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# EXTENT OF WATER LILY (*Nuphar lutea*) BEDS AND THEIR USE BY LARVAL FISHES IN THE ROANOKE RIVER, NORTH CAROLINA

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*Abstract:* Vegetated areas within river systems support a wide variety of zooplankters that are utilized by larval fishes as a food source and can serve as a refuge from predation. Water lilies (*Nuphar lutea*) dominated the emergent vegetation in the Roanoke River, North Carolina, and were most abundant in the mainstem Roanoke and the Cashie rivers, one of two tributaries. A pushnet was used to estimate the utilization of water lily beds by larval fishes. Twelve larval fish taxa were collected but of these only three were consistently found in the water lily beds: centrarchids (Centrarchidae); darters (Percidae); and cyprinids (Cyprinidae). The larval fishes collected in this study occurred at times of year that were similar to those found in other studies. Zooplankton species composition and consumption by larval fishes was compared in open-water samples and water lily bed samples. *Daphnia, Bosmina,* and copepods were found more frequently in open-water samples and other cladocerans were found more frequently in water lily bed samples. Cladocerans and rotifers were the primary prey taxa of larval fishes in the water lily beds and cladocera and copepods were the primary prey taxa in open water. Larval fish feeding success was greater during periods of high prey density.

*Key Words:* larval fishes; Centrarchidae; Percidae; Cyprinidae; zooplankton; water lilies.

## INTRODUCTION

Vegetated areas within river systems can be important to young fish as a refuge from predation (Werner et al., 1983) while still allowing them to have access to open-water zooplankton. As fish larvae increase in length, capturing the open-water zooplankton becomes more energetically-profitable (Mittlebach, 1981) since these zooplankters are not concealed by vegetation and therefore require less effort to capture. Vegetated areas support a wide variety of zooplankters that are utilized as food by many larval fish taxa (Miller and Kramer, 1971; Siefert, 1972; Keast and Eadie, 1985; Jackson and Schmitz, 1987; Engel, 1990). In lakes, certain fish species utilize specific vegetated areas as larvae and may switch to using other vegetation types as juveniles (Conrow et al., 1990), or they may switch to open-

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water areas (Mittlebach, 1981). In Lac Heney, Quebec, Faber (1981) found that those species spawned in shallow areas utilized the vegetated areas more extensively than those species spawned in open-water. Larval fish were more abundant in the Schuylkill River (PA) and Drake's Creek (KY) where vegetation was common with little or no water current (Gerlach and Kahnle, 1981; Floyd et al., 1984) than in areas of stronger current which lacked vegetation.

The lower Roanoke River is relatively deep with fast current for a coastal stream and has steep banks that support only limited vegetation. The only extensively vegetated areas are formed by water lilies, *Nuphar lutea*. There were two objectives in this study: 1) to determine the relative extent of water lily bed areas in the Roanoke River delta; and 2) to determine the zooplankton prey that were consumed by larval fish taxa in the vegetated areas.

## STUDY AREA

The Roanoke River drains 25,035 km$^2$, 87% of which is located above Roanoke Rapids Dam, 215 km upstream from the study area. The remaining 13% of the watershed lies within the Coastal Plain Province and is bounded by bald cypress-tupelo gum swamp forest and small blackwater tributaries. The study area includes the main river channel, the Roanoke, and two tributaries: the Middle and Eastmost rivers; and the Cashie River (Fig. 1). Flow rate in the river is determined to a great degree by the water releases of three hydroelectric dams at Kerr Lake, Lake Gaston, and Roanoke Rapids.

The Roanoke River flows into western Albemarle Sound approximately 120 km from the Atlantic Ocean. Although the western sound is primarily freshwater, there is some saltwater intrusion (<5 ppt) under certain physical conditions (Zincone and Rulifson, 1992). The adult fish community within the study area is composed of fresh and brackish water species and several anadromous marine species (Menhinick et al., 1974).

