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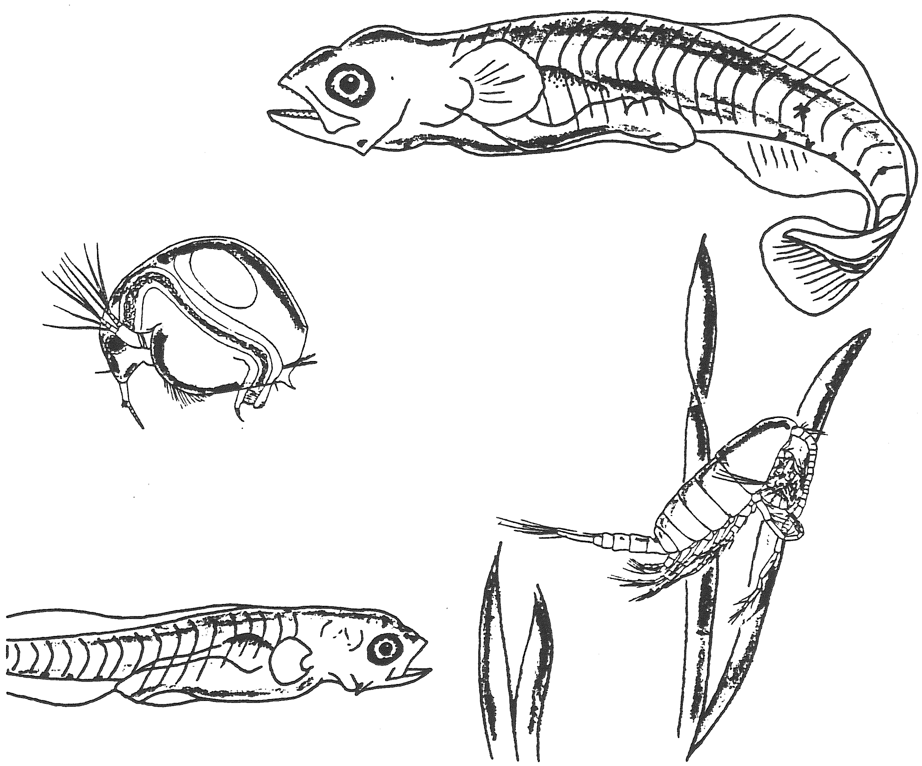
FOOD and FEEDING of YOUNG STRIPED BASS in the LOWER ROANOKE RIVER and WESTERN ALBEMARLE SOUND, NORTH CAROLINA, 1990-1991

Completion Report for Projects 90-2 and 91-2 to:
North Carolina Striped Bass Study Management Board,
and
North Carolina Wildlife Resources Commission



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Completion Report for Projects 90-2 and 91-2

For

North Carolina Striped Bass Study Management Board
P.O. Box 972, Morehead City, NC 28557

and

North Carolina Wildlife Resources Commission
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EXECUTIVE SUMMARY

This study was conducted during the springs of 1990 and 1991 to provide information on possible causes of the decline in the Roanoke/Albemarle striped bass stock. Striped bass in this system migrate approximately 130 miles upstream in the spring (April through June) to spawn in the main channel of the Roanoke River. This location is the primary and only documented spawning ground for this stock. Spawning activity, and subsequent passage of developing eggs and larvae downstream, is directly influenced by water releases from Roanoke Rapids Reservoir at River Mile 137, which controls 87% of the lower River instream flow. A number of environmental factors have been suggested as potential contributors to stock decline: channelization, dredge and fill projects, dams and impoundments, industrial water intakes and discharges, chemical pollution, turbidity, low oxygen levels, sewage outfalls, poor timing of water release from reservoirs upstream, reduced spawning habitat, reduced nursery habitat, poor food availability, generally poor water quality, and spawning grounds too accessible to fishermen. All these factors in combination may cause a number of biological problems for striped bass such as reduced egg viability, poor survival of larvae during downstream drift from spawning grounds to nursery areas, and poor survival of juveniles on the nursery grounds.

The objective of the study was to was to collect information about the food chain in the lower River, Delta and western Albemarle Sound during April through June and how it changes under prevailing environmental conditions, especially river flow. Data sets on water quality, larvae, and zooplankton generated by this study will be used by the U.S. Geological Survey to assist in calibrating the hydrological models being developed for the lower River and Albemarle Sound (i.e., providing concurrent biological data with their hydrographic modeling efforts). An understanding of the transit times and resultant distributions of zooplankton and larvae within the watershed under different flow regimes could assist resource managers in controlling river flows in the spring to increase chances of successful striped bass recruitment.

River Flow. In 1990, more than half (59%) of the days during the April-June period had mean instream flows (measured at River Mile 133.6) ≥10,000 cubic feet per second (cfs) and 35% of the days had flows ≥6,000 and <10,000 cfs. Only 5.5% of the days had flows lower than 6,000 cfs. The mean April-June flow was 13,386 cfs, similar to the value for 1989. A basinwide May rainfall of 7.5 inches resulted in a 20,000 cfs discharge from late May through mid-June. In 1991, the mean April-June discharge was 10,992 cfs; slightly more than half (58%) of the days had mean instream flows between 6,000 and 10,000 cfs.

Water Quality. Water temperatures usually were slightly cooler in the River than in Batchelor Bay and western Albemarle Sound. Dissolved oxygen content of the water remained above 4 mg/L in both years; Albemarle Sound waters had higher values in June than either the River or Bay. An oxygen sag, concurrent with a sudden increase in river flow, was observed in April 1991; this event was followed in May by a sudden increase in water temperature and dissolved oxygen content, and decrease in pH, and a slight increase in flows. Whether the events in May were related is uncertain. The lower Roanoke River and western Albemarle Sound were oligohaline in both years; in 1991 no salinity was observed in the western Sound until mid-May.

Phytoplankton and Chlorophyll *a*. In both years chlorophyll *a* concentrations ranged from less than 0.1 to over 12 µg/L, but were mostly between 2 and 6 µg/L. Average values were higher in the River and in the Sound than in Batchelor Bay. Phytoplankton were dominated by diatoms and green algae. Cell densities ranged widely, from less than 100 cells/ml to over 2,000 cells/ml, but values in the range 500-1,000 cells/ml were most common. Algal densities were highest in the River early in the sampling period, and tended to decline later. Phytoplankton biomass in the River was noticeably lower in 1990 and 1991 than that measured in the same area in 1985 and 1986. An inverse relationship between river flow and phytoplankton biomass was observed, a phenomenon common in riverine ecosystems.

Zooplankton. Zooplankton abundance in the Roanoke/Albemarle system was low relative to other systems supporting spawning populations of striped bass. Abundance was not uniform throughout the watershed but typically was concentrated in several areas. The lower Cashie River had the highest concentrations within the Delta. In Batchelor Bay, greatest zooplankton abundance was along the western shore, and in western Albemarle Sound zooplankton were most abundant along the north shore near Edenton Bay. Taxonomic groups comprising the zooplankton indicated a freshwater community dominated by cladocerans (especially *Daphnia*) in the River and copepods in western Albemarle Sound. Batchelor Bay was a transition area for zooplankton communities, with dominant taxonomic groups a function of River flow.

Striped Bass Eggs. In both years striped bass eggs were observed at Hamilton (RM 57), Williamston (RM 37), and Jamesville (RM 19). In 1990, eggs were collected as far downstream as the upper reaches of the Thoroughfare (connecting to the Cashie River) and Middle River (a Delta distributary). No eggs were collected in Batchelor Bay or western Albemarle Sound in either year.

Larval Striped Bass Abundance. In both years, River flow was a major factor affecting larval transport and distribution, including which route through the Delta portions of larval cohorts took in reaching Batchelor Bay and the western Sound. In 1990, the overall abundance of striped bass larvae was low at all sampling locations. Two small abundance peaks were observed in mid-May. Densities were greater in 1991 under moderate flow conditions; abundance was greatest the third week in May.

Larval Feeding. Feeding by larvae in 1990 was not successful based on examination of stomach contents, and was only slightly better in 1991. No larvae were feeding in the River in 1990; larvae in the Bay and Sound consumed mostly copepodid copepods and *Bosmina*. In 1991, only 3% of 921 River larvae in feeding condition had consumed prey: tiny bivalves, *Bosmina*, and other cladocerans (e.g., *Daphnia*). Feeding success was better in the Bay and Sound, with copepodids and adult copepods the dominant food items.

We conclude that one factor affecting the number of Roanoke striped bass larvae recruiting successfully to the forming year class in Albemarle Sound is the match/mismatch phenomenon of larvae with the zooplankton food source. This phenomenon is driven by seasonal and daily patterns in River flow. Seasonally moderate instream flow patterns position the larvae lower in the River and Delta where zooplankton densities are highest, then gradually carry the larvae to western Sound nurseries. Low flows cannot provide the current needed by larvae to move them into Batchelor Bay and Sound in a timely fashion, and high flows flush both zooplankton and larvae out of the Delta before feeding is initiated. Completion and validation of the U.S. Geological Survey's flow model of this system should verify this match-mismatch phenomenon and assist in developing an environmentally beneficial water release strategy for the April-June period.

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INTRODUCTION

Striped bass (*Morone saxatilis*) has sustained economically important recreational and commercial fisheries along the Atlantic coast for several hundred years. In North Carolina, the major fishery for the species, also known regionally as "rock" or "rockfish", is in the Roanoke/Chowan/Albemarle system, which contributes about 93% of the State sportfishing landings (Baker 1968) and the bulk of striped bass landed commercially. In the 1880s, Edenton, North Carolina, was the site of attempts to spawn and raise young striped bass for the early stocking programs along the eastern seaboard and eventually in California. At the present time, the principal spawning grounds for Roanoke/Albemarle striped bass is between Halifax (River Mile 120) and Weldon (RM 130) (Hassler et al. 1981) from mid-April through mid-June (Rulifson 1989).

Nearly 6% of North Carolina's land surface is drained by the Roanoke River; the annual average rate of discharge for the watershed is approximately 8,500 cubic feet per second (cfs), more than any other North Carolina river (Moody et al. 1985). This volume represents about one-half of the freshwater input to Albemarle Sound (Giese et al. 1985).

In 1940, a devastating August hurricane led to an investigation by the U.S. Army Corps of Engineers into the need for flood control in the Roanoke River Basin. In 1952, Kerr Reservoir was completed for flood control and hydroelectric generation, the first of six impoundments to be constructed within the watershed between 1950 and 1963. Outflow from Kerr Reservoir is controlled by the John H. Kerr Dam at River Mile (RM) 179.5. Two reservoirs are positioned downstream of Kerr Reservoir: Lake Gaston completed in 1963, and Roanoke Rapids Reservoir completed in 1955. Water releases through the Roanoke Rapids facility, located at RM 137, control 87% of the instream flow of the lower Roanoke River. However, the most important dam to the watershed downstream is Kerr Reservoir because of its storage capacity and its direct influence on the two downstream reservoirs.

Even prior to construction and operation of the Roanoke Rapids facility, much public concern was expressed about water quality of the lower Roanoke River and its affects on the fisheries and quality of living within the basin. Once completed, the Roanoke Rapids Dam blocked access to the historical spawning grounds farther upstream (McCoy 1959). On 2 May 1955, North Carolina Congressman Herbert C. Bonner called a meeting at Weldon, NC, of all Federal and State agencies, industry, and private citizens interested in the Roanoke River. From this meeting a Roanoke River Steering Committee was formed to examine multiple use problems of the Roanoke River and monitor changes in the striped bass population. On 30 June 1959, the Steering Committee issued its report, stating "The Roanoke River constitutes, by far, the most important spawning area for striped bass in North Carolina. Protection of the striped bass spawning in the Roanoke River should receive consideration equal to that given other primary uses of the water. The entire study area of the river -- including that section of the main stem at or below the industrial plants at Plymouth -- should contain water during the spawning season of such quantity and quality as established for the maintenance of fish life" (Fish 1959).

In the late 1970s, there was a drastic reduction in the number of striped bass harvested throughout its range on the east coast, and in the Roanoke/Albemarle system. This decline in the stocks led to a variety of fishery regulatory activities including shortened seasons, reduced creel limits, increased minimum size limits, changes in commercial net regulations, and, in some areas, a complete moratorium on striped bass fishing. In 1979, the U.S. Congress passed an amendment to the Anadromous Fish Conservation Act (Public Law No. 96-118, 16 U.S.C. 757g) establishing the Emergency Striped Bass Study (ESBS) to examine the status of stocks, identify causes of the decline, and determine the economic impact of reduced harvests (Chafee 1980). The Atlantic States Marine Fisheries Commission (ASMFC), as part of their Interstate Fisheries Management Plan (IFMP), developed an IFMP for striped bass (ASMFC 1981). In 1984, Congress enacted The Atlantic Striped Bass Conservation Act (P.L. No. 98-613); an amendment to the Act in 1986 (P.L. No. 99-432) authorized the implementation of a Federal moratorium on striped bass harvest for those states failing to comply with the coastwide plan (USDOI and USDOC 1987). Due to the large population of striped bass within the Roanoke River/Albemarle Sound and its economic importance, congressional monies were designated for the Roanoke system to be administered by a North Carolina Striped Bass Study Management Board. Our study of the food base available to young striped bass, and how it may be influenced by environmental conditions, is one of several studies funded by the Board to assess the status of the population and develop a strategy for stock restoration.

Additional research, built on the findings of the Roanoke River Steering Committee, indicated that several factors may have contributed to the stock decline. Reduced egg viability may be involved (Guier et al. 1980, Hassler et al. 1981) although the number of eggs spawned each year should provide sufficient recruitment to the population (Kornegay 1981, Kornegay and Mullis 1984). Low survival of juveniles on the nursery grounds also may be a contributor, but predation on striped bass larvae by other finfish is not a major factor in larval mortality (Rulifson 1984a). A survey for young of year striped bass (the Juvenile Abundance Index, or JAI) conducted each year in western Albemarle Sound indicates that the recruitment of juveniles has decreased from a pre-stock crash average of 6.28 juveniles/trawl (1970-1977) to a post-stock crash average of 0.81 (1978-1987) juveniles/trawl (Rulifson and Manooch 1990a). Low recruitment of larvae and juveniles to the nursery grounds was observed in 1983, a year of very high spring river flow (Rulifson 1984b). Recruitment remained low during the 1980s except for 1988 (JAI=4.09) and 1989 (4.27), the highest JAI values since 1976. These two years represent the first time since 1976-77 that two consecutive indexes were greater than 1.0 (Rulifson and Manooch 1990b). Prevailing river flows were found to be highly correlated with the annual JAI (Rulifson and Manooch 1990b, Rulifson et al. 1991).

Poor larval striped bass recruitment led to investigations in the early 1980s concerning the availability of zooplankton prey (Rulifson 1984a). Results indicated that low survival of larvae could be attributed to poor feeding success, perhaps caused by a mismatch in time and space between striped bass larvae and abundance of zooplankton prey. This mismatch may occur because of abrupt changes in water flow during the spawning period. Concern over this mismatch and related problems of water regulation in the Roanoke River watershed led to the formation of the Roanoke River Water Flow Committee (Flow Committee) in 1988. Their analysis of water flow regulation practices by hydroelectric dams and its effects on wildlife and other uses led to recommendations by the Flow Committee to change the manner in which water flow was released downstream in the spring (Manooch and Rulifson 1989).

Striped bass larvae and zooplankton studies were started in Albemarle Sound by the NC Division of Marine Fisheries (DMF) in 1982 and were continued in 1983 (Rulifson 1984a). Results of these studies led to an extensive survey of the lower Roanoke River by East Carolina University and the NC Wildlife Resources Commission (WRC) in 1984 and 1985 (Rulifson et al. 1986). The survey was continued in 1986 with the addition of several stations in Albemarle Sound (Rulifson et al. 1988); from 1987 to the present time 12 stations in the Sound have been sampled on a regular basis (Rulifson et al. 1992).

The objective of the study reported herein was to collect additional information about the food chain in the lower Roanoke River and western Albemarle Sound and how it changes under prevailing environmental conditions, especially river flow. Results of the study will be used in conjunction with U.S. Geological Survey (USGS) efforts to develop a mathematical model of water flow of the lower Roanoke River and Albemarle Sound so that transport of phytoplankton, zooplankton, and larval fish can be estimated. As of this writing, USGS modeling efforts are not to the point of development required to predict water transport. Therefore, results of the study reported herein describe the overall effects of instream flow on phytoplankton, zooplankton, and larval fish distribution.

METHODS

Ichthyoplankton samples were taken by WRC personnel at Stations 1-5 (Figure 1) by towing a 0.5 m^2 square-mouth opening Tucker trawl (505 μm mesh) in an oblique manner for six minutes. Two tows were made at each station. Samples were collected from 1 May to 27 May, 1990 and from 7 May to 26 May, 1991. East Carolina University personnel sampled river Stations 6-13, 15, and 16 (and Station 5 after 27 May, 1990 but not in 1991) and all Sound stations by towing paired, conical 0.5-m diameter nets (505 μm mesh) in an oblique manner for six minutes. Zooplankton was collected at all stations by towing a single, conical 250 μm mesh net for two minutes. Estimates of water volume filtered were made with General Oceanics flowmeters mounted in the mouth of each net. Ichthyoplankton and zooplankton samples were preserved with 10% formalin containing rose bengal dye.

Phytoplankton (whole water) and chlorophyll *a* samples were taken at Stations 1, 4, 8, 15, 26, and 31. Phytoplankton was preserved with Lugol's acetic acid-iodine solution; both phytoplankton and chlorophyll *a* were examined in the laboratory. Water temperature and

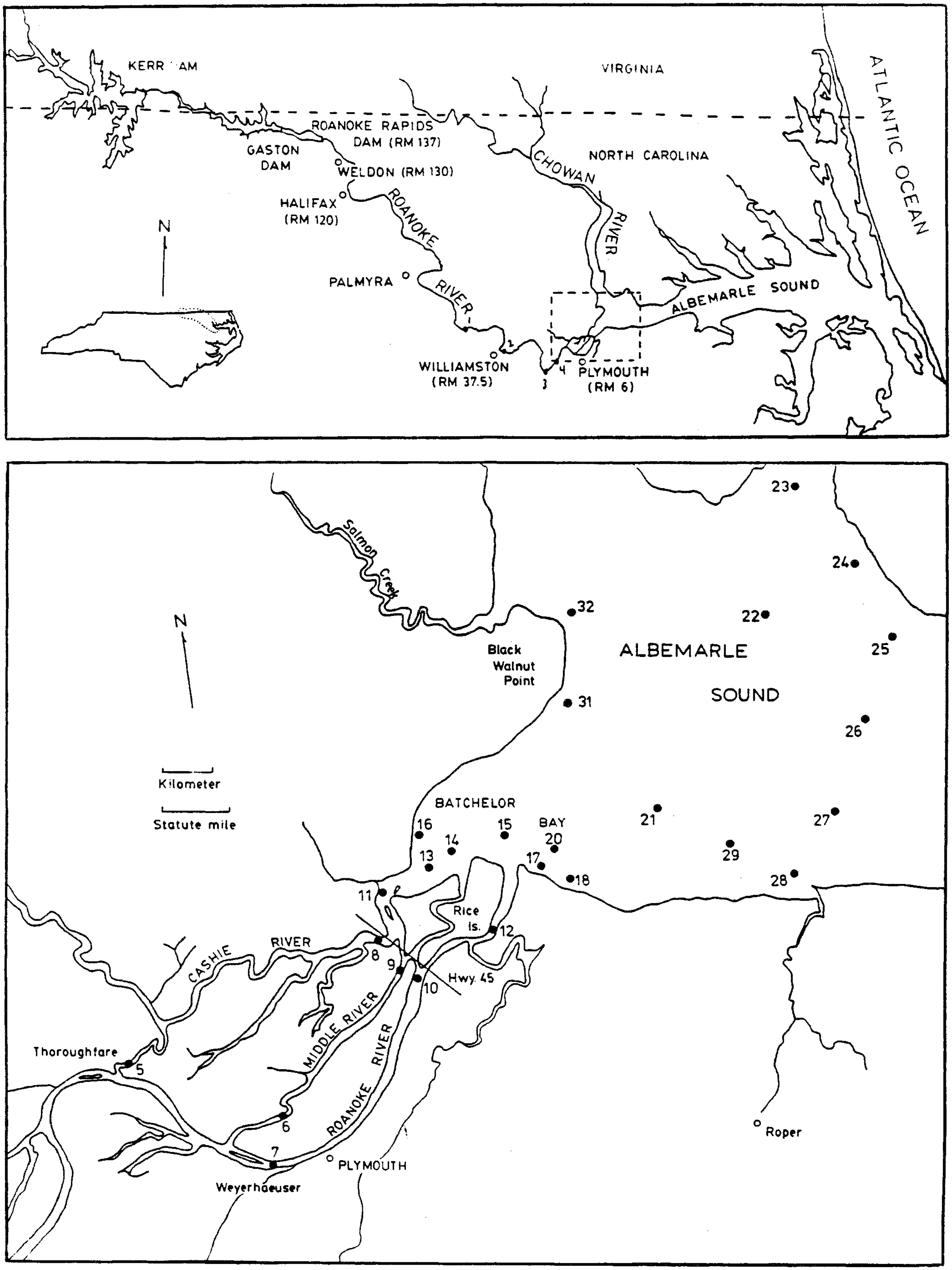


Figure 1. Map depicting the locations of sampling sites used in 1990 and 1991. Not all stations were sampled each trip.

dissolved oxygen were measured at all stations; pH, salinity, and conductivity were measured at Stations 6-13, 15, and 16 and all Sound stations. Details of the methodology for chlorophyll and phytoplankton analyses were presented by Rulifson et al. (1992).

Sample locations in the River and western Sound were similar to those used in prior years (Rulifson et al. 1988) with the addition of Stations 16, 31, and 32 and the deletion of Stations 14, 17, 25, 27, and 29 (Figure 1, Table 1). The sample schedule for each year depended on the level of spawning activity upstream of Barnhill's Landing (RM 117), which is monitored by ECU personnel. In 1990, sampling in the lower River was initiated soon after evidence of spawning was observed at Barnhill's Landing (18 April). Sampling began earlier in 1991 to encompass the entire season and to better define early zooplankton development (1 March). In both years, sampling frequency started on a weekly basis at selected stations and increased to include all stations as the spawning level increased. Alternate sampling of River and Sound began after the peak of spawning was observed at Weldon (RM 130), upstream from Barnhill's Landing.

Larvae and small fish were removed from all ichthyoplankton and zooplankton samples for identification and enumeration. *Morone* larvae were identified, measured (mm TL) and stage of development noted using Mansueti (1964), Lippson and Moran (1974), and Olney et al. (1983). Total number collected at a station was converted to density (number/100 m^3) to allow abundance comparisons among stations and dates. *Morone* larvae in feeding condition were examined for gut contents. Each prey item was identified (Table 2) to the lowest taxon practical (Gosner 1971, Pennak 1979, Merritt and Cummins 1984) and counted. The average number of each prey item ingested per fish was calculated by counting the total number of each item and then dividing by the number of fish examined that contained prey.

Zooplankton samples were processed using a standard subsample method. Each sample was diluted to 500 ml. A 5-ml subsample was removed from the sample and all organisms were identified as above and counted. This procedure was repeated two more times. The average number of each taxonomic group was reported as number/m^3 of water filtered.

