Technical Report

Massachusetts Division of Marine Fisheries
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ABSTRACT

The spawning habitat of anadromous rainbow smelt in the Weymouth-Fore River, within the cities of Braintree and Weymouth, was monitored during 1988-1990 to document temporal, spatial and biological characteristics of the spawning run. Smelt deposited eggs primarily in the Monatiquot River, upstream of Route 53, over a stretch of river habitat that exceeded 900 m and included over 8,000 m^2 of suitable spawning substrate. Minor amounts of egg deposition were found in Smelt Brook, primarily located below the Old Colony railroad embankment where a 6 ft culvert opens to an intertidal channel. The Smelt Brook spawning habitat is degraded by exposure to chronic stormwater inputs, periodic raw sewer discharges and modified stream hydrology. Overall, the entire Weymouth-Fore River system supports one of the larger smelt runs in Massachusetts Bay, with approximately 10,000 m^2 of available spawning substrate.

Observations of egg deposition during 1988-1990 indicate that spawning typically begins in early March and egg incubation is complete by late May. Egg deposition observed in the Weymouth-Fore River during 1989 was substantially higher than observed in 1988 and 1990, or any year since. The movement of yolk-sac larval smelt from the spawning habitat to the upper estuary was recorded for the period of April 14th through May 26th. Measurements of basic water chemistry recorded suitable conditions of temperature, salinity, dissolved oxygen and pH for adult attraction and egg survival under most conditions.

Annual observations since 1990 confirm that smelt continued to spawn in the Weymouth-Fore River and this spawning run supports a modest sportfishery in Hingham Bay and Quincy Bay. Despite the relatively favorable rank among Massachusetts Bay smelt runs, the Weymouth-Fore River appears to be following a region-wide trend of declining smelt populations during the last 15-20 years. The causal factors for this trend are not well identified. Structural impediments of adult smelt migrations to spawning habitat and the chronic degradation of spawning habitat from stormwater inputs are common concerns for many river systems in Massachusetts Bay that support smelt. Symptoms of these two concerns were identified within the Weymouth-Fore River system. Recommendations are provided in regard to these potential sources of impact to the Weymouth-Fore River smelt population.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Rainbow smelt (*Osmerus mordax*) is a small anadromous fish that inhabit the Atlantic coast of North America. Rainbow smelt also occur in landlocked, freshwater populations in North America. Most anadromous smelt populations are currently found from Newfoundland to Massachusetts. Smelt mature in coastal waters and in the lower reaches of estuaries, then ascend into freshwater zones to spawn during springtime spawning runs. Fertilized eggs are negatively buoyant and adhere to the substrate and aquatic vegetation. Newly deposited eggs are approximately 1 mm in diameter and transparent. The duration of egg incubation is directly related to water temperature, with cooler temperatures resulting in longer incubation (McKenzie, 1964). Smelt eggs in Massachusetts Bay typically hatch in the range of 10 to 21 days after fertilization. Upon hatching, larvae are immediately transported downstream into the tidal zone where feeding on zooplankton begins. Observations of deposited eggs form the basis for delineating smelt spawning habitat.

Smelt spawning activity is variable among river systems in regard to spawning substrates, the timing of spawning, and water temperature range (Kendall 1926; Bigelow and Schroeder 1953; Rupp 1959; Hurlbert 1974; and Pettigrew 1997). Investigations of Massachusetts smelt runs have found that spawning begins between late February and mid-March when water temperatures reach 4-6 C^o, and concludes in May (Crestin 1973; Lawton et al. 1990; Chase, 1992 and 1996). Spawning smelt concentrate at shallow riffles beyond the interface of fresh and brackish water at night during flood tides (Clayton 1976; Murawski et al. 1980). After spawning, smelt usually return to deeper downstream areas during daylight. For most smelt runs in Massachusetts Bay, there is little specific information available on spawning locations. The variability in spawning activity, nocturnal spawning, and a closed season for fishing all contribute to a lack of familiarity and documentation of smelt spawning habitat in many coastal river systems.

Smelt are valued as forage for other fish and have supported traditional recreational fisheries and modest commercial fisheries in New England since the 19^{th} century (Kendall, 1926). In Massachusetts, smelt and are fished by hook and line after they migrate from coastal waters to estuaries in the fall. The fishery is closed by regulation from March 15th to June 15th to protect spawning fish. Smelt fishing typically occurs at shoreline structures in embayments and through the ice in the upper estuary when there is sufficient ice cover. Fisheries in Massachusetts Bay have declined recently, and some smelt runs now attract only a small fraction of the interest and fishing effort of 15-20 years ago. Watershed alterations such as obstructions to passage and spawning habitat degradation are suspected as influences in recent declines in smelt population.

Smelt spawning habitat in the Weymouth-Fore River (Fore River) was monitored by the Division of Marine Fisheries (DMF) during 1988-1990, as part of the Massachusetts Bay Smelt Spawning Habitat Monitoring Program. The primary objective of this program was to document temporal, spatial and biological characteristics of smelt spawning in Massachusetts Bay river systems. The resulting baseline data can be applied to the resource management goals of protecting valuable estuarine and river habitats and sustaining the Commonwealth's smelt fisheries. Secondary objectives of the program include the characterization of river systems through the collection of baseline water chemistry, stream discharge, and ichthyoplankton data, and documenting the occurrence of other anadromous species. This report documents sampling in the Fore River, which was one of over thirty river systems monitored by DMF during 1988-1995.

STUDY AREA

The Fore River is located in the Weymouth and Weir River Watershed Basin (Halliwell et al. 1982), approximately 16 km south of the city of Boston. The Fore River refers to the tidal portion of this river system, and flows into Hingham Bay (Figure 1) on the southern side of the large coastal embayment called Boston Harbor. Upstream of tidal influence to the confluence of its tributaries it is called the Monatiquot River. The primary source of freshwater flow is Great Pond in Randolph and Braintree. Smaller water bodies and freshwater swamps in Randolph, Braintree, and Weymouth also contribute to the Fore River discharge. The drainage area of both tidal and freshwater portions of this river system (from Rt. 3A upstream) is 93.5 km^2 (Wandle, 1984). The Fore River also receives freshwater from Smelt Brook that flows for about 2 km from Pond Meadow Lake in Braintree before joining the Fore River at Weymouth Landing. The drainage area of Smelt Brook is 5.4 km^2 (Wandle, 1984). Great Pond and Pond Meadow Lake are both reservoirs altered for municipal water supplies. The Monatiquot River and Smelt Brook both do not have stream flow gauge stations. For this report, Town River (Quincy) is not included as part of the Fore River estuarine system.

The shoreline of the Fore River estuary has undergone numerous changes since the colonial period to improve the land for transportation, commerce and residential use. Several structures within this network of development may have influenced the Fore River smelt population in the 20th century by altering stream channels, restricting passage, and direct mortality related to water withdrawals. The Old Colony railroad (Bay Colony, Figure 1) ran a passenger service from 1848 to 1959 and freight service continued until 1983. The railroad corridor includes two crossings at important stretches of smelt spawning habitat in Smelt Brook and the Monatiquot River. The Edgar Station operated near Rt. 3A in Weymouth as a coal-fired, electricity generating plant from 1925 until its retirement in 1978. The Edgar Station depended on Fore River water for cooling and was permitted to withdraw about 523 million gallons per day. Both the Old Colony rail service and Edgar Station are under review for reinstating operations at the time of this report. Smelt Brook has undergone extensive modifications during the 20th century to increase available land and reduce flooding. Most recently, in 1975, a flood relief conduit was added to the Smelt Brook under the business district of Weymouth Landing as part of a large flood control project (ACOE, 1976). Although most raw sewage discharges to the Fore River have been eliminated, a sewer overflow adjacent to Smelt Brook spawning habitat continues to discharge raw sewage periodically.

The following rivers flowing into Hingham Bay have been known to support large smelt runs: Weir River, Back River, Fore River, and Town River (Reback and DeCarlo, 1970). This region has traditionally supported a large sportfishery for smelt. By 1874 the threat of overfishing was evident and restrictions were made to limit smelt fishing to hook-and-line and prohibit fishing during the spawning season (Kendal, 1926). A 1916 report by the Massachusetts Commissioners of Fisheries and Game noted the depleted condition of smelt fisheries in Massachusetts and considered the Back River and Fore River to contain the only remaining natural breeding grounds of importance (MCFG, 1917). The Fore River remains one of the larger smelt runs in Massachusetts today, and a modest sportfishery continues in the estuary and Quincy Bay and Hingham Bay.

