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FOOD AND FEEDING OF YOUNG STRIPED BASS IN ROANOKE RIVER AND WESTERN ALBEMARLE SOUND, NORTH CAROLINA, 1984-1985

Completion Report for Project AFS-24

For

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Morehead City, NC 28557

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ABSTRACT

Objectives of the 1984 and 1985 studies were to determine densities of striped bass life stages, zooplankton, and phytoplankton in the lower Roanoke River and western Albemarle Sound, North Carolina; the location at which feeding by larvae was initiated; and the prey items selected by young striped bass. Sampling was conducted from 18 May to 18 June in 1984, and from 26 April to 10 June in 1985. River flow varied considerably during the 1984 study and generally was much higher than normal; in 1985 flow was less variable and lower than normal. River flow was correlated with the distribution and abundance of phytoplankton, zooplankton, and several striped bass life stages in 1984; flow varied so little in 1985 that no correlations were observed. Chlorophyll a concentrations were mostly between 4-7 ug/l in 1984 with no clear spatial or temporal patterns in the data; 1985 levels were higher (5-15 ug/l) with lowest values upriver, highest values downriver, and intermediate values in western Albemarle Sound. The phytoplankton community resembled that of a lake more closely than that of an estuarine environment in both years. Only about 15% of the 150 cell types identified appeared in more than 10% of the samples. Phytoplankton cell densities (mostly 300-700 cells/ml) and biomass (300-800 ug wet weight/l) were lower in 1984 than in 1985 (8000-10,000 cells/ml; 500-2000 ug wet weight/l). Spatial and temporal distributions of cell densities and biomass in 1985 were similar to those for chlorophyll a. Green algae were numerically dominant in 1984 but were secondary to diatoms in 1985. Blue-green algae were not present in significant quantities in either year. In both years most algae collected were small species that are potentially usable as food for grazing zooplankton. Concentrations of zooplankton were lower in 1984 and higher in 1985, probably due to changes in the flow regime between the two years. Maximum concentrations (about 21,000/m^3 in 1985) were at least one order of magnitude lower than comparable zooplankton communities in northern estuaries supporting striped bass populations. Zooplankton were primarily freshwater species dominated numerically by cladocerans in 1984 and by copepods in 1985. Comparison of zooplankton and phytoplankton biomasses suggests that zooplankton production was not limited by phytoplankton concentrations in either year. In

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INTRODUCTION

For several hundred years the striped bass (Morone saxatilis) fishery in the Roanoke River and Albemarle Sound, North Carolina, has been an important component of the lives of coastal residents as a source of income, sport, and social interaction. The major spawning area for Albemarle Sound striped bass is located in the Roanoke River, a swiftly-flowing coastal stream that empties into the extreme western end of the Sound. Spawning occurs upstream between Halifax (River Mile 120) and Weldon (RM 130), North Carolina, from late April through early June (Hassler et al. 1981). The historical spawning grounds further upstream were blocked by construction of the Roanoke Rapids Dam at RM 137 (McCoy 1959). Eggs develop to the hatching stage as they are transported downstream by currents. After hatching, the larvae are transported downstream through the Roanoke River delta and into western Albemarle Sound to the historical nursery grounds (Street 1975).

Research conducted in Chesapeake Bay suggests that striped bass must have a strong, successful year class at least every six years in order to maintain and preserve stock size; a strong year class has not occurred in Chesapeake stocks since 1970 (USDOI and USDOC 1985). The Albemarle Sound striped bass stock has been in decline for over a decade; a strong year class of Roanoke River striped bass has not been observed since 1970, and no significant year classes have been produced since 1976 (Hassler et al. 1981; USDOI and USDOC 1985).

Studies conducted since the late 1970's have examined several factors that may contribute to the decline of the Roanoke stock. Reduced egg viability was suspected as the initial cause for decline of the adult population (Guier et al. 1980, Hassler et al. 1981), although "adequate" numbers of viable striped bass eggs are spawned each year to produce sufficient recruitment to the population (Kornegay 1981, Kornegay and Mullis 1984). Another potential problem may be poor survival of juvenile striped bass on the nursery grounds in the western Sound (Hassler et al. 1981). The juvenile trawl index conducted each year in Albemarle Sound suggests that the numbers of juvenile striped bass are too low to produce sufficient recruitment to the population (Hassler et al. 1981). Low recruitment of larvae and early juveniles to the nursery ground was observed in

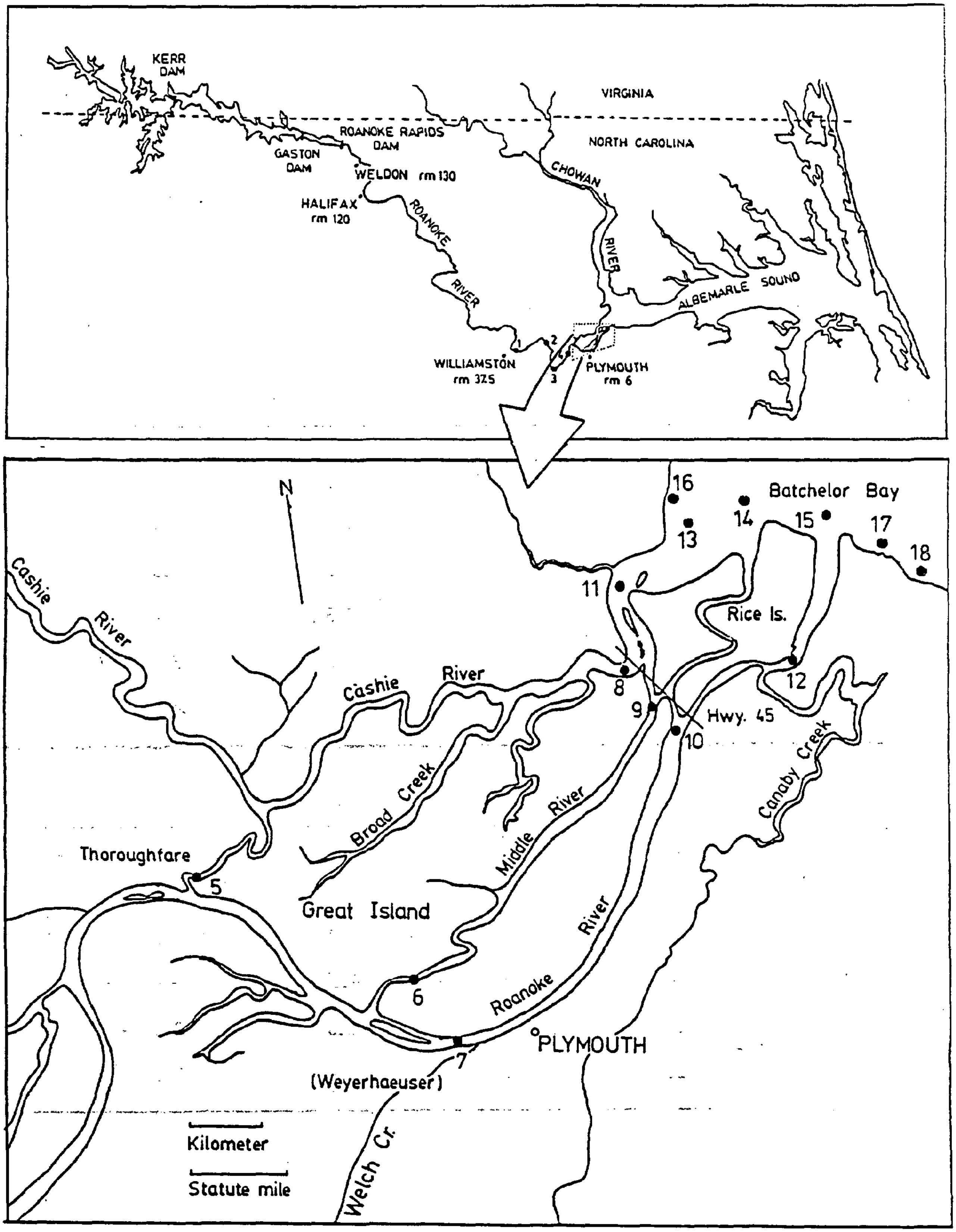

Figure 1. Map of the Roanoke River and western Albemarle Sound, North Carolina, depicting sampling locations used in 1984 and 1985.

m wide from the river mouth to Plymouth, NC and 2.4 m deep by 24.4 m wide from Plymouth to Palmyra.

Outflow of the Roanoke River at the mouth is the second highest of any North Carolina estuary; the annual average is approximately 252 m^3/second, or about 0.01 $m^3/sec/km^2$ (Giese et al. 1979). However, flow rate is highly regulated by several reservoirs created primarily for hydropower generation. The farthest downstream of these reservoirs is Roanoke Rapids Lake (dam at RM 137), which is therefore most important in its effects on flow in the Roanoke River Estuary (Giese et al. 1979). The Roanoke River provides approximately 50% of the freshwater input into Albemarle Sound. The tides and water flow patterns near the river mouth are influenced to a great extent by prevailing winds and amount of water released from Roanoke Rapids Dam. The lower Roanoke River is essentially a freshwater system, even under extreme drought conditions, because of the combination of relatively high outflow, small cross-sectional area, low-flow augmentation from Roanoke Rapids Lake, and low salinity in Albemarle Sound (Giese et al. 1979).

METHODS

Sample Collections

Sampling for ichthyoplankton, zooplankton, and phytoplankton in the lower river and western Sound was conducted in the springs of 1984 and 1985. Collection efforts were initiated just prior to the estimated peak spawning activity of adult striped bass in upstream areas near Weldon and Halifax (Figure 1). In 1984 sampling efforts began on 18 May and terminated on 18 June when striped bass larvae were no longer present in the samples. In 1985, spawning activity was the earliest on record. Sampling efforts began on 26 April and continued through 10 June.

Similar sampling locations were used in 1984 and 1985. Stations 1, 2, 3, and 4 were positioned between Williamston (RM 37.5) and just upstream of the Roanoke River delta. These stations were sampled by North Carolina Wildlife Resources Commission personnel on alternate nights for a two-week period.

ratio. A flowmeter with slow speed propeller was mounted in the net frame. Initially, samples of six minute duration were taken against the current, but sample duration was reduced to three minutes to minimize clogging problems caused by high concentrations of suspended solids in the water. Zooplankton samples were preserved in 5% buffered formalin containing Rose Bengal.

Phytoplankton samples (whole water) were taken at each station by submerging a one-liter plastic bottle just below the water's surface and allowing it to fill. Each sample was preserved with Lugols' acetic acid-iodine solution (Wetzel and Likens 1979). Additional water samples were collected and chilled for laboratory measurements of chlorophyll a. Methods of collection and preservation were the same for both years.

Whole water samples were collected from eight locations in 1985 to determine water quality of the Roanoke River just above the spawning grounds, and in the lower river, delta, and western Albemarle Sound. Water samples were collected daily from just below Roanoke Rapids at Weldon, North Carolina (Stations 20 and 21), during the period of 23 April to 6 May. Water samples from the lower river (Stations 1 and 3) were taken by North Carolina Wildlife Resources Commission personnel on alternate nights from 4 May to 16 May. Samples from Station 5 were collected on alternate nights from 4 May through 10 June. Delta (Stations 7 and 10) and western Sound (Station 15) water samples were collected on alternate nights from 4 April through 10 June.

Three water samples were collected at each site by submerging 16-oz. plastic bottles below the water's surface heel-first to a depth of approximately 0.4 m. Two water samples, one for heavy metals analyses and a second for PO_4-P analyses, were stabilized by packing them in ice. The third sample was preserved with 2 ml of 25% H_2SO_4 for nitrogen and total phosphorus analyses. The samples were shipped by courier to the NCDNRCD Division of Environmental Management (Water Quality Section) in Raleigh, North Carolina, for analysis using U.S. Environmental Protection Agency standard procedures (USEPA 1979). Temperature (^{o}C) was measured by thermometer; dissolved oxygen (mg/l) and pH were measured by Hach kit.

On 27-29 August 1985, N.C. Wildlife Resources Commission personnel monitored temperature, oxygen, and salinity along three transects (6 stations

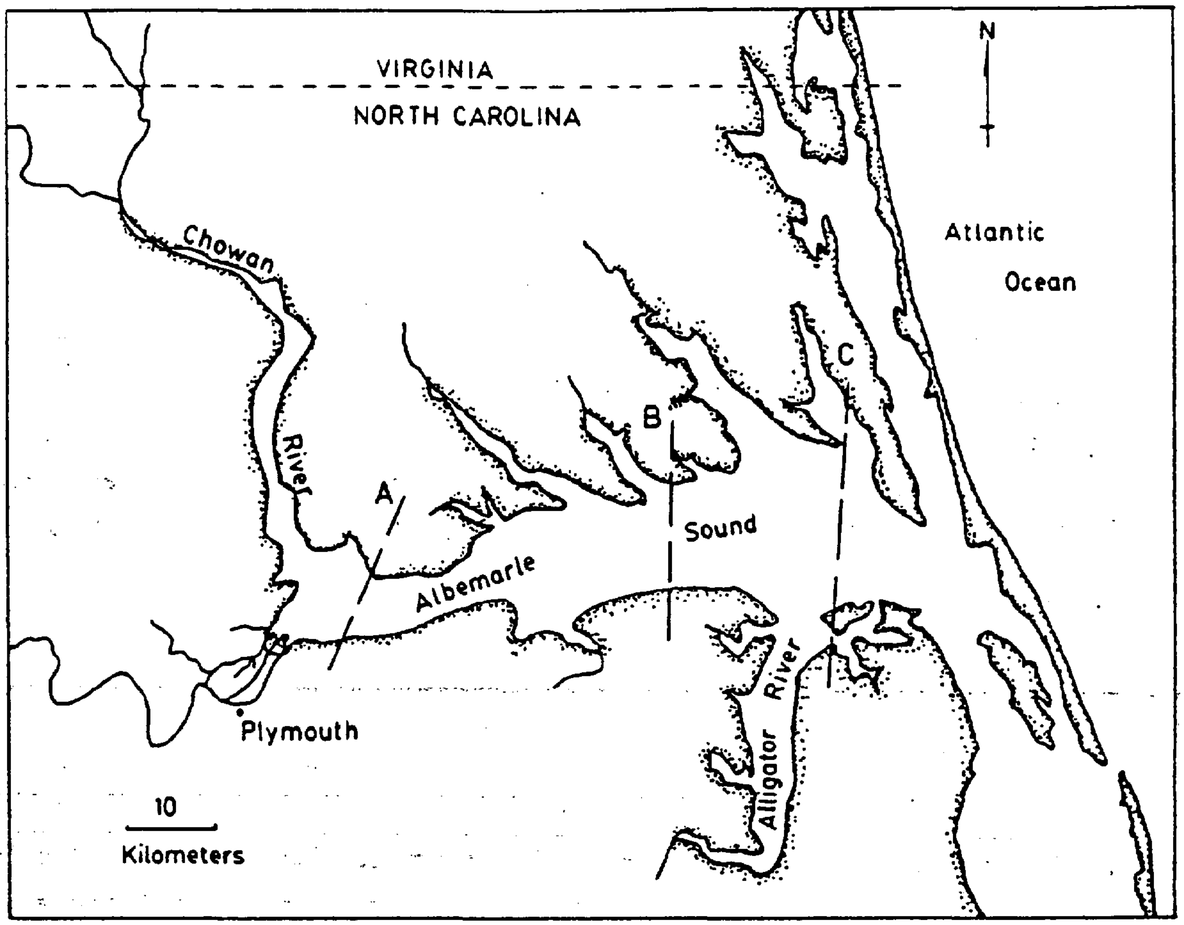

Figure 2. Map of Albemarle Sound, North Carolina, depicting western (A), central (B), and eastern (C) transects for water quality measurements in August 1985.

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Table 2 (continued).

Variable name	Description
PHYTOB	Phytoplankton wet wet biomass (ug/l) averaged for all stations by date
PHYTOD	Phytoplankton cell density (cell/ml) averaged for all stations by date
TZO	Density (number/m^3) of all zooplankton averaged for delta and western Sound stations by date
BOSM	Density (number/m^3) of all *Bosmina* averaged for delta and western Sound stations by date
CLAD	Density (number/m^3) of all Cladocerans (excluding *Leptodora*) averaged for delta and western Sound stations by date
COPE	Density (number/m^3) of all Copepods for delta and western Sound stations by date
STAGE1	Density of striped bass larvae with yolk (Stage 1) averaged for delta and western Sound stations by date

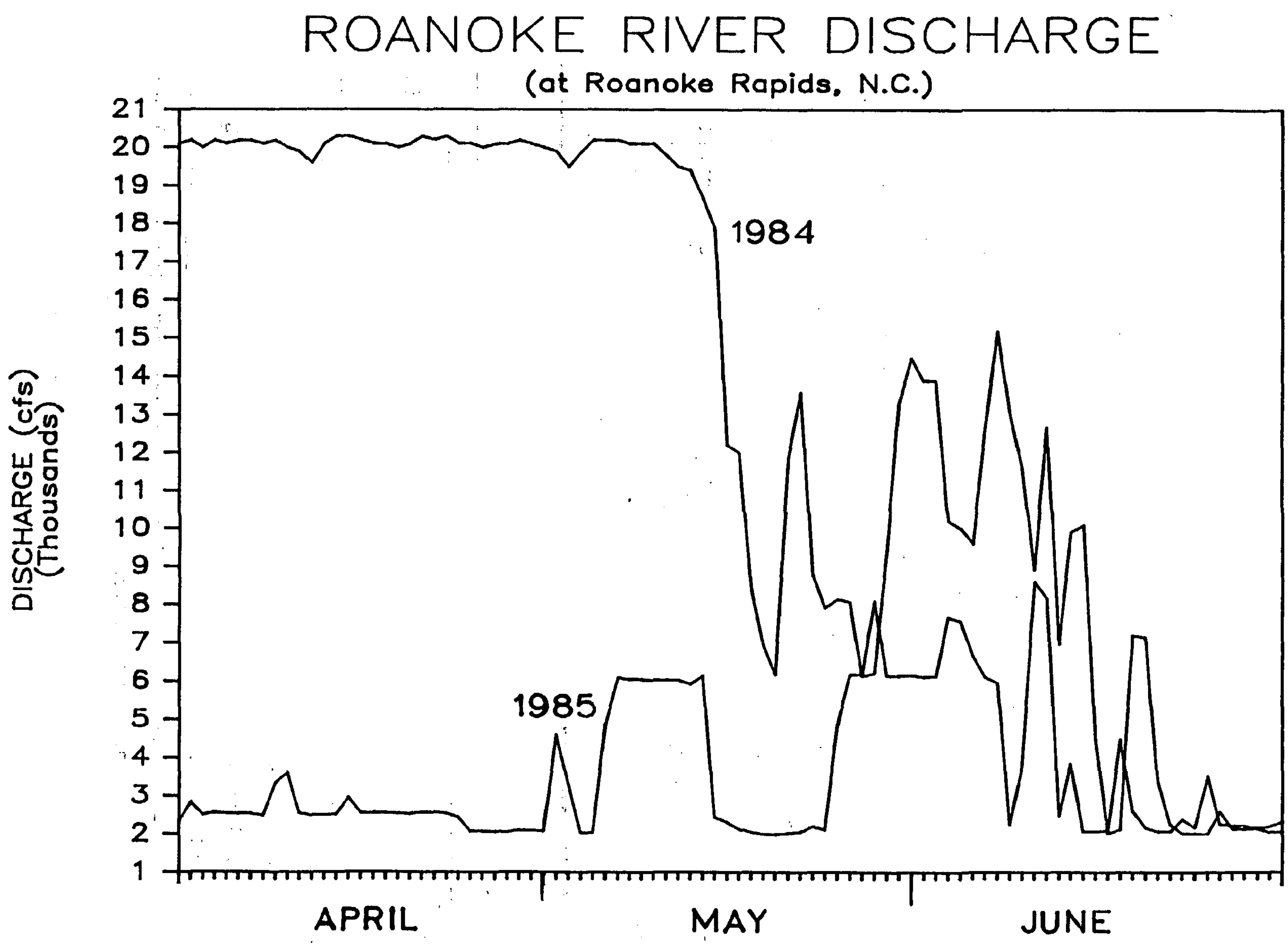

Figure 3. Mean daily discharge (cfs x 1000) at Roanoke Rapids, North Carolina in 1984 and 1985 (data from U.S. Geological Survey).