Phytoplankton cell densities were determined using the membrane filtration method (APHA 1975). The preserved algae were concentrated by filtering the sample through a 0.45-µm pore size membrane filter. Concentrated algae were counted using an inverted microscope and reported as number of individuals per liter. These counts were converted to volume (cubic microns) by estimating the volume of an average individual of each species with geometric formulae. The total volume of algae per liter was converted to weight by assuming a specific gravity of unity.

Table 1. Descriptions of the fixed sampling locations used in the striped bass food and feeding study, 1990-1991. Descriptions are facing downstream; i.e., right bank = south or Plymouth side. RM = river mile. Refer to Figure 1 for graphical information.

Station number	Approximate latitude/ longitude	Physical description
1	35:57:00N, 77:02:30W (RM 57)	Hamilton - Roanoke R. mainstem; strong currents; steep banks; little submerged or emergent vegetation; soft bottom covered with thick layers of pine bark.
2	35:51:00N, 77:02:30W (RM 37)	Williamston - the former Station 1 (1984-88)
3	35:48:15N, 76:53:45W (RM 19)	Jamesville - the former Station 2 (1984-88)
4	35:50:00N, 76:51:45W (RM 16)	Power lines - similar to Station 1; several "snags"
5	35:56:36N, 76:48:11W	In the uppermost Thoroughfare about 0.5 RM downstream of its exit from the Roanoke River; mean depth 5.6 m, maximum 7.6 m.
6	35:53:22N, 76:45:06W	In the uppermost Middle River about 0.5 RM downstream of its exit from the Roanoke River; mean depth 5.1 m, maximum 12.2 m.
7	35:52:45N, 76:45:16W (RM 7.5)	Roanoke River mainstem adjacent to Weyerhaeuser and just above Welch Creek and the diffuser pipe; moderate currents; steep banks and deep on right shore (Plymouth) gradating to extensive shallow, narrow channel, sides covered with emergent lily pads on left shore; mean depth 6.8 m, maximum 9.8 m.
8	35:56:27N, 76:43:24W	Cashie River just upstream of N.C. Highway 45 bridge; moderate currents; steep bank and deep water on left side gradating to extensive shallow, unnavigable shelf with emergent lily pads on right shore; mud bottom; mean depth 6.9 m, maximum 12.2 m.
9	35:56:01N, 76:42:58W	Middle River just upstream of the N.C. Highway 45 bridge; moderate currents; straight and fairly uniform section of river; mean depth 5.1 m, maximum 18.3 m in the river bend just downstream.

Table 1 continued.

Station number	Approximate latitude/ longitude	Physical description
10	35:55:45N, 76:42:36W (RM 3)	Roanoke River main stem about 500 m upstream of the N.C. Highway 45 bridge; fairly wide and shallow; bottom more sandy than mud; mean depth 4.3 m, maximum 6.1 m.
11	35:57:07N, 76:43:22W	Cashie River mouth downstream of N.C. Highway 45 bridge just upstream of Batchelor Bay; deep water on left bank gradating to shallow waters and islands on right bank; mean depth 7.3 m, maximum 10.7 m.
12	35:56:47N, 76:41:06W (RM 1)	Near the Roanoke River mouth about 600 m downstream of its confluence with Canaby Creek and upstream of navigation marker R12; shelf with lily pads on left and right banks; mean depth 6.3 m, maximum 8.5 m.
13	35:57:18N, 76:43:00W	Batchelor Bay just seaward of the Cashie River discharge into western Albemarle Sound; mean depth 1.8 m, maximum 4.6 m; numerous submerged and floating snags; hard sand bottom littered with leaves and detritus.
15	35:57:31N, 76:41:16W	Batchelor Bay just seaward of the Roanoke River discharge into western Albemarle Sound; Similar to Station 13; mean depth 2.5 m, maximum 4.6 m.
16	35:57:34N, 76:42:47W	Southwest shore of Batchelor Bay just north of Cashie River mouth; Similar to Station 13; mean depth 1.9 m, maximum 3.0 m.
18	35:56:36N, 76:39:39W	South shore of Albemarle Sound about 1 km east of Roanoke River mouth; mean depth 2.4 m, maximum 3.1 m.
20	35:57:18N, 76:41:05W	Southwest Albemarle Sound about 0.75 km from Roanoke River mouth; mean depth 3.1 m, maximum 4.3 m.
21	35:57:05N, 76:39:20W	Southwest Albmarle Sound at navigation buoy 1 (4-second flashing green); about 3 km NE of the Roanoke River mouth; reduced currents, varies with river discharge and prevailing winds; mean depth 3.8 m, maximum 5.2 m; hard sand bottom with some submerged snags.

Table 1 continued.

Station number	Approximate latitude/ longitude	Physical description
22	36:00:28N, 76:37:02W	Northwest Albemarle Sound at Buoy AS (Morse Code A) about 7.5 km from mouth of Roanoke River; mean depth 5.0 m, maximum 6.4 m; hard sand bottom; probably influenced by Chowan River discharge.
23	36:02:06N, 76:36:07W	Edenton Bay in northwest Albemarle Sound about 10 km from Roanoke River mouth; usually some salinity (0.2-0.5 ppt); probably influenced by Roanoke River discharge only in high flow years; mean depth 4.5 m, maximum 5.2 m.
24	36:01:25N, 76:35:35W	Northwest Albemarle Sound; mean depth 4.3 m, maximum 5.5 m.
26	35:58:22N, 76:35:22W	Central western Albemarle Sound about mid-way along the old Norfolk and Southern Railroad bridge; mean depth 5.0 m, maximum 6.1 m.
28	35:56:35N, 76:36:01W	South shore of western Albemarle Sound near Mackey's Landing; about 6 km east of the Roanoke River mouth; mean depth 3.8 m, maximum 5.2 m.
31	36:00:24N, 76:39:45W	Western shore of western Albemarle Sound near Black Walnut Point; about 4 km from Roanoke River mouth; historical nursery grounds for YOY striped bass; mean depth 3.2 m, maximum 4.7 m.
32	35:58:38N, 76:40:36W	Western shore of western Albemarle Sound at Black Walnut Point and mouth of the Chowan River; offshore of the mouth of Salmon Creek; historical nursery grounds for YOY striped bass; mean depth 3.8 m, maximum 4.6 m.

Table 2. Taxonomic relationships of zooplankton collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina.

- Phylum Cnidaria
  - Class Hydrozoa
    - Order Hydroida
      - Family Hydridae
        - *Hydra* species and *Cordylophora lacustris*
- Phylum Platyhelminthes
  - Class Turbellaria (flatworms)
- Phylum Rotatoria (rotifers
- Phylum Nematoda (nematodes)
- Phylum Tardigrada
- Phylum Annelida
  - Class Polychaeta (polychaete worms)
  - Class Oligochaeta
    - Order Plesiopora pleiothecata
      - Family Naididae
        - *Stylaria lacustris*
        - *Dero* species
      - Family Aeolosomatidae
        - *Aeolosoma leidyi*
  - Class Hirudinea (leeches)
- Phylum Arthropoda
  - Class Arachnoidea
    - Suborder Trombidiformes
      - Hydracarina families
  - Class Crustacea
    - Subclass Malacostraca
      - Superorder Peracarida
        - Order Amphipoda
          - Suborder Gammaroidea
            - Family Gammaridae
              - *Gammarus* species
        - Order Isopoda (isopods)
        - Order Mysidacea (oppossum shrimps)
        - Order Cumacea
        - Order Tanaidacea
      - Superorder Eucarida
        - Order Decapoda
          - Family Paguridae (hermit crabs)
          - Family Palaemonidae (grass shrimps)
    - Subclass Branchiopoda
      - Superorder Oligobranchiopoda
        - Order Cladocera
          - Family Leptodoridae
            - *Leptodora kindti*
          - Family Bosminidae
            - *Bosmina* species
          - Family Daphnidae
            - *Daphnia* species
          - Family Sididae
          - Family Chydorinae

Table 2. Zooplankton taxonomic relationships (continued).

- Subclass Ostracoda (seed shrimps)
- Subclass Copepoda
  - Order Eucopepoda
    - Suborder Calanoida (adult calanoid copepods)
    - Suborder Cyclopoida (adult cyclopoid copepods)
    - Suborder Harpacticoida (adult harpacticoid copepods)
    - nauplius copepods (early stages)
    - other copepodids
  - Order Branchiura
    - Suborder Arguloida
      - Family Argulidae
        - *Argulus* species

Class Insecta
- Subclass Apterygota
  - Order Collembola (springtails)
- Subclass Pterygota
  - Order Ephemeroptera (mayflies)
  - Order Odonata (dragonflies)
  - Order Orthoptera
  - Order Megaloptera (alderflies)
  - Order Hemiptera (true bugs)
    - Family Belostomatidae (giant waterbugs)
    - Family Corixidae
    - Family Gerridae
  - Order Plecoptera (stoneflies)
  - Order Hymenoptera (wasps)
- Subclass Endoptergota
  - Order Trichoptera (caddisflies)
  - Order Neuroptera
    - Family Sisyridae (spongillaflies)
  - Order Coleoptera
    - Suborder Adephaga
      - Family Dytiscidae (predaceous diving beetles)
      - Family Gyrinidae (whirligig beetles)
      - Family Haliplidae
        - *Peltodytes* species (crawling water beetles)
    - Suborder Polyphaga
      - Family Elmidae (riffle beetles)
  - Order Diptera
    - Suborder Nematocera
      - Family Culicidae
        - Subfamily Culicinae (mosquitos)
        - Subfamily Chaoborinae
          - *Chaoborous* species (phantom midges)
      - Family Chironominidae (chironomids)
      - Family Heleidae
      - Family Dixidae
    - Suborder Cyclorrhapha
      - Family Ephydridae (shoreflies)
  - Order Thysanoptera (thrips)

Table 2. Zooplankton taxonomic relationships (continued).

- Phylum Mollusca
  - Class Bivalvia
  - Class Gastropoda
- Phylum Chordata
  - Subphylum Vertebrata
    - Class Amphibia
      - Order Anura
        - Family Ranidae (tadpoles)

RESULTS

Water Quality

River Flow. The 1990 mean annual instream flow of the Roanoke River (10,495 cfs) ranked 12th for the period of record, and the April-June mean flow of 13,386 cfs was similar to that observed in 1989. High flows of 20,000 cfs in the first half of April were regulated to be within the Flow Committee guidelines in the latter half of April, but high inflow in mid-May forced a deviation from the target instream flows (Figure 2). An attempt to return to flow guidelines failed after a basinwide May rainfall of 7.5 in (3.68 in above normal), which resulted in a 20,000 cfs discharge from late May through mid-June. April basinwide rainfall was about normal; June rainfall (2.68 in) was 1.15 in below normal. For the April-June period, 59.4% of the days had instream flows ≥10,000 cfs and 35.2% of the days had flows ≥6,000 and <10,000 cfs. Only 5.5% of the days had flows lower than 6,000 cfs.

Moderately high and stable flows in March 1991 increased to about 20,000 cfs through 20 April, when flows ranged between 6,000 and 9,000 cfs through May (Figure 2). The mean April-June discharge was 10,992 (± 554) cfs, which was the 19th highest average of the 80-year record. Slightly over half (58%) of the days in the second quarter were comprised of flows between 6,000 and 10,000 cfs. Rainfall in March (5.14 inches) was 1.27 inches above normal; April, May and June rainfall was below normal.

Water Temperature. The pattern of water temperature changed each year as a function of the seasonality of prevailing air temperature, weather fronts, and instream flow regulated primarily by discharge of reservoir waters. In general, water temperatures were warmer in Batchelor Bay and western Albemarle Sound than in the lower Roanoke River and Delta at the same time (Figure 3). Cooler waters in April were common in 1990 and 1991.

Dissolved Oxygen. In general the dissolved oxygen content of the lower River, Batchelor Bay, and western Albemarle Sound remained above 4 mg/L in both years. Usually River waters had higher dissolved oxygen content compared to Batchelor Bay; Albemarle Sound waters in mid-June were usually slightly higher in oxygen content than either the River or Bay (Figure 4). A more appropriate way of assessing whether waters were adequately oxygenated is to present the values as percent saturation, which takes into account the prevailing water temperature and the theoretical concentration of dissolved oxygen. Low and stable values were observed in April 1990, increasing only slightly in mid-May. Albemarle Sound dissolved oxygen values were much higher in June than either the River or Bay (Figure 5). In 1991, March samples indicated that dissolved oxygen in all three areas were close to or exceeded 100% saturation, but in April an oxygen sag was noted. These low oxygen saturation levels persisted through April 1991 when moderate increases were noted in May and June (Figure 5).

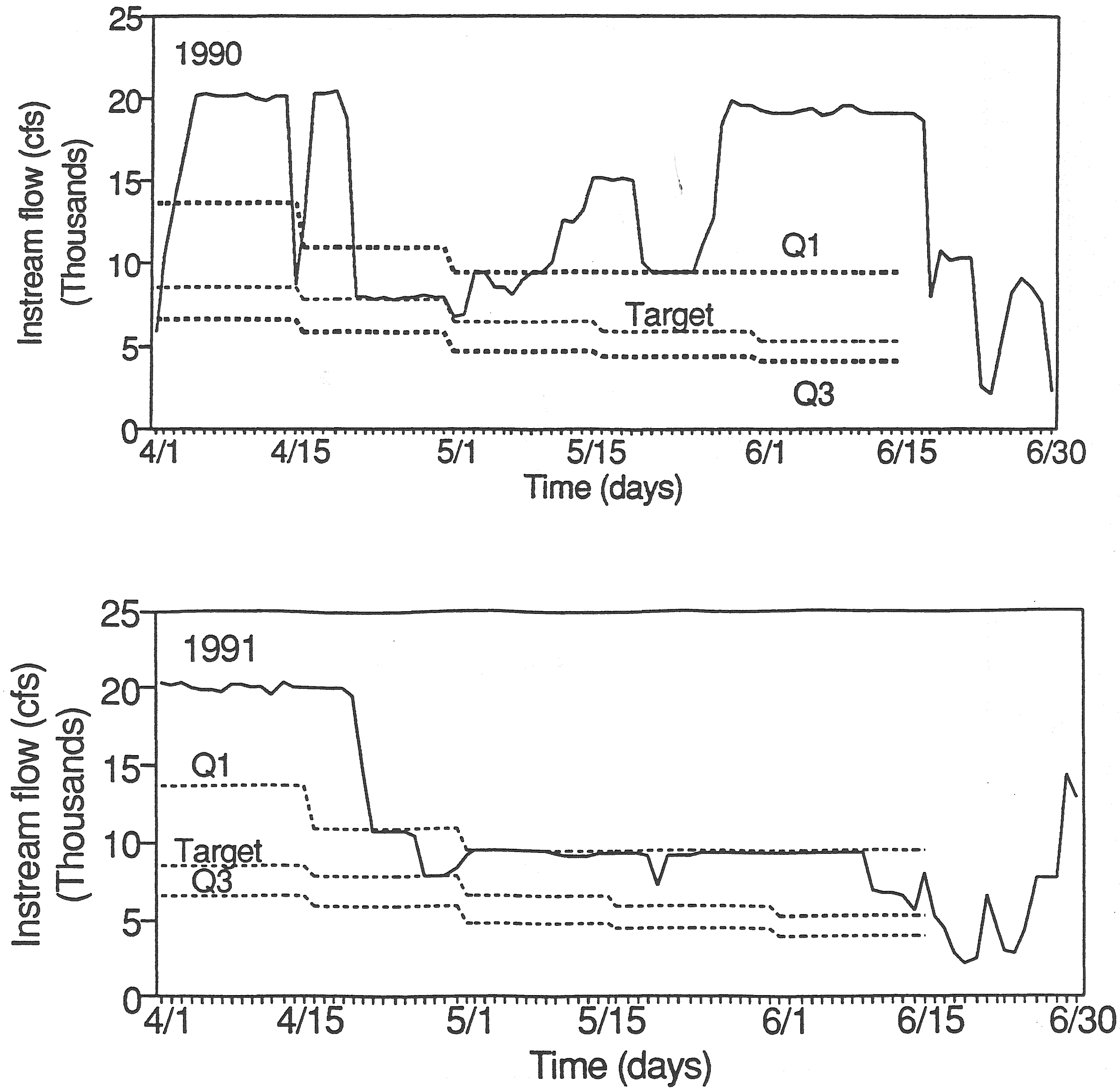


Figure 2. Average daily instream flow of the lower Roanoke River, North Carolina, for the period April through June 1990 and 1991 as recorded by U.S. Geological Survey gage at River Mile 133.6 (USGS data). Flow Committee recommendations for instream flow during this period shown as Q_1 (lowest 25% of historical flows), Target (historical median flows), and Q_3 (highest 25% of historical flows) (Manooch and Rulifson 1989).

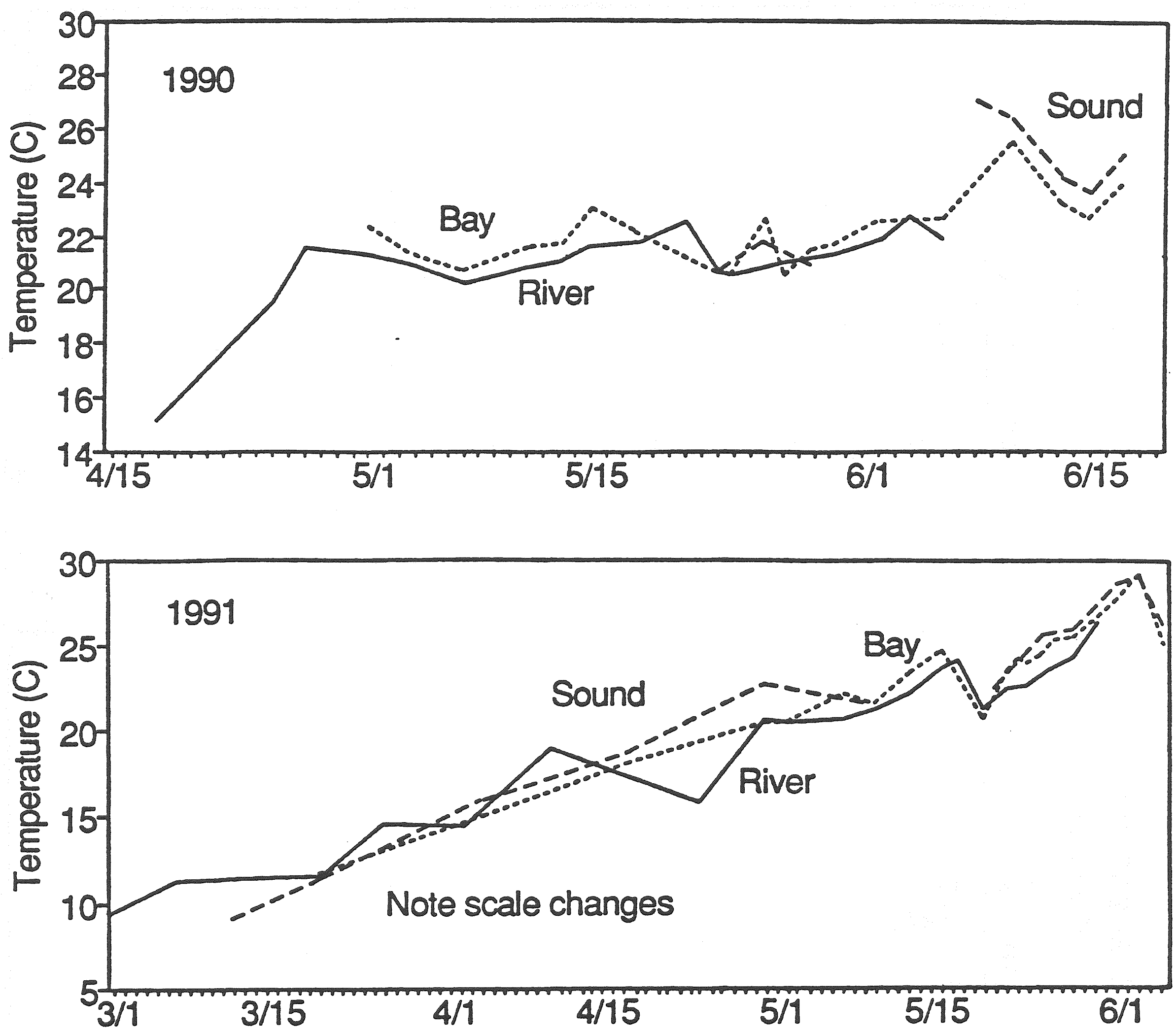


Figure 3. Average water temperature (°C), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

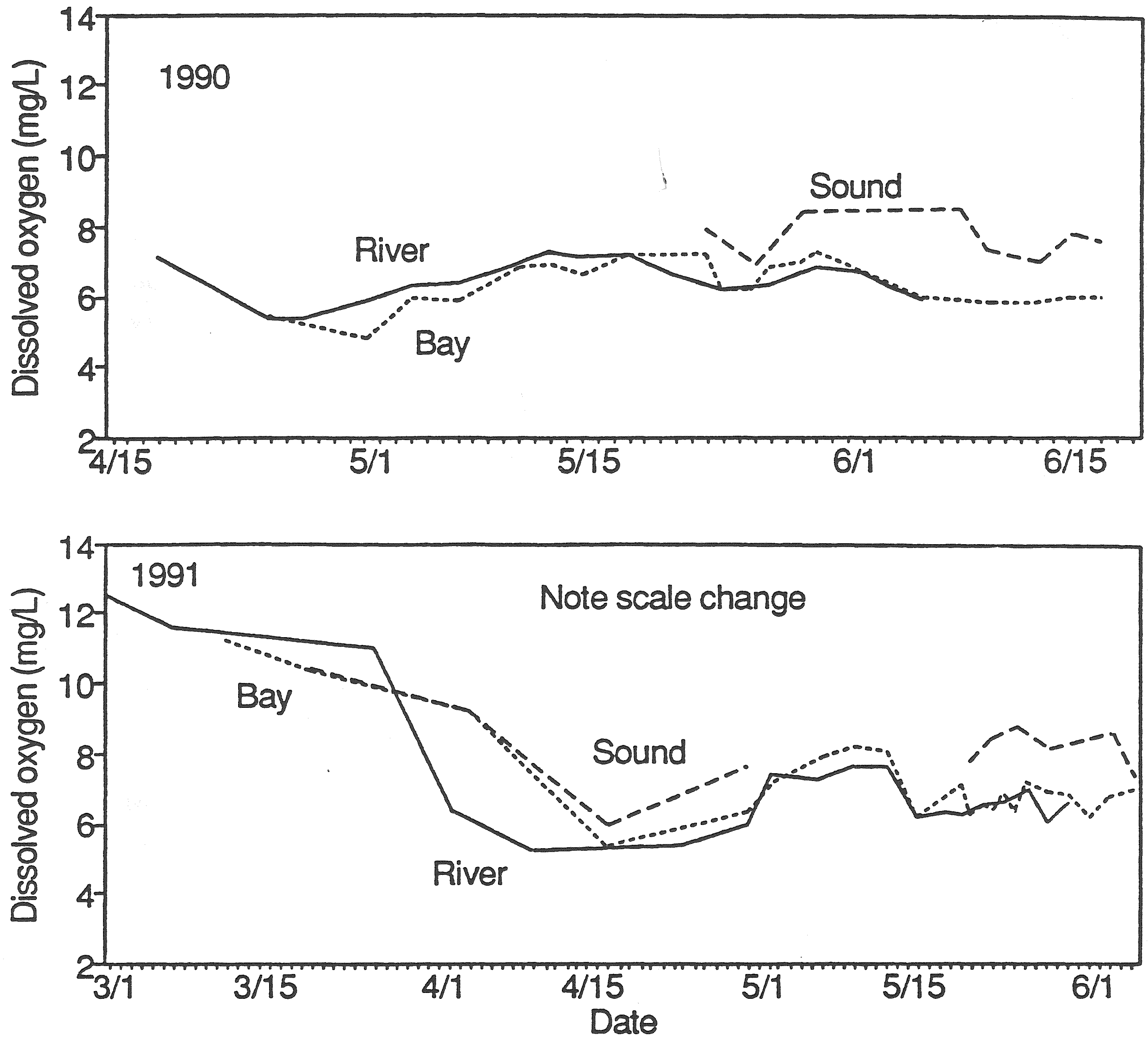


Figure 4. Average dissolved oxygen levels (mg/L), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