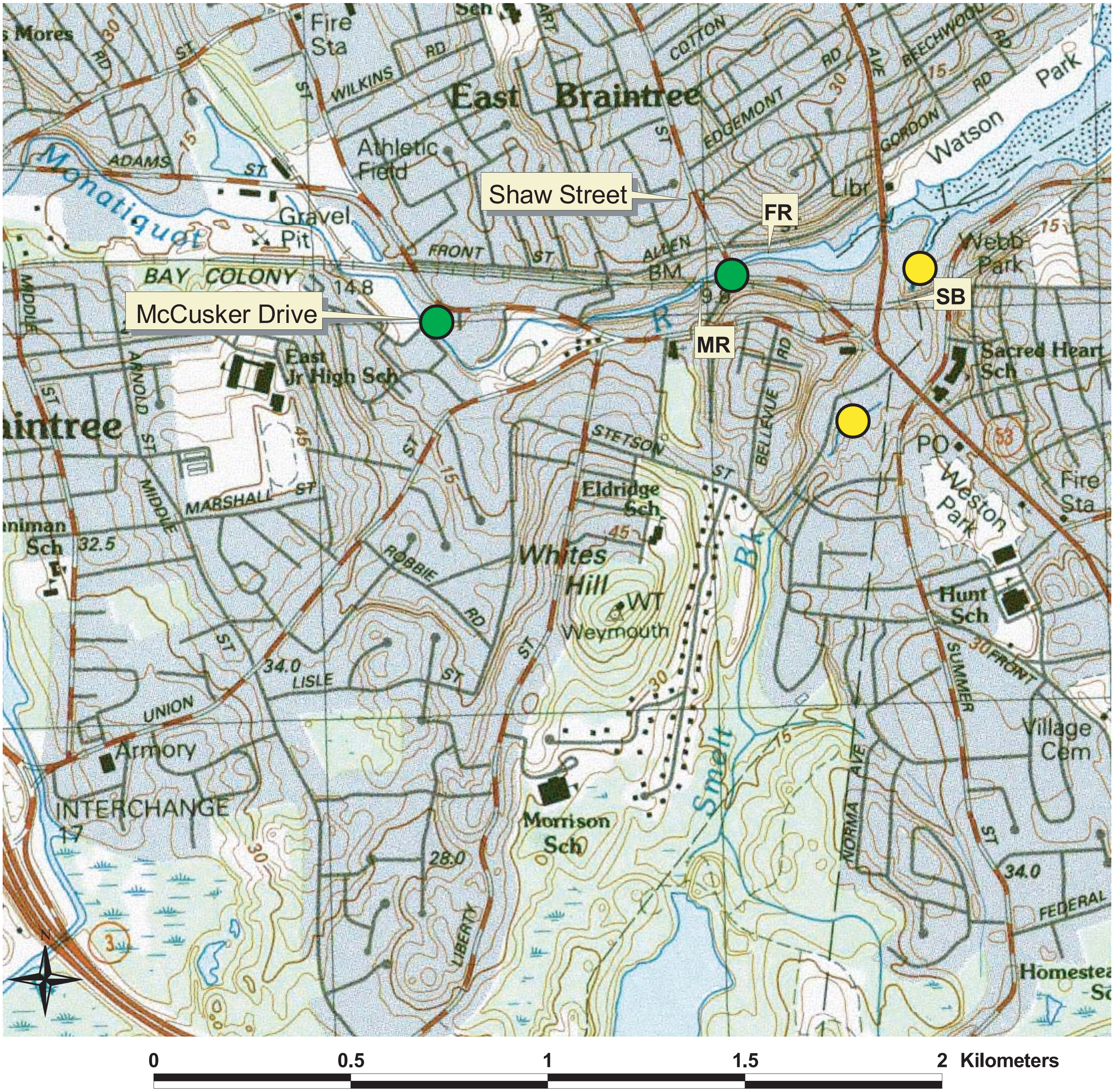
Sampling locations were selected at known smelt spawning habitat in the Fore River (MR, Figure 2) and Smelt Brook (SB, Figure 2) in order to monitor egg deposition and measure water chemistry. A downstream location was also selected at the Braintree Yacht Club in the Fore River (FR, Figure 2) to collect ichthyoplankton and measure water chemistry.

Figure 1. Weymouth-Fore River

Source: MassGIS

Note: The Weymouth- Back River is visible on the eastern edge of Figure 1.

Figure 2. Smelt spawning habitat in Weymouth-Fore River



Source: MassGIS

Spawning Habitat: range is marked with green dots in Monatiquot River and yellow dots in Smelt Brook.

Sample Stations: FR --- Braintree Yacht Club, water chemistry and ichthyoplankton.

SB --- Smelt Brook, water chemistry and egg deposition.

MR --- Monatiquot River, water chemistry and egg deposition.

METHODS

The two spawning habitat stations were sampled twice each week from March 1st through May 31st. During each visit, the river substrate was inspected for adhesive smelt eggs and water chemistry was measured. Eggs were identified on the basis of size, oil globule, and seasonal comparison with other species (Cooper, 1978; and Elliot and Jimenez, 1981). The timing of station visits were not randomly set or fixed by hour or tide, and more dependent on traffic and daily sampling schedule constraints.

The following water chemistry parameters (with accuracy in parentheses) were measured at sampling stations during each visit: water temperature (±0.5°C), dissolved oxygen (±0.2 mg/l), salinity (±1.0 ppt), and pH (±0.1). Stem thermometers were used for temperature data and accuracy was confirmed using a certified thermometer. Dissolved oxygen was measured with a YSI 51B meter that was calibrated prior to each sampling trip and every three hours with ambient oxygen. Salinity was measured with a Reichart temperature compensated salinity refractometer that was checked against distilled water each week. Water pH was measured with an Orion SA 250 pH meter that was calibrated prior to each sampling trip and every three hours with standard pH buffers (4.0, 7.0. 10.0).

Tidal conditions for Boston Harbor (White 1988, 1989, and 1990) were used along with local observations to determine tidal influence and tide stage (±0.5 hour). Bottom water samples were collected at station FR with a Van-Dorn style horizontal water sampler. No river discharge measurements were made during this study nor were available from other sources.

Ichthyoplankton samples were collected at the station FR for the purpose of confirming smelt larvae survival and movement into the Fore River estuary. A rectangular plankton net (0.14 m^2) with 0.505 mm mesh, was used to sample the ebb flow of surface water shortly after high tide. A 2030-R General Dynamics flowmeter attached to the net frame was used to measure stream flow rates (m/sec) and water volume (m^3). Samples were preserved in 5% phosphate buffered formalin and returned to the laboratory for sorting and microscopic analysis. All finfish eggs and larvae were measured to the nearest 0.1 mm and identified with the aid of manuals by Colton and Marak (1969), Scotton et al. (1973), Lippson and Moran (1974), and Elliot and Jimenez (1981).

After the completion of three sampling seasons, stream measurements were made of the habitat where smelt egg deposition was found. The wetted perimeter of the streambed where eggs were found was measured to the nearest 0.1 m using a tape measure. Mid-stream length measurements were applied to average width measurements to produce spawning habitat area (m^2). Attempts were made to estimate the spawning period for each season, based on observations of egg deposition. Spawning period is defined as the time between the date of first egg deposition and the date when hatching is complete. The dates of spawning period were estimated as the mid-point date between the sample visit when viable eggs were first (or last) observed and the nearest sample visit when no eggs were observed.

RESULTS

Spawning Habitat

Smelt egg deposition was readily observed in the Fore River during each sampling season. These observations allow the delineation of temporal and spatial use of spawning habitat by smelt in the Fore River system. A majority of smelt spawning during 1988-1990 occurred upstream of Rt. 53 in the Monatiquot River. Minor egg deposition was found in Smelt Brook during 1989 and 1990. Overall, smelt spawning occurred over approximately a kilometer of river length and included nearly 10,000 m^2 of river substrate.

Monatiquot River. Smelt eggs were deposited in the Monatiquot River from the Shaw Street Bridge upstream to the McCusker Drive overpass (Figure 2). Adhesive eggs were first detected at the intertidal habitat upstream of Shaw Street where a salt wedge is present during most flood tides. The stretch from Shaw Street to the Old Colony railroad bridge embankment (station MR) is the transition zone from tidal to freshwater habitat. Egg deposition was light and patchy near Shaw Street, and increased below the railroad bridge embankment. The embankment narrows the river width to 7 m where boulders create an elevation rise that can inhibit smelt passage during lower tides. Upstream of the railroad embayment the river takes on a typical lotic environment with shallow riffles and several deeper pools. The substrate was primarily gravel and small cobble, with minor patches of sand and silt associated with pools. Egg deposition was observed at most suitable riffles up until McCusker Drive. The concrete lip of the sluiceway below McCusker Drive creates a modest vertical rise (15-25 cm depending on flow) that prevents further smelt passage. The Monatiquot River spawning habitat measured 964.5 m in length and 8797 m^2 in area (Table A1).

