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Largemouth Bass Predation on Stocked Striped Bass in Smith Mountain Lake, Virginia

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Abstract.—First-year survival of striped bass *Morone saxatilis* stocked into lakes and reservoirs is often poor, but causes of mortality have not been determined. We quantified losses of stocked, age-0 striped bass to predation by largemouth bass *Micropterus salmoides* in Smith Mountain Lake, Virginia, where first-year striped bass survival averages 25% and the largemouth bass is the principal littoral piscivore. To examine their diet composition and abundance, largemouth bass were sampled throughout the month following the stocking of striped bass in two coves in 1994 and one cove in 1995. We used a bioenergetics model to extrapolate total prey consumption over the month and the numerical contribution of striped bass to the largemouth bass diet. Only 14 striped bass were recovered in 1,147 largemouth bass stomachs over the 2 years. Percentage losses of striped bass to largemouth bass predation were 0.1% in each cove in 1994 and 3.0% in the single cove in 1995. Predation may have been constrained by the small size (24–74 mm) of striped bass and by the availability of spawning alewives *Alosa pseudoharengus* as alternate prey (i.e., adult alewives constituted the bulk of the largemouth bass summer diet). In pool experiments, largemouth bass ate significantly more alewives than striped bass when both prey were available; their consumption of striped bass increased in trials where alewives were absent. Abundance of alternate prey and their use by largemouth bass should be assessed before selecting striped bass stocking sites. Spreading the stocking over multiple sites to reduce predation mortality was unnecessary in Smith Mountain Lake.

Sport fisheries for striped bass *Morone saxatilis* have been established in more than 100 U.S. lakes and reservoirs (Axon and Whitehurst 1985). Successful striped bass reproduction is rare in these systems; the vast majority of fisheries for landlocked striped bass are dependent on frequent stockings of age-0 hatchery-reared fish (Pritchard et al. 1979; Cheek et al. 1985). Striped bass stocking success is highly variable. First-year survival is often less than 20% (Bailey 1975; Moore et al. 1991), but causes for high early mortality of stocked striped bass have received little study.

Intense predation on newly stocked age-0 fish has been documented for a variety of freshwater sportfishes, including walleyes *Stizostedion vitreum* (Santucci and Wahl 1993), esocids (Stein et al. 1981; Wahl and Stein 1989), and salmonids (Keith and Barkley 1971). The tendency of age-0 striped bass to occupy unvegetated littoral habitats near stocking sites (Van Den Avyle and Higginbotham 1979) leaves them vulnerable to predation by nearshore piscivores, such as largemouth bass *Micropterus salmoides,* which is usually the most abundant nearshore predator in warmwater lakes and reservoirs and has been indicted as the principal consumer of stocked walleyes (Santucci and Wahl 1993) and esocids (Stein et al. 1981).

Smith Mountain Lake, Virginia, is stocked each summer with approximately 300,000 age-0 striped bass (36/ha), of which 25%, on average (1973–1996), have survived their first year (Sutton 1997). We assessed the impact of predation by largemouth bass, the predominant littoral piscivore in Smith Mountain Lake, on age-0 striped bass survival. Our primary objective was to estimate the percentage of striped bass eaten by black bass in the first month poststocking. Adult alewives are the principal summer prey of largemouth bass in Smith Mountain Lake. Our second objective was to compare consumption of age-0 striped bass by largemouth bass in the presence and absence of adult alewives as alternate prey.

Study Area

Smith Mountain Lake is an 8,400-ha hydroelectric impoundment in southcentral Virginia (Figure 1). The reservoir consists of two long, nar-

