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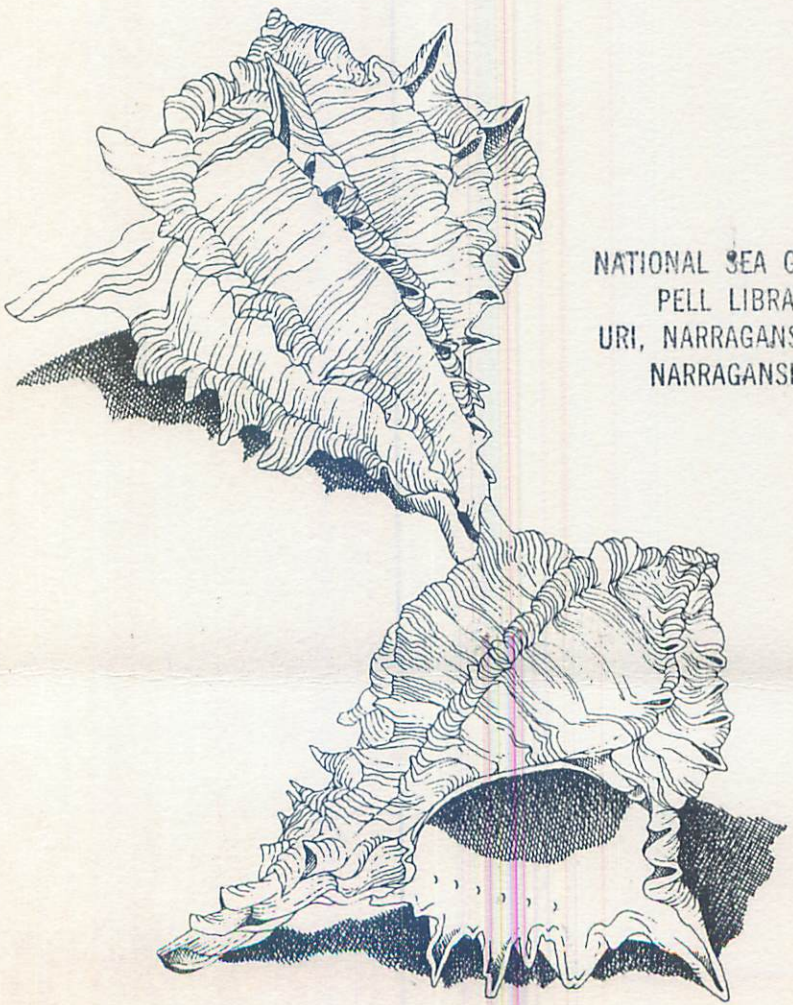

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CHARACTERISTICS OF A BLUE-GREEN ALGAL BLOOM IN THE NEUSE RIVER, NORTH CAROLINA

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ABSTRACT

During the summer of 1983 a massive blue-green algal bloom, dominated by Microcystis aeruginosa, developed in the lower Neuse River, N.C. In this report we present detailed data on the spatial and temporal extent of the bloom and associated water chemistry. The data were based on an intensive sampling program during August and September covering 154 km of the river from Goldsboro downstream past New Bern . At times the algal bloom spanned over 100 km, from Seven Springs to Street's Ferry Bridge. It was most intense at Fort Barnwell, as indicated by chlorophyll a concentrations up to 1500 ug/liter. Below Fort Barnwell, the blue-green algal bloom diminished rapidly , but there was a chrysophyte bloom farther downriver in the headwaters of the Neuse Estuary near New Bern. Concentrations of inorganic nitrogen and phosphorus decreased downriver; however, measurable quantities were found throughout most of the river. There was little evidence that nitrogen, phosphorus, or carbon limited growth of the riverine bloom algae, at least during bloom development. The nutrient closest to becoming limiting, however, was nitrogen, and some evidence exists to indicate that limitation arose once the bloom was established.

The paper and pulp mill above New Bern was shown to increase nutrient concentrations in the river locally. The effluent from this mill appeared to have little impact on the blue-green algal bloom, but its relationship to the estuarine bloom is unclear.

Nutrient concentrations were no higher in 1983 than during nonbloom years; thus it is unlikely that increased nutrient availability within a particular volume of water was responsible for the bloom. Unusually low river flow in 1983 may have been a key factor promoting bloom development.

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INTRODUCTION

Blue-green algal blooms have occurred periodically in the lower Neuse River since the late 1970s. These blooms aroused public concern over the apparent deterioration of water quality in the river and the threat this posed to the Neuse Estuary farther downstream. This concern led to increased research, monitoring and management efforts sponsored by several agencies. In this report, we describe the results of one such effort funded jointly by the University of North Carolina Sea Grant College Program and the Water Resources Research Institute.

Specifically, we present the results of an intensive sampling program directed toward characterizing the distribution of nutrients, algae and algal productivity during a massive blue-green bloom that occurred in 1983. Also, we discuss the interaction of biological, chemical and physical variables in promoting, maintaining and causing the decline of the blue-green algal bloom. Lastly, we provide evidence that although the blue-green algal bloom was restricted to the river, its occurrence coincided with a secondary bloom of other algae downstream at the head of the estuary.

Description of the river system

The Neuse River Basin, a major watershed in North Carolina, drains about 12 percent of the state's land area. Its headwaters at the junction of the Flat and Eno Rivers are within the Piedmont above the recently constructed Falls of the Neuse Reservoir and the urban areas of Durham and Raleigh. The river flows southeasterly through the coastal plain to New Bern where it broadens and mixes with seawater to form the Neuse River Estuary. The Estuary in turn empties into the southern end of Pamlico Sound (Figure 1).

The majority of the land within the basin is agricultural or forested (approximately 88 percent). According to a preliminary nutrient budget (N.C. Department of Natural Resources and Community Development (NCDNRCD) 1983) 79 percent of the total nitrogen loading and 55 percent of the total phosphorus loading to the river come from nonpoint sources. The remainder (21 percent of the nitrogen and 45 percent of the phosphorus) is from 16 municipal and industrial point sources. Most of these are sewage treatment facilities, but the largest discharge is from a paper pulp mill near the river's mouth.

There is general agreement that growth of population, intensified agriculture and industrialization have increased the quantities of nitrogen and phosphorus entering the Neuse River. In 1980, about 1.2 million people lived in the basin, a 19 percent increase in population over the preceding decade. But it has been estimated that total nitrogen concentrations and average loading increased by a much higher percentage (about 60 percent) during the 1970s (NCDNRCD 1983). The result of high loading rates and rapid recycling is that the Neuse River appears to have nitrogen and

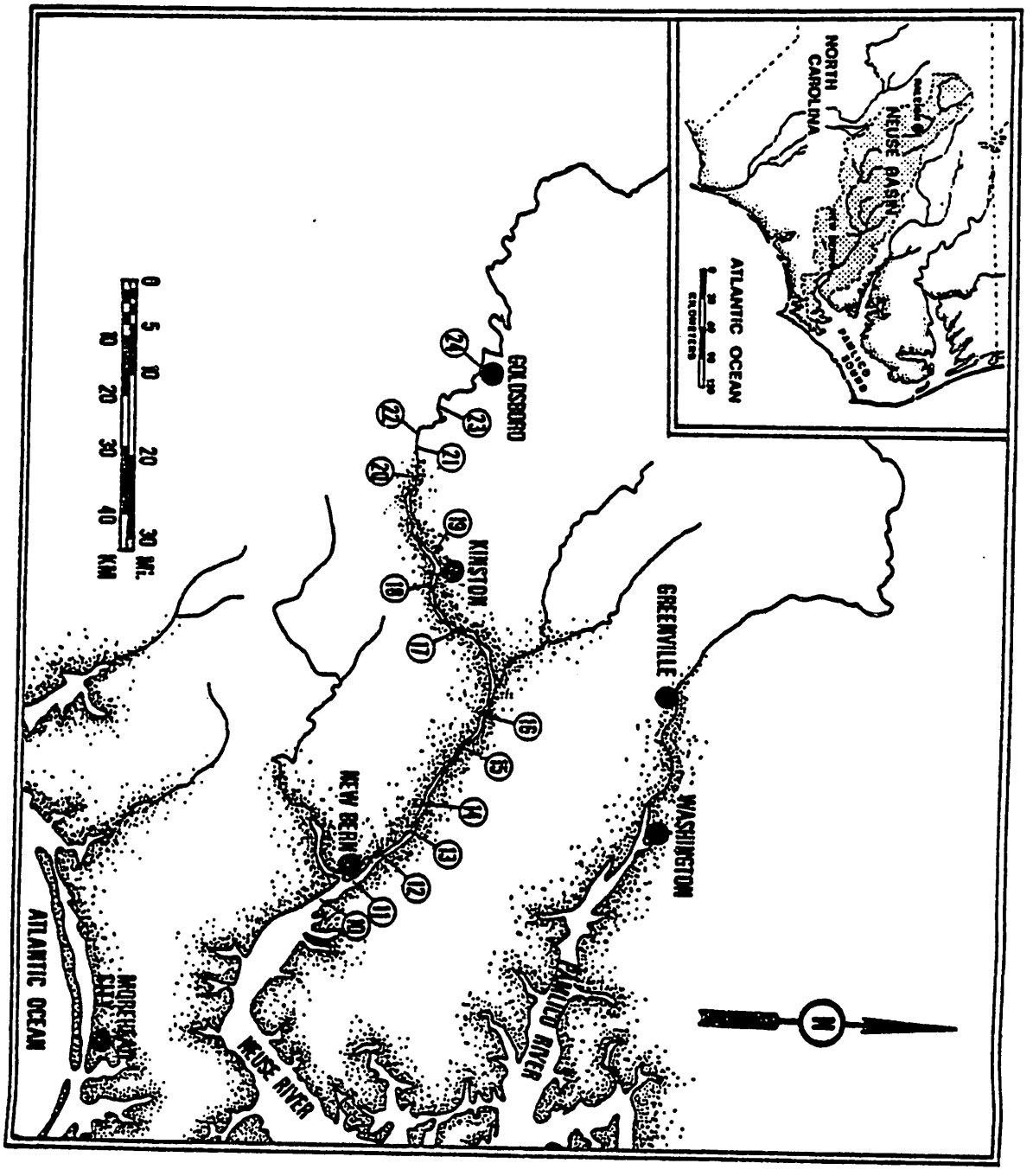

FIGURE 1. MAP OF THE NEUSE RIVER STUDY AREA, SHOWING LOCATIONS OF SAMPLING STATIONS

phosphorus available in excess of algal demands under most conditions (Paerl 1983a, Stanley 1983). The water quality concerns for the Neuse River follow those for the Chowan River, which already has been classified by the state as a "nutrient sensitive waterway." The intent of this classification is to prohibit increases in nutrient concentrations in the river (NCDNRCD 1982). Thus, declaration of the Neuse Rover is another nutrient sensitive system is being considered as a first step toward curtailing the deterioration of the river's water quality and its value as an ecological resource.

Previous studies of the Neuse

Other than chemical data collected by the U.S. Geological Survey during a few years in the 1950s and 1960s, most of the information about water quality in the Neuse River has been gathered since the 1970s. Harned (1980) summarized the data collected through 1978 from Clayton, a piedmont site, and from Kinston, a coastal plain site. Hobbie and Smith (1975) reported on studies of the Neuse River Estuary during the early 1970s. Both reports indicated high nitrogen and phosphorus concentrations, although they were generally higher in the river than in the estuary.

Monitoring of the Neuse has increased in intensity since 1978. The N.C. Division of Environmental Management conducts a nutrient and phytoplankton monitoring program, and their data have been summarized in various reports (e.g., NCDNRCD 1980, 1982, 1983, 1984). These reports emphasize the recurrence of blue-green algal blooms on the Neuse, the presence of high nutrient concentrations, the importance of the physical environment in triggering blooms, and the need to reduce nutrient loading.

Research on water quality in the lower Neuse has been ongoing since 1980. Paerl (1983a, 1987) and Paerl and Bowles (1987) conducted a series of algal bioassays from which they concluded that nitrogen and phosphorus often are not limiting to algal growth, but that nitrogen is closer to limiting concentrations than phosphorus. Dissolved inorganic carbon was found to be a potentially limiting factor to primary productivity because of the low alkalinity of the Neuse water. Paerl (1983) also provided evidence that low river flow increases the likelihood of bloom development during summer months when temperature and solar radiation are high. Lastly, Paerl (1983a, 1984) suggested that although elevated salinities can deter the growth of the blue-green algae (Microcystis aeruginosa, Anabaena spiroides and Aphanizomenon flos aquae) in the estuary, the intrusion of saline waters into the river was not sufficient to account for the decline of the 1981 bloom, because salt wedges did not spatially overlap with upstream regions where blooms developed.

Stanley (1983) examined nitrogen cycling, algal photosynthesis and standing crop at a station near Clayton and at a coastal plain station, Cowpen Landing, during 1982, a nonbloom year. He found high nutrient concentrations and low algal biomass and primary productivity throughout the year at both stations. Although most of the total inorganic nitrogen (TIN) was NO_3-N, 80 percent of the assimilated nitrogen was NH_4-N. Also,

ammonification rates were generally sufficient to replenish assimilated nitrogen. Again the conclusion was made that nutrients are consistently present in quantities to allow bloom formation and that river flow represents an important regulating factor.

The importance of river flow was reiterated by Stanley and Christian (1984) and Christian et al. (1986). Based on data from several years under widely varying conditions, their conclusion was that chlorophyll a in the lower Neuse remains low (less than 20 ug/liter) and is independent of river flow at flows (measured upriver at Kinston) above 800 to 1,000 cubic feet per second, regardless of the time of year. But at lower discharge rates, chlorophyll a in the river rises dramatically. Stanley and Christian (1984) postulated that at high flows time-of-travel decreases (i.e., river velocity increases), water clarity decreases and turbulence increases, resulting in less favorable conditions for bloom algae and hence prevention of bloom formation. A short time-of-travel means that algae are flushed into the estuary prior to reaching bloom proportions. They tested this hypothesis by means of a mathematical model based on field studies of time-of-travel at different flows and laboratory studies of the growth rates of M. aeruginosa, the blue-green alga that is dominant during blooms (Christian, et al. 1986). The hypothesis was supported by results of model simulation runs, which showed agreement between observed and predicted bloom occurrence over the period from May 1979 through July 1985. The results indicated that water temperature, day length and river flow are key factors in determining whether or not blooms form, assuming nutrient sufficiency for the months May through September. July was found to be the month during which bloom potential is the greatest.

There have been several other recent publications that have added to the ecological information base for the Neuse. These include reports on ecological changes occurring at the freshwater-seawater interface (Christian et al. 1984), primary productivity (Fisher et al. 1982b) and sediment-water interactions within the estuary (Fisher et al. 1982a, Matson et al. 1983). In addition, the physiological ecology of bloom algae has been studied by Paerl and co-workers (Paerl 1983b, Paerl et al. 1985). Thus, a general understanding of the Neuse ecosystem is developing, largely as a result of the concern about the blue-green algal blooms and the need to protect the river and estuary.

Objectives

As described above, blue-green algal blooms have been the focus of Neuse River monitoring and research for several years. But until 1983 there had been no detailed study of nutrient and algal dynamics during the course of a bloom. A massive bloom that developed on the Neuse that summer afforded us the opportunity for such a study. We designed a sampling program to address the following questions:

1) What was the areal extent of the bloom and how long did it last?

2) What was the species composition, cell density and biomass of the algal assemblage during the course of the bloom?

3) What were the patterns of nutrient concentrations in the river during the bloom period?

4) What effects did effluent from Weyerhaeuser's paper and pulp mill have on bloom dynamics?

5) What relationship was there between river flow and bloom characteristics?

6) Did the estuarine microbial community react in any unusual way that could be linked to the freshwater bloom?

In this report we describe results from this sampling effort with respect to these questions.

METHODS

During the first half of 1983, a semimonthly sampling program was maintained at Cowpen Landing, a site on the lower Neuse River a few kilometers upstream from the freshwater-seawater interface (Figure 1). In July, we noted an increase in chlorophyll a concentrations at Cowpen and visible signs of bloom development there and elsewhere in the river. To determine the extent of this bloom, we immediately extended our sampling downriver into the estuary and upriver to Kinston. By mid-August it had become apparent that this was indeed a major blue-green algal bloom. On August 23, we began intensive monitoring. From this date until September 9, we sampled daily or every other day at 15 stations between river marker 22 below New Bern (station 10) and Goldsboro (station 24) (see Figure 1 and Table 1 for station locations). Stations 16 to 24 were intentionally located at highway bridges crossing the river so that we would not have to sample this section of the river by boat. The Goldsboro station was above the bloom, and the station below New Bern was in brackish water downriver from the bloom. Samples were collected on a less frequent schedule (September 13, 19 and 26) as the bloom declined.

Surface water samples were usually collected early in the morning. One person sampled stations 16 to 24 by lowering a bucket from the highway bridges; another person sampled stations 10 to 15 from a boat. Salinity and temperature of the samples were measured in the field, and sample water was placed in acid washed, one-gallon plastic jugs and kept in subdued light for transport to the laboratory.

Usually the samples were in the laboratory by late morning or early afternoon. There subsamples were taken for nutrient, chlorophyll a, algal biomass and primary productivity measurements. Glass fiber filters (Whatman GF/C) were used to separate the dissolved and particulate fractions. Nutrient samples were stored frozen (nitrogen and phosphorus),

Table 1. Locations of Neuse River sampling stations

Station	Latitude-Longitude	Location
10	N35°04'50"-W77°00'20"	River Marker 22
11	N35°06'22"-W77°01'57"	River Marker 34 (New Bern)
12	N35°09'04"-W77°04'25"	River Marker 52
13	N35°11'16"-W77°05'43"	River Marker 67
14	N35°12'37"-W77°07'23"	State Road 1400 Bridge (Streets Ferry)
15	N35°19'19"-W77°10'00"	State Road 1449 Bridge (Cowpen Landing)
16	N35°18'46"-W77°18'19"	State Road 1470 Bridge (Fort Barnwell)
17	N35°17'45"-W77°29'48"	N.C. Highway 55 Bridge
18	N35°14'46"-W77°35'03"	N.C. Highways 11-55 Bridge (Kinston)
19	N35°15'40"-W77°37'05"	U.S. Highway 70 Bypass Bridge (Kinston - west)
20	N35°13'28"-W77°46'01"	State Road 1152 Bridge
21	N35°13'58"-W77°49'18"	State Road 1002 Bridge
22	N35°13'44"-W77°50'48"	State Road 1731 Bridge (Seven Springs)
23	N35°15'41"-W77°54'38"	N.C. Highway 111 Bridge
24	N35°20'12"-W77°59'51"	State Road 1915 Bridge (Goldsboro)

or refrigerated for a short time and analyzed later by standard methods given in Table 2. Ammonium concentration analyses were done on day of sampling. The algal samples were preserved with Lugol's acetic acid solution and later were counted by light microscopy. To concentrate the preserved algae prior to counting, we used the membrane filtration method (Am. Public Health Assoc. 1980). Algal wet weight biomass was calculated from the algal cell counts and the estimated average volume of each species. As is customary for this kind of analysis, we assumed a specific gravity of unity for the algae (i.e., 1 mm^3 = 1 mg wet weight).

Algal photosynthesis was measured by the carbon-14 technique (Steemann-Nielsen 1952). Samples were incubated for two to four hours in 150 ml glass bottles with 1 ml of a one uCi/ml solution of $NaH^{14}CO_3$. The bottles were placed in a water bath under soft white fluorescent tubes that provided near-saturation light intensity (Christian et al. 1986). Temperature of the water bath was maintained near ambient river temperature by an automatic heat exchange device. After incubation aliquots of the samples were filtered through Whatman 934/AH glass fiber filters. The filters were assayed for radioactivity using a liquid scintillation counter. Total inorganic carbon was determined by infrared analysis.

Most of the data in this report are presented in the form of contour maps of the concentration or rate plotted against sampling date (x-axis) and distance upriver or downriver from New Bern (y-axis) (e.g., Figure 2). These contour maps were generated by SYMAP, a computer mapping program (Dougenik and Sheehan 1979). Station numbers are also listed along the right margin of each map. Alphabetic symbols A through F within the maps show the locations and dates of individual samples. These six symbols represent six value ranges that were chosen for each data set. Each range is depicted by a different shading pattern such that more intense shading corresponds to higher values of the variable. Lines separating the levels of shading are isopleths of particular values. Interpolation between sample values was done by the default procedure in SYMAP.

