

MASSACHUSETTS DIVISION OF MARINE FISHERIES
SPORTFISHERIES TECHNICAL ASSISTANCE PROGRAM

MASSACHUSETTS BAY SMELT SPAWNING HABITAT MONITORING PROGRAM

Preliminary Report on the Danvers River System

prepared by

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INTRODUCTION

A field sampling program was initiated in 1988 to delineate and monitor rainbow smelt (Osmerus mordax) spawning habitat in river systems located along Massachusetts Bay. The primary objective of the program is to document temporal, spatial and biological characteristics of smelt spawning in these river systems. This program will provide baseline data useful to resource management goals of protecting spawning habitat and sustaining the Commonwealth's smelt fisheries.

Smelt provide a valuable fall and winter fishery in many communities along the coast of Massachusetts. Smelt migrate from coastal waters into estuaries in the fall and are fished by hook and line until the fishery is closed on March 15th for the spawning season. Massachusetts Bay smelt populations are suspected to be well below historical levels of abundance. Consequently, sport-fishing catch and effort has sharply declined in the past decade.

Smelt are anadromous, maturing in coastal waters and the lower reaches of estuaries, then moving upstream past the extent of saltwater encroachment to spawn in the increased flow of shallow riffles. Eggs adhere to the substrate and aquatic vegetation. Observations of deposited eggs form the basis for delineating smelt spawning habitat.

Smelt populations exhibit much variability between river systems in the timing of spawning and selection of spawning habitat, using a range of water temperature, salinity and substrate type (Kendall 1927; Bigelow and Schroeder 1953; Rupp 1959). Spawning typically initiates when water temperatures reach 4-6 C°,

development may result in silt and sediment settling over spawning habitat, which can reduce egg survival. The relationship between spawning habitat alteration and the reduction of smelt populations in Massachusetts has not been evaluated.

It is possible that natural predation is contributing to the declines in Massachusetts smelt populations. The recent decline of smelt abundance has coincided with increases in populations of the following predators of smelt: bluefish, striped bass, cormorant and harbor seal. Although no definitive information is presently available, it is suspected that the summer feeding of striped bass, bluefish and cormorants, and the winter feeding of harbor seals could result in increased levels of natural mortality on smelt in the past decade. The declines in Massachusetts smelt populations may be a result of the cumulative impact of recent changes in predator-prey relationships, fishing pressure, and ongoing degradation of spawning habitat.

Secondary objectives of the program include the characterization of river systems through the collection of baseline water chemistry data, the collection of smelt life history data, and the documentation of the occurrence of other anadromous species. This report documents sampling in the Danvers River system, which was one of six Massachusetts Bay river systems chosen for study when the program was initiated in 1988. Recommendations are made to improve smelt and other anadromous fish runs in the Danvers River system. The restoration of anadromous fish will provide benefits by augmenting the forage base for important commercial and recreational species and by enhancing recreational fishing opportunities.