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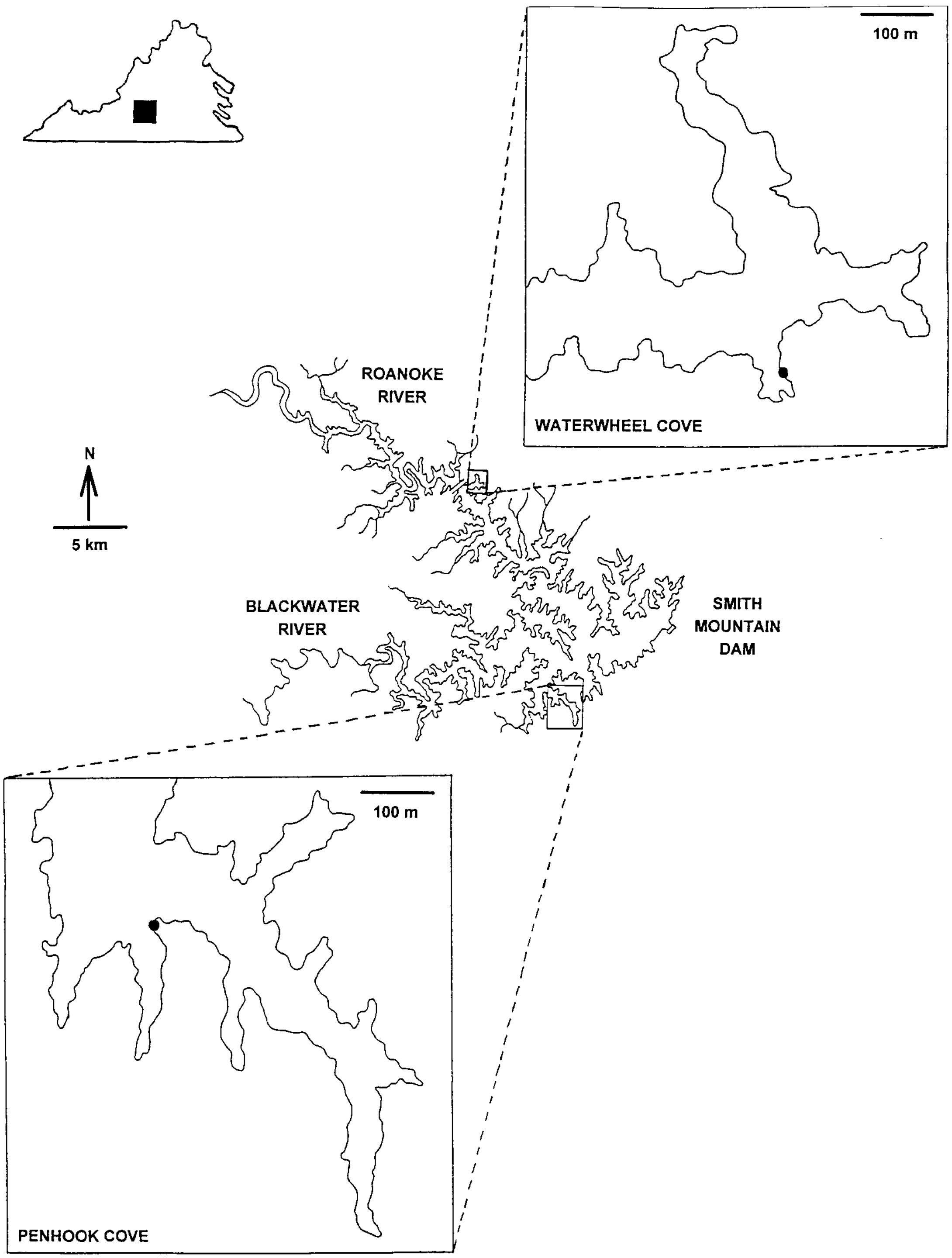

FIGURE 1.—Smith Mountain Lake, Virginia, with enlargements of Waterwheel and Penhook coves in which striped bass were stocked and largemouth bass were collected. Dots represent release sites.

TABLE 1.—Total number and mean (SD) size and 48-h cage mortality of striped bass stocked into Smith Mountain Lake, Virginia.

Cove	Date	Number stocked	Total length (mm)	Weight (g)	Cage mortality (%)
Penhook	15 Jun 1994	140,342	42 (8)	0.65 (0.44)	[a]
Waterwheel	22 Jun 1994	160,105	32 (6)	0.30 (0.27)	1.8 (1.4)
Waterwheel	12 Jul 1995	103,000	47 (13)	1.02 (0.99)	23.8 (17.9)

[a] Cage mortality trials not conducted.

row arms (40 and 20 km, respectively) fed by the Roanoke and Blackwater rivers and a broad lower lake extending 10 km from the confluence of the arms to the dam. Smith Mountain Lake has a maximum pool elevation of 242 m, mean depth of 16.8 m, and 805 km of shoreline. The lower lake is mesotrophic and grades steeply into the limnetic zone. The arms are more riverine and eutrophic and have more extensive littoral areas. The primary sport fishes are striped bass and largemouth bass, and the forage base is predominantly alewives and gizzard shad *Dorosoma cepedianum.*

Methods

Field study.—Age-0 striped bass from the Brookneal Hatchery, operated by the Virginia Department of Game and Inland Fisheries (VDGIF), were stocked into Smith Mountain Lake during mid-June in 1994. A severe flood prevented striped bass culture at the Brookneal Hatchery in 1995, so age-0 striped bass were obtained from North Carolina hatcheries and stocked later and larger than in 1994 (Table 1). Age-0 striped bass were stocked in approximately equal batches at two sites in 1994 and 1995: Waterwheel Cove (37 ha), located at midlake on the Roanoke River arm, and Penhook Cove (61 ha), 15 km downlake on the Blackwater River arm (Figure 1). Both coves had little rooted aquatic vegetation, and structural cover was mostly boat docks and fallen timber.