Table 3. Water quality information for lower Roanoke River, delta, and western Albemarle Sound, North Carolina, for the period 26 April - 10 June 1985. Stations as in Figure 1.

Variable		Station 20	1	3	5	7	10	15
D.O. (mg/l)	n	12	7	7	15	18	18	16
	$\bar{x}$	8.9	7.6	6.0	6.5	6.4	6.9	6.3
	S.D.	0.67	0.53	1.41	0.55	0.92	1.24	0.9
	min	8.1	7.0	4.0	6.0	4.0	5.0	4.0
	max	9.6	8.0	8.0	7.5	8.0	9.0	8.0
Temp (oC)	n	12	7	7	15	19	20	19
	$\bar{x}$	21.9	22.6	22.4	23.8	24.1	25.1	24.6
	S.D.	0.97	0.53	0.79	1.61	1.47	1.85	1.98
	min	21	22	21	21	21	22	21
	max	23.5	23	23	27	27	30	28
NH_3-N (mg/l)	n	13	7	7	15	20	20	19
	$\bar{x}$	0.07	0.05	0.06	0.06	0.10	0.18	0.16
	S.D.	0.05	0.02	0.02	0.04	0.19	0.18	0.12
	min	0.03	0.03	0.04	0.01	0.02	0.01	0.02
	max	0.21	0.09	0.07	0.18	0.72	0.65	0.52
TKN (mg/l)	n	13	7	7	15	20	20	19
	$\bar{x}$	0.33	0.27	0.29	0.27	0.40	0.46	0.44
	S.D.	0.06	0.12	0.07	0.07	0.43	0.21	0.20
	min	0.2	0.06	0.2	0.2	0.2	0.2	0.20
	max	0.4	0.4	0.4	0.4	2.0	1.0	1.0
NO_3+NO_2-N (mg/l)	n	13	7	7	15	20	20	19
	$\bar{x}$	0.16	0.21	0.22	0.23	0.21	0.16	0.19
	S.D.	0.04	0.06	0.06	0.14	0.18	0.05	0.05
	min	0.09	0.16	0.17	0.03	0.03	0.06	0.10
	max	0.22	0.31	0.30	0.54	0.94	0.26	0.33
PO_4-P (mg/l)	n	13	7	7	15	20	20	19
	$\bar{x}$	0.04	0.01	0.01	<0.01	0.01	0.03	0.03
	S.D.	0.01	0.05	0.05	0.05	0.04	0.04	0.02
	min	0.02	0.01	<0.01	<0.01	<0.01	<0.01	0.01
	max	0.07	0.02	0.02	0.02	0.07	0.13	0.10

HEAVY METALS. Aluminum was the only element with concentrations consistently above minimum detectable level (100 ug/l) during the 1985 sampling period (Appendix A). Highest values reached 2,400 ug/l just above the spawning grounds (Station 20) near Weldon, North Carolina. Average concentrations were highest upstream (835.7 ug/l), decreasing downriver to 426-466 ug/l in the delta (Station 10) and western Sound (Station 15, Table 3). Other elements detected in small concentrations were mercury (0.2-0.8 ug/l), lead (200 ug/l), zinc (20-50 ug/l), and copper (30 ug/l) (Appendix A).

Summer Water Quality - Albemarle Sound

Measurements at stations along the transects across the Sound in late August 1985 indicated stratification of the water column in certain locations. Vertical profiles of temperature, salinity, and dissolved oxygen for stations on the westernmost transect "A" indicated there was mixed fresh water at Station 1A in the shallow waters near Horniblow Point (north) and Station 6A east of the railroad trestle (south). The water column was stratified at Stations 2A-5A in the open area of the western Sound, with warmer, fresh water from the Roanoke and Chowan Rivers overlying slightly cooler and brackish water from central Albemarle Sound (Figure 4). The water column across transect "B" was comprised of brackish water of fairly uniform consistency in salinity, temperature, and dissolved oxygen. These data indicated good vertical mixing of the water column in central Albemarle Sound (Figure 5). Vertical stratification of the water column was apparent near the bottom in the deeper areas (Stations 2C-5C) of eastern Albemarle Sound (Figure 6). Most of the water column was brackish water (5 o/oo) overlying a wedge of saltier water (8-11 o/oo). The shallow areas along the north (Station 1C) and south (Station 6C) shores of eastern Albemarle Sound were brackish (5 o/oo), well-mixed waters high in dissolved oxygen (9 mg/l).

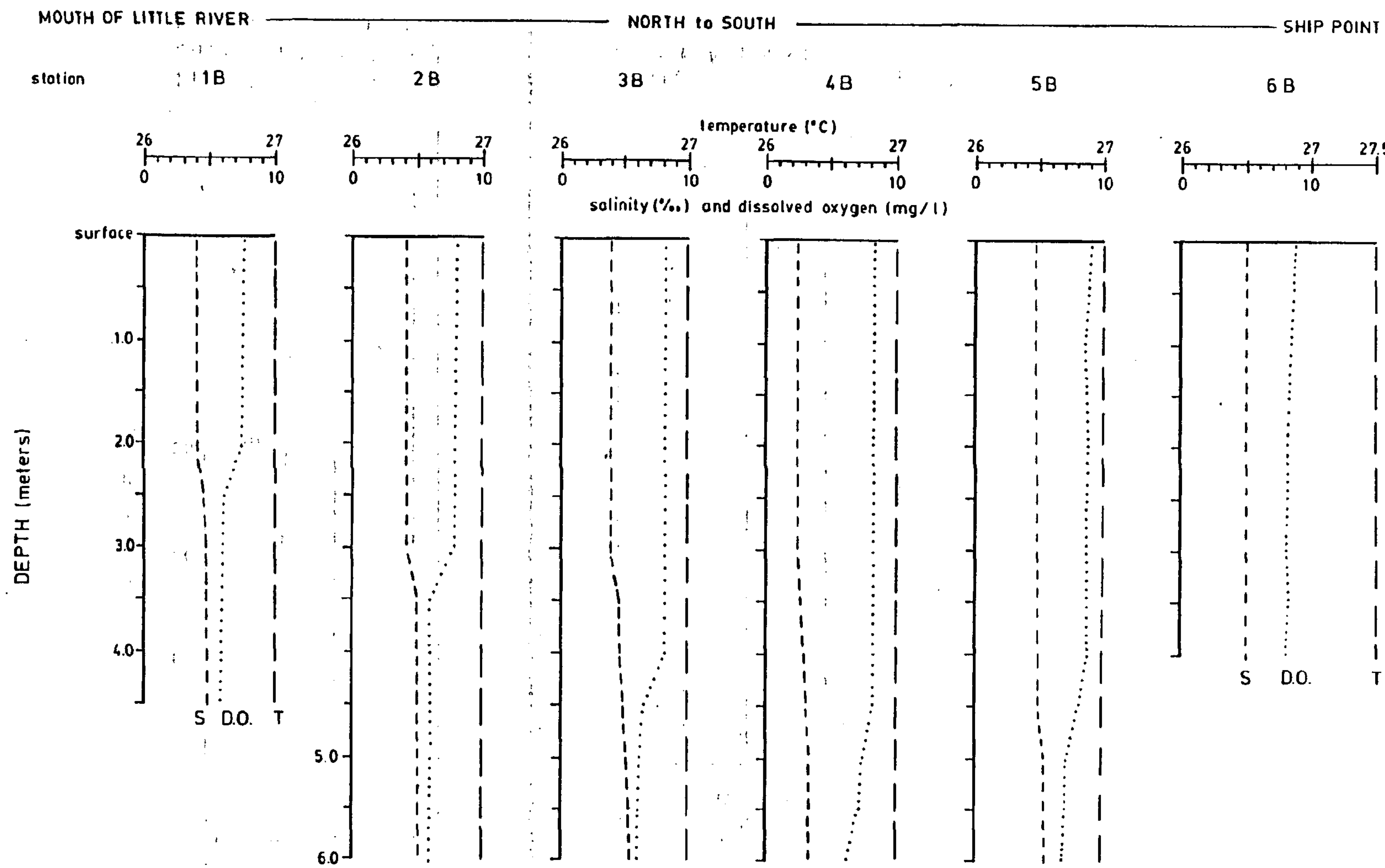

Figure 5. Profiles of water temperature (°C), dissolved oxygen (mg/l), and salinity (o/oo) collected in August 1985 from central Albemarle Sound (Transect B), North Carolina. Data provided by Wildlife Resources Commission, Division of Inland Fisheries.

Ichthyoplankton

SPECIES COMPOSITION. Larvae of fish species from both estuarine and freshwater habitats were collected in 1984 and 1985. Those larvae identified to species included striped bass, white perch (Morone americana), pirate perch (Aphredoderus sayanus), common carp (Cyprinus carpio), eastern mudminnow (Umbra pygmaea), yellow perch (Perca flavescens), Atlantic croaker (Micropogonias undulatus), longnose gar (Lepisosteus osseus), Atlantic needlefish (Strongylura marina), Atlantic menhaden (Brevoortia tyrannus), brown bullhead (Ictalurus nebulosus), white catfish (Ictalurus catus), and hogchoker (Trinectes maculatus). Juvenile American eel (Anguilla rostrata) were also collected. Other larval fishes were present but were not identified to species: herring (Clupeidae sp.), Notropis sp., centrarchids, and darters (Percidae). Larvae of the white sucker (Catostomus commersoni) were caught in the lower Roanoke River only in 1984.

A total of 2829 fish identified as striped bass were caught in ichthyoplankton nets in 1984, with the greatest concentration of larvae ($3/m^3$) at Station 10 on 23 May. Striped bass larvae were more abundant in 1985. A total of 3217 striped bass larvae were collected; greatest numbers ($7.7/m^3$) of larvae with yolk were found at Station 6 on 12 May. Striped bass in several stages of development were found throughout the study area.

DISTRIBUTION OF STRIPED BASS EGGS. In 1984 striped bass eggs comprised 2.9% of the total catch of striped bass. Eggs were present at Stations 1-6 just after sampling was initiated, and remained in samples through 31 May (Table 4). The most downstream point in the delta for occurrence of striped bass eggs was Station 12 on 22-23 May. Egg abundance (Figure 7) was negatively correlated with sampling date (r=-0.702) and river flow (Figure 8) lagged by three days (FLOWL3, r=-0.685)(Table 5). Julian date and river flow, lagged by three days, explained 60% of the variability in average egg abundance (n=11; df=9; R^2=0.60; P=0.025) in the study area for 1984 (Table 6).

Striped bass eggs were not found at any of the sampling locations in 1985.

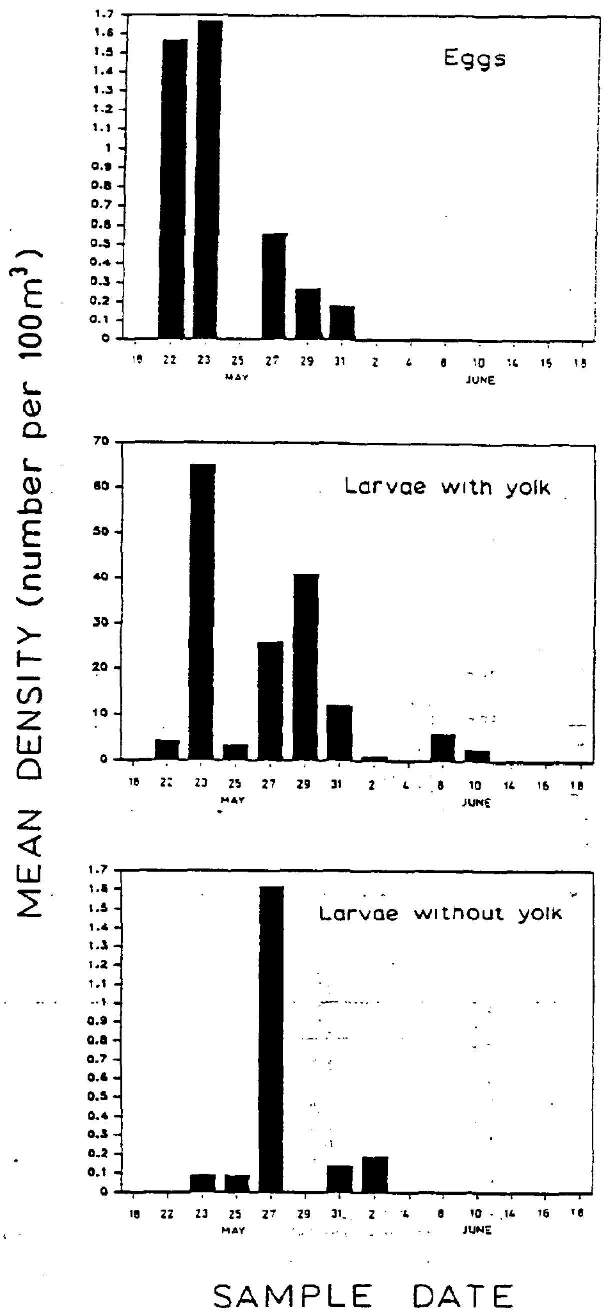

Figure 7. Relationship of sampling date to mean density (number/100 m³) of striped bass eggs, larvae with yolk (Stage 1), and larvae without yolk (Stage 2) present in the study area (Stations 1-18) in 1984.

Table 5. Results of Pearson product-moment correlation analyses for average densities of several striped bass life stages and zooplankton present in the Roanoke sampling area (Stations 1-18) and their relationships to sampling date (JULDATE) and various flow configurations (cfs) of the Roanoke River in 1984 (data from USGS). Descriptions of independent variables in Table 2. Numbers given are Pearson correlation coefficients (r).

Independent variable	Striped bass				Zooplankton			
	n	Eggs	larvae, yolk	larvae, no yolk	n	All	Clado-cerans	Cope-pods
JULDATE	11	-0.702	-0.515	-0.251	14	0.163	-0.409	0.481
FLOW0	11	-0.026	-0.374	-0.492	14	0.276	0.383	0.078
FLOWL1	11	0.161	-0.107	-0.298	14	0.100	0.381	-0.041
FLOWL2	11	-0.284	-0.184	-0.336	14	-0.016	0.110	0.182
FLOWL3	11	-0.685	-0.643	-0.242	14	0.007	0.139	-0.061
FLOWL4	11	-0.498	-0.544	-0.160	14	0.204	0.134	-0.077
FLOWMA2	11	-0.045	-0.253	-0.500	14	0.270	0.425	0.094
FLOWMA2L1	11	0.016	-0.215	-0.367	14	-0.031	0.367	0.017
FLOWMA2L2	11	-0.370	-0.356	-0.274	14	-0.034	0.219	0.074
FLOWMA2L3	11	-0.626	-0.576	-0.236	14	0.048	0.009	0.017
FLOWMA3	11	-0.051	-0.195	-0.485	14	0.262	0.432	0.098

DISTRIBUTION OF STAGE 1 LARVAE. In 1984, larvae with yolk (Stage 1) comprised 96% of the striped bass caught and were present in the study area from 22 May until 10 June (Table 7). Stage 1 larvae were most abundant in the lower river (stations 1-4) and delta (stations 5-12). Mean study area density of Stage 1 larvae was negatively correlated with sampling date (r=-0.515) and FLOWL3 (r=-0.643). Prediction of larval abundance using sampling date and flow in the multiple linear regression (Table 6) was significant at P<0.10).

In 1985, stage 1 larvae comprised only 67% of larval striped bass collected. Stage 1 larvae were present in the study area from initiation of sampling (26 April) until 6 June. No stage 1 larvae were present in samples collected on 10 June (Table 8). Peak abundance occurred on 12 May (Figure 9). Greatest densities throughout the study period occurred in the lower river (Stations 1-4) and upper delta (Stations 5-7). Correlation analysis indicated weak, but significant, correlations of Stage 1 larvae with STATION and TIME (Table 9). However, samples were collected in the same order on each sampling trip, which made it impossible to ascertain the relative importance of these two variables on striped bass density. Stepwise regression (SAS Institute 1982) selected STATION and copepod density as two factors predicting the abundance of Stage 1 larvae (P<0.001, n=170); however, the R^2 was quite low (0.113), suggesting that other factors not considered in the analysis were responsible for variability in the data (Table 10). The average density of Stage 1 larvae in the delta and western Sound (Stations 5-15) was not highly correlated with any of the variables considered (Table 11), and none met the 0.15 significance level for entry into a stepwise regression model (Table 12).

DISTRIBUTION OF STAGE 2 LARVAE. In 1984, Stage 2 larvae were limited in number (1.2% of total striped bass catch), and occurred at Stations 3 and 5 in the lower river early in the sampling season. Stage 2 larvae were last observed in samples from western Albemarle Sound on 2 June (Table 13). Correlations of stage 2 larval abundance with sampling date and river flow were not significant (P>0.10) due to the low numbers of larvae collected. An additional 298 striped bass larvae were found in zooplankton catches. No striped bass larvae without oil globules, and no juveniles, were collected in the study area in 1984.

Table 8. Distribution and abundance (number/100 m^3) of Stage 1 (with yolk) striped bass larvae in Roanoke River and western Albemarle Sound, North Carolina, in 1985. Asterisk (*) indicates no sample collected.