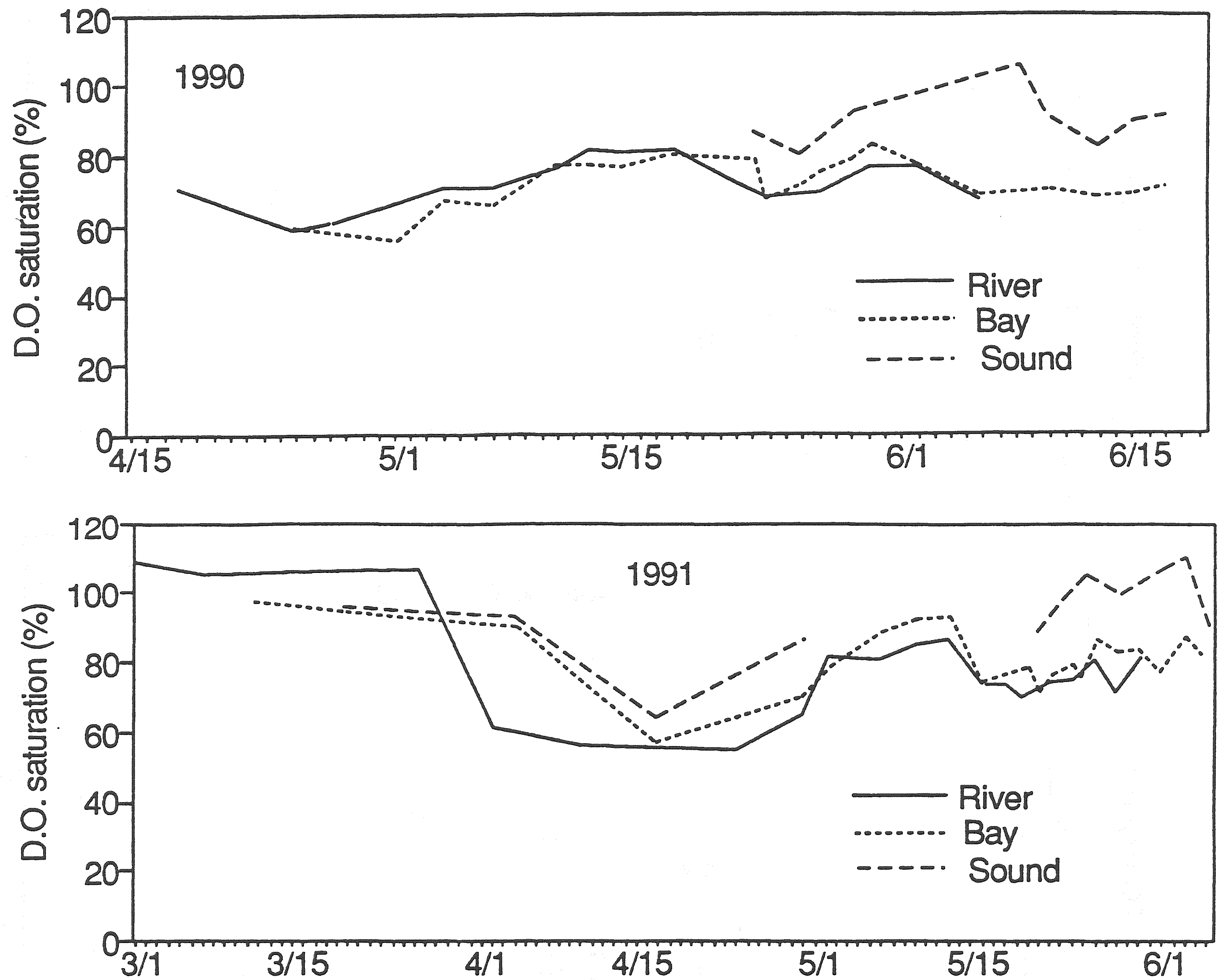


Figure 5. Average dissolved oxygen saturation (%), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

Surface Water pH. In both 1990 and 1991, Bay and Sound waters remained near or above 7.0 (Figure 6). A sudden dip in pH evident in early May 1991 were concurrent with sudden increases in dissolved oxygen concentration; at this same time instream flow increased at Roanoke Rapids (Figure 2). Whether these changes in water quality and instream flow were related is unknown.

Salinity. The lower Roanoke River and western Albemarle Sound are oligohaline (0.0-0.4 ppt) each year during the April-June period. Although Bay and Sound waters averaged slightly higher in salinity, occasionally some river stations were more saline due to prevailing water currents. On many occasions the northern Albemarle Sound stations were more saline than southern counterparts . Whether the western Sound and River are oligohaline or fresh depends on the amount of ocean water entering through the barrier island inlets, especially Oregon Inlet, as a function of prevailing weather patterns and freshwater input to Albemarle Sound. In 1991, essentially no salinity was measured in the Sound or River until mid-May even though freshwater input to Albemarle Sound was moderate to low during the same period (Figure 7).

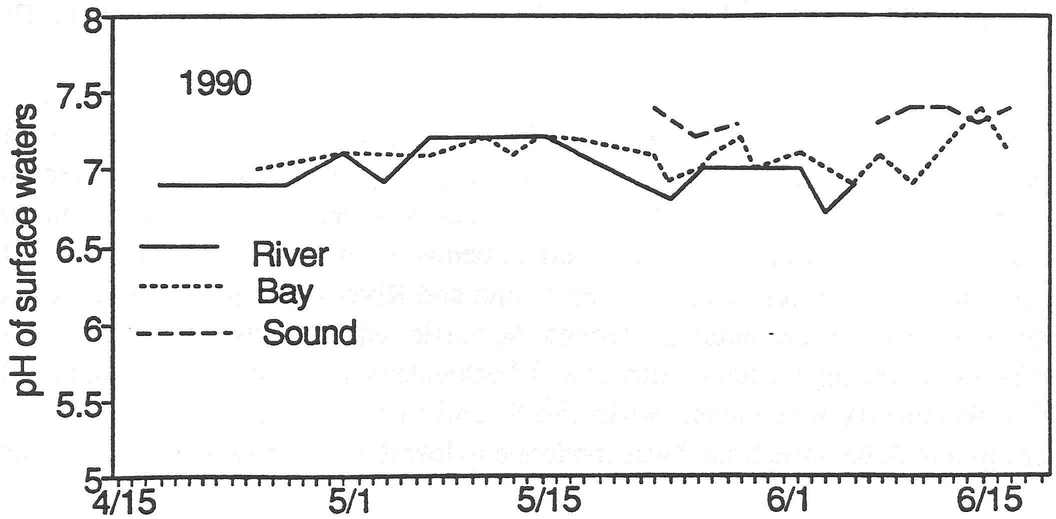
Phytoplankton and Chlorophyll *a*

Three measures of phytoplankton abundance were used in the Roanoke study: 1) chlorophyll *a* (µg/L), 2) phytoplankton cell density (cells/L), and 3) phytoplankton wet weight biomass (µg/L). It is worthwhile to consider all three, because they do not always closely agree, and because in the literature there are chlorophyll *a*, density, and biomass data for many freshwater and estuarine systems.

Historically, chlorophyll *a* levels have generally been less than 10 µg/liter in the lower Roanoke River and western Albemarle Sound (Rulifson et al. 1992). In the spring of 1990 and 1991 the chlorophyll *a* concentrations ranged from less than 0.1 to over 12 µg/L, but were mostly between 2 and 6 µg/L. In both years, average values were higher in the River and in the Sound than in Batchelor Bay (Figure 8).

A total of 154 phytoplankton species have been identified from the study area. The group showing the highest diversity is the Bacillariophyceae (diatoms) (77 species), followed by the Chlorophyceae (green algae) (42 species). In addition, there are a few representatives of other classes each year: Chrysophyceae (9 species), Dinophyceae (dinoflagellates)(9 species), Euglenophyceae (euglenophytes) (5 species), and Cyanophyceae (blue-greens) (2 species). In addition there are species which could not be identified and therefore were placed in the 'Unknown' category (10). A listing of the species found through 1986 is given in Rulifson et al. (1988).

In 1990 and 1991, as in previous years, most of the phytoplankton taxa occurred infrequently, but there were a few which were relatively common. Only 5 of the cell types appeared in more than 10% of the samples (Table 3). Representatives of two classes -



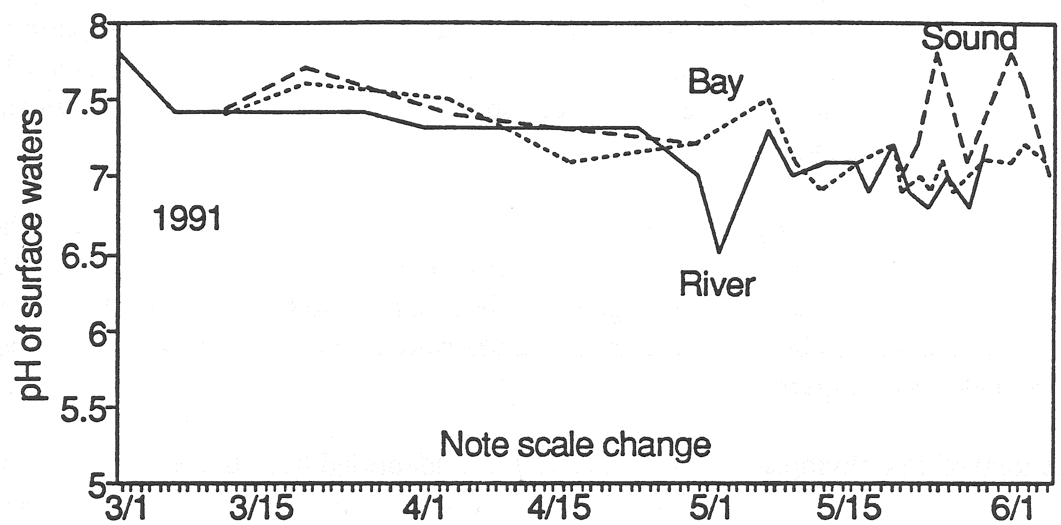


Figure 6. Average surface water pH, by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

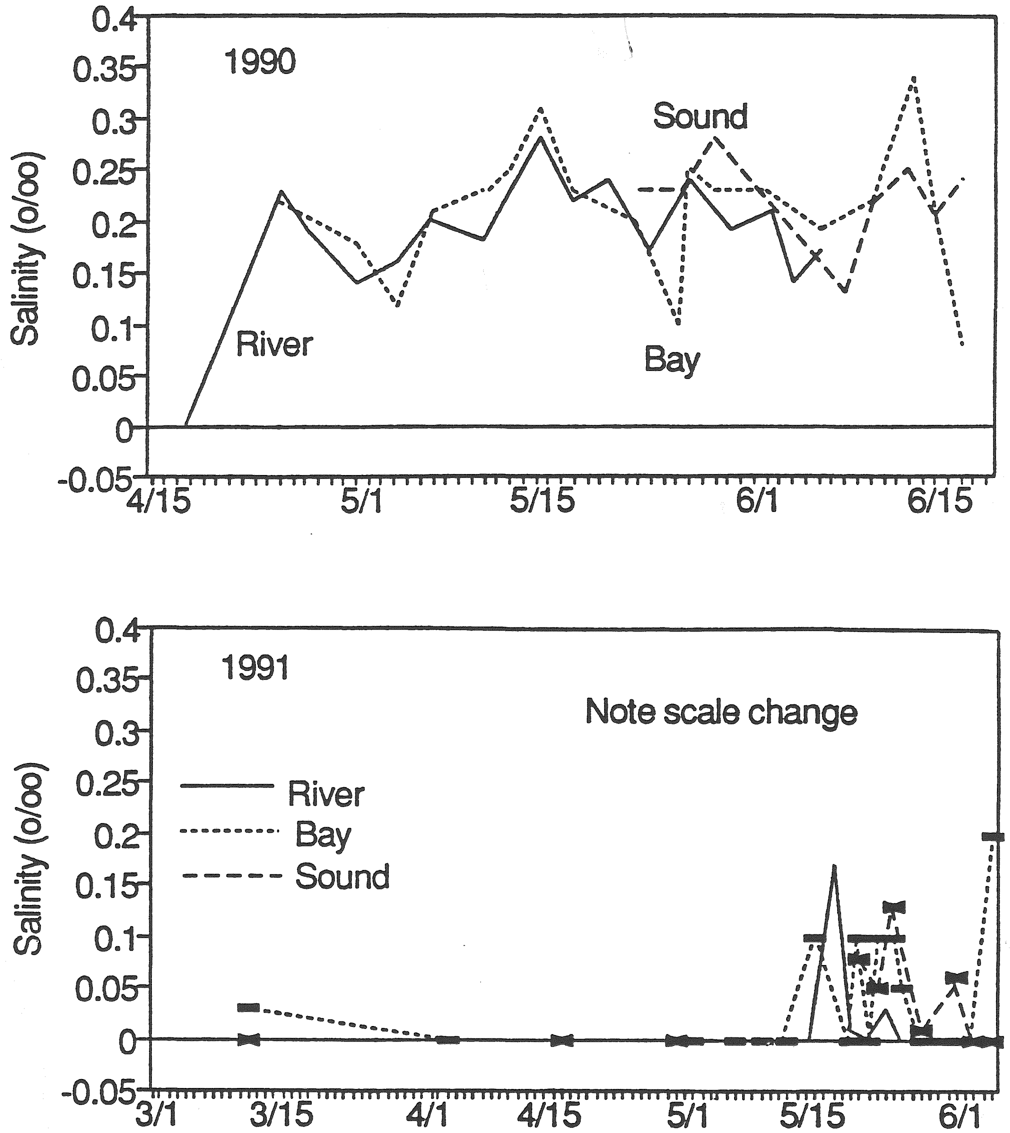


Figure 7. Average salinity (ppt), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

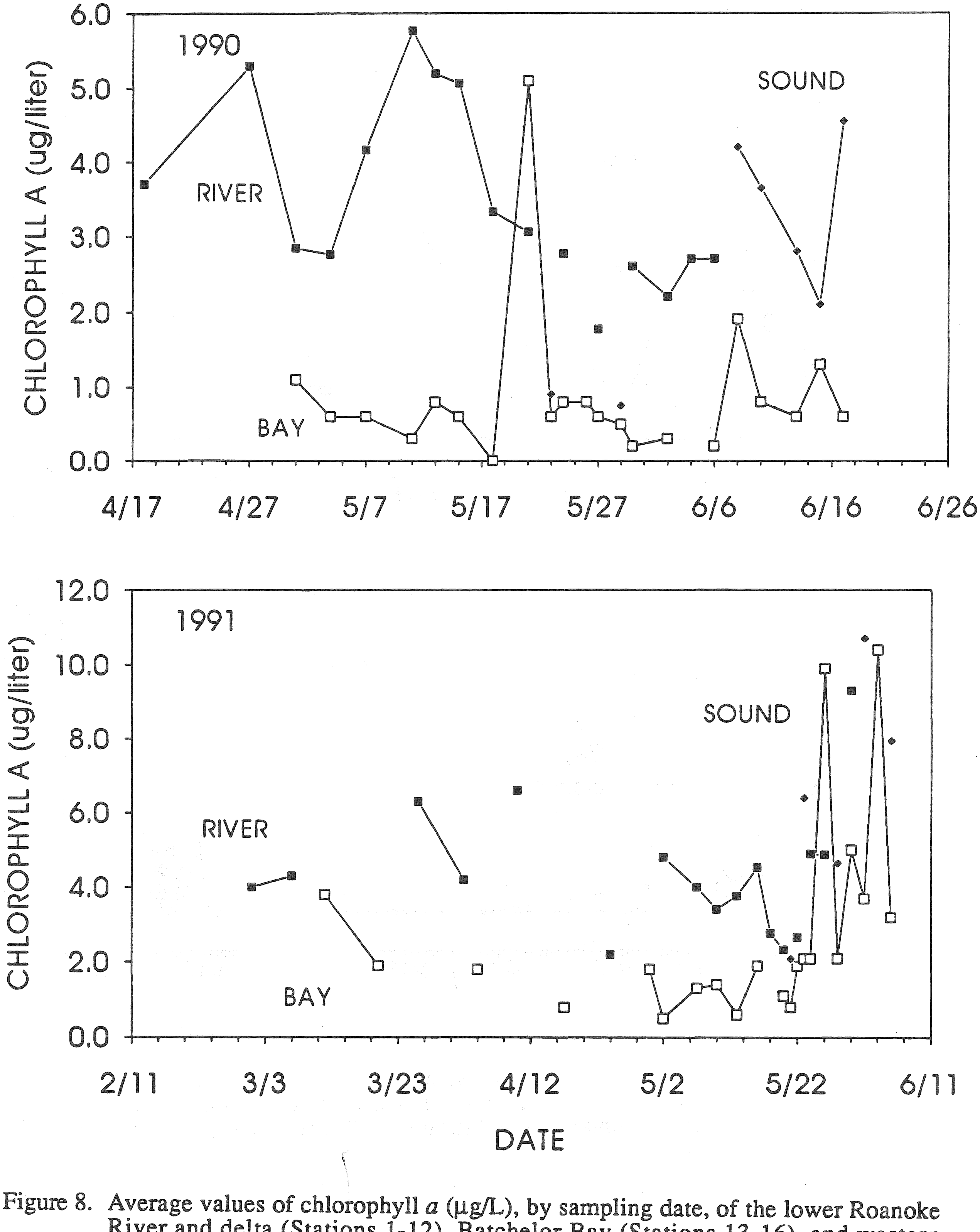


Figure 8. Average values of chlorophyll *a* (µg/L), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

Table 3. Most frequently occurring phytoplankton taxa, and their relative occurrence in samples (%), in the lower Roanoke River and western Albemarle Sound, North Carolina, in 1990 and 1991. Class BAC = Bacillariophyceae; CHL = Chlorophyceae; CHR = Chrysophyceae; EUG = Euglenophyceae; UNK = Unknown.

Taxon	Cell type	Class	1990	1991
Schizogonium murale	24	CHL	13	15
Cyclotella sp.	72	BAC	12	8
Zygnema sp.	462	CHL	3	2
Coscinodiscus sp.	468	BAC	5	5
Melosira granulata	508	BAC	15	6
Unknown 460	460	UNK	9	5
Synedra sp. 3	509	BAC	5	6
Fragilaria sp. 4	511	BAC	3	.
Fragilaria sp. 3	463	BAC	11	.
Unknown 502	502	UNK	10	8
Cyclotella sp.	3	BAC	.	4
Navicula sp. 14	104	BAC	.	6

Bacillariophyceae (diatoms) and Chlorophyceae (green algae) - dominate this list. In 1990 the most common type was *Melosira granulata*, a diatom present in 15% of the samples. Other common diatoms included a species of *Cyclotella* and a species of *Fragillaria*. The most common green alga was *Schizogonium murale*, which was the most common of all species in the following year (1991). *Zygnema*, *Coscinodiscus*, *Synedra*, *Cyclotella* and *Navicula* were the other common genera.

Phytoplankton cell densities ranged widely, from less than 100 cells/ml to over 2,000 cells/ml in a few samples, but values in the range 500-1,000 were most common (Appendix Table A-1). In both 1990 and 1991, algal densities in the River were highest early in the sampling period, and tended to decline later (Figure 9). Densities in the Bachelor Bay region showed less of a temporal pattern, and overall were lower than in the River.

Biomass of the phytoplankton (µg wet weight/L) also was highly variable, but there were some trends (Figure 10). For most samples the biomass fell between 50 and 300 µg/L. As expected, based on the chlorophyll *a* and cell density results, algal biomass was usually higher in the River than in the Sound or Batchelor Bay. Unusually high biomass values (greater than 10,000 µg wet weight/L) were measured in a few samples, and were the result of either very high densities of average-sized cells, or relatively low densities of very large phytoplankters (Appendix Table A-2).

Zooplankton

Zooplankton abundance is not uniform throughout the watershed, but typically is concentrated in several areas (Appendix Tables A-3 and A-4). Within the Roanoke River delta, the Cashie River consistently has the greatest zooplankton abundance . Station 8 in the Cashie River and Station 11 at the Cashie River mouth averaged 959 individuals/m^3 and 591/m^3, respectively, in 1990 and 462/m^3 and 576/m^3, respectively, in 1991. Station 9 in the lower Middle River and Station 10 in the Roanoke main stem also had greater abundance on average than locations farther upstream. In Batchelor Bay, Station 16 along the western shore typically had the highest zooplankton concentration, and in western Albemarle Sound zooplankton were most abundant at Stations 22-24 near Edenton Bay along the north shore (Appendix Table A-4, Figure 11).