Smelt Brook. The spawning habitat observed in Smelt Brook has been greatly modified by flood control efforts. These modifications and stormwater inputs have reduced the quality of this brook for smelt spawning habitat. Smelt Brook empties through two round culverts into a stone lined channel that runs for over 200 m before meeting the Fore River. The channel drains to a shallow freshwater flow at ebb tide and fills with 2 m of seawater at flood tide. The highest smelt egg densities were found at the smaller culvert opening (6 ft diameter). Smelt continued spawning inside the 6 ft culvert for an undetermined distance. We presumed that no spawning occurred above the upstream opening of the culverts where a steep spillway precluded passage on the upstream side of Rt. 53. Light and intermittent egg deposition was observed at the opening of the larger culvert (8 ft diameter) and for 160 m downstream of the culverts. The substrate below the culverts was degraded by sedimentation and various articles of trash. The downstream limit of egg deposition was intertidal and not typical smelt spawning habitat: barnacles, soft-shell clams, and rockweed were present. For 1989 and 1990, egg deposition was found over a stretch of Smelt Brook that measured 170 m in length and 819 m^2 in area (Table A2).

1988 Spawning Season. During the first sampling season, all monitoring of smelt spawning habitat was directed from Shaw Street to 200 m upstream of the railroad bridge embankment. No monitoring occurred at Smelt Brook or near McCusker Drive. Spawning began on approximately March 15th when the water temperature was 4 C° (Table 1). Spawning events that resulted in the highest egg densities occurred throughout April and the first week in May. The highest egg densities were observed at the railroad bridge embankment. The spawning period was estimated to have ended on May 15th. Prior to the spawning season, little smelt fishing occurred directly in the Fore River because the mild winter prevented safe ice cover. The spring weather in 1988 was characterized as drier (-3.5 in. rain from normal) and slightly cooler than long-term averages at Boston's Logan airport (NOAA, 1988).

1989 Spawning Season. Monitoring in 1989 included Smelt Brook and the entire stretch of Monatiquot River spawning habitat. Spawning was estimated to have begun on March 4th when the water temperature was approximately 1 C° at both stations MR and SB. Spawning activity was light and intermittent until late March. From late March until mid-May there were frequent events of heavy egg deposition. Schooling adult smelt were observed in the daytime at the Smelt Brook culverts and below McCusker Drive during this period. On two occasions in late April, several thousand smelt were observed schooling in front of the sluiceway at McCusker Drive. The highest egg densities in 1989 were observed in the 50 m below McCusker Drive, whereas, the highest densities observed in 1988 and 1990 were at the railroad embankment. The spawning period ended on May 25th, but this is an approximate date, because although viable eggs were found on that date, no further site visits were made in May. The spring weather in 1989 was characterized as slightly drier and cooler than long-term averages at Boston's Logan airport (NOAA, 1989).

1990 Spawning Season. The approximate date of first spawning was March 11th (4 C° water temp.) and eggs were first found at the railroad bridge embankment. Egg deposition was concentrated at the embankment and for 100 m upstream during the peak spawning season of late March through April. Few eggs were found at Smelt Brook until late April and no eggs or adults were observed at McCusker Drive until May 1st. Light and sporadic spawning activity was evident during the first half of May in the Montiquot River. A few viable eggs were found as late as May 26th. The spring weather in 1990 was characterized by a very dry March, wetter April and May, and slightly cooler than long-term averages at Boston's Logan airport (NOAA, 1989). Relative to the prior two seasons, low water flow conditions during the early season, and lower egg deposition than in 1988 and 1989 were distinct observations made during the 1990 season.

Table 1. Smelt spawning period estimates for the Weymouth-Fore River, 1988-1990.

			Water Temperature (C^0)			
Year	**Spawning Period**	**Days**	**Start**	**End**	**Range**	**Mean**
1988	March 15th - May 15th	62	4.0	14.0	2.0 - 16.0	9.6
1989	March 4th - May 25th	83	1.0	17.0	0.0 - 18.0	8.4
1990	March 11th - May 27th	78	4.0	17.8	0.0 - 19.0	10.2

Water Chemistry

Monatiquot River. Water chemistry measurements were made at station MR below the railroad bridge (Figure 2). For the parameters measured, no unusual water quality conditions were identified (Table 2, and Tables A3-A5). All dissolved oxygen measurements during March-May were at or near saturation, providing adequate oxygen for aquatic respiration. Water pH measurements indicated the river was able to buffer acidic precipitation, and maintain pH levels near neutral under normal conditions. Tidal influence was observed at this location within two hours of high tide at most tidal amplitudes. However, no measurements detected any salinity during the spawning period, indicating the observed tidal influence was the backing up of freshwater flow.

Smelt Brook. Water chemistry measurements were made during 1989 and 1990 at the downstream opening of the 6 ft culvert (station SB). Water temperature, dissolved oxygen, and pH (Tables A6-A7) were similar to those at the Monatiquot River station and were within a suitable range for smelt spawning and egg survival. The salinity measurements indicate the substantial influence of tidal intrusion over the spawning habitat. Low salinity (1-4 ppt) was often detected in surface waters, although varied greatly depending on tide stage, amplitude, and rainfall patterns. At higher tide stages, the bottom water was consistently in the 25-30 ppt range. Egg exposure to salinity this high is not typical for most smelt spawning habitats in Massachusetts Bay.

Braintree Yacht Club. Water chemistry measurements were made from the yacht club float that reached closest to the river channel (station FR, Figure 2, Tables A8-A10). Substantial salinity and modest thermal stratification were recorded at all tide stages. Bottom salinity averaged 29 ppt in 1988/1990 and 30 ppt in 1989, and displayed little variation to tidal or rainfall conditions. Surface flow was dominated by river discharge. Surface salinity averaged between 3 and 5 ppt during the three spring seasons and did not exceed 9 ppt. Depth measurements made at the sampling station ranged between 2 to 5 m from low to high tide.

Table 2. Weather and water chemistry summary from Fore River smelt spawning habitat station MR, Braintree, 1988-1990. Data are averages (Tables A3-A5) except station visits and NOAA Rainfall data are total values. Air temperature and rainfall data were recorded at Hingham, Massachusetts (NOAA, 1988-1990).

Sample Period	**Station Visits** (No.)	**NOAA Air Temp.** (C^0)	**NOAA Rainfall** (in.)	**Water Temp.** (C^0)	**Salinity** (ppt)	**pH**	**D.O.** (mg/l)
1988							
March	9	3.8	4.1	5.8	0.0	7.4	
April	8	7.6	1.9	9.6	0.0	7.4	
May	7	13.7	3.7	14.2	0.0	7.6	
Season	24	8.4	9.7	9.5	0.0	7.5	
1989							
March	10	2.3	3.8	3.7	0.0	7.5	13.6
April	6	7.1	4.4	10.5	0.0	7.5	11.3
May	4	13.5	5.2	15.5	0.0	7.3	10.3
Season	20	7.6	13.4	8.1	0.0	7.5	12.2
1990							
March	8	4.4	2.0	4.0	0.0	7.4	13.5
April	8	8.6	5.3	9.2	0.0	7.3	11.7
May	8	12.3	7.6	14.9	0.0	7.4	10.5
Season	24	8.4	14.9	9.4	0.0	7.4	11.9

Ichthyoplankton

Ichthyoplankton samples were collected on 18 dates at yacht club float (station FR, Figure 2, Table A11). It should be emphasized that these collections targeted smelt larvae in surface flows using a 0.505-mm mesh net. A wider range of species and possibly more smelt may have been caught with a smaller mesh net that sampled the entire water column. At least seven species of fish were collected. Smelt was the most common fish larvae caught, occurring in 61% of the net sets. All smelt larvae were caught from April 14th - May 26th. Atlantic tomcod (*Microgadus tomcod*) were the second most common fish larvae, occurring in 32% of the net tows. All tomcod were caught from March 15th - April 19th. A large majority of smelt larvae were yolk-sac larvae (mean TL = 7.0 mm). High densities of yolk-sac larvae were collected during the peak of the spawning season (10.7/m^3 on 4/14/88 and 5.6/m^3 on 4/28/89). These observations reflect on the proximity of the spawning habitat and the concentration of recently hatched larvae in the downstream surface flow of river water.

Other Anadromous and Catadromous Fish

Previous studies that have discussed anadromous fish in the Weymouth-Fore and Back Rivers did not report on the existence of a spawning run of river herring in the Fore River at the time of their surveys (Belding, 1921; Reback and DeCarlo, 1970; and Iwanowicz et al., 1973). We observed river herring schooling downstream of the McCusker Drive spillway in late April and early May during both 1989 and 1990. The schools of river herring observed were small (<100 fish). In recent years, we have observed more herring at this location, and at times, identified both alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in the schools. Catadromous American eel (*Anguilla rostrata*) were commonly observed each sampling season. Glass eels (elvers) entered the Monatiquot River during late March or early April in large numbers, and by May most elvers observed had developed darker pigmentation. We did not observe white perch (*Morone americana*) or American shad (*Alosa sapidissima*) during the study period, however, incidental catches of white perch (Stone and Webster, 1976; MRI, 1993, and MRI 1999) and shad (MRI, 1993) have been made in the lower estuary while conducting ecological sampling related to power plant permitting.

