Spatial And Temporal Distribution Of Larval Alewives And Gizzard Shad in a Virginia Reservoir

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Abstract: Compatibility and complementarity of age-O alewife and gizzard shad as coexistent forage fishes were evaluated through analysis of their distribution, spawning periods, and growth rates in Smith Mountain Lake, Virginia, in 1983. Gizzard shad larvae appeared to be confined to the upper reservoir and alewife larvae to the down-lake region. Spatial segregation prevents direct trophic competition while increasing potential feeding encounters for juvenile piscivores. Gizzard shad spawning peaked in June; alewife spawning peaked in July. Age-O gizzard shad became too large for age-O and age-1 piscivorous game fishes by mid-summer, but later spawning and slower growth of the alewife assured its morphological availability to these predators for the remainder of the year. The alewife appears to be compatible with gizzard shad, and the species are complementary in providing spatial and temporal feeding opportunities for juvenile piscivores in Smith Mountain Lake.

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The alewife (*Alosa pseudoharengus*) is establishing abundant populations in an increasing number of southeastern reservoirs. Alewives have been purposely stocked in some systems to augment the pelagic forage fish base and have frequently migrated to downstream reservoirs as well (Ney 1981, Daniel 1984). Suitability of the alewife as a pelagic forage fish for southeastern reservoirs was evaluated by Kohler and Ney (1981) from a study of the species' trophic relationships in Claytor Lake, Virginia. This impoundment has no other pelagic prey species, but many of the systems in which the alewife has or may become established also contain large populations of gizzard shad (*Dorosoma cepedianum*) that are heavily utilized by piscivores.

The extent to which alewife and gizzard shad are compatible as coexistent forage species is unknown. This species combination may be beneficial in expanding the overall trophic availability of the forage base by raising total forage fish production. However, total forage fish production will be limited to the extent that the forage species are themselves competitors. Alewives and gizzard shad are most likely to be in direct competition during the larval stage (≤ mm TL) when both species are zooplanktivores. Gizzard shad later switch to a vegetation/detritus diet (Kutkuhn 1957, Bodola 1966).

Feeding opportunities for piscivores could also be enhanced by complementary differences in the morphological and spatial availability of alewives and gizzard shad. Morphological availability (i.e. the presence of forage fish of a size which can be ingested by a given predator) is a function of timing of reproduction and subsequent growth rates. Spatial availability is dependent on the distribution of each forage species within the reservoir.

This paper describes the temporal and spatial distribution of gizzard shad and alewife larvae in Smith Mountain Lake, Virginia. We apply this information to assess: (1) complementarity between alewife and gizzard shad in providing morphologically and spatially available forage for juvenile piscivores; and (2) the potential for trophic competition between these clupeids which could limit total forage supply.

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Methods

Smith Mountain Lake is an 8,340-ha hydroelectric impoundment of the Roanoke River in south-central Virginia. The reservoir consists of 2 long, narrow tributary arms, the Roanoke River (40 km) and Blackwater River (20 km) segments, and a broad and deep lower lake extending 10 km above the dam. Maximum depth is 61 m at the dam, and the lake has a mean depth of 17 m. The lower lake is oligotrophic with oxygen concentrations in the cool hypolimnetic waters reduced, but not depleted, during the summer months. Littoral regions contain only sparse cover and grade steeply into the profundal zone. In contrast, the tributary arms are more eutrophic from domestic and industrial effluents. Upper reservoir waters may be devoid of oxygen 5 m below the surface during summer months. Littoral regions contain more vegetation and other cover than the lower lake and slope more gradually into the main channels.

Because of the distinct differences between the lower and upper lake (i.e. fertility, thermal regime, and habitat), the lake was divided into 2 sections for this study. The upper lake (Roanoke River arm) extended downstream to Hales Ford

Bridge and the lower lake from the bridge to the dam. The Blackwater River arm was not sampled because its characteristics are similar to those of the Roanoke River arm. A main channel (offshore) and a cove (near-shore) site in both the upper and lower lake were sampled on a weekly basis for larval fish from late April through the end of August 1983.

