

Food Habits and Diet Overlap of Larval *Lepomis* spp. and Gizzard Shad in a Piedmont Reservoir

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Abstract: The food habits of larval *Lepomis* spp. and gizzard shad (*Dorosoma cepedianum*) in Hyco Reservoir, North Carolina, were studied during 1982. Results indicated that *Lepomis* spp. began feeding at a length of 4 mm on copepod nauplii and the rotifers *Polyarthra* and *Filinia*. Selection later (10 mm) shifted to *Bosmina*, *Daphnia*, and *Mesocyclops*, while *Diaphanosoma* was strongly selected for by all sizes of larvae. The crustaceans *Diaptomus*, *Ceriodaphnia*, and *Holopedium*, along with most rotifers, were not selected. Gizzard shad began feeding primarily on large phytoplankters at 4 mm, then shifted to nauplii and *Polyarthra* at 5 mm, then to *Daphnia* at 12 mm. *Bosmina* and *Diaphanosoma* were eaten occasionally; and *Diaptomus*, *Ceriodaphnia*, *Holopedium*, and most rotifers were not selected. Both fish species ate significantly greater amounts of zooplankton during the day than at night, and *Lepomis* spp. ate significantly more zooplankton than gizzard shad overall. A niche overlap index indicated that there is some competition and diet overlap only among small (5-6 mm) *Lepomis* spp. and gizzard shad larvae. Diet overlap then decreased with increasing fish size, and densities of the principal zooplankton prey items were sufficiently great to permit resource sharing among these predators.

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Gizzard shad and sunfishes (*Lepomis* spp.) are 2 important components of the fish community in many reservoirs. Kutkuhn (1957) stated that crustacean zooplankton were important food elements of recently hatched gizzard shad. Cramer and Marzolf (1970) found gizzard shad 20 mm total length utilizing crustacean zooplankton almost exclusively with *Cyclops*, *Bosmina*, and *Daphnia* the prey most frequently used.

Taylor (1977) studied larval *Lepomis* spp. food habits and found cladocerans,

especially *Bosmina longirostris*, to be the most important prey items. Werner (1969) determined that the most important food items of bluegill (*L. macrochirus*) fry were *Daphnia galatea* and copepods followed by *Ceriodaphnia lacustris*, *Bosmina longirostris*, and *Chaoborus* sp. Siefert (1972) found the rotifer *Polyarthra* and copepod nauplii selected for at the initiation of feeding (at 5 mm) followed by other rotifers and cyclopoid copepods at a fish length of 7 mm and cladocerans ≥ 8 . Lemly and Dimmick (1982) found copepod nauplii and copepodids to be the primary food of larval bluegill. Food selectivity of a given larval fish species is obviously variable and likely depends on the prey species available, their relative proportions, and the prey densities (O'Brien et al. 1976).

The present study was initiated to determine principal prey items and prey selectivity of larval stage of *Lepomis* spp. and gizzard shad, major species in Hyco Reservoir, North Carolina. We also wished to determine if there is food resource overlap between *Lepomis* spp. and gizzard shad and if the possibility of competition for prey exists between these predators. The authors thank W. T. Bryson, K. A. MacPherson, W. H. Tarplee, and B. J. Ward for helpful comments and suggestions.

Methods

Hyco Reservoir is an impoundment of Hyco River approximately 16 km northwest of Roxboro, North Carolina, near the Virginia border. It has a surface area of about 1,760 ha, a mean depth of 5.5 m, and a maximum depth of 13 m. Average retention time is about 6 months. Hyco Reservoir is a mesotrophic system. Some selected chemical constituents of the reservoir and their 1982 mean values include chlorophyll α (11.3 $\mu\text{g/liter}$), total Kjeldahl nitrogen (0.32 mg/liter), and total phosphorus (0.02 mg/liter). The reservoir was completed in 1964 and filled in 1965. The reservoir provides cooling water for the Roxboro Steam Electric Plant (RSEP), a 4-unit 2477 MWe coal-fired generating station, operated by Carolina Power and Light Company (CP&L).