DISCUSSION

The monitoring efforts of 1988-1990 allowed us to conclude that the spawning run of smelt in the Fore River is one of the largest in Massachusetts Bay. This conclusion is based on the amount of available spawning habitat and observed egg deposition, both relatively large compared to other smelt runs in Massachusetts Bay. The spawning stock from the Fore River supports sportfisheries for smelt in the Boston Harbor region, one of the few regions left in Massachusetts with viable smelt fisheries.

The relatively high abundance of smelt in the Fore River has been recognized by previous ecological surveys in the area. A DMF study on the marine resources of Hingham Bay found smelt to be the third most numerically dominant fish caught at intertidal seine stations in 1970 (Iwanowicz, et al. 1973). Impingement monitoring at Edgar Station on the Fore River found smelt to be the third most numerically dominant fish impinged at the water intake during 1975 and 1976 (Stone and Webster, 1976). Recently, studies related to proposals for constructing a new power plant at Edgar Station provide evidence of a large spawning run of smelt and the importance of Fore River as nursery habitat for smelt. Boston Edison conducted an ecological study during 1989-1992 in preparation for permitting a new once-through cooling, electricity generating plant (UEC, 1992). Subsequently, Boston Edison sold the property to Sithe Energy Development, who conducted a second round of study during 1998 and 1999 (MRI, 1999).

During 1989-1992 and 1998-1999, studies at the Edgar Station property included ichthyoplankton, trawling and seining collections to characterize fish populations that could be impacted by plant operations (MRI, 1999). During both study periods, smelt were among the top three numerically dominant fish for the three collection methods. During 1998-1999, smelt was the numerically dominant fish in ichthyoplankton collections (36% of all fish larvae) and in trawl collections (53% of fish in 4.9-m trawl catches). Most of the smelt caught by trawl and seine were young-of-the-year smelt captured during the fall season in the lower estuary.

The 1998-1999 study also included an estimate of adult smelt biomass to assist evaluations of the potential effects of power plant operations on the local smelt population (MRI, 1999). The egg production method was used, wherein egg deposition and drift were estimated and used to back-calculate adult smelt equivalency. The estimate for the Monatiquot River and Smelt Brook spawning habitat in 1999 was 312,505 adult smelt, however, there was substantial variation associated with the estimate (95% confidence intervals: 109-489 thousand adult smelt). The investigations were discontinued following 1999, in part due to an agreement by Sithe Energy Development to adopt air-cooled condensers for their power plant proposal. The decision to not use Fore River water in an open-cycle cooling system eliminates concerns related to the entrainment, impingement, and thermal influences from the power plant on smelt.

<u>Observations since 1990</u>

The smelt spawning habitat in the Fore River has been visited by this program each season since 1990 to obtain a sense of the status of annual spawning runs. Most visits were made during the peak spawning season to observe egg deposition. In some years we made one or two visits during mid-April and other seasons numerous visits (1997, 2000, 2001) were made. In 1997, we transferred smelt eggs (<100,000) from the Monatiquot River to the Crane River, Danvers, during a DMF smelt restoration project. We made weekly visits during the 2001 spawning season to monitor the smelt run in relation to a proposal to reinstate the Old Colony train line. From these visits we have gained a better understanding of smelt population trends in the Fore River, and have learned that the delineation of Smelt Brook spawning habitat made during 1988-1989 was not complete.

Population Trends. Substantial annual variation was observed in the size of spawning runs, amount of egg deposition and catches in local sportfisheries during the period of 1988-2001. Overall, we have seen no clear relationship between observations of egg deposition and subsequent recruitment to the Fore River spawning stock or local sportfisheries for smelt. The egg deposition observed in 1989 stands out as the highest densities observed in the Fore River by this program during 1988-2001. The spawning seasons in 1994, 1995 and 2000 were notable for egg deposition well above average densities. The only year during this period with an available population assessment was 1999 (MRI, 1999) and the egg deposition that produced the estimate of over 300,000 adults could be qualitatively classified as average. Very low egg densities were observed during 1990-1992 and again during 1996-1998. A large majority of adult smelt in recent Massachusetts Bay spawning runs are age-2 (Chase, 1993 and 1996). Two years following the high egg deposition observed in 1989, 1994, and 1995 we observed very poor egg deposition in the Fore River and received reports of lackluster smelt fishing in Hingham and Quincy Bay. Additionally, better than average fishing seasons appear to have little synchrony to earlier observations of egg deposition. The participation and catch in the 1994 fall/winter sportfishery for smelt in this region was probably the highest during 1988-2000, while 1993, 1995, and 2000 showed better than average catches. These fisheries catch adult smelt of which age-2 smelt are most common. None of these fishery seasons correspond to observations of large numbers of eggs two years earlier. We caution that these are qualitative observations: we did not conduct quantitative assessments of either the smelt population or local sportfisheries.

The variability seen in Fore River smelt spawning runs has been noted in other New England smelt populations (Kendall, 1926; and Rupp, 1959). Poor relationships between egg production and recruitment to the spawning stock are common for marine fish populations (Rothschild, 1986). We have observed some consistency in the annual strength of Massachusetts Bay smelt spawning runs among the larger populations. When high or low egg densities are observed in the Fore River, similar trends are often observed in the Back River (Weymouth) or Neponset River (Dorchester/Milton). Overall, the Fore River and these larger Boston Harbor smelt runs have varied widely in year class strength since 1988 and continue to support modest sportfisheries in the region. A widely held, but undocumented concern exists among smelt fishermen that populations in Massachusetts Bay have greatly declined during the past 20 years. The Fore River population appears to have declined during this period, although possibly not as severely as smaller coastal river systems in the region.

Smelt Brook. Our understanding of smelt passage in Smelt Brook as of 1990 was that smelt could enter and spawn in the culverts below the railroad bed in Smelt Brook, but could not pass above the grated spillway found on the upstream side of Rt. 53. We recorded the area of substrate where we actually observed smelt eggs and recognized there was uncertainty over the distance smelt would pass and spawn in the culverts. Since then, we have learned that smelt passage above the grated spillway was incorporated into the US Army Corps of Engineers flood control project constructed during the mid-1970s (ACOE, 1976). A 2 ft. by 4 ft. sluice gate was constructed near the grated spillway of the 8 ft culvert that can be operated to allow smelt passage from the 6 ft culvert. The two culverts are separate for the entire length (347 m for 8 ft culvert). The 6 ft culvert is not continuous: box culverts, stone channels, and a smaller round culvert makes up some of the distance to the sluice gate. The Operation and Maintenance Manual for the project stipulates that the sluice gate should be opened from March 1st to May 31st each year to allow smelt passage at the discretion of the Weymouth-Braintree Regional Recreational-Conservation District (ACOE, 1976). Therefore, upstream smelt passage is possible via spring flows that are directed through the 6-ft culvert.

Through discussions with the Recreational-Conservation District (J. Paul Toner, pers. comm., 2000) we learned that smelt migrations above the sluice gate have been observed in recent years. In addition to the substrate within the 6 ft culvert, smelt have access to spawn in over 200 m of channelized streambed from the sluice gate upstream until a raised culvert prevents further passage. This additional amount of potential spawning habitat in the Smelt Brook is noted in Table A2. We visited the upstream stretch on a weekly basis during the 2001 spawning season and did not find smelt eggs or evidence of smelt passage. A more formal effort commissioned by the Massachusetts Bay Transportation Authority (MBTA) in 2001 also did not find evidence of smelt spawning above the sluice gate (MRI, 2001). The MBTA study did find minor evidence of spawning upstream of station SB, adjacent to a Weymouth Landing pub where the 6 ft culvert is briefly day-lighted.

The realization that more spawning habitat is available to smelt in Smelt Brook is encouraging, although it is also apparent that the complexity of these flood control structures are a serious challenge to upstream smelt movements. Suitable spawning habitat is found above the sluice gate, however the spawning habitat below the sluicegate where most spawning occurs has been severely degraded by sewage and stormwater inputs, and is compromised by highly saline flood tides. It appears likely that smelt in Smelt Brook have not had an open channel to spawn in for nearly 50 years. The city of Weymouth received a license in 1953 (Norfolk Registry of Deeds, Dedham, MA, File No. 1576, License No. 247) for flood control work that filled the open Smelt Brook channel and diverted flows into the 6 ft culvert. The continued presence of smelt in Smelt Brook is a reflection of the resilience incorporated into the spawning habits of this species. There are few examples in Massachusetts Bay of smelt runs persisting in river systems that require passage in culverts that exceed 100 m. There is still great concern for this spawning run because of the small number of returning adults and poor condition of existing spawning habitat. We have consistently observed very high mortality of smelt eggs deposited below the culvert openings. It is possible that the spawning habitat use and egg deposition in Smelt Brook is largely subsidized by production in the Monatiquot River.