Larval fish (<35 mm TL) were collected with a 500-micron mesh cone-shaped net, 0.5 m in diameter at the opening. Sampling was conducted after dark to minimize net avoidance (Ehrlich 1975). Stratified tows were conducted for larval shad and alewives at depths of 1, 3, and 5 m at each of the 4 sites. Two samples were taken at each depth. Surface water temperature was measured at each site just prior to the tows. Standardized hauls were made by towing at a constant speed of 1 m/second for 5 minutes. A calibrated flow meter, mounted in the mouth of the net, was used to estimate the volume of water filtered. The average volume of water filtered per haul was approximately 68 ± 17 m^3.

The range of total lengths of young-of-the-year alewife and gizzard shad was determined throughout growing season by periodic collections with a variety of supplemental techniques including electroshocking, midwater trawling, light-trapping, and gillnetting.

Larval fish were preserved in 4% buffered formalin (Braum 1978) immediately upon capture. In the laboratory, fish larvae were separated from the plankton and debris and were then placed in small plastic vials containing 40% ethanol. Individual specimens were identified, counted, and total length measured to the nearest mm. Alewife and gizzard shad are quite similar in appearance throughout early development and growth. Identification of larval shad and alewife was accomplished with a phase-contrast microscope based on the characters presented by Tin (1982). Statistical comparisons of the numbers of larval fish between depths and between sites were made using the Wilcoxon signed rank test. All tests were 2-sided and were considered significant at the $P = 0.05$ level.

Results

Spatial Distribution

Gizzard shad and alewife larvae did not co-occur in any of our tow net samples. No alewife larvae were collected in the upper lake and no gizzard shad larvae were taken in the lower lake over the 4.5-month sampling period (Table 1). Both species were concentrated in the upper 3 m of the water column. Average abundance at 1 m versus 3 m did not differ significantly at any site, but densities at 5 m were markedly lower ($P < 0.001$, each site). Collections from 1-m and 3-m tows were pooled in subsequent analyses.

Gizzard shad larvae were significantly more abundant ($P < 0.01$) at the cove site in the upper lake than in the main channel (Table 1). In contrast, there was no significant difference ($P = 0.34$) in the density of larval alewives between cove and main channel collection sites in the lower lake.

Table 1. Mean densities (number/1,000 m³) of alewife and gizzard shad larvae collected at sites in Smith Mountain Lake, Virginia, in 1983.

	Lower lake				Upper lake			
	Cove		Main channel		Cove		Main channel	
Depth (m)	Alewife	Shad	Alewife	Shad	Alewife	Shad	Alewife	Shad
1	121	0	83	0	0	877	0	317
3	157	0	159	0	0	1040	0	160
5	41	0	9	0	0	71	0	21

Mean densities of larval gizzard shad at both sites in the upper lake were several times as great as mean densities of alewife larvae at the two down-lake sites. Greatest densities of shad at both sites occurred on June 20 (2,706 and 1,101/1,000 m^3, cove and channel, respectively). Peak alewife densities were encountered at the cove site on July 5 (427/1,000 m^3) and in the channel on July 12 (454/1,000 m^3).

Temporal Distribution

Prolarvae (<5 mm TL) of both species were not fully vulnerable to the sampling gear. Therefore, relative abundance of 5 to 10 mm fish was selected as an index of spawning periods and intensities because: (1) larvae of this size range were both abundant and fully vulnerable to sampling equipment; and (2) development to this size from fertilization is rapid, requiring only about 1 week at water temperatures recorded in Smith Mountain Lake (Scott and Crossman 1973). Durations of spawning periods, however, were estimated by the first and final appearance of prolarvae of both shad and alewife. Sites in the upper and lower lakes were combined to characterize the spawning periods of gizzard shad and alewife, respectively.

Gizzard shad spawned in Smith Mountain Lake from mid May until late June at water temperatures between 22° and 28° C. Alewives had a considerably longer spawning period lasting approximately 10 weeks. Beginning in late May, alewife spawning continued through the first week of August at water temperatures between 19° and 28° C. Larval density peaked earlier for gizzard shad than for alewives (Fig. 1). Gizzard shad had a minor peak in late May with the major peak occurring around the middle of June. The major peak for alewives occurred during the first week of July. Although peak spawning occurred for both species in different areas of the lake and at different times, the water temperature at which peak spawning occurred was nearly identical (27–28° C) for both species (Fig. 1).