Stage 1	STATION																Total by Date	Avg. by Date
DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
4/26/85	*	*	*	*	*	3.74	23.95	2.21	0.00	11.22	0.00	2.20	0.00	0.00	0.00	*	43.32	4.33
4/28/85	*	*	*	*	*	28.60	5.80	0.00	2.56	0.00	0.00	0.00	2.02	0.00	0.00	*	38.98	3.90
4/30/85	*	*	*	*	*	5.17	3.70	0.00	22.76	14.90	3.06	53.75	0.00	0.00	2.09	*	105.43	10.54
5/2/85	*	*	*	*	*	6.55	16.35	0.00	0.96	6.45	1.58	0.97	0.00	0.00	0.00	*	32.86	3.29
5/4/85	90.77	20.71	7.91	1.05	6.10	55.58	14.91	5.89	15.90	0.00	0.00	0.93	0.00	0.00	0.00	*	219.75	14.65
5/6/85	76.27	40.03	35.79	19.41	95.04	23.05	21.30	5.79	3.81	0.00	8.32	0.00	0.00	0.00	0.00	*	328.81	21.92
5/8/85	69.90	115.01	66.83	4.55	5.30	250.83	307.23	0.00	0.00	0.00	0.80	0.00	8.88	0.00	0.00	*	829.23	55.28
5/10/85	73.46	141.30	33.87	270.94	31.11	91.30	34.15	93.34	76.21	0.00	12.05	0.00	3.09	1.59	5.54	*	812.95	54.20
5/12/85	23.75	20.75	76.78	149.51	173.02	352.28	694.26	41.15	173.01	0.00	16.74	0.00	3.43	9.24	23.85	*	1756.77	117.12
5/14/85	85.14	61.37	73.39	18.38	0.00	11.57	8.23	177.46	66.61	0.00	26.46	0.00	1.08	0.00	7.25	*	536.94	35.80
5/16/85	2.70	34.30	43.92	15.31	25.02	83.00	*	4.30	0.00	32.01	3.47	0.00	0.00	0.00	2.37	*	251.30	17.95
5/18/85	*	*	*	*	*	55.49	6.45	0.93	93.83	0.00	13.34	6.90	0.00	0.00	0.96	*	178.01	17.80
5/20/85	*	*	*	*	40.17	1.96	13.39	8.97	3.26	7.60	2.32	22.89	0.00	0.00	2.32	*	102.88	9.35
5/22/85	*	*	*	*	26.23	0.00	22.36	0.96	0.00	0.00	4.88	1.09	0.00	0.00	0.00	*	55.52	5.06
5/24/85	*	*	*	*	5.99	10.25	0.84	0.00	1.08	0.70	0.91	27.93	0.00	0.00	0.00	*	47.70	4.34
5/26/85	*	*	*	*	15.60	0.00	1.93	1.08	0.00	0.00	3.25	0.00	0.00	0.00	0.00	*	21.86	1.99
5/29/85	*	*	*	*	0.77	2.86	1.01	0.00	1.94	0.00	0.00	3.01	*	*	*	*	9.59	1.20
6/2/85	*	*	*	*	0.90	8.87	0.00	8.22	0.00	2.10	0.00	0.00	0.00	0.00	0.00	*	20.09	1.83
6/6/85	*	*	*	*	1.09	4.49	0.00	0.00	1.06	0.00	0.00	0.00	1.01	0.00	0.00	*	7.65	0.70
6/10/85	*	*	*	*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total by station	421.89	433.47	343.39	473.15	426.34	1000.59	1175.87	230.35	463.04	74.93	97.18	119.67	19.51	10.83	44.38	0.00		
Avg. by station	60.27	61.92	49.06	69.31	28.42	50.03	61.89	14.52	23.15	3.75	4.86	5.98	1.03	0.57	2.34	0.00		

Table 9. Results of Pearson product-moment correlation analysis for densities (number/100 m^3) of two striped bass life stages, their feeding habits, and their relationship to food density (number/m^3) and spatio-temporal variables in 1985. Numbers given are Pearson correlation coefficients (r). Descriptions of independent variables in Table 2.

Independent variable	Density				% of larvae with food			
	n	larvae, yolk	n	larvae, no yolk	n	larvae, yolk	n	larvae, no yolk
JULDATE	176	-0.009	176	-0.013	99	-0.291**	84	-0.502***
STATION	176	-0.298***	176	0.246***	99	0.144	84	0.278*
TIME	176	0.177*	176	0.144	99	-0.244*	84	-0.304**
CLADOCERA	171	-0.040	171	-0.038	95	0.249*	81	0.401***
COPEPODA	171	-0.119	171	-0.109	95	0.380***	81	0.369***

Significance level:
* P≤0.05
** P≤0.01
*** P≤0.001

Table 11. Results of Pearson product-moment correlation analysis for densities of two striped bass life stages, zooplankton, phytoplankton and spatio-temporal variables in 1985. Numbers given are Pearson correlation coefficents (r). NA= value not applicable.

Independent variable	n	Striped bass: larvae, yolk	Striped bass: larvae, no yolk	Zooplankton: all	Zooplankton: Bosmina	Zooplankton: Cladocera	Zooplankton: Copepoda-	Phytoplankton: wet wt. biomass	Phytoplankton: cell density
JULDATE	20	-0.198	-0.268	-0.715***	-0.725***	-0.684***	-0.594**	0.063	-0.660**
TEMP	20	-0.272	-0.324	-0.384+	-0.333	-0.323	-0.321	0.020	-0.578**
FLOWO	20	0.216	-0.055	-0.493*	-0.485*	-0.411+	-0.537*	-0.286	-0.073
FLOWL1	20	-0.188	-0.237	-0.323	-0.345	-0.299	-0.289	-0.107	-0.436+
FLOWL2	20	-0.078	-0.087	-0.133	-0.154	-0.170	-0.069	-0.093	-0.026
FLOWL3	20	-0.236	-0.009	-0.289	-0.183	-0.244	-0.329	0.238	-0.186
BOSM	20	-0.165	-0.191	0.893***	NA	0.870***	0.791***	-0.087	0.471*
CLAD	20	-0.116	-0.131	0.960***	0.870***	NA	0.703***	-0.058	0.606**
COPE	20	-0.333	-0.148	0.863***	0.791***	0.703***	NA	-0.347	0.209
TZO	20	-0.217	-0.145	NA	0.893***	0.960***	0.863***	-0.170	0.522*
PHYTOB	20	-0.261	-0.262	-0.170	-0.087	-0.058	-0.347	NA	-0.166
PHYTOD	20	0.253	-0.257	0.522*	-0.471*	0.607**	0.209	-0.167	NA

Significance level:
+ P<0.10
* P<0.05
** P<0.01
*** P<0.001

Table 12. continued.

Dependent variable	df	Variables Considered	Model Selected	B_i	Regression coefficient	R^2	Prob>F	C_p
Phytoplankton:								
wet weight biomass	19	JULDATE, TEMP, FLOWO, FLOWL1, FLOWL2, FLOWL3	none met the 0.15 significance level for entry into model					
cell density	19	JULDATE, TEMP, FLOWO, FLOWL1, FLOWL2, FLOWL3		b_0	27732.550	0.531	0.002	2.202
			JULDATE	b_1	-194.609***			
			FLOWO	b_2	0.503+			

Significance level:
+ P<0.10
* P<0.05
** P<0.01
*** P<0.001

Stage 2 larvae represented 33% of the striped bass collected in 1985. Stage 2 larvae occurred infrequently in samples collected at the end of April, but increased in abundance through mid-May (Table 14). Stage 2 larvae were collected through 10 June 1985, but were not abundant after 22 May. Greatest densities of Stage 2 larvae were located in the lower river and upper delta (Stations 4-9). Correlation analysis confirmed a significant correlation of Stage 2 larval density with STATION (Table 9). Average density of Stage 1 larvae in the study area was the best predictor of average Stage 2 densities (R^2=0.40, n=20, P=0.002) as determined by Stepwise procedure (Table 12), suggesting that striped bass larvae remained in the lower Roanoke River and delta to develop and grow in 1985.

MOVEMENT, GROWTH, AND DEVELOPMENT. Striped bass larvae were subdivided into 15 size class groupings of 0.5-mm intervals to estimate movement, growth and development within the study area in 1985. The number of larvae falling into each size class for any given station and date were converted to percentages to allow comparison of relative frequency of occurrence by date. Size of larvae increased with distance from the spawning ground. Larvae collected at Station 1 (Williamston) ranged in size from 3.5-6.5 mm TL (Table 15). Most larvae were 5.0-6.0 mm TL, suggesting that river flow transported the larvae quickly through the Williamston area. Fish at Station 2 were slightly larger than those caught upstream, ranging from 4.0 mm to 7.0 mm TL. A second cohort of smaller striped bass moved through this region on 10 May 1985 (Table 16). The second cohort was observed moving through Station 3 (Jamesville) on 12 May (Table 17), and through Station 4 approximately the same time (Table 18). Larval striped bass caught at upper delta stations (Stations 5-7) were all between 5.0 and 7.0 mm TL. Passage of smaller-sized cohorts was evident on the following dates: 26 April, 6 May, 20 May, and 2 June (Tables 19, 20, 21). Larvae in the lower delta (Stations 8-12) ranged from 5.0 mm TL to over 10.0 mm TL, suggesting that larvae remained in the lower delta area to feed and grow (Tables 22, 23, 24, 25, 26). The largest striped bass larvae were caught in Batchelor Bay (Stations 13-15), most of which had absorbed the yolk and oil. Sizes ranged from 5.0-24.0 mm TL (Tables 27, 28, 29). Few larvae were caught in

Table 15. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 1. Asterisk (*) indicates no sample collected.

Date	n	Size Class (mm) 3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/30	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/04	62	2	11	16	27	16	26	2	0	0	0	0	0	0	0	0	100
5/06	54	0	0	0	2	15	81	2	0	0	0	0	0	0	0	0	100
5/08	46	0	2	4	11	22	61	0	0	0	0	0	0	0	0	0	100
5/10	56	0	0	0	43	52	5	0	0	0	0	0	0	0	0	0	100
5/12	19	0	0	0	47	53	0	0	0	0	0	0	0	0	0	0	100
5/14	52	0	0	0	15	81	4	0	0	0	0	0	0	0	0	0	100
5/16	3	0	0	0	67	33	0	0	0	0	0	0	0	0	0	0	100
5/18	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/20	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/22	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/29	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/06	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/10	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 17. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 3. Asterisk (*) indicates no sample collected.

Date	n	Size Class (mm) 3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/30	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/04	28	0	0	0	0	0	36	46	18	0	0	0	0	0	0	0	100
5/06	35	0	0	3	0	3	69	23	3	0	0	0	0	0	0	0	100
5/08	48	0	0	0	0	2	63	35	0	0	0	0	0	0	0	0	100
5/10	37	0	0	0	0	14	78	8	0	0	0	0	0	0	0	0	100
5/12	23	0	0	0	22	57	22	0	0	0	0	0	0	0	0	0	100
5/14	40	0	0	0	0	3	93	5	0	0	0	0	0	0	0	0	100
5/16	34	0	0	0	3	0	79	18	0	0	0	0	0	0	0	0	100
5/18	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/20	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/22	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/29	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/06	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/10	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 19. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 5. Asterisk (*) indicates no sample collected.

		Size Class (mm)															
Date	n	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/30	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/04	8	0	0	0	0	0	25	38	38	0	0	0	0	0	0	0	100
5/06	123	0	0	0	0	4	66	28	2	0	0	0	0	0	0	0	100
5/08	67	0	0	0	0	0	28	58	13	0	0	0	0	0	0	0	100
5/10	33	0	0	0	0	3	76	18	3	0	0	0	0	0	0	0	100
5/12	96	0	0	0	2	2	69	25	2	0	0	0	0	0	0	0	100
5/14	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/16	65	0	0	0	0	0	88	11	2	0	0	0	0	0	0	0	100
5/18	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/20	38	0	0	0	8	32	61	0	0	0	0	0	0	0	0	0	100
5/22	46	0	0	0	0	4	87	9	0	0	0	0	0	0	0	0	100
5/24	9	0	0	0	0	0	89	0	11	0	0	0	0	0	0	0	100
5/26	15	0	0	0	0	0	80	20	0	0	0	0	0	0	0	0	100
5/29	1	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100
6/02	1	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
6/06	1	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	100
6/10	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 21. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 7. Asterisk (*) indicates no sample collected.

Date	n	Size Class (mm) 3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	16	0	0	0	6	19	63	13	0	0	0	0	0	0	0	0	100
4/28	5	0	0	0	0	0	20	60	20	0	0	0	0	0	0	0	100
4/30	11	0	0	0	0	0	91	9	0	0	0	0	0	0	0	0	100
5/02	25	0	0	0	0	8	52	36	4	0	0	0	0	0	0	0	100
5/04	43	0	0	0	0	19	65	16	0	0	0	0	0	0	0	0	100
5/06	26	0	0	0	0	0	50	38	12	0	0	0	0	0	0	0	100
5/08	152	0	0	0	1	7	63	26	3	0	0	0	0	0	0	0	100
5/10	47	0	0	0	0	32	60	9	0	0	0	0	0	0	0	0	100
5/12	97	0	0	0	1	7	78	12	1	0	0	0	0	0	0	0	100
5/14	17	0	0	0	0	6	88	6	0	0	0	0	0	0	0	0	100
5/16	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/18	28	0	0	0	0	32	68	0	0	0	0	0	0	0	0	0	100
5/20	24	0	0	0	4	4	83	8	0	0	0	0	0	0	0	0	100
5/22	60	0	0	0	0	15	85	0	0	0	0	0	0	0	0	0	100
5/24	1	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100
5/26	2	0	0	0	0	0	50	50	0	0	0	0	0	0	0	0	100
5/29	3	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
6/02	2	0	0	0	0	50	50	0	0	0	0	0	0	0	0	0	100
6/06	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/10	2	0	0	0	50	50	0	0	0	0	0	0	0	0	0	0	100

Table 23. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 9. Asterisk (*) indicates no sample collected.

Date	n	Size Class (mm) 3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	7	0	0	0	0	14	29	29	14	14	0	0	0	0	0	0	100
4/30	22	0	0	0	0	0	50	23	23	5	0	0	0	0	0	0	100
5/02	7	0	0	0	0	0	14	29	29	14	0	14	0	0	0	0	100
5/04	19	0	0	0	0	5	63	21	5	0	0	5	0	0	0	0	100
5/06	8	0	0	0	0	0	88	13	0	0	0	0	0	0	0	0	100
5/08	16	0	0	0	6	6	88	0	0	0	0	0	0	0	0	0	100
5/10	72	0	0	0	1	4	57	38	0	0	0	0	0	0	0	0	100
5/12	137	0	0	0	0	1	81	17	1	0	0	0	0	0	0	0	100
5/14	100	0	0	0	0	1	79	16	4	0	0	0	0	0	0	0	100
5/16	4	0	0	0	0	25	75	0	0	0	0	0	0	0	0	0	100
5/18	56	0	0	0	2	14	82	2	0	0	0	0	0	0	0	0	100
5/20	3	0	0	0	0	0	67	33	0	0	0	0	0	0	0	0	100
5/22	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/24	2	0	0	0	0	0	50	0	0	0	0	0	0	0	0	50	100
5/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/29	2	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	100
6/02	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/06	1	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	100
6/10	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 25. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 11. Asterisk (*) indicates no sample collected.

Date	n	Size Class (mm) 3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/30	3	0	0	0	0	0	0	0	33	33	33	0	0	0	0	0	100
5/02	2	0	0	0	0	0	0	0	50	0	50	0	0	0	0	0	100
5/04	1	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	100
5/06	15	0	0	0	0	7	73	7	7	0	0	0	7	0	0	0	100
5/08	1	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100
5/10	12	0	0	0	0	33	67	0	0	0	0	0	0	0	0	0	100
5/12	18	0	0	0	6	0	83	11	0	0	0	0	0	0	0	0	100
5/14	27	0	0	0	4	0	85	7	0	0	0	0	0	0	0	4	100
5/16	6	0	0	0	0	17	83	0	0	0	0	0	0	0	0	0	100
5/18	16	0	0	0	0	13	63	13	0	0	0	0	0	0	0	13	100
5/20	2	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
5/22	5	0	0	0	0	0	0	40	60	0	0	0	0	0	0	0	100
5/24	1	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
5/26	3	0	0	0	0	0	67	33	0	0	0	0	0	0	0	0	100
5/29	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/02	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/06	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/10	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 27. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 13. Asterisk (*) indicates no sample collected.

		Size Class (mm)															
Date	n	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	14	0	0	0	0	0	7	21	64	7	0	0	0	0	0	0	100
4/30	1	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	100
5/02	3	0	0	0	0	0	0	33	33	0	33	0	0	0	0	0	100
5/04	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/06	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/08	9	0	0	0	0	0	44	56	0	0	0	0	0	0	0	0	100
5/10	4	0	0	0	25	0	25	25	25	0	0	0	0	0	0	0	100
5/12	5	0	0	0	0	0	60	40	0	0	0	0	0	0	0	0	100
5/14	13	0	0	0	15	0	85	0	0	0	0	0	0	0	0	0	100
5/16	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/18	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100
5/20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100
5/22	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/24	1	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
5/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/29	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/02	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/06	1	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
6/10	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 29. Relative frequency (%) of larval striped bass size classes (mm TL) collected from 26 April to 10 June 1985 at Station 15. Asterisk (*) indicates no sample collected.

Date	n	Size Class (mm) 3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	>10.0	Tot. %
4/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/28	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4/30	1	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	100
5/02	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/04	2	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100
5/06	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/08	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/10	7	0	0	0	0	29	71	0	0	0	0	0	0	0	0	0	100
5/12	41	0	0	0	0	5	83	12	0	0	0	0	0	0	0	0	100
5/14	7	0	0	0	0	29	71	0	0	0	0	0	0	0	0	0	100
5/16	6	0	0	0	17	0	67	0	0	0	0	0	0	0	0	17	100
5/18	1	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
5/20	7	0	0	0	0	0	14	0	0	0	0	0	0	0	0	86	100
5/22	2	0	0	0	0	0	50	0	0	0	0	0	0	0	0	50	100
5/24	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/26	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5/29	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/02	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/06	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6/10	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 30. Stomach contents of striped bass larvae collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1984. Larval count = number in feeding condition; * = value not applicable.

Date (m/d/y)	Station	Larval count	Species	Number examined	Stage	Fish length (TL, mm) Mean	Min.	Max.	% empty gut	% with food	Food item
5/23/84	3	1	MOSA	1	OIL	5.0	*	*	100	0	
5/25/84	7	1	MOSA	1	OIL	6.0	*	*	100	0	
5/25/84	13	1	MOSA	1	OIL	6.0	*	*	100	0	
5/25/84	14	1	MOSA	1	YOLK	6.0	*	*	100	0	
5/27/84	13	1	MOSA	1	OIL	6.0	*	*	100	0	
5/29/84	7	2	MOSA	1	OIL	5.5	*	*	100	0	
5/29/84	9	1	MOSA	1	OIL	5.5	*	*	100	0	
5/29/84	14	1	MOSA	1	OIL	5.0	*	*	0	100	1 beetle larva
5/29/84	15	2	MOSA	3	OIL	5.3	5.0	6.0	67	33	2 Daphnia
5/31/84	11	1	MOSA	1	OIL	6.0	*	*	100	0	
5/31/84	14	11	MOSA	8	OIL	6.0	5.5	6.5	100	0	
6/02/84	9	1	MOSA	1	OIL	6.0	*	*	100	0	
6/02/84	13	1	MOSA	1	OIL	5.0	*	*	100	0	
6/02/84	14	1	MOSA	1	YOLK	5.5	*	*	100	0	
6/08/84	14	1	MOSA	1	YOLK	5.5	*	*	0	100	1 Daphnia
6/08/84	15	2	MOSA	2	YOLK	5.2	5.5	5.0	100	0	
6/10/84	14	1	MOSA	1	OIL	6.5	*	*	100	0	

Table 32. Stomach contents of Stage 1 (with yolk) striped bass larvae collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1985. n = number examined; * = value not applicable.