Concerns for the Fore River Smelt Population

The cause and effect of declines in smelt populations in Massachusetts Bay during the last 20 years is not well quantified. However, it is not difficult to visualize the threats confronting populations of fish when their adapted spawning locations have become centers of human development during the last 300 years. Smelt spawning habitat in Massachusetts Bay is typically located in coastal rivers that were historically developed for water power, commerce and transportation, and more recently, for residency and flood control. These activities have resulted in a variety of challenges to spawning runs of smelt, including passage impediments, streambed alterations, acute pollution discharges, and chronic stormwater inputs. The watershed of the Fore River contains over 170,000 people in the three coastal cities (Quincy, Braintree, and Weymouth), is highly urbanized (Mass. Bay Program, 1997) and contains all the above challenges to smelt. The following paragraphs summarize observations related to major concerns to the Fore River smelt populations.

Adult Smelt Passage. Spawning smelt in the Monatiquot River have access to a relatively large amount of spawning habitat. No major impediment to adult passage or evidence of habitat limitations on egg deposition was observed. The rapids at station MR can act as a temporary impediment to smelt movements until the flood tide reduces the turbulence and elevation rise caused by a pile of boulders. The degree to which this reduces passage depends on the timing of smelt movements relative to river flow and tide stage. Smelt will spawn at this junction and we have repeatedly observed poor egg survival here and suspect large numbers of eggs die after being swept downstream. The lip of the McCusker Drive sluiceway presents a barrier to smelt passage under most flow conditions. A small amount of spawning habitat (Table A1) could be gained by passage above this lip. The conditions in Smelt Brook are not as favorable to upstream passage. Smelt must pass through about 300 m of culvert before reaching a small sluice gate. We suspect that the grade increase from the 6 ft culvert face to the sluice gate opening combined with strong spring flows must create difficult passage for smelt.

Stormwater Inputs. Stormwater dynamics in the watershed may be impacting the smelt spawning habitat by the contribution of pollutants and reductions in base flows. Sediments, nutrients, and toxins are carried from the watershed to the Fore River via stormwater flows. Reductions in pervious surfaces can result in the concentration of some pollutants at sensitive habitats. Increased development near Rt. 93 in recent years may exacerbate this concern. Relative to other Massachusetts Bay smelt runs, the Fore River still possesses stretches with strong flows, and adequate shading and land buffering, all which help reduce the negative influences of stormwater inputs. However, we suspect that alterations to watershed stormwater dynamics have resulted in specific local changes to streambed sedimentation, nutrient concentrations and freshwater discharge. These stormwater related concerns are difficult to quantify but are suspected to have an influence on observed degradation of water and habitat quality in the Fore River. Sedimentation impacts are clearly observed below the Smelt Brook culverts and the conditions have degraded since we began visiting this location in 1988.

Freshwater Discharge. We are concerned over the sustainability of adequate base flows to provide suitable conditions for egg deposition and survival during the spring spawning period. In recent years we have observed large gravel banks upstream of MR that become exposed to air as the season progresses and water levels decline. Eggs deposited in late-March or early April are susceptible to exposure during their long incubation period. We have observed high egg mortality in some years due to this problem. However, without discharge data from a stream gauge station on the Fore River it is not possible to know if this problem is related to reductions in base flows. It is possible that climatic trends, changes in river hydrology or changes in municipal water withdrawal practices may influence the exposure of the gravel banks in recent years. We suspect that losses of pervious surfaces in the watershed contribute to the problem by reducing the retention and participation of stormwater in base flows.

Nutrient Inputs. Our concern relates to the potential for higher nutrient concentrations to degrade smelt spawning habitat by increasing periphyton growth rates and altering natural algal communities. Nutrient inputs largely originate from watershed sources and therefore can be considered a subset of stormwater concerns. Additional mention is warranted because nutrient inputs also occur from direct atmospheric deposition and point sources (ex. Smelt Brook sewer overflow). We have routinely observed sharp increases in periphyton growth during the spawning season, typically beginning during late-March or early-April. We have observed periods of high periphyton growth that coincide with large events of egg deposition, resulting in high egg mortality. The growth of periphyton presumably is not optimal for egg respiration and metabolism during this period when incubation lasts 2-3 weeks. This condition is most pronounced along stretches of the Fore River where flow and shading are reduced.

Other sources of Mortality. We have little information on threats to Fore River smelt once they leave the upper estuary. Fishing and natural mortality rates of larval, juvenile and adult smelt in this region are not known. We suspect that fishing mortality is not a major influence in smelt population dynamics because a commercial fishery is absent and the sportfishery involves very little catch and effort. Concerns have been raised by the sportfishing community over increases in predation, particularily from cormorrants, seals and striped bass. We have observed large numbers of gulls and cormorrants feeding on smelt at choke points in the spawning run (stations SB and MR). We would not expect that natural predation is driving population trends. However, we have little information on this topic and on local trophic interactions that involve larval and adult smelt.

RECOMMENDATIONS

1. *Stream flow gauge station*. Annual discharge data on freshwater flows in the Fore River will be essential for aquatic resource management in this valuable river system. We recommend that a gauge station is installed and continuously operated on the Monatiquot River.

2. *Adult smelt passage improvements (Monatiquot River)*. Minor physical alterations to the sluiceway lip at McCusker Drive and the boulder pile at station MR could assist adult smelt passage. We recommend that these options be evaluated when resource restoration funds become available for the region. We also recommend that local interests monitor the accumulation of debris at the McCusker Driver sluiceway each spring season and remove the debris when necessary.

3. *Adult smelt passage improvements (Smelt Brook).* Improvements to adult smelt in Smelt Brook will be a greater challenge because of the complexity of the existing flood control structures. Structural changes to flood conduits will be costly. We recommend that the present operation requirements for the flood control system are evaluated by all concerned parties and that structural and operational methods to improve smelt passage are identified.

4. *Riverbank protection.* Locations with stable river banks, adequate vegetative shading and buffering and clear passage for migrating fish should be protected. River stretches that are lacking suitable conditions should be considered for local restoration projects.

5. *Stormwater Inputs.* We recommend that local, state and federal authorities consider the importance of smelt spawning habitat during planning and construction for projects that contain stormwater conveyances to the Fore River. We recommend that all such projects should strive to comply with Best Management Practices and seek advanced stormwater treatment and/or retention when in close proximity to sensitive habitats.

6. *Sewer Overflow.* The sanitary sewer overflow located at station SB should be eliminated. We understand that plans are under evaluation to reduce the frequency of these raw sewage overflows. Given the proximity to smelt spawning habitat, soft-shell clam beds, and the upper estuary of the Fore River, we recommend that future raw discharges should not be permitted.

7. *Nutrient impacts.* The relationships related to the source and fate of nutrient inputs in river systems that support anadromous fish need to be better understood. Scientific research should be conducted on these relationships, however, local efforts can contribute immediately by reducing the consumption of materials that can result in increased water concentrations of nutrients in the Fore River.

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This report supersedes the progress report issued on smelt spawning habitat in the Fore River in 1990 (B. Chase, Progress Report for 1988 and 1989 on the Weymouth-Fore River, Mass. Division of Marine Fisheries, STAP Doc. No. 89-02). This report contains corrections of a small number of transcription errors on water chemistry measurements and measurements of ichthyoplankton lengths from the 1990 progress report.

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APPENDIX

Table A1. Measurements of smelt spawning habitat in the Monatiquot River. Measurements were made of the wetted perimeter of river stretches where smelt eggs were observed during 1988-1990.

River Stretch	Length (m)	Width (No.)	Width (Ave. m)	Area (m^2)	Notes
A. Shaw St. to RR Bridge	60	6	12.8	768	intertidal zone with low egg deposition
B. RR Bridge to boulders	42	4	7.5	315	intertidal zone with high egg deposition
C. Straight stretch above rapids to Commercial St.	60	4	12.9	774	tidal influence possible, few eggs
	60	4	16.7	1002	tidal influence possible, more eggs
	60	4	12.8	768	Prime riffle habitat
	60	4	10.1	606	Prime riffle habitat
	55	4	7.2	396	Prime riffle habitat
D. Under Commercial St. Bridge	13.5	2	4.6	62	minor egg deposition under bridge
E. Straight stretch above Bridge until narrow bend	40	3	6.8	272	Prime riffle habitat
	60	4	7.7	462	Prime riffle habitat
	40	3	7.4	296	Prime riffle habitat
	60	4	8.2	492	Prime riffle habitat
	60	4	7.7	462	Prime riffle habitat
	40	3	8.0	320	Prime riffle habitat
	50	4	6.8	340	Prime riffle habitat
	20	2	6.6	132	Prime riffle habitat
F. Rapids leading up to McCusker Drive	40	3	6.6	264	fast flow can impede passage
	40	3	6.6	264	fast flow can impede passage
	40	3	6.7	268	fast flow can impede passage
	22	2	9.2	202	pool before sluiceway lip
G. Upstream of McCusker to impassable rapid	42	3	7.9	332	potential habitat; have not observed eggs above sluiceway lip
Total habitat with eggs	922.5			8465	
Total potential habitat	964.5			8797	

APPENDIX

Table A2. Measurements of smelt spawning habitat in Smelt Brook. Measurements (A-D) were made of the wetted perimeter of river stretches where smelt eggs were observed during 1988-1990. Measurements E-G were made of potential upstream habitat during 2001. River stretch F (inside culvert) is an approximation from A upstream to the daylighted box culvert. We did not include from the box culvert to the sluicegate because little is known of the physical structure or spawning use of this segment.

