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William A. Burke. ORGANIC CARBON AND DEOXYGENATION IN THE PAMLICO RIVER ESTUARY. (Under the direction of Graham J. Davis)
Department of Biology, January 1978.

The distribution, sources and sinks of organic carbon were studied in the Pamlico River Estuary during 1975-1977. The main source of organic carbon was from phytoplankton productivity, which, together with other sources from within the estuary, provided 64% of the organic carbon inputs. The remaining 36% was mainly from tributaries. Organic carbon losses (sinks) were 80% as water column respiration and 20% as outflow. Sedimentation and benthic respiration are undetermined losses.

Total organic carbon (TOC) varied seasonally with the highest levels occurring during the summer months when flow rates were low. Also, TOC normally displayed a gradient with the highest levels consistently in the upper reaches near Washington, N.C. Approximately 79% of the TOC in the estuary consisted of dissolved organic carbon (DOC) which accounted for most of the seasonal variations in TOC. Levels of particulate organic carbon (POC) were fairly constant throughout the year with the exception of sporadic increases in phytoplankton biomass.

The dry and calm summers of 1976 and 1977 provided an excellent opportunity to study deoxygenation in the estuary. The normally sluggish circulation of the Pamlico River depends primarily on wind stress for mixing, and both wind speed and direction are important in determining the extent of mixing. Deoxygenation was observed spanning the entire length of the estuary and well into Pamlico Sound, and has even been observed during the winter in association with an intense algal bloom. Deoxygenation is normally limited to the deeper mid-channel regions of

the estuary except in the upper reaches where it may extend throughout much of the water column and into relatively shallow areas in extreme cases.

The largest input of organic carbon to the estuary is from productivity of phytoplankton which is more readily available to organisms utilizing oxygen than the less abundant and more refractory inputs from tributaries. Because of this, the regulation of inorganic nutrient sources (especially nitrogen) is more important for controlling increases in organic loading than are tributary inputs of organic carbon. Although deoxygenation depends on physical conditions which result in stratification of the water column, episodes of oxygen depletion may be more severe and occur more frequently if conditions become more favorable for higher phytoplankton production.

ORGANIC CARBON
AND DEOXYGENATION
IN THE PAMLICO RIVER ESTUARY

A Thesis
Presented to
the Faculty of the Department of Biology
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In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Biology

by
William A. Burke
January 1978

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AND DEOXYGENATION
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by

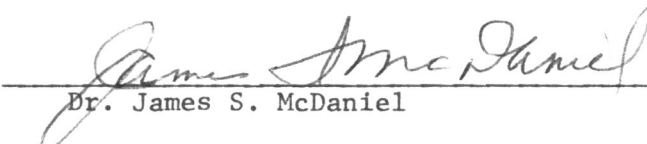
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INTRODUCTION

Fundamental in understanding the ecological framework which supports an ecosystem is a knowledge of the distribution and cycling of carbon within the system. Since the classic work of Birge and Juday (1934), many investigations have been undertaken to understand these relationships. In lacustrine systems, the primary source of organic carbon is normally autochthonous primary production (Lind, 1971; Wetzel et al., 1972; Brinson, 1973; Wetzel and Rich, 1973; Wetzel and Otsuki, 1974; Jordan and Likens, 1975). However, little work has been done in regard to organic carbon in estuaries. In many estuaries, the allochthonous inputs are about equal to, or even exceed the autochthonous inputs (Teal, 1962; Copeland and Birkhead, 1973; Matson and Buck, 1977). In estuaries dominated by marshes, allochthonous organic detritus is often the primary link between primary and secondary production, with the major flow of energy along the "detritus food chain" rather than the "grazing food chain" (Odum and de la Cruz, 1967). However, autochthonous inputs are becoming important in many estuaries where anthropogenic inputs of inorganic nutrients are leading to eutrophic conditions with increased primary production (Barlow et al., 1963; Basu, 1965; Reuter, 1977). This can adversely affect the aquatic environment by increasing the organic loading beyond the assimilatory capacity of the system. In many estuaries this has led to deoxygenation, often with associated fish kills (Carpenter et al., 1969; Klashman et al., 1970; May, 1973; Knudson and Belaire, 1975; Segar, 1977). Persistent summer deoxygenation has been reported in the Pamlico River

Estuary for many years (Copeland et al., 1969).

The large drainage basin of the Pamlico River ensures that abundant allochthonous organic carbon will be contributed to the standing stock of organic carbon in the estuary. The importance of this source can be compared with the organic carbon of autochthonous origin. The objective of this study was to compare the seasonal variation and total quantities of each of these sources, and to evaluate their effect on the distribution of the standing stock of organic carbon in the estuary.

Since recurrent deoxygenation and associated fish die-off in the Pamlico River are dependent on an available supply of organic carbon, it is important for management purposes to understand its origin (allochthonous vs. autochthonous) in addition to anthropogenic influences on these sources. As energy flow and carbon flow are closely parallel, a better understanding of organic carbon will help to determine the nature and availability of consumer food sources as well as the capacity of the aquatic and surrounding terrestrial watershed to support this estuarine ecosystem.

The Pamlico River Estuary

The Pamlico River Estuary is a natural, temperate, oligo- to mesohaline estuary extending approximately 60 km from Washington, N.C. to the Pamlico Sound (Fig. 1). Most of the land surrounding the estuary and its drainage basin is forest and agricultural with tobacco, soybeans, and corn being the most important crops. Along the lower reaches of the estuary are well-established high salt marshes consisting mainly of Spartina alterniflora and Juncus roemerianus. The estuary varies in

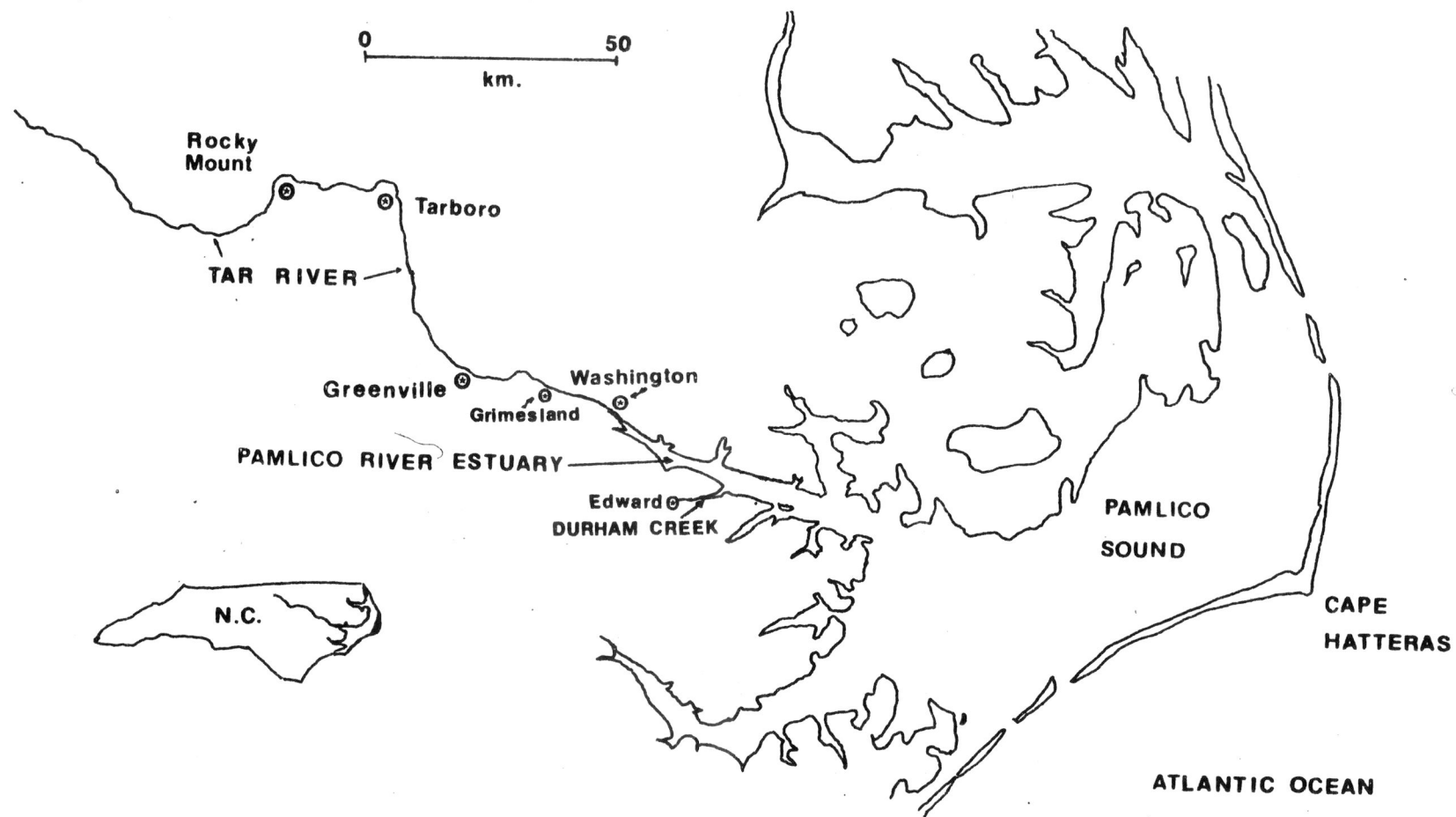


Figure 1. Location of the Pamlico River Estuary in eastern North Carolina.

width from about 0.5 km near Washington, N.C. to about 6.5 km at its mouth and is relatively shallow with an average depth of about 3 m. Salinity ranges from fresh water to about 20 ‰. Salt water enters the estuary from the Pamlico Sound which is connected to the Atlantic Ocean through numerous inlets in the Outer Banks. Fresh water input is by the many tributaries, the Tar River being the most important in terms of discharge. Lunar tides are almost negligible, averaging 15-20 cm. However, strong winds can often generate severe wind "tides" which can significantly alter the hydrography of the estuary. Salinity stratification, often with accompanying deoxygenation, may become quite pronounced during periods of calm due to a lack of mixing. Temperature in the estuary ranges from 0° to 32°C.

Diversity of phytoplankton, zooplankton, benthic invertebrates and aquatic plants in the Pamlico River is characteristically low. The phytoplankton are dominated by dinoflagellates with major blooms of Heterocapsa (Peridinium) triquetrum during the winter and Gymnodinium, Gyrodinium and Polykrikos during the summer (Hobbie, 1971). Zooplankton are dominated by the copepod, Acartia tonsa (Peters, 1968). During the summer, the ctenophore, Mnemiopsis leydi, becomes important in the food chain (Miller, 1970). In the oligohaline portion of the estuary, Rangia cuneata is the dominant benthic invertebrate whereas Macoma balthica dominates the saltier regions near Pamlico Sound (Tenore, 1970). Vallisneria americana comprises the largest portion of the submersed macrophytes with other species including Ruppia maritima, Potamogeton perfoliatus var. bupleuriodes, and Najas guadalupensis (Davis and Brinson, 1976).

Fish species are abundant and include, among others, the southern

flounder, American eel, croaker, spot, speckled and gray trout, and bluefish. Migrating stocks include striped bass, alewife, shad and herring. Commercial harvesting of blue crabs, shrimp and eels is important economically, but much of the estuary has been closed to shellfishing for many years.

The primary industry along the estuary consists of a large phosphate mining operation located about midway down the estuary (T.G.I., Fig. 2) which discharges significant amounts of phosphate mining wastes into the estuary. Studies of this effluent have indicated that it does not significantly affect the biota of the estuary (Carpenter, 1971) and that nitrogen is most often the element limiting primary production (Harrison and Hobbie, 1974). Another phosphate mining plant is currently under construction near South Creek.

Overall, the Pamlico River is relatively oligotrophic with evidence of cultural eutrophication limited to the upper reaches near Washington, N.C. However, increases in urbanization, industrialization and agricultural intensity along the estuary and its drainage basin have led to a growing concern of the effects of increased organic and nutrient loading on the well-being of this valuable North Carolina resource.

MATERIALS AND METHODS

Sampling

Estuarine Organic Carbon Study (August 1975-July 1976).-- At monthly intervals, water samples were collected with a Van Dorn water sampler at depths of 1 and 3 m at 22 stations along the Pamlico River (Fig. 2). These samples were analyzed in duplicate for particulate organic carbon (POC) and dissolved organic carbon (DOC). Hydrographic measurements during this study included temperature, salinity and dissolved oxygen.

Tributary Organic Carbon Study (July 1975-September 1976).-- Water samples were collected at 0.5 m depth from the Tar River at Grimesland, N.C. and from Durham Creek at Edward, N.C. (Fig. 1). Duplicate samples were analyzed for POC and DOC. Sampling intervals were irregular and were chosen to encompass a wide range of flow.

Carbon-Nutrient-Biomass Study (August 1976-July 1977).-- Water samples were collected on alternate months at 0.5 m from both the surface and bottom at six stations along the Pamlico River (Fig. 3). Hydrographic measurements included temperature, salinity, conductivity and dissolved oxygen, and water samples were collected and analyzed in triplicate for POC, DOC, phytopigments, and respiration rates. Levels of nitrate, nitrite, ammonium, total Kjeldahl nitrogen, dissolved Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, dissolved reactive phosphate, sodium, potassium, calcium and magnesium were measured. Phytoplankton productivity and secretion, and alkalinity and pH were also measured on surface (0.5 m) water samples at each station. Quarterly measurements

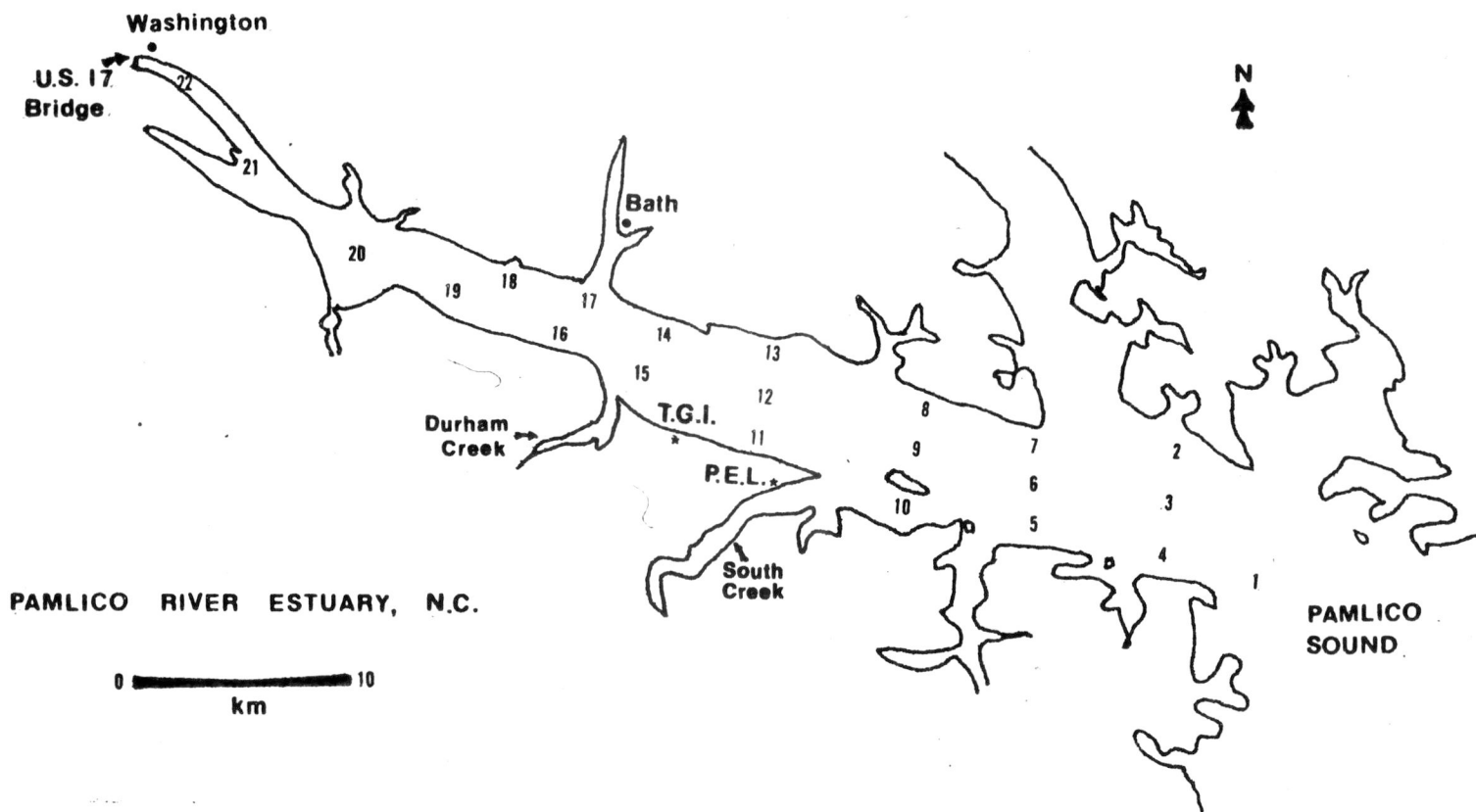


Figure 2. Location of sampling stations for the Estuarine Organic Carbon study (August 1975 - July 1976). Samples were collected monthly at 1 and 3 m. Locations of the Pamlico Estuarine Laboratory (P.E.L.) and Texasgulf, Inc. (T.G.I.), a large phosphate mining operation, are shown.

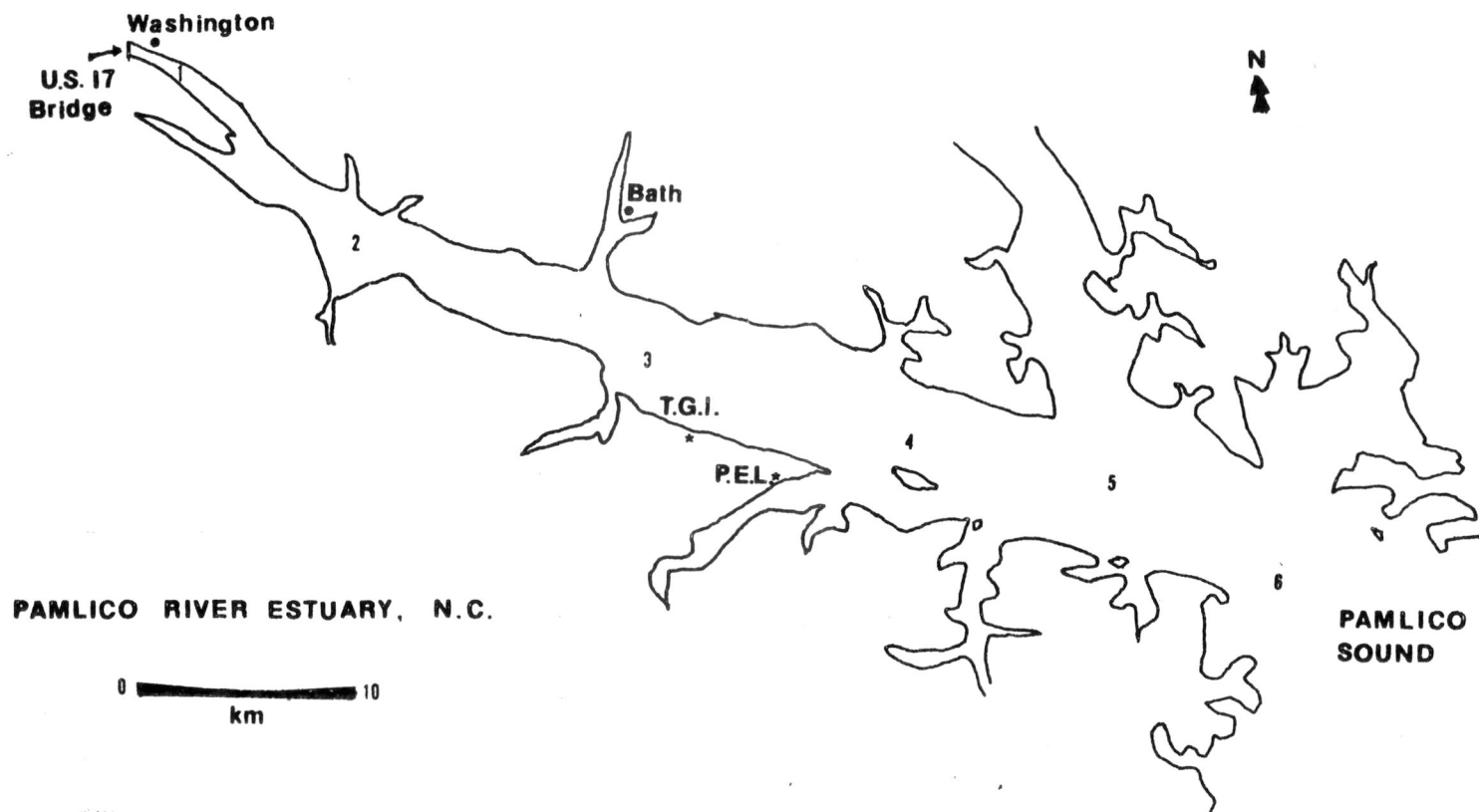


Figure 3. Location of sampling stations for the Carbon-Nutrient-Biomass study (August 1976 - July 1977). Samples were collected on alternate months at depths of 0.5 m from both the surface and bottom. Locations of the Pamlico Estuarine Laboratory (P.E.L.) and Texasgulf, Inc. (T.G.I.), a large phosphate mining operation are shown.

were made of phytoplankton biomass with dominant species identified.

Diurnal Studies (1975-1977).-- Diurnal studies of phytoplankton productivity were conducted on five occasions. Some included all analyses of the Carbon-Nutrient-Biomass study.

Additional Hydrographic Studies (1975-1977).-- Special hydrographic studies of the extent and severity of the deoxygenation in the estuary were made. Sampling dates and stations varied according to the severity of deoxygenation.

Analyses

Hydrography.-- Measurements of temperature, salinity and conductivity were made with a YSI Model 33 S-C-T meter. Dissolved oxygen was measured with a YSI Model 51A oxygen meter and electrode. All reported dissolved oxygen values are corrected for temperature and salinity.

Carbon.-- Water samples to be analyzed for organic carbon were stored on ice for transport back to the laboratory, where necessary filtration was normally accomplished within 12 h of collection. Filtration for this and other determinations was with Gelman type A/E glass fiber filters (0.2 μm average pore size). POC determinations were made by dichromate oxidation (Strickland and Parsons, 1972). DOC was analyzed on a Beckman Model 915 Organic Carbon Analyzer after the filtered water was acidified and purged with nitrogen gas for 15 min.

Nutrients.-- Aliquots of water were immediately filtered for nutrients and stored in the dark on ice for transport back to the laboratory

where they were frozen within 8 h of collection for later analysis. Particulate fractions were estimated by subtracting the dissolved fraction from the total. Kjeldahl digestions (EPA, 1976) were used for the nitrogen determinations, and nitrate was determined by the UV spectrophotometric method (APHA, 1971). Ammonium-nitrogen analysis was by the indolphenol method (Scheiner, 1976) except for the 11 August 1976 Carbon-Nutrient-Biomass run where an Orion electrode was used. The azo-spectrophotometric method (EPA, 1976) was used for nitrite. Phosphorus analyses involved conversion of phosphorus to orthophosphate by persulfate digestion, and subsequent colorimetric determination of soluble orthophosphate (EPA, 1976).

Cations.-- Water to be analyzed for sodium, potassium, calcium and magnesium was immediately filtered, acidified, and frozen on dry ice for transport back to the laboratory. Cations were analyzed on a Perkin-Elmer Model 403 Atomic Absorption Spectrometer (Perkin-Elmer, 1973).

Phytopigments.-- Water to be analyzed for phytopigments was stored in the dark on ice for transport back to the laboratory with filtration within 12 h of collection. The samples were stored in a desiccator and frozen until analyzed. Determinations of chlorophyll a (corrected and uncorrected for phaeophytin), chlorophyll b, chlorophyll c, carotenoids, and phaeopigments were made according to Strickland and Parsons (1972). All analyses were made within 30 days of collection.

pH and Alkalinity.-- Water samples for pH and alkalinity were stored in the dark at mean ambient water temperature until measured (within 4 h). Determinations of pH were with a Corning Model 10 pH meter, while alkalin-

ity analyses were by titration with 0.02 N sulfuric acid to pH 4.5 (Strickland and Parsons, 1972).

Productivity and Secretion.-- Water samples for pelagial phytoplankton productivity and secretion were stored in the dark at ambient water temperature until incubation (within 6 h). Productivity determinations were with the light/dark ^{14}C method according to Strickland and Parsons (1972), and secretion was analyzed according to Berman (1976). Into duplicate light bottles and a dark bottle (125 ml) containing a surface (0.5 m) water sample from each station, 5 μCi of $\text{NaH}^{14}\text{CO}_3$ were injected. The bottles were then placed horizontally in a bottle holder, which allowed for equal shading of the light bottles, and suspended in South Creek (P.E.L., Fig. 2) at a depth of 0.5 m. The bottles were incubated for a 2 h period (1300-1500 EST) during the Carbon-Nutrient-Biomass study, and for 4 h periods beginning at 0400 EST during diurnal studies. Also, during a diurnal study in both summer and winter, the bottles were incubated on station at 0.5 m, 1.5 m, and 2.5 m to estimate productivity variations with depth. Following incubation, the samples were filtered and washed with filtered ambient water. The samples were then placed in 20 ml of a toluene-based cocktail for counting. Counting was with a Packard Model 3320 Tri-Carb Liquid Scintillation Spectrometer, and amount of quenching (due to chlorophyll) was measured on each sample using the external standardization method (Packard Instrument Co.). Quenching was generally insignificant (15% in extreme cases) and reported values are uncorrected.

Determinations of secretion (and autolysis) by phytoplankton were made on the filtrate from the productivity bottles. Two ml of this

filtrate were placed in a scintillation vial, and all inorganic carbon was removed through acidification and storage in a vacuum desiccator for 24 h. For counting, 18 ml of a toluene-based cocktail was added.

Phytoplankton Biomass.-- Phytoplankton samples were collected 0.5 m from both the surface and bottom, and fixed with a modified Lugol's solution containing 10 g I₂, 21.85 g sodium acetate, 20 g potassium iodide, and 200 ml water. This modified solution gives better preservation of coccolithophores (Hobbie, 1971). For determining the biomass of the phytoplankton, the Utermöhl sedimentation method according to Lund et al. (1958) was used. Fifty cm³ of sample were allowed to settle for 24 h into a counting chamber. Random fields were then counted on a Wild M40 inverted microscope until at least 100 individuals of the most abundant species were counted. This gives approximately $\pm 20\%$ at the 95% confidence level (Lund et al., 1958). The counts were converted to numbers per liter by considering the amount of sample settled, the area of the counting chamber, and the area of the counting chamber counted. These numbers were converted to volume per liter by multiplying by the volume of the organism, and finally to biomass by assuming a specific gravity of one. References used in identification included Campbell (1973), Prescott (1970), Whitford and Schumacher (1969), Wolle (1894), Paragallo (1965), Cleve-Euler (1951), Vinyard (1974), Vinyard (1975), and Wood and Lutes.

Respiration.-- Water samples to be analyzed for respiration rates were stored in the dark on ice for transport back to the laboratory. The samples were incubated at mean ambient water temperature at time of collection. Oxygen readings were taken daily for the first 5 days and

every second or third day thereafter. Dissolved oxygen readings were made with a YSI Model 54A oxygen meter with an electrode equipped with a stirrer. To prevent oxygen from becoming limiting, samples were reaerated whenever the dissolved oxygen level dropped below 4 ppm. Respiration rates were calculated based on the initial 24 h drop in oxygen. Five day respiration levels reported are the total amount of oxygen utilized after 5 days. Changes in oxygen were plotted against time to give relative fractions of labile versus refractory carbon. This method is further described by Ogura (1975).

Carbon Budget

Standing Stock of Organic Carbon in the Estuary.-- Carbon concentrations for each station and depth within a sector were averaged to represent the carbon concentration for that sector. This concentration was then multiplied by the volume of the sector, determined planimetrically (at mean low water), to give the amount of carbon in the sector. Sector volumes are given in Appendix A. Addition of sector standing stocks gave the standing stock of carbon in the estuary.

Standing stocks of organisms were determined by multiplying the mean biomass of an organism at a station (surface and bottom) by the volume of the sector represented by the station. Summation of the sector standing stocks gave the standing stock estimate for the estuary.

Total Tributary Input of Organic Carbon to the Estuary.-- Carbon concentrations were plotted against discharge (from U.S.G.S., 1976, 1977) for both the Tar River and Durham Creek, the two gauged tributaries of the Pamlico River. Discharge for the Tar River at Grimesland, N.C. was

assumed to be proportional to the measured discharge at Tarboro, N.C. where the gauging station is located (Fig. 1). The resulting correlations were used to give mean concentrations of these tributaries (based on mean discharge during the study period), which were then multiplied by the total water input to give the annual import of organic carbon to the estuary by these tributaries. By dividing the annual import of these tributaries by the area of their respective drainage basins, a value representing the annual input per unit area of drainage basin was obtained. Since the Tar River and Durham Creek represent the two extremes of mean organic carbon concentration (based on preliminary data of 14 tributaries during July 1975), these values were averaged to give a mean value for annual import of organic carbon per unit area of drainage basin for the other, non-gauged tributaries. This value was then multiplied by the drainage basin areas of these tributaries, as determined by Harrison and Hobbie (1974), to give the annual input of organic carbon to the estuary by these tributaries.

Input of Organic Carbon by Phytoplankton.-- The productivity and secretion rates at 0.5 m depth at each station were first extrapolated to daily rates based on diurnal productivity and secretion curves which were integrated by cutting and weighing. The productivity and secretion values based on 2 h incubations were multiplied by factors of 4.12 and 4.47, respectively, to make this conversion. Based on diurnal productivity experiments during summer and winter, productivity at 1.5 m and 2.5 m depth was 27% and 3%, respectively, of that at 0.5 m. Phytoplankton productivity was negligible at depths below 3 m in the estuary. The input of organic carbon from phytoplankton for each sector was estimated

by multiplying the mean daily productivity and secretion rates for each depth at a station by the volume of the sector at each corresponding depth. These were then multiplied by 365 days to give an annual value. Summation of these annual sector production and secretion values gave the annual particulate productivity and secretion inputs to the estuarine organic carbon pool.

Output of Organic Carbon through Respiration.--- Respiration rates were measured as the total oxygen uptake during the initial 24 h of the respiration experiment. The mean surface and bottom values at each station were averaged to give the mean respiration for that station. This value was then multiplied by the volume of the corresponding sector to give the total respiration for that sector. This was put on an annual basis to give annual uptake of oxygen per sector. Summation of the sector values gives total estuarine uptake of oxygen per year, which was then converted to carbon units by multiplying by 0.300 (Ryther, 1956).

Estuarine Discharge.--- Estuarine discharge of organic carbon was estimated from the 22 station Estuarine Organic Carbon study by using the method of Harrison and Hobbie (1974) which corrects the organic carbon concentration at the mouth of the estuary for dilution by sea (Pamlico Sound) water.

RESULTS AND DISCUSSION

Organic Carbon

Standing Stock.-- The distribution of organic carbon was surveyed in the Pamlico River during the Estuarine Organic Carbon study, where the 22 stations represented 11 sectors (Fig. 4 and Table 1). Means of hydrographic measurements and carbon concentrations during this study are plotted in Fig. 5. Total organic carbon (TOC) varied seasonally in estuarine waters with the highest concentrations in the summer months. There was a TOC gradient for the estuarine sectors with the highest concentrations in the upper reach. This gradient was apparently associated with the effects of decreasing flow and increasing salinity on settling rates. Also, the estuary becomes much wider in the area of Blount's Bay (Sector 3) providing greater dilution of organic carbon entering from the Tar River. Hobbie (1977) suggests that uptake of organic matter by the estuarine clam, Rangia cuneata, may be an important sink in the upper reaches. The average standing stock of TOC in the Pamlico River during this study was 7,277 tonnes (approximately 25.7 g/m^2).

Dissolved organic carbon (DOC) accounted for most of the seasonal variations of organic carbon with high concentrations during the summer and low concentrations during the winter (Fig. 6). High concentrations of DOC often accompanied high discharge of the Tar River (e.g. August 1975; Fig. 6). Levels of DOC were often negatively correlated with salinity, but during periods of low flow tended to show fewer differences between the upper reaches and the mouth of the estuary. This suggests

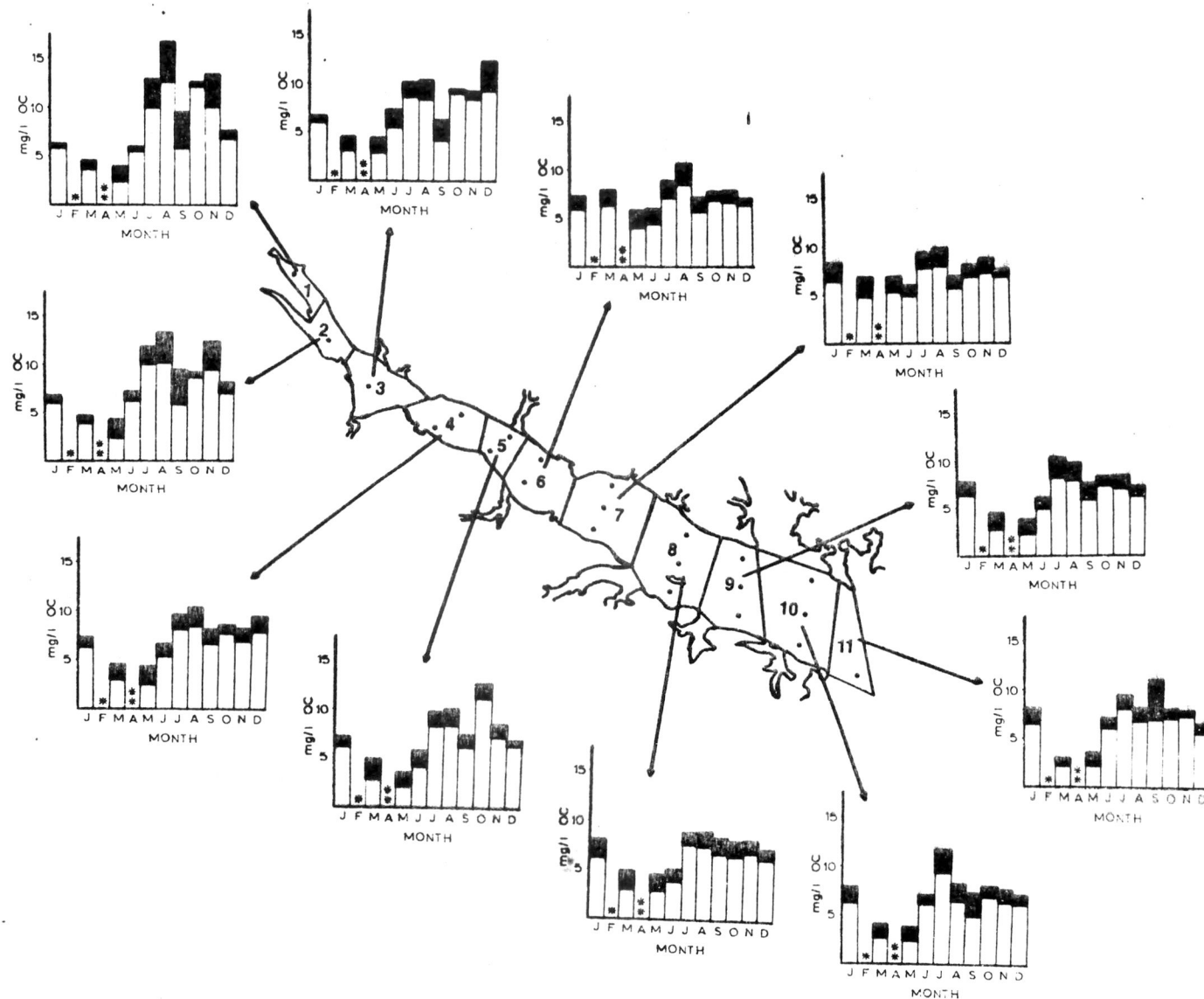


Figure 4. Organic Carbon in the Pamlico River Estuary. Monthly concentrations of organic carbon from August 1975 to July 1976 are graphed. February values (*) are not shown due to an obvious analytical error. No samples were taken during April (**). Darkened areas of histogram bars represent particulate organic carbon, and light areas represent dissolved organic carbon. Sampling stations within the 11 sectors are indicated on the map by dots (•).

Table 1. Distribution of organic carbon in the Pamlico River Estuary (means by sector for August 1975 to July 1976). Sector locations are shown in Figure 4.

Sector	km ²	km ³	$\bar{X}$ Tonnes per Sector for 10 Months			$\bar{X}$ mg/liter per Sector for 10 Months		
			DOC	POC	TOC	DOC	POC	TOC
1	5.9	0.0079	57 (7)*	16 (4)	73 (11)	7.3 (1.1)	2.0 (0.5)	9.3 (1.4)
2	12.9	0.0223	153 (18)	42 (8)	194 (21)	6.8 (0.8)	1.9 (0.3)	8.7 (0.9)
3	21.9	0.0514	330 (41)	83 (13)	413 (42)	6.4 (0.8)	1.6 (0.2)	8.0 (0.8)
4	20.5	0.0510	316 (34)	77 (6)	393 (32)	6.2 (0.7)	1.5 (0.1)	7.7 (0.6)
5	11.7	0.0377	235 (31)	55 (6)	290 (32)	6.2 (0.8)	1.5 (0.1)	7.7 (0.8)
6	22.3	0.0781	473 (31)	122 (12)	595 (35)	6.1 (0.4)	1.6 (0.2)	7.6 (0.4)
7	37.7	0.1237	774 (43)	199 (16)	973 (48)	6.3 (0.3)	1.6 (0.1)	7.9 (0.4)
8	43.3	0.1355	769 (76)	215 (13)	984 (73)	5.7 (0.6)	1.6 (0.1)	7.3 (0.5)
9	35.7	0.1421	823 (89)	230 (20)	1,053 (93)	5.8 (0.6)	1.6 (0.1)	7.4 (0.7)
10	49.2	0.2155	1,245 (138)	342 (38)	1,588 (150)	5.8 (0.6)	1.6 (0.2)	7.4 (0.7)
11	21.8	0.0974	566 (62)	154 (30)	721 (74)	5.8 (0.6)	1.6 (0.3)	7.4 (0.8)
Total	282.7	0.9626	5,742	1,535	7,277	6.2 ($\bar{X}$)	1.6 ($\bar{X}$)	7.8 ($\bar{X}$)

* Standard error of mean

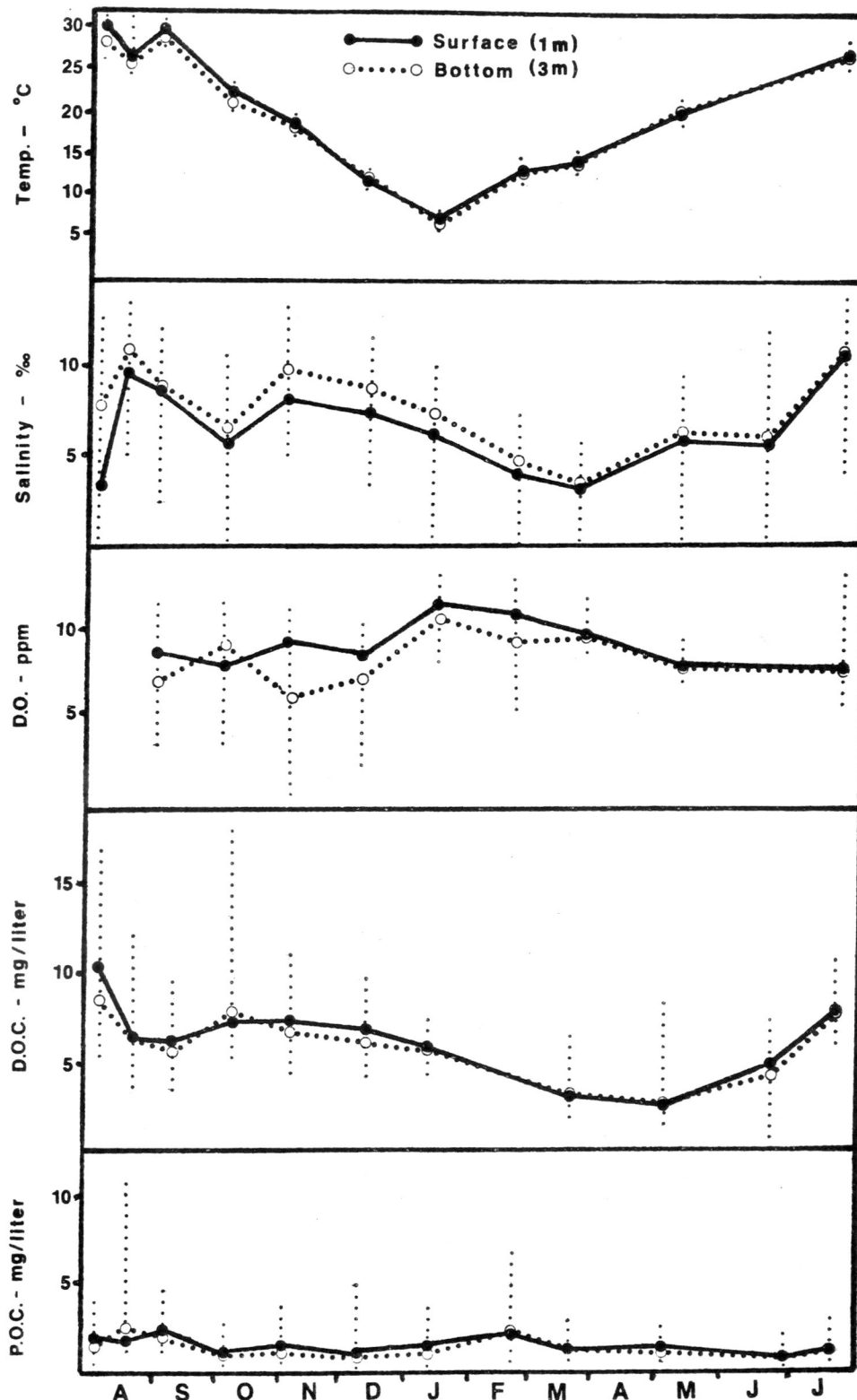


Figure 5. Monthly means of hydrographic and carbon data at 1 and 3 m during the Estuarine Organic Carbon study (August 1975 - July 1976). Ranges of the individual stations are shown.

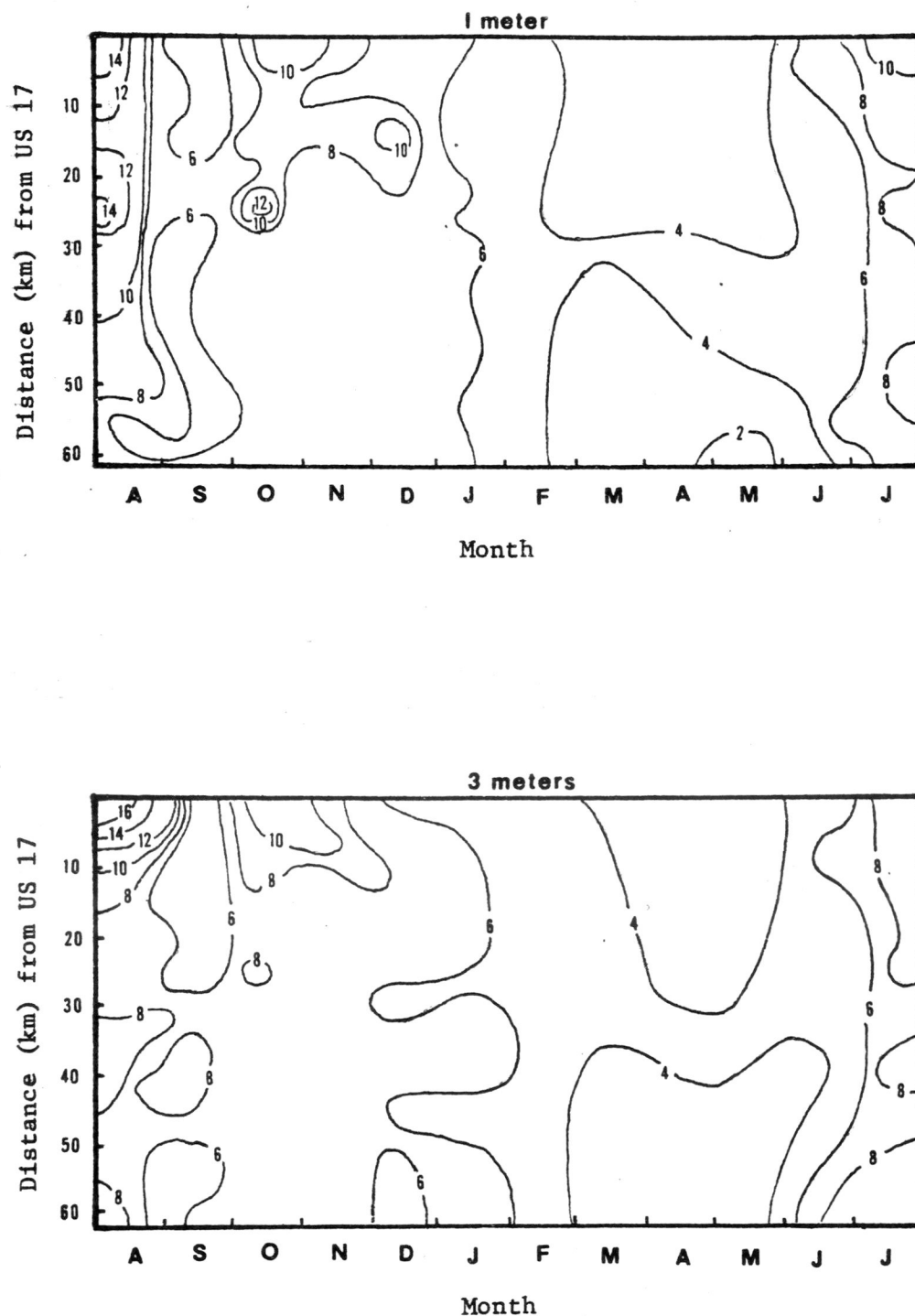


Figure 6. Distribution of dissolved organic carbon (mg/liter) at 1 and 3 m depths in the Pamlico River Estuary during 1975-1976.

that a large portion of the DOC in the estuary originates from land runoff. Crawford (1971) noted a similar relationship for DOC in South Creek, and Happ et al. (1977) obtained similar results in a Louisiana estuary. The average standing stock of DOC in the Pamlico River was 5,742 tonnes (approximately 20.3 g/m^2), which averaged 79% of TOC. These concentrations compare favorably with earlier studies of South Creek (Crawford, 1971) and the Pamlico River (Harrison, 1973).