The zooplankton community resembles that of a freshwater community in this oligohaline estuary, but the species composition of the community changes from the River through the Bay into the western Sound (Appendix Tables A-7 through A-10). For the period of study, cladocerans dominated the River zooplankton community (Table 4), representing about 60% of the individuals in 1990 but only 35% in 1991. Dominant cladocerans were *Daphnia* (44.8% in 1990; 34.6% in 1991). The other dominant taxonomic group in the River was copepods (30-36%), primarily cyclopoids (24-28%) and to a lesser extent calanoids (5.6-6.8%). Single rotifers were abundant in samples collected in 1991, comprising 18.5% of the River

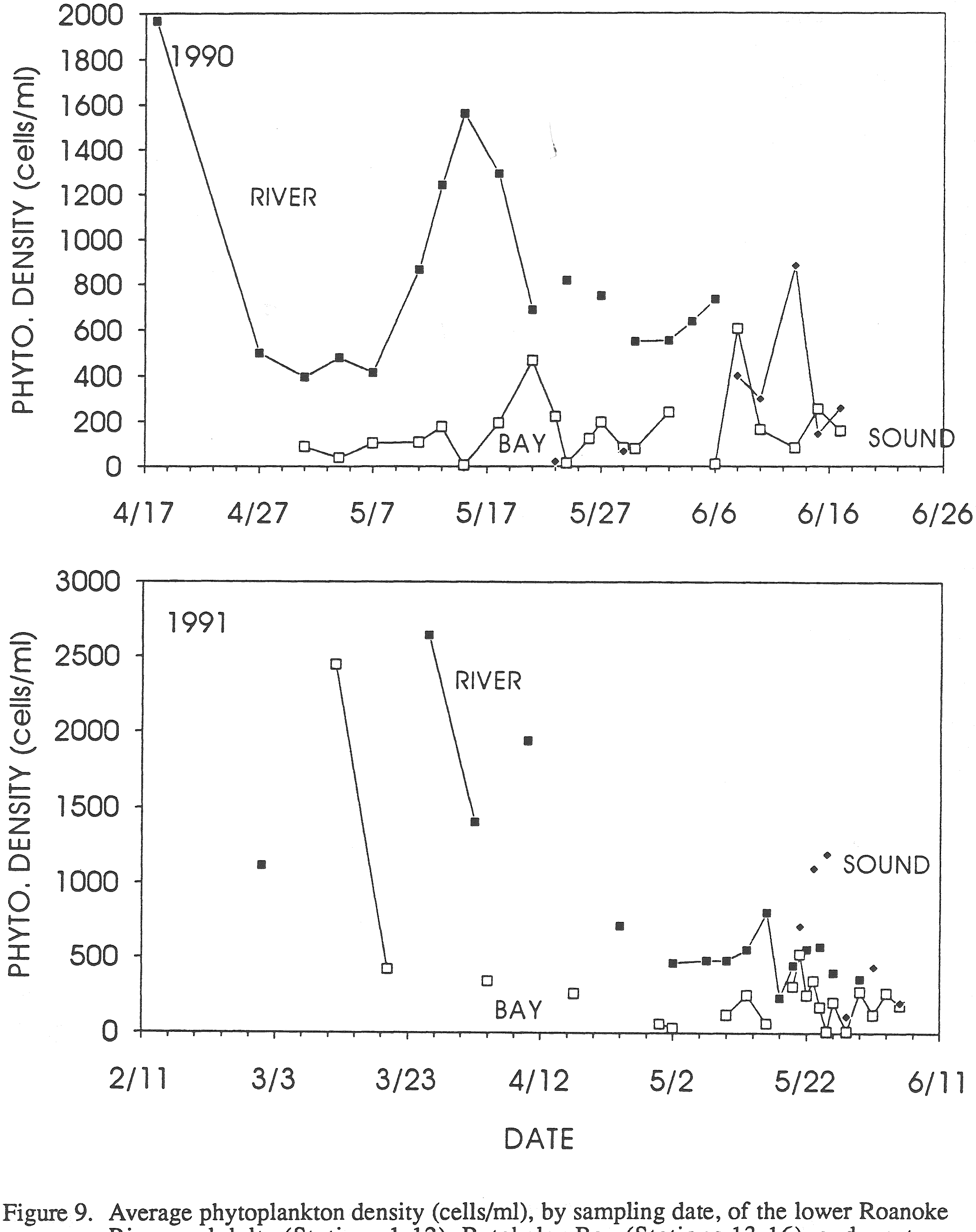


Figure 9. Average phytoplankton density (cells/ml), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

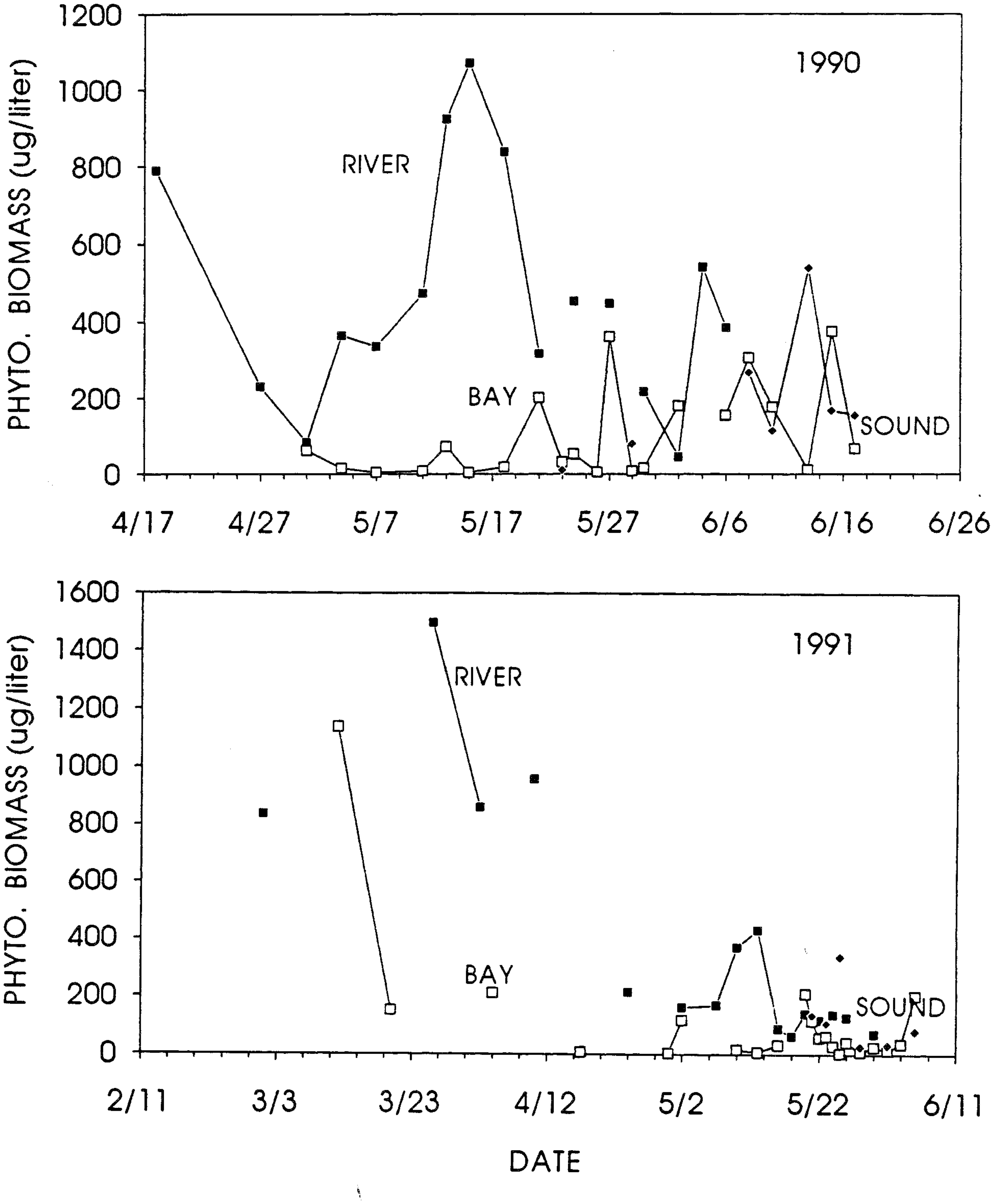


Figure 10. Average phytoplankton biomass (µg/L), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

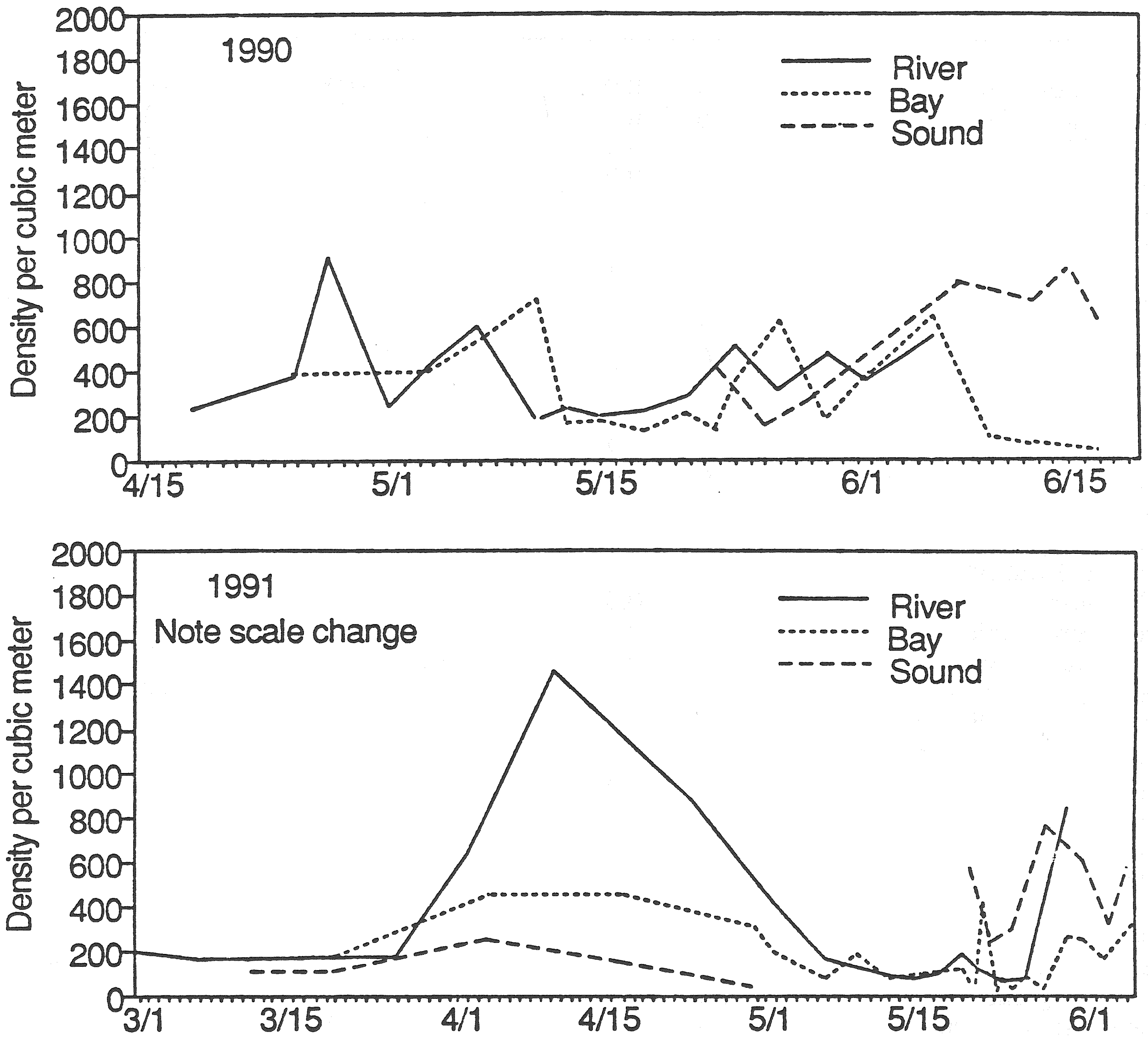


Figure 11. Average zooplankton density (number/ml), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

Table 4. Relative contribution (% using density) of each taxonomic group to the spring zooplankton community of the lower Roanoke River (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (.) = not observed in samples.

	River		Bay		Sound	
Taxonomic group	1990	1991	1990	1991	1990	1991
Amphipoda-gammarid egg	0.0	0.0	0.1	0.0	0.0	.
Amphipoda - Gammaridae	1.6	0.7	4.8	2.7	1.3	0.3
Arachnida	0.2	0.3	0.1	0.3	0.2	0.1
Bivalvia	0.0	0.0	.	.	0.0	0.0
Bivalvia-larvae	0.0	0.3	0.2	0.1	.	0.0
Caddisfly adult	.	.	.	.	.	.
Caddisfly larvae	0.1	0.1	0.1	0.1	0.0	.
Clad. - Bosmina	2.8	7.8	3.5	16.9	1.3	2.5
Clad. - Daphnia	44.8	12.8	37.6	11.2	4.8	1.0
Clad. - Leptodora	0.0	0.0	0.0	0.2	10.3	2.7
Cladocera - other	12.0	11.2	10.4	9.9	9.1	7.1
Clad.-unid. egg	0.1	1.6	0.1	1.0	0.0	0.0
Clad.-unid. juvenile	0.9	1.2	0.8	1.0	0.0	0.1
Coleopt.-Dytiscidae larvae	0.0	0.0	0.0	.	0.0	.
Coleopt.-Gyrinidae adult	.	.	.	.	.	.
Coleopt.-Gyrinidae larvae	0.0	.	0.0	.	.	.
Coleopt.-Peltodytes larvae	.	.	.	.	.	.
Coleoptera	.	0.0	.	0.0	.	.
Coleoptera-Elmidae	.	0.0	.	.	.	.
Collembola larvae	.	0.0	0.0	.	.	.
Copepoda-egg mass	0.1	0.5	0.2	0.7	0.0	0.1
Copepoda-nauplius	0.0	0.1	0.0	0.0	.	.
Copepoda-Argulus sp.	.	.	.	.	.	0.0
Copepoda-Calanoida	5.6	6.8	10.0	9.9	2.4	2.2
Copepoda-Cyclopoida	24.0	28.4	27.8	31.6	68.3	82.2
Copepoda-Harpacticoida	0.0	0.0	.	0.0	.	0.0
Copepodids	0.3	0.2	0.3	0.2	0.0	0.0
Cumacea	.	.	.	.	0.0	.
Decapoda - shrimp larvae	.	.	.	.	.	.
Dipt.-biting midge larvae	0.0	0.0	0.0	0.0	.	0.0
Dipt.-biting midge pupae	0.0	0.0	.	.	.	.
Dipt.-chironomid adult	0.0	0.0	0.1	0.0	0.0	0.0
Dipt.-chironomid larvae	0.4	0.6	0.4	0.7	0.3	0.0
Dipt.-chironomid pupae	0.0	0.0	0.0	0.0	0.1	0.0
Dipt.-mosquito adult	.	.	.	.	.	.
Dipt.-mosquito larvae	0.0	0.0	.	.	.	.
Dipt.-mosquito pupae	.	.	.	.	.	.
Dipt.-phantom midge adult	.	.	.	.	.	.
Dipt.-phantom midge larvae	0.4	0.9	0.3	0.6	0.5	0.7
Dipt.-phantom midge pupae	0.0	0.1	0.1	0.0	0.0	0.1
Dipt.-Dixidae adult	.	.	.	.	.	.
Diptera	0.0	0.0	.	0.0	0.0	0.0

Table 4 (continued).

Taxonomic group	River 1990	River 1991	Bay 1990	Bay 1991	Sound 1990	Sound 1991
Eph.-mayfly adults	.	.	.	.	.	.
Eph.-mayfly nymphs	0.0	0.0	0.0	0.0	0.7	0.0
Gastropoda-snail	.	.	.	.	.	.
Gastropoda - egg	.	.	.	.	.	.
Hemiptera	.	0.0	.	.	0.0	.
Hemiptera-Belostomatidae	.	.	.	.	.	.
Hemiptera-Corixidae	0.0	0.0	0.0	.	0.0	.
Hemiptera-Gerridae	.	.	.	.	.	.
Hirudinea	.	.	.	.	.	.
Hydra	0.4	0.8	0.0	.	0.0	.
Hydra - medusa	.	.	.	.	.	.
Hymenoptera-ant	.	0.0	.	.	.	0.0
Hymenoptera-diving wasp	.	0.0	.	.	.	0.0
Isopoda	0.0	.	0.0	0.0	0.1	0.0
Megalopt.-alderfly larvae	.	0.0	.	.	.	.
Mysidacea - Mysis shrimp	.	.	.	.	.	0.0
Mysidacea - Mysis zoea	.	.	.	.	.	.
Nematoda	0.0	0.0	.	0.0	0.0	0.0
Odonata	0.0	0.0	0.0	0.0	.	.
Oligo.-Aeolosoma	0.2	0.4	0.0	0.2	0.0	.
Oligo.-Dero	0.0	0.1	.	.	.	.
Oligo.-Stylaria	0.3	0.3	0.5	0.3	0.0	0.0
Ostracoda	2.9	4.6	1.5	.	0.2	0.1
Plecoptera adult	.	.	.	.	.	.
Plecoptera nymph	.	.	.	.	.	.
Polychaeta	.	.	.	.	.	.
Rotifer - colonial	0.1	1.1	.	.	.	.
Rotifer - single	2.3	18.5	0.0	1.1	0.0	0.1
Spongillafly adult	.	.	0.7	7.9	0.0	0.4
Spongillafly larvae	.	.	.	0.0	.	.
Tanaid	.	.	.	.	.	.
Tardigrada	.	0.0	.	.	.	.
Thysanoptera (thrip)	0.0	0.1	0.0	0.0	.	0.0
Tubellaria	.	0.0	.	0.0	.	.
Unidentified	0.1	0.1	.	0.1	0.0	0.0
Total average density (/m^3)	342	196	337	208	555	482
(n) Total samples	149	140	45	52	62	63

zooplankton community. Batchelor Bay is a region of transition for the zooplankton community. Cladocerans still dominated the community (52% in 1990, 40% in 1991). *Leptodora*, a predatory cladoceran seldom observed in River samples, was not present in Bay zooplankton in 1990 and represented about 0.2% of the community in 1991 (Table 4). Copepods increased in importance (38% in 1990, 42% in 1991), with both cyclopoids and calanoids comprising a greater number of individuals (Table 4). Gammarid amphipods were most abundant in Batchelor Bay representing 4.8% of the zooplankton density in 1990 and 2.7% in 1991. Adult spongillafly were important in the Batchelor Bay zooplankton samples in 1991 (7.9%). In the western Sound, copepods were the dominant group representing about 71% of the community in 1990 and 84% in 1991. The remainder of the community was mostly cladocerans (26% in 1990, 13% in 1991), with *Leptodora* representing the dominant genus of the group in 1990 (10.3%).

Another method of examining the relative importance of taxonomic groups to the zooplankton community is to estimate the wet weight biomass of each taxon. This method lessens the importance of the number of individuals relative to its size. We determined biomass by measuring the body dimensions of selected zooplankters and calculating wet weight biomass using geometric formulae (Rulifson et al. 1992). Biomass estimates were conservative in that 1) the number calculated did not include estimated weights of appendages, and 2) rarely encountered zooplankton taxa were not considered.

River and Bay zooplankton biomass was primarily cladocerans, especially *Daphnia*; cyclopoid copepods were more important biomass contributors in the western Sound (Table 5). In all three study areas, two other major biomass contributors were gammarid amphipods and phantom midge larvae. In 1990, wet weight biomass was greatest in the Cashie River at Stations 8 (183 g/m^3) and 11 (142 g/m^3); biomass dropped to less than one-half at these stations in 1991 (Appendix Table A-5). The estimated mean biomass of zooplankton in the River was 71 g/m^3 in 1990 and 28 g/m^3 in 1991. A similar trend was observed in Bay and Sound data (Appendix Table A-6). In Batchelor Bay zooplankton biomass was highest at Station 13 (143 g/m^3), but in 1991 dropped to less than one-third (46 g/m^3) that observed in 1991. Highest biomass values in the Sound were along the north shore near Edenton Bay (Stations 22-24), but mean 1991 values were about half that recorded in 1990 (Appendix Table A-6).

Striped Bass and White Perch Egg Distribution

Striped bass eggs appeared in lower River samples in both 1990 and 1991 (Table 6). Average egg densities were highest at Station 1 (RM 57) near Hamilton, North Carolina, in both years. In 1990, eggs were collected in the upper sections of two Delta distributaries - Middle River (Station 6) and the Thoroughfare (Station 5); eggs were not collected this far downstream in 1991 nor in any other year of the eight-year study (1984-1991). In 1991, eggs were collected as far downstream as Station 3 (RM 19). No eggs were collected in Batchelor Bay or western Albemarle Sound in either year.

Table 5. Relative contribution (% using biomass) of each taxonomic group to the spring zooplankton community of the lower Roanoke River (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (.) = not observed in samples, or no weight estimate available.

	River		Bay		Sound	
Taxonomic group	1990	1991	1990	1991	1990	1991
Amphipoda-gammarid egg	.	.	0.0	0.0	0.0	.
Amphipoda - Gammaridae	15.6	10.3	37.8	31.6	14.3	4.5
Arachnida	0.4	0.8	0.2	0.6	0.3	0.3
Bivalvia	0.1	0.1	.	.	0.0	0.2
Bivalvia-larvae	0.0	0.0	0.0	0.0	.	0.0
Caddisfly adult	.	.	.	.	.	.
Caddisfly larvae	0.2	0.3	0.1	0.1	0.0	.
Clad. - Bosmina	0.4	1.7	0.4	3.1	0.2	0.5
Clad. - Daphnia	46.8	19.2	31.4	14.1	5.4	1.5
Clad. - Leptodora	0.1	0.0	0.0	0.4	19.7	6.9
Cladocera - other	13.9	18.7	9.7	13.8	11.6	12.0
Clad.-unid. egg	0.0	0.0	0.0	0.0	0.0	0.0
Clad.-unid. juvenile	0.0	0.0	0.0	0.0	0.0	0.0
Coleopt.-Dytiscidae larvae	0.0	0.0	0.1	.	0.0	.
Coleopt.-Gyrinidae adult	.	.	.	.	.	.
Coleopt.-Gyrinidae larvae	0.1	.	0.2	.	.	.
Coleopt.-Peltodytes larvae	.	.	.	.	.	.
Coleoptera	.	.	.	.	.	.
Coleoptera-Elmidae	.	0.1	.	.	.	.
Collembola larvae	.	0.0	0.0	.	.	.
Copepoda-egg mass	0.0	0.0	0.0	0.0	0.0	.
Copepoda-nauplius	0.0	0.0	0.0	0.0	.	.
Copepoda-Calanoida	0.8	1.5	1.2	1.8	0.4	0.5
Copepoda-Cyclopoida	11.4	19.4	10.6	18.1	35.5	56.6
Copepoda-Harpacticoida	0.0	0.0	.	0.0	.	0.0
Copepodids	0.0	0.0	0.0	0.0	0.0	0.0
Decapoda - shrimp larvae	.	.	.	.	.	.
Dipt.-biting midge larvae	0.1	0.0	0.1	0.0	.	0.0
Dipt.-biting midge pupae	.	0.6	.	.	.	.
Dipt.-chironomid adult	0.4	0.8	1.1	1.4	0.6	0.3
Dipt.-chironomid larvae	2.0	4.3	1.7	3.9	1.6	0.4
Dipt.-chironomid pupae	0.4	.	0.4	0.2	.	0.7
Dipt.-mosquito adult	.	.	.	.	.	.
Dipt.-mosquito larvae	0.0	0.0	.	.	.	.
Dipt.-mosquito pupae	.	.	.	.	.	.
Dipt.-phantom midge adult	.	.	.	.	.	.
Dipt.-phantom midge larvae	5.0	14.9	3.1	8.0	6.6	12.4
Dipt.-phantom midge pupae	0.8	2.6	1.2	0.5	0.1	2.9
Dipt.-Dixidae adult	.	.	.	.	.	.
Diptera	.	.	.	.	.	.
Eph.-mayfly adults	.	.	.	.	.	.
Eph.-mayfly nymphs	0.1	0.1	0.0	0.0	1.5	0.0

Table 5. Zooplankton contribution (% by biomass, continued).