	River Stretch	**Length** (m)	**Width** (No.)	**Width** (Ave. m)	**Area** (m^2)	**Notes**
A	Inside 6-ft culvert	10	1	1.5	15	found eggs up to 10 m inside culvert
B	Culvert opening downstream	60	4	4.7	282	most eggs were located at culvert opening to 20 m downstream
C	Continue downstream in channel	60	4	6.1	366	minor egg deposition in low tide channel
D	Continue downstream in channel	40	4	3.9	156	minor egg deposition in low tide channel
E	Inside 6-ft. culvert (upstream of A)	170	1	1.5	255	potential habitat
F	Open stream channel upstream of sluicegate	198	11	2.0	396	potential habitat: good quality habitat
G	Box spillway leading to impassable culvert	13	2	4.5	59	potential habitat
	Total habitat with eggs	170			819	
	Total potential habitat	551			1529	

APPENDIX **Table A3.** Water Chemistry Measurements

Sample Location: Monatiquot River, railroad bridge (MR)

Year: 1988

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDAL INFLUENCE	TIDE AMP. (ft.)	AIR TEMP. (C°)	WATER TEMP. (C°)	SALINITY (ppt)	pH
3-03-88	0926	low +4.0	No	9.6	10.5	4.0	0.0	
3-08-88	1215	low +3.5	No	8.7	12.5	5.0	0.0	6.9
3-10-88	1105	low +0.5	No	8.0	8.0	6.0	0.0	7.8
3-14-88	0925	high +1.5	Yes	9.8	1.0	4.0	0.0	7.9
3-16-88	1130	high +1.5	Yes	10.8	7.0	4.5	0.0	6.8
3-21-88	0945	low +1.5	No	11.2	-3.0	2.0	0.0	7.5
3-24-88	0854	high +4.5	No	9.6	11.0	6.0	0.0	7.7
3-28-88	0837	high tide	Yes	8.6	6.0	8.5	0.0	7.2
3-31-88	1509	high +4.5	No	9.2	12.0	12.0	0.0	7.3
4-04-88	0945	low +1.5	No	9.2	9.0	12.0	0.0	7.4
4-07-88	1411	low +4.0	No	8.4	6.0	9.0	0.0	7.6
4-11-88	0909	high +1.5	Yes	9.6	5.0	9.0	0.0	7.5
4-14-88	1112	high +0.5	Yes	10.4	6.0	8.5	0.0	7.3
4-20-88	1040	low +1.0	No	9.0	6.5	9.0	0.0	7.3
4-22-88	1008	high +5.5	No	8.1	7.5	7.5	0.0	7.5
4-25-88	1110	high +3.5	No	8.4	11.5	9.0	0.0	7.7
4-28-88	1028	high tide	Yes	8.7	13.0	13.0	0.0	7.1
5-02-88	1240	low +5.5	Yes	9.1	6.5	11.0	0.0	7.4
5-05-88	0850	low tide	No	8.8	17.0	14.0	0.0	7.5
5-09-88	1142	high +5.5	No	9.7	13.5	16.0	0.0	7.5
5-11-88	0848	high +0.5	Yes	9.6	12.5	14.0	0.0	7.7
5-19-88	0913	low tide	No	8.8	9.0	13.5	0.0	7.7
5-23-88	0905	high +3.0	No	8.7	18.5	16.5	0.0	7.7
5-26-88	1053	high +2.0	No	8.3	13.5	14.5	0.0	7.5
6-02-88	0842	low +0.5	No	9.1	9.5	14.5	0.0	7.6
Average					9.2	9.7	0.0	7.5

Tidal delay: Approximately 45 minutes from Boston Harbor

APPENDIX **Table A4.** Water Chemistry Measurements

Sample Location: Monatiquot River, railroad bridge (MR)

Year: 1989

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDAL INFLUENCE	TIDE AMP. (ft.)	AIR TEMP. (C°)	WATER TEMP. (C°)	SALINITY (ppt)	pH	D.O. (ppm)
3-01-89	1037	high +5.0	No	9.0	5.0	2.0	0.0		
3-03-89	0915	high +2.0	No	9.4	-1.5	0.5	0.0	7.8	15.0
3-06-89	1356	high +3.5	No	11.0	-4.0	1.0	0.0		
3-08-89	1514	high +3.0	No	11.7	-5.0	0.0	0.0		
3-10-89	0909	low +1.5	No	11.2	-0.5	0.5	0.0	7.5	15.0
3-15-89	0845	high +3.0	No	9.8	9.0	4.5	0.0	7.6	13.8
3-20-89	1510	high +4.5	No	9.7	4.0	5.0	0.0		
3-24-89	1425	high +1.0	No	9.5	4.0	7.0	0.0	7.9	12.8
3-27-89	1245	low +3.5	No	8.6	14.0	9.0	0.0		
3-31-89	0845	high +2.5	No	9.3	3.0	7.0	0.0	6.9	11.5
4-07-89	0923	low +2.0	No	11.2	10.0	8.0	0.0	7.4	11.9
4-14-89	0940	high +2.0	No	9.2	9.0	7.0	0.0	7.3	11.6
4-19-89	1455	high +3.0	No	9.3	8.0	12.0	0.0		
4-21-89	0845	low +2.0	No	9.3	9.0	11.5	0.0	7.6	11.0
4-25-89	1405	low +4.5	Yes	8.7	9.0	13.0	0.0		
4-28-89	0830	high +3.0	No	9.7	8.0	11.5	0.0	7.5	10.8
5-05-89	0920	low +3.0	No	10.7	15.0	15.0	0.0	7.2	10.0
5-12-89	0910	high +3.0	No	9.5	15.0	13.0	0.0	7.3	10.6
5-18-89	0900	low +4.5	No	8.9	15.5	16.0	0.0		
5-25-89	1315	low +3.5	No	8.9	18.5	18.0	0.0		
6-09-89	1254	low +2.0	No	9.1	14.0	17.0	0.0	6.9	9.6
Average					7.6	8.5	0.0	7.4	12.0

Tidal delay: Approximately 45 minutes from Boston Harbor

APPENDIX **Table A5.** Water Chemistry Measurements

Sample Location: Monatiquot River, railroad bridge (MR)

Year: 1990

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDAL INFLUENCE	TIDE AMP. (ft.)	AIR TEMP. (C°)	WATER TEMP. (C°)	SALINITY (ppt)	pH	D.O. (ppm)
3-01-90	0928	low +1.0	No	10.4	-2.0	0.0	0.0	7.4	14.7
3-06-90	0910	high +2.0	No	9.9	-3.5	0.5	0.0	7.3	14.5
3-08-90	0845	low +5.5	Yes	10.1	-6.0	0.0	0.0	7.2	15.0
3-14-90	1415	high +0.5	Yes	9.6	8.0	8.0	0.0	7.5	13.3
3-20-90	0850	high +3.0	No	8.8	6.0	8.0	0.0	7.4	11.3
3-22-90	0840	high +1.0	No	9.2	5.5	6.0	0.0	7.4	13.0
3-27-90	0843	low +3.0	No	11.1	-3.0	4.5	0.0	7.5	12.8
3-29-90	0833	low +1.0	No	10.8	0.0	5.0	0.0	7.5	13.0
4-03-90	0858	high +2.0	No	9.9	4.0	5.5	0.0	7.3	12.1
4-05-90	0849	high tide	Yes	9.7	4.5	6.0	0.0	7.3	12.8
4-10-90	1358	high +1.0	Yes	9.7	12.5	9.0	0.0	7.4	12.2
4-12-90	0856	low +0.5	No	9.3	4.0	8.5	0.0	7.3	11.3
4-17-90	0900	high +3.5	No	9.2	10.0	11.5	0.0	7.3	10.8
4-19-90	0843	high +1.5	No	9.1	4.0	8.0	0.0	7.4	12.0
4-24-90	0911	low +3.5	No	10.7	8.0	13.5	0.0	7.3	
4-26-90	0857	low +1.5	No	10.8	9.5	11.5	0.0	7.3	10.8
5-01-90	0912	high +3.5	No	10.4	8.5	10.5	0.0	7.4	10.6
5-08-90	1419	high +2.0	No	9.2	12.0	13.0	0.0	7.6	11.0
5-11-90	1313	low +5.5	Yes	9.0	10.0	17.0	0.0	7.2	9.6
5-15-90	1350	low +3.0	No	8.5	18.5	19.0	0.0	7.4	10.6
5-18-90	1230	low tide	No	9.4	14.5	13.5	0.0	7.2	11.4
5-22-90	1237	high +2.0	No	10.1	10.0	10.5	0.0	7.4	11.8
5-26-90	1615	high +2.0	No	10.3	17.5	17.5	0.0	7.4	9.6
5-29-90	1327	low +3.0	No	9.7	13.5	18.0	0.0	7.5	9.0
Average					6.9	9.4	0.0	7.4	11.9