			Fish length				Food type						
							Copepoda		Cladocera				
Date	Station	n	Mean	Min	Max	% with food	Copepodite	Adult	Bosmina	Alonella	Daphnia	Chydorus	Other
4/26/85	6	2	5.5	5.5	5.5	0							
	7	15	5.9	5.0	6.5	60	0.0	0.0	1.4				
	8	1	6.5	*	*	100	0.0	0.0	1.0				
	10	6	6.3	6.0	7.0	100	0.3	0.0	3.3				
	12	1	7.0	*	*	100	0.0	0.0	3.0				
4/28/85	6	22	6.3	5.5	7.0	99	0.1	0.0	3.0				
	7	5	6.5	6.0	7.0	20	0.0	0.0	4.0				
	9	2	6.7	6.5	7.0	50	0.0	0.0	3.0				
	12	2	6.5	6.0	7.0	100	1.0	0.0	5.0				
	13	3	6.8	6.5	7.0	100	3.3	0.0	1.0				
4/30/85	6	2	6.0	5.0	7.0	100	0.0	0.0	2.5				
	7	4	6.1	6.0	6.5	100	0.2	0.0	1.0				
	9	21	6.5	6.0	7.5	86	0.3	0.0	6.4				
	10	9	6.6	6.0	7.5	100	0.4	0.0	5.7				
	11	3	7.5	7.0	8.0	100	0.3	1.3	4.0				
	12	45	6.9	6.0	7.5	100	2.3	0.0	3.0	0.1	0.1	0.2	
	15	2	7.0	7.0	7.0	100	3.0	0.0	3.0				
5/02/85	6	6	6.3	6.0	7.0	83	0.4	0.0	4.6				
	7	17	6.3	5.5	7.0	94	0.2	0.0	1.8				
	9	1	6.0	*	*	0							
	11	2	7.5	7.0	8.0	100	1.5	0.0	3.5				
	12	1	6	*	*	0							
5/04/85	4	7	6.5	6.0	7.0	57	0.0	0.0	3.8				
	5	6	6.5	6.0	7.0	67	0.0	0.0	1.6				
	6	28	6.4	6.0	9.5	75	0.1	0.0	3.0				
	7	19	6.0	5.5	6.5	63	0.0	0.0	2.9				
	8	6	6.8	6.0	8.0	83	1.4	0.0	0.8				
	9	15	6.3	5.5	8.5	67	0.5	0.0	1.4				
	12	1	6.0	*	*	100	0.0	0.0	6.0				
5/06/85	4	14	6.4	6.0	7.0	14	0.0	0.0	2.0				
	5	32	6.2	6.0	6.5	53	0.1	0.0	1.4		0.1		
	6	29	6.0	5.0	7.0	72	0.2	0.0	2.3				<0.1 ostracod
	7	24	6.3	6.0	7.0	71	0.0	0.0	2.8	0.1			<0.1 unident. cladoceran; detritus
	8	5	7.3	7.0	8.0	100	0.2	0.0	2.8				
	9	4	6.0	6.0	6.0	25	0.0	0.0	0.0				unidentified
	11	11	6.4	6.0	9.0	91	0.7	0.0	1.9				
5/08/85	4	4	6.0	6.0	6.0	25	0.0	0.0	1.0				
	5	4	6.5	6.0	7.0	0							
	6	116	6.3	6.0	6.5	22	0.0	0.0	2.1				

Table 32. (cont'd)

Date	Station	n	Fish length Mean	Fish length Min	Fish length Max	% with food	Copepoda Copepodite	Copepoda Adult	Cladocera Bosmina	Cladocera Alonella	Cladocera Daphnia	Cladocera Chydorus	Other
	10	6	5.9	5.5	6.0	50	0.0	0.0	1.3				0.3 rotifer
	11	2	6.0	6.0	6.0	50	0.0	0.0	2.0				
	12	13	6.1	6.0	6.5	85	0.0	0.0	2.5				
	15	1	6	*	*	100	0.0	0.0	1.0				
5/22/85	5	10	5.9	5.5	6.0	90	0.0	0.0	2.7				
	7	10	5.9	5.5	6.0	70	0.0	0.0	1.8				
	8	1	6.0	*	*	100	0.0	0.0	1.0				
	11	5	6.7	6.5	7.0	100	0.0	0.0	3.8				
	12	1	5.0	*	*	100	0.0	0.0	3.0				
5/24/85	5	7	6.1	6.0	7.0	86	0.0	0.0	2.8				
	6	11	6.3	6.0	7.0	100	0.0	0.0	5.6				
	7	1	6.5	*	*	0							
	9	1	6.0	*	*	100	0.0	0.0	1.0				1.0 ostracod
	11	1	6.0	*	*	100	0.0	0.0	1.0				
	12	20	6.0	6.0	6.5	80	0.8	0.0	1.2		0.1		0.9 copepod eggs
5/26/85	5	11	6.1	6.0	6.5	73	0.2	0.0	0.9				0.7 copepod eggs
	7	2	6.2	6.0	6.5	50	0.0	0.0	1.5				
	8	1	7.0	*	*	100	0.0	0.0	1.0				
	11	3	6.2	6.0	6.5	100	0.0	0.0	3.0				
5/29/85	5	1	6.5	*	*	0							
	6	3	5.8	5.5	6.0	0							
	7	1	6.0	*	*	0							
	9	2	5.5	5.5	5.5	0							
	12	2	5.5	5.5	5.5	0							
6/02/85	5	1	6.0	*	*	0							
	6	8	5.7	5.5	6.0	0							
	8	7	6.0	5.5	6.5	43	0.0	0.0	0.7				0.3 insect
	10	2	6.0	6.0	6.0	0							
6/06/85	5	1	5.5	*	*	0							
	6	4	5.9	5.5	6.0	0							
	9	1	5.5	*	*	100	0.0	0.0	2.0				
	13	1	6.0	*	*	0							

Table 33. (cont'd)

							Food type						
							Copepoda		Cladocera				
Date	Sta-tion	n	Fish length Mean	Min	Max	% with food	Cope-podite	Adult	Bos-mina	Alon-ella	Daph-nia	Chy-dorus	Other
	5	10	6.2	6.0	6.5	60	0.0		2.5				
	6	2	6.2	6.0	6.5	50	0.0		4.0				
	7	1	7.0	*	*	100	0.0		1.0				
	8	1	11.0	*	*	100	1.0		0.0				
	9	4	6.1	6.0	6.5	25	0.0		0.0				1.0 ostracod
	11	5	4.9	5.5	6.0	100	0.8		1.4				detritus
	14	1	7.5	*	*	100	12.0		0.0				
5/08/85	2	1	7.0	*	*	0							
	3	3	6.2	6.0	6.5	0							
	4	96	6.4	6.0	7.0	12	0.0		1.3				
	5	20	6.4	6.0	7.0	30	0.0		1.2				
	6	6	6.1	6.0	6.5	33	0.0		1.0				
	7	16	5.7	5.5	6.5	31	0.0		2.2				
	8	2	7.5	6.0	9.0	100	4.5		0.0				
	9	16	5.9	5.0	6.0	75	0.0		2.5				
	12	6	6.2	6.0	6.5	83	1.8		0.6		0.2		
5/10/85	3	1	6.0	*	*	0							
	4	1	6.0	*	*	0							
	6	20	6.1	6.0	7.0	10	0.0		1.0				
	7	8	5.8	5.5	6.5	12	0.0		1.0				
	8	2	6.5	6.0	7.0	50	2.0		0.0				
	11	3	5.7	5.0	6.0	33	2.0		0.0				
5/12/85	5	12	6.2	6.0	7.0	0							
	6	22	5.9	5.0	6.0	0							
	7	8	5.8	5.5	6.5	0							
	9	20	6.0	5.5	6.5	15	0.0		1.3				
	13	1	6.0	*	*	0							
	14	2	6.0	6.0	6.0	100	2.0		0.0				
	15	17	6.0	6.0	6.5	41	1.0		0.3				
5/14/85	6	12	5.8	5.0	6.0	8	0.0		1.0				
	7	8	6.1	6.0	6.5	0							
	8	6	6.2	6.0	7.0	83	0.4		2.4				
	9	20	6.0	6.0	6.5	15	0.0		1.3				
	13	12	5.8	5.0	6.0	67	0.3		0.9				
	14	2	6.0	6.0	6.0	100	0.0		1.0				
	15	1	6.0	*	*	100	0.0		1.0				
5/16/85	4	8	6.1	6.0	6.5	0							
	5	20	6.0	6.0	6.5	0							detritus

were the primary food items. Larvae ranging in size from 15.0-23.5 mm TL consumed larger organisms than striped bass larvae still possessing oil or yolk. Food items included both copepodid and adult copepods, Daphnia, chironomids, amphipods, clams, and fish including several identified as Morone (Table 34). No smaller cladocerans such as Bosmina, Alonella, or Chydorus were found in stomachs of the larger larvae.

PARASITISM OF LARVAE. Internal parasites were found in 64 (2%) of 3217 Morone larvae examined. These parasites apparently were of two types (Figure 10): (I) a tear-drop shaped organism of 0.2-0.3 mm diameter (across the short axis), which was connected to the gut by a filament; and (II) a spherical type organism of 0.5-0.8 mm diameter.

The Type I parasite, tentatively identified as a protocephalid larva (Cestoda:Proteocephalidae), was only found attached to the intestine and stomach within the gut cavity and was less abundant than the Type II parasite. The Type II parasite (unidentified) was found in three locations: 1) epithelium of the gut cavity, 2) near the anus, and 3) anterior to the heart. The primary location was within the gut cavity.

There was no evidence of a particular size of Morone larvae being more susceptible than others to parasitism. Lengths of parasitized fish ranged from 5.0 to 24.0 mm TL ($\bar{x}$=10.7). This was not tested statistically since not all fish larvae were examined closely for parasites; only those larvae examined for gut contents were checked for parasites. In addition, the population of larvae subject to collection were the smaller larvae, which have less ability to avoid capture.

Samples from all stations, except 1-4, contained parasitized larvae. Stations 8, 11, and 13 had seven or more parasitized larvae; no other station had more than four. It may be coincidence that the three stations with the highest occurrence of parasitized fish larvae were in close proximity to each other; however, these stations also exhibited the highest densities of other fish species, thereby perhaps enhancing parasite abundance.

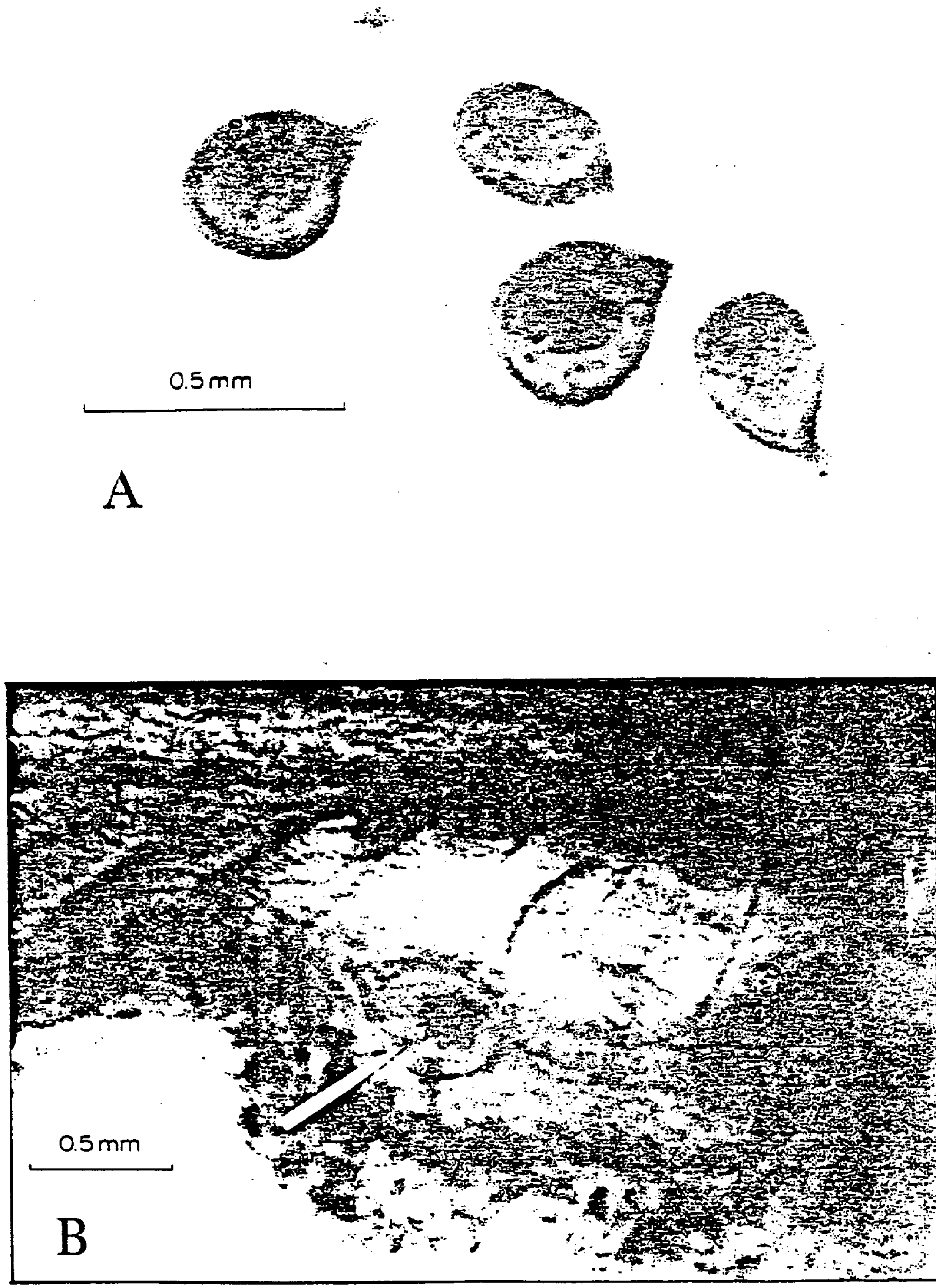

Figure 10. Parasites found in Morone larvae. (A) Type I parasite (protocephalid larva) in gut cavity; (B) Type II parasite (unidentified) in epithelium, as indicated by the arrow.

Table 35. Taxonomic relationship of zooplankton organism groupings (after Borror and DeLong 1964).

- Phylum Nematoda (nematode worms)
- Phylum Annelida
  - Class Polychaeta (polychaete worms)
  - Class Oligochaeta
    - Order Plesiopora plesiothecata
      - Family Naididae
        - *Stylaria lacustris*
        - *Dero* sp.
      - Family Aeolosomatidae
        - *Aeolosoma leidyi*
- Phylum Arthropoda
  - Class Arachnida (spiders)
  - Class Crustacea
    - Subclass Malacostraca
      - Superorder Pericarida
        - Order Amphipoda
          - Suborder Gammaridea
            - *Gammarus* sp. (gammarid; amphipod)
        - Order Isopoda (isopods)
      - Superorder Eucarida
        - Order Decapoda
          - Family Paguridae (hermit crabs)
          - Family Palaemonidae (grass shrimps)
    - Subclass Branchiopoda
      - Order Diplostraca
        - Suborder Cladocera
          - Family Leptodoridae
            - *Leptodora kindti*
          - Family Bosminidae
            - *Bosmina* sp.
          - Faimly Daphnidae
            - *Daphnia* sp.
          - Other cladocerans
    - Subclass Ostracoda (mussel or seed shrimps)
    - Subclass Copepoda
      - Order Eucopepoda
        - Suborder Calanoida (adult calanoid copepods)
        - Suborder Cyclopoida (adult cyclopoid copepods)
        - Suborder Harpacticoida (adult harpacticoid copepods)
  - Class Insecta
    - Subclass Endoptergota
      - Order Coleoptera
        - Family Gyrinidae (whirligig beetles)
      - Order Diptera
        - Family Culicidae
          - Subfamily Culicinae (mosquitos)
          - Subfamily Chironominae
            - *Chaoborus* sp. (phantom midge)
            - Other chironomids
        - Family Heleidae (biting midges)
    - Subclass Apterygota
      - Order Collembola (springtails)
      - Order Ephemeroptera
        - *Ephemerella* sp. (mayfly)
      - Order Odonata (dragonflies)
      - Order Plecoptera (stoneflies)
      - Order Trichoptera (caddisflies)
      - Order Neuroptera
        - Family Sisridae (Spongilla flies)
      - Order Hemiptera (true bugs)
    - Subclass Pterygota
      - Order Hymenoptera (wasps)
- Phylum Coelenterata
  - Class Hydrozoa
    - Order Hydroida
      - Family Hydridae
      - *Hydra* sp. (hydras)
- Phylum Molluska
  - Class Bivalvia
    - Family Mactridae
      - *Rangia cuneata* (freshwater clam)
  - Class Gastropoda (snails)

Table 37. Densities (number/m^3) of zooplankton collected in lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1984. Station numbers as in Figure 1.

DATE	STATION 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Date Average
5/18/84	*	*	*	*	803.7	691.7	594.1	1165.8	640.9	1190.6	557.1	829.3	412.7	355.1	1277.0	*	*	*	774.4
5/22/84	400.5	499.6	447.5	352.0	334.5	245.5	350.1	679.1	580.1	767.9	336.7	850.9	538.4	312.7	401.5	*	*	*	476.5
5/23/84	144.1	164.1	330.9	305.3	216.1	549.4	452.3	509.9	1246.9	463.4	264.2	408.2	359.7	242.4	354.8	*	*	*	401.2
5/25/84	310.1	245.1	420.8	372.4	517.8	286.1	593.6	713.2	517.8	918.3	785.9	451.8	627.2	318.0	221.6	*	*	*	487.0
5/27/84	372.9	472.9	363.9	566.9	605.1	942.3	541.8	534.8	1229.4	443.9	548.4	358.9	501.0	*	201.4	*	*	*	548.9
5/29/84	370.6	649.8	523.6	719.1	924.1	965.3	426.6	1110.6	515.9	249.5	641.2	169.4	992.8	275.2	298.2	*	*	*	622.1
5/31/84	149.7	144.4	303.6	454.9	456.3	487.2	536.6	784.9	4119.3	736.8	2973.7	505.8	390.2	487.1	316.9	*	*	*	856.5
6/2/84	159.3	116.7	172.5	312.5	310.7	411.1	386.2	1151.3	301.4	521.8	2234.8	92.0	1256.7	940.1	405.5	*	*	*	583.2
6/4/84	*	*	*	*	824.8	244.4	244.4	433.9	995.9	244.7	397.3	255.9	305.7	623.8	425.3	*	*	*	454.2
6/8/84	*	*	*	*	1390.8	521.5	368.7	705.3	1377.8	435.3	561.8	189.2	830.1	486.1	296.7	*	*	*	651.2
6/10/84	*	*	*	*	792.2	536.6	231.0	330.2	993.4	165.0	485.3	199.4	591.8	819.0	582.2	*	*	*	525.1
6/14/84	*	*	*	*	*	*	*	604.8	954.7	347.1	757.0	462.7	499.4	407.4	397.1	774.2	140.4	381.9	473.1
6/16/84	*	*	*	*	*	*	*	611.1	1107.9	209.4	543.6	270.2	532.3	416.9	477.7	1124.2	563.3	363.7	491.2
6/18/84	*	*	*	*	*	*	*	547.4	1150.9	195.9	1631.2	385.4	655.4	425.3	353.4	821.9	489.8	364.6	565.2

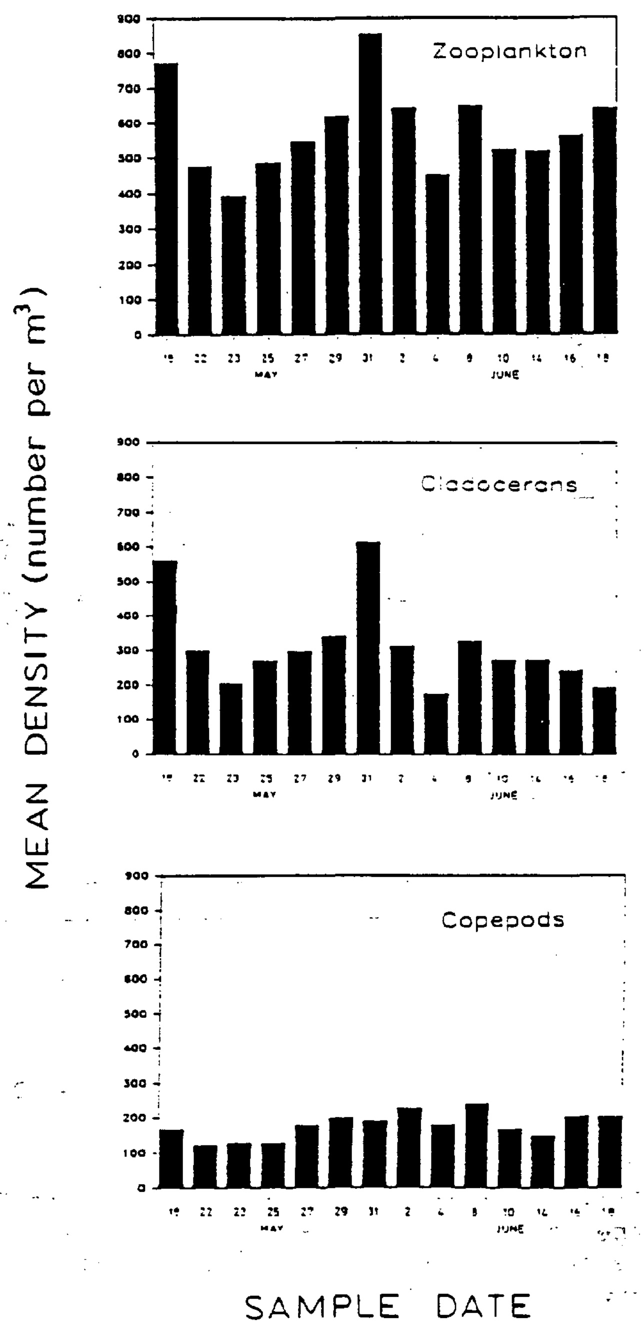

Figure 11. Relationship of sampling date to mean density (number/m^3) of total zooplankton, cladocerans (excluding *Leptodora*), and copepods present in the sampling area (Stations 1-18) in 1984.