RESULTS AND DISCUSSION

Salinity and temperature

The overall surface salinity pattern during the month of intensive study is shown in Figure 2. Sea water was detected as far as 10 km upstream from New Bern between stations 14 and 15. Downriver, salinity increased gradually to around 5 ppt at the station (10) just below New Bern. Although only surface salinities are shown in Figure 2, we also measured bottom salinities at each station. The results were that above New Bern there was little difference between the surface and bottom measurements, indicating that there was no strong salt wedge in this vicinity. Paerl (1987), sampling less frequently but during the same period, did find a salt wedge near our station 12. Below New Bern, however, a salt wedge was more evident. The lack of a strong salt wedge upriver probably was due to the very low river flow (Figure 3), which

Table 2. Methods used for chemical and biological analyses of water samples

Variable	Preservation Mode	Analysis Technique	Reference
Nitrogen concentrations:			
Ammonium	same day measurements	colorimetric	Solorzano (1969)
Nitrate & nitrate	freezing	cadmium reduction	Strickland & Parsons (1972)
Filterable Kjeldahl	filtration/freezing	Kjeldahl	APHA (1980)
Particulate Kjeldahl	filtration/freezing	Kjeldahl	APHA (1980)
Phosphorus concentrations:			
Filterable reactive	filtration/freezing	molybdate	EPA (1979)
Total filterable	filtration/freezing	persulfate digestion	EPA (1979)
Total	freezing	persulfate digestion	EPA (1979)
Total inorganic carbon	refrigeration	infrared analysis	Stanley (1983)
Chlorophyll *a*	filtration/freezing	acetone extraction colorimetric	Strickland & Parsons (1972)
Primary productivity	N/A	$^{14}CO_2$ uptake	Stanley (1983)
Algal species & biomass	Lugol's solution	microscopy	APHA (1980)
Temperature	N/A	YSI meter	
Salinity	N/A	YSI meter	

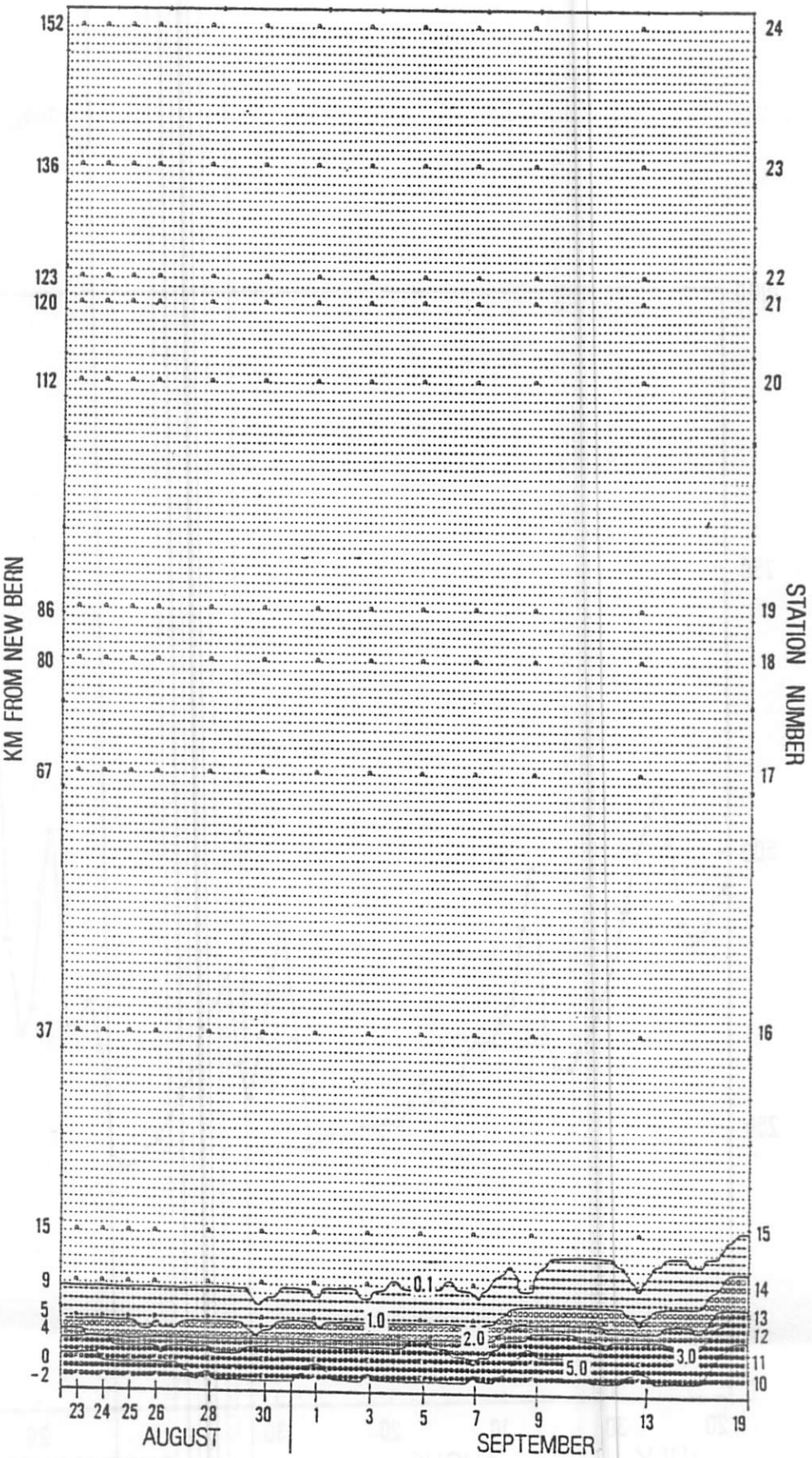

FIGURE 2. CONTOUR MAP OF SALINITY FROM AUG. 23 TO SEPT. 19, 1983

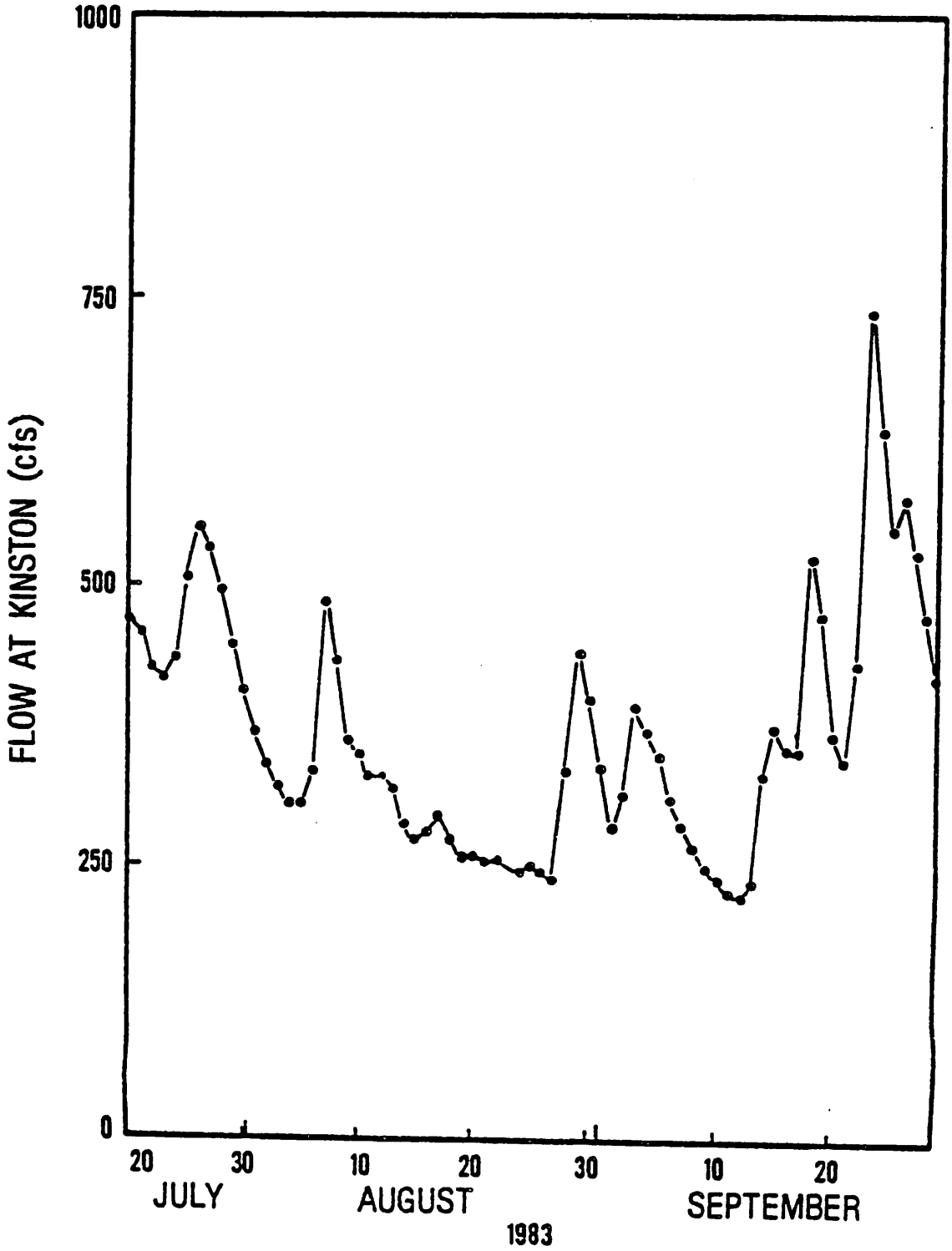

FIGURE 3. NEUSE RIVER FLOW (CFS) AT KINSTON DURING STUDY PERIOD

failed to provide the horizontal advective force necessary to create a strong salt wedge.

At stations 10 through 15, water temperatures ranged from 23C to 29C during the month of intensive study. They were highest during August, and declined slowly to 26C on September 13. Lower temperatures were found on September 19 after a rain storm on the previous day. For a given day there was no noticeable variation in temperature among the stations. Usually surface and bottom water temperatures were the same, but occasionally bottom temperatures were slightly (less than 2C) cooler than surface temperatures.

Algal chlorophyll a and wet weight biomass

Between January and mid-July 1983 chlorophyll a concentrations at Cowpen Landing were uniformly low (Figure 4), ranging from less than 1 ug/liter on several occasions to 14 ug/liter in March. Similarly, 21 of the 24 river samples collected in 1982 during another study had chlorophyll a concentrations less than 15 ug/liter (Stanley 1983). Such low chlorophyll a levels are probably typical of nonbloom periods in the Neuse River.

As the 1983 bloom developed during late July, chlorophyll a concentrations rose dramatically (Figure 4). Unfortunately, the intensive sampling did not begin early enough to document this rise. But by 23 August, the concentrations were mostly over 40 ug/liter along a 105 km stretch of the river between stations 15 and 21 (Figure 5). Throughout the intensive study period, concentrations were generally low at the two most upriver stations, highest at Fort Barnwell (station 16), relatively low near the freshwater-seawater interface (stations 12 and 13), and intermediate-to-high farther out in the estuary (stations 10 and 11) below New Bern. The highest chlorophyll a concentration measured was 1541 ug/liter at station 16 on August 30.

There is evidence that the temporal-spatial pattern of chlorophyll a during the bloom was closely linked to variations in river discharge. Summer flow in the Neuse, based on U.S. Geological Survey data from 1931 to 1986, averages about 2000 cfs, but was much lower in 1983 because of unusually low rainfall in the spring and summer (Figure 3). In the month preceding the start of our intensive sampling, flow at Kinston had declined from around 500 cfs to 250 cfs. The decline was temporarily reversed once by increased runoff on Aug. 6 and 7, but otherwise continued uninterrupted until Aug. 28 (Figure 3). Blue-green algae apparently increased in density during this extended period of low flow (by a mechanism outlined below) until they reached bloom levels upriver. The flow rose sharply on Aug. 28 and 29, and this increased discharge seems to have resulted in a washout of algae in the river between Goldsboro and Kinston, resulting in somewhat lower chlorophyll a concentrations (Figure 5). As flow subsided during the next three days, chlorophyll a levels began to increase again in this region. The increases in chlorophyll a concentration were generally comparable to what would be predicted from growth rate estimates and

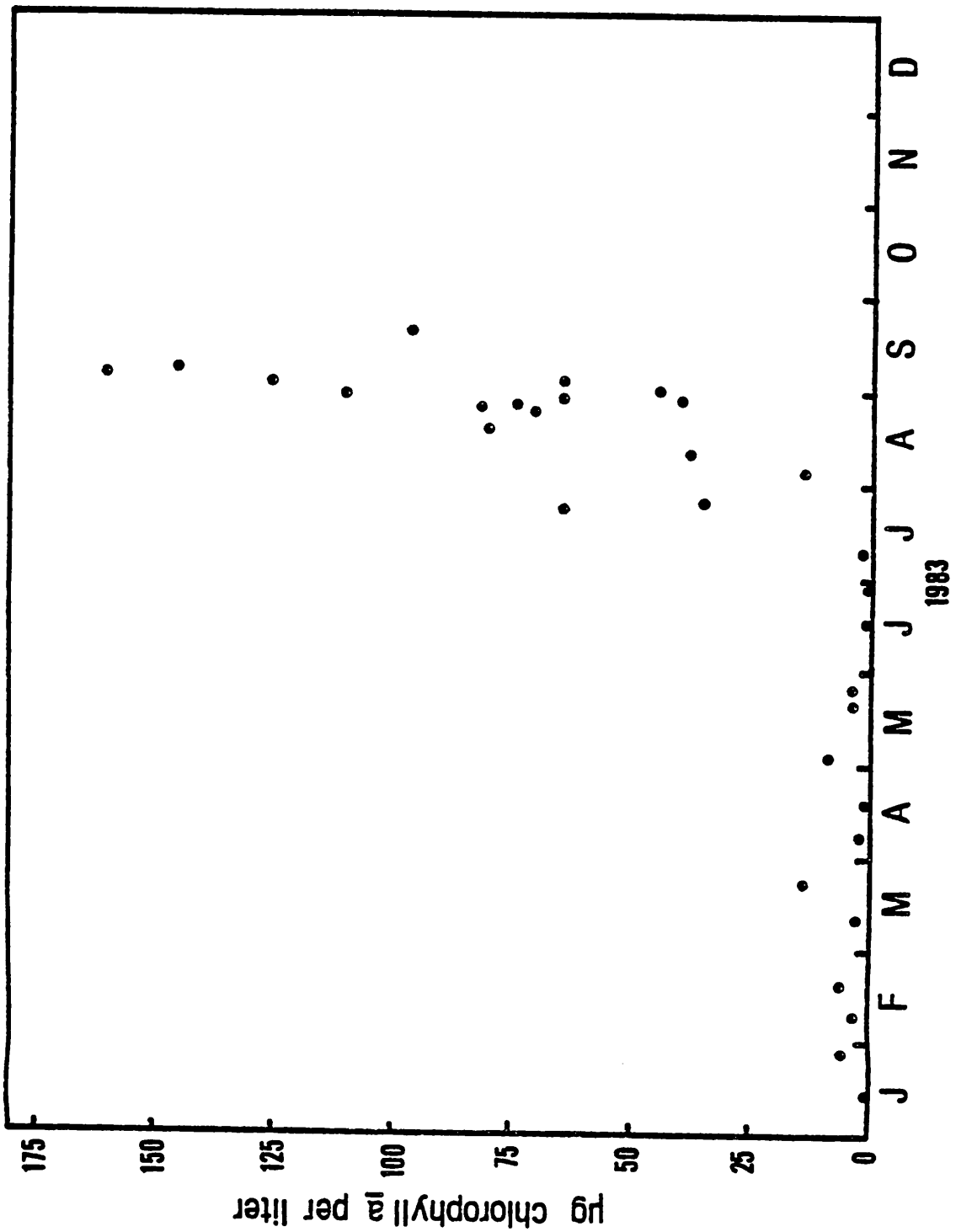

FIGURE 4. CHLOROPHYLL A CONCENTRATIONS AT COWPEN LANDING DURING 1983

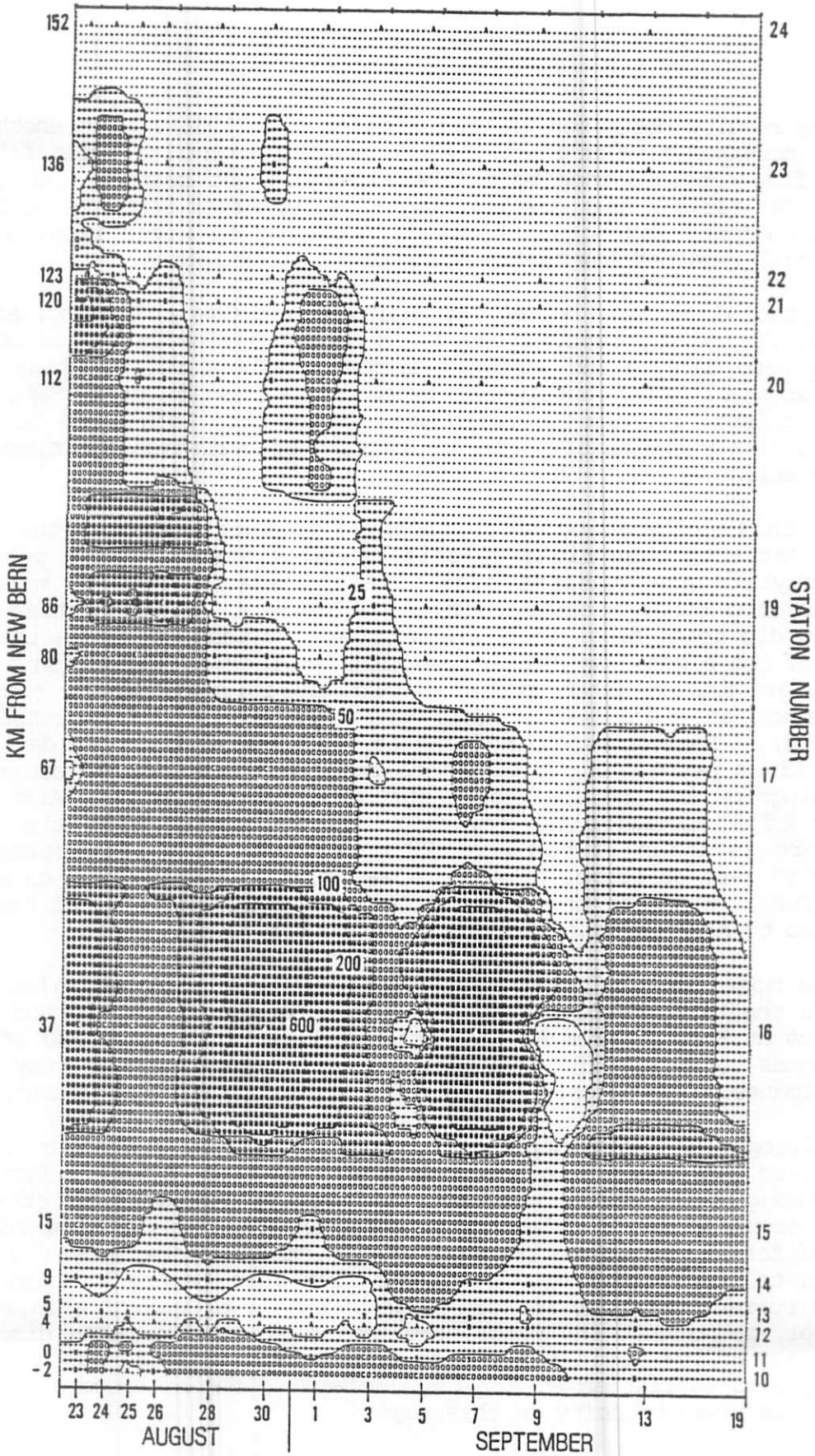

FIGURE 5. CONTOUR MAP OF CHLOROPHYLL A CONCENTRATIONS

modeling results described in Christian et al. (1986). But another storm led to increased flow on Sept. 2 and 3 and chlorophyll a again fell. Even though flow subsided once more, the algae did not respond with increased growth, for reasons that are unknown. Finally, after Sept. 12, a series of rainfall events led to substantial increases in river flow, and algal chlorophyll remained low in the Goldsboro-Kinston region.

Farther downriver, between Ft. Barnwell and Cowpen Landing, effects of the Aug. 28 and 29, Sept. 2 and 3 and Sept. 13 flow increases on chlorophyll a were delayed and somewhat dampened. The first of these slugs of low-chlorophyll water apparently reached station 15 about Sept. 4, the second on Sept. 10, and the third about Sept. 18. This seems to us to be the most likely explanation for the pattern of variation in chlorophyll at these stations.

If this explanation of chlorophyll variation during the bloom is indeed correct, then river velocities calculated from the patterns of chlorophyll concentrations over time and space ought to match those computed from other methods. If we assume that our sequential synoptic sampling did track slugs of bloom organisms, we can calculate the rate of travel of the bloom. We assume then that the high concentration of chlorophyll a at Kinston (station 19) on Aug. 26 corresponded to that of the first event at station 21. This was a period of fairly constant flow (Figure 3). The corresponding rate of travel was 11 km per day (0.46 km per h; 13 cm per sec). Computations based on movements of other chlorophyll slugs during the study gave similar rates of travel. Also, several gallons of a Rhodamine WT dye solution were dumped into the river at Goldsboro (station 24) on Aug. 22 and traced 37 km downstream. The calculated rate of travel of the dye was 13 km per day (0.55 km per h; 15 cm per sec). Based on these velocities, the estimated time of travel from Goldsboro to Kinston was approximately 6 to 6.5 days.

The model described by Christian et al. (1986) was also used to estimate the time-of-travel of river water between Goldsboro and Kinston. Discharge at Kinston from Aug. 23 through Aug. 27 averaged 250 cfs. This corresponds to a rate of travel of 14.3 km per day which is very close to the estimates based on chlorophyll a concentration and dye patterns.

Chlorophyll a concentrations decreased rapidly downriver from Fort Barnwell to less than 50 ug/liter at a station 5 km above New Bern (Figure 5). Although this dramatic decline of several hundred ug chlorophyll a/liter occurred over a relative short distance (32 km), the amount of time required for the water to traverse this distance probably was quite long compared to the time-of-travel upriver from Fort Barnwell. Paerl (1987), using a current meter to measure flow in the lower end of this region of the river, found that the water sometimes flows upriver when discharge at Kinston is as low as it was during the summer of 1983. Subsequent dye studies by us (Christian et al. 1986) have also demonstrated a substantial decrease in river velocity in this region.

The region of low chlorophyll a concentrations between Fort Barnwell and New Bern coincided with two features of the river. First, as seen in

Figure 2, the lower end of this region was at the freshwater-seawater interface (FSI), where river water and ocean water mixing begins. However, it is clear that the chlorophyll decline began far upriver from the FSI, which rules out the possibility that salinity caused the decline. This is supportive of the findings of Paerl (1983a). Second, the Weyerhaeuser pulp and paper mill releases its effluent into this region. The effluent darkly stains the water, and during the study period it represented about 9 percent of the total flow (see later discussion). Coloration decreased farther downstream as estuarine water, river water and effluent mixed.

At the head of the Neuse Estuary near New Bern, chlorophyll a concentrations rose again to 50 ug/liter or more. This secondary peak in the estuary was large relative to chlorophyll concentrations there during nonbloom summers. This is shown in Figure 6, which is a plot of chlorophyll at New Bern from the early 1970s (Hobbie and Smith 1975) and from our measurements during several more recent years. It is quite evident that the estuarine bloom in 1983 was concomitant with the freshwater, riverine bloom.

Figure 7 is a contour plot of total, wet weight biomass of phytoplankton. Generally, biomass showed less variability than chlorophyll a concentrations, but some of the apparent differences are a result of differences in the contour ranges used in the plots. Also, phytoplankton samples were taken less frequently than chlorophyll samples. However, a comparison of Figures 5 and 6 shows that the overall patterns in chlorophyll a and wet weight biomass are obviously similar. With a few exceptions, upriver stations had the lowest biomasses. The highest biomasses were at Ft. Barnwell (i.e. 162.4 mg/liter on Aug. 28 and 107.0 mg/liter on Sept. 1). Biomass declined downriver from Fort Barnwell until a secondary bloom was observed at the head of the estuary.

Dividing the total phytoplankton biomass into blue-green (Figure 8) and nonblue-green (Figure 9) components shows obvious differences in the biomass and distribution patterns of these two groups. Blue-green algae were found only once in the Goldsboro samples and only twice (Sept. 9 and 13) at station 23, 16 km below Goldsboro. However, the two peaks in chlorophyll near Seven Springs (Figure 4) were the result of blue-green algae. Blue-green algal biomass was greatest at Fort Barnwell where it accounted for almost all of the total algal biomass. M. aeruginosa was the dominant species, reaching densities as high as 4,700 million cells/liter (station 16, August 28). Below Ft. Barnwell blue-green algal biomass decreased until none were found at the final two stations during the entire study period. However, between Sept. 19 and 26, rain caused a washout of blue-green algae into the estuary from the Neuse River and perhaps other tributaries. Consequently, on Sept. 26, M. aeruginosa was found at estuarine stations as far down as Janiero (Figure 1).