Tidal delay: Approximately 45 minutes from Boston Harbor

APPENDIX **Table A6.** Water Chemistry Measurements

Sample Location: Smelt Brook, 6-ft culvert opening (SB)

Year: 1989

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDAL INFLUENCE	TIDE AMP. (ft.)	AIR TEMP. (C^o)	WATER TEMP. (C^o)		SALINITY (ppt)		pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-03-89	0952	high +4.5	Yes	9.4	-0.5	1.0	1.5	0.0	17.0	7.7		14.5	
3-06-89	1447	high +4.5	No	11.0	-3.0	2.0		0.0					
3-08-89	1536	high +3.5	Yes	11.7	-5.0	1.0		3.0					
3-10-89	0845	low +1.5	No	11.2	-1.5	1.5		0.0		7.0		14.8	
3-15-89	0754	high +2.0	Yes	9.8	10.5	3.5	2.0	10.0	29.0	7.5		11.8	10.3
3-20-89	1550	high +5.5	Yes	9.7	4.0	6.0		1.0					
3-24-89	1410	high +2.0	Yes	9.5	4.5	7.0	6.0	0.0	28.0	7.8		13.7	10.2
3-27-89	1220	low +3.5	Yes	8.6	14.0	10.0		4.0					
3-31-89	0833	high +2.5	Yes	9.3	2.0	7.0	7.0	0.0	0.0	6.8	6.8	11.6	11.6
4-07-89	0830	low +1.5	No	11.2	6.0	9.0	5.0	0.0		6.5			
4-14-89	0810	high +1.0	Yes	9.2	6.5	8.0	8.0	0.0	27.0	7.0		11.7	
4-19-89	1435	high +3.0	Yes	9.3	9.5	11.0	11.0	2.0	3.0				
4-21-89	0755	low +1.0	No	9.3	8.0	10.0		0.0		7.5		11.5	
4-25-89	1320	low + 4.0	Yes	8.7	12.0	12.5	10.0	2.0	15.0				
4-28-89	0800	high +3.5	Yes	9.7	10.5	10.0	10.5	1.0	25.0	7.0	7.8	11.0	8.0
5-05-89	0820	low +2.5	No	10.7	13.0	13.0		0.0		7.2		10.8	
5-12-89	0840	high +3.0	Yes	9.5	14.5	13.0	12.5	0.0	2.0	6.9	6.9	10.5	10.4
5-18-89	0830	low +4.5	Yes	8.9	15.0	14.5	14.0	0.0					
5-25-89	1245	low +4.0	Yes	8.9	18.0	17.5		3.0					
6-09-89	1308	low +2.5	Yes	9.1	14.0	16.5		1.0		6.9		9.0	
Average					7.6	8.7	8.0	1.4	16.2	7.2		11.9	

Tidal Delay: Approximately 30 minutes from Boston Harbor

APPENDIX **Table A7.** Water Chemistry Measurements

Sample Location: Smelt Brook, 6-ft culvert opening (SB)

Year: 1990

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDAL INFLUENCE	TIDE AMP. (ft.)	AIR TEMP. (C°)	WATER TEMP. (C°)		SALINITY (ppt)		pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-01-90	0940	low +1.0	No	10.4	-1.5	1.0		0.0		7.3		14.3	
3-06-90	0926	high +1.5	Yes	8.5	-3.5	2.0		0.0		7.2		13.8	
3-08-90	0915	high tide	Yes	9.2	-4.0	0.5	1.0	0.0	27.0	7.1	8.1	14.8	13.2
3-14-90	1440	high +1.0	Yes	9.6	9.0	8.0	5.0	0.0	28.0	7.3	8.3	12.8	15.0
3-20-90	0810	high +2.5	Yes	8.8	6.0	8.0		2.0		7.3		11.0	
3-22-90	0853	high +1.0	Yes	9.2	6.0	6.0		2.0		7.3		12.6	
3-27-90	0858	low +3.5	Yes	11.1	-3.5	3.5	3.5	0.0	0.0	7.4	7.4	13.0	13.0
3-29-90	0849	low +1.5	No	10.8	0.0	4.5		0.0		7.7		12.8	
4-03-90	0915	high +2.5	Yes	9.9	4.0	6.0		0.0		7.4		12.0	
4-05-90	0904	high tide	Yes	9.7	5.5	6.0	5.0	0.0	28.0	7.5	8.0	12.6	
4-10-90	1408	high +1.0	Yes	9.7	13.0	9.0	6.5	3.0	28.0	7.6	8.1	12.7	12.0
4-12-90	0911	low +1.0	No	9.3	4.5	7.5		0.0		7.1		11.6	
4-17-90	0916	high +4.0	No	9.2	9.0	11.0		0.0		7.2		10.8	
4-24-90	0925	low +4.0	Yes	10.7	8.5	11.0	10.0	0.0	25.0	7.2	8.2		
4-26-90	0913	low +2.0	No	10.8	10.5	11.0		0.0		7.4		10.7	
5-01-90	0924	high +4.0	No	10.4	8.0	11.0		0.0		7.4		10.4	
5-08-90	1403	high +2.0	Yes	9.2	9.0	13.5		1.0		7.4		10.7	
5-11-90	1300	low +5.5	Yes	9.0	10.0	17.0	14.0	1.0	30.0	7.2	7.8	9.6	8.5
5-15-90	1339	low +3.5	Yes	8.5	16.0	19.0		2.0		7.4		10.1	
5-18-90	1209	high +5.5	No	9.4	12.0	13.5		0.0		7.2		11.5	
5-22-90	1208	high +2.0	Yes	10.1	9.0	11.5	11.0	0.0	25.0	7.4	7.6	11.5	8.5
5-26-90	1558	high +2.0	Yes	10.3	15.0	16.0		2.0		7.4		9.6	
5-29-90	1315	low +3.0	Yes	9.7	13.5	16.5		0.0		7.4		9.4	
Average					6.8	9.3	7.0	0.6	23.9	7.3	7.9	11.7	11.7

Tidal Delay: Approximately 30 minutes from Boston Harbor

APPENDIX **Table A8.** Water Chemistry Measurements

Sample Location: Braintree Yacht Club, Fore River (FR)

Year: 1988

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDE AMP. (ft.)	DEPTH (ft.)	AIR TEMP. (C°)	WATER TEMP. (C°)		SALINITY (ppt)		pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-03-88	0905	low +3.5	9..6		11.0	4.0		3.0					
3-08-88	1150	low +3.0	8.7		12.0	4.5		8.0		7.9			
3-10-88	1030	low +0.5	8.0	7.5	14.0	6.0	4.0	3.0	29.0	7.1	8.2		
3-14-88	0830	high +0.5	9.8	17.4	0.5	3.5	3.5	4.0	28.0	8.4	8.5		
3-16-88	1035	high +0.5	10.8	16.4	8.0	5.0	4.5	6.0	31.0	7.8	8.4		
3-21-88	0930	low +1.5	10.1	7.5	-2.0	2.0	4.0	3.0	28.0	7.5	8.3		
3-24-88	0830	high +4.5	9.6	8.2	12.0	4.5	3.5	6.0	29.0	8.0	8.3		
3-28-88	0910	high +1.0	8.6	13.1	7.5	9.0	5.0	5.0	30.0	7.5	8.2		
3-31-88	1452	high +4.5	9.2	8.2	14.0	12.0	8.0	3.0	27.0	7.2	8.1		
4-04-88	0850	low +2.0	9.2	8.2	14.0	11.0	7.5	5.0	31.0	7.4			
4-07-88	1353	low +4.0	8.4	13.1	5.5	8.5	7.5	4.0	29.0	7.6			
4-11-88	0828	high +1.0	9.6	14.1	5.0	9.0	7.5	3.0	26.0	7.6	8.0		
4-14-88	1138	high +1.0	10.4	14.8	6.0	9.0	8.0	5.0	30.0	7.6	8.1		
4-20-88	1054	low +1.5	9.0	8.2	6.5	9.0	8.0	5.0	31.0	7.4	8.0		
4-22-88	1046	low tide	8.1	8.2	8.0	8.0	7.5	6.0	30.0	7.8	8.2		
4-25-88	1015	high +2.5	8.4		11.0	8.5	8.0	8.0	30.0	7.7			
4-28-88	1045	high +0.5	8.7	13.1	13.0	12.5	9.0	4.0	30.0	7.1			
5-02-88	1254	high tide	9.1	16.4	7.0	11.0	9.0	4.0	29.0	7.4	7.9		
5-05-88	0923	low +0.5	8.8	4.9	17.0	15.0	11.5	4.0	30.0	7.6	8.0		
5-09-88	1209	low tide	9.7	6.6	12.5	16.5	12.0	6.0	30.0	7.7			
5-11-88	0911	high +1.0	9.6	11.5	14.0	14.0	12.0	3.0	29.0	7.5			
5-19-88	0921	low +0.5	8.8	6.6	9.0	13.5	13.5	2.0	22.0	7.7			
5-23-88	0824	high +2.5	8.7		19.0	16.0	13.0	7.0	31.0	7.7	7.8		
5-26-88	1020	high +1.5	8.3		17.0	15.0	14.0	5.0	30.0	7.6	7.5		
6-02-88	0918	low +1.5	9.1		9.0	14.0	14.5	4.0	28.0	7.4	7.5	8.3	3.8
Average					10.0	9.6	8.5	4.6	29.0	7.6	8.1		

