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Predation on Recently Released Larval American Shad in the Susquehanna River Basin

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Abstract.—The release of 18-d-old larvae of American shad *Alosa sapidissima* is a major component of a program to restore shad in the Susquehanna River. At stocking sites we documented predation by the resident fish community on recently released American shad. Fish collections were made on three occasions 30–60 min after release of 0.38, 0.67, and 1.5 million larval American shad. All 15 species captured at the stocking sites had consumed larval shad. American shad larvae were in the stomachs of nearly 90% of the 1,163 examined fish and represented over 90% of stomach contents by weight. The predation rate was greatest for juvenile smallmouth bass *Micropterus dolomieu* (mean, 345 larvae/fish from 15 specimens) at the site of the highest-level shad stocking. The release of larval shad apparently triggered a feeding response in some cyprinids, and consumption of larvae increased with the number of shad released for numerically dominant spotfin shiners *Cyprinella spiloptera* and mimic shiners *Notropis volucellus*. Our results suggest that predation may be a key factor governing the survival of recently released American shad larvae near stocking sites in the Susquehanna River. Further research leading to a better understanding of predation on larval American shad is warranted in order to identify alternative stocking procedures that may reduce predation.

Identification of factors governing recruitment variability is essential for understanding the population dynamics of fishes (Cushing 1981). Recruitment variability often depends on survival during early life (Crecco et al. 1983; Øiestad 1985) and is influenced by several biotic and abiotic factors (Cushing and Dickson 1976; Crecco and Savoy 1985). However, predation, particularly during early life, may be the main cause of mortality (Cushing 1974; Hunter 1981; Øiestad 1985). Consequently, an understanding of predator–prey relationships associated with predation on larval fishes is critical for understanding recruitment variability (Margulies 1990).

Predation shapes the structure and functioning of many natural communities, and predator and prey densities may be the paramount variables (Holling 1966). Profound natural or human alterations of predator or prey densities offer opportunities for insight into predator–prey relationships. Stocking of waters with hatchery-reared fish is one of the most basic techniques to alter predator and prey densities. Stocking often results in high predation because hatchery fish have not developed adequate predator avoidance behaviors (Helfman 1986). Although hunger is believed to be the primary motivation for predation (Curio 1976), the large instantaneous increase in prey at stocking sites may trigger a feeding response in nonfeeding fish.

The restoration of American shad *Alosa sapidissima* is a major goal of fisheries agencies in the Susquehanna River basin (Susquehanna River Anadromous Fish Restoration Committee, unpublished data). A substantial part of the restoration program is the stocking of young American shad cultured from out-of-basin egg sources (Columbia, Delaware, and Hudson rivers). Because juvenile American shad suffer high mortality from handling and transportation stress, most shad are released as 18-d-old larvae, when they range in size from 6 to 16 mm. Although survival rates for the first 18 d after hatch are higher for hatchery-reared American shad larvae than for wild larvae (Crecco et al. 1983), much of this advantage may be lost with concentrated stocking in areas of heavy predator abundance. Consequently, we sought to document the extent of predation on recently stocked American shad, to identify the major predators, and determine if further investigation was warranted to describe predator–prey relationships.

Methods

Fish collections were made on three occasions within the Susquehanna River basin in conjunction with the routine stocking of American shad larvae by the Pennsylvania Fish Commission. The three samples were taken in conjunction with stocking low (0.38 million), medium (0.67 million), and high (1.50 million) numbers of American shad. Stocking sites were at Thompsontown

TABLE 1.—Sample sizes (*N*) and total lengths of fish species that ate American shad larvae in the Susquehanna River basin, 1989.

	Thompsontown, Jun 1			Montgomery Ferry, Jul 9			Montgomery Ferry, Jul 11		
		Total length (mm)			Total length (mm)			Total length (mm)	
Species	*N*	Mean	Range	*N*	Mean	Range	*N*	Mean	Range
Central stoneroller *Campostoma anomalum*							1	30.0	
Creek chub *Semotilus atromaculatus*				5	38.4	33–42			
Fallfish *Semotilus corporalis*				62	25.8	19–33	19	34.8	20–96
Rosyface shiner *Notropis rubellus*	2	67.5	66–69						
Spotfin shiner *Cyprinella spiloptera*	254	50.4	26–100	360	42.3	20–75	304	50.0	29–106
Spottail shiner *Notropis hudsonius*	1	40.0		8	71.4	67–78			
Mimic shiner *Notropis volucellus*	39	41.3	29–58	18	43.9	30–67	36	49.6	34–64
Bluntnose minnow *Pimephales notatus*	8	58.8	38–85						
Banded killifish *Fundulus diaphanus*	2	46.5	32–61	1	55.0				
Rock bass *Ambloplites rupestris*	3	63.3	45–85						
Redbreast sunfish *Lepomis auritus*	10	61.5	35–102				1	84.0	
Bluegill *Lepomis macrochirus*							2	95.0	93–97
Smallmouth bass *Micropterus dolomieu*	2	93.0		1	25.0		15	105.7	77–122
Largemouth bass *Micropterus salmoides*				2	43.5	37–50	2	39.5	37–42
Tessellated darter *Etheostoma olmstedi*				3	24.3	22–27	2	27.0	26–28