Table 39. Mean densities (number/m^3), by station, of zooplankton collected in lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1985. Station numbers as in Figure 1.

	STATION															
Organism grouping	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nematodes	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.2	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Stylaria	0.0	0.0	0.0	0.0	0.0	0.3	0.2	1.5	2.1	0.2	1.2	0.7	1.0	0.3	0.1	0.0
Aeolosoma	0.9	2.6	1.9	0.8	1.1	0.2	0.3	0.8	0.7	0.6	0.7	0.4	0.2	0.0	0.6	0.0
Arachnids	0.9	0.0	0.0	0.9	1.1	0.3	1.3	3.6	1.0	0.1	2.1	1.1	1.0	1.0	0.5	0.0
Gammarids	0.0	1.8	0.8	0.0	1.3	0.8	0.6	1.0	0.1	0.2	3.3	0.3	16.2	17.5	27.6	13.5
Leptodora	0.0	0.9	0.0	0.0	0.5	0.2	0.2	4.4	0.3	0.6	6.4	1.2	47.3	95.3	46.9	3.4
Bosmina	13.5	10.8	29.8	72.9	118.9	289.0	252.6	244.2	202.3	222.1	219.9	213.4	395.5	253.0	250.4	6.7
Daphnia	7.2	3.5	3.7	66.4	74.9	179.2	176.0	164.7	97.5	115.0	140.1	172.4	179.1	86.7	954.5	3.4
Other cladocerans	19.9	4.4	20.6	47.2	84.7	152.5	99.6	303.0	145.6	135.4	145.2	104.5	113.6	59.9	54.1	16.8
Ostracods	15.2	17.8	9.9	12.0	19.6	46.8	26.8	251.2	95.6	21.4	131.4	24.6	36.5	16.6	25.5	6.7
Calanoid copepod	4.6	7.9	7.8	8.9	67.8	70.1	38.9	261.7	53.6	97.6	147.7	50.6	178.4	99.2	98.8	16.8
Cycloploid copepod	7.2	1.7	19.9	39.3	172.0	281.9	249.6	1921.0	398.7	179.1	1046.1	294.0	793.0	477.7	404.4	87.6
Harpacticoid copepod	1.8	0.0	1.9	11.9	47.4	48.1	53.8	821.7	78.2	62.4	333.9	36.1	155.3	126.6	71.9	23.6
Isopods	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.1	0.2	0.0	0.0
Coleoptera larvae	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	6.4	0.7	0.0	0.1	0.0	1.8	1.6	0.0
Coleoptera adult	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.4	0.2	0.3	0.0	0.2	0.3	0.0
Mosquito larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mosquito adult	0.0	0.0	0.0	1.0	0.0	0.3	0.0	0.9	0.1	0.0	0.5	0.4	0.0	0.1	0.3	0.0
Phantom midge larvae	0.0	0.0	0.0	0.9	16.7	1.8	4.9	29.5	3.3	6.3	14.7	7.5	9.2	5.2	5.9	6.7
Phantom midge pupae	0.0	0.9	0.0	1.9	3.6	1.5	1.4	2.4	2.8	1.5	1.8	1.2	1.8	0.4	0.4	0.0
Chironomid larvae	0.9	0.9	0.9	1.9	4.8	3.9	2.3	7.0	5.6	1.1	6.4	0.9	1.3	0.9	1.6	0.0
Chironomid adult	0.0	0.0	0.0	0.0	0.2	1.0	0.6	1.3	0.9	0.1	1.2	0.4	0.5	0.0	0.4	0.0
Biting midges	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4	0.4	0.2	0.0	0.0	0.4	0.0	0.0	0.0
Springtails	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.2	0.0	0.5	0.1	0.0	0.0	0.0	0.0
Order Diptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.2	0.0	0.0
Mayfly nymphs	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Mayfly adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dragonfly larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Dragonfly nymphs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stoneflies	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caddis fly larvae	0.0	0.9	1.9	0.0	0.2	0.8	0.5	0.9	0.5	0.2	0.2	0.0	0.3	0.3	0.2	0.0
Caddis fly adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.0
Spongillafly larvae	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Spongillafly adult	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.1	0.1	0.5	0.4	0.1	0.0	0.8	0.3	0.0
Diving wasp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.0	0.1	0.2	0.0	0.0
Order Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydra	2.7	1.7	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Rangia	0.0	0.9	1.7	1.0	1.9	0.2	0.4	0.2	0.0	0.1	0.3	0.0	0.3	0.0	0.1	0.0
Snail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	2.9	0.0	1.8	1.0	5.4	5.3	3.9	7.2	6.5	4.6	7.5	3.6	3.5	2.9	4.8	6.7
Total density by station	77.6	56.8	104.3	266.9	623.2	1085.8	914.4	4034.6	1103.5	851.1	2262.5	914.5	1926.1	1247.4	1951.3	192.1
Average volume sampled (m3)	5.3	5.5	5.4	5.2	7.7	11.2	11.6	10.8	11.6	10.0	11.8	10.7	11.9	11.8	11.5	9.9
(n) Dates sampled	7	7	7	7	15	19	18	19	20	20	19	20	17	18	18	1

Table 41. Mean densities (number/m^3), by date, of zooplankton collected in lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1985. Station numbers as in Figure 1.

	DATE																			
Organism grouping	426	429	430	52	54	56	59	510	512	514	516	519	520	522	524	526	529	62	66	610
Nematodes	0.0	0.3	0.0	0.3	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.4
Stylaria	0.3	0.6	0.0	0.3	0.6	0.9	1.2	0.0	1.6	0.6	1.7	0.0	0.0	0.9	0.4	0.3	0.0	1.2	0.0	0.3
Aeolosoma	0.0	0.5	2.0	0.9	1.2	0.6	1.4	1.5	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.9	0.0	0.3
Arachnids	0.4	3.0	0.4	1.3	1.4	0.9	0.3	1.1	0.6	0.5	1.3	1.1	0.0	0.0	1.0	1.9	1.9	2.5	0.6	2.2
Gammarids	2.3	3.3	1.6	9.2	.0	14.6	1.0	1.5	1.3	5.9	5.1	7.5	5.8	8.1	3.6	0.9	0.3	4.2	30.2	1.9
Leptodora	2.9	2.0	6.9	113.7	47.8	41.2	5.2	9.1	8.6	0.2	2.3	14.1	5.0	6.7	9.6	6.6	1.8	0.3	0.2	0.4
Bosmina	946.7	1100.8	939.6	599.4	203.8	156.1	92.7	103.0	89.0	41.8	33.3	40.4	57.5	80.0	287.0	57.7	46.3	28.5	21.6	17.3
Daphnia	218.6	574.5	2197.5	457.3	180.8	101.7	102.9	26.8	22.1	12.3	69.0	14.6	27.0	30.3	28.7	27.3	15.0	9.9	3.6	33.4
Other cladocerans	33.8	47.8	112.1	742.4	180.8	117.3	222.3	63.4	85.5	82.4	153.9	95.3	44.8	60.7	38.1	49.3	34.1	47.6	13.8	9.5
Ostracods	62.1	128.7	101.4	357.3	34.0	50.9	62.3	36.1	29.0	19.6	84.1	38.3	73.7	13.5	59.9	25.5	17.5	18.3	1.6	13.2
Calanoid copepod	43.2	128.2	231.4	88.3	28.5	91.6	90.9	63.3	51.6	83.0	104.1	57.7	44.3	81.4	158.2	58.9	102.7	176.8	84.2	138.1
Cyclopioid copepod	1147.7	1774.3	1266.1	671.3	555.0	606.7	333.8	189.5	139.9	113.6	198.4	354.7	522.2	549.7	589.7	1001.8	430.4	177.0	94.3	195.0
Harpacticoid copepod	44.4	170.8	164.3	252.5	330.6	146.8	142.9	74.2	30.7	29.6	81.1	174.9	196.4	259.3	234.4	263.7	311.0	113.0	31.6	47.6
Isopods	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Coleoptera larvae	39.3	0.6	0.8	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Coleoptera adult	0.0	0.9	0.3	0.0	0.5	0.2	0.0	0.7	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
Mosquito larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mosquito adult	0.0	0.3	0.8	0.4	0.5	0.2	0.6	0.2	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.0	0.3
Phantom midge larvae	4.3	6.9	13.6	9.4	8.8	4.7	4.2	3.4	1.6	3.2	1.1	12.8	11.2	9.4	11.1	28.2	29.9	2.7	5.5	7.9
Phantom midge pupae	1.6	0.9	0.0	0.5	1.0	3.1	2.4	1.3	0.0	0.5	2.0	2.7	2.9	0.4	1.4	0.3	2.0	4.4	2.0	2.3
Chironomid larvae	0.8	14.1	5.5	3.6	1.8	3.1	1.2	2.1	1.0	1.0	1.5	1.1	1.9	2.3	7.5	3.1	1.8	2.5	2.1	5.0
Chironomid adult	0.0	0.0	0.0	0.0	0.2	0.5	0.3	0.7	0.4	0.9	0.4	1.8	0.3	0.2	0.2	1.1	0.4	1.2	0.3	1.7
Biting midges	0.0	1.0	0.0	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Springtails	0.0	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Order Diptera	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Mayfly nymphs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.2	0.3	0.0	0.0	0.3	0.2	0.0
Mayfly adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dragonfly larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dragonfly nymphs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stoneflies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caddis fly larvae	0.4	0.0	1.2	0.3	0.0	0.4	1.5	0.4	0.0	0.0	1.2	0.6	0.9	0.0	0.0	0.6	0.9	0.0	0.3	0.0
Caddis fly adult	0.0	0.0	0.3	0.0	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spongillafly larvae	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spongillafly adult	0.0	0.0	0.0	0.0	0.0	0.8	0.0	1.2	1.0	0.3	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Diving wasp	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Order Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydra	0.0	0.0	0.0	0.0	0.5	0.0	0.0	2.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rangia	0.3	0.0	0.0	0.3	0.4	0.0	1.2	0.0	0.4	0.0	0.9	0.3	0.0	0.2	0.3	0.0	1.5	0.9	0.4	0.0
Snail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	10.6	15.5	9.7	6.9	6.5	5.6	1.4	4.3	3.1	2.7	3.6	4.0	5.9	1.3	1.3	1.4	0.8	2.7	2.2	8.7
Total density by date	2553.8	3977.3	5956.4	3315.9	1590.9	1349.5	1070.1	595.8	470.0	399.6	746.9	823.3	1006.8	1104.9	1432.8	1530.5	993.9	595.5	295.6	485.5
Average volume sampled (m3)	17.2	10.5	10.6	12.5	8.6	9.7	9.8	10.4	9.9	10.8	9.3	11.6	9.7	10.6	10.8	9.2	9.8	9.9	10.1	10.4
(n) Stations sampled	5	10	10	10	15	15	15	15	15	15	14	10	11	11	11	11	8	11	11	9

not at river stations. In 1985, *Leptodora* was found as far upriver as Station 2 (Table 39), although it remained most abundant in western Albemarle Sound.

CLADOCERA. Cladocerans comprised the most abundant zooplankter group in 1984; their relative contribution (minus *Leptodora*) averaged 51.8% by station (Table 42) and 53.2% by date (Table 43). Cladocerans were most abundant at Stations 9 and 11, averaging 756.0/m^3 and 531.6/m^3, respectively (Table 36). Lowest densities occurred at Stations 1, 2, and 3 (156.7-216.7/m^3). Greatest mean densities of cladocerans (615.1/m^3) were observed on 31 May 1984, influenced to large extent by Station 9 and Station 11 (Table 44). Lowest average densities of 177.4/m^3 occurred on 4 June. No correlations were observed (Table 5) between mean density of cladocerans and sampling date or river flow, and no multiple regression model to predict cladoceran abundance was significant at $P<0.05$ (Table 6).

In 1985, all cladocerans combined were the second most abundant group of zooplankton (after copepods), representing a relative contribution of 29.2% by date (Table 45) and 43.8% by station (Table 46). The category was subdivided into *Bosmina*, *Daphnia*, and other cladocerans (excluding *Leptodora*) in 1985 to determine abundance relationships between striped bass larvae and their primary food sources. *Bosmina* were the most abundant cladocerans, comprising 12.4% of the zooplankton by date (Table 45) and 19.1% by station (Table 46). *Daphnia* was the second most abundant, representing 7.6% of all zooplankton by date and 13.1% by station. Cladocerans were patchy in distribution. On several occasions, cladocerans exhibited high abundance within the study area, notably at Station 15 on 30 April 1985 (Table 47). The density value of 19,869/m^3 reflects a high concentration of *Daphnia* in the area on 30 April; at Station 13, approximately 2 km away, the concentration of cladocerans was low (450/m^3). Average densities of *Bosmina* in the study area (Stations 5-15) were significantly correlated with JULDATE, FLOWO , and phytoplankton cell density (Table 11). Stepwise regression (Table 12) selected the variables JULDATE and average water temperature (TEMP) as best predictors of *Bosmina* abundance (R^2=0.595; n=20; $P<0.001$). For Cladocera as a group, only the sampling date (JULDATE) was an important predictor of average cladoceran abundance (R^2=0.468; n=20; $P<0.001$).

Table 43. Relative contribution (%), by date, of organism groups in zooplankton samples collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1984. Station numbers as in Figure 1.

	DATE														
Organism grouping	519	522	523	525	527	529	531	62	64	68	610	614	616	618	Overall contribution
Nematodes	0.0	0.0	0.1	.0	0.0	0.1	.0	0.1	0.0	.0	0.0	0.0	0.0	0.0	.0
Polychaete worm	.0	.0	0.1	0.1	0.2	0.1	.0	.0	0.2	.0	0.1	0.0	.0	0.0	0.1
Stylaria	0.4	0.6	0.6	0.4	0.6	0.4	0.3	0.3	0.4	0.2	0.1	0.1	.0	.0	0.3
Dero	0.1	.0	0.1	0.1	.0	0.0	.0	.0	0.1	0.0	.0	0.0	.0	0.0	.0
Aeolosoma	0.1	0.1	0.1	0.1	0.3	.0	.0	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.1
Arachnids	0.3	0.1	0.3	0.3	0.6	0.3	0.0	0.2	0.3	0.4	0.1	0.3	0.3	0.4	0.3
Gammarids	0.1	1.3	1.1	1.2	0.6	1.9	1.1	2.0	6.3	1.1	1.3	1.6	0.8	3.9	1.8
Paguridae	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Paguridae zoea	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Leptodora	.0	0.0	0.0	0.0	0.0	0.4	0.8	0.1	0.1	0.1	5.9	2.2	8.9	9.1	2.0
Other cladocerans	72.4	63.1	52.3	56.5	54.9	55.4	71.8	49.0	39.1	50.7	52.7	53.3	43.4	30.4	53.2
Ostracods	0.7	2.4	4.9	6.0	4.3	6.5	0.8	7.4	3.1	5.6	3.8	9.6	5.7	21.1	5.9
Calanoid copepod	0.6	2.9	2.7	2.1	3.1	4.3	3.5	4.8	4.0	7.8	10.3	6.4	12.5	5.9	5.1
Cyclopoid copepod	15.7	19.9	25.3	21.9	20.6	23.6	15.6	21.7	28.3	22.4	17.4	18.5	18.3	19.1	21.0
Harpacticoid copepod	5.5	3.4	5.0	2.9	3.1	4.3	3.3	9.1	7.6	7.1	4.6	3.9	5.6	6.9	5.2
Coleoptera larvae	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Gyrinidae larvae	0.1	.0	0.0	0.0	.0	.0	0.0	0.0	0.1	0.1	.0	.0	0.0	0.0	.0
Gyrinidae adult	0.4	0.3	1.1	1.6	1.1	.0	0.2	0.6	1.8	0.5	0.1	.0	0.0	0.1	0.6
Mosquito larvae	.0	0.0	0.0	0.0	.0	0.0	.0	.0	0.2	0.0	0.0	.0	0.0	0.0	.0
Mosquito pupae	0.0	0.0	.0	.0	.0	0.2	0.1	.0	0.1	0.0	0.1	0.0	.0	0.0	.0
Mosquito adult	.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Phantom midge larvae	0.3	0.4	0.1	0.1	0.2	0.1	0.1	0.9	1.2	0.7	0.6	0.6	1.6	0.9	0.6
Phantom midge pupae	0.2	0.2	0.5	0.3	0.4	.0	0.1	0.2	0.7	0.3	0.2	0.6	0.5	0.4	0.3
Chironomid larvae	0.3	1.3	1.8	1.8	1.5	0.6	0.6	1.0	2.7	1.3	0.8	0.3	0.4	0.6	1.1
Chironomid adult	0.5	0.1	0.1	0.1	.0	0.1	.0	.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1
Biting midges	0.1	0.1	0.1	0.2	.0	.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.1	0.1
Mayfly nymphs	.0	0.1	0.1	0.1	.0	0.1	.0	0.1	0.0	.0	0.0	.0	0.1	.0	.0
Mayfly adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Order Odonata	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Dragonfly larvae	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Dragonfly nymphs	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	.0
Caddis fly larvae	.0	.0	.0	.0	0.1	0.0	0.1	.0	0.1	.0	0.0	.0	0.0	0.0	.0
Caddis fly adult	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Spongillafly larvae	.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	.0
Spongillafly adult	0.0	0.1	0.0	0.1	0.2	0.0	0.0	.0	0.2	0.0	.0	0.0	0.0	.0	.0
Diving wasp	0.1	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	.0
Order Hemiptera	0.2	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Hydra	0.0	0.6	1.0	0.7	0.5	0.3	0.5	0.8	0.4	0.0	.0	0.0	0.0	0.0	0.3
Rangia	.0	0.2	0.4	0.1	0.1	0.3	0.1	0.2	0.0	0.2	0.5	0.8	0.2	0.0	0.2
Snail	.0	0.0	0.1	0.1	0.0	0.0	0.0	.0	0.3	0.0	0.0	0.0	0.0	0.0	.0
Unidentified	1.5	2.6	2.0	2.9	1.6	0.9	0.7	1.2	2.1	1.0	1.2	1.4	1.3	0.9	1.5
Total percentage	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 45. Relative contribution (%), by station, of organism groups in zooplankton samples collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1985. Station numbers as in Figure 1.