Daily growth rates of young-of-the-year alewife and gizzard shad were estimated from maximum total lengths of specimens collected on successive sampling dates. Growth of both species appeared to be linear into September, averaging 0.90 mm/day for alewife and 1.33/mm day for gizzard shad. The comparatively short spawning period and rapid growth of gizzard shad versus alewife caused a disjunction in length distributions between the species by mid-July (Fig. 2).

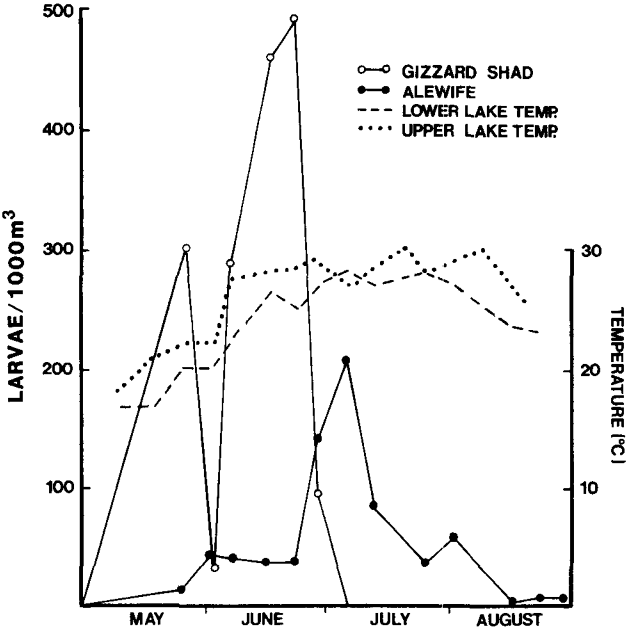

Figure 1. Densities of 5–10 mm TL alewife and gizzard shad and corresponding surface water temperatures in Smith Mountain Lake, Virginia, in 1983.

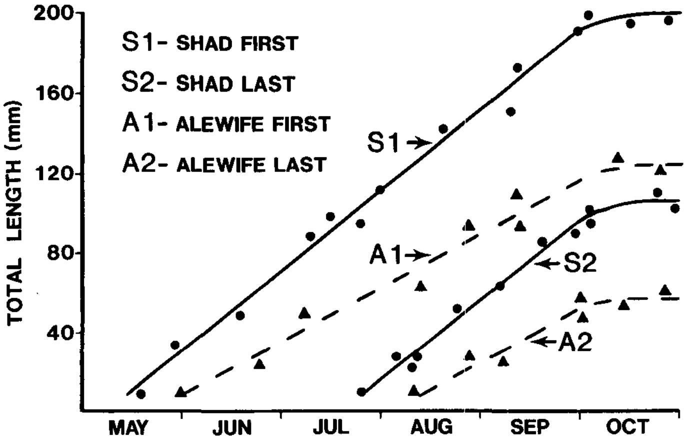

Figure 2. Estimated patterns of first-year growth of alewife and gizzard shad in Smith Mountain Lake, Virginia, in 1983. Dots and triangles represent size ranges indicative of first and last-spawned cohorts of gizzard shad and alewife, respectively.

Discussion

Alewife and gizzard shad larvae exhibited strong spatial segregation in Smith Mountain Lake in 1983. Our sampling design was not sufficiently extensive to determine if larval distributions were completely disjunctive: the mid-lake area, where overlap would be most likely to occur, was not surveyed. However, distributions of these species in our collections are consistent with reports from other, morphometrically similar reservoirs where each occurs alone. Densities of larval gizzard shad are commonly higher in upper tributary arms of reservoirs than in broader and deeper downstream areas (Taber 1969, Storck et al. 1978), perhaps due to the differential availability of suitable spawning areas (Downey and Toetz 1983). The littoral zone in the upper region of Smith Mountain Lake contains more cover and slopes much more gradually toward the main channel than it does in the lower lake. In contrast, alewives spawn less discriminately over sand-gravel substrate (Rothschild 1966; Norden 1967). In Claytor Lake, Virginia, the major spawning site of alewives is also near the dam (Nigro and Ney 1982). Adult alewives may use the deep pelagic waters of a reservoir as a staging area for nocturnal spawning forays into the adjacent littoral zone (Nigro 1980; Kelso and Ney 1982).