on the Juniata River (Juniata County) and at Montgomery Ferry on the Susquehanna River (Perry County) in Pennsylvania. Routine stocking procedures were followed during this investigation. A 7.6-m × 1.2-m (4.8-mm-mesh) seine was repeatedly hauled through the stocking site and through areas immediately downstream (about 100 m^2) 30–60 min after stocking, until capture rate markedly decreased (<10 fish/haul). Fish were also collected immediately prior to stocking in order to describe their prestocking feeding habits.

Specimens were preserved in 10% formalin. To stop digestion, the abdomens of fish longer than 100 mm were slit prior to preservation. Preserved fish were later transferred to 70% ethanol. During the transfer to alcohol, regurgitated American shad larvae (about 500) were noted. Regurgitation was most pronounced for centrarchids collected at the high-level shad stocking site. The stomach contents of all fish collected were examined under a microscope. Prey from the anterior one-third of the digestive tract were used to describe the diet of cyprinids, which lack true stomachs. To quantify dietary composition, dry-weight estimates from representative specimens of all prey taxa were used. Condition factors of predators ($K = 10^5 W/L^3$; W is wet weight in grams; L is total length in millimeters) were determined as described by Anderson and Gutreuter (1983). We used t-tests (K) and chi-square analyses (percent empty stomachs) to test for significant differences ($P < 0.05$) between pre- and postrelease intervals. Our use of K was to detect differences in stomach fullness.

Results and Discussion

Predation on American shad larvae was substantial on all sample dates. All 15 fish species collected preyed on American shad larvae (Table 1). We presume that all shad consumed had been recently released because no shad larvae were found in fish stomachs before stocking and natural reproduction of American shad is negligible in the upper basin. Spotfin shiners were the most abundant and mimic shiners the second most abundant predator at all sites. Most of the collected centrarchids were juveniles.

At Thompsontown, shad larvae composed 75–100% of the stomach contents (dry weight) of nine fish species (Table 2). Smallmouth bass (66 larvae/fish), redbreast sunfish (35 larvae/fish), bluntnose minnows (19 larvae/fish), and banded killifish (14 larvae/fish) consumed the most shad per predator. Spotfin shiners, which represented 79% of the fish sample at Thompsontown, were the major predators and had consumed an average of 8 larvae/fish. Frequency of occurrence of American shad larvae in the diet was at least 50% for all predatory species.

American shad larvae made up 72–100% of the diets of nine predators at Montgomery Ferry on July 9 (Table 2). Stomachs of spottail shiners (56 larvae/fish) and largemouth bass (27 larvae/fish) contained the most shad. Spotfin shiners were the dominant predators; they represented 78% of the total catch and averaged 9 larvae/fish. Fallfish, all subyearlings, consumed 5 larvae/fish on average.

TABLE 2.—Percentage dry weights, average numbers per stomach, and frequencies of occurrence of American shad larvae in predator stomachs in the Susquehanna River basin, 1989.

Species	Thompsontown, Jun 1 383,000 larvae stocked			Montgomery Ferry, Jul 9 666,000 larvae stocked			Montgomery Ferry, Jul 11 1,533,000 larvae stocked		
	% dry weight	Mean larvae per stomach	Frequency (%)	% dry weight	Mean larvae per stomach	Frequency (%)	% dry weight	Mean larvae per stomach	Frequency (%)
Central stoneroller							100	3.0	100
Creek chub				78	6.0	100			
Fallfish				97	5.4	98	99	5.4	90
Rosyface shiner	91	3.0	50						
Spotfin shiner	90	8.0	78	94	8.9	95	97	13.4	95
Spottail shiner	100	5.0	100	100	56.4	100			
Mimic shiner	85	1.7	51	99	12.7	100	100	15.0	97
Bluntnose minnow	100	19.3	50						
Banded killifish	75	14.0	100	100	14.0	100			
Rock bass	80	8.3	100						
Redbreast sunfish	87	35.4	100				100	268.0	100
Bluegill							78	138.0	100
Smallmouth bass	83	65.5	100	100	12.0	100	97	345.3	100
Largemouth bass				73	26.5	100	100	14.0	100
Tessellated darter				72	3.0	100	50	2.0	50

Shad larvae occurred in over 95% of the stomachs of all species.