Levels of particulate organic carbon (POC) were fairly constant throughout the year with the exception of sporadic increases associated with high phytoplankton biomass and seasonal variations in the upper reach (Fig. 7). In these western sectors, highest concentrations were during the low-flow summer months except for November. Higher November levels were probably due to the increased allochthonous detritus inputs associated with autumn leaf fall. Occasionally high concentrations of POC at the mouth of the estuary may have been due to irregular flushing of the surrounding high marshes by wind "tides". Concentrations of POC were typically 21% of TOC. The mean standing stock of POC in the estuary was 1,535 tonnes (approximately 5.4 g/m^2). These POC concentrations compare favorably with corrected data obtained by Peters (1968) near Indian Island (Sector 8).

Standing stocks of TOC, DOC and POC were calculated from the six-station Carbon-Nutrient-Biomass study for comparison with the 22 station study of the previous year. These standing stocks were 8,790 tonnes (31.1 g/m^2), 7,114 tonnes (25.2 g/m^2) and 1,676 tonnes (5.9 g/m^2) respectively. Typically, DOC was 81% and POC 19% of TOC giving a DOC:POC ratio of 4.2:1. These values are similar to those of the Estuarine Organic

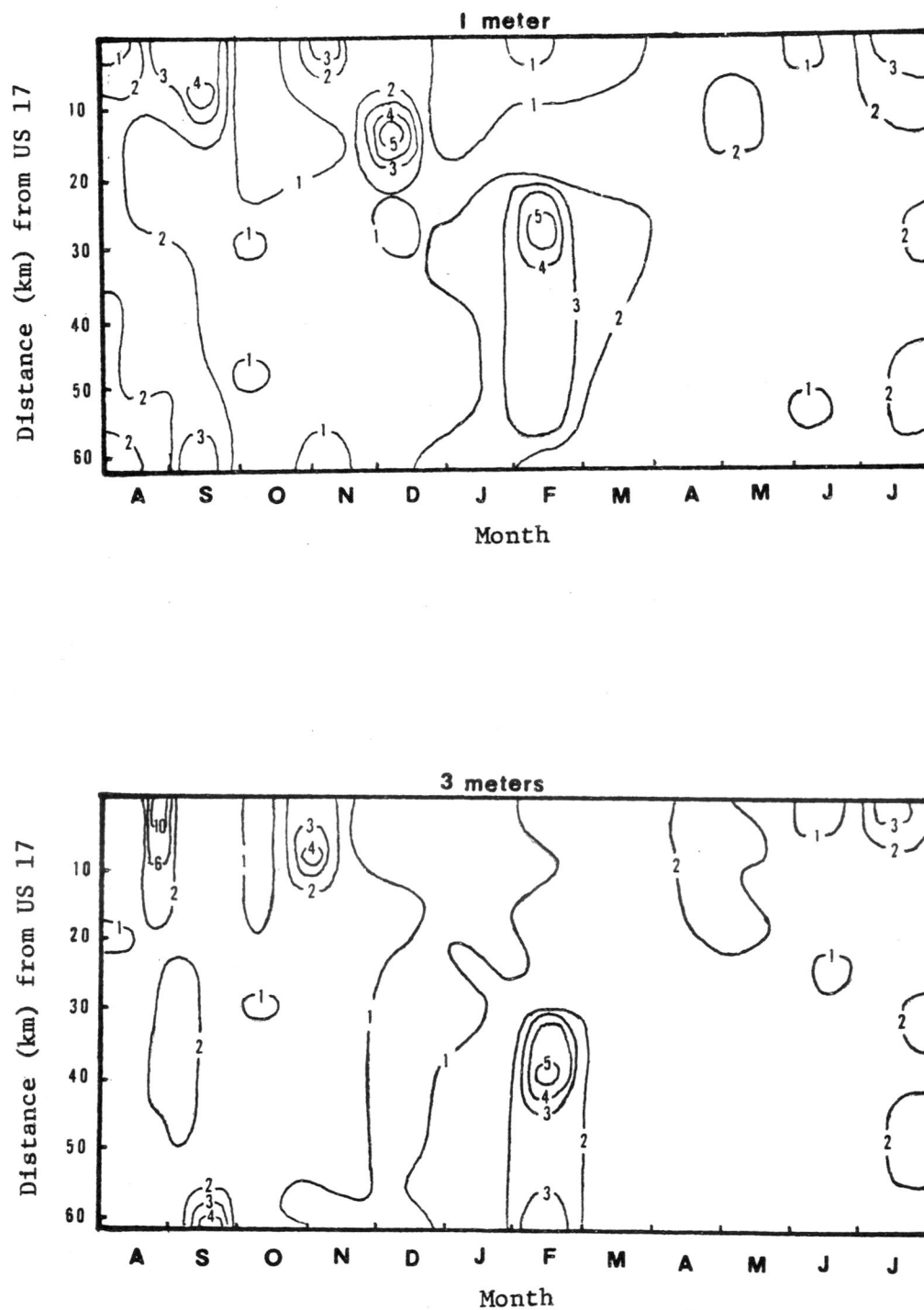


Figure 7. Distribution of particulate organic carbon (mg/liter) at 1 and 3 m depths in the Pamlico River Estuary during 1975-1976.

Carbon study where the ratio was 3.9:1, but are not as accurate since they are based on fewer samples.

Quarterly samples for phytoplankton biomass were collected during the Carbon-Nutrient-Biomass study for comparison with POC. The quarterly cycle of phytoplankton biomass is shown in Fig. 8. Individual phytoplankton biomass samples ranged from 0.253 g wet weight/m³ to 23.184 g wet weight/m³ and were dominated by dinoflagellates. On 16 October 1976, a very high biomass was measured at Station 1 associated with a bloom of Gymnodinium and Gyrodinium, and there was a gradient of phytoplankton biomass downstream. On 2 March 1977, the largest biomass was recorded at Station 2 corresponding to blooms of Heterocapsa (Peridinium) triquetrum and Katodinium rotundatum. This bloom became even more intense during the weeks following this sampling (M. White and D. Kornegay, personal communication). High nitrate concentrations, probably associated with agricultural runoff flowing down the Tar River, were observed on this date upstream from this bloom at Station 1. Diatoms (mostly Melosira, Nitzschia and Navicula flowing in from the Tar River) made up most of the biomass at Station 1 on this date. Due to the lack of mixing associated with salinity stratification in this area, these organisms probably settled rapidly to the bottom being replaced by the motile dinoflagellates at Stations 2 and 3. Diatoms (predominantly Skeletonema costatum, Pleurosigma sp. and Coscinodiscus sp.) also became important downstream (at Stations 5 and 6) where wind stress and resultant mixing coupled with decreasing turbidities probably added to the growth of this population.

On 23 May 1977, the phytoplankton biomass throughout the estuary was relatively low, perhaps due to nutrient depletion by the winter

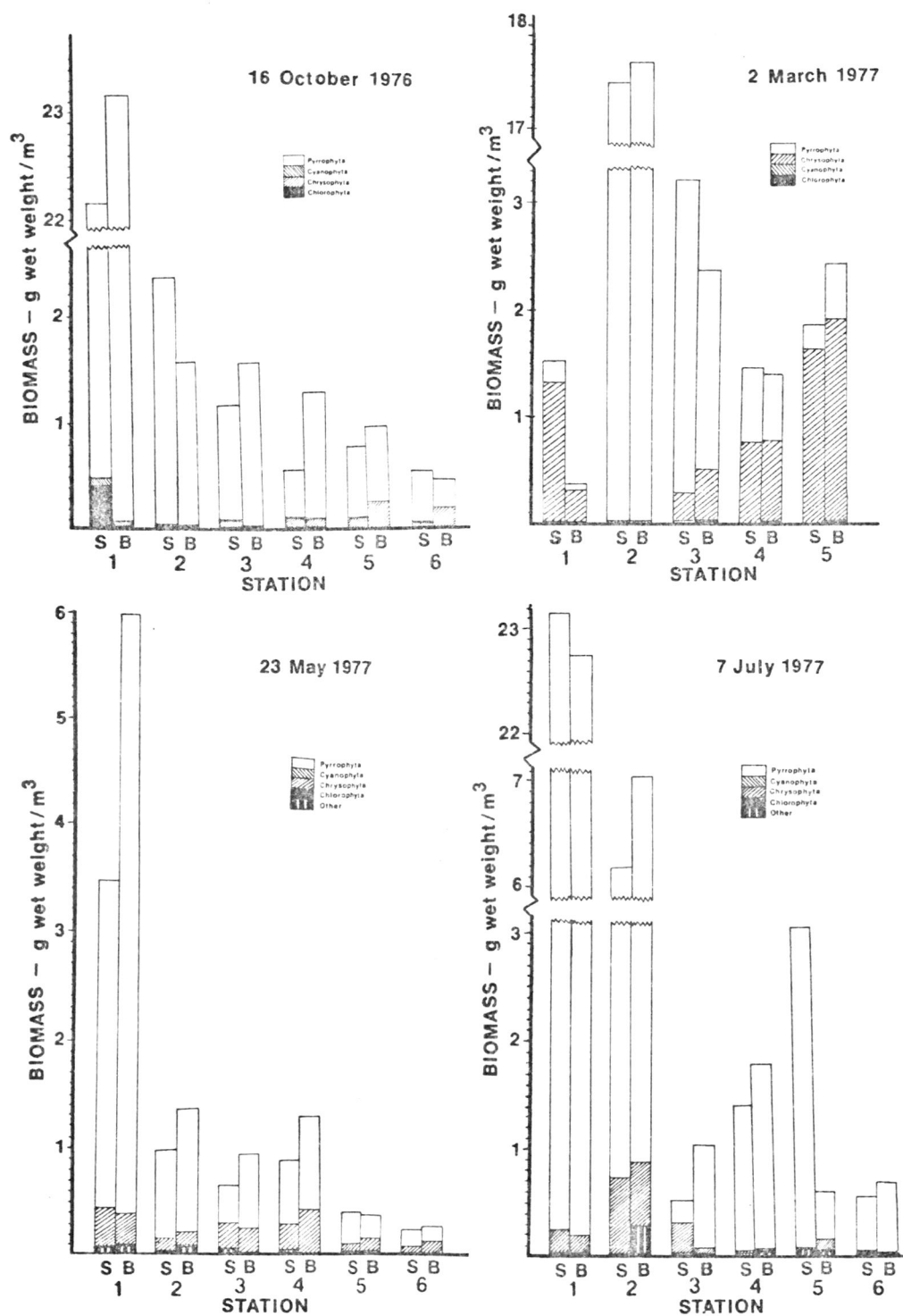


Figure 8. Phytoplankton biomass at six stations in the Pamlico River Estuary during 1976-1977. Samples were collected 0.5 m from both the surface (S) and bottom (B). Station locations are shown in Fig. 3.

blooms. Blue-green algae were dominant in numbers but, due to their small size, were insignificant in the overall biomass. A relatively high biomass was recorded at Station 1 associated with high numbers of Gymnodinium and Glenodinium. On 7 July 1977, there was a very high biomass of phytoplankton at Station 1 associated with high numbers of Gymnodinium and Gyrodinium. The large colonial dinoflagellate, Polykrikos, became important in the lower reaches.

Analysis of phytopigments on the two dates not sampled for phytoplankton biomass during the Carbon-Nutrient-Biomass study indicate that biomass was high on 11 August 1976 and low on 5 December 1976. Hobbie (1971) obtained similar results with peak biomasses occurring during August-September and January-March and low biomasses during October-December and late April-early June. The discrepancy between the studies in October is probably due to the unseasonably calm, dry autumn weather during 1976 which extended summer stratification.

Phytoplankton biomass during 1976-1977 correlated well with POC (Fig. 9), and phytoplankton carbon accounted for an annual mean of 26% of the total POC with the quarterly averages ranging from 9% to 53%. Estuarine standing stock of phytoplankton based on these collections averaged 2,025.5 tonnes, which, assuming phytoplankton carbon is 13% of wet weight (Strickland, 1960), is approximately 263.3 tonnes of carbon (0.93 g C/m^2). Chlorophyll a correlated well with phytoplankton biomass (Fig. 10), and phytoplankton carbon:chlorophyll a ratios averaged 52:1 with a range of 9:1 to 111:1 (chlorophyll a corrected for phaeophytin) and 47:1 with a range of 9:1 to 85:1 (uncorrected for phaeophytin). Particulate nitrogen and phosphorus also correlated well with phytoplankton biomass (Figs. 11 and 12) indicating that these parameters

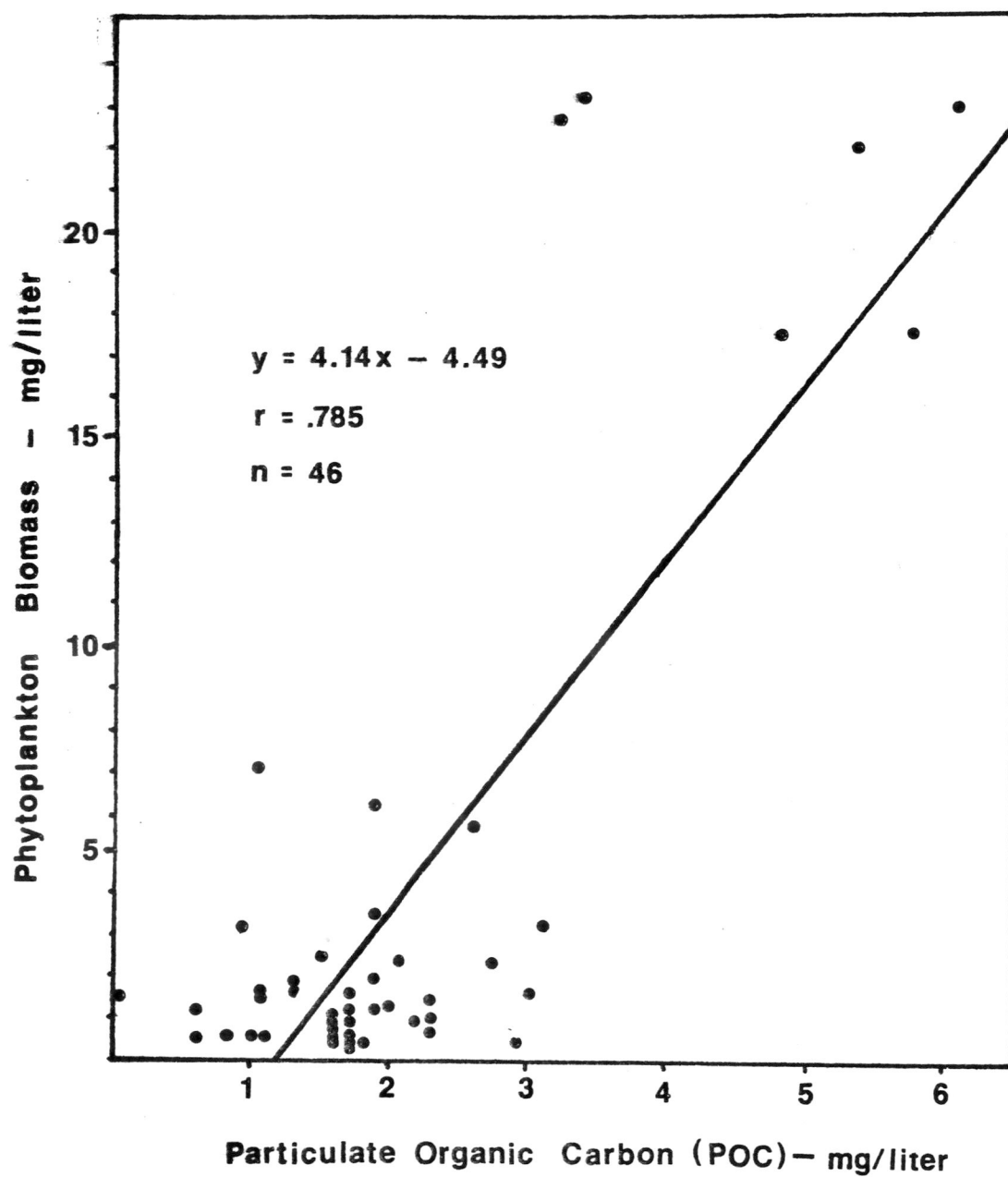


Figure 9. Phytoplankton biomass as a function of particulate organic carbon in the Pamlico River during 1976-1977 ($P < 0.01$).

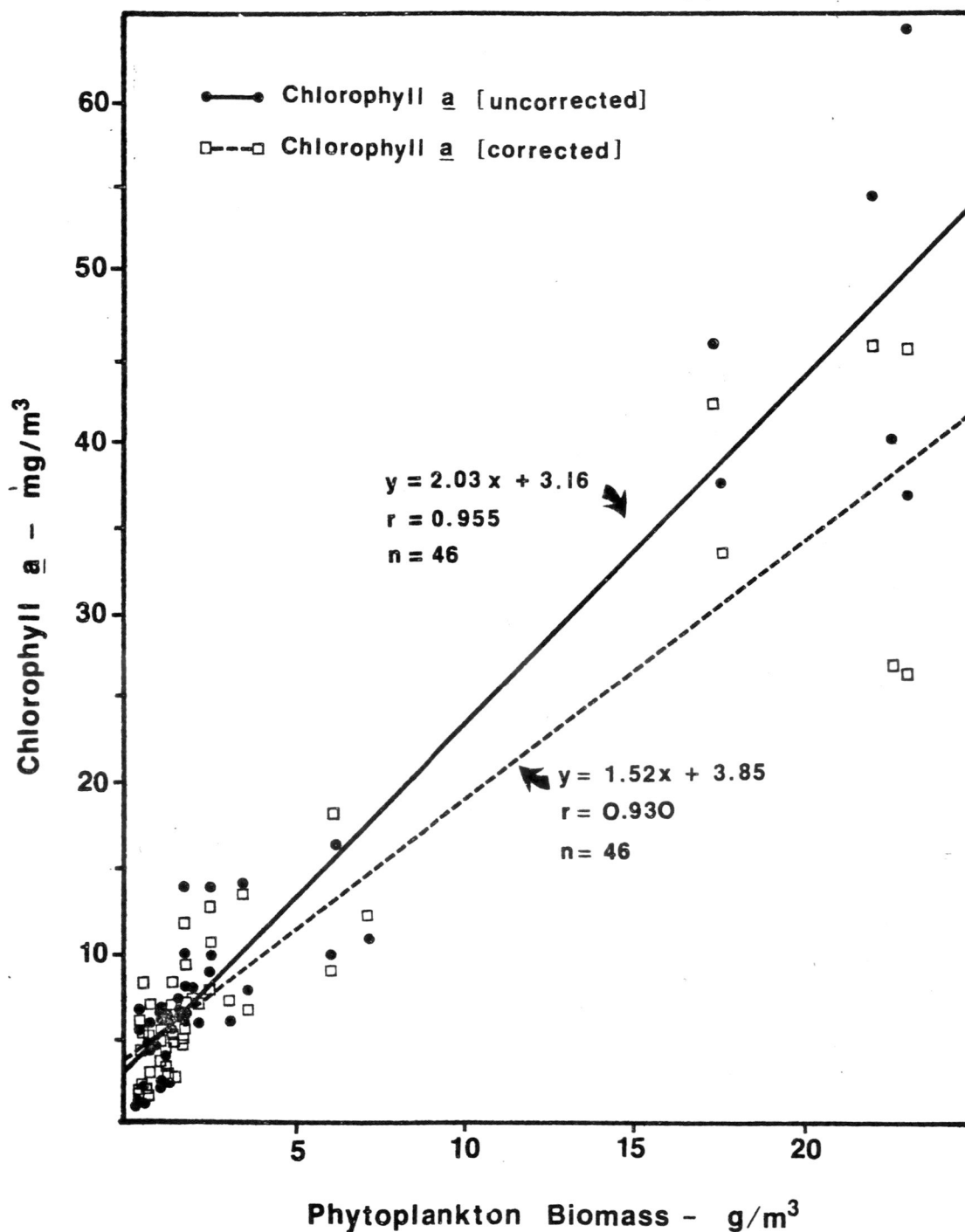


Figure 10. Chlorophyll a (corrected and uncorrected for phaeophytin) as a function of phytoplankton biomass in the Pamlico River during 1976-1977 ($P < 0.01$ in both cases).

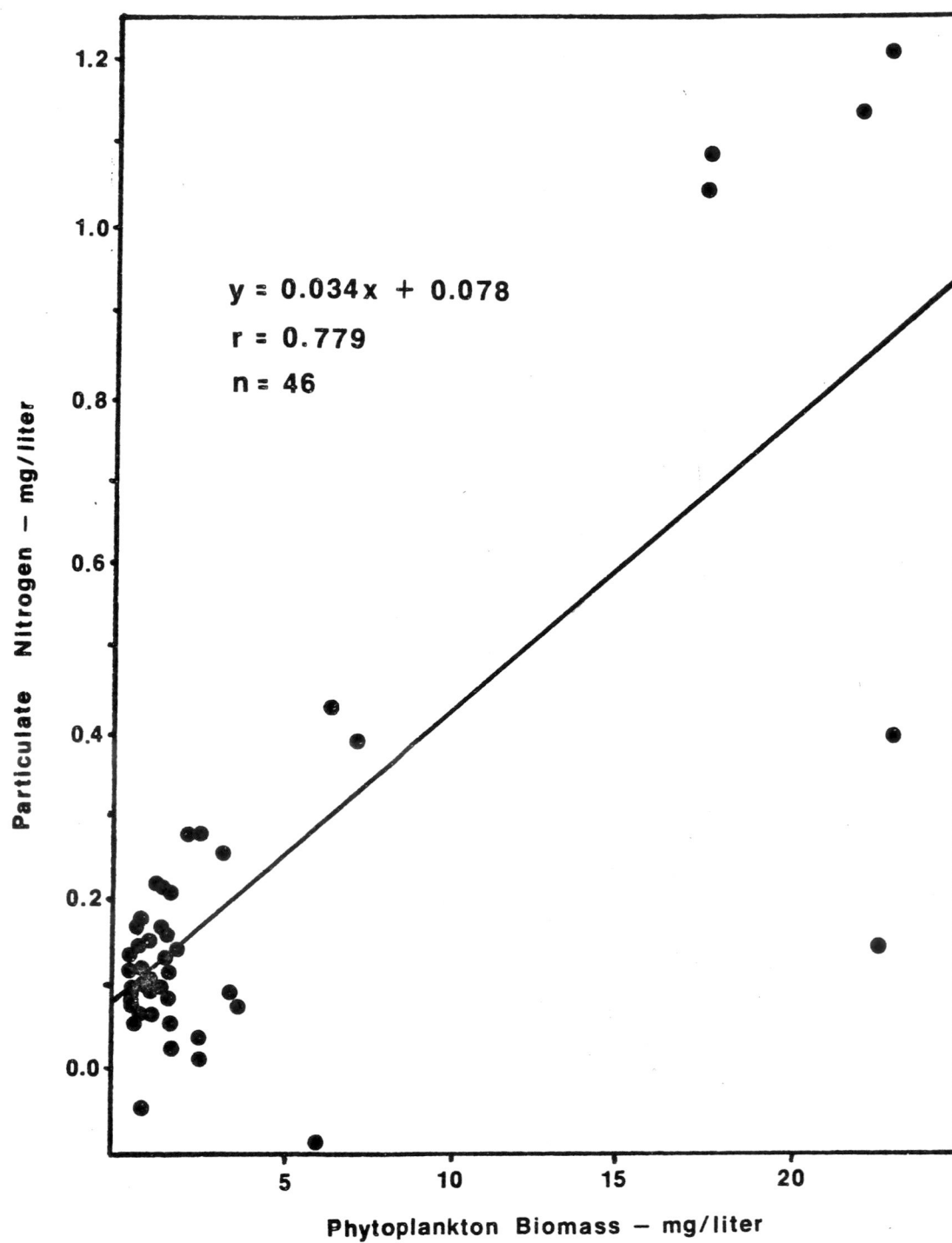


Figure 11. Particulate nitrogen as a function of phytoplankton biomass in the Pamlico River during 1976-1977 ($P < 0.01$).

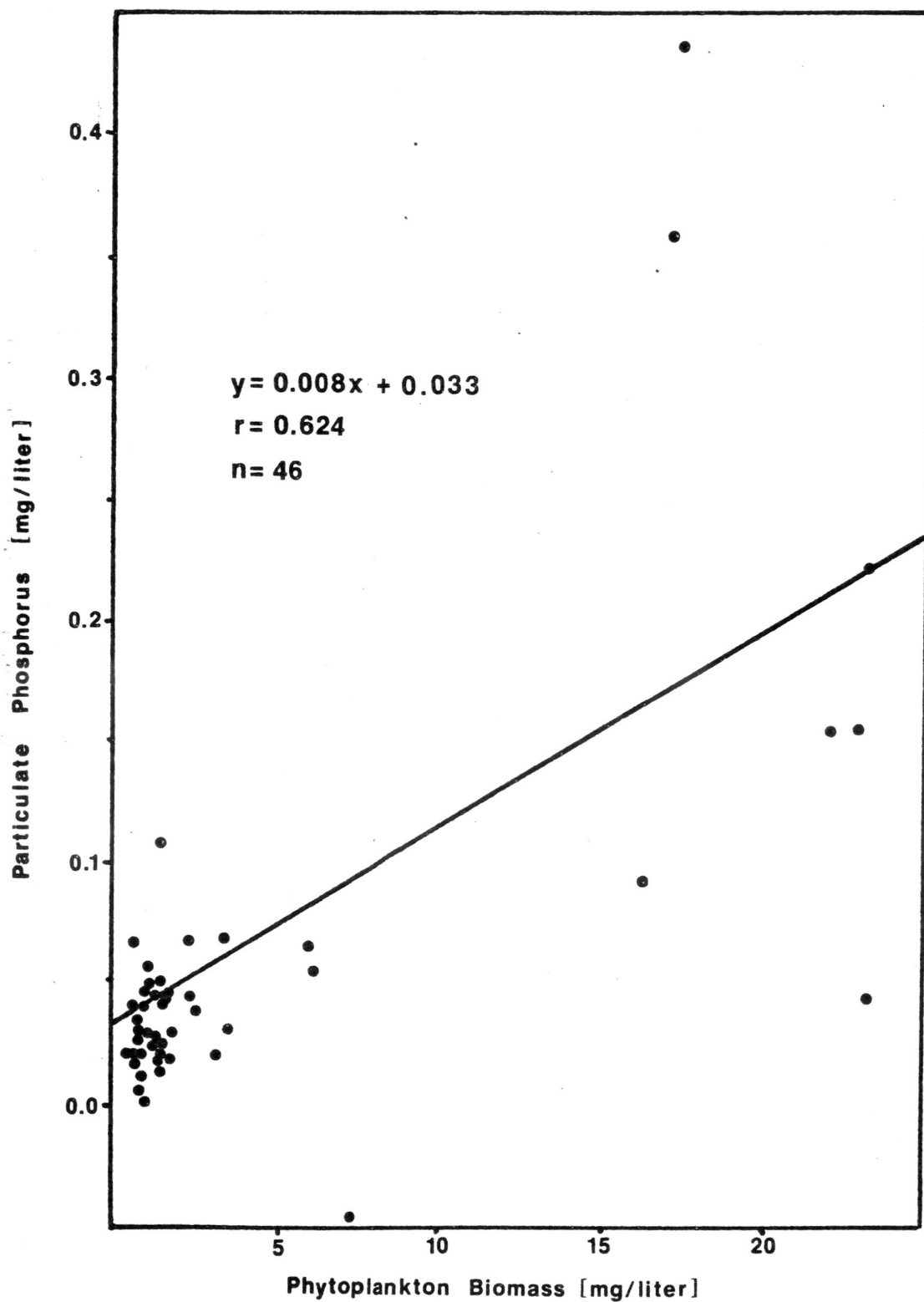


Figure 12. Particulate phosphorus as a function of phytoplankton biomass in the Pamlico River during 1976-1977 ($P < 0.01$).

may be useful as biomass indicators in the estuary. Due to the great variability of phytoplankton biomass in the Pamlico River (Hobbie, 1971), and our limited sampling only at mid-river stations, care should be used in extrapolation of these relationships.

Bacterial biomass was estimated during the Carbon-Nutrient-Biomass study on 7 July 1977 (James C. Anderson, unpublished data) using the epifluorescence technique (Daley and Hobbie, 1975). There was a gradient downstream with individual biomass samples ranging from 0.374 to 1.320 g wet weight/m³. Bacterial carbon accounted for 3.3% of the total POC. Standing stock of bacteria was estimated at 469.3 tonnes (wet weight) which, assuming bacterial carbon is equal to 7.9% of the wet weight (Ferguson and Rublee, 1976), converts to 37.1 tonnes of bacterial carbon (131 mg C/m²). Biomass of bacteria in the winter has not been measured in the Pamlico River. Crawford (1971), however, studied uptake rates of glucose and amino acids in the estuary and found maximum heterotrophic activity during July-September with minimum rates during the winter.

The zooplankton populations of the Pamlico River Estuary were studied by Peters (1968) during 1967 and 1968, and by Hobbie et al. (unpublished data) during 1971 and 1972. The dominant zooplankter was Acartia tonsa which accounted for 73% of the organisms present (Hobbie et al., unpublished data). The mean density of this species for seven collections from August 1966 to June 1967 was 3,101/m³ (Peters, 1968). Assuming an average dry weight of 8 µg per organism based on a Patuxent River study of the organism (Heinle, 1966), the average biomass of Acartia adults and copepodids was 24.8 mg dry weight/m³. To account for the nauplii which were not sampled due to sampling net size, an average ratio of

4.66 (nauplii to adults and copepodids) and an average weight of 1.5 μg per organism was used (Heinle, 1966). This gives an average annual biomass of 21.6 mg dry weight/ m^3 . Thus, the overall mean biomass of Acartia for the year was 46.4 mg dry weight/ m^3 . Using similar calculations, an estimate of 11.8 mg dry weight/ m^3 was obtained for the 1971-1972 study (Hobbie et al., unpublished data). These calculations of Acartia biomass were provided by Drs. B.J. Peterson and J.E. Hobbie. By averaging these two estimates and assuming that Acartia tonsa makes up 73% of the total zooplankton crop, a total zooplankton standing stock of 39.9 mg dry weight/ m^3 is obtained. Assuming that 41.6% of the dry weight is carbon (Bougis, 1976), zooplankton standing stock in the Pamlico River was approximately 17 mg C/ m^3 (56 mg C/ m^2).

Allochthonous Inputs.-- The Tar River is the main source of allochthonous organic carbon in the Pamlico River Estuary. During the Tributary Organic Carbon study, attempts were made to correlate organic carbon concentration with discharge in this river at Grimesland, N.C. It was assumed that the flow at Grimesland was proportional to the measured flow at Tarboro (Fig. 13). The data yielded significant ($P < 0.01$) correlations of:

$$\log \text{POC} = -0.155 \log Q + 0.746 \quad (r = 0.40)$$

and

$$\text{DOC} = 4.148 \log Q - 7.100 \quad (r = 0.59)$$

where Q is equal to the discharge at Tarboro in ft^3/sec (U.S.G.S., 1976, 1977) and DOC and POC concentrations are in mg/liter (Fig. 14). Based on mean discharge over the study period, these relationships yield annual

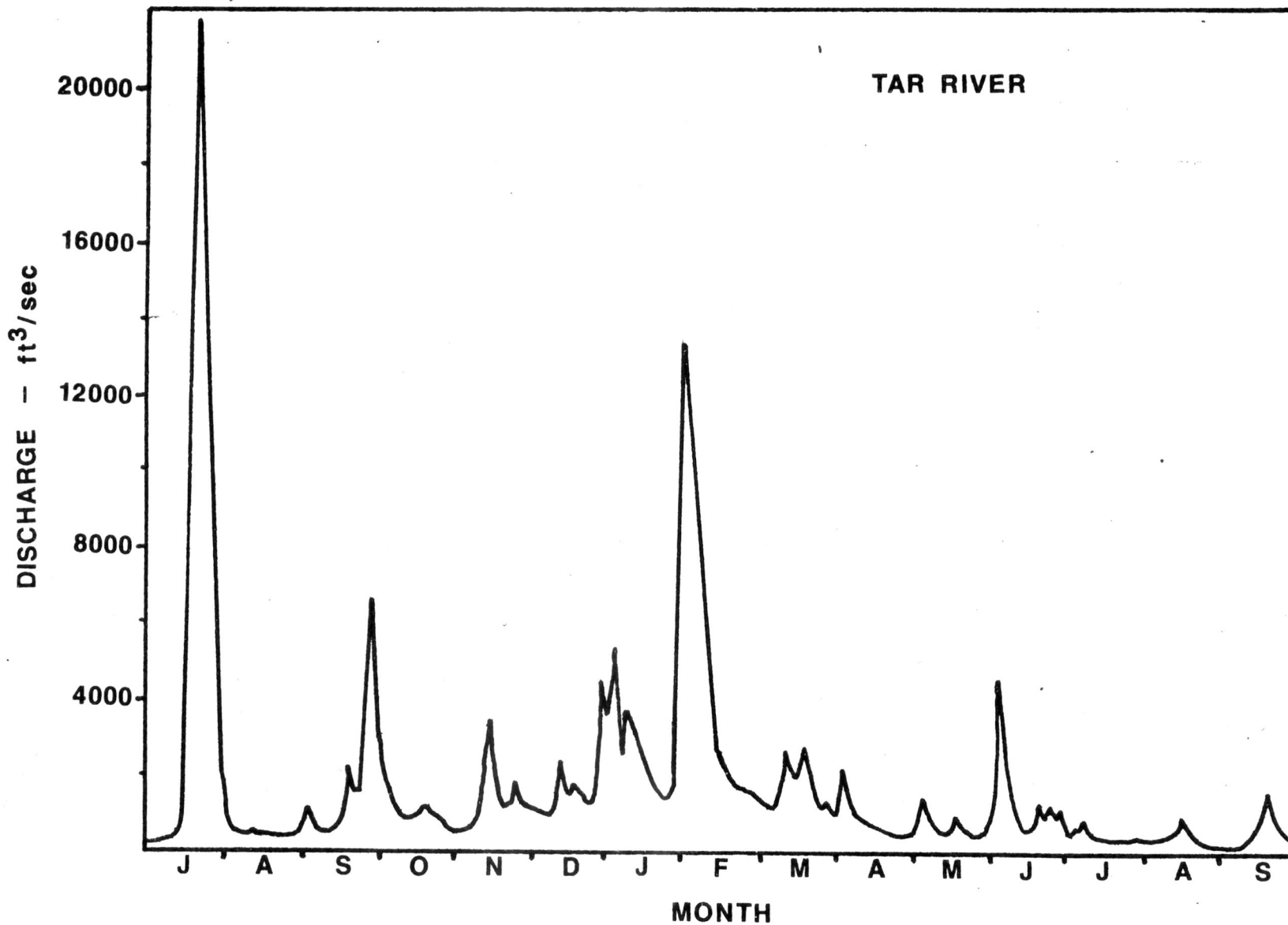


Figure 13. Discharge of the Tar River (at Tarboro, N.C.) during the Tributary Organic Carbon study, July 1975-September 1976 (adapted from U.S.G.S., 1976, 1977).

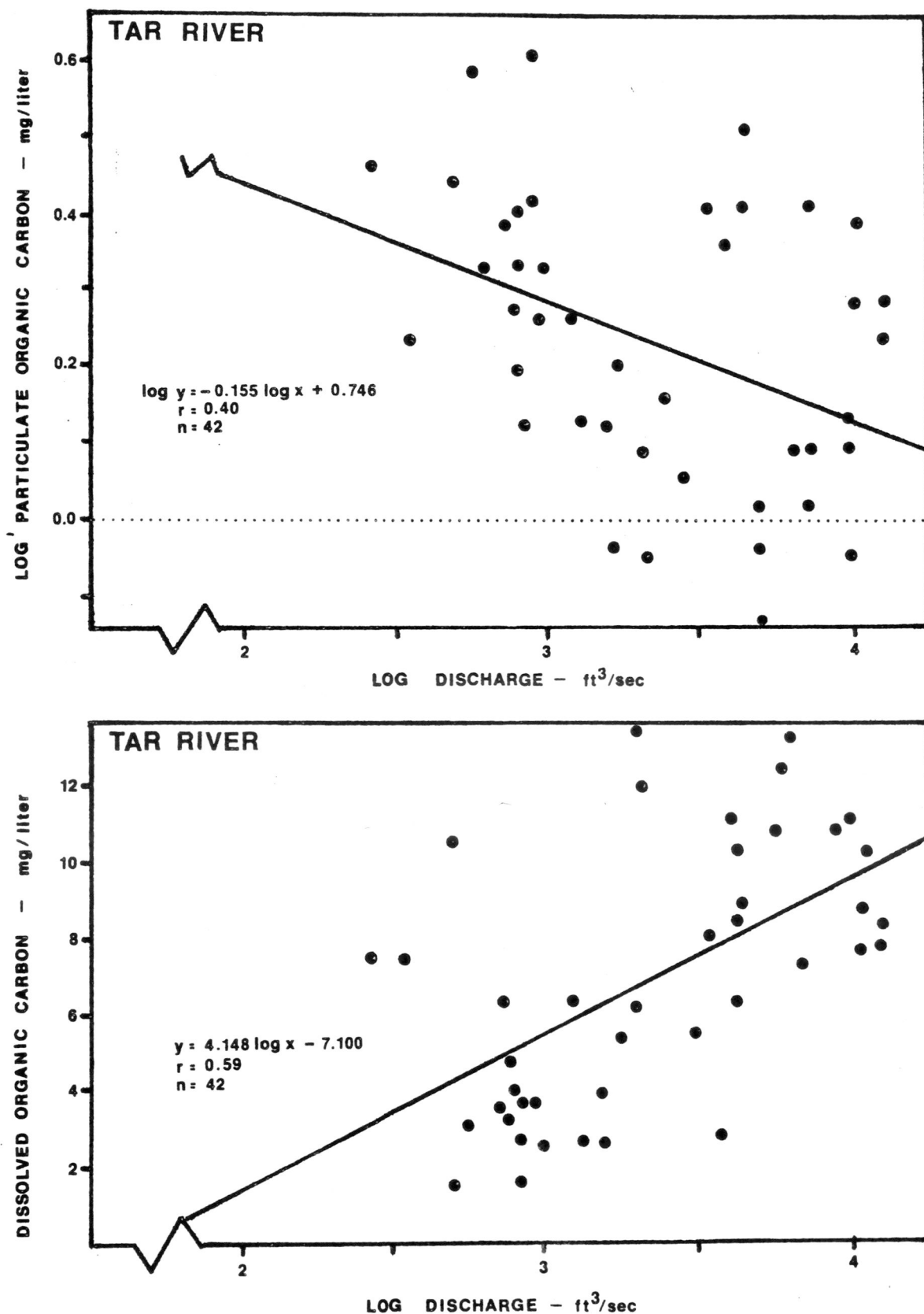


Figure 14. Concentrations of particulate organic carbon (top) and dissolved organic carbon (bottom) as a function of discharge in the Tar River during 1975-1976 ($P < 0.01$ in both cases).

mean organic carbon concentrations of 1.7 mg/liter (POC) and 6.9 mg/liter (DOC) for a total of 8.6 mg/liter (TOC). These concentrations are lower than that of the Neuse River at Goldsboro, N.C. where mean annual concentrations were 2.7 mg/liter (POC), 7.3 mg/liter (DOC) and 10.0 mg/liter (TOC) (Malcolm and Durum, 1976). Mean DOC:POC based on the regressions for the Tar River was 4.1:1, much less than the 10:1 value considered average for lacustrine and stream systems (Wetzel and Rich, 1973). The total import of organic carbon into the Pamlico River by the Tar River was 18,918 tonnes/yr, which is very close to the 18,951 tonnes/yr discharged by the Neuse River (Malcolm and Durum, 1976). Based on this value, the Tar River drainage basin contributes $2.4 \text{ g TOC/m}^2/\text{yr}$.

A similar study of Durham Creek yielded the following significant ($P < 0.01$) correlation:

$$\text{POC} = -0.616 \log Q + 1.892 \quad (r = 0.65)$$

where Q is equal to the discharge in ft^3/sec at Edward, N.C. (U.S.G.S., 1976, 1977) (Fig. 15), and the POC concentration is in mg/liter (Fig. 16). DOC did not correlate with flow, but there was a significant ($P < 0.05$) correlation between DOC and POC:

$$\text{DOC} = 22.376 \text{ POC} + 1.051 \quad (r = 0.42)$$

where both concentrations are in mg/liter (Fig. 17). Based on these relationships, the mean concentrations of organic carbon in Durham Creek were 0.7 mg/liter (POC) and 17.4 mg/liter (DOC) for a total of 18.1 mg/liter (TOC). The total organic carbon contributed to the Pamlico River by Durham Creek during the study period was 1,064 tonnes/yr, and

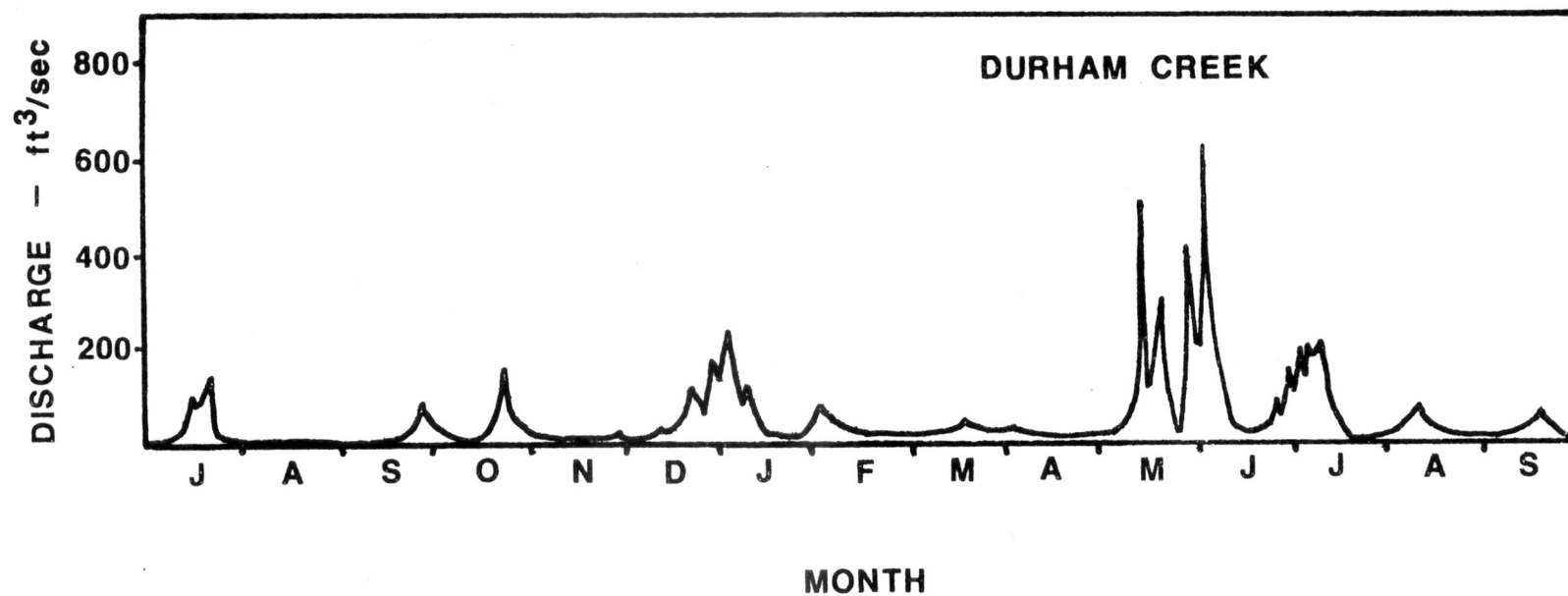


Figure 15. Discharge of Durham Creek (at Edward, N.C.) during the Tributary Organic Carbon study, July 1975-September 1976 (adapted from U.S.G.S., 1976, 1977).

