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Duke Power
McGuire Nuclear Station
12700 Hagers Ferry Road
Huntersville, NC 28078

January 7, 2004

Ms. Coleen Sullins
Deputy Director
Division of Water Quality
North Carolina Department of Environment
and Natural Resources
1617 Mail Service Center
Raleigh, NC 27699-1617

Subject: McGuire Nuclear Station
Lake Norman Environmental Monitoring Program: 2002 Summary Report

Certified: 7002 2030 0000 0802 5496

Dear Ms. Sullins:

Enclosed are three copies of the annual Lake Norman Environmental Monitoring Program: 2002 Summary Report, as required by NPDES permit NC0024392 for McGuire Nuclear Station. Fishery studies continue to be coordinated with the Division of Inland Fisheries of the North Carolina Wildlife Resource Commission to address Lake Norman fishery management concerns.

Results of the 2002 data were comparable with that of previous years.

If you have any questions concerning this report, please contact either, John Williamson (704) 875-5894, or Robert W. Caccia (704) 382-3696.

Sincerely,

Gary Peterson
McGuire Site Vice President

xc: Mr. Scott Van Horn North Carolina Wildlife Resource Commission

LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2002 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

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January 2004

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EXECUTIVE SUMMARY

As required by the National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 2002.

McGUIRE NUCLEAR STATION OPERATION

The monthly average capacity factor for MNS was 101.0 %, 97.3 %, and 72.0 % during July, August, and September of 2002, respectively (Table 1-1). These are the months when conservation of cool water and discharge temperatures are most critical and the thermal limit for MNS increases from a monthly average of 95.0°F (35.0°C) to 99.0°F (37.2°C). The average monthly discharge temperature was 97.8°F (36.6°C) for July, 98.4°F (36.9°C) for August, and 94.2°F (34.6°C) for September 2002. The volume of cool water in Lake Norman was tracked throughout the year to ensure that an adequate volume was available to comply with both the Nuclear Regulatory Commission Technical Specification requirements and the NPDES discharge water temperature limits.

WATER CHEMISTRY

Temporal and spatial trends in water temperature and dissolved oxygen (DO) data collected in 2002 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in the winter of 2002 were 1-5 °C warmer throughout the water column in both the mixing and background zones, and appeared to be reflective of the unusually mild winter meteorology.

Reservoir-wide isotherm and isopleth information for 2002, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics characteristic of historical conditions and similar to other Southeastern reservoirs of comparable size, depth, flow conditions, and trophic status.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 2002 was generally similar to historical conditions, and no significant mortalities of large striped bass were observed during the summer. All chemical parameters measured in 2002 were within the concentration ranges previously reported for the lake during both MNS's preoperational and operational years. Conductance values were slightly higher in 2002 than in 2001, as were chloride, magnesium, and sodium concentrations. These differences apparently were related to record low precipitation totals, and low reservoir inflow and outflow rates. Manganese concentrations in the bottom waters in the summer and fall of 2002 often exceeded the NC water quality standard, as has been observed historically. This is characteristic of waterbodies that experience hypolimnetic deoxygenation during the summer.

PHYTOPLANKTON

Lake Norman continues to support highly variable and diverse phytoplankton communities. No obvious short term or long term impacts of station operations were observed.

In 2002 lake-wide mean chlorophyll *a* concentrations were generally in the low range, and the November mean was the lowest recorded for that period. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. Lake-wide mean chlorophyll declined from February to May, increased to the maximum in August, then declined to the annual minimum in November. This seasonal pattern had never been recorded during the Maintenance Monitoring Program. The highest chlorophyll value recorded in 2002, 16.29 ug/l, was below the NC State Water Quality standard of 40 ug/l.

In most cases, total phytoplankton densities and biovolumes observed in 2002 were lower than those observed during 2001, and standing crops were within ranges established over previous years. Phytoplankton densities and biovolumes during 2002 never exceeded the NC guidelines for algae blooms. As in past years, high standing crops were usually observed at up-lake locations; while comparatively low values were noted down-lake.

Seston dry weights were generally higher in 2002 than in 2001, and down-lake to up-lake differences were apparent most of the time. Conversely, ash-free dry weights were usually lower in 2002 than in 2001. The proportions of ash-free dry weights to dry weights in 2002 were considerably lower than those of 2001, indicating an increase in organic composition among 2002 samples. The lake-wide mean secchi depth in 2002 was the second deepest recorded since measurements were first reported in 1992. High secchi depths over the last few years were likely due to low rainfall.

Diversity, or numbers of taxa, of phytoplankton had increased substantially since 2001, and the total number of individual taxa was the highest yet recorded. The taxononic composition of phytoplankton communities during 2002 was similar to those of many previous years. Diatoms were dominant at most locations during all sampling periods except August, when green algae were dominant. Blue-green algae were slightly more abundant during 2002 than during 2001, however, their contribution to total densities seldom exceeded 2%.

The phytoplankton index (Myxophycean) characterized Lake Norman as oligotrophic during 2002, and was the lowest annual index value recorded.

ZOOPLANKTON

Lake Norman continues to support a highly diverse and viable zooplankton community. Long term and seasonal changes observed over the course of the study, as well seasonal and spatial variability observed during 2002, were likely due to environmental factors and appears not to be related to plant operations.

Maximum epilimnetic and whole column zooplankton densities occurred in May, while minimum epilimnetic densities were recorded in February (Locations 5.0, 9.5, and 11.0), and November (Locations 2.0 and 15.9). Minimum whole column densities were observed in February (Locations 2.0 through 9.5), and August (11.0 and 15.9). Mean zooplankton densities tended to be higher among Background Locations than among Mixing Zone locations during 2002, and a general pattern of increasing values from downlake to uplake was observed. In addition, long term trends showed much higher year-to-year variability at Background Locations than at Mixing Zone Locations.

Epilimnetic zooplankton densities in August were within ranges of those observed in August of previous years. The epilimnetic densities at Locations 5.0, 11.0, and 15.9 in May 2002 were the highest recorded from these locations during the Program, and may have represented an ongoing lag response to changing phytoplankton standing crops at that time. Record low densities for February were observed at Locations 2.0 and 5.0, while a record low density for November occurred at Locations 15.9. Record low densities may have been in response to long term drought conditions through much of 2002.

One hundred and nine zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (Fifty-one were identified during 2002). One previously unreported rotifer was identified during 2002.

Overall relative abundance of copepods in 2002 had decreased substantially since 2001, and they were only dominant during August. Cladocerans were occasionally dominant at only one location in August, while rotifers were dominant in all samples collected during the other three quarters. Overall, the relative abundance of rotifers had increased considerably since 2001, and their relative abundances were often similar to years prior to 1995. Historically, copepods and rotifers have shown annual peaks in May; while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms with adults rarely accounting for more than 8% of zooplankton densities. The most important adult copepods were *Tropocyclops*, *Epischura*, and *Mesocyclops* as was the case in previous years. *Bosmina* was the predominant cladoceran, as has also been the case in most previous years of the Program. *Bosminopsis* dominated most cladoceran populations in August. The most abundant rotifers observed in 2002, as in many previous years, were *Polyarthra*, *Conochilus*, and *Kellicottia*, while *Karetella* and *Syncheata* were occasionally important among rotifer populations.

FISHERIES

In accordance with the Lake Norman Maintenance Monitoring Program for the NPDES permit for MNS, specific fish monitoring programs were coordinated with the NCWRC and continued during 2002. Spring electrofishing indicated that 14 to 20 species of fish and 1 hybrid complex composed fish populations in the 3 sampling locations, and that numbers and biomass of fish in 2002 were generally similar to those previously noted at these locations since 1993. Lake Norman continues to support fish populations that are consistent with the trophic status and productivity of this reservoir.

Few dead striped bass were noted during the summer survey period indicating no major die-offs occurred. Relative weight (Wr) of Lake Norman striped bass in November and December may have improved somewhat in 2002 over that noted in 2001, but large striped bass continued to exhibit low Wr's at this time of the year.

Forage fish densities in the five zones of Lake Norman ranged from 5,068 to 12,580 fish/ha in July 2002. Forage fish densities were highest uplake (Zone 5) and lowest downlake. The estimated lakewide population was approximately 103 million fish. Purse seine sampling indicated that these fish were 74.75% threadfin shad and 25.25% alewives.

September 2002 forage fish densities ranged from a low of 3,228 (Zone 4) to a high of 9,363 (Zone 5). The estimated lakewide forage population was approximately 74 million fish. Purse seine sampling indicated that these fish were 70.27% threadfin shad and 29.73% alewives.

Forage fish densities in the five zones of Lake Norman ranged from 1,413 to 2,172 fish/ha in December 2002. There were considerably fewer fish in the uplake zones compared to July and September estimates; densities were fairly homogeneous throughout the lake. The estimated forage population was approximately 25 million fish. Purse seine sampling indicated that these fish were 75.26% threadfin shad, 24.55% alewives, and 0.19% hybrid shad.

Open water purse seine samples have undergone a dramatic shift in recent years. From 1993 through 1999, when the first alewife was collected, purse seine samples were totally composed of small threadfin shad (typically ≤55 mm). From 2000 through 2002 the open water forage fish community has shown increasing contributions from alewives (now ~25% of the community) and a concurrent wider size range of individuals.

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CHAPTER 1
McGUIRE NUCLEAR STATION OPERATION

INTRODUCTION

As required by the National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS) issued by the North Carolina Department of Environment and Natural Resources (NC DENR), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 2002.

OPERATIONAL DATA FOR 2002

The monthly average capacity factor for MNS was 101.0 %, 97.3 %, and 72.0 % during July, August, and September of 2002, respectively (Table 1-1). These are the months when conservation of cool water and discharge temperatures are most critical and the thermal limit for MNS increases from a monthly average of 95.0°F (35.0°C) to 99.0°F (37.2°C). The average monthly discharge temperature was 97.8°F (36.6°C) for July, 98.4°F (36.9°C) for August, and 94.2°F (34.6°C) for September 2002. The volume of cool water in Lake Norman was tracked throughout the year to ensure that an adequate volume was available to comply with both the Nuclear Regulatory Commission Technical Specification requirements and the NPDES discharge water temperature limits.

Table 1-1. Average monthly capacity factors (%) calculated from daily unit capacity factors [Net Generation (Mwe per unit day) x 100 / 24 h per day x 1129 mw per unit] and monthly average discharge water temperatures for McGuire Nuclear Station during 2002.

	MONTHLY AVERAGE CAPACITY FACTORS (%)			MONTHLY AVERAGE NPDES DISCHARGE TEMPERATURES	
Month	**Unit 1**	**Unit 2**	**Station**	^{o}F	^{o}C
January	105.4	104.8	**105.1**	69.2	20.7
February	105.2	80.6	**92.9**	69.0	20.6
March	93.2	8.2	**50.7**	66.0	18.9
April	104.7	104.7	**104.7**	78.4	25.8
May	103.9	104.0	**104.0**	83.9	28.8
June	102.4	102.8	**102.6**	91.8	33.2
July	100.9	101.2	**101.0**	97.8	36.6
August	101.0	93.5	**97.3**	98.4	36.9
September	42.3	101.6	**72.0**	94.2	34.6
October	64.5	102.6	**83.6**	85.8	29.9
November	104.7	104.1	**104.4**	77.4	25.2
December	105.2	102.0	**103.6**	70.5	21.4
Averages	**94.4**	**92.5**	**93.5**		

CHAPTER 2
WATER CHEMISTRY

INTRODUCTION

The objectives of the water chemistry portion of the McGuire Nuclear Station (MNS) NPDES Maintenance Monitoring Program are to:

1. Maintain continuity in Lake Norman's chemical data base so as to allow detection of any significant station-induced and/or natural change in the physicochemical structure of the lake; and
2. Compare, where appropriate, these physicochemical data to similar data in other hydropower reservoirs and cooling impoundments in the Southeast.

This year's report focuses primarily on 2001 and 2002. Where appropriate, reference to pre-2001 data will be made by citing reports previously submitted to the North Carolina Department of Environment, Health, and Natural Resources (NCDENR).

METHODS AND MATERIALS

The complete water chemistry monitoring program for 2002, including specific variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1, whereas specific chemical methodologies and associated analytical reporting limits, along with the appropriate references are presented in Table 2-2. Measurements of temperature, dissolved oxygen (DO), DO saturation, pH, and specific conductance were taken, in situ, throughout the water column at each of the stations sampled with a Hydrolab Data-Sonde (Hydrolab 1986) starting at the lake's surface (0.3 m) and continuing at 1 m intervals to one meter above lake bottom. Pre- and post-calibration procedures associated with operation of the Hydrolab were strictly followed, and appropriately documented in hard-copy format. Hydrolab data were captured and stored electronically. Water samples for laboratory analysis were collected with a Kemmerer water bottle at the surface (0.3 m), and from one meter above bottom, where specified, and placed in non-reusable PET bottles. Samples for the analysis of soluble nutrients (orthophosphate, nitrite-nitrate, and ammonia) were obtained in the field by filtering a known volume of water through a 0.45 micron glass-fiber filter. Upon collection, all water samples were immediately preserved, and stored in the dark, and on ice, to minimize the possibility of physical, chemical or microbial transformation.

Water quality data were subjected to various graphical and statistical techniques in an attempt to describe spatial and temporal trends within the lake, and interrelationships among constituents. Whenever analytical values were encountered that were equal to or less than the method reporting limit, these were set equal to the reporting limit for statistical purposes. Data were analyzed using two approaches, both of which were consistent with earlier studies (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). The first method involved partitioning the reservoir into mixing, background, and discharge zones, consolidating the data into these sub-sets, and making comparisons among zones and years. In this report, the discharge includes only Location 4; the mixing zone encompasses Locations 1 and 5; the background zone includes Locations 8, 11, and 15. The second approach, applied primarily to the in-situ data, emphasized a much broader lake-wide investigation and encompassed the plotting of monthly isotherms and isopleths, and summer-time striped bass habitat. Several quantitative calculations were also performed on the in-situ Hydrolab data; these included the calculation of the areal hypolimnetic oxygen deficit (AHOD), maximum whole-water column and hypolimnion oxygen content, maximum whole-water column and hypolimnion heat content, mean epilimnion and hypolimnion heating rates over the stratified period, and the Birgean heat budget.

Heat ($Kcal/cm^2$) and oxygen content (mg/cm^2) and mean concentration (mg/L) of the reservoir were calculated according to Hutchinson (1957), using the following equation:

$$Lt = A_0^{-1} \bullet \int_{z_0}^{z_m} TO \bullet A_z \bullet d_z$$

where;

Lt = reservoir heat ($Kcal/cm^2$) or oxygen (mg/cm^2) content

A_o = surface area of reservoir (cm^2)

TO = mean temperature (°C) or oxygen content of layer z

A_z = area (cm^2) at depth z

d_z = depth interval (cm)

z_o = surface

z_m = maximum depth

RESULTS AND DISCUSSION

Precipitation Amount

Total annual precipitation in the vicinity of MNS in 2002 totaled 39.81 inches (Figure 2-2); this was slightly higher than observed in 2000 (33.68 inches) and 2001 (33.68 inches), but appreciably less than the long-term precipitation average for this area (46.3 inches). Precipitation through the period January to September 2002 (24.02 inches) was one of the driest nine-month periods on record, and about 5 inches less than observed in 2001. The highest total monthly rainfall in 2002 occurred in December with a value of 6.13 inches.

Temperature and Dissolved Oxygen

Water temperatures measured in 2002 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3, 2-4), as occurred in 2001. This similarity in temperature patterns between zones has been a dominant feature of the thermal regime in Lake Norman since MNS began operations in 1983. Water temperatures in the winter of 2002 (January and February) were consistently warmer throughout the entire water column in both zones than observed in 2001 (Figure 2-3, 2-4). Water temperatures at this time ranged from about 1-5 °C warmer than measured in 2001, and was partially reflective of the unusually mild January and preceding December meteorology. Interannual variability in water temperatures during the spring, summer, and fall months was observed in both the mixing and background zones, but temperature differences between years were typically minimal and therefore were not considered of biological significance. The observed differences were also well within the observed historical variability (DPC 1985, 1989, 1991, 1993. 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). The major temperature differences between year 2001 and 2002 were observed in early winter (December) when 2002 temperatures ranged from 4 to 6 °C cooler than measured in 2001. These differences can be traced to the cooler than average meteorological conditions observed during December 2002 versus 2001.

Temperature data at the discharge location in 2002 were generally similar to 2001 (Figure 2-5) and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Temperature data for March 2002 was significantly cooler than observed in March 2001 due to station load reduction on the day of sampling; however, station discharge temperatures for March 2002 were typical for this time of year. The warmest discharge temperature of 2002 at location 4 occurred in August and measured 38.5 °C, or 2.8 °C warmer than measured in August, 2001 (DPC 2002).

Seasonal and spatial patterns of DO in 2002 were reflective of the patterns exhibited for temperature, i. e., generally similar in both the mixing and background zones (Figures 2-6 and 2-7). As observed with water column temperatures, this similarity in dissolved oxygen patterns between zones has been a dominant feature of the oxygen regime in Lake Norman since MNS began operations in 1983. Winter (January and February) DO values in 2002 were consistently lower than measured in 2001, and appeared to be related predominantly to the warmer water column temperatures measured in 2002 versus 2001. The warmer water would be expected to exhibit a lower oxygen content because of the direct effect of temperature on oxygen solubility, which is an inverse relationship, and indirectly via a reduced convective mixing regime which would suppress reaeration of the water column.

Spring and summer DO values in 2002 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6 to 8 mg/L in the surface waters to lows of 0 to 2 mg/L in the bottom waters. This pattern is similar to that measured in 2001 and earlier years (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1998, 1999, 2000, 2001, 2002). Metalimnetic and hypolimnetic DO values during the spring and summer of 2002 generally ranged from 0.1 mg/L to 2.5 mg/L lower than measured in 2001; exceptions to this were observed in June and September when DO values were slightly higher than measured in 2001. All dissolved oxygen values recorded in 2002 were well within the historical range (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002).

Considerable differences were observed between 2001 and 2002 fall and early winter DO values in both the mixing and background zones, especially in the metalimnion and hypolimnion during November and December (Figures 2-6 and 2-7). These interannual differences in fall DO levels are common in Catawba River reservoirs and can be explained by the effects of variable weather patterns on water column cooling and mixing. Warmer air temperatures would delay water column cooling (Figure 2-3, 2-4) which, in turn, would delay the onset of convective mixing of the water column and the resultant reaeration of the metalimnion and hypolimnion. Conversely, cooler air temperatures would promote the rate and magnitude of this process resulting in higher DO values sooner in the year. The 2002 November and December DO data indicate that fall reaeration was more complete than observed in the corresponding months in year 2001. Interannual differences in DO patterns are common in Southeastern reservoirs, and can reflect yearly differences in hydrological, meteorological, and limnological forcing variables (Cole and Hannon 1985; Petts, 1984).

The seasonal pattern of DO in 2002 at the discharge location was similar to that measured historically, with the highest values observed during the winter and lowest observed in the summer and early fall (Figure 2-5). The lowest DO concentration measured at the discharge location in 2002 (5.4 mg/L) occurred in August, and was similar to DO levels measured in August 2000 (5.4 mg/L), and August 2001 (5.5). Low DO values measured at the discharge location during the summer and early fall occurred concurrently with hypolimnetic water usage at MNS for condenser cooling water needs.

Reservoir-wide Temperature and Dissolved Oxygen

The monthly reservoir-wide temperature and dissolved oxygen data for 2002 are presented in Figures 2-8 and 2-9. These data are similar to that observed in previous years and are characteristic of cooling impoundments and hydropower reservoirs in the Southeast (Cole and Hannon, 1985; Hannon et al., 1979; Petts, 1984). For a detailed discussion on the seasonal and spatial dynamics of temperature and dissolved oxygen during both the cooling and heating periods in Lake Norman, the reader is referred to earlier reports (DPC 1992, 1993, 1994, 1995, 1996).

The seasonal heat content of both the entire water column and the hypolimnion for Lake Norman in 2002 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 2001 and 2002 are found in Table 2-3. Annual minimum heat content for the entire water column in 2002 (10.04 Kcal/cm^2; 10.2 °C) occurred in early January, whereas the maximum heat content (28.25 Kcal/cm^2; 28.2 °C) occurred in early August. Heat content of the hypolimnion exhibited a somewhat different temporal trend as that observed for the entire water column. Annual minimum hypolimnetic heat content occurred in early January and measured 5.6 Kcal/cm^2 (9.0 °C), whereas the maximum occurred in early September and measured 15.35 Kcal/cm^2
(24.3 °C). Heating of both the entire water column and the hypolimnion occurred at approximately a linear rate from minimum to maximum heat content. The mean heating rate of the entire water column equalled 0.088 Kcal/cm^2/day versus 0.042 Kcal/cm^2/day for the hypolimnion. The 2002 heat content and heating rate data were slightly higher than measured in 2001, but similar to earlier years (DPC 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2002).

The seasonal oxygen content and percent saturation of the whole water column, and the hypolimnion, are depicted for 2002 in Figure 2-10b. Additional oxygen data can be found in Table 2-4 which presents the 2002 AHOD for Lake Norman and similar estimates for 18 Tennessee Valley Authority (TVA) reservoirs. Reservoir oxygen content was greatest in mid-winter when DO content measured 10.1 mg/L for both the whole water and the hypolimnion. Percent saturation values at this time approached 90.1 % for the entire water column and 87.8% for the hypolimnion. Beginning in early spring, oxygen content began to decline precipitously in both the whole water column and the hypolimnion, and continued to do so in a linear fashion until reaching a minimum in mid-summer. Minimum summer volume-weighted DO values for the entire water column measured 4.21 mg/L (54.8 % saturation), whereas the minimum for the hypolimnion was 0.12 mg/L (1.4 % saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.030 mg/cm^2/day (0.047 mg/L/day) (Figure 2-10b), and is similar to that measured in 2001 (DPC 2002).

Hutchinson (1938, 1957) proposed that the decrease of dissolved oxygen in the hypolimnion of a waterbody should be related to the productivity of the trophogenic zone. Mortimer (1941) adopted a similar perspective and proposed the following criteria for AHOD associated with various trophic states; oligotrophic - $\leq$ 0.025 mg/cm^2 /day, mesotrophic - 0.026 mg/cm^2/day to 0.054 mg/cm^2/day, and eutrophic - $\geq$ 0.055 mg/cm^2/day. Employing these limits, Lake Norman should be classified as mesotrophic based on the calculated AHOD value of 0.030 mg/cm^2/day for 2002. The oxygen based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 2002 AHOD value is also similar to that found in other Southeastern reservoirs of comparable depth, chlorophyll *a* status, and secchi depth (Table 2-4).

Striped Bass Habitat

Suitable pelagic habitat for adult striped bass, defined as that layer of water with temperatures $\leq$ 26 °C and DO levels $\geq$ 2.0 mg/L, was found lake-wide from October 2001 through mid-June 2002. Beginning in mid-June 2002, habitat reduction proceeded rapidly throughout the reservoir both as a result of deepening of the 26 °C isotherm and metalimnetic and hypolimnetic deoxygenation (Figure 2-11). Habitat reduction was most severe from mid-July through early September when no suitable habitat was observed in the reservoir except for a small zone of refuge in the upper, riverine portion of the reservoir, near the confluence of

Lyles Creek with Lake Norman, and the lower portion of the lake near the dam. The reservoir was completely devoid of habitat for adult striped bass from the period 29 July to 3 September, or about 30-35 days. Habitat measured in the upper reaches of the reservoir appeared to be influenced by both inflow from Lyles Creek and discharges from Lookout Shoals Hydroelectric facility, which were somewhat cooler than ambient conditions in Lake Norman. Upon entering Lake Norman, this water apparently mixes and then proceeds as a subsurface underflow (Ford 1985) as it migrates downriver.

Physicochemical habitat was observed to have expanded appreciably by mid-September, primarily as a result of epilimnion cooling and deepening, and in response to changing meteorological conditions. The temporal and spatial pattern of striped bass habitat expansion and reduction observed in 2002 was similar to that previously reported in Lake Norman and many other Southeastern reservoirs (Coutant 1985, Matthews 1985, DPC 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). No significant mortalities of large striped bass were observed in 2002; a few (< 10) dead fish were found over the summer period, but these appeared to be the result of other causes, e.g., hooking mortalities, which are common throughout the Southeast.

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 2002, ranging from 1.02 to 5.06 NTUs (Table 2-5). Bottom turbidity values were also relatively low over the study period, ranging from 2.09 to 7.86 NTUs (Table 2-5). These values were slightly higher than measured in 2001 (Table 2-5), but well within the historical range (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002).

Specific conductance in Lake Norman in 2002 ranged from 69 to 110 umho/cm, and was similar to that observed in 2001 (Table 2-5), and historically (DPC 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Conductance values in 2002 were, on the average, about 10 umhos/cm higher than observed in 2001; this difference may have been related to below average precipitation totals, and the correspondingly below average reservoir inflow and outflow rates in 2002 which would tend to concentrate dissolved constituents within the water column. Specific conductance values in surface and bottom waters were generally similar throughout the year except during the period of intense thermal stratification, i.e., August and November. Increases in bottom conductance values appeared to be related primarily to the release of soluble iron and manganese from the lake bottom under anoxic conditions (Table 2-5). This phenomenon is common in both natural lakes and reservoirs that exhibit hypolimnetic oxygen depletion (Hutchinson 1957, Wetzel 1975).

pH and Alkalinity

During 2002, pH and alkalinity values were similar among MNS discharge, mixing and background zones (Table 2-5); they were also similar to values measured in 2001 (Table 2-5) and historically (DPC 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Individual pH values in 2002 ranged from 6.2 to 7.4, whereas alkalinity ranged from 16 to 22 mg/L of $CaCO_3$.

Major Cations and Anions

The concentrations (mg/L) of major ionic species in the MNS discharge, mixing, and mid-lake background zones are provided in Table 2-5. The overall ionic composition of Lake Norman during 2002 was similar to that reported for 2001 (Table 2-5) and previously (DPC 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Interestingly, the concentration of several constituents (chloride, magnesium, and sodium) in 2002 were slightly higher than measured in 2001, and this may have been related to low reservoir inflow/outflow rates, as discussed for conductance. It's also likely that these increased constituent levels were responsible for the higher conductance values observed in 2002 versus 2001. Lake-wide, the major cations were sodium, calcium, magnesium, and potassium, whereas the major anions were bicarbonate, sulfate, and chloride.

Nutrients

Nutrient concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 2001 and 2002 are provided in Table 2-5. Overall, nitrogen and phosphorus levels in 2002 were low and similar to those measured in 2001 and historically (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Total phosphorus and ortho-phosphorus concentrations appeared to be slightly higher in 2002 than 2001, but these differences can be attributed to higher analytical reporting limits for these tests applied in 2002, versus 2001, i.e., 10 ug/L and 5 ug/L, respectively.

Metals

Metal concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 2002 were similar to that measured in 2001 (Table 2-5) and historically (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Iron concentrations near the surface were generally low (≤ 0.1 mg/L) during 2002, whereas iron levels near the bottom of some sites were slightly higher during the stratified period. Similarly, manganese concentrations in the surface and bottom waters were generally low (≤ 0.1 mg/L) in both 2001 and 2002, except during the summer and fall when bottom waters were anoxic (Table 2-5). This phenomenon, i.e., the release of iron and manganese from bottom sediments because of increased solubility induced by low redox conditions (low oxygen levels), is common in stratified waterbodies (Wetzel 1975). Manganese concentrations near the bottom rose above the NC water quality standard (0.5 mg/L) at various locations throughout the lake in summer and fall of both years, and is characteristic of historical conditions (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002).

Heavy metal concentrations in Lake Norman never exceeded NC water quality standards, and there were no appreciable differences between 2001 and 2002. Most values were also typically below the analytical reporting limit for the specific constituent. Zinc values appeared to be higher in 2002 than 2001, but these differences can be attributed to the analytical reporting limit for the later year. In year 2001 the reporting limit for zinc was 5 ug/L, whereas in 2002 the reporting limit was increased to 20 ug/L due to a change in methodology.

FUTURE STUDIES

No changes are planned for the Water Chemistry portion of the Lake Norman maintenance monitoring program during 2003.

SUMMARY

Temporal and spatial trends in water temperature and DO data collected in 2002 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in the winter of 2002 were 1-5 °C warmer throughout the water column in both the mixing and background zones, and appeared to be reflective of the unusually mild winter meteorology. Interannual variability in water temperatures during the spring, summer and fall months was observed in both zones, but differences between years were within observed historical variability. Winter dissolved oxygen values in 2002 were lower than measured in 2001, and appeared to be related to the warmer water column temperatures which would limit oxygen solubility and suppress convective reaeration of the water column. Spring and summer oxygen values were highly variable throughout the water column but similar to historical trends.

Reservoir-wide isotherm and isopleth information for 2002, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics characteristic of historical conditions and similar to other Southeastern reservoirs of comparable size, depth, flow conditions, and trophic status.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 2002 was generally similar to historical conditions, and no significant mortalities of large striped bass were observed during the summer. All chemical parameters measured in 2002 were within the concentration ranges previously reported for the lake during both MNS's preoperational and operational years. Conductance values were slightly higher in 2002 than in 2001, as were chloride, magnesium, and sodium concentrations. These differences apparently were related to record low precipitation totals, and low reservoir inflow and outflow rates. Manganese concentrations in the bottom waters in the summer and fall of 2002 often exceeded the NC water quality standard, as has been observed historically. This is characteristic of waterbodies that experience hypolimnetic deoxygenation during the summer.

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Table 2-1. Water chemistry program for the McGuire Nuclear station NPDES long-term monitoring on Lake Norman.

2002 McGUIRE NPDES SAMPLING PROGRAM

PARAMETERS	LOCATIONS	1	2	4	5	8	9.5	11	13	14	15	15.9	62	69	72	80	16
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
IN-SITU ANALYSIS																	
Temperature	Hydrolab																
Dissolved Oxygen	Hydrolab	In-situ measurements are collected monthly at the above locations at 1m intervals from 0.3m to 1m above bottom.															
pH	Hydrolab	Measurements are taken weekly from July-August for striped bass habitat.															
Conductivity	Hydrolab																
NUTRIENT ANALYSES																	
Ammonia	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Nitrate+Nitrite	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Orthophosphate	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Total Phosphorus	AA-TP,DG-P	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Silica	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cl	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
TKN	AA-TKN	Q/T,B										Q/T,B		Q/T,B			
ELEMENTAL ANALYSES																	
Aluminum	ICP-24	Q/T,B	S/T,B	S/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Calcium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Iron	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Magnesium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Manganese	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Potassium	306-K	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sodium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Zinc	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cadminum	ICP-MS		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Copper	ICP-MS		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Lead	ICP-MS		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
ADDITIONAL ANALYSES																	
Alkalinity	T-ALKT	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Turbidity	F-TURB	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sulfate	UV_SO4		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T
Total Solids	S-TSE		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T
Total Suspended Solids	S-TSSE		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T

CODES: Frequency Q = Quarterly (Feb, May, Aug, Nov) S = Semi-annually (Feb,Aug) T = Top (0.3m) B = Bottom (1m above bottom)

Table 2-2. Analytical methods and reporting limits employed in the McGuire Nuclear Station NPDES long-term maintenance monitoring program for Lake Norman.

Parameter	Method (EPA/APHA)	Preservation	Reporting Limit
Alkalinity, Total	Total inflection point, EPA 310.1	4 °C	0.01 meq/L
Aluminum	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	0.05 mg/L
Cadmium, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	0.5 ug/L
Calcium	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	30 ug/L
Chloride	Colorimetric, EPA 325.2	4 °C	1.0 mg/L
Copper, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 ug/L
Iron	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	10 ug/L
Lead, total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 ug/L
Magnesium	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	30 ug/L
Manganese, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	1.0 ug/L
Nitrogen, Ammonia	Colorimetric, EPA 350.1	4 °C	20 ug/L
Nitrogen, Nitrite + Nitrate	Colorimetric, EPA 353.2	4 °C	20 ug/L
Nitrogen, Total Kjeldahl	Colorimetric, EPA 351.2	4 °C	100 ug/L
Phosphorus, Orthophosphorus	Colorimetric, EPA 365.1	4 °C	5 ug/L
Phosphorus, Total	Colorimetric, EPA 365.1	4 °C	10 ug/L
Potassium	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	250 ug/L
Silica	APHA 4500Si-F	0.5% HNO_3	500 ug/L
Sodium	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	1.5 mg/L
Solids, Total	Gravimetric, EPA 160.2	4 °C	0.1 mg/L
Solids, Total Suspended	Gravimetric, EPA 160.2	4 °C	0.1 mg/L
Sulfate	Ion Chromatography	4 °C	0.1 mg/L
Turbidity	Turbidimetric, EPA 180.1	4 °C	0.05 NTU
Zinc, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	1.0 ug/L

References: USEPA 1983, and APHA et. al., 1995

Table 2-3. Heat content calculations for the thermal regime in Lake Norman for 2001 and 2002.

	2001	2002
Maximum areal heat content (g cal/cm^2)	27,964	28,252
Minimum areal heat content (g cal/cm^2)	7,451	10,042
Maximum hypolimnetic (below 11.5 m) areal heat content (g cal/cm^2)	15,173	15,347
Birgean heat budget (g cal/cm^2)	20,513	18, 210
Epilimnion (above 11.5 m) heating rate (°C /day)	0.094	0.113
Hypolimnion (below 11.5 m) heating rate (°C /day)	0.062	0.066

Table 2-4. A comparison of areal hypolimnetic oxygen deficits (AHOD), summer chlorophyll a (chl a), secchi depth (SD), and mean depth of Lake Norman and 18 TVA reservoirs.