## METHODS

### Sampling Design Rationale

Samples were collected with two types of gear and came from two sources: samples from the water lily beds were collected with a square 250$_{\mu}$ mesh pushnet (0.085 m$^2$ mouth area) and samples from the river were collected with a circular towed-net (250$_{\mu}$ mesh, 0.5 m diam.). The river samples were part of a concurrent larval striped bass distribution study (Rulifson et al., 1992) and therefore the collection of the samples from the water lily beds was timed in such a way as to sample for striped bass larvae. Each net was best suited for its area of use: the square pushnet was easily controlled in the water lily beds and could be used in shallow water; the towed-net was used in conjunction with paired (500$_{\mu}$ mesh, 0.5 m diam.) ichthyoplankton nets that were towed simultaneously in an oblique manner. This sample combination required certain constraints since both sets of samples were collected by the same personnel. The towed-net samples were taken on alternate nights, therefore the water lily bed samples were taken on those nights not used for towed-net samples. To conserve effort, May pushnet samples were to be taken only when striped bass density in the river was high (determined by

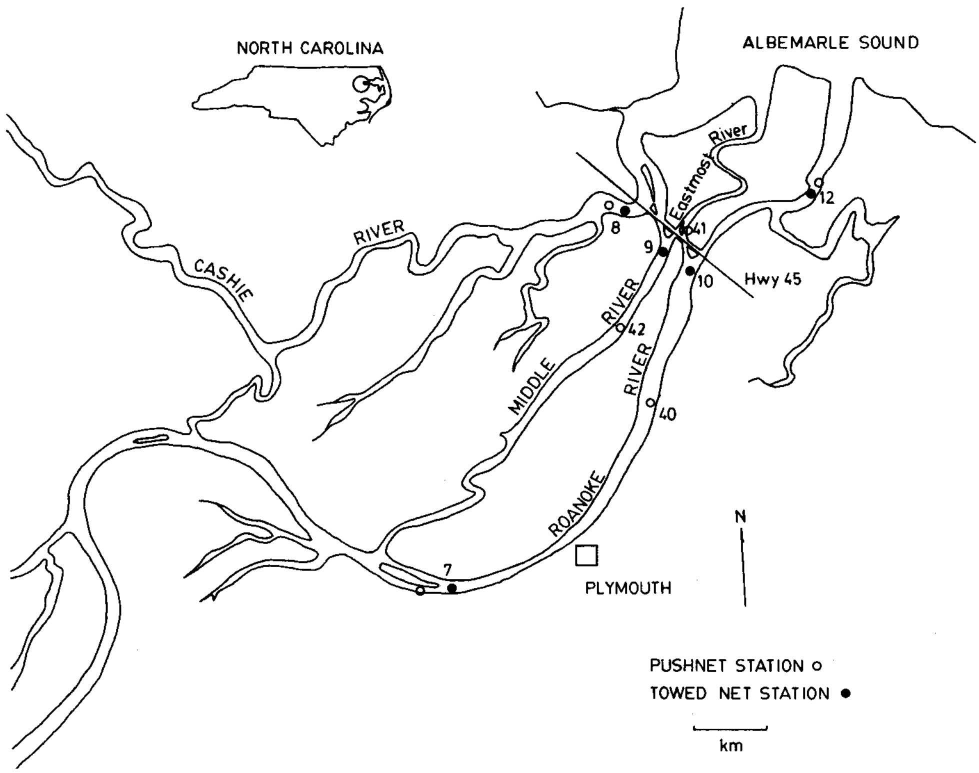


FIG. 1. Station locations for pushnet and towed-net samples in the lower Roanoke River Delta, 1987 and 1988.

towed-net: mean volume sampled was 27.1 $m^3$; SD = 2.7) under the assumption that taking the water lily bed samples at this time would produce the greatest probability that striped bass larvae would occur in the water lily beds. However, in 1987, under flood conditions (0.9 m/sec), we did not find any striped bass larvae in the river during the first week after spawning started. We therefore collected the May samples three days after egg density was high in the spawning area (spawning occurs 193 to 209 km upstream from the study area). The three days would allow the developing larvae to reach the study area and water lily beds. In 1988, May samples were taken according to our original criterion. The samples collected in June of both years were taken after the end of striped bass spawning and when the majority of larvae would not be expected to be in the river: any presence of striped bass in the water lily beds at this time would indicate use.

## Water Lily Beds

The formation of water lilies is dependent upon water temperature and river stage but generally begins in early April. Water lilies die back at the end of August or early September, thus the surveys to determine the extent of water lily bed surface area were made at convenient times within this period: in May 1987 (high water flow), April 1988 (low flow; <0.3 m/sec), and August 1989 (moderate flow; 0.15–0.6 m/sec), but the times of the surveys were not dictated by river flow. In 1987–1988, the size of each vegetated area was estimated using LORAN lines of position for reference. In 1989, each vegetated area was measured using fixed points and a tape measure in conjunction with cross-channel depth profiles.