Day and night surface larval fish samples were collected weekly during the peak spawning season of April-June 1982 using a replicate push-net apparatus (Tarplee et al. 1979). Six-minute horizontal surface samples were collected with 0.5-m conical nets (0.560-mm mesh) in 7 areas. General Oceanic flowmeters mounted in each net enabled the estimation of the volume of water filtered for each sample. After each sample was collected, nets were washed down and the sample placed in a collection jar, labeled, and preserved with 4% formaldehyde.

In the laboratory, larval fishes were sorted from the samples and placed in labeled vials containing 2% buffered formaldehyde. Each larval fish was identified to the lowest practical taxon. *Lepomis* spp. were too small for precise speciation but consisted mainly of bluegill (*L. macrochirus*) and green sunfish (*L. gibbosus*).

Zooplankton samples were obtained concurrently with the larval fish pushnet samples by towing 13-cm Wisconsin plankton nets for 0.5 minutes side-by-side with the push nets. Adult copepods and cladocerans were collected using a No. 10 (0.156-mm) mesh-sized net; and copepod nauplii, rotifers, and protozoans were

collected with a No. 20 (0.076-mm) mesh-sized net. Zooplankton samples were preserved in the field in 2% formaldehyde. In the laboratory, aliquots containing at least 200 organisms were removed from both the No. 10 and No. 20 net samples and counted using a counting wheel and dissecting microscope.

Larval fish collected on 10, 20, and 24 May and 1 and 21 June were used for gut content analysis. These dates were chosen because of the large proportion of *Lepomis* spp. and/or gizzard shad larvae in the samples on those dates. When present, a total of 5 *Lepomis* spp. and 5 gizzard shad of various sizes was chosen for analysis from day samples for each date and sampling location. Night samples from May 24 and June 1 were processed in a similar manner.

Gut content analysis consisted of measuring the total length (TL) of the larval fish to the nearest 0.1 mm with a stage micrometer and then placing the larva on a slide in a drop of water. The digestive system was excised using insect needles and a small scalpel and the body of the larva was removed. The guts were shredded and the contents were spread out and covered with a coverslip. The slide was then examined using a compound microscope, and gut content items were identified to the lowest possible taxon. Identification of amorphous or badly degraded material was not attempted. Identification of stomach contents was facilitated by counting the corresponding zooplankton samples immediately before conducting gut analysis from a particular larval fish sample. A total of 146 *Lepomis* spp. and 108 gizzard shad was analyzed. Because of the field sampling method, the majority of fishes analyzed were < 10 mm (TL).

Food habits of the fish were studied first by combining all fish examined from day samples and determining selectivity for the zooplankton prey by the fish. The percent composition of food items found in the stomachs of the larvae was computed. Food selectivity was determined by applying a linear food selection index (Strauss 1979):

$$L = r_i - p_i.$$

In this index, r = proportion (%) of food organism in the diet and p = proportion (%) of food organism in the environment. Values range from -1 to $+1$ with positive values indicating preference and negative values indicating inaccessibility or avoidance. The expected index value for random feeding is zero. Extreme values occur only when the prey item is rare but consumed almost exclusively or is very abundant but rarely consumed. Values were examined statistically for departure from zero using T-statistics. Corrections were made to attempt to account for variability from subsampling and heterogeneity caused by station and date differences following Strauss (1982).

The possibility of food resource overlap between the fish species was examined using Hurlbert's (1978) index:

$$B = \sum_{i=1}^z (R_{iA}R_{iB}/R_{iR}).$$

In this index, z = number of prey taxa common to both fish species, R_{iA} , R_{iB} = % composition of the prey taxa in Species A (gizzard shad) and Species B (*Lepomis*

spp.) and $R_{IR} = \%$ composition of the prey taxa in the reservoir. The value of B is zero when no prey are shared by both predators, 1.0 when both predators utilize each prey taxa in proportion to its reservoir abundance, and >1.0 when each predator species utilizes rare prey species more intensively and diet preferences of the predators tend to overlap. Thus values of B greater than 1.0 indicate increasing resource overlap and, for rare prey, competition.