Reservoir	AHOD ($mg/cm^2/day$)	Summer Chl a (ug/L)	Secchi Depth (m)	Mean Depth (m)
Lake Norman (2002)	0.030	2.6	2.2	10.3
TVA [a]				
Mainstem				
Kentucky	0.012	9.1	1.0	5.0
Pickwick	0.010	3.9	0.9	6.5
Wilson	0.028	5.9	1.4	12.3
Wheelee	0.012	4.4		5.3
Guntersville	0.007	4.8	1.1	5.3
Nickajack	0.016	2.8	1.1	6.8
Chickamauga	0.008	3.0	1.1	5.0
Watts Bar	0.012	6.2	1.0	7.3
Fort London	0.023	5.9	0.9	7.3
Tributary				
Chatuge	0.041	5.5	2.7	9.5
Cherokee	0.078	10.9	1.7	13.9
Douglas	0.046	6.3	1.6	10.7
Fontana	0.113	4.1	2.6	37.8
Hiwassee	0.061	5.0	2.4	20.2
Norris	0.058	2.1	3.9	16.3
South Holston	0.070	6.5	2.6	23.4
Tims Ford	0.059	6.1	2.4	14.9
Watauga	0.066	2.9	2.7	24.5

[a] Data from Higgins et al. (1980), and Higgins and Kim (1981)

Table 2-5. Quarterly surface (0.3 m) and bottom (bottom minus 1 m) water chemistry for the MNS discharge, mixing zone, and background locations on Lake Norman during 2001 and 2002. Values less than detection were assumed to be the detection limit for calculating a mean.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2 80				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001
Turbidity (ntu)																						
Feb	3.75	2.01	6.30	3.76	3.63	1.61	3.39	2.65	3.29	1.58	4	1.30	5.53	1.50	5.06	1.14	6.77	1.41	4.08	1.40	7.86	2.17
May	1.59	1.55	3.50	1.37	1.02	1.24	2.41	1.22	1.48	1.52	1.43	1.27	2.63	1.82	1.63	1.36	2.8	2.57	2.19	1.48	NS	2.53
Aug	1.45	1.65	2.57	2.52	1.5	1.75	2.09	2.46	1.4	1.74	1.46	1.69	3.63	4.08	1.32	1.52	2.99	2.30	2.11	1.58	2.49	4.01
Nov	2.80	1.92	2.8	2.75	3.13	1.93	3.69	4.62	3.05	1.43	2.98	2.30	7.63	4.62	2.72	1.04	5.77	8.98	3.32	1.99	6.46	12.50
Annual Mean	2.40	1.78	3.79	2.6	2.32	1.6	2.90	2.7	2.31	1.6	2.47	1.6	4.81	3.0	2.66	1.3	4.58	3.8	2.93	1.6	5.60	5.3
Specific Conductance (umho/cm)																						
Feb	72.0	57	71.0	56	72	56	71	56	74	58	73	57	71.0	56	70	56	70	56	70	58	69	59
May	75.0	49	73	48.9	74	49.3	73	49	75	50	75	50	73	49.2	74	49.3	73	49.5	72	49.6	72	50.8
Aug	77.0	67.1	78.0	76.5	75.0	67.4	79.0	73.1	74.0	67.6	75.0	NS	81.0	NS	75.0	67.2	77.0	72	74.0	67.1	79.0	72.5
Nov	74.0	73.1	110.0	108	74.0	73	77.0	98	74.0	74.7	74.0	73.8	74.0	74	74.0	72.8	72.0	73	73.0	72.2	73.0	71.9
Annual Mean	74.5	61.6	83.0	72.3	73.8	61.3	75.0	68.9	74.3	62.6	74.3	60.3	74.8	59.7	73.3	61.3	73.0	62.7	72.3	61.7	73.3	63.6
pH (units)																						
Feb	7.0	7.1	6.7	7.1	7.2	7.2	6.8	7.1	7.2	7.3	7.2	7.2	6.9	7.0	6.4	7.2	6.7	7.0	6.6	7.2	6.6	7.0
May	6.9	7.2	6.6	6.9	7.1	7.5	6.6	6.9	7.0	7.2	7.1	7.3	6.8	6.8	7.3	7.3	6.6	6.9	7.2	7.2	6.6	6.7
Aug	7.1	7.5	6.3	6.4	7.4	7.6	6.4	6.3	7.1	7.4	7.2	NS	6.6	NS	6.9	7.9	6.2	6.4	7.7	8.1	6.3	6.4
Nov	6.6	7.6	6.8	6.9	7.1	7.4	6.9	6.8	7.0	7.5	7.0	7.6	6.9	7.1	7.1	7.6	7.1	7.0	7.1	7.6	7.0	6.9
Annual Mean	6.90	6.60	6.60	6.84	7.20	7.42	6.68	6.79	7.07	7.10	7.13	7.37	6.80	6.99	6.93	7.49	6.66	6.82	7.15	7.52	6.63	6.75
Alkalinity (mg CaCO3/l)																						
Feb	20.0	16.5	19.5	16.5	19.5	16.0	19.5	16.5	19.5	16.5	19.5	16.5	19.5	16.5	19.5	17.0	19.0	16.5	19.0	16.5	18.5	16.5
May	16.5	15.5	17.0	16.0	17.0	16.0	16.5	16.0	17.0	16.0	17.0	16.0	17.0	16.0	17.0	16.0	17.0	16.0	16.0	15.5	NA	16.0
Aug	17.5	17.0	18.0	17.5	18.0	17.0	18.0	17.0	17.5	17.0	17.5	17.5	22.0	21.0	17.5	16.5	18.0	14.0	17.5	16.5	19.5	18.0
Nov	19.0	18.0	19.0	35.0	18.5	18.6	20.0	19.5	18.5	18.5	18.5	19.0	19.0	18.5	18.0	18.5	18.0	18.5	18.5	18.5	18.0	18.5
Annual Mean	18.25	16.76	18.38	21.26	18.25	16.88	18.50	17.26	18.13	17.01	18.13	17.26	19.38	18.01	18.00	17.01	18.00	16.26	17.75	16.76	18.67	17.26
Chloride (mg/l)																						
Feb	7.3	6.1	6.9	6.2	6.6	6.1	6.8	6.2	6.9	6.1	6.6	6.0	6.7	6.1	6.6	6.1	6.4	6.1	6.9	6.2	6.9	6.3
May	6.7	5.5	6.6	5.2	6.6	5.5	6.4	5.3	6.5	5.4	6.6	5.5	6.4	5.5	6.5	5.7	6.4	5.4	6.6	5.4	NS	5.1
Aug	7.0	6.8	6.7	6.7	7.1	6.7	6.7	6.7	7.0	6.7	7.0	7.1	6.8	7.4	7.1	6.8	6.8	7.1	7.0	6.6	6.9	6.7
Nov	7.2	6.5	NS	5.9	7.5	6.1	7.3	6.3	7.4	6.2	7.4	NS	7.4	6.0	7.3	6.2	7.5	6.2	7.2	6.3	7.3	6.2
Annual Mean	7.05	6.23	6.73	6.00	6.95	6.10	6.80	6.13	6.95	6.10	6.90	6.20	6.83	6.25	6.88	6.20	6.78	6.20	6.93	6.13	7.03	6.08
Sulfate (mg/l)																						
Feb	6.05	NS	6.72	NS	NS	6.2	NS	6.6	6.67	6.3	6.8	NS	6.74	NS	NS	6.2	6	6.1	6.69	NS	6.66	NS
May	5.32	NS	5.86	NS	5.59	6.7	5.78	6.5	7.3	6.6	6.03	NS	5.37	NS	4.78	6.7	5.8	6.7	5.32	NS	NS	NS
Aug	6.40	NS	NS	NS	NS	6.7	NS	6.6	6.24	7.0	6.09	6.9	6.30	6.5	6.24	6.9	14.44	6.6	5.93	NS	6.24	NS
Nov	6.80	NS	6.80	NS	6.77	6.0	6.6	6.5	6.99	6.7	6.75	NS	6.74	NS	6.82	6.7	6.92	6.2	6.59	NS	6.62	NS
Annual Mean	6.14	NS	6.46	NS	6.18	6.38	6.17	6.53	6.80	6.66	6.42	6.91	6.29	6.51	5.95	6.64	8.29	6.40	6.14		5.86	
Calcium (mg/l)																						
Feb	3.25	3.20	3.05	3.34	2.92	3.71	3.62	3.21	3.26	3.31	3.34	2.96	3.15	3.22	3.05	3.14	3.07	2.98	3.20	2.90	2.89	3.03
May	3.28	3.17	3.31	3.39	3.26	3.25	3.29	3.09	3.26	3.11	3.29	3.21	3.31	3.41	3.24	3.46	3.29	3.30	3.36	3.54	NS	3.13
Aug	3.53	3.33	3.75	3.44	3.52	3.35	3.82	3.49	3.52	3.37	3.52	3.38	3.96	3.37	3.49	3.34	3.82	3.58	3.59	3.36	3.95	3.60
Nov	3.41	3.47	3.41	4.37	3.46	4.36	3.51	3.96	3.43	3.78	3.44	3.79	3.43	3.64	3.45	3.88	3.40	3.52	3.51	3.35	3.52	3.28
Annual Mean	3.37	3.29	3.38	3.64	3.29	3.67	3.56	3.44	3.37	3.39	3.40	3.34	3.46	3.41	3.31	3.45	3.40	3.35	3.42	3.28	3.45	3.26
Magnesium (mg/l)																						
Feb	1.57	1.53	1.58	1.62	1.54	1.72	1.77	1.59	1.67	1.62	1.57	1.52	1.60	1.57	1.55	1.55	1.55	1.52	1.60	1.50	1.47	1.56
May	1.55	1.51	1.57	1.64	1.55	1.61	1.56	1.55	1.57	1.61	1.56	1.60	1.56	1.67	1.55	1.68	1.55	1.58	1.51	1.70	NS	1.50
Aug	1.67	1.60	1.70	1.65	1.68	1.63	1.71	1.66	1.65	1.61	1.65	1.62	1.78	1.72	1.65	1.62	1.74	1.70	1.65	1.61	1.79	1.69
Nov	1.72	1.66	1.72	1.88	1.72	2.00	1.74	1.87	1.72	1.86	1.74	1.87	1.72	1.81	1.73	1.89	1.70	1.75	1.70	1.69	1.70	1.67
Annual Mean	1.63	1.57	1.64	1.70	1.62	1.74	1.70	1.67	1.65	1.67	1.63	1.65	1.67	1.69	1.62	1.68	1.64	1.64	1.62	1.63	1.65	1.61

NS = Not Sampled

Table 2-5. (Continued)

	LOCATION:	Mixing Zone 1.0				Mixing Zone 2				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
	DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS	YEAR:	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001
Potassium (mg/l)																							
Feb		1.80	1.83	1.77	1.84	1.85	1.79	1.86	1.83	1.80	1.82	1.80	1.87	1.83	1.78	1.87	1.79	1.84	1.76	1.80	1.86	1.75	1.83
May		1.91	1.84	1.96	1.82	1.94	1.77	1.91	1.75	1.89	1.81	1.93	1.78	1.90	1.75	1.88	1.82	1.91	1.72	1.83	1.82	NS	1.82
Aug		2.11	1.83	2.11	1.85	2.11	1.87	2.07	1.92	2.03	1.88	2.05	1.86	2.11	1.87	2.00	1.85	2.08	1.85	2.04	1.82	2.07	1.84
Nov		2.12	1 96	2.12	2 02	2.18	2 01	2.23	1.97	2.17	1 94	2.22	1.98	2.17	1 99	2.14	1 95	2.16	1.93	2.12	1.95	2 10	1.87
Annual Mean		1 99	1.87	1.99	1.88	2.02	1 86	2.02	1 87	1.97	1.86	2.00	1.87	2 00	1.85	1.97	1 85	2.00	1.82	1 95	1 86	1 97	1.84
Sodium (mg/l)																							
Feb		7.08	6.78	7.82	7.25	8.03	6.80	7.54	6.92	8.08	7.22	7.29	7.06	8.05	6.87	7.83	6.87	7.62	7.14	7.75	7.48	7.91	7.29
May		7.81	6.89	8.11	6.98	7.90	7.13	7.93	6.95	7.80	7.39	7.71	6 88	7.57	6.94	8.03	6.94	7.71	7.09	7.95	7.21	NS	6 96
Aug		8.28	7.09	7.94	6.35	8.31	6.70	8.05	6.74	7.85	6.40	8.18	6 68	7.83	7.17	8.05	6.89	7.90	6.95	8.41	6.57	8	6.76
Nov		7.16	7.38	7.16	7 46	7.72	8 17	7 65	7 66	7.15	7.85	7.77	8 23	7.58	8 02	7 55	7 82	7.27	7 50	8 03	7 50	7.76	7 55
Annual Mean		7.58	7.04	7.76	7 01	7.99	7.20	7.79	7.07	7.72	7.22	7.74	7.21	7.76	7 25	7 87	7.13	7 63	7.17	8 04	7.19	7.89	7.14
Aluminum (mg/l)																							
Feb		0.092	0.050	0.142	0 061	0.080	0.050	0.151	0.057	0.087	0.051	0.101	0.050	0.163	0.060	0.085	0.050	0.172	0.064	0.135	0.050	0.311	0 080
May		0.050	0.050	0.065	0 050	0 050	0.050	0.051	0.050	0.05	0.050	0.050	0.050	0.063	0 050	0.050	0.050	0 063	0.050	0.050	0.052	NS	0.084
Aug		0.050	0.050	0.060	0 050	0.050	0.050	0.050	0 050	0.05	0.050	0.050	0.050	0.107	0.050	0.050	0.050	0.070	0.050	0.050	0.050	0.066	0.094
Nov		0 076	0 050	0.076	0 050	0 089	0 050	0 082	0 053	0 095	0 050	0 087	0 050	0 240	0 050	0 067	0 050	0 188	0 074	0 106	0 050	0 237	0 054
Annual Mean		0 07	0.05	0 086	0 05	0 067	0.05	0 084	0 053	0 071	0 05	0 072	0 05	0.143	0 05	0 063	0 05	0.123	0.06	0 085	0 05	0 205	0 08
Iron (mg/l)																							
Feb		0.108	0.028	0.198	0 033	0.113	0.029	0.205	0 032	0.103	0.027	0.137	0.020	0.245	0.034	0.121	0.023	0.270	0.032	0.185	0 026	0.452	0 050
May		0.052	0.015	0.117	0 010	0.044	0.013	0.098	0.010	0.041	0.014	0.034	0.013	0.115	0.010	0.056	0.019	0.122	0.017	0.103	0.027	NS	0.047
Aug		0.066	0.029	0.119	0.057	0.062	0.034	0 086	0.047	0.061	0.028	0.064	0.028	0.239	0.010	0.049	0 024	0.143	0.068	0.063	0.034	0.142	0.155
Nov		0 107	0 018	0.107	0 537	0.125	0 024	0 211	0 044	0.138	0 015	0.133	0 013	0.385	0.030	0.101	0.011	0.255	0 070	0.141	0 010	0 309	0 067
Annual Mean		0 083	0.023	0.135	0 159	0.086	0.025	0.150	0 033	0.086	0 021	0.092	0.019	0 246	0 021	0 082	0 019	0.198	0 047	0.123	0 024	0.301	0 080
Manganese (mg/l)																							
Feb		0 01	0.01	0.05	0.02	0.01	0.01	0.05	0 02	0.01	0.01	NS	0.01	0.05	0.02	0.02	0.01	NS	0.01	0.02	0.02	0.05	0.03
May		0 01	0.01	0.03	0.02	0 01	0.00	0.03	0 01	0.01	0.01	0.01	0.01	0.04	0.03	0.01	0.00	0.03	0.01	0.01	0.00	NS	0.04
Aug		0.02	0.02	NS	0.72	0.02	0.02	0.52	0.54	0.02	0.02	0.02	0.02	1.76	0.22	0.01	0.02	0 63	0.94	0.03	0.01	1.22	1.14
Nov		0.11	NS	0.11	NS	0 09	NS	0 64	NS	0.13	NS	0.12	NS	0.33	NS	0 08	NS	0.03	NS	0 05	NS	0 08	NS
Annual Mean		0 04	0 01	0 06	0.25	0 03	0 01	0.31	0.19	0 04	0.01	0.05	0 01	0.54	0 09	0.03	0.01	0 23	0.32	0 03	0.01	0 45	0.40
Cadmium (ug/l)																							
Feb		NS	NS	NS	NS	0.5	0 5	0.5	0.5	0.5	0.5	NS	NS	NS	NS	0.5	0.5	0.5	0.5	NS	NS	NS	NS
May		0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0 5	NS	0.5	NS	NS	NS
Aug		NS	NS	NS	NS	0.5	0.5	0.5	0.5	0 5	0.5	NS	NS	NS	NS	0.5	0.5	0.5	0.5	NS	NS	NS	NS
Nov		0.5	NS	0 5	NS	0 5	NS	0 5	NS	0 5	NS	0.5	NS	0.5	NS	0 5	NS	0 5	NS	0 5	NS	0 5	NS
Annual Mean		0.5		0 5		0.5		0 5	0.5	0 5	0 5	0 5		0 5		0 5	0.5	0 5	0.5	0 5		0 5	
Copper (ug/l)																							
Feb		NS	NS	NS	NS	2.0	2.0	2.1	2.0	2.0	2.0	NS	NS	NS	NS	2.0	2.0	2.5	2.0	2.4	NS	NS	NS
May		6.8	NS	3.0	NS	2.4	NS	2.3	NS	2.2	NS	2.3	NS	4.5	NS	2.2	NS	2.3	NS	3.3	NS	NS	NS
Aug		NS	NS	NS	NS	2.8	2.0	2.3	2.0	2.3	2.0	NS	NS	NS	NS	2.5	2.0	2.2	2.0	NS	NS	NS	NS
Nov		2 0	NS	2.0	NS	2 2	NS	2.3	NS	2.3	NS	2 0	NS	2 4	NS	2.3	NS	2 4	NS	3.1	NS	3.1	NS
Annual Mean		4 4		2.5		2.3	2.0	2.2	2 0	2.2	2 0	2 0		2.1		2.2	2 0	2.3	2 0	2 9		3.1	
Lead (ug/l)																							
Feb		NS	NS	NS	NS	2	2	2	2	2	2	NS	NS	NS	NS	2	2	2	2	2	NS	NS	NS
May		2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	NS	NS
Aug		NS	NS	NS	NS	2	2	2	2	2	2	NS	NS	NS	NS	2	2	2	2	NS	NS	NS	NS
Nov		2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS
Annual Mean		2		2		2	2	2	2	2	2	2		2		2	2	2	2	2		2	

NS = Not sampled

Table 2-5. (Continued)

PARAMETERS	Mixing Zone 1.0 Surface 2002	Mixing Zone 1.0 Surface 2001	Mixing Zone 1.0 Bottom 2002	Mixing Zone 1.0 Bottom 2001	Mixing Zone 2 Surface 2002	Mixing Zone 2 Surface 2001	Mixing Zone 2 Bottom 2002	Mixing Zone 2 Bottom 2001	MNS Discharge 4.0 Surface 2002	MNS Discharge 4.0 Surface 2001	Mixing Zone 5.0 Surface 2002	Mixing Zone 5.0 Surface 2001	Mixing Zone 5.0 Bottom 2002	Mixing Zone 5.0 Bottom 2001	Background 8.0 Surface 2002	Background 8.0 Surface 2001	Background 8.0 Bottom 2002	Background 8.0 Bottom 2001	Background 11.0 Surface 2002	Background 11.0 Surface 2001	Background 11.0 Bottom 2002	Background 11.0 Bottom 2001
Zinc (ug/l)																						
Feb	5	5	5	5	5	5	5	5	5	5	6	5	5	5	7	5	5	5	5	5	10	5
May	5	5	5	5	5	5	5	5	5	5	9	5	5	5	5	5	5	5	5	5	NS	5
Aug	5	5	8	9	5	5	5	6	5	5	5	5	5	5	5	5	5	5	6	5	5	5
Nov	20	6	20	7	20	5	20	5	20	5	20	5	20	5	20	5	20	5	20	5	20	5
Annual Mean	8.8	5.3	9.5	6.5	8.8	5.0	8.8	5.3	8.8	5.0	10.0	5.0	8.8	5.0	9.3	5.0	8.8	5.0	9.0	5.0	11.7	5.0
Nitrate (ug/l)																						
Feb	110	110	120	120	110	120	130	120	120	110	110	110	120	120	120	110	130	110	150	150	220	160
May	120	130	170	150	130	130	170	150	130	140	130	130	160	150	120	130	190	170	150	640	NS	140
Aug	20	30	170	260	20	30	160	270	20	30	20	30	90	170	20	30	150	1460	20	20	160	260
Nov	50	690	50	710	60	820	50	50	60	20	60	50	50	50	60	40	70	100	140	90	140	100
Annual Mean	75.0	240.0	127.5	310.0	80.0	275.0	127.5	147.5	82.5	75.0	80.0	80.0	105.0	122.5	80.0	77.5	135.0	460.0	115.0	225.0	173.3	165.0
Ammonia (ug/l)																						
Feb	20	20	40	40	20	20	50	30	30	20	20	20	40	30	20	20	190	20	40	30	50	40
May	20	20	20	60	20	20	20	50	20	30	20	20	20	50	20	20	20	60	20	20	NS	90
Aug	20	20	20	70	20	20	40	50	20	20	20	10	80	60	20	20	60	20	20	20	50	20
Nov	60	30	60	600	60	20	110	90	60	20	60	20	80	70	60	30	50	80	50	120	60	210
Annual Mean	30.0	22.5	35.0	192.5	30.0	20.0	55.0	55.0	32.5	22.5	30.0	17.5	55.0	52.5	30.0	22.5	80.0	45.0	32.5	47.5	53.3	90.0
Total Phosphorous (ug/l)																						
Feb	10	4	10	5	10	4	10	5	10	4	10	4	10	4	10	63	10	4	10	7	16	8
May	10	6	10	5	10	16	10	8	10	5	10	7	26	6	18	7	10	5	10	8	NS	6
Aug	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	17
Nov	10	10	10	10	10	10	22	10	10	10	10	10	10	10	10	10	10	18	10	11	10	11
Annual Mean	10.0	7.5	10.0	7.5	10.0	10.0	13.0	8.3	10.0	7.3	10.0	7.8	14.0	7.5	12.0	22.5	10.0	9.3	10.0	9.0	12.0	10.5
Orthophosphate (ug/l)																						
Feb	5	2	5	2	6	2	5	2	5	2	5	2	5	2	5	2	5	2	5	2	5	2
May	5	2	5	2	5	2	5	2	5	2	5	2	14	2	5	2	5	2	5	2	NS	2
Aug	5	5	5	8	5	5	5	5	5	5	5	7	5	7	5	5	5	7	5	7	5	7
Nov	5	5	5	5	5	5	13	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Annual Mean	5.0	3.5	5.0	4.3	5.3	3.5	7.0	4	5.0	4	5.0	4	7.3	4	5.0	4	5.0	4	5.0	4.0	5.0	4
Silica (mg/l)																						
Feb	3.2	2.9	3.4	3.0	3.3	3.0	3.5	3.0	3.3	3.0	3.3	2.9	3.4	3.0	3.3	2.9	3.5	2.8	3.6	3.6	3.8	3.7
May	3.4	2.9	3.8	3.2	3.4	2.9	3.8	3.1	3.4	2.9	3.4	2.9	4.0	3.2	3.3	3.0	3.9	3.3	3.8	2.9	NS	3.5
Aug	3.0	2.4	4.3	4.0	3.0	2.7	4.4	4.1	3.0	2.7	3.0	2.7	4.4	4.1	3.0	2.6	4.3	4.0	3.2	2.7	4.4	4.2
Nov	4.3	3.4	4.3	4.7	4.5	3.2	4.5	3.4	4.4	3.2	4.5	3.3	4.5	3.4	4.4	3.1	4.3	4.3	4.8	3.5	4.8	4.5
Annual Mean	3.5	2.9	4.0	3.7	3.6	3.0	4.1	3.4	3.5	3.0	3.6	3.0	4.1	3.4	3.5	2.9	4.0	3.6	3.9	3.2	4.3	4.0

NS = Not Sampled

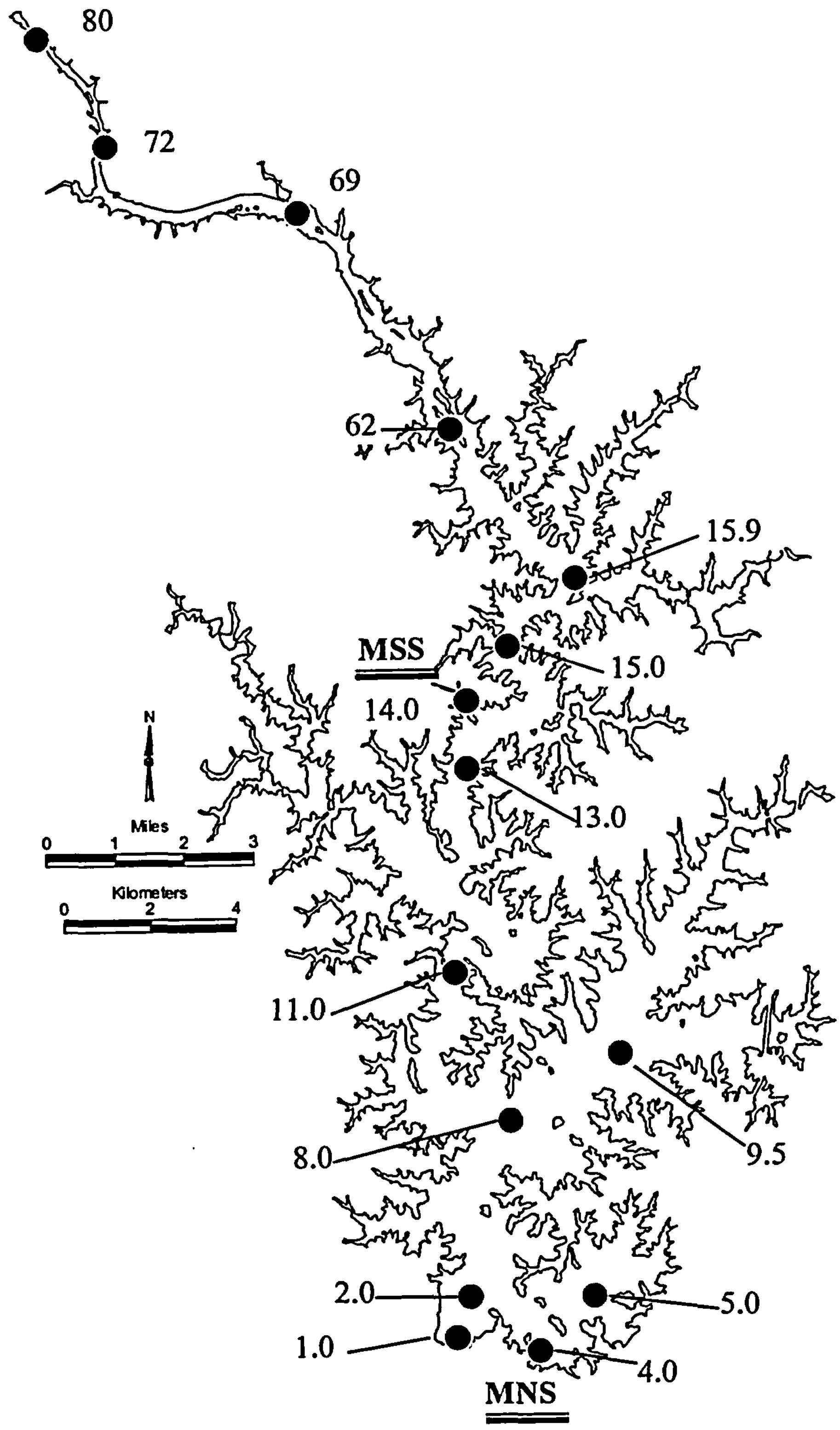

Figure 2-1. Water quality sampling locations for Lake Norman.

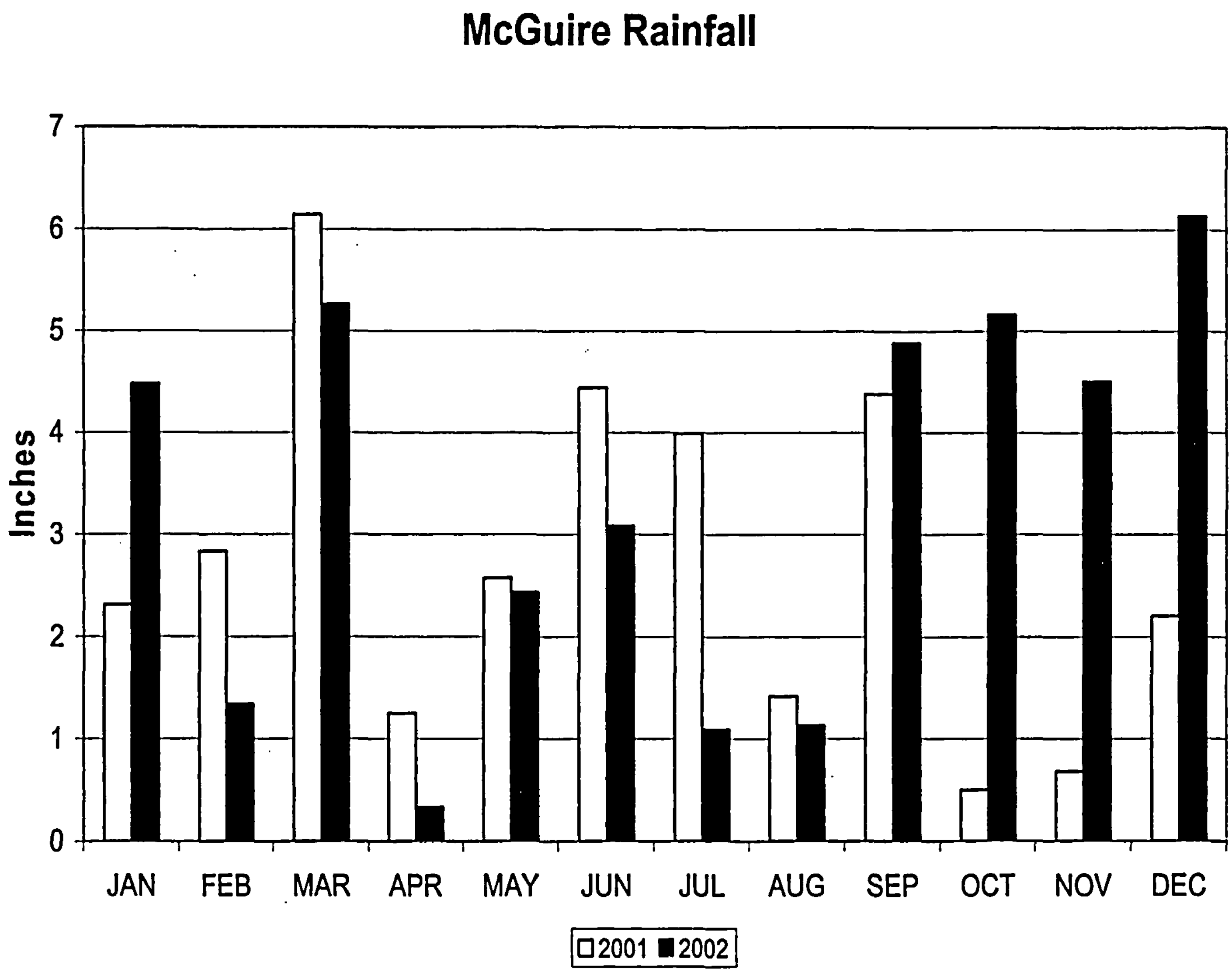

Figure 2-2. Monthly precipitation in the vicinity of McGuire Nuclear Station.

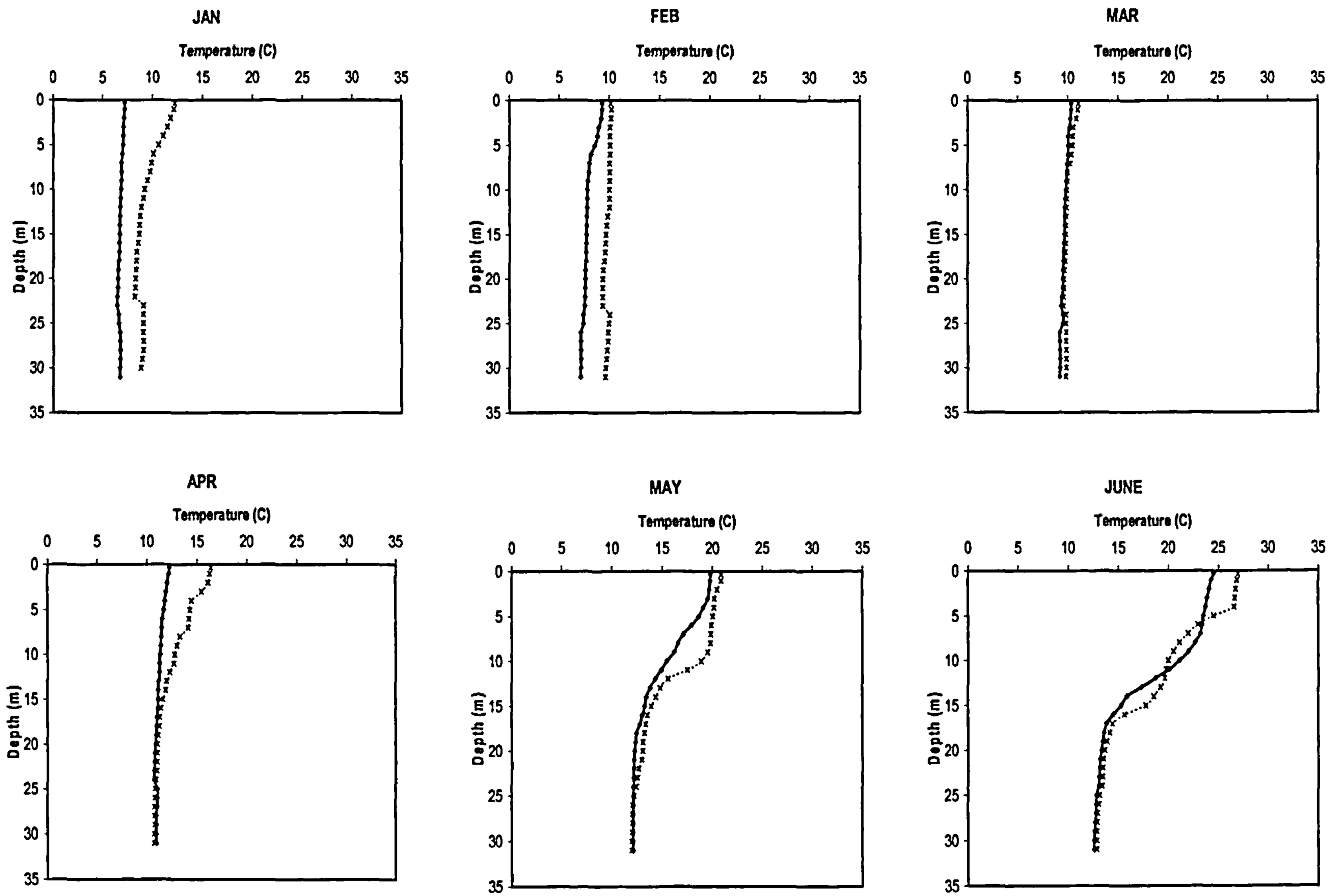

Figure 2-3. Monthly mean temperature profiles for the McGuire Nuclear Station background zone in 2002 (××) and 2001 (♦♦).

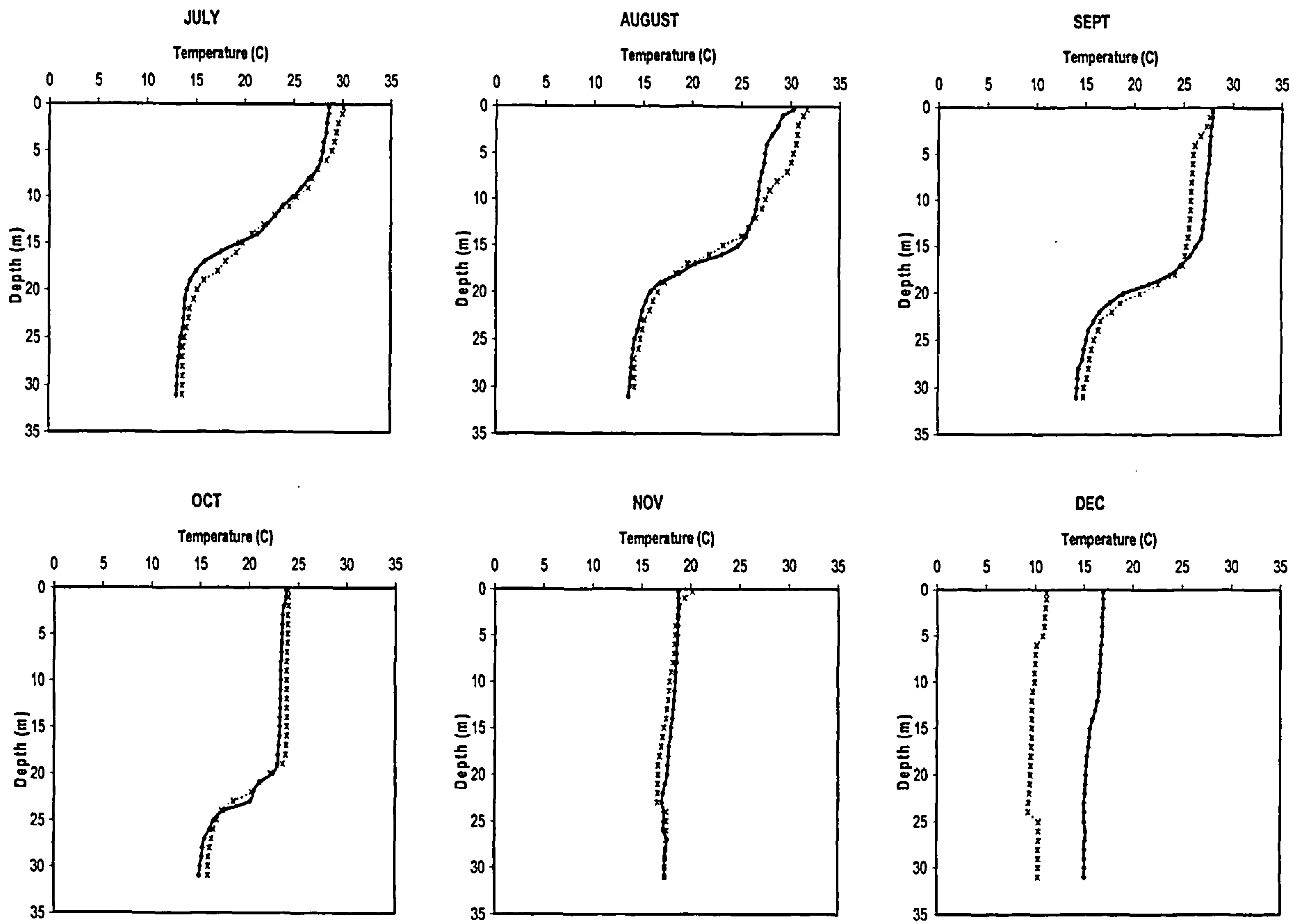

Figure 2-3. (con't).

