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Rainbow Smelt Population Monitoring and Restoration on the Gulf of Maine Coast of Massachusetts

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Rainbow smelt *Osmerus mordax* resources in Massachusetts have received little attention since the 1970s when sport fisheries attracted many anglers, resulting in large catches in numerous embayments. A recent survey of smelt spawning habitat found evidence that many smelt runs had declined since the 1980s (Chase 2006). Growing concern over the status of New England smelt resources prompted interest in assessing smelt populations and in developing restoration strategies. A fyke net survey of anadromous smelt on the Gulf of Maine coast of Massachusetts was initiated in 2004 to monitor annual spawning run demographics and to assist restoration experiments.

Fyke nets were set in six known smelt runs during the spring spawning seasons of 2005–2007. Four rivers were selected as annual population monitoring stations based on a range of expected run size and watershed characteristics. The Crane and North rivers, where recent restoration efforts improved habitat and documented a reestablished smelt run (Chase 2006), were selected to evaluate the methods and benefits of stocking smelt larvae. Nets were set in the intertidal zone below the downstream limit of smelt egg deposition. Three sets were made per week from March 7 to May 18 in each season. Captured fish were counted, measured, and released. Weekly samples of smelt were collected for aging and gametes in two rivers, Fore and Saugus, with the larger smelt runs. The collected smelt eggs were fertilized, incubated, marked with oxytetracycline (OTC), and stocked as yolk sac larvae. All smelt caught at the restoration sites will be inspected for marked otoliths. Analyses were conducted on size and age composition, and age comparisons were made to studies from the 1970s in the study area (Murawski and Cole 1978; Lawton et al. 1990).

The spawning run peak occurred between the last week of March and the first week of May, although smelt were captured during each week of sampling. The run onset was earlier and the duration longer than that in smelt runs at the northern end of their range (McKenzie 1964; Pettigrew et al. 2009). Each river displayed distinct characteristics of run peak and duration. The Fore River had a 10-week spawning season each year with a consistent peak during the second week of April. Contrary to expectations, the peak run in the Parker River (the most northern) occurred 3–4 weeks earlier than the peak in the Jones River (the most southern).

Fyke net catch rates varied widely among rivers, with the highest in the Fore River and the lowest in the two restoration rivers. Analyses of peak season catches (weeks 4–9) were made to assess the potential of using catch-per-unit-effort (CPUE) data as relative indices of abundance. The nominal CPUE data had high coefficients of variance, and transformed CPUE data also displayed high variance that could present difficulties for discerning annual trends in some rivers. Large year-to-year changes in CPUE were found with little evidence of annual synchrony among rivers. Stronger than average cohorts were evident in the Fore River for 2003 and in the Saugus River for 2005.

Fore River smelt scales were aged in 2005 (N = 274) and 2006 (N = 265), and age and length keys were applied to all measured smelt to construct age composition for each river. In both years, only ages 1–3 were represented in the Fore River age key. Smelt larger than the upper limit of the age

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key were few (<1% > 239 mm) and were assigned to age 4 based on the age data of Murawski and Cole (1978) and Lawton et al. (1990). The earlier studies on smelt in the study area found that age structure was dominated by age-2 smelt, and age 3 was the next most abundant age-class. Our catches had a reduced presence of older smelt and a higher proportion of age-1 smelt.

Mean total length by sex was tested (one-way analysis of variance) to determine if there were significant differences ($P < 0.05$) in length at age among rivers. For both years and sexes, the Jones River age-1 smelt were significantly shorter than age-1 smelt in the other rivers. All within-year comparisons showed that Saugus River age-1 smelt and Parker River age-2 smelt were longest among rivers, and Saugus River age-2 smelt were the shortest (Table 1), although not all comparisons were significantly different. Length data from previous Massachusetts smelt studies have similar mean lengths at age (Table 1), and the same traits of shorter Jones River age-1 smelt and longer Parker River age-2 smelt.

Annual survival rates (S) and instantaneous total mortality (Z) were calculated using the Chapman and Robson equation. The age-1 male cohort was excluded from mortality estimates because they are only partially recruited to the spawning run. Total annual mortality of age-2 smelt during 2005–2006 was high, ranging from 75% to 99%. The average annual survival for 2005–2006 data was 0.12, compared to 0.21 for the earlier studies in the Jones and Parker rivers. The precision of Chapman and Robson estimates declines as Z increases. This condition was found when few age 3, and no age 4, smelt were caught. Age structure was compared to the earlier Jones and Parker River data with chi-square contingency tables to test the hypothesis that age frequencies have the same distribution among years. All comparisons of past and present age structure were significantly different ($P < 0.05$). That age frequencies are independent is likely due to the large increase in age-1 smelt, and the decrease in age-3 smelt, in contemporary spawning runs.

More than 1 million smelt larvae, marked as embryos with 500 mg/L OTC, were stocked in the Crane River in both 2005 and 2006. Smelt marked with 500 mg/L in a 2006 controlled experiment failed to yield a consistent fluorescent mark in a blind test 1 year later. Smelt from that same experiment marked with 1,000 mg/L OTC passed the blind test. The 1.6 million smelt stocked in 2007 were marked with 500 mg/L OTC as larvae, and early results of a 2007 control experiment have found a stronger mark than that produced with embryo marking.

The analyses of catch data indicate that present

Table 1.—Smelt mortality and total length (mm) at age from fyke net catches and comparative data from earlier studies in Massachusetts (Murawski and Cole 1980; Lawton et al. 1990). The length data from 1974 to 1981 were only available as averages for all the years of the studies. Only age-1 and age-2 smelt were caught in the Jones River during 2005 (NA). S = annual survival rate; Z = instantaneous mortality.

River	Year	N	S	Z	Z (SE)	Age 1 M	Age 1 F	Age 2 M	Age 2 F
Parker River	1974	561	0.29	1.23	0.069				
Parker River	1975	1,358	0.11	2.18	0.075	141	140	188	197
Parker River	2005	482	0.04	3.30	0.262	139	139	190	198
Parker River	2006	123	0.25	1.39	0.042	137	139	190	192
Jones River	1979	13,093	0.20	1.62	0.017				
Jones River	1980	18,012	0.11	2.21	0.020				
Jones River	1981	5,298	0.33	1.10	0.016	132	130	184	190
Jones River	2005	449		NA		128	131	175	181
Jones River	2006	614	0.18	1.72	0.122	127	131	186	191
Fore River	2005	1,050	0.01	4.98	0.407	138	141	177	188
Fore River	2006	973	0.18	1.69	0.076	135	137	186	191
Saugus River	2005	141	0.04	3.11	0.560	141	144	172	183
Saugus River	2006	1,192	0.17	1.79	0.099	143	143	182	183

smelt runs have a truncated age distribution with a higher percentage of age-1 fish than previously documented. Mortality rates are higher than previously reported, as few smelt are reaching ages 3 and 4 in the present runs. These conditions support management concerns of declining smelt populations in Massachusetts.

The stressed condition of the Jones River smelt run raises questions related to the partial recruitment of age-1 smelt. Jones River age-1 smelt were smaller than that found in northern runs, and their proportion in the spawning run has increased. For short-lived species, spawning at an earlier age can be a response to environmental stress or a tactic to yield higher evolutionary fitness than remaining at sea an additional year to gain larger size (Gross 1987). Fyke net sampling and experimental stocking will continue and include examinations of the status of age-1 smelt, potential stressors related to age structure changes, and the influence of repeat spawning on population data.

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