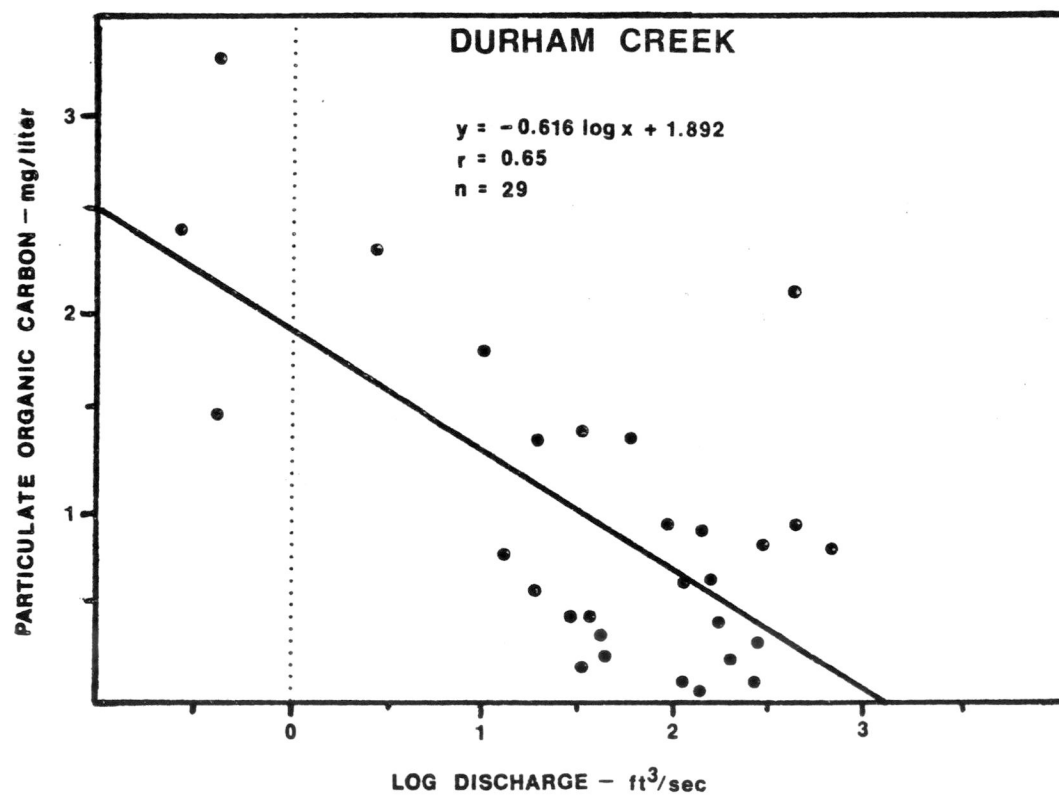


Figure 16. Particulate organic carbon as a function of discharge in Durham Creek during 1975-1976 ($P < 0.01$).

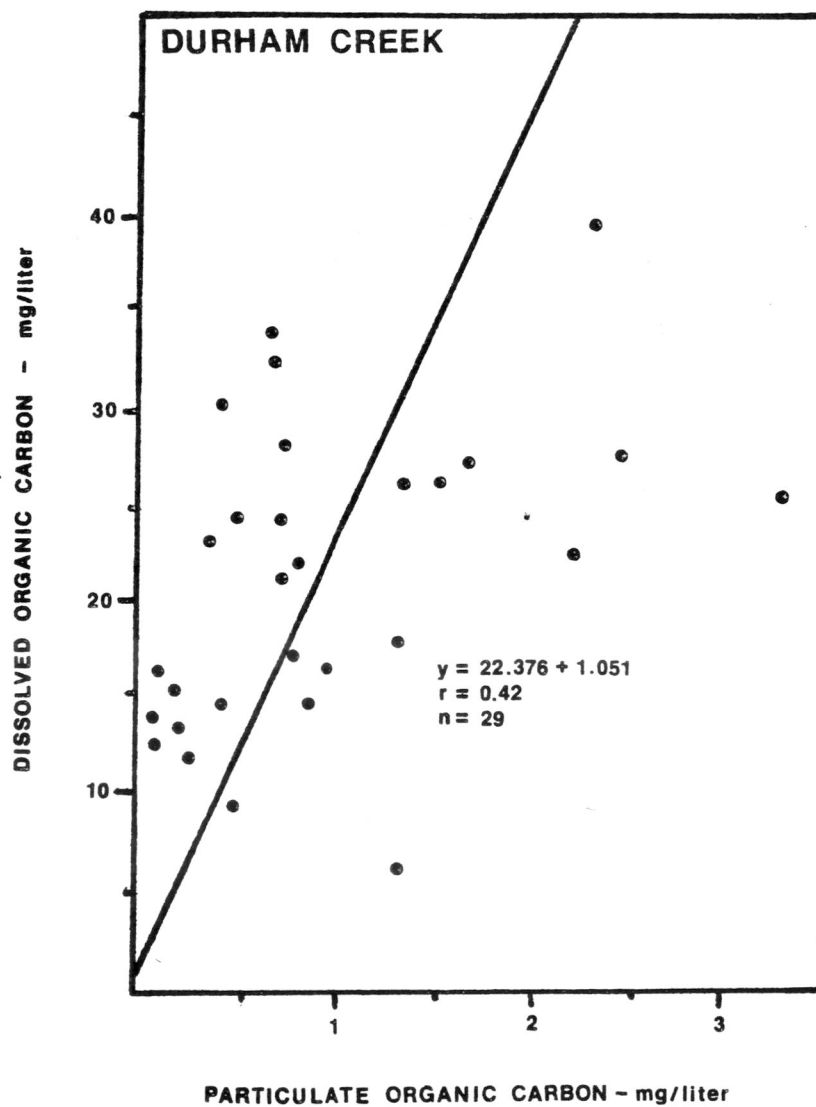


Figure 17. Dissolved organic carbon as a function of particulate organic carbon in Durham Creek during 1975-1976 ($P < 0.05$).

the drainage basin contributed $9.5 \text{ g TOC/m}^2/\text{yr}$. This latter value is extremely high even when compared with tropical ecosystems (Brinson, 1976), but can be attributed to the swamp input to the creek. Durham Creek is typical of the many "black-water" streams found in coastal North Carolina and consistently had high DOC:POC ratios ($\bar{X} = 24.9:1$). Similar relationships exist for the Sopchoppy River, a Florida "black-water" river where the DOC:POC was 19.1:1 (Malcolm and Durum, 1976).

For the remaining tributaries of the Pamlico River, it was assumed that the drainage basins contributed an amount of organic carbon equal to the mean of the Tar River and Durham Creek estimates ($5.95 \text{ g/m}^2/\text{yr}$). This value is likely high, but probably more realistic than using either estimate alone, since preliminary data indicated that the Tar River and Durham Creek represented the two extremes of organic carbon concentrations for 14 tributaries during July 1975. This value is comparable with export of $6.4 \text{ g TOC/m}^2/\text{yr}$ from a small watershed to a New England estuary (Matson and Buck, 1977). The annual input of organic carbon to the Pamlico River from tributaries other than the Tar River and Durham Creek was estimated at 18,155 tonnes. The annual input of organic carbon to the estuary by all tributaries, including the Tar River and Durham Creek, was 38,137 tonnes.

Another source of allochthonous organic carbon in the Pamlico River is rainfall and dryfall. No data have been collected on the contribution of dryfall to the carbon budget of the estuary. However, Brinson *et al.* (1977) report a weighted mean organic carbon input by rainfall of 1.8 g/m^2 at Grimesland, N.C. from December 1975–November 1976. Extrapolating this value to the area of the estuary ($28.27 \times 10^7 \text{ m}^2$) gives an

annual input of organic carbon to the estuary of 509 tonnes.

Input of organic carbon by the high salt marsh characteristic of the lower reaches of the Pamlico River has not been studied, and it is not known whether this input is significant in the overall organic carbon budget of the estuary. However, the water adjacent to these marshes is often extremely turbid with suspended peat, and erosion of exposed (unprotected) grass marshes during 1975 in the Albemarle-Pamlico region ranged from 6 to 20 ft/yr (Bellis et al., 1975) indicating that this input may be significant. This source is presumably refractory in nature and probably does not significantly affect the deoxygenation problem in the estuary.

Ground water and septic tank seepage is yet another source of allochthonous organic carbon in the estuary which needs further study. Levels of DOC were measured in two septic tank sorption fields along the Pamlico River on six occasions during 1975 (Davis et al., 1976). Natural DOC levels as measured in a deep well were found to be in the range of 3 - 6 mg/liter. Levels of DOC in the sorption fields often reached six times this value. Much of this DOC presumably moves into the estuary, but whether this input is significant in the organic carbon budget of the estuary is not known and requires further study.

Sediment release of organic matter into the water column is another source of organic carbon in the Pamlico River which requires further study.

Autochthonous Inputs.-- Phytoplankton productivity accounts for most of the autochthonous input of organic carbon into the Pamlico River Estuary. Phytoplankton productivity measured during the Carbon-Nutrient-Biomass

study gave a significant ($P < 0.01$) correlation between production and biomass (Fig. 18), and a seasonal cycle of production with peaks during the annual Heterocapsa (Peridinium)/Katodinium and Gymnodinium/Gyrodinium/Polykrikos blooms (Fig. 19). Average daily production was estimated at 549 mg C/m^2 , which gives an annual productivity value of $200 \text{ g C/m}^2/\text{yr}$. The average annual input of organic carbon to the Pamlico River as phytoplankton production was 56,501 tonnes (Table 2). The average daily growth rate (turnover rate) was calculated based on the following equation:

$$K = \frac{1}{t(\text{days})} \ln \frac{\text{Phytoplankton carbon} + \text{Daily productivity}}{\text{Phytoplankton carbon}}$$

Thus, based on the standing stock of phytoplankton carbon measured quarterly with the productivity samples ($\bar{X} = 0.93 \text{ g/m}^2$), the daily growth rate (K) was 0.464/day. The average turnover time was 2.2 days (169 times per year). Assimilation ratios for the phytoplankton averaged 6.3 mg C/mg chlorophyll a/hr (chlorophyll a corrected for phaeophytin) and 5.8 mg C/mg chlorophyll a/hr (chlorophyll a uncorrected for phaeophytin).

In contrast, Copeland et al. (1969) reported that in situ ^{14}C production studies at six stations in the Pamlico River and South Creek showed little apparent seasonal cycle and no direct relationship between phytoplankton productivity and biomass during 1966-1967. Average daily production was 148 mg C/m^2 , which gives an annual productivity estimate of $54 \text{ g C/m}^2/\text{yr}$. Based on a average chlorophyll a concentration of 10 mg/m^3 and using a carbon to chlorophyll a ratio of 47:1 (data from Hobbie, 1971), the average standing stock of phytoplankton is estimated as 1.6 g C/m^2 . Thus, the population turned over about 34 times per year

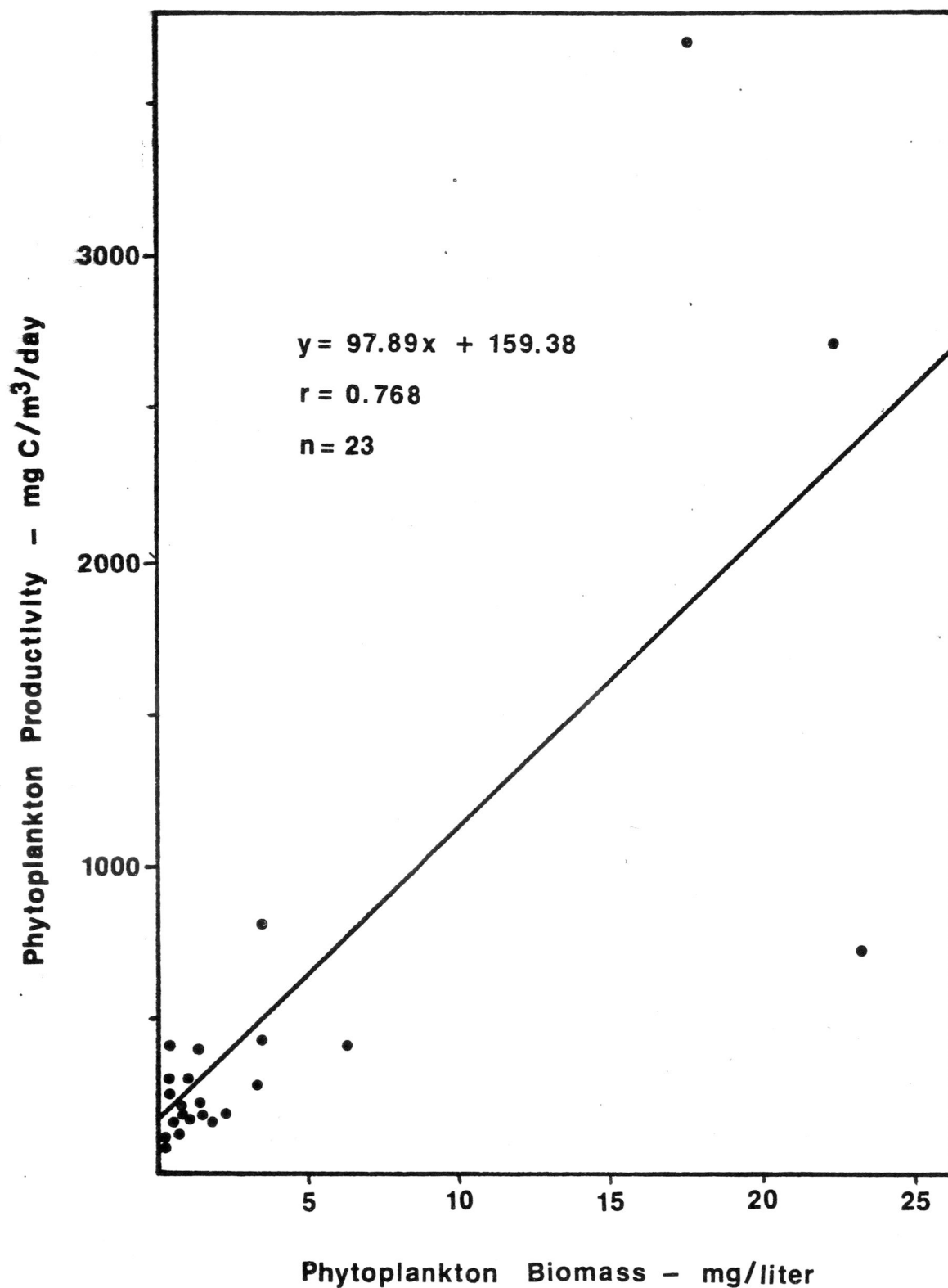


Figure 18. Phytoplankton productivity as a function of phytoplankton biomass in the Pamlico River during 1976-1977 ($P < 0.01$).

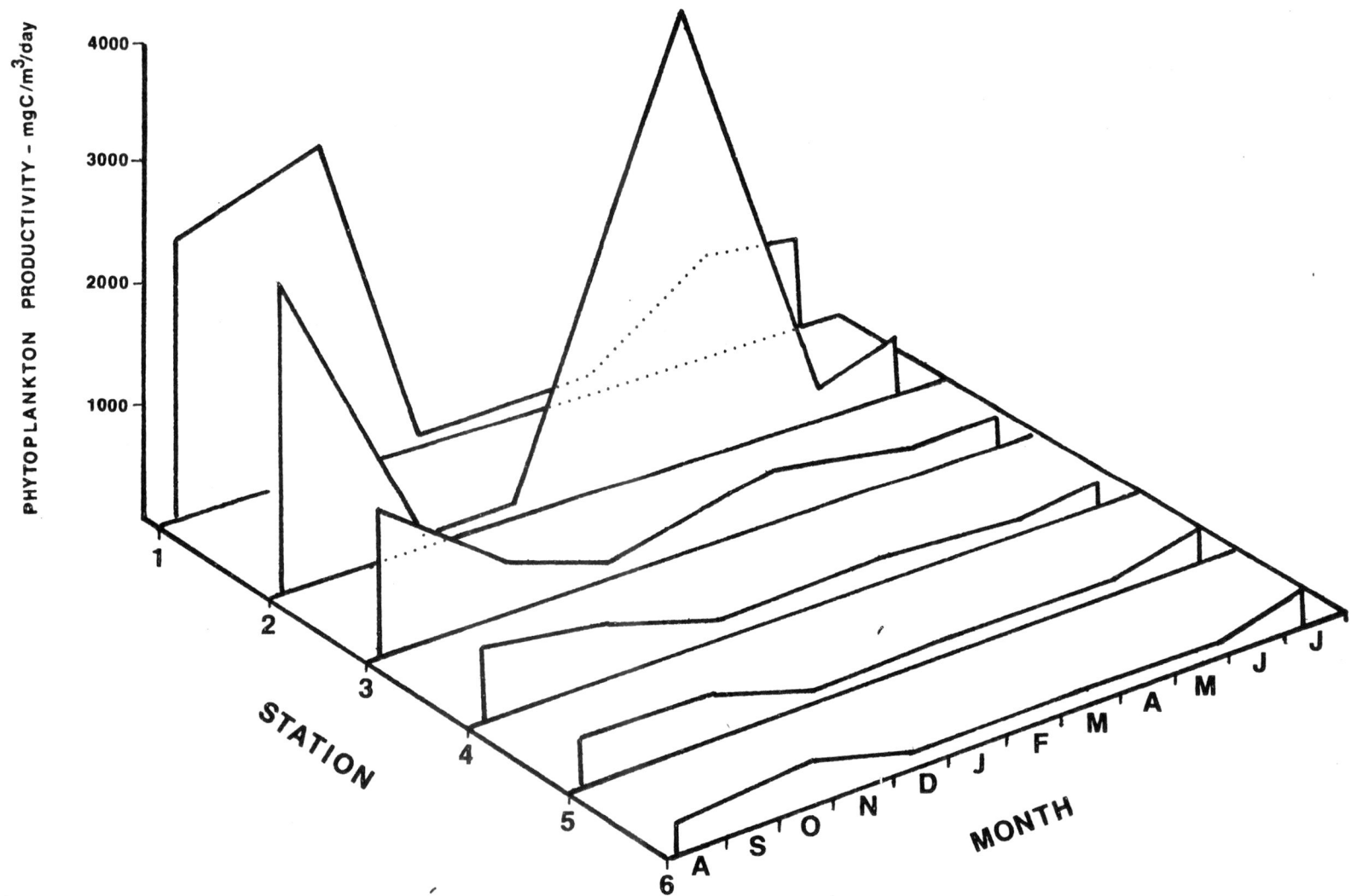


Figure 19. Annual cycle of phytoplankton productivity in the Pamlico River Estuary during 1976-1977. Production estimates are based on in situ ^{14}C incubations of water collected on alternate months at 0.5 m depth. Station locations are shown in Fig. 3.

Table 2. In situ phytoplankton ^{14}C production estimates at six stations in the Pamlico River. Samples were collected 0.5 m from the surface at the six stations on alternate months from August 1976 to July 1977. Station locations are shown in Fig. 3.

Station	Number of Observations	$\bar{X}$ Productivity ^a (mg C/m ³ /day)	$\bar{X}$ Productivity (mg C/m ² /day)	Annual Production (tonnes C/sector/yr)
1	6	1,166.2 (458.8) ^b	1,280	6,731
2	6	1,210.4 (634.5)	1,424	20,113
3	6	383.6 (157.9)	463	10,455
4	6	287.4 (68.4)	347	10,679
5	6	231.4 (48.8)	288	6,455
6	6	202.8 (35.0)	258	2,068
TOTAL				56,501 (= 200 g C/m ² /yr)

^a Upper meter of water column

^b Standard error of mean

or replaced itself every 11 days, and, based on the above equation, has an average daily growth rate of 0.088/day.

It may appear that in the 10 years between the studies, the estuary has begun to show significant signs of eutrophication. However, the large differences between the two investigations can be primarily attributed to differences in station locations for the two studies. This study had two stations further upstream than any stations in the earlier investigation and, in spite of the small area and volume of these sectors, they heavily weighed the total production estimates (Fig. 19 and Table 2). However, neither this production estimate nor that of Copeland *et al.* (1969) was weighed for day to day variances in irradiation. The production estimate from this study is probably high since measurements were often made on clear to partly cloudy days. Production estimates in other estuarine studies are comparable with the two estimates. Thayer (1971) obtained an estimate of $67 \text{ g C/m}^2/\text{yr}$ for the estuarine system near Beaufort, N.C. using the ^{14}C method, and Stross and Stottlemeyer (1966) estimated productivity of the Patuxent River Estuary to be from 193 to $330 \text{ g C/m}^2/\text{yr}$ using the same method.

In addition to phytoplankton productivity, secretion (including autolysis) was measured during the Carbon-Nutrient-Biomass study. Average daily secretion was 118 mg C/m^2 which gives an annual secretion value of 43.2 g C/m^2 . Algal secretion averaged 21% of production. This relatively high percentage may have been due to the short time of incubation (Sharp, 1977). Total organic carbon input to the Pamlico River Estuary from phytoplankton secretion was 12,218 tonnes/yr (Table 3).

A much smaller input of autochthonous organic carbon to the Pamlico River is from submersed macrophytes. Total aquatic macrophyte production

Table 3. In situ phytoplankton ^{14}C secretion estimates at six stations in the Pamlico River. Samples were collected 0.5 m from the surface at the six stations on alternate months from August 1976 to July 1977. Station locations are shown in Fig. 3.

Station	Number of Observations	$\bar{X}$ Secretion ^a (mg C/m ³ /day)	$\bar{X}$ Secretion (mg C/m ² /day)	Annual Secretion (tonnes C/sector/yr)
1	6	383.1 (298.0) ^b	421	2,211
2	6	135.9 (67.1)	160	2,258
3	6	89.8 (45.8)	108	2,448
4	6	105.9 (56.0)	128	3,935
5	6	26.2 (10.6)	33	739
6	6	61.5 (42.0)	78	627

TOTAL

12,218
(= 43 g C/m²/yr)

^a Upper meter of water column

^b Standard error of mean

has been calculated for the Pamlico River based on biomass studies during 1975 (Davis and Brinson, 1976). Total estuarine productivity of Vallisneria americana, the dominant species, was estimated to be 644 tonnes organic dry weight (ODW) (seasonal aboveground production = 184 g ODW/m²). Total estuarine production of other rooted species (Potamogeton perfoliatus var. bupleuroides, Najas guadalupensis and Ruppia maritima) was 24 tonnes ODW/yr. These values give an annual input of organic carbon to the Pamlico River by aquatic macrophytes of 301 tonnes (assuming C = 0.45 x ODW).

Biomass of the filamentous red alga, Compsopogon coeruleus, in the estuary in August 1974 was estimated to be 272 tonnes ODW (Davis and Brinson, 1976). Filamentous algal biomass in 1975 was principally composed of Cladophora glomerata, and amounted to approximately 11 tonnes ODW. Informal observations suggested that filamentous algal biomass remained low during 1976-1977.

Data on benthic and periphyton production in the Pamlico River are very limited. Production of benthic microalgae has been measured on two occasions at three depths in South Creek (Stanley, 1971). A mean of 41.94 mg C/m²/day was obtained at a depth of 1 m, and 1.92 mg C/m²/day at 2 m. Benthic production was normally limited to water depths of 1.5 m or less. Estuarine bottom areas (determined planimetrically) corresponding to these depths were $2.493 \times 10^7 \text{ m}^2$ (1 m) and $2.728 \times 10^7 \text{ m}^2$ (2 m). Extrapolating the benthic production estimates to these areas gives a very rough estimate of benthic production of 401 tonnes/yr.

Sherk (1969) studied the production of periphyton communities which developed on glass slides suspended in artificial estuaries simu-

lating conditions in the Pamlico River. Productivity levels ranged from 0.35 to 39.3 g C/m²/yr with a mean of 20 g C/m²/yr at 600 foot-candles. The area of suitable substrate for periphyton is not known; however, benthic macrophytes colonize approximately 1% of the area of the estuary (approximately $2.827 \times 10^6 \text{ m}^2$) as determined by remote sensing (Davis and Brinson, 1976), and serve as one substrate for epiphytic growth. Assuming one square meter of suitable substrate per square meter of bottom area in plant beds gives an estimate of 57 tonnes of organic carbon production per year by epiphytic algae. Again, due to the many assumptions, this cannot be considered accurate.

Few investigations of the importance of chemosynthesis in the production of organic carbon have been made. Harrison and Hobbie (1974) found that nitrification did not appear to cause the significant oxygen demand in the Pamlico River that has been reported in other systems. In another study of six stations during the summer of 1975, little evidence of chemosynthetic activity was found using ¹⁴CO₂ dark fixation with nitrification inhibitors (Santford Overton, unpublished data).

Outputs of Organic Carbon.-- The largest apparent output of organic carbon in the Pamlico River Estuary is pelagial respiration. Respiration was measured during the Carbon-Nutrient-Biomass study during 1976-1977 (Table 4). Respiration rates were generally higher in the upper reach of the estuary and normally much higher in the summer than in the winter. Individual samples ranged from undetectably low levels to 0.243 mg/liter/hr. Summer rates compared well with a six-station study undertaken during the summer of 1975 (Kirby, 1978). The annual loss of organic carbon due to water column respiration, assuming 1 g of O₂ is equal to

Table 4. Water column respiration estimates at six stations in the Pamlico River. Samples were collected at the six stations 0.5 m from both the surface and bottom on alternate months from August 1976 to July 1977. Station locations are shown in Fig. 3.

Station	Number of Observations	$\bar{X}$ (Surface + Bottom) Respiration (mg/l/hr)	Volume (liters) of Sector ($\times 10^{10}$)	Tonnes O_2 per Sector per yr.	Tonnes C per Sector per yr.
1	12	0.102 (0.021) [†]	2.44	21,801	6,540
2	12	0.049 (0.004)	9.27	39,791	11,937
3	12	0.034 (0.002)	20.73	61,742	18,523
4	12	0.031 (0.004)	28.40	77,123	23,137
5	12	0.032 (0.006)	26.33	73,808	22,142
6	12	0.031 (0.006)	9.14	24,824	7,447
TOTAL			96.31	299,086	89,726

[†] Standard error of mean

0.30 g of carbon (Ryther, 1956), was approximately 89,726 tonnes. This value is likely high since, experimentally, oxygen was not limiting.

Another loss of organic carbon which has not been studied sufficiently is benthic respiration. This parameter was investigated during the summer of 1975 in the shallow areas of the estuary using in situ black plastic domes for incubation (Kornegay, 1978). Data from eight stations from Blount's Bay (Sector 3, Fig. 4) to Mare Point (Sector 8, Fig. 4) showed that, with increasing distance downstream, there was an overall decrease both in the mean oxygen uptake rates and the amount of sediment organic matter. Tenore (1970) described a general decrease in macrobenthos from upriver to downriver. Hence, it appears that oxygen uptake rates are influenced both by microbial utilization of sediment organic matter and, to some extent, density of benthos. Mean oxygen uptake rates ranged from 0.0096 g/m²/hr to 0.0520 g/m²/hr. All stations were, however, located in water from 1.0 to 1.5 m in depth. No estimates of benthic respiration in the mid-channel region have been made.

Another major loss of organic carbon in the Pamlico River is estuarine discharge. This throughput was estimated from the Estuarine Organic Carbon study data using the method of Harrison and Hobbie (1974) and found to be approximately 21,916 tonnes of organic carbon per year.

Other sources of pelagial carbon loss have not been studied. A study of sedimentation rates is needed.

Organic Carbon Budget and Pelagial Carbon Flow.-- The overall organic carbon budget for the Pamlico River is shown in Table 5. Overall input of organic carbon amounted to 108,124 tonnes per year, and overall output amounted to 111,642 tonnes per year, leaving a balance of -3,518

Table 5. Annual organic carbon budget for the Pamlico River Estuary.

INPUT		
Allochthonous	Input (Tonnes of C)	Percent of total
Tar River	18,918	17.5
Durham Creek	1,064	1.0
Other tributaries	18,155	16.8
Rainfall ^a	509	0.4
Dryfall	?	-
Ground water + septic tank seepage	?	-
Marsh input	?	-
Sediment release	?	-
Subtotal	38,646	35.7
Autochthonous		
Phytoplankton production	56,501	52.2
Phytoplankton secretion	12,218	11.3
Macrophyte production ^b	301	0.3
Benthic production ^c	401	0.4
Periphyton production ^d	57	0.1
Chemosynthesis	?	-
Subtotal	69,478	64.3
Total input	108,124	100.0
OUTPUT		
	Output (Tonnes of C)	Percent of total
Water column respiration	89,726	80.0
Estuarine discharge	21,916	20.0
Sediment respiration	?	-
Sedimentation	?	-
Total output	111,642	100.0
BALANCE		
Balance (Tonnes of C)	-3,518	

^a Extrapolated from Brinson *et al.* (1977)

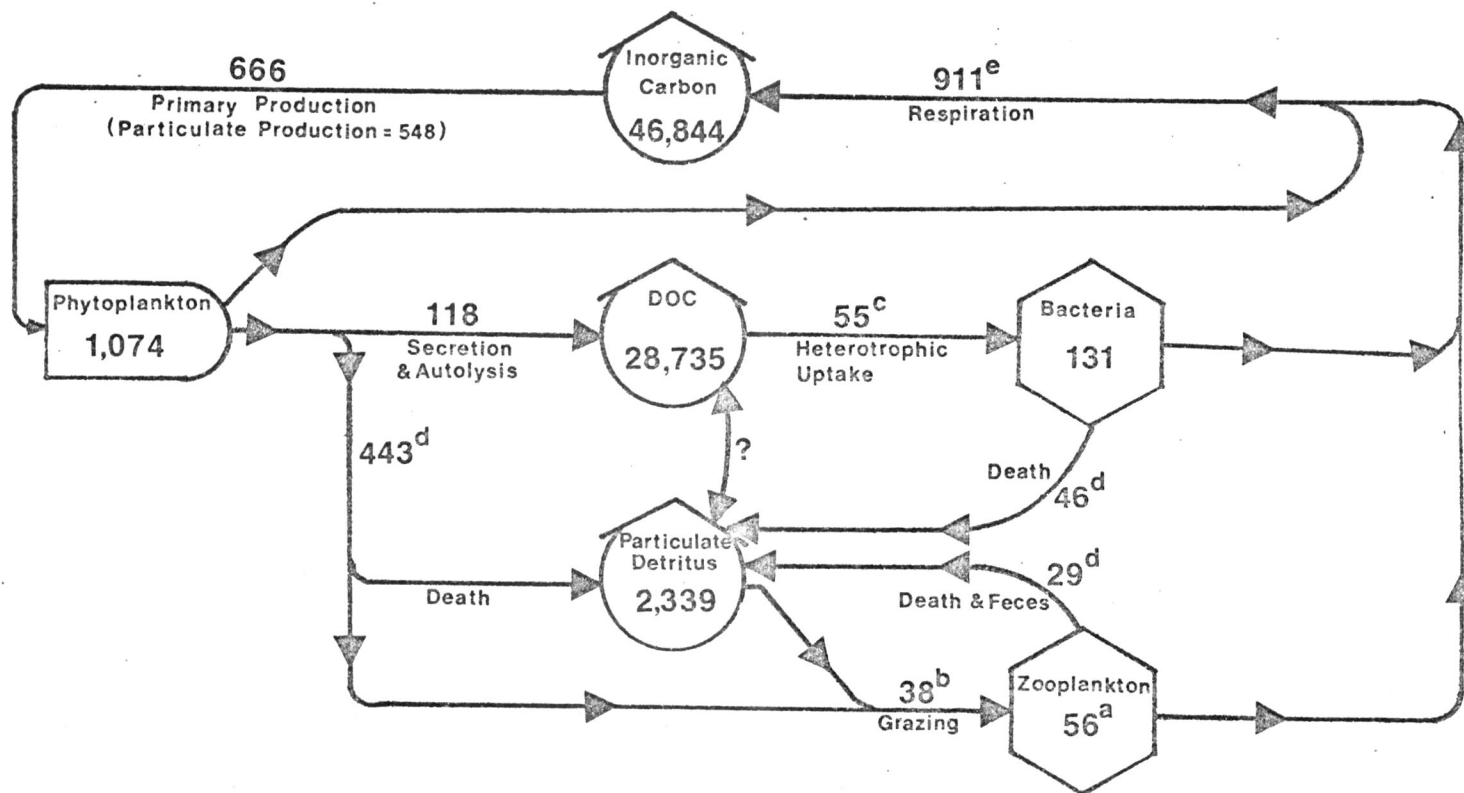
^b Davis and Brinson (1976)

^c Extrapolated from Stanley (1971)

^d Extrapolated from Sherk (1969)

tonnes per year. Autochthonous inputs accounted for 64.3% of the total inputs indicating that management of inorganic nutrient influx, rather than organic carbon influx, may be more important in controlling deoxygenation.

Estimated carbon flow in the water column, as measured on 7 July 1977, is depicted in Fig. 20. The large amount of inorganic carbon on this and other dates indicates that inorganic carbon is probably seldom limiting in the Pamlico River. Phytoplankton biomass on this date averaged $1,074 \text{ mg C/m}^2$ with a mean productivity (including secretion) of $666 \text{ mg C/m}^2/\text{day}$ (particulate productivity = $548 \text{ mg C/m}^2/\text{day}$). Phytoplankton input to the DOC pool through secretion was $118 \text{ mg C/m}^2/\text{day}$, and input to the POC pool, based on the daily growth rate, was $443 \text{ mg C/m}^2/\text{day}$. Bacterial biomass as measured on this date (J.C. Anderson, unpublished data) was 131 mg C/m^2 , and bacterial production was estimated as 10% of phytoplankton particulate production at $55 \text{ mg C/m}^2/\text{day}$ (Crawford, 1971). Bacterial input to the POC pool, again based on the daily growth rate, was estimated at $46 \text{ mg C/m}^2/\text{day}$. Zooplankton biomass was estimated based on data from Peters (1968) and Hobbie *et al.* (unpublished data) at 56 mg C/m^2 . Production of Acartia tonsa was estimated as 5% of phytoplankton particulate production (Heinle, 1966) and this was extrapolated to a total zooplankton productivity value of $38 \text{ mg C/m}^2/\text{day}$ by assuming that Acartia tonsa makes up 73% of the total zooplankton crop (Hobbie *et al.*, unpublished data). Zooplankton input to the POC pool based on daily growth rate was estimated at $29 \text{ mg C/m}^2/\text{day}$. Standing stock of particulate detritus on 7 July 1977 was $2,339 \text{ mg C/m}^2$, and standing stock of DOC was $28,735 \text{ mg C/m}^2$.



^a Extrapolated from Peters (1968) and Hobbie *et al.* (unpublished data) using correction factors from Heinle (1966).

^b Estimated as 5% of particulate primary production for *Acartia tonsa* (Heinle, 1966) and assuming that *Acartia* is 73% of total zooplankton crop.

^c Estimated as 10% of particulate primary production (Crawford, 1971).

^d Estimated from daily growth rates.

^e The respiration estimate is probably high since measurements were made under conditions where dissolved oxygen was not limiting.

Figure 20. Pelagial carbon flow in the Pamlico River on 7 July 1977. Standing stock values are in mg C/m² and carbon flow rates are in mg C/m²/day. Compartmental symbols are from Odum (1971).

Deoxygenation

An important impact of the stock of the DOC and POC in the Pamlico River Estuary is that it is the food used in microbial respiration, thus driving the deoxygenation which has been described in the estuary for many years (Copeland et al., 1969). Extensive areas of the river bottom waters become deoxygenated during periods of hot, calm weather in association with salinity stratification. Deoxygenation normally occurs in the deeper regions of the estuary and has been observed extending well into Pamlico Sound. With the formation of a definite halocline, the water column becomes quite stable and requires a great deal of energy in the form of wind or flow to overcome this stratification. Above the halocline, in the euphotic zone, oxygen is produced in photosynthesis and the productivity to respiration ratio (P/R) is greater than one. Below the compensation level, however, the P/R ratio is less than one. With a lack of mixing, deoxygenation will occur (Fig. 21). Fish and other organisms may die as oxygen decreases, further compounding the oxygen problem due to the high respiration rates of the bacteria associated with their decomposition. Also, with low oxygen levels, hydrogen sulphide, a highly toxic respiratory depressant, may be produced.

A preliminary study of deoxygenation in the Pamlico River was accomplished during the summer of 1975 (T.M. Vicars, unpublished data). On 3 June 1975, a 30-station study showed little evidence of stratification and deoxygenation. On 22 July 1975, a deoxygenated (<1.0 mg/liter) area of about 5 km^2 was studied between Core Point and Texasgulf, Inc. (Sectors 5 and 6, Fig. 4). Gar, bluefish, gizzard shad, croaker, mullet and blue crabs were observed floating dead into shore when the wind

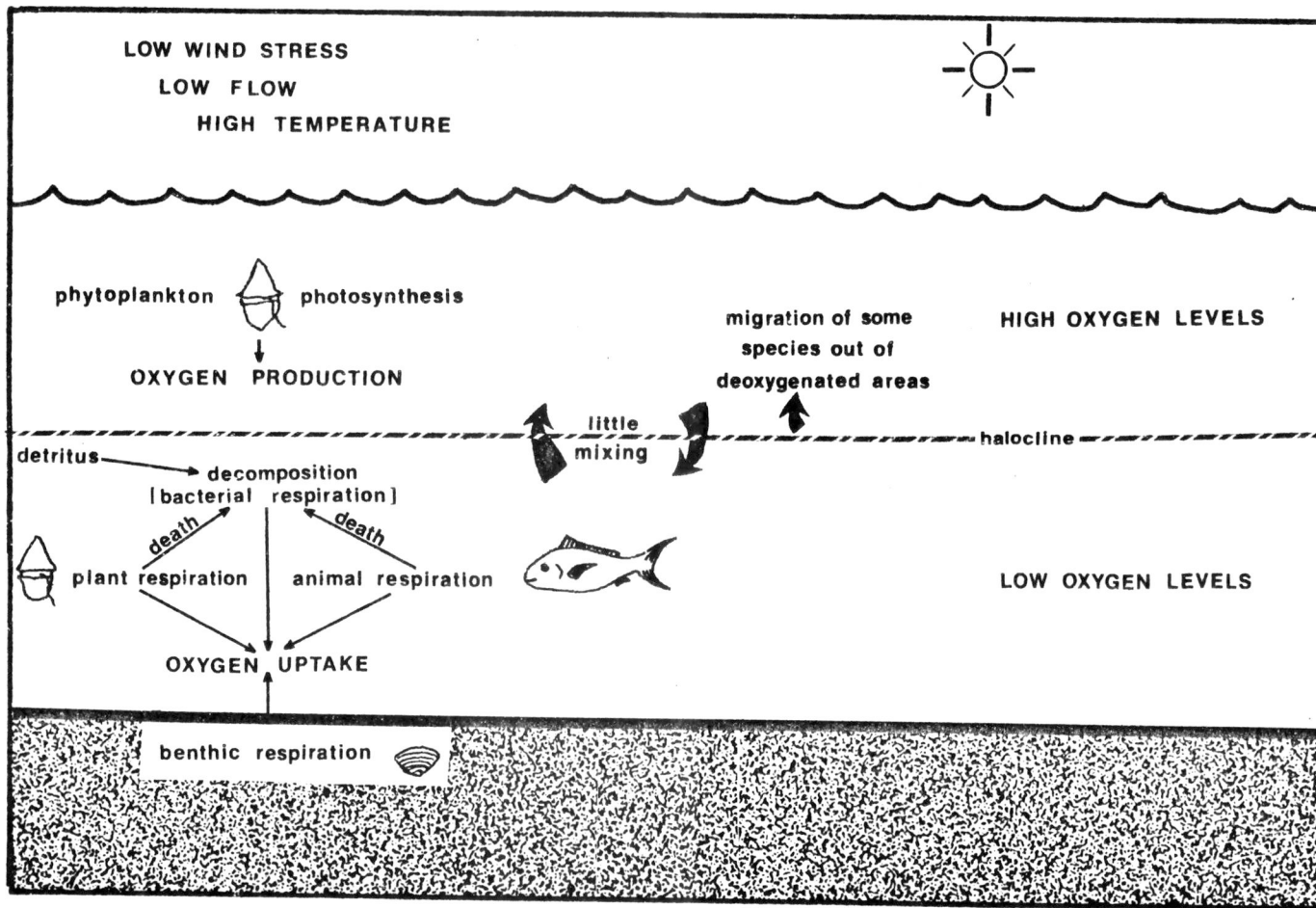


Figure 21. A stylized drawing of the deoxygenation process in the Pamlico River Estuary.

shifted to the northeast (J.W. Kornegay, personal communication). On 7 August 1975, the estuary was poorly mixed along most of its length and deoxygenation was observed in the upper reach (Fig. 22). On 12-13 August 1975, a diurnal study near Indian Island (Sector 8, Fig. 4) showed the effects of wind on the stratification of the water column. With a wind shift to the northeast associated with frontal passage, and an increase in wind velocity, the stratification and its associated deoxygenation were observed to quickly dissipate (Fig. 23). Increasing surface salinity after this wind shift was due to the easterly vector of the wind.

During 1976, the deoxygenation problem was studied more intensively. On 21 June 1976, the estuary was well-mixed (Fig. 24) with strong southwesterly winds (15-20 kts) and scattered thundershowers throughout the day, and was still mixed on 24 June 1976 (Fig. 25). A period of calm during this and successive days led quickly to severe deoxygenation after 5 days on 29 June 1976 (Fig. 26). Diurnal oxygen curves for the surface and bottom of the water column on 30 June-1 July 1976 near Blount's Bay (Station 2, Fig. 3) are shown in Figs. 27 and 28. Increasing dissolved oxygen levels associated with algal photosynthesis during the day were limited to the surface due to the high turbidities (average Secchi = 0.7 m) and low mixing.

Strong southwesterly winds (10-20 kts) on 30 June 1976 were probably responsible for the estuary being somewhat mixed in the lower reaches on 2 July 1976 (Fig. 29). Northeasterly winds on 3-4 July kept the estuary mixed downriver as seen in the hydrography of 5 July 1976 (Fig. 30). Several days of calm or light winds out of the west and southwest led to stratification and severe deoxygenation throughout the estuary

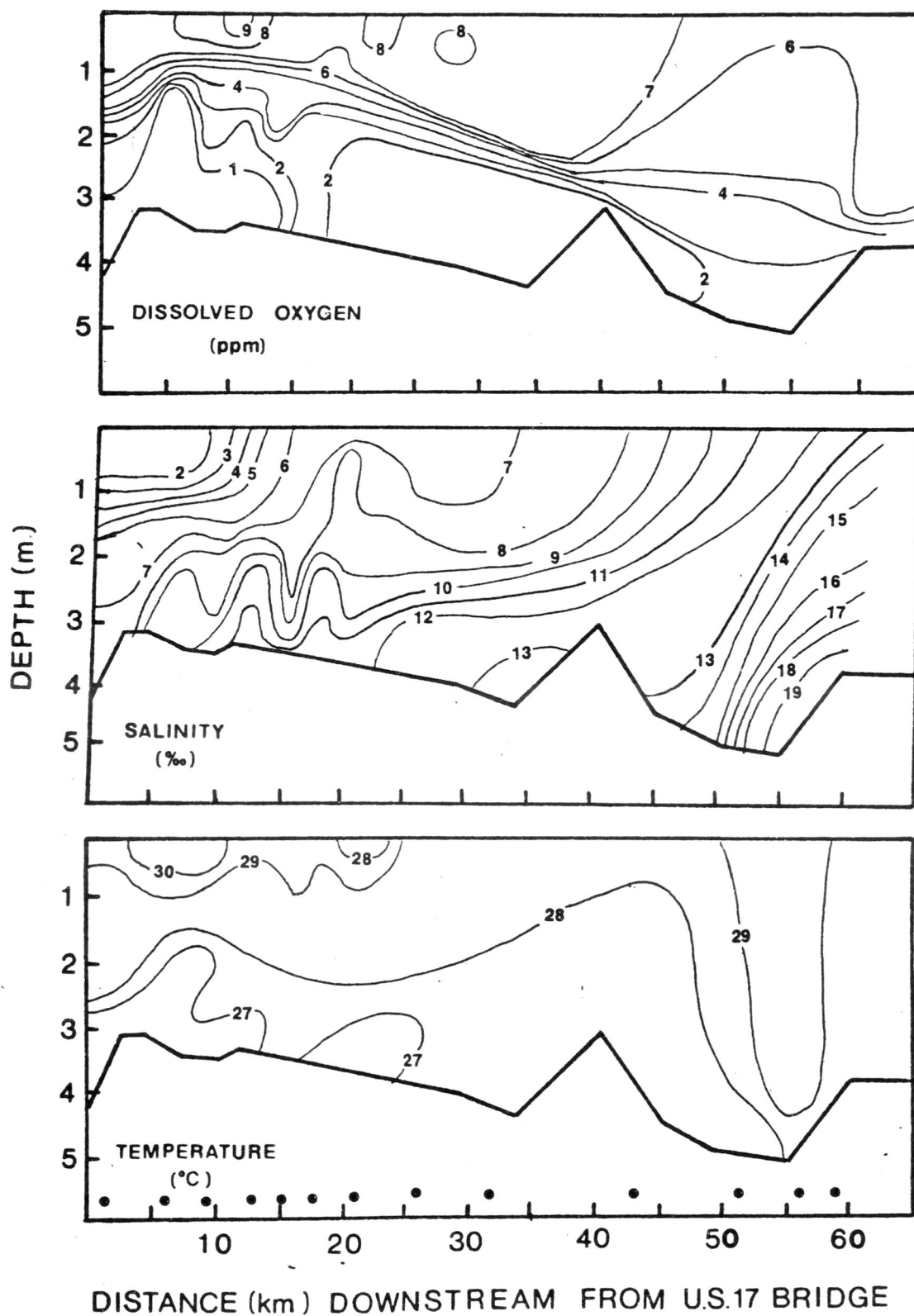


Figure 22. Hydrography of the Pamlico River on 7 August 1975. Dots along bottom axis indicate stations measured.