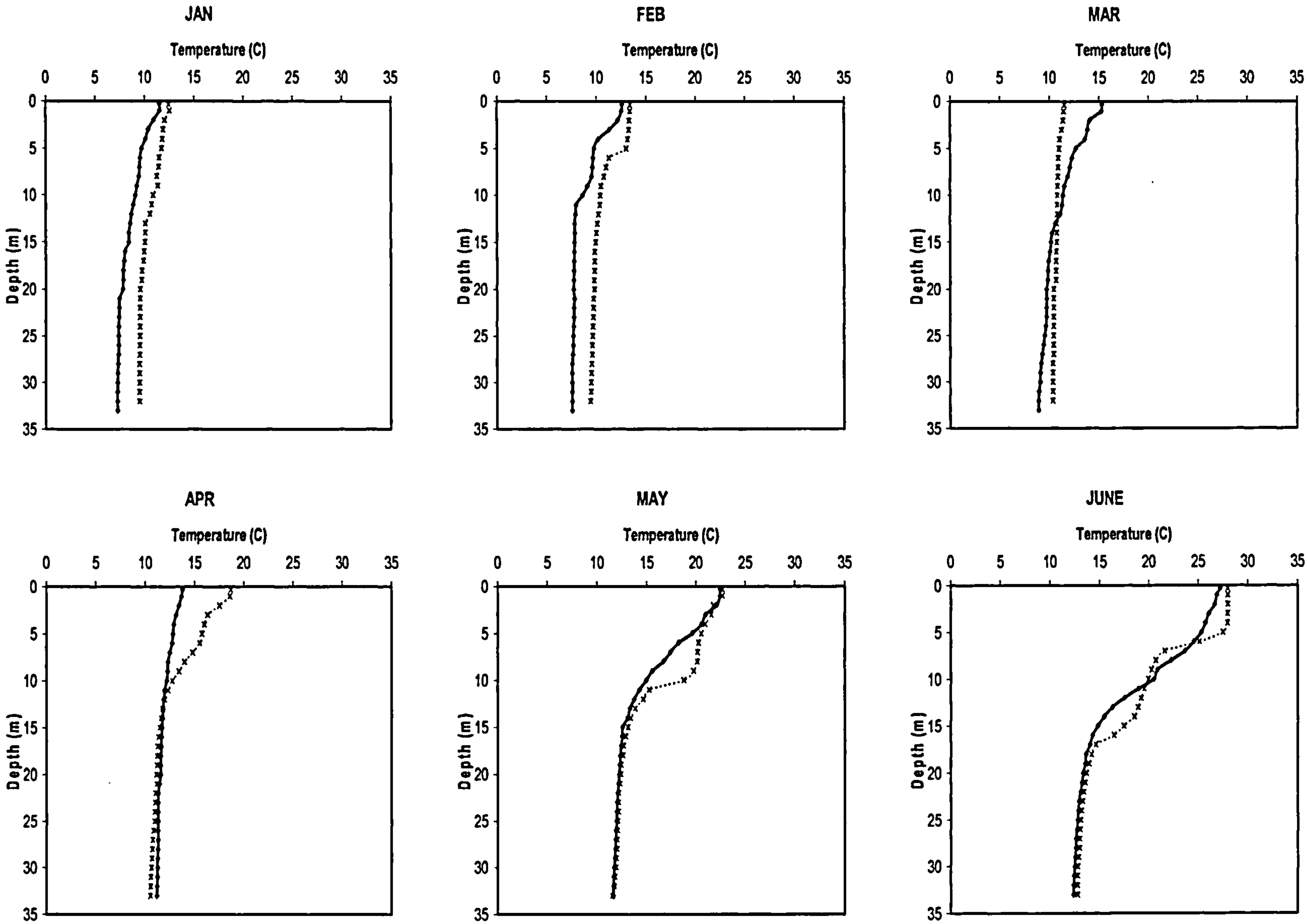

Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 2002 (××) and 2001 (♦♦).

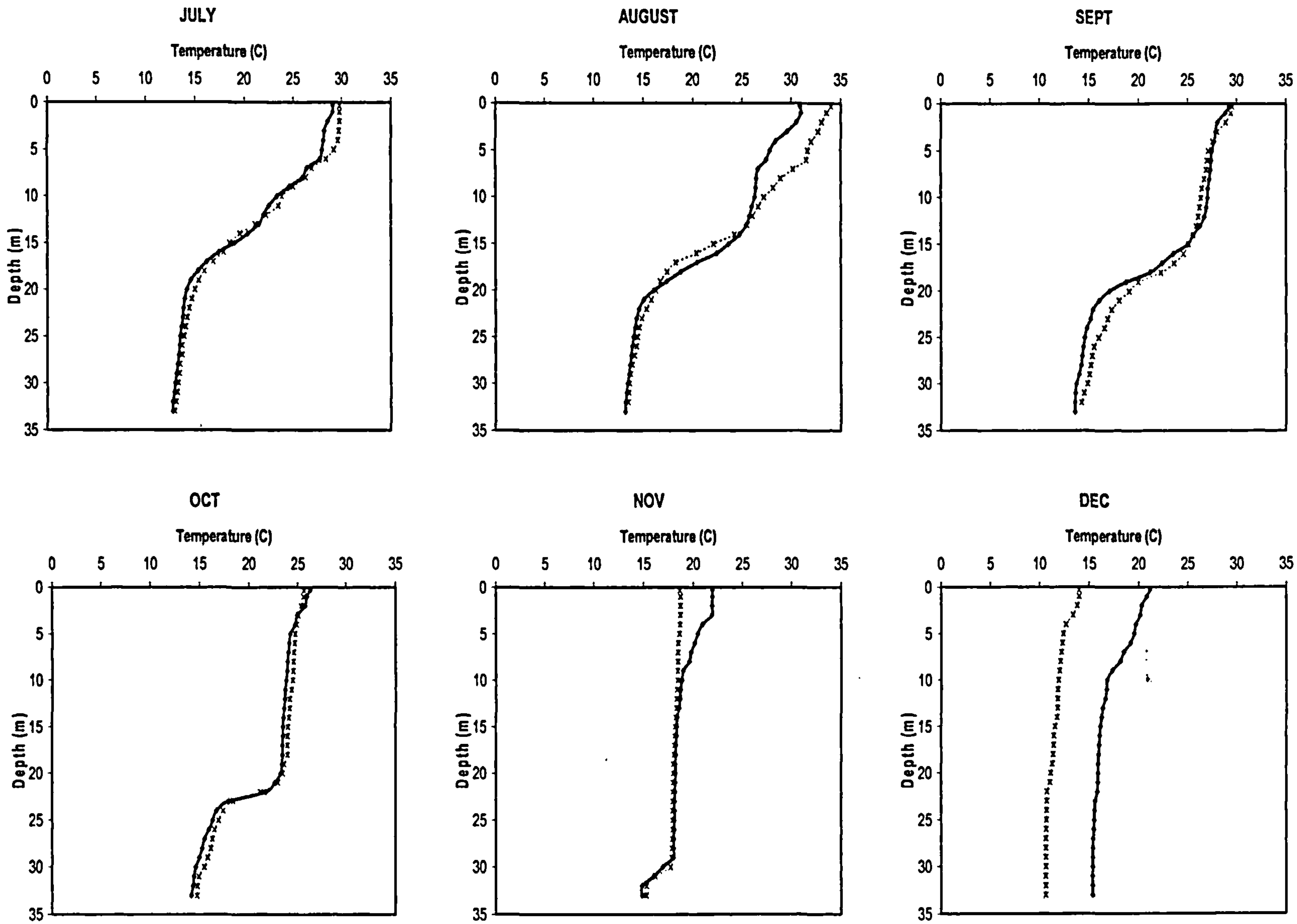

Figure 2-4. (con't).

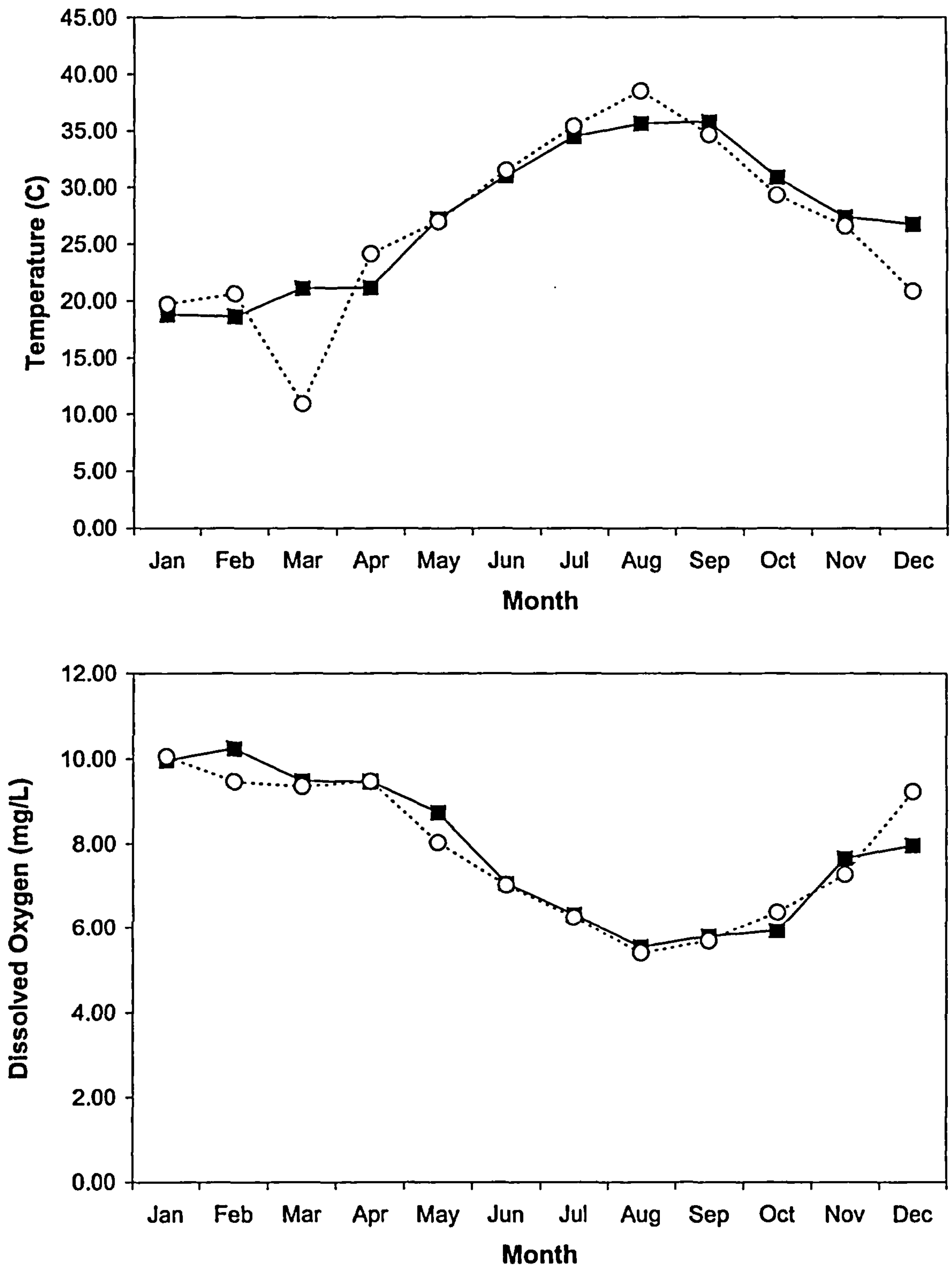

Figure 2-5. Monthly surface (0.3m) temperature and dissolved oxygen data at the discharge location (loc. 4.0) in 2002 (○) and 2001 (■).

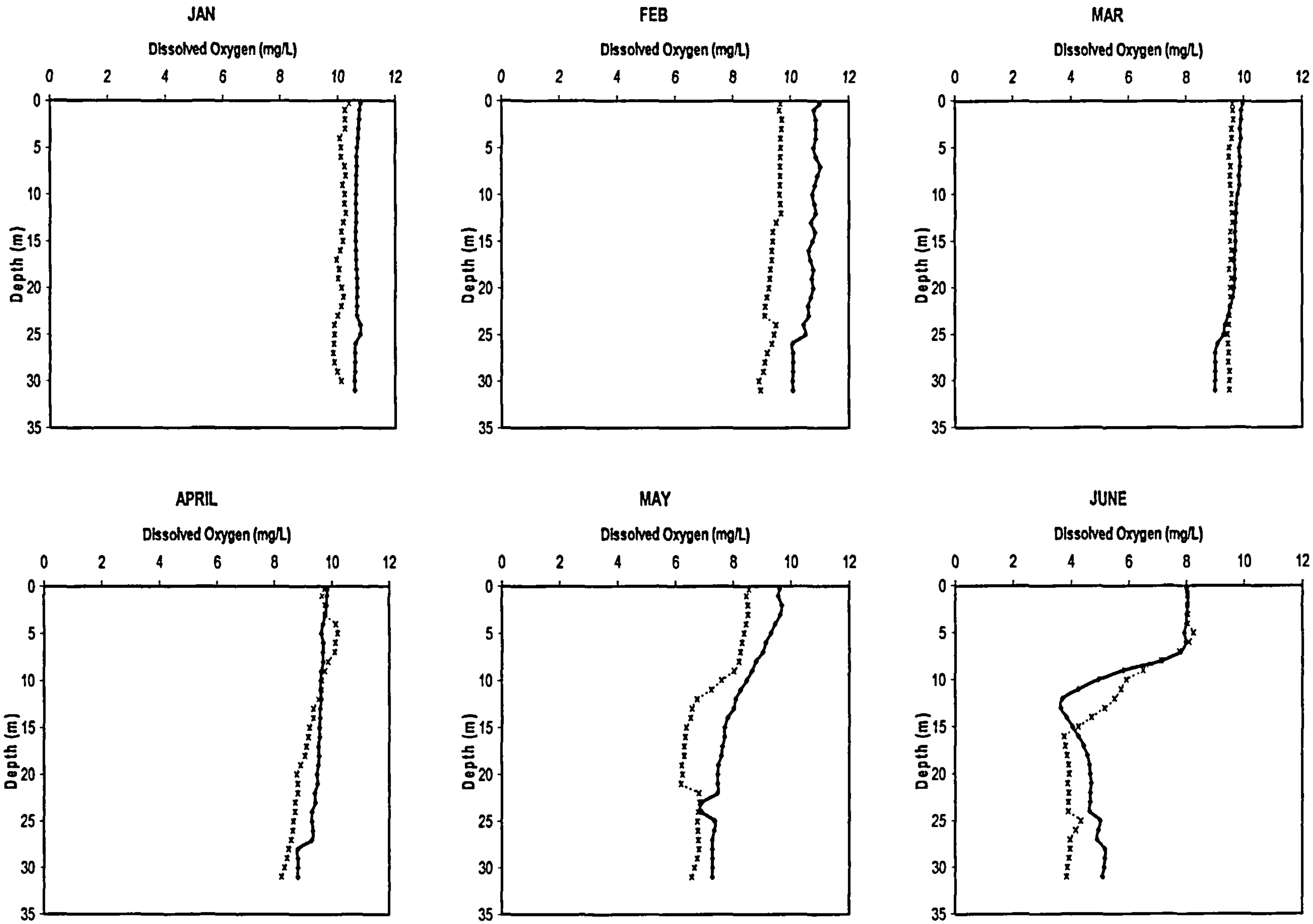

Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 2002 (××) and 2001 (♦♦).

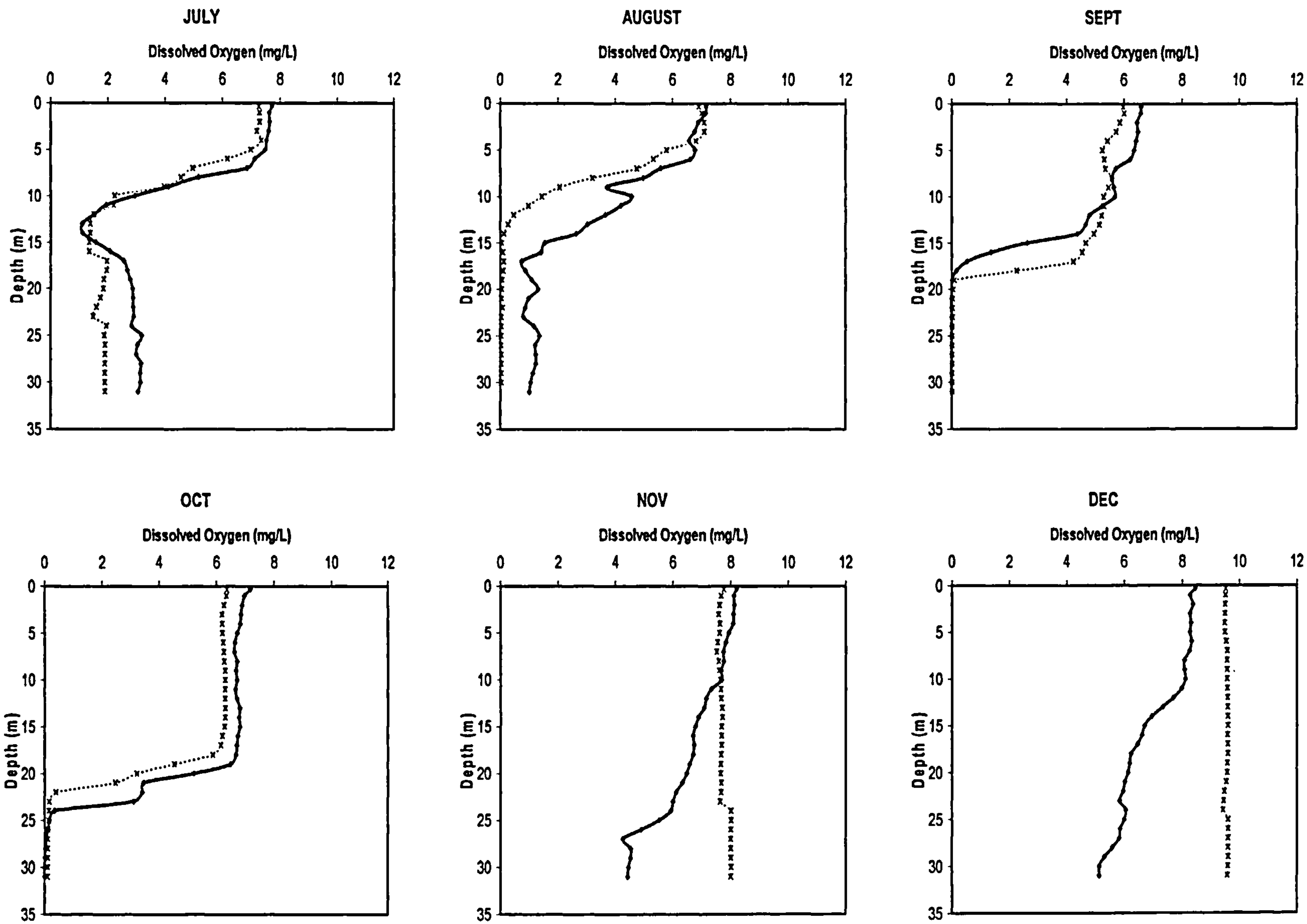

Figure 2-6. (con't).

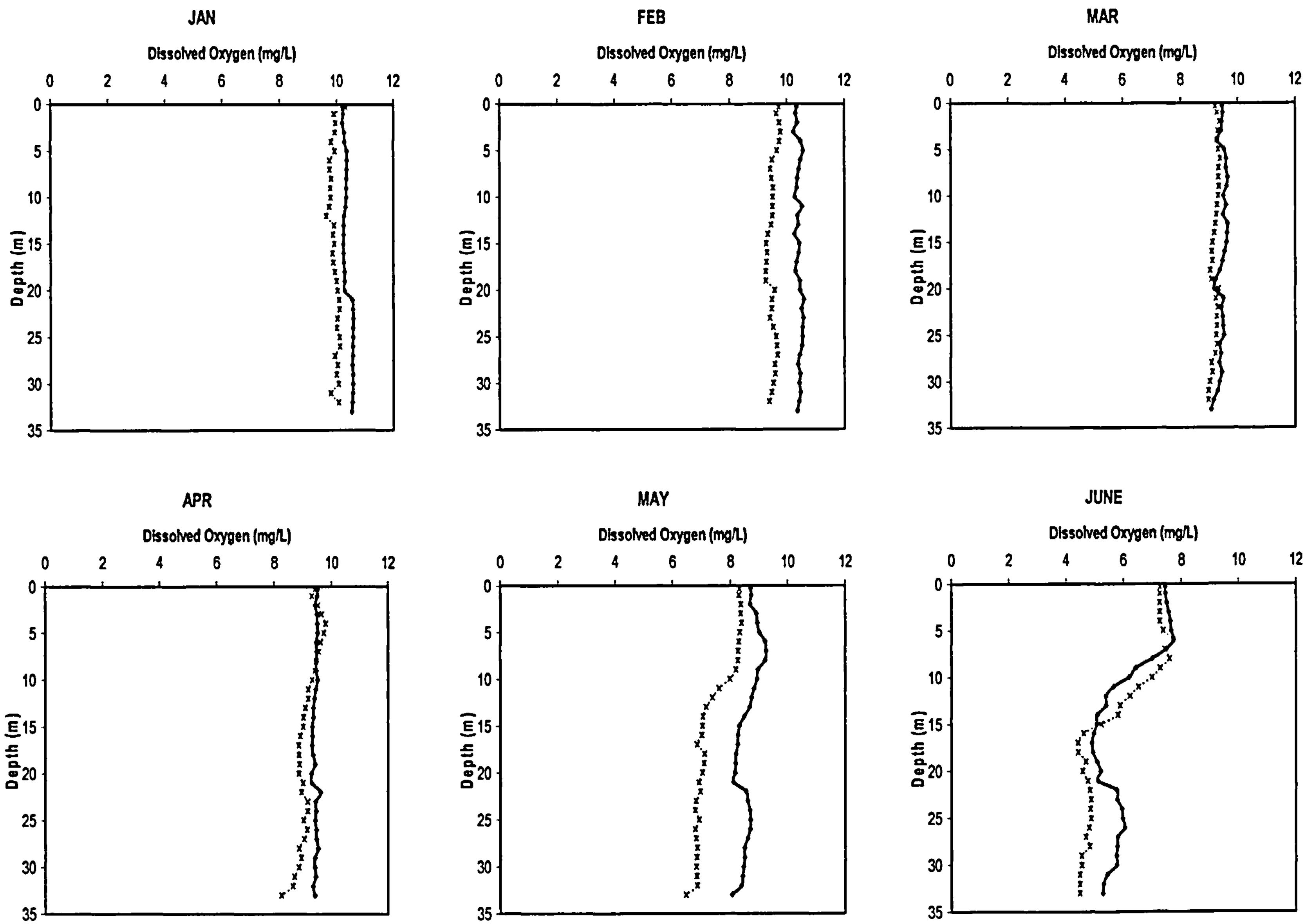

Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 2002 (××) and 2001 (♦♦).

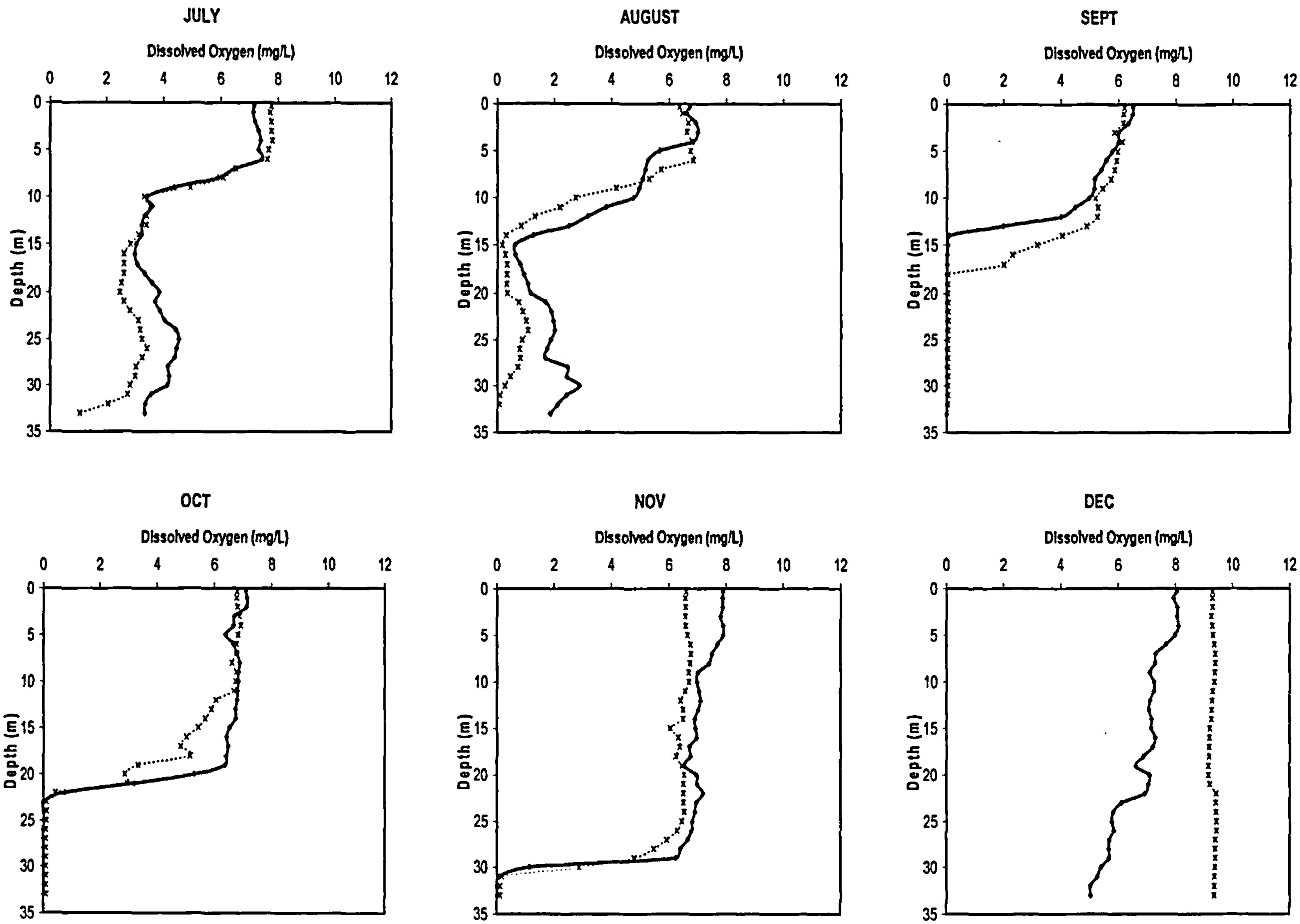

Figure 2-7. (con't).

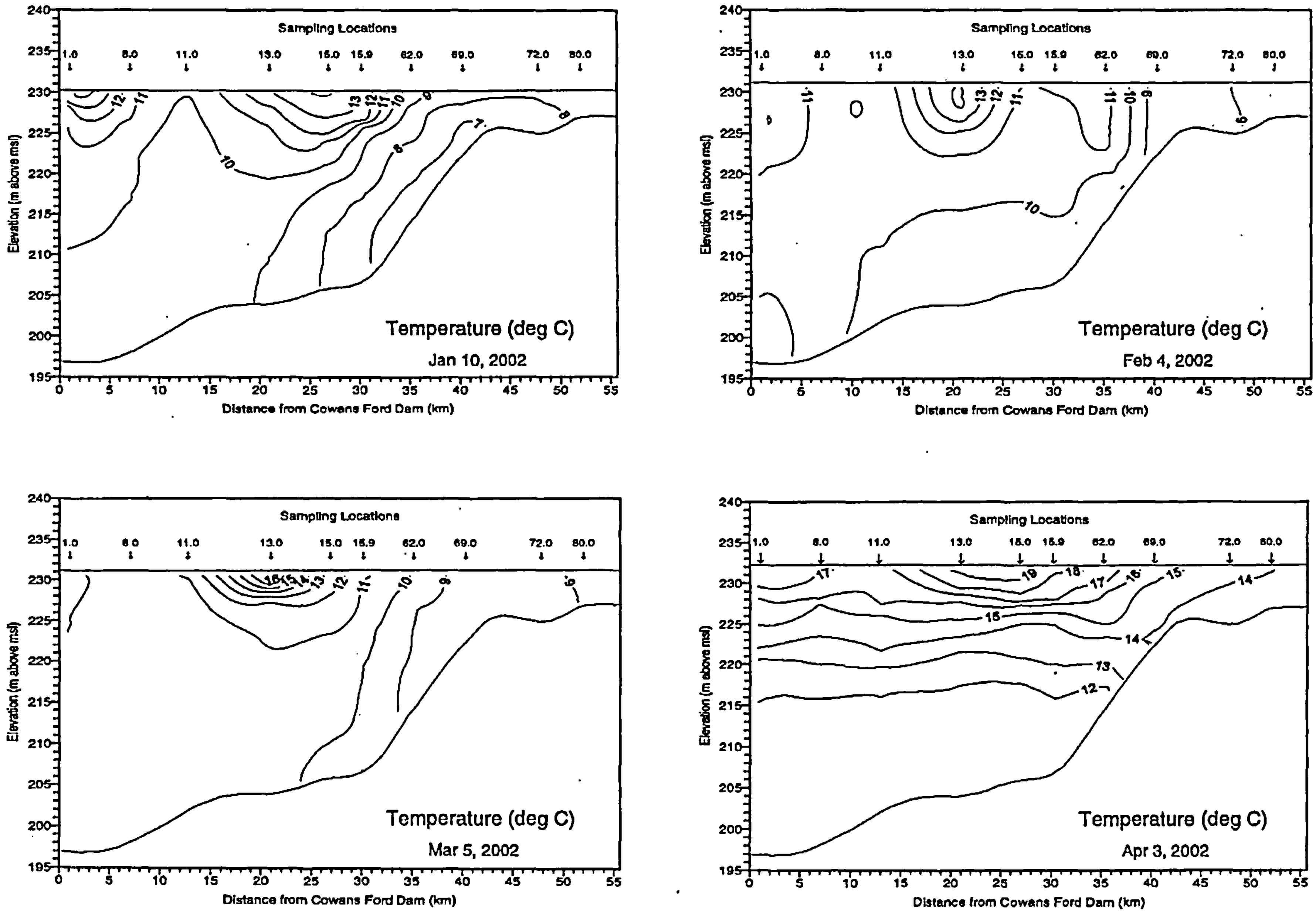

Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 2002.

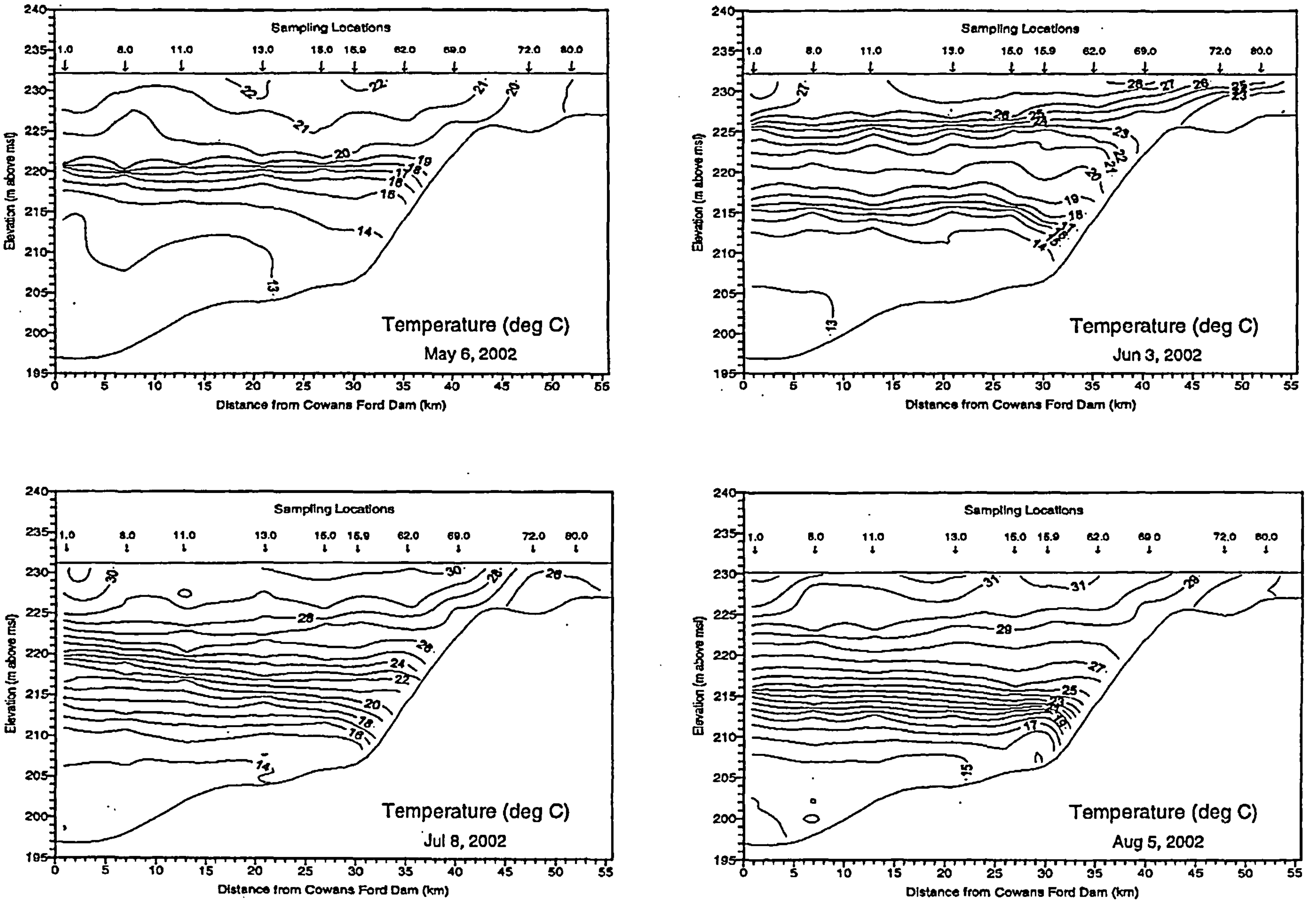

Figure 2-8. Continued.