Taxonomic group	River		Bay		Sound	
	1990	1991	1990	1991	1990	1991
Gastropoda-snail	.	.	.	.	.	.
Gastropoda-egg	.	.	.	.	.	.
Hemiptera	.	.	.	.	0.	.
Hemiptera-Belostomatidae	.	.	.	.	.	.
Hemiptera-Corixidae	0.0	0.1	.	.	0.1	.
Hemiptera-Gerridae	.	.	.	.	.	.
Hirudinea	.	.	.	.	.	.
Hydra	0.5	1.3	0.0	.	0.0	.
Hydra - medusa	.	.	.	.	.	.
Hymenoptera-ant	.	0.1	.	.	.	.
Hymenoptera-diving wasp	.	0.0	.	.	.	.
Isopoda	0.0	.	0.0	0.1	0.3	0.1
Megalopt.-alderfly larvae	.	0.2	.	.	.	.
Mysidacea - Mysis shrimp	.	.	.	.	.	0.0
Mysidacea - Mysis zoea	.	.	.	.	.	.
Nematoda	0.0	0.0	.	0.0	0.0	0.0
Odonata	.	.	.	.	.	.
Oligo.-Aeolosoma	0.0	0.0	0.0	0.0	0.0	.
Oligo.-Dero	0.0	0.1	.	.	.	.
Oligo.-Stylaria	0.4	0.6	0.5	0.5	0.0	0.0
Ostracoda	0.2	0.6	0.1	0.3	0.0	0.0
Plecoptera adult	.	.	.	.	.	.
Plecoptera nymph	.	.	.	.	.	.
Polychaeta	.	.	.	.	.	.
Rotifer - colonial	0.1	1.3	0.0	1.1	0.0	0.1
Rotifer - single	0.0	0.0	0.0	0.0	0.0	0.0
Spongillafly adult	.	.	.	.	.	.
Spongillafly larvae	.	.	.	.	.	.
Tanaid	.	.	.	.	.	.
Tardigrada	.	.	.	.	.	.
Thysanoptera (thrip)	.	.	.	.	.	.
Tubellaria	.	0.1	.	0.2	.	.
Total average biomass (g/m^3)	71	28	97	35	106	71
(n) Total samples	149	140	45	52	62	63

Table 6. Average density (number/100 m^3) of striped bass and white perch eggs in the lower Roanoke River, Middle River, and Cashie River, North Carolina, 1990-1991. Number of efforts in parenthesis.

	Roanoke R. mainstem stations							Middle R. stations		Cashie R. stations		
Year	1	2	3	4	7	10	12	6	9	5	8	11
Striped bass												
1990	29	1	<1	<1	0	0	0	<1	0	<1	0	0
	(10)	(10)	(10)	(9)	(13)	(16)	(14)	(13)	(15)	(10)	(15)	(14)
1991	23	2	<1	0	0	0	0	0	0	0	0	0
	(9)	(9)	(9)	(9)	(11)	(12)	(11)	(11)	(12)	(9)	(12)	(11)
White perch												
1990	<1	0	0	0	0	<1	0	0	<1	0	0	0
	(10)	(10)	(10)	(9)	(13)	(16)	(14)	(13)	(15)	(10)	(15)	(14)
1991	<1	1	<1	0	<1	0	0	<1	0	0	0	0
	(9)	(9)	(9)	(9)	(11)	(12)	(11)	(11)	(12)	(9)	(12)	(11)

Few white perch eggs were collected in either year. In 1990, white perch eggs were collected at Stations 1 (RM 57) and 10 (RM 3) in the Roanoke, and in the lower Middle River (Station 9). In 1991, white perch eggs were distributed in the Roanoke River from RM 57 to RM 7.5 (Station 7), and in the upper portion of the Middle River (Table 6). No white perch eggs were collected in Batchelor Bay or western Albemarle Sound in either year.

Larval Striped Bass Abundance

In 1990, the overall abundance of striped bass larvae was low at all locations of the study area. Two small peaks in average River abundance of about 35 larvae/100 m^3 about two weeks apart occurred in the middle of May (Figure 12). This pattern seems inconsistent with spawning activity upstream. Two spawning peaks three days apart were recorded by Rulifson (unpublished data): 7 May, 15% of all eggs; and 10 May, 20%. The remainder of the eggs spawned for the season were distributed fairly uniformly throughout the season. Again, the length frequency distribution indicated a young cohort of larvae in the river along with a larger group of larvae similar in size to those in Batchelor Bay and western Albemarle Sound (Figure 13). In the Delta, the average larval densities were highest in the Middle River (Stations 6 and 9) and at Station 7 near Plymouth (Appendix Table A-11).

A closer examination of larval striped bass abundance indicates that River flow was a major factor affecting the their distribution in the Delta. In 1990, peak abundance of larvae at RM 57 (Hamilton) was observed on sampling trip 6 (11 May) corresponding to a spawning peak (15% of the total 1990 egg production) on 7 May. A small peak 20 miles downstream (Williamston) on the same date suggests that this larval cohort was just reaching this area (Figure 14). By sampling trip 7 (13 May) the cohort was located between RM 16 and RM 7.5 on the main river, with a portion of the cohort leaving the main river to be transported into Middle River. Note that under the 1990 flow conditions few striped bass larvae entered the Thoroughfare to connect with the Cashie River (Figure 14). A second cohort, not observed in samples upstream, appeared in the lower River and Middle River on sampling trip 11 (24 May) after a rise and fall of instream flow (Figure 2). The appearance of the second cohort is unexplained; it does not correspond with spawning activity upstream. Also of interest is the concentration of striped bass larvae in the Cashie River mouth (Station 11) on sampling trip 6 (11 May), which is earlier than would be predicted based on the larval densities at other stations. These results suggest another spawning location other than the Roanoke River (e.g. Cashie River), since no major spawning event in the Roanoke was recorded prior to 7 May.

The pattern of larval striped bass abundance in 1991 was considerably different from that observed in other years. Dates of larval presence in the River were similar, but larval presence in Batchelor Bay was of a fairly short duration with peak abundance exceeding that of the River (Figure 12). Peak spawning activity occurred on 8-9 May (20%), and 11-14 May (41%) (Rulifson 1991). Length frequency data indicated that Bay larvae were larger than those in the River (Figure 13).

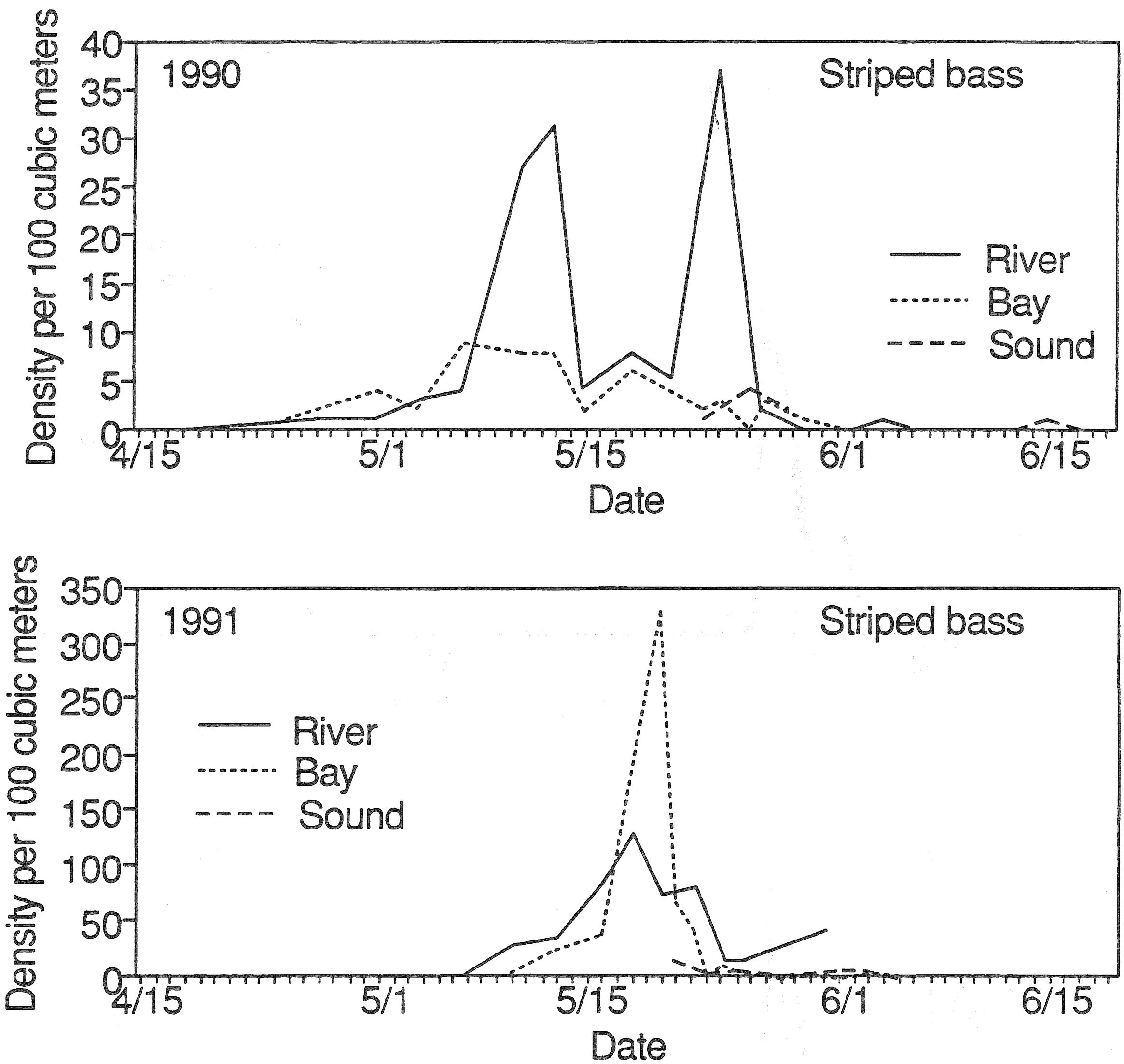
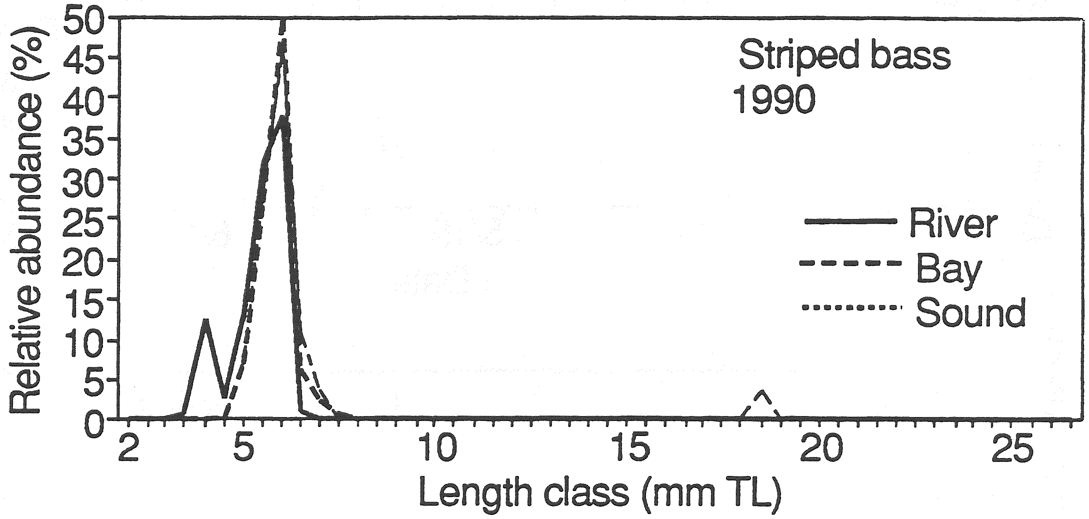


Figure 12. Average larval striped bass density (number/100 m^3), by sampling date, of the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.



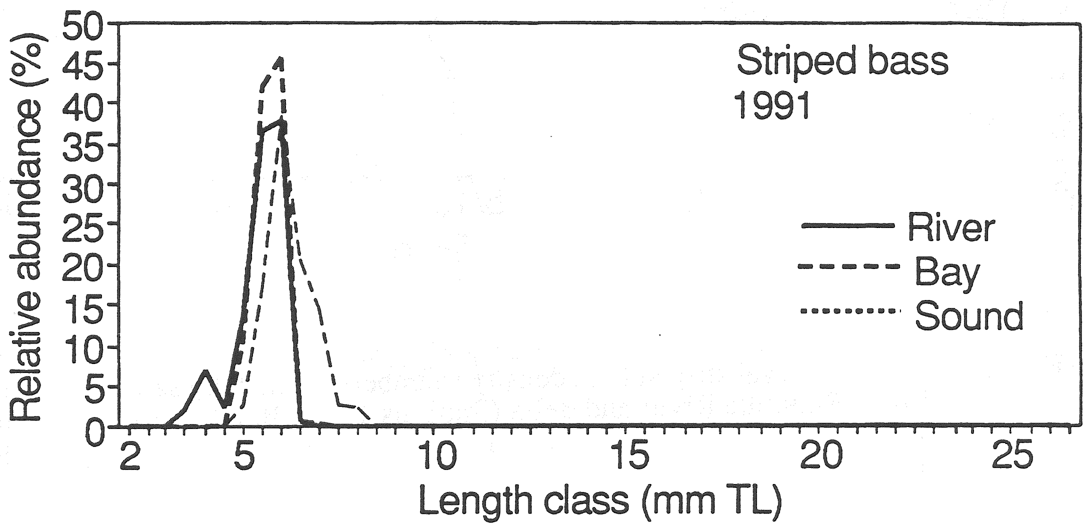


Figure 13. Relative abundance (%) of striped bass larvae, by 0.5-mm TL size class, collected from the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

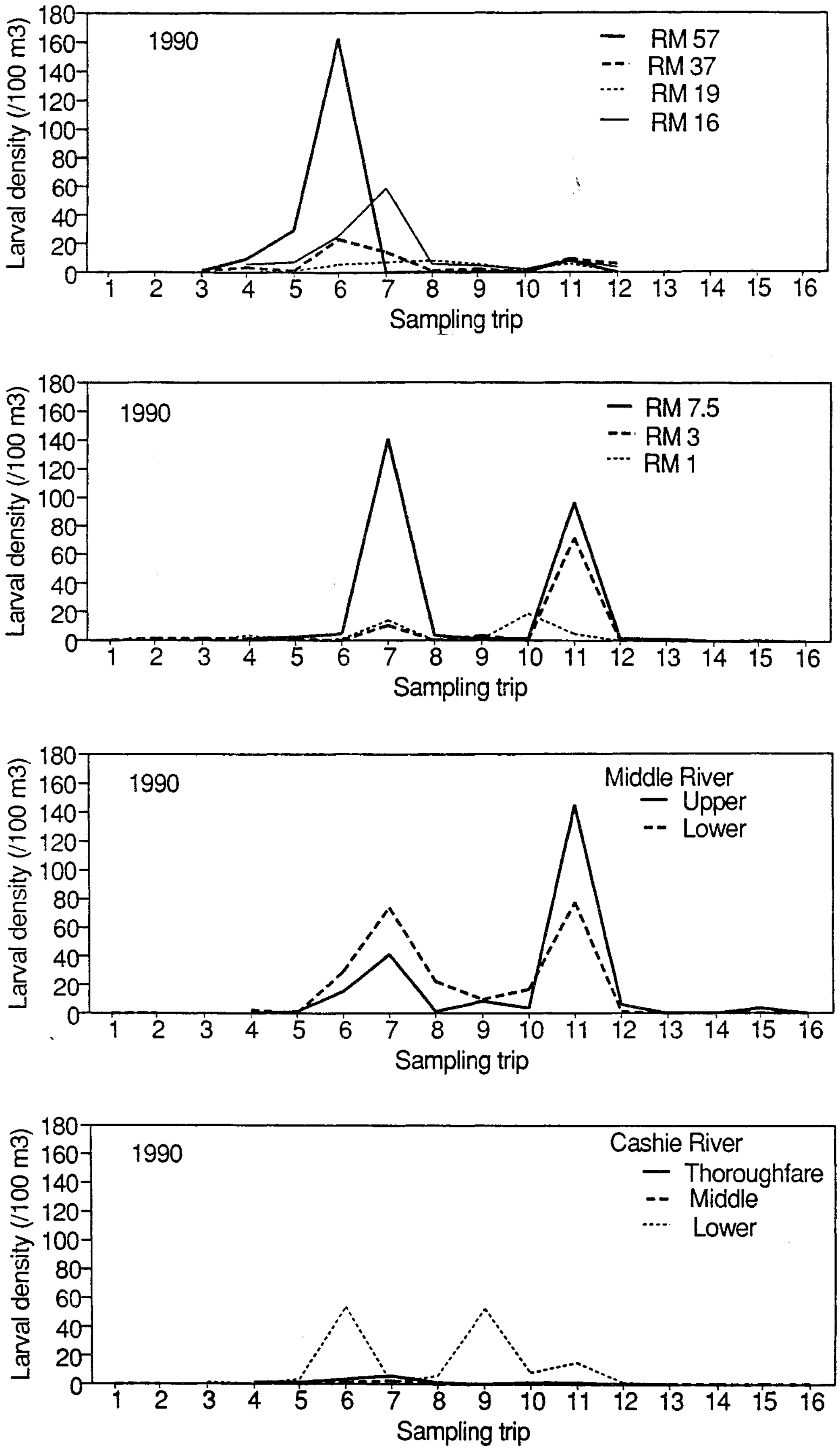


Figure 14. Temporal and spatial changes in the 1990 densities of larval striped bass (/100 m^3) in the lower Roanoke River from River Mile 16-57 (upper panel) and Delta: lower River, RM 1-7.5; Middle River; and Cashie River including the Thoroughfare. Refer to Figure 1 for station positions.

Closer inspection of the 1991 data clearly show downstream transport of striped bass larvae under moderate and stable instream flows (Figure 15). Peak larval abundance upstream was observed during sampling trips 4-6 (10-16 May) corresponding with three spawning events upstream several days earlier (8-14 May; 62.2% of the total egg production). This larval cohort had moved downstream as far as RM 16 by sampling trip 6 (16 May) and appearing in the Delta by sampling trip 7 (18 May). At this time, greatest densities were in the upper Middle River (630/100 m^3) and Thoroughfare (201/100 m^3). In the Roanoke mainstem, the larval cohort was near the mouth (Figure 15). This larval transport pattern resulted in peak larval abundance in Batchelor Bay on 20 May at Station 13 (675/100 m^3) and Station 16 (306/100 m^3) (Appendix Table A-12).

The relative abundance and distribution of white perch larvae was not examined in detail. However, it should be noted that the length frequency distributions in both years indicated that white perch larvae were smaller than striped bass larvae, and that Bay and Sound white perch larvae were larger than those in the River (Figure 16).

Larval Feeding

Feeding by larval striped bass in 1990 was not successful based on examination of gut contents. Only one larva collected in the River was developed to the point at which feeding was possible; no food was present in the gut. Larval feeding in the Bay was first observed at Station 16 on 13 May, by 23 May at Black Walnut Point, and at other locations of western Ablemarle Sound by 26 May (Table 7). Only seven Bay larvae were in feeding condition, and 29% of those contained food (*Bosmina* and copepodids). In the Sound, 15 larvae were in feeding condition and 73% contained food. Copepodid copepods were the prey consumed most often (85% of all food) followed by *Bosmina* (10%) and other cladocerans including *Daphnia* (3.5%) (Table 8). It must be remembered that we collected and examined those larvae that were survivors (e.g., successful at predator avoidance, etc.) and so it is reasonable to expect that a higher proportion of Bay and Sound larvae are feeding successfully. The length frequency distributions indicated that larvae in feeding condition were slightly larger than the general population (Figure 17).

Larval feeding was only slightly better in 1991 (Table 8). Larval feeding in the River was first observed on 18 May and in the Bay and Sound by 21 May (Table 7). Only 3% of the 921 River larvae capable of feeding contained food in guts but the diet was quite varied; prey were *Bosmina* (36%), small bivalves (25%), other cladocerans (11%), copepodid copepods (8%), detritus (6%), copepod nauplii (4%), biting midge and chironomid larvae and pupae (4%), and ostracods (2%). In the Bay, only 2% of 771 larvae capable of feeding had ingested prey: copepod adults (33%), *Bosmina* (19%), copepodid copepods (14%), bivalves (14%), and ostracods (5%). In the Sound, 47% of 194 larvae capable of feeding had consumed prey, primarily copepodids (58%) and copepod adults (39%) (Table 8). The length frequency distribution for 1991 shows that larvae capable of feeding were slightly larger than the general

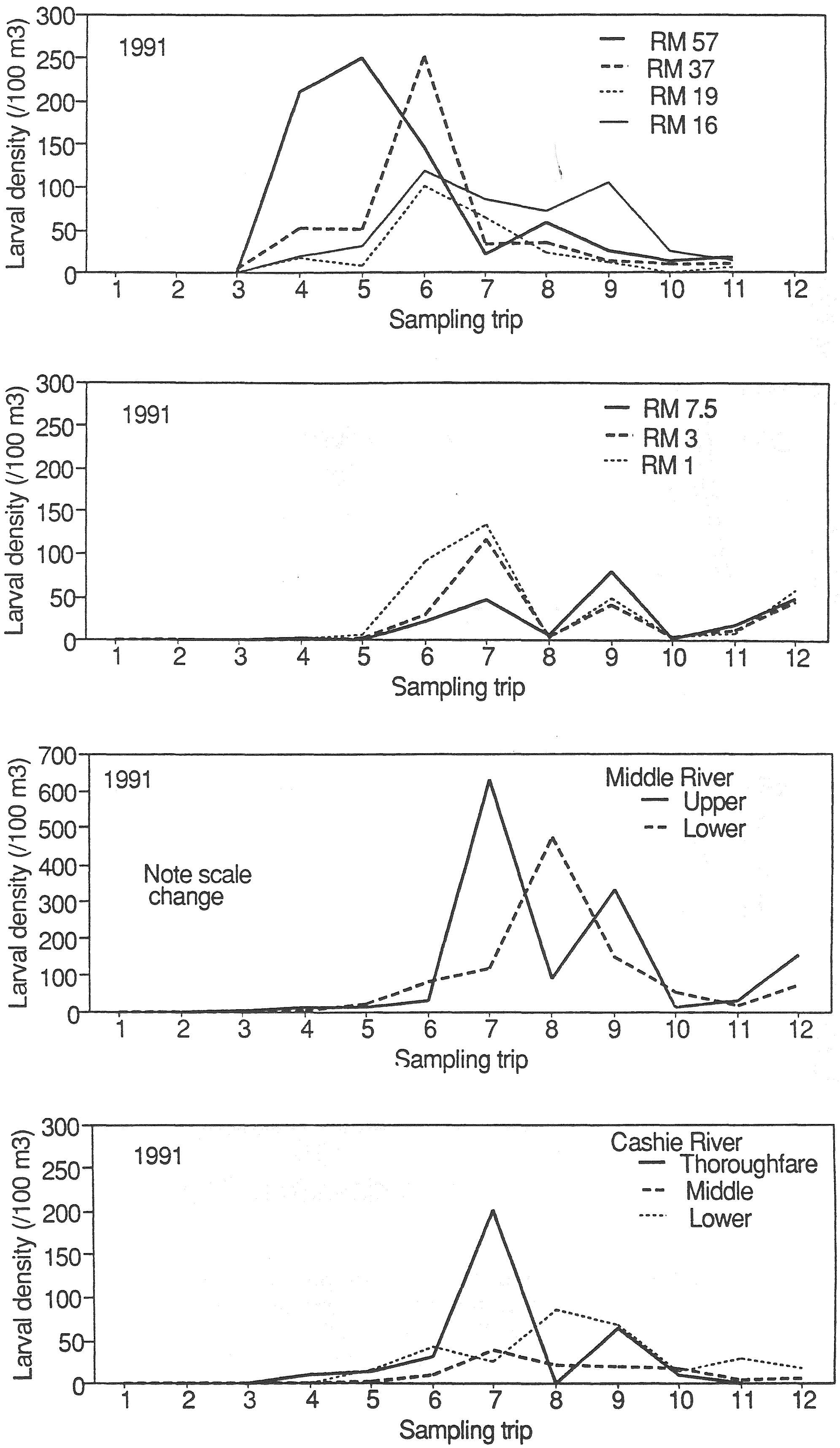


Figure 15. Temporal and spatial changes in the 1991 densities of larval striped bass (/100 m^3) in the lower Roanoke River from River Mile 16-57 (upper panel) and Delta: lower River, RM 1-7.5; Middle River; and Cashie River including the Thoroughfare. Refer to Figure 1 for station positions.