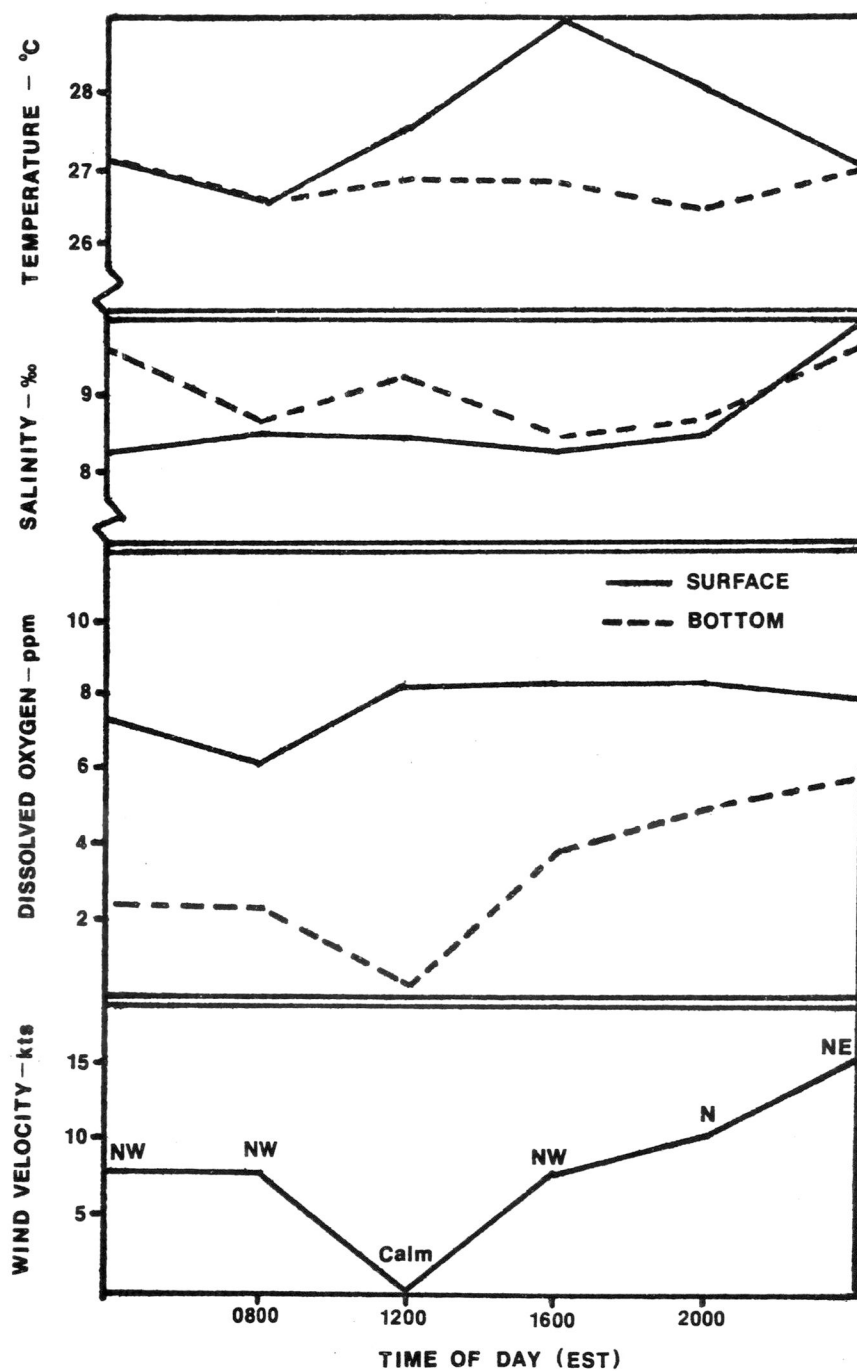


Figure 23. Diurnal hydrographic and wind data at Daymark 3 near Indian Island on 12 August 1975.

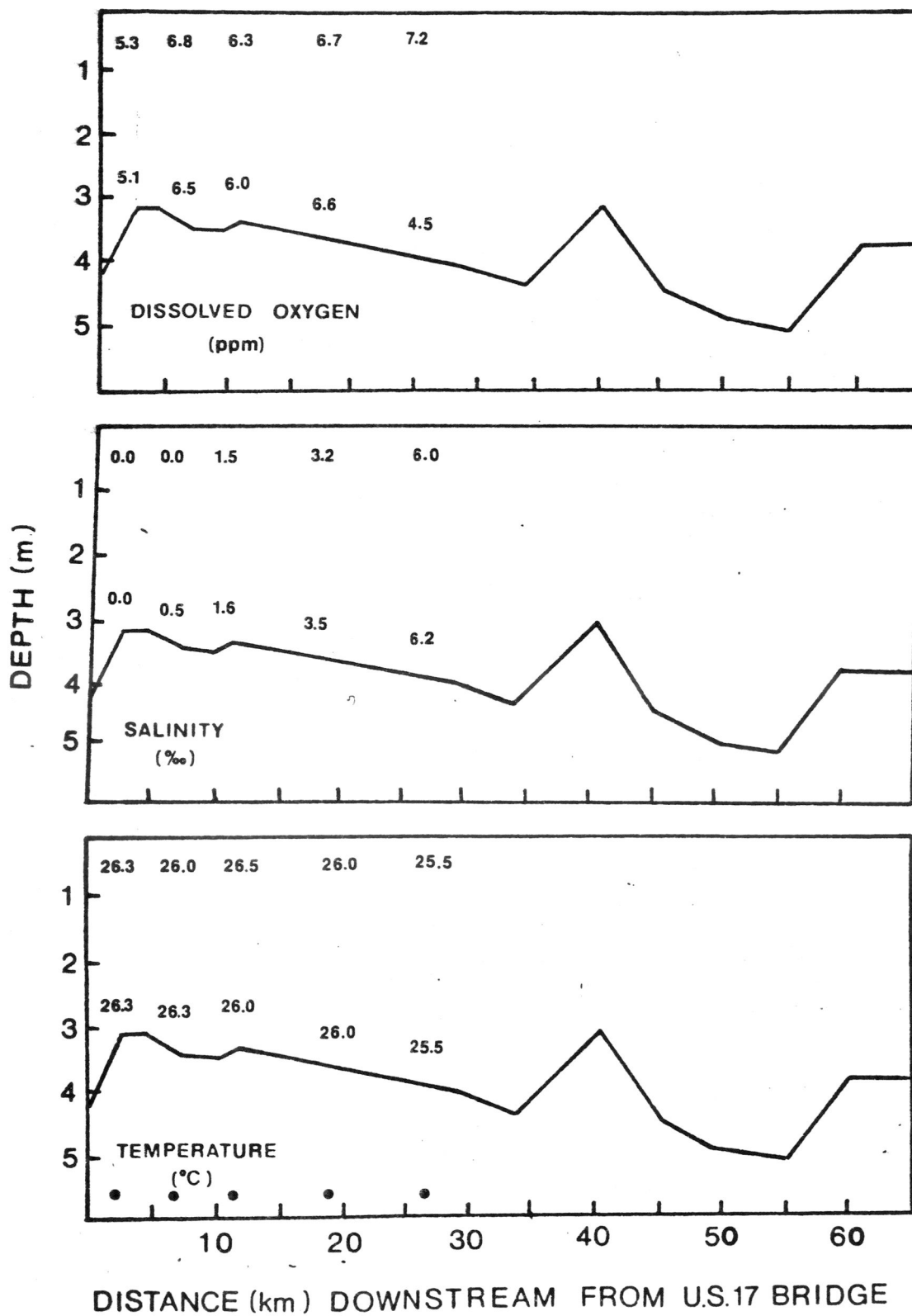


Figure 24. Hydrography of the Pamlico River on 21 June 1976. Dots along bottom axis indicate stations measured.

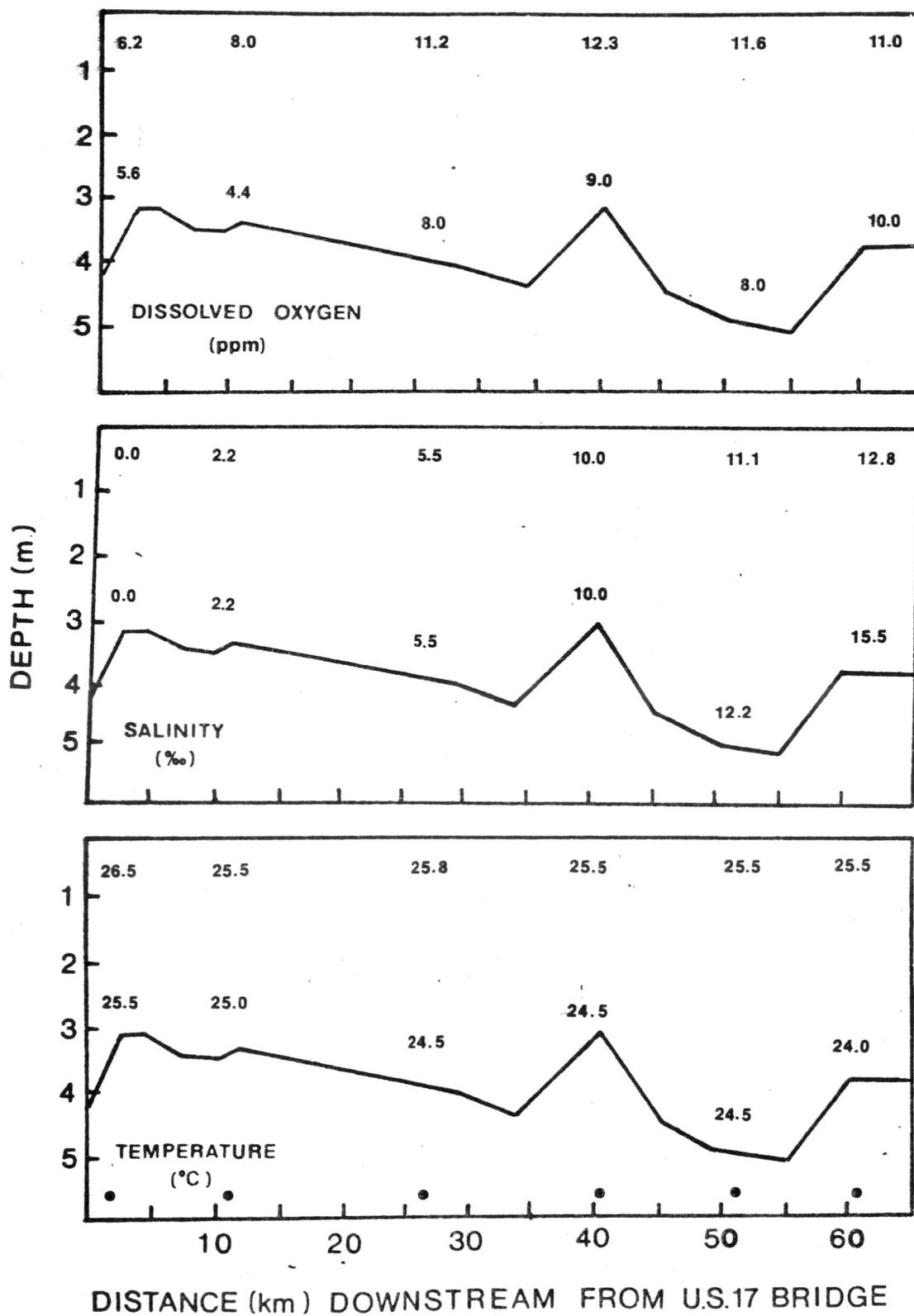


Figure 25. Hydrography of the Pamlico River on 24 June 1976. Dots along bottom axis indicate stations measured.

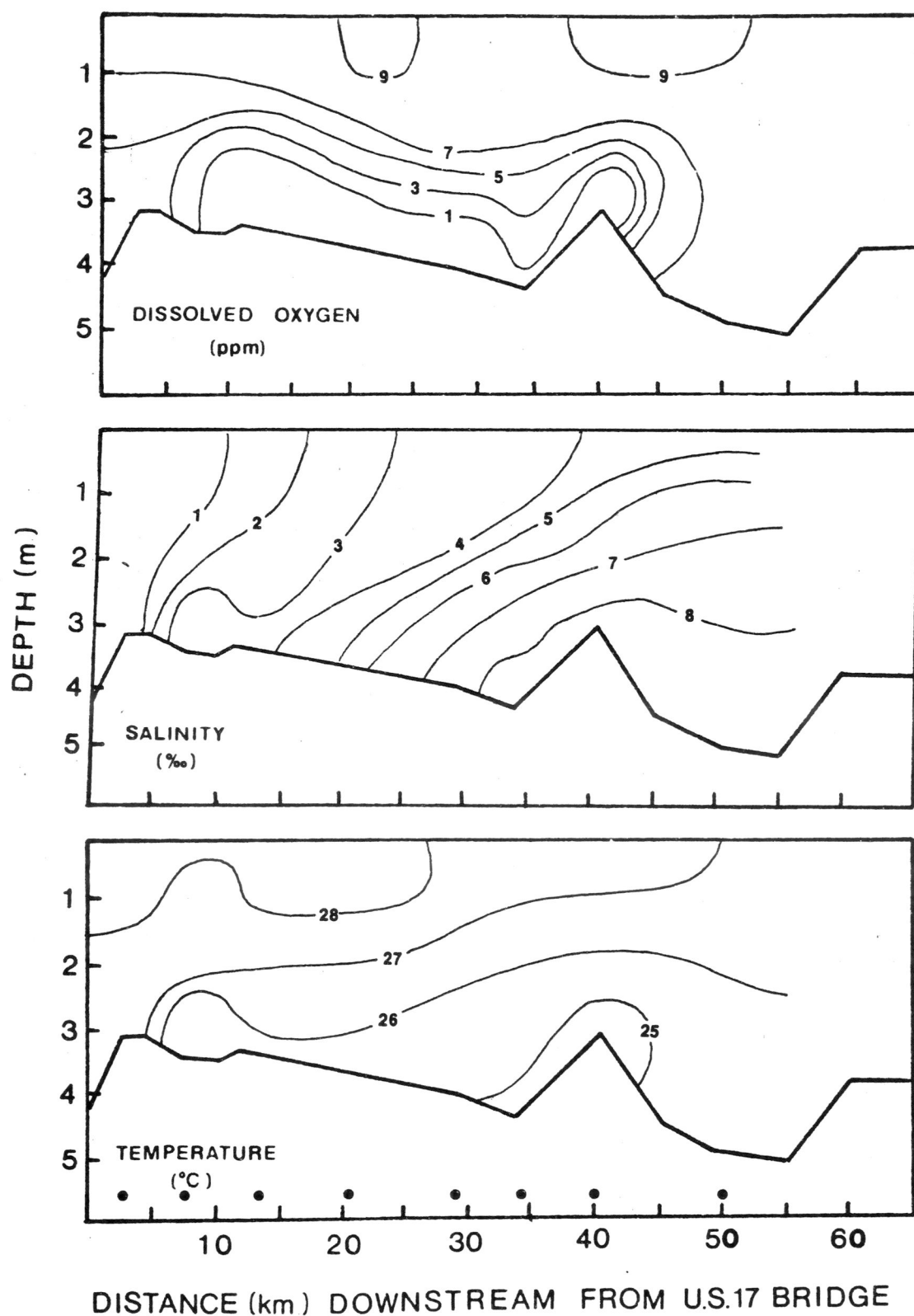


Figure 26. Hydrography of the Pamlico River on 29 June 1976. Dots along bottom axis indicate stations measured.

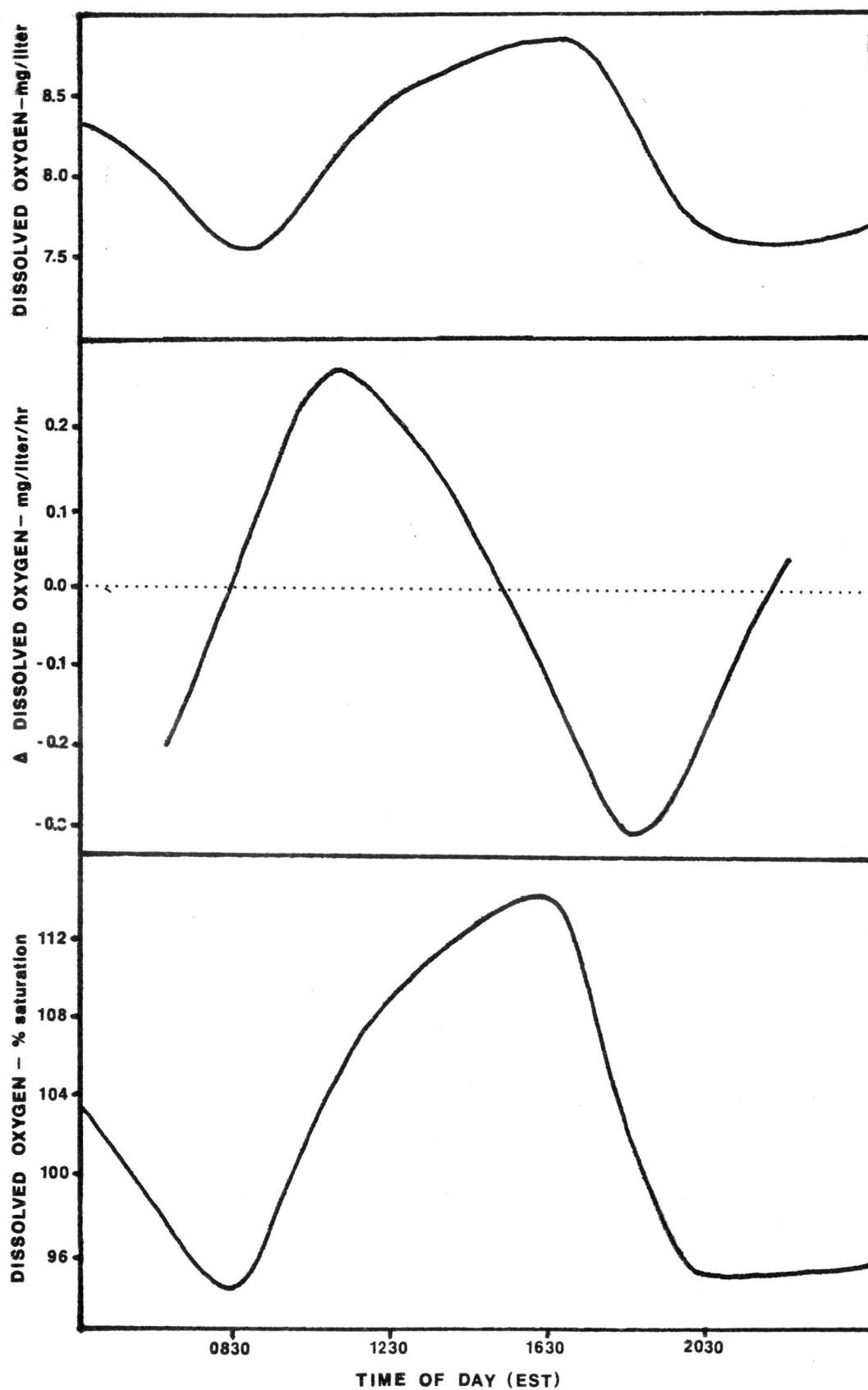


Figure 27. Diurnal dissolved oxygen curves measured at 0.5 m depth at Daymark 9 near Blount's Bay on 30 June--1 July 1976.

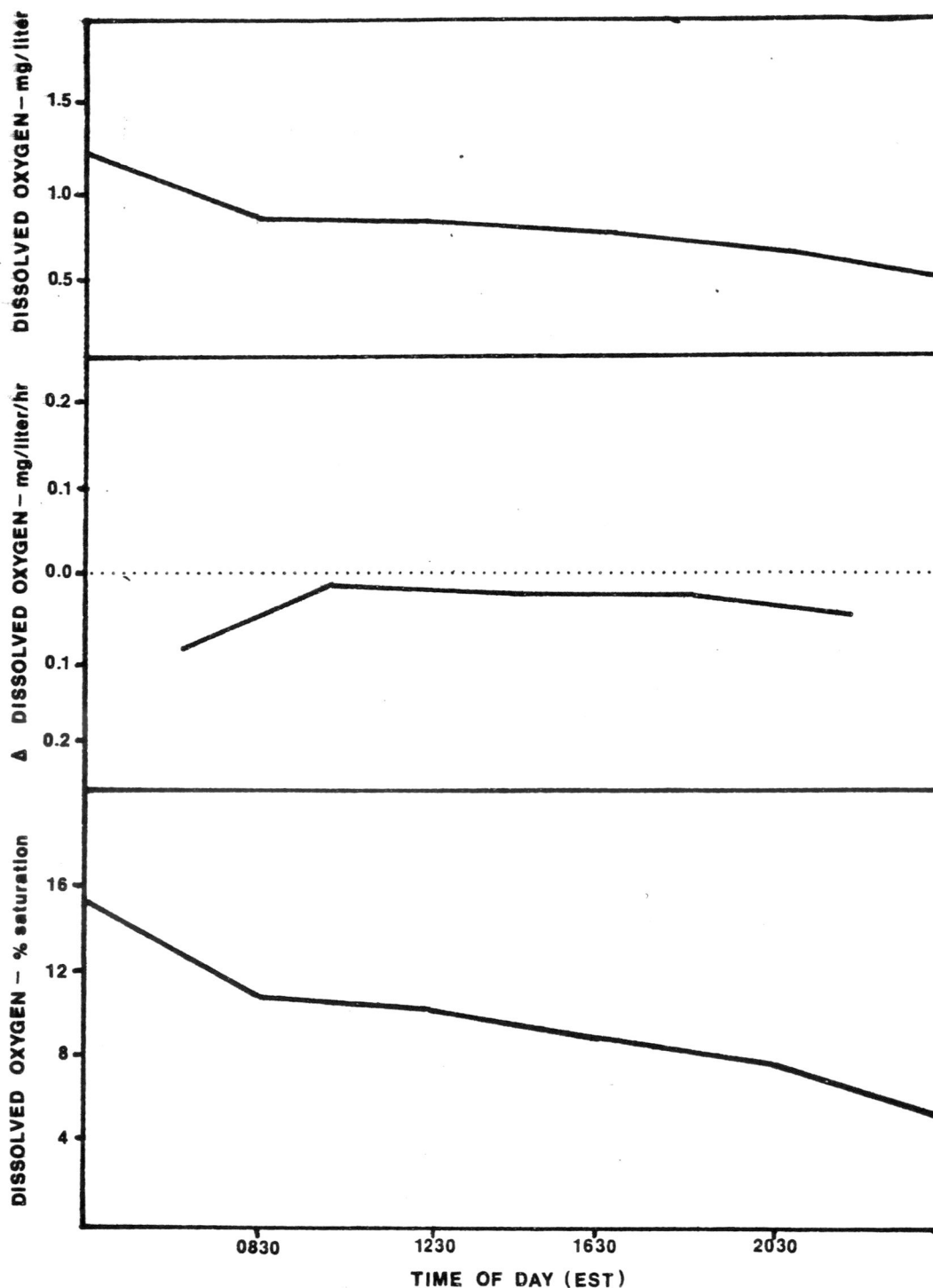


Figure 28. Diurnal dissolved oxygen curves measured 0.5 m from the bottom at Daymark 9 near Blount's Bay on 30 June--1 July 1976.

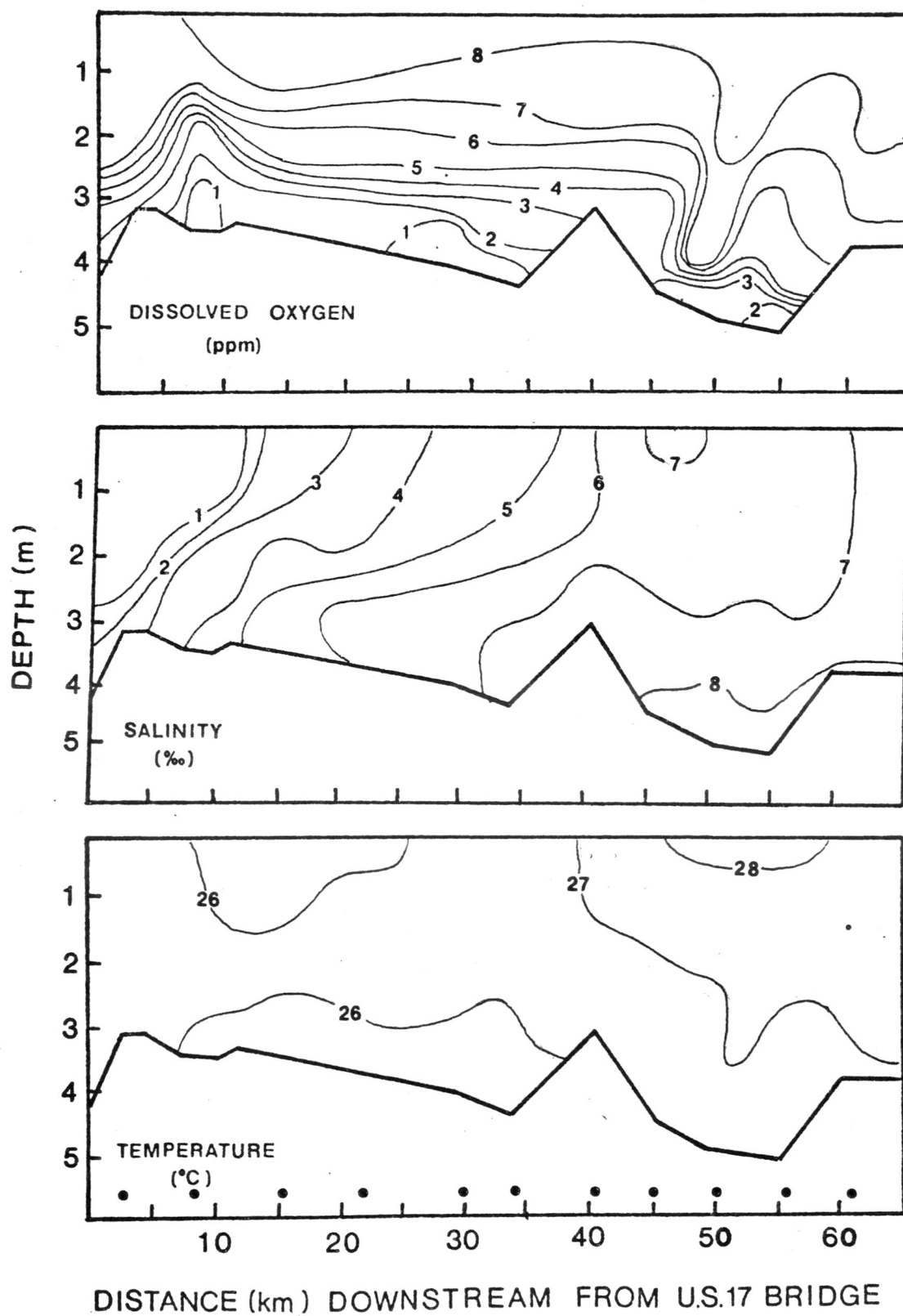


Figure 29. Hydrography of the Pamlico River on 2 July 1976. Dots along bottom axis indicate stations measured.

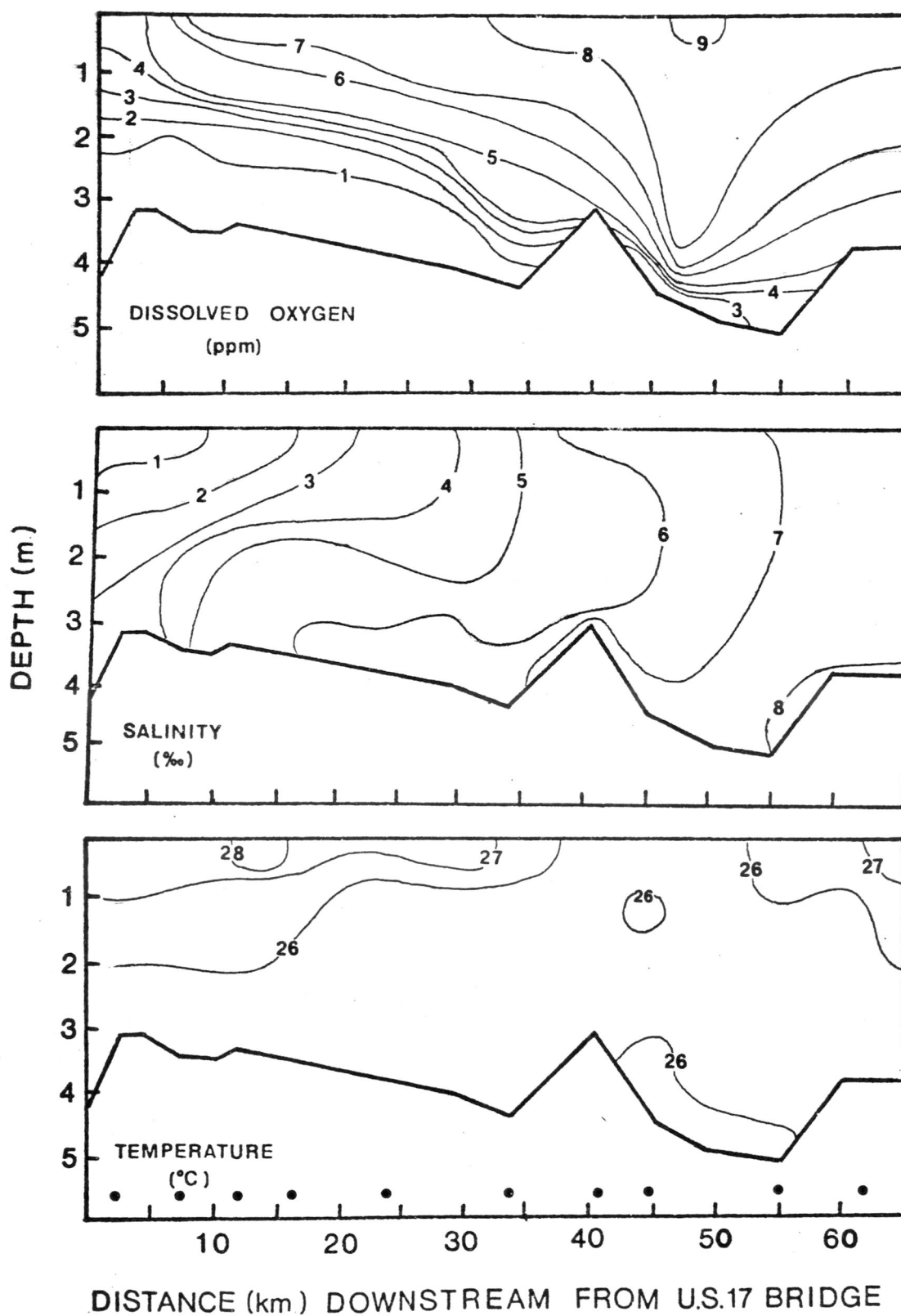


Figure 30. Hydrography of the Pamlico River on 5 July 1976. Dots along bottom axis indicate stations measured.

except at the mouth on 8 July 1976 (Fig. 31). Continued calm or light winds during the following week led to continued stratification as seen on 14 July 1976 (Fig. 32). The effects of low rainfall and low Tar River discharge are apparent in the increased salinities on this date. A salinity of 2 ‰ was recorded at Grimesland, N.C. (Fig. 1) on this date where normally the water is fresh (C. Duncan, unpublished data).

Frontal passage with a shift of the wind to the northeast on 18 July 1976, and northeasterly winds during 19 July 1976 probably led to the break-up of the stratification on 20 July 1976 (Figs. 33 and 34). Between morning and afternoon of this date, the layer of deoxygenated water rose in the area of Washington, N.C. so that it lay at a depth of 1.5 m with layers of water with normal oxygen content above and below it. Large numbers of fish were observed in the upper meter of water above this layer. Also associated with this break-up were a small fish kill (predominantly menhaden, flounder and spot) and a bloom of the blue-green alga, Microcystis, which is known to produce substances toxic to fish. Hydrogen sulphide was also detected. Therefore, the fish kill may have been due to a combination of factors including low oxygen levels, hydrogen sulphide, and toxins produced by an algal species.

Moderate wind stress during the following week kept the estuary fairly mixed as observed during the Estuarine Organic Carbon study on 27 July 1976. However, a small fish kill in Chocowinity Bay (Sector 2, Fig. 4) may indicate that some stratification had set in upriver. Frontal passage with northeast and easterly winds during 3-4-5 August 1976 may have caused the hydrography pattern on 6 August 1976 (Fig. 35)

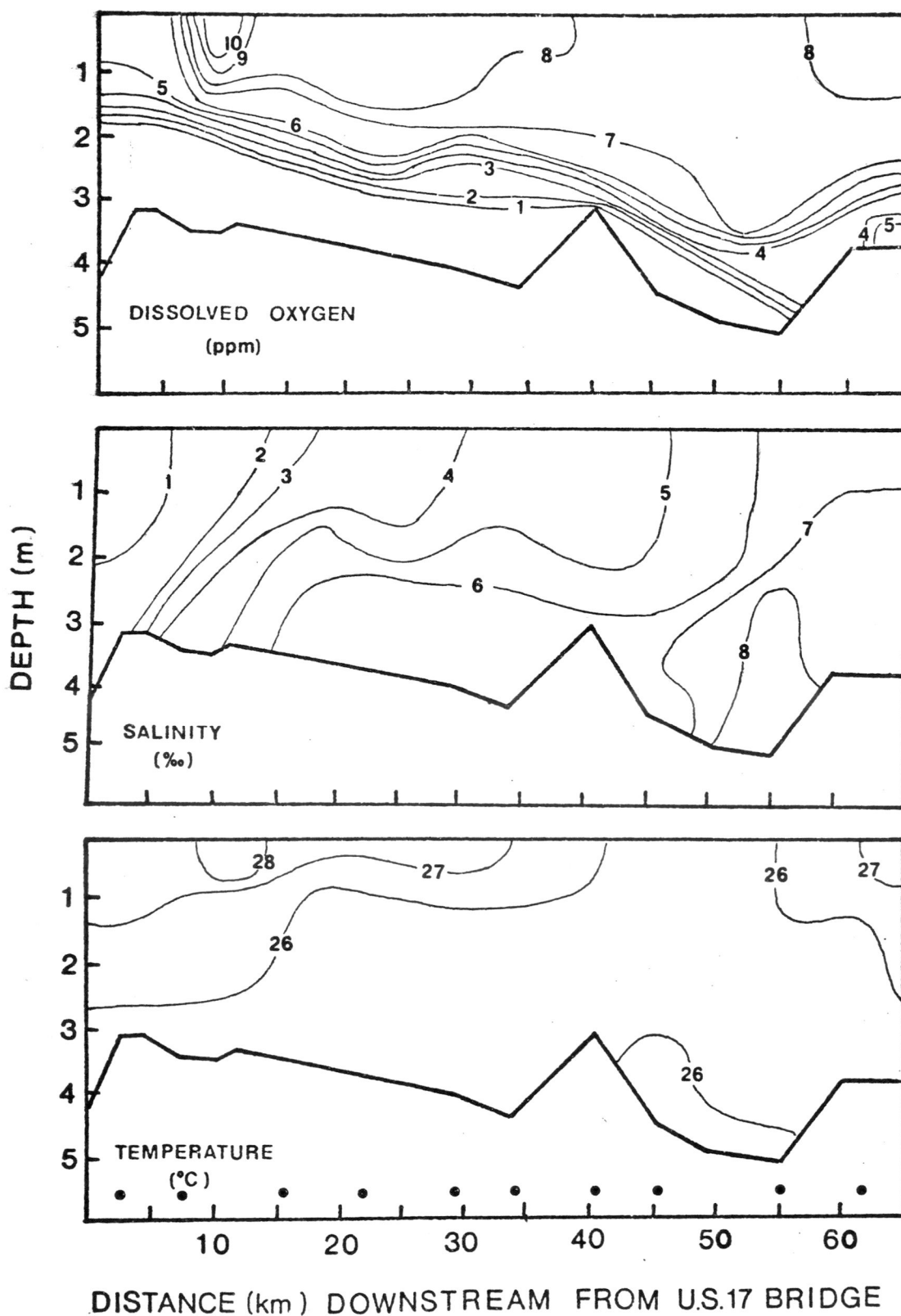


Figure 31. Hydrography of the Pamlico River on 8 July 1976. Dots along bottom axis indicate stations measured.

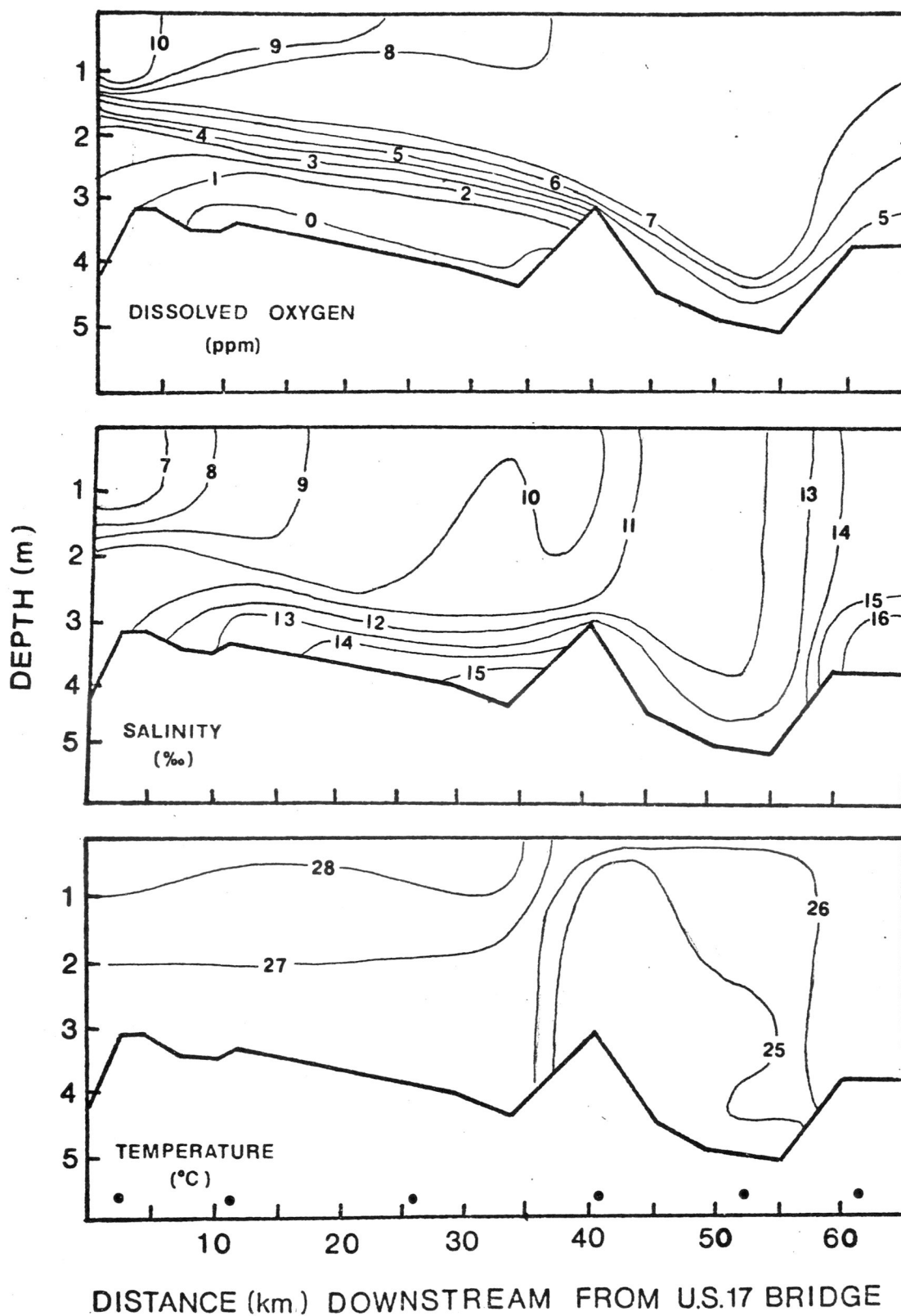


Figure 32. Hydrography of the Pamlico River on 14 July 1976. Dots along bottom axis indicate stations measured.

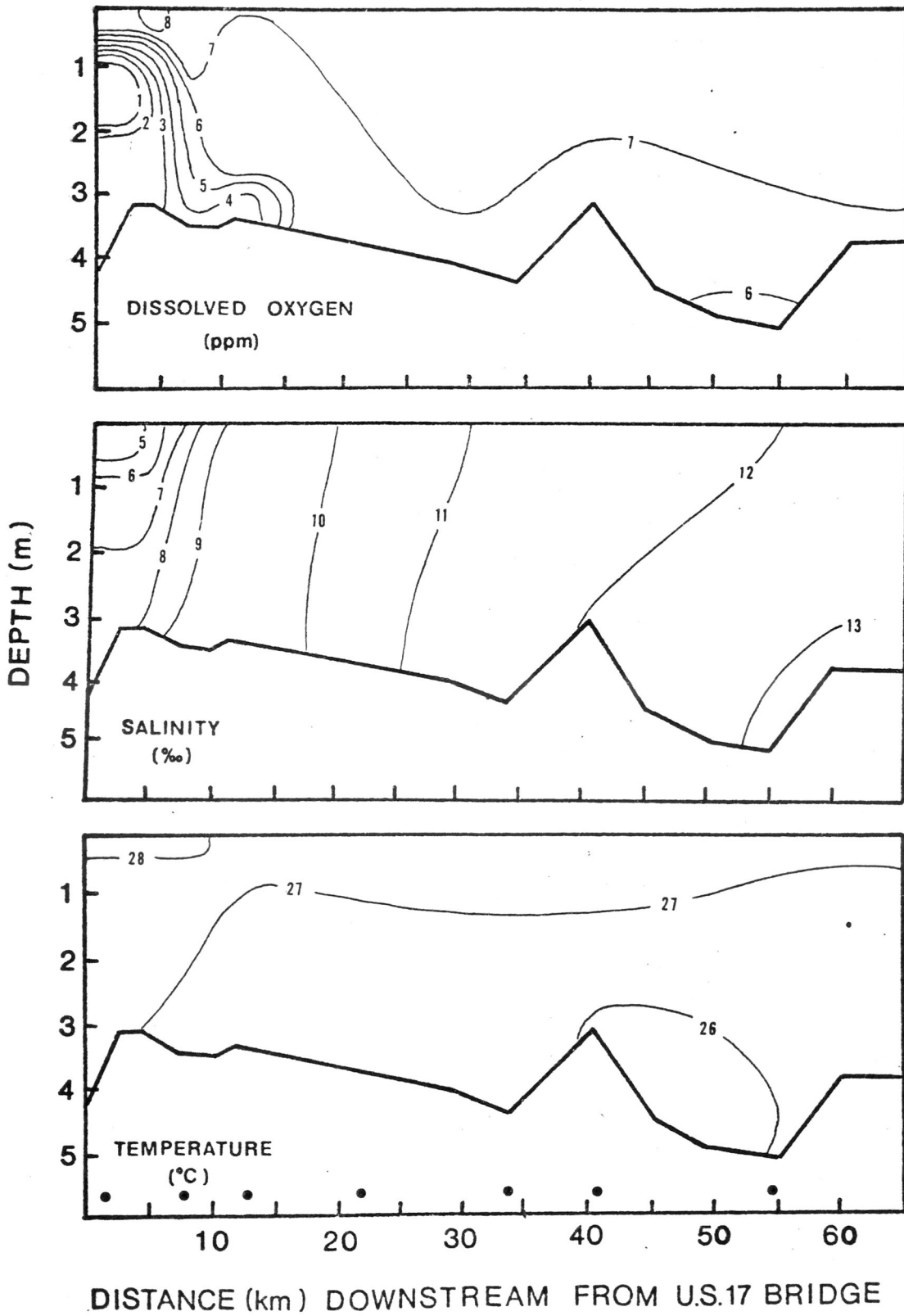


Figure 33. Hydrography of the Pamlico River on 20 July 1976 (A.M.).
Dots along bottom axis indicate stations measured.