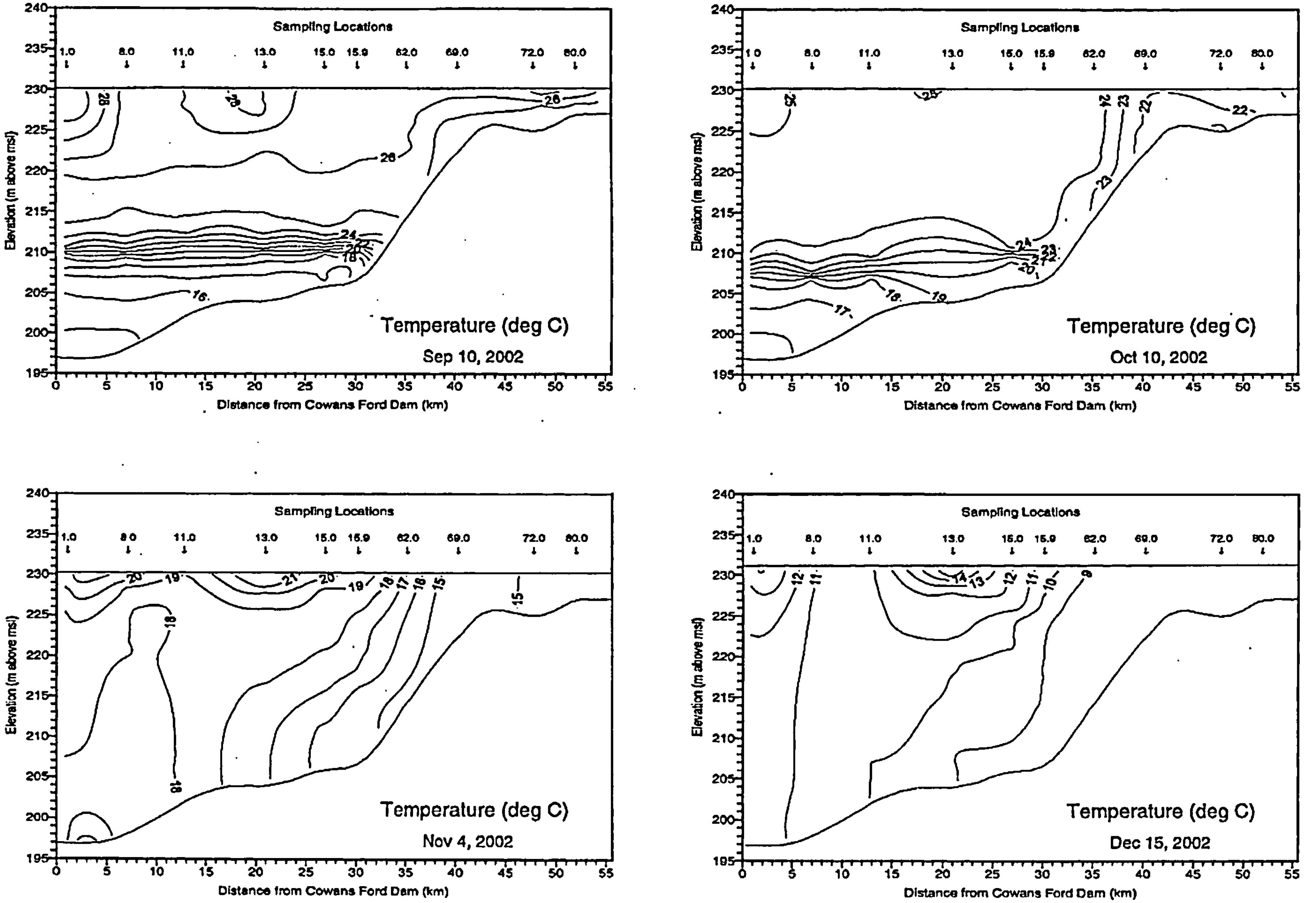

Figure 2-8. Continued.

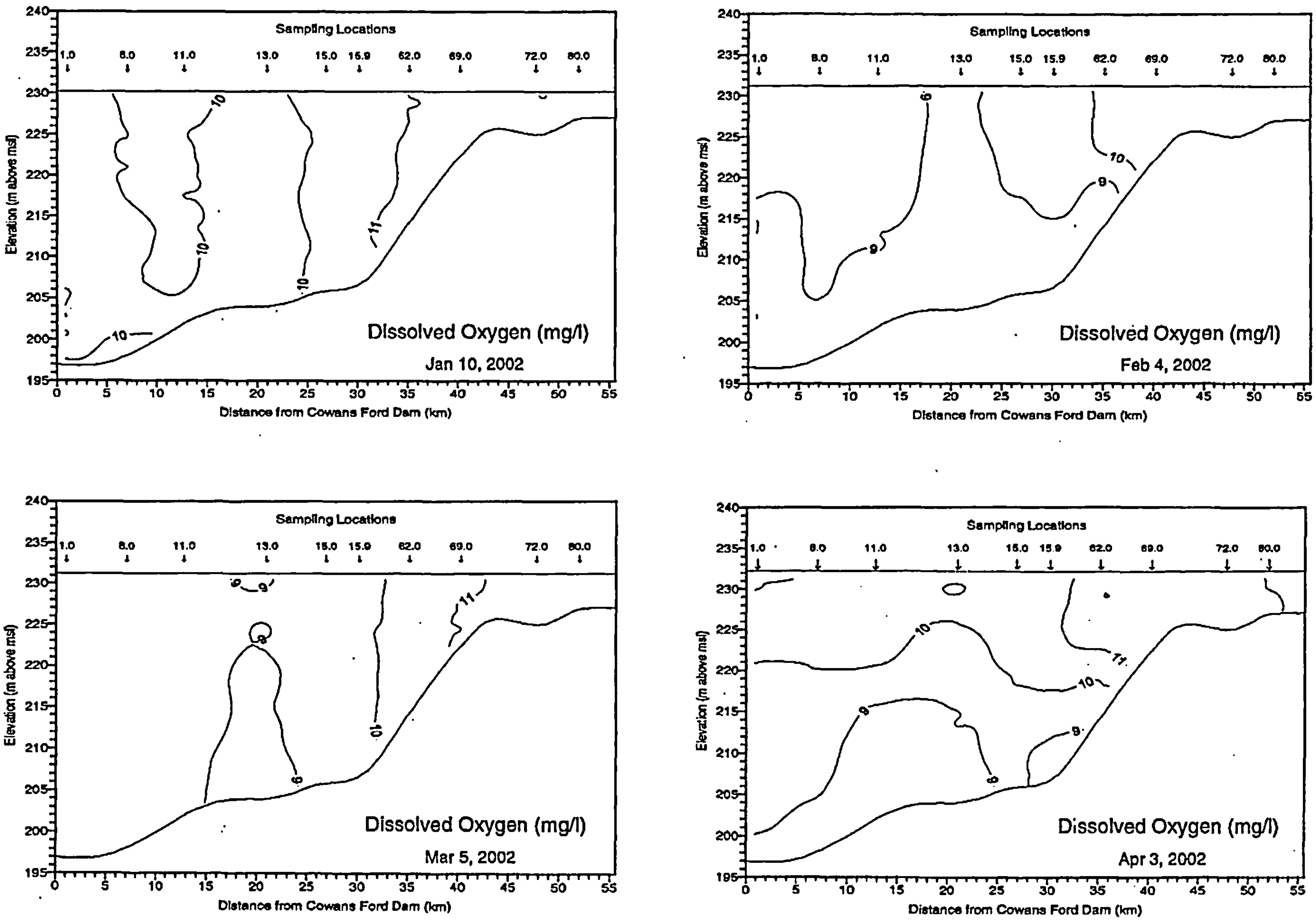

Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 2002.

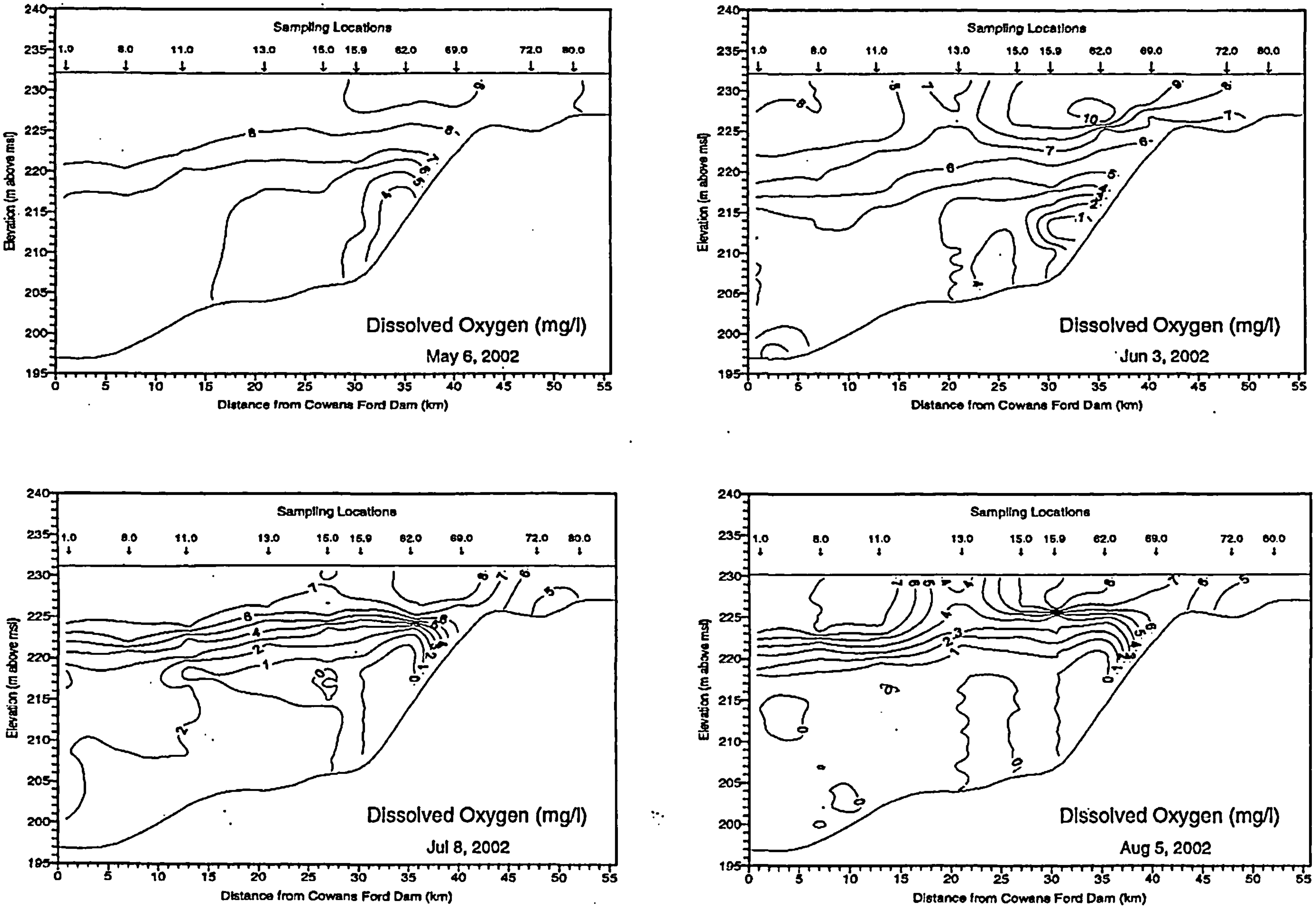

Figure 2-9. Continued.

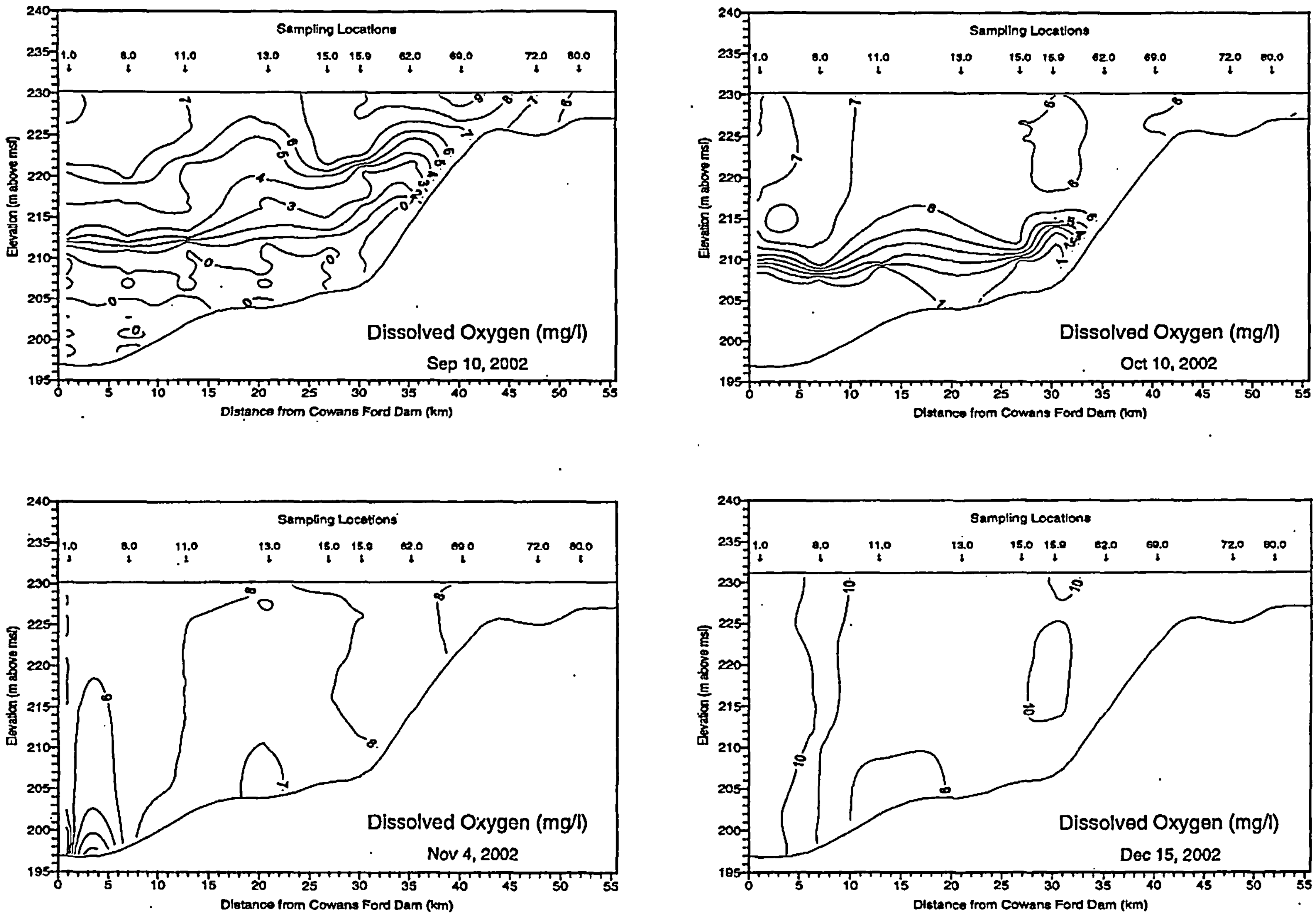

Figure 2-9. Continued.

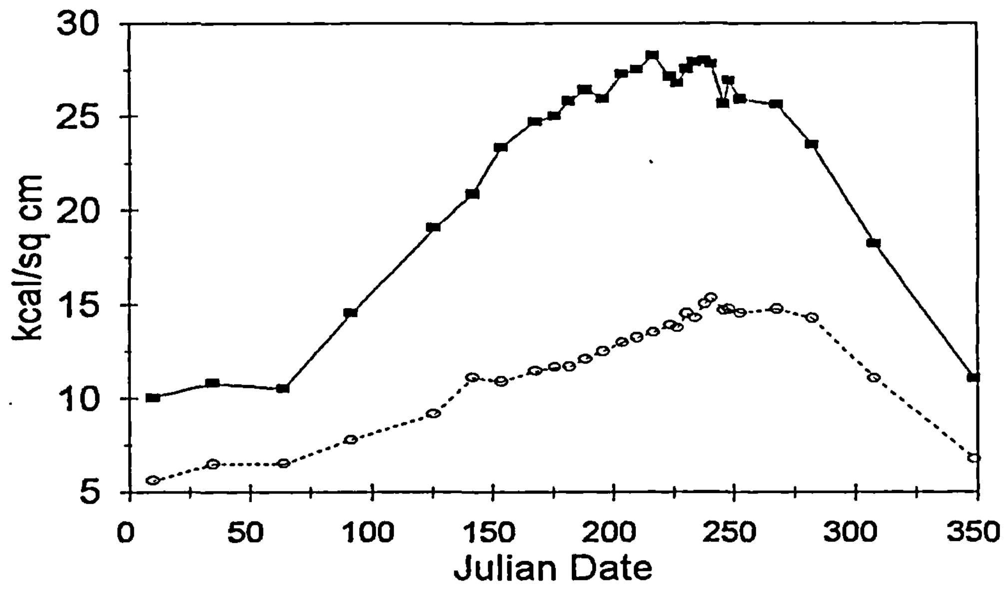

Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (O) in Lake Norman in 2002.

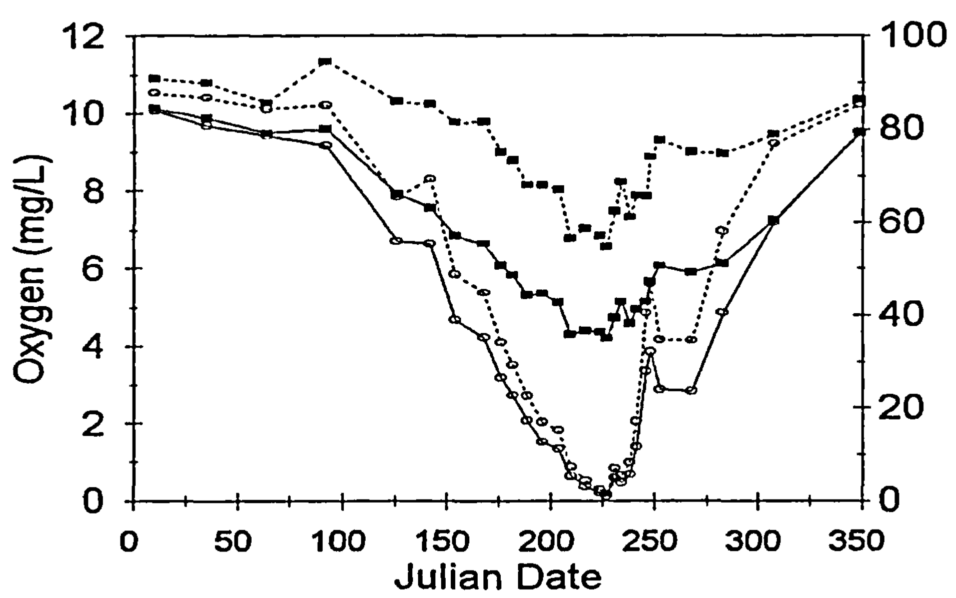

Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (O) of Lake Norman in 2002.

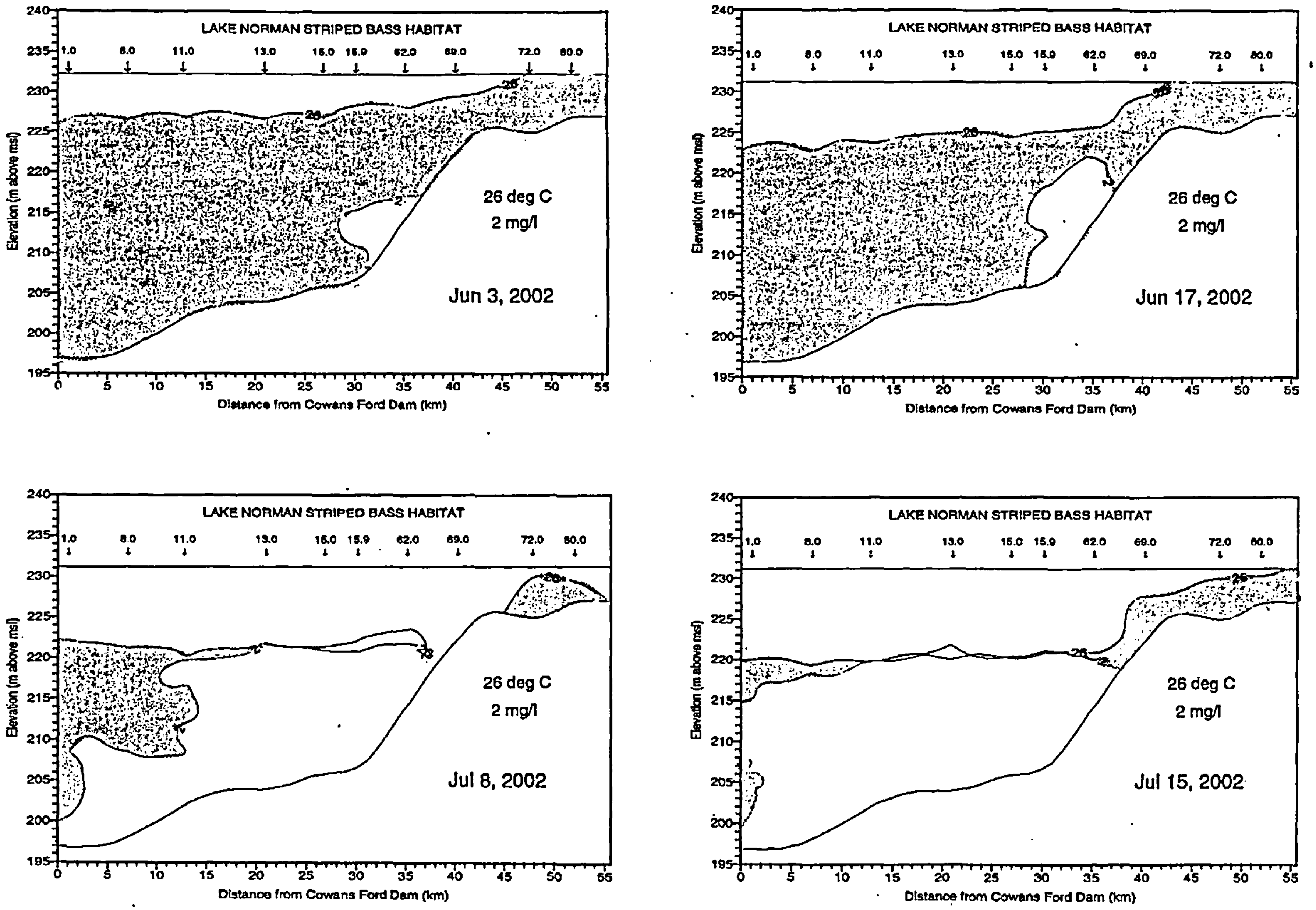

Figure 2-11. Striped bass habitat ((temperatures ≤20 C and dissolved oxygen ≥2 mg/L) in Lake Norman, summer 2002.

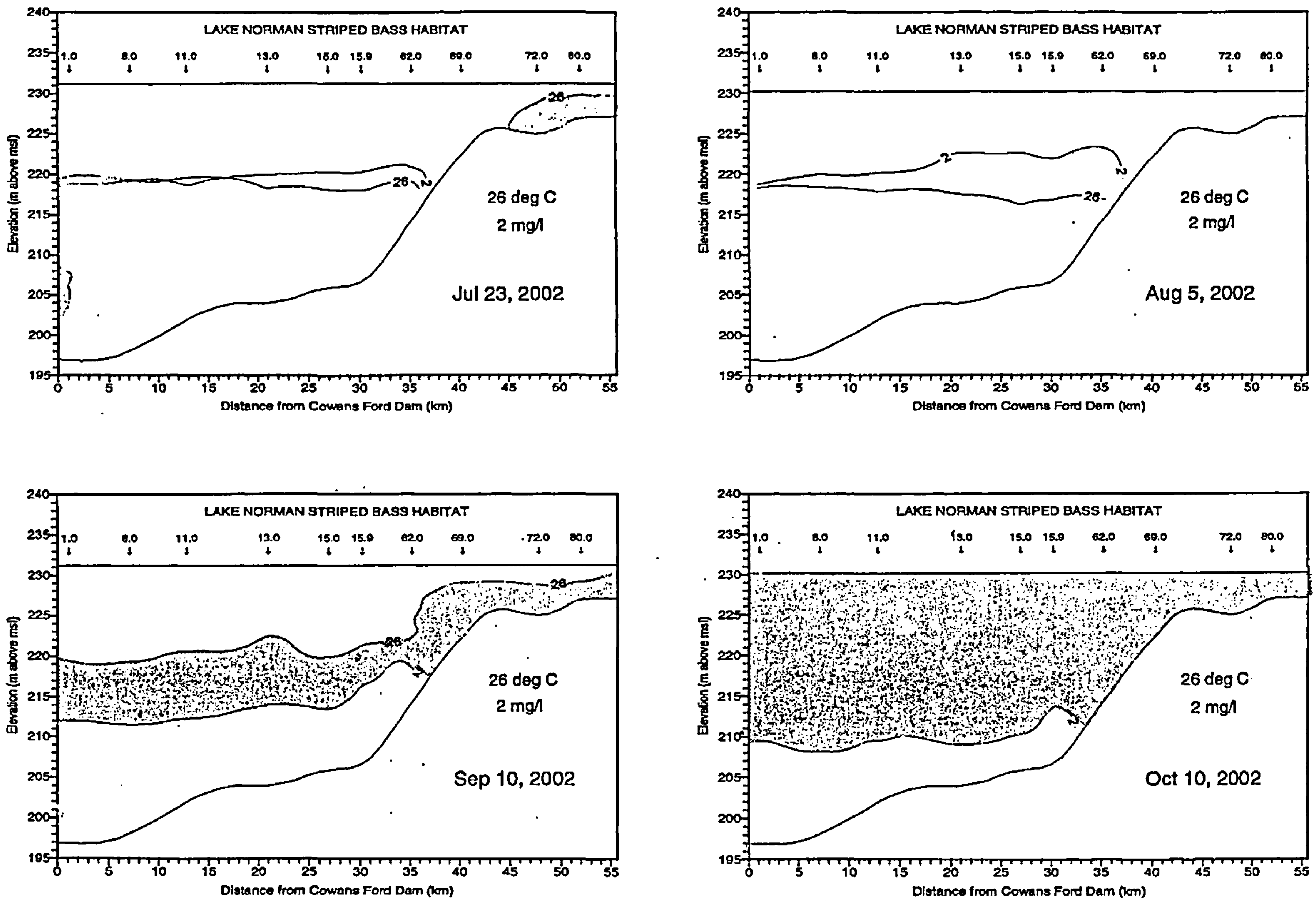

Figure 2-11. Continued

CHAPTER 3
PHYTOPLANKTON

INTRODUCTION

Phytoplankton standing crop parameters were monitored in 2002 in accordance with the NPDES permit for McGuire Nuclear Station (MNS). The objectives of the phytoplankton section for the Lake Norman Maintenance Monitoring Program are to:

1. Describe quarterly patterns of phytoplankton standing crop and species composition throughout Lake Norman; and
2. Compare phytoplankton data collected during this study (February, May, August, November 2002) with historical data collected in other years during these months.

In previous studies on Lake Norman considerable spatial and temporal variability in phytoplankton standing crops and taxonomic composition have been reported (Duke Power 1976, 1985; Menhinick and Jensen 1974; Rodriguez 1982). Rodriguez (1982) classified the lake as oligo-mesotrophic based on phytoplankton abundance, distribution, and taxonomic composition. Past Maintenance Monitoring Program studies have tended to confirm this classification.

METHODS AND MATERIALS

Quarterly sampling was conducted at Locations 2.0, 5.0 (Mixing Zone), 8.0, 9.5, 11.0, 13.0, 15.9, and 69.0 in Lake Norman (see map of locations in Chapter 2, Figure 2-1). Duplicate grabs from 0.3, 4.0, and 8.0 m (i.e., the estimated euphotic zone) were taken and then composited at all but Location 69.0, where grabs were taken at 0.3, 3.0, and 6.0 m due to the shallow depth. Sampling was conducted on 4 February, 6 May, 5 August, and 4 November 2002. Phytoplankton density, biovolume and taxonomic composition were determined for samples collected at Locations 2.0, 5.0, 9.5, 11.0, and 15.9; chlorophyll *a* concentrations and seston dry and ash-free dry weights were determined for samples from all locations. Chlorophyll *a* and total phytoplankton densities and biovolumes were used in determining phytoplankton standing crop. Field sampling and laboratory methods used for chlorophyll *a*, seston dry weights and population identification and enumeration were identical to those used by Rodriguez (1982). Data collected in 2002 were compared with corresponding data from quarterly monitoring beginning in August 1987.

A one way ANOVA was performed on chlorophyll *a* concentrations, phytoplankton densities and seston dry and ash free dry weights by quarter. This was followed by a Duncan's Multiple Range Test to determine which location means were significantly different.

RESULTS AND DISCUSSION

Standing Crop

Chlorophyll *a*

Chlorophyll *a* concentrations (mean of two replicate composites) ranged from a low of 1.28 ug/l at Location 9.5 in May, to a high of 16.29 ug/L at Location 69.0 in August (Table 3-1, Figure 3-1). All values were below the North Carolina water quality standard of 40 ug/L (NCDEHNR 1991). Lake-wide mean chlorophyll concentrations in February, May, and August were within ranges of those recorded in previous years, while the lake-wide mean in November was the lowest recorded for that period (Figure 3-2). The seasonal trend in 2002 of low values in February, increasing slightly in May, achieving maximum values in August, then declining to the annual lake-wide minimum in November, has never been observed during the course of the Lake Norman Maintenance Monitoring Study. Based on quarterly mean chlorophyll concentrations, Lake Norman was in the low mesotrophic range during February and August, and in the upper oligotrophic range in May and November 2002. Over 62% of individual chlorophyll values were less than 4 ug/L (oligotrophic), while only one value was greater than 12 ug/L (eutrophic). Lake-wide quarterly mean concentrations of below 4 ug/L have been recorded on eight previous occasions, while concentrations of greater than 12 ug/L were only recorded during May of 1997 and 2000, and August of 2001 (Duke Power 2002).

During 2002 chlorophyll *a* concentrations showed a higher degree of spatial variability than in 2001. Maximum concentrations were observed at Location 69.0 during all but November, when that location had the lowest chlorophyll concentration. Minimum concentrations occurred at Location 2.0 in February, Location 9.5 in May and August, and Location 69.0 in November (Table 3-2). The trend of increasing chlorophyll concentrations from down-lake to up-lake, which had been observed during most quarters of 2000 and 2001, was apparent in varying degrees during most quarters of 2002 (Table 3-1, Figure 3-1). Locations 15.9 (uplake, above Plant Marshall) and 69.0 (the uppermost riverine location) had significantly higher chlorophyll values than Mixing Zone locations during all sample periods (Table 3-2). Flow in the riverine zone of a reservoir is subject to wide fluctuations depending, ultimately, on meteorological conditions (Thornton, *et* al. 1990), although influences may be moderated due to upstream dams. During periods of high flow, algal production and standing crop would be depressed, due in great part, to washout. Conversely, production and standing crop would increase during periods of low flow and high retention time. Over long periods of low flow, production and standing crop would gradually decline once more. These conditions result in the high variability in chlorophyll concentrations observed between Locations 15.9 and 69.0 throughout the year, as opposed to Locations 2.0 and 5.0 which were very similar during each sampling period.

Average quarterly chlorophyll concentrations during the period of record (August 1987 – November 2002) have varied considerably. During February 2002, Locations 2.0 through 9.5, and 15.9 had chlorophyll concentrations in the mid range, while chlorophyll concentrations at Locations 11.0 and 13.0 were in the low range. The value at Location 69.0 was the second highest February concentration recorded for this location (Figure 3-3). Long term February peaks at locations 2.0 through 9.5 occurred in 1996; while long term February peaks at Locations 11.0 through 15.9 were observed in 1991. The highest February value at location 69.0 occurred in 2001. Locations 2.0 through 11.0 had lower chlorophyll concentrations in February 2002 than in February 2001, while concentrations at Locations 13.0 through 69.0 were higher than in February 2001.

During May, August, and November, chlorophyll concentrations at most locations were lower than normal, and several record low concentrations were recorded: Locations 8.0 and 9.5 in May; Locations 5.0, 8.0, and 9.5 in August; and all but Locations 2.0 and 13.0 in November. Location 69.0 demonstrated comparatively high chlorophyll concentrations during all but November, when this location had a record low for that period. In most cases, chlorophyll concentrations during 2002 were lower than in 2001 (Figure 3-3).

Long term May peaks at Locations 2.0 and 9.5 occurred in 1992; at location 5.0 in 1991; at Locations 8.0, 11.0, and 13.0 in 1997; and at Location 69.0 in 2001. Long term August peaks in the Mixing Zone were observed in 1998; while year-to-year maxima at Locations 8.0 and 9.5 occurred in 1993. Long term August peaks at Locations 11.0 and 13.0 were observed in 1991 and 1993, respectively. The highest August chlorophyll concentration from

Location 15.9 was observed in 1998, while Location 69.0 experienced its long term August peak in 2001. Long term November peaks at Locations 5.0, 8.0, and 11.0 through 15.9 occurred in 1996; while November maxima at Locations 2.0 and 9.5 were observed in 1997. The highest November chlorophyll concentration at location 69.0 occurred in 1991.

Total Abundance

Density and biovolume are measurements of phytoplankton abundance. The lowest density during 2002 occurred at Location 9.5 in November (597 units/ml), and the lowest biovolume (258 mm^3/m^3) occurred at this location during May (Table 3-3, Figure 3-1). The maximum density (4,850 units/ml) and biovolume (3,696 mm^3/m^3) were observed at Location 15.9 in August. As with chlorophyll concentrations, most standing crop values during 2002 were lower than those of 2001 (Duke Power Company 2002). Phytoplankton densities and biovolumes during 2002 never exceeded the NC guidelines for algae blooms of 10,000 units/ml density, and 5,000 mm^3/m^3 biovolume (NCDEHNR 1991). Densities and biovolumes in excess of NC guidelines were recorded in 1987, 1989, 1997, 1998, and 2000 (Duke Power 1988, 1990, 1998, 1999, 2001).

Total densities at locations in the Mixing Zone during 2002 were within the same statistical ranges during all sampling periods (Table 3-4). In all sampling periods Location 15.9 had significantly higher densities than all other locations. During all but August, phytoplankton densities showed a spatial trend similar to that of chlorophyll, that is lower values at down-lake locations versus up-lake locations.

Seston

Seston dry weights represent a combination of algal matter, and other organic and inorganic material. Dry weights during 2002 were most often higher than those of 2001. A general pattern of increasing values from down-lake to up-lake was observed in all quarters to some extent (Figure 3-1). Statistically, Location 69.0 had significantly higher values than other locations during all quarters of 2002 (Table 3-5). From 1995 through 1997 seston dry weights had been increasing (Duke Power 1998). Values since 1998 represented a reversal of this trend, and were in the low range at most locations during 1999 through 2001 (Duke Power 2002). Low dry weights over the past four to five years were likely a result of prolonged drought conditions.