To evaluate mortality from stocking stress, we held individuals from the 1994 and 1995 Waterwheel Cove stockings in floating cages for 48 h and then tallied the dead. Three or four 3,000-L cages containing 70–100 fish were used each year (trial). We did not conduct cage studies in Penhook Cove because a secure area was not available. However, handling procedures, transport time, and water temperature at stocking were virtually identical for both coves, so stocking stress mortalities should have been similar. We compared mortality of caged striped bass in 1994 and 1995 with a *t*-test (Zar 1974).

We collected age-0 striped bass and piscivorous (age-1 and older) largemouth bass by eletrofishing at night. In 1994 we electrofished the entire shoreline of both coves (Waterwheel = 5,152 m, Penhook = 5,957 m) on the date of stocking, three nights later, and once per week thereafter for the next 3 weeks. In 1995, we sampled only Waterwheel Cove, but more intensively: the first 5 nights poststocking, then twice weekly for the next 3 weeks. Striped bass were placed on ice, and their lengths (0.1 mm) and weights (0.1 g) were measured in the laboratory. We evacuated largemouth bass stomach contents with clear acrylic tubes (Van Den Avyle and Roussel 1979) and removed several scales for age estimation. Each largemouth bass was measured for total length (TL; 1.0 mm) and weight (1.0 g), injected with an anchor tag (if >150 mm TL) or fin-clipped (if 125–150 mm TL), and released. Abundance of bass in each cove was estimated using the Jolly–Seber multiple census technique (Jolly 1965; Seber 1965).

In the laboratory, stomach contents were identified to the following major taxa: alewife, striped bass, crayfish, sunfish, and minnows. Partially digested fish unidentifiable to these taxa comprised a composite average of 14% of total stomach contents, most of which was recognizable as clupeids and none had the shape or size of fingerling striped bass. Unidentifiable fish remains were apportioned as alewife, sunfish, and minnow based on the identifiable percentages (wet weight) of these taxa in largemouth bass stomachs. Diet composition was further adjusted to account for the small size (0.5–1.5 g) of striped bass and their more rapid evacuation from largemouth bass stomachs relative to alewives (mean of 8.5 g). The gastric evacuation rate equation developed by Rogers and Burley (1991) for smallmouth bass *M. dolomieui* was used to derive multiplication factors of 2.00 in 1994 and 1.93 in 1995 for percentage of striped bass in the largemouth bass diet.

The total number of striped bass consumed by largemouth bass in each cove was estimated as the product of the number of largemouth bass present (estimated from the Jolly–Seber multiple census) and the average number of striped bass eaten per largemouth bass. To determine the latter, we first applied the Wisconsin bioenergetic model to estimate total food consumption by an individual largemouth bass over the sampling period. We used bioenergetic input parameters presented by Hewett and Johnson (1992) and site-specific inputs of epilimnetic water temperature and daily mean weights of largemouth bass of each age-group, 1 through 5. Daily mean weights were estimated by dividing mean age-specific weight gain by the number of days in the sampling period. Total food consumption per largemouth bass was then multiplied by the percentage (wet weight) of age-0 striped bass in the diet, and this product was divided by the mean live weight of age-0 striped bass to provide the number of striped bass consumed by an individual largemouth bass. We calculated the contribution of striped bass to the largemouth bass diet and estimated predation mortality for the first week and first month poststocking.

Laboratory experiments.—We evaluated the potential of adult (age 1 and older) alewives to buffer predation by comparing the number of age-0 striped bass consumed by a single largemouth bass in the presence and absence of alewives. We used adult alewives as alternate prey because the largemouth bass we examined in our field study did not eat age-0 alewives, which were offshore and spatially unavailable to them (Tisa 1988). Two experiments (8 trials each) were conducted in circular ponds (1.83-m diameter filled to a 0.5-m depth). In experiment 1, one largemouth bass (300–450 mm) was introduced to a pool containing five adult alewives (means 109 mm, 10.0 g) and five age-0 striped bass (means 66 mm, 4.0 g). We compared numbers of alewives and age-0 striped bass eaten using Wilcoxon's signed rank test (Hollander and Wolfe 1973). In experiment 2, one largemouth bass was confined with only five age-0 striped bass as potential prey. Numbers of striped bass eaten in experiments 1 and 2 were compared using the Mann–Whitney *U*-test (Hollander and Wolfe 1973). We assumed statistical significance in all tests at $\alpha = 0.05$. Both experiments included eight 48-h trials, and every trial was conducted with a different largemouth bass, unfed for the previous 24 h.

