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Predation on Atlantic Salmon Smolts by Striped Bass after Dam Passage

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Abstract.—We documented predation on smolts of Atlantic salmon *Salmo salar* by striped bass *Morone saxatilis* foraging in the tailrace of the Essex Dam on the Merrimack River, Lawrence, Massachusetts, and assessed factors that may affect smolt susceptibility to predation. During 6 d of diurnal angling from 6 to 28 May, we captured 212 striped bass, 41 of which contained prey remains. More than 48% of striped bass that contained prey had consumed smolts. Atlantic salmon smolts composed more than 80% of the total mass of prey remains recovered and included both individuals of stocked-fry and stocked-smolt origin. Based on information from this pilot study, a focused investigation of striped bass predation on smolts after passage of the Essex Dam began in 1998.

Because smolts of Atlantic salmon *Salmo salar* begin seaward migration from New England rivers during early spring (Moring 1987; Moring et al. 1995), there is potential overlap with the arrival of striped bass *Morone saxatilis* migrating from the Chesapeake Bay and Hudson River (see Boreman and Lewis 1987). Warner and Kynard (1986) suggested that subadult striped bass might concentrate below hydroelectric dams and consume injured or moribund anadromous fish. Further, in recent years striped bass numbers have increased as a result of restoration, protection of nursery areas, and limits on numbers and sizes of fish taken by sport and commercial anglers (Field 1997).

Our objectives were to (1) document whether smolts contribute to the diet of striped bass foraging in the tailrace of the Essex Dam on the Merrimack River in Lawrence, Massachusetts, (2) identify evidence of injury to smolts prior to predation, (3) determine the origin (i.e., if hatchery-reared fish stocked as fry or as smolts) of smolts consumed by striped bass, and (4) assess the contribution of smolts to the striped bass diet, relative to other prey collected.

Study Area

The Merrimack River basin drains an area of 12,975 km^2; 76% of the drainage is in central New Hampshire and the remainder is in northeastern Massachusetts (Stolte 1994). More than 60% of habitat suitable for smolt production in the basin is within the Pemigewasset River (Stolte 1994), which forms the headwaters of the Merrimack River. In rearing habitat within the Pemigewasset River as well as in other areas in the Merrimack River basin, unfed fry are stocked from April through June and remain in the river system for approximately 2 years. From the Pemigewasset River to the mouth of the Merrimack River (210 river km from the ocean), migrating smolts encounter seven hydropower facilities and one earthen dam constructed for flood control (see Blackwell et al. 1998). However, fish stocked as smolts, from late March through April, begin migration approximately 70 river km from the ocean and encounter two hydroelectric dams.

This pilot study was conducted at the Essex Dam, the lowermost dam on the Merrimack River (approximately 49 river km from the mouth). The Essex Dam maintains a gross head (i.e., the difference between reservoir elevation and point of discharge) of 9.14 m, has two turbines with 224-m^3/s capacity, and is outfitted with a downstream bypass. However, the downstream bypass is considered ineffective in passing Atlantic salmon smolts, and the effects of turbine passage at the Essex Dam are unclear (J. Warner, U.S. Fish and Wildlife Service [USFWS], personal communication).

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Methods

Striped bass were captured by angling in the tailrace of the Essex Dam from a structure immediately below the powerhouse. We used artificial lures resembling smolts in color or shape. Angling for striped bass was initiated on 6 May 1997 and sampling occurred from 0845 to 1700 hours (when facility personnel were on station). Sampling was initiated when river flows had decreased such that the tailrace area could be accessed safely and angling equipment could be used efficiently. We ended our sampling in accordance with an arbitrary limit placed on our state collector's permit that reflected the pilot status of our investigation. Scale samples, fork length (cm), mass (kg), and date of capture were recorded for each striped bass. Prey remains were collected from striped bass by gastric lavage by using a bilge pump with 4,136 L/h capacity.

Prey remains were stored on ice and placed in freezers upon return to the laboratory. For prey identification we used keys by Robins et al. (1986) and Scott and Scott (1988) and a reference collection of fish scales, vertebrae, cleithra, and hatchery-reared smolts. Additional data recorded for the prey items recovered included mass (g); a subjective digestion grade of 1 for fresh, 2 for slightly digested, 3 for advanced digestion, or 4 for bone; and a length grade of 1 for intact, 2 for reasonably accurate, and 3 for a vertebral column without head or tail (see Harrison et al. 1983). Scale analysis and fork length were used to distinguish the origin of recovered smolts. Also, evidence of injury to smolts from turbine blades or abrasion was noted.

Finally, we calculated three statistics to describe the contribution of each prey taxon to the striped bass diet. Frequency of occurrence—the percentage of all striped bass that contained prey and had consumed a particular prey item—provided a measure of rarity of each prey taxon in the diet. We defined the gravimetric contribution of each prey taxon to the diet, the mean percent mass, as the total gravimetric percentage of a taxon relative to the total mass of prey consumed for all striped bass, divided by the number of striped bass containing prey remains. The numerical contribution of each prey taxon to the diet was simply the total number of individuals of each taxon consumed during the sampling period. Each statistic has associated biases when considered alone (Reintjes and King 1953; Hyslop 1980), but prey taxa that are well represented relative to each measure can be considered as important for the time and place sampled (Harrison et al. 1983). All measurement data are reported as the mean ± SD.