Seston ash-free dry weights represent organic material and may reflect trends of algal standing crops. In some cases, this relationship held true in 2002; most notably at Location 69.0, which had high ash-free dry weights, as well as elevated chlorophyll values during February, May, and August of 2002 (Tables 3-1, 3-2, and 3-5). In addition, ash-free dry weights, like chlorophyll and standing crops were lower in 2002 than in 2001. During all but February, the only significant statistical difference was that Location 69.0 had higher ash-free dry weights than other locations. The proportions of ash free dry weights to dry weights during 2002 were considerably lower than in 2001 and 2000, indicating higher organic composition among samples in 2002 as compared to previous years. Between 1994 and 1997 a trend of declining organic/inorganic ratios was observed (Duke Power 1995, 1996, 1997, 1998, 2001, 2002).

Secchi Depths

Secchi depth is a measure of light penetration. Secchi depths were often the inverse of suspended sediment (seston dry weight), with the shallowest depths at Locations 13.0 through 69.0 and deepest from Locations 9.5 through 2.0 down-lake. Depths ranged from 0.61 m at Location 69.0 in November, to 3.95 m at Location 2.0 in May (Table 3-1). The lake-wide mean secchi depth during 2002 was slightly higher than in 2001, and was the second highest recorded since measurements were first reported in 1992. The highest lake-wide mean secchi depth was recorded for 1999 (Duke Power 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). Again, high secchi depths were likely due to low rainfall over the past few years.

Community Composition

One indication of "balanced indigenous populations" in a reservoir is the diversity, or number of taxa observed over time. Lake Norman typically supports a rich community of phytoplankton species this was certainly true in 2002. Ten classes comprising 89 genera and 208 species, varieties, and forms of phytoplankton were identified in samples collected during 2002, as compared to 64 genera and 118 lower taxa identified in 2001 (Table 3-6). The 2002 total represented the highest number of individual taxa recorded in any year since monitoring began in 1987. Twenty-two taxa previously unrecorded during the Maintenance Monitoring Program were identified during 2002.

Species Composition and Seasonal Succession

The phytoplankton community in Lake Norman varies both seasonally and spatially within the reservoir. In addition, considerable variation occurs between years for the same months sampled.

During February 2002, diatoms (Bacillariophyceae) dominated densities at Locations 2.0 through 9.5, while cryptophytes (Cryptophyceae) were dominant at Locations 11.0 and 15.9 (Table 3-7, Figures 3-4 through 3-8). In May, diatoms were dominant at all locations. During most previous years, cryptophytes, and occasionally diatoms, dominated February phytoplankton samples in Lake Norman. Diatoms have typically been the predominant forms in May samples of previous years; however, cryptophytes dominated May samples in 1988, and were co-dominants with diatoms in May 1990, 1992, 1993, and 1994 (Duke Power 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002). The most abundant diatom during February was *Tabellaria fenestrata* (Locations 2.0 through 9.5), while the most abundant cryprophyte at Locations 11.0 and 15.9 was the small flagellate *Rhodomonas minuta*. In addition, *R. minuta* was found in high abundances at locations dominated by diatoms. During May, the most abundant diatoms were Cyclotella *stelligera* (Locations 2.0 through 9.5), and *Fragillaria crotonensis* (Locations 11.0 and 15.9). All of these species have been common and abundant at various times throughout the course of the Program. *Rhodomonas minuta* has been one of the most common and abundant forms observed in Lake Norman samples since monitoring began in 1987. Cryptophytes are characterized as light limited, often found deeper in the water column, or near surface under low light conditions, which are common during winter (Lee 1989). In addition, *R. minuta*'s small size and high surface to volume ratio would allow for more efficient nutrient uptake during periods of limited nutrient availability (Harris 1978).

During August 2002 green algae (Chlorophyceae) dominated densities at all Locations (Figures 3-4 through 3-8). The most abundant green alga was the small desmid, *Cosmarium asphearosporum* var. *strigosum* (Table 3-7). During August periods of the Lake Norman study prior to 1999, green algae (Chlorophyceaea), with blue-green algae (Myxophyceae) as occasional dominants or co-dominants, were the primary constituents of summer phytoplankton assemblages, and the predominant green alga was also *C. asphearosporum* var. *strigosum*. During August periods of 1999 through 2001, Lake Norman phytoplankton were dominated by diatoms, primarily the small pinnate *Anomoeoneis vitrea* (Table 3-7). *A. vitrea* was described as a major contributor to periphyton communities on natural substrates during studies conducted from 1974 through 1977 (Derwort 1982). The possible causes of this significant shift in summer taxonomic composition were discussed in the 1999 report, and included deeper light penetration (the three deepest lake-wide secchi depths were recorded from 1999 through 2001), extended periods of low water due to draw-down, shifts in nutrient inputs and concentrations, and macrophyte control procedures upstream (Duke Power 2000). Whatever the cause, the phenomenon was lake-wide, and not localized near MNS or Marshall Steam Station (MSS); therefore, it was most likely due to a combination of environmental factors, and not station operations.

During November 2002, densities at all locations were again dominated by diatoms (Figures 3-4 through 3-8). The dominant species at Location 2.0 was *C. stelligera*, while the dominant species at all other locations was *T. fenestrata* (Table 3-7). During the November quarters of previous years diatoms have been dominant on most occasions, with occasional dominance by cryptophytes.

Blue-green algae (Myxophyceae), which are often implicated in nuisance blooms, were never abundant in 2002 samples. Their overall contribution to phytoplankton densities was slightly higher in 2002 than in 2001, and similar to that of 2000. Densities of blue-greens seldom exceeded 2% of totals. The highest percent composition of Myxophyceae (4.7%) during all sampling periods in 2002 occurred at Location 15.9 in August. Prior to 1991, blue-green algae were often dominant at up-lake locations during the summer (Duke Power 1988, 1989, 1990, 1991, 1992).

Phytoplankton index

Phytoplankton indexes have been used with varying degrees of success ever since the concept was formalized by Kolkwitz and Marsson in 1902 (Hutchinson 1967). Nygaard (1949) proposed a series of indexes based on the number of species in certain taxonomic categories (Divisions, Classes, and Orders). The Myxophycean index was selected to help determine long term changes in the trophic status of Lake Norman. This index is a ratio of the number of blue-green algae taxa to desmid taxa, and was designed to reflect the "potential" trophic status as opposed to chlorophyll, which gives an "instantaneous" view of phytoplankton concentrations. The index was calculated on an annual basis for the entire lake, for each sampling period, and for each location during 2002 (Figure 3-9).

For the most part, the long term annual Myxophycean index values confirmed that Lake Norman has been primarily in the oligo-mesotrophic (low to intermediate) range since 1988 (Figure 3-9). Values were in the high, or eutrophic, range in 1989, 1990, and 1992; in the intermediate, or mesotrophic, range in 1991, 1993, 1994, 1996, 1998, 2000, and 2001; and in the low, or oligotrophic, range in 1988, 1995, 1997, and 1999. The index for 2002 fell into the oligotrophic range, and was the lowest annual index value recorded during the Maintenance Monitoring Program.

The highest index value among sample periods of 2002 was observed in May, and the lowest index value occurred in November (Figure 3-9). The highest lake-wide chlorophyll was in August, with the minimum in November, therefore, the index did not completely reflect chlorophyll concentrations observed throughout the lake during 2002. The index values for locations during 2002 showed a gradual decline in values from Locations 2.0 through 9.5, with values increasing from Locations 9.5 through 15.9, which had the maximum index value. This tended to reflect the pattern of increasing algae concentrations from mid-lake to up-lake locations observed during most quarters of 2002. During 2001, a pattern of increasing trophic state from down-lake to up-lake locations was observed during most sampling periods (Duke Power 2002).

FUTURE STUDIES

No changes are planned for the phytoplankton portion of the Lake Norman Maintenance Monitoring Program during 2003.

SUMMARY

In 2002 lake-wide mean chlorophyll *a* concentrations were generally in the low range, and the November mean was the lowest recorded for that period. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. Lake-wide mean chlorophyll declined from February to May, increased to the maximum in August, then declined to the annual minimum in November. This seasonal pattern had never been recorded during the Maintenance Monitoring Program. Some spatial variability was observed in 2002; however, maximum chlorophyll concentrations were most often observed up-lake, while comparatively low chlorophyll concentrations were recorded from Mixing Zone and mid lake locations. Location 69.0, the furthest upstream location, demonstrated maximum chlorophyll concentrations in February, May, and August of 2002, but had the lowest chlorophyll value in November. The highest chlorophyll value recorded in 2002, 16.29 ug/l, was below the NC State Water Quality standard of 40 ug/l.

In most cases, total phytoplankton densities and biovolumes observed in 2002 were lower than those observed during 2001, and standing crops were within ranges established over previous years. Phytoplankton densities and biovolumes during 2002 never exceeded the NC guidelines for algae blooms. Standing crop values in excess of bloom guidelines have been recorded during five previous years of the Program. As in past years, high standing crops were usually observed at up-lake locations; while comparatively low values were noted down-lake.

Seston dry weights were generally higher in 2002 than in 2001, and down-lake to up-lake differences were apparent most of the time. Conversely, ash-free dry weights were usually lower in 2002 than in 2001. Maximum dry and ash-free dry weights were most often observed at Location 69.0, while low values were most often noted at Locations 2.0 through 11.0. The proportions of ash-free dry weights to dry weights in 2002 were considerably lower than those of 2001, indicating an increase in organic composition among 2002 samples.

Secchi depths reflected suspended solids, with shallow depths related to high dry weights. The lake-wide mean secchi depth in 2002 was the second deepest recorded since measurements were first reported in 1992. High secchi depths over the last few years were likely due to low rainfall.

Diversity, or numbers of taxa, of phytoplankton had increased substantially since 2001, and the total number of individual taxa was the highest yet recorded. The taxonomic composition of phytoplankton communities during 2002 was similar to those of many previous years. Diatoms were dominant at most locations during all sampling periods except August, when green algae were dominant. A shift in community composition was first observed in August 1999 when diatoms, primarily the periphytic form *Anomoeonies vitrea*, dominated phytoplankton assemblages at Lake Norman locations. This pattern was again observed during August periods of 2000 and 2001. During August of 2002, green algae were dominant, as had been the case in most August periods prior to 1999. These shifts were likely the result of a variety of environmental factors, and not related to station operations. Blue-green algae were slightly more abundant during 2002 than during 2001, however, their contribution to total densities seldom exceeded 2%.

The most abundant alga, on an annual basis, was the cryptophyte *Rhodomonas minuta*. Common and abundant diatoms were *Tabellaria fenestrata* in February and November; and Cyclotella *stelligera* and *Fragilaria fenestrate* in May 2002. The small desmid, *Cosmarium asphearosporum* var. *strigosum* was dominant in August 2002. All of these taxa have been common and abundant throughout the Maintenance Monitoring Program.

The phytoplankton index (Myxophycean) characterized Lake Norman as oligotrophic during 2002, and was the lowest annual index value recorded. Quarterly index values increased from February to May, then declined through August and November. Quarterly values did not completely reflect seasonal changes in phytoplankton standing crops. Location values tended to reflect increases in phytoplankton standing crops from mid-lake to up-lake.

Lake Norman continues to support highly variable and diverse phytoplankton communities. No obvious short term or long term impacts of station operations were observed.

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Table 3-1. Mean chlorophyll *a* concentrations (ug/l) in composite samples and secchi depths (m) observed in Lake Norman, NC, in 2002.

Chlorophyll *a*

Location	FEB	MAY	AUG	NOV
2.0	3.16	1.40	3.36	2.03
5.0	3.42	1.58	3.31	2.19
8.0	3.62	1.40	3.20	2.54
9.5	3.84	1.28	2.27	2.27
11.0	4.23	3.12	5.39	3.23
13.0	3.45	4.87	4.33	4.19
15.9	6.33	5.65	7.90	5.50
69.0	8.84	11.75	16.29	1.28

Secchi depths

Location	FEB	MAY	AUG	NOV
2.0	2.12	3.95	3.20	2.35
5.0	1.13	3.06	2.44	2.30
8.0	1.71	3.04	2.70	2.25
9.5	1.63	2.97	2.80	3.30
11.0	1.49	2.70	2.32	2.40
13.0	1.14	2.17	1.62	1.95
15.9	1.22	2.27	2.19	1.90
69.0	1.20	1.70	1.10	0.61

Table 3-2. Duncan's multiple Range Test on chlorophyll *a* concentrations in Lake Norman, NC, during 2002.

February	Location	**2.0**	**5.0**	**13.0**	**8.0**	**9.5**	**11.0**	**15.9**	**69.0**
	Mean	3.16	3.42	3.45	3.62	3.84	4.23	6.33	8.84
May	Location	**9.5**	**2.0**	**8.0**	**5.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	1.28	1.40	1.40	1.58	3.12	4.87	5.65	11.75
August	Location	**9.5**	**8.0**	**5.0**	**2.0**	**13.0**	**11.0**	**15.9**	**69.0**
	Mean	5.69	6.00	6.40	6.73	7.37	7.66	8.30	32.57
November	Location	**69.0**	**2.0**	**5.0**	**9.5**	**8.0**	**11.0**	**13.0**	**15.9**
	Mean	3.34	3.46	4.47	4.71	5.72	8.10	8.21	9.54

Table 3-3. Total mean phytoplankton densities and biovolumes from samples collected in Lake Norman, NC, during 2002.

Density (units/ml)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	1054	1054	1194	1366	1879	1309
MAY	755	851	641	1506	2179	1186
AUG	1687	1458	1130	2688	4850	2363
NOV	621	599	597	954	1783	911

Biovolume (mm^3/m^3)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	1026	1054	1194	1366	1879	1304
MAY	277	472	258	704	1232	589
AUG	676	1189	679	1818	3696	1612
NOV	414	584	357	654	1382	678

Table 3-4. Duncan's multiple Range Test on phytoplankton densities in Lake Norman, NC, during 2002.

February	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Mean	1054	1054	1194	1366	1879
May	Location	**9.5**	**2.0**	**5.0**	**11.0**	**15.9**
	Mean	641	755	851	1506	2179
August	Location	**9.5**	**5.0**	**2.0**	**11.0**	**15.9**
	Mean	1130	1458	1687	2688	4850
November	Location	**9.5**	**5.0**	**2.0**	**11.0**	**15.9**
	Mean	597	599	621	954	1783

Table 3-5. Duncan's multiple Range Test on dry and ash free dry weights (mg/L) in Lake Norman, NC during 2002.

DRY WEIGHT

February	Location	**2.0**	**5.0**	**8.0**	**9.5**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	1.82	2.11	2.11	2.35	2.35	3.37	3.72	7.60
May	Location	**9.5**	**2.0**	**8.0**	**15.9**	**5.0**	**11.0**	**13.0**	**69.0**
	Mean	0.53	0.82	0.86	1.17	1.26	1.30	1.67	6.75
August	Location	**8.0**	**9.5**	**5.0**	**11.0**	**2.0**	**15.9**	**13.0**	**69.0**
	Mean	1.36	1.38	1.51	1.87	1.93	2.55	2.58	9.02
November	Location	**8.0**	**9.5**	**2.0**	**15.9**	**5.0**	**11.0**	**13.0**	**69.0**
	Mean	1.10	1.74	1.85	2.20	2.23	2.55	2.99	13.60

ASH FREE DRY WEIGHT

February	Location	**9.5**	**15.9**	**13.0**	**11.0**	**2.0**	**5.0**	**69.0**	**8.0**
	Mean	0.10	0.10	0.10	0.10	0.10	0.40	0.58	0.64
May	Location	**9.5**	**8.0**	**15.9**	**11.0**	**2.0**	**13.0**	**5.0**	**69.0**
	Mean	0.23	0.27	0.29	0.39	0.40	0.44	0.53	1.46
August	Location	**5.0**	**8.0**	**9.5**	**11.0**	**13.0**	**2.0**	**15.9**	**69.0**
	Mean	0.76	0.82	0.82	1.03	1.07	1.12	1.27	2.96
November	Location	**5.0**	**2.0**	**8.0**	**9.5**	**15.9**	**11.0**	**13.0**	**69.0**
	Mean	0.32	0.32	0.35	0.41	0.64	0.64	0.82	2.53

Table 3-6. Phytoplankton taxa identified in quarterly samples collected in Lake Norman from February 1988 to November 2002.

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
CLASS: CHLOROPHYCEAE															
Acanthosphaera zachariasi Lemm.			X	X		X									
Actidesmium hookeri Reinsch						X									
Actinastrum hantzchii Lagerheim	X		X	X	X	X	X								X
Ankistrodesmus braunii (Naeg) Brunn								X	X	X	X	X	X	X	X
A. convolutus Corda													X		
A. falcatus (Corda) Ralfs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
A. fusiformis Corda sensu Korsch.		X	X	X	X	X	X								
A. nannoselene Skuja													X		
A. spiralis (Turner) Lemm.	X	X	X	X		X				X					
A. spp. Corda				X		X									
Arthrodesmus convergens Ehrenberg								X							X
A. incus (Breb.) Hassall	X			X				X			X			X	X
A. octocornis															X
A. subulatus Kutzing									X	X	X		X	X	X
A. spp. Ehrenberg						X	X								
Asterococcus limneticus G. M. Smith			X	X	X	X	X					X			X
Botryococcus braunii Kutzing				X	X										
Carteria frtzschii Takeda	X												X		
C. globosa															X
C. spp. Diesing	X		X		X	X				X					
Characium spp. Braun		X													
Chlamydomonas spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chlorella vulgaris Beyerink										X					
Chlorogonium euchlorum Ehrenberg			X						X	X			X		
C. spirale Scherffel & Pascher							X	X							
Closteriopsis longissima W. & W.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Closterium cornu Ehrenberg												X			X
C. gracile Brebisson									X						
C. incurvum Brebisson	X						X	X	X	X	X	X	X	X	X
C. tumidum Johnson													X		
C. spp. Nitzsch		X	X	X		X									
Coccomonas orbicularis Stein											X				X
Coelastrum cambricum Archer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. microporum Nageli								X	X		X		X		
C. reticulatum (Dang.) Sinn.												X			
C. sphaericum Nageli			X	X			X		X			X	X	X	X
C. proboscideum Bohlin				X											
C. spp. Nageli			X	X											
Cosmarium angulosum v. *concin.* (Rab) W&W													X		X
C. asphaerosporum v. *strigosum* Nord.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. contractum Kirchner				X			X	X	X	X	X	X	X	X	X
C. moniliforme (Turp.) Ralfs													X		
C. phaseolus f. *minor* Boldt.										X	X		X		X

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
C. pokornyanum (Grun.) W. & G.S. West											X				X
C. polygonum (Nag.) Archer								X	X	X	X	X	X	X	X
C. raciborskii															X
C. regnellii Wille						X			X	X	X	X	X	X	X
C. regnesi Schmidle				X	X	X									X
C. subreniforme															X
C. tenue Archer	X							X	X	X	X	X	X	X	X
C. tinctum Ralfs	X					X	X	X	X	X	X	X	X	X	X
C. tinctum v. *subretusum* Messik.													X		
C. tinctum v. *tumidum* Borge.										X		X	X	X	X
C. trilobatum v. *depressum*															X
C. tumidum															X
C. spp. Corda	X	X	X	X	X	X	X								
Crucigenia apiculata															X
Crucigenia crucifera (Wolle) Collins	X		X	X				X	X	X	X	X	X	X	X
C. fenestrata Schmidle				X											X
C. irregularis Wille	X				X	X	X		X		X		X		X
C. rectangularis (A. Braun) Gay											X				
C. tetrapedia (Kirch.) West & West	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dictyospaerium ehrenbergianum Nageli	X												X		X
D. pulchellum Wood	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dimorphococcus spp. Braun			X												
Elakatothrix gelatinosa Wille	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Errerella bornheimiensis															X
Euastrum ansatum v. *dideltiforme*															X
E. binale															X
E. denticulatum (Kirch.) Gay								X	X	X	X	X	X	X	X
E. spp. Ehrenberg	X		X		X	X									
Eudorina elegans Ehrenberg	X								X						X
Franceia droescheri (Lemm.) G. M. Sm.	X							X	X	X	X	X	X	X	X
F. ovalis (France) Lemm.	X	X	X	X	X	X	X						X		X
Gloeocystis botryoides (Kutz.) Nageli													X		
G. gigas Kutzing	X	X							X	X	X	X	X	X	X
G. major Gerneck *ex.* Lemmermann											X				
G. planktonica (West & West) Lemm.		X	X	X	X	X	X	X	X	X	X	X	X	X	X
G. vesiculosa Naegeli											X				X
G. spp. Nageli	X	X	X	X	X	X	X								
Golenkinia paucispina West & West	X														X
G. radiata Chodat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gonium pectorale Mueller											X				X
G. sociale (Duj.) Warming	X							X			X	X			X
Kirchneriella contorta (Schmidle) Bohlin	X	X	X	X	X	X	X				X				X
K. elongata G.M. Smith													X		
K. lunaris (Kirch.) Mobius	X	X		X											
K. lunaris v. *dianae* Bohlin		X								X			X		X
K. lunaris v. *irregularis* G.M. Smith													X		

Table 3-6 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
K. obesa W. West	X	X	X	X	X	X	X								
K. subsolitaria G. S. West	X							X	X	X	X	X	X		X
K. spp. Schmidle	X							X	X	X					X
Lagerheimia ciliata (Lag.) Chodat															X
L. citriformis (Snow) G. M. Smith										X					
L. longiseta (Lemmermann) Printz															X
L. quadriseta (Lemm.) G. M. Smith		X	X	X	X										
L. subsala Lemmerman	X		X	X	X	X	X		X	X	X		X		X
Mesostigma viride Lauterborne	X							X	X	X	X	X	X		X
Micractinium pusillum Fresen.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Monoraphidium contortum Thuret	X	X		X	X	X	X								
M. pusillum Printz	X	X		X	X	X	X								
Mougeitia elegantula Whittrock	X							X	X	X	X	X	X	X	X
M. spp. Agardh	X				X	X	X								
Nephrocytium agardhianum Nageli	X			X											X
N. limneticum (G.M. Smith) G.M. Smith	X											X			X
Oocystis borgii Snow											X	X	X		X
O. ellyptica W. West	X										X				X
O. lacustris Chodat	X														
O. parva West & West	X	X	X					X	X	X	X	X	X	X	X
O. pusilla Hansgirg		X	X			X	X	X	X	X	X	X	X	X	X
O. pyriformis Prescott											X				X
O. spp. Nageli			X												
Pandorina charkowiensis Kprshikov															
P. morum Bory		X	X		X	X									
Pediastrum biradiatum Meyen															
P. duplex Meyen	X		X	X		X		X	X	X		X	X	X	X
P. clatheatum															X
P. duplex v. *gracillimum* West and West										X	X				X
P. tetras v. *tetroadon* (Corda) Rabenhorst	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Meyen			X	X											
Planktosphaeria gelatinosa G. M. Smith	X							X							X
Quadrigula closterioides (Bohlin) Printz				X					X	X				X	X
Q. lacustris (Chodat) G. M. Smith	X														X
Scenedesmus abundans (Kirchner) Chodat	X	X	X												
S. abundans v. *asymetrica* (Schr.) G. Sm.	X	X	X	X	X	X	X		X	X			X		X
S. abundans v. *brevicauda* G. M. Smith								X							
S. acuminatus (Lagerheim) Chodat					X	X	X	X	X		X	X	X	X	X
S. armatus v. *bicaudatus* (Gug.-Pr..)Chod	X		X	X	X	X	X	X	X	X	X	X	X	X	X
S. bijuga (Turp.) Lagerheim	X	X	X			X	X	X	X	X	X	X	X	X	X
S. bijuga v. *alterans* (Reinsch) Hansg.															
S. brasiliensis Bohlin								X	X	X	X	X	X	X	X
S. denticulatus Lagerheim	X	X	X	X	X	X	X	X	X		X	X	X	X	X
S. dimorphus (Turp.) Kutzing			X		X	X	X			X	X	X	X		X
S. incrassulatus G. M. Smith															
S. quadricauda (Turp.) Brebisson	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. smithii Teiling									X						X

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
S. spp. Meyen		X	X	X	X	X	X								
Schizochlamys compacta Prescott									X		X		X		X
S. gelatinosa A. Braun													X		X
Schoederia setigera (Schroed.) Lemm.	X			X											X
Selenastrum gracile Reinsch				X					X						X
S. minutum (Nageli) Collins	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. westii G. M. Smith	X				X			X	X		X	X			X
Sorastrum americanum (Bohlin) Schm.										X					
Sphaerocystis schoeteri Chodat	X		X					X			X	X	X		X
Sphaerozosma granulatum Roy & Bl.	X														
Stauastrum americanum (W&W) G. Sm.	X							X	X	X	X	X	X	X	X
S. apiculatum Brebisson										X	X	X	X	X	X
S. brachiatum Ralfs										X	X	X			X
S. brevispinum Brebisson											X				
S. chaetocerus (Schoed.) G. M. Smith					X	X	X								
S. curvatum W. West			X	X	X	X	X	X	X	X	X	X	X	X	X
S. cuspidatum Brebisson										X	X	X	X	X	X
S. dejectum Brebisson	X	X	X	X	X		X						X		
S. dickeii v. *maximum* West & West	X														
S. dickeii v. *rhomboidium*															X
S. gladiosum Turner						X									
S. leptocladum v. *sinuatum* Wolle				X											
S. manfeldtii v. *fluminense* Schumacher	X		X	X			X	X		X	X		X		X
S. megacanthum Lundell	X					X	X								
S. ophiura v. *cambricum* (Lund) W. & W.													X		
S. orbiculare Ralfs							X								X
S. paradoxum Meyen		X	X	X	X	X	X				X	X			
S. paradoxum v. *cingulum* West & West															
S. paradoxum v. *parvum* W. West											X				X
S. pentacerum															X
S. subcruciatum Cook & Wille								X		X	X	X	X		X
S. tetracerum Ralfs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. turgescens de Not.	X														
S. vestitum															X
S. spp. Meyen		X	X	X	X		X								
Stichococcus scopulinus															X
Stigeoclonium spp. Kutzing														X	
Tetraedron arthrodesmiforme															X
Tetraedron bifurcatum v. *minor* Prescott									X						
T. caudatum (Corda) Hansgirg	X	X	X		X		X		X	X	X	X	X	X	X
T. limneticum Borge					X										
T. lobulatum (Naeg.) Hansgirg													X		
T. lobulatum v. *crassum* Prescott						X									
T. minmum (Braun) Hansgirg	X	X	X				X	X	X		X	X	X	X	X
T. muticum (Braun) Hansgirg	X			X	X	X	X	X	X		X				
T. obesum (W & W) Wille *ex* Brunnthaler									X						

Table 3-6 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
T. pentaedricum West & West		X					X								
T. planktonicum G. M. Smith											X		X		X
T. regulare Kutzing				X	X	X	X								
T. regulare v. *bifurcatum* Wille											X				
T. regulare v. *incus* Teiling	X	X				X									
T. trigonum (Nageli) Hansgirg	X		X	X		X			X	X	X		X	X	X
T. trigonum v. *gracile* (Reinsch) DeToni					X				X				X		
T. spp. Kutzing	X		X			X									
Tetrallantos lagerheimii														X	
Tetraspora lamellosa Prescott													X		
T. spp. Link						X	X								
Tetrastrum heteracanthum (Nor.) Chod.			X												X
Treubaria setigerum (Archer) G. M. Sm.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Westella botryoides (W. & W.) Wilde.											X		X		
W. linearis G. M. Smith	X										X		X		
Xanthidium critatatum v. *uncinatum*															X
X. spp. Ehrenberg							X								X
CLASS: BACILLARIOPHYCEAE															
Achnanthes lanceolata															X
A. microcephala Kutzing		X	X					X	X	X	X	X	X	X	X
A. spp. Bory	X	X	X	X	X	X	X		X						
Amphiphora ornata															X
Anomoeoneis vitrea (Grunow) Ross	X		X				X	X	X		X	X	X	X	X
A. spp. Pfitzer							X								
Asterionella formosa Hassall	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Attheya zachariasi J. Brun	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Cocconeis placentula Ehrenberg	X										X	X			
C. spp. Ehrenberg							X								
Cyclotella comta (Ehrenberg) Kutzing		X					X	X	X	X	X	X	X	X	X
C. glomerata Bachmann								X	X	X	X	X			
C. meneghiniana Kutzing	X	X					X	X	X	X	X	X	X		X
C. pseudostelligera Hustedt +															
C. stelligera Cleve & Grunow	X		X	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Kutzing	X	X	X												
Cymbella affinis Kutzing													X		
C. minuta (Bliesch & Rabn.) Reim.			X		X	X		X	X		X	X			X
C. tumida (Breb.) van Huerck							X								
C. turgida (Gregory) Cleve	X														
C. spp. Agardh	X			X											
Denticula elegans															X
D. thermalis Kutzing											X				X
Diploneis spp. Ehrenberg			X												
Eunotia flexuosa v. *eurycephala* Grun.													X		
E. zasuminensis (Cab.) Koerner		X	X	X	X	X	X	X	X	X	X	X	X	X	
Fragilaria crotonensis Kitton	X		X	X	X	X	X	X	X	X	X	X	X	X	X

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
Frustulia rhomboides (Ehr.) de Toni	X														
Gomphonema angustatum															X
G. parvulum															X
G. spp. Agardh				X			X								
Melosira ambigua (Grun.) O. Muller	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. distans (Her.) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. granulata (Ehr.) Ralfs	X		X	X		X									
M. granulata v. *angustissima* O. Muller	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. italica (Ehr.) Kutzing	X														
M. varians Agardh					X	X					X				
M. spp. Agardh	X	X	X	X	X	X	X		X			X		X	X
Meridion circulare															X
Navicula cryptocephala Kutzing			X						X	X					X
N. exigua (Gregory) O. Muller								X							X
N. exigua v. *capitata* Patrick									X						
N. subtilissima Cleve								X					X		
N. spp. Bory		X	X	X	X	X	X								
Nitzschia acicularis W. Smith	X		X	X	X	X			X	X	X	X	X	X	X
N. agnita Hustedt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. holsatica Hustedt	X	X	X	X				X		X	X	X	X	X	X
N. linearis W. Smith													X		
N. palea (Kutzing) W. Smith	X						X	X	X	X	X				X
N. sublinearis Hustedt									X		X			X	X
N. spp. Hassall	X	X	X	X	X	X	X								X
Pinnularia spp. Ehrenberg						X									X
Rhizosolenia spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Skeletonema potemos (Weber) Hilse	X					X		X	X		X	X	X		X
Stephanodiscus spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X				
Surirella linearis v. *constricta* (Ehr.) Gr0.											X				
Synedra actinastroides Lemmerman							X								
S. acus Kutzing	X					X	X			X	X		X		X
S. delicatissima Lewis					X	X	X								
S. filiformis v. *exilis* Cleve-Euler											X		X	X	X
S. planktonica Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. rumpens Kutzing	X							X	X	X	X	X	X	X	X
S. rumpens v. *fragilarioides* Grunow	X														
S. rumpens v. *scotica* Grunow	X														
S. ulna (Nitzsch) Ehrenberg	X			X				X	X	X	X	X	X		X
S. spp. Ehrenberg	X	X	X	X	X	X	X								
Tabellaria fenestrata (Lyngb) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. flocculosa (Roth.) Kutzing	X		X				X						X		
CLASS: CHRYSOPHYCEAE															
Aulomonas purdyii Lackey	X						X	X	X	X	X	X	X		X
Bicoeca petiolatum (Stien) Pringsheim										X	X				
Calycomonas pascheri (Van Goor) Lund								X					X		
Chromulina spp. Chien.	X										X				X

Table 3-6 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
Chrysosphaerella solitaria Lauterb.				X	X	X	X	X	X	X	X	X	X	X	X
Codomonas annulata Lackey									X	X	X	X	X	X	
Dinobryon bavaricum Imhof	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. cylindricum Imhof			X	X	X	X	X		X		X				X
D. divergens Imhof		X	X		X	X	X	X	X			X			X
D. sertularia Ehrenberg	X							X					X		X
D. spp. Ehrenberg	X	X	X	X				X	X	X	X	X	X	X	X
Domatomococcus cylindricum Lackey											X	X			
Erkinia subaequicilliata Skuja	X	X	X				X	X	X	X	X	X	X	X	X
Kephyrion littorale Lund											X				X
K. rubi-claustri Conrad	X														X
K. skujae Ettl	X														
K. spp. Pascher		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mallomonas acaroides Perty							X								
M. akrokomos (Naumann) Krieger			X								X	X	X		
M. alpina Pascher											X		X		
M. caudata Conrad		X	X	X	X	X	X	X				X	X	X	X
M. globosa Schiller			X								X		X	X	X
M. producta Iwanoff													X		X
M. pseudocoronata Prescott	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. tonsurata Teiling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. spp. Perty	X	X	X	X	X	X	X						X		
Ochromonas granularis Doflein											X	X	X	X	X
O. mutabilis Klebs													X		
O. spp. Wyss	X	X					X	X	X	X	X	X	X	X	X
Pseudokephyrion schilleri Conrad											X	X		X	X
P. tintinabulum Conrad											X				
Rhizochrisis polymorpha Naumann												X	X	X	X
R. spp. Pascher	X			X											
Salpingoeca frequentissima (Zach.) Lem.											X	X	X		
Stelexomonas dichotoma Lackey	X	X	X	X	X	X	X	X	X	X	X		X		X
Stokesiella epipyxis Pascher										X	X	X			
Synura spinosa Korschikov	X		X					X	X	X	X	X	X	X	X
S. uvella Ehrenberg	X	X	X	X		X	X							X	
S. spp. Ehrenberg		X	X	X	X	X	X								
Uroglenopsis americana (Caulk.) Lemm.	X							X	X	X		X			
CLASS: HAPTOPHYCEAE															
Chrysochromulina parva Lackey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: XANTHOPHYCEAE															
Characiopsis dubia Pascher								X	X		X	X	X	X	X
Dichotomococcus curvata Korschikov															
Ophiocytium caoitatum v. *longisp.* (M) L.						X	X								
CLASS: CRYPTOPHYCEAE															
Cryptomonas erosa Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3-6 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
C. erosa v. *reflexa* Marsson			X								X	X	X	X	X
C. gracilia Skuja													X		
C. marsonii Skuja		X	X	X	X	X	X								
C. ovata Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. phaseolus Skuja		X	X	X	X	X	X								
C. reflexa Skuja	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Ehrenberg		X	X	X	X	X	X								
Rhodomonas minuta Skuja	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: MYXOPHYCEAE															
Agmenellum quadriduplicatum Brebisson					X	X	X	X		X	X	X	X	X	X
Anabaena catenula (Kutzing) Born.	X									X	X				
A. inaequalis (Kutz.) Born.													X		
A. scheremetievi Elenkin										X	X	X		X	
A. wisconsinense Prescott	X							X	X	X	X	X	X	X	X
A. spp. Bory	X	X	X	X	X	X	X		X			X		X	X
Anacystis incerta (Lemm.) Druet & Daily		X	X	X	X	X	X				X		X	X	
A. spp. Meneghini															
Chroococcus dispersus (Keissl.) Lemm.											X		X		
C. limneticus Lemmermann	X		X							X	X	X	X	X	X
C. minor Kutzing															X
C. turgidus (Kutz.) Lemmermann				X		X									
C. spp. Nageli		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coelosphaerium kuetzingiana Nageli			X												
Dactylococcopsis irregularis Hansgirg			X	X			X								
D. rupestris Hansgirg													X		
D. smithii Chodat and Chodat										X	X		X		
D. spp. Hansgirg													X		
Gomphospaeria lacustris Chodat	X	X	X	X	X	X	X								
Lyngbya contorta Lemmermann				X	X										
L. limnetica Lemmermann		X	X	X	X	X	X								
L. ochracea (Kutz.) Thuret													X		X
L. subtilis W. West		X	X	X	X		X								
L. spp. Agardh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Merismopedia tenuissima Lemmermann											X				
Microcystis aeruginosa Kutz. *emend* Elen.		X	X	X	X	X	X	X	X		X	X	X	X	
Oscillatoria amphibian															X
O. geminata Meneghini	X		X					X	X	X	X	X	X	X	X
O. limnetica Lemmermann	X							X	X	X	X	X	X	X	X
O. splendida Greville								X	X		X				X
O. subtilissima Kutz.													X	X	X
O. spp. Vaucher	X	X					X							X	
Phormidium angustissimum West & West		X	X	X			X								
P. spp. Kutzing	X	X	X			X	X								
Raphidiopsis curvata Fritsch & Rich	X				X		X	X	X	X	X	X	X		X
R. mediterranea Skuja												X			

Table 3-6 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
Rhabdoderma sigmoidea Schm. & Lautrb.		X													
Spirulina subsala															X
Synecococcus lineare (Sch. & Lt.) Kom.			X	X	X	X	X	X	X		X	X	X	X	
CLASS: EUGLENOPHYCEAE															
Euglena acus Ehrenberg			X									X			
E. minuta Prescott		X											X		X
E. polymorpha Dangeard									X					X	X
E. spp. Ehrenberg	X	X	X	X		X	X	X	X		X	X		X	
Lepocinclus ovum (Ehr.) Lemm.													X		
L. spp. Perty	X										X				
Phacus cuvicauda Swirenko													X		
P. longicauda (Ehr.) Dujardin													X		
P. orbicularis Hubner					X										
P. tortus (Lemm.) Skvortzow		X	X		X										
P. spp. Dujardin		X													
Trachelomonas acanthostoma (Stk.) Defl.	X													X	
T. hispida (Perty) Stein						X		X				X		X	X
T. pulcherrima Playfair	X														
T. volvocina Ehrenberg	X							X				X		X	
T. spp. Ehrenberg			X	X			X								
CLASS: DINOPHYCEAE															
Ceratium hirundinella (OFM) Schrank	X	X	X		X		X	X		X	X	X	X		
Glenodinium borgei (Lemm.) Schiller	X								X						
G. gymnodinium Penard		X	X	X	X	X				X					
G. palustre (Lemm.) Schiller															
G. penardiforme (linde.) Schiller												X	X		
G. quadridens (Stein) Schiller			X				X								
G. spp. (Ehrenberg) Stein				X			X								
Gymnodinium aeruginosum Stein											X	X	X		
G. spp. (Stein) Kofoid & Swezy			X	X	X	X	X	X		X	X		X	X	X
Peridinium aciculiferum Lemmermann	X														
P. inconspicuum Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. cinctum															X
P. intermedium Playfair											X	X	X	X	X
P. pusillum (Lenard) Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. umbonatum Stein					X	X	X								
P. wisconsinense Eddy	X		X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Ehrenberg			X	X	X	X	X								
CLASS: CHLOROMONADOPHYCEAE															
Gonyostomum depresseum Lauterborne	X							X			X	X			X
G. semen (Ehrenberg) Diesing			X												
G. spp. Diesing	X		X				X								

Table 3-7. Dominant classes their most abundant species, and their percent composition (in parenthesis) at Lake Norman locations during each sampling period of 2002.