Tidal Delay: Approximately 30 minutes from Boston Harbor

APPENDIX **Table A9.** Water Chemistry Measurements

Sample Location: Braintree Yacht Club, Fore River (FR)

Year: 1989

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDE AMP. (ft.)	AIR TEMP. (C°)	WATER TEMP. (C°)		SALINITY (ppt)		pH		D.O. (mg/l)	
					Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-01-89	1030	(ice cover)	9.0									
3-03-89	0850	high +1.5	9.4	0.0	0.0		1.0		7.5		14.6	
3-06-89	1342	high +3.5	11.0	-3.0	1.0		7.0					
3-08-89	1451	high +3.0	11.7	-5.0	0.0		2.0					
3-10-89	0942	low +2.5	11.2	-1.5	0.5		1.0		7.4		14.7	
3-15-89	0725	high +1.5	9.8	11.0	4.0	3.0	9.0	31.0	7.7		13.6	10.9
3-20-89	1445	high +4.5	9.7	4.5	5.0	4.0	7.0	34.0				
3-24-89	1400	high +1.0	9.5	5.0	6.5		1.0		7.7		13.1	
3-27-89	1310	low +4.5	8.6	13.5	9.0	7.0	5.0	34.0				
3-31-89	0730	high +1.5	9.3	2.5	7.0	6.0	0.0	28.0	7.0	7.6	11.6	9.1
4-07-89	0900	low +2.0	11.2	7.0	10.0	7.5	0.0	26.0	7.6	7.8	11.9	8.5
4-14-89	0830	high +1.0	9.2	12.0	9.0	7.0	4.0	30.0	7.1		11.2	10.4
4-19-89	1512	high +3.5	9.3	8.0	12.0	8.5	4.0	32.0				
4-21-89	0820	low +2.5	9.3	9.0	11.5	8.5	0.0	28.0	7.3	8.2	11.2	10.2
4-25-89	1340	low +4.5	8.7	12.0	12.5		2.0					
4-28-89	0709	high +4.0	9.7	7.0	11.0	10.0	4.0	29.0	6.9	8.1	9.9	8.8
5-05-89	0850	low +3.0	10.7	15.0	15.0	11.0	2.0	30.0	7.4	8.1	10.0	9.0
5-12-89	0746	high +2.0	9.5	15.0	12.5	11.0	4.0	30.0	7.0	7.9	10.0	7.7
5-18-89	0941	low +5.0	8.9	19.0	17.0		3.0					
5-25-89	1300	low +3.0	8.9	19.0	20.0		2.0					
6-09-89	1850	high +2.0	9.1	12.5	16.0	14.0	1.0	28.0	7.2	7.7	9.0	5.6
Average				8.1	9.0	8.1	3.0	30.0	7.3	7.9	11.7	8.9

Tidal Delay: Approximately 30 minutes from Boston Harbor

APPENDIX **Table A10.** Water Chemistry Measurements

Sample Location: Braintree Yacht Club, Fore River

Year: 1990

DATE	TIME OF DAY	TIDE STAGE (hrs.)	TIDE AMP. (ft.)	AIR TEMP. (C^o)	WATER TEMP. (C^o) Surface	WATER TEMP. (C^o) Bottom	SALINITY (ppt) Surface	SALINITY (ppt) Bottom	pH Surface	pH Bottom	D.O. (mg/l) Surface	D.O. (mg/l) Bottom
3-14-90	1500	high +1.5	9.6	9.0	8.0	4.0	3.0	30.0	8.0	8.4	14.0	15.0
3-22-90	0915	high +1.5	9.2	6.0	6.5	6.0	4.0	30.0	7.7	8.2	12.9	11.6
4-10-90	1430	high +1.5	9.7	11.0	9.0	6.5	3.0	29.0	7.7	8.0	12.6	11.8
4-19-90	0910	high +2.0	9.1	4.0	8.0	7.5	0.0	28.0	7.5	8.1	12.0	11.9
5-08-90	1330	high +1.5	9.2	10.5	13.5	11.0	4.0	30.0	7.6	7.8	10.7	8.8
5-26-90	1530	high +1.5	10.3	15.5	16.5	11.5	7.0	28.0	7.5	7.7	9.4	9.0
Average				9.3	10.3	7.8	3.5	29.2	7.7	8.0	11.9	11.4

Tidal Delay: Approximately 30 minutes from Boston Harbor

Table A11. Ichthyoplankton samples from the Fore River (station FR), Braintree, 1988-1990.

Date	Species		Type	No.	Ave. Size (mm)	Density (No./100 m^3)
3/16/1988	Atlantic tomcod	*Microgadus tomcod*	larva	2	6.4	NA
3/28/1988	Atlantic tomcod	*Microgadus tomcod*	larva	4	8.4	NA
4/14/1988	rainbow smelt	*Osmerus mordax*	larva	227	7.5	1071
"	winter flounder	*Pleuronectes americanus*	larva	3	7.8	14
4/25/1988	rainbow smelt	*Osmerus mordax*	larva	116	6.8	316
"	Atlantic silverside	*Menidia menidia*	egg	6	1.1	16
"	P-S group	(see note)	egg	4	0.8	11
5/2/1988	rainbow smelt	*Osmerus mordax*	larva	30	6.6	NA
5/11/1988	rainbow smelt	*Osmerus mordax*	larva	13	6.4	37
5/23/1988	rainbow smelt	*Osmerus mordax*	larva	2	8.6	5
"	P-S group	(see note)	egg	2	1.1	5
5/26/1988	none					
3/15/1989	Atlantic tomcod	*Microgadus tomcod*	larva	61	7.0	140
"	radiated shanny	*Ulvaria subbifurcata*	larva	1	5.8	2
3/31/1989	Atlantic tomcod	*Microgadus tomcod*	larva	7	7.6	NA
4/14/1989	rainbow smelt	*Osmerus mordax*	larva	13	7.3	21
"	Atlantic silverside	*Menidia menidia*	egg	3	1.1	5
"	radiated shanny	*Ulvaria subbifurcata*	larva	1	8.4	2
"	unidentified fish		egg	3	-	5
4/28/1989	rainbow smelt	*Osmerus mordax*	larva	217	6.4	556
5/12/1989	rainbow smelt	*Osmerus mordax*	larva	2	11.2	3
"	rainbow smelt	*Osmerus mordax*	larva	7	5.8	10
"	Atlantic silverside	*Menidia menidia*	egg	1	1.1	1
6/9/1989	Atlantic silverside	*Menidia menidia*	larva	4	6.3	NA
3/22/1990	Atlantic tomcod	*Microgadus tomcod*	larva	2	8.0	3
4/10/1990	Atlantic tomcod	*Microgadus tomcod*	larva	1	11.4	2
4/19/1990	Atlantic tomcod	*Microgadus tomcod*	larva	1	11.8	2
"	rainbow smelt	*Osmerus mordax*	larva	14	8.2	26
"	striped seasnail	*Liparis liparis*	larva	1	5.7	2
5/8/1990	rainbow smelt	*Osmerus mordax*	larva	45	7.5	NA
5/26/1990	rainbow smelt	*Osmerus mordax*	larva	2	5.9	NA

Notes: Average sizes are total length for larvae and diameter for eggs.
"NA" = flow was too low to measure with flow meter.
Paralichthys-Scopthalmus group is most likely windowpane (*Scopthalmus aquosus*).