Results and Discussion

Food Habits of Larval *Lepomis* spp.

Prey selectivity by fish with all size groups combined was determined (Table 1). The rotifers *Polyarthra* spp. and *Filinia longiseta* were both selected for by *Lepomis* spp. The cladocerans *Bosmina longirostris* and *Diaphanosoma brachyurum* were also selected for with *Diaphanosoma* having the highest linear selection index value. Copepod nauplii comprised the largest percentage of the prey community and were also selected for. Copepodites made up only a small percentage of the zooplankton but were a selected food item as indicated by a relatively high linear selection index value (0.04).

The protozoan *Diffugia* was found in high reservoir densities but was not selected. The rotifers *Conochiloides coenobasis*, *Conochilus unicornis*, *Pompholyx*

Table 1. Strauss' linear food selection index of day samples of *Lepomis* spp. and gizzard shad larvae for prey taxa comprising $\geq 1\%$ of zooplankton community. The density (d) in organisms $\times m^{-3}$ and percent of the total community in the reservoir for each prey taxa (%) are shown.

Prey Taxa	d	%	<i>Lepomis</i> spp.	Gizzard Shad
Copepoda				
nauplii	60,444	18.5	0.07	0.13
<i>Diaptomus pallidus</i>	27,795	8.5	-0.07	-0.08
<i>Mesocyclops edax</i>	4,571	1.4	0.01	-0.01
Cladocera				
<i>Daphnia ambigua</i>	6,539	2.0	-0.01	0.01
<i>Ceriodaphnia reticulata</i>	45,068	13.8	-0.10	-0.13
<i>Bosmina longirostris</i>	18,909	5.8	0.08	-0.04
<i>Diaphanosoma brachyurum</i>	22,578	6.9	0.18	-0.02
<i>Holopedium amazonicum</i>	28,459	8.7	-0.05	-0.05
Rotifera				
<i>Keratella</i> spp.	6,837	2.0	-0.01	-0.02
<i>Asplanchna priodonta</i>	6,956	2.1	-0.02	-0.02
<i>Polyarthra</i> spp.	6,425	2.0	0.11	0.49
<i>Filinia longiseta</i>	3,191	1.0	0.04	0.01
<i>Pompholyx sulcata</i>	12,701	3.9	-0.04	-0.04
<i>Conochilus unicornis</i>	5,902	1.8	-0.01	-0.01
<i>Conochiloides coenobasis</i>	6,109	1.8	-0.02	-0.02
Protozoa				
<i>Diffugia</i> sp.	56,450	17.3	-0.21	-0.21

Table 2. Food habits of *Lepomis* spp. larvae showing size range of larvae (4 = 4.0–4.9, etc.), the number of larvae examined of each size range (*N*), mean number of prey items eaten (\bar{x}), and Strauss' linear food selection index by prey species and larvae size^a.