TABLE 1.—Prey categories and statistics for prey remains recovered from striped bass (N = 41) collected in the tailrace of the Essex Dam on the Merrimack River.

Prey category	Frequency of occurrence	Mean percent mass (g)	N
Atlantic salmon	48.8	45.8	32
Atlantic salmon (suspected)[a]	51.2	36.2	28
Unidentified fish (not Atlantic salmon)[b]	9.8	8.2	4
Unidentified fish[c]	4.9	2.5	3
Sea lamprey *Petromyzon marinus*	4.9	4.9	2
Alewife *Alosa pseudoharengus*	2.4	2.4	1

[a] Prey remains included vertebrae or vertebral columns only.
[b] Prey remains were distinguishable from Atlantic salmon, but no further identification was made due to the degree of digestion.
[c] Prey remains were not distinguishable from Atlantic salmon or other species due to the degree of digestion.

The presence or absence of spill (enabling downstream migration of smolts without turbine passage) was monitored throughout the study. Also, we assumed that the mean diurnal water temperature (°C, ±SD) recorded at the U.S. Geological Survey gauging station in Lowell, Massachusetts, was reflective of conditions at the Essex Dam, approximately 18 river km downstream.

Results

We captured 212 striped bass during sampling on 6, 8, 13, 14, 21, and 28 May. Prey remains were recovered from 41 individuals. Ranges for mass and fork length of striped bass were 0.11–5.10 kg (mean, 0.93 ± 0.58 kg) and 30–78 cm (mean, 40.37 ± 6.34 cm), respectively. The estimated age of striped bass ranged from 2.5 to 9.5 years (mean, 3.5 ± 1.0 years). Striped bass containing smolts or prey remains resembling but not definitely identified as smolts (see below) ranged in mass from 0.57 to 4.65 kg (1.33 ± 0.76 kg), in fork length from 38 to 69 cm (44.62 ± 6.46 cm), and in age from 2.5 to 7.5 years (4.0 ± 1.1 years).

Six categories of prey remains were recovered (Table 1), however the greatest number of prey categories recovered from any stomach was two. Atlantic salmon smolts were the predominant prey recovered based on the three statistics used (Table 1) and represented more than 80% of the approximately 1,000 g of prey remains recovered. Recovered smolts with length grades of 1 and 2 (N = 15) ranged from 8.9 to 19.1 cm (15.2 ± 3.1 cm), whereas the fork length of smolts stocked in

the Merrimack River ranged from 11.5 to 24.5 cm (based on a prestocking sample of 865 fish from rearing pools at the Green Lake National Fish Hatchery; USFWS, unpublished data); 97.7% were greater than or equal to 16.5 cm. After examining both fork length and scale growth of 23 smolts recovered from striped bass, we considered 14 to have been stocked as smolts, 6 stocked as fry, and 3 were of unknown origin. Smolts suspected to be of stocked-fry origin ($N = 6$ of length grade 1 or 2) ranged from 8.9 to 16.7 cm (12.5 ± 2.6 cm), whereas smolts identified as of stocked-smolt origin ($N = 7$ of length grade 1 or 2) ranged from 13.8 to 19.1 cm (17.2 ± 2.0 cm).

Diurnal river temperature during the study ranged from 10°C to 15°C (12.2 ± 1.4°C) with the lowest and highest temperatures recorded on 7 and 28 May, respectively. Spill at the dam, though minimal at times, was present throughout the sampling period.

Discussion

We observed no evidence of prior injury to smolts recovered from striped bass. Still, internal injury and decreased predator avoidance behavior resulting from dam passage (Raymond 1979) cannot be dismissed. Further, of those smolts for which an accurate fork length was obtained (including both stocked-fry and stocked-smolt origin fish), approximately 53% were less than 16.5 cm long, falling within the smaller size ranges of stocked smolts. In addition, though our sample size of intact fish of stocked-smolt origin was small ($N = 7$), the mean fork length of these individuals (17.2 cm) also fell within the smaller size ranges of stocked smolts (9.5% < 17.5 cm). Our data, however, are insufficient to assign a biological significance to these differences.

We note that it is possible that smolts of stocked-fry origin and individuals stocked as smolts in April may have migrated past the Essex dam before 6 May or after 28 May. Peaks in smolt migration from the headwaters of the Merrimack River have been recorded from 20 May to 2 June with some fish moving as late as 10 June (J. F. McKeon, USFWS, unpublished data). Further, representative samples of the striped bass population foraging in the tailrace of the Essex Dam or the prey species consumed by these fish were probably not obtained. However, these data provided the first evidence that striped bass consume Atlantic salmon smolts during the riverine phase of migration. Further, the information gathered in this pilot study has provided a foundation for a full investigation, that began in 1998, with the purpose of quantifying striped bass predation at the Essex Dam.

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