Predation on American shad larvae was greatest at the highest stocking level (1.5 million) at Montgomery Ferry on July 11 (Table 2). Shad larvae represented 50–100% of the stomach contents of nine predators at this time. Stomachs of smallmouth bass (345 larvae/fish), redbreast sunfish (268 larvae/fish), and bluegills (138 larvae/fish) contained the most larvae (Table 2). As in the other samples, spotfin shiners were the most abundant predator—80% of those collected—and averaged 13 larvae/fish. The frequency of shad larvae in stomachs ranged from 50 to 100% per species.

Only spotfin shiners and mimic shiners were collected in sufficient numbers on all three sampling dates to examine how American shad consumption per predator changed relative to the number of larvae stocked. Consumption of larvae by both species increased with the number of shad released (Figure 1). At the highest stocking numbers, stomachs of spotfin shiners contained an average of 13 shad larvae and those of mimic shiners had 15 larvae.

The frequencies of empty stomachs of spotfin shiners, mimic shiners, and fallfish decreased after the release of American shad larvae (Table 3). With one exception—fallfish on July 11—these differences were significant. Consistent with these changes, condition factors (K) of these three species at Montgomery Ferry increased after American shad were released (Table 3). Spotfin shiners had a significantly higher mean K after stocking at Montgomery Ferry on both dates; mimic shiners exhibited a significantly higher K only at the highest shad stocking level. However some of the observed differences may be partially related to differences in sample size between pre- and poststocking periods.

Little information exists about predation on larval fish by multispecies fish assemblages. Much of the available information, reviewed by Bailey and Houde (1989), concerns marine species. Fewer studies have been conducted on freshwater assemblages (e.g., Loftus and Hulsman 1986; Brandt et al. 1987). Most investigations examined predation on larval fishes by one or two predator species, although McGovern and Olney (1988) identified several potential predators on larval striped bass *Morone saxatilis* in laboratory studies. Consequently, our study helps fill an information gap on predation on larvae by natural multispecies fish assemblages.

Although American shad larvae were the main dietary component of fishes at the time of release, it is not known if the predators became satiated at the stocking quantities (0.38–1.5 million larvae) we investigated. The stocking of enough hatchery fish to satiate (swamp) predators can reduce overall mortality (Peterman and Gatto 1978). McGovern and Olney (1988) reported that under laboratory conditions, spottail shiners and satinfin