### Pushnet Samples

Six pushnet stations (Fig. 1) were sampled in May and June of 1987 and 1988. Three of these stations (7, 8, 12) were located in the most extensive water lily beds and were selected to coincide with the stations used in the concurrent towed-net study. The remaining three stations were placed in smaller water lily beds and were sampled opportunistically.

Pushnet samples were taken in pairs: one directed upstream and one directed downstream. Date and station combinations in 1987 were 13 May, stations 8, 12, and 42 (1 sample); 8 June, stations 7, 8, and 12; combinations in 1988 were 23 May, stations 12, 40 (1 sample), and 41; 8 June, stations 7, 8, 12 (1 sample), and 40. poor weather on three occasions resulted in only one sample (upstream) being taken. The net was held 15 cm under the water surface at the bow of a small outboard-powered boat and pushed through the water lily beds for two minutes at a constant speed. The pushnet volume sampled was determined by pushing the net at the sampling speed for 0.03 hour, measuring the distance travelled, and then multiplying the distance by the mouth area of the net. The average volume sampled was 7.2 $m^3$ (SD = 0.16 $m^3$). Pushnet samples were used to estimate both ichthyoplankton and zooplankton density.

Towed-net samples were always taken in the upstream direction. One sample was taken at each station on two alternate nights (except 3 June, 1988, when samples were taken only on one night) and used as a pair to calculate average density of organisms. The date and station combinations used in 1987 were 12 and 14 May at stations 8, 9, and 12, and 5 and 7 June at stations 7, 8, and 12. In 1988, the combinations were 22 and 26 May at stations 7, 9, 10, and 12, and 3 June at stations 7, 8, 10, and 12.

The sample contents were washed into a collecting cup and preserved with 10% formalin containing rose bengal dye. Fish larvae were removed from each sample in the laboratory, identified, and counted. Gut contents were examined from those larvae capable of feeding (determined by the presence of developed jaws and an inflated gas bladder). Zooplankton counts in each sample were estimated by a standard subsampling method: each sample (minus fish larvae) was diluted to 500 ml and from that three 5-ml subsamples were removed, replacing 5-ml of water after each subsample. Zooplankton and organisms consumed by fish larvae were identified to the lowest practical taxon using Pennak (1978), McCafferty (1981), and Merritt and Cummins (1984).

### Statistical Methods

Total catch by sampling direction was compared using the non-parametric Mann-Whitney *U* test since the variances of the two samples were unequal ($s_{max}/s_{min} = 4.58$). Samples taken in the downstream direction collected a significantly

Table 1

Surface area coverage (m$^2$) by water lilies and percent of surface area within each distributary. Mean surface area (m$^2$) of water lily beds for each distributary was 98,848 (Roanoke), 22,135 (Middle), 25,120 (Eastmost), and 167,776 (Cashie).

| | Roanoke | | | Middle | Eastmost | Cashie |
|---|---|---|---|---|---|---|
| | Station | | | | | |
| Year | 7 | 12 | 40 | 42 | 41 | 8 |
| 1987 | 39,750 | 7,200 | 150 | 850 | 900 | 18,280 |
| Percent | 40.2 | 7.3 | 0.15 | 3.8 | 3.6 | 11.0 |
| 1988 | 37,500 | 6,800 | 100 | 750 | 600 | 17,500 |
| Percent | 37.9 | 6.9 | 0.10 | 3.4 | 3.4 | 10.4 |
| 1989 | 32,600 | 7,000 | 150 | 1,300 | 840 | 13,975 |
| Percent | 33.0 | 7.1 | 0.15 | 5.9 | 5.9 | 8.3 |

greater number of larvae (n = 1,013; *U* statistic = 100.5; p = 0.02) than the samples taken in an upstream direction (n = 416; *U* statistic = 25.5) but there was no significant difference in catch by sampling direction for the three most abundant taxa (clupeids, p = 0.51; centrarchids, p = 0.24; cyprinids, p = 0.93). No attempt was made to compare fish density among individual stations because of the low number of samples and unequal sampling design. We did not attempt to compare gear types (pushnet, towed-net) or to make direct comparisons of fish or zooplankton density between water lily beds and the open river because of the different collection methods. We compared the relative prey consumption and zooplankton population composition in the river and in the water lily beds to determine if the same fish species consumed the same prey in each habitat.

## RESULTS

### Water Lily Beds

The water lily beds at stations 7, 8, and 12 were an order of magnitude more extensive than the beds at the other three stations in all years (Table 1). The water lily beds at station 7 accounted for the greatest percentage of the total water lily beds in the main Roanoke River and nearly half of the total water lily beds in the main river were found at stations 7 and 12.