Results

The 48-h mortality rate of caged age-0 striped bass fingerlings (Table 1) was substantially

TABLE 2.—Diet composition (% wet weight) of largemouth bass captured in two coves (Penhook and Waterwheel) where striped bass were stocked in 1994 and 1995, as measured over the first month poststocking.

Food item	Penhook, 1994	Waterwheel, 1994	Waterwheel, 1995
Alewife	82.30	87.02	65.97
Minnow	0.53		0.09
Striped bass	0.41	0.10	2.49
Sunfish	2.13	1.11	9.74
Crayfish	14.72	11.50	19.11
Other		0.27	2.60

(>10×) and significantly greater in 1995 than in 1994 ($t = -4.66$; df = 5; $P < 0.01$). Water temperature during cage trials was 27°C in both years.

Estimated densities of age-1 and older largemouth bass in 1994 were 8.1/ha (95% confidence interval [CI] = 0.7−19.1/ha) in Penhook Cove and 16.9/ha (2.1–30.8) in Waterwheel Cove. Estimated density in Waterwheel Cove in 1995 increased to 26.9/ha (95% CI = 1.1 − 8.7). In both years, striped bass were found in largemouth bass stomachs predominantly during the first week poststocking and then infrequently. In 1994, a single age-0 striped bass was recovered from the stomach of an age-4 largemouth bass captured in Penhook Cove ($N = 326$), and two were retrieved from an age-1 largemouth bass in Waterwheel Cove ($N = 448$). Alewives constituted more than 80% of largemouth bass stomach contents at both sites during mid-June through mid-July (Table 2). Striped bass composed a minute fraction of the largemouth bass diet over the first week poststocking in Penhook (0.26%) and Waterwheel Coves (0.19%). Over the first month following stocking, age-0 striped bass contributed an estimated 0.14% of the largemouth bass diet in Penhook Cove and 0.10% in Waterwheel Cove. Over the first week poststocking in 1995, five largemouth bass (two age 1 and three age 2) captured in Waterwheel Cove (N = 373) contained 11 age-0 striped bass, composing 4.16% of the largemouth bass diet; this became 2.49% over the first month. Alewives predominated the largemouth bass diet in both years; crayfish were next most important, especially in 1995 (Table 2). As alewives completed spawning and moved offshore, crayfish gradually replaced alewives in the largemouth bass diet in 1995, and in August crayfish composed 60–80% of largemouth bass stomach contents.

Predation mortality was more severe in Waterwheel Cove in 1995 than in 1994. In 1995, an

TABLE 3.—Number of striped bass fingerlings recovered from the largemouth bass stomachs examined and estimated total losses (95% confidence intervals, CI) to largemouth bass predation in Smith Mountain Lake for the first week and first month following striped bass stocking.

Cove and year	Number of largemouth bass examined		Number of striped bass recovered		Estimated total number of striped bass eaten (95% CI)	
	Week	Month	Week	Month	Week	Month
Penhook, 1994	137	326	1	1	71 (6–167)	152 (14–271)
Waterwheel, 1994	190	448	2	2	99 (121–181)	208 (26–380)
Waterwheel, 1995	240	373	11	11	1,295 (49–3,009)	3,062 (115–7,115)

estimated 1.24% of stocked striped bass were eaten by largemouth bass within the first week and 2.97% within the first month. In 1994, only 0.06% of stocked striped bass were eaten in the first week and 0.13% in the first month (Table 3). Penhook Cove predation losses in 1994 were also very low at 0.05% for the first week and 0.11% for the first month poststocking.

In pool experiment 1, significantly more alewives were eaten (mean = 2.88) than striped bass (mean = 0.625) when the two prey species were confined together (T = 0; $N = 8$; $P < 0.01$). At least one and as many as all five alewives were eaten in each of these eight trials, but no striped bass were consumed in four trials and no more than two were eaten in any trial. In pool experiment 2, consumption of striped bass was not significantly different from experiment 1 ($U_1 = 20.5$, $U_2 = 43.5$; $N_1 = 8$, $N_2 = 8$; $P = 0.23$) when alewives were absent (mean of 2.50 per trial). The frequency distribution of striped bass predation losses in the absence of alewives was bimodal: 0–1 striped bass were eaten in four trials, whereas 4–5 striped bass were eaten in the other four trials.