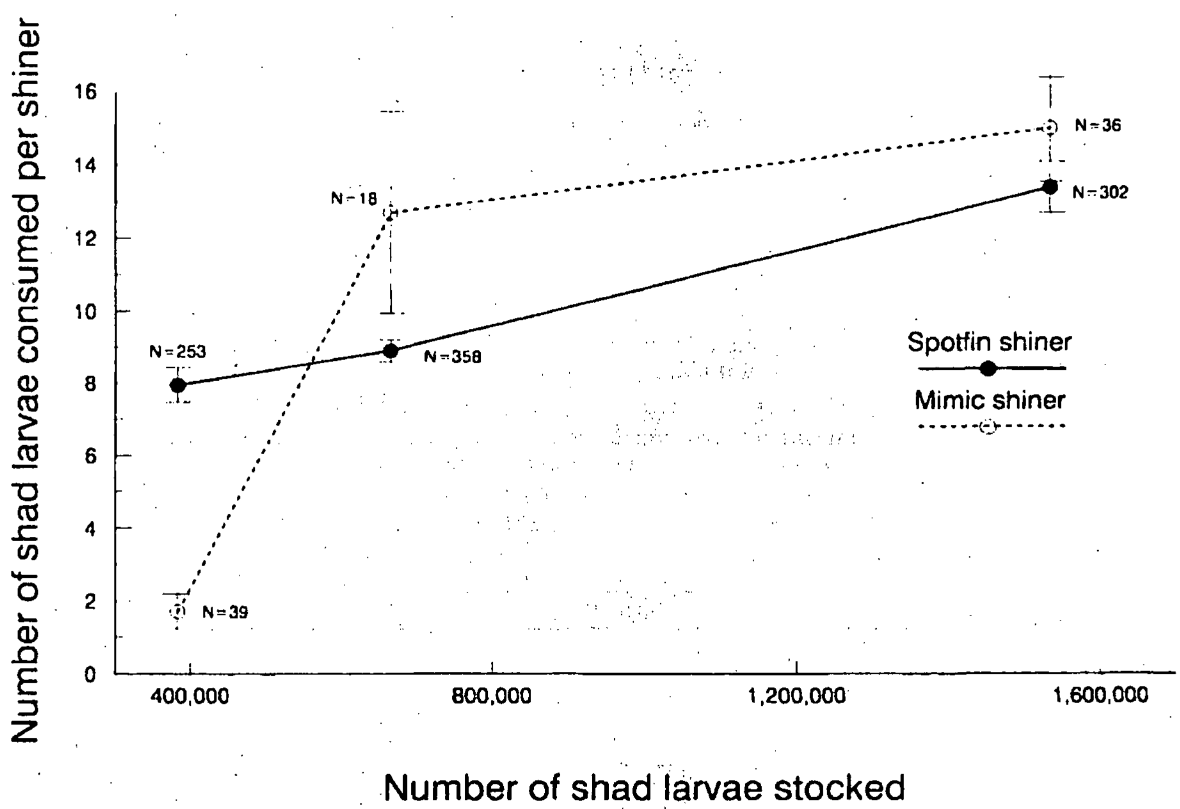

FIGURE 1.—Consumption (±SE) of American shad larvae by spotfin and mimic shiners at three stocking levels (N = sample size).

shiners *Cyprinella analostana* consumed 150 and 81 larvae/fish, respectively. Although no spottail shiners were collected when 1.5 million larvae were stocked, those taken after 0.67 million larvae were released contained 56 shad/fish. Consumption by spottail shiners may increase at higher stocking levels if they exhibit the same response shown by mimic and spotfin shiners (Figure 1).

Although predator satiation could not be determined on any of the three sampling dates, our data suggest that stocking had a profound effect on resident fish ecology at Thompsontown and Montgomery Ferry. Every fish species collected (15) consumed American shad, and the shad larvae contributed about 90% of the diet of the fishes examined. Furthermore, the availability of large

TABLE 3.—Frequencies of empty stomachs and mean condition factors (K) for spotfin shiner, mimic shiner, and fallfish before and after release of American shad in the Susquehanna River basin, 1989.

	Thompsontown, Jun 1[a]		Montgomery Ferry, Jul 9			Montgomery Ferry, Jul 11		
Species	N	% empty	N	% empty	K	N	% empty	K
Spotfin shiner								
Prestocking	124	30.6[b]	51	43.1[b]	0.865[c]	52	44.2[b]	0.902[c]
Poststocking	254	14.2[b]	360	2.2[b]	0.918[c]	304	3.9[b]	0.943[c]
Mimic shiner								
Prestocking	92	95.7[b]	21	81.0[b]	0.886	30	73.3[b]	0.851[c]
Poststocking	39	41.0[b]	18	0[b]	0.950	36	2.8[b]	0.978[c]
Fallfish								
Prestocking			61	49.2[b]	0.984	15	40.0	0.921
Poststocking			62	0[b]	1.051	19	11.8	0.969

[a] Mean condition factors were not calculated for Thompsontown samples.
[b] Significant difference ($P < 0.05$) between paired numbers, chi-square test.
[c] Significant difference ($P < 0.05$) between paired numbers, t-test.

numbers of shad larvae apparently triggered a midday feeding response by some of the cyprinids (Table 3).

Assessing mortality from predation is difficult because needed information includes prey identification and quantification in stomachs and estimates of predator and prey abundance (Bailey and Houde 1989). Quantification of consumed prey includes estimation of prey handling time, gut capacity, and satiation and digestion rates. Our data are insufficient to assess predation mortality of American shad larvae. However, our data are sufficient to suggest that predation is probably a key factor governing the survival of recently released American shad larvae in the Susquehanna River. Further research is necessary to develop a better understanding of predator–prey relationships associated with larval American shad releases so that modifications of existing stocking procedures can be implemented to reduce mortality from predation. Because predation on hatchery-reared fish is usually highest at or around the time of release (Peterman and Gatto 1978) this research should focus on aspects of predation within 24 h of stocking.

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