LOC	FEBRUARY	MAY
2.0	BACILLARIOPHYCEAE (51.7) *Taballaria fenestrata* (27.8)	BACILLARIOPHYCEAE (46.2) *Cyclotella stelligera* (32.4)
5.0	BACILLARIOPHYCEAE (49.0) *T. fenestrata* (23.6)	BACILLARIOPHYCEAE (52.9) *C. stelligera* (33.6)
9.5	BACILLARIOPHYCEAE (52.3) *T. fenestrata* (22.8)	BACILLARIOPHYCEAE (46.9) *C. stelligera* (33.8)
11.0	CRYPTOPHYCEAE (56.0) *Rhodomonas minuta* (50.4)	BACILLARIOPHYCEAE (56.4) *Fragilaria crotonensis* (27.1)
15.9	CRYPTOPHYCEAE (71.2) *R. minumta* (67.2)	BACILLARIOPHYCEAE (55.5) *F. crotonensis* (32.4)
	AUGUST	NOVEMBER
2.0	CHLOROPHYCEAE (53.0) *Cosmarium asphear. strig.* (29.5)	BACILLARIOPHYCEAE (41.0) *C. stelligera* (7.4)
5.0	CHLOROPHYCEAE (65.7) *C. asphearosporum strig.* (35.4)	BACILLARIOPHYCEAE (58.9) *T. fenestrata* (19.4)
9.5	CHLOROPHYCEAE (69.9) *C. asphearosporum strig.* (29.8)	BACILLARIOPHYCEAE (54.4) *T. fenestrata* (8.7)
11.0	CHLOROPHYCEAE (65.3) *C. asphearosporum strig.* (35.3)	BACILLARIOPHYCEAE (47.1) *T. fenetrata* (16.8)
15.9	CHLOROPHYCEAE (47.5) *C. asphearosporum strig.* (28.5)	BACILLARIOPHYCEAE (42.2) *T. fenestrata* (10.3)

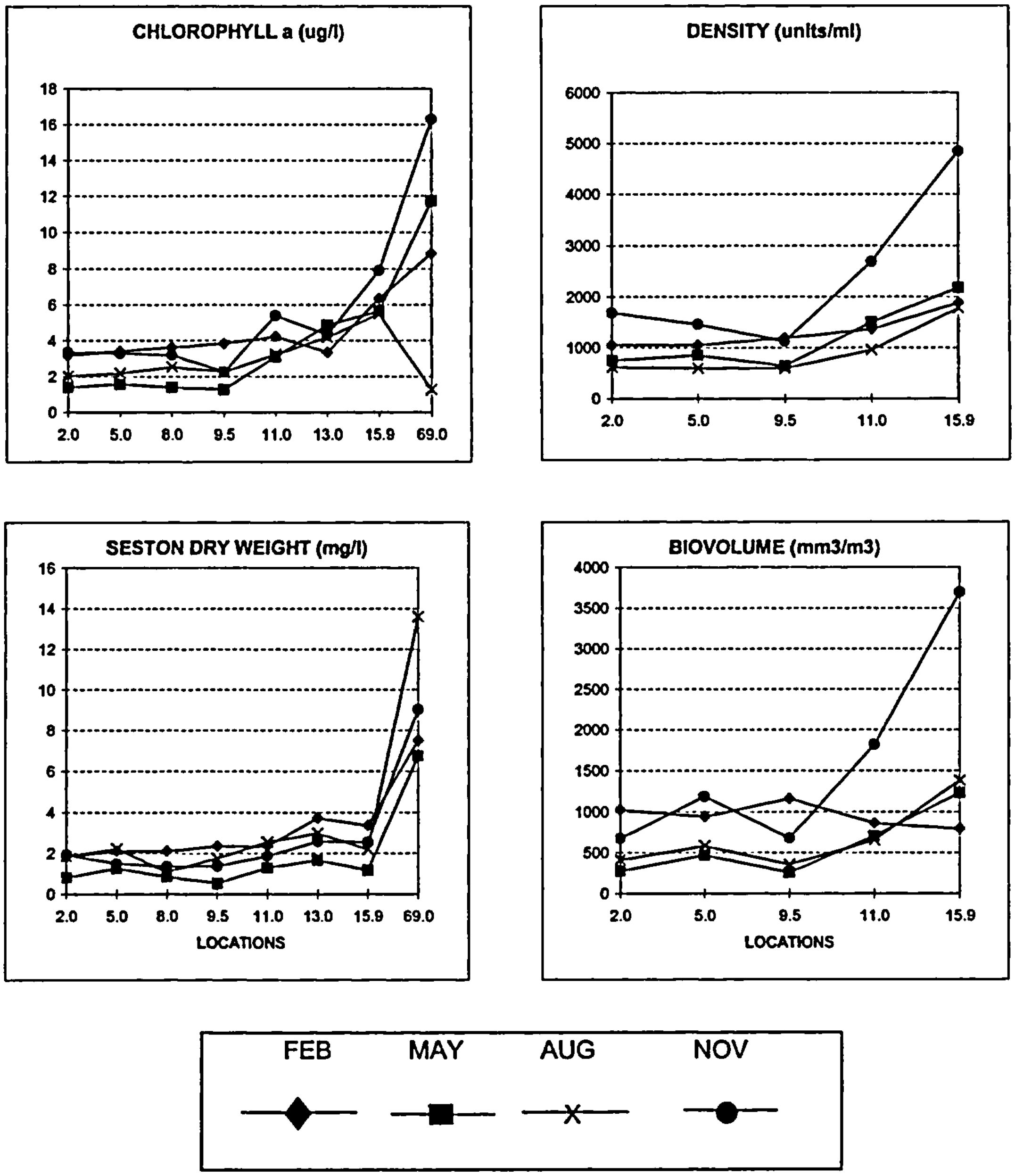


Figure 3-1. Phytoplankton chlorophyll *a*, densities, and biovolumes; and seston weights at locations in Lake Norman, NC, in February, May, August, and November 2002.

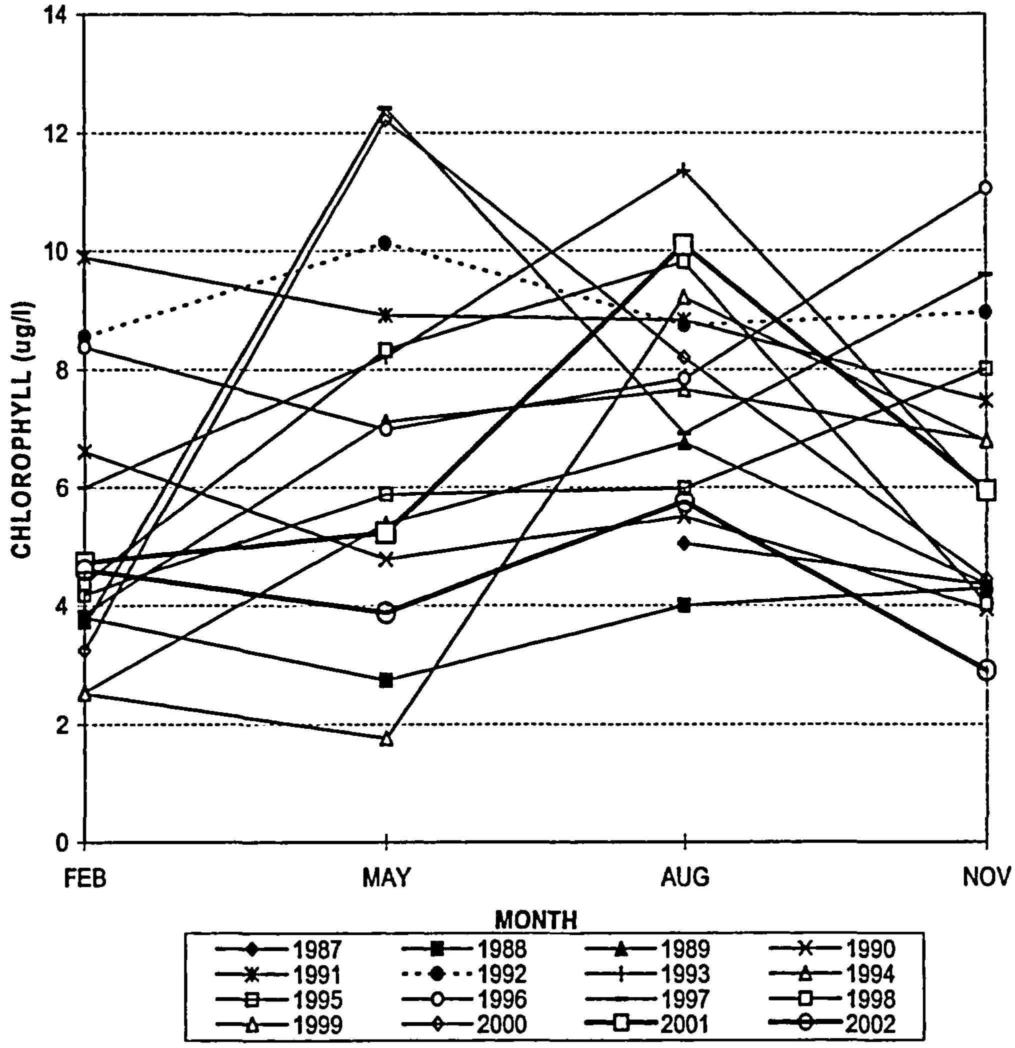


Figure 3-2. Phytoplankton chlorophyll *a* annual lake means from all locations in Lake Norman, NC, for each quarter since August 1987.

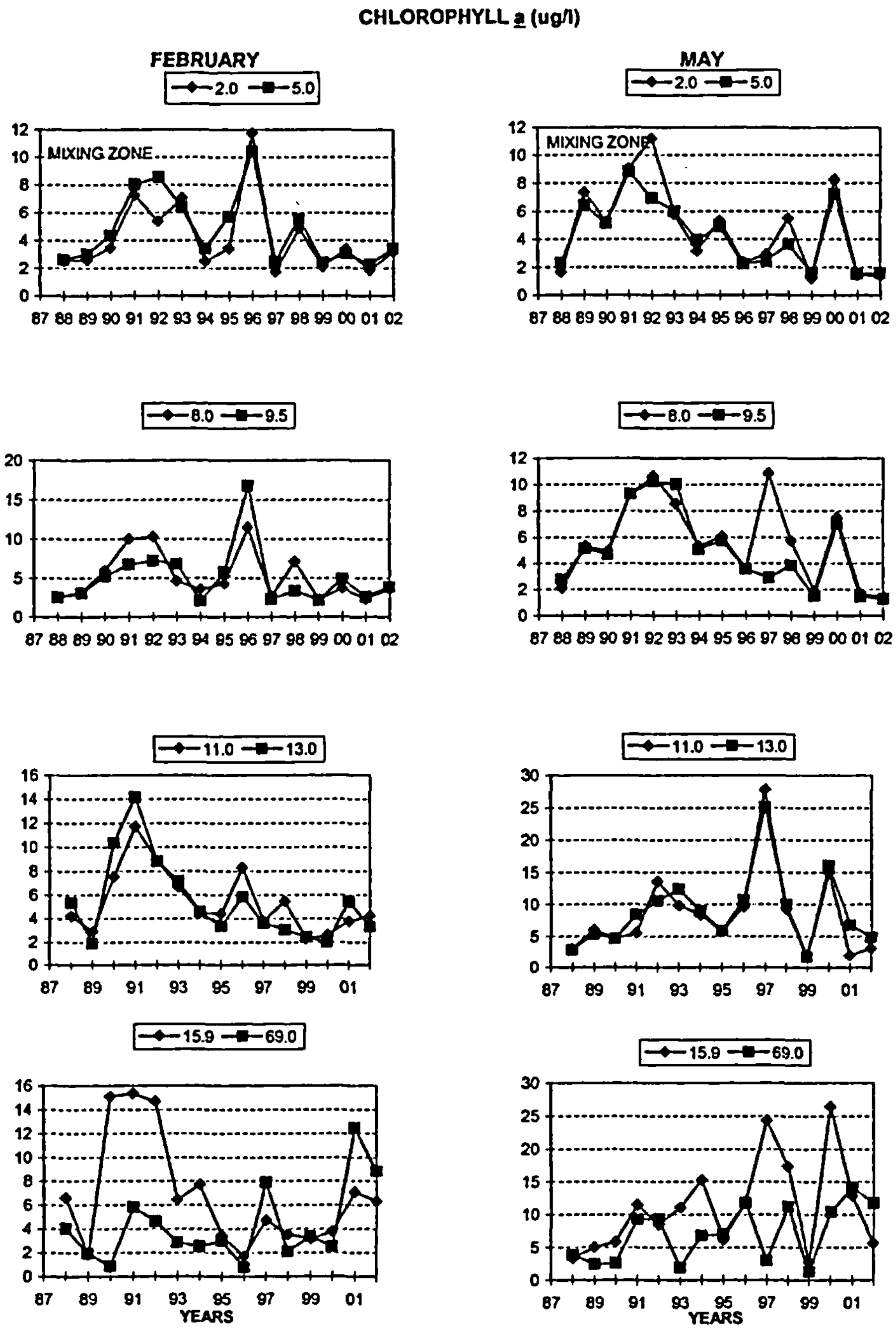


Figure 3-3. Phytoplankton chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from August 1987 through November 2002.

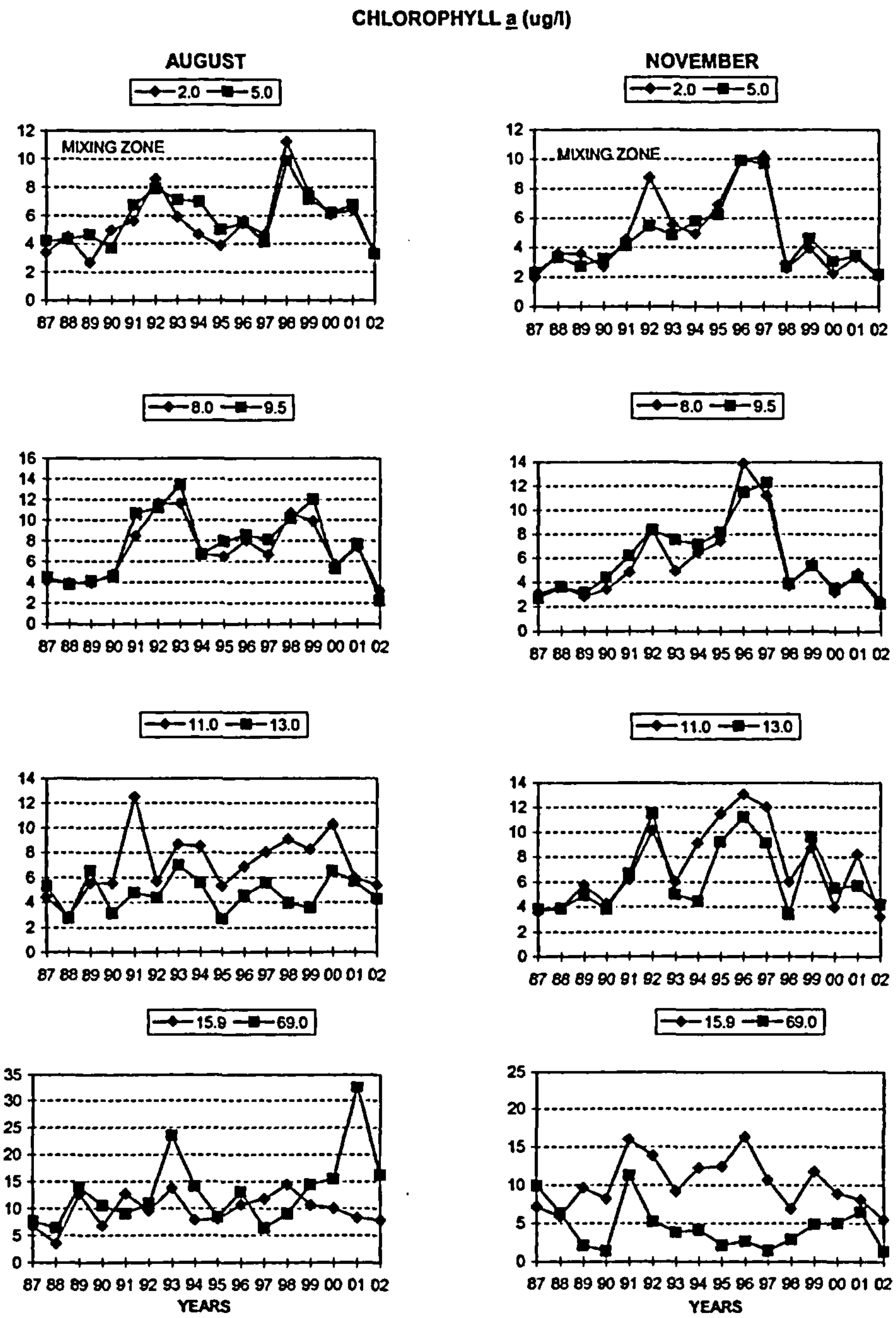


Figure 3-3 (continued).

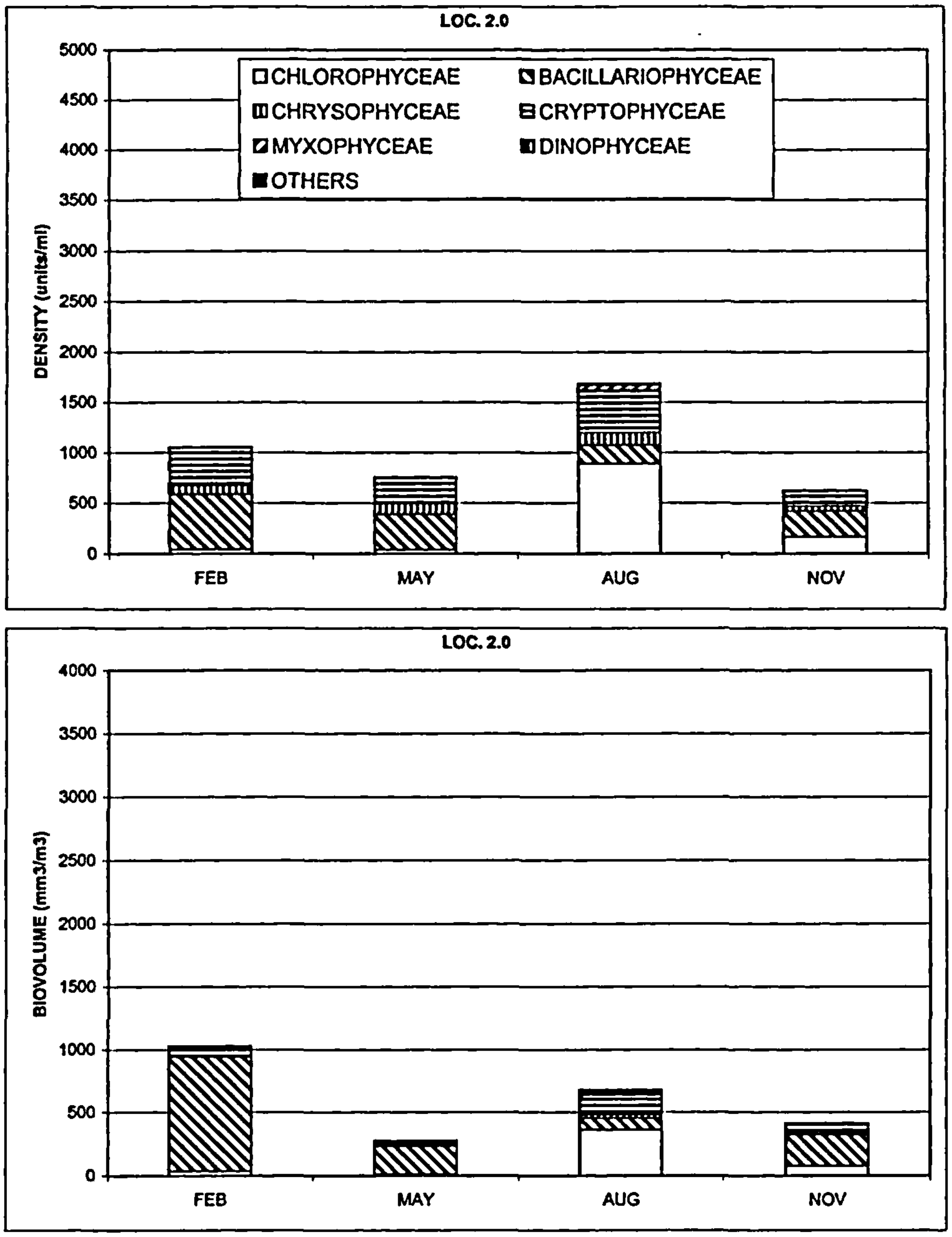
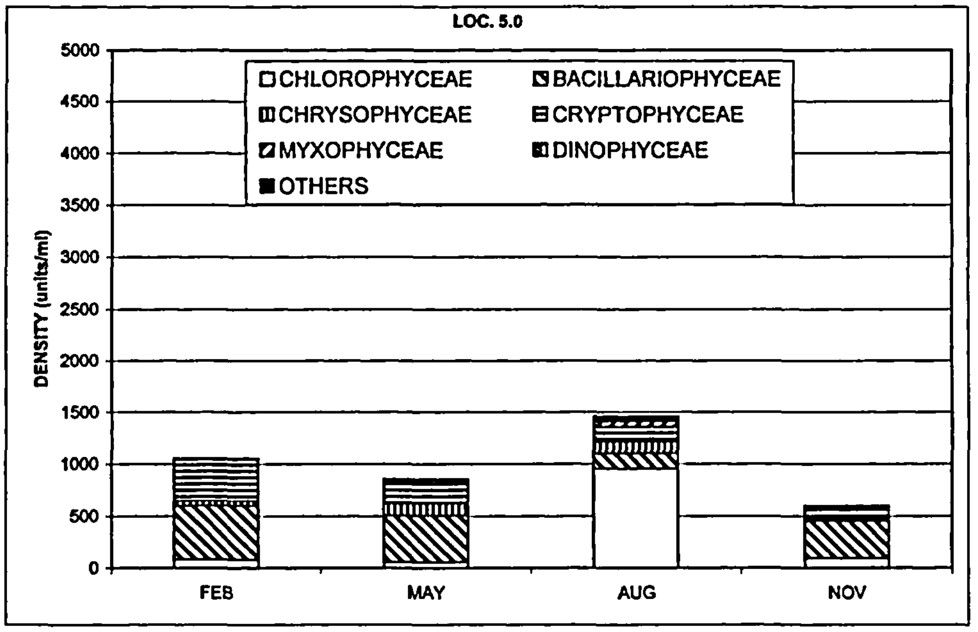


Figure 3-4. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 2.0 in Lake Norman, NC, during 2002.



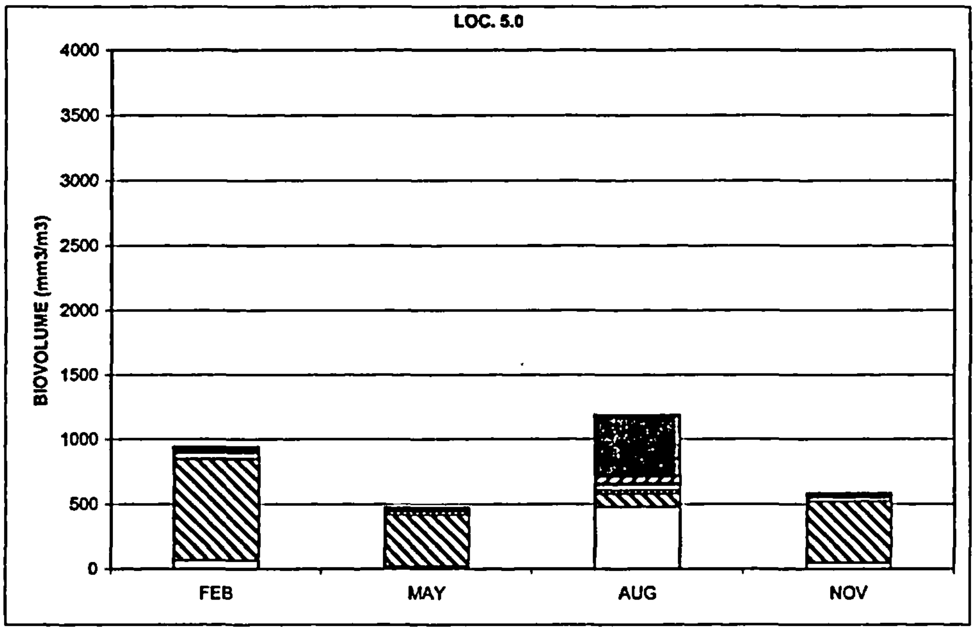


Figure 3-5. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 5.0 in Lake Norman, NC, during 2002.

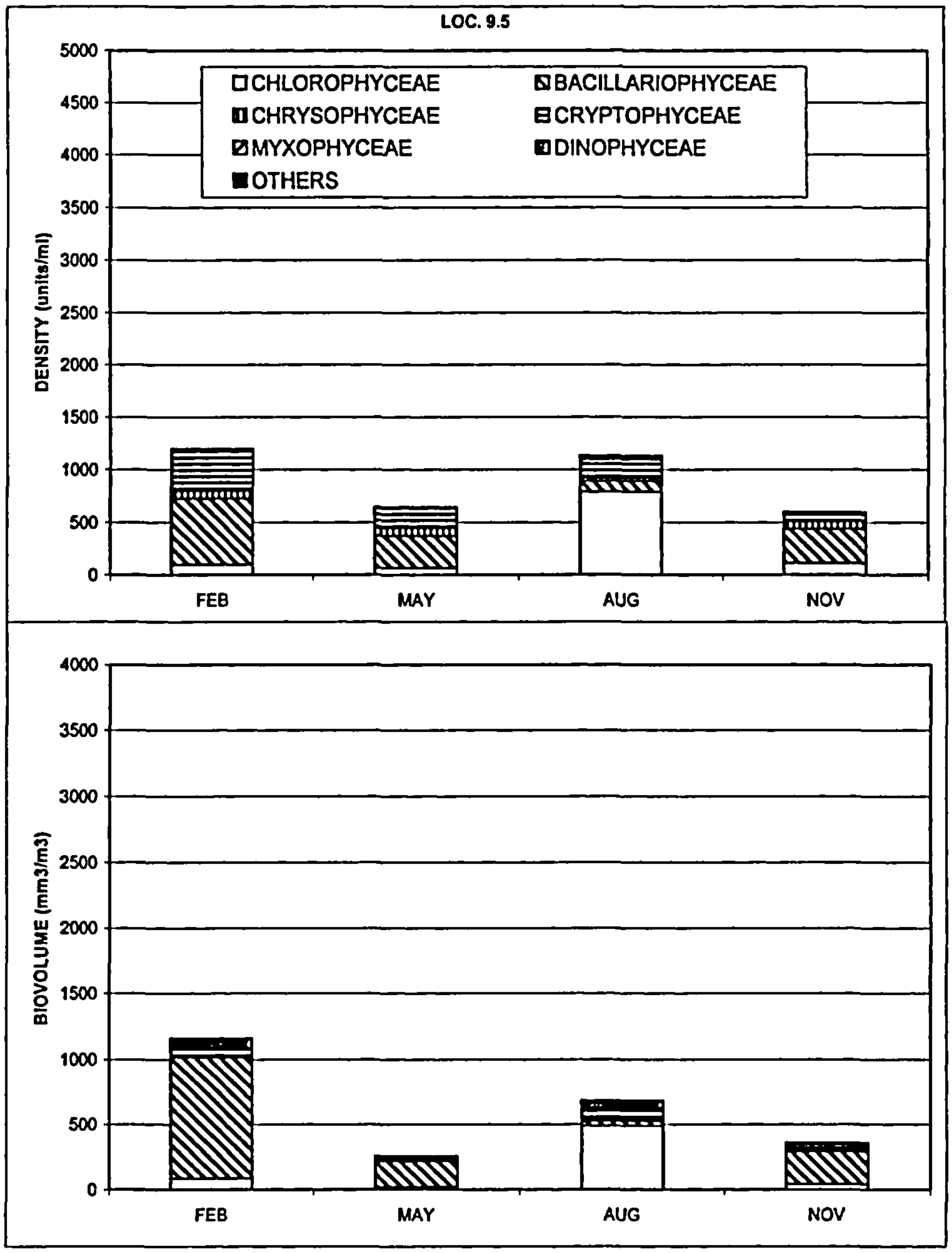


Figure 3-6. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC, during 2002.

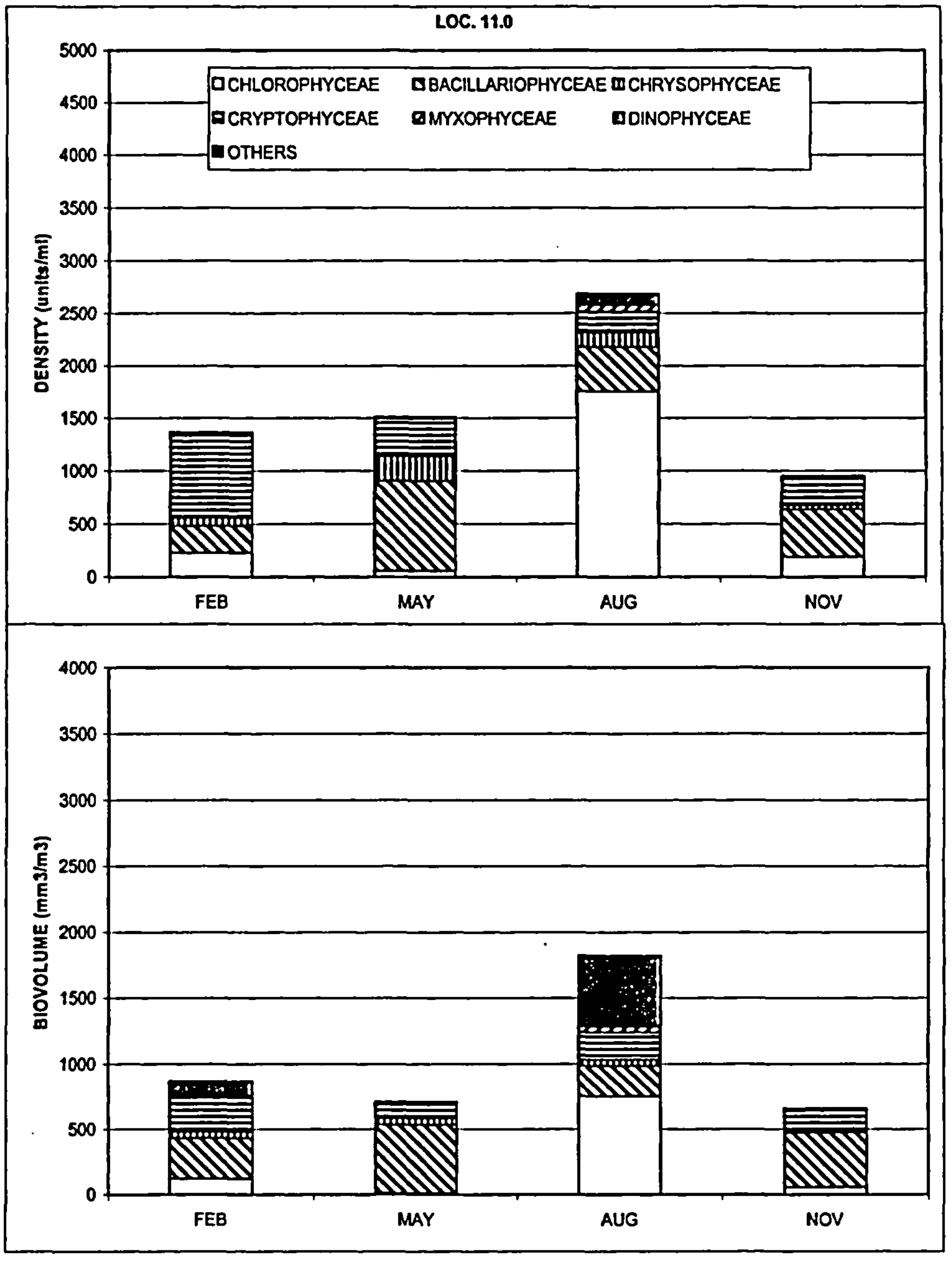


Figure 3-7. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC, during 2002

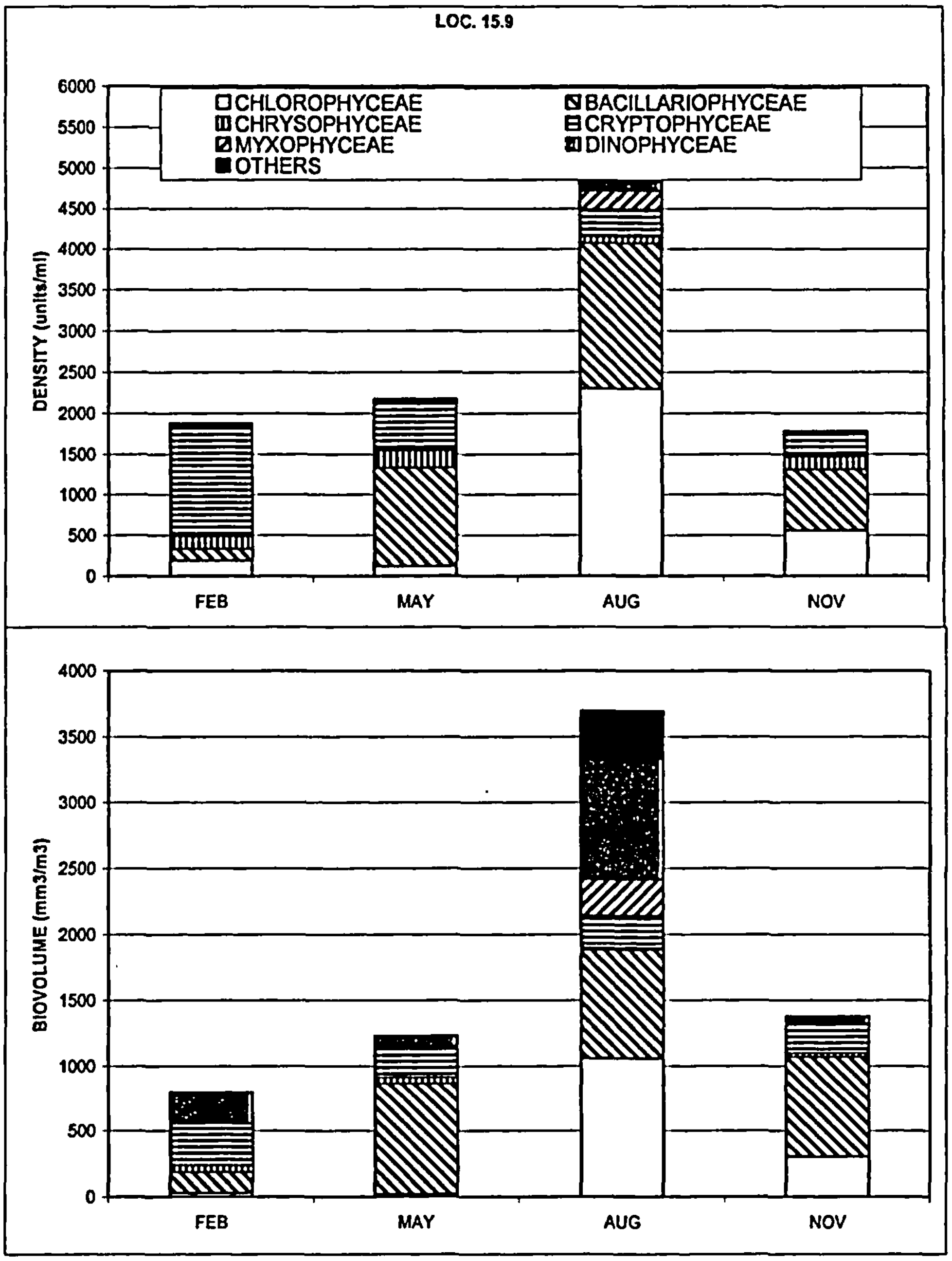


Figure 3-8. Class composition (density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC, during 2002.