### Pushnets

Twelve fish taxa (945 larvae) were recorded in 1987 and 11 taxa (484 larvae) were recorded in 1988 (Table 2). The most abundant taxa in 1987 were clupeids (Clupeidae; 45.2%) and centrarchids (Centrarchidae; 43.5%). In 1988, centrarchids accounted for 82.4% of the total catch, clupeids 12.2%. The remainder was divided between 14 other taxa. Three taxa were represented by juvenile fishes only. Centrarchids and clupeids dominated the combined total catch in density (4.3 and 2.2 larvae/m$^3$), and percent abundance (60.5 and 30.9%).

Five samples accounted for the majority of the larvae collected: 376 clupeids (one sample, May 1987; 77.2% of total collected); and 517 centrarchids (three samples in June 1987 and one sample in June 1988; 53.9% of total collected).

Table 2
Fish taxa collected by pushnet in water lily beds, 1987–88. All stations combined. TL = total length. juv. = juvenile.

| | 1987 | | | 1988 | | | |
|---|---|---|---|---|---|---|---|
| | | TL (mm) | | | TL (mm) | | |
| Taxa | n | Mean | Range | n | Mean | Range | Total |
| Centrarchids | 411 | 6.5 | 4.0–15.0 | 399 | 5.5 | 4.0–8.0 | 810 |
| Clupeids | 427 | 9.3 | 3.5–17.0 | 59 | 8.5 | 4.0–13.0 | 486 |
| Cyprinids | 39 | 9.1 | 5.0–17.0 | 5 | 8.5 | 6.0–17.0 | 44 |
| White perch | 40 | 3.5 | 2.5–4.5 | 1 | 2.0 | | 41 |
| Darters | 7 | 5.2 | 5.0–5.5 | 10 | 9.0 | 4.5–17.0 | 17 |
| Menhaden, juv. | 10 | 38.2 | 34.0–42.0 | 0 | | | 10 |
| Carp | 5 | 7.3 | 6.5–8.0 | 0 | | | 5 |
| American eel, juv. | 1 | 56.0 | | 1 | 55.0 | | 2 |
| Pirate perch | 0 | | | 2 | 12.5 | 9.0–16.0 | 2 |
| Atl. needlefish | 1 | 17.0 | | 0 | | | 1 |
| Brown bullhead, juv. | 1 | 22.0 | | 0 | | | 1 |
| Striped bass | 0 | | | 1 | 6 | | 1 |
| Suckers | 0 | | | 1 | 16 | | 1 |
| Inland silverside | 0 | | | 1 | 4 | | 1 |
| Yellow perch | 2 | 7.7 | 7.0–8.5 | 0 | | | 2 |
| Unidentified | 1 | | | 4 | | | 5 |
| Total | 945 | 8.6 | | 484 | 6.4 | | 1,429 |

## Zooplankton

Twenty-six taxa of zooplankton were identified in 1987 and 17 in 1988 (Table 3). Six zooplankton taxa were considered to be potential prey for larval fishes based on fish mouth gape and zooplankter size (maximum of 0.9 mm prey width): *Daphnia, Bosmina,* other cladocerans, copepods (including nauplii and copepodites), ostracods, and rotifers (Table 4). The following results consider only the potential prey taxa.

Cladocerans (excluding *Bosmina* and *Daphnia*) had the greatest density in the pushnet samples in both years with a mean of 701.4/m$^3$, at least nine times greater than any other taxa considered. The remaining five taxa (and their mean density) were copepods (43.7/m$^3$), ostracods (9.4/m$^3$), *Daphnia* (7.9/m$^3$), rotifers (0.8/m$^3$), and *Bosmina* (0.2/m$^3$). *Bosmina* were collected only once.

Copepods had the greatest density in the river in both years with a mean of 118.8/m$^3$, approximately twice that of *Daphnia* (61.7/m$^3$) and other cladocerans (59.1/m$^3$). The remaining three potential prey taxa were *Bosmina* (24.1/m$^3$), ostracods (4.7/m$^3$), and rotifers (0.8/m$^3$). Rotifers occurred in only two samples.