	DATE																				
Organism grouping	4/26	4/28	4/30	5/2	5/4	5/6	5/8	5/10	5/12	5/14	5/16	5/18	5/20	5/22	5/24	5/26	5/29	6/2	6/6	6/10	Overall Contribution
Nematodes	0.0	.0	0.0	.0	.0	.0	0.0	0.0	0.0	0.0	0.0	.0	.0	0.0	0.0	0.0	.0	0.0	0.0	0.1	.0
Stylaria	.0	.0	0.0	.0	.0	0.1	0.1	0.0	0.3	0.2	0.2	0.0	0.0	0.1	.0	.0	0.0	0.2	0.0	0.1	0.1
Aeolosoma	0.0	.0	.0	.0	0.1	.0	0.1	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.1	0.0	0.1	0.1
Arachnids	.0	0.1	.0	.0	0.1	0.1	.0	0.2	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.2	0.4	0.2	0.4	0.1
Gammarids	0.1	0.1	.0	0.3	.0	1.1	0.1	0.3	0.3	1.5	0.7	0.9	0.6	0.7	0.2	0.1	.0	0.7	10.2	0.4	0.9
Leptodora	0.1	.0	0.1	3.4	3.0	3.0	0.5	1.5	1.8	.0	0.3	1.7	0.5	0.6	0.7	0.4	0.2	.0	0.1	0.1	0.9
Bosmina	36.9	27.7	18.6	18.1	13.1	11.6	8.7	17.6	18.9	10.5	4.5	4.9	5.7	7.2	20.0	3.8	4.6	4.8	7.3	3.6	12.4
Daphnia	8.5	14.4	43.5	13.8	11.4	7.5	9.6	4.6	4.7	3.1	9.2	1.8	2.7	2.7	2.0	1.8	1.5	1.7	1.2	6.9	7.6
Other cladocerans	1.3	1.2	2.2	22.4	11.4	8.7	20.8	10.8	18.2	20.6	20.6	11.6	4.4	5.5	2.7	3.2	3.4	8.0	4.7	1.9	9.2
Ostracods	2.4	3.2	2.0	10.8	2.1	3.8	5.8	6.2	6.2	4.9	11.3	4.7	7.8	1.2	4.2	1.7	1.8	3.1	0.5	2.7	4.3
Calanoid copepod	1.9	3.2	4.6	2.7	1.8	6.8	8.5	10.8	11.0	20.8	13.9	7.0	4.4	7.4	11.0	3.8	10.3	29.7	28.5	28.4	10.8
Cyclopoid copepod	44.8	44.6	25.0	20.2	34.9	45.0	31.2	32.4	29.8	23.4	26.6	43.1	51.9	49.8	41.2	65.5	43.1	29.7	31.9	40.2	37.9
Harpacticoid copepod	1.7	4.3	3.2	7.6	20.8	10.9	13.4	12.7	6.5	7.4	10.9	21.2	19.5	23.5	16.4	17.2	31.1	19.0	10.7	9.8	13.4
Isopods	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	.0
Coleoptera larvae	1.5	.0	.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.1
Coleoptera adult	0.0	.0	.0	0.0	.0	.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	.0
Mosquito larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mosquito adult	0.0	.0	.0	.0	.0	.0	0.1	.0	0.0	.0	0.1	0.0	0.0	0.0	0.0	.0	0.0	0.1	0.0	0.1	.0
Phantom midge larvae	0.2	0.2	0.3	0.3	0.6	0.3	0.4	0.6	0.3	0.8	0.2	1.6	1.1	0.9	0.8	1.8	3.0	0.5	1.8	1.6	0.9
Phantom midge pupae	0.1	.0	0.0	.0	0.1	0.2	0.2	0.2	0.0	0.1	0.3	0.3	0.3	.0	0.1	.0	0.2	0.7	0.7	0.5	0.2
Chironomid larvae	.0	0.4	0.1	0.1	0.1	0.2	0.1	0.4	0.2	0.3	0.2	0.1	0.2	0.2	0.5	0.2	0.2	0.4	0.7	1.0	0.3
Chironomid adult	0.0	0.0	0.0	0.0	.0	.0	.0	0.1	0.1	0.2	0.1	0.2	.0	.0	.0	0.1	.0	0.2	0.1	0.3	0.1
Biting midges	0.0	.0	0.0	.0	.0	.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	.0
Springtails	0.0	.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Order Diptera	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	.0
Mayfly nymphs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	.0	.0	0.0	0.0	0.1	0.1	0.0	.0
Mayfly adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dragonfly larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Dragonfly nymphs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stoneflies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Caddis fly larvae	.0	0.0	.0	.0	0.0	.0	0.1	0.1	0.0	0.0	0.2	0.1	0.1	0.0	0.0	.0	0.1	0.0	0.1	0.0	.0
Caddis fly adult	0.0	0.0	.0	0.0	.0	.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Spongillafly larvae	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Spongillafly adult	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.1	0.0	.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Diving wasp	0.0	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	.0
Order Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydra	0.0	0.0	0.0	0.0	.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Rangia	.0	0.0	0.0	.0	.0	0.0	0.1	0.0	0.1	0.0	0.1	.0	0.0	.0	.0	0.0	0.2	0.2	0.1	0.0	.0
Snail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0
Unidentified	0.4	0.4	0.2	0.2	0.4	0.4	0.1	0.7	0.7	0.7	0.5	0.5	0.6	0.1	0.1	0.1	0.1	0.5	0.8	1.8	0.5
Total percentage	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 47. Densities (number/m^3) of Cladocera (excluding Leptodora) collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1985. Station numbers as in Figure 1.

	STATION																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Date Average
4/26/85	*	*	*	*	*	*	*	*	325.8	542.7	*	2454.5	*	1920.3	752.1	*	1199.1
4/28/85	*	*	*	*	*	1766.8	826.3	1590.6	1926.4	326.9	2097.0	1279.0	5258.1	1756.7	403.4	*	1723.1
4/30/85	*	*	*	*	*	252.7	2349.2	1209.3	410.4	3923.2	910.2	1921.3	449.9	1196.2	19869.5	*	3249.2
5/2/85	*	*	*	*	*	4339.4	1979.8	1944.9	1712.6	3370.5	876.1	2057.7	519.2	510.5	181.4	*	1799.1
5/4/85	19.7	6.2	45.1	603.1	1415.5	844.2	227.8	1753.7	349.8	219.6	1397.4	453.9	424.4	415.5	380.4	*	570.4
5/6/85	30.1	0.0	88.1	68.2	383.9	335.0	895.6	1639.2	228.4	371.6	604.3	656.7	185.2	68.3	81.1	*	375.1
5/8/85	146.0	103.2	156.1	316.8	219.3	443.8	226.7	1842.9	277.6	78.2	714.8	241.7	1045.3	31.6	418.5	*	417.8
5/10/85	12.6	0.0	45.1	91.0	85.7	222.5	173.7	492.3	922.9	74.2	275.7	9.7	393.9	64.0	35.6	*	193.3
5/12/85	0.0	5.9	32.6	33.4	40.6	129.5	329.1	554.9	632.9	22.4	662.1	2.9	125.5	298.3	77.9	*	196.5
5/14/85	19.4	0.0	6.1	106.2	54.2	123.1	141.9	437.0	152.3	7.5	84.7	5.0	442.2	368.1	51.6	*	136.6
5/16/85	57.3	11.1	5.5	83.0	244.4	709.9	*	279.6	707.2	33.7	631.3	275.0	275.0	160.1	107.6	*	256.1
5/18/85	*	*	*	*	*	135.4	153.2	283.7	314.9	25.1	354.6	50.4	76.5	50.1	58.1	*	150.3
5/20/85	*	*	*	*	47.9	193.7	303.5	346.5	80.2	2.2	124.5	231.3	18.6	25.0	50.8	*	129.2
5/22/85	*	*	*	*	159.2	257.1	50.8	415.3	238.5	19.2	361.5	83.9	123.8	110.0	55.5	*	170.9
5/24/85	*	*	*	*	764.4	835.2	1374.5	222.5	226.1	64.3	195.3	23.5	51.7	63.4	71.3	*	353.8
5/26/85	*	*	*	*	337.1	337.8	279.8	195.9	139.5	4.4	90.3	0.0	32.9	8.5	0.0	*	134.3
5/29/85	*	*	*	*	55.3	21.4	70.2	167.2	57.6	267.2	89.3	35.0	*	*	*	*	95.4
6/2/85	*	*	*	*	119.4	265.3	60.4	67.1	50.8	40.3	77.5	73.6	30.9	120.0	40.0	*	85.9
6/6/85	*	*	*	*	57.8	25.1	44.6	47.5	44.6	14.6	0.2	63.7	78.3	27.1	25.7	*	39.0
6/10/85	*	*	*	*	143.3	57.5	30.3	79.7	110.6	23.4	11.9	57.5	*	*	*	27.0	60.1

Table 48. Densities (number/m^3) of Copepoda collected from the lower Roanoke River, delta, and western Albemarle Sound, North Carolina, in 1984. Station numbers as in Figure 1.

	STATION																		Date Average
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
5/18/84	*	*	*	*	117.1	94.2	61.7	345.5	94.5	263.0	158.0	135.8	97.2	110.1	382.0	*	*	*	169.0
5/22/84	135.6	172.7	125.3	96.5	77.8	53.4	92.8	200.3	106.3	172.2	133.3	145.6	150.9	62.2	97.7	*	*	*	124.8
5/23/84	43.9	59.5	90.8	91.6	33.4	216.3	177.6	189.6	532.3	160.3	44.7	90.5	126.0	41.1	56.6	*	*	*	130.6
5/25/84	142.0	75.4	76.8	95.1	141.6	65.4	246.8	177.5	127.4	211.9	192.2	68.2	232.2	97.7	17.3	*	*	*	131.2
5/27/84	149.2	182.2	111.0	112.7	127.2	410.3	212.6	199.9	434.8	41.8	156.4	78.2	203.8	*	51.1	*	*	*	180.1
5/29/84	330.2	270.8	178.0	334.6	301.2	292.9	151.4	330.7	160.8	55.4	105.6	47.5	345.9	36.3	51.2	*	*	*	200.8
5/31/84	51.9	60.2	99.3	149.4	194.5	210.8	275.9	353.0	315.7	237.4	203.2	256.6	116.6	191.4	159.7	*	*	*	191.0
6/2/84	51.1	53.9	70.2	116.4	102.3	137.0	179.9	263.2	107.3	76.6	1123.1	15.8	459.6	255.3	239.8	*	*	*	217.0
6/4/84	*	*	*	*	335.9	115.0	116.9	133.7	516.1	40.8	71.9	82.9	158.2	220.9	155.0	*	*	*	181.3
6/8/84	*	*	*	*	630.8	217.8	99.3	257.2	537.4	43.7	273.9	45.6	283.1	98.1	127.2	*	*	*	242.6
6/10/84	*	*	*	*	503.2	159.2	73.5	149.1	201.7	30.0	152.7	57.0	161.9	154.1	219.3	*	*	*	169.7
6/14/84	*	*	*	*	*	*	*	147.6	161.1	77.6	211.0	61.9	155.3	219.2	110.3	343.5	33.2	127.3	149.8
6/16/84	*	*	*	*	*	*	*	142.2	209.7	51.1	143.8	135.1	231.8	157.9	234.7	756.7	42.1	157.1	205.6
6/18/84	*	*	*	*	*	*	*	311.7	249.6	46.0	817.8	107.1	173.2	145.1	50.8	149.8	73.1	137.0	205.4

Table 50. Chlorophyll a concentration (ug/liter) in the Roanoke River and western Albemarle Sound, North Carolina, in 1984. Dashes indicate no samples taken.

Date (mm/dd/yy)	Station 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
05/18/84	---	---	---	---	---	6.4	3.6	2.8	5.2	4.4	4.4	6.0	5.8	4.4	4.0	2.8	---	---
05/22/84	7.5	13.7	9.6	12.0	4.0	4.4	5.6	5.6	20.8	5.2	3.6	4.4	3.2	4.4	6.4	---	---	---
05/23/84	8.7	5.3	4.0	4.9	5.2	5.2	4.8	4.0	5.2	6.8	10.4	6.4	4.4	1.6	6.4	---	---	---
05/25/84	11.0	9.5	1.0	8.4	7.4	6.3	6.7	4.4	6.3	6.7	6.8	6.8	6.0	5.6	11.2	---	---	---
05/27/84	9.4	8.0	2.7	6.2	6.0	4.0	6.2	5.3	7.1	5.6	5.2	7.2	4.0	---	8.4	---	---	---
05/29/84	8.8	12.0	11.4	6.3	6.6	9.0	6.0	4.4	4.0	12.0	10.0	5.6	5.8	12.0	5.6	---	---	---
05/31/84	13.4	1.0	9.6	12.0	10.4	6.7	6.0	5.3	7.2	5.7	7.3	6.9	4.6	1.4	9.2	---	---	---
06/02/84	6.4	1.0	6.4	6.0	2.7	6.0	3.3	5.3	1.2	2.8	2.9	2.0	1.5	1.3	1.0	---	---	---
06/04/84	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
06/08/84	---	---	---	---	9.7	6.5	8.5	6.8	6.3	10.5	6.7	10.0	7.1	2.0	9.4	---	---	---
06/10/84	---	---	---	---	8.5	9.9	10.4	8.9	12.4	4.4	6.1	11.8	10.4	5.2	8.4	---	---	---
06/14/84	---	---	---	---	---	---	---	6.1	12.3	2.7	6.0	6.0	8.0	3.6	5.5	7.6	10.8	1.0
06/16/84	---	---	---	---	---	---	---	6.0	1.2	8.6	9.1	9.1	10.0	4.8	8.0	8.0	7.1	4.0
06/18/84	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mean	9.3	7.2	6.4	8.0	6.7	6.2	6.0	5.6	7.4	6.3	6.7	6.8	5.8	4.2	6.9	7.8	9.0	2.5

Table 51. Chlorophyll a concentration (ug/liter) in the Roanoke River and western Albemarle Sound, North Carolina, in 1985. Dashes indicate no samples taken.

Date	Station														
(mm/dd/yy)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
04/26/85	---	---	---	---	---	12.8	9.3	7.2	7.6	1.5	---	6.0	8.8	11.6	11.2
04/28/85	---	---	---	---	---	9.2	11.6	14.8	14.0	16.0	11.6	9.6	2.0	1.7	4.8
04/30/85	---	---	---	---	---	8.8	15.6	10.0	14.4	16.8	5.6	23.2	12.1	2.5	8.8
05/02/85	---	---	---	---	---	10.8	10.8	8.4	12.8	19.2	14.0	17.6	1.7	1.3	2.0
05/04/85	7.6	8.0	10.0	13.6	12.8	14.8	27.6	6.0	14.0	13.2	8.8	10.4	9.6	8.0	8.8
05/06/85	5.6	7.6	6.8	11.2	11.2	19.6	19.6	14.0	26.0	30.8	23.2	22.4	8.0	10.4	3.2
05/08/85	11.6	9.2	10.0	12.0	12.3	6.8	6.0	14.4	15.6	4.9	18.0	29.2	12.0	12.0	27.2
05/10/85	1.6	2.4	2.4	4.0	4.0	6.0	4.4	3.6	10.8	6.0	6.8	9.2	8.8	5.2	7.2
05/12/85	3.8	7.6	5.6	3.6	5.6	8.0	8.4	16.8	11.2	9.6	10.0	19.3	7.2	6.8	6.8
05/14/85	4.4	4.8	4.4	2.8	2.8	5.2	4.3	10.4	8.0	13.2	9.2	6.8	4.4	2.8	14.4
05/16/85	13.4	21.6	17.2	21.6	15.6	16.4	18.4	48.9	23.2	31.6	35.1	33.2	16.4	11.2	32.5
05/18/85	---	---	---	---	---	15.2	12.0	16.8	6.8	13.2	6.8	20.4	1.0	6.4	1.3
05/20/85	---	---	---	---	8.0	10.8	7.2	10.8	12.4	6.8	11.2	10.8	1.0	12.8	27.6
05/22/85	---	---	---	---	18.0	13.6	10.4	16.0	18.4	23.6	9.2	27.2	1.7	18.8	15.2
05/24/85	---	---	---	---	6.9	9.2	10.8	10.4	13.6	7.6	12.0	4.5	2.4	1.6	1.7
05/26/85	---	---	---	---	3.6	12.4	12.8	14.8	13.6	21.2	32.4	12.8	6.4	4.8	4.8
05/29/85	---	---	---	---	6.0	4.0	4.4	15.6	6.4	10.0	11.2	13.6	---	---	---
06/02/85	---	---	---	---	8.0	6.4	8.0	8.4	4.4	5.6	4.4	2.8	3.6	6.4	---
06/06/85	---	---	---	---	5.6	1.7	4.4	2.4	6.8	4.4	4.8	2.0	2.5	1.0	1.0
06/10/85	---	---	---	---	2.1	5.6	19.6	7.6	2.4	15.2	9.2	25.6	10.0	---	---
Mean	8.3	8.8	8.1	9.8	8.2	9.9	11.3	12.9	12.1	13.5	12.8	15.3	6.3	7.0	10.5

Table 52 (continued)

Identification	Cell type	Cell volume (cubic microns)	Frequency of occurrence
*Navicula sp. 2 Bory	412	4691	1.14
*Navicula sp. 3 Bory	203	276	10.86
*Navicula sp. 4 Bory	201	733	5.14
*Navicula sp. 5 Bory	26	951	2.29
*Navicula sp. 6 Bory	405	1000	3.43
*Navicula sp. 7 Bory	126	995	6.86
*Navicula sp. 8 Bory	439	251	1.71
*Navicula sp. 9 Bory	137	1047	2.86
*Navicula sp. 10 Bory	205	2111	1.14
*Navicula sp. 11 Bory	19	1016	0.57
*Navicula sp. 12 Bory	477	2513	4.00
*Navicula sp. 13 Bory	46	1129	1.71
*Navicula sp. 14 Bory	104	146	1.14
*Neidium sp. Pfitzer	452	12063	0.57
*Neidium ladogense Oestrup	441	2403	0.57
Nitzschia gracilis Hantzsch	231	4592	1.71
Nitzschia sp. 1 Hassall	182	1268	1.14
*Nitzschia sp. 2 Hassall	440	1005	2.86
*Nitzschia sp. 3 Hassall	173	879	0.57
*Nitzschia sp. 4 Hassall	469	7854	0.57
Pinnularia sp. 1 Ehrenberg	129	3609	1.14
*Pinnularia sp. 2 Ehrenberg	158	6283	4.00
*Pinnularia sp. 3 Ehrenberg	371	5341	4.00
Skeletonema sp. Greg	74	75	1.71
Stauroneis sp. Ehrenberg	147	535	0.57
*Surirella sp. 1 Turpin	174	26704	0.57
Surirella sp. 2 Turpin	199	81279	0.57
*Synedra sp. 1 Ehrenberg	317	732	3.43
*Synedra sp. 2 Ehrenberg	480	6597	0.57
*Unknown #248	248	2261	0.57
*Unknown #273	273	31856	0.57
Unknown #276	276	2827	0.57
Unknown #75	75	23703	0.50
Chlorophyceae			
*Actinastrum hantzchii Lagerheim	49	276	8.57
*Closterium sp. Nitzsch	59	213	4.00
Crucigenia fenestrata Schmidle	50	101	0.57
*Crucigenia rectangularis A. Braun	242	390	1.71
*Crucigenia sp. 1 Morren	8	439	4.00
Crucigenia sp. 2 Morren	232	110	0.57
Netrium sp. Nageli	73	49	1.14
*Pediastrum duplex Meyen	1	1000	0.57
*Pediastrum sp. 1 Meyen	280	432	1.14