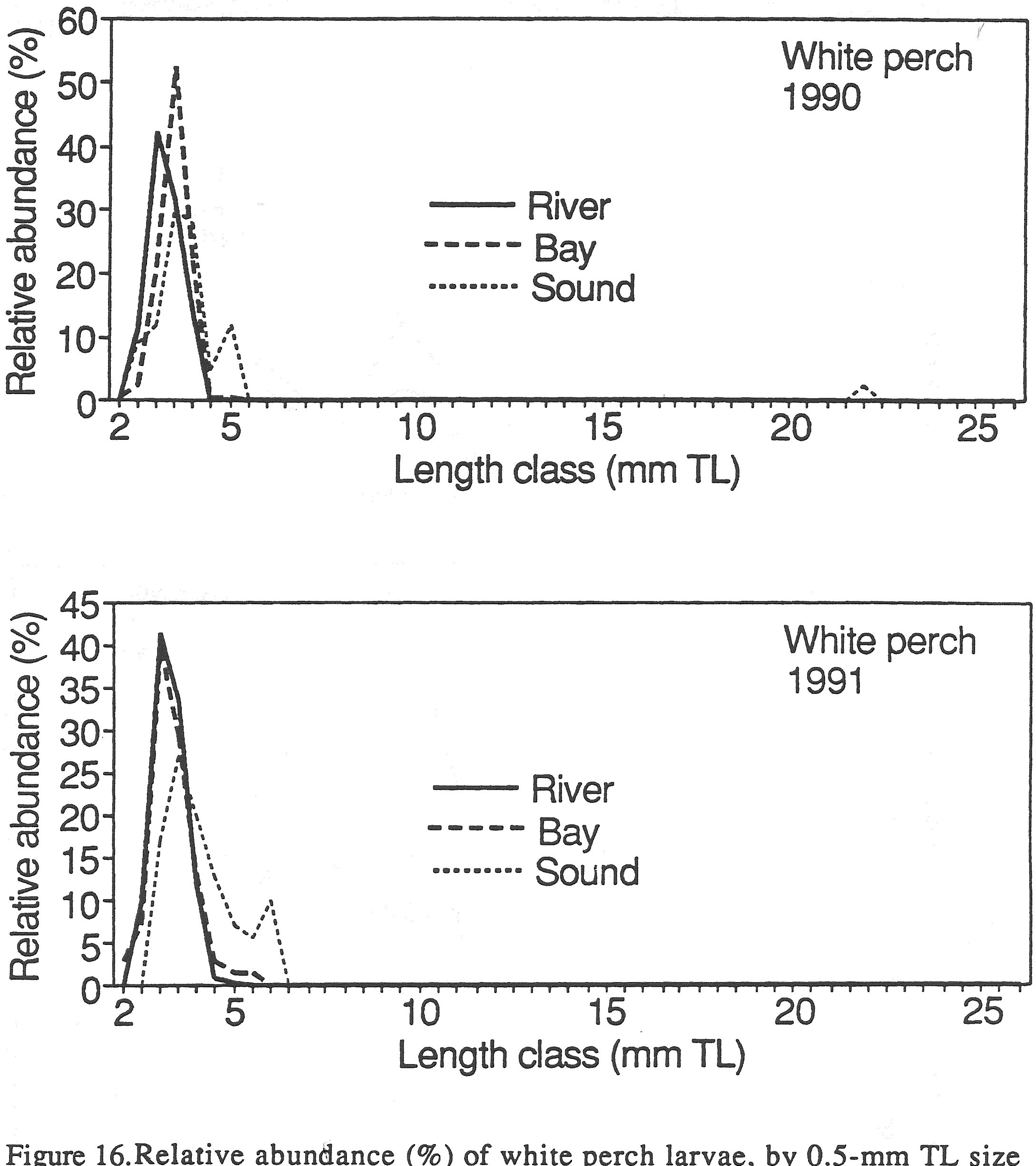


Figure 16. Relative abundance (%) of white perch larvae, by 0.5-mm TL size class, collected from the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990 and 1991.

Table 7. Date at which feeding by striped bass and undifferentiated *Morone* larvae was first observed in the lower Roanoke River (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Asterisk (*) indicates date of first sample. Stage 1 striped bass = yolk; Stage 2 = no yolk.

	Stage 1		Stage 2		*Morone*	
	1990	1991	1990	1991	1990	1991
Sta. 1						
Sta. 2						
Sta. 3						
Sta. 4						
Sta. 5						
Sta. 6				May 18		
Sta. 7						
Sta. 8				May 18		
Sta. 9				May 18		
Sta. 10						
Sta. 11				May 18		
Sta. 12				May 18		
Sta. 13				May 20		
Sta. 14						
Sta. 15				May 25		
Sta. 16			May 13			
Sta. 17						
Sta. 18			May 26	May 28		
Sta. 20				May 25		May 25
Sta. 21			May 26	May 21		May 25
Sta. 22			May 29	May 21	May 23	May 21*
Sta. 23				May 21		May 23
Sta. 24			Jun 15	May 21		May 23
Sta. 26				May 23	Jun 13	May 25
Sta. 28			May 26			May 28
Sta. 31			May 23*	May 21	Jun 13	May 23
Sta. 32				May 23		May 23

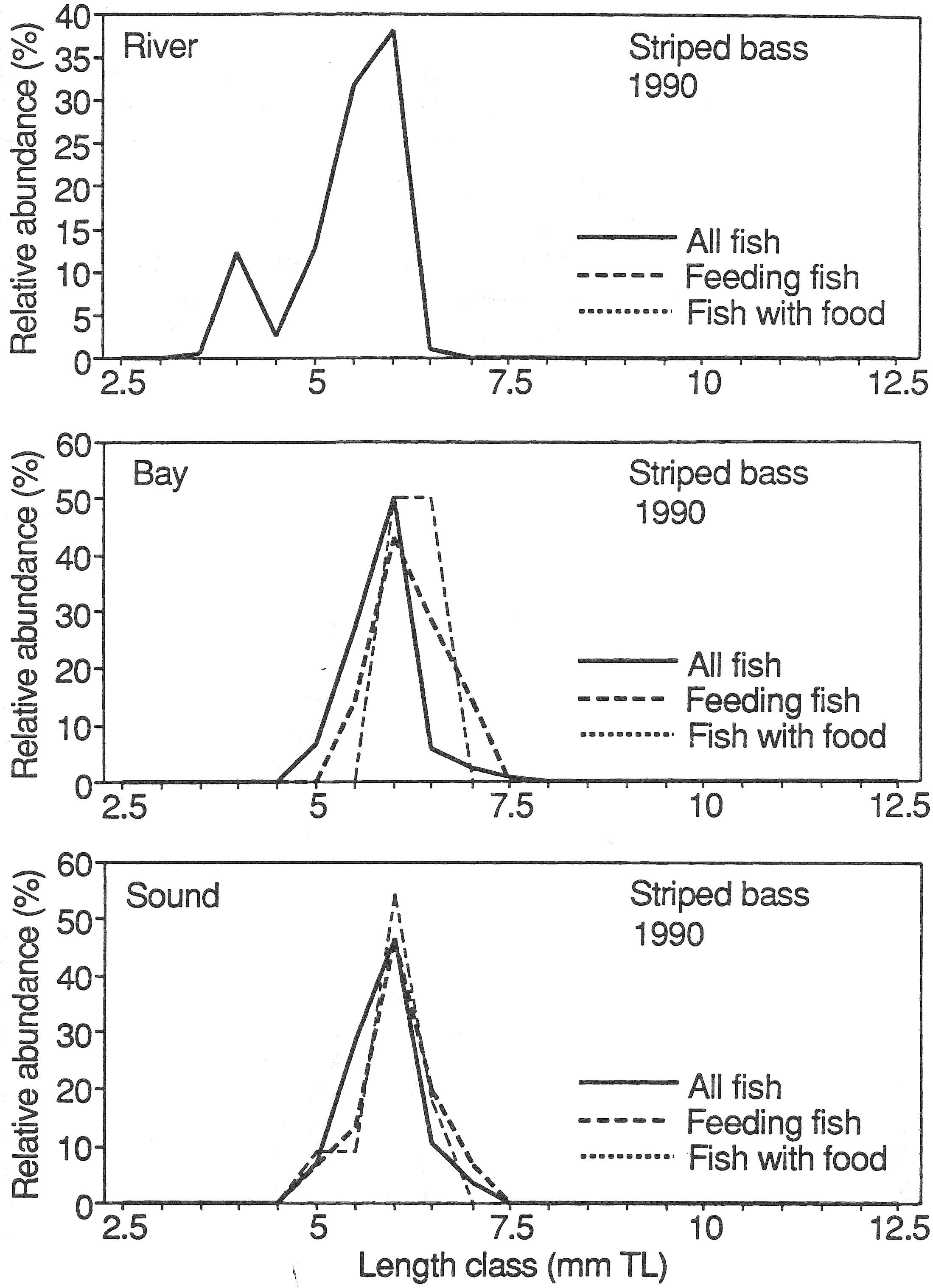


Figure 17. Relative abundance (%) of all striped bass larvae, those capable of feeding, and those with prey in stomachs, collected from the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1990.

Table 8. Relative contribution (% by enumeration) of prey consumed by larval striped bass in the lower Roanoke River (Stations 1-12), Batchelor Bay (Stations 13-16) and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (.) = not observed in striped bass stomachs.

	River		Bay		Sound	
Taxonomic group	1990	1991	1990	1991	1990	1991
Cladocera - *Bosmina*	.	36.17	50	19.05	10.12	0.85
Clad.-other (*Daphnia*)	.	10.64	.	.	3.57	0.28
Copepoda-nauplius	.	4.26	.	.	.	.
Copepodids	.	8.51	50	14.29	85.71	58.36
Copepod adults	.	.	.	33.33	.	39.38
Ostracoda	.	2.13	.	4.76	.	.
Biting midge & chironomid larvae/pupae	.	4.26	.	.	.	.
Rotifer-single & colonial	.	.	.	.	0.60	0.85
Bivalvia	.	25.53	.	14.29	.	.
Detritus	.	6.38	.	.	.	.
Unidentified	.	2.13	.	14.29	.	0.28
Total prey items	0	47	2	21	168	353
Total fish examined	1	921	7	771	15	194
Total fish with food (%)	0	3	29	2	73	47

population for the River, Bay, and Sound (Figure 18), but the rate of feeding success was not a function of fish length.

DISCUSSION

In 1990 and 1991, phytoplankton biomass in the Roanoke was noticeably lower than it had been during the 1985 and 1986 sampling periods (Rulifson et al. 1992). There is good evidence that this difference was caused by differences in river flow rates. This inverse relationship between instream flow and phytoplankton biomass appears to be common in riverine ecosystems. For example, Christian et al. (1986) showed that in the lower Neuse River, phytoplankton biomass depends on the river flow. Using a combination of laboratory growth studies and mathematical modeling, they were able to demonstrate that when river flows are high, the growth of the algae is retarded by a combination of light limitation (i.e., high turbidity) and short residence time in the river (i.e., rapid water velocity). Consequently, algae-poor runoff water from upriver is swept through the lower river and into the estuary so quickly that the algal populations do not have time to build up. Conversely, lower flows result in less turbidity and less light limitation on growth, along which longer residence times within the river. The result is higher algal densities near the mouth of the river. This inverse relationship between river flow and algal biomass has also been demonstrated for a number of other systems, including the Potomac River estuary (Christian et al. 1986). In summary, the phytoplankton biomass in the Roanoke River and western Albemarle Sound is strongly regulated by the instream flow regime.

For zooplankton, the abundance of the community as a whole did not appear to be correlated with river flow, but the individual taxonomic groups within the community were more abundant at some locations compared to others and so river flow is thought to be a major influence on the zooplankton community structure. Rulifson et al. (1992) concluded that unique zooplankton communities are present within the study area. Each community is defined by the way in which the presence and abundance of each taxonomic group changes in relation to other members of the community. The River community is from Hamilton throughout the lower Roanoke River to its mouth, Middle River, and the Thoroughfare (Figure 1). The Cashie River community is represented by Stations 8 and 11. Batchelor Bay is a zooplankton community transition zone. Three communities are present: Stations 13 and 14, Stations 15 and 16, and Station 17 along the south shore. The transition area extends out from the Bay into the western Sound with a community representing Stations 20, 21, and 31. Along the north shore near Edenton Bay, Stations 22-24 represent a unique community, and a western Sound group includes Stations 18, 26, 28, and 32. These communities represent the general pattern for eight years of data (1984-1991). Understanding how these zooplankton communities change as a function of river flow is critical to determining how important river flow regulation may be in ultimate success or failure of the recruiting striped bass year class. Completion of the USGS flow model will provide the information necessary to determine the importance of instream flow.

River flow is important in egg and larval transport downstream, including which route

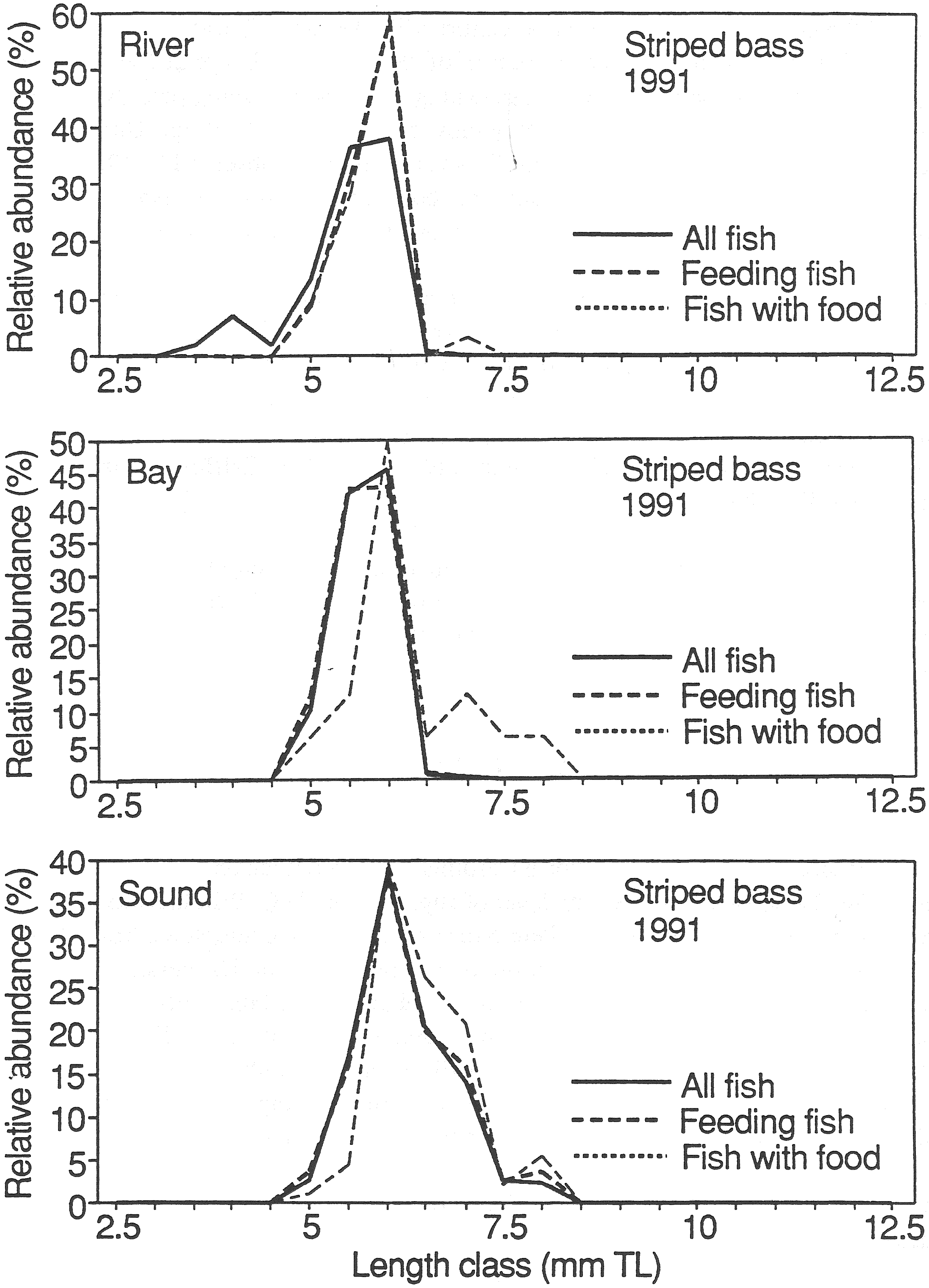


Figure 18. Relative abundance (%) of all striped bass larvae, those capable of feeding, and those with prey in stomachs, collected from the lower Roanoke River and delta (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32) in the spring of 1991.

through the Delta portions of the larval cohort will take to reach Batchelor Bay and the western Sound. This means that proper regulation of reservoir discharge at RM 137 (i.e., Roanoke Rapids Dam) during the pre-spawning, spawning, and post-spawning periods can direct larvae to the areas of the Delta and Batchelor Bay most conducive for feeding. Unnaturally prolonged high flows or conversely, low instream flows such as those observed in 1985 and 1986, break down the timing schedule of phytoplankton, zooplankton, and larval fish abundances causing a mismatch in time and space of the newly feeding larvae and the food resource.

This river flow/recruitment relationship is not unique to the Roanoke River system but has been documented for other regulated rivers with striped bass populations: the Ogeechee (Bettross 1991) and Savannah (Van Den Avyle et al. 1990) rivers in Georgia; and the San Francisco/Delta ecosystem and Sacramento-San Joaquin system in California (Chadwick 1964; Turner and Chadwick 1972; Stevens 1977; Chadwick et al. 1977; Stevens 1980; Herrgesell et al. 1983; Rozengurt and Herz 1985; Stevens et al. 1985, 1987; California Fish and Game 1987; Kjelson and Brandes 1987).

There is a clear need for a better downstream watershed management strategy than the one currently used by the power company and U.S. Army Corps of Engineers. However, development of a more environmentally beneficial water release strategy will not be possible until the UGSG completes the water transport modeling of the lower River, Delta, and western Sound.

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APPENDIX

Table A-1. Phytoplankton density (cells/L) in the lower Roanoke River (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (P) N= night samples.

		STATION																	
DATE	P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	26	31	AVE.
04/18/90	N	.	.	.	.	.	.	.	2301	2613	988	.	.	.	.	.	.	.	1967
04/27/90	N	.	.	.	.	.	.	.	501	540	457	.	.	.	.	.	.	.	499
05/01/90	N	370	.	.	.	.	.	.	394	.	.	.	.	.	.	88	.	.	284
05/04/90	N	890	.	.	594	.	.	.	365	.	.	.	.	.	.	39	.	.	472
05/07/90	N	1075	.	.	418	.	.	.	409	.	.	.	.	.	.	102	.	.	501
05/11/90	N	1748	.	.	1407	.	.	.	326	.	.	.	.	.	.	107	.	.	897
05/13/90	N	1898	.	.	1650	.	.	.	832	.	.	.	.	.	.	175	.	.	1139
05/15/90	N	1501	.	.	2657	.	.	.	462	.	.	.	.	.	.	5	.	.	1156
05/18/90	N	1432	.	.	1304	.	.	.	1281	.	.	.	.	.	.	190	.	.	1052
05/21/90	N	1938	.	.	516	.	.	.	861	.	.	.	.	.	.	467	.	.	946
05/23/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	219	24	19	87
05/24/90	N	1442	.	.	783	.	.	.	856	.	.	.	.	.	.	15	.	.	774
05/26/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	122	.	.	122
05/27/90	N	861	.	.	876	.	.	.	623	.	.	.	.	.	.	195	.	.	639
05/29/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	83	.	68	76
05/30/90	N	.	.	.	.	.	.	.	550	.	.	.	.	.	.	78	.	.	314
06/02/90	N	.	.	.	.	.	.	.	555	.	.	.	.	.	.	238	.	.	397
06/04/90	N	.	.	.	.	.	.	.	637	.	.	.	.	.	.	.	.	.	637
06/06/90	N	.	.	.	.	.	.	.	735	.	.	.	.	.	.	10	.	.	373
06/08/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	608	.	399	504
06/10/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	161	443	156	253
06/13/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	83	190	1577	617
06/15/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	253	29	253	178
06/17/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	156	433	83	224
AVE.	N	1316	.	.	1134	.	.	.	731	1577	723	.	.	.	.	162	224	365	779
03/01/91	N	.	.	.	.	.	.	.	868	1066	1415	.	.	.	.	.	.	.	1116
03/12/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2445	.	.	2445
03/20/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	422	.	.	422
03/26/91	N	.	.	.	.	.	.	.	2539	2838	2544	.	.	.	.	.	.	.	2640
04/02/91	N	.	.	.	.	.	.	.	1406	.	.	.	.	.	.	.	.	.	1406
04/04/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	341	.	.	341
04/10/91	N	.	.	.	.	.	.	.	1938	.	.	.	.	.	.	.	.	.	1938
04/17/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	260	.	.	260
04/24/91	N	.	.	.	.	.	.	.	714	.	.	.	.	.	.	.	.	.	714
04/30/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	61	.	.	61
05/02/91	N	.	.	.	.	.	.	.	689	458	243	.	.	.	.	36	.	.	357
05/07/91	N	720	.	.	808	.	.	.	311	603	204	.	.	.	.	.	.	.	529
05/10/91	N	.	.	.	1253	.	.	.	453	117	97	.	.	.	.	122	.	.	408
05/13/91	N	817	.	.	706	.	.	.	404	.	.	.	.	.	.	248	.	.	544
05/16/91	N	735	.	.	769	.	.	.	842	.	.	.	.	.	.	63	.	.	602
05/18/91	N	715	.	.	399	.	.	.	58	.	.	.	.	.	.	.	.	.	391
05/20/91	N	263	.	.	355	.	.	.	540	.	.	.	.	.	.	307	.	.	366
05/21/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	523	466	961	650
05/22/91	N	769	.	.	584	.	.	.	530	.	.	.	.	.	.	248	.	.	533
05/23/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	345	1387	811	848
05/24/91	N	399	.	.	491	.	.	.	657	.	.	.	.	.	.	170	.	.	429
05/25/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	1034	1354	800
05/26/91	N	394	.	.	311	.	.	.	487	.	.	.	.	.	.	204	.	.	349
05/28/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	219	5	78
05/30/91	N	.	.	.	.	.	.	.	355	.	.	.	.	.	.	272	.	.	314
06/01/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	122	.	438	280
06/03/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	263	.	.	263
06/05/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	180	292	107	193
AVE.	N	602	.	.	631	.	.	.	799	1016	901	.	.	.	.	317	680	613	695

Table A-2. Phytoplankton biomass (mg/L) in the lower Roanoke River (Stations 1-12), Batchelor Bay (Stations 13-16), and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (P) N= night samples.