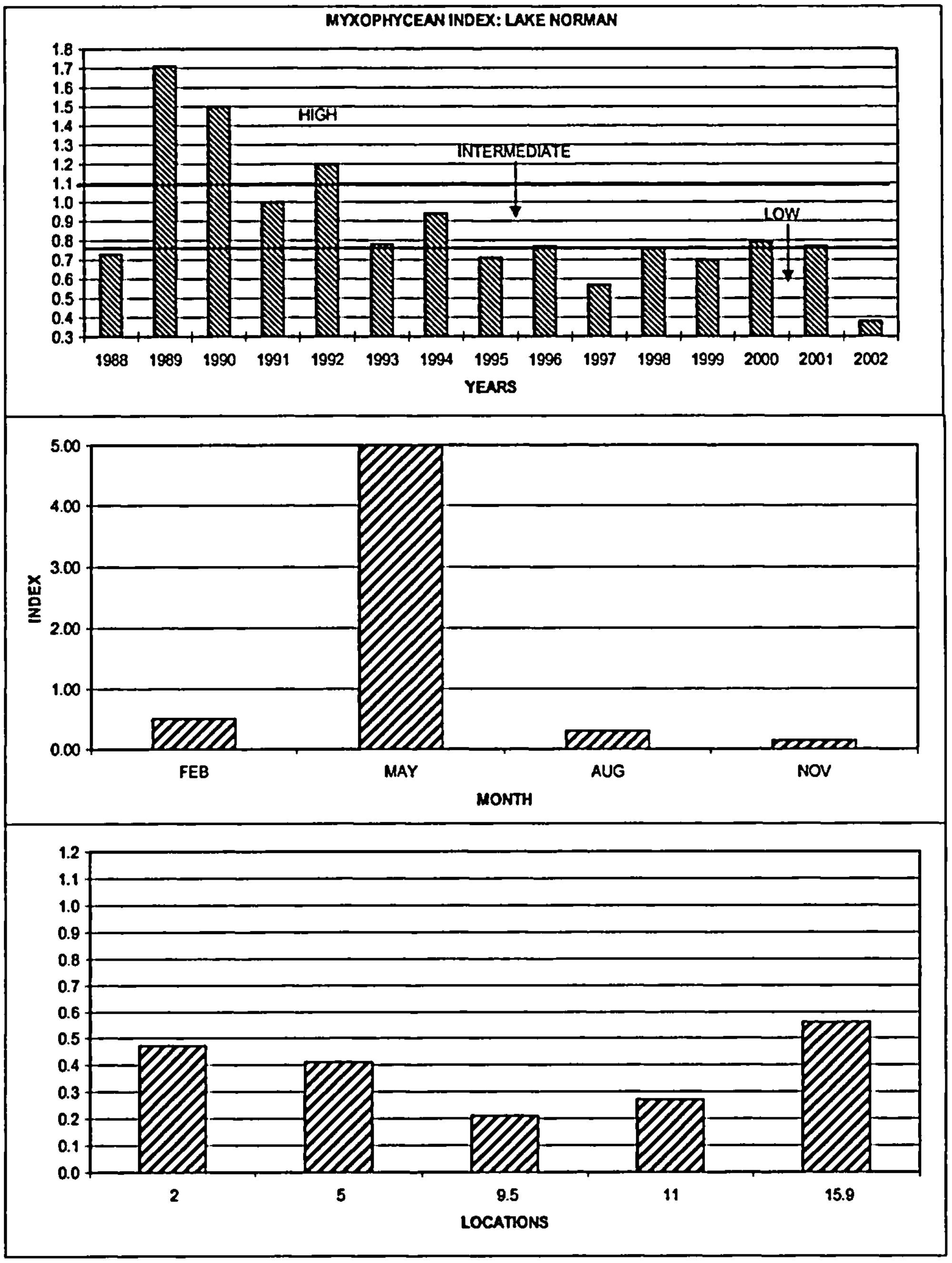


Figure 3-9. Myxophycean index values by year (top), each quarter in 2002 (mid), and each location in Lake Norman, NC, during 2002.

CHAPTER 4
ZOOPLANKTON

INTRODUCTION

The objectives of the Lake Norman Maintenance Monitoring Program for zooplankton are to:

1. Describe and characterize quarterly patterns of zooplankton standing crops at selected locations on Lake Norman; and
2. compare and evaluate zooplankton data collected during this study (February, May, August, and November 2002) with historical data collected during the period 1987-2001.

Previous studies of Lake Norman zooplankton populations have demonstrated a bimodal seasonal distribution with highest values generally occurring in the spring, and a less pronounced fall peak. Considerable spatial and year-to-year variability has been observed in zooplankton abundance in Lake Norman (Duke Power 1976, 1985; Hamme 1982; Menhinick and Jensen 1974).

METHODS AND MATERIALS

Duplicate 10 m to surface and bottom to surface net tows were taken at Locations 2.0, 5.0, 9.5, 11.0, and 15.9 in Lake Norman (Chapter 2, Figure 2-1) on 4 February, 6 May, 5 August, and 4 November 2002 (Note: Samples from Location 5.0 in November were not counted due to loss of preservative). For discussion purposes the 10 m to surface tow samples are called epilimnetic samples and the bottom to surface net tow samples are called whole column samples. Locations 2.0 and 5.0 are defined as the Mixing Zone and Locations 9.5, 11.0 and 15.9 are defined as Background Locations. Field and laboratory methods for zooplankton standing crop analysis were the same as those reported in Hamme (1982). Zooplankton standing crop data from 2002 were compared with corresponding data from quarterly monitoring begun in August 1987.

A one way ANOVA was performed on epilimnetic total zooplankton densities by quarter. This was followed by a Duncan's Multiple Range Test to determine which location means were significantly different.

RESULTS AND DISCUSSION

Total Abundance

During 2002, typical seasonal variability was observed in epilimnetic samples. Maximum epilimnetic densities were highest in May at all locations (Table 4-1, Figure 4-1). The lowest epilimnetic densities at Locations 5.0, 9.5, and 11.0 occurred in February, while annual minimum densities at Locations 2.0 and 15.9 were observed in November. Epilimnetic densities ranged from a low of 16,585/m^3 at Location 5.0 in February, to a high of 578,166/m^3 at Location 15.9 in May. This maximum was the highest zooplankton density yet observed during the Program. Maximum densities in the whole column samples were also observed in May, while minimum whole column densities were observed at Locations 2.0, 5.0, and 9.5 in February, and at Locations 11.0 and 15.9 in August. Whole column densities ranged from 12,819/m^3 at Location 5.0 in February, to 280,769/m^3 at Location 15.9 in May.

Historically, maximum epilimnetic zooplankton densities at Lake Norman locations have most often been observed in May, with annual peaks observed in February about 25% of the time. Annual maxima have only occasionally been recorded for August and November.

Total zooplankton densities were most often higher in epilimnetic samples than in whole column samples during 2002, as has been the case in previous years (Duke Power 2002). This is related to the ability of zooplankton to orient vertically in the water column in response to physical and chemical gradients and the distribution of food sources, primarily phytoplankton, which are generally most abundant in the euphotic zone (Hutchinson 1967).

Although spatial distribution varied among locations from season to season, a general pattern of increasing values from Mixing Zone to Background locations was observed during 2002 (Tables 4-1 and 4-2, Figures 4-1 and 4-4). Location 15.9, the uppermost location, had significantly higher densities than Mixing Zone locations in February and May, while Location 11.0 had significantly higher values than Mixing Zone locations in August and November (Table 4-2). In most previous years of the Program, Background Locations had higher mean densities than Mixing Zone locations (Duke Power 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002).

Historically, both seasonal and spatial variability among epilimnetic zooplankton densities had been much higher among Background Locations than among Mixing Zone locations. The uppermost location, 15.9, showed the greatest range of densities during 2002 (Table 4-1, Figures 4-2 and 4-3). Apparently epilimnetic zooplankton communities are more greatly influenced by environmental conditions at the up-lake locations than at the down-lake locations. Location 15.9 represents the transition zone between river and reservoir where populations would be expected to fluctuate due to the dynamic nature of this region of Lake Norman. At the locations nearest the dam (Locations 2.0 and 5.0), seasonal variations are dampened and the overall production would be lower due to the relative stability of this area (Thornton, et al. 1990). A similar trend was observed in the phytoplankton communities (Chapter 3).

Several records were set among epilimnetic densities during 2002. In fact, the only quarter when densities were within seasonal ranges was August (Figure 4-3). During February 2002, the lowest long term densities ever recorded occurred at Locations 2.0 and 5.0. Locations 5.0, 11.0, and 15.9 experienced record high epilimnetic densities for May during 2002, while a record low density for November was observed at Location 15.9. These record high and low densities were likely responses to short term changes in phytoplankton concentrations and availability, as well as environmental conditions such as low inputs due to the long term drought.

The highest February densities recorded during the Program at Locations 5.0 and 9.5 occurred in 1995, while Locations 2.0 and 11.0 experienced February maxima in 1996 (Figure 4-2). The long term February maximum at Location 15.9 was observed in 1992. Long term maximum densities for May occurred at Locations 2.0 and 9.5 in 2000, while the highest May values at Locations 5.0, 11.0, and 15.9 occurred in May 2002. Long term August maxima occurred in 1988 at all but Location 15.9, which had its highest August value in 1996 (Figure 4-3). November long term maxima at Locations 2.0 through 9.5 occurred in 1988, and at Locations 11.0 and 15.9 in November 1999. Since 1990, the densities at Mixing Zone Locations in May, August, and November have not fluctuated much between years, while year-to-year fluctuations in densities during February have occasionally been quite substantial, particularly between 1991 and 1997. The Background Locations continue to exhibit considerable year-to-year variability in all seasons (Figures 4-2 and 4-3).

Community Composition

One hundred and nine zooplankton taxa have been identified since the Lake Norman Maintenance Monitoring Program began in August 1987 (Table 4-3). Fifty-one taxa were identified during 2002, as compared to forty-six taxa recorded during 2001 (Duke Power 2002). One previously unreported taxon, the rotifer *Platyia patulus* was identified in 2002.

Copepods, which were most often dominant during 2001, showed a significant decline in relative abundance during 2002. These microcrustaceans were dominant only during August in samples collected at all but Location 9.5, where cladocerans were most abundant (Table 4-1, Figures 4-4 and 4-5). Rotifers dominated zooplankton densities at all locations during the other three sampling periods of 2002. During most years of the Program, microcrustaceans dominated Mixing Zone samples, but were considerably less important among Background Locations (Figures 4-6 through 4-8). From 1995 through 1998, a trend of increasing relative abundance among microcrustaceans was observed throughout Lake Norman. Since 2000, this trend has reversed, with a subsequent increase in relative abundances of rotifers to the extent that taxonomic composition in 2002 was similar to that found during years prior to 1995.

Copepoda

Copepod populations were consistently dominated by immature forms (primarily nauplii) during 2002, as has always been the case. Adult copepods rarely constituted more than 8% of the total zooplankton density at any location. *Tropocyclops* and *Epischura* were the most important constituents of adult populations in epilimnetic samples, while *Tropocyclops* and *Mesocyclops* were principal components of adult populations in whole column samples (Table 4-4).

Copepods tended to be more abundant, if not dominant, at Background Locations than at Mixing Zone Locations during 2002, and their densities peaked in May at both Mixing Zone and Background Locations. Copepods showed similar spatial and seasonal trends during 2001 (Table 4-1, Figure 4-5). Historically, maximum copepod densities were most often observed in May.

Cladocera

Bosmina was the most abundant cladoceran observed in 2002 samples, as has been the case in most previous studies (Duke Power 2002, Hamme 1982). *Bosmina* often comprised greater than 5% of the total zooplankton densities in both epilimnetic and whole column samples, and was the dominant zooplankter in several samples from February and November (Table 4-4). *Bosminopsis* was also important among cladocerans in August when it dominated cladoceran populations at most locations. *Bosminopsis* expressed lower dominance during August 2002 as compared to August 2001. During May, *Daphnia* dominated cladoceran populations at Location 9.5, while *Diaphanosoma* was the dominant cladoceran in whole column samples from Location 2.0. Similar patterns of *Daphnia*-*Bosminopsis* dominance have been observed in past years of the Program (Duke Power 2002).

Long-term seasonal trends of cladoceran densities were variable: From 1990 to 1993, peak densities occurred in February; while in 1994, 1995, 1997, and 2000, maxima were recorded in May (Figure 4-5). During 1996 and 1999, peak cladoceran densities occurred in May in the Mixing Zone, and in August among Background Locations. Maximum cladoceran densities in 1998 occurred in August. In 2001, maximum cladoceran densities in the Mixing Zone occurred in February, while Background locations showed peaks in November. The pattern observed in 2002 was the same as in 1996 and 1999. Spatially, cladocerans were more important at Mixing Zone Locations than at other locations (Table 4-1, Figure 4-4).

Rotifera

Polyarthra was the most abundant rotifer in 2002 samples (Table 4-4). This taxon dominated rotifer populations at Locations 2.0 through 9.5, and 11.0 (whole column), in May; Location 5.0 (whole column), 11.0, and 15.9 (whole column) in August; and was dominant in all samples analyzed in November (Table 4-4). *Conochilus* dominated rotifer populations at Locations 2.0, 9.5 and 15.9 (epilimnion) in August. *Kellicottia* was the dominant rotifer in whole column samples from Locations 5.0, and 9.5 in February; and Locations 11.0 (epilimnion) and 15.9 in May. *Keratella* and *Synchaeta* were dominant rotifers in most February samples All of these taxa have been identified as important constituents of rotifer populations, as well as zooplankton communities, in previous studies (Duke Power 2002; Hamme 1982).

Long term tracking of rotifer populations indicated high year-to-year seasonal variability. Peak densities have most often occurred in February and May, with an occasional peak in August (Figure 4-5, Duke Power 1989, 2002). During 2002, peak densities were observed in May.

FUTURE STUDIES

No changes are planned for the zooplankton portion of the Lake Norman Maintenance Monitoring Program in 2003 and 2004.

SUMMARY

Maximum epilimnetic and whole column zooplankton densities occurred in May, while minimum epilimnetic densities were recorded in February (Locations 5.0, 9.5, and 11.0), and November (Locations 2.0 and 15.9). Minimum whole column densities were observed in February (Locations 2.0 through 9.5), and August (11.0 and 15.9). As in past years, epilimnetic densities were higher than whole column densities. Mean zooplankton densities tended to be higher among Background Locations than among Mixing Zone locations during 2002, and a general pattern of increasing values from downlake to uplake was observed. In addition, long term trends showed much higher year-to-year variability at Background Locations than at Mixing Zone Locations.

Epilimnetic zooplankton densities in August were within ranges of those observed in August of previous years. The epilimnetic densities at Locations 5.0, 11.0, and 15.9 in May 2002 were the highest recorded from these locations during the Program, and may have represented an ongoing lag response to changing phytoplankton standing crops at that time. Record low densities for February were observed at Locations 2.0 and 5.0, while a record low density for November occurred at Locations 15.9. Record low densities may have been in response to long term drought conditions through much of 2002.

One hundred and nine zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (Fifty-one were identified during 2002). One previously unreported rotifer was identified during 2002.

Overall relative abundance of copepods in 2002 had decreased substantially since 2001, and they were only dominant during August. Cladocerans were occasionally dominant at only one location in August, while rotifers were dominant in all samples collected during the other three quarters. Overall, the relative abundance of rotifers had increased considerably since 2001, and their relative abundances were often similar to years prior to 1995. Historically, copepods and rotifers have shown annual peaks in May; while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms with adults rarely accounting for more than 8% of zooplankton densities. The most important adult copepods were *Tropocyclops*, *Epischura*, and *Mesocyclops* as was the case in previous years. *Bosmina* was the predominant cladoceran, as has also been the case in most previous years of the Program. *Bosminopsis* dominated most cladoceran populations in August. The most abundant rotifers observed in 2002, as in many previous years, were *Polyarthra*, *Conochilus*, and *Kellicottia*, while *Karetella* and *Syncheata* were occasionally important among rotifer populations.

Lake Norman continues to support a highly diverse and viable zooplankton community. Long term and seasonal changes observed over the course of the study, as well seasonal and spatial variability observed during 2002, were likely due to environmental factors and appears not to be related to plant operations.

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Table 4-1. Total zooplankton densities (no. X 1000/m³), densities of major zooplankton taxonomic groups, and percent composition (in parentheses) of major taxa in 10m to surface (10-S) and bottom to surface (B-S) net tow samples collected from Lake Norman in February, May, August, and November 2002.

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
2/4/02	10-S	COPEPODA	4.9	4.6	10.1	15.9	27.8
			(16.2)	(27.5)	(23.8)	(25.7)	(22.0)
		CLADOCERA	6.9	4.1	9.4	15.4	30.4
			(22.4)	(24.9)	(22.2)	(24.8)	(24.0)
		ROTIFERA	18.8	7.9	22.9	30.6	68.5
			(61.4)	(47.5)	(54.0)	(49.5)	(54.0)
		TOTAL	**30.6**	**16.6**	**42.4**	**61.9**	**126.7**
	B-S						
	depth (m)						
	of tow	COPEPODA	4.3	4.3	12.2	14.4	16.3
	for each		(15.3)	(33.5)	(25.1)	(27.9)	(21.6)
	Location	CLADOCERA	9.5	4.2	11.2	10.3	18.6
	2.0=29		(33.6)	(32.5)	(23.0)	(19.9)	(24.6)
	5.0=18	ROTIFERA	14.5	4.4	25.2	27.1	40.6
	9.5=20		(51.1)	(34.0)	(51.8)	(52.3)	(53.8)
	11.0=24						
	15.9=20	**TOTAL**	**28.3**	**12.8**	**48.6**	**51.8**	**75.5**
5/6/02	10-S	COPEPODA	34.2	39.2	35.9	64.4	84.6
			(28.6)	(28.3)	(34.0)	(13.4)	(14.6)
		CLADOCERA	19.1	29.5	15.0	15.8	8.1
			(16.0)	(21.3)	(14.2)	(3.2)	(1.4)
		ROTIFERA	66.4	69.7	54.6	402.0	485.4
			(55.4)	(50.4)	(51.8)	(83.4)	(84.0)
		TOTAL	**119.7**	**138.4**	**105.5**	**482.2**	**578.1**
	B-S						
	Depth (m)						
	of tow	COPEPODA	15.1	20.4	27.9	35.1	47.2
	for each		(32.8)	(25.0)	(41.7)	(20.5)	(16.8)
	Location	CLADOCERA	8.7	13.0	11.1	7.8	5.6
	2.0=30		(18.8)	(16.0)	(16.6)	(4.5)	(2.0)
	5.0=20	ROTIFERA	22.3	48.0	27.9	128.7	228.0
	9.5=20		(48.4)	(59.0)	(41.7)	(75.0)	(81.2)
	11.0=25						
	15.9=20	**TOTAL**	**46.1**	**81.4**	**66.9**	**171.6**	**280.8**

Table 4-1 (continued).

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
8/5/02	10-S	COPEPODA	25.1	34.7	20.0	40.4	25.6
			(40.0)	(53.5)	(30.7)	(39.1)	(43.8)
		CLADOCERA	13.2	10.8	24.8	21.3	13.1
			(21.1)	(16.6)	(38.0)	(20.6)	(22.4)
		ROTIFERA	24.4	19.4	20.4	41.7	19.7
			(38.9)	(29.9)	(31.3)	(40.3)	(33.7)
		TOTAL	**62.7**	**64.9**	**65.2**	**103.4**	**58.4**
	B-S depth (m) of tow for each Location 2.0=29 5.0=18 9.5=19 11.0=25 15.9=20	COPEPODA	26.4	34.2	20.0	27.2	33.2
			(60.6)	(50.8)	(30.7)	(53.0)	(49.9)
		CLADOCERA	10.6	19.6	24.8	8.7	12.8
			(24.3)	(29.2)	(38.0)	(17.0)	(19.3)
		ROTIFERA	6.5	13.5	20.4	15.4	20.0
			(15.0)	(20.0)	(31.3)	(30.0)	(30.1)
		TOTAL	**43.5**	**67.3**	**65.2**	**51.3**	**66.4***
11/4/02	10-S	COPEPODA	8.9	NS	13.2	26.4	24.8
			(32.8)		(26.3)	(23.5)	(43.7)
		CLADOCERA	9.0		11.6	12.6	3.7
			(33.2)		(23.1)	(11.2)	(6.4)
		ROTIFERA	9.2		25.5	73.2	28.3
			(34.0)		(50.6)	(65.3)	(49.8)
		TOTAL	**27.1**		**50.3**	**112.2**	**56.8**
	B-S depth (m) of tow for each Location 2.0=29 5.0=18 9.5=20 11.0=18 15.9=20	COPEPODA	11.8	NS	15.4	35.1	28.9
			(34.1)		(26.6)	(35.0)	(41.8)
		CLADOCERA	10.2		13.2	12.3	3.6
			(29.5)		(22.9)	(12.3)	(5.2)
		ROTIFERA	12.6		29.1	52.7	36.7
			(36.4)		(50.5)	(52.7)	(53.0)
		TOTAL	**34.6**		**57.7**	**100.1**	**69.2**

*= *Chaoborus* observed in sample (440/m^3, 0.66%).
NS = No sample data available

Table 4-2. Duncan's Multiple Range Test on epilimnetic zooplankton densities (no. X 1000/m^3) in Lake Norman, NC during 2002.

February	Location	**5.0**	**2.0**	**9.5**	**11.0**	**15.9**
	Mean	16.6	30.6	42.4	61.9	126.7
May	Location	**9.5**	**2.0**	**5.0**	**11.0**	**15.9**
	Mean	105.5	119.7	138.4	482.2	578.1
August	Location	**15.9**	**2.0**	**5.0**	**9.5**	**11.0**
	Mean	58.5	62.7	64.9	65.2	103.4
November	Location	**5.0**	**2.0**	**9.5**	**15.9**	**11.0**
	Mean	NS	27.1	50.4	56.8	112.2

Table 4-3. Zooplankton taxa identified from samples collected quarterly on Lake Norman from 1988 through 2002.

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
COPEPODA															
Cyclops thomasi Forbes	X	X	X				X	X		X	X	X	X	X	X
C. vernalis Fischer									X						
C. spp. O. F. Muller	X	X	X	X	X	X	X	X	X	X	X			X	X
Diaptomus birgei Marsh	X	X	X	X		X							X		
D. mississippiensis Marsh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. pallidus Herick		X	X			X		X	X	X		X			
D. reighardi Marsh												X			
D. spp. Marsh	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Epishura fluviatilis Herrick								X	X	X	X	X	X	X	X
Ergasilus spp.									X						
Eucyclops agilis (Koch)											X				
Mesocyclops edax (S. A. Forbes)	X	X	X				X	X	X	X	X	X	X	X	X
M. spp. Sars	X	X		X	X	X	X	X	X	X				X	X
Tropocyclops prasinus (Fischer)	X	X	X					X	X	X	X	X	X	X	X
T. spp.	X	X	X	X	X	X	X	X	X	X				X	X
Calanoid copepodites	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyclopoid copepodites	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Harpacticoidea					X	X			X						
Nauplii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Parasitic copepods												X			
CLADOCERA															
Alona spp.Baird									X	X					
Alonella spp. (Birge)							X					X			
Bosmina longirostris (O. F. M.)	X	X	X			X				X	X	X	X	X	X
B. spp. Baird	X	X		X	X	X	X	X	X	X	X		X	X	X
Bosminopsis dietersi Richard	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ceriodaphnia lacustris Birge				X						X	X	X	X	X	
C. spp. Dana	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chydorus spp. Leach				X		X	X	X	X	X		X		X	X
Daphnia ambigua Scourfield	X	X	X						X	X	X	X		X	
D. catawba Coker									X	X				X	
D. galeata Sars									X						
D. laevis Birge									X						
D. longiremis Sars									X	X			X	X	
D. lumholzi Sars				X		X	X	X	X		X	X	X		
D. mendotae (Sars) Birge										X	X	X	X		
D. parvula Fordyce	X	X	X					X	X	X	X	X	X	X	X
D. pulex (de Geer)									X	X					

Table 4-3 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
CLADOCERA (continued)															
D. pulicaria Sars									X	X					
D. retrocurva Forbes									X	X	X	X	X		X
D. schodleri Sars									X						
D. spp. Mullen	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Diaphanosoma brachyurum (Lievin)										X	X	X	X	X	X
D. spp. Fischer	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Eubosmina spp. (Baird)				X											
Holopedium amazonicum Stinge.	X	X	X							X	X	X	X	X	X
H. gibberum Zaddach			X							X	X				
H. spp. Stingelin	X	X		X	X	X	X	X	X	X			X	X	X
Ilyocryptus sordidus (Lieven)	X	X	X												
I. spinifer Herrick												X			
I. spp. Sars					X	X	X				X		X		
Latona setifera (O.F. Muller)				X											
Leptodora kindtii (Focke)	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Leydigia spp. Freyberg						X	X	X	X	X					
Moina spp. Baird				X											
Sida crystallina O. F. Muller	X		X	X	X										
Simocephalus expinosus					X										
Simocephalus spp. Schodler												X			
ROTIFERA															
Anuraeopsis spp. Lauterborne	X	X	X	X	X	X		X		X		X			
Asplanchna brightwelli Gosse											X		X		
A. priodonta Gosse											X	X	X		
A. spp. Gosse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brachionus caudata Barr. & Daday	X	X	X												
B. havanensis Rousselet	X	X	X							X					
B. patulus O. F. Muller	X	X	X								X				
B. spp. Pallas				X		X		X	X		X				
Chromogaster ovalis (Bergendel)										X	X	X		X	
C. spp. Lauterborne	X	X	X	X	X	X	X	X	X						
Collotheca balatonica Harring									X	X	X	X	X		X
C. mutabilis (Hudson)									X	X	X	X	X		
C. spp. Harring	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Colurella spp. Bory de St. Vincent									X						
Conochiloides dossuarius Hudson										X	X	X	X	X	X
C. spp. Hlava	X	X	X	X	X	X	X	X	X	X				X	
Conochilus unicornis (Rousselet)	X	X	X							X	X	X	X	X	X

Table 4-3 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
ROTIFER (continued)															
C. spp. Hlava	X	X	X	X	X	X	X	X	X	X				X	X
Filinia spp. Bory de St. Vincent						X	X				X				
Gastropus stylifer Imhof											X	X	X	X	
G. spp. Imhof	X	X	X		X	X	X	X	X	X	X			X	
Hexarthra mira Hudson										X	X	X	X		X
H. spp. Schmada	X	X	X	X	X	X	X	X	X	X				X	
Kellicottia bostoniensis (Rousselet)	X	X	X				X	X	X	X	X	X	X	X	X
K. longispina Kellicott										X	X	X	X	X	X
K. spp. Rousselet	X	X	X	X	X	X	X	X	X	X				X	X
Keratella cochlearis												X	X		
K. taurocephala Myers										X		X			
K. spp. Bory de St. Vincent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lecane spp. Nitzsch	X	X	X		X		X	X		X	X		X		X
Macrochaetus subquadratus Perty										X	X				
M. spp. Perty	X	X	X	X		X			X			X	X		X
Monostyla stenroosi (Meissener)	X		X												
M. spp. Ehrenberg	X	X	X				X	X	X		X				
Notholca spp. Gosse							X		X		X				
Platyias patulus Harring															X
Ploeosoma hudsonii Brauer				X			X	X	X	X	X	X	X	X	X
P. truncatum (Levander)	X	X	X				X	X	X	X	X	X	X	X	X
P. spp. Herrick	X	X	X	X	X	X	X	X	X		X			X	
Polyarthra euryptera (Weirzeijski)	X	X	X								X				
P. major Burckhart										X		X	X		X
P. vulgaris Carlin	X	X	X							X		X	X	X	X
P. spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pompholyx spp. Gosse									X						
Ptygura libra Meyers										X	X		X		X
P. spp. Ehrenberg	X	X	X		X	X	X	X	X	X					X
Synchaeta spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichocerca capucina (Weireijski)	X	X	X				X	X	X	X	X				X
T. cylindrica (Imhof)	X	X	X					X	X	X	X	X	X		X
T. longiseta Schrank										X					
T. multicrinis (Kellicott)											X	X	X		X
T. porcellus (Gosse)								X	X	X		X	X		X
T. pusilla Jennings										X					
T. similis Lamark								X							
T. spp. Lamark	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichotria spp. Bory de St. Vincent									X						X

Table 4-3 (continued) page 4 of 4

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
ROTIFERA (continued)															
Unidentified Bdelloida	X	X	X		X	X	X			X	X	X			
Unidentified Rotifera				X	X	X	X	X	X	X	X	X	X		
INSECTA															
Chaoborus spp. Lichtenstein	X	X	X	X	X	X					X	X		X	X
OSTRACODA (unidentified)											X				

Table 4-4. Dominant taxa among copepods (adults), cladocerans, and rotifers, and their percent composition (in parentheses) of copepod, cladoceran and rotifer densities in Lake Norman samples during 2002.

	FEBRUARY	MAY	AUGUST	NOVEMBER
		COPEPODA	**EPILIMNION**	
2.0	*Mesocyclops/Tropocyclops* (1.8 ea)*	*Tropocyclops* (5.2)	*Tropocyclops* (5.3)*	*Epishura* (1.6)*
5.0	*Tropocyclops* (17.3)	*Epishura* (2.6)	*Tropocyclops* (5.6)*	No sample
9.5	*Tropocyclops* (2.4)	*Mesocyclops* (4.4)	*Tropocyclops* (8.6)	*Tropocyclops* (4.7)*
11.0	*Epischura* (1.7)	*Epishura* (1.4)	*Tropocyclops* (2.7)	*Tropocyclops* (1.2)*
15.9	No adults present	*Mesocyclops* (3.2)	*Tropocyclops* (3.4)*	*Tropocyclops* (6.6)*
		COPEPODA	**WHOLE COLUMN**	
2.0	*Mesocyclops/Tropocyclops* (8.5 ea)	*Mesocyclops* (6.7)	*Mesocyclops* (4.8)	*Diaptomus* (5.6)
5.0	*Tropocyclops* (14.4)	*Epishura* (3.7)	*Tropocyclops* (7.2)	No sample
9.5	*Diaptomus* (1.7)	*Mesocyclops* (8.2)	*Tropocyclops* (8.6)	*Tropocyclops* (10.0)
11.0	*Tropocyclops* (2.5)*	*Tropocyclops* (3.8)	*Mesocyclops* (7.4)	*Diaptomus* (8.7)
15.9	*Cyclops* (5.2)*	*Epishura* (6.4)	*Tropocyclops* (8.0)	*Tropocyclops* (7.0)
		CLADOCERA	**EPILIMNION**	
2.0	*Bosmina* (100.0)	*Bosmina* (40.6)	*Bosminopsis* (69.8)	*Bosmina* (83.6)
5.0	*Bosmina* (100.0)	*Bosmina* (83.3)	*Bosminopsis* (62.2)	No sample
9.5	*Bosmina* (97.4)	*Daphnia* (40.7)	*Bosminopsis* (55.5)	*Bosmina* (94.6)
11.0	*Bosmina* (92.0)	*Bosmina* (83.7)	*Bosminopsis* (60.8)	*Bosmina* (90.2)
15.9	*Bosmina* (99.4)	*Bosmina* (100.0)	*Bosmina* (49.8)	*Bosmina* (66.5)
		CLADOCERA	**WHOLE COLUMN**	
2.0	*Bosmina* (98.7)	*Diaphanosoma* (40.1)	*Bosmina* (57.3)	*Bosmina* (80.6)
5.0	*Bosmina* (93.4)	*Bosmina* (67.6)	*Bosmina* (69.0)	No sample
9.5	*Bosmina* (92.7)	*Daphnia* (41.2)	*Bosminopsis* (55.5)	*Bosmina* (96.6)
11.0	*Bosmina* (89.4)	*Bosmina* (79.0)	*Bosminopsis* (53.4)	*Bosmina* (68.4)
15.9	*Bosmina* (98.9)	*Bosmina* (78.3)	*Bosminopsis* (48.9)	*Bosmina* (88.3)

Table 4-4 (continued)

	FEBRUARY	MAY	AUGUST	NOVEMBER
		ROTIFERA	**EPILIMNION**	
2.0	*Keratella* (84.8)	*Polyarthra* (87.5)	*Conochilus* (35.8)	*Polyarthra* (48.3)
5.0	*Keratella* (66.7)	*Polyarthra* (84.8)	*Ptygura* (37.5)	No sample
9.5	*Keratella* (35.3)	*Polyarthra* (81.7)	*Conochilus* (35.9)	*Polyarthra* (48.0)
11.0	*Synchaeta* (66.4)	*Kellicottia* (61.0)	*Polyarthra* (35.7)	*Polyarthra* (83.1)
15.9	*Synchaeta* (52.4)	*Kellicottia* (72.4)	*Conochilus* (53.1)	*Polyarthra* (66.2)
		ROTIFERA	**WHOLE COLUMN**	
2.0	*Keratella* (75.4)	*Polyarthra* (81.6)	*Conochilus* (35.3)	*Polyarthra* (77.0)
5.0	*Kellicottia* (33.8)	*Polyarthra* (79.8)	*Polyarthra* (43.0)	No sample
9.5	*Kellicottia* (27.5)	*Polyarthra* (77.9)	*Conochilus* (35.9)	*Polyarthra* (51.5)
11.0	*Synchaeta* (55.3)	*Polyarthra* (54.0)	*Polyarthra* (46.3)	*Polyarthra* (86.6)
15.9	*Synchaeta* (40.7)	*Kellicottia* (76.0)	*Polyarthra* (40.1)	*Polyarthra* (61.3)

* = Only adults present in samples.