The upriver algal assemblage was dominated by eukaryotic, nonblue-green algae except during the two previously described peaks in biomass (Figure 9). Also, in the reach between Seven Springs (station 22) and Kinston (stations 17 and 18), eukaryotic algae dominated the assemblage much of the time. However, in the Ft. Barnwell-Cowpen Landing area, these

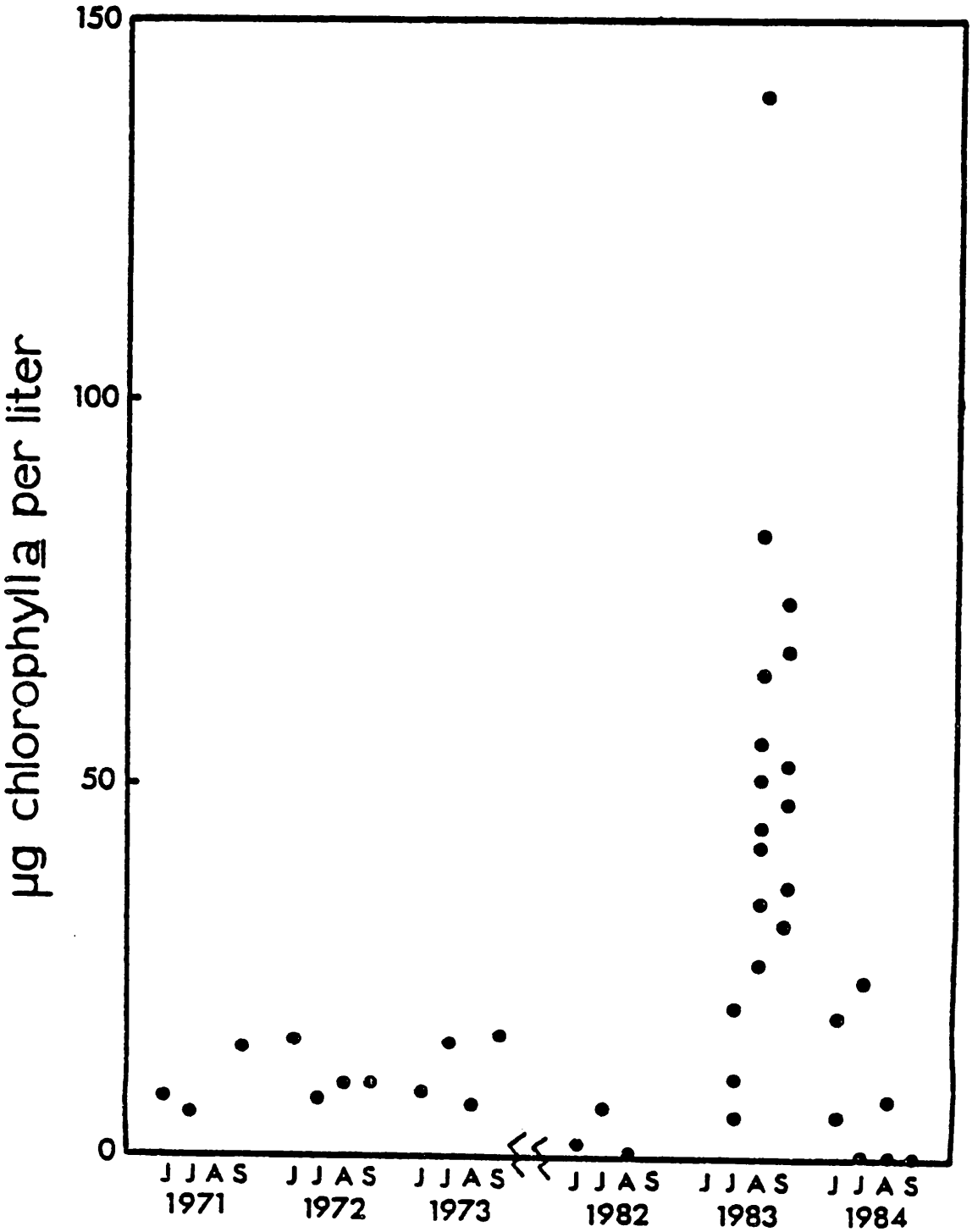

FIGURE 6. SUMMER CONCENTRATIONS OF CHLOROPHYLL A AT NEW BERN

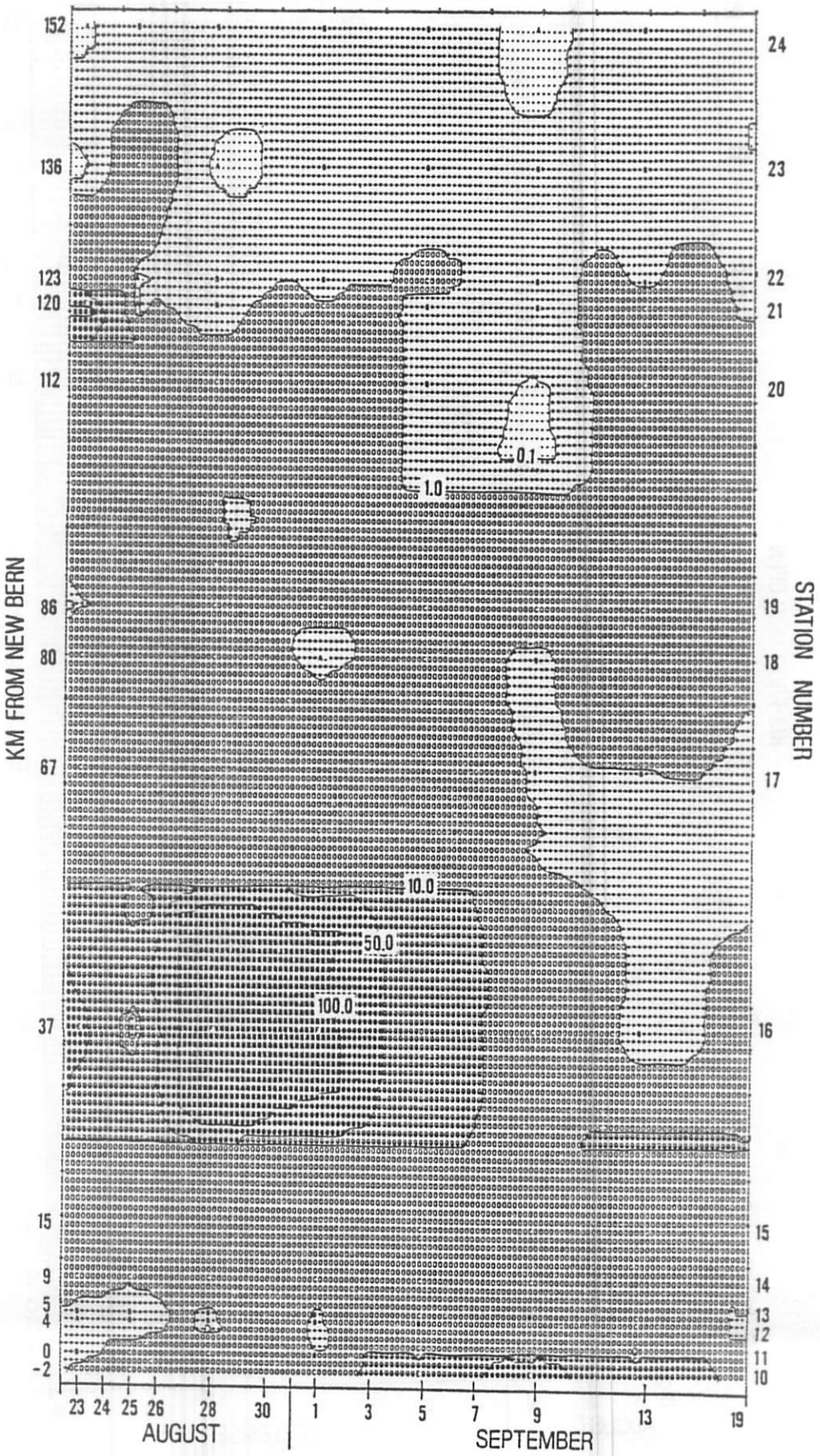

FIGURE 7. CONTOUR MAP OF TOTAL, WET WEIGHT BIOMASS OF PHYTOPLANKTON

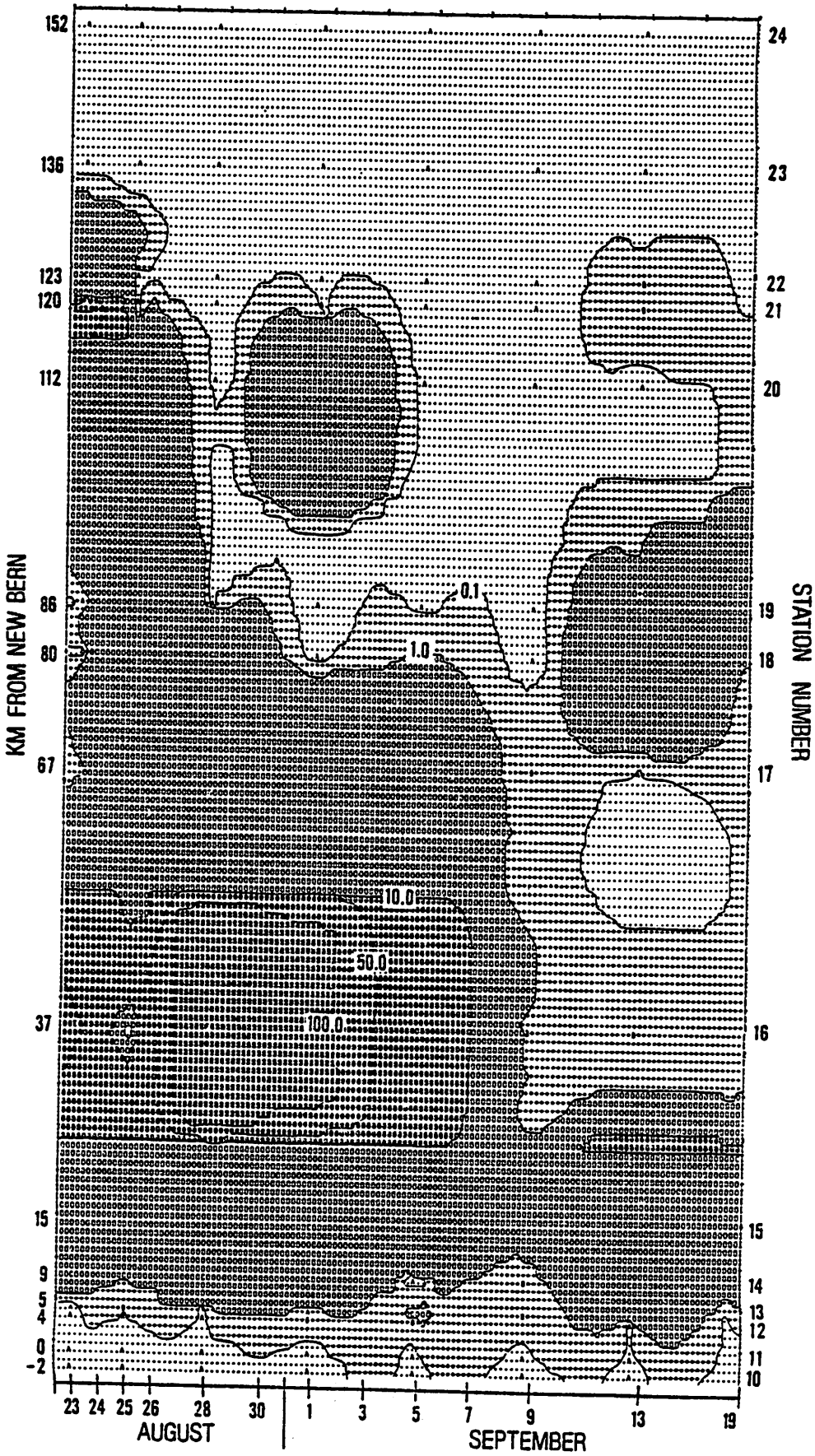

FIGURE 8. CONTOUR MAP OF BLUE-GREEN ALGAL BIOMASS

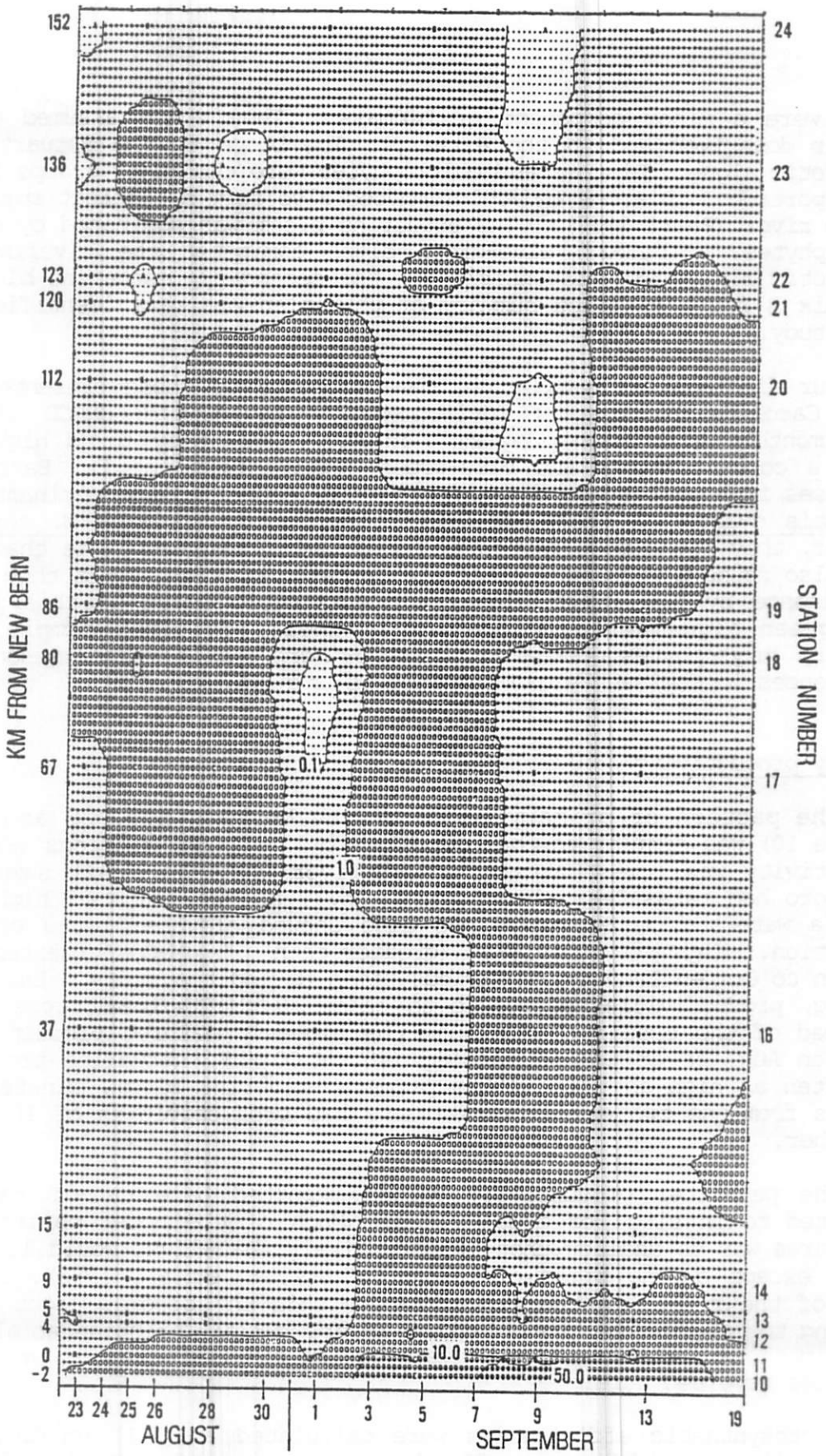

FIGURE 9. CONTOUR MAP OF NONBLUE-GREEN ALGAL BIOMASS

algae were a minor component of biomass. They again assumed dominance farther downriver and in the estuary. The bloom in the estuary was all eukaryotic algae. Diatoms and chlorophytes were the major groups in freshwater portions. Diatoms and chlorophytes also form a distinct spring bloom in the river (Paerl 1987). The estuarine bloom was dominated by nondiatom chrysophytes. Although blue-green algae dominated the riverine bloom, eukaryotic algae were responsible for the secondary, estuarine bloom. See Appendix E for a detailed summary of phytoplankton taxa identified during this study.

Our findings are similar in some respects to those presented by the North Carolina Division of Environmental Management (NCDNRCD 1984) from their monthly monitoring program. In Aug. 1983, they found high chlorophyll a concentrations and blue-green algal biomass at Ft. Barnwell and decreases in both farther downriver. They identified the dominant alga as Anacystis cyanae, which we believe to be synonymous with M. aeruginosa. However, they found more diversity among the blue-green algae than we did. They also found a secondary bloom at New Bern, but for August they reported a dominance by blue-green algae, not eukaryotic algae at this location. Blue-green algae were not present in their September sample, and in October, chrysophytes dominated their New Bern sample. The reason for the differences in dominant algae reported is unknown.

Primary productivity

The pattern of primary productivity between Aug. 23 and Sept. 9 (Figure 10) was similar to that of chlorophyll a concentrations (Figure 5). Productivity was lowest at the most upriver stations. All samples from Goldsboro had rates less than 1 uM CO_2/h. The two slugs of high chlorophyll a waters from Seven Springs also showed elevated rates of primary production. High productivities (greater than 20 uM CO_2/h) extended from Kinston to Cowpen Landing at various times during the study. Below Cowpen Landing, productivities decreased to below 10 uM CO_2/h but rose again at the head of the estuary. Although the highest measured productivity was found on Aug. 28 at Cowpen Landing (40 uM CO_2/h), estuarine productivity was often as high as that in the primary, riverine bloom. Nineteen of 22 samples from the two estuarine stations had productivities of 10 uM CO_2/h or higher.

The per-liter productivity values reported here cannot readily be converted to in situ or areal rates. Much of the upper portion of our study area was so shallow that it is unlikely that light would limit algal growth except during times of blooms (Christian et al. 1986). In deeper parts of the river, in the estuary and within the blooms, light could be limiting to many of the phytoplankton (Paerl 1983a; Christian et al. 1986). Thus, in those instances, depth averaged, in situ rates would be less than the rates reported here.

Photosynthetic efficiencies were calculated as: 1) um CO_2/(h x ug chlorophyll a), and 2) as um CO_2/(h x mg wet wt. of phytoplankton). Mean values of the first efficiency index for the 15 stations over the study

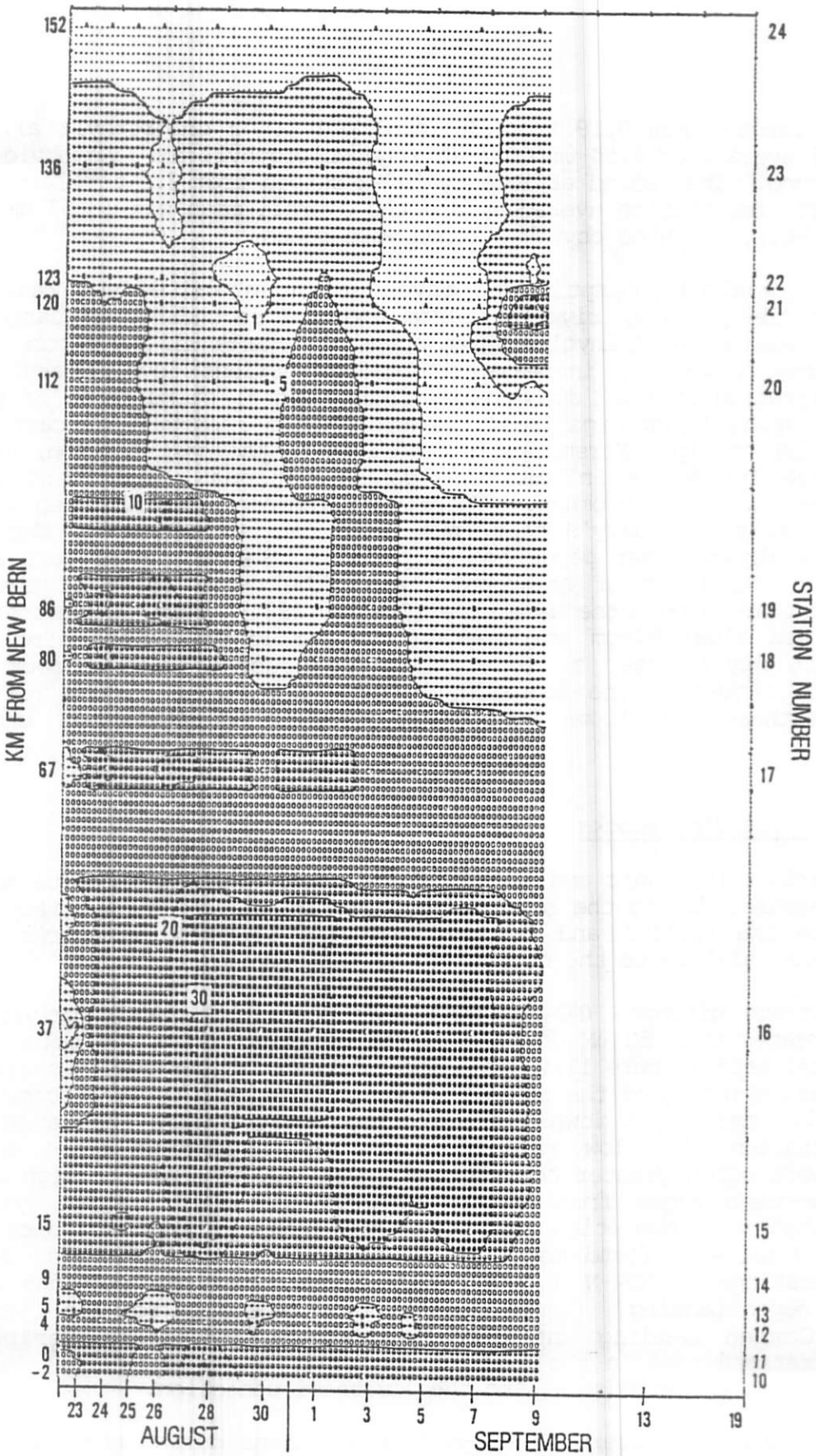

FIGURE 10. CONTOUR MAP OF PRIMARY PRODUCTIVITY NEAR LIGHT SATURATION AND AT IN SITU TEMPERATURE

period ranged from 0.19 to 2.36 um CO_2/(h x ug chlorophyll a), with an overall average of 0.54 um CO_2/ (h x ug chlorophyll a). No obvious trends were found. The second efficiency index ranged from 2.0 to 122.6 um CO_2/(h x mg wet) for station averages, and the overall mean was 18.53 um CO_2/(h x mg wet wt.). Again no obvious trends were found.

It would be tempting to invoke a cause and effect relationship between the primary, riverine bloom and the secondary, estuarine bloom. The mechanism would involve three steps: 1) the death and decomposition of the former bloom, 2) increased inorganic nutrient levels resulting from mineralization of the decomposing algae, and 3) stimulation of growth of the secondary bloom organisms. However, two observations cast doubt on this relationship. First, as is described in the next section, there were no large increases in nutrient concentrations concomitant with the decreases in algal biomass. There were increases in nitrogen concentrations near the estuary's head, but these can be related to the effluent from the Weyerhaeuser paper and pulp mill. Second, there were unusually high concentrations of chlorophyll a in the upper reach of the Pamlico River Estuary around the same time (Stanley 1984), even though there was no blue-green algal bloom upstream in the Tar River. This circumstantial evidence may be used to infer that the Neuse riverine bloom was not directly linked to the estuarine bloom. More work on the relationship between these two blooms in ongoing (Stanley and Christian, unpublished data).

Nutrient Standing Stocks

Various inorganic and organic forms on nitrogen, phosphorus and carbon were measured during the study (Table 2). In the following discussion, we describe the spatial and temporal patterns of standing stocks of these nutrients relative to the occurrence of the blooms.

Nitrate nitrogen (NO_3-N) concentrations at the most upriver station were greater than 50 uM on half of the sampling dates and below 20 uM on the other half (Figure 11). The higher concentrations were generally found near the beginning of the study period. During this period, concentrations generally decreased downriver. Such decreases were less evident when concentrations were low upriver. Above Cowpen Landing, NO_3-N concentrations were often greater than 10 uM. Thus, the presence of high densities of blue-green algae from Kinston to Fort Barnwell were not necessarily associated with depletion of NO_3. Near Cowpen Landing, concentrations below 10 uM were found most of the time. Paerl (1987) also found low concentrations of NO_3-N during the same period at his stations a few km below Cowpen Landing. Concentrations were generally between 1 and 10 uM below Cowpen Landing until the estuary was reached. Periodically, concentrations rose in the area of the Weyerhaeuser effluent. Within the estuary, concentrations fell to the limits of detection.