Table 52 (continued)

Identification	Cell type	Cell volume (cubic microns)	Frequency of occurrence
Cyanophyceae			
Anabaena sp. Bory	484	113	2.29
**Chroococcus* sp. Nageli	107	130	2.29
Dinophyceae			
**Gymnodinium danicans* Campbell	296	4064	2.86
**Gymnodinium* sp. 1 Stein	80	2540	5.14
Gymnodinium sp. 2 Stein	311	3941	0.57
Peridinium sp. Ehrenberg	312	6283	1.14
Unknown #323	323	260	0.57
Euglenophyceae			
**Euglena* sp. 1 Ehrenberg	435	188	2.86
**Euglena* sp. 2 Ehrenberg	231	843	12.57
Trachelomonas sp. Ehrenberg	327	524	41.71
Unknown #344	344	7634	0.57
Unknown #527	527	100	0.50
Unknown			
*Unknown #108	108	3224	0.57
*Unknown #140	140	754	24.57
*Unknown #149	149	44234	0.57
Unknown #151	151	24	0.57
*Unknown #197	197	1920	0.57
*Unknown #235	235	302	1.71
Unknown #249	249	43	0.57
Unknown #331	331	2488	0.57
*Unknown #360	360	524	0.57
*Unknown #363	363	13119	1.71
Unknown #369	369	9600	0.57
*Unknown #376	376	6434	2.29
Unknown #379	379	1728	0.57
Unknown #431	431	985203	1.14
Unknown #44	44	4	0.57
*Unknown #476	476	4580	1.14
Unknown #482	482	34	0.57
Unknown #486	486	1437	1.14
Unknown #460	460	2009	0.55

Table 53. (continued)

Identification	Cell type	Cell volume (cubic microns)	Frequency of occurrence
*Fragilaria sp. 1 Lyngbye	167	559	1.27
Frustulia sp. 2 Agardh	243	488	0.84
Frustulia sp. 3 Agardh	37	1016	0.84
*Gomphonema sp. 2 Agardh	458	3384	0.84
*Gyrosigma sp. 2 Hassall	373	31416	5.49
Melosira granulata Muller	508	88	98.31
Melosira sp. Agardh	454	3619	1.27
*Navicula sp. 7 Bory	126	995	8.86
*Navicula sp. 5 Bory	26	951	0.42
Navicula sp. 15 Bory	448	53097	0.42
*Navicula sp. 4 Bory	201	733	7.59
*Navicula sp. 3 Bory	203	276	0.42
*Navicula sp. 10 Bory	205	2111	2.11
Navicula sp. 16 Bory	398	565	3.38
*Navicula sp. 9 Bory	137	1047	0.42
Navicula sp. 17 Bory	250	1270	1.69
*Navicula sp. 2 Bory	412	4691	1.27
*Navicula sp. 14 Bory	104	146	6.33
*Navicula sp. 1 Bory	234	1463	6.33
*Navicula sp. 13 Bory	46	1129	4.64
Navicula sp. 18 Bory	495	785	2.11
*Navicula sp. 12 Bory	477	2513	1.69
*Navicula sp. 8 Bory	439	251	1.69
Navicula sp. 19 Bory	374	452	0.42
*Navicula sp. 6 Bory	405	1000	0.42
*Navicula sp. 11 Bory	19	1016	0.42
Navicula sp. 20 Bory	186	214	0.42
*Neidium ladogense Oestrup	441	2403	0.42
*Neidium sp. Pfitzer	452	12063	0.42
Nitzschia sp. 5 Hassall	336	1979	0.84
*Nitzschia sp. 4 Hassall	469	7854	1.27
*Nitzschia sp. 2 Hassall	440	1005	4.64
*Nitzschia sp. 3 Hassall	173	879	0.84
Nitzschia sp. 6 Hassall	308	152	0.84
*Pinnularia sp. 2 Ehrenberg	158	6283	0.42
*Pinnularia sp. 3 Ehrenberg	371	5341	1.27
Surirella sp. 3 Turpin	520	7854	0.42
*Surirella sp. 1 Turpin	174	26704	0.42
Synedra sp. 3 Ehrenberg	509	680	58.65
*Synedra sp. 1 Ehrenberg	317	732	2.53
*Unknown #248	248	2261	0.42
*Unknown #273	273	31856	0.84
Unknown #274	274	8	3.80
Unknown #467	467	503	0.42
Unknown #513	513	7396	1.69

Table 53. (continued)

Identification	Cell type	Cell volume (cubic microns)	Frequency of occurrence
Gymnodinium sp. 3 Stein	288	503	0.42
Unknown #293	293	508	0.42
*Unknown #323	323	260	0.84
Unknown #396	396	785	0.42
Euglenophyceae			
*Euglena sp. 1 Ehrenberg	435	188	0.84
*Euglena sp. 2 Ehrenberg	281	848	2.53
*Trachelomonas sp. Ehrenberg	327	524	0.84
Unknown			
*Unknown #108	108	3224	0.84
*Unknown #140	140	754	0.42
*Unknown #149	149	44234	0.84
Unknown #193	193	198	0.42
*Unknown #197	197	1920	1.27
Unknown #23	23	64	6.75
*Unknown #235	235	302	0.84
Unknown #27	27	228	0.42
Unknown #30	30	100	0.84
Unknown #313	313	100	4.64
Unknown #342	342	2771	4.22
*Unknown #360	360	524	2.11
*Unknown #363	363	13119	1.27
Unknown #367	367	264	0.42
*Unknown #376	376	6434	2.53
Unknown #389	389	12095	0.42
Unknown #391	391	1696	0.42
Unknown #407	407	402	82.70
*Unknown #476	476	4580	0.84
Unknown #48	48	508	0.84
Unknown #502	502	1056	0.42

murale, present in 96% of the samples. Other common green algae included a species of Zygnema, Actinastrum hantzchii, and Stichococcus sp.. Synedra, Fragilaria, Cyclotella, Coscinodiscus, and Diploneis were the other genera of diatoms represented in 10% of more of the samples.

Phytoplankton cell densities ranged from 42 cells/ml to 2248 cells/ml in 1984, but there was no discernable pattern in the distribution (Table 55). Values less than 100/ml or greater than 1000/ml were not common; most densities were between 300 and 700/ml. Biomass of the phytoplankton (ug wet weight/l) was also highly variable, but showed no clear pattern (Table 56). Phytoplankton biomass for most samples fell between 300 and 800 ug/l; occasionally small or large extremes were observed. For example, values were less than 10 ug wet weight/l at Station 14 on 18 May and 31 May (Table 56). Unusually high biomass values (e.g., 18,170 and 12,900 ug wet weight/l at Station 3 on 27 May and Station 2 on 31 May, respectively) were the result of either very high densities of average-sized cells (27 May), or relatively low densities of very large phytoplankters (31 May).

In 1985, phytoplankton cell densities ranged from 24 cells/ml to 23,558 cells/ml, and there were distinct temporal and spatial patterns in the distribution (Table 57). The densities tended to be higher early in the sampling period (late April-early May) than in late May and early June. The mean density for all stations ranged from 8000-10,000 cells/l from 26 April through 4 May, but declined gradually after then to around 1000-2000 cells/l from 22 May through 10 June. Mean algal densities, averaged by station over time, were relatively low at the upper Roanoke River stations, but increased in the delta (Stations 6, 7, 9, 10, and 12) and in western Albemarle Sound at the mouth of the Roanoke River (Station 15). Algal cell densities were lowest in the Cashie River (Stations 8 and 11) and in western Albemarle Sound at the mouth of the Cashie River (Stations 13, 14, and 16, Table 57).

Phytoplankton biomass (ug wet weight/l) was also highly variable in 1985, but showed about the same temporal and spatial patterns as algal cell density (Table 58). Biomass varied from 2-11,605 ug wet weight/l; most values ranged between 500 and 2000 ug wet weight/l. During the sampling period, the average biomass for all stations declined from 1500-3400 ug wet weight/l early in the

Table 56. Phytoplankton wet weight biomass (ug/l) in the Roanoke River and western Albemarle Sound, North Carolina, during 1984.

Station	Date														
	05/18	05/22	05/23	05/25	05/27	05/29	05/31	06/02	06/04	06/08	06/10	06/14	06/16	06/18	MEAN
1	---	---	238	343	381	561	231	277	---	---	---	---	---	---	339
2	---	398	517	303	112	1251	12900	15	---	---	---	---	---	---	2214
3	---	151	165	201	18170	289	157	229	---	---	---	---	---	---	2766
4	---	176	299	466	5	704	66	100	---	---	---	---	---	---	259
5	78	114	165	364	69	867	117	730	716	118	362	---	---	---	336
6	241	417	63	181	197	310	---	173	493	318	220	---	---	---	261
7	279	391	127	182	573	475	---	1011	951	333	865	---	---	---	519
8	384	205	354	300	87	568	---	71	38	184	390	160	615	750	316
9	95	384	309	95	82	450	188	287	282	178	391	251	105	220	237
10	88	234	500	226	219	129	37	22	112	155	890	90	174	183	219
11	202	116	253	631	209	270	---	110	273	318	499	101	471	211	282
12	276	249	1000	380	515	373	---	116	125	447	593	196	367	324	382
13	82	76	54	838	53	70	919	218	66	569	168	259	297	468	296
14	1	49	13	18	---	295	6	40	218	275	106	55	754	377	170
15	67	233	235	857	575	122	123	83	120	741	106	296	88	275	280
16	---	---	---	---	---	---	---	---	---	---	---	327	18	91	145
17	---	---	---	---	---	---	---	---	---	---	---	399	51	242	592
18	---	---	---	---	---	---	---	---	---	---	---	28	84	124	79
MEAN	163	228	286	359	1518	449	1474	232	309	331	417	197	275	297	

Table 58. Phytoplankton wet weight biomass (ug/l) in the Roanoke River and western Albemarle Sound during 1985. Dashes indicate no sample taken.

Station	Date (mm/dd)																			
	04/26	04/28	04/30	05/02	05/04	05/06	05/08	05/10	05/12	05/14	05/16	05/18	05/20	05/22	05/24	05/26	05/29	06/02	06/06	06/10	Mean
1	---	---	---	---	1195	1762	2220	750	1586	1267	626	---	---	---	---	---	---	---	---	---	1344
2	---	---	---	---	762	669	1799	838	1545	1641	13149	---	---	---	---	---	---	---	---	---	2922
3	---	---	---	---	1531	1613	1361	1555	1509	682	1543	---	---	---	---	---	---	---	---	---	1400
4	---	---	---	---	664	451	2162	1638	1168	785	767	---	---	---	---	---	---	---	---	---	1091
5	---	---	---	---	1217	1947	1273	534	932	710	1332	---	529	1026	234	142	818	1184	657	111	846
6	2666	2762	1740	1676	1540	1524	2015	519	306	585	833	3031	1204	761	922	138	800	1940	1484	625	1354
7	3486	6497	3047	1374	2206	1953	2427	267	1321	639	428	1292	1073	227	432	221	532	744	1038	230	1472
8	873	845	1603	862	1511	1436	628	385	6450	466	553	437	1144	480	502	24	402	1092	993	285	1049
9	2064	4103	1719	3265	2312	2635	3928	843	1218	1076	1211	526	377	363	1952	150	376	533	1000	125	1514
10	1754	4705	11605	4072	1003	2295	5482	431	681	1509	3324	774	1677	815	812	137	233	455	1003	1216	2202
11	690	1204	1098	2257	468	1230	1044	865	1068	261	304	1177	345	431	372	94	421	202	637	125	717
12	1484	1973	3371	1551	3220	---	1349	3082	366	900	933	1013	857	1163	118	53	2175	382	708	184	1244
13	604	714	48	234	2343	476	1851	1321	488	90	586	188	34	178	202	84	407	---	422	---	571
14	202	1436	297	27	387	246	504	877	887	437	102	2	117	54	231	10	---	160	133	---	367
15	2607	9810	1593	317	376	55	3403	1493	657	767	753	2	171	257	6	72	428	---	170	---	1302
16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	537	537
Mean	1643	3405	2612	1564	1482	1220	2096	1030	1345	783	1766	844	684	528	526	107	659	744	750	382	

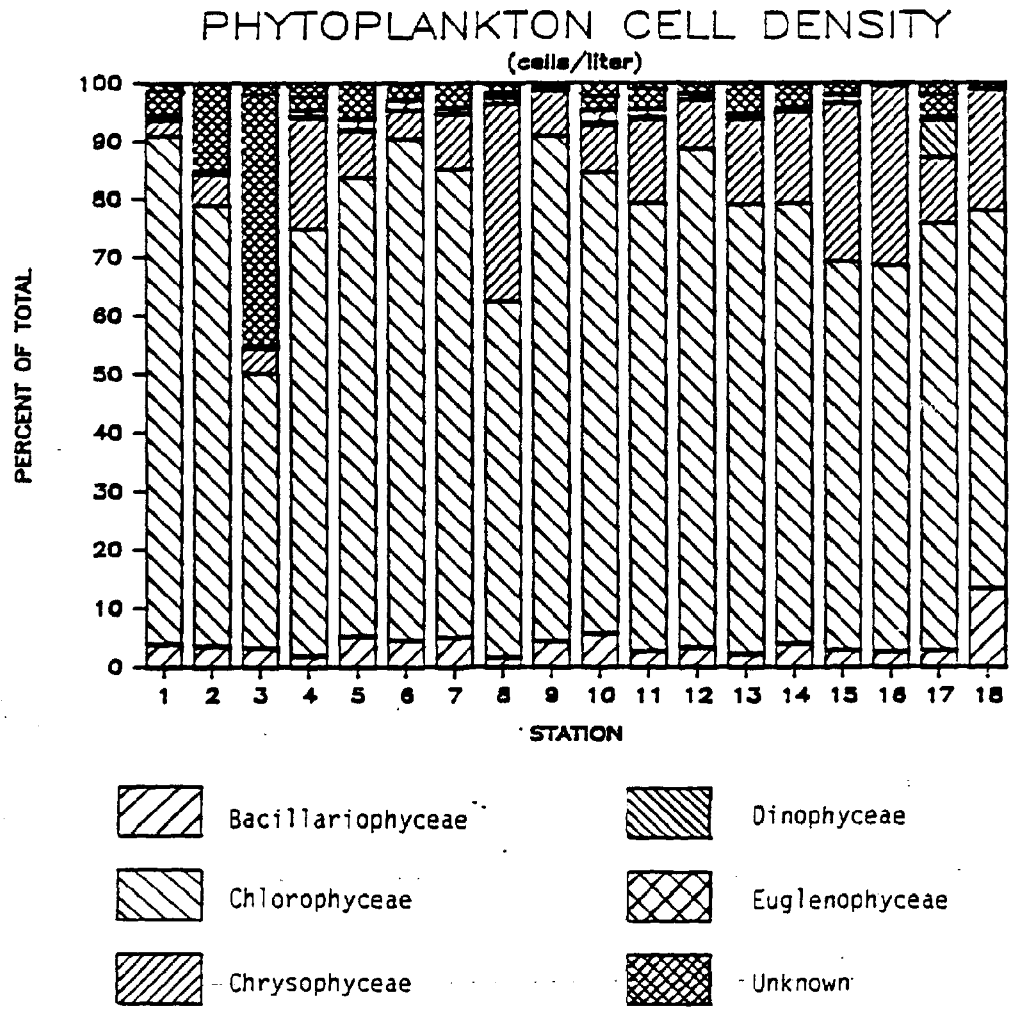

Figure 14. Relative abundance (% of total cell density) of different algal classes in the Roanoke River and western Albemarle Sound, North Carolina, in 1984, averaged for each sampling station.

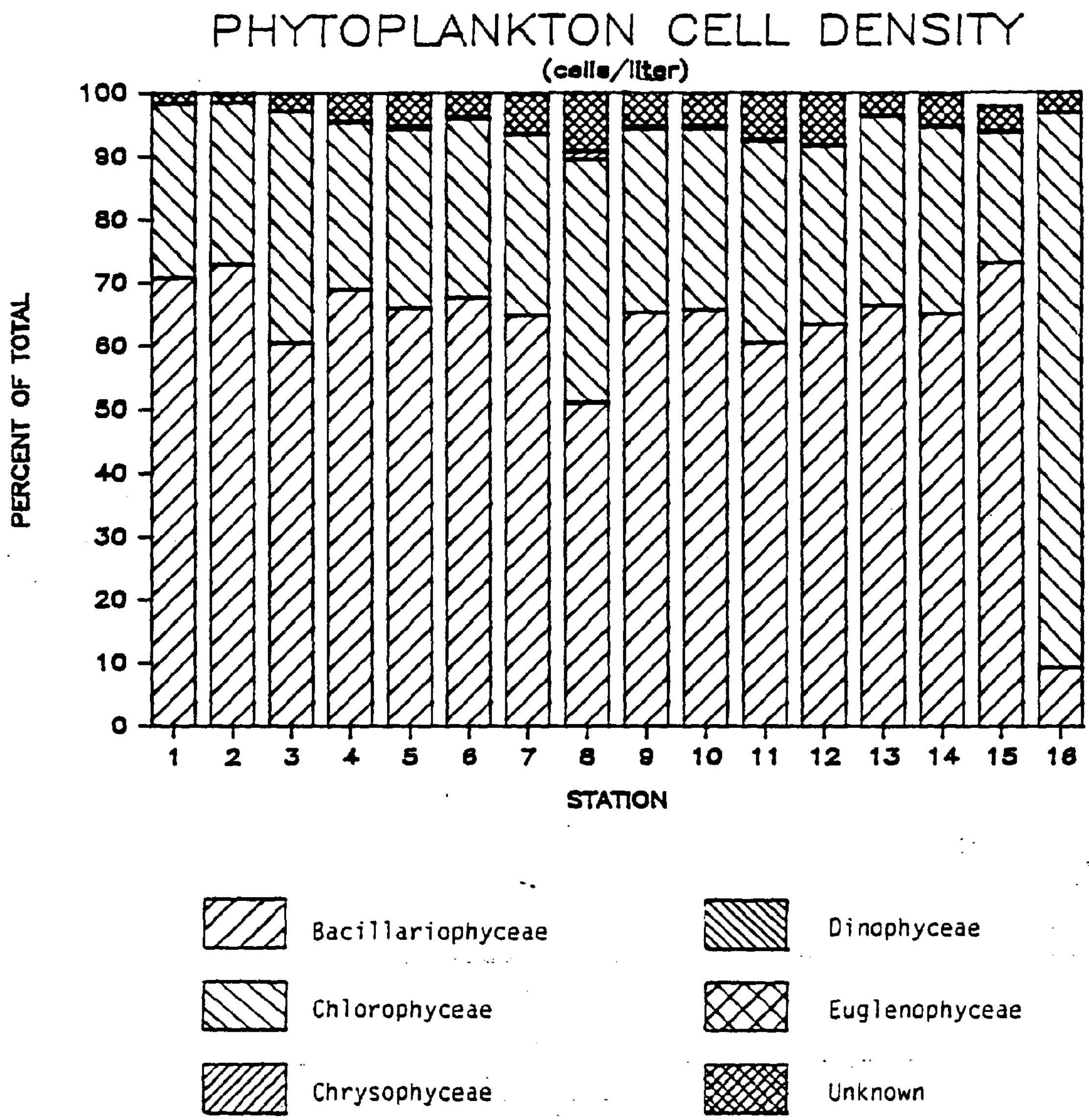

Figure 16. Relative abundance (% of total cell density) of different algal classes in the Roanoke River and western Albemarle Sound, North Carolina, in 1985, averaged for each sampling station.