Size (mm)	4	5	6	7	8	9	10–18
<i>N</i>	9	29	19	13	8	3	13
(\bar{x})	5.0	5.2	12.4	10.3	16.3	10.7	34.9
Copepoda							
nauplii	0.11	0.25	0.19	0.24	0.01	0.16	-0.09
<i>Diaptomus pallidus</i>	-0.09	-0.09	-0.08	-0.09	-0.09	-0.09	-0.06
<i>Mesocyclops edax</i>	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.04
Cladocera							
<i>Daphnia ambigua</i>	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	0.01
<i>Ceriodaphnia reticulata</i>	-0.14	-0.14	-0.13	-0.09	-0.12	-0.14	-0.06
<i>Bosmina longirostris</i>	-0.05	-0.03	-0.05	-0.04	-0.04	-0.05	0.29
<i>Diaphanosoma brachyurum</i>	0.06	0.05	0.23	0.18	0.38	0.46	0.12
<i>Holopedium amazonicum</i>	-0.05	-0.05	-0.05	-0.05	-0.04	-0.05	-0.05
Rotifera							
<i>Keratella</i> spp.	-0.02	-0.01	-0.01	0.00	0.01	-0.02	0.00
<i>Asplanchna priodonta</i>	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
<i>Polyarthra</i> spp.	0.34	0.29	0.18	0.08	0.13	-0.02	0.00
<i>Filinia longiseta</i>	0.13	0.07	0.05	0.04	0.06	0.02	-0.01
<i>Pompholyx sulcata</i>	-0.04	-0.04	-0.04	-0.03	-0.04	-0.04	0.04
<i>Conochilus unicornis</i>	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
<i>Conochiloides coenobasis</i>	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Protozoa							
<i>Diffugia</i>	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21

^aAll selection index values different from zero were significant ($P \leq 0.05$)

sulcata, and *Keratella* spp. were also not selected. The copepod *Diaptomus pallidus* was not eaten, possibly because of its evasive ability (Drenner and McComas 1980). *Daphnia ambigua* and *Ceriodaphnia reticulata*, which are not known for escape abilities, were nonetheless not selected. The cladoceran *Holopedium amazonicum* was also not selected, possibly because of its surrounding gelatinous matrix.

Lepomis spp. larvae were grouped by 1-mm size groups and the linear selection indices were computed for each (Table 2). The data indicate that nauplii, *Polyarthra*, and *Filinia* were selected for by the smaller larvae with selection later changing to *Bosmina*, *Mesocyclops*, and *Daphnia*. *Diaphanosoma* seemed to be a preferred item for all sizes of larvae with the smallest larve eating the smaller *Diaphanosoma*. Although few *Lepomis* spp. >10 mm (TL) were collected during the study, those large larvae examined were found to have captured evasive prey such as *Diaptomus* and benthic macroinvertebrates (chironomids and beetle larvae). None of the *Lepomis* spp. size groups studied utilized phytoplankton as a food source. There was distinct increases in the number of prey items eaten along with increased size of larvae. Doubling of prey intake occurred at 6-mm length and there was another large increase at 10 mm.

When selection indices were tested for departure from zero, regardless of corrections, everything eaten showed significance. This resulted from large inherent biological heterogeneity in the natural zooplankton communities ($P < 0.05$). The

fish had anywhere from 15 to 25 prey species to choose from at any time with very high numbers of certain prey items available. Therefore, heterogeneity was great enough so that any selectivity became significant.

Gizzard Shad Larval Food Habits

Gizzard shad larvae expressed overall selectivity for only a few food items (Table 1). Rotifers (*Polyarthra* spp. and *Filinia longiseta*) and copepod nauplii were the most selected for items among small zooplankton comprising >1% of the total community. The sampling gear used in our study selected for small gizzard shad larvae (<20.0 mm TL), possibly limiting their prey selectivity to the smaller zooplankton. In our study the only large form selected for in the pooled data was *Daphnia ambigua*. Among forms which comprised <1% of the zooplankton community, copepodites were also selected for (linear selection index 0.02).

Those zooplankters which gizzard shad did not eat were mostly the same ones *Lepomis* spp. did not. These included *Diaptomus*, *Ceriodophnia*, *Holopedium*, and most rotifers. Caution must be used when the index is applied to soft-bodied rotifers; they may be digested rapidly making them indistinguishable in the gut contents.

Table 3 lists gizzard shad food selectivity by size group for day samples. As

Table 3. Food habits of larval gizzard shad showing size range of larvae (4 = 4.0–4.9, etc.), number of larvae examined of each size range (N), mean number of prey items eaten (\bar{x}), and Strauss' linear food selection index by prey species and larvae size^a.