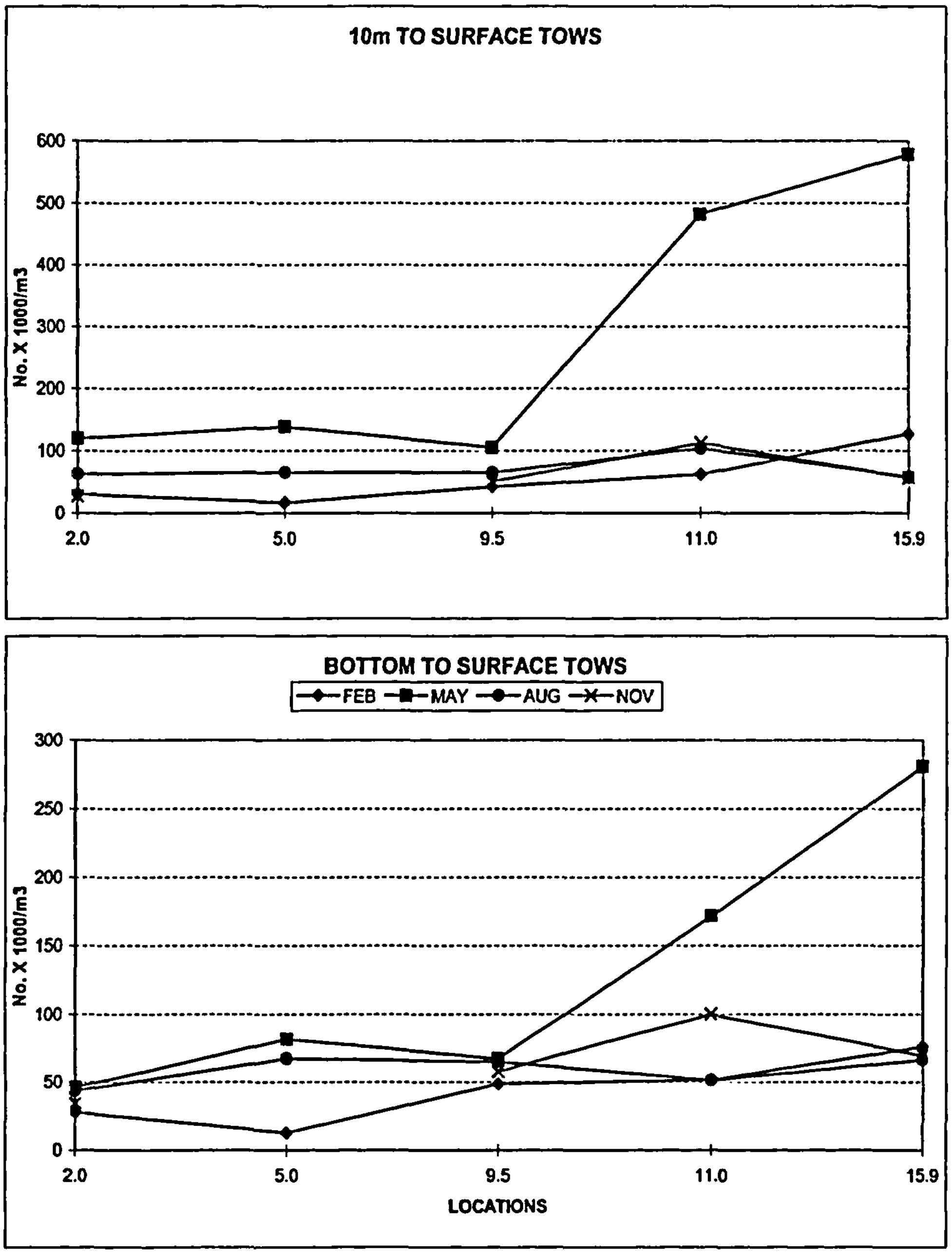


Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman, NC, in 2002.

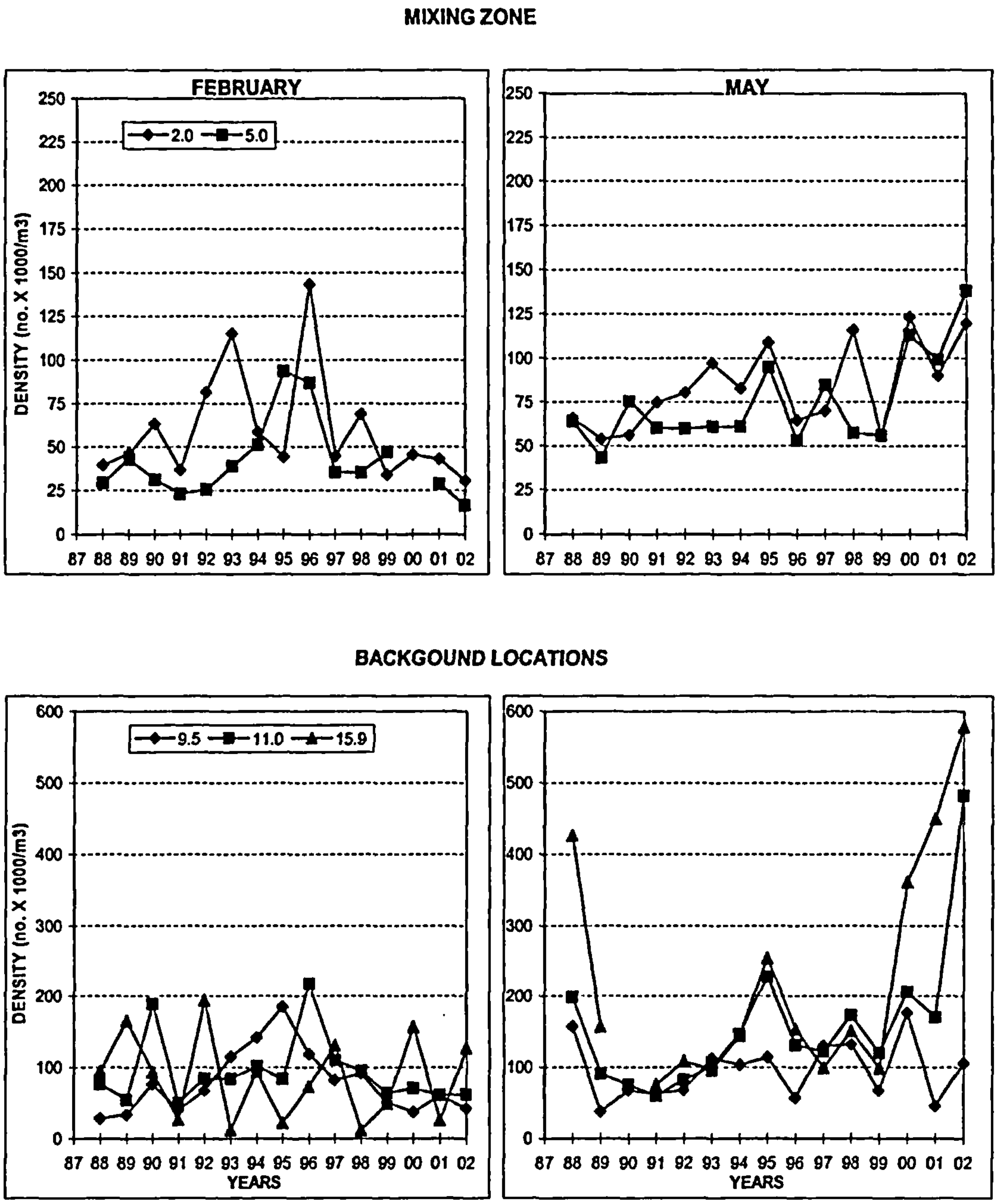
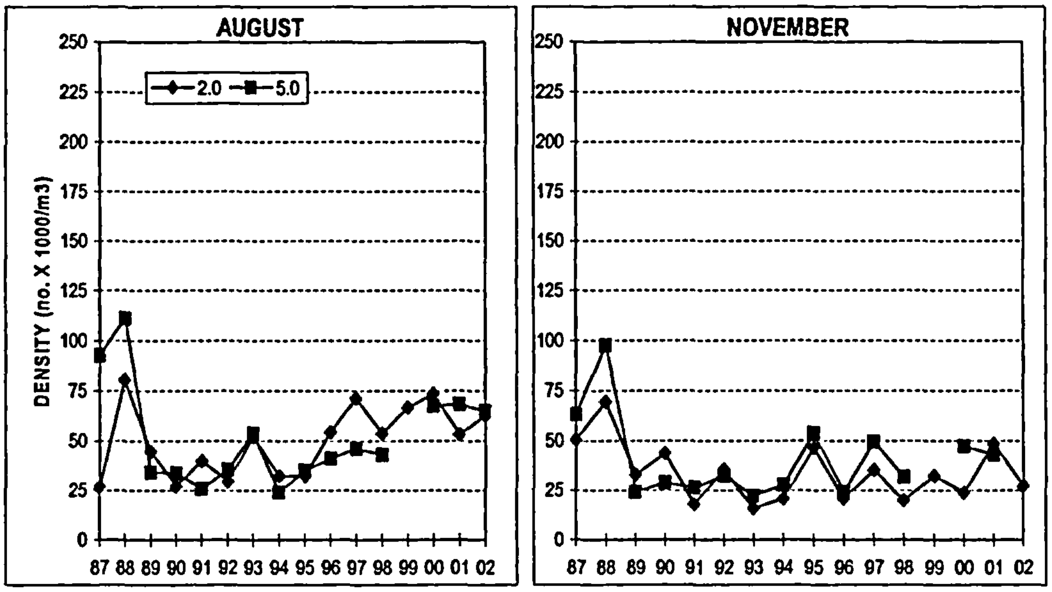


Figure 4-2. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in February and May of 1988 through 2002.

MIXING ZONE



BACKGROUND LOCATIONS

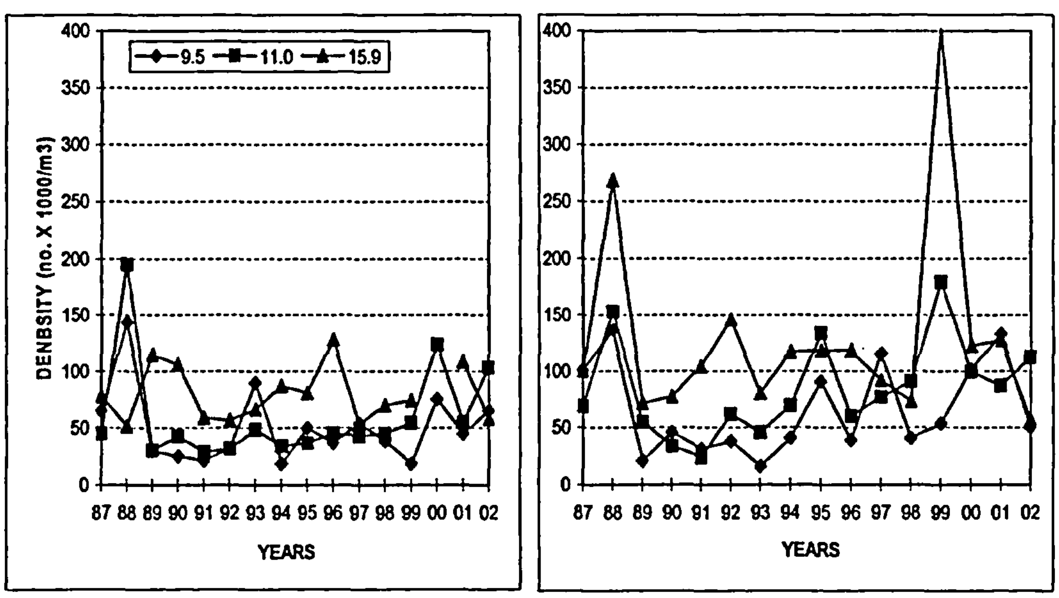


Figure 4-3. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in August and November of 1987 through 2002.

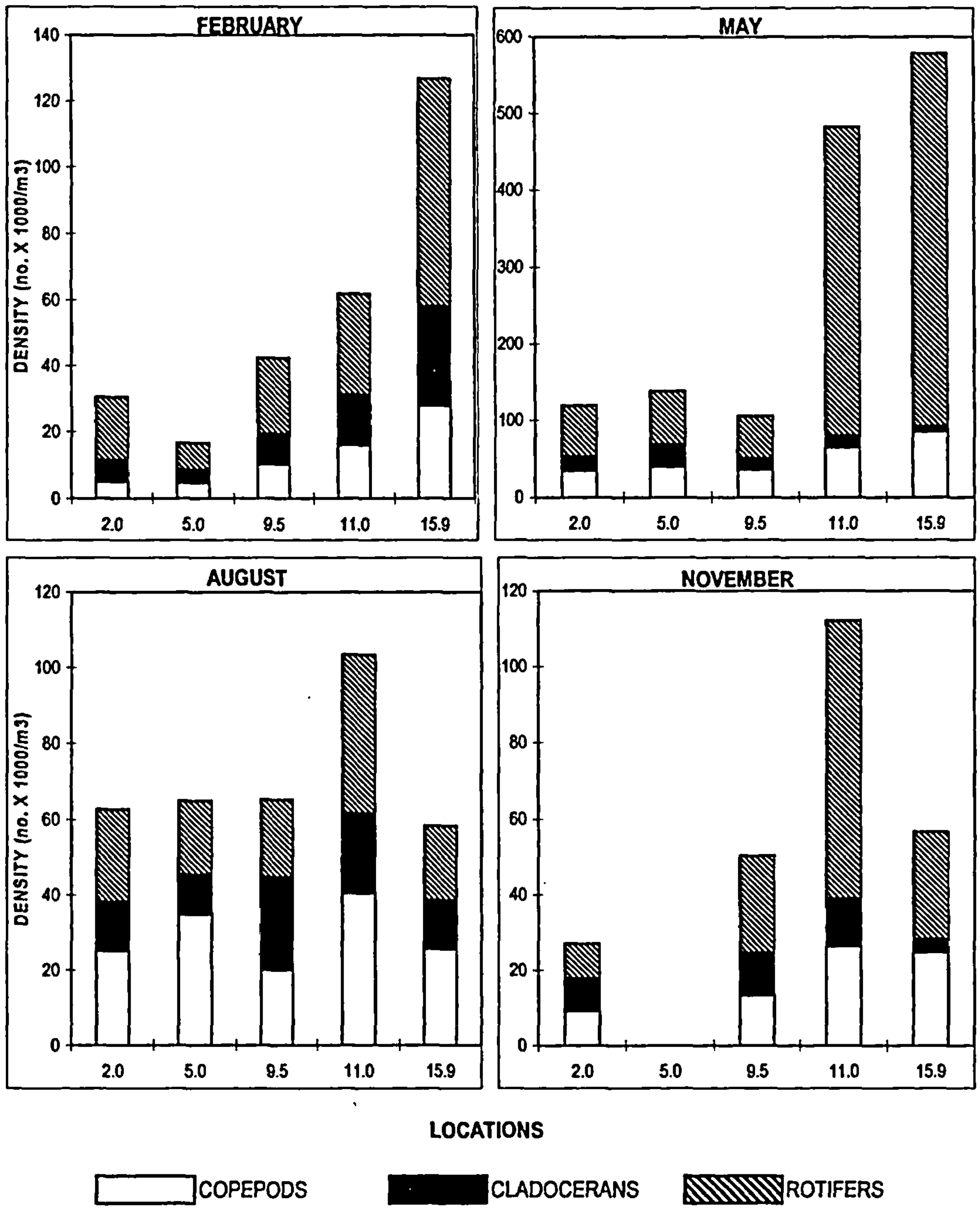


Figure 4-4. Zooplankton community composition by month for epilimnetic samples collected in Lake Norman, NC, in 2002.

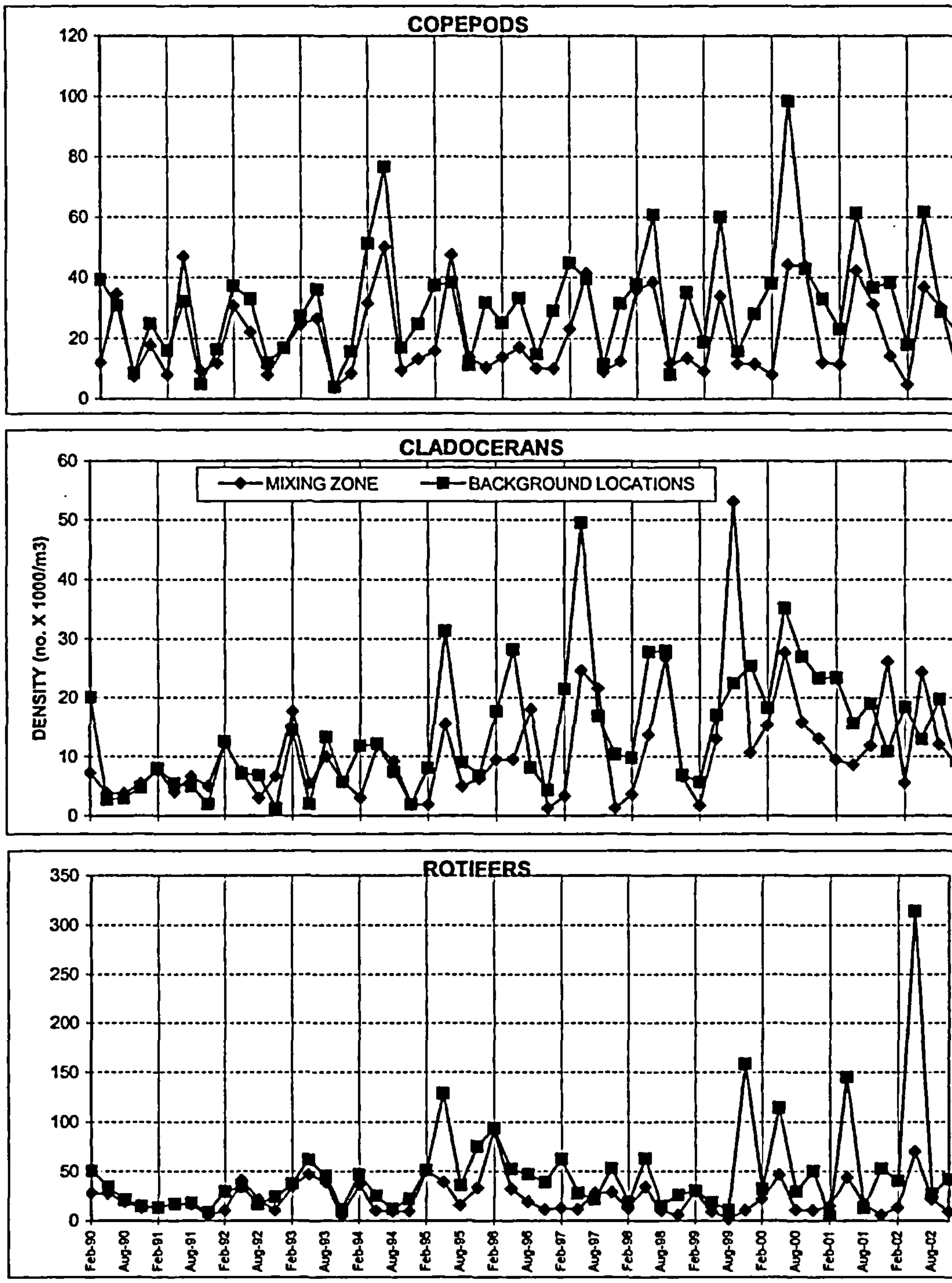
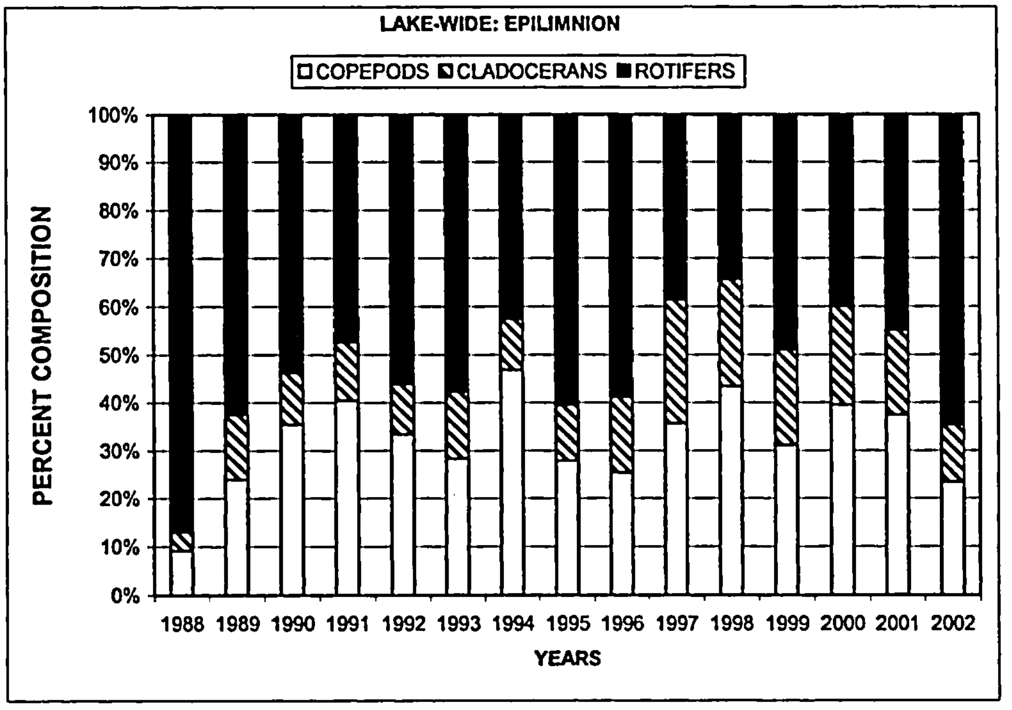


Figure 4-5. Zooplankton composition by quarter for epimlimnetic samples collected in Lake Norman, NC, from 1990 through 2002 (Note: Mixing Zone in November 2002 represents Location 2.0 only).



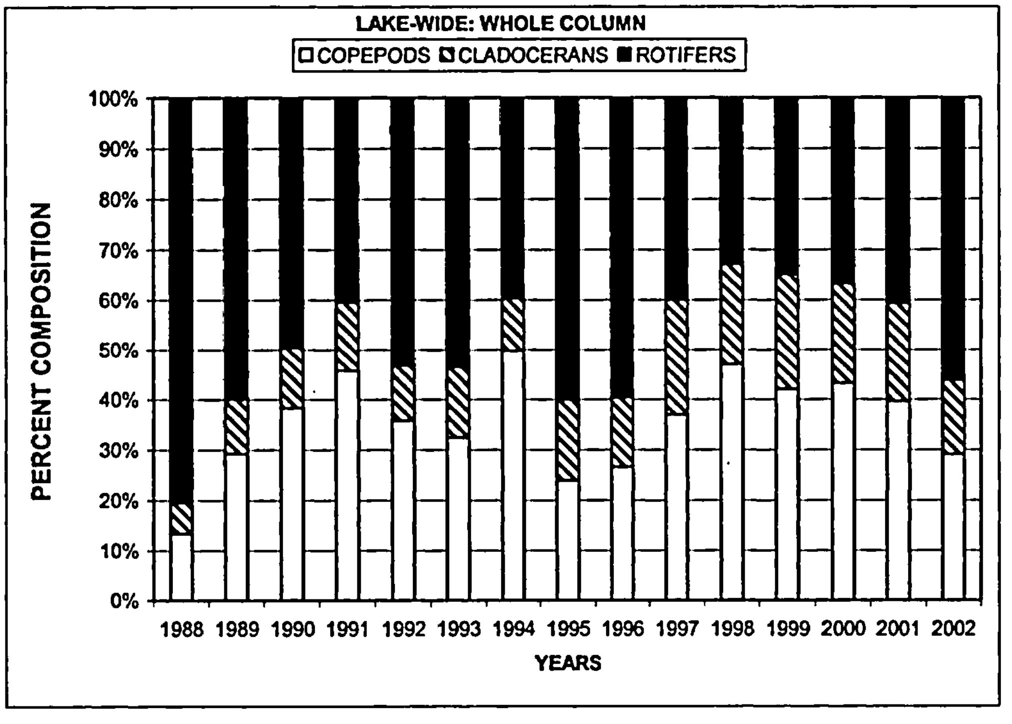
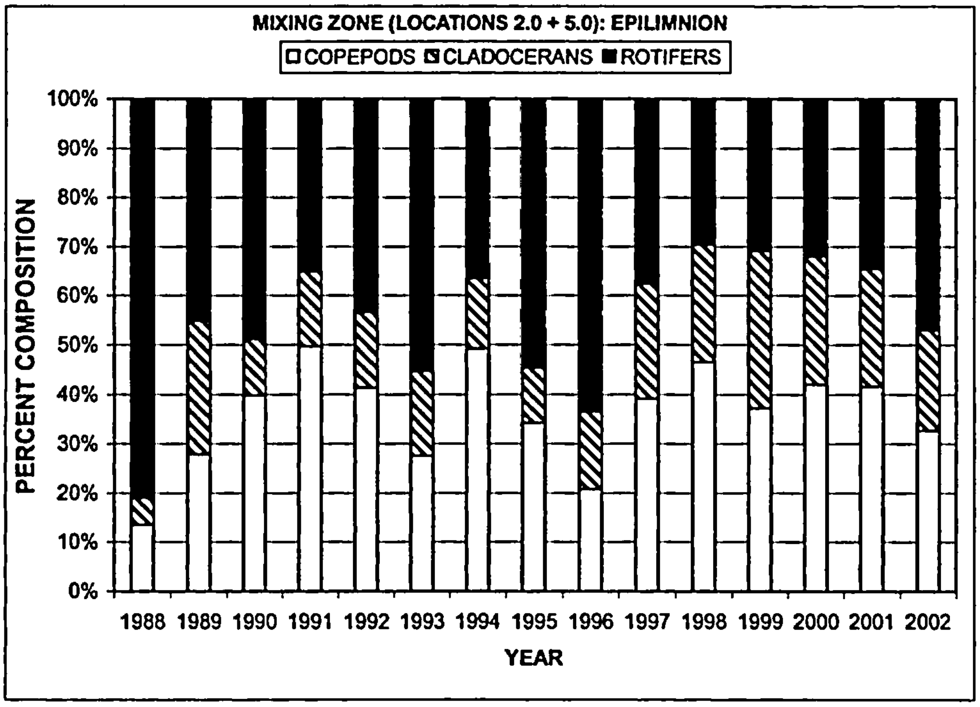


Figure 4-6. Annual lake-wide percent composition of major zooplankton taxonomic groups from 1988 through 2002 (Note: Does not include Location 5.0 in November 2002).



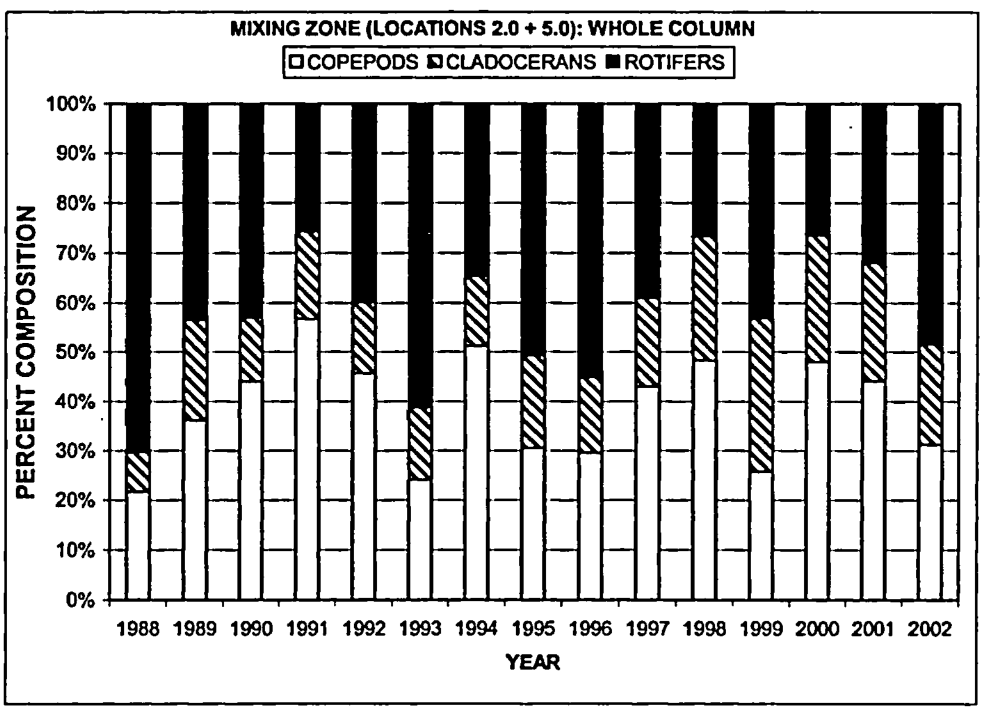


Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from Mixing Zone Locations: 1988 through 2002 (Note: Does not include Location 5.0 in November 2002).

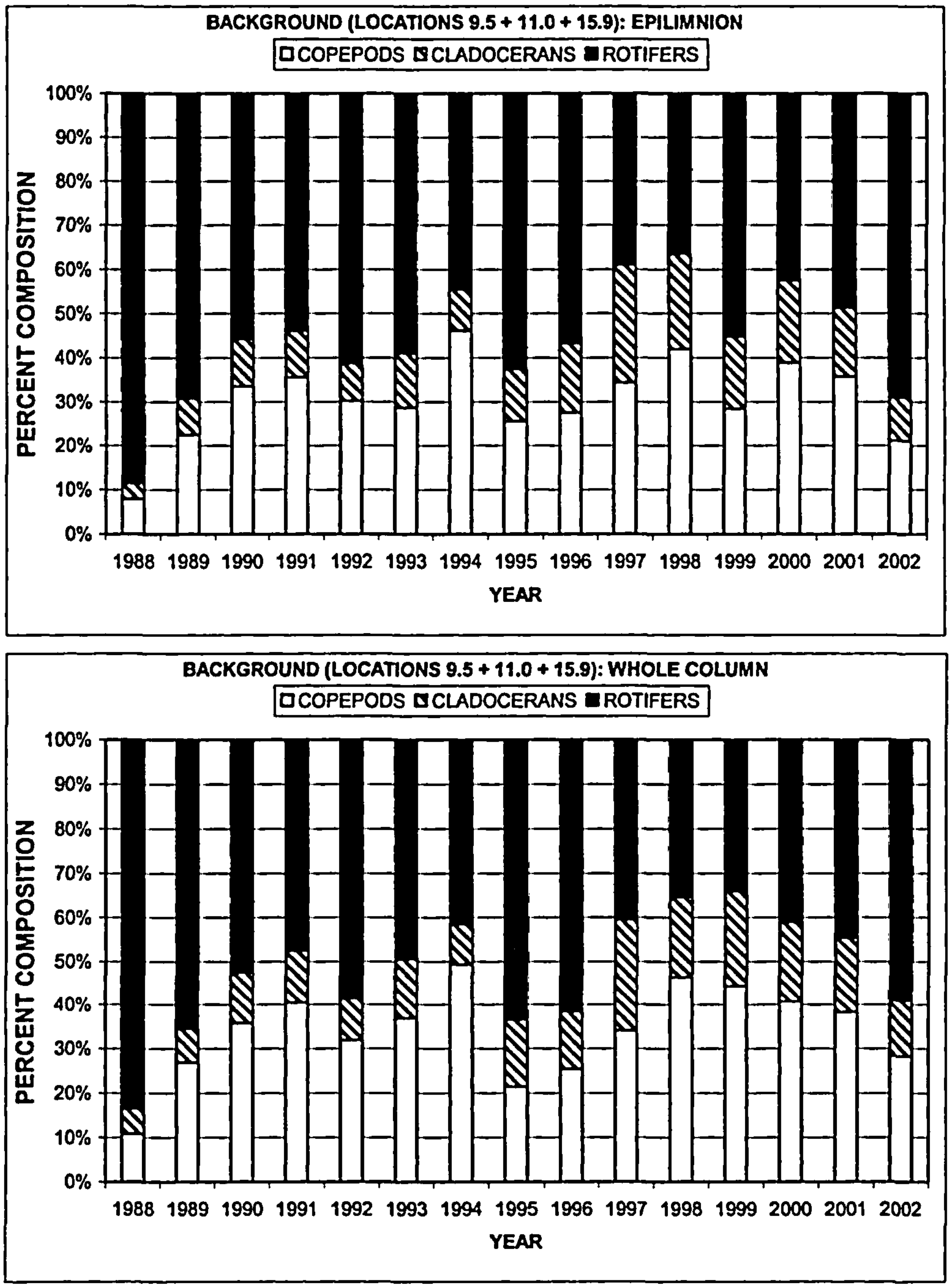


Figure 4-8. Annual percent composition of major zooplankton taxonomic groups from Background Locations: 1988 through 2002.

CHAPTER 5
FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters continued during 2002. The components of this Lake Norman Fish Monitoring Program were to:

1. Continue spring electrofishing surveys of littoral fish populations;
2. Continue summer striped bass (scientific names of fish mentioned in this chapter are listed in Table 5-1) mortality monitoring;
3. Continue fall hydroacoustic and purse seine surveys of pelagic fish populations (Attachment 1);
4. Continue cooperative striped bass study with the North Carolina Wildlife Resources Commission (NCWRC) to evaluate striped bass growth and condition as a function of stocking rates, forage availability, and summer striped bass habitat;
5. Continue supporting the NCWRC/North Carolina State University (NCSU) striped bass bioenergetics study.

METHODS AND MATERIALS

Spring electrofishing surveys were conducted in April at three locations: (1) near MNS, (2) near Marshall Steam Station (MSS), and (3) a mid-lake reference area (REF) located between MNS and MSS. The locations sampled in 2002 were the same locations sampled since implementation of this sampling program in 1993. Ