the Taunton River watershed and the drainage areas of Narragansett Bay and Buzzards Bay. The Cape Cod, Martha's Vineyard, and Nantucket watersheds are reported in part 2 of the series, and part 3 includes the watersheds of the South Shore of Massachusetts.

MATERIALS AND METHODS

All rivers and streams flowing into Massachusetts' coastal waters, from the Rhode Island to New Hampshire borders, were considered. Most were surveyed from mouth to headwaters. General physical characteristics were noted and data of specific importance to anadromous fish recorded.

All known or encountered obstructions and fishways were photographed using a high resolution digital camera, and their locations were recorded using handheld Global Positioning System (GPS) units. Site specific details were documented for the first impassable obstruction and its impoundment area to assist in the evaluation of future alterations or fish passage possibilities. On some streams, information was gathered on additional impassable obstructions as well. River obstruction type, construction material, and structural and hydraulic heights were recorded. When a fishway was present, the type of design, construction materials, number of baffles, pools and weirs as well as operational condition were noted. Measurements including length, inside width (IW) and outside width (OW), baffle height, pool length, steep notch width and pool depth were also recorded for each fishway.

Total stream length, obstruction river mile, and impoundment acreage were calculated for all systems using Map Tech Terrain Pro Navigator Software, version 5.02. To calculate impoundment acreage, the impoundment boundary was traced three times and resultant values averaged to achieve a better area estimate.

Water pH was tested at one point on each system using either a Horiba U-10 Waterchecker, an Oakton Waterproof pH Testr2 or a LaMotte Wide Range pH kit (model P-3100). These data should be used with caution since they represent only a single point measurement.

Distances and heights were documented via tape measures and telescoping rods or an Opti-Logic 400 LH Hypsometryx Rangefinder, Sonin Combo PRO ultrasonic electronic measurer and a DISTO classic hand-held laser meter. The electronic measuring devices were utilized when the distance was very large or physical obstructions limited access to the object to be measured.

The presence of anadromous species in a system was determined from a variety of sources including past Division surveys, regional biologist accounts, and local herring and shellfish wardens and harbormaster accounts. If alewives or blueback herring have not been specifically identified, the generic term river herring is used in the species present listing.

For the purposes of this report, an obstruction was defined as any feature, natural or manmade, that negatively effects the upstream or downstream movement of anadromous fish species. While dams were considered most often, the term also applied to natural elevation changes such as those caused by falls and severe rapids or less dramatic gradients that may result in extremely shallow stream depths. Culverts that create elevation changes, cause fish to hesitate due to abrupt lighting changes, restrict stream flow or have submerged outlets were also considered obstructtions and impediments to passage.

When present, fishways were rated based on their condition and function. Condition, which was listed as poor, fair, good or excellent, described the physical structure and referred to the level of deterioration of the ladder. Function, rated as not passable, inefficient passage, or passable, described how well the structure can pass fish. A fishway was listed as not passable if fish are unable to utilize it. If there is any room for improvement in the design or placement of the ladder that would enable the structure to better pass fish, it was listed as inefficient passage. If the fishway passes fish at optimum levels and no improvements could be made to it, it was listed as passable.

LIFE HISTORIES

There are seventeen species of anadromous fish in the Commonwealth of Massachusetts (see Appendix 1). Below we discuss the life history of the four species that have been the focus of DMF's restoration efforts through the improvement of fish passage.

River Herring:

The river herring are actually two closely related members of the family *Clupeidae*, the alewife (*Alosa pseudoharengus*) and the blueback (*Alosa aestivalis*) herring. The two species are very difficult to tell apart and, short of a study of their morphometric characteristics, the best method to distinguish them is the color of the peritoneum, the body cavity lining. In the alewife this tissue is gray or silvery while in the blueback herring it is a sooty black color. Although the alewife tends to be larger, up to about 12 inches, there is much overlap in size.

While both species are capable of spawning in riverine or lacustrine environments, there is a decided preference for the latter on the part of alewives while bluebacks generally choose a stream or river type of habitat. In general, most systems contain both species.

Alewives tend to spawn 3 to 4 weeks earlier than bluebacks in the same system. Although actual spawning probably occurs much later, alewives have been observed in Massachusetts streams as early as February and, in one instance, January. Alewives begin spawning when water temperatures reach 51 and bluebacks 57 degrees F. Both species cease spawning when the water warms to 81º F. Blueback eggs are semi-buoyant and tend to drift with the current while alewife eggs will remain in contact with the substrate or current. After utilizing the freshwater habitat for a nursery area for most of the summer, the juvenile herring undertake a massive migration to the ocean in the fall. In the case of alewives, a smaller but significant out migration in late spring/early summer has been documented in some systems.