## Gut Analysis

Cladocerans (excluding *Bosmina*) and rotifers had the two highest percentages in larval fish guts in 1987 and 1988 in the water lily beds (Tables 4 and 5), followed by *Bosmina* and copepods. *Daphnia* and ostracods were never consumed and gammarids and fish only rarely. Dipteran larvae were consumed primarily by

Table 3
Zooplankton density (n/m³) from pushnet samples at water lily bed stations, 1987–1988.

| | 1987 | | | | | | |
|---|---|---|---|---|---|---|---|
| | May 13 | | | June 8 | | | |
| Taxa Station | 8 | 12 | 42 | 7 | 8 | 12 | Mean Density |
| Cladocera | 164.3 | 145.8 | 189.8 | 1,585.6 | 2,907.4 | 837.9 | 971.8 |
| Stylaria sp. | 16.2 | 9.3 | 4.7 | 94.9 | 275.5 | 11.5 | 68.7 |
| Dipteran larva | 11.6 | 12.7 | 13.9 | 0 | 47.4 | 130.8 | 36.1 |
| Copepoda | 11.6 | 13.9 | 27.8 | 13.8 | 52.1 | 0 | 19.9 |
| Ostracoda | 7.0 | 2.3 | 9.3 | 0 | 85.7 | 4.7 | 18.2 |
| Aeolosoma sp. | 7.0 | 0 | 0 | 9.2 | 51.0 | 0 | 11.2 |
| Gammaridae | 4.6 | 13.9 | 37.0 | 0 | 7.0 | 4.7 | 11.2 |
| Daphnia sp. | 4.7 | 11.5 | 0 | 0 | 48.6 | 0 | 10.8 |
| Dero sp. | 0 | 2.3 | 0 | 13.8 | 11.5 | 11.5 | 6.5 |
| Arachnida | 2.3 | 0.0 | 0 | 0 | 13.9 | 11.5 | 4.6 |
| Unidentified | 4.7 | 4.7 | 4.7 | 0 | 2.3 | 2.3 | 3.1 |
| Heleidae | 0 | 0 | 0 | 0 | 13.9 | 0 | 2.3 |
| Chironomidae | 0 | 0 | 0 | 157.4 | 7.0 | 0 | 27.4 |
| Rotatoria | 9.3 | 0 | 0 | 0 | 0 | 0 | 1.55 |
| Hydra sp. | 4.7 | 0 | 0 | 2.3 | 4.7 | 0 | 1.95 |
| Ephemeroptera | 0 | 0 | 4.7 | 2.3 | 2.3 | 0 | 1.55 |
| Collembola | 2.3 | 2.3 | 0 | 2.3 | 0 | 0 | 1.15 |
| Dipteran adult | 0 | 0 | 0 | 0 | 4.7 | 0 | 0.8 |
| Plecoptera | 0 | 0 | 0 | 0 | 2.3 | 0 | 0.4 |
| Megaloptera | 2.3 | 0 | 0 | 0 | 0 | 0 | 0.4 |
| Gyrinidae | 0 | 0 | 0 | 2.3 | 0 | 0 | 0.4 |
| Trichoptera | 0 | 0 | 0 | 0 | 2.3 | 0 | 0.4 |
| Bosmina sp. | 0 | 0 | 0 | 2.3 | 0 | 0 | 0.4 |

| | 1988 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | May 23 | | | June 8 | | | | |
| Taxa Station | 12 | 40 | 41 | 7 | 8 | 12 | 40 | Mean Density |
| Cladocera | 125.0 | 319.4 | 152.8 | 435.2 | 203.7 | 423.6 | 39.4 | 242.7 |
| Copepoda | 23.1 | 4.6 | 30.1 | 69.5 | 37.0 | 291.7 | 11.6 | 66.8 |
| Aeolosoma sp. | 4.7 | 9.3 | 9.3 | 46.3 | 289.3 | 7.0 | 2.3 | 52.6 |
| Dipteran larva | 4.6 | 23.1 | 12.8 | 63.6 | 168.2 | 56.9 | 20.9 | 50.0 |
| Stylaria sp. | 0 | 0 | 0 | 2.3 | 122.7 | 0 | 4.7 | 18.5 |
| Gammaridae | 0 | 27.8 | 2.3 | 13.9 | 0 | 44.0 | 4.7 | 13.2 |
| Ostracoda | 0 | 0 | 0 | 7.0 | 2.3 | 39.4 | 4.7 | 7.6 |
| Gerridae | 0 | 41.7 | 0 | 0 | 0 | 0 | 2.3 | 6.3 |
| Daphnia sp. | 0 | 4.6 | 16.2 | 2.3 | 0 | 2.3 | 2.3 | 4.0 |
| Chironomidae | 9.3 | 0 | 2.3 | 0 | 2.3 | 0 | 0 | 2.0 |
| Unidentified | 9.3 | 0 | 0 | 0 | 0 | 2.3 | 2.3 | 2.0 |
| Arachnida | 0 | 0 | 0 | 0 | 2.3 | 9.3 | 0 | 1.7 |
| Hemiptera | 0 | 0 | 7.0 | 0 | 2.3 | 0 | 0 | 1.3 |
| Isopoda | 0 | 0 | 0 | 0 | 0 | 4.7 | 0 | 0.7 |
| Ephemeroptera | 0 | 4.6 | 0 | 0 | 0 | 0 | 0 | 0.7 |
| Hydra sp. | 0 | 4.6 | 0 | 0 | 0 | 0 | 0 | 0.7 |
| Nematoda | 0 | 0 | 0 | 2.3 | 0 | 0 | 0 | 0.3 |

Table 4

Mean prey density and the percent of potential prey taxa in guts of larval and juvenile fishes (upper number of couplet) and the percent of fish taxa that fed on the prey taxa (lower number in couplet) in pushnet samples, 1987. juv. = juvenile.

| | | Mean prey density | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cladocerans | Rotifers | Bosmina | Copepods | | | | |
| | n/m³ | 1,160.1 | 1.6 | 0.2 | 20.6 | | | | |
| | | Potential Prey Taxa[a] | | | | | Total Organisms Counted | Percent Fish With Detritus | Percent Fish Without Food |
| Fish taxa | n | Cladocerans | Rotifers | Bosmina | Copepod | Unident. | | | |
| Centrarchids | 172 | 27.1 | 64.3 | 6.5 | 0.8 | 1.0 | 383 | 65.7 | 33.0 |
| | | 5.8 | 17.4 | 4.6 | 1.7 | 1.7 | | | |
| Clupeids | 44 | 4.9 | 70.1 | 19.5 | 0 | 4.9 | 82 | 77.3 | 9.5 |
| | | 6.8 | 38.6 | 4.5 | | 9.1 | | | |
| Cyprinids | 18 | 4.9 | 84.1 | 11.0 | 0 | 0 | 82 | 84.1 | 5.5 |
| | | 11.1 | 33.3 | 16.7 | | | | | |
| Darters | 4 | 80.0 | 20.0 | 0 | 0 | 0 | 5 | 0 | 25.0 |
| | | 75.0 | 25.0 | | | | | | |
| Yellow perch | 2 | 75.0 | 0 | 0 | 0 | 0 | 4 | 50.0 | 0 |
| | | 50.0 | | | | | | | |
| Carp | 2 | 0 | 0 | 83.3 | 16.7 | 0 | 24 | 100 | 0 |
| | | | | 50.0 | 50.0 | | | | |
| Atlantic needlefish | 1 | 0 | 100 | 0 | 0 | 0 | 6 | 100 | 0 |
| | | | 100 | | | | | | |
| White perch | 1 | 0 | 83.3 | 0 | 0 | 16.7 | 6 | 0 | 0 |
| | | | 100 | | | 100 | | | |
| Menhaden, juv. | 8 | 80.0 | 0 | 8.0 | 6.2 | 1.8 | 337 | 100 | 0 |
| | | 100 | | 75.0 | 62.5 | 75.0 | | | |
| Brown bullhead, juv. | 1 | 33.3 | 0 | 0 | 41.7 | 0 | 22 | 100 | 0 |
| | | 100 | | | 100 | | | | |
| American eel, juv. | 1 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 |
| | | | | 100 | | | | | |
| Total n | 254 | | | | | | | | |
| % in diet | | 35.1 | 34.1 | 8.6 | 3.3 | 1.3 | 952 | 69.7 | 24.8 |
| % fish utilization | | 13.6 | 28.3 | 10.5 | 4.2 | | | | |

[a] Ostracods (18.9/m³) and Daphnia (11.8/m³) were not consumed.

juvenile fish and were not considered as potential prey. In 1987, larval centrarchids, clupeids, cyprinids, Atlantic needlefish, and white perch, consumed more rotifers than any other prey taxa. In 1988, only centrarchids consumed rotifers, darters consumed cladocerans, *Bosmina,* and copepods, and larval clupeids contained no food. Rotifers and cladocerans composed the highest percentage of prey taxa (72.9%; both years combined), followed by *Bosmina* (10.4%) and copepods (4.4%). The above four taxa accounted for 87.7% of the prey consumed.