Discussion

Although the intensity of largemouth bass predation on age-0 striped bass was greater in 1995 than in 1994, early poststocking predation was so low in both years that it could not be considered to be a major factor in first-year striped bass survival. More frequent sampling during the week following stocking in 1994 might have raised the observed incidence of predation to 1995 levels, but the schedule employed during the remainder of the sampling periods in both years (two nights per week) was probably adequate. Previous studies of predation by largemouth bass on stocked sport fishes have found that most of the impact occurred during the first week (Stein et al. 1981; Wahl and Stein 1989; Santucci and Wahl 1993). The higher predation mortality in 1995 versus 1994 might have been due to enhanced striped bass vulnerability. Striped bass stocked in 1995 were more than twice the weight of those stocked in 1994, making them potentially more attractive to largemouth bass. Striped bass stocked in 1995 also apparently suffered greater prestocking stress as evidenced by the 10-fold increase in mortality in the 48-h cage trials. Higher cage mortalities may have been due to longer transport time in 1995 (6 h) than in 1994 (1–2 h). Although we did not observe the behavior of caged striped bass, stress that results in lethargic or erratic swimming can raise the potential for predator attack (Stein et al. 1981).

Estimated percentage losses of striped bass to largemouth bass predation in Smith Mountain Lake (0.1–3.0%) are considerably lower than those reported in similar studies for stocked esocids in Ohio lakes (26–45% by Stein et al. 1981; 12–30% by Wahl and Stein 1989) and for stocked walleyes in Ridge Lake, Illinois (mean of 11%, Santucci and Wahl 1993). Factors that can affect predation mortality include predator density, prey size and behavior, and the abundance of alternate prey (Webb 1984; Hambright 1991; Einfalt and Wahl 1997). Densities of largemouth bass in our study (8–30/ha) were higher than in the Ohio lakes (5–8/ha) but much lower than in Ridge Lake (98–225/ha). Striped bass were also stocked into Smith Mountain Lake at much smaller size (24–70 mm) than the Ohio esocids (145–200 mm). In Ridge Lake, 6% of walleyes stocked at 48–61 mm suffered predation, whereas 17% of those stocked at 132–145 mm were eaten. At the size stocked into Smith Mountain Lake, striped bass are benthophagic (Sutton 1997), and their bottom-dwelling behavior might have further reduced their vulnerability to sight-oriented predators such as largemouth bass. Wahl and Stein (1989) hypothesized that muskellunge *Esox masquinongy* were more vulnerable to predation by largemouth bass than northern pike *E. lucius* in Ohio impoundments because muskellunge were suspended in the water column while northern pike were associated with the substrate. However, largemouth bass in Smith Mountain Lake fed heavily on crayfish, indicating that they searched the substrate for prey.

The presence of spawning alewives in the Smith Mountain Lake littoral area may also have buffered predation on striped bass. Adult alewives are more than 10-fold heavier than age-0 striped bass and probably energetically more profitable to largemouth bass predators. Both adult alewives and age-0 striped bass are near shore at night, but alewives are more behaviorally vulnerable. Groups of spawning alewives splash in tight circles at the surface (Scott and Crossman 1973), whereas we observed striped bass distributed along the bottom in small, loose aggregations. Largemouth bass showed no attraction to aggregations of striped bass in the Smith Mountain Lake stocking coves; striped bass were concentrated over a sand–gravel substrate, whereas largemouth bass were distributed rather evenly along the entire shoreline. The rate at which largemouth bass ate age-0 striped bass (total of 14 fingerlings in seven largemouth bass of three age groups) is also indicative of incidental, opportunistic feeding. Results from our laboratory experiments suggest that largemouth bass prefer adult alewives to fingerling striped bass. However, our second set of trials demonstrated that largemouth bass will eat age-0 striped bass when alternative prey are not available. We did not observe largemouth bass feeding behavior in the circular pools, but alewives schooled in the water column and striped bass were distributed along the bottom, as observed in Smith Mountain Lake.

In Smith Mountain Lake, immediate poststocking predation on striped bass by largemouth bass accounted for little first-year mortality. In this reservoir, a wider distribution of stocked striped bass to reduce local densities seems unnecessary to curtail predation. The severity of largemouth bass predation on stocked striped bass in other systems cannot be directly predicted from the Smith Mountain Lake experience, but the availability of alternative prey may be critical. We advise prestocking assessment of the nearshore abundance of alternative prey and the utilization of that prey by largemouth bass.

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