MASSACHUSETTS BAY SMELT SPAWNING HABITAT MONITORING PROGRAM

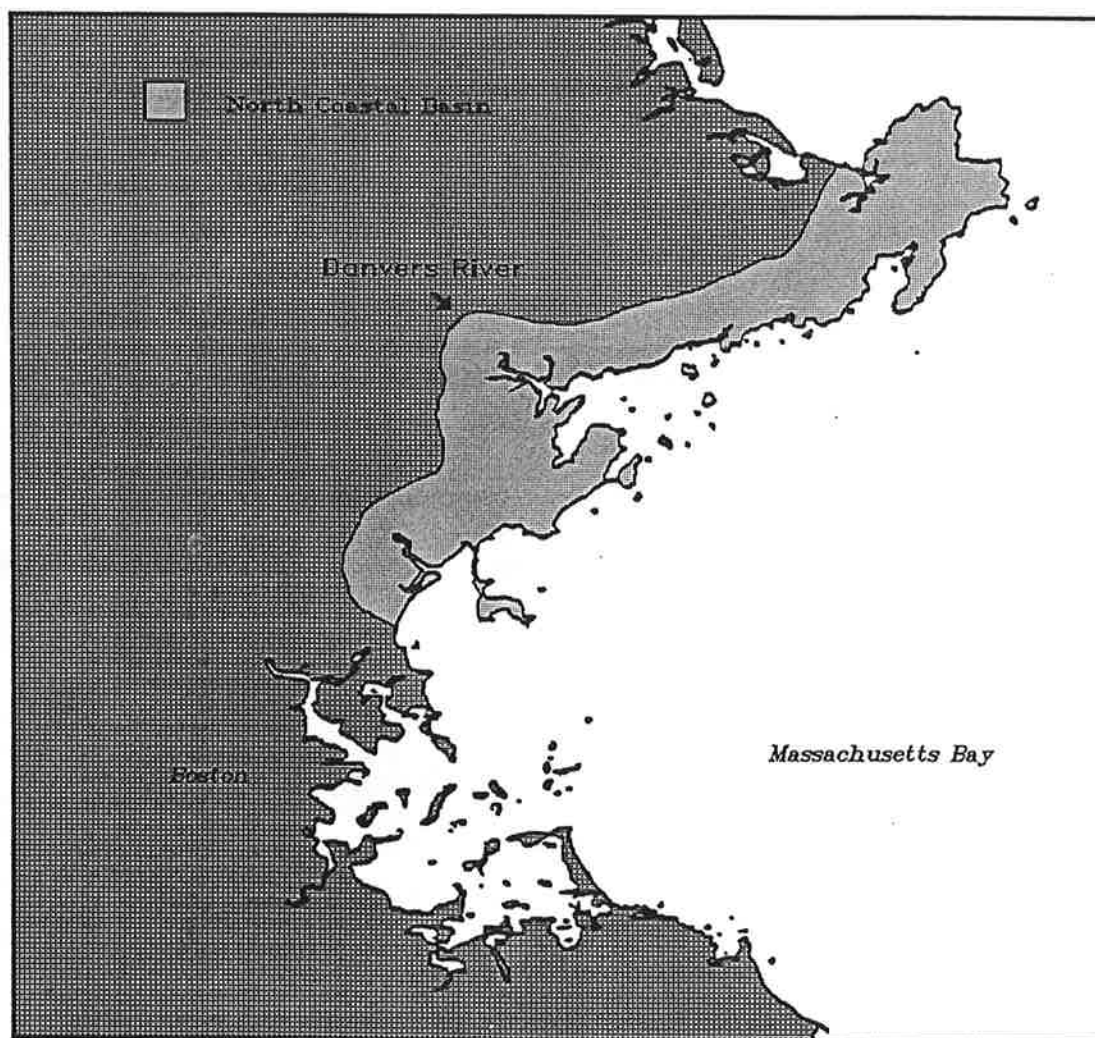


Figure 1. North Coastal Basin

conducted. Sampling conducted during 1965 for the MDMF Beverly-Salem Harbor Study found smelt to be the second most abundant species at the Danvers River beach seine location (Jerome et al. 1967). The 1972 Anadromous Fish Project Report by MDMF (Reback and DeCarlo 1972) did not mention a run of smelt in the Danvers River. Smelt have been known to spawn at one location in the Danvers River, at the interface of fresh and brackish water in the Porter River (H. R. Iwanowicz, pers. comm.)¹. Anecdotes passed on from old-time fishermen indicate that smelt runs in the Crane, North and Bass Rivers may have existed at one time.

All freshwater streams flowing into the Danvers River were surveyed in 1988 to select sample sites for potential spawning habitat. As a result of this survey, the Waters River was not selected because of insufficient freshwater flow and poor substrate conditions. Bass River was not selected because of obstructions to passage into the freshwater zone. North River was sampled in 1988, after which monitoring was discontinued because no evidence of spawning was found and the substrate was severely degraded due to chronic pollution.

The Crane River and Porter River were sampled from 1988 to 1990 (Figure 2). Spawning habitat sites were sampled below the Purchase Street culvert (CR-1) in the Crane River and upstream of Rt. 62 in the Porter River (PR-1). Ichthyoplankton samples were taken at the abandoned railroad bridge upstream of Rt. 35 in the Crane River (CR-3) and at the Rt. 128 bridge in the Porter River (PR-4) in 1989 and 1990.

1 H. R. Iwanowicz, Senior Marine Fisheries Biologist, MDMF, Salem.

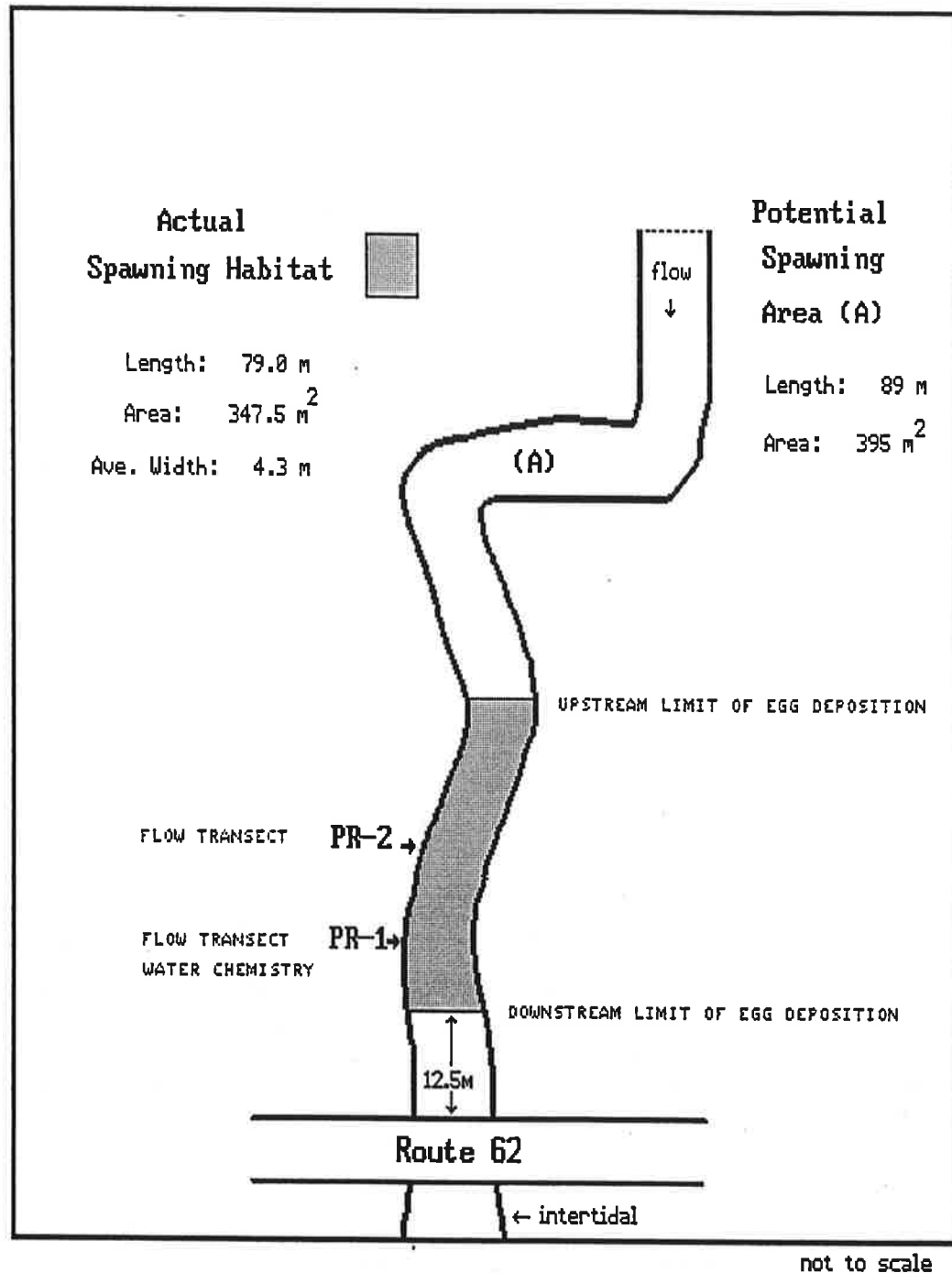
movements. A 0.14 m^2 rectangular plankton net with 0.505 mm mesh, was used to sample the ebb flow of surface water, within 2 hours of high tide. A 2030-R General Dynamics flowmeter attached to the net frame was used to measure stream flow rates (m/sec) and water volume sampled (m^3). Samples were preserved 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).