Cladocerans and copepods were the most abundant prey taxa in the towed-net samples in 1987 (Table 6) and 1988 (14.9/m³) and 98.3/m³). In 1987, rotifers were the most abundant prey in clupeid guts. Cladocerans accounted for 17.5% of the clupeid diet but were present in only 1.7% of clupeids examined. Cyprinid

Table 5

Mean prey density and percent of potential prey taxa in guts of larval and juvenile fish (upper number of couplet) and the percent of fish taxa that fed on the prey taxa (lower number of couplet) in pushnet samples, 1988. juv. = juvenile.

| | | Mean Prey Density | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cladocerans | Rotifers | Bosmina | Copepods | | | |
| | n/m³ | 242.7 | 0 | 0 | 66.8 | | | |
| | | Potential Prey Taxa[a] | | | | Total Organisms Counted | Percent fish | |
| Fish Taxa | n | Cladocerans | Rotifers | Bosmina | Copepods | | With Detritus | Without Food |
| Centrarchids | 238 | 0 | 80.5<br>2.9 | 19.5<br>0.4 | 0 | 41 | 3.4 | 92.0 |
| Clupeids | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| Darters | 7 | 38.9<br>42.8 | 0 | 38.9<br>42.8 | 16.7<br>14.3 | 18 | 71.4 | 14.3 |
| Cyprinids | 5 | 100<br>20.0 | 0 | 0 | 0 | 2 | 40.0 | 60.0 |
| Pirate perch | 2 | 65.0<br>100 | 0 | 0 | 25.0<br>50.0 | 20 | 0 | 0 |
| Striped bass | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 100<br>(1) |
| Suckers | 1 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| American eel, juv. | 1 | 77.8<br>100 | 0 | 0 | 0 | 9 | 0 | 0 |
| Total n | 308 | | | | | | | |
| % in diet | | 32.2 | 44.4 | 12.2 | 5.5 | 90 | 5.2 | 89.9 |
| % fish utilization | | 30.4 | 30.4 | 17.4 | 8.7 | | | |

[a] Ostracods (7.6/m³) and Daphnia (4.0/m³) were not consumed.

guts contained more cladocerans than any other prey taxa and 44.4% of the cyprinids had cladocerans in their guts. Rotifers accounted for only 13.3% of the cyprinid diet but were present in 44.4% of the cyprinid guts examined (Table 6). In 1988, only four of 23 fish guts contained prey: one centrarchid, one cyprinid, and one clupeid each had consumed one rotifer, and one sucker, Catostomidae, had consumed a gammarid. Rotifers and ostracods were low in abundance (1.0/m³ and 3.9/m³).

Nearly the same percentage of centrarchids fed on *Bosmina* in 1987 as on cladocerans but cladocerans accounted for more than four times the percentage of the diet (Table 5). *Bosmina* accounted for nearly 20% of the clupeid diet but were present in only 4.5% of clupeids examined. A greater proportion of centrarchids, clupeids, and cyprinids fed on rotifers than on any other prey taxa.

Feeding success (defined as fishes with food at time of capture) wa much greater in the water lily beds in 1987 than in 1988. Feeding success in the river was nearly equal in both years. The overall potential prey density was higher in 1987 in both habitats.

Table 6

Mean prey density and percent of potential prey taxa in guts of larval and juvenile fish (upper number of couplet) and the percent of fish taxa that fed on the prey taxa (lower number of couplet) in towed-net samples, 1987.

| | | Mean Prey Density[a] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cladocerans | Rotifers | Copepods | Ostracods | | | |
| | n/m³ | 101.8 | 0.1 | 29.1 | 4.9 | | | |
| | | Potential Prey Taxa | | | | Total Organisms Counted | Percent fish | |
| Fish Taxa | n | Cladocerans | Rotifers | Copepods | Ostracods | | With Detritus | Without Food |
| Clupeids | 175 | 17.5<br>1.7 | 78.9<br>14.3 | 1.7<br>0.6 | 1.7<br>0.6 | 57 | 1.7 | 80.0 |
| Cyprinids | 9 | 73.3<br>44.4 | 13.3<br>44.4 | 0 | 11.1<br>22.2 | 45 | 33.3 | 11.1 |
| Centrarchids | 6 | 0 | 0 | 0 | 0 | | 0 | 100 |
| Carp | 1 | 0 | 0 | 0 | 0 | | 100 | 0 |
| Total n | 191 | | | | | 102 | 3.7 | 77.5 |
| % in diet | | 42.1 | 50.0 | 1.0 | 5.9 | | | |
| % fish utilization | | 3.7 | 15.2 | 0.5 | 1.6 | | | |

[a] Bosmina (2.5/m³) and Daphnia (64.0/m³) were not consumed.