Once in the marine environment, river herring feed on zooplankton such as micro-crustaceans, fish eggs and fish larvae. Maturity occurs at 3 to 5 years and the fish return to their natal streams utilizing their olfactory sense to guide them to the home waters. Repeat spawning occurs more often in northern than in southern populations. Mortality during a spawning season in the south may reach up to 90%.

Formerly an important local food source, river herring were smoked, salted or pickled. Human consumption is now a minor use and the fish are primarily sought after as bait for commercial and sport fishing.

American shad:

The American shad (*Alosa sapidissima*) is also a member of the *Clupeidae* and, with the exception of its size, closely resembles the river herring. The series of 4 to 6 lateral dark spots on the shad's side, posterior to the gill cover, and the fact that its upper jaw extends beyond the eye serve to distinguish it from alewives and blueback herring. Adult males may weigh up to 6 pounds and females can grow to 8 pounds although larger specimens are occasionally reported. Shad may grow to 2 feet in length although individuals of 30 inches have been recorded.

Shad are river spawners, ascending the larger systems such as the Comnnecticut and Merrimack Rivers when spring water temperatures reach approximately 62 degrees F. A few smaller Massachusetts streams, notably the Palmer and Indianhead Rivers, support small but important populations. Males reach sexual maturity at 3 to 5 years old and females from 4 to 6. Eggs are semi-buoyant and tumble along the stream bottom until hatched. Juveniles spend their first summer in the river feeding on microscopic zooplankton and insects until they depart for the marine environment in the fall.

New England shad populations over-winter in the mid-Atlantic coastal region and migrate northward in the spring, using their olfactory sense to locate natal rivers. Post-spawn adults and immature fish congregate in the Gulf of Maine and Bay of Fundy during the summer before moving to their wintering grounds. There is no commercial fishery for American shad in Massachusetts where it is considered a sportfish and is eagerly sought by anglers in rivers where the fish congregate in sufficient numbers.

Rainbow smelt:

Rainbow smelt (*Osmerus mordax*) are small fish that rarely exceed 7 to 9 inches as adults and weigh 1 to 6 ounces. Mature females are larger than their male counterparts. The smelt can be distinguished from other small coastal Massachusetts species by its deeply forked tail and adipose fin anterior to the caudal fin. Both sexes mature at about 2 years of age although some precocious one year olds may participate in spawning. Spawning begins in late winter/early spring in Massachusetts when water temperatures reach 40 to 42 degrees F.

Spawning takes place just above the head of the tide in fast flowing, often turbulent water usually associated with rocky or boulder substrate. Eggs are broadcast, fertilized and immediately become attached to the substrate or vegetation by means of a stalk-like appendage which protrudes from the egg surface. Spawning occurs at night with the adult smelt retreating to deeper water downstream during the day.

Larvae are about 1/4 inch when hatched and are carried downstream to the estuary. The juvenile fish feed on zooplankton, especially microscopic crustaceans. Adults feed on small crustaceans such as shrimp and gammarids as well as crabs, worms and small fish. Adult smelt spend the summer in relatively shallow waters less than a mile from shore and move into bays and estuaries during the fall and winter. Smelt feed actively during the winter and as a result support a small but intense rod and reel fishery from docks and piers and, when ice conditions permit, ice shanties. No commercial fishery exists and in order to protect the species during its spawning run, possession of smelt during the spring is illegal according to state law.

MANAGEMENT

The management of river herring (alewives and blueback herring), American shad and rainbow smelt in coastal waters and streams is delegated to the Division of Marine Fisheries through Chapter 130 of the Massachusetts General Laws. Anadromous salmonids (trout and Atlantic salmon) come under the jurisdiction of the Division of Fisheries and Wildlife. DMF's management techniques fall into three general categories: regulation, propagation and fishway construction.

Regulations

Fisheries for anadromous fishes are subject to the General Laws of the Commonwealth. Chapter 130 of the General Laws establishes specific laws for the management of river herring, American shad, and rainbow smelt in coastal waters and empowers the Director of the Division of Marine Fisheries to create regulations for the protection of these species. Current state regulations are intended to protect existing populations while allowing reasonable usage of the resource by the public. This is accomplished by the standard fishery management techniques of imposing a no fishing period, daily bag limits, restrictions on methods of catch or some combination of the above. (Specific state regulations for all river herring can be viewed in Appendix 2).

In addition to the generic state regulations, Sections 93 and 94 of Chapter 130 allow cities and towns or anyone who creates a fishery to develop their own river herring regulations with the approval of DMF. Autonomous local control of these fisheries, as was established in the past by numerous Special Acts of Legislature, proved for a number of reasons to be ineffective. Conversely, it is not possible for the state to effectively manage the numerous populations in the Commonwealth. Consequently, the repeal of the Special Acts and an emphasis on local control with oversight by DMF has proved to be a satisfactory compromise.