A Teledyne Gurley 622-G water current meter was used to measure stream velocity (m/sec) at spawning sites for 1991-1993. Sample transects were chosen where depth and width dimensions allowed for a uniform stream flow measurement. The m^2 dimension of the transect was multiplied by the average stream velocity to determine stream flow in cubic meters/second.

Upon completion of the sampling season, stream measurements were made to determine the area of available spawning habitat. Spawning areas were stratified into segments based on landmarks and shape of stream channel. Within each segment, length and width measurements were taken with a measuring tape ($\pm 0.1 \text{ m}$). Lengths were measured at mid-stream. Depth was measured by wading rule ($\pm 1 \text{ cm}$) along transects used for stream width or velocity measurements. Wet stream widths were measured at least every 20 m of stream length and averaged for each stream segment. Average widths and lengths were multiplied to produce total area (m^2) for each stream segment. Total spawning habitat was estimated from the area sum of all stream segments.

FIGURE 3.

PORTER RIVER SPAWNING HABITAT



Water chemistry data are reported in the Appendix and summarized in Table 1. Water chemistry samples were taken at the first riffle, approximately 30 m above the Rt. 62 culvert. The water temperatures that coincided with the start of the spawning period varied between seasons. Despite cold air (NOAA, 1989) and water temperature in early March of 1989, egg deposition was estimated to have begun on March 11th, at a water temperature of 1.0° C. Increased water depth at the spawning habitat due to tidal influence was observed on four occasions. On March 18, 1988, during a 3.4 m (11.2 ft) high tide, salinities of 1‰ (top) and 21‰ (bottom) were measured at the sample site. For average high tides, saltwater intrusion did not reach the substrate where eggs were deposited.

Egg survival does not appear to be threatened by acidity in the Porter River; the clay-lined stream bed may provide buffering. The pH measurements were very uniform for all three seasons: 7.6 ave., s = 0.29 (1988); 7.5 ave., s = 0.23 (1989); 7.5 ave., s = 0.16 (1990). Dissolved oxygen levels were saturated or near saturation throughout the study period.

Stream flow was measured on four occasions in the Porter River, using two transects (Figure 3; Table 2). The average flows ranged from 0.128-0.283 m³/sec (4.5 to 10.0 cfs). A small amount of substrate was exposed on April 17, 1991, when the flow of 0.128 m³ was measured. There was adequate water flow coverage of the substrate where eggs were deposited during the other three measurements (Table 2), which averaged 0.258 m³/second.

Porter River Ichthyoplankton Samples

Nineteen ichthyoplankton samples were taken in the Porter River (Table 3). The most frequently caught species was sand lance (6/19), followed by smelt (4/19). Smelt larvae were caught between May 10th and June 7th, with an average density of 5 larvae/100 m³, in samples that contained smelt larvae. Twelve species of finfish were represented in the samples, including a single winter flounder larvae. The most frequently caught finfish egg was the from the Labridae-Limanda group which, considering the season and egg size, were probably cunner eggs. Three juveniles were also caught in the ichthyoplankton net: mummichog, Atlantic herring and blueback herring. During extensive ichthyoplankton sampling in Salem Sound in the late 1970's, sand lance was found to be the most abundant larvae, and cunner was, by a large margin, the most abundant egg (Elliot et al. 1979).

Other Species

A notable observation was the catch of a 46 mm juvenile blueback herring on May 20, 1988. This catch provides evidence that there may be a river herring run in the Danvers River, with spawning probably occurring in the Crane or Porter Rivers. Catadromous American eel elvers were observed each year in the Porter River, beginning in mid-April. On April 27, 1988, a fyke net was retrieved after an overnight set in the Porter River, located approximately 75 m downstream of the Rt. 62 culvert. Nineteen adult smelt were caught, as well as 20 mummichog and 3 stickleback (Gasterosteidae). The 8 female and 11 male smelt were all aged as two year olds; the size range was 133-151 mm total length (ave. = 142 mm, s = 5.04).