The spatial pattern of NO_3-N concentrations during the first half of the 1983 study period was similar to that for yearly averages (1979-1982) presented in Stanley (1983). But during the latter half of the study, the

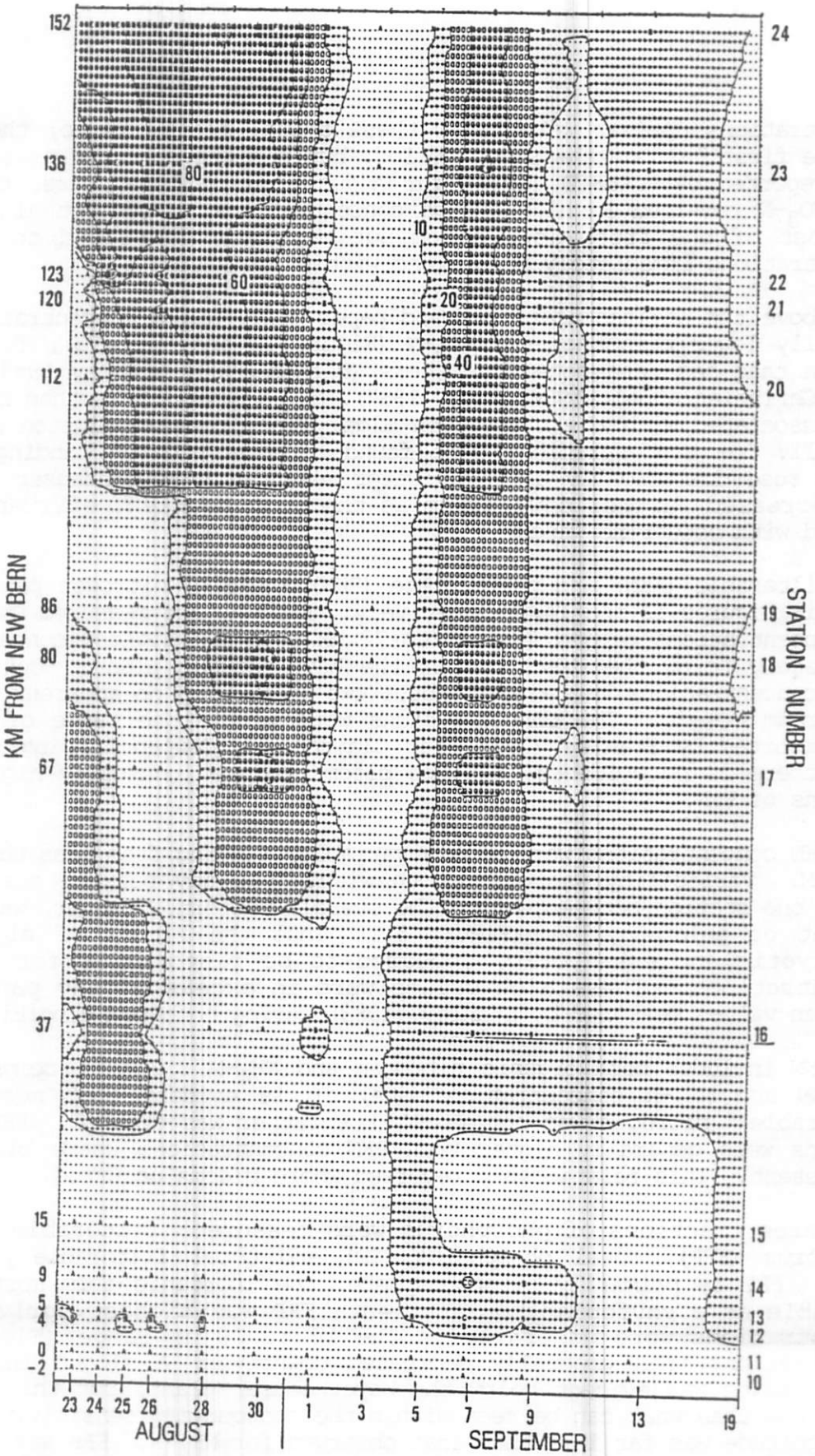

FIGURE 11. CONTOUR MAP OF NO_3 AND NO_2 CONCENTRATIONS

concentrations upriver were below these annual means. Also, the pattern for the first half of the study period, but not the second, was similar to that reported by NCDNRCD (1984) for August 1983. It appears, therefore, that NO_3-N remained in high enough concentrations to support algal growth for most of the freshwater bloom but may have decreased to limiting concentrations immediately before and within the estuary.

Above the Weyerhaeuser pulp and paper mill, NH_4-N concentrations were generally lower than those of NO_3-N (Figure 12 and Table 3), following a pattern that has been noted by others (Harned 1980, Stanley 1983, NCDNRCD 1984, Christian et al. 1984, Paerl 1987). NH_4-N levels less than 2 uM NH_4-N were associated with the blue-green algal bloom between Kinston and Fort Barnwell. Low concentrations were found often at Cowpen Landing. NH_4-N levels rose dramatically as river water mixed with Weyerhaeuser effluent, but decreased farther downstream as the high-nutrient effluent became diluted with estuarine water.

Filterable (FKN) and particulate (PKN) Kjeldahl nitrogen patterns are shown in Figures 13 and 14, respectively. FKN was not measured until Sept. 1. Concentrations ranged from 25 to 72 uM with the highest concentrations immediately below the discharge of the Weyerhaeuser plant. Outside this area, concentrations varied only about two fold, with no apparent upstream-downstream trends. The concentrations were within the range of FKN (sic DKN) reported by Stanley (1983) for Clayton and Cowpen Landing for 1982. Thus, there is no evidence that the bloom produced unusually high concentrations of FKN.

PKN concentrations were highly variable, ranging from less than 0.5 to 2800 uM. Variability was great both within one day between stations and within one station between days. The overall pattern, however, was similar to that of chlorophyll *a* (Figure 5). Thus the blooms of algae, both prokaryotic and eukaryotic, appeared to be responsible for high PKN concentrations. These high values were in excess of any particulate nitrogen values measured by Stanley (1983) during nonbloom conditions.

FKN includes both organic nitrogen and NH_4-N. From a comparison of the FKN and NH_4-N concentration data, it is evident that most of the "filterable" nitrogen was not NH_4-N, but rather was organic. FKN concentrations were generally higher than PKN concentrations where blooms were not present. This relationship reversed where blooms occurred.

Three fractions of phosphorus were measured: filterable reactive phosphorus (FRP), total phosphorus (TP) and total filterable phosphorus (TFP). FRP is primarily orthophosphate, the inorganic form most readily available as a phytoplankton nutrient. FRP was highest upriver where concentrations were generally in the 10 to 20 uM range (Figure 15). Concentrations then gradually decreased downriver. A slight increase in concentration was evident below the Weyerhaeuser plant, but this rise was often less than what can be seen within the contour map sensitivity. Also, the magnitude was far less than that observed for NH_4-N. FRP was lowest at the head of the estuary, but concentrations never went below 2.5 uM at any time or location. If FRP were important in limiting phytoplankton growth,

FIGURE 12. CONTOUR MAP OF NH_4 CONCENTRATIONS

Table 3. Arithmetic means of concentrations of selected nutrients in the Neuse River during August and September, 1983. All concentrations are uM.

Station	FRP	TFP	TP	NH_4	NO_3+NO_2	TIN	TIN:FRP
24	15.0	14.6	13.9	8.7	42	53	3.8
23	13.8	14.2	12.8	8.5	39	50	4.2
22	11.6	12.8	11.8	6.5	32	40	4.1
21	10.7	11.5	13.1	6.4	29	37	3.9
20	9.8	10.7	10.9	5.5	28	35	3.9
19	7.3	8.7	10.4	3.1	19	23	3.8
18	7.2	8.9	17.0	2.2	19	22	3.9
17	6.8	8.9	17.3	2.6	19	22	3.8
16	6.6	8.7	16.9	4.3	14	18	2.8
15	6.6	7.9	9.7	1.8	5	6	0.9
14	5.1	6.5	7.9	4.1	7	11	2.0
13	5.8	7.9	8.1	24.8	10	35	6.0
12	5.3	7.3	35.5	21.2	10	30	5.9
11	3.9	5.5	6.7	4.6	3	8	2.0
10	3.9	5.6	7.3	1.7	2	4	0.9

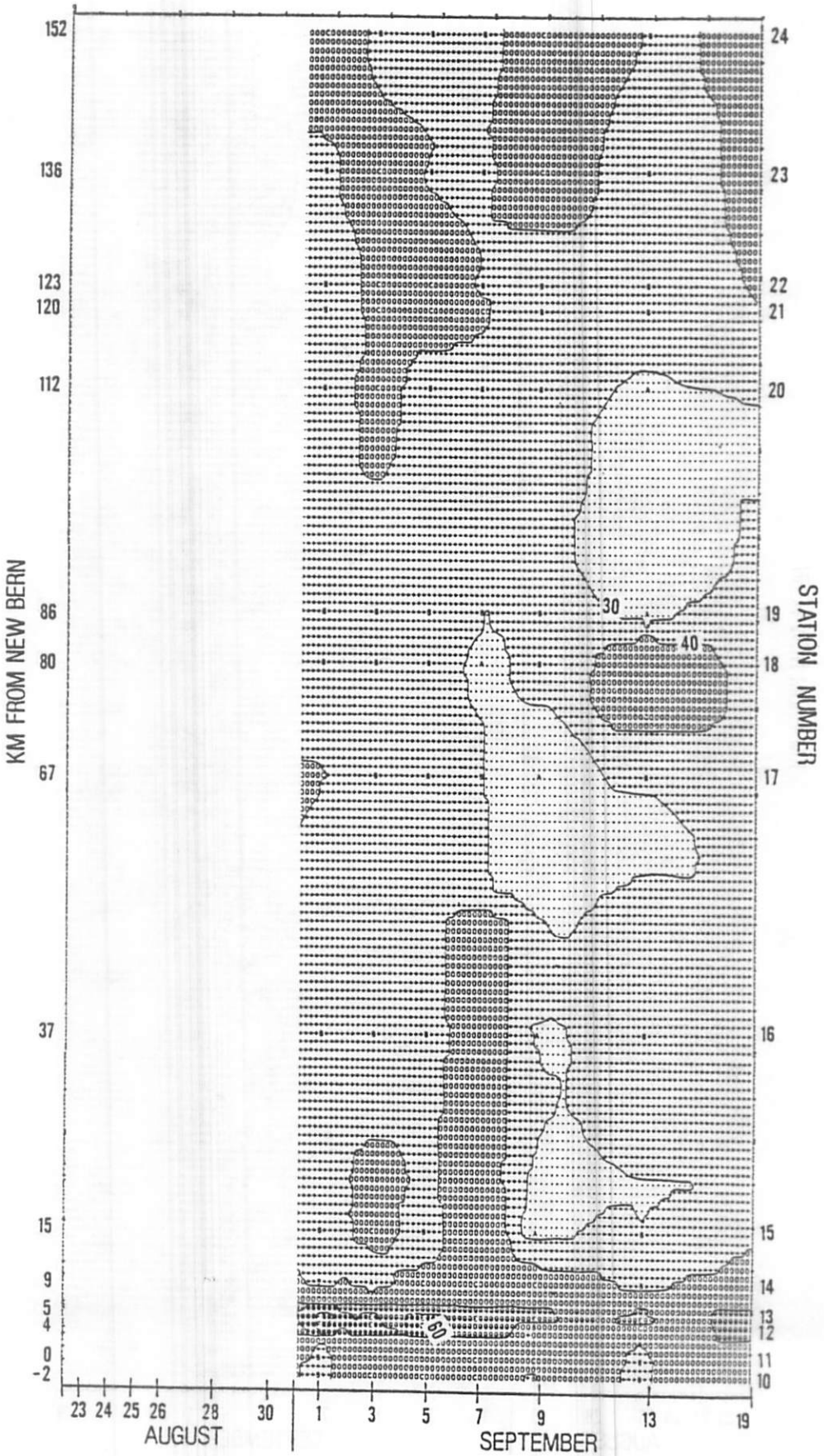

FIGURE 13. CONTOUR MAP OF FILTERABLE KJELDAHL N (FKN) CONCENTRATIONS

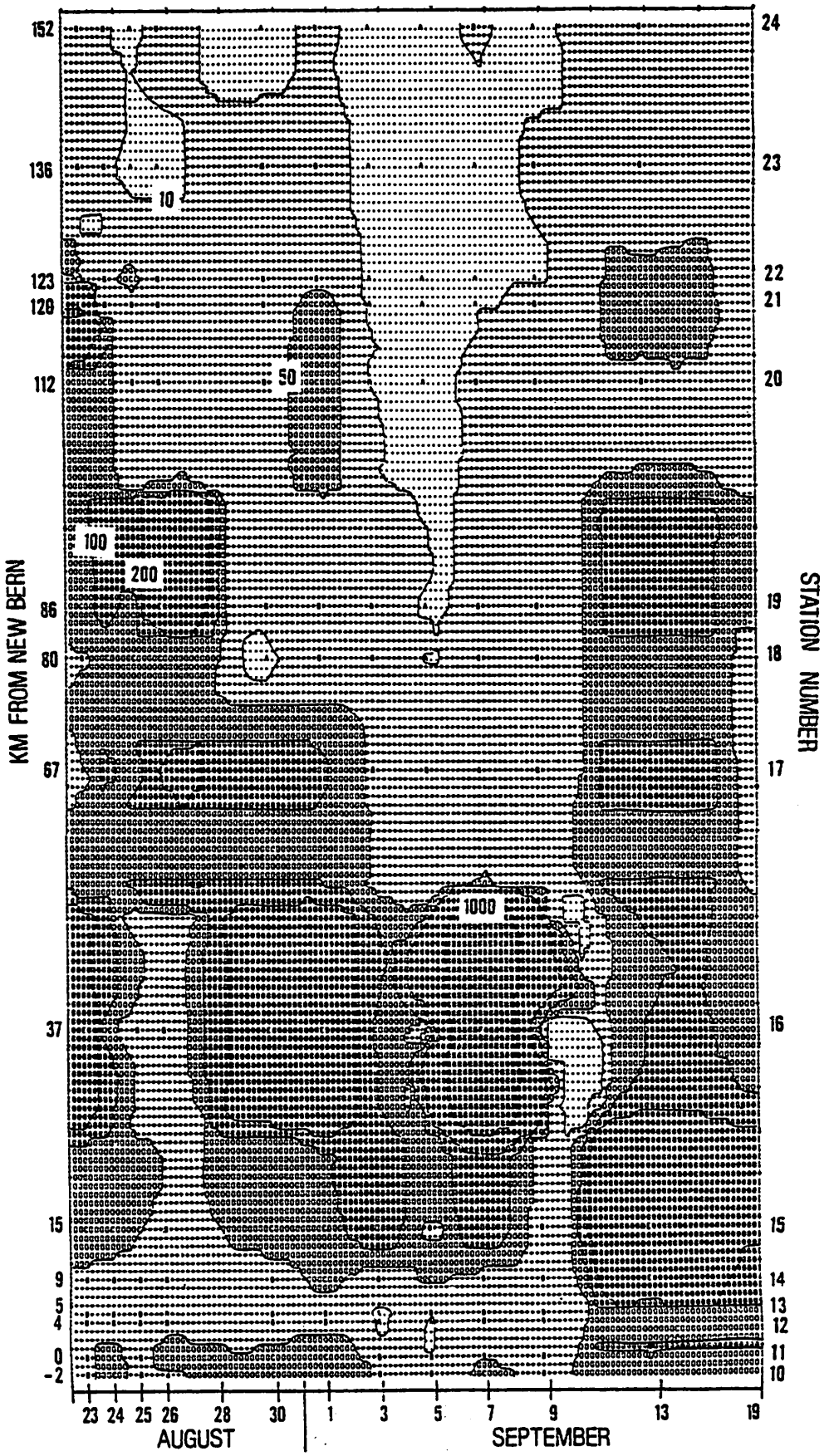

FIGURE 14. CONTOUR MAP OF PARTICULATE KJELDAHL N (PKN) CONCENTRATIONS

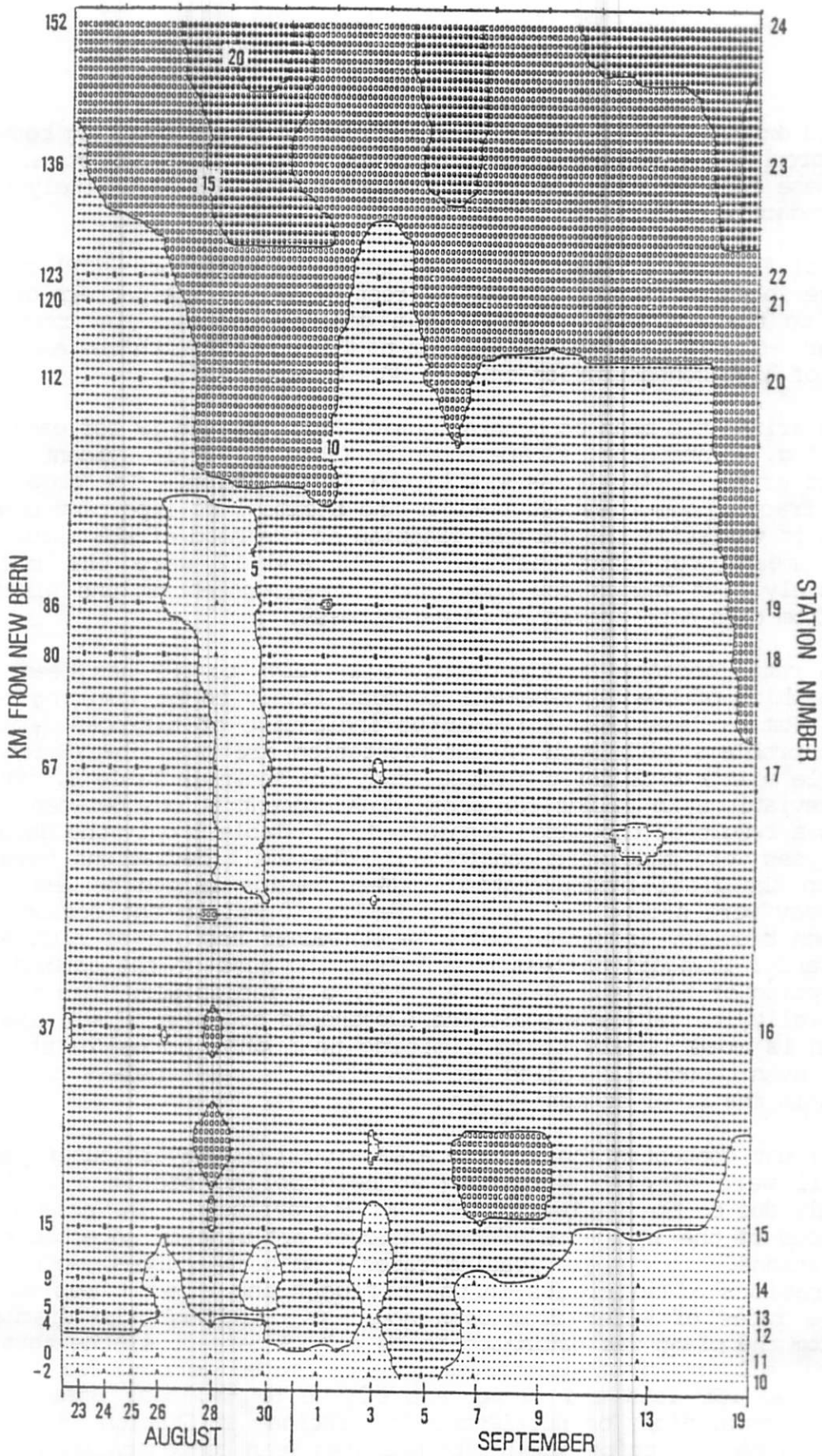

FIGURE 15. CONTOUR MAP OF FILTERABLE REACTIVE PHOSPHORUS (FRP) CONCENTRATIONS

one would expect greater variability and a much closer coupling between FRP and chlorophyll a concentrations than is found (Imberger et al. 1983). Thus, these results are inferential evidence that FRP is unlikely to limit bloom productivity.

Total filterable phosphorus (TFP) and total phosphorus (TP) concentrations are shown in Figures 16 and 17, respectively. The pattern of TFP was similar to that of FRP. There was a general decrease in concentration downriver. The TP pattern was similar to TFP and FRP with the exception of islands of high concentration on Aug. 30 and Sept. 7.

The arithmetic mean concentrations of FRP, TFP and TP for each station between Aug. 23 and Sept. 13 are shown in Table 4. It is evident that most of the river borne phosphorus was in the FRP fraction. The proportion in the FRP fraction was greatest upriver and became less important downriver, although it was still the largest fraction at the head of the estuary. The high TP means for stations 16, 17, 18 and 12 were the result of inordinately high values for Aug. 30. Mean concentrations without the values from this date are shown in parentheses.

The ratio of total inorganic nitrogen (TIN) to FRP has been used to indicate which of the two elements is most likely to be limiting to algal growth. Ratios less than 15:1 may be indicative of nitrogen limitation, although problems with such an interpretation are possible (Smith 1984). The sample mean ratios for the Neuse study are shown in Table 3. There are slight deviations in values for phosphorus concentrations between Tables 3 and 4 as a result of the dates considered. In Table 3 only the dates where all analyses were made were considered. The small deviations have little impact on the final interpretation. Mean ratios ranged between 6:1 and 0.9:1. They were around 4:1 upriver, fell to 0.9:1 in the region of peak blue-green biomass, increased below Weyerhaeuser because of high ammonium levels, and fell again to less than 1:1 at the head of the estuary. With the exception of four stations on Aug. 30, all ratios were less than 10:1. The generally low ratios support the hypothesis of Paerl (1983, 1987) that nitrogen is more likely to be limiting than phosphorus in the Neuse. However, even though the ratios are low, there is nevertheless considerable nitrogen in the river at most times.

Nutrient concentrations in the area around the Weyerhaeuser paper and pulp mill were often higher than at neighboring stations. This was presumably due to the loading from the mill's effluent. In Table 5 we show predictions of the influence of Weyerhaeuser effluent on selected nutrient concentrations. To compare loading rates from both sources, we multiplied concentrations of nutrients in the effluent and river times estimated discharge rates of water from both sources. Although the discharge of water from the plant was estimated to be only 9 percent of the total river discharge, mill nutrient discharges were estimated to comprise 14 percent of the total FRP load and 70 percent of the NH_4-N load. Based on these estimates, predictions of nutrient concentrations at Station 13 were made, and they turned out to be similar to measured mean concentrations for NO_3 + NO_2, FRP and TP. Predicted TKN levels at Station 13 were higher than the measured, and those of NH_4 and FKN were lower than measured. Rapid

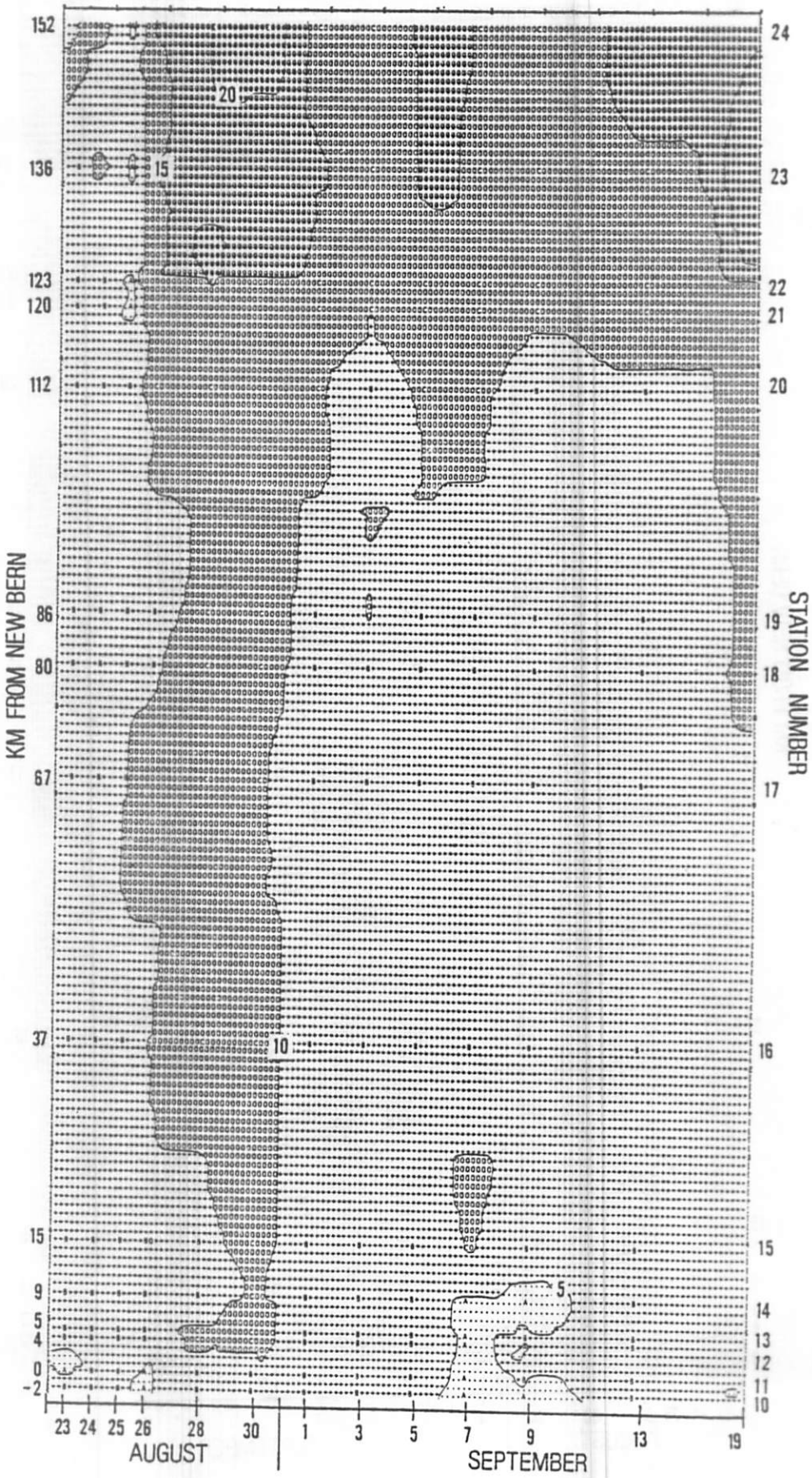

FIGURE 16. CONTOUR MAP OF TOTAL FILTERABLE PHOSPHORUS (TFP) CONCENTRATIONS

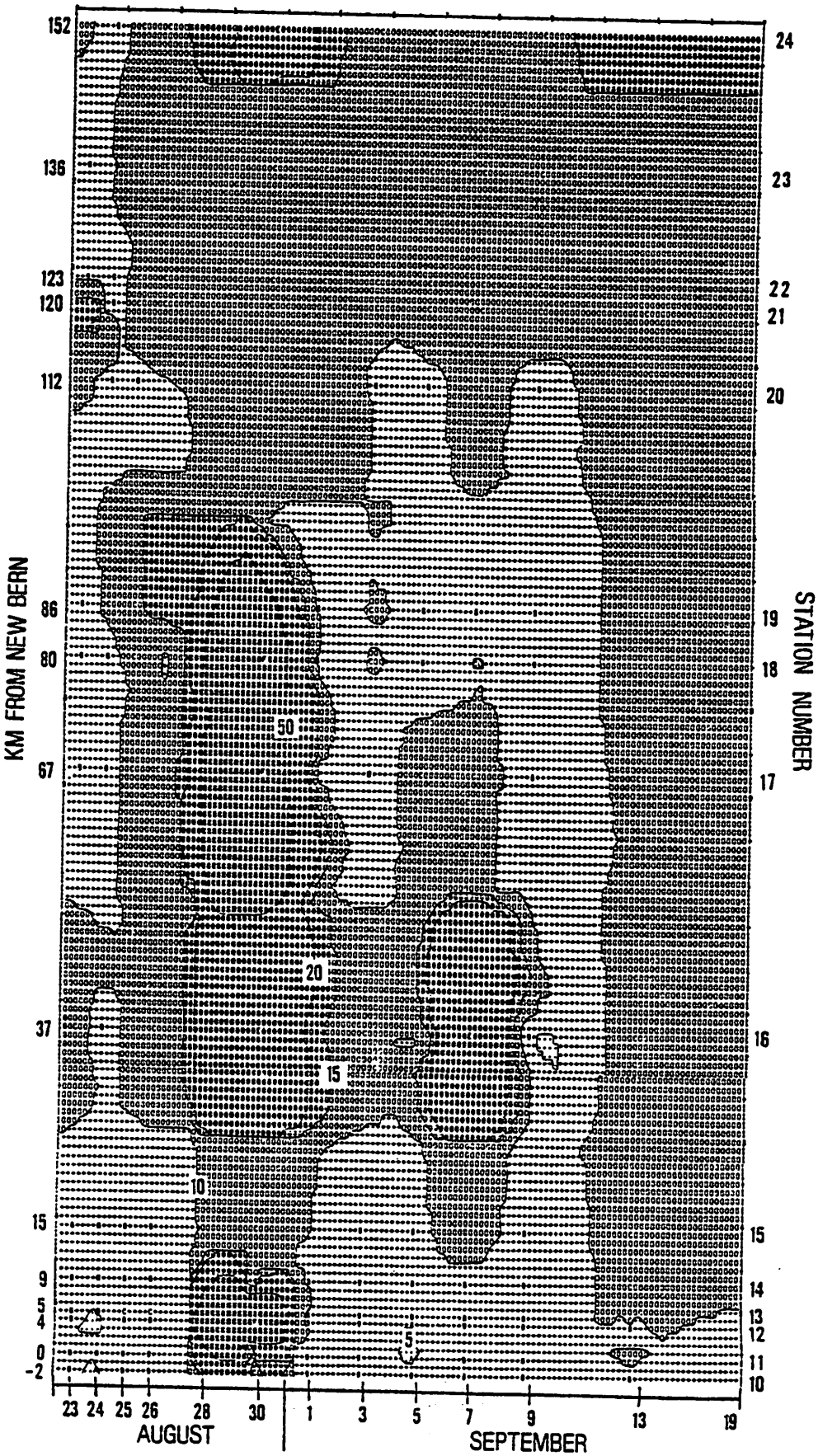

FIGURE 17. CONTOUR MAP OF TOTAL PHOSPHORUS (TP) CONCENTRATIONS

Table 4. Mean concentrations by station for phosphorus for Aug. 23-Sept. 7 and Sept. 13, 1983. All concentrations are uM. Standard deviations are given also.

Station	Filterable Reactive Phosphorus (FRP)	Total Filterable Phosphorus (TFP)	Total Phosphorus (TP)
24	14.6 + 3.6	14.2 + 5.1	14.6 + 4.5
23	13.1 + 2.1	13.2 + 4.0	13.4 + 3.3
22	11.2 + 3.8	12.3 + 4.4	12.1 + 2.4
21	9.9 + 2.5	12.2 + 5.6	13.2 + 5.5
20	9.3 + 2.0	10.5 + 2.5	11.1 + 2.1
19	6.8 + 1.6	8.6 + 1.9	10.6 + 3.0
18	6.8 + 1.5	8.8 + 2.4	16.4 + 26.3 (8.5)
17	6.6 + 1.5	9.2 + 3.2	17.5 + 25.7 (9.4)
16	6.8 + 1.7	8.6 + 2.3	15.8 + 10.6 (12.9)
15	6.8 + 1.9	8.0 + 1.8	10.0 + 2.8
14	5.3 + 1.1	6.8 + 1.5	8.1 + 1.6
13	6.0 + 1.1	8.3 + 2.3	8.4 + 1.6
12	5.5 + 1.2	7.7 + 2.2	7.1 + 1.9
11	4.1 + 1.0	5.6 + 1.4	6.7 + 1.6
10	3.9 + 0.8	5.8 + 1.2	7.4 + 2.0

Table 5. Potential influence of Weyerhaeuser effluent on nutrient concentrations in the Neuse River.

Variable	Unit	NH_4	NO_3+NO_2	TKN	FKN	FRP	TP	Water
Predicted effluent concentration[1]	uM	99	25	515	204	8.5	24	-
Effluent loading rate[2]	m mole/sec	117	29	608	241	10	29	-
Mean conc. at Sta. 14	uM	4	7	118	38	5	8	-
River loading rate[3]	m mole/sec	49	86	1,455	469	62	99	-
Total loading rate[4]	m mole/sec	166	115	2.063	710	72	128	-
% effluent loading	%	70	25	29	34	14	23	9
Predicted conc. at Sta. 13[4]	uM	12	9	153	53	5	9	-
Measured mean conc. at Sta. 13	uM	25	10	101	65	6	8	-

[1]Mean values from Stanley (unpublished data).

[2]Loading rate of water = 1.18 m^3/sec based on NCDNRCD 1984.

[3]Flow = 12.33 m^3/sec. This value is the average river discharge from August 23-September 19, 1983 times 1.5 as drainage area correction (13.51 m^3/sec) minus the amount of water used by Weyerhaeuser (1.18 m^3/sec).

[4]Effluent plus river values.

recycling between these three nutrient forms and estimation uncertainties may be the reasons for the discrepancies.

Total inorganic carbon (TIC) patterns during the study are shown in Figure 18. In the low alkalinity waters of the Neuse, TIC concentrations generally remained below 1 mM upriver from the FSI and the paper mill. TIC concentrations above this region were as low as 0.3 mM and were often in the 0.4 to 0.6 mM range. These low TIC concentrations in the Neuse River, along with evidence from algal bioassay experiments have led Paerl (1983) to postulate that carbon may be a limiting nutrient at times.

In summary, there were three factors primarily responsible for the observed patterns of nutrient standing stocks: the blooms, Weyerhaeuser's paper and pulp mill effluent, and the estuary's influence. Of the three elements examined, nitrogen showed the closest association with each of these. TIN declined somewhat in association with the bloom, rose in the region of the effluent, and declined in the estuary. PKN fluctuations were associated with blooms, and FKN rose in the region of the effluent. Filterable phosphorus species and TIC were less variable.

Interactions Among Variables

In order to test for interactions among the various chemical, biological, and physical factors studied, Spearman rank correlation analyses were made. This nonparametric method of analysis was used because we had no reason to believe that correlations would be linear or that covariation would be parametric, two assumptions inherent in the more common Pearson correlation analysis. The results are shown in Tables 6 through 9. Significance was considered at the $p<0.05$ level, and 86 of 172 analyses were significant. Most of these were significant at the $p<0.005$ level. We consider the correlations within four categories: 1) particulate standing stocks, 2) photosynthesis rates and algal standing crops, 3) nutrient standing stocks, and 4) nutrient standing stocks and algal characteristics.

The particulate standing stocks considered were PKN, chlorophyll *a*, blue-green algal biomass, nonblue-green algal biomass, and total phytoplankton biomass (Table 6). PKN correlated significantly and positively with chlorophyll *a* concentrations, blue-green algal and total phytoplankton biomass, but not with nonblue-green algal biomass. Thus the pattern of particulate nitrogen concentrations was most related to the riverine bloom of blue-green algae. Chlorophyll *a* concentrations and total phytoplankton biomass were positively correlated. In contrast, blue-green and nonblue-green algal biomasses were not correlated either positively or negatively with each other. These results confirm the earlier discussions we have presented.

Photosynthesis or primary production rate correlated positively with all measures of algal standing crop (Table 7). Photosynthetic efficiency indices did not correlate with photosynthesis rate. Photosynthetic efficiency 1 (um CO_2/(hr x ug chlorophyll *a*)) was negatively correlated

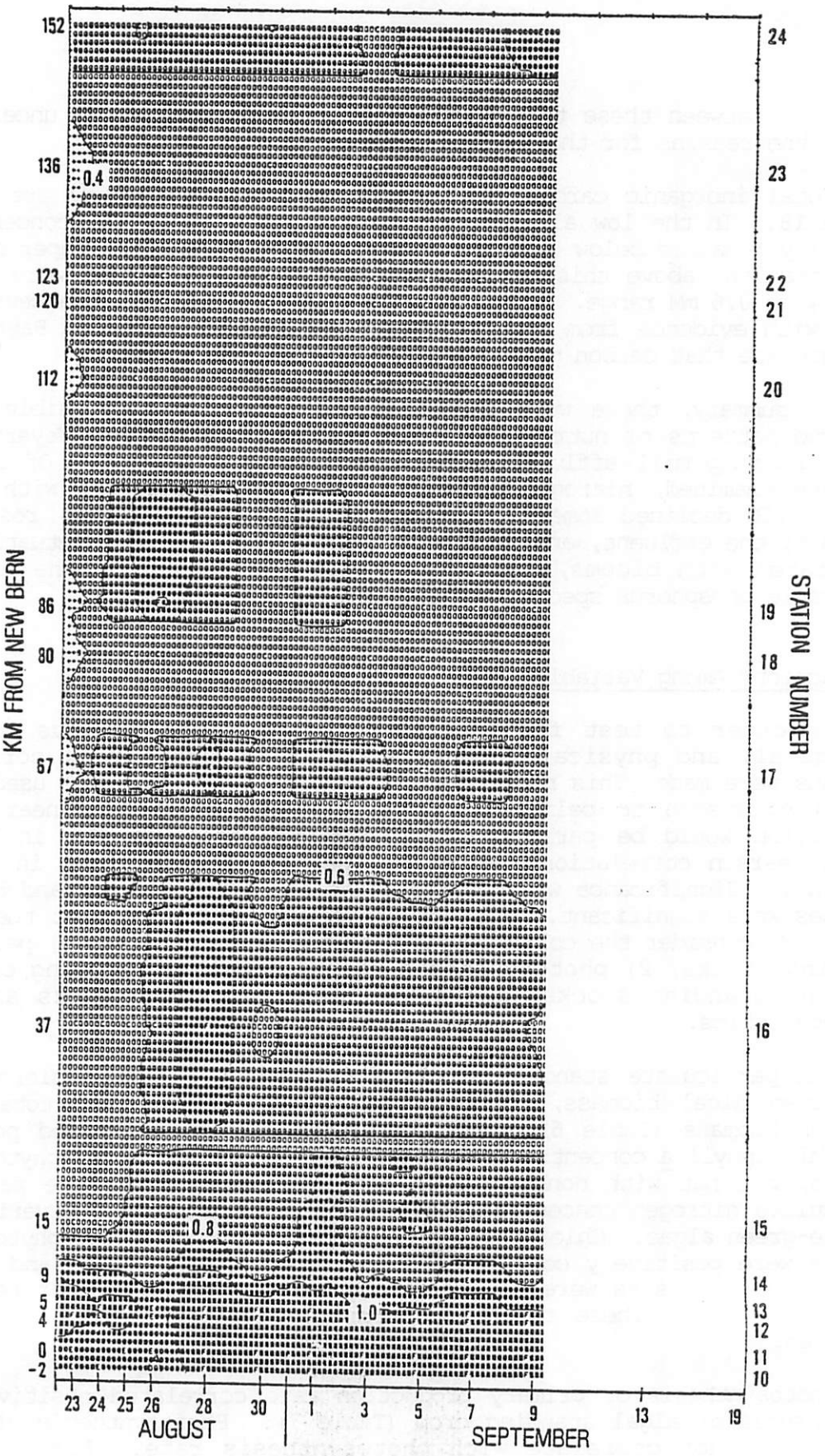

FIGURE 18. CONTOUR MAP OF TOTAL INORGANIC CARBON (TIC) CONCENTRATIONS

Table 6. Spearman rank correlation analyses for particulate standing stocks. The calculated coefficients and significance are given.

	PKN	Chlorophyll *a*	Blue-green algal biomass	Non blue-green algal biomass
Total phytoplankton biomass	0.462 (0.001)	0.641 (0.001)	0.593 (0.001)	0.568 (0.001)
Non blue-green algal biomass	0.130 (0.187)	0.271 (0.003)	-0.084 (0.366)	
Blue-green algal biomass	0.392 (0.001)	0.396 (0.001)		
Chlorophyll *a*	0.696 (0.001)			

Table 7. Spearman rank correlation analyses between photosynthetic variables and algal standing stock. Correlation coefficients and significance are given.

	Photosynthesis rate	Photosynthetic efficiency 1	Photosynthetic efficiency 2
PKN	0.773 (0.001)	-0.167 (0.042)	-0.168 (0.156)
Chlorophyll *a*	0.778 (0.001)	-0.429 (0.001)	-0.298 (0.005)
Total phytoplankton biomass	0.617 (0.001)	-0.169 (0.116)	-0.774 (0.001)
Blue-green algal biomass	0.358 (0.001)	-0.140 (0.192)	-0.461 (0.001)
Non blue-green algal biomass	0.316 (0.003)	-0.099 (0.361)	-0.454 (0.001)
Photosynthesis rate		0.103 (0.189)	-0.064 (0.555)
Photosynthetic efficiency 1			0.391 (0.001)

with PKN and chlorophyll a. Photosynthetic efficiency 2 (um CO_2/(hr x mg wet wt.)) was negatively correlated with chlorophyll, and all phytoplanktonic biomass. The two efficiencies were positively correlated. Thus as biomass increased the efficiency of photosynthesis decreased. There are two possible explanations for these negative correlations between biomass and efficiencies. First, as biomass increased, the physiological capabilities of the phytoplankton may have been compromised as density-dependent limitation. The second explanation is related to the sensitivity of the various measurements. The highest efficiencies were found when biomass values were very low, bordering on the limits of detection. The inaccuracy and imprecision of these latter measures are incorporated into the denominator of the efficiency calculation. As such inordinately high efficiencies may be derived.

The interrelationships between nutrient species are shown in Table 8. Correlations between nutrient species generally reflect similar or inverse trends with distance downriver. For example, TIC concentrations were low along much of the river but began to rise at Fort Barnwell and continued to increase under the influence of brackish water mixing. Many of the other nutrients began with high concentrations upriver and decreased in concentration downriver. As a result, TIC was negatively correlated with NO_3-N , FRP and TFP. Nitrogen and phosphorus species generally correlated well within element and between elements in a positive fashion. The major exception to this was FKN, which did not correlate with either NO_3-N or TFP and correlated negatively with FRP. FKN varied little along most of the river but rose in the neighborhood of the paper and pulp mill as a result of its effluent. The ratio of TIN to FRP was most strongly related to nitrogen species as opposed to phosphorus species. It correlated positively with all species of nitrogen and did not correlate at all with phosphorus species.

The interrelationships between algal characteristics and nutrients are shown in Table 9. The only nutrient species that did not show any relationship to algal properties was FKN. As discussed previously, the major source of variation to FKN was the paper and pulp mill. TIC demonstrated a unique relationship with algal standing stock and photosynthesis characteristics. It was positively correlated with PKN, productivity and photosynthetic efficiencies. These correlations appear to be linked to the activities at the estuary's head and a general increase in TIC concentration from Fort Barnwell downriver. As such there is little statistical evidence of TIC limitation to bloom algae in this region. Although nonblue-green algae may still be subject to TIC limitation at times, the buoyant blue-green algae of the blooms may circumvent such limitation (Paerl and Ustach 1982). In contrast, NH_4-N and TIN were negatively correlated with all measures of algal standing crop and production rate. Also, NO_3-N, FRP, TFP, and TIN: FRP were negatively correlated with measures of total algal standing crop (PKN, chlorophyll a, total phytoplankton biomass) and productivity. These relationships may reflect the uptake of nutrients by both blooms and the influence of the paper and pulp mill effluent. Lower algal biomass and productivities, and higher nutrient concentrations were found in the area of the effluent. Most increases in concentrations could be ascribed to the effluent itself.

Table 8. Spearman rank correlation analyses for nutrient concentrations. Correlation coefficients and significance are given.

	NH_4-N	FKN	NO_3-N	TIN	FRP	TFP	TIN:FRP
TIC	0.153 (0.059)	0.429 (0.001)	-0.303 (0.001)	-0.148 (0.071)	-0.424 (0.001)	-0.322 (0.001)	-0.010 (0.907)
TIN:FRP	0.548 (0.001)	0.412 (0.001)	0.757 (0.001	0.913 (0.001)	0.072 (0.362)	0.146 (0.065)	
TFP	0.233 (0.002)	-0.122 (0.214)	0.327 (0.001)	0.389 (0.001)	0.693 (0.001)		
FRP	0.225 (0.004)	-0.225 (0.033)	0.441 (0.001)	0.442 (0.001)			
TIN	0.590 (0.001)	0.372 (0.001)	0.863 (0.001)				
NO_3-N	0.215 (0.004)	-0.082 (0.405)					
FKN	0.576 (0.001)						

Table 9. Spearman rank correlation analyses between nutrient concentrations and algal characteristics. Correlation coefficients and significance are given.

	NH_4-N	FKN	NO_3-N	TIN	FRP	TFP	TIN:FRP	TIC
PKN	-0.56 (0.001)	-0.11 (0.254)	-0.36 (0.001	-0.57 (0.00)	-0.43 (0.00)	-0.41 (0.001)	-0.48 (0.001)	-0.16 (0.048)
Chlorophyll a	-0.55 (0.001)	0.04 (0.619)	-0.35 (0.001)	0.51 (0.001)	-0.46 (0.001)	-0.40 (0.001)	-0.398 (0.001)	0.16 (0.161)
Total phytoplankton biomass	-0.51 (0.001)	-0.20 (0.083)	-0.38 (0.001)	-0.59 (0.001)	-0.26 (0.006)	-0.26 (0.004)	-0.45 (0.001)	0.01 (0.883)
Blue-green algal biomass	-0.22 (0.023)	-0.20 (0.080)	-0.16 (0.082)	-0.31 (0.002)	-0.09 (0.352)	-0.03 (0.739)	-0.27 (0.010)	0.07 (0.509)
Non blue-green algal biomass	-0.41 (0.001)	-0.18 (0.111)	-0.15 (0.091)	-0.31 (0.002)	-0.22 (0.020)	-0.12 0.178)	-0.14 (0.169)	0.02 (0.807)
Photosynthesis rate	-0.59 (0.001)	0.00 (0.953)	-0.52 (0.001)	-0.66 (0.001)	-0.53 (0.001)	-0.46 (0.001)	-0.50 (0.001)	0.33 (0.001)
Photosynthetic efficiency 1	0.03 (0.638)	-0.18 (0.106)	-0.14 (0.063)	-0.12 (0.129	-0.20 (0.013)	-0.17 (0.029)	-0.02 (0.727)	0.35 (0.001)
Photosynthetic efficiency 2	0.16 (0.121)	0.01 (0.940)	0.16 (0.138)	0.25 (0.017)	-0.22 (0.060)	-0.05 (0.634)	0.30 (0.011)	0.22 (0.041)

Nutrient species were more readily related to total phytoplankton characteristics than to either blue-green or nonblue-green algal biomasses individually. This probably reflects the fact that two separate blooms were observed: one of each kind. Thus each category only accounted for the uptake of nutrients within a specific portion of the transect.

The relationships between nutrients and photosynthetic efficiencies are difficult to interpret. The strangest correlation ($p<0.001$) was found between photosynthetic efficiency 1 (um CO_2/(h x mg chlorophyll a)) and TIC. This was a positive correlation in which high TIC concentrations in the region of the estuary were found where efficiency was high at times. Other correlations concerning efficiencies were significant at the $p<0.05$ level but not at the $p<0.01$ level. Given the general lack of strong correlation and lack of correspondence between correlations with the two efficiencies, we refuse to develop inferences concerning these parameters.

CONCLUSIONS

This report includes the most complete description of a blue-green algal bloom on the Neuse River yet published. The blue-green algal bloom during the summer of 1983 began to develop in July and continued into September. High densities of Microcystis aeruginosa, the dominant organism were found at times from Seven Springs to Street's Ferry Bridge, spanning over 100 km of the lower Neuse. The bloom was most intense at Fort Barnwell, but scums formed over the entire span of the bloom. Chlorophyll a concentrations peaked at approximately 1500 ug/liter, with densities of nearly 5,000 million M. aeruginosa cells/liter. Few other blue-green algal species were found in our samples, although others sampling the Neuse at that time found greater diversity of blue-green algae (NCDNRCD 1984). In the region between Seven Springs and Fort Barnwell, eukaryotic algae contributed significantly to algal biomass. Overall though, the algal bloom of 1983 was dominated by M. aeruginosa and was extensive in both time and space.