Size (mm)	4	5	6	7	8	9	10–22
N	11	6	13	7	10	9	10
(\bar{x})	b	3.7	3.5	1.3	6.1	7.8	7.9
Copepoda							
nauplii	-0.01	0.23	0.06	0.15	0.05	0.09	0.26
<i>Diaptomus pallidus</i>	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.08
<i>Mesocyclops edax</i>	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Cladocera							
<i>Daphnia ambigua</i>	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.06
<i>Ceriodaphnia reticulata</i>	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.10
<i>Bosmina longirostris</i>	-0.05	-0.05	-0.05	0.06	-0.05	-0.05	-0.04
<i>Diaphanosoma brachyurum</i>	-0.07	-0.07	-0.07	0.04	-0.07	0.03	0.02
<i>Holopedium amazonicum</i>	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04
Rotifera							
<i>Keratella</i> spp.	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
<i>Asplanchna priodonta</i>	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
<i>Polyarthra</i> spp.	0.73	0.57	0.72	0.43	0.59	0.54	0.20
<i>Filinia longiseta</i>	-0.01	-0.01	-0.01	-0.01	0.01	0.03	0.02
<i>Pompholyx sulcata</i>	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
<i>Conochilus unicornis</i>	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
<i>Conochiloides coenobasis</i>	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.21
Protozoa							
<i>Diffugia</i>	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21

^aAll selection index values different from zero were significant ($P \leq 0.05$)

^bPrey at this size consisted mainly of phytoplankton.

with *Lepomis* spp., due to gear selectivity, only very limited data is available for large gizzard shad larvae. The data show the selectivity for *Polyarthra* and nauplii with occasional selectivity for *Filinia*. *Daphnia* were selected for by larger larvae and *Diaphanosoma* and *Bosmina* were occasionally selected for. This is in contrast to *Lepomis* spp., which showed strong overall selectivity for *Diaphanosoma* and *Bosmina*. What is not expressed in the table, but is of interest, is the fact that the smallest gizzard shad larvae (4 mm) consumed phytoplankton as well. These phytoplankton were large cells or colonies like *Coelastrum*. This food source was utilized less as the fish grew. In contrast to *Lepomis* spp., aquatic insect larvae were not found in the guts of any of the gizzard shad larvae examined.

Day Versus Night Feeding

On 2 dates (24 May and 1 June), both day and night samples were analyzed to test for differences between periods in feeding. In general, daytime feeding was much more extensive for both species than night feeding (Table 4). The majority of fish collected at night containing prey organisms were taken shortly after dusk when remains of prey ingested during the daytime were still recognizable. *Lepomis* spp. generally fed more extensively in the daytime. Gizzard shad always fed more extensively in the daytime with night feeding usually an order of magnitude less than during the day. When all size ranges were pooled, an F test indicated that *Lepomis* spp. larvae ate significantly more mean total zooplankton (day 25.1 items; night 14.9 items); *Polyarthra* (day 3.1 items, night 1.3 items), and *Filinia* (day 1.8 items; night 0.0 items) during the day than at night ($P \leq 0.05$). Werner (1969) suggested that bluegill fry feed by sight successfully only during the day and were able to feed at night only by chance tactile encounter when zooplankton densities were about 4,000 organism /liter, 20 times the normal density in Hyco Reservoir. We conclude that because few food items are ingested at night, food habit analyses of larval *Lepomis* spp. and gizzard shad taken at night are impractical.

Table 4. Mean number of prey items eaten by size group and period for *Lepomis* spp. and gizzard shad.

Size Group (mm)	<i>Lepomis</i> spp.		Gizzard Shad	
	Day	Night	Day	Night
4	5.0	1.0	13.6 ^a	0.0
5	5.2	6.1	a	a
6	12.4	4.1	3.5	0.5
7	10.3	7.7	a	a
8	16.3	4.9	6.1	0.5
9	10.7	17.7	7.9	0.2
10	28.8	8.2	8.0	0.0
11	24.5	7.5	14.3	0.2

^aFish of that size not found in both periods.

^bPrey items consisted mostly of large motile phytoplankton cells.

Table 5. Mean numbers of zooplankton prey items eaten by larval *Lepomis* spp. and gizzard shad from day samples.

Prey Items	<i>Lepomis</i> spp.	Gizzard Shad
Total zooplankton	12.57 ^a	4.39
nauplii	3.11 ^a	1.37
<i>Diaptomus pallidus</i>	0.17	0.01
<i>Mesocyclops edax</i>	0.24	0.00
<i>Daphnia ambigua</i>	0.15	0.09
<i>Ceriodaphnia reticulata</i>	0.46 ^a	0.04
<i>Bosmina longirostris</i>	1.66 ^b	0.03
<i>Diaphanosoma brachyurum</i>	3.12 ^a	0.22
<i>Keratella</i> spp.	0.15 ^b	0.00
<i>Polyarthra</i> spp.	1.58	2.22
<i>Filinia longiseta</i>	0.59 ^b	0.09

^aIndicates significant difference ($P < 0.01$)

^bIndicates significant difference ($P < 0.05$)

Diet Overlap and Resource Competition

The data show that larval *Lepomis* spp. and gizzard shad shared certain segments of the zooplankton prey population. Competition between the predators could occur if selected prey was rare or limiting in the plankton. The possibility for interspecific competition existed and might have affected distribution and abundances of these larval fish species.

We determined the numbers of each prey item contained in the stomachs and compared the amounts between species. Table 5 expresses the mean numbers from various zooplankton taxa groups eaten by each species. An analysis of variance compared the numbers eaten and significant differences are shown. In no case did gizzard shad eat a significantly greater amount from a taxa group than did *Lepomis* spp. The *Lepomis* spp. larvae were more voracious zooplankton feeders than gizzard shad. Despite this, field data showed that gizzard shad were more numerous than *Lepomis* spp. in all areas sampled except 1 (Birchfield 1983). This may have been a function of habitat because the water was shallow at that station and may have provided better spawning areas for *Lepomis* spp. than the other areas. The greater amount of zooplankton eaten by *Lepomis* larvae, therefore, did not appear to enhance the *Lepomis* spp. population but may simply be a normal situation (a function of metabolic or digestive rate or better swimming or hunting ability).

To obtain greater insight into diet overlap between species, we applied Hurlbert's (1978) index. This index was chosen because of the availability of data on prey in the environment. Table 6 expresses the interspecific index values for each 1-mm size group from 4 through 11 mm. The low value at 4 mm indicates that there was virtually no diet overlap between fish species at that size. This is because a large part of the gizzard shad diet at 4 mm length was phytoplankton. *Lepomis* spp. consumed no phytoplankton at any size range studied. Values at 5 and 6 mm indicate that there

Table 6. Hurlbert's index as applied to dietary resource overlap between *Lepomis* spp. and gizzard shad by size group.

Size Group (mm)	Hurlbert's Index
4	1.25
5	16.41
6	12.83
7	5.01
8	8.21
9	1.91
10	3.01
11	1.89

was some diet overlap at these sizes. The 2 prey organisms shared by both predators were nauplii and the rotifer *Polyarthra*. Nauplii were abundant in the zooplankton, but *Polyarthra* comprised <2% of the community and strong selection of this prey by both predators was responsible for the greater overlap values. The index rapidly decreased after 6 mm, primarily because the *Lepomis* were eating a much greater variety of zooplankton, with cladocerans, especially *Diaphanosoma*, making up greater proportions of their diet and rotifers, such as *Polyarthra*, less. Nauplii continued to comprise large portions of the diets of both fish species >6 mm, but high nauplii densities in the reservoir reduced the possibility for competition.

The only likely competition for rare prey was for *Polyarthra* and only for a short period. Densities of most zooplankton prey, such as nauplii and cladocerans, were sufficiently great to permit resource sharing among the predators.

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