Crane River

Three seasons of sampling produced no direct evidence of smelt spawning in the Crane River. Ample habitat was found where flow and substrate conditions were suitable for spawning, but passage to these locations was obstructed by the pump house sluiceway on Purchase Street, Danvers (Figure 4). Under most flow and tide conditions, the elevation change at the sluiceway is too steep for smelt to ascend. During very high tides and low flow conditions, such as observed on May 8, 1989 (3.7 m/12.2 ft. high tide), passage could be possible. This combination of flow and tide condition occurs infrequently in the spring, and was observed only once in the three year study period. Passage above the sluiceway could allow a smelt population to use the approximately 2,000 m² of potential spawning habitat above the pump house. Some stretches of the Crane River along the Walnut Grove Cemetery have excellent flow and substrate characteristics for smelt spawning.

On May 8, 1989, six eggs were found adhered to the substrate above the pump house. Three live eggs were brought back to the Cat Cove Marine Laboratory for hatching and identification. The eggs were 1.2 mm in diameter, and identification was narrowed down to smelt or blueback herring. The embryos died before hatching, preventing a positive identification of the species. It is possible that smelt passed above the pump house during the high tides a few days before. The eggs may have been blueback herring: there were no obvious stalks on the eggs which can characterize smelt eggs. Also, a school of eight river herring was observed in the pool before the sluiceway on May 13, 1988. No other eggs were found during the three sample seasons.

Ichthyoplankton samples taken at the abandoned railroad bridge on the Crane River also raised the question of the presence of a smelt run. Of 19 samples collected, smelt were the most frequently caught species (Table 4), followed by grubby and sand lance. The average density of smelt larvae found in the five samples containing smelt larvae was $2.7/100\text{ m}^3$. Smelt larvae were caught between April 27th and May 17th. It is not possible to determine if the larvae hatched out in the Crane River or were advected from the Porter River. Given the close proximity of the confluence of the Porter River to the sample site, it is likely that the larvae entered the Crane River during a flood tide. Overall, after 73 site visits during 3 seasons, it is reasonable to assume the Crane River does not have a smelt run. The chief limiting factor appears to be the obstruction of passage at the pump house.

No unusual characteristics were found with the water chemistry sampling (Table 5). There was ample dissolved oxygen for aquatic respiration throughout the study period. The pH levels were uniform in all three years, averaging 7.5 ($s = 0.22, 0.20, 0.19$ for 1988-1990, respectively).

North River

The North River was monitored for egg deposition in 1988 and water chemistry was sampled on the downstream side of the Rt. 114 culvert. No evidence of smelt spawning was found that season; consequently, monitoring of the site was discontinued. Potential spawning habitat in the North River was clearly degraded due to chronic pollution inputs. Discoloration and oil sheens in the water were commonly observed. Sediment testing in the North River

Table 5. Water Chemistry Summary: Crane River

		On Site Visits (#)	On Site Air Temp (C)	NOAA Air Temp (C)	NOAA Rainfall (in.)	SURFACE WATER CHEMISTRY			
						Temp (C)	Salinity (ppt)	pH	D.O. (ppm)
1988	March	9	3.9	3.6	3.7	4.1	0	7.3	-
	April	9	8.7	7.8	2.9	10.1	0	7.5	-
	May	8	14.1	14.0	4.4	15.6	0	7.7	-
	Season	26	8.7	8.5	11.0	9.7	0	7.5	-
1989	March	9	2.4	2.8	3.0	4.9	0	7.5	12.6
	April	8	9.4	7.2	4.3	9.6	0	7.4	11.7
	May	6	12.5	15.0	4.0	14.4	0	7.5	10.4
	Season	23	7.5	8.3	11.3	9.0	0	7.5	11.7
1990	March	8	6.1	3.7	1.9	5.5	0	7.5	13.8
	April	9	9.9	8.8	6.2	10.7	0	7.5	12.1
	May	7	12.9	12.2	6.5	14.1	0	7.5	10.6
	Season	24	9.5	8.2	14.6	10.2	0	7.5	12.2

Notes: NOAA air temperature and rainfall data are from Peabody, MA, station (NOAA 1988-1990). Monthly and seasonal data are averages of individual samples reported in tables 13-15.

DISCUSSION

The current abundance of smelt in the Danvers River system is probably well below levels found prior to industrial development. This survey, as well as anecdotal accounts, indicate that smelt may have previously spawned in the North, Crane and Bass Rivers. The same is true for river herring in the Crane and Bass Rivers. Presently, a small population of smelt spawn in the Porter River, and blueback herring appear to spawn in the Crane River. However, the size of the blueback herring population is so small that its detection nearly eluded three years of monitoring.

The causal factors for the decline of anadromous fish in the Danvers River cannot be known for certain, but there are some conditions in the tributaries that have clearly had local impacts. The construction of cooling ponds for the United Shoe Company on the Bass River blocked passage of anadromous fish to upstream freshwater locations. The dam in the Crane River cut off a run of alewives that formerly spawned in Mill Pond (Reback and DeCarlo 1972). The pump house sluiceway in the Crane River is another example of a physical obstruction that severely limits the amount of spawning habitat available to smelt.

Anadromous fish runs may have also been negatively impacted from the degradation of spawning substrate and water quality. The North River is the most obvious example of the impact of chronic pollution on spawning habitat. To an unknown degree, land and water use practices also have degraded the quality of habitat for aquatic organisms throughout the Danvers River estuary. Two primary sources of impact, observed but not quantified during the monitoring program, were sedimentation and nutrient loads.

Conant St. CSO was located less than 50 m downstream of the smelt spawning habitat in the Porter River. Raw sewage discharges were observed during each sampling season at this location, on the following dates: March 29, 1988, April 17, 1989, and April 6, 1990. The April discharges coincided with the onset of blooms of green algae in the stream, and appeared to enhance the extent of the blooms. Water quality testing in the region in 1985 found the Porter River at Rt. 62 to have the fourth highest level of total coliform bacteria (35,000 /100 ml) out of 22 sample sites (MDWPC 1985). Raw sewage discharges also were observed at Liberty Street (May 13, 1988) and were evident in several ichthyoplankton samples. Since the study period, two of the Porter River CSOs were eliminated, including Conant St., and most are slated for removal over the next few years (SESD 1991).