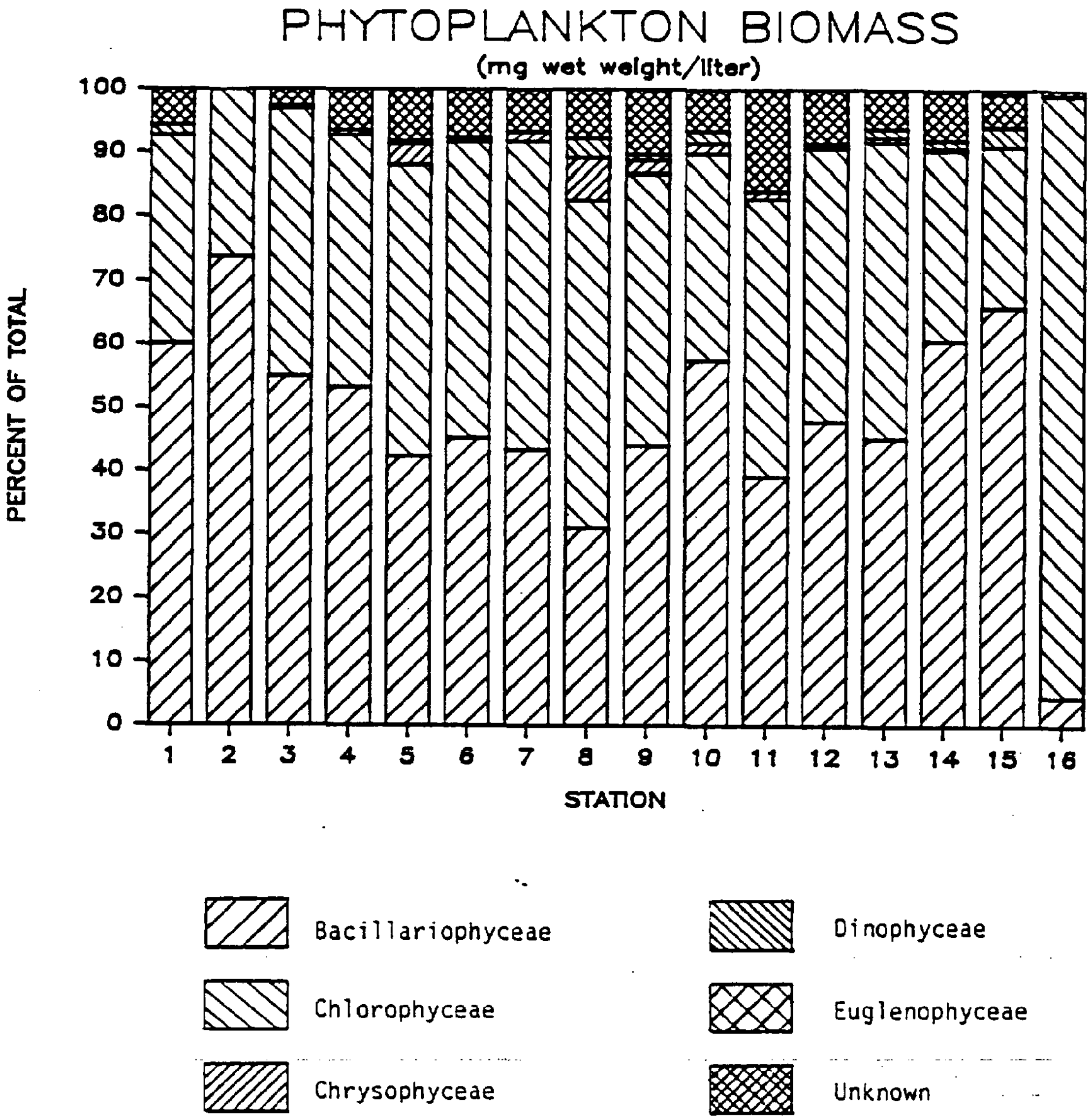

Figure 17. Relative abundance (% of total wet weight) of different algal classes in the Roanoke River and western Albemarle Sound, North Carolina, in 1985, averaged for each sampling station.

In 1984, chlorophyll a and phytoplankton biomass were relatively low in the Roanoke study area, and also in the nearby Pamlico River Estuary, where data were collected on a bi-weekly basis throughout the year. In May and June 1984, phytoplankton cell density and biomass were only slightly higher in the upper (freshwater) portion of the Pamlico than in the Roanoke study area (Stanley and Daniel 1985). However, it is obvious from examination of the data for the Pamlico from previous years that the algal biomass there is normally much higher. It appears that unusually high river flow in early June 1984 resulted in washout of most of the Pamlico phytoplankton (Stanley and Daniel 1985). Similarly, the unusually high flow in the Roanoke River probably caused a washout of the phytoplankton in 1984. This hypothesis is supported by the fact that in 1985 both Roanoke and Pamlico phytoplankton biomass was higher, while flows were lower for the same May-June period (D.W. Stanley, unpublished data). Christian et al. (1986) found that algal density in the lower Neuse River is strongly controlled by fluctuation in river discharge.

There was no significant correlation between Roanoke chlorophyll a concentrations and phytoplankton biomass, which is not surprising for a system like the lower Roanoke River. A regression of chlorophyll against phytoplankton biomass yielded an R^2 value of 0.05, indicating no relationship between the two parameters. Two possible reasons for this come to mind. First, it is well known that the biomass:chlorophyll ratio varies widely (seven-fold or more) in phytoplankton, depending on the species composition and nutritional status of the cells (Valiella 1984). Second, the chlorophyll a levels measured for the Roanoke were near the lower limit of detection by the method used in our laboratory. In any case, the biomass:chlorophyll ratio for the Roanoke study area averaged 51:1, which is close to the value of 50:1 often reported as an average (e.g., Valiella 1984). Both parameters are useful: chlorophyll a for comparison to other systems because it is commonly measured in aquatic ecosystems of all types, and wet weight biomass because it is useful for addressing questions concerning trophic structure and functioning.

Most of the algae are small species that should be usable as food for grazing zooplankton in the Roanoke River. Blue-green algae, which are usually classified as undesirable food for zooplankters, were not present in significant

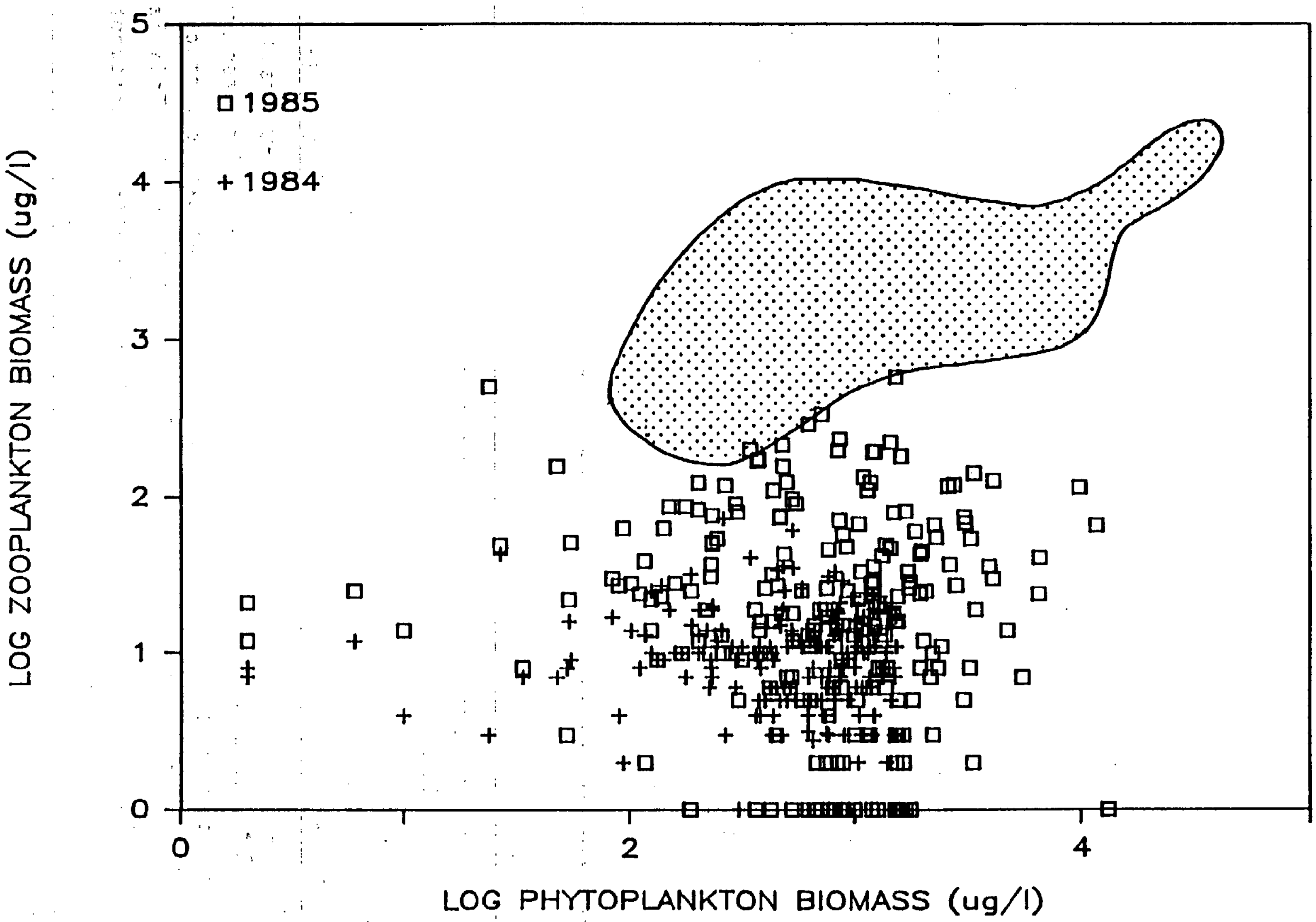

Figure 19. Log phytoplankton biomass vs. log zooplankton biomass for Roanoke study area samples in 1984 and 1985. Shaded area indicates range of values compiled for 13 lakes by McCauley and Kalff (1981).

by yolksac striped bass larvae. Unfortunately, no historical data base exists for Roanoke River and western Albemarle Sound zooplankton to indicate what level of food availability is necessary to produce successful striped bass year classes.

Higher than normal river flow in 1984 probably caused striped bass eggs and larvae to be washed out from the Roanoke River before feeding began. Striped bass eggs were found in the Roanoke River delta below the Highway 45 bridge (Station 12), which is approximately 125 river miles downstream from the major spawning ground. Larvae with yolk were common throughout the study site, including the Bachelor Bay stations. The few larvae in feeding condition were found exclusively in the mouth of the Cashie River (Station 11) and Batchelor Bay (Stations 13, 14, and 15) in the presence of low zooplankton densities.

Rulifson and Stanley (1985) interpreted these results to mean that the 1984 year class would not be an abundant one, at least not as abundant as the 1982 and 1983 year classes. This was confirmed by the juvenile abundance index (USDOI and USDOC 1985) conducted in Albemarle Sound that year, which was approximately 50% of the 1983 index and less than 1% of the highest index on record (26.4 fish per haul, 1959). The index value obtained by the North Carolina Division of Marine Fisheries was 0.0 striped bass young-of-the-year (YOY) per trawl; Dr. W.W. Hassler of North Carolina State University obtained a value of 0.36 (Sara Winslow, Division of Marine Fisheries, Elizabeth City, NC, personal communication). Rulifson and Stanley (1985) predicted that under lower flow conditions, zooplankton densities in the river should increase, and first feeding of striped bass larvae should be initiated in the lower river thus optimizing young striped bass survival.

This hypothesis was supported by results of the 1985 study. River flow was lower than in 1984, zooplankton densities were higher, and striped bass larvae began feeding in the Roanoke River between Plymouth and Jamesville. The juvenile abundance index for 1985 indicated better survival of striped bass than in 1984. The Division of Marine Fisheries obtained an abundance index value of 0.32 YOY striped bass per trawl, and Hassler obtained a value of 1.30 (Sara Winslow, personal communication). These values are still quite low relative to minimum of 2% of the larvae examined had parasites (Figure 13). The effects of parasitism on striped bass larvae at this stage of development is not documented in the literature, although other investigators have cited incidences of parasitism in other ecosystems (e.g., Buckley et al. 1985).

Incidence of deformed striped bass larvae was lower in 1985 than in 1984. Results of the earlier study indicated that up to 5% of the larvae examined were deformed (Figure 20). Less than 2% of the larvae examined in 1985 were in this condition. The causative agent responsible for this condition has not been determined. One possibility may be starvation of the larvae. Certainly, the rate of development and rate at which the oil globule is used is directly correlated with prey concentration (Eldridge et al. 1981; Rogers and Westin 1981). Another possibility may be that poor water quality is placing stress on the larvae during critical larval development (Palawski et al. 1985). Since water flows were higher in 1984, corresponding with increased incidence of deformed larvae, it is possible that physio-chemical properties of the runoff (e.g., sudden changes in water temperature, pH, or pollutant substances) at sublethal levels could have contributed to the deformities.

One suspected cause of larval striped bass mortality is excessive levels of aqueous aluminum in the presence of moderately low pH. Studies designed specifically to examine water quality of striped bass spawning grounds and nursery habitats, especially in Chesapeake Bay, have failed to identify any one causative agent for declining striped bass stocks (USDOI and USDOC 1985). These studies were correlated with extensive laboratory research. The possible exception is high aluminum in moderately acidic waters. *In situ* experiments of exposing striped bass larvae (24 hours after hatching) to natural waters of the Nanticoke River, a primary striped bass spawning tributary in Chesapeake Bay, were conducted to determine mortality rates (Hall et al. 1985). All 68 of the organic and inorganic contaminants monitored during the study were present in low concentrations, with the exception of aluminum (120 ug/l in filtered samples). The average Nanticoke River pH was about 6.3, not extremely acidic but potentially stressful for larval striped bass (Hall et al. 1985). Recent laboratory experiments at the Columbia National Fisheries Research Laboratory showed that 19-day old striped bass larvae exposed to pH 6.5 died in seven days;

when 100 ug/l was added, death occurred within five days. Results of our water quality study in 1985 indicated total aluminum concentrations in the Roanoke River ranged from 200-2400 ug/l (unfiltered samples) and the water was moderately acidic (pH 6.0-6.8), suggesting a potential problem for striped bass larvae in the Roanoke. A pH range of 6.0-10.0 is favorable for survival of striped bass larvae and young (Regan et al. 1968); the optimum pH is 7.5 (Davies 1970, 1973). However, an instant change (pulse) of 0.8-1.0 pH units, even within the favorable range, will cause high mortality in striped bass larvae (Doroshov 1970). Short-term fluctuations of pH in the Roanoke River and the corresponding concentrations of toxic (labile) aluminum present, have not been determined and warrant examination.

7). Chlorophyll a concentrations were mostly between 4 and 7 ug/l in 1984 with no clear spatial or temporal patterns in the data. However, 1985 levels were higher (mostly between 5 and 15 ug/l) with a spatial pattern (lowest upriver, highest downriver, intermediate in western Albemarle Sound). Chlorophyll appeared to be negatively correlated with river flow.

8). The phytoplankton community resembled that of a lake more closely than that of an estuarine environment. About 150 phytoplankton cell types were identified; diatoms (Bacillariophyceae) exhibited the highest diversity followed by green algae (Chlorophyceae). Only 23 of the cell types appeared in more than 10% of the samples.

9). Phytoplankton densities between 300 and 700 cells/ml were common in 1984. No pattern was discernable in the distribution. Phytoplankton biomass fell between 300 and 800 ug wet weight/l for most samples.

10). Phytoplankton cell densities were higher in 1985 with distinct temporal and spatial patterns. Densities tended to be higher (8000-10,000 cells/l) early in the study (late April-early May) than later in May and early June (1000-2000 cells/ml). Densities were relatively low upriver in the Roanoke, and increased in the lower Roanoke and in western Albemarle Sound. Phytoplankton biomass showed the same temporal and spatial patterns as algal cell density. Most biomass values ranged between 500 and 2000 ug wet weight/l. Average biomass for the study area declined from 1500-3400 ug wet weight early in the sampling period to around 400-700 ug wet weight/l in early June.

11). Green algae (Chlorophyceae) were numerically dominant at all stations in 1984, comprising 47-87% of the total cell density. Chyrsophyceae and Bacillariophyceae (diatoms) were of secondary importance. Generally, bulk of the total algal biomass was made up of green algae (44%), diatoms (15%), and chrysophytes (16%).

12). In 1985 diatoms replaced green algae as the major class, both in terms of cell density (40-60% at most stations) and biomass (40-60%). Green algae was second, comprising 25-30% of the total cell density and 20-40% of total biomass. Chrysophytes were also less important in 1985 than in 1984.

13). Most algae collected from the study area were small species that are potentially usable as food for grazing zooplankton.

larvae into western Albemarle Sound in 1984. Low river flow in 1985 allowed larvae to remain within the Roanoke River and delta to feed and grow.

23). Striped bass eggs, representing 2.9% of the total catch in 1984, were found throughout the study area including Albemarle Sound. Mean egg abundance within the study area was negatively correlated with river flow measured at Roanoke Rapids, N.C., lagged by three days. No eggs were found in the study area in 1985.

24). Stage 1 larvae (with yolk) comprised 96% of the catch in 1984 and 67% in 1985. Greatest concentrations in 1984 were from Williamston to the area just above the Thoroughfare (Stations 1-4), and also in the lower delta. Highest abundance in 1985 was from Williamston into the upper Roanoke River delta (Stations 6 and 7).

25). Stage 2 larvae (beyond yolk stage) comprised only 1.2% of the catch in 1984 and 33% in 1985. No larvae that had absorbed the oil globule were caught in 1984. Larvae with oil were most abundant in the lower Roanoke River and delta in 1985; larger larvae (up to 24 mm TL) were found in the lower delta and western Albemarle Sound late in the sampling season.

26). The number of striped bass larvae in feeding condition was much greater in 1985 than 1984. Only 1% were in feeding condition in 1984; of those, 11% had food items in their guts. All feeding larvae were caught in western Albemarle Sound. In 1985, first-feeding larvae were caught as far upstream as Station 4. Approximately 48% of Stage 1 larvae and 39% of Stage 2 larvae had consumed food items.

27). In 1985 the number of larvae with food was correlated with sampling date, sample collection time, and density of cladocerans and copepods present. Major food items were cladocerans, primarily Bosmina, and copepodid stage copepods. Larger Stage 2 larvae consumed larger food items such as Daphnia, copepodid and adult copepods, and fish (including Morone larvae).

28). Internal parasites were found in at least 2% of all Morone larvae examined in 1985. These parasites were of two types: Type I, tentatively identified as a protocephalid larva, attached to the intestine and stomach; and Type II (unidentified) attached at three locations (gut cavity, near the anus, and anterior to the heart).

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The appendices, a total of 447 pages, are not included, but will be made available on request.