The bloom's development was associated with the low flow conditions on the Neuse resulting from lack of rainfall and high summer evapotranspiration rates leading to low water influx to the river. No blue-green algae were found in samples from Goldsboro, indicating that densities there were below our limits of detection. Algal biomass generally increased downriver and reached its maximum in the region where the river widens and deepens (Fort Barnwell) resulting in a decrease in velocity (Christian et al. 1986). The bloom persisted for several weeks in this region, declining only with the shorter days and colder temperatures of September and the occurrence of a rainstorm that may have washed algae farther downstream. The bloom declined between Fort Barnwell and Cowpen Landing, although apparently healthy algae were found in the latter region. Details regarding the sedimentation of dead algae and the rates of decomposition during the bloom's decline are unknown. By the time water reached the estuarine region near New Bern, the blue-green algal bloom was no longer apparent.

At the head of the estuary a second bloom occurred. This was dominated by eukaryotic chrysophytes. The chlorophyll a concentrations near New Bern exceeded those of recent years. The link between the primary, riverine bloom and this secondary, estuarine bloom is tenuous however. Nutrient concentrations did increase just upstream from the estuary, but these increases could be ascribed to paper and pulp mill effluent as well as the decomposition and mineralization from the riverine bloom. Also, the nearby Pamlico River estuary, whose tributary did not have a blue-green algal bloom, demonstrated high chlorophyll a concentrations during this time.

Inorganic forms of nitrogen and phosphorus decreased from upriver down. Total inorganic carbon increased in the lower reach of the river. Of the three elements, nitrogen concentrations showed the closest association with the bloom. Potentially limiting concentrations of nitrogen were found during a short time near and below the peak of the bloom (Paerl

1987). There is little evidence that any of these three elements could limit the bloom's development. There was evidence, based on nutrient ratios, that nitrogen was closer to becoming limiting than phosphorus.

The paper and pulp mill above New Bern was shown to influence nutrient concentrations. The effluent of the mill dramatically increased nitrogen concentrations in the river. Phosphorus concentrations rose to a lesser extent. Also, the dark color of the effluent may have retarded primary productivity by increasing light attenuation. Thus, at the low flow conditions that existed, the mill's effluent had significant local impacts on the river. The importance of these impacts downstream are unknown.

Lastly, river flow was extremely low for a long time during the summer of 1983. Flow at Kinston below 500 cfs was sustained for about 40 days. Low flows have occurred in summer of more recent years, but they have not been maintained as low for as long as in 1983. These low flow conditions appear to be a major element in promoting bloom formation (Christian et al. 1986). High spring flow has also been implicated as a causative agent in summer bloom formation (Paerl 1987). The mechanisms for this are not as well developed as for the low flow hypothesis, but a correlation appears to exist. It is apparent, though, that a variety of factors must combine n the appropriate way to allow for bloom development. These factors include at least availability of nutrients and light, temperature and other physical conditions which support active and sustained growth of the blue-green algae.

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Appendix A. Chlorophyll a concentrations (ug/l) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	40	55	<1	33	112	61	82	95	72	87	56	32	24
11	28	65	45	56	141	83	43	68	37	48	58	53	78
12	23	<1	28	10	8	11	19	8	13	46	31	40	29
13	15	30	17	7	24	12	8	36	29	30	18	21	20
14	26	34	21	22	46	23	29	18	152	43	32	117	60
15	59	82	78	40	64	88	44	130	64	160	42	146	111
16	460	77	54	65	213	1541	341	95	16	1260	34	75	16
17	36	168	68	126	67	68	103	24	42	56	21	32	6
18	50	80	216	111	40	38	17	37	17	2	<1	11	3
19	47	208	38	288	16	22	13	30	5	<1	18	11	12
20	94	73	22	40	8	26	59	10	<1	1	6	18	7
21	768	97	40	37	8	17	97	9	7	2	1	2	<1
22	44	30	4	30	8	19	26	4	11	<1	4	6	<1
23	18	104	11	4	8	29	10	4	4	2	8	15	<1
24	4	2	<1	2	<1	16	2	<1	2	1	1	<1	3

Appendix B. Phytoplankton wet weight biomass (mg/l) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	1.03	---	2.22	---	2.43	---	4.80	---	53.19	---	99.18	42.80	0.91
11	0.50	---	1.55	---	2.32	---	0.91	---	8.02	---	33.99	1.31	2.25
12	0.09	---	0.11	---	0.15	---	0.93	---	0.98	---	---	3.92	0.19
13	0.15	---	0.69	---	0.23	---	0.26	---	4.57	---	0.82	1.49	0.26
14	4.11	---	1.24	---	8.18	---	6.64	---	4.72	---	1.09	10.49	0.21
15	14.75	---	26.40	---	14.01	---	10.52	---	9.14	---	2.29	22.64	14.96
16	59.01	---	0.49	---	162.44	---	106.97	---	22.20	---	2.97	0.88	1.45
17	1.56	---	12.29	---	17.58	---	22.73	---	12.12	---	0.92	0.77	0.48
18	2.77	---	17.88	---	9.09	---	0.01	---	3.34	---	0.54	11.78	1.03
19	0.16	---	22.54	---	1.40	---	1.60	---	1.76	---	2.32	3.04	3.39
20	25.57	---	6.16	---	1.64	---	12.56	---	0.43	---	0.08	1.57	3.40
21	99.08	---	0.07	---	0.66	---	1.14	---	0.76	---	0.45	3.16	0.35
22	6.65	---	0.05	---	0.74	---	0.49	---	1.22	---	0.95	0.62	0.62
23	0.08	---	1.99	---	0.05	---	0.28	---	0.15	---	0.16	0.87	0.07
24	0.08	---	0.22	---	0.61	---	0.13	---	0.38	---	0.03	0.43	0.10

Appendix C. Wet weight biomass (mg/l) of nonblue-green algae at Neuse River stations sampled between 23 August (23A) and 9 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	1.03	---	2.22	---	2.43	---	4.80	---	53.19	---	99.18	42.80	0.91
11	0.50	---	1.55	---	2.32	---	0.91	---	8.02	---	33.99	1.31	2.25
12	0.09	---	0.11	---	0.13	---	0.49	---	0.22	---	---	3.92	0.12
13	0.13	---	0.29	---	0.18	---	0.23	---	3.10	---	0.13	0.20	0.22
14	0.21	---	0.14	---	0.12	---	0.15	---	4.72	---	0.19	0.38	0.14
15	0.18	---	0.55	---	0.11	---	0.18	---	1.72	---	1.06	0.98	1.23
16	0.20	---	0.49	---	0.24	---	0.34	---	0.23	---	2.04	0.59	1.05
17	0.74	---	1.26	---	4.27	---	0.10	---	5.69	---	0.31	0.77	0.25
18	2.77	---	0.91	---	1.98	---	0.01	---	2.14	---	0.50	0.26	0.94
19	0.16	---	3.95	---	1.40	---	1.60	---	1.76	---	2.31	1.32	0.29
20	0.69	---	0.16	---	1.64	---	1.57	---	0.43	---	0.07	1.54	3.19
21	0.53	---	0.07	---	0.66	---	1.14	---	0.76	---	0.45	2.75	0.23
22	0.19	---	0.05	---	0.74	---	0.49	---	1.22	---	0.95	0.49	0.60
23	0.08	---	1.99	---	0.05	---	0.28	---	0.15	---	0.10	0.83	0.07
24	0.08	---	0.22	---	0.61	---	0.13	---	0.38	---	0.03	0.43	0.10

Appendix D. Wet weight biomass (mg/l) of blue-green algae at Neuse River stations sampled between 23 August (23A) and 19 Setember (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	0.00	---	0.00	---	0.00	---	0.00	---	0.00	---	0.00	0.00	0.00
11	0.00	---	0.00	---	0.00	---	0.00	---	0.00	---	0.00	0.00	0.00
12	0.00	---	0.00	---	0.02	---	0.44	---	0.76	---	---	0.00	0.07
13	0.02	---	0.40	---	0.05	---	0.03	---	1.47	---	0.69	1.29	0.05
14	3.90	---	1.10	---	8.06	---	6.49	---	0.00	---	0.90	10.11	0.07
15	14.56	---	25.85	---	13.89	---	10.34	---	7.42	---	1.23	21.67	13.73
16	58.81	---	0.00	---	162.20	---	106.63	---	21.97	---	0.93	0.29	0.40
17	0.83	---	11.03	---	13.30	---	22.63	---	6.43	---	0.61	0.00	0.23
18	0.00	---	16.96	---	7.11	---	0.00	---	1.20	---	0.03	11.53	0.09
19	0.00	---	18.59	---	0.00	---	0.00	---	0.00	---	0.01	1.72	3.10
20	24.88	---	6.00	---	0.00	---	10.99	---	0.00	---	0.01	0.03	0.21
21	98.55	---	0.00	---	0.00	---	0.00	---	0.00	---	0.00	0.41	0.12
22	6.46	---	0.00	---	0.00	---	0.00	---	0.00	---	0.00	0.13	0.01
23	0.00	---	0.00	---	0.00	---	0.00	---	0.00	---	0.06	0.03	0.00
24	0.00	---	0.00	---	0.00	---	0.00	---	0.00	---	0.00	0.00	0.00

Appendix E. Phytoplankton species composition, cell density, and biomass data for the Neuse River, 23 August - 19 September, 1983. "Cell type" is a code number used in our laboratory to facilitate computer computations of algal density and biomass.

Class 1 = Bacillariophyceae
Class 2 = Chlorophyceae
Class 3 = Chrysophyceae
Class 4 = Cyanophyceae
Class 5 = Dinophyceae
Class 6 = Euchlorophyceae
Class 7 = Euglenophyceae
Class 8 = Haptophyceae
Class 9 = Xanthophyceae
Class 10= Unknown Cell Types

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
23 Aug	10	300	Calycomonas ovalis	3	1995	220
23 Aug	10	80	Gymnodinium sp.	5	57	145
23 Aug	10	100	Gymnodinium sp.	5	323	627
23 Aug	10	72	Cyclotella sp.	1	19	7
23 Aug	10	98	Prorocentrum minimum	5	19	11
23 Aug	11	296	Gymnodinium danicans	5	47	193
23 Aug	11	300	Calycomonas ovalis	3	2637	290
23 Aug	11	98	Prorocentrum minimum	5	23	13
23 Aug	12	64	Unknown #64	3	213	12
23 Aug	12	300	Calycomonas ovalis	3	166	18
23 Aug	12	6	Unknown #6	2	95	17
23 Aug	12	10	Scenedesmus sp.	2	23	14
23 Aug	12	399	Navicula sp.	1	23	30
23 Aug	13	300	Calycomonas ovalis	3	71	8
23 Aug	13	6	Unknown #6	2	1591	277
23 Aug	13	126	Navicula sp.	1	47	47
23 Aug	13	444	Epithemia sp.	1	23	6
23 Aug	13	10	Scenedesmus sp.	2	23	14
23 Aug	13	268	Scenedesmus sp.	2	23	31
23 Aug	13	438	Cyclotella sp.	1	71	25
23 Aug	13	445	Microcystis aeruginosa	4	118	4
23 Aug	13	40	Anabaena sp.	4	1425	19
23 Aug	14	446	Microcystis aeruginosa	4	114040	3877
23 Aug	14	242	Crucigenia rectangularis	2	213	83
23 Aug	14	41	Stichococcus sp.	2	3	0
23 Aug	14	10	Scenedesmus sp.	2	23	14
23 Aug	14	438	Cyclotella sp.	1	23	8
23 Aug	14	40	Anabaena sp.	4	1568	20
23 Aug	14	191	Scenedesmus quadricauda	2	71	50
23 Aug	14	6	Unknown #6	2	332	58
23 Aug	14	49	Actinastrum hantzschii	2	95	26
23 Aug	15	446	Microcystis aeruginosa	4	427649	14540
23 Aug	15	64	Unknown #64	3	142	8
23 Aug	15	268	Scenedesmus sp.	2	23	31
23 Aug	15	434	Pediastrum sp.	2	190	19
23 Aug	15	325	Eunotia sp.	1	23	115

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
23 Aug	15	40	Anabaena sp.	4	1853	24
23 Aug	16	446	Microcystis aeruginosa	4	1729600	58806
23 Aug	16	64	Unknown #64	3	126	7
23 Aug	16	438	Cyclotella sp.	1	285	99
23 Aug	16	263	Scenedesmus sp.	2	31	42
23 Aug	16	264	Scenedesmus sp.	2	63	50
23 Aug	17	446	Microcystis aeruginosa	4	24328	827
23 Aug	17	103	Cyclotella sp.	1	47	1
23 Aug	17	268	Scenedesmus sp.	2	142	188
23 Aug	17	196	Scenedesmus obliquus	2	95	29
23 Aug	17	442	Pediastrum biradiatum	2	2755	416
23 Aug	17	197	Unknown #197	10	47	91
23 Aug	17	147	Stauroneis sp.	1	47	25
23 Aug	18	440	Nitzschia sp.	1	95	96
23 Aug	18	6	Unknown #6	2	217056	37768
23 Aug	18	438	Cyclotella sp.	1	190	66
23 Aug	18	64	Unknown #64	3	190	11
23 Aug	18	408	Gyrosigma sp.	1	95	2458
23 Aug	18	268	Scenedesmus sp.	2	95	125
23 Aug	19	6	Unknown #6	2	278447	48450
23 Aug	19	126	Navicula sp.	1	95	95
23 Aug	19	438	Cyclotella sp.	1	95	33
23 Aug	19	196	Scenedesmus obliquus	2	95	29
23 Aug	20	446	Microcystis aeruginosa	4	731756	24880
23 Aug	20	201	Navicula sp.	1	71	52
23 Aug	20	124	Gomphonema sp.	1	23	25
23 Aug	20	408	Gyrosigma sp.	1	23	614
23 Aug	21	446	Microcystis aeruginosa	4	2898510	98549
23 Aug	21	6	Unknown #6	2	237	41
23 Aug	21	46	Navicula sp.	1	59	67
23 Aug	21	402	Cocconeis sp.	1	118	402
23 Aug	21	126	Navicula sp.	1	59	59
23 Aug	22	446	Microcystis aeruginosa	4	190066	6462
23 Aug	22	126	Navicula sp.	1	57	57
23 Aug	22	49	Actinastrum hantzschii	2	19	5
23 Aug	22	130	Cymatopleura sp.	1	19	100
23 Aug	22	6	Unknown #6	2	209	36
23 Aug	22	268	Scenedesmus sp.	2	19	25
23 Aug	23	6	Unknown #6	2	2755	480
23 Aug	23	443	Spirogyra sp.	2	47	98
23 Aug	24	108	Unknown #108	10	15	49
23 Aug	24	324	Bacillaria paradoxa	1	15	33
25 Aug	10	300	Calycomonas ovalis	3	7049	775
25 Aug	10	296	Gymnodinium danicans	5	345	1404
25 Aug	10	98	Prorocentrum minimum	5	69	39

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
25 Aug	11	296	Gymnodinium danicans	5	323	1313
25 Aug	11	300	Calycomonas ovalis	3	1976	217
25 Aug	11	98	Prorocentrum minimum	5	38	21
25 Aug	12	64	Unknown #64	3	228	13
25 Aug	12	300	Calycomonas ovalis	3	190	21
25 Aug	12	438	Cyclotella sp.	1	95	33
25 Aug	12	268	Scenedesmus sp.	2	19	25
25 Aug	13	445	Microcystis aeruginosa	4	11708	398
25 Aug	13	234	Navicula sp.	1	38	56
25 Aug	13	235	Unknown #235	10	114	34
25 Aug	13	377	Scenedesmus sp.	2	76	38
25 Aug	13	268	Scenedesmus sp.	2	114	150
25 Aug	13	6	Unknown #6	2	608	106
25 Aug	13	438	Cyclotella sp.	1	76	26
25 Aug	13	41	Stichococcus sp.	2	2	1
25 Aug	14	446	Microcystis aeruginosa	4	32311	1099
25 Aug	14	41	Stichococcus sp.	2	3	1
25 Aug	14	6	Unknown #6	2	1330	232
25 Aug	14	120	Selenastrum sp.	2	114	2
25 Aug	14	438	Cyclotella sp.	1	19	7
25 Aug	14	268	Scenedesmus sp.	2	38	50
25 Aug	14	49	Actinastrum hantzschii	2	171	47
25 Aug	15	446	Microcystis aeruginosa	4	1710	258
25 Aug	15	191	Scenedesmus quadricauda	2	63	45
25 Aug	15	268	Scenedesmus sp.	2	95	125
25 Aug	15	6	Unknown #6	2	190	33
25 Aug	15	41	Stichococcus sp.	2	31	1
25 Aug	15	438	Cyclotella sp.	1	158	55
25 Aug	15	377	Scenedesmus sp.	2	31	16
25 Aug	15	49	Actinastrum hantzschii	2	158	44
25 Aug	16	263	Scenedesmus sp.	2	57	75
25 Aug	16	268	Scenedesmus sp.	2	76	100
25 Aug	16	6	Unknown #6	2	266	46
25 Aug	16	64	Unknown #64	3	1102	63
25 Aug	16	49	Actinastrum hantzschii	2	133	37
25 Aug	16	442	Pediastrum biradiatum	2	627	95
25 Aug	16	278	Scenedesmus sp.	2	19	5
25 Aug	16	438	Cyclotella sp.	1	76	26
25 Aug	16	98	Prorocentrum minimum	5	19	11
25 Aug	16	352	Pediastrum sp.	2	76	15
25 Aug	17	445	Microcystis aeruginosa	4	323113	10986
25 Aug	17	201	Navicula sp.	1	38	28
25 Aug	17	64	Unknown #64	3	57	3
25 Aug	17	147	Stauroneis sp.	1	19	10
25 Aug	17	408	Gyrosigma sp.	1	38	983

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
25 Aug	17	438	Cyclotella sp.	1	95	33
25 Aug	17	442	Pediastrum biradiatum	2	1197	181
25 Aug	17	437	Microcystis sp.	4	1406	48
25 Aug	17	264	Scenedesmus sp.	2	19	15
25 Aug	18	446	Microcystis aeruginosa	4	498924	16963
25 Aug	18	438	Cyclotella sp.	1	71	25
25 Aug	18	234	Navicula sp.	1	23	35
25 Aug	18	6	Unknown #6	2	95	17
25 Aug	18	64	Unknown #64	3	332	19
25 Aug	18	442	Pediastrum biradiatum	2	760	115
25 Aug	18	268	Scenedesmus sp.	2	23	31
25 Aug	18	201	Navicula sp.	1	23	17
25 Aug	18	408	Gyrosigma sp.	1	23	614
25 Aug	18	317	Synedra sp.	1	23	17
25 Aug	18	430	Cocconeis sp.	1	23	19
25 Aug	19	445	Microcystis aeruginosa	4	546631	18585
25 Aug	19	408	Gyrosigma sp.	1	152	3932
25 Aug	19	258	Pediastrum tetras	2	76	17
25 Aug	20	49	Actinastrum hantzschii	2	19	5
25 Aug	20	126	Navicula sp.	1	38	38
25 Aug	20	445	Microcystis aeruginosa	4	1539	52
25 Aug	20	442	Pediastrum biradiatum	2	570	86
25 Aug	20	201	Navicula sp.	1	38	28
25 Aug	20	377	Scenedesmus sp.	2	19	10
25 Aug	20	446	Microcystis aeruginosa	4	174861	5945
25 Aug	21	201	Navicula sp.	1	38	28
25 Aug	21	324	Bacillaria paradoxa	1	19	42
25 Aug	22	126	Navicula sp.	1	38	38
25 Aug	22	374	Navicula sp.	1	19	2
25 Aug	23	443	Spirogyra sp.	2	19	39
25 Aug	23	126	Navicula sp.	1	38	38
25 Aug	24	129	Pinnularia sp.	1	19	69
25 Aug	24	259	Surirella sp.	1	19	135
25 Aug	24	430	Cocconeis sp.	1	19	15
28 Aug	10	300	Calycomonas ovalis	3	6699	737
28 Aug	10	102	Cyclotella sp.	1	3183	19
28 Aug	10	80	Gymnodinium sp.	5	617	1569
28 Aug	10	98	Prorocentrum minimum	5	190	106
28 Aug	11	300	Calycomonas ovalis	3	8616	948
28 Aug	11	64	Unknown #64	3	2576	147
28 Aug	11	102	Cyclotella sp.	1	1098	7
28 Aug	11	80	Gymnodinium sp.	5	422	1073
28 Aug	12	191	Scenedesmus quadricauda	2	38	27
28 Aug	12	300	Calycomonas ovalis	3	836	92
28 Aug	12	103	Cyclotella sp.	1	95	2

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
28 Aug	12	64	Unknown #64	3	114	7
28 Aug	12	445	Microcystis aeruginosa	4	437	15
28 Aug	13	235	Unknown #235	10	19	6
28 Aug	13	191	Scenedesmus quadricauda	2	57	40
28 Aug	13	300	Calycomonas ovalis	3	95	10
28 Aug	13	41	Stichococcus sp.	2	5	1
28 Aug	13	445	Microcystis aeruginosa	4	1463	50
28 Aug	13	49	Actinastrum hantzschii	2	285	79
28 Aug	14	446	Microcystis aeruginosa	4	231881	7884
28 Aug	14	64	Unknown #64	3	57	3
28 Aug	14	445	Microcystis aeruginosa	4	5283	180
28 Aug	14	49	Actinastrum hantzschii	2	228	63
28 Aug	14	438	Cyclotella sp.	1	57	20
28 Aug	14	264	Scenedesmus sp.	2	19	15
28 Aug	14	196	Scenedesmus obliquus	2	19	6
28 Aug	14	235	Unknown #235	10	19	6
28 Aug	14	6	Unknown #6	2	304	53
28 Aug	15	446	Microcystis aeruginosa	4	408643	13894
28 Aug	15	64	Unknown #64	3	285	16
28 Aug	15	438	Cyclotella sp.	1	237	82
28 Aug	15	6	Unknown #6	2	237	41
28 Aug	16	446	Microcystis aeruginosa	4	4770670	162202
28 Aug	17	446	Microcystis aeruginosa	4	391537	13312
28 Aug	17	64	Unknown #64	3	95	5
28 Aug	17	408	Gyrosigma sp.	1	76	1966
28 Aug	17	438	Cyclotella sp.	1	76	26
28 Aug	17	199	Surirella sp.	1	19	1515
28 Aug	17	130	Cymatopleura sp.	1	19	100
28 Aug	17	1	Pediastrum duplex	2	589	589
28 Aug	17	147	Stauroneis sp.	1	57	31
28 Aug	18	446	Microcystis aeruginosa	4	209073	7108
28 Aug	18	363	Unknown #363	10	19	249
28 Aug	18	408	Gyrosigma sp.	1	38	983
28 Aug	18	201	Navicula sp.	1	38	28
28 Aug	18	268	Scenedesmus sp.	2	76	100
28 Aug	18	273	Unknown #273	1	19	605
28 Aug	18	223	Eunotia sp.	1	19	13
28 Aug	19	130	Cymatopleura sp.	1	19	100
28 Aug	19	408	Gyrosigma sp.	1	19	492
28 Aug	19	254	Scenedesmus sp.	2	38	6
28 Aug	19	72	Cyclotella sp.	1	19	7
28 Aug	19	1	Pediastrum duplex	2	646	646
28 Aug	19	259	Surirella sp.	1	19	135
28 Aug	19	201	Navicula sp.	1	19	14
28 Aug	20	201	Navicula sp.	1	38	28