DATE	P	STATION 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	26	31	AVE.
04/18/90	N	.	.	.	.	.	.	.	865	1014	492	.	.	.	.	.	.	.	790
04/27/90	N	.	.	.	.	.	.	.	109	471	114	.	.	.	.	.	.	.	231
05/01/90	N	306	.	.	.	.	.	.	83	.	.	.	.	.	.	61	.	.	150
05/04/90	N	967	.	.	553	.	.	.	179	.	.	.	.	.	.	17	.	.	429
05/07/90	N	900	.	.	479	.	.	.	195	.	.	.	.	.	.	5	.	.	395
05/11/90	N	656	.	.	649	.	.	.	300	.	.	.	.	.	.	9	.	.	404
05/13/90	N	1303	.	.	1637	.	.	.	213	.	.	.	.	.	.	72	.	.	806
05/15/90	N	1130	.	.	1916	.	.	.	227	.	.	.	.	.	.	5	.	.	820
05/18/90	N	881	.	.	793	.	.	.	885	.	.	.	.	.	.	19	.	.	645
05/21/90	N	1547	.	.	237	.	.	.	400	.	.	.	.	.	.	202	.	.	597
05/23/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	5	16	18
05/24/90	N	1096	.	.	287	.	.	.	622	.	.	.	.	.	.	53	.	.	515
05/26/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	6
05/27/90	N	810	.	.	752	.	.	.	143	.	.	.	.	.	.	361	.	.	517
05/29/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	80	45
05/30/90	N	.	.	.	.	.	.	.	217	.	.	.	.	.	.	16	.	.	117
06/02/90	N	.	.	.	.	.	.	.	45	.	.	.	.	.	.	180	.	.	113
06/04/90	N	.	.	.	.	.	.	.	541	.	.	.	.	.	.	.	.	.	541
06/06/90	N	.	.	.	.	.	.	.	385	.	.	.	.	.	.	155	.	.	270
06/08/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	306	.	268	287
06/10/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	177	145	83	135
06/13/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13	220	857	363
06/15/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	375	3	333	237
06/17/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	67	209	98	125
AVE.	N	960	.	.	811	.	.	.	338	743	303	.	.	.	.	102	116	248	453
03/01/91	N	.	.	.	.	.	.	.	309	1015	1183	.	.	.	.	.	.	.	836
03/12/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1139	.	.	1139
03/20/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	151	.	.	151
03/26/91	N	.	.	.	.	.	.	.	1145	2164	1178	.	.	.	.	.	.	.	1496
04/02/91	N	.	.	.	.	.	.	.	859	.	.	.	.	.	.	.	.	.	859
04/04/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	210	.	.	210
04/10/91	N	.	.	.	.	.	.	.	958	.	.	.	.	.	.	.	.	.	958
04/17/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	.	.	7
04/24/91	N	.	.	.	.	.	.	.	215	.	.	.	.	.	.	.	.	.	215
04/30/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	5
05/02/91	N	.	.	.	.	.	.	.	307	30	145	.	.	.	.	118	.	.	150
05/07/91	N	290	.	.	386	.	.	.	89	125	74	.	.	.	.	.	.	.	193
05/10/91	N	.	.	.	1368	.	.	.	77	21	11	.	.	.	.	17	.	.	299
05/13/91	N	112	.	.	781	.	.	.	81	.	.	.	.	.	.	8	.	.	246
05/16/91	N	36	.	.	125	.	.	.	52	.	.	.	.	.	.	33	.	.	62
05/18/91	N	950	.	.	65	.	.	.	59	.	.	.	.	.	.	.	.	.	358
05/20/91	N	124	.	.	249	.	.	.	33	.	.	.	.	.	.	209	.	.	154
05/21/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	115	69	200	128
05/22/91	N	59	.	.	154	.	.	.	81	.	.	.	.	.	.	58	.	.	88
05/23/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62	188	27	92
05/24/91	N	48	.	.	104	.	.	.	169	.	.	.	.	.	.	30	.	.	88
05/25/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	307	369	227
05/26/91	N	439	.	.	53	.	.	.	201	.	.	.	.	.	.	41	.	.	184
05/28/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	21	33	21
05/30/91	N	.	.	.	.	.	.	.	69	.	.	.	.	.	.	26	.	.	48
06/01/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14	.	32	23
06/03/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	36	.	.	36
06/05/91	N	.	.	.	.	.	.	.	.	.	.	.	.	.	.	202	139	22	121
AVE.	N	257	.	.	365	.	.	.	294	671	518	.	.	.	.	119	145	114	310

Table A-3. Zooplankton density (number/m^3) in the lower Roanoke River (Stations 1-12), North Carolina, 1990-1991. Period (P) N= night samples.

		STATION												
DATE	P	1	2	3	4	5	6	7	8	9	10	11	12	AVE.
04/18/90	N	.	.	.	.	.	.	.	.	260	227	.	.	243
04/25/90	N	.	.	.	.	.	.	.	379	.	.	.	.	379
04/27/90	N	.	.	.	.	.	.	.	1598	469	664	.	.	911
05/01/90	N	39	180	136	.	.	.	.	.	.	211	701	196	244
05/04/90	N	54	136	177	310	171	336	562	420	173	229	461	2111	428
05/07/90	N	71	182	102	190	277	380	311	3824	265	53	1243	411	609
05/11/90	N	46	62	58	134	196	154	133	574	101	82	647	111	191
05/13/90	N	56	46	46	90	86	160	87	1205	61	41	802	83	230
05/15/90	N	54	39	118	56	168	378	187	846	101	26	351	55	198
05/18/90	N	54	38	479	383	347	221	74	431	78	73	359	47	215
05/21/90	N	212	341	251	535	382	290	377	258	85	70	410	178	282
05/24/90	N	122	400	575	416	857	796	461	697	498	553	432	342	512
05/27/90	N	43	180	259	243	170	242	168	1211	130	84	835	161	310
05/30/90	N	.	.	.	.	234	333	240	1278	152	166	774	680	482
06/02/90	N	.	.	.	.	.	304	229	825	232	227	382	265	352
06/04/90	N	.	.	.	.	.	640	318	291	732	457	485	354	468
06/06/90	N	.	.	.	.	.	666	642	548	628	517	385	475	552
AVE.	N	75	160	220	262	289	377	291	959	264	230	591	391	342
03/01/91	N	.	.	.	.	.	.	.	332	107	132	.	.	190
03/07/91	N	.	.	.	.	.	.	.	210	125	130	.	.	155
03/26/91	N	.	.	.	.	.	.	.	50	186	283	.	.	173
04/02/91	N	.	.	.	.	.	.	.	565	675	717	.	.	652
04/10/91	N	.	.	.	.	.	.	.	643	2181	1547	.	.	1457
04/24/91	N	.	.	.	.	.	.	.	775	1000	838	.	.	871
05/02/91	N	.	.	.	.	.	302	325	706	439	442	498	298	430
05/07/91	N	51	179	270	296	240	161	236	159	109	19	119	35	156
05/10/91	N	56	113	164	152	281	93	57	204	90	66	213	62	129
05/13/91	N	50	76	86	93	119	142	43	132	91	21	241	16	93
05/16/91	N	35	59	37	53	87	18	17	196	25	41	184	95	70
05/18/91	N	57	31	23	13	17	45	55	404	120	16	340	24	95
05/20/91	N	71	36	45	55	72	66	20	1014	68	39	637	59	182
05/22/91	N	38	32	49	57	96	153	25	432	58	14	478	12	120
05/24/91	N	55	34	24	35	34	34	9	288	35	22	169	51	66
05/26/91	N	27	22	16	35	39	39	19	363	41	6	289	15	76
05/30/91	N	.	.	.	.	.	26	1232	1381	26	42	3164	72	849
AVE.	N	49	65	79	88	109	98	185	462	316	257	576	67	196

Table A-4. Zooplankton density (number/m^3) in Batchelor Bay (Stations 13-16) and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (P) N= night samples.

		STATION																
DATE	P	13	14	15	16	17	18	20	21	22	23	24	26	28	31	32	AVE1	AVE2
04/25/90	N	560	.	220	387	.	151	.	.	.	.	.	.	.	.	.	389	151
05/01/90	N	659	.	270	260	.	.	.	.	.	.	.	.	.	.	.	396	.
05/04/90	N	447	.	217	522	.	.	.	.	.	.	.	.	.	.	.	396	.
05/07/90	N	1089	.	140	447	.	.	.	.	.	.	.	.	.	.	.	559	.
05/11/90	N	572	.	617	1017	.	.	.	.	.	.	.	.	.	.	.	735	.
05/13/90	N	184	.	151	127	.	.	.	.	.	.	.	.	.	.	.	154	.
05/15/90	N	278	.	86	192	.	.	.	.	.	.	.	.	.	.	.	185	.
05/18/90	N	81	.	225	85	.	.	.	.	.	.	.	.	.	.	.	130	.
05/21/90	N	186	.	259	.	.	.	.	.	.	.	.	.	.	.	.	223	.
05/23/90	N	.	.	130	.	.	170	334	142	716	786	697	214	387	202	436	130	408
05/24/90	N	609	.	391	57	.	.	.	.	.	.	.	.	.	.	.	352	.
05/26/90	N	.	.	.	.	.	72	48	273	.	.	.	.	236	.	.	.	157
05/27/90	N	787	.	130	951	.	.	.	.	.	.	.	.	.	.	.	623	.
05/29/90	N	.	.	.	.	.	258	74	128	113	533	545	97	242	416	211	.	262
05/30/90	N	355	.	68	113	.	.	.	.	.	.	.	.	.	.	.	179	.
06/02/90	N	515	.	218	431	.	.	.	.	.	.	.	.	.	.	.	388	.
06/06/90	N	526	.	247	1157	.	.	.	.	.	.	.	.	.	.	.	643	.
06/08/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	436	1152	.	794
06/10/90	N	.	.	99	.	.	1179	375	346	1169	384	2351	294	271	250	1060	99	768
06/13/90	N	.	.	70	.	.	77	165	92	1221	1069	1302	600	169	1048	1392	70	713
06/15/90	N	.	.	.	.	.	.	.	.	1441	1449	598	.	.	69	724	.	856
06/17/90	N	.	.	45	.	.	29	69	96	1168	1385	1274	1093	724	30	182	45	605
AVE.	N	489	.	199	442	.	277	178	180	971	934	1128	460	338	350	737	377	555
03/12/91	N	226	.	134	139	.	105	.	.	.	.	.	.	.	.	.	166	105
03/20/91	N	161	.	201	166	.	110	.	.	.	.	.	.	.	.	.	176	110
04/04/91	N	570	.	257	518	.	260	.	.	.	.	.	.	.	.	.	448	260
04/17/91	N	386	.	601	392	.	152	.	.	.	.	.	.	.	.	.	460	152
04/30/91	N	272	.	128	529	.	44	.	.	.	.	.	.	.	.	.	310	44
05/02/91	N	257	.	176	150	.	.	.	.	.	.	.	.	.	.	.	194	.
05/07/91	N	76	.	101	78	.	.	.	.	.	.	.	.	.	.	.	85	.
05/10/91	N	273	.	167	126	.	.	.	.	.	.	.	.	.	.	.	189	.
05/13/91	N	134	.	39	63	.	.	.	.	.	.	.	.	.	.	.	79	.
05/16/91	N	76	.	140	82	.	.	.	.	.	.	.	.	.	.	.	99	.
05/20/91	N	200	.	82	68	.	.	.	.	.	.	.	.	.	.	.	117	.
05/21/91	N	.	.	53	.	.	112	95	215	1326	787	1339	688	887	67	252	53	577
05/22/91	N	794	.	164	286	.	.	.	.	.	.	.	.	.	.	.	415	.
05/23/91	N	.	.	15	.	.	68	28	84	583	616	347	340	203	135	110	15	251
05/24/91	N	116	.	40	50	.	.	.	.	.	.	.	.	.	.	.	69	.
05/25/91	N	.	.	31	.	.	771	39	106	353	616	231	253	351	32	195	31	295
05/26/91	N	79	.	53	159	.	.	.	.	.	.	.	.	.	.	.	97	.
05/28/91	N	.	.	31	.	.	1593	1033	496	362	1155	1353	416	718	43	490	31	766
05/30/91	N	251	.	91	468	.	.	.	.	.	.	.	.	.	.	.	270	.
06/01/91	N	.	.	252	.	.	1337	581	405	.	.	.	.	.	404	330	252	611
06/03/91	N	.	.	156	.	.	548	68	351	.	.	.	.	.	.	.	156	322
06/05/91	N	.	.	319	.	.	653	296	645	394	437	441	620	625	1348	295	319	575
AVE.	N	258	.	147	218	.	479	306	329	604	722	742	463	557	338	279	208	482

Table A-5. Zooplankton biomass (g/m^3) in the lower Roanoke River (Stations 1-12), North Carolina, 1990-1991. Period (P) N= night samples.

		STATION												
DATE	P	1	2	3	4	5	6	7	8	9	10	11	12	AVE.
04/18/90	N	.	.	.	.	.	.	.	.	51	34	.	.	43
04/25/90	N	.	.	.	.	.	.	.	81	.	.	.	.	81
04/27/90	N	.	.	.	.	.	.	.	197	74	108	.	.	126
05/01/90	N	7	27	25	.	.	.	.	.	.	44	166	30	50
05/04/90	N	6	22	42	67	32	48	111	82	49	43	95	472	89
05/07/90	N	11	22	14	29	50	58	70	752	67	17	265	61	118
05/11/90	N	7	9	8	27	50	30	24	110	37	19	155	39	43
05/13/90	N	7	9	14	17	13	70	23	234	49	12	142	19	51
05/15/90	N	6	5	23	11	32	73	34	168	27	3	89	11	40
05/18/90	N	6	6	98	82	58	43	12	94	37	21	54	20	44
05/21/90	N	28	51	49	113	77	85	88	78	84	13	103	35	67
05/24/90	N	19	60	116	82	172	156	98	144	187	122	237	86	123
05/27/90	N	8	36	47	51	34	49	32	169	37	19	165	28	56
05/30/90	N	.	.	.	.	57	78	53	331	53	37	202	111	115
06/02/90	N	.	.	.	.	.	60	44	166	56	44	129	71	81
06/04/90	N	.	.	.	.	.	136	58	61	146	87	119	129	105
06/06/90	N	.	.	.	.	.	123	122	84	109	96	72	90	99
AVE.	N	11	25	44	53	58	77	59	183	71	45	142	86	71
03/01/91	N	.	.	.	.	.	.	.	38	16	16	.	.	23
03/07/91	N	.	.	.	.	.	.	.	19	15	15	.	.	16
03/26/91	N	.	.	.	.	.	.	.	5	20	30	.	.	18
04/02/91	N	.	.	.	.	.	.	.	67	85	87	.	.	80
04/10/91	N	.	.	.	.	.	.	.	66	221	180	.	.	156
04/24/91	N	.	.	.	.	.	.	.	119	198	165	.	.	161
05/02/91	N	.	.	.	.	.	53	53	326	65	70	83	54	100
05/07/91	N	9	26	42	59	42	26	39	39	34	2	46	5	31
05/10/91	N	9	16	28	24	49	13	11	57	44	10	43	25	27
05/13/91	N	8	10	15	12	16	28	10	14	23	4	42	2	15
05/16/91	N	5	10	8	13	17	3	3	27	5	13	28	29	13
05/18/91	N	13	7	5	4	2	9	7	71	29	5	74	4	19
05/20/91	N	15	6	8	10	11	9	3	166	10	7	116	23	32
05/22/91	N	11	13	9	11	28	33	3	68	26	2	76	1	24
05/24/91	N	12	5	10	16	7	4	2	31	28	14	29	27	15
05/26/91	N	19	7	1	3	8	4	10	52	15	1	31	4	13
05/30/91	N	.	.	.	.	.	4	5	80	20	9	84	19	32
AVE.	N	11	11	14	17	20	17	13	73	50	37	59	18	28

Table A-6. Zooplankton biomass (g/m^3) in Batchelor Bay (Stations 13-16) and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (P) N= night samples.

		STATION																
DATE	P	13	14	15	16	17	18	20	21	22	23	24	26	28	31	32	AVE1	AVE2
04/25/90	N	90	.	60	61	.	128	.	.	.	.	.	.	.	.	.	71	128
05/01/90	N	363	.	87	68	.	.	.	.	.	.	.	.	.	.	.	173	.
05/04/90	N	92	.	51	64	.	.	.	.	.	.	.	.	.	.	.	69	.
05/07/90	N	247	.	42	108	.	.	.	.	.	.	.	.	.	.	.	132	.
05/11/90	N	140	.	190	194	.	.	.	.	.	.	.	.	.	.	.	175	.
05/13/90	N	28	.	37	48	.	.	.	.	.	.	.	.	.	.	.	38	.
05/15/90	N	134	.	21	29	.	.	.	.	.	.	.	.	.	.	.	61	.
05/18/90	N	23	.	51	21	.	.	.	.	.	.	.	.	.	.	.	32	.
05/21/90	N	69	.	144	.	.	.	.	.	.	.	.	.	.	.	.	106	.
05/23/90	N	.	.	33	.	.	68	72	59	93	91	82	27	63	46	51	33	65
05/24/90	N	149	.	86	10	.	.	.	.	.	.	.	.	.	.	.	82	.
05/26/90	N	.	.	.	.	.	18	9	97	.	.	.	.	101	.	.	.	56
05/27/90	N	330	.	19	177	.	.	.	.	.	.	.	.	.	.	.	175	.
05/29/90	N	.	.	.	.	.	37	21	51	20	90	62	26	96	82	40	.	53
05/30/90	N	80	.	21	85	.	.	.	.	.	.	.	.	.	.	.	62	.
06/02/90	N	147	.	61	120	.	.	.	.	.	.	.	.	.	.	.	109	.
06/06/90	N	105	.	72	219	.	.	.	.	.	.	.	.	.	.	.	132	.
06/08/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	92	178	.	135
06/10/90	N	.	.	17	.	.	152	44	102	197	50	319	77	72	64	209	17	129
06/13/90	N	.	.	23	.	.	38	51	30	213	187	238	109	55	407	222	23	155
06/15/90	N	.	.	.	.	.	.	.	.	278	259	114	.	.	6	109	.	153
06/17/90	N	.	.	12	.	.	33	15	58	215	236	230	175	148	5	41	12	116
AVE.	N	143	.	57	93	.	68	35	66	170	152	174	83	89	100	121	97	106
03/12/91	N	22	.	7	14	.	11	.	.	.	.	.	.	.	.	.	14	11
03/20/91	N	13	.	18	15	.	13	.	.	.	.	.	.	.	.	.	16	13
04/04/91	N	52	.	24	50	.	25	.	.	.	.	.	.	.	.	.	42	25
04/17/91	N	56	.	96	45	.	18	.	.	.	.	.	.	.	.	.	66	18
04/30/91	N	53	.	35	66	.	10	.	.	.	.	.	.	.	.	.	51	10
05/02/91	N	30	.	33	22	.	.	.	.	.	.	.	.	.	.	.	28	.
05/07/91	N	18	.	28	22	.	.	.	.	.	.	.	.	.	.	.	23	.
05/10/91	N	110	.	40	23	.	.	.	.	.	.	.	.	.	.	.	58	.
05/13/91	N	49	.	4	12	.	.	.	.	.	.	.	.	.	.	.	21	.
05/16/91	N	22	.	37	29	.	.	.	.	.	.	.	.	.	.	.	29	.
05/20/91	N	37	.	52	9	.	.	.	.	.	.	.	.	.	.	.	33	.
05/21/91	N	.	.	15	.	.	18	15	26	143	91	139	74	98	8	45	15	66
05/22/91	N	109	.	19	26	.	.	.	.	.	.	.	.	.	.	.	51	.
05/23/91	N	.	.	2	.	.	9	10	16	88	93	42	49	27	68	33	2	43
05/24/91	N	59	.	18	16	.	.	.	.	.	.	.	.	.	.	.	31	.
05/25/91	N	.	.	12	.	.	88	10	23	64	77	32	30	49	4	38	12	41
05/26/91	N	43	.	19	26	.	.	.	.	.	.	.	.	.	.	.	29	.
05/28/91	N	.	.	7	.	.	166	110	83	68	149	185	77	95	12	171	7	112
05/30/91	N	20	.	36	14	.	.	.	.	.	.	.	.	.	.	.	23	.
06/01/91	N	.	.	147	.	.	147	64	62	.	.	.	.	.	53	135	147	92
06/03/91	N	.	.	21	.	.	60	15	64	.	.	.	.	.	.	.	21	46
06/05/91	N	.	.	56	.	.	108	46	101	78	89	86	118	109	154	47	56	94
AVE.	N	46	.	33	26	.	56	39	54	88	100	97	70	76	50	78	35	71

Table A-7. Average density (number/m^3) of zooplankton taxa, by station, in the lower Roanoke River (Stations 1-12), North Carolina, for 1990. Period (P) N=night samples.

YEAR=90 PERIOD=N	STATION												
TAXONOMIC GROUP	1	2	3	4	5	6	7	8	9	10	11	12	AVE.
Amphipoda - gammarid egg	.	.	.	.	.	.	.	0	0	.	0	.	0
Amphipoda - Gammaridae	.	0	0	2	3	5	2	10	13	1	21	5	6
Arachnida	0	1	1	1	0	1	0	3	0	0	0	0	1
Bivalvia	0	1	.	.	0	0	.	.	.	.	.	.	0
Bivalvia - larv.	.	.	.	.	.	.	.	0	0	1	.	.	0
Caddisfly larv.	0	1	1	0	0	0	0	0	0	0	1	0	0
Clad.- Bosmina	10	12	10	3	8	9	4	26	11	10	10	3	10
Clad.- Daphnia	20	60	94	128	126	185	161	393	126	120	213	213	153
Clad.- Leptodora	0	.	.	.	.	.	0	.	.	.	.	1	0
Cladocera - other	7	10	49	46	49	40	28	112	26	27	91	18	42
Cladocera - unid. egg	.	1	.	.	0	.	0	2	0	0	0	1	1
Cladocera - unid. juv.	0	2	1	1	1	3	2	16	1	1	5	2	3
Coleopt.-Dytiscidae larv.	.	.	.	.	.	.	0	.	.	0	.	.	0
Coleopt.-Gyrinidae larv.	.	.	.	.	.	.	.	0	0	.	.	.	0
Copepoda - egg mass	.	.	.	.	0	0	0	2	.	0	3	.	1
Copepoda - nauplius	1	.	.	.	.	.	.	.	.	0	.	.	0
Copepoda - Calanoida	6	10	9	13	15	13	11	74	14	8	46	8	19
Copepoda - Cyclopoida	20	40	42	55	67	96	68	230	59	47	140	118	82
Copepoda - Harpacticoida	.	.	.	0	.	.	.	.	.	.	.	.	0
Copepodids	1	0	.	0	.	0	0	4	1	1	2	1	1
Dipt.-biting midge larv.	.	.	.	0	1	0	.	0	0	.	1	0	0
Dipt.-chironimid pup.	.	.	.	.	0	0	0	0	.	.	1	0	0
Dipt.-chironomid adult	.	.	0	.	.	.	.	.	0	0	.	0	0
Dipt.-chironomid larv.	.	1	1	2	1	1	1	2	2	2	5	1	2
Dipt.-mayfly nymphs	.	0	.	.	0	0	0	0	0	0	.	.	0
Dipt.-mosquito larv.	.	0	.	0	0	.	.	.	0	.	.	.	0
Dipt.-phantom midge larv.	.	0	1	1	0	0	1	6	0	0	3	3	2
Dipt.-phantom midge pup.	.	.	0	.	0	0	0	1	0	.	0	0	0
Diptera	.	.	.	.	.	.	.	.	.	0	.	0	0
Hemiptera - Corixidae	.	.	.	.	0	.	.	.	.	.	.	.	0
Hydra	6	6	2	0	1	2	1	0	1	2	.	0	2
Isopoda	.	.	.	.	.	.	.	.	.	0	0	0	0
Nematoda	.	.	.	.	.	0	.	.	.	0	.	.	0
Odonata	.	.	.	.	0	0	.	.	.	0	0	0	0
Oligo.- Aeolosoma	1	0	0	0	1	1	0	0	0	1	1	0	1
Oligo.- Dero	.	.	0	1	0	0	.	.	0	0	.	.	0
Oligo.- Stylaria	.	.	0	0	0	2	1	3	1	0	4	1	1
Ostracoda	1	3	6	5	5	13	6	44	5	4	20	5	10
Rotifer - colonial	.	.	0	0	1	1	1	0	0	1	0	1	1
Rotifer - single	2	12	2	3	5	3	1	28	2	1	25	8	8
Thysanoptera (thrip)	.	.	0	.	0	.	.	.	0	.	.	.	0
Unidentified	0	0	0	0	1	0	.	0	0	0	0	0	0
Total density (/m3)	75	160	220	262	289	377	291	959	264	230	591	391	342
Avg. volume sampled (m3)	19	19	20	21	21	23	22	22	24	23	21	23	21
(n) Dates sampled	10	10	10	9	10	13	13	15	15	16	14	14	149

Table A-8. Average density (number/m^3) of zooplankton taxa, by station, in Batchelor Bay (Stations 13-16) and western Albemarle Sound (Stations 17-32), North Carolina, for 1990. Period (P) N=night samples.