Land adjacent to intertidal areas of the Danvers River system are heavily settled and developed. Recreational boating has been popular for decades, and vessel densities in the Danvers River have increased in the past decade. In the Crane/Porter River harbor area there were three marinas and a fleet of approximately 450 vessels in 1980 (S.P. and Town of Danvers 1981). Presently, there are six marinas and over 600 vessels in this area. This high concentration of boating activity may have contributed to the degradation of the Danvers River estuary as a source of pollutant inputs and erosion impacts to the surrounding salt marsh. Other developments that result in the loss of intertidal habitat also may contribute to this problem. Also, stormwater drains that flow into the Danvers River are sources of nutrients, fecal coliform, sediments and other pollutants.

been eliminated, but others in the Porter River are still active. The removal of all active CSOs in the Danvers River is recommended. Sedimentation is a land use problem with numerous sources in the area. One source that can be contained is sand run-off the roadways in the winter. All new construction of stormwater drains that connect to the Danvers River system should be regulated to prevent sediment entry to the waterways. Overall, improved land and water use management is needed to prevent source and non-source nutrient and sediment inputs from further degrading habitat conditions.

Crane River

Although the Crane River does not presently have a smelt run, it possesses great potential for restoration. With nearly 2,000 m² of substrate available for smelt spawning habitat, the Crane River should be considered a priority for restoration efforts in this program. A prerequisite to restoration will be the modification of the sluiceway on Purchase St. to allow for passage. The MDMF Anadromous Fish Project will be consulted for sluiceway design and support from the pump house property owner will be necessary.

Once passage above Purchase St. is secured, a proposal will be developed to stock smelt eggs under a closely monitored, three year study. The Crane River can be used as a control stream to assess the effectiveness of egg transfers for restoring smelt populations. Fertilized eggs will be collected from Massachusetts Bay donor streams and gametes will be stripped from mature adults (Akielaszek et al. 1985) and transferred to the Crane River. Egg hatching, larval movement and returning adults will be subsequently monitored.

permits should also be investigated and brought to compliance. As water and habitat quality improves, it is expected that North River could support a smelt run. This should be a long term goal, that utilizes the experience of smelt restoration in the Crane River.

It is also recommended that a river clean-up be initiated with support of surrounding communities. The clean-up of large amounts of discarded trash will require funding and the ability to transfer large objects out of the river. Such efforts will accelerate the restoration of river habitat, and raise the public's awareness of the ecological value of the North River.

Bass River

Bass River was not monitored for smelt spawning because passage into the freshwater zone is blocked by the cooling pond for the former United Shoe factory. The factory is no longer operating and new development is being considered for the property (Haley & Aldrich, Inc. 1992). Although no documentation of a former anadromous fish run was found, there is potential for alewife habitat in the Upper and Lower Shoe Ponds (17 acres) that flow into Bass River. Consideration should be given to restoring natural tidal flow and removing obstructions to anadromous fish passage. The establishment of a smelt run in the Bass River and an alewife run up into Shoe Pond should be evaluated as a long-term management goal for anadromous fish in the Danvers River system. The successful restoration of anadromous fish in the Bass River and at other locations in the Danvers River system can provide benefits in the form of an improved forage base and enhanced recreational fishing opportunities.

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APPENDIX

DANVERS RIVER ICHTHYOPLANKTON SAMPLES

Table 6. Porter River: 1988

Date	Velocity (m/sec.)	Sample Volume (m ³)	Species	Type	Number	Average Size (mm)	Number (/100 m ³)
3-15-88	NA	NA	sand lance	larvae	3	12*	NA
			Atlantic herring	juvenile	1	28.0	
4-29-88	0.479	32.2	sand lance	larvae	1	12*	3.1
5-06-88	0.542	31.8	none				
5-10-88	0.841	56.5	rainbow smelt	larvae	1	9*	1.8
			P-S group	egg	3	1.1	5.3
5-20-88	0.432	32.6	blueback herring	juvenile	1	46.0	3.1
			Atlantic silverside	larvae	1	6*	3.1
5-24-88	0.540	72.5	mummichog	juvenile	1	31.0	1.4
			rainbow smelt	larvae	1	12*	1.4
			Atlantic silverside	larvae	1	4.6	1.4
			L-L group	egg	16	1.1	22.1
6-07-88	0.667	61.7	rainbow smelt	larvae	8	13.3	13.0
			winter flounder	larvae	1	5.6	1.6
			L-L group	egg	336	1.0	544.6

notes: Samples taken from Liberty St. at Pope's Landing in 1988 only.