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
28 Aug	20	31	Scenedesmus sp.	2	19	14
28 Aug	20	223	Eunotia sp.	1	19	13
28 Aug	20	130	Cymatopleura sp.	1	19	100
28 Aug	20	408	Gyrosigma sp.	1	57	1475
28 Aug	20	440	Nitzschia sp.	1	19	19
28 Aug	20	8	Crucigenia sp.	2	19	8
28 Aug	21	49	Actinastrum hantzschii	2	76	21
28 Aug	21	201	Navicula sp.	1	38	28
28 Aug	21	376	Unknown #376	10	19	122
28 Aug	21	408	Gyrosigma sp.	1	19	492
28 Aug	22	201	Navicula sp.	1	118	87
28 Aug	22	408	Gyrosigma sp.	1	23	614
28 Aug	22	49	Actinastrum hantzschii	2	47	13
28 Aug	22	98	Prorocentrum minimum	5	47	27
28 Aug	23	201	Navicula sp.	1	57	42
28 Aug	23	49	Actinastrum hantzschii	2	19	5
28 Aug	24	49	Actinastrum hantzschii	2	19	5
28 Aug	24	201	Navicula sp.	1	57	42
28 Aug	24	258	Pediastrum tetras	2	19	4
28 Aug	24	430	Cocconeis sp.	1	38	30
28 Aug	24	408	Gyrosigma sp.	1	19	492
28 Aug	24	440	Nitzschia sp.	1	38	38
1 Sep	10	300	Calycomonas ovalis	3	13542	1490
1 Sep	10	80	Gymnodinium sp.	5	1267	3218
1 Sep	10	6	Unknown #6	2	1029	179
1 Sep	10	98	Prorocentrum minimum	5	158	89
1 Sep	11	300	Calycomonas ovalis	3	7331	806
1 Sep	11	64	Unknown #64	3	882	50
1 Sep	12	445	Microcystis aeruginosa	4	12924	439
1 Sep	12	300	Calycomonas ovalis	3	997	110
1 Sep	12	235	Unknown #235	10	190	57
1 Sep	12	6	Unknown #6	2	2518	438
1 Sep	12	64	Unknown #64	3	142	8
1 Sep	12	268	Scenedesmus sp.	2	190	250
1 Sep	12	264	Scenedesmus sp.	2	47	37
1 Sep	12	196	Scenedesmus obliquus	2	47	196
1 Sep	13	6	Unknown #6	2	2584	450
1 Sep	13	10	Scenedesmus sp.	2	57	33
1 Sep	13	235	Unknown #235	10	76	23
1 Sep	13	107	Chroococcus sp.	4	76	10
1 Sep	13	264	Scenedesmus sp.	2	57	45
1 Sep	13	41	Stichococcus sp.	2	2	1
1 Sep	13	268	Scenedesmus sp.	2	57	75
1 Sep	13	40	Anabaena sp.	4	570	7
1 Sep	13	8	Crucigenia sp.	2	19	8

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
1 Sep	13	445	Microcystis aeruginosa	4	361	12
1 Sep	13	313	Unknown #314	10	323	1
1 Sep	13	300	Calycomonas ovalis	3	57	6
1 Sep	14	438	Cyclotella sp.	1	171	59
1 Sep	14	6	Unknown #6	2	209	36
1 Sep	14	22	Cyclotella sp.	1	38	60
1 Sep	14	300	Calycomonas ovalis	3	19	2
1 Sep	14	445	Microcystis aeruginosa	4	760	26
1 Sep	14	49	Actinastrum hantzschii	2	114	31
1 Sep	14	120	Selenastrum sp.	2	19	1
1 Sep	15	446	Microcystis aeruginosa	4	304106	10340
1 Sep	15	438	Cyclotella sp.	1	133	46
1 Sep	15	6	Unknown #6	2	855	149
1 Sep	15	64	Unknown #64	3	513	29
1 Sep	15	272	Scenedesmus sp.	2	19	43
1 Sep	15	31	Scenedesmus sp.	2	19	43
1 Sep	15	114	Eunotia sp.	1	19	14
1 Sep	15	201	Navicula sp.	1	19	15
1 Sep	16	64	Unknown #64	3	570	33
1 Sep	16	446	Microcystis aeruginosa	4	3136090	106627
1 Sep	16	254	Scenedesmus sp.	2	190	29
1 Sep	16	191	Scenedesmus quadricauda	2	95	67
1 Sep	16	10	Scenedesmus sp.	2	95	56
1 Sep	16	268	Scenedesmus sp.	2	95	125
1 Sep	17	446	Microcystis aeruginosa	4	665232	22618
1 Sep	17	49	Actinastrum hantzschii	2	47	13
1 Sep	17	268	Scenedesmus sp.	2	23	31
1 Sep	17	438	Cyclotella sp.	1	118	41
1 Sep	17	254	Scenedesmus sp.	2	23	4
1 Sep	17	40	Anabaena sp.	4	665	9
1 Sep	17	201	Navicula sp.	1	23	17
1 Sep	17	6	Unknown #6	2	380	66
1 Sep	18	438	Cyclotella sp.	1	23	8
1 Sep	19	197	Unknown #197	10	19	36
1 Sep	19	6	Unknown #6	2	76	13
1 Sep	19	49	Actinastrum hantzschii	2	19	5
1 Sep	19	374	Navicula sp.	1	19	9
1 Sep	19	199	Surirella sp.	1	19	1545
1 Sep	20	408	Gyrosigma sp.	1	57	1475
1 Sep	20	191	Scenedesmus quadricauda	2	38	27
1 Sep	20	49	Actinastrum hantzschii	2	57	16
1 Sep	20	201	Navicula sp.	1	19	19
1 Sep	20	46	Navicula sp.	1	19	21
1 Sep	20	440	Nitzschia sp.	1	19	19
1 Sep	20	446	Microcystis aeruginosa	4	323113	10986

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
1 Sep	21	10	Scenedesmus sp.	2	19	11
1 Sep	21	439	Navicula sp.	1	57	14
1 Sep	21	408	Gyrosigma sp.	1	38	983
1 Sep	21	252	Didymosphenia sp.	1	19	54
1 Sep	21	49	Actinastrum hantzschii	2	38	10
1 Sep	21	440	Nitzschia sp.	1	19	19
1 Sep	21	441	Neidium ladogense	1	19	46
1 Sep	22	254	Scenedesmus sp.	2	19	3
1 Sep	22	441	Neidium ladogense	1	19	46
1 Sep	22	197	Unknown #197	10	133	255
1 Sep	22	397	Unknown #397	10	19	176
1 Sep	22	201	Navicula sp.	1	19	14
1 Sep	23	439	Navicula sp.	1	19	6
1 Sep	23	441	Neidium ladogense	1	19	46
1 Sep	23	371	Pinnularia sp.	1	38	203
1 Sep	23	201	Navicula sp.	1	38	28
1 Sep	24	402	Cocconeis sp.	1	38	129
5 Sep	10	10	Scenedesmus sp.	2	38	22
5 Sep	10	64	Unknown #64	3	722	41
5 Sep	10	300	Calycomonas ovalis	3	2984	328
5 Sep	10	320	Unknown #320	5	266	52665
5 Sep	10	80	Gymnodinium sp.	5	38	97
5 Sep	11	300	Calycomonas ovalis	3	2299	253
5 Sep	11	64	Unknown #64	3	1007	57
5 Sep	11	118	Crucigenia tetrapedia	2	19	1
5 Sep	11	72	Cyclotella sp.	1	323	126
5 Sep	11	320	Unknown #320	5	38	7524
5 Sep	12	235	Unknown #235	10	63	19
5 Sep	12	191	Scenedesmus quadricauda	2	126	89
5 Sep	12	107	Chroococcus sp.	4	63	8
5 Sep	12	98	Prorocentrum minimum	5	63	35
5 Sep	12	450	Merismopaedia sp.	4	1267	22
5 Sep	12	300	Calycomonas ovalis	3	253	28
5 Sep	12	41	Stichococcus sp.	2	4	1
5 Sep	12	64	Unknown #64	3	63	4
5 Sep	12	446	Microcystis aeruginosa	4	21604	735
5 Sep	13	352	Pediastrum sp.	2	532	107
5 Sep	13	49	Actinastrum hantzschii	2	152	42
5 Sep	13	41	Stichococcus sp.	2	29	3
5 Sep	13	357	Scenedesmus sp.	2	76	153
5 Sep	13	191	Scenedesmus quadricauda	2	228	161
5 Sep	13	373	Gyrosigma sp.	1	76	2388
5 Sep	13	40	Anabaena sp.	4	3421	44
5 Sep	13	446	Microcystis aeruginosa	4	40218	1367

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
5 Sep	13	445	Microcystis aeruginosa	4	1672	57
5 Sep	14	49	Actinastrum hantzschii	2	791	219
5 Sep	14	72	Cyclotella sp.	1	221	86
5 Sep	14	41	Stichococcus sp.	2	7	1
5 Sep	14	373	Gyrosigma sp.	1	95	2986
5 Sep	14	72	Cyclotella sp.	1	31	12
5 Sep	14	196	Scenedesmus obliquus	2	31	10
5 Sep	14	191	Scenedesmus quadricauda	2	31	22
5 Sep	14	442	Pediastrum biradiatum	2	918	139
5 Sep	14	1	Pediastrum duplex	2	982	982
5 Sep	14	376	Unknown #376	10	31	204
5 Sep	15	41	Stichococcus sp.	2	5	1
5 Sep	15	1	Pediastrum duplex	2	665	665
5 Sep	15	126	Navicula sp.	1	23	24
5 Sep	15	197	Unknown #197	10	23	46
5 Sep	15	72	Cyclotella sp.	1	71	28
5 Sep	15	357	Scenedesmus sp.	2	23	48
5 Sep	15	64	Unknown #64	3	166	9
5 Sep	15	373	Gyrosigma sp.	1	23	746
5 Sep	15	242	Crucigenia rectangularis	2	95	37
5 Sep	15	268	Scenedesmus sp.	2	47	63
5 Sep	15	446	Microcystis aeruginosa	4	218101	7415
5 Sep	16	126	Navicula sp.	1	19	19
5 Sep	16	201	Navicula sp.	1	57	42
5 Sep	16	272	Scenedesmus sp.	2	19	43
5 Sep	16	72	Cyclotella sp.	1	57	22
5 Sep	16	19	Navicula sp.	1	19	19
5 Sep	16	49	Actinastrum hantzschii	2	76	21
5 Sep	16	268	Scenedesmus sp.	2	19	25
5 Sep	16	328	Unknown #328	1	19	38
5 Sep	16	446	Microcystis aeruginosa	4	646226	21972
5 Sep	17	1	Pediastrum duplex	2	688	689
5 Sep	17	268	Scenedesmus sp.	2	142	188
5 Sep	17	373	Gyrosigma sp.	1	142	4478
5 Sep	17	49	Actinastrum hantzschii	2	47	13
5 Sep	17	72	Cyclotella sp.	1	23	9
5 Sep	17	31	Scenedesmus sp.	2	23	9
5 Sep	17	376	Unknown #376	10	23	153
5 Sep	17	201	Navicula sp.	1	23	17
5 Sep	17	395	Eunotia sp.	1	23	13
5 Sep	17	41	Stichococcus sp.	2	10	1
5 Sep	17	352	Pediastrum sp.	2	190	38
5 Sep	17	446	Microcystis aeruginosa	4	189116	6430
5 Sep	18	201	Navicula sp.	1	19	14
5 Sep	18	1	Pediastrum duplex	2	1254	1254

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
5 Sep	18	376	Unknown #376	10	19	122
5 Sep	18	49	Actinastrum hantzschii	2	19	5
5 Sep	18	272	Scenedesmus sp.	2	38	86
5 Sep	18	373	Gyrosigma sp.	1	19	597
5 Sep	18	41	Stichococcus sp.	2	5	1
5 Sep	18	147	Stauroneis sp.	1	19	10
5 Sep	18	466	Unknown #466	3	35352	1202
5 Sep	19	268	Scenedesmus sp.	2	57	75
5 Sep	19	373	Gyrosigma sp.	1	28	896
5 Sep	19	201	Navicula sp.	1	9	7
5 Sep	19	49	Actinastrum hantzschii	2	19	5
5 Sep	19	31	Scenedesmus sp.	2	9	3
5 Sep	19	199	Surirella sp.	1	9	772
5 Sep	19	201	Navicula sp.	1	9	7
5 Sep	20	49	Actinastrum hantzschii	2	28	8
5 Sep	20	376	Unknown #376	10	19	122
5 Sep	20	373	Gyrosigma sp.	1	9	299
5 Sep	21	130	Cymatopleura sp.	1	9	50
5 Sep	21	373	Gyrosigma sp.	1	19	597
5 Sep	21	268	Scenedesmus sp.	2	9	13
5 Sep	21	123	Achnanthes sp.	1	9	49
5 Sep	21	126	Navicula sp.	1	9	9
5 Sep	21	201	Navicula sp.	1	28	21
5 Sep	21	328	Unknown #328	1	9	19
5 Sep	21	147	Stauroneis sp.	1	9	5
5 Sep	22	373	Gyrosigma sp.	1	38	1194
5 Sep	22	201	Navicula sp.	1	19	14
5 Sep	22	49	Actinastrum hantzschii	2	28	8
5 Sep	23	10	Scenedesmus sp.	2	9	6
5 Sep	23	441	Neidium ladogense	1	9	23
5 Sep	23	268	Scenedesmus sp.	2	9	13
5 Sep	23	365	Navicula sp.	1	9	90
5 Sep	23	197	Unknown #197	10	9	18
5 Sep	24	373	Gyrosigma sp.	1	9	299
5 Sep	24	402	Cocconeis sp.	1	19	64
5 Sep	24	126	Navicula sp.	1	19	19
9 Sep	10	300	Calycomonas ovalis	3	3535	389
9 Sep	10	64	Unknown #64	3	5587	319
9 Sep	10	320	Unknown #320	5	494	97807
9 Sep	10	427	Unknown #427	2	38	351
9 Sep	11	300	Calycomonas ovalis	3	684	75
9 Sep	11	64	Unknown #64	3	532	30
9 Sep	11	320	Unknown #320	5	171	33856
9 Sep	13	10	Scenedesmus sp.	2	57	33
9 Sep	13	41	Stichococcus sp.	2	5	1

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
9 Sep	13	64	Unknown #64	3	38	2
9 Sep	13	300	Calycomonas ovalis	3	76	8
9 Sep	13	268	Scenedesmus sp.	2	19	25
9 Sep	13	281	Euglena sp.	7	19	16
9 Sep	13	107	Chroococcus sp.	4	38	5
9 Sep	13	118	Crucigenia tetrapedia	2	19	1
9 Sep	13	446	Microcystis aeruginosa	4	20147	685
9 Sep	14	235	Unknown #235	10	114	34
9 Sep	14	64	Unknown #64	3	494	28
9 Sep	14	41	Stichococcus sp.	2	4	1
9 Sep	14	49	Actinastrum hantzschii	2	228	63
9 Sep	14	450	Merismopaedia sp.	4	38	1
9 Sep	14	446	Microcystis aeruginosa	4	12544	427
9 Sep	14	445	Microcystis aeruginosa	4	13874	472
9 Sep	15	49	Actinastrum hantzschii	2	522	144
9 Sep	15	196	Scenedesmus obliquus	2	47	14
9 Sep	15	268	Scenedesmus sp.	2	47	63
9 Sep	15	197	Unknown #197	10	47	91
9 Sep	15	1	Pediastrum duplex	2	712	713
9 Sep	15	446	Microcystis aeruginosa	4	31503	1071
9 Sep	15	445	Microcystis aeruginosa	4	4799	163
9 Sep	16	191	Scenedesmus quadricauda	2	456	321
9 Sep	16	254	Scenedesmus sp.	2	152	23
9 Sep	16	64	Unknown #64	3	76	4
9 Sep	16	72	Cyclotella sp.	1	342	133
9 Sep	16	235	Unknown #235	10	38	11
9 Sep	16	201	Navicula sp.	1	38	28
9 Sep	16	357	Scenedesmus sp.	2	38	76
9 Sep	16	242	Crucigenia rectangularis	2	38	15
9 Sep	16	268	Scenedesmus sp.	2	114	150
9 Sep	16	373	Gyrosigma sp.	1	38	1194
9 Sep	16	119	Achnanthes exigua	1	8	1
9 Sep	16	446	Microcystis aeruginosa	4	27369	931
9 Sep	17	118	Crucigenia tetrapedia	2	7	1
9 Sep	17	191	Scenedesmus quadricauda	2	95	67
9 Sep	17	72	Cyclotella sp.	1	76	30
9 Sep	17	22	Cyclotella sp.	1	38	60
9 Sep	17	254	Scenedesmus sp.	2	19	3
9 Sep	17	412	Navicula sp.	1	19	89
9 Sep	17	324	Bacillaria paradoxa	1	19	42
9 Sep	17	201	Navicula sp.	1	19	14
9 Sep	17	446	Microcystis aeruginosa	4	15186	514
9 Sep	17	445	Microcystis aeruginosa	4	2831	96
9 Sep	18	272	Scenedesmus sp.	2	76	172
9 Sep	18	22	Cyclotella sp.	1	57	90

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
9 Sep	18	126	Navicula sp.	1	38	38
9 Sep	18	417	Navicula sp.	1	19	19
9 Sep	18	72	Cyclotella sp.	1	19	7
9 Sep	18	49	Actinastrum hantzschii	2	19	5
9 Sep	18	268	Scenedesmus sp.	2	38	50
9 Sep	18	96	Microcystis aeruginosa	4	19	25
9 Sep	18	446	Microcystis aeruginosa	4	437	15
9 Sep	18	445	Microcystis aeruginosa	4	475	16
9 Sep	19	223	Eunotia sp.	1	19	13
9 Sep	19	191	Scenedesmus quadricauda	2	76	54
9 Sep	19	147	Stauroneis sp.	1	38	20
9 Sep	19	201	Navicula sp.	1	19	14
9 Sep	19	1	Pediastrum duplex	2	304	304
9 Sep	19	268	Scenedesmus sp.	2	38	50
9 Sep	19	373	Gyrosigma sp.	1	57	1791
9 Sep	19	49	Actinastrum hantzschii	2	38	10
9 Sep	19	64	Unknown #64	3	38	2
9 Sep	19	272	Scenedesmus sp.	2	19	43
9 Sep	19	96	Microcystis aeruginosa	4	19	43
9 Sep	19	118	Crucigenia tetrapedia	2	76	5
9 Sep	19	446	Microcystis aeruginosa	4	608	21
9 Sep	19	445	Microcystis aeruginosa	4	190	6
9 Sep	20	137	Navicula sp.	1	38	40
9 Sep	20	96	Microcystis aeruginosa	4	19	20
9 Sep	20	279	Scenedesmus sp.	2	19	22
9 Sep	20	49	Actinastrum hantzschii	2	19	5
9 Sep	20	446	Microcystis aeruginosa	4	228	8
9 Sep	21	49	Actinastrum hantzschii	2	38	10
9 Sep	21	26	Navicula sp.	1	9	9
9 Sep	21	117	Cymatopleura sp.	1	9	127
9 Sep	21	373	Gyrosigma sp.	1	9	299
9 Sep	22	371	Pinnularia sp.	1	9	13
9 Sep	22	119	Achnanthes exigua	1	9	51
9 Sep	22	201	Navicula sp.	1	38	28
9 Sep	22	96	Microcystis aeruginosa	4	28	21
9 Sep	22	49	Actinastrum hantzschii	2	19	5
9 Sep	22	376	Unknown #376	10	9	61
9 Sep	22	148	Diploneis sp.	1	9	17
9 Sep	22	199	Surirella sp.	1	9	772
9 Sep	23	371	Pinnularia sp.	1	9	51
9 Sep	23	201	Navicula sp.	1	9	7
9 Sep	23	325	Eunotia sp.	1	9	46
9 Sep	23	446	Microcystis aeruginosa	4	1349	46
9 Sep	23	445	Microcystis aeruginosa	4	323	11
9 Sep	24	49	Actinastrum hantzschii	2	9	3

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
9 Sep	24	126	Navicula sp.	1	9	9
9 Sep	24	430	Cocconeis sp.	1	19	15
13 Sep	10	300	Calycomonas ovalis	3	3112	342
13 Sep	10	320	Unknown #320	5	213	42320
13 Sep	10	98	Prorocentrum minimum	5	71	40
13 Sep	10	281	Euglena sp.	7	47	40
13 Sep	10	64	Unknown #64	3	356	20
13 Sep	11	300	Calycomonas ovalis	3	7716	849
13 Sep	11	64	Unknown #64	3	3193	182
13 Sep	11	93	Gymnodinium verruculosum	5	76	7
13 Sep	11	80	Gymnodinium sp.	5	38	97
13 Sep	12	300	Calycomonas ovalis	3	228	25
13 Sep	12	64	Unknown #64	3	228	13
13 Sep	12	320	Unknown #320	5	19	3762
13 Sep	12	197	Unknown #197	10	19	36
13 Sep	12	235	Unknown #235	10	38	11
13 Sep	12	191	Scenedesmus quadricauda	2	76	54
13 Sep	12	217	Scenedesmus bijuga	2	19	9
13 Sep	13	191	Scenedesmus quadricauda	2	76	54
13 Sep	13	8	Crucigenia sp.	2	76	33
13 Sep	13	107	Chroococcus sp.	4	380	49
13 Sep	13	64	Unknown #64	3	76	4
13 Sep	13	300	Calycomonas ovalis	3	76	8
13 Sep	13	268	Scenedesmus sp.	2	76	100
13 Sep	13	445	Microcystis aeruginosa	4	36340	1236
13 Sep	14	41	Stichococcus sp.	2	16	2
13 Sep	14	268	Scenedesmus sp.	2	114	150
13 Sep	14	72	Cyclotella sp.	1	76	30
13 Sep	14	196	Scenedesmus obliquus	2	114	35
13 Sep	14	235	Unknown #235	10	38	11
13 Sep	14	120	Selenastrum sp.	2	228	5
13 Sep	14	446	Microcystis aeruginosa	4	297264	10107
13 Sep	15	242	Crucigenia rectangularis	2	475	185
13 Sep	15	72	Cyclotella sp.	1	190	74
13 Sep	15	49	Actinastrum hantzschii	2	47	13
13 Sep	15	268	Scenedesmus sp.	2	95	125
13 Sep	15	41	Stichococcus sp.	2	9	1
13 Sep	15	402	Cocconeis sp.	1	47	161
13 Sep	15	264	Scenedesmus sp.	2	142	112
13 Sep	15	442	Pediastrum biradiatum	2	1330	201
13 Sep	15	446	Microcystis aeruginosa	4	627219	21325
13 Sep	15	445	Microcystis aeruginosa	4	9978	339
13 Sep	16	22	Cyclotella sp.	1	142	224
13 Sep	16	64	Unknown #64	3	570	33
13 Sep	16	268	Scenedesmus sp.	2	95	125

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
13 Sep	16	223	Eunotia sp.	1	23	13
13 Sep	16	114	Eunotia sp.	1	23	16
13 Sep	16	242	Crucigenia rectangularis	2	23	9
13 Sep	16	72	Cyclotella sp.	1	95	37
13 Sep	16	272	Scenedesmus sp.	2	23	54
13 Sep	16	430	Cocconeis sp.	1	23	19
13 Sep	16	126	Navicula sp.	1	23	24
13 Sep	16	446	Microcystis aeruginosa	4	8600	292
13 Sep	17	123	Achnanthes sp.	1	19	99
13 Sep	17	72	Cyclotella sp.	1	152	59
13 Sep	17	268	Scenedesmus sp.	2	19	25
13 Sep	17	22	Cyclotella sp.	1	38	60
13 Sep	17	442	Pediastrum biradiatum	2	1235	187
13 Sep	17	254	Scenedesmus sp.	2	57	9
13 Sep	17	191	Scenedesmus quadricauda	2	57	40
13 Sep	17	117	Cymatopleura sp.	1	19	255
13 Sep	17	201	Navicula sp.	1	38	28
13 Sep	17	300	Calycomonas ovalis	3	38	4
13 Sep	17	196	Scenedesmus obliquus	2	19	6
13 Sep	18	191	Scenedesmus quadricauda	2	57	40
13 Sep	18	72	Cyclotella sp.	1	57	22
13 Sep	18	268	Scenedesmus sp.	2	57	75
13 Sep	18	201	Navicula sp.	1	38	28
13 Sep	18	22	Cyclotella sp.	1	57	90
13 Sep	18	446	Microcystis aeruginosa	4	339078	11529
13 Sep	19	268	Scenedesmus sp.	2	38	50
13 Sep	19	22	Cyclotella sp.	1	38	60
13 Sep	19	41	Stichococcus sp.	2	2	1
13 Sep	19	96	Microcystis aeruginosa	4	57	6
13 Sep	19	373	Gyrosigma sp.	1	38	1194
13 Sep	19	446	Microcystis aeruginosa	4	50557	1719
13 Sep	20	96	Microcystis aeruginosa	4	38	1
13 Sep	20	26	Navicula sp.	1	9	9
13 Sep	20	199	Surirella sp.	1	9	772
13 Sep	20	72	Cyclotella sp.	1	38	15
13 Sep	20	201	Navicula sp.	1	19	14
13 Sep	20	191	Scenedesmus quadricauda	2	9	7
13 Sep	20	49	Actinastrum hantzschii	2	9	3
13 Sep	20	149	Unknown #149	10	9	420
13 Sep	20	373	Gyrosigma sp.	1	9	299
13 Sep	20	446	Microcystis aeruginosa	4	845	29
13 Sep	21	149	Unknown #149	10	57	2522
13 Sep	21	201	Navicula sp.	1	19	14
13 Sep	21	371	Pinnularia sp.	1	19	102
13 Sep	21	123	Achnanthes sp.	1	19	99