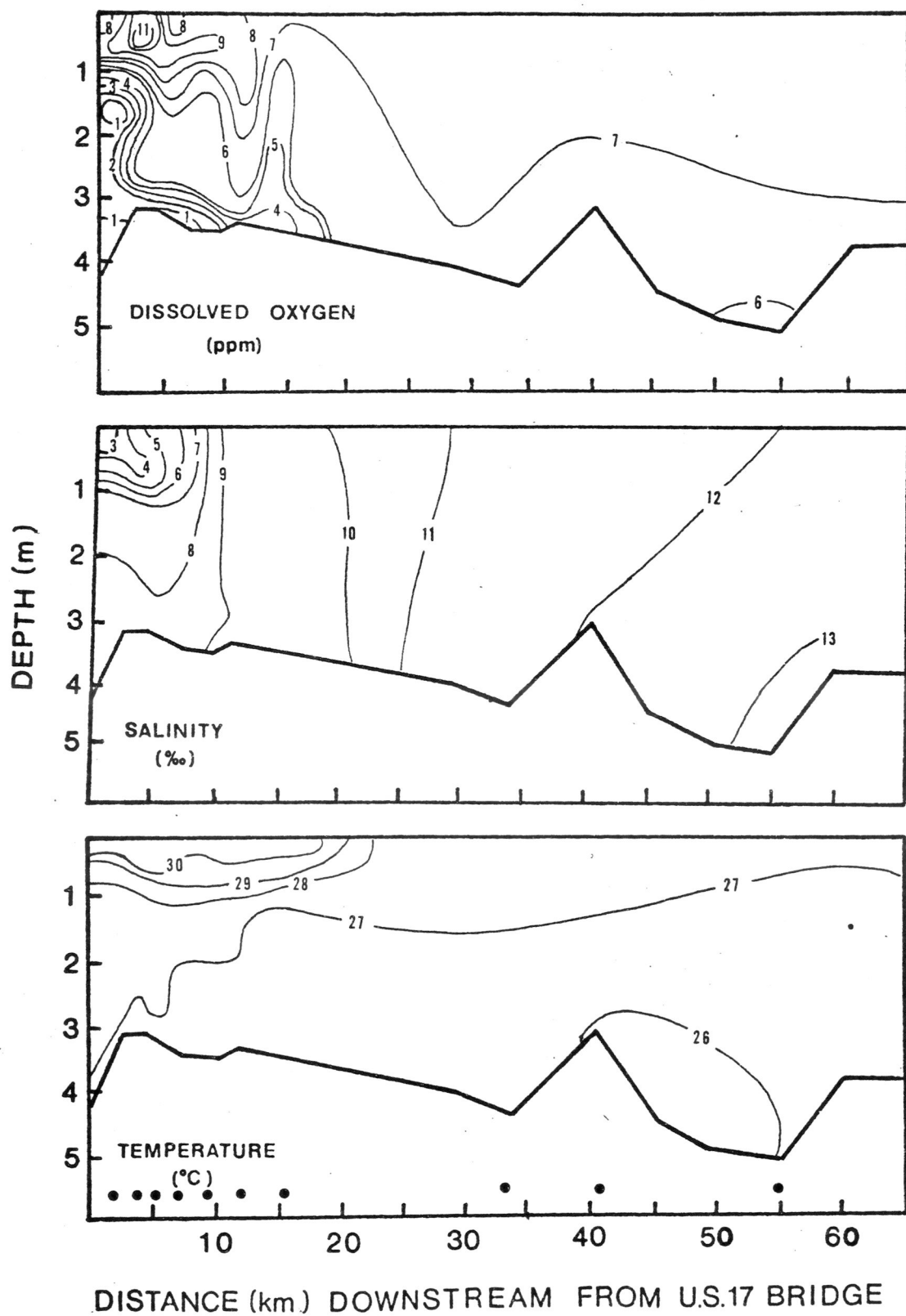


Figure 34. Hydrography of the Pamlico River on 20 July 1976 (P.M.).
Dots along bottom axis indicate stations measured.

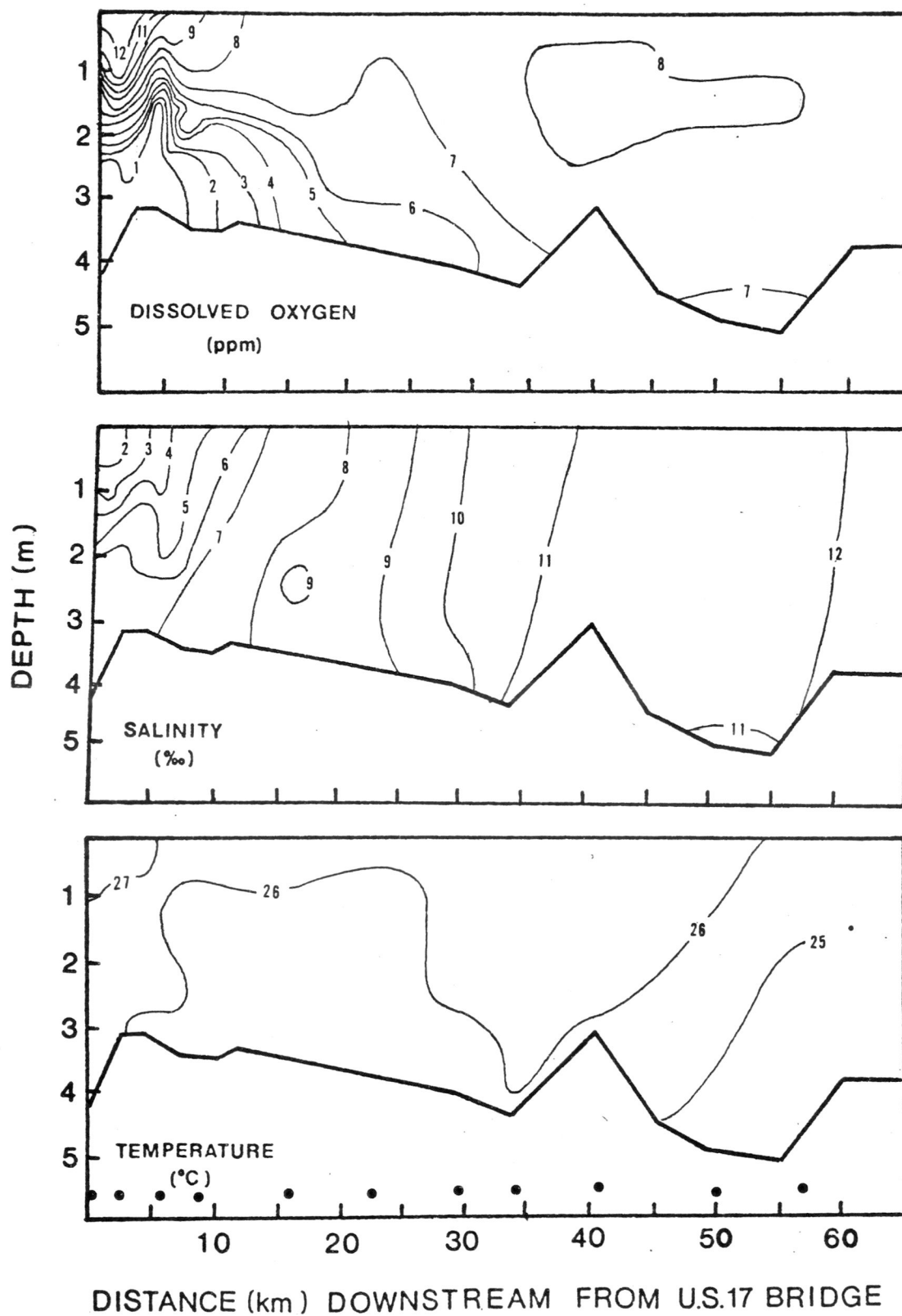


Figure 35. Hydrography of the Pamlico River on 6 August 1976. Dots along bottom axis indicate stations measured.

Winds of up to 45 kts out of the northeast associated with the passage of Hurricane Belle off Cape Hatteras caused the well-mixed hydrography pattern on 11 August 1976 (Fig. 36). Indications of the initial stages of stratification and resultant deoxygenation are apparent upriver near Washington, N.C. This may have intensified during the following days due to calm weather. Passage of Tropical Storm Dottie to the south of the estuary on 20-21 August 1976 with easterly and north-easterly winds of 30-35 kts probably broke up any stratification that may have developed. By 24 August 1976, deoxygenation was beginning to occur in the upper reaches (Fig. 37). A North Carolina Air Stagnation Advisory was in effect during 26-27 August 1976 and deoxygenation was recorded throughout the estuary on this latter date (Fig. 38). Dissolved oxygen levels of less than 1 mg/liter were recorded on this date well into Pamlico Sound. Continued drought conditions are apparent in the high salinities occurring throughout the estuary.

Strong winds (15-20 kts) out of the east and northeast during the night of 30 August and throughout the day on 31 August 1976 were probably responsible for the downriver mixing apparent in the hydrography pattern on 31 August (Fig. 39). Colder temperatures during the night of 30 August (approximately 12°C) were probably responsible for the temperature inversion in the upper reach. Stratification and deoxygenation were again reported on 10 September 1976 (D. Kornegay, personal communication).

No readings were taken between this date and 16 October 1976. On this date (Fig. 40), low dissolved oxygen concentrations were noted in the upper reach perhaps associated with low wind stress and a high biological oxygen demand due to a dinoflagellate bloom in this area. On 5 December 1976, salinity stratification occurred west of Indian

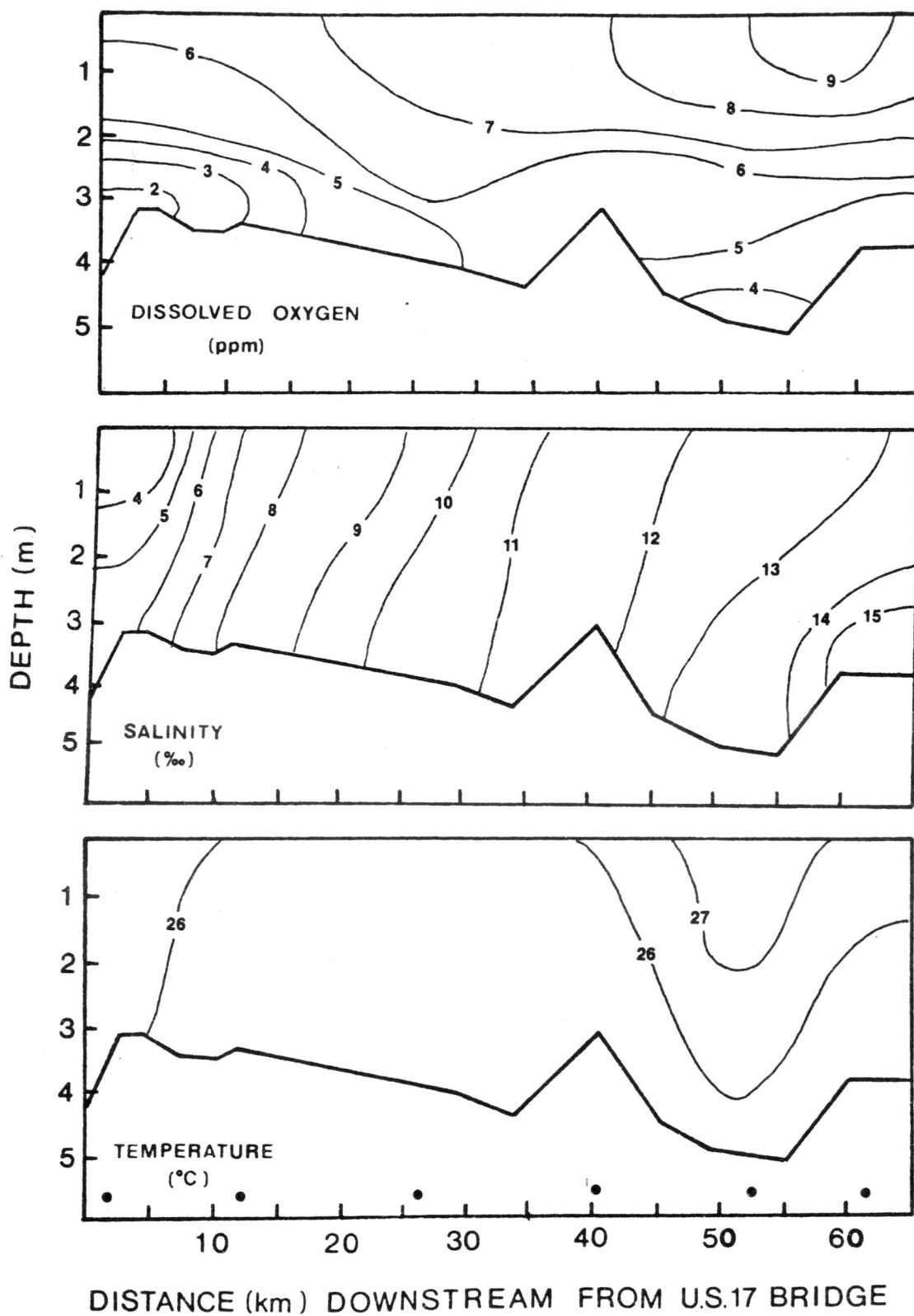


Figure 36. Hydrography of the Pamlico River on 11 August 1976. Dots along bottom axis indicate stations measured.

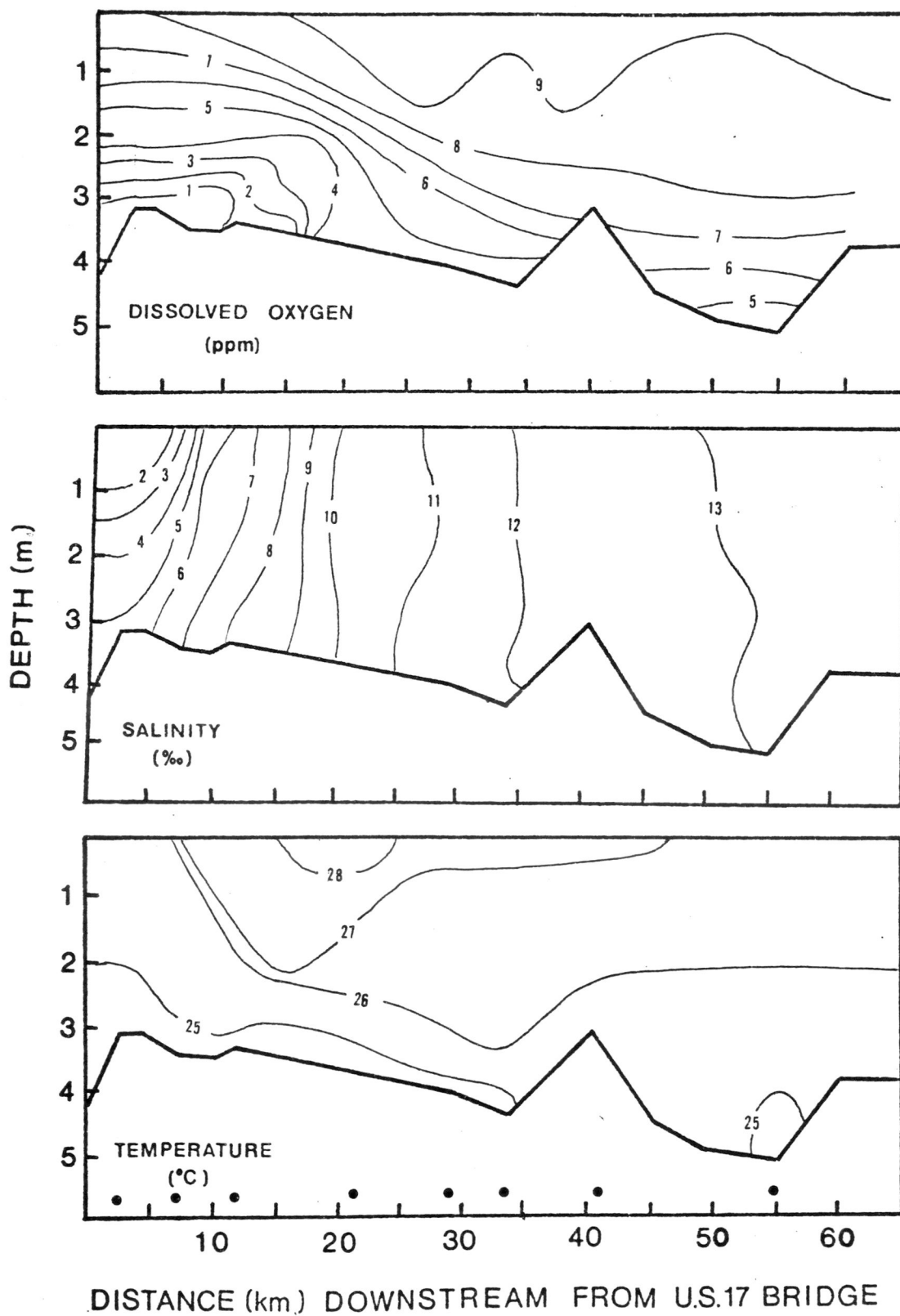


Figure 37. Hydrography of the Pamlico River on 24 August 1976. Dots along bottom axis indicate stations measured.

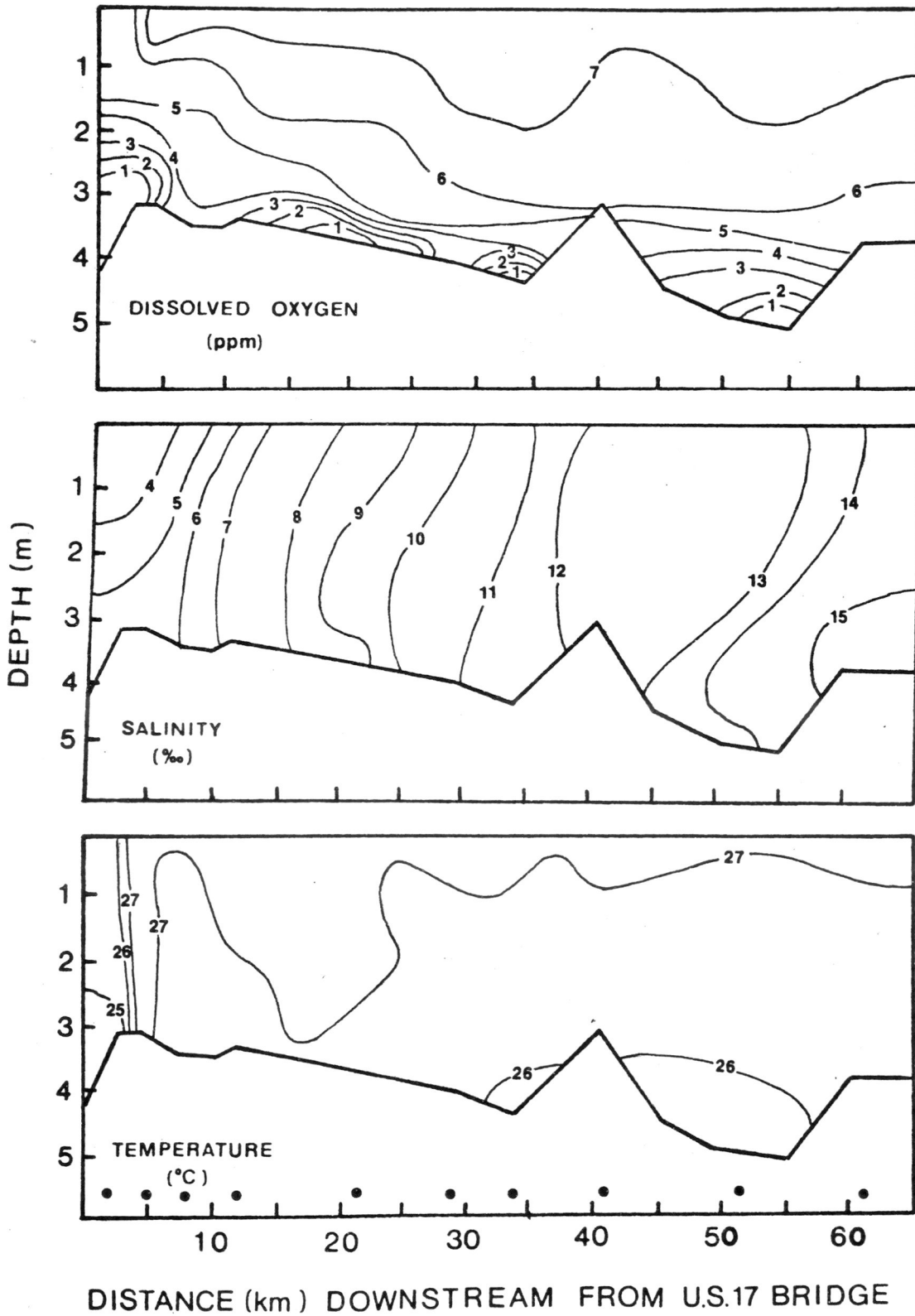


Figure 38. Hydrography of the Pamlico River on 27 August 1976. Dots along bottom axis indicate stations measured.

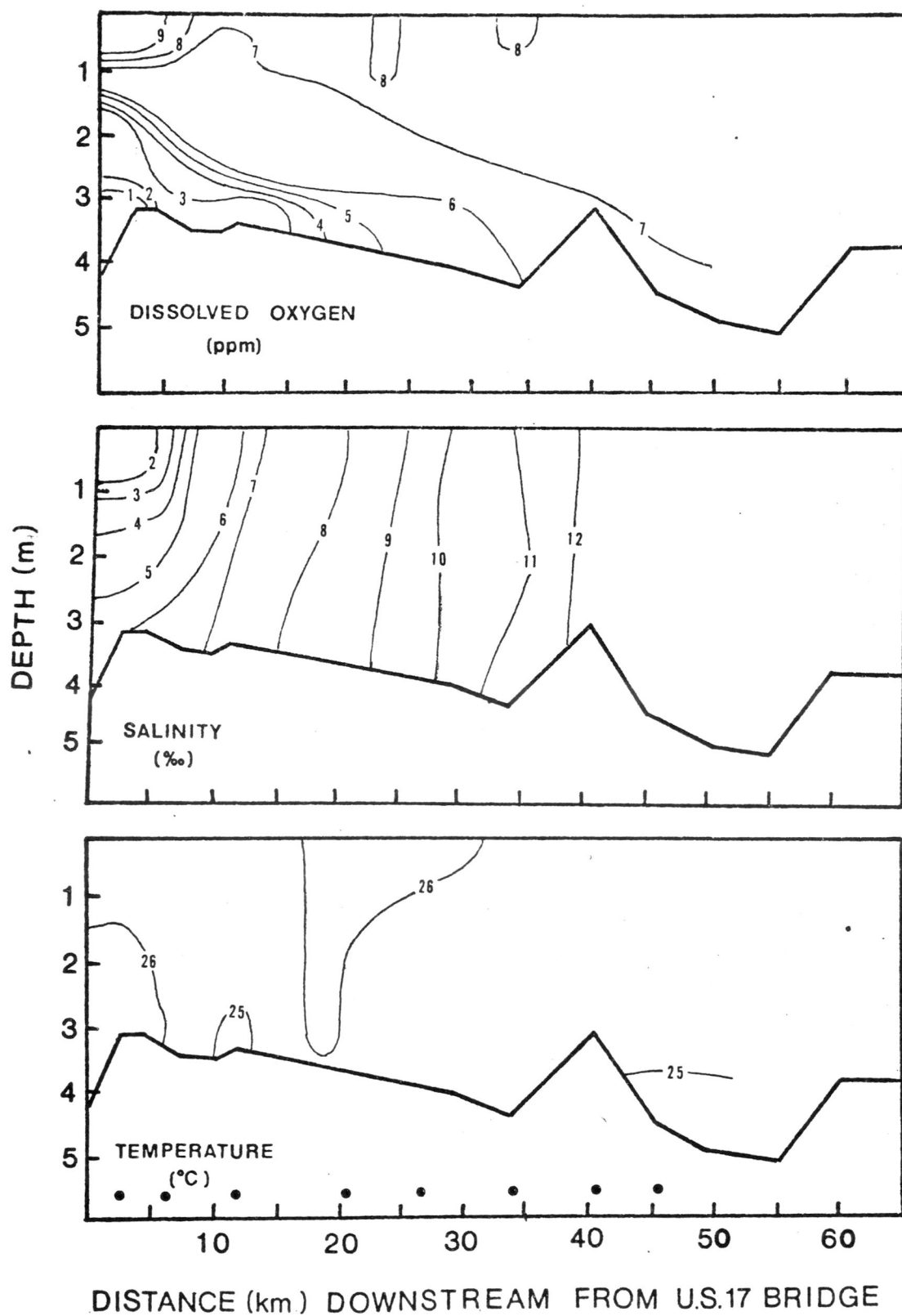


Figure 39. Hydrography of the Pamlico River on 31 August 1976. Dots along bottom axis indicate stations measured.

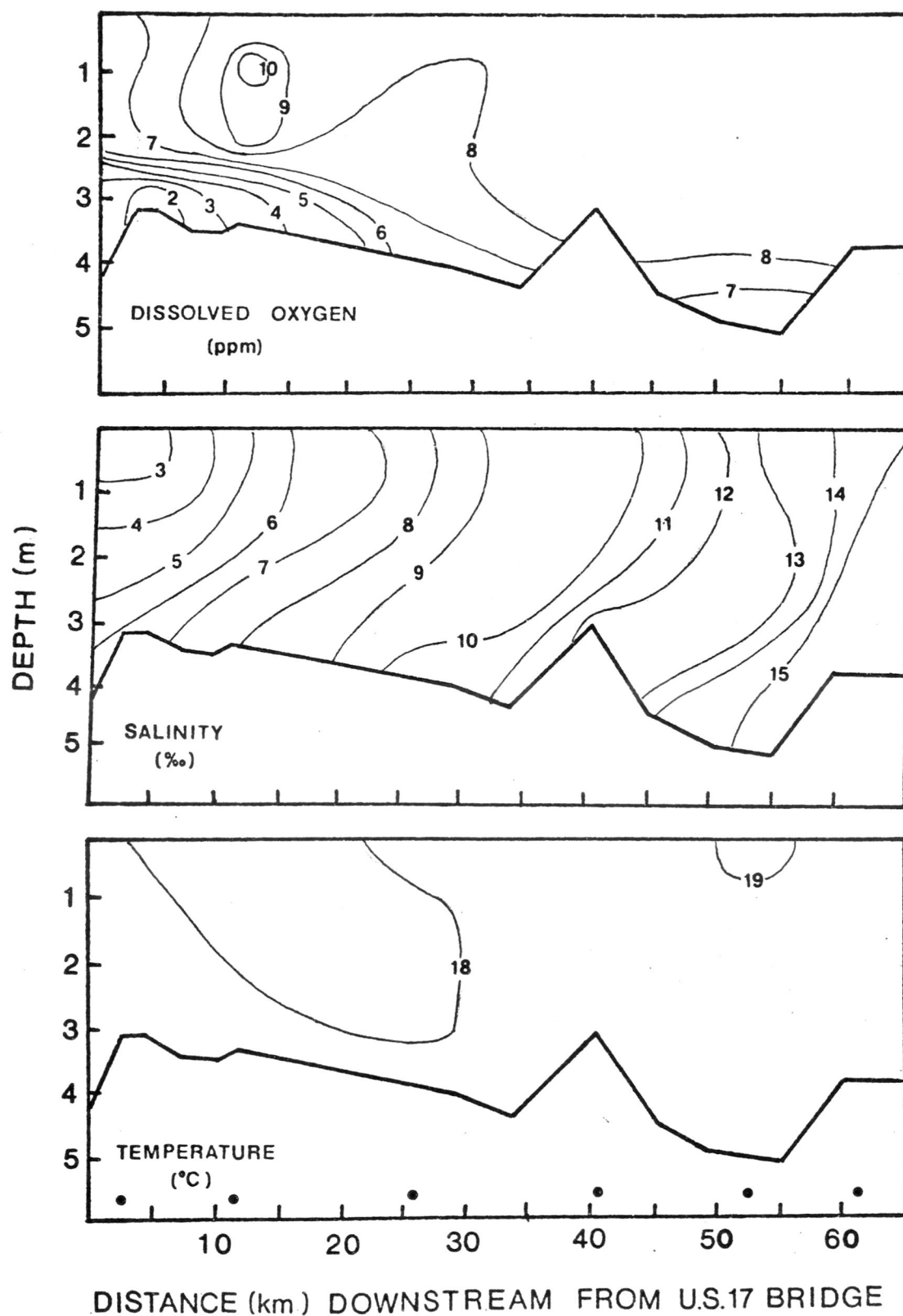


Figure 40. Hydrography of the Pamlico River on 16 October 1976. Dots along bottom axis indicate stations measured.

Island (Fig. 41). Dissolved oxygen stratification was also apparent in this area, but did not reach the low levels characteristic of the summer months. High salinities on this date were due to the continuing drought conditions, and the very low water temperatures were due to the record low air temperatures which occurred during November and early December. These extremely low temperatures continued throughout most of the winter and in late January and early February (1977) the entire estuary was covered with a sheet of ice with the exception of a narrow band in mid-channel.

On 2 March 1977, salinity stratification was recorded in the upper reach of the estuary near Washington, N.C. probably associated with the high Tar River discharge (Fig. 42). A dinoflagellate bloom (Heterocapsa triquetrum) was located between 5 and 20 km from the U.S. 17 bridge on this date. Low wind stress, high Tar River discharge, and the oxygen demand associated with the high labile carbon levels in this bloom were probably responsible for the low oxygen levels in this area on 10 March 1977 (Fig. 43) (M. White and D. Kornegay, unpublished data).

The estuary was again mixed on 23 May 1977 when the winds were from the east and northeast at 5 to 15 kts (Fig. 44). On 9 June 1977, a diurnal study near Blount's Bay (Station 2, Fig. 3) showed how quickly the stratified water column can become mixed. With an increase in wind velocity and a shift in wind direction associated with frontal passage, the stratified system became completely mixed within 4 h (Fig. 45). On 27 June 1977, salinity stratification and poorly oxygenated water extended from Washington, N.C. to Indian Island (Fig. 46). Fish kills were reported in South Creek (25 June) and near Durham Creek (28 June),

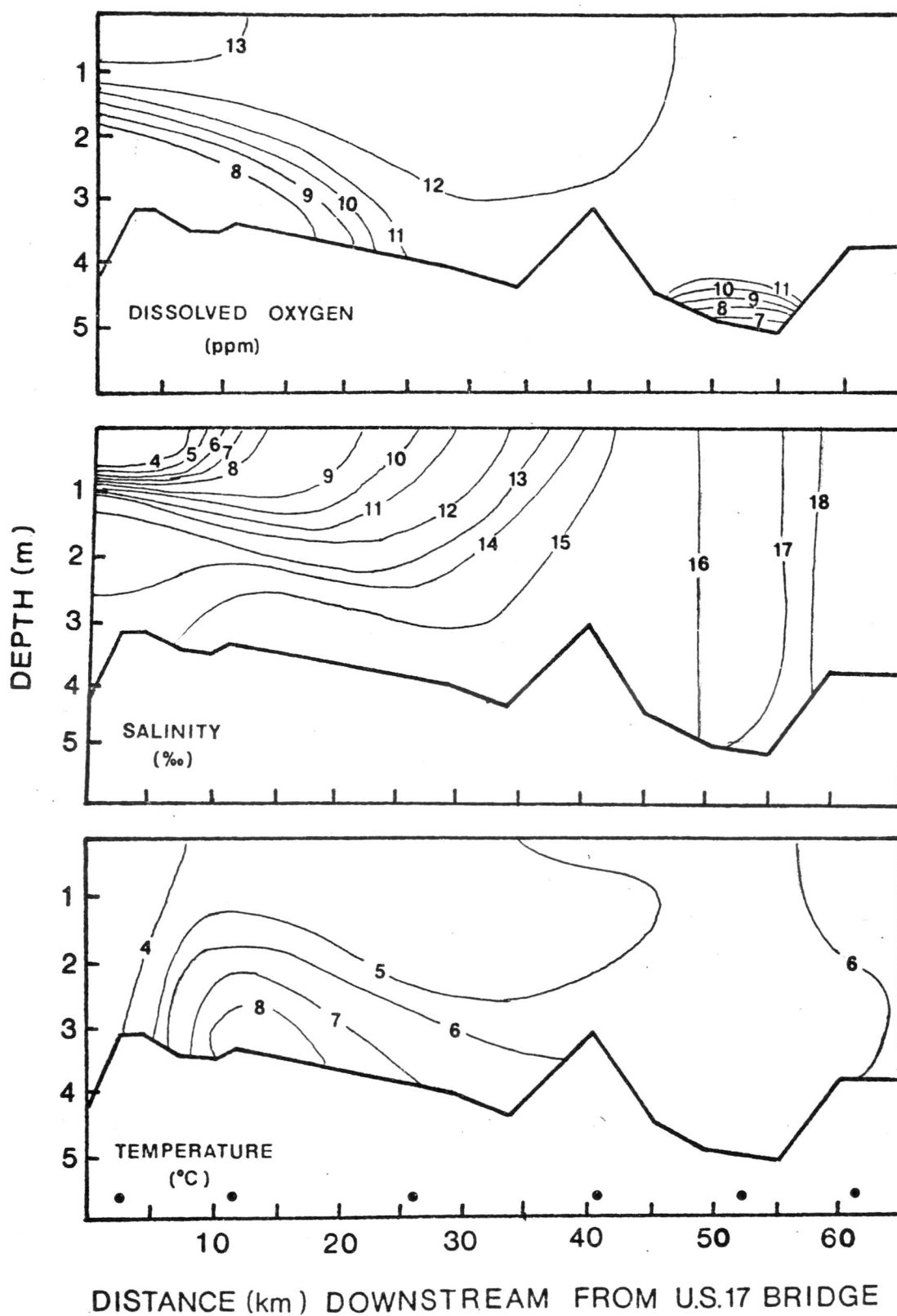


Figure 41. Hydrography of the Pamlico River on 5 December 1976. Dots along bottom axis indicate stations measured.

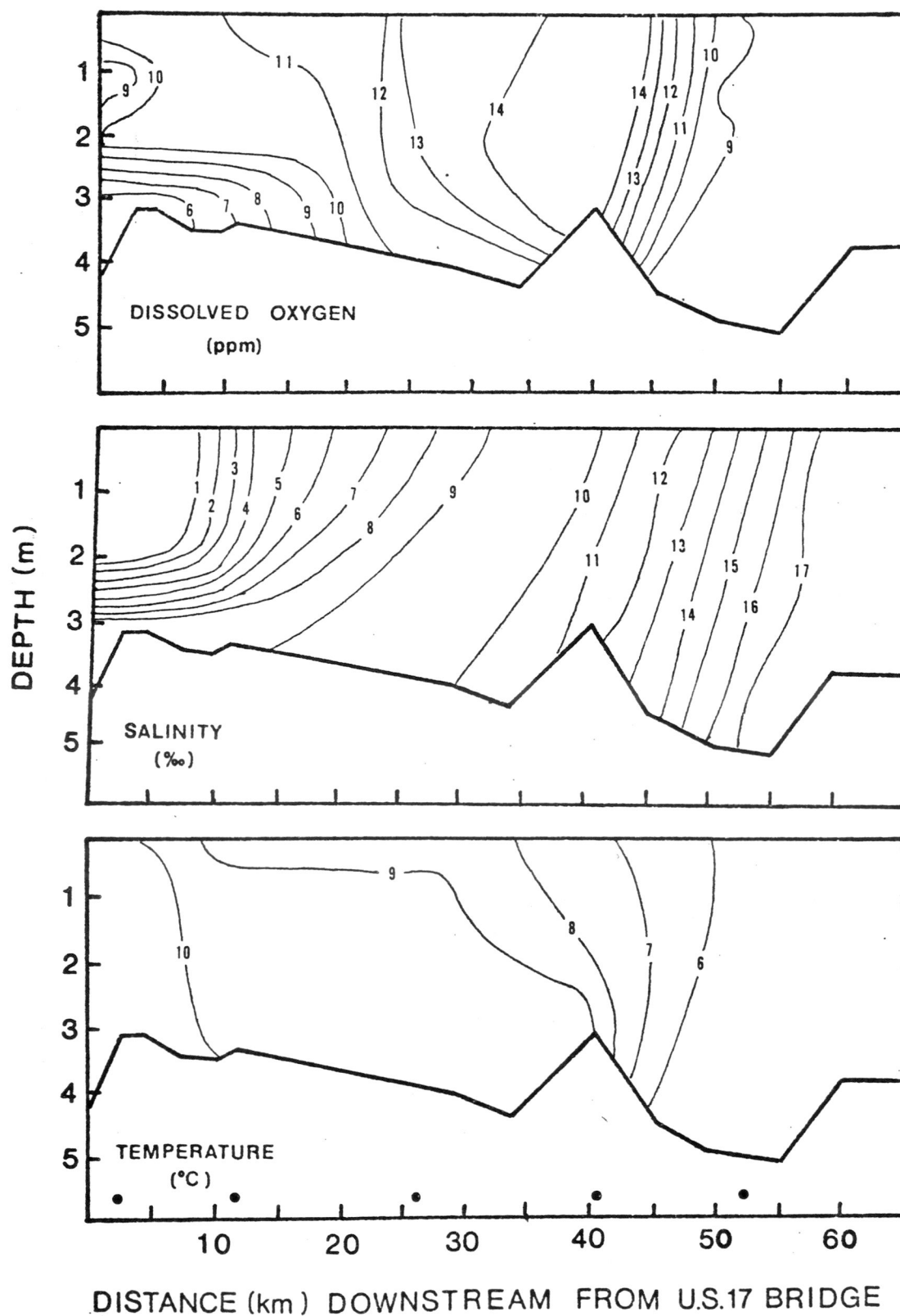


Figure 42. Hydrography of the Pamlico River on 2 March 1977. Dots along bottom axis indicate stations measured.

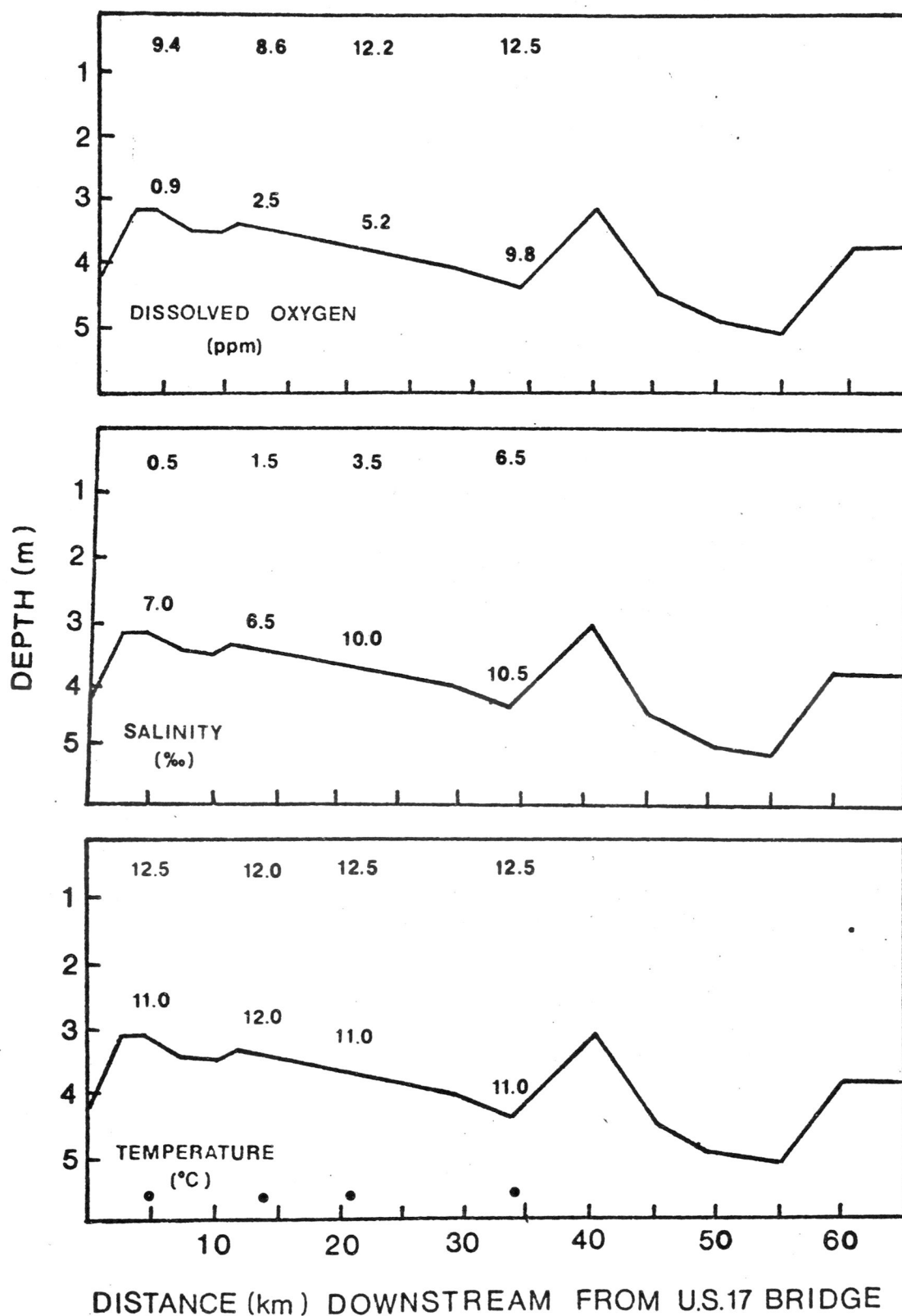


Figure 43. Hydrography of the Pamlico River on 10 March 1977 (Data from M. White and D. Kornegay). Dots along bottom axis indicate stations measured.

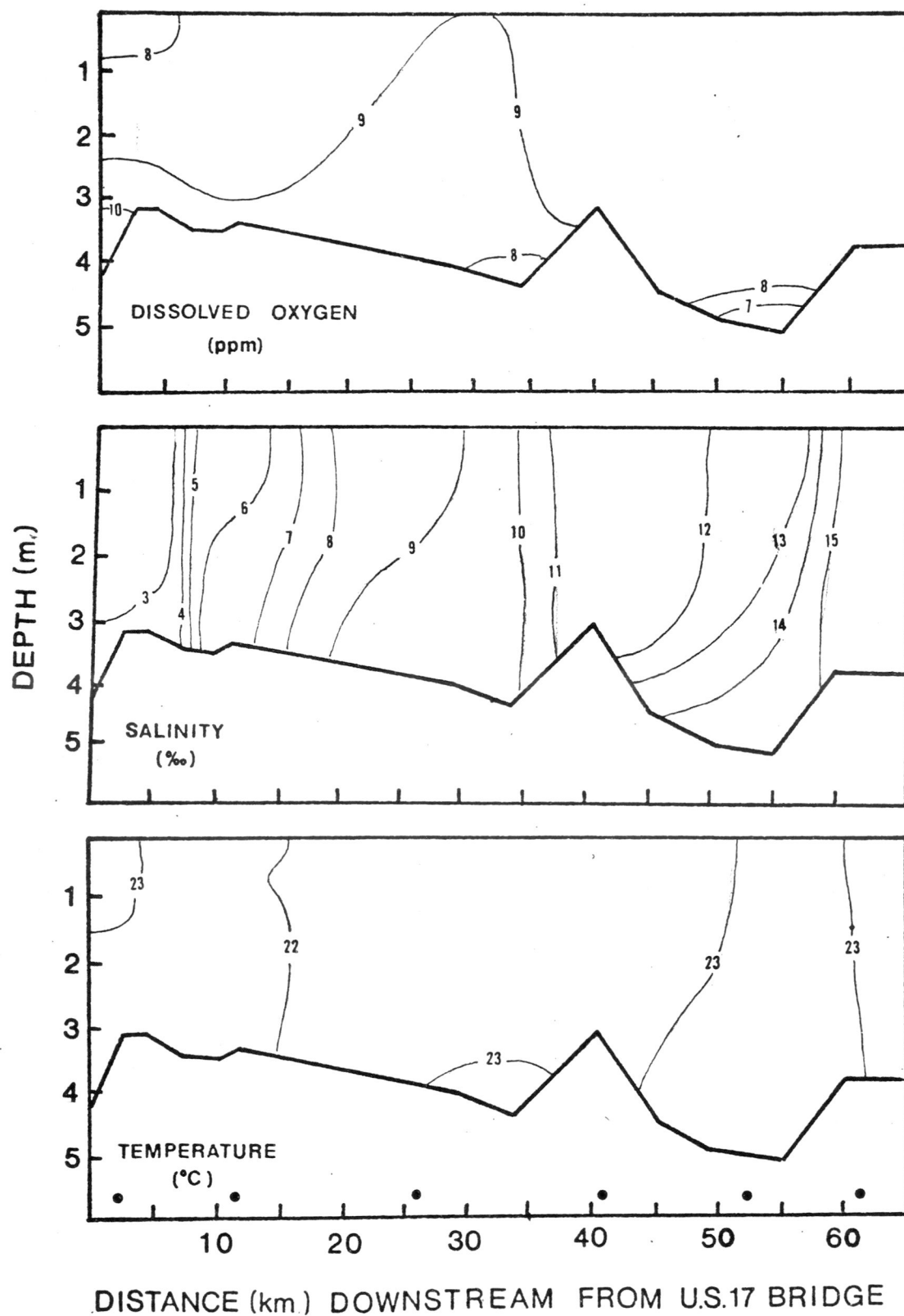


Figure 44. Hydrography of the Pamlico River on 23 May 1977. Dots along bottom axis indicate stations measured.