NA: not available

Ave. size: total length for larvae, diameter for eggs; "*" indicates estimated size

L-L group: Labridae-Limanda egg group

P-S group: Paralichthydes-Scophthalmus egg group

APPENDIX

DANVERS RIVER ICHTHYOPLANKTON SAMPLES

Table 8. Crane River: 1988

Date	Velocity (m/sec.)	Sample Volume ³ (m)	Species	Type	Number	Average Size (mm)	Number (/100 m ³)
3-15-88	NA	NA	sand lance grubby	larvae larvae	2 1	12* 11*	NA
4-29-88	0.541	63.6	rainbow smelt	larvae	1	6.4	1.6
5-06-88	0.411	31.1	none				
5-10-88	0.618	51.9	none				
5-20-88	0.386	48.7	none				
5-24-88	0.639	80.6	Atlantic silverside L-L group	larvae egg	2 3	4.6 1.1	2.5 3.7
6-07-88	0.294	34.6	Atlantic silverside winter flounder L-L group P-S group	larvae larvae egg egg	5 1 24 3	4.1 5.5 1.0 0.94	14.5 2.9 69.4 8.7

notes: NA: not available
Ave. size: total length for larvae, diameter for eggs; "*" indicates estimated size
L-L group: Labridae-Limanda egg group
P-S group: Paralichthyes-Scophthalmus egg group

APPENDIX

Table 10. Water Chemistry

Sample Site:

Porter River, Rt. 62 Bridge

Year:

1988

DATE	TIME OF DAY	TIDE STAGE	TIDAL INFLUENCE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
							Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-01-88	0931	low +5.0	N	9.3	1	2.5	2.0		0					
3-04-88	1102	low +4.5	N	9.6	5	2.5	3.0		0					
3-08-88	1000	low +1.0	N	9.5	1	2.0	2.5		0		7.7			
3-11-88	1056	low +0.0	N	9.3	1	3.5	3.5		0		7.8			
3-15-88	1050	high +1.5	Y	10.3	4	3.0	4.0		0		7.0			
3-18-88	1029	low +4.5	Y	11.2	3	7.0	5.5	5.5	1	21	7.6	8.3		
3-22-88	0944	low +0.5	N	10.8	1	0.0	1.5		0		7.6			
3-25-88	1016	high +4.5	N	9.0	4	7.5	8.0		0		7.6			
3-29-88	1040	high +1.0	N	8.8	1	10.0	7.5		0		7.4			
4-01-88	1423	high +2.5	N	9.3	4	9.5	9.5				7.2			
4-05-88	1318	low +5.5	N	9.0	3	15.0	11.5				7.6			
4-08-88	1428	low +2.0	N	8.2	4	6.0	7.0		0		7.8			
4-13-88	1603	low +0.0	N	10.1	3	5.0	11.5		0		8.0			
4-15-88	1421	high +2.5	N	10.6	4	5.5	8.0		0		7.8			
4-19-88	1038	low +1.5	N	11.1	2	7.5	7.0		0		7.5			
4-21-88	1013	low +0.0	N	10.1	3	11.0	6.5		0		7.8			
4-26-88	1300	high +4.0	N	8.4	1	13.5	13.0		0		8.5			
4-29-88	1041	high +0.0	N	8.8	1	13.5	11.0		0		7.5			
5-03-88	0926	low +1.5	N	9.0	4	6.0	8.5		0		7.7			
5-06-88	1503	low +5.0	N	8.7	5	13.0	13.0		0		7.3			
5-10-88	0917	high +1.5	N	9.6	5	8.5	10.5		0		7.6			
5-13-88	1413	high +3.5	N	9.8	1	21.0	17.5		0		7.7			
5-17-88	1014	low +2.5	N	9.4	4	15.0	13.0		0		7.7			
5-20-88	1506	low +5.0	N	8.5	4	11.5	12.0		0		7.7			
5-24-88	1149	high +4.5	N	8.5	2	22.0	18.0				7.7			
5-27-88	1534	low +0.0	N	8.3	1	22.0	18.0				7.8			
6-01-88	1040	low +3.0	N	9.0	4	18.0	15.0		0		7.2		9.6	
6-07-88	1612	low +3.5	N	9.7	2	19.0	17.0				7.6		10.1	
Season Average						10.0	9.5				7.6			

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Table 12. Water Chemistry

Sample Site:

Porter River, Rt. 62

Year:

1990

DATE	TIME OF DAY	TIDE STAGE	TIDAL INFLUENCE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
							Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-02-89	1110	low +1.5	N	9.8	1	4.0	3.0				7.5		15.0	
3-05-90	1017	high +3.0	N	8.4	1	-5.0	0.5				7.4		15.0	
3-09-90	1329	high +3.0	N	10.2	1	2.5	5.5		0		7.7		14.6	
3-15-90	1327	low +5.0	N	9.2	2	18.0	10.0		0		7.7		14.3	
3-21-90	1150	high +4.5	N	8.9	4	4.0	6.0		0		7.4		13.5	
3-23-90	1047	high +1.5	N	9.6	2	14.0	8.5		0		7.7		15.0	
3-26-90	1106	low +5.5	Y	10.9	1	9.5	6.5		1		7.6		13.2	
3-30-90	1109	low +2.5	N	10.3	4	2.0	5.0		0		7.6		13.7	
4-02-90	1226	low +0.0	N	10.4	4	5.0	6.0		0		7.7		13.3	
4-06-90	1142	high +1.0	N	9.7	4	4.5	7.0		0		7.4		12.2	
4-09-90	1230	high +0.0	N	9.7	1	8.0	8.5				7.5		12.4	
4-13-90	1718	high +2.0	N	9.0	2	4.5	10.0		0		7.7		11.1	
4-16-90	1206	low +1.0	N	8.2	1	13.0	11.5		0		7.4		12.9	
4-20-90	1150	high +3.5	N	9.3	4	12.0	9.5		0		7.5		14.3	
4-23-90	1504	high +4.0	N	10.4	2	14.0	16.0		0		7.6		11.4	
4-27-90	1534	high +1.0	N	10.5	2	24.0	19.0		0		7.8		11.8	
4-30-90	1125	low +0.0	N	9.4	5	8.0	9.0		0		7.3		10.9	
5-07-90	1536	high +4.0	N	9.2	6	10.0	12.0		0		7.4		11.0	
5-10-90	1613	high +2.5	N	9.1	4	19.5	17.0		0		7.6		10.3	
5-14-90	1449	low +4.5	N	8.6	1	16.0	17.0		0		7.6		10.7	
5-17-90	1326	low +1.0	N	8.9	6	10.0	12.0		0		7.2		10.0	
5-21-90	1509	high +5.5	N	9.8	4	6.0	9.5		0		7.3		10.7	
5-24-90	1524	high +3.0	N	10.4	2	13.0	13.5		0		7.6		11.4	
5-28-90	1421	low +4.5	N	9.9	1	20.0	17.5		0		7.8		10.4	
Season Average	1309					9.9	10.0				7.5		12.5	