Spatial segregation of alewife and gizzard shad larvae effectively eliminates the potential for direct (interference) trophic competition between the species which could impact the production of either. Spatial segregation should also increase feeding opportunities for juvenile piscivores throughout systems that contain both forage species versus systems that have only one. However, it is not yet possible to generalize the occurrence and degree of spatial segregation between larval alewives and gizzard shad in lentic waters. In particular, systems that differ from the shallow upstream-deep downstream configuration may also experience different distributions of these larval clupeids. Where alewife and gizzard shad larvae do share a horizontal distribution, they are also likely to occur at the same depths. In Smith Mountain Lake, both species were present in greatest abundance near the surface, as has been reported elsewhere for gizzard shad (Netsch et al. 1971) and alewife (Graham 1956, O'Gorman 1977).

The higher densities of larval gizzard shad that we recorded at our nearshore cove site do not reflect a general distributional pattern for the species. Larval gizzard shad abundance has been reported to be higher (Mayhew 1974), lower (Storck et al. 1982), or the same (Netsch et al. 1971) at nearshore versus offshore sites. While adult alewives are principally pelagic except during spawning, distributions of larvae have not been previously reported. Although larval gizzard shad densities were usually higher than alewife densities in our Smith Mountain Lake samples, their separate spatial distributions makes it impossible to extrapolate the relative abundance of one to the other without much more extensive sampling.

The difference in the timing of spawning observed in Smith Mountain Lake may be partially explained by the thermal regime; the upper lake warmed more rapidly than did the lower lake. Alewife and gizzard shad appear to possess very similar temperature preferenda for spawning. Peak spawning has been reported for gizzard shad at 22–24° C (Downey and Toetz 1983), and for alewife, at 21–24° C (Nigro and Ney 1982). In Smith Mountain Lake, peak spawning for both species occurred at a surface water temperature near 28° C, the thermal limits of egg viability for alewife (Edsall 1970). However, a general review of extant early life history information on both species indicates that alewives will probably spawn longer and later than gizzard shad if thermal limits are not exceeded. Alewives may be fractional, repeat spawners, which would contribute to an extended reproductive period (Nigro and Ney 1982).

Later spawning and slower first-year growth both contribute to enhancing the morphological availability of alewife to juvenile piscivores. As an illustration, we applied the equation of Jenkins and Morais (1978) which estimates maximum ingestible prey total length for predators of a given total length to our reproduction-growth data for alewife and gizzard shad (depicted in Fig. 2). Based on these calculations, even the last-spawned gizzard shad would be too large for 200 mm TL striped bass (*Morone saxatilis*), 180 mm TL largemouth bass (*Micropterus salmoides*), and 300 mm TL walleye (*Stizostedion vitreum*) by early August. In contrast, all age-O alewife would be morphologically available to these predators throughout the remainder of the year. The disjunctive size distribution of age-O gizzard shad and alewife should ensure an abundant supply of ingestible forage fish throughout the growing season, if juvenile piscivores can locate them in their different habitats.

Our analysis indicates that alewife and gizzard shad are not strongly competitive for spawning sites or larval food supply in Smith Mountain Lake. Differences in distribution, reproductive period, and growth rates should also benefit piscivorous game fishes by increasing total spatial and morphological availability of the forage fish resource. Analyses of the actual utilization of alewife in the presence of gizzard shad will be required to confirm the latter. Although the alewife appears to be both compatible with, and complementary to the gizzard shad as a forage species in Smith Mountain Lake, its introduction into other waters should only be made with extreme caution. The alewife has negative characteristics (Ney et al. 1982) that can adversely impact a resident fish community. The net effect of the establishment of an alewife population will vary with the physical, chemical and biological characteristics of the waterbody.

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