Perhaps of greatest importance to the protection of anadromous fish resources is Section 19 of Chapter 130. This statute gives the Director of Marine Fisheries the authority to order removal of an obstruction to fish passage or order construction of passage facilities at the expense of the owner. Section 19 is responsible for the existence of many fishways that may not have been built otherwise. Other laws such as Section 95, which prohibits unauthorized taking of herring from created fisheries, and Section 96, which prevents the taking of herring after June 15, also aid in the management of this species.

Other anadromous fish are also protected by state law. According to Section 34, smelt may not be taken or possessed from March 15 to June 15 in order to protect spawning broodstocks. Section 100C prohibits taking of American shad by any means other that hook and line and the daily bag limit is 6 shad. Section 17 enables the Director of the Division of Marine Fisheries to set regulations for the management of anadromous fish in coastal waters as well as for other marine species.

Propagation

Propagation may be the oldest fisheries management technique and has been applied to anadromous fish in Massachusetts since the 17th century if not earlier. DMF's propagation strategy for river herring has been to collect adult fish from productive populations just prior to spawning and transport them to a new potential spawning ground that has been made accessible, usually through fishway construction. The offspring of the transplanted adults become imprinted on this habitat just prior to their seaward migration and return there to spawn when they mature. This technique has been extremely successful and is also used to restore populations that have been depleted by overfishing, drought, fish kills or other causes.

American shad propagation has been carried on by DMF since the late 1960's. Both fertilized eggs and adult shad have been transported from home streams to potential habitats. While some limited success has been achieved, the shad stocking programs have not matched river herring propagation as an important management tool. Other states have been more successful in this area and refinement of methods and techniques in the future could result in a productive shad restoration program.

Rainbow smelt stocking has been carried on in the Commonwealth for over a hundred years. Early attempts did not take habitat requirements into consideration and accordingly the results were less than satisfactory. Both fertilized eggs and adult brood stock have been used for transplanting in the past, each with success. The current method used by DMF is to collect newly fertilized eggs on trays of sphagnum moss or some other material to which the eggs will attach and survive. Once a sufficient number of eggs have been deposited on the trays they are transported to the host stream on which the larval smelt will become imprinted.

Fishway Construction

Massachusetts has been a leader in the field of fishway construction. Records indicate that 18th century colonists recognized the need for fish passage around newly built dams and passed laws requiring access for fish. This tradition has carried into the 21st century. The Commonwealth has maintained its own fishway construction crew since 1934 and, in 1967, DMF established an Anadromous Fish Project which dealt with fish ladder design as well as all the other aspects of anadromous fish management. The result has been the more than 140 fishways documented by this survey, most of which have been designed and/or constructed by DMF. Typically, funding for materials has been provided by towns, local organizations, or state and federal grants, with design expertise and labor coming from the Division's anadromous fish program.

Several fishway types are currently in use on coastal Massachusetts streams. (See Appendix 3 for illustrations and photos of typical fishway designs.) The most common is some variation on the weir-pool design. This style has the advantage of adequate function under low flow regimes and is the favored design when public viewing is desired. Its drawbacks are the need for frequent manual adjustment and its inability to pass species other than river herring with any efficiency. Many of the weir-pool fishways currently in operation have been in place for fifty years or more and are both deteriorated and obsolete in design.

In the late 1960's, DMF began to use a Denil design for most of its newly constructed fishways. This type was more effective in passing species other than river herring and could operate with a minimum of flow adjustment. In addition, fish tended to move through the structure more quickly creating less backup than is experienced with the weir-pool ladder. The disadvantage is the need for relatively high flow volumes to insure fish passage. The Denil soon became the preferred design where applicable and is still frequently used.

The first installation of a prefabricated, aluminum Alaskan steeppass fishway by DMF took place in 2000. Similar to the Denil in function, this style offered the benefit of reduced costs by eliminating the need for large, labor intensive construction projects. Also, impacts to streambeds, wetlands and adjacent uplands were minimized. In addition, the steeppass has been found to be useful in the modification of dilapidated, inefficient weir-pool ladders. Its disadvantages are similar to those of the Denil type and its cost becomes a factor when many sections are required to overcome an obstruction.

A mechanical fish lift is currently in operation on the Merrimack River. Operated by CHI Energy, the lift at the Essex Dam in Lawrence is primarily designed to pass Atlantic salmon and American shad although other species such as blueback herring utilize it in substantial numbers. Also, a vertical slot or Ice Harbor fishway in addition to a lift is utilized at the Pawtucket Dam in Lowell.