YEAR=90 PERIOD=N	STATION																
TAXONOMIC GROUP	13	14	15	16	17	18	20	21	22	23	24	26	28	31	32	AVE1	AVE2
Amphipoda - gammarid egg	.	.	.	1	.	.	.	.	.	0	.	.	.	.	.	1	0
Amphipoda - Gammaridae	33	.	11	9	.	14	3	19	1	3	2	3	18	6	4	18	7
Arachnida	1	.	0	0	.	2	0	1	1	.	0	1	1	1	2	0	1
Bivalvia	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	0
Bivalvia - larv.	1	.	0	1	.	.	.	.	.	.	.	.	.	.	.	1	.
Caddisfly larv.	0	.	0	0	.	0	.	.	.	.	0	.	.	.	.	0	0
Clad.- Bosmina	18	.	8	13	.	9	6	2	14	4	10	11	4	7	6	13	7
Clad.- Daphnia	159	.	71	198	.	41	68	69	2	0	2	6	24	32	14	143	26
Clad.- Leptodora	.	.	.	0	.	2	2	6	156	85	61	86	28	76	74	0	58
Cladocera - other	62	.	22	32	.	34	20	13	84	87	109	35	36	26	63	39	51
Cladocera - unid. egg	0	.	.	0	.	0	.	.	.	.	.	.	.	.	.	0	0
Cladocera - unid. juv.	5	.	1	3	.	.	1	.	0	0	0	.	0	.	0	3	0
Coleopt.-Dytiscidae larv.	.	.	.	0	.	.	0	.	.	.	.	.	.	.	.	0	0
Coleopt.-Gyrinidae larv.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	0	.
Collembola larv.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Copepoda - egg mass	0	.	0	2	.	1	0	.	.	.	.	.	.	.	.	1	1
Copepoda - nauplius	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Copepoda - Calanoida	45	.	14	58	.	22	15	14	24	11	8	6	8	12	12	39	13
Copepoda - Cyclopoida	143	.	61	108	.	148	58	52	677	733	886	309	215	169	555	104	380
Copepodids	1	.	1	2	.	.	.	0	.	.	.	.	.	.	.	1	0
Cumacea	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	0
Dipt.-biting midge larv.	0	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Dipt.-chironimid pup.	0	.	0	0	.	0	0	.	.	.	.	.	.	6	.	0	2
Dipt.-chironomid adult	.	.	0	0	.	0	.	.	.	0	.	.	1	.	.	0	0
Dipt.-chironomid larv.	2	.	1	2	.	0	0	.	.	0	.	.	.	14	1	2	3
Dipt.-mayfly nymphs	.	.	0	0	.	.	.	0	1	1	39	.	.	.	0	0	8
Dipt.-phantom midge larv.	2	.	1	2	.	1	0	.	8	7	6	1	1	0	4	1	3
Dipt.-phantom midge pup.	0	.	0	0	.	.	.	.	0	0	.	.	.	.	.	0	0
Diptera	.	.	.	.	.	.	.	1	.	.	.	.	0	.	.	.	1
Hemiptera - Corixidae	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	.	0
Hydra	0	.	0	.	.	.	0	.	.	.	.	.	.	.	.	0	0
Isopoda	.	.	0	.	.	.	0	0	0	1	1	1	1	.	1	0	1
Nematoda	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	0
Odonata	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Oligo.- Aeolosoma	0	.	.	0	.	.	0	.	.	.	.	.	.	0	.	0	0
Oligo.- Stylaria	2	.	2	1	.	0	0	.	.	.	.	.	.	.	.	2	0
Ostracoda	9	.	3	5	.	1	2	1	1	0	2	1	1	1	1	5	1
Rotifer - colonial	0	.	0	.	.	.	0	.	.	.	.	.	.	.	.	0	0
Rotifer - single	4	.	1	4	.	0	1	1	0	.	.	.	0	.	.	3	0
Thysanoptera (thrip)	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	0	.
Unidentified	0	.	1	0	.	.	.	.	.	0	.	.	.	.	.	0	0
Total density (/m3)	489	.	199	442	.	277	178	180	971	934	1128	460	338	350	737	377	555
Avg. vol. sampled (m3)	24	.	23	24	.	25	25	23	27	25	24	24	23	24	25	24	24
(n) Dates sampled	14	.	18	13	.	7	6	6	6	6	6	5	6	7	7	45	62

Table A-9. Average density (number/m^3) of zooplankton taxa, by station, in the lower Roanoke River (Stations 1-12), North Carolina, for 1991. Period (P) N=night samples.

YEAR=91 PERIOD=N	STATION												
TAXONOMIC GROUP	1	2	3	4	5	6	7	8	9	10	11	12	AVE.
Amphipoda - gammarid egg	.	.	.	.	.	.	.	.	.	.	0	.	0
Amphipoda - Gammaridae	0	0	1	1	1	1	1	1	3	1	6	3	2
Arachnida	0	1	1	1	1	0	0	1	1	1	1	1	1
Bivalvia	1	.	.	.	.	0	.	.	.	.	.	.	0
Bivalvia - larv.	0	1	2	.	.	0	0	1	1	1	.	.	1
Caddisfly larv.	1	0	0	0	0	0	.	0	0	0	0	0	0
Clad.- Bosmina	2	6	4	2	3	6	4	27	58	33	13	4	13
Clad.- Daphnia	4	16	12	12	14	18	17	40	64	55	27	12	24
Clad.- Leptodora	.	.	.	.	.	.	0	.	.	.	.	0	0
Cladocera - other	3	3	13	14	15	15	19	42	55	43	19	12	21
Cladocera - unid. egg	0	.	.	0	0	.	0	3	16	10	1	0	3
Cladocera - unid. juv.	0	0	0	0	1	2	1	6	6	5	2	1	2
Coleopt.-Dytiscidae larv.	.	.	.	.	.	.	.	.	.	0	.	.	0
Coleoptera	.	.	.	0	.	.	.	.	.	.	.	.	0
Coleoptera - Elmidae	.	0	.	.	.	.	0	.	.	.	.	.	0
Collembola larv.	1	.	.	0	0	.	.	.	.	.	.	.	0
Copepoda - egg mass	.	.	.	0	.	0	0	5	0	0	7	.	2
Copepoda - nauplius	.	.	.	.	.	.	.	1	.	0	.	.	1
Copepoda - Calanoida	5	3	5	7	6	5	2	47	6	2	75	3	14
Copepoda - Cyclopoida	11	16	28	37	54	40	24	147	86	93	97	23	55
Copepoda - Harpacticoida	.	.	.	.	.	.	.	.	0	0	.	.	0
Copepodids	.	.	0	0	.	0	1	1	1	1	1	0	1
Dipt.-biting midge larv.	0	.	.	.	.	.	.	.	0	.	0	.	0
Dipt.-biting midge pup.	.	.	.	0	.	.	.	.	.	.	.	.	0
Dipt.-chironimid pup.	.	0	.	.	.	0	.	0	0	.	0	0	0
Dipt.-chironomid adult	.	.	.	.	.	.	.	0	0	.	0	.	0
Dipt.-chironomid larv.	2	1	1	3	3	1	0	1	2	1	3	1	1
Dipt.-mayfly nymphs	0	.	0	0	0	0	.	0	0	.	.	.	0
Dipt.-mosquito larv.	.	.	.	.	.	.	0	0	.	0	.	.	0
Dipt.-phantom midge larv.	0	.	0	0	0	0	.	11	1	0	5	1	2
Dipt.-phantom midge pup.	.	.	.	.	.	.	0	1	0	.	2	0	1
Diptera	0	.	0	0	.	0	.	0	0	0	0	.	0
Hemiptera	0	0	0	0	0	0	.	.	.	.	.	0	0
Hemiptera - Corixidae	.	.	0	.	.	.	0	.	.	.	.	.	0
Hydra	9	9	4	1	1	1	1	0	1	1	0	0	2
Hymenoptera - ant	.	.	.	.	0	.	.	.	.	.	.	.	0
Hymenoptera- diving wasp	.	.	.	.	.	.	.	0	.	.	.	.	0
Megalopt.-alderfly larv.	0	.	.	.	.	.	.	.	.	.	.	.	0
Nematoda	.	0	.	.	.	.	.	.	0	.	.	.	0
Odonata	.	.	.	.	.	.	.	.	0	.	.	.	0
Oligo.- Aeolosoma	1	1	1	.	0	0	1	0	1	3	.	.	1
Oligo.- Dero	0	.	0	0	1	.	0	.	.	.	0	0	0
Oligo.- Stylaria	1	0	1	0	0	1	0	1	1	1	3	1	1
Ostracoda	3	3	4	6	5	5	3	38	5	2	33	3	9
Rotifer - colonial	0	1	1	1	1	1	1	9	3	2	5	0	2
Rotifer - single	3	2	0	0	0	0	110	79	5	2	277	2	40
Tardigrada	.	.	.	.	.	.	0	.	.	.	.	.	0

Table A-9. Continued.

YEAR=91 PERIOD=N	STATION												
TAXONOMIC GROUP	1	2	3	4	5	6	7	8	9	10	11	12	AVE.
Thysanoptera (thrip)	0	0	1	0	1	0	.	0	0	.	.	.	0
Tubellaria	.	.	.	0	.	.	.	.	.	.	.	.	0
Unidentified	1	0	1	1	0	0	.	0	0	0	0	.	0
Total density (/m3)	49	65	79	88	109	98	185	462	316	257	576	67	196
Avg. volume sampled (m3)	30	30	31	30	29	43	42	40	40	40	41	45	37
(n) Dates sampled	9	9	9	9	9	11	11	17	17	17	11	11	140

Table A-10. Average density (number/m^3) of zooplankton taxa, by station, in Batchelor Bay (Stations 13-16) and western Albemarle Sound (Stations 17-32), North Carolina, for 1991. Period (P) N=night samples.

YEAR=91 PERIOD=N	STATION																
TAXONOMIC GROUP	13	14	15	16	17	18	20	21	22	23	24	26	28	31	32	AVE1	AVE2
Amphipoda - gammarid egg	0	.	.	0	.	.	.	.	.	.	.	.	.	.	.	0	.
Amphipoda - Gammaridae	7	.	7	1	.	1	1	3	1	1	.	0	1	5	2	5	2
Arachnida	1	.	1	0	.	0	1	1	0	1	0	0	0	1	0	1	1
Bivalvia	.	.	.	.	.	1	0	.	0	.	.	.	.	.	0	.	0
Bivalvia - larv.	1	.	0	.	.	.	.	.	.	.	.	.	0	.	.	0	0
Caddisfly larv.	0	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	.
Clad.- Bosmina	44	.	15	51	.	24	3	12	8	13	10	22	4	2	6	37	10
Clad.- Daphnia	20	.	23	24	.	10	9	6	0	0	0	3	0	5	1	22	4
Clad.- Leptodora	0	.	1	0	.	4	2	9	27	22	26	20	7	4	22	0	14
Cladocera - other	27	.	18	15	.	21	8	45	32	42	34	43	67	23	41	20	36
Cladocera - unid. egg	1	.	2	4	.	1	.	0	.	.	.	.	.	.	.	2	0
Cladocera - unid. juv.	1	.	2	3	.	1	1	0	0	0	1	1	0	0	0	2	0
Coleoptera	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Copepoda - egg mass	4	.	0	0	.	0	0	.	0	0	1	.	0	.	0	1	0
Copepoda - nauplius	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Copepoda - Argulus sp.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	0
Copepoda - Calanoida	31	.	12	20	.	4	5	18	22	7	14	15	1	15	7	21	11
Copepoda - Cyclopoida	89	.	48	59	.	405	272	224	505	625	648	352	470	279	183	65	396
Copepoda - Harpacticoida	0	.	.	.	.	.	0	.	.	.	.	.	.	.	.	0	0
Copepodids	1	.	0	0	.	1	0	0	0	0	.	.	0	.	0	0	0
Dipt.-biting midge larv.	0	.	0	.	.	0	0	.	.	.	.	.	.	0	.	0	0
Dipt.-chironimid pup.	0	.	0	.	.	1	.	0	.	.	0	.	1	0	.	0	0
Dipt.-chironomid adult	0	.	0	.	.	.	0	.	.	.	.	.	.	.	0	0	0
Dipt.-chironomid larv.	1	.	1	2	.	1	0	.	.	0	1	0	0	0	.	1	0
Dipt.-mayfly nymphs	.	.	0	0	.	.	.	.	.	.	.	.	0	.	.	0	0
Dipt.-phantom midge larv.	2	.	0	1	.	1	0	3	7	6	5	5	2	1	8	1	4
Dipt.-phantom midge pup.	0	.	.	.	.	.	0	.	.	.	.	0	0	.	5	0	1
Diptera	.	.	0	0	.	.	1	.	.	.	0	.	0	.	.	0	0
Hymenoptera - ant	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	0
Hymenoptera- diving wasp	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	0
Isopoda	.	.	.	0	.	.	.	0	0	1	0	0	.	0	0	0	0
Mysidacea - Mysis shrimp	.	.	.	.	.	0	.	0	.	.	.	.	0	.	.	.	0
Nematoda	.	.	.	0	.	.	.	.	.	0	0	.	.	.	.	0	0
Odonata	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Oligo.- Aeolosoma	1	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	.
Oligo.- Stylaria	1	.	1	0	.	.	0	.	.	.	.	.	.	.	.	1	0
Ostracoda	10	.	4	5	.	0	0	0	0	1	1	1	0	1	2	6	1
Rotifer - colonial	2	.	3	2	.	2	.	.	.	.	.	.	.	.	.	2	2
Rotifer - single	13	.	9	29	.	3	1	7	1	0	1	1	0	1	2	17	2
Spongillafly adult	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Thysanoptera (thrip)	.	.	0	.	.	.	.	.	.	.	.	.	.	0	.	0	0
Tubellaria	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.
Unidentified	0	.	0	0	.	0	.	.	.	.	0	.	0	.	.	0	0
Total density (/m3)	258	.	147	218	.	479	306	329	604	722	742	463	557	338	279	208	482
Avg. vol. sampled (m3)	40	.	40	40	.	40	40	40	40	42	39	39	40	41	41	40	40
(n) Dates sampled	15	.	22	15	.	12	7	7	5	5	5	5	5	6	6	52	63

Table A-11. Density (number/100 m^3) of striped bass larvae in the lower Roanoke River (Stations 1-12), North Carolina, 1990-1991. Period (P) N=night samples.

DATE	P	STATION 1	2	3	4	5	6	7	8	9	10	11	12	AVE.
04/18/90	N	.	.	.	.	.	.	.	0	0	0	.	.	0
04/27/90	N	.	.	.	.	.	.	.	0	0	2	.	.	1
05/01/90	N	2	1	0	.	.	.	.	.	.	1	2	0	1
05/04/90	N	10	4	0	6	2	0	1	1	3	1	0	4	3
05/07/90	N	29	1	1	7	1	2	3	0	0	2	4	0	4
05/11/90	N	162	24	6	26	4	16	5	2	29	0	54	1	27
05/13/90	N	0	14	7	59	6	41	141	3	74	11	1	14	31
05/15/90	N	0	2	8	6	1	1	4	0	22	0	6	0	4
05/18/90	N	0	3	6	5	0	8	2	0	10	4	53	2	8
05/21/90	N	0	0	1	3	1	4	1	2	17	0	9	19	5
05/24/90	N	8	10	6	8	1	144	96	0	78	71	15	5	37
05/27/90	N	0	6	0	4	0	6	2	0	1	0	2	0	2
05/30/90	N	.	.	.	.	0	0	1	0	0	0	0	0	0
06/02/90	N	.	.	.	.	.	0	0	0	0	0	0	0	0
06/04/90	N	.	.	.	.	.	4	0	0	0	0	0	1	1
06/06/90	N	.	.	.	.	.	0	0	0	0	0	0	0	0
Ave.Density		21	7	3	14	2	17	20	1	16	6	11	3	10
Ave.Volume		47	45	44	48	48	41	42	43	43	42	43	44	44
n (efforts)		10	10	10	9	10	13	13	15	15	16	14	14	149
04/24/91	N	.	.	.	.	.	.	.	1	0	0	.	.	0
05/02/91	N	.	.	.	.	.	0	0	0	0	0	0	1	0
05/07/91	N	0	4	0	0	0	4	0	0	1	0	0	0	1
05/10/91	N	212	54	17	20	9	16	3	0	4	1	0	2	28
05/13/91	N	250	52	8	31	13	17	1	2	21	3	16	6	35
05/16/91	N	148	253	101	120	31	31	22	11	82	29	43	93	81
05/18/91	N	21	34	64	87	201	630	48	39	120	118	26	136	127
05/20/91	N	59	35	24	72	0	93	6	22	473	5	86	3	73
05/22/91	N	25	13	12	105	64	335	80	20	151	41	69	49	80
05/24/91	N	15	9	1	26	11	14	2	18	57	5	15	5	15
05/26/91	N	19	9	7	15	1	35	17	5	18	12	29	8	15
05/30/91	N	.	.	.	.	.	158	49	7	74	45	18	58	59
Ave.Density		83	52	26	53	37	121	21	11	84	22	27	33	47
Ave.Volume		46	47	44	45	47	47	46	930	46	47	49	46	120
n (efforts)		9	9	9	9	9	11	11	12	12	12	11	11	125

Table A-12. Density (number/100 m^3) of striped bass larvae in Batchelor Bay (Stations 13-16) and western Albemarle Sound (Stations 17-32), North Carolina, 1990-1991. Period (P) N=night samples.

		STATION																
DATE	P	13	14	15	16	17	18	20	21	22	23	24	26	28	31	32	AVE1	AVE2
04/25/90	N	2	.	0	1	.	0	.	.	.	.	.	.	.	.	.	1	0
05/01/90	N	7	.	2	4	.	.	.	.	.	.	.	.	.	.	.	4	.
05/04/90	N	4	.	1	1	.	.	.	.	.	.	.	.	.	.	.	2	.
05/07/90	N	10	.	10	8	.	.	.	.	.	.	.	.	.	.	.	9	.
05/11/90	N	23	.	0	0	.	.	.	.	.	.	.	.	.	.	.	8	.
05/13/90	N	5	.	9	11	.	.	.	.	.	.	.	.	.	.	.	8	.
05/15/90	N	0	.	3	3	.	.	.	.	.	.	.	.	.	.	.	2	.
05/18/90	N	12	.	2	2	.	.	.	.	.	.	.	.	.	.	.	6	.
05/23/90	N	.	.	2	.	.	0	0	0	0	0	0	0	0	6	0	2	1
05/24/90	N	7	.	0	1	.	.	.	.	.	.	.	.	.	.	.	3	.
05/26/90	N	.	.	0	.	.	2	4	8	.	.	.	.	1	.	.	0	4
05/27/90	N	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	3	.
05/29/90	N	.	.	.	.	.	.	.	.	1	0	.	.	.	5	1	.	2
05/30/90	N	1	.	2	0	.	.	.	.	.	.	.	.	.	.	.	1	.
06/02/90	N	0	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	.
06/06/90	N	0	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	.
06/08/90	N	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	0
06/10/90	N	.	.	0	.	.	0	0	0	0	0	0	0	0	0	0	0	0
06/13/90	N	.	.	0	.	.	0	0	0	0	0	0	0	0	0	0	0	0
06/15/90	N	.	.	.	.	.	.	.	.	.	0	1	.	.	.	.	.	1
06/17/90	N	.	.	0	.	.	0	0	0	0	0	0	0	0	.	0	0	0
Ave.Density		6	.	2	3	.	0	1	2	0	0	0	0	0	2	0	4	1
Ave.Volume		46	.	48	48	.	48	48	49	46	46	46	46	47	46	46	47	47
n (efforts)		12	0	18	12	0	6	5	5	5	6	5	4	5	5	6	42	52
04/17/91	N	0	.	0	0	.	0	.	.	.	.	.	.	.	.	.	0	0
04/30/91	N	0	.	0	0	.	0	.	.	.	.	.	.	.	.	.	0	0
05/02/91	N	0	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	.
05/07/91	N	1	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	.
05/10/91	N	0	.	0	2	.	.	.	.	.	.	.	.	.	.	.	1	.
05/13/91	N	22	.	6	41	.	.	.	.	.	.	.	.	.	.	.	23	.
05/16/91	N	30	.	69	14	.	.	.	.	.	.	.	.	.	.	.	38	.
05/20/91	N	675	.	9	306	.	.	.	.	.	.	.	.	.	.	.	330	.
05/21/91	N	.	.	68	.	.	7	33	21	18	1	35	0	0	2	0	68	12
05/22/91	N	101	.	11	8	.	.	.	.	.	.	.	.	.	.	.	40	.
05/23/91	N	.	.	0	.	.	0	1	2	4	0	1	7	1	2	11	0	3
05/24/91	N	17	.	2	12	.	.	.	.	.	.	.	.	.	.	.	10	.
05/25/91	N	.	.	5	.	.	0	44	1	0	0	0	0	0	0	1	5	5
05/26/91	N	0	.	5	2	.	.	.	.	.	.	.	.	.	.	.	2	.
05/28/91	N	.	.	0	.	.	1	0	3	0	0	0	0	0	5	2	0	1
05/30/91	N	1	.	3	0	.	.	.	.	.	.	.	.	.	.	.	1	.
06/01/91	N	.	.	0	.	.	1	22	0	.	.	.	.	.	0	0	0	5
06/03/91	N	.	.	1	.	.	0	9	3	.	.	.	.	.	.	.	1	4
06/05/91	N	.	.	.	.	.	.	.	.	0	0	0	1	0	0	.	.	0
Ave.Density		71	.	10	32	.	1	18	5	4	0	7	2	0	2	3	38	4
Ave.Volume		55	.	47	48	.	46	45	42	45	46	46	46	45	46	45	50	45
n (efforts)		12	0	18	12	0	8	6	6	5	5	5	5	5	6	5	42	56