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
13 Sep	21	96	Microcystis aeruginosa	4	19	99
13 Sep	21	49	Actinastrum hantzschii	2	38	10
13 Sep	21	446	Microcystis aeruginosa	4	8914	303
13 Sep	21	445	Microcystis aeruginosa	4	3212	109
13 Sep	22	49	Actinastrum hantzschii	2	12	3
13 Sep	22	96	Microcystis aeruginosa	4	25	7
13 Sep	22	371	Pinnularia sp.	1	12	68
13 Sep	22	201	Navicula sp.	1	12	9
13 Sep	22	191	Scenedesmus quadricauda	2	12	9
13 Sep	22	373	Gyrosigma sp.	1	12	398
13 Sep	22	446	Microcystis aeruginosa	4	3915	133
13 Sep	23	1	Pediastrum duplex	2	334	335
13 Sep	23	96	Microcystis aeruginosa	4	15	15
13 Sep	23	49	Actinastrum hantzschii	2	30	8
13 Sep	23	201	Navicula sp.	1	15	11
13 Sep	23	373	Gyrosigma sp.	1	15	478
13 Sep	23	446	Microcystis aeruginosa	4	1003	34
13 Sep	24	96	Microcystis aeruginosa	4	12	1
13 Sep	24	373	Gyrosigma sp.	1	12	398
13 Sep	24	49	Actinastrum hantzschii	2	12	3
13 Sep	24	126	Navicula sp.	1	25	25
19 Sep	10	300	Calycomonas ovalis	3	3104	341
19 Sep	10	64	Unknown #64	3	3231	184
19 Sep	10	48	Unknown #48	10	63	32
19 Sep	10	80	Gymnodinium sp.	5	63	161
19 Sep	12	300	Calycomonas ovalis	3	437	48
19 Sep	12	64	Unknown #64	3	589	34
19 Sep	12	446	Microcystis aeruginosa	4	2090	71
19 Sep	13	120	Selenastrum sp.	2	76	3
19 Sep	13	107	Chroococcus sp.	4	57	7
19 Sep	13	41	Stichococcus sp.	2	10	1
19 Sep	13	268	Scenedesmus sp.	2	76	100
19 Sep	13	300	Calycomonas ovalis	3	190	21
19 Sep	13	64	Unknown #64	3	76	4
19 Sep	13	446	Microcystis aeruginosa	4	1121	38
19 Sep	14	64	Unknown #64	3	190	11
19 Sep	14	270	Pediastrum sp.	2	1254	45
19 Sep	14	268	Scenedesmus sp.	2	19	25
19 Sep	14	41	Stichococcus sp.	2	2	1
19 Sep	14	49	Actinastrum hantzschii	2	57	16
19 Sep	14	72	Cyclotella sp.	1	38	15
19 Sep	14	446	Microcystis aeruginosa	4	1976	67
19 Sep	15	72	Cyclotella sp.	1	152	59
19 Sep	15	64	Unknown #64	3	988	56
19 Sep	15	270	Pediastrum sp.	2	342	12

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
19 Sep	15	1	Pediastrum duplex	2	950	950
19 Sep	15	41	Stichococcus sp.	2	11	1
19 Sep	15	107	Chroococcus sp.	4	608	79
19 Sep	15	446	Microcystis aeruginosa	4	401496	13651
19 Sep	16	201	Navicula sp.	1	57	42
19 Sep	16	263	Scenedesmus sp.	2	19	25
19 Sep	16	49	Actinastrum hantzschii	2	19	5
19 Sep	16	440	Nitzschia sp.	1	19	19
19 Sep	16	72	Cyclotella sp.	1	38	15
19 Sep	16	41	Stichococcus sp.	2	20	2
19 Sep	16	26	Navicula sp.	1	19	18
19 Sep	16	405	Navicula sp.	1	19	19
19 Sep	16	234	Navicula sp.	1	38	56
19 Sep	16	10	Scenedesmus sp.	2	57	33
19 Sep	16	1	Pediastrum duplex	2	646	646
19 Sep	16	446	Microcystis aeruginosa	4	11822	402
19 Sep	17	264	Scenedesmus sp.	2	19	15
19 Sep	17	10	Scenedesmus sp.	2	57	33
19 Sep	17	41	Stichococcus sp.	2	2	1
19 Sep	17	49	Actinastrum hantzschii	2	38	10
19 Sep	17	402	Cocconeis sp.	1	38	129
19 Sep	17	126	Navicula sp.	1	95	95
19 Sep	17	147	Stauroneis sp.	1	19	10
19 Sep	17	446	Microcystis aeruginosa	4	6709	228
19 Sep	18	373	Gyrosigma sp.	1	19	597
19 Sep	18	126	Navicula sp.	1	19	19
19 Sep	18	49	Actinastrum hantzschii	2	19	5
19 Sep	18	258	Pediastrum tetras	2	19	4
19 Sep	18	442	Pediastrum biradiatum	2	1862	281
19 Sep	18	201	Navicula sp.	1	38	28
19 Sep	18	446	Microcystis aeruginosa	4	190	6
19 Sep	18	445	Microcystis aeruginosa	4	2470	84
19 Sep	19	147	Stauroneis sp.	1	19	10
19 Sep	19	201	Navicula sp.	1	57	42
19 Sep	19	49	Actinastrum hantzschii	2	38	10
19 Sep	19	72	Cyclotella sp.	1	19	7
19 Sep	19	197	Unknown #197	10	114	219
19 Sep	19	446	Microcystis aeruginosa	4	91231	3102
19 Sep	20	373	Gyrosigma sp.	1	19	597
19 Sep	20	49	Actinastrum hantzschii	2	38	10
19 Sep	20	448	Navicula sp.	1	38	2018
19 Sep	20	201	Navicula sp.	1	38	28
19 Sep	20	449	Cymbella sp.	1	19	536
19 Sep	20	446	Microcystis aeruginosa	4	4067	138
19 Sep	20	445	Microcystis aeruginosa	4	2090	71

Appendix E, continued

Date	Station	Cell Type	Identification	Class	Density (cells/ml)	Biomass (ug/l)
19 Sep	21	49	Actinastrum hantzschii	2	19	5
19 Sep	21	357	Scenedesmus sp.	2	19	38
19 Sep	21	201	Navicula sp.	1	76	56
19 Sep	21	10	Scenedesmus sp.	2	19	11
19 Sep	21	158	Pinnularia sp.	1	19	119
19 Sep	21	446	Microcystis aeruginosa	4	950	32
19 Sep	21	445	Microcystis aeruginosa	4	2622	89
19 Sep	22	373	Gyrosigma sp.	1	19	597
19 Sep	22	49	Actinastrum hantzschii	2	19	5
19 Sep	22	446	Microcystis aeruginosa	4	399	14
19 Sep	23	201	Navicula sp.	1	19	14
19 Sep	23	158	Pinnularia sp.	1	9	60
19 Sep	24	440	Nitzschia sp.	1	9	10
19 Sep	24	49	Actinastrum hantzschii	2	9	3
19 Sep	24	323	Unknown #323	5	9	49
19 Sep	24	402	Cocconeis sp.	1	9	32

Appendix F. Primary productivity (uM CO_2/h) near light saturation at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	9.5	13.1	10.0	4.9	33.1	17.8	20.3	20.2	19.9	19.5	15.9	---	---
11	10.4	15.8	12.7	9.3	27.4	16.0	17.5	18.9	15.8	12.7	17.3	---	---
12	7.3	8.7	8.7	4.6	5.8	4.2	7.9	2.2	2.7	8.9	6.4	---	---
13	2.1	3.3	3.7	1.8	7.4	2.8	5.0	4.5	6.4	8.7	4.0	---	---
14	---	10.5	9.7	6.3	13.8	8.7	14.5	9.0	46.4	9.5	7.4	---	---
15	13.6	18.1	22.4	9.8	40.0	10.6	16.7	24.8	18.9	27.0	8.5	---	---
16	0.6	15.3	13.9	14.5	34.9	35.0	36.2	20.6	21.7	28.4	7.7	---	---
17	3.9	24.6	12.5	20.4	19.8	8.6	15.8	8.2	7.7	9.3	6.2	---	---
18	5.5	23.5	14.9	12.4	11.9	3.4	5.8	9.4	4.1	3.0	2.9	---	---
19	5.9	24.4	9.3	26.3	8.4	2.0	4.0	7.8	2.6	1.3	1.7	---	---
20	9.4	13.5	5.4	2.5	1.9	1.4	13.0	2.6	0.8	0.5	0.9	---	---
21	7.5	5.0	7.6	3.6	1.2	0.9	6.1	1.0	0.8	0.8	24.7	---	---
22	4.9	3.5	2.0	1.0	1.0	0.6	5.1	0.8	0.8	0.8	0.9	---	---
23	1.5	3.3	1.4	0.5	2.2	1.8	4.5	0.8	0.5	0.7	1.8	---	---
24	0.6	0.6	0.2	0.3	0.2	0.4	0.6	0.3	0.6	0.6	0.5	---	---

Appendix G. Nitrate plus nitrite nitrogen concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	<1	1	1	<1	4		<1	6	<1	<1	1	1	<1
11	1	1	<1	1	6	9	<1	4	7	5	4	3	2
12	11	3	13	13	10	9	9	4	9	11	7	9	16
13	9	3	9	1	9	8	9	2	11	21	17	10	16
14	4	8	7	<1	1	7	<1	3	14	20	16	<1	14
15	1	<1	6	4	2	4	1	6	14	1	3	3	14
16	6	44	39	4	1	5	11	6	17	17	14	12	13
17	34	16	<1	<1	13	64	11	4	11	51	13	12	12
18	17	1	1	2	43	64	13	6	11	54	11	14	9
19	---	1	<1	3	43	57	11	5	11	56	14	14	10
20	2	21	49	50	71	50	13	4	10	56	11	13	10
21	<1	37	49	61	79	46	11	4	11	46	10	11	9
22	<1	86	51	61	64	43	9	6	10	49	11	11	9
23	32	62	77	100	61	64	10	4	11	60	11	11	7
24	64	77	---	100	57	86	16	4	9	51	13	13	9

Appendix H. Ammonium nitrogen concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	5.7	0.9	<0.7	1.6	<0.7	1.2	<0.7	5.0	1.3	0.7	1.3	<0.7	---
11	6.4	<0.7	0.8	1.5	<0.7	11.3	<0.7	12.5	12.6	6.6	0.8	<0.7	---
12	9.3	15.2	17.6	20.6	29.0	24.0	24.6	34.5	26.0	20.2	15.9	17.7	---
13	---	25.3	30.0	33.6	24.8	25.4	25.9	30.5	18.9	19.5	23.0	24.8	---
14	8.6	8.4	4.6	1.3	2.1	3.6	1.3	8.8	1.8	3.1	4.4	<0.7	---
15	6.4	<0.7	0.9	<0.7	<0.7	0.9	1.6	1.7	1.1	4.4	1.2	<0.7	---
16	5.0	<0.7	<0.7	<0.7	2.3	<0.7	1.4	1.5	3.1	2.9	<0.7	2.9	---
17	7.9	<0.7	<0.7	3.7	<0.7	2.1	4.8	1.5	1.2	2.9	1.3	3.6	---
18	5.7	<0.7	1.2	1.8	<0.7	3.1	1.3	1.2	3.1	3.8	3.4	<0.7	---
19	5.0	<0.7	1.8	4.6	<0.7	7.2	2.9	1.6	5.1	4.0	2.9	<0.7	---
20	5.0	<0.7	1.9	6.1	4.8	7.0	<0.7	14.9	7.9	8.1	5.1	3.3	---
21	5.0	<0.7	4.1	6.1	6.9	8.1	1.8	13.7	10.6	8.0	8.9	3.4	---
22	6.4	2.3	4.7	7.1	5.8	7.1	1.2	11.8	10.1	7.7	9.6	4.0	---
23	7.9	4.3	7.1	8.7	5.8	10.4	5.4	13.5	11.8	9.9	12.6	4.7	---
24	7.9	7.0	8.3	9.2	6.5	7.6	8.6	9.7	7.5	8.9	13.5	10.1	---

Appendix I. Filterable Kjeldahl nitrogen (FKN) concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	---	---	---	---	---	---	35.1	49.4	45.8	49.2	39.1	39.2	46.2
11	---	---	---	---	---	---	34.2	54.0	52.0	43.0	44.6	36.2	48.4
12	---	---	---	---	---	---	75.3	61.6	66.0	55.0	39.1	43.7	57.6
13	---	---	---	---	---	---	71.9	62.0	62.0	63.7	63.4	67.1	67.3
14	---	---	---	---	---	---	31.2	29.2	42.8	48.5	44.6	32.9	36.7
15	---	---	---	---	---	---	30.9	47.1	35.2	52.9	26.5	30.5	35.7
16	---	---	---	---	---	---	33.6	35.5	33.2	52.0	29.4	39.2	32.5
17	---	---	---	---	---	---	40.0	35.5	39.1	30.0	25.2	30.8	32.8
18	---	---	---	---	---	---	35.7	34.8	35.8	27.2	32.3	54.5	32.8
19	---	---	---	---	---	---	34.2	32.8	36.8	30.0	32.3	24.5	32.5
20	---	---	---	---	---	---	35.1	44.1	34.5	36.2	32.6	28.1	29.2
21	---	---	---	---	---	---	31.5	42.1	45.4	40.5	35.9	38.0	39.3
22	---	---	---	---	---	---	30.3	45.8	45.8	39.2	33.6	34.1	41.9
23	---	---	---	---	---	---	38.2	46.1	39.5	39.2	46.2	35.9	47.4
24	---	---	---	---	---	---	49.4	37.2	32.8	36.2	49.8	39.8	54.7

Appendix J. Particulate Kjeldahl nitrogen (PKN) concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	40	66	32	37	---	75	162	45	22	69	47	189	127
11	42	72	30	86	---	66	88	39	10	36	38	201	219
12	44	24	14	18	---	13	35	4	10	26	24	85	61
13	30	32	13	23	---	18	22	10	22	28	21	110	85
14	42	42	21	15	---	38	69	29	56	34	34	443	132
15	77	77	52	47	---	64	82	156	45	172	31	506	287
16	377	63	17	38	---	255	404	92	66	2671	24	102	84
17	38	119	59	203	---	114	105	39	34	40	24	136	22
18	47	63	50	87	---	8	23	44	10	20	13	116	27
19	59	160	43	361	---	12	23	34	8	13	12	125	57
20	125	72	14	16	---	18	82	8	5	13	10	44	14
21	983	23	25	23	---	22	83	5	2	10	12	65	33
22	70	17	74	16	---	12	35	4	4	9	10	52	29
23	23	14	7	9	---	19	15	7	2	7	11	37	26
24	31	12	5	15	---	1	15	1	7	11	8	40	13

Appendix K. Filterable reactive phosphorus (PO_4) concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	3.9	3.9	4.5	3.2	3.9	3.2	4.5	3.9	5.5	2.6	---	3.9	3.2
11	3.2	3.9	4.2	2.9	2.9	4.5	4.5	4.2	6.5	3.9	---	3.9	2.6
12	5.8	5.2	5.5	4.2	5.2	4.8	7.7	4.8	7.7	4.5	---	4.8	3.5
13	7.1	6.8	7.1	5.2	5.2	5.2	7.1	4.8	7.4	4.5	---	5.2	3.9
14	6.1	6.5	5.8	4.5	5.8	4.2	6.5	4.5	6.1	3.9	---	3.9	3.5
15	6.5	6.5	6.5	5.2	10.0	5.2	8.4	4.5	7.1	9.7	---	5.2	4.2
16	5.2	6.8	7.7	5.2	10.7	5.2	7.7	5.2	8.1	6.5	---	6.8	5.2
17	6.1	7.1	7.7	8.1	4.8	4.8	9.0	4.8	7.7	6.8	---	5.2	10.0
18	6.8	7.7	8.1	7.1	4.5	5.2	9.7	5.5	7.7	6.8	---	5.8	11.0
19	7.1	7.4	7.7	4.8	4.8	5.2	10.0	5.5	7.7	7.7	---	7.4	12.3
20	8.4	7.7	7.7	8.7	11.0	12.3	11.6	5.2	10.3	9.7	---	9.7	15.2
21	7.4	7.7	8.4	8.7	12.3	13.5	13.2	5.5	12.3	11.0	---	11.0	17.4
22	7.7	8.4	8.4	9.7	13.5	16.1	15.5	5.5	12.3	11.6	---	11.9	19.0
23	10.0	10.3	11.0	12.3	15.5	15.2	14.2	11.9	15.5	14.8	---	13.9	21.3
24	11.9	11.9	11.6	14.2	17.4	23.5	11.0	12.6	16.1	14.8	---	15.5	20.0

Appendix L. Total filterable phosphorus (TFP) concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	7.7	5.2	5.5	4.8	7.1	7.7	5.2	6.5	5.2	3.9	3.9	5.2	5.2
11	3.2	5.2	5.2	4.8	6.5	8.1	5.2	6.5	7.1	4.5	5.2	5.2	4.5
12	6.8	5.8	6.5	7.1	11.6	11.6	8.1	7.7	8.4	4.8	4.8	6.5	5.5
13	8.4	8.1	7.7	9.7	10.3	13.5	7.7	7.1	8.1	4.8	5.8	6.8	6.1
14	6.5	7.1	6.5	8.7	5.8	10.0	7.1	7.1	6.1	4.5	3.9	5.2	5.5
15	6.8	6.8	6.8	9.7	9.0	11.6	7.7	6.5	6.8	10.3	7.1	6.5	6.5
16	6.1	7.1	8.1	10.0	12.6	12.3	7.1	8.4	9.0	5.2	8.4	9.0	8.4
17	6.8	7.4	9.0	45.5	14.2	10.3	8.4	7.7	9.7	5.2	7.1	6.8	8.1
18	7.4	7.7	8.5	9.7	14.2	11.6	8.4	9.0	8.4	5.5	7.4	6.8	11.6
19	7.1	7.7	8.1	7.7	11.6	11.6	9.0	10.0	9.0	5.5	7.4	7.4	11.6
20	9.0	8.1	8.1	11.0	12.6	16.8	10.3	9.0	10.3	10.3	9.0	9.7	14.5
21	7.7	8.4	4.2	12.9	15.2	16.1	12.3	10.0	12.3	11.6	10.3	11.0	17.4
22	8.4	8.4	4.2	15.2	20.0	16.8	14.2	10.0	12.6	12.6	11.0	12.9	19.7
23	9.7	10.0	4.5	14.5	19.4	15.2	15.2	12.3	15.5	14.5	13.5	14.8	25.5
24	11.9	11.9	11.6	14.2	17.4	23.5	11.0	12.6	16.1	14.8	---	15.5	20.0

Appendix M. Total phosphorus (TP) concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 Setember (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	6.1	3.9	7.1	7.1	---	11.6	7.7	7.1	6.5	8.1	5.8	9.0	
11	5.5	6.1	6.5	5.5	---	8.1	6.5	7.1	4.5	6.5	6.8	10.3	
12	5.2	3.9	6.5	8.1	---	---	9.0	5.2	7.7	9.0	7.4	9.0	
13	6.5	5.5	10.0	10.0	---	7.7	8.1	7.7	9.0	9.0	6.8	10.6	
14	5.2	6.1	7.4	9.7	---	7.7	9.7	9.0	8.1	7.4	5.8	10.3	
15	8.1	7.4	8.4	8.1	---	14.8	10.0	8.1	8.1	15.5	6.8	11.0	
16	14.5	6.5	11.6	11.6	---	44.5	17.1	11.0	11.0	45.2	7.7	11.6	
17	5.5	9.0	11.0	13.5	---	90.3	11.9	8.4	11.6	11.6	7.7	10.3	
18	6.1	8.4	11.0	10.0	---	95.5	7.1	10.3	8.4	10.0	9.0	10.3	
19	7.1	11.0	13.5	17.4	---	---	9.0	10.3	9.0	8.4	7.7	10.6	
20	10.3	9.7	9.7	---	---	12.0	16.1	9.0	9.7	10.6	9.4	12.6	
21	28.7	7.7	12.3	11.0	---	13.6	13.6	10.3	11.0	11.0	11.0	14.2	
22	9.7	8.4	11.0	11.0	---	14.2	14.5	10.3	11.0	11.9	12.3	15.5	
23	7.7	9.7	12.9	12.6	---	14.2	13.6	12.6	14.2	13.5	13.5	16.1	
24	10.3	7.1	12.6	14.5	---	21.6	---	13.9	14.8	12.9	14.5	16.8	

Appendix N. Total inorganic carbon (TIC) concentrations (uM) at Neuse River stations sampled between 23 August (23A) and 19 September (19S), 1983.

Station	Date												
	23A	24A	25A	26A	28A	30A	1S	3S	5S	7S	9S	13S	19S
10	0.95	0.98	---	0.79	1.05	1.11	1.15	1.09	1.22	1.21	1.28	---	---
11	0.93	---	0.87	0.81	1.14	1.17	1.37	1.15	1.16	1.22	1.02	---	---
12	1.15	0.95	---	0.84	1.30	1.17	1.37	1.06	1.06	1.22	1.08	---	---
13	---	1.07	1.14	0.93	1.29	1.08	1.30	0.98	1.01	1.13	1.03	---	---
14	---	0.82	0.80	0.71	1.00	0.74	0.85	0.78	0.65	0.91	0.73	---	---
15	0.56	0.53	0.61	0.63	0.78	0.62	0.83	0.78	0.81	0.67	0.62	---	---
16	0.57	0.49	0.59	0.60	1.00	0.55	0.73	0.70	0.70	0.71	0.60	---	---
17	0.34	0.72	0.59	0.57	0.85	0.54	0.66	0.63	0.52	0.64	0.57	---	---
18	0.35	0.64	0.54	0.59	0.73	0.51	0.67	0.52	0.50	0.61	0.59	---	---
19	0.36	0.62	---	1.00	0.69	0.49	0.70	0.51	0.47	0.55	0.52	---	---
20	0.37	0.67	0.60	---	0.68	0.51	0.72	0.41	0.47	0.59	0.66	---	---
21	---	---	0.65	0.56	0.76	0.60	---	0.49	0.60	0.61	0.71	---	---
22	---	---	0.60	0.55	0.76	0.58	0.70	0.50	0.59	0.59	0.75	---	---
23	0.37	---	0.60	0.56	0.77	0.55	0.70	0.50	0.68	0.64	0.73	---	---
24	0.70	0.73	0.59	0.63	0.77	0.60	0.69	0.56	0.68	0.79	0.81	---	---