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Table 14. Water Chemistry

Sample Site:

Crane River (CR-1)

Year:

1989

DATE	TIME OF DAY	TIDE STAGE	TIDAL INFLUENCE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
							Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-02-89	1100	high +4.0	N	9.1	2	0.0	2.0		0		7.1		13.1	
3-06-89	1048	high +0.0	N	11.0	4	-2.0	3.0		0		7.7		12.4	
3-09-89	1015	low +3.5	N	11.6	2	-1.5	2.0		0		7.7		14.0	
3-13-89	1003	high +5.5	N	9.2	1	-3.0	2.5		0		7.5		12.4	
3-16-89	830	high +1.0	N	9.4	2	5.0	5.0		0		7.2		12.2	
3-20-89	1148	high +1.0	N	9.7	2	3.0	5.5		0		7.5		13.2	
3-23-89	1445	high +2.0	N	9.7	2	3.5	6.5		0		7.7		12.7	
3-27-89	1100	low +1.5	N	9.7	1	11.5	8.0		0		7.6		12.2	
3-30-89	1028	high +5.0	N	8.0	6	5.0	9.5		0		7.7		11.0	
4-04-89	1430	high +3.0	N	10.9	4	7.5	8.0		0		7.2		11.9	
4-06-89	1024	low +4.5	N	11.3	6	10.5	11.0		0		7.1		10.3	
4-11-89	1240	low +1.5	N	9.1	2	7.0	8.0		0		7.5		12.6	
4-13-89	1122	high +4.5	N	9.6	1	9.0	8.5		0		7.4		12.9	
4-17-89	1134	high +0.5	N	9.2	2	12.5	8.5		0		7.5		11.0	
4-20-89	1855	low +0.0	N	9.4	2	11.0	12.0		0		7.4		10.9	
4-24-89	1050	low +1.5	N	8.9	2	8.0	9.0		0		7.5		13.1	
4-27-89	1138	low +0.0	N	8.5	4	10.5	12.0		0		7.8		10.7	
5-01-89	1055	high +2.0	N	10.0	4	10.0	11.0		0		7.4		10.4	
5-04-89	1640	high +5.0	N	10.7	2	16.0	16.5		0		7.7		10.6	
5-08-89	1000	low +1.0	N	10.0	3	8.0	15.5		0		7.6		9.6	
5-11-89	1621	low +4.5	N	8.8	5	11.5	11.0		0		7.4		10.5	
5-15-89	1530	low +0.0	N	8.8	2	15.5	17.0		0		7.6		10.1	
5-17-89	1256	high +2.0	N	8.8	2	14.0	15.5		0		7.5		11.1	
6-06-89	1133	low +3.0	N	9.6	5	14.5	18.5		0		7.3		6.8	
Season Average		1206				7.8	9.4				7.5		11.5	

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Table 16. Water Chemistry

Sample Site:

Porter River, Pope's Landing

Year:

1988

DATE	TIME OF DAY	TIDE STAGE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-01-88	0845	low +4.5	9.3	1	1.5	3.0		28					
3-04-88	1045	low +4.5	9.6	5	1.5	2.5		25					
3-08-88	0946	low +1.0	9.5	1	1.0	3.0				7.4			
3-11-88	1045	low +0.5	9.3	1	6.0	4.5		16		8.3			
3-15-88	0920	high +0.5	10.3	4	2.0	4.0	4.0	28	28	8.4	8.3		
3-18-88	1018	low +5.0	11.2	4	6.5	4.5		30		8.3			
3-22-88	0931	low +0.5	10.8	1	-2.5	1.0		19		8.0			
3-25-88	1007	high +4.5	9.0	4	7.5	7.0		20		8.0			
3-29-88	0910	high +0.0	8.8	1	6.5	6.5	5.5	24	29	8.1			
4-01-88	1452	high +3.5	9.3	4	10.0	9.5		22		8.0			
4-05-88	1335	high +0.0	9.0	3	14.5	9.5		28		8.0			
4-08-88	1451	low +3.5	8.2	4	5.0	7.0		27		8.1			
4-13-88	1552	low +0.0	10.1	3	6.0	11.0		27		8.0			
4-15-88	1423	high +2.5	10.6	4	5.5	9.0		28		8.0			
4-19-88	1023	low +1.5	11.1	2	5.5	8.5		28		8.1			
4-21-88	1008	low +0.0	10.1	3	10.5	7.5		23		7.9			
4-26-88	1353	high +5.0	8.4	2	12.0	12.0		30		8.1			
4-29-88	1054	high +0.0	8.8	1	14.0	10.5	11.0	26	26	7.9			
5-03-88	0914	low +1.5	9.0	4	6.0	9.5		25		7.9			
5-06-88	1521	low +5.5	8.7	5	13.0	13.0	12.0	28	30	8.0			
5-10-88	0814	high +1.0	9.6	5	9.0	13.0		29		8.1			
5-13-88	1423	high +4.0	9.8	1	17.5	17.5		25		8.0			
5-17-88	1002	low +2.5	9.4	4	14.5	15.0		27		8.0			
5-20-88	1540	low +5.5	8.5	4	11.5	12.0	12.0	26	27	8.0			
5-24-88	0820	high +1.5	8.5	2	21.0	17.0	16.5	28	27	7.7			
5-27-88	1541	low +0.0	8.3	1	20.0	22.0		12		8.0			
6-01-88	1026	low +3.0	9.0	4	18.0	16.0		26		8.0		7.6	
6-07-88	1910	high +0.5	9.7	2	16.0	14.5		30		8.2		9.7	
Season Average					9.3	9.6				8.0			

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Water Chemistry

Table 18.