## DISCUSSION

The estimated surface area of the water lily beds remained nearly the same in each survey except for station 42 in Middle River. This station was the shallowest of the six stations surveyed and may have been estimated more accurately in 1989. The three most extensive areas (stations 7, 8, 12) represented 15% of the total water lily beds in the lower Roanoke River.

Vegetated areas can reduce the vulnerability of larval fishes to predation by altering predator behavior (Cooper and Crowder, 1979). These areas also provide refuge for certain zooplankters that can be a source of food for larval fishes.

Fifteen taxa of fishes were collected in our study but only three were found consistently in the water lily beds: centrarchids and cyprinids, which spawn in shallow areas, and darters. Floyd et al. (1984) also found that centrarchids dominated the vegetated area. Menhinick et al. (1974) reported two killifish species from the Roanoke-Albemarle area: banded killifish (*Fundulus diaphanus*) from Albemarle Sound and two records of lined top-minnow (*F. lineolatus*) from the Roanoke River. Neither species was collected in our study perhaps because of the lack of suitable spawning habitat. Spawning banded killifish are reported to prefer filamentous algae (Cooper, 1936), *Vallisneria* (Webster, 1942), or fibrous, grassy bottoms (Lippson and Moran, 1974), none of which is present in the study area. Conrow et al. (1990) collected one lined top-minnow in floating emergent vegetation in a Florida lake.

Most fish larvae depend upon drift to reach their nursery areas and are not well equipped to migrate out of currents (Marcy, 1976). Three taxa, striped bass, white perch, and clupeids, principally utilize drift during their spring migration to the nursery area in the Roanoke Delta. It is our hypothesis that these three taxa do not reach the necessary physical size within the river to actively migrate out of the current to the vegetated areas. The greatest number of clupeids and white perch collected in the water lily beds were taken during high river flows (May 1987) when their densities in the river were also high (2.24 and 0.36/m$^3$; Rulifson et al., 1992). When river flows are high, it would be expected that larvae spawned upriver could be swept into the water lily beds. This did not occur with striped bass but only five striped bass were collected in the river in 1987. Recruitment of striped bass was relatively low in 1987 (Henry and Taylor, 1993). In May of 1988, under much lower river flow and densities of larval clupeids (0.11/m$^3$) and white perch (0.02/m$^3$; Rulifson et al., 1992), fewer clupeids and only one white perch were collected in the water lily beds. Only one striped bass larva was collected in 1988 in the vegetated areas although river density at that time was relatively high at 1.18/m$^3$. In general, it appears that clupeids, striped bass, and white perch are carried through the Delta by the river current and either can not or do not actively seek the vegetated areas. The larvae of these three taxa that reach the vegetated areas may do so by chance in conjunction with high larval fish density and high river flow.

If our hypothesis is true, the next logical step would be to determine if striped bass, clupeids, and white perch larvae can develop "normally" within an enclosed area of lily pads. If they can, then it would seem that these three taxa do not seek the vegetated areas.

The larval and juvenile fish collected in this study occurred at times of year that were similar to those found by Marcy (1976), Johnson and Edwards (1977), and Gerlach and Kahnle (1981). Our pushnet catch rate for larvae (1,547/hour) was much lower than the 3,690/hour reported by Conrow et al. (1990) but we sampled about only one-third the volume of water. Conrow et al. (1990) found that larval fish length was directly related to utilization of certain types of lake habitat. There was no evidence of this in our study as all species that were common to both habitats occurred there at similar lengths.

We did find differences in those zooplankton taxa common to both areas: *Daphnia, Bosmina,* and copepods were found more frequently in river samples and other cladocerans were collected more frequently in water lily beds. These differences may reflect differing responses by these zooplankters to light and vegetation.

Larval fish feeding success was higher during periods of greater overall prey density. Rotifers, the primary taxa consumed, were rarely collected in samples from either habitat and *Bosmina* were rarely collected in water lily beds. We cannot determine from our data whether this was due to inadequate sampling (because of net mesh size) or to naturally low populations or to extensive grazing by predators. Other cladocerans were not as important as a food source even though they were higher in density. Larval fish in both habitats consumed cladocerans and rotifers, but cladocerans were more abundant only in the water lily beds.

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