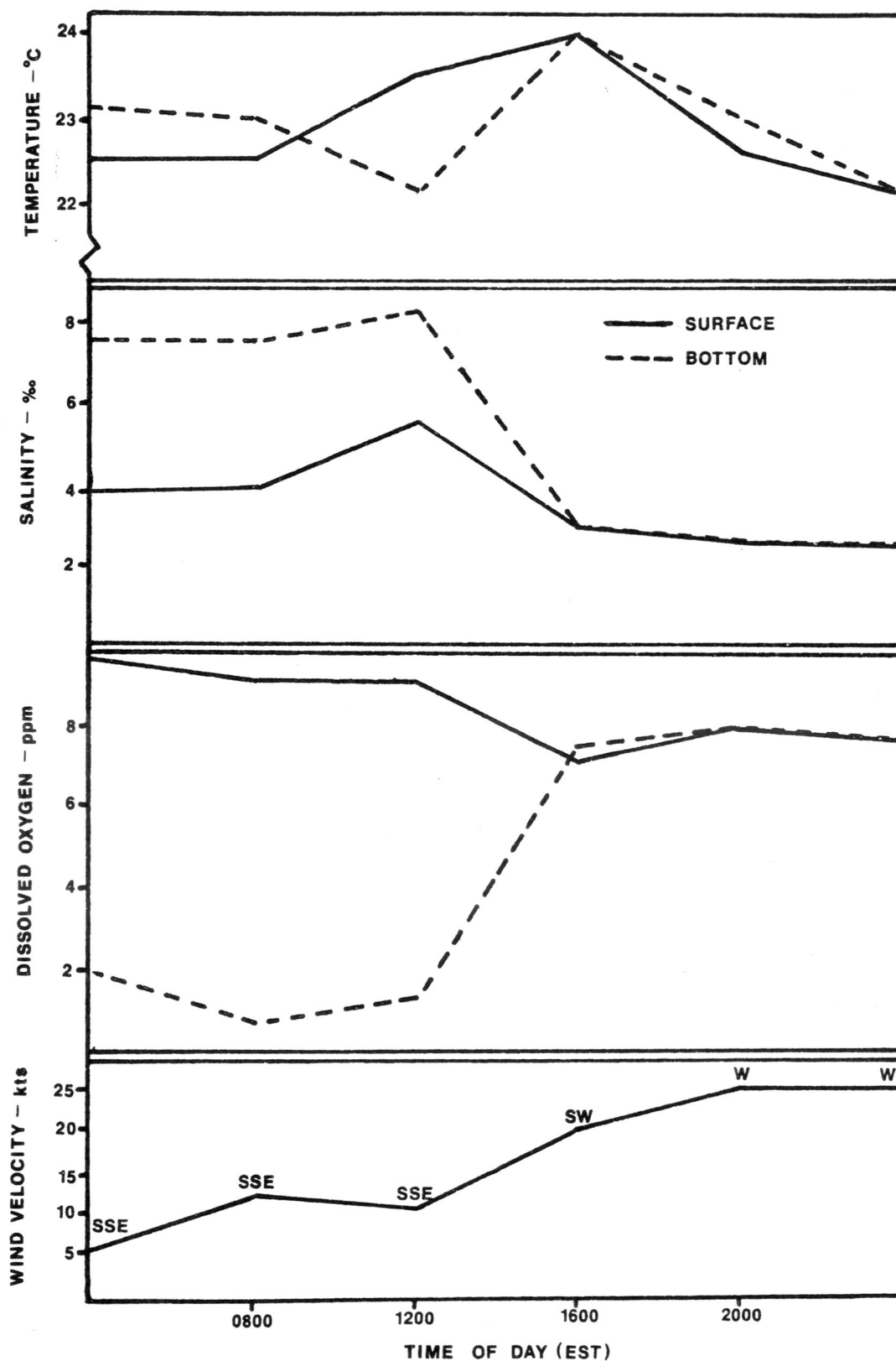


Figure 45. Diurnal hydrographic and wind data for surface (0.5 m) and bottom (0.5 m from bottom) at Daymark 9 near Blount's Bay on 9 June 1977.

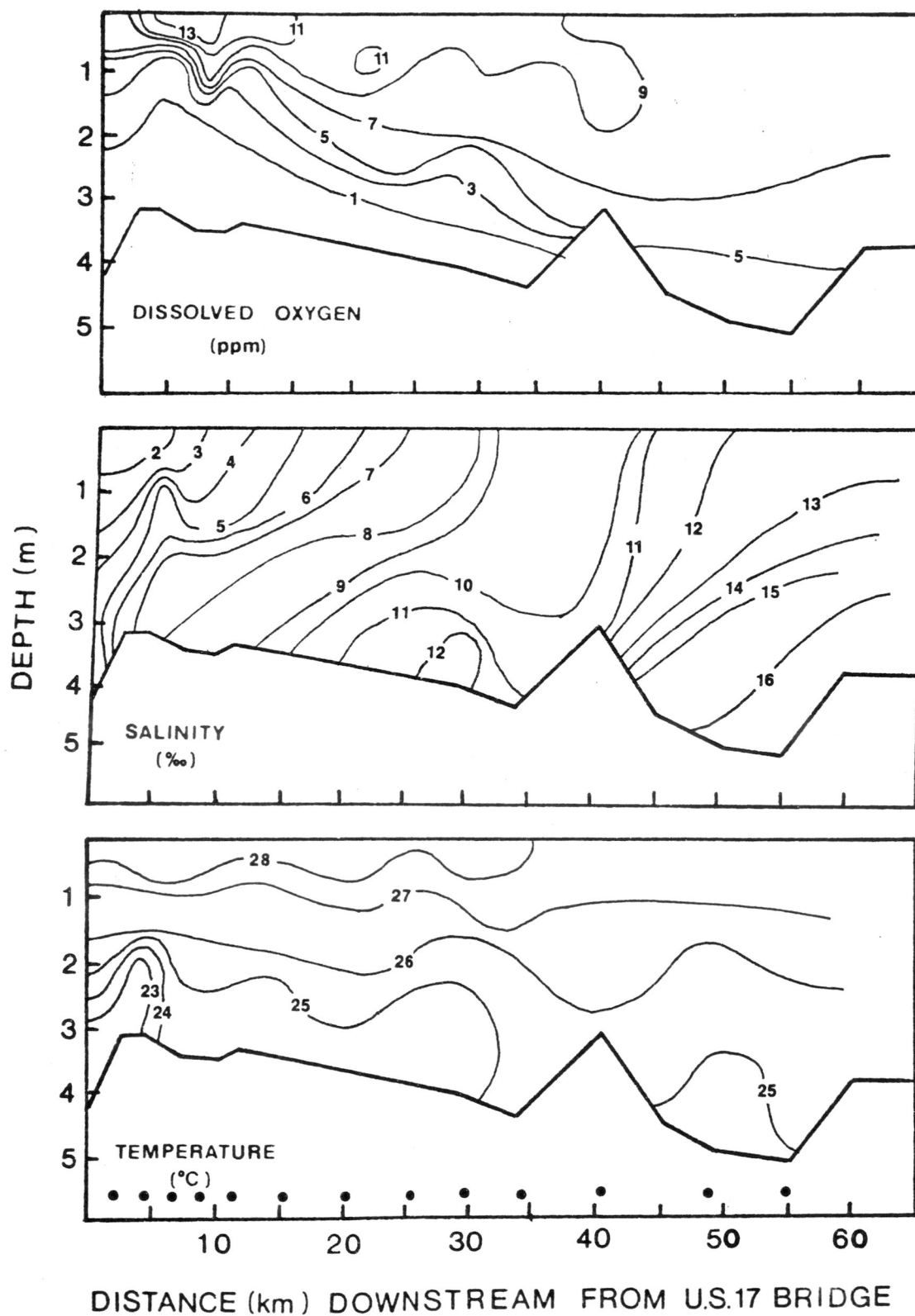


Figure 46. Hydrography of the Pamlico River on 27 June 1977. Dots along bottom axis indicate stations measured.

and a "flounder walk" occurred in the Blount's Bay area on 1 July 1977 (Barry Adams, personal communication). On this occasion, several thousand flounder left the water and came up onto the beach, much to the delight of the local residents. This occurrence is similar to the "jubilee" which occurs in Mobile Bay, Alabama under certain conditions of dissolved oxygen levels and wind conditions (May, 1973).

A North Carolina Air Stagnation Advisory was in effect for the period from 5-9 July 1977, and salinity stratification and severe deoxygenation were recorded on 7 July 1977 (Fig. 47) where the low oxygen levels existed throughout most of the water column near Washington, N.C. The high dissolved phosphorus and orthophosphate levels associated with this anaerobic layer in the upper reach on this date (Appendix B Table 3) is striking and may suggest regeneration of sediment phosphorus at low oxygen levels as observed for other aquatic systems (Wetzel, 1975). Also, there were no significant differences in both phytopigments and phytoplankton biomass between the aerobic and anaerobic layers on this date, indicating that algal respiration in the turbid bottom waters may be important in areas of deoxygenation. Fish kills were reported near Durham Creek (5 July) and in Chocowinity Bay (9-10 July) (Barry Adams, personal communication).

The estuary was still stratified on 13-14 July when the distribution of deoxygenation was studied at 50 stations from Washington, N.C. to Pamlico Point (Figs. 48, 49, and 50). It is apparent from this study that the deoxygenation is normally limited to the mid-channel regions of the estuary. A fish kill was observed near Chocowinity Bay on 14-15 July consisting mainly of menhaden, flounder, croaker, gar and perch.

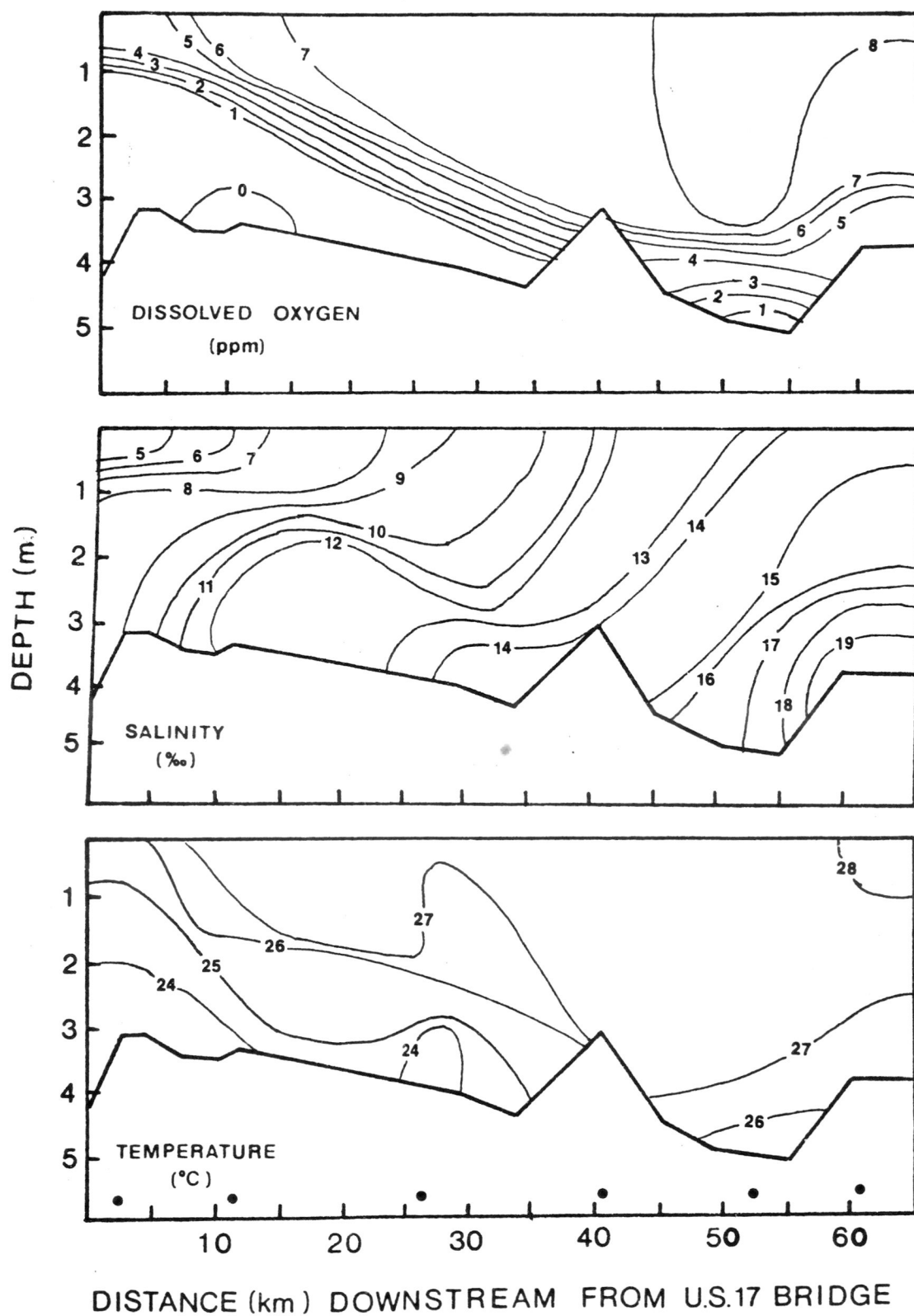


Figure 47. Hydrography of the Pamlico River on 7 July 1977. Dots along bottom axis indicate stations sampled.

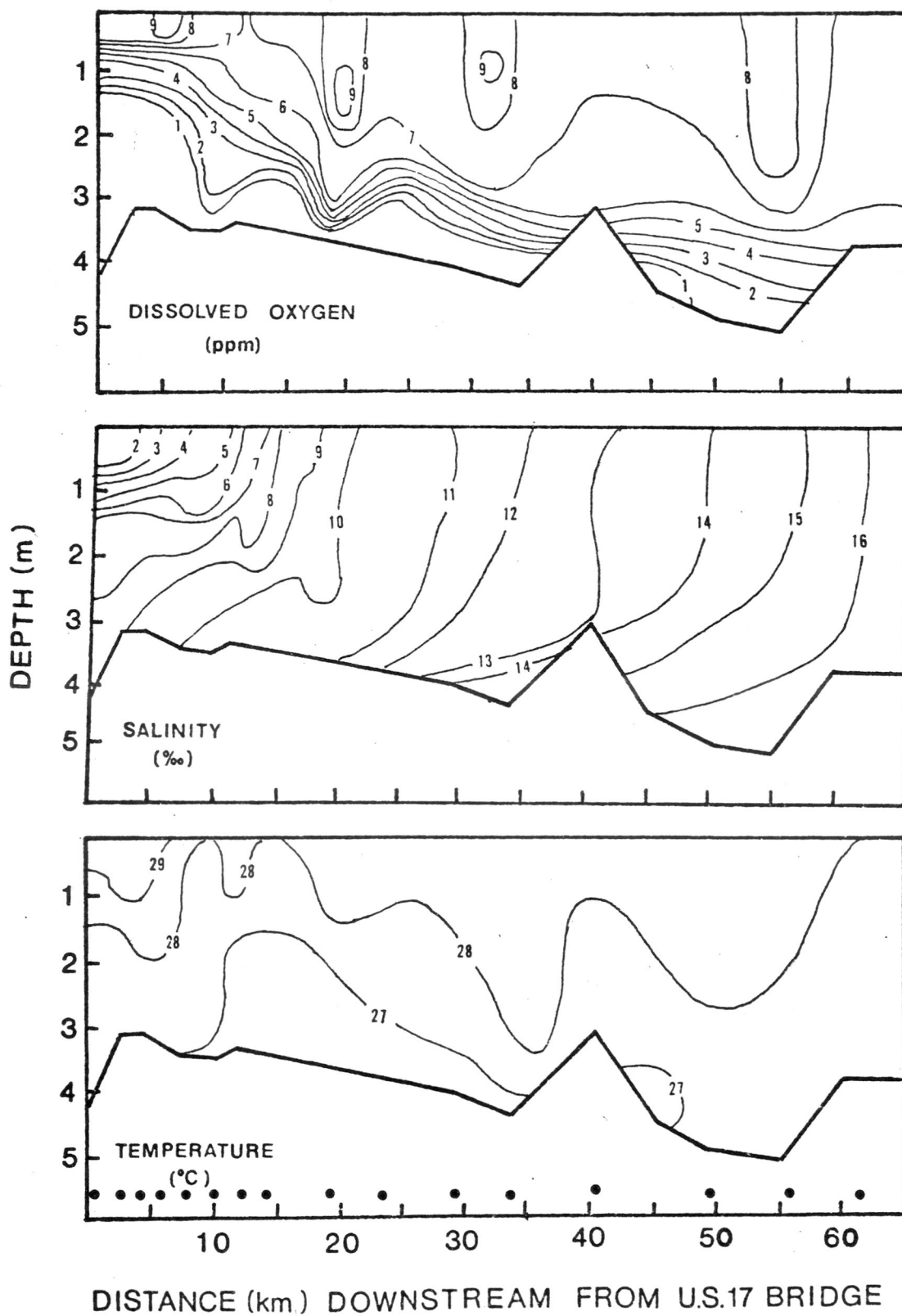


Figure 48. Hydrography of the Pamlico River on 13-14 July 1977. Dots along bottom axis indicate stations measured.

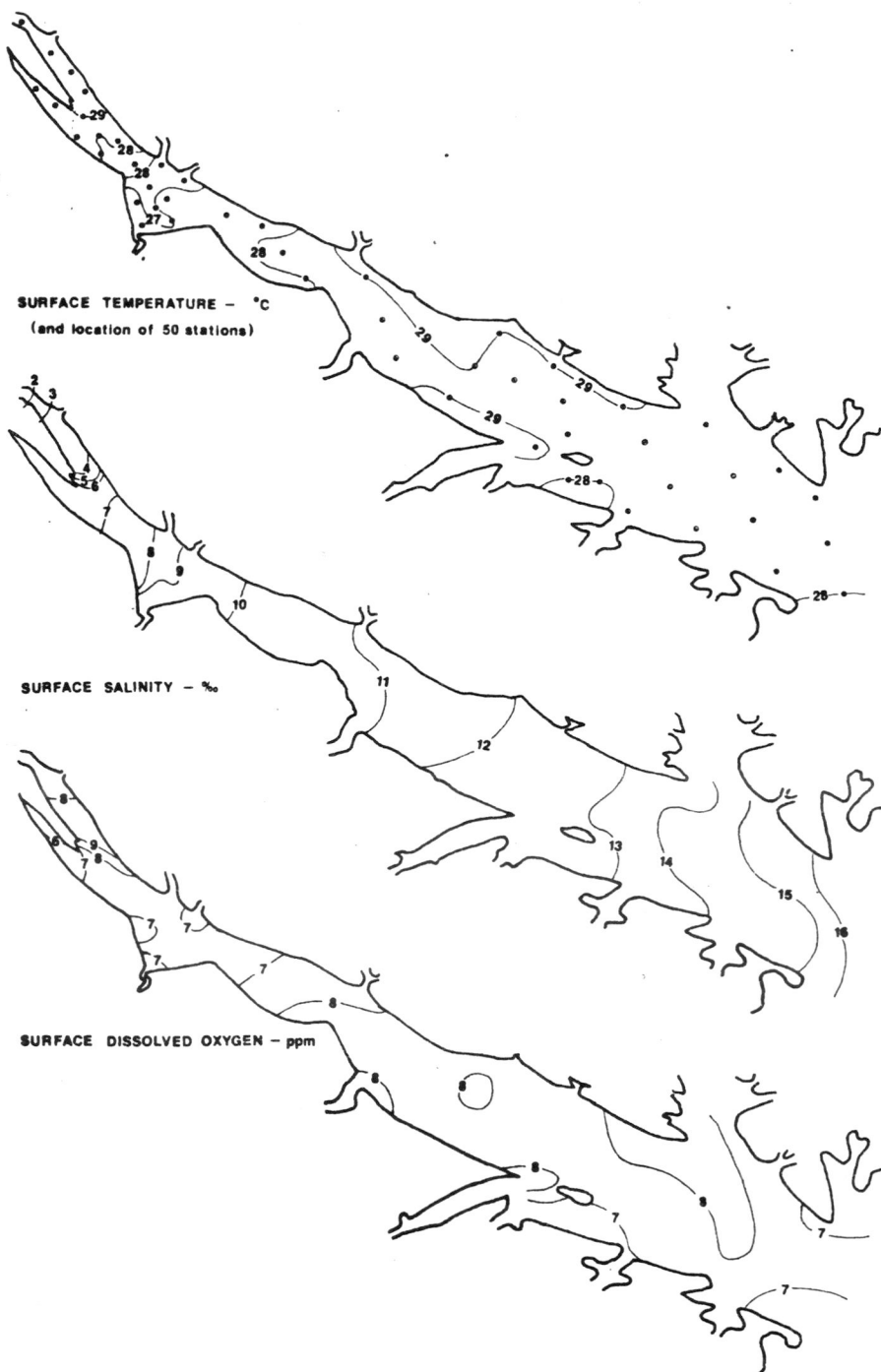


Figure 49. Hydrography of the Pamlico River at 0.5 m depth as measured at 50 stations on 13-14 July 1977.

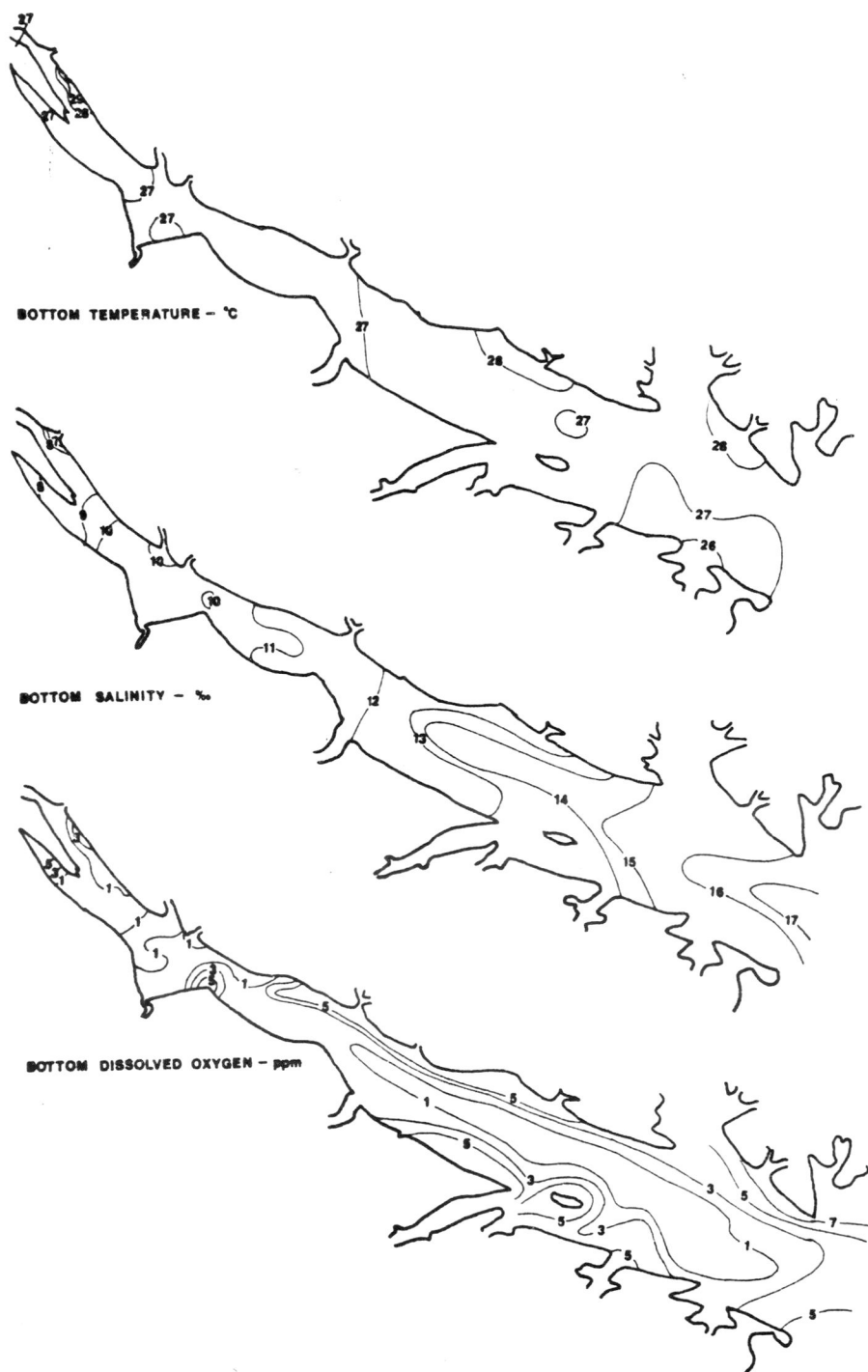


Figure 50. Hydrography of the Pamlico River as measured 0.5 m from the bottom at 50 stations on 13-14 July 1977 showing extent of deoxygenation. Station locations are shown in Fig. 49.

Another fish kill was reported in this same area on 18 July and another in Blount's Bay and Creek on 22 July (Barry Adams, personal communication).

These studies of the Pamlico River hydrography have indicated that wind constitutes the primary mixing force in the estuary, and that both wind speed and direction are important in determining the amount of mixing which will occur. Easterly and northeasterly winds normally are associated with the break-up of the stratified water column, but strong winds from any direction may cause this.

In most cases, deoxygenation is limited to the deeper, mid-channel area of the Pamlico River, except in the regions west of Maul's Point (i.e. Sectors 1, 2 and 3; Fig. 4) where the deoxygenation may occur throughout much of the water column and even into relatively shallow areas. This is presumably due to the high levels of carbon in these regions which occur not only due to the allochthonous inputs of the Tar River, but also very high inputs of autochthonous carbon due to phytoplankton blooms throughout much of the year. The lability of these carbon sources is important in determining the potential for deoxygenation. During the Carbon-Nutrient-Biomass surveys, respiration dynamics were studied in relation to relative fractions of labile versus refractory carbon. Following the approach of Ogura (1975), changes in oxygen were plotted against time as seen in Fig. 51 where typical curves for summer and winter are shown for Stations 1 and 6. Labile carbon becomes limiting as the rate curve approaches an asymptote. The upper reach normally has the highest concentration of labile carbon, probably due to the high phytoplankton biomass in this area.

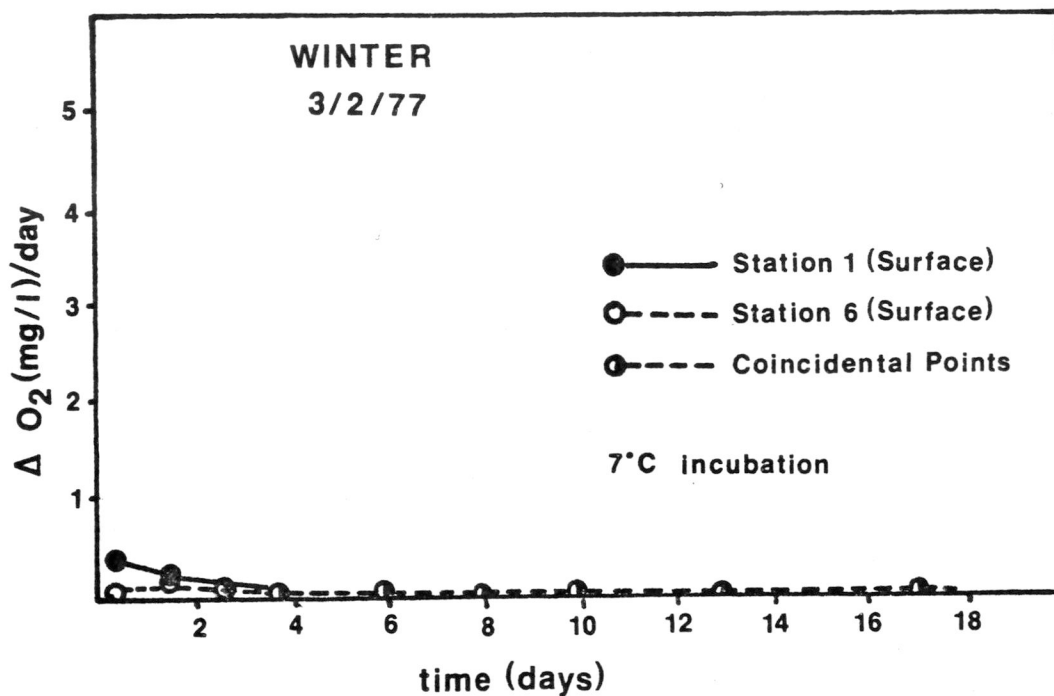
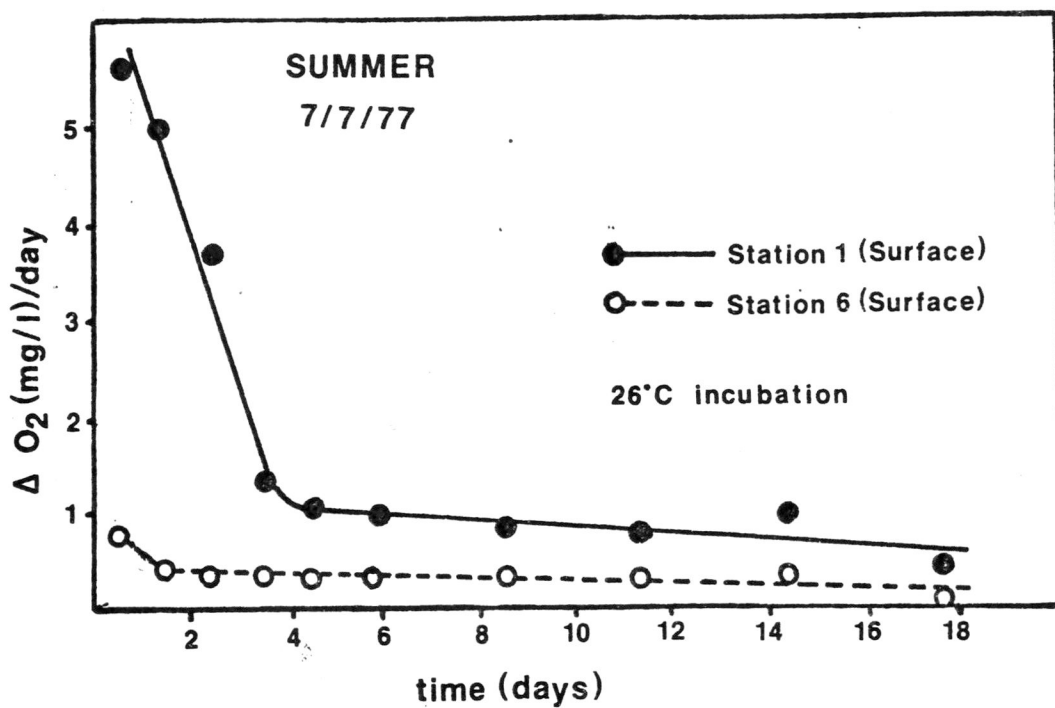


Figure 51. Plots of typical summer and winter respiration dynamics in the Pamlico River.

Particulate C:N ratios also may indicate the lability of the available carbon. During the Carbon-Nutrient-Biomass study, mean monthly C:N ratios ranged from 5:1 (when phytoplankton biomass was high) to 22:1 (when phytoplankton biomass was low). The mean annual C:N ratio for the estuary was 10:1. Rapid oxidation of this food source may be important in areas of deoxygenation.

Temperature is also important when considering the potential for deoxygenation (Flegal and Schroeder, 1976). By plotting the total oxygen uptake after 5 days in the respiration experiment versus particulate organic carbon concentration, the effects of temperature on the potential for deoxygenation become obvious (Fig. 52). During the winter, when temperatures and microbial activities are low, the potential for deoxygenation is also low, even at high concentrations of POC. Even so, deoxygenation was observed in the Pamlico River during the annual Heterocapsa (Peridinium) triquetrum bloom during the winter of 1976-1977 (M. White and D. Kornegay, personal communication). The low slope of the August/26° regression line in Fig. 52 may have been due to analytical error since an oxygen blank was not used during this month.

From a management point of view, it is apparent that increases in organic loading in the estuary would be detrimental. Since the primary input of organic carbon to the Pamlico River is autochthonous primary production, and this is primarily labile carbon, control of inorganic nutrients may be more important in controlling increases in organic loading than the more refractory allochthonous inputs. It is therefore important to determine which nutrients are most often limiting to primary production. The inorganic nutrient data are fragmentary in this study, especially when compared to the detailed studies by others over the past

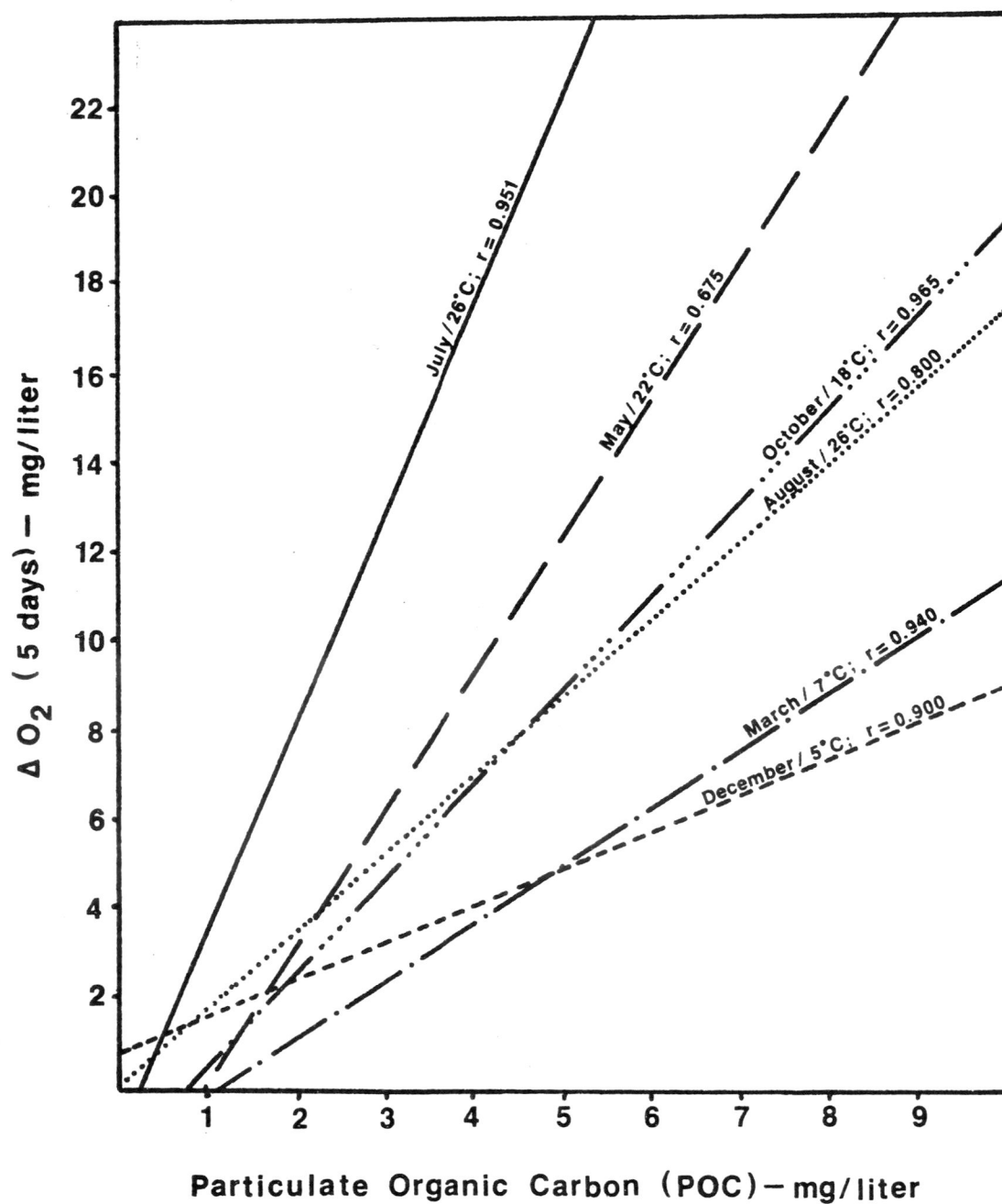


Figure 52. Particulate organic carbon as a function of total oxygen uptake after 5 days at mean ambient water temperature ($P < 0.01$ for all regressions except May where $P < 0.05$). Collection months and incubation temperatures are shown.

10 years (e.g. Harrison and Hobbie, 1974; Hobbie, 1972), and therefore have not been analyzed in detail. Other data reported, but which have not been thoroughly analyzed, include conductivity, pH, phytopigments, and Secchi disc transparency, and are included in Appendix B. The data for calcium, magnesium, sodium and potassium appear to be the first reported for the Pamlico River. As would be expected, levels here would not limit primary productivity.

A management scheme for the control of nutrients and allochthonous organic carbon in the Pamlico River is shown in Fig. 53. It is important that the federal and state agencies with the resources to implement these programs be identified as soon as possible since any major increase in organic carbon loading may serve to amplify the deoxygenation problem such that additional aggravations may develop.

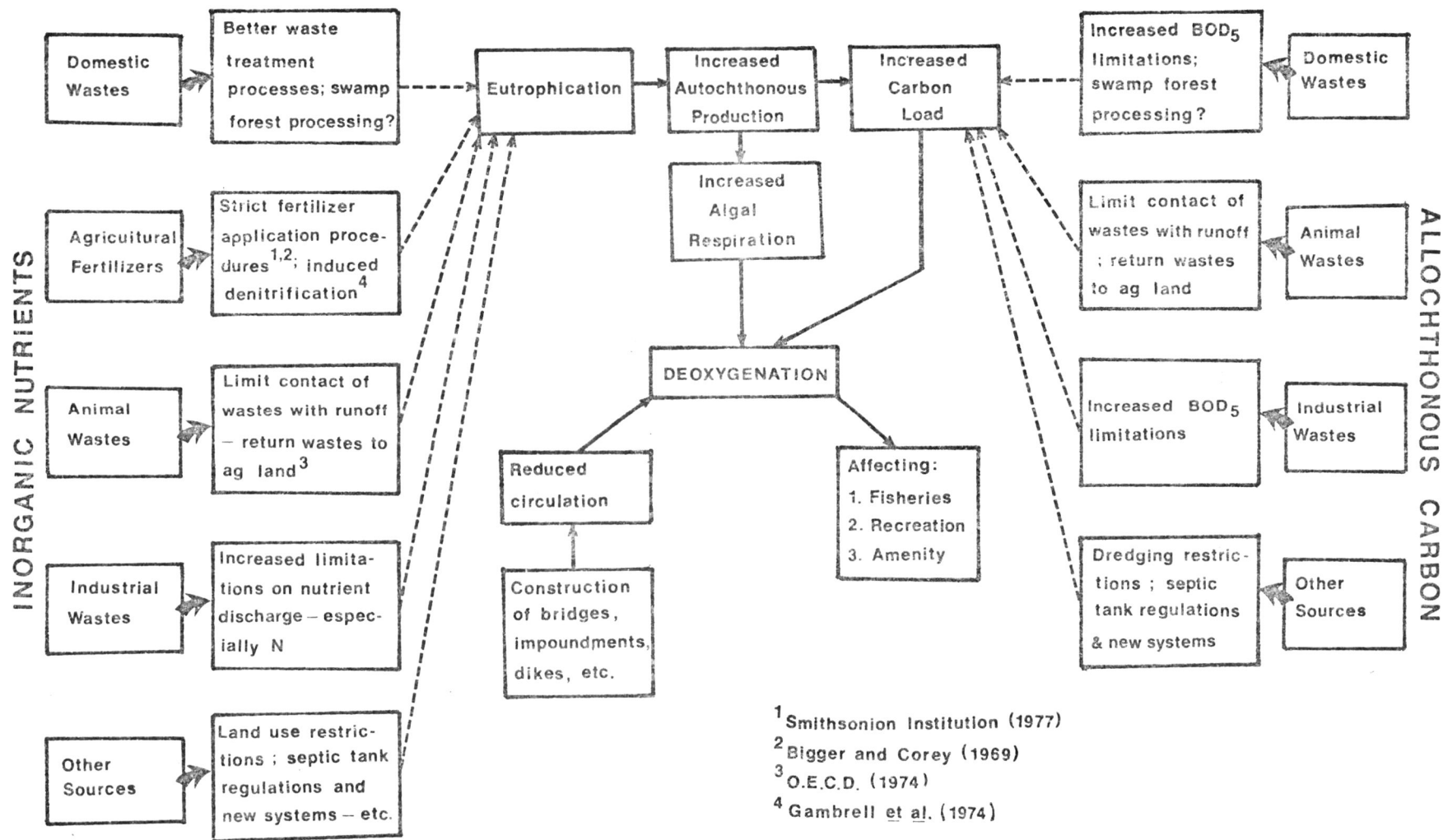


Figure 53. Management scheme for control of deoxygenation in the Pamlico River Estuary.

SUMMARY AND CONCLUSIONS

Organic carbon concentrations in the Pamlico River Estuary varied with season and with locations. Highest levels of total organic carbon (TOC) occurred during the summer months when flow rates were low. Highest concentrations of TOC were measured in the upper reaches near Washington, N.C., where the annual mean concentration was 9.3 mg/liter. Annual mean TOC concentrations ranged between 7.3 and 7.9 mg/liter for the middle and lower sections of the estuary. Approximately 79% of the TOC consisted of dissolved organic carbon (DOC) which accounted for most of the variation in TOC. Levels of particulate organic carbon (POC) were fairly constant throughout the year averaging between 1.6 and 2.0 mg/liter. Exceptionally high POC concentrations were observed in association with sporadic increases in phytoplankton biomass.

Total annual input of organic carbon was estimated at 108,124 tonnes and total annual losses at 111,642 tonnes leaving an unaccounted balance of -3,518 tonnes. The total input of organic carbon was distributed as follows: allochthonous 35.7%; autochthonous 64.3% (52.2% phytoplankton production, 11.3% phytoplankton secretion, 0.3% macrophyte production, 0.4% benthic primary production, 0.1% periphyton production). Organic carbon losses (sinks) were 80% as water column respiration and 20% as estuarine discharge. Sedimentation and benthic respiration were not determined.

Water column respiration, the primary loss of organic carbon from the estuary, was correlated with POC concentration which, in turn, was correlated with phytoplankton biomass. Respiration rates rarely corre-

lated with DOC concentrations.

The dry and calm summers of 1976 and 1977 provided excellent opportunities for studying deoxygenation phenomena in the estuary. Although the most severe episodes of oxygen depletion occurred during the summer in the upper half of the estuary, it has been observed spanning the entire length of the estuary and into Pamlico Sound. Dissolved oxygen depletion also was observed during the winter in association with an intense algal bloom. Deoxygenation is normally limited to the deeper mid-channel regions of the estuary except in the upper reaches where it may extend throughout much of the water column and into relatively shallow areas in extreme cases. This region receives high allochthonous inputs from the Tar River and is the location of the most severe phytoplankton biomass during the year.

The factors contributing to episodes of oxygen depletion are wind velocity and direction, salinity (density) stratification, and a supply of labile organic carbon. Strong winds and storms initiate mixing after a period of deoxygenation and maintain an oxygenated water column until calm conditions resume and a vertical density gradient is re-established. The frequency and severity of deoxygenation during the colder months is significantly reduced owing to generally better mixed conditions and higher throughflow of water from runoff. Also, lower temperatures result in reduced rates of respiration by organisms in the water column and sediments. Although the greatest amounts of allochthonous organic carbon are contributed to the estuary by winter runoff, much of this is presumed refractory in nature. Non-refractory (biologically labile) organic carbon appears to be a consequence of phytoplankton primary productivity

which is generally highest in the summer and in the upper region of the estuary. Winter and early spring phytoplankton blooms produce the labile carbon source for deoxygenation potential, but physical conditions are seldom conducive for it to occur.

Since the highly labile autochthonous carbon of primary production is the primary input of organic carbon to the estuary, control of nutrients may be the key to controlling deoxygenation. Due to the very high phytoplankton biomass and associated productivity levels that occur in the region west of Maul's Point (Sectors 1, 2 and 3, Fig. 4), this area may indeed be considered eutrophic. Anaerobic conditions with subsequent mixing causing nutrient regeneration from the sediments may be the driving force behind the summer algal blooms, but anthropogenic influences (primarily agricultural runoff and domestic wastes) appear to be responsible for the winter algal blooms. With increased urbanization of the Tar-Pamlico drainage basin, and increased commercial and recreational development of the estuary itself, immediate control programs are necessary to ensure that more serious eutrophic conditions do not develop.

RECOMMENDATIONS

1. Since autochthonous primary production was determined to be the largest input of organic carbon to the Pamlico River Estuary, and this source is predominantly labile, control of nutrients may be more important in controlling deoxygenation than the presumably more refractory allochthonous inputs. For this reason, nutrient levels in the estuary should not be allowed to increase since the Pamlico River has already exceeded its capacity to assimilate its organic load, especially in the upper reaches. A management scheme for this recommendation is outlined in Figure 53. This figure summarizes and extends recommendations by others arising from varied studies of the estuary over the past decade. Strict land use restrictions and education of farmers in careful fertilizer application procedures are relatively inexpensive measures which should be considered as immediate countermeasures to the continuing eutrophication of the estuary. Long-term countermeasures should include better waste treatment processes and enforcement of disposal regulations at all levels. Due to the sluggish circulation of the estuary, the construction of any structures or impoundments which may restrict flow and circulation should be carefully studied before any action is taken.
2. A study of the causes and consequences of the annual winter Heterocapsa (Peridinium) bloom is needed, especially in light of the fact that deoxygenation of the bottom waters accompanied this bloom during March 1977.

3. Phytoplankton have been shown to be an important source of carbon in areas of deoxygenation. However, the relative importance of respiration by phytoplankton, and phytoplankton contributions to the DOC and POC pools utilized in microbial respiration, need to be further elucidated.
4. Several factors which were not studied during this investigation may be significant in the organic carbon budget of the estuary and warrant further investigation. These include sediment respiration, sedimentation rates, release of organic matter by sediments, marsh inputs to the organic carbon pool, and groundwater and septic tank sorption field inputs (both inorganic nutrient and organic carbon loading). Estuarine input from high marshes should be investigated with special reference to the lability of peat which is continuously eroded.
5. The results of this study substantiate the concept that chlorophyll a is a good indicator of particulate organic carbon in the system with its concomitant contribution to deoxygenation potential.

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GLOSSARY

Terms and Abbreviations

C	-- organic carbon
^{14}C	-- radioactive carbon-14
$^{\circ}\text{C}$	-- degree(s) Celsius
DOC	-- dissolved organic carbon
EST	-- Eastern Standard Time
ft^3	-- cubic feet
g	-- gram(s)
h	-- hour(s)
km	-- kilometer(s)
km^2	-- square kilometer(s)
km^3	-- cubic kilometer(s)
kts	-- knots
l	-- liter(s)
ln	-- natural logarithm
m	-- meter(s)
m^2	-- square meter(s)
m^3	-- cubic meter(s)
meq	-- milli-equivalents
mi^2	-- square mile(s)
min	-- minute(s)
mg	-- milligram(s)
ml	-- milliliter(s)
mmho	-- millimho(s)
μCi	-- microcurie(s)
μm	-- micrometer(s)
$^{\circ}/\text{oo}$	-- part(s) per thousand (salinity)
N	-- nitrogen
n	-- number of observations
ODW	-- organic dry weight
POC	-- particulate organic carbon
ppm	-- part(s) per million
r	-- correlation coefficient
sec	-- second(s)
TOC	-- total organic carbon
tonne	-- metric tonne (1000 kg)
$\bar{X}$	-- mean
yr	-- year

APPENDICES

APPENDIX ABBREVIATIONS

S	Surface (1.0 m in Estuarine Organic Carbon study and 0.5 m in Carbon-Nutrient-Biomass study)
B	Bottom (3.0 m in Estuarine Organic Carbon study and 0.5 m from bottom in Carbon-Nutrient-Biomass study)
POC	Particulate organic carbon (mg/liter)
DOC	Dissolved organic carbon (mg/liter)
SAL	Salinity (°/oo)
TEMP	Temperature (°C)
DO	Dissolved oxygen (ppm)
SECC	Secchi reading (m)
COND	Conductivity (mmhos)
CHLRA	Chlorophyll <u>a</u> (mg/m ³) - uncorrected for phaeophytin
CHLRAC	Chlorophyll <u>a</u> (mg/m ³) - corrected for phaeophytin
CHLRB	Chlorophyll <u>b</u> (mg/m ³)
CHLRC	Chlorophyll <u>c</u> (mg/m ³)
CAROT	Carotenoids (mg/m ³)
PHAEO	Phaeophytin (mg/m ³)
NA	Sodium (g/liter)
K	Potassium (g/liter)
MG	Magnesium (g/liter)
CA	Calcium (g/liter)
NTOT	Total Kjeldahl Nitrogen (mg/liter)
NDISS	Dissolved Kjeldahl Nitrogen (mg/liter)
NPART	Particulate Kjeldahl Nitrogen (mg/liter)
NO3	Nitrate nitrogen (mg/liter)

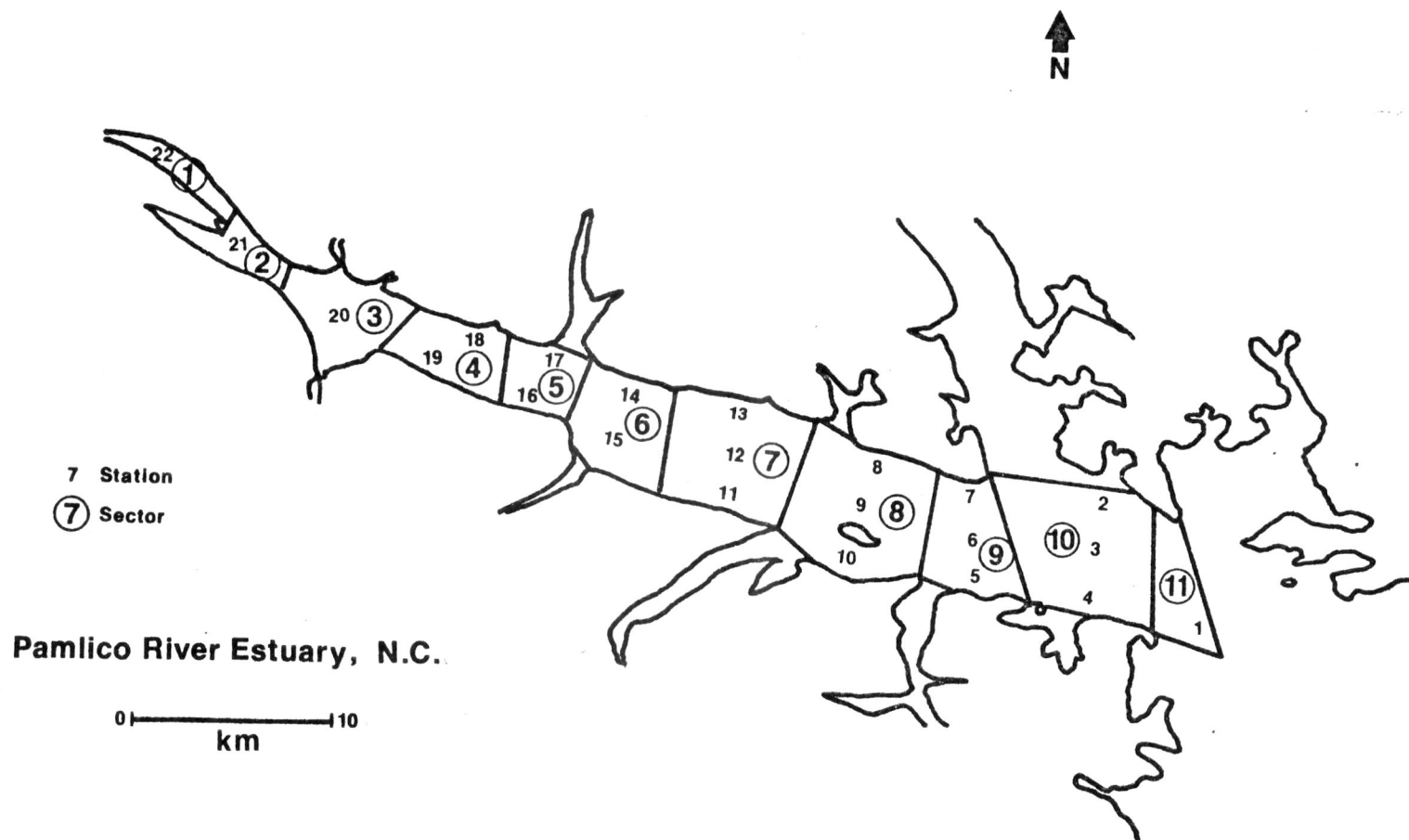
APPENDIX ABBREVIATIONS (continued)

NO2	Nitrite nitrogen (mg/liter)
NH4	Ammonium nitrogen (mg/liter)
PTOT	Total phosphorus (mg/liter)
PDISS	Dissolved phosphorus (mg/liter)
PORTHO	Reactive phosphate (mg/liter)
PPART	Particulate phosphorus (mg/liter)
PHYTO	Phytoplankton biomass (mg/liter)
PYRR	Pyrrophyta biomass (mg/liter)
CHRYS	Chrysophyta biomass (mg/liter)
CHLOR	Chlorophyta biomass (mg/liter)
CYAN	Cyanophyta biomass (mg/liter)
OTHER	Biomass of other phytoplankton divisions (mg/liter)
RESP1(26)	Water column respiration with incubation temperature ($^{\circ}$ C) in parentheses (mg/liter/hr)
RESP5(26)	Total oxygen uptake after 5 days in the respiration study (ppm). Incubation temperature ($^{\circ}$ C) is in parentheses.
pH	pH
ALKAL	Alkalinity (meq/liter)
PRODUC	Phytoplankton productivity ($\text{g C/m}^3/\text{day}$) at 0.5 m depth
SECRET	Phytoplankton secretion ($\text{g C/m}^3/\text{day}$) at 0.5 m depth
SKY/WX	Sky cover/Weather (- = thin; 0 = clear; θ = scattered; $\oplus$ = broken; $\opl�$ = overcast; H = haze; T = thunderstorm; RW = rain showers)
WIND	Estimated wind direction and speed (kts) (C = calm; N = north; E = east; S = south; W = west)
BACT	Bacterial biomass (mg/liter)
***	No data

Appendix A. Areas of Estuarine Sectors and Tributary Drainage Basins
Used in Calculations.

Appendix A Table 1. Sector areas and volumes used in calculating the total amount of organic carbon in estuarine waters during the Estuarine Organic Carbon Study (August 1975 - July 1976). Station and sector locations are shown in Appendix A Figure 1.

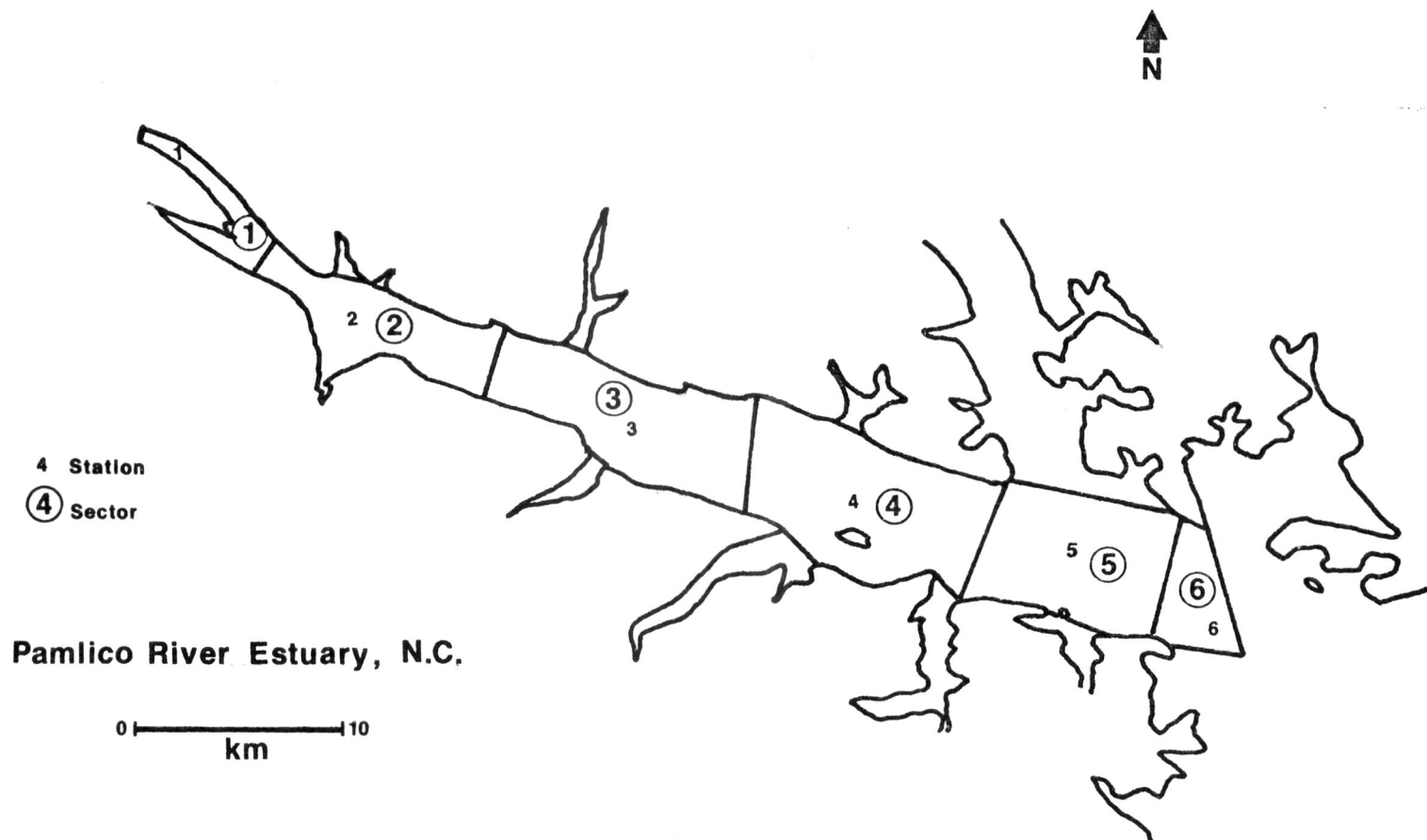
Sector	Area ($\text{m}^2 \times 10^7$)	$\bar{X}$ Depth (m)	Volume ($\text{m}^2 \times 10^7$)
1	0.59	1.3	0.79
2	1.29	1.7	2.23
3	2.17	2.4	5.14
4	2.05	2.5	5.10
5	1.17	3.2	3.77
6	2.23	3.5	7.81
7	3.77	3.3	12.37
8	4.33	3.1	13.55
9	3.57	4.0	14.21
10	4.92	4.4	21.55
11	2.18	4.5	9.74
TOTAL	28.27	3.4 ($\bar{X}$)	96.26



Appendix A Figure 1. Station locations for the Estuarine Organic Carbon study (August 1975–July 1976) and corresponding sectors used in calculating the total amount of organic carbon in the estuary.

Appendix A Table 2. Sector areas and volumes used in calculations involving total pelagial respiration, phytoplankton production and secretion, and standing stocks of organic carbon, phytoplankton and bacteria during the Carbon-Nutrient-Biomass study (August 1976-July 1977). Station and sector locations are shown in Appendix A Figure 2.

Sector/Station	Area ($\text{m}^2 \times 10^7$)	$\bar{X}$ Depth (m)	Total Volume ($\text{m}^3 \times 10^7$)	Volume (0 - 1 meters) ($\text{m}^3 \times 10^7$)	Volume (1 - 2 meters) ($\text{m}^3 \times 10^7$)	Volume (2 - 3 meters) ($\text{m}^3 \times 10^7$)
1	1.44	1.7	2.44	1.32	0.94	0.17
2	3.87	2.4	9.27	3.65	3.11	2.20
3	6.18	3.4	20.73	5.89	5.34	4.70
4	8.44	3.4	28.40	8.03	7.27	6.47
5	6.14	4.3	26.33	5.97	5.64	5.20
6	2.20	4.2	9.14	2.17	2.10	1.96
TOTAL	28.27	3.4 ($\bar{X}$)	96.31	27.03	24.40	20.70



Appendix A Figure 2. Station locations for the Carbon-Nutrient-Biomass study (August 1976-July 1977) and corresponding sectors used in calculations involving total pelagial respiration, phytoplankton production and secretion, and standing stocks of organic carbon, phytoplankton and bacteria.

Appendix A Table 3. Tributary drainage basin areas used in calculating tributary organic carbon inputs to the Pamlico River (adapted from Harrison and Hobbie, 1974).

Tributary	Area of Drainage Basin (mi ²)	% of Total Pamlico Drainage
Tar River	3,085.0	71.6
Durham Creek	43.1	1.0
Runyon Creek	26.3	0.6
Chocowinity Bay	43.4	1.0
Blount's Creek	53.6	1.2
Broad Creek	27.0	0.6
Upper Goose Creek	11.6	0.3
Bath Creek	36.0	0.8
Lee Creek	1.1	0.0
North Creek	12.9	0.3
South Creek	58.0	1.3
Bond Creek	9.4	0.2
Goose Creek	38.1	0.9
Middle Prong	10.6	0.2
Pungo River	850.0	19.7
Total Tributary Drainage	4,306.1	100.0

Appendix B. Summary of Data

Appendix B Table 1. Data collected during the Estuarine Organic Carbon Study (August 1975 - July 1976)

Date: 080275

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	2.1	6.8	5.8	28.5	***	***
1B	1.8	9.5	12.6	27.8	***	***
2S	1.3	5.6	8.0	28.0	***	***
2B	1.4	5.9	13.1	27.5	***	***
3S	1.3	5.5	5.4	28.8	***	***
3B	1.3	7.8	6.2	29.0	***	***
4S	1.3	5.1	4.8	29.2	***	***
4B	1.4	8.5	5.1	28.2	***	***
5S	2.2	5.5	4.2	29.0	***	***
5B	1.6	6.9	4.7	29.0	***	***
6S	1.9	7.4	4.2	28.6	***	***
6B	1.2	5.6	10.5	27.8	***	***
7S	2.1	12.5	5.2	29.8	***	***
7B	1.2	11.3	8.8	28.0	***	***
8S	1.5	10.8	4.0	29.0	***	***
8B	2.1	7.8	8.8	28.2	***	***
9S	1.4	8.6	3.2	29.0	***	***
9B	1.2	6.7	4.0	29.0	***	***
10S	1.3	11.2	3.2	29.8	***	***
10B	1.6	7.4	5.4	28.5	***	***
11S	1.9	10.4	3.0	30.1	***	***
11B	1.4	12.3	4.0	28.2	***	***
12S	3.6	9.2	2.3	29.8	***	***
12B	1.1	6.8	11.2	27.0	***	***
13S	1.8	11.9	3.3	30.3	***	***
13B	2.7	7.5	8.0	28.0	***	***
14S	1.8	11.1	2.2	30.2	***	***
14B	0.9	5.0	7.6	27.0	***	***
15S	3.8	12.7	1.7	30.2	***	***
15B	1.5	7.9	8.7	27.0	***	***
16S	1.9	15.5	1.0	30.5	***	***
16B	1.2	6.7	8.3	26.5	***	***
17S	2.1	12.6	1.5	30.5	***	***
17B	1.0	6.4	8.3	27.0	***	***
18S	2.0	12.1	1.3	30.0	***	***
18B	1.0	5.3	8.0	26.8	***	***
19S	2.0	12.9	0.8	31.0	***	***
19B	0.9	9.8	7.8	26.5	***	***
20S	2.0	11.8	0.3	29.8	***	***
20B	1.7	9.3	7.0	26.8	***	***
21S	1.9	13.6	0.2	29.8	***	***
21B	1.2	10.9	5.2	26.5	***	***
22S	1.6	14.9	0.0	29.8	***	***
22B	1.0	16.9	2.0	26.7	***	***

Appendix B Table 1. (continued)

Date: 081675

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.1	6.0	10.2	26.5	***	***
1B	1.5	4.6	10.2	27.0	***	***
2S	1.6	5.5	9.2	27.0	***	***
2B	1.7	6.4	9.8	27.0	***	***
3S	1.9	5.9	10.2	27.0	***	***
3B	1.1	4.8	10.2	27.0	***	***
4S	2.9	11.6	9.8	26.5	***	***
4B	2.6	5.3	9.8	26.5	***	***
5S	2.0	8.9	9.2	26.0	***	***
5B	2.5	7.6	10.0	26.0	***	***
6S	2.7	10.1	10.1	26.5	***	***
6B	2.1	4.8	10.0	26.5	***	***
7S	2.6	5.5	9.9	26.0	***	***
7B	1.7	6.5	10.3	25.5	***	***
8S	1.9	3.6	10.6	26.0	***	***
8B	1.4	3.3	10.6	25.5	***	***
9S	1.8	9.4	10.7	26.0	***	***
9B	1.7	6.3	10.6	25.5	***	***
10S	2.1	5.6	8.5	27.5	***	***
10B	2.0	7.2	11.2	26.5	***	***
11S	3.1	4.8	10.0	26.0	***	***
11B	2.9	5.8	10.0	26.0	***	***
12S	1.4	4.9	9.7	26.5	***	***
12B	1.5	6.3	9.8	26.0	***	***
13S	1.8	6.2	9.8	26.0	***	***
13B	2.2	6.2	10.0	25.0	***	***
14S	2.4	5.9	9.8	26.5	***	***
14B	2.2	11.1	11.0	25.5	***	***
15S	1.9	6.1	10.0	25.5	***	***
15B	3.5	6.1	14.0	24.0	***	***
16S	1.4	7.2	9.5	25.0	***	***
16B	1.7	6.4	13.0	24.0	***	***
17S	2.3	6.3	10.0	24.0	***	***
17B	2.5	5.1	12.5	23.5	***	***
18S	1.9	6.2	9.0	29.2	***	***
18B	2.4	8.0	12.2	28.0	***	***
19S	1.6	6.6	9.2	29.0	***	***
19B	1.5	6.4	12.9	27.8	***	***
20S	1.7	5.7	10.2	29.5	***	***
20B	2.5	5.8	11.2	27.5	***	***
21S	2.5	6.3	7.5	29.5	***	***
21B	6.6	9.2	11.2	27.9	***	***
22S	3.7	5.7	5.2	30.5	***	***
22B	10.4	12.3	9.0	28.5	***	***

Appendix B. Table 1. (continued)

Date: 090675

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	3.6	6.9	11.8	28.0	10.1	***
1B	4.7	6.9	12.2	28.5	7.9	***
2S	1.5	4.3	11.8	29.0	8.0	***
2B	1.6	4.3	12.0	28.5	8.2	***
3S	3.3	4.4	11.0	29.5	9.6	***
3B	1.6	4.3	12.5	28.5	7.7	***
4S	3.1	6.7	10.0	30.0	9.2	***
4B	3.7	5.9	10.5	28.5	6.4	***
5S	2.1	4.2	8.4	29.0	8.0	***
5B	1.9	5.8	9.2	29.0	8.7	***
6S	2.1	5.3	10.0	29.5	9.1	***
6B	1.8	5.6	10.0	29.0	8.7	***
7S	1.9	6.6	9.5	30.0	8.7	***
7B	1.6	7.0	9.5	30.0	8.9	***
8S	1.6	7.3	9.7	30.0	9.3	***
8B	1.6	5.5	8.2	30.0	8.6	***
9S	2.1	7.3	9.4	30.0	9.5	***
9B	2.0	6.9	9.2	30.0	8.9	***
10S	1.6	5.9	8.5	29.0	7.4	***
10B	1.7	6.9	8.3	29.0	7.1	***
11S	1.5	5.8	9.0	29.5	7.7	***
11B	1.3	4.1	8.2	29.0	7.1	***
12S	1.3	6.1	9.2	29.2	7.6	***
12B	1.4	4.3	9.2	29.0	11.2	***
13S	1.4	8.8	9.5	29.5	8.2	***
13B	1.2	4.3	9.0	29.0	7.3	***
14S	1.7	3.6	9.2	29.5	7.4	***
14B	1.6	5.1	9.2	29.5	8.2	***
15S	1.4	8.8	8.9	29.5	10.6	***
15B	1.5	4.9	9.0	29.5	8.0	***
16S	1.2	7.3	8.0	29.0	6.6	***
16B	1.4	6.6	7.9	28.5	5.6	***
17S	1.6	5.5	9.0	30.0	8.2	***
17B	1.6	4.9	9.0	29.0	8.2	***
18S	1.7	5.5	8.2	29.0	7.2	***
18B	1.5	5.3	8.5	28.5	4.7	***
19S	2.0	9.4	7.5	30.0	8.8	***
19B	1.4	6.1	8.2	29.0	8.8	***
20S	2.3	4.1	6.5	30.0	9.0	***
20B	1.9	4.2	7.5	28.5	3.7	***
21S	4.2	5.8	5.2	29.8	9.1	***
21B	3.2	5.5	6.8	28.5	4.1	***
22S	3.9	5.5	2.5	29.9	9.1	***
22B	3.7	5.8	3.4	29.0	3.1	***

Appendix B Table 1. (continued)

Date: 100675

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.3	6.4	9.4	20.7	8.4	***
1B	1.1	7.6	9.8	20.5	11.4	***
2S	2.3	7.6	9.5	20.8	9.3	***
2B	1.3	5.9	11.0	20.8	8.9	***
3S	0.8	6.7	9.0	21.0	8.0	***
3B	0.5	6.4	9.2	20.3	11.0	***
4S	1.0	7.0	9.0	20.5	9.1	***
4B	0.8	7.8	9.1	20.5	10.6	***
5S	0.9	6.7	8.0	20.8	9.6	***
5B	1.0	6.6	8.2	20.3	11.5	***
6S	0.7	6.6	8.5	21.0	9.4	***
6B	1.0	7.3	8.5	20.7	11.7	***
7S	1.4	8.8	8.9	20.5	9.3	***
7B	1.3	7.5	9.1	20.3	11.8	***
8S	1.4	6.5	8.2	21.0	9.3	***
8B	0.9	7.1	8.6	20.8	9.9	***
9S	1.3	6.1	8.2	20.5	8.7	***
9B	2.8	7.1	7.2	20.3	11.4	***
10S	1.4	5.4	5.8	20.5	10.7	***
10B	1.5	6.6	6.1	20.2	11.4	***
11S	1.2	6.7	6.4	21.0	7.0	***
11B	0.9	8.0	6.4	20.9	8.1	***
12S	1.9	6.6	5.8	21.0	7.7	***
12B	1.6	5.9	6.0	20.9	9.6	***
13S	1.0	6.4	6.5	21.0	7.0	***
13B	1.1	6.9	7.2	20.8	7.8	***
14S	1.1	7.6	5.0	21.2	7.0	***
14B	0.8	6.8	5.5	21.2	10.2	***
15S	1.0	5.8	3.8	20.5	8.1	***
15B	1.3	6.8	4.8	20.5	11.6	***
16S	1.0	7.6	3.8	21.8	7.7	***
16B	0.6	8.5	3.9	20.8	8.5	***
17S	2.8	18.4	4.7	22.0	8.4	***
17B	2.6	9.6	5.5	21.5	6.0	***
18S	0.7	7.0	3.0	20.8	8.6	***
18B	1.1	7.9	5.9	22.0	3.5	***
19S	0.5	8.2	3.7	21.0	8.5	***
19B	1.0	7.9	4.2	21.0	8.0	***
20S	0.4	9.1	1.5	20.2	7.9	***
20B	0.3	9.0	3.2	21.0	7.6	***
21S	0.6	7.0	0.9	20.0	7.5	***
21B	0.9	9.9	3.0	21.0	5.7	***
22S	0.6	11.8	0.3	20.0	4.6	***
22B	0.8	11.9	1.2	20.0	5.5	***

Appendix B Table 1. (continued)

Date: 110575

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	0.7	6.8	9.5	17.8	10.2	***
1B	0.8	7.6	13.8	17.8	6.4	***
2S	0.7	5.3	12.1	18.3	8.6	***
2B	0.9	5.1	13.2	17.8	7.3	***
3S	1.0	6.4	10.3	18.5	9.3	***
3B	0.7	6.1	12.2	18.0	8.4	***
4S	2.8	8.7	6.0	17.5	11.4	***
4B	2.2	7.2	5.8	17.5	11.1	***
5S	2.3	7.6	6.9	17.5	10.3	***
5B	1.6	7.6	9.8	17.1	6.6	***
6S	1.4	7.1	8.8	18.0	9.5	***
6B	1.5	8.5	10.0	17.0	7.9	***
7S	1.0	5.9	10.6	18.1	8.5	***
7B	1.0	4.7	12.5	18.0	8.0	***
8S	1.1	6.1	10.5	18.5	8.6	***
8B	1.0	5.5	12.1	17.9	7.8	***
9S	1.0	6.4	8.8	18.4	9.5	***
9B	1.5	7.1	11.5	17.5	6.2	***
10S	2.0	8.0	7.8	18.2	11.3	***
10B	1.1	8.0	11.2	17.5	5.3	***
11S	1.9	8.2	7.5	18.5	10.6	***
11B	1.4	7.1	10.5	18.0	5.0	***
12S	2.3	8.2	7.2	18.8	11.9	***
12B	1.4	6.5	7.3	18.0	4.3	***
13S	1.1	6.7	9.5	18.2	8.0	***
13B	1.6	5.8	10.8	17.7	7.6	***
14S	0.9	6.2	9.0	18.0	7.0	***
14B	1.2	6.4	10.3	17.5	6.4	***
15S	1.9	7.5	6.5	18.5	10.9	***
15B	1.2	6.1	9.1	17.5	5.7	***
16S	1.7	7.4	7.0	18.2	8.7	***
16B	1.5	6.8	8.9	17.8	4.3	***
17S	1.1	7.4	8.2	18.0	6.6	***
17B	1.0	6.7	9.0	17.8	6.3	***
18S	1.5	7.5	5.7	18.2	11.5	***
18B	1.4	6.9	8.4	17.5	5.2	***
19S	1.3	6.2	8.0	18.2	6.8	***
19B	1.0	7.1	8.7	17.7	5.8	***
20S	0.7	8.8	5.3	18.8	10.4	***
20B	1.2	7.7	7.6	18.0	4.7	***
21S	1.9	7.3	5.1	18.0	8.0	***
21B	4.0	11.3	7.0	18.0	2.1	***
22S	3.9	10.3	5.1	18.3	3.9	***
22B	2.9	9.4	6.0	17.5	0.6	***

Appendix B Table 1. (continued)

Date: 120975

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.2	6.5	9.8	11.3	8.3	***
1B	0.8	4.6	12.2	12.0	7.5	***
2S	1.2	7.5	10.9	11.5	8.0	***
2B	0.9	5.8	11.1	11.5	8.1	***
3S	1.0	7.0	10.1	11.3	8.6	***
3B	1.0	5.3	10.9	11.5	8.3	***
4S	1.4	6.7	9.0	11.2	8.7	***
4B	0.5	6.0	9.3	11.2	8.4	***
5S	1.6	7.0	8.1	11.2	9.4	***
5B	1.3	5.2	9.5	11.5	8.8	***
6S	1.2	6.4	8.8	11.5	8.8	***
6B	0.7	6.4	9.8	11.3	8.5	***
7S	1.2	5.7	9.8	11.2	8.1	***
7B	0.7	6.3	10.7	11.5	7.8	***
8S	2.2	6.5	9.4	11.3	8.3	***
8B	0.7	5.8	9.9	11.5	8.1	***
9S	2.1	7.5	7.9	11.3	9.0	***
9B	1.0	5.5	9.5	11.8	8.0	***
10S	0.7	6.2	6.5	11.5	9.0	***
10B	0.3	5.5	8.8	11.5	8.0	***
11S	1.4	7.0	7.5	11.0	9.2	***
11B	0.6	7.0	9.5	11.9	7.9	***
12S	1.3	5.9	7.9	11.3	8.6	***
12B	0.8	7.2	9.2	11.5	8.2	***
13S	0.9	6.6	8.2	11.5	8.0	***
13B	0.7	6.2	9.8	11.8	7.7	***
14S	0.6	6.7	7.9	11.0	8.4	***
14B	0.5	6.2	9.3	11.8	7.5	***
15S	1.1	7.3	6.8	11.0	9.2	***
15B	0.4	4.9	8.2	11.3	7.8	***
16S	0.5	6.1	6.1	11.0	7.9	***
16B	0.6	6.7	6.8	11.0	7.7	***
17S	0.5	6.4	7.0	11.0	8.2	***
17B	0.6	6.2	8.4	11.5	7.6	***
18S	1.8	7.9	5.5	10.8	10.3	***
18B	1.2	6.8	8.5	11.5	7.0	***
19S	3.3	9.1	6.5	11.0	7.5	***
19B	0.9	6.8	8.5	11.3	7.2	***
20S	5.1	10.1	4.3	10.5	8.8	***
20B	1.4	8.0	8.3	11.5	5.4	***
21S	1.6	7.0	3.5	10.2	7.5	***
21B	0.6	6.8	7.2	11.5	3.4	***
22S	1.3	7.5	3.5	10.5	5.7	***
22B	0.7	5.9	7.4	11.5	2.2	***

Appendix B Table 1. (continued)

Date: 011576

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	2.1	6.0	9.4	7.5	12.2	***
1B	1.3	6.9	10.5	7.5	11.3	***
2S	1.8	4.4	9.6	6.9	12.3	***
2B	1.7	6.1	10.0	6.9	11.5	***
3S	1.8	6.4	10.9	7.0	12.4	***
3B	1.9	6.5	9.5	6.9	11.7	***
4S	1.5	6.7	8.9	7.2	12.9	***
4B	1.7	6.7	8.9	7.2	12.2	***
5S	1.6	7.7	7.8	7.5	12.6	***
5B	1.3	4.6	7.9	7.5	12.3	***
6S	1.3	6.2	8.9	7.0	12.2	***
6B	1.4	6.6	8.9	7.0	11.6	***
7S	1.7	6.5	8.6	7.4	13.1	***
7B	2.5	5.8	8.9	7.0	11.9	***
8S	2.0	5.7	8.0	7.6	13.2	***
8B	2.1	6.1	8.2	7.1	12.9	***
9S	1.8	5.5	7.8	7.0	12.5	***
9B	1.8	6.8	8.0	7.2	11.6	***
10S	2.5	5.8	6.3	7.5	12.3	***
10B	1.1	6.6	7.0	7.5	11.5	***
11S	0.9	6.8	6.6	8.0	11.4	***
11B	1.0	6.8	6.9	7.1	11.3	***
12S	2.1	6.0	6.5	7.8	12.0	***
12B	1.8	5.9	6.8	7.2	11.7	***
13S	3.7	6.4	6.8	7.6	13.4	***
13B	2.2	6.3	7.2	7.2	12.0	***
14S	3.7	5.9	6.5	7.9	13.1	***
14B	0.9	6.1	6.8	7.2	11.7	***
15S	0.6	5.6	5.4	8.0	10.7	***
15B	0.3	5.8	6.0	7.5	10.5	***
16S	0.4	5.5	5.0	8.0	10.0	***
16B	0.7	6.5	5.0	8.0	10.0	***
17S	2.2	6.6	5.5	8.0	11.2	***
17B	1.1	5.5	8.0	7.5	9.1	***
18S	1.9	5.7	4.5	8.0	11.2	***
18B	1.2	6.7	8.1	7.6	8.6	***
19S	0.8	5.6	5.5	8.0	10.5	***
19B	0.8	6.3	8.2	7.5	9.1	***
20S	0.8	5.4	3.0	7.8	10.1	***
20B	0.8	6.2	7.0	7.8	8.2	***
21S	0.8	5.8	1.8	7.5	10.5	***
21B	0.7	6.2	3.5	7.5	9.9	***
22S	1.3	7.5	2.9	7.0	8.6	***
22B	0.7	5.9	3.1	7.0	8.4	***

Appendix B Table 1. (continued)

Date: 022676

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.4	***	7.8	13.0	10.3	***
1B	3.9	***	8.0	12.3	9.7	***
2S	1.4	***	6.8	12.9	9.5	***
2B	1.6	***	7.4	12.7	9.3	***
3S	1.3	***	6.5	12.8	10.4	***
3B	1.7	***	7.2	12.7	9.8	***
4S	1.3	***	6.2	12.8	11.0	***
4B	5.1	***	6.3	12.8	10.0	***
5S	7.7	***	5.1	12.5	11.9	***
5B	4.6	***	5.8	12.2	10.1	***
6S	1.8	***	6.0	12.9	11.4	***
6B	2.3	***	6.5	12.5	10.5	***
7S	1.8	***	5.7	13.0	10.8	***
7B	1.8	***	6.6	12.5	9.4	***
8S	1.8	***	4.9	12.4	12.6	***
8B	2.5	***	5.3	12.8	11.1	***
9S	1.9	***	5.1	13.0	12.1	***
9B	3.3	***	5.2	12.8	11.8	***
10S	6.2	***	5.3	12.2	12.0	***
10B	6.5	***	7.0	12.5	5.2	***
11S	2.0	***	4.8	12.5	11.6	***
11B	5.5	***	4.9	13.7	10.9	***
12S	2.8	***	4.4	14.9	12.2	***
12B	2.6	***	4.2	12.5	11.3	***
13S	6.9	***	3.9	13.5	12.5	***
13B	4.5	***	4.7	12.5	9.5	***
14S	7.3	***	3.5	14.0	12.5	***
14B	1.4	***	4.0	12.8	10.2	***
15S	3.3	***	3.8	13.5	11.3	***
15B	1.0	***	4.0	12.5	10.0	***
16S	4.4	***	2.9	14.2	12.3	***
16B	0.8	***	4.1	13.0	7.6	***
17S	4.1	***	2.5	14.1	12.0	***
17B	1.1	***	3.0	13.0	10.6	***
18S	1.4	***	2.1	14.2	11.2	***
18B	0.9	***	3.8	13.0	7.9	***
19S	1.5	***	2.2	14.1	11.1	***
19B	1.1	***	3.5	13.0	8.4	***
20S	1.3	***	0.8	13.8	10.7	***
20B	1.4	***	3.3	13.0	8.2	***
21S	0.7	***	0.2	13.9	9.6	***
21B	0.9	***	2.8	13.0	6.1	***
22S	1.0	***	0.2	14.0	8.8	***
22B	1.0	***	0.2	12.8	8.3	***

Appendix B Table 1. (continued)

Date: 032576

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.2	2.6	6.0	14.2	9.7	***
1B	1.1	2.2	6.2	13.7	9.7	***
2S	1.6	2.6	5.4	14.2	10.1	***
2B	1.4	2.8	5.5	13.8	10.6	***
3S	1.4	2.9	5.7	14.2	10.6	***
3B	1.5	2.5	6.1	13.7	9.9	***
4S	1.5	2.6	5.6	14.0	9.7	***
4B	1.4	2.5	5.8	13.7	9.8	***
5S	1.8	2.8	4.4	14.2	9.5	***
5B	1.9	2.9	4.9	14.0	9.7	***
6S	1.6	2.8	5.0	14.0	10.2	***
6B	1.5	2.6	5.7	13.8	10.1	***
7S	2.1	2.8	4.7	14.3	10.5	***
7B	2.3	2.7	5.5	13.7	9.3	***
8S	2.8	2.9	4.9	12.4	10.3	***
8B	2.6	2.9	5.3	12.8	10.1	***
9S	1.8	2.7	5.5	14.4	10.0	***
9B	1.7	3.4	5.5	14.0	10.2	***
10S	1.6	2.9	4.2	14.5	9.9	***
10B	1.6	2.8	4.5	13.5	9.7	***
11S	1.6	2.6	4.0	14.2	10.6	***
11B	1.6	3.0	2.9	14.0	10.9	***
12S	2.2	2.6	4.1	14.2	9.0	***
12B	1.8	7.0	4.3	14.0	8.8	***
13S	2.7	6.4	3.8	14.3	10.8	***
13B	2.4	7.0	3.7	14.3	10.8	***
14S	2.2	5.9	2.5	14.5	11.7	***
14B	***	***	3.1	14.3	11.0	***
15S	2.2	6.5	2.9	14.1	10.9	***
15B	***	***	3.0	13.9	10.8	***
16S	1.9	2.6	1.7	14.5	11.0	***
16B	***	***	1.2	14.2	11.0	***
17S	2.5	2.8	1.0	14.5	10.8	***
17B	***	***	1.2	14.3	11.0	***
18S	1.8	3.0	0.5	15.0	10.4	***
18B	***	***	1.5	14.5	9.2	***
19S	1.7	2.7	0.5	14.8	10.6	***
19B	***	***	0.9	14.5	10.5	***
20S	1.5	3.0	0.0	13.0	10.0	***
20B	***	***	0.0	14.9	10.0	***
21S	0.8	3.8	0.0	14.7	10.0	***
21B	***	***	0.0	14.5	9.2	***
22S	0.8	3.5	0.0	14.5	8.6	***
22B	***	***	0.0	14.3	8.5	***

Appendix B Table 1. (continued)

Date: 051176

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.7	1.7	10.0	18.0	8.0	***
1B	1.2	2.3	10.0	18.0	8.0	***
2S	1.6	2.6	8.7	19.0	8.4	***
2B	1.5	1.9	8.9	19.5	8.4	***
3S	1.9	2.6	8.9	18.5	8.4	***
3B	1.3	2.8	8.5	19.0	8.2	***
4S	1.6	2.0	8.1	18.7	8.3	***
4B	1.1	2.5	8.5	18.5	7.4	***
5S	1.2	2.6	7.4	19.0	8.4	***
5B	1.1	2.1	7.9	19.0	7.4	***
6S	2.4	2.1	8.3	18.5	8.2	***
6B	1.6	2.3	8.3	18.5	8.2	***
7S	1.8	1.9	8.2	19.0	8.3	***
7B	1.7	2.2	8.3	19.0	8.2	***
8S	1.5	2.6	7.6	19.0	8.0	***
8B	2.6	3.4	7.6	19.0	8.2	***
9S	1.5	3.3	6.8	19.5	8.7	***
9B	1.1	3.2	7.5	19.0	8.1	***
10S	1.8	1.8	6.0	19.5	8.2	***
10B	2.4	2.6	6.5	19.0	6.9	***
11S	1.8	9.0	5.8	20.0	8.5	***
11B	2.0	6.2	4.5	20.0	8.6	***
12S	1.7	3.1	5.8	20.0	8.9	***
12B	1.4	3.1	6.2	20.0	8.7	***
13S	2.1	4.9	5.5	20.0	8.5	***
13B	1.6	4.7	5.9	20.3	8.5	***
14S	1.7	4.3	5.5	19.8	8.7	***
14B	1.8	4.2	6.0	19.5	8.5	***
15S	1.6	3.8	6.0	19.5	8.5	***
15B	2.0	3.5	6.2	19.8	8.4	***
16S	1.4	2.2	5.2	20.5	7.9	***
16B	1.3	2.4	5.7	20.0	7.6	***
17S	1.3	2.2	5.0	19.5	8.6	***
17B	1.8	2.0	5.0	19.8	8.5	***
18S	1.2	2.3	3.4	20.8	8.0	***
18B	2.2	2.7	3.9	20.5	7.2	***
19S	1.9	2.5	3.0	19.5	8.2	***
19B	2.6	2.5	4.2	19.5	8.1	***
20S	2.0	2.5	3.0	20.0	8.5	***
20B	1.5	2.8	3.0	20.0	8.3	***
21S	2.6	2.2	1.7	20.5	9.3	***
21B	2.3	2.5	1.8	20.2	9.1	***
22S	1.3	2.2	0.0	19.5	7.0	***
22B	2.0	2.3	0.0	19.5	6.9	***

Appendix B Table 1. (continued)

Date: 062376

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.1	3.8	11.1	***	***	1.7
1B	1.2	8.1	12.2	***	***	***
2S	0.8	8.2	11.7	***	***	1.2
2B	1.4	6.6	11.7	***	***	***
3S	0.8	5.9	11.7	***	***	1.5
3B	0.6	5.9	12.2	***	***	***
4S	1.0	5.9	10.5	***	***	1.4
4B	1.3	4.0	11.1	***	***	***
5S	0.9	6.2	11.1	***	***	1.4
5B	1.0	3.4	10.0	***	***	***
6S	1.7	4.1	8.3	***	***	1.3
6B	1.0	6.4	10.0	***	***	***
7S	0.8	6.4	11.1	***	***	1.2
7B	1.1	3.0	8.9	***	***	***
8S	1.8	5.2	6.7	***	***	1.0
8B	1.1	4.8	6.7	***	***	***
9S	1.2	3.4	7.8	***	***	1.2
9B	1.3	1.2	8.9	***	***	***
10S	1.1	5.2	7.8	***	***	1.2
10B	1.1	3.4	8.9	***	***	***
11S	0.9	6.7	5.5	***	***	1.1
11B	1.1	5.3	7.2	***	***	***
12S	1.3	2.8	5.5	***	***	1.1
12B	0.7	3.0	7.2	***	***	***
13S	1.6	5.3	6.7	***	***	0.8
13B	1.5	5.8	7.2	***	***	***
14S	2.4	4.3	3.3	***	***	0.9
14B	1.5	4.3	6.1	***	***	***
15S	1.4	3.6	5.5	***	***	1.1
15B	1.4	4.6	4.4	***	***	***
16S	1.2	5.5	2.2	***	***	1.2
16B	0.6	4.9	2.2	***	***	***
17S	1.9	4.6	3.3	***	***	0.9
17B	1.0	3.2	3.9	***	***	***
18S	1.4	4.9	1.1	***	***	0.9
18B	0.5	5.2	1.1	***	***	***
19S	1.7	6.1	2.2	***	***	0.9
19B	1.6	4.5	2.8	***	***	***
20S	1.9	5.3	0.0	***	***	0.8
20B	1.8	5.6	0.0	***	***	***
21S	1.1	5.5	0.0	***	***	0.5
21B	1.1	6.7	0.0	***	***	***
22S	0.7	6.3	0.0	***	***	0.6
22B	0.3	4.4	0.0	***	***	***

Appendix B Table 1. (continued)

Date: 072776

STATION	POC	DOC	SAL	TEMP	DO	SECCHI
1S	1.8	7.5	14.2	26.6	13.2	1.7
1B	1.7	8.3	15.6	27.0	11.5	***
2S	1.9	9.3	13.0	27.0	11.6	1.4
2B	3.8	9.2	13.0	27.0	11.5	***
3S	2.8	8.5	13.0	26.2	9.7	1.4
3B	2.7	10.1	13.0	25.0	9.4	***
4S	2.0	8.6	12.8	26.8	8.1	1.2
4B	2.1	9.9	12.6	26.8	8.0	***
5S	1.9	7.3	12.0	26.5	7.8	1.2
5B	2.3	6.9	12.6	26.8	5.4	***
6S	2.8	8.9	12.2	27.0	8.4	1.2
6B	3.2	7.5	12.2	27.0	8.4	***
7S	2.8	9.2	11.6	26.7	8.4	1.1
7B	1.5	8.4	11.6	26.0	8.5	***
8S	1.5	8.8	11.3	27.0	8.4	1.1
8B	1.0	9.2	11.3	26.8	8.3	***
9S	1.5	6.5	11.3	26.3	8.1	1.3
9B	1.2	8.7	11.5	26.5	8.1	***
10S	2.1	8.2	11.3	27.1	7.7	0.9
10B	1.5	8.6	11.3	27.1	7.4	***
11S	1.9	6.7	10.7	26.2	8.3	1.2
11B	2.2	6.5	10.9	26.2	8.2	***
12S	1.8	6.5	11.0	26.5	8.2	1.2
12B	2.1	8.4	11.0	26.8	8.0	***
13S	1.5	10.2	10.9	27.2	7.7	0.9
13B	1.8	7.2	10.9	27.0	7.1	***
14S	2.2	6.8	10.1	27.0	9.0	1.1
14B	1.7	6.9	10.1	27.0	8.5	***
15S	1.8	7.1	10.1	27.8	7.2	1.2
15B	1.4	7.1	10.1	27.8	7.0	***
16S	2.1	7.1	9.8	26.5	6.3	1.1
16B	1.8	7.5	9.9	26.4	6.3	***
17S	1.7	9.2	10.0	27.5	7.8	0.9
17B	1.6	8.9	10.0	27.6	7.8	***
18S	2.0	7.8	9.1	26.5	6.4	0.9
18B	1.4	8.6	8.5	26.5	6.0	***
19S	1.5	7.9	9.9	27.6	8.3	0.8
19B	1.4	7.4	9.9	27.7	8.0	***
20S	1.7	8.6	8.4	26.9	6.4	0.8
20B	1.5	8.2	8.5	26.9	6.3	***
21S	2.3	9.8	7.2	27.0	7.7	0.7
21B	1.7	9.7	7.2	27.0	7.0	***
22S	3.3	11.2	4.3	27.0	6.6	0.5
22B	3.0	8.2	5.0	27.0	5.8	***

Appendix B Table 2. Data collected during the Tributary Organic Carbon Study (July 1975 - September 1976).