Sample Site:

Porter River, Rt. 128 Bridge

Year:

1990

DATE	TIME OF DAY	TIDE STAGE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-23-90	1015	high +1.5	9.6	3	13.5	8.0	8.0	26	26	8.0	8.0	12.4	12.2
4-09-90	1310	high +0.5	9.7	1	8.0	8.0	7.5	25	26	8.0	8.0	10.7	10.9
4-27-90	1510	high +0.5	10.5	2	28.0	14.0	13.5	30	30	8.0	8.0	11.2	11.2
5-14-90	1605	high +0.0	8.6	1	21.0	17.5	14.0	18	26	7.8	7.8	10.0	10.2
5-28-90	1635	high +0.5	9.9	2	22.0	18.0	18.0	28	28	7.8	7.8	9.3	9.3

Table 19.

Sample Site:

Crane River, Railroad Bridge

Year:

1990

DATE	TIME OF DAY	TIDE STAGE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-26-90	1200	high +0.5	10.9	2	9.0	7.0	7.0	30	30	8.2	8.2	10.4	10.4
4-06-90	1100	high +1.0	9.7	4	5.0	6.5	6.0	18	22	7.5	7.9	11.1	10.8
4-27-90	1615	high +2.0	10.5	2	28.0	14.5	14.0	30	30	8.1	8.1	11.5	11.8
5-14-90	1655	high +1.0	8.6	1	17.5	20.0	16.0	10	24	7.9	7.9	9.6	9.5
5-28-90	1710	high +1.0	9.9	2	22.0	19.0	18.0	28	28	7.8	7.8	9.3	9.2

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Table 21. Water Chemistry

Sample Site:

Crane River, RR Bridge (CR-3)

Year:

1989

DATE	TIME OF DAY	TIDE STAGE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-02-89	1020	high +4.0	9.1	2	-1.5	2.0		13				12.3	
3-06-89	1025	high +0.0	11.0	4	-2.0	2.0	2.0	28	28	7.9		10.9	11.0
3-09-89	952	low +3.0	11.6	3	-1.0	0.0		25		7.8		11.9	
3-13-89	948	high +5.5	9.2	1	-2.0	3.0		10		7.6		11.6	
3-16-89	750	high +1.0	9.4	2	4.0	6.0	6.0	30	30	7.9		9.9	10.0
3-20-89	1040	high +0.0	9.7	2	2.0	5.0	5.0	29	29	7.9		10.0	10.1
3-23-89	1315	high +0.5	9.7	2	3.0	7.5		8		7.8		11.9	
3-27-89	1044	low +1.5	9.7	1	14.0	10.0		1		7.9		12.2	
3-30-89	1017	high +5.0	8.0	6	4.5	8.5		4		7.8		10.6	
4-04-89	1410	high +3.0	10.9	4	6.5	7.0		14		7.7		10.5	
4-06-89	1014	low +3.5	11.3	6	9.5	8.0		27		7.6		9.1	
4-11-89	1216	low +1.5	9.1	2	7.0	10.0		2		7.6		12.6	
4-13-89	1112	high +4.5	9.6	1	8.0	10.0		4		7.6		12.6	
4-17-89	1100	high +0.5	9.2	2	10.0	9.0	8.0	13	26	8.0	8.3	10.1	9.7
4-24-89	1032	low +1.5	8.9	2	8.0	9.5		1		7.9		12.1	
4-27-89	1128	low +0.0	8.5	4	10.5	12.0		5		7.9		10.6	
5-01-89	925	high +0.5	10.0	4	9.0	10.5	10.5	25	26	8.4	8.4	8.7	8.7
5-04-89	1649	high +5.0	10.7	2	14.0	16.0		5		7.8		11.3	
5-08-89	930	low +0.5	10.0	3	9.0	15.0		2		7.7		10.2	
5-11-89	1745	high +0.0	8.8	4	11.0	11.5	11.0	4	26	7.6	7.9	9.4	8.1
5-15-89	1549	low +0.5	8.8	2	17.0	19.5		2		7.7		10.7	
5-17-89	1125	high +0.5	8.8	2	16.0	16.0	14.0	17	16	7.7	7.7	8.2	8.4
6-06-89	1123	low +3.0	9.6	5	14.0	17.0		10		7.3		6.9	
6-08-89	1725	high +1.0	9.2	4	17.0	16.0	16.0	26	28	7.8	7.8	6.8	6.6
Season Average	1162				7.8	9.6		13	26	7.8		10.5	

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Table 23. Weather Index

- | | | |
|----|-----------------------|-----------------------|
| 1. | clear sky | (< 5% clouds) |
| 2. | partly cloudy | (5 to < 25% clouds) |
| 3. | mostly cloudy | (25 to < 75% clouds) |
| 4. | cloud cover | (> 75% clouds) |
| 5. | light rain | |
| 6. | medium rain | |
| 7. | heavy rain | |
| 8. | snow | |
| 9. | other (ex. hail, fog) | |