TAR RIVER				DURHAM CREEK			
DATE	FLOW ^a	DOC	POC	DATE	FLOW ^b	DOC	POC
072975	2100	13.4	1.2	101875	32.0	17.9	1.3
092675	4730	10.0	0.9	101975	145.0	16.6	0.8
092875	6280	10.8	1.2	102075	152.0	14.8	0.4
092975	6600	12.4	1.0	102775	38.0	22.8	0.3
093075	6700	13.2	1.2	120975	19.0	6.3	1.3
100175	4570	10.7	3.2	121875	79.0	15.0	0.8
100275	2310	11.7	1.4	122075	101.0	13.2	0.0
010176	3800	8.0	2.5	010176	227.0	14.3	0.0
010376	4890	8.6	0.7	010376	154.0	16.0	0.1
010576	5000	8.9	1.0	010576	107.0	16.3	0.0
012876	7100	7.2	2.9	012876	34.0	12.0	0.4
012976	9740	10.6	2.4	012976	36.0	12.3	0.2
013076	11100	8.8	1.7	013076	33.0	9.8	0.4
013176	12600	7.6	1.6	013176	31.0	13.6	0.1
020276	12400	8.3	1.7	022676	21.0	24.5	0.5
020376	11200	10.0	1.3	033176	14.0	21.5	0.7
020476	10600	7.8	1.2	050376	0.4	24.0	3.3
020576	10200	10.7	0.9	050476	0.4	26.6	1.6
040676	1510	2.8	0.9	051176	0.3	28.0	2.5
041376	875	3.0	1.5	060376	415.0	22.0	2.2
042776	489	1.5	2.8	060476	626.0	24.6	0.7
050376	796	3.1	2.7	060576	489.0	22.0	0.8
050376	796	3.8	1.9	060676	320.0	28.8	0.7
050476	1320	2.6	1.3	060776	210.0	30.0	0.3
050676	1010	2.4	1.8	060876	149.0	33.0	0.6
050776	882	3.7	2.1	060976	109.0	33.9	0.6
050876	822	3.6	1.3	080976	58.0	25.7	1.3
050976	709	6.5	2.4	091076	2.9	39.3	2.3
051076	623	10.2	2.1	091576	11.0	27.5	1.8
051176	591	3.2	3.8				
060376	777	4.5	2.1				
060476	1690	5.2	1.5				
060576	3880	3.0	2.1				
060676	4310	6.2	2.5				
060776	2860	5.2	1.1				
060876	2000	6.3	0.9				
060976	1460	3.9	1.3				
061176	887	1.5	4.1				
062476	1160	6.4	1.9				
062876	730	3.3	2.6				
072276	256	7.4	2.9				
091576	344	7.4	1.7				

^a U.S.G.S. (1975, 1976) - measured at Tarboro (ft³ sec⁻¹)

^b U.S.G.S. (1975, 1976) - measured at Edward (ft³ sec⁻¹)

Appendix B Table 3. Data collected during the Carbon-Nutrient-Biomass Study (August 1976 - July 1977).

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	TEMP	26.5	26.1	25.8	25.4	25.9	25.9	26.0	25.6	27.9	26.0	26.5	25.9
101676	TEMP	18.0	18.5	17.7	18.5	18.3	18.0	18.4	18.2	19.1	18.5	18.9	18.3
120576	TEMP	3.4	3.8	4.1	8.0	4.9	6.0	5.2	5.0	6.0	6.0	6.4	5.9
030277	TEMP	10.1	10.5	9.0	9.8	9.0	9.5	8.5	9.0	5.8	5.5	***	***
052377	TEMP	23.0	23.5	22.0	22.5	22.3	23.1	22.5	22.5	23.0	23.5	23.0	23.0
070777	TEMP	25.3	23.8	27.2	25.0	27.0	24.0	27.8	27.8	27.8	25.5	28.0	26.5
081176	SAL	3.7	5.8	7.5	8.3	9.9	10.5	11.3	11.5	12.5	13.8	13.0	15.4
101676	SAL	2.8	5.7	6.2	8.5	9.2	10.0	11.5	11.5	13.2	15.0	15.0	15.1
120576	SAL	3.5	14.2	8.2	15.5	11.8	14.5	15.5	15.4	16.2	17.0	18.4	18.4
030277	SAL	0.0	8.0	4.5	8.8	9.5	10.0	12.0	11.5	17.0	17.0	***	***
052377	SAL	2.1	3.5	5.2	6.7	8.6	9.3	11.2	11.2	12.6	14.2	15.1	15.1
070777	SAL	5.0	9.0	7.1	12.3	9.8	14.0	12.2	12.5	14.0	17.0	14.9	19.0
081176	COND	7.0	10.0	13.2	15.0	17.2	18.5	20.0	20.5	21.9	23.9	22.3	26.3
101676	COND	4.1	5.8	6.5	12.5	13.9	14.9	16.9	17.0	19.2	21.8	22.0	22.1
120576	COND	3.8	14.7	8.9	16.5	12.9	15.9	16.5	16.4	17.5	18.2	19.8	19.7
030277	COND	0.1	10.1	6.0	10.2	12.0	13.0	15.0	13.0	17.6	17.2	***	***
052377	COND	3.8	5.9	8.8	10.3	14.1	15.0	18.0	18.0	21.0	23.9	24.9	24.9
070777	COND	8.0	15.1	12.1	21.0	17.0	24.0	21.2	21.5	24.0	28.9	25.4	31.2
081176	DO	6.0	2.0	6.9	2.9	7.6	4.4	8.0	5.7	9.6	4.4	9.0	4.4
101676	DO	7.0	2.1	8.5	4.2	8.2	7.6	8.5	8.0	8.6	6.1	8.3	8.2
120576	DO	13.2	7.4	12.9	7.6	12.4	11.6	12.1	12.1	11.5	6.4	11.6	11.7
030277	DO	10.9	5.9	11.7	8.6	13.6	11.9	14.7	14.8	9.4	8.6	***	***
052377	DO	7.5	10.1	8.4	8.6	9.2	7.9	8.6	8.3	8.3	6.6	8.6	8.4
070777	DO	4.8	0.3	6.7	0.0	7.4	0.1	7.8	7.2	8.4	0.9	8.0	4.3
081176	SECC	0.6	***	0.7	***	0.9	***	1.1	***	1.1	***	1.5	***
101676	SECC	0.5	***	1.0	***	1.4	***	1.5	***	1.5	***	1.6	***
120576	SECC	0.8	***	0.9	***	1.8	***	1.8	***	2.4	***	2.4	***
030277	SECC	0.5	***	0.5	***	1.3	***	1.2	***	1.3	***	***	***
052377	SECC	0.6	***	0.8	***	0.9	***	1.1	***	1.2	***	1.4	***
070777	SECC	0.5	***	0.6	***	0.9	***	1.2	***	1.4	***	1.2	***

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	CHLRA	24.4	21.2	16.1	15.2	7.3	10.2	7.7	7.8	4.8	5.0	4.4	4.6
101676	CHLRA	54.4	64.2	9.8	13.9	9.6	8.0	6.1	6.1	4.1	6.2	2.6	4.4
120576	CHLRA	3.1	19.3	13.8	19.1	4.8	8.6	3.4	6.5	3.0	3.7	2.8	3.0
030277	CHLRA	7.0	5.6	45.8	37.9	13.8	13.9	5.5	5.6	7.7	9.1	***	***
052377	CHLRA	7.8	9.7	4.5	4.4	2.9	3.2	2.5	2.3	1.7	1.6	1.5	1.6
070777	CHLRA	36.8	40.1	16.6	10.9	5.2	4.2	7.0	6.0	6.2	4.7	7.1	6.1
081176	CHLRAC	21.3	18.2	16.0	13.6	7.3	8.4	8.7	7.8	5.9	5.7	4.5	5.7
101676	CHLRAC	45.5	45.2	10.6	11.5	9.1	6.7	5.3	6.8	3.1	5.2	2.7	4.0
120576	CHLRAC	3.0	15.6	10.1	13.9	4.2	8.0	3.0	6.5	3.0	3.2	2.8	3.0
030277	CHLRAC	4.4	2.2	42.2	33.4	13.4	12.7	4.9	5.6	7.0	7.6	***	***
052377	CHLRAC	6.7	9.0	4.5	4.4	3.3	3.3	2.7	2.7	2.0	1.9	1.8	1.8
070777	CHLRAC	26.4	26.6	18.2	12.2	6.0	4.9	8.3	7.1	7.4	5.4	8.3	7.0
081176	CHLRB	2.2	1.8	1.5	1.3	0.7	0.8	0.3	0.1	0.3	-0.1	-0.1	-0.1
101676	CHLRB	2.6	2.9	2.3	-0.6	1.4	0.2	-0.8	-1.0	-1.6	-0.8	-0.6	-1.4
120576	CHLRB	-0.7	2.4	-1.5	1.9	-0.9	-0.6	-0.8	-1.2	-0.7	-0.5	-0.7	-0.5
030277	CHLRB	0.1	-0.7	12.8	17.0	1.5	2.1	0.9	1.4	1.7	0.9	***	***
052377	CHLRB	1.7	1.9	0.2	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
070777	CHLRB	23.2	12.7	0.7	0.6	0.5	0.4	0.6	0.6	0.2	0.2	0.2	0.6
081176	CHLRC	17.4	15.9	7.4	6.5	3.0	4.0	5.1	2.1	1.6	0.8	1.1	1.1
101676	CHLRC	49.8	51.6	12.5	7.6	6.1	-2.6	1.3	5.2	-1.7	-1.3	-1.1	-1.9
120576	CHLRC	-0.1	18.6	4.0	17.4	-0.7	1.2	-1.3	-1.3	-1.4	-1.5	-0.7	-0.5
030277	CHLRC	1.2	0.1	77.1	85.9	12.2	12.8	4.1	2.4	6.3	4.0	***	***
052377	CHLRC	6.4	8.9	1.5	1.8	0.8	1.0	1.3	1.3	0.7	0.7	0.9	1.1
070777	CHLRC	85.1	63.6	11.8	7.4	3.0	2.4	5.0	4.4	4.0	4.2	4.7	4.4
081176	CAROT	22.7	20.3	19.9	19.2	9.4	12.0	9.6	9.9	7.8	6.2	6.6	6.1
101676	CAROT	54.0	68.0	13.7	18.0	13.4	8.8	8.5	9.0	5.0	7.8	3.2	5.5
120576	CAROT	2.7	23.4	15.2	24.1	5.6	11.4	4.0	8.9	3.5	4.0	3.7	4.2
030277	CAROT	2.3	6.0	50.7	36.3	14.7	16.8	5.1	4.0	2.4	8.5	***	***
052377	CAROT	8.3	10.7	5.6	5.9	4.0	4.6	4.0	3.8	3.2	3.0	2.8	3.2
070777	CAROT	44.0	46.0	22.1	15.2	8.2	6.8	10.4	10.0	9.2	7.3	11.3	8.8

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	PHAE0	5.6	3.9	4.4	6.3	1.8	4.3	0.6	1.9	1.3	0.3	0.9	0.4
101676	PHAE0	26.7	43.8	2.6	7.4	3.9	3.8	2.8	1.0	2.3	3.0	0.4	1.5
120576	PHAE0	0.7	10.4	8.6	12.5	1.9	2.9	1.3	3.1	0.9	1.4	1.4	1.2
030277	PHAE0	5.3	6.2	18.8	18.8	4.2	5.6	2.5	1.6	3.2	4.7	***	***
052377	PHAE0	11.2	11.0	3.8	3.2	0.0	1.9	0.9	0.0	-0.3	-0.1	0.1	0.3
070777	PHAE0	27.4	31.3	1.9	1.0	0.1	0.1	-0.1	0.0	0.0	0.5	0.1	0.4
081176	NA	1.362	2.038	3.400	3.600	4.000	4.200	3.125	3.300	3.075	4.725	3.550	3.500
101676	NA	1.650	3.225	2.375	3.225	3.950	3.825	4.825	3.575	4.250	4.200	3.350	3.625
120576	NA	0.912	3.175	2.438	2.975	3.075	3.200	3.925	3.775	2.875	5.000	4.675	3.225
030277	NA	0.015	1.400	1.450	2.238	2.060	1.825	2.925	3.000	2.700	3.550	***	***
052377	NA	1.000	1.100	1.800	2.125	3.100	3.275	3.775	4.050	4.875	5.000	6.400	6.000
070777	NA	0.850	1.388	1.888	2.550	2.550	3.450	3.900	4.000	4.650	5.800	4.600	5.550
081176	K	0.041	0.059	0.093	0.097	0.106	0.114	0.105	0.095	0.093	0.140	0.095	0.089
101676	K	0.050	0.060	0.041	0.095	0.114	0.125	0.155	0.115	0.150	0.155	0.100	0.114
120576	K	0.032	0.115	0.085	0.100	0.095	0.111	0.106	0.101	0.111	0.195	0.160	0.120
030277	K	0.002	0.051	0.054	0.083	0.079	0.062	0.115	0.108	0.102	0.135	***	***
052377	K	0.032	0.040	0.076	0.082	0.076	0.122	0.140	0.150	0.174	0.178	0.228	0.212
070777	K	0.028	0.038	0.069	0.071	0.080	0.116	0.142	0.138	0.166	0.196	0.172	0.200
081176	MG	0.110	0.165	0.280	0.300	0.325	0.350	0.310	0.285	0.275	0.430	0.245	0.240
101676	MG	0.100	0.175	0.119	0.262	0.312	0.338	0.425	0.312	0.438	0.450	0.250	0.338
120576	MG	0.100	0.350	0.262	0.275	0.281	0.338	0.288	0.300	0.325	0.512	0.475	0.325
030277	MG	0.003	0.138	0.162	0.250	0.212	0.256	0.288	0.319	0.300	0.431	***	***
052377	MG	0.097	0.120	0.212	0.250	0.350	0.369	0.425	0.469	0.525	0.550	0.625	0.638
070777	MG	0.081	0.112	0.206	0.244	0.231	0.356	0.406	0.438	0.488	0.562	0.506	0.575
081176	CA	0.035	0.055	0.095	0.075	0.100	0.105	0.112	0.110	0.095	0.160	0.085	0.087
101676	CA	0.050	0.060	0.047	0.102	0.130	0.130	0.154	0.119	0.154	0.161	0.095	0.112
120576	CA	0.040	0.130	0.095	0.097	0.102	0.125	0.112	0.102	0.112	0.169	0.169	0.108
030277	CA	0.006	0.056	0.059	0.092	0.076	0.095	0.102	0.112	0.102	0.132	***	***
052377	CA	0.035	0.048	0.075	0.087	0.120	0.130	0.150	0.162	0.185	0.192	0.210	0.220
070777	CA	0.032	0.037	0.072	0.087	0.082	0.125	0.140	0.145	0.162	0.192	0.170	0.190

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	NTOT	0.830	1.040	0.373	0.390	0.248	0.265	0.136	0.147	0.200	0.220	***	***
101676	NTOT	1.420	0.800	0.320	0.460	0.187	0.295	0.256	0.204	0.204	0.190	0.173	0.200
120576	NTOT	0.690	0.800	0.635	1.080	0.430	0.480	0.435	0.365	0.460	0.540	***	0.400
030277	NTOT	0.610	0.710	1.520	1.660	0.580	0.570	0.350	0.370	0.550	0.330	***	***
052377	NTOT	0.750	0.525	0.585	0.710	0.630	0.530	0.565	0.610	0.555	0.530	0.500	0.490
070777	NTOT	1.730	0.750	0.800	0.720	0.610	0.530	0.490	0.500	0.520	0.600	0.520	0.550
081176	NDISS	0.510	0.470	0.218	0.178	0.132	0.128	0.140	***	0.128	0.580	0.380	0.248
101676	NDISS	0.280	0.400	0.275	0.250	0.136	0.140	0.096	0.110	0.109	0.130	0.112	0.148
120576	NDISS	0.660	0.480	0.320	0.400	0.285	0.330	0.305	0.330	0.500	0.350	0.185	0.182
030277	NDISS	0.590	0.630	0.470	0.570	0.320	0.295	0.230	0.245	0.270	0.315	***	***
052377	NDISS	0.680	0.615	0.480	0.495	0.478	0.590	0.470	0.445	0.422	0.432	0.415	0.415
070777	NDISS	0.520	0.600	0.370	0.332	0.430	0.310	0.410	0.365	0.430	0.480	0.332	0.405
081176	NPART	0.320	0.570	0.155	0.212	0.116	0.137	-0.004	***	0.072	-0.360	***	***
101676	NPART	1.140	0.400	0.045	0.210	0.051	0.155	0.160	0.094	0.095	0.060	0.061	0.052
120576	NPART	0.030	0.320	0.315	0.680	0.145	0.150	0.130	0.035	-0.040	0.190	***	0.218
030277	NPART	0.020	0.080	1.050	1.090	0.260	0.275	0.120	0.125	0.280	0.015	***	***
052377	NPART	0.070	-0.090	0.105	0.215	0.152	-0.060	0.095	0.165	0.133	0.098	0.085	0.075
070777	NPART	1.210	0.150	0.430	0.388	0.180	0.220	0.080	0.135	0.090	0.120	0.120	0.145
081176	NO3	0.120	0.060	0.080	0.136	0.600	0.168	0.136	0.200	0.156	0.212	0.120	0.136
101676	NO3	0.152	0.420	0.170	0.192	0.232	0.232	0.468	0.192	0.200	0.280	0.232	0.255
120576	NO3	0.320	0.285	0.208	0.235	0.202	0.230	0.268	0.305	0.285	0.295	0.248	0.394
030277	NO3	0.672	0.271	0.290	0.166	0.140	0.184	0.209	0.239	0.268	0.321	***	***
052377	NO3	0.072	0.120	0.276	0.304	0.108	0.128	0.168	0.204	0.216	0.232	0.292	0.264
070777	NO3	0.160	0.196	0.260	0.308	0.240	0.184	0.292	0.308	0.252	0.320	0.316	0.312
081176	NO2	0.0018	0.0015	0.0010	0.0013	0.0010	0.0010	0.0010	0.0010	0.0010	0.0020	0.0010	0.0010
101676	NO2	0.0025	0.0043	0.0023	0.0040	0.0015	0.0015	0.0018	0.0012	0.0015	0.0008	0.0010	0.0012
120576	NO2	0.0032	0.0021	0.0019	0.0014	0.0009	0.0008	0.0008	0.0008	0.0009	0.0003	0.0005	0.0004
030277	NO2	0.0059	0.0035	0.0041	0.0022	0.0013	0.0014	0.0006	0.0013	0.0018	0.0016	***	***
052377	NO2	0.0025	0.0022	0.0018	0.0016	0.0014	0.0013	0.0011	0.0011	0.0011	0.0009	0.0007	0.0006
070777	NO2	0.0054	0.0037	0.0028	0.0024	0.0023	0.0015	0.0018	0.0014	0.0016	0.0024	0.0014	0.0016

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	NH4	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
101676	NH4	0.257	0.151	0.024	0.045	0.018	0.025	0.011	0.034	0.014	0.017	0.048	0.036
120576	NH4	0.490	0.221	0.030	0.050	0.050	0.042	0.016	0.041	0.035	0.056	***	0.022
030277	NH4	0.098	0.500	0.019	0.015	0.017	0.033	0.012	0.038	0.036	0.020	***	***
052377	NH4	0.025	0.015	0.006	0.007	0.010	0.014	0.007	0.010	0.008	0.006	0.013	0.011
070777	NH4	0.012	0.017	0.009	0.028	0.009	0.036	0.010	0.014	0.012	0.080	0.010	0.015
081176	PTOT	0.136	0.254	0.187	0.220	0.207	0.271	0.222	0.134	0.087	0.082	***	***
101676	PTOT	0.237	0.181	0.128	0.135	0.163	0.191	0.209	0.182	0.178	0.149	0.143	0.120
120576	PTOT	0.200	0.110	0.090	0.160	0.080	0.100	0.100	0.090	0.080	0.080	***	0.060
030277	PTOT	0.145	0.262	0.399	0.490	0.105	0.108	0.080	0.091	0.038	0.053	***	***
052377	PTOT	0.073	0.116	0.110	0.126	0.149	0.137	0.129	0.126	0.071	0.069	0.050	0.055
070777	PTOT	0.375	0.447	0.241	0.428	0.300	0.399	0.292	0.296	0.188	0.136	0.170	0.137
081176	PDISS	0.085	0.109	0.138	0.127	0.191	0.240	0.156	0.182	0.076	0.077	0.067	0.094
101676	PDISS	0.081	0.137	0.081	0.089	0.146	0.161	0.139	0.135	0.130	0.106	0.074	0.080
120576	PDISS	0.100	0.060	0.070	0.090	0.070	0.090	0.090	0.090	0.070	0.070	0.050	0.050
030277	PDISS	0.098	0.048	0.038	0.051	0.033	0.037	0.061	0.063	0.016	0.011	***	***
052377	PDISS	0.040	0.049	0.058	0.072	0.089	0.136	0.099	0.100	0.050	0.046	0.025	0.032
070777	PDISS	0.152	0.281	0.185	0.472	0.266	0.289	0.271	0.265	0.165	0.109	0.137	0.122
081176	PORTHO	0.059	0.076	0.124	0.103	0.191	0.260	0.140	0.159	0.048	0.069	0.053	0.081
101676	PORTHO	0.047	0.078	0.050	0.058	0.117	0.130	0.115	0.112	0.105	0.085	0.060	0.058
120576	PORTHO	0.070	0.030	0.040	0.050	0.050	0.060	0.070	0.060	0.050	0.040	0.030	0.030
030277	PORTHO	0.060	0.026	0.023	0.035	0.022	0.019	0.049	0.050	0.006	0.005	***	***
052377	PORTHO	0.015	0.018	0.033	0.048	0.074	0.121	0.083	0.084	0.034	0.032	0.014	0.020
070777	PORTHO	0.109	0.237	0.152	0.470	0.243	0.272	0.249	0.250	0.149	0.093	0.113	0.097
081176	PPART	0.051	0.145	0.049	0.093	0.016	0.031	0.066	-0.048	0.011	0.005	***	***
101676	PPART	0.156	0.044	0.047	0.046	0.017	0.030	0.070	0.047	0.048	0.043	0.069	0.040
120576	PPART	0.100	0.050	0.020	0.070	0.010	0.010	0.010	0.000	0.010	0.010	***	0.010
030277	PPART	0.047	0.214	0.361	0.439	0.072	0.071	0.019	0.028	0.022	0.042	***	***
052377	PPART	0.033	0.067	0.052	0.054	0.060	0.001	0.030	0.026	0.021	0.023	0.025	0.023
070777	PPART	0.223	0.155	0.056	-0.044	0.034	0.110	0.021	0.031	0.023	0.027	0.033	0.015

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
101676	PHYTO	22.152	23.184	2.348	1.501	1.556	1.547	0.525	1.274	0.755	0.958	0.535	0.446
030277	PHYTO	1.522	0.368	17.447	17.637	3.222	2.359	1.507	1.451	1.891	2.422	***	***
052377	PHYTO	3.478	5.974	0.966	1.351	0.934	0.645	0.857	1.295	0.383	0.355	0.253	0.289
070777	PHYTO	23.128	22.745	6.149	7.100	0.553	1.052	1.414	1.841	3.009	0.695	0.548	0.679
101676	PYRR	21.699	23.131	2.329	1.498	1.103	1.526	0.418	1.130	0.652	0.715	0.477	0.255
030277	PYRR	0.192	0.065	17.441	17.586	2.933	1.852	0.755	0.674	0.229	0.501	***	***
052377	PYRR	3.041	5.565	0.837	1.118	0.637	0.414	0.545	0.833	0.253	0.200	0.172	0.149
070777	PYRR	22.870	22.546	5.421	6.228	0.266	0.963	1.387	1.782	2.902	0.404	0.524	0.661
101676	CHRY	0.007	0.050	0.018	0.002	0.049	0.017	0.091	0.088	0.098	0.244	0.050	0.192
030277	CHRY	1.328	0.303	0.007	0.051	0.288	0.506	0.752	0.776	1.663	1.918	***	***
052377	CHRY	0.375	0.286	0.126	0.183	0.241	0.230	0.267	0.462	0.129	0.151	0.083	0.140
070777	CHRY	0.234	0.182	0.726	0.648	0.284	0.085	0.017	0.010	0.000	0.173	0.020	0.015
101676	CHLOR	0.385	0.003	0.000	0.000	0.000	0.000	0.010	0.001	0.000	0.000	0.000	0.000
030277	CHLOR	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	***	***
052377	CHLOR	0.018	0.025	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
070777	CHLOR	0.007	0.008	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
101676	CYAN	0.061	0.000	0.000	0.000	0.004	0.004	0.005	0.005	0.005	0.000	0.008	0.000
030277	CYAN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.003	***	***
052377	CYAN	0.000	0.000	0.000	0.004	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
070777	CYAN	0.017	0.009	0.001	0.002	0.003	0.004	0.010	0.021	0.019	0.006	0.003	0.003
101676	OTHER	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
030277	OTHER	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
052377	OTHER	0.044	0.098	0.000	0.044	0.055	0.000	0.044	0.000	0.000	0.004	0.000	0.000
070777	OTHER	0.000	0.000	0.000	0.221	0.000	0.000	0.000	0.028	0.088	0.032	0.001	0.000
081176	RESP1(26)	0.069	0.122	0.040	0.035	0.033	0.032	0.039	0.030	0.038	0.026	0.031	0.028
101676	RESP1(18)	0.158	0.190	0.055	0.053	0.042	0.053	0.054	0.038	0.054	0.077	0.036	0.078
120576	RESP1(05)	0.031	0.067	0.022	0.067	0.032	0.036	0.024	0.050	0.033	0.030	0.039	0.029
030277	RESP1(07)	0.010	0.035	0.049	0.074	0.021	0.028	0.001	0.006	0.000	0.001	0.000	0.001
052377	RESP1(22)	0.053	0.083	0.040	0.040	0.029	0.029	0.250	0.319	0.025	0.031	0.026	0.024
070777	RESP1(26)	0.243	0.160	0.071	0.043	0.036	0.032	0.036	0.036	0.039	0.032	0.046	0.036

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	RESP5(26)	5.9	9.6	3.7	3.3	3.1	2.6	4.0	2.4	3.2	2.5	2.5	2.5
101676	RESP5(18)	11.5	10.4	2.7	2.9	2.4	2.2	2.2	2.1	2.2	4.1	1.4	2.2
120576	RESP5(05)	2.1	4.1	1.3	5.3	1.7	1.9	1.6	3.2	1.8	1.7	2.3	1.5
030277	RESP5(07)	0.3	2.3	4.4	7.4	2.4	2.4	0.1	0.2	0.0	0.1	***	***
052377	RESP5(22)	5.6	7.0	3.5	3.4	2.4	2.6	2.6	2.6	2.4	2.4	2.2	2.0
070777	RESP5(26)	16.7	13.2	5.3	3.7	2.9	2.6	3.5	2.5	3.4	2.3	3.7	2.4
081176	POC	2.2	4.5	2.2	2.0	2.3	2.6	1.6	1.4	2.8	1.3	0.8	1.5
101676	POC	5.4	6.1	2.1	3.0	1.7	1.7	1.6	2.0	1.6	2.3	1.6	1.7
120576	POC	1.2	3.5	1.2	5.4	1.1	2.2	1.1	1.3	1.4	1.3	1.1	1.1
030277	POC	0.0	2.9	4.8	5.8	3.1	2.7	1.3	1.1	1.9	1.5	***	***
052377	POC	1.9	2.6	2.2	2.3	1.6	2.3	1.7	1.9	1.7	1.8	1.7	1.6
070777	POC	3.4	3.2	1.9	1.0	0.6	0.6	1.1	1.3	0.9	1.0	0.8	1.1
081176	DOC	7.8	9.6	8.0	7.7	7.6	7.9	7.3	7.2	7.1	7.2	8.3	6.4
101676	DOC	10.2	8.5	7.4	7.5	15.5	5.9	5.6	5.6	6.1	5.8	3.9	5.0
120576	DOC	6.7	7.0	6.3	9.1	6.6	7.5	3.7	6.1	6.9	7.7	5.2	7.3
030277	DOC	9.0	7.8	8.3	9.0	7.3	7.8	9.8	7.5	6.0	6.1	***	***
052377	DOC	7.4	8.9	8.8	8.8	8.5	8.2	7.1	8.4	7.5	7.4	5.2	7.1
070777	DOC	11.4	11.5	15.5	7.8	8.1	8.9	7.9	8.7	7.9	7.4	7.9	5.3
081176	pH	7.80	***	8.05	***	8.35	***	8.55	***	8.35	***	8.40	***
101676	pH	6.57	***	6.55	***	6.55	***	7.83	***	7.57	***	7.81	***
120576	pH	7.04	***	8.04	***	7.91	***	7.90	***	8.27	***	7.93	***
030277	pH	6.30	***	6.30	***	8.50	***	7.10	***	7.30	***	***	***
052377	pH	6.70	***	7.00	***	7.30	***	7.55	***	7.62	***	7.67	***
070777	pH	6.90	***	7.10	***	7.60	***	7.75	***	7.75	***	7.50	***
081176	ALKAL	0.80	***	0.96	***	1.08	***	1.16	***	1.00	***	1.12	***
101676	ALKAL	0.46	***	0.56	***	0.60	***	1.12	***	1.12	***	1.28	***
120576	ALKAL	0.54	***	0.84	***	1.00	***	1.16	***	1.26	***	1.36	***
030277	ALKAL	0.24	***	0.44	***	0.88	***	0.95	***	1.14	***	***	***
052377	ALKAL	0.62	***	0.56	***	1.00	***	1.08	***	1.18	***	1.34	***
070777	ALKAL	0.82	***	0.98	***	0.85	***	1.22	***	1.32	***	1.34	***

Appendix B Table 3. (continued)

DATE	TEST	1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B
081176	PRODUC	2.399	***	2.586	***	1.142	***	0.566	***	0.388	***	0.198	***
101676	PRODUC	2.731	***	0.197	***	0.417	***	0.410	***	0.314	***	0.320	***
120576	PRODUC	0.112	***	0.072	***	0.096	***	0.169	***	0.102	***	0.128	***
030277	PRODUC	0.204	***	3.724	***	0.437	***	0.249	***	0.181	***	***	***
052377	PRODUC	0.817	***	0.218	***	0.228	***	0.131	***	0.104	***	0.103	***
070777	PRODUC	0.733	***	0.465	***	0.169	***	0.200	***	0.299	***	0.287	***
081176	SECRET	0.241	***	0.453	***	0.296	***	0.227	***	0.065	***	0.033	***
101676	SECRET	1.863	***	0.160	***	0.137	***	0.327	***	0.005	***	0.269	***
120576	SECRET	0.001	***	0.003	***	0.002	***	0.001	***	0.004	***	0.000	***
030277	SECRET	0.027	***	0.092	***	0.014	***	0.012	***	0.017	***	***	***
052377	SECRET	0.054	***	0.035	***	0.029	***	0.017	***	0.013	***	0.008	***
070777	SECRET	0.111	***	0.072	***	0.060	***	0.051	***	0.054	***	0.041	***
081176	SKY/WX	0	***	0	***	0	***	0/H	***	0	***	0	***
101676	SKY/WX	0	***	0	***	0	***	0	***	0	***	0	***
120576	SKY/WX	0	***	0	***	0	***	0	***	0	***	0	***
030277	SKY/WX	0	***	0	***	0	***	0	***	0	***	0	***
052377	SKY/WX	0	***	-0	***	0	***	0	***	-0	***	0	***
070777	SKY/WX	-0	***	0/H	***	0/H	***	-0	***	-0	***	0	***
081176	WIND	C	***	C	***	C	***	C	***	LtV2	***	SE5	***
101676	WIND	S5	***	SW5	***	WSW5	***	WSW5	***	W5	***	W5	***
120576	WIND	NW5	***	NNE10	***	NE15	***	NE15	***	NE15	***	NE15	***
030277	WIND	WNW10	***	NW15	***	NW20	***	N25	***	NNE10	***	***	***
070777	WIND	SW3	***	SW3	***	SW5	***	SW8	***	SW8	***	SW3	***
070777	BACT ^a	1.320	0.628	0.838	0.649	0.546	0.426	0.437	0.449	0.456	0.374	0.471	0.419

^a James C. Anderson, unpublished data

Appendix B Table 4. Summary of Diurnal Data

081275 - Daymark 3 near Indian Island

TEST	S/B or DEPTH (m)	0400	0800	1200	1600	2000	2400
TEMP	S	27.0	26.5	27.5	29.0	28.0	27.0
TEMP	B	27.0	26.5	26.8	26.8	26.5	27.0
SAL	S	8.2	8.4	8.4	8.2	8.5	10.0
SAL	B	9.5	8.5	9.2	8.4	8.6	9.7
COND	S	14.500	15.000	15.000	14.500	15.200	18.000
COND	B	16.800	16.200	16.200	15.000	15.100	17.400
DO	S	7.1	6.2	8.0	8.2	8.2	7.6
DO	B	2.1	2.2	0.3	3.8	4.6	5.5
WIND	-	NW 7.5	NW 7.5	C	NW 7.5	N 10	NE 15
SECC	-	***	0.9	0.9	0.9	***	***

063076-070176--

Daymark 9 (Blount's B) 0430

Daymark 9 (Blount's B) 0430		0830	1230	1630	2030	0030	
TEMP	S	27.0	27.4	28.3	28.8	27.5	27.0
TEMP	B	25.5	25.8	25.8	26.0	26.0	26.0
SAL	S	1.8	1.8	1.9	2.0	2.0	2.0
SAL	B	4.8	4.9	5.0	5.0	4.5	4.5
COND	S	2.900	3.080	3.300	3.800	3.850	3.700
COND	B	8.000	8.500	9.100	9.000	8.200	8.100
DO	S	8.3	7.4	8.5	8.8	7.5	7.6
DO	B	1.2	0.8	0.8	0.7	0.6	0.4
SECC	-	***	0.8	0.6	0.6	***	***
PRODUC ^a	S	24.0	886.0	740.0	68.0	***	***
pH	S	7.90	7.95	8.10	8.30	***	***
ALKAL	S	1.02	0.58	0.48	0.52	***	***
DOC	S	7.0	8.0	4.9	5.7	7.5	8.1
DOC	B	4.7	4.7	4.4	4.6	6.5	7.0
POC	S	1.5	2.0	2.0	2.0	1.4	1.0
POC	B	1.7	1.6	1.6	1.4	1.4	1.2
WIND	-	SW 10	SW 10	SW 10	SW 15	SW 20	SW 20
SKY/WX	-	☉	☉	☉	☉	☉	☉

^a mg/m³/4 h at 0.5 m based on 4 h incubation beginning 1 h after time shown

Appendix B Table 4 (continued)

031277 - Daymark 3 near Indian Is.

TEST	S/B or DEPTH(m)	0400	0800	1200	1600	2000	2400
TEMP	0.5	11.8	11.6	14.3	15.2	***	***
TEMP	1.5	11.9	11.6	14.0	13.9	***	***
TEMP	2.5	10.2	11.1	13.0	12.8	***	***
SAL	0.5	10.8	11.1	10.5	10.8	***	***
SAL	1.5	10.8	12.0	11.0	10.9	***	***
SAL	2.5	12.0	12.0	11.0	11.2	***	***
COND	0.5	13.500	14.500	14.200	14.600	***	***
COND	1.5	13.600	15.400	14.800	14.600	***	***
COND	2.5	14.900	15.400	14.900	14.900	***	***
DO	0.5	10.5	12.7	13.0	13.8	***	***
DO	1.5	11.8	12.4	13.0	14.2	***	***
DO	2.5	10.6	12.0	12.0	13.0	***	***
SECC	-	***	1.7	1.6	1.4	***	***
pH	0.5	8.10	8.05	8.40	***	***	***
pH	1.5	8.07	7.93	8.38	***	***	***
pH	2.5	7.65	7.98	7.99	***	***	***
ALKAL	0.5	1.00	1.06	1.02	***	***	***
ALKAL	1.5	0.98	1.00	1.06	***	***	***
ALKAL	2.5	1.04	1.02	1.06	***	***	***
PRODUC ^b	0.5	2.07	30.36	42.35	***	***	***
PRODUC ^b	1.5	0.80	15.18	17.46	***	***	***
PRODUC ^b	2.5	0.00	6.74	5.94	***	***	***
WIND	-	NE 5	NE 15	ENE 25	E 25	***	***
SKY/WX	-	0	⊖	⊖	⊖ RW	***	***

^b mg C/m³/4 h -- based on 4 h incubations beginning at time shown

Appendix B Table 4 (continued)

060977 - Daymark 9 near Blount's Bay

TEST	S/B or DEPTH(m)	0400	0800	1200	1600	2000	2400
TEMP	S	22.5	22.5	23.5	24.0	22.5	22.0
TEMP	B	23.2	23.0	22.1	24.0	23.0	22.0
SAL	S	3.8	3.9	5.5	2.9	2.5	2.4
SAL	B	7.5	7.5	8.3	2.9	2.5	2.4
COND	S	6.400	6.600	9.500	4.980	4.170	3.960
COND	B	11.200	12.500	14.000	4.920	4.180	3.990
DO	S	9.8	9.2	9.0	7.1	7.9	7.4
DO	B	1.7	0.7	1.2	7.4	7.9	7.4
SECC	-	***	0.7	0.6	***	***	***
PRODUC ^b	S	53.8	55.8	251.0	72.0	***	***
SECRET ^b	S	6.2	4.3	12.6	2.4	***	***
pH	S	6.3	8.2	8.3	6.8	***	***
ALKAL	S	0.34	0.63	0.68	0.48	***	***
DOC	S	7.5	7.3	7.2	12.5	9.9	9.0
DOC	B	7.5	8.2	7.8	9.3	8.6	8.8
POC	S	2.6	2.5	2.8	2.0	2.0	2.3
POC	B	1.9	2.0	1.9	1.6	1.7	2.0
CHLRA	S	15.9	16.9	19.2	19.6	26.6	29.1
CHLRA	B	17.3	18.2	17.7	25.2	27.7	27.8
CHLRAC	S	11.9	14.6	15.4	16.1	18.7	21.2
CHLRAC	B	13.5	15.2	13.5	19.4	18.4	18.4
CHLRB	S	0.0	1.3	0.7	4.2	6.1	5.1
CHLRB	B	1.8	1.7	1.1	5.4	5.2	6.7
CHLRC	S	3.0	8.4	11.1	14.5	17.9	23.1
CHLRC	B	9.3	9.7	6.6	17.9	19.1	23.4
CAROT	S	17.8	18.7	20.3	20.8	29.2	32.1
CAROT	B	18.8	19.5	20.9	28.5	28.6	30.2
PHAE0	S	11.6	9.1	12.4	12.5	22.2	23.1
PHAE0	B	11.9	10.8	12.6	18.2	24.9	25.5
NA	S	1.175	1.275	1.225	0.938	0.700	0.795
NA	B	1.725	1.438	1.775	0.938	0.795	0.795

Appendix B Table 4 (continued)

060977 (continued)

TEST	S/B or DEPTH(m)	0400	0800	1200	1600	2000	2400
K	S	0.048	0.051	0.048	0.038	0.028	0.030
K	B	0.068	0.056	0.066	0.038	0.031	0.030
MG	S	0.125	0.138	0.125	0.094	0.062	0.075
MG	B	0.181	0.150	0.188	0.087	0.075	0.075
CA	S	0.054	0.054	0.049	0.039	0.032	0.035
CA	B	0.072	0.060	0.070	0.041	0.036	0.036
NO2	S	0.0028	0.0029	0.0031	0.0038	0.0071	0.0045
NO2	B	0.0024	0.0024	0.0024	0.0032	0.0038	0.0038
NO3	S	0.103	0.073	0.018	0.051	0.066	0.011
NO3	B	0.132	0.106	0.158	0.073	0.073	0.077
NH4	S	0.010	0.041	0.027	0.044	0.048	0.110
NH4	B	0.032	0.028	0.048	0.048	0.121	0.088
NTOT	S	0.490	0.235	0.360	0.370	0.430	0.196
NTOT	B	0.255	0.480	0.355	0.360	0.385	0.290
NDISS	S	0.263	0.238	0.100	0.315	0.156	0.200
NDISS	B	0.210	0.232	0.210	0.240	0.210	0.205
PTOT	S	0.131	0.144	0.087	0.203	0.168	0.081
PTOT	B	0.140	0.161	0.235	0.101	0.219	0.256
PDISS	S	0.081	0.101	0.083	0.089	0.109	0.097
PDISS	B	0.112	0.099	0.109	0.080	0.093	0.093
PORTHO	S	0.056	0.060	0.061	0.065	0.080	0.064
PORTHO	B	0.092	0.071	0.094	0.057	0.059	0.070
WIND	-	SSE 5	SSE 12	SSE 10	SW 20	W 25	W 25
SKY/WX	-	☉	☉	☉ T RW	0	0	0

^b mg C/m³/4 h -- based on 4 h incubations beginning at time shown

Appendix B Table 4 (continued)

072877 - Daymark 9 near Blount's Bay

TEST	S/B or DEPTH(m)	0000	0400	0800	1200	1600	2000
TEMP	S	25.8	25.1	25.0	25.5	26.8	25.5
TEMP	B	25.8	25.3	25.5	25.6	25.1	24.9
SAL	S	8.9	8.9	8.5	9.0	9.1	9.0
SAL	B	9.0	9.0	9.1	9.1	9.1	9.1
COND	S	15.700	15.800	14.800	15.800	15.900	15.800
COND	B	15.800	15.900	16.000	15.900	15.900	16.000
DO	S	6.0	5.8	6.0	7.4	8.2	7.8
DO	B	5.8	5.5	4.9	5.5	4.8	4.9
DOC	S	8.1	8.0	7.8	8.5	9.0	8.9
DOC	B	7.8	7.5	7.8	8.0	8.5	7.9
POC	S	1.4	1.3	1.4	1.7	1.7	1.5
POC	B	1.6	1.6	1.7	1.5	1.4	1.5
SECC	-	***	***	0.6	0.6	0.5	***
PRODUC ^b	S	***	92.0	296.8	401.1	48.8	***
SECRET ^b	S	***	15.3	32.1	40.9	10.3	***
pH	S	6.80	6.80	6.80	6.85	6.85	6.85
ALKAL	S	1.14	1.16	1.26	1.34	1.32	1.28
CHLRA	S	9.9	9.5	8.7	10.6	10.9	9.5
CHLRA	B	8.9	8.7	9.0	4.6	6.1	5.9
CHLRAC	S	8.1	8.1	8.0	9.1	8.0	8.4
CHLRAC	B	8.0	8.1	8.6	4.3	5.5	5.4
CHLRB	S	0.5	0.4	0.8	0.5	1.1	0.4
CHLRB	B	0.1	0.0	0.8	0.0	0.7	0.6
CHLRC	S	5.1	4.8	5.7	6.3	7.3	6.1
CHLRC	B	4.6	5.0	7.1	3.2	4.1	3.8
CAROT	S	10.0	10.1	9.5	14.6	12.2	8.8
CAROT	B	9.9	9.0	9.9	6.1	7.8	8.6
PHAE0	S	5.4	4.6	3.9	5.1	5.8	5.9
PHAE0	B	5.1	2.1	6.1	0.7	3.9	2.8

^b mg/m³/4 h -- based on 4 h incubations beginning at time shown

Appendix B Table 4 (continued)

072877 (continued)

TEST	S/B or DEPTH(m)	0000	0400	0800	1200	1600	2000
NA	S	3.200	3.000	2.900	1.900	2.500	3.100
NA	B	3.000	3.100	2.900	3.100	2.100	2.800
K	S	0.122	0.118	0.102	0.072	0.090	0.120
K	B	0.118	0.120	0.098	0.120	0.072	0.104
MG	S	0.384	0.381	0.312	0.219	0.275	0.375
MG	B	0.381	0.375	0.300	0.369	0.225	0.325
CA	S	0.115	0.125	0.104	0.069	0.090	0.110
CA	B	0.111	0.116	0.104	0.106	0.070	0.100
NO2	S	0.0032	0.0022	0.0026	0.0028	0.0029	0.0032
NO2	B	0.0026	0.0026	0.0024	0.0021	0.0026	0.0025
NO3	S	0.235	0.198	0.160	0.204	0.160	0.190
NO3	B	0.163	0.198	0.160	0.220	0.165	0.170
NH4	S	0.017	0.020	0.019	0.126	0.019	0.019
NH4	B	0.018	0.019	0.030	0.018	0.019	0.021
NTOT	S	0.720	0.790	0.770	0.960	0.610	0.595
NTOT	B	0.840	0.640	0.670	0.680	0.550	0.620
NDISS	S	0.780	0.390	0.340	0.315	0.570	0.365
NDISS	B	0.450	0.590	0.390	0.408	0.355	0.305
PTOT	S	0.284	0.242	0.267	0.283	0.275	0.270
PTOT	B	0.290	0.255	0.271	0.273	0.277	0.274
PDISS	S	0.231	0.217	0.198	0.212	0.223	0.216
PDISS	B	0.232	0.215	0.180	0.216	0.211	0.147
PORTHO	S	0.199	0.185	0.171	0.183	0.191	0.190
PORTHO	B	0.193	0.189	0.158	0.187	0.181	0.129
WIND	-	N 15	N 5	N 8	N 12	N 5	N 2
SKY/WX	-	☉	☉	☉	☉	☉	☉
RESP5(26)	S	***	***	***	4.2	***	5.8
RESP5(26)	B	***	***	***	5.0	***	4.1
RESP1(26)	S	***	***	***	0.025	***	0.042
RESP1(26)	B	***	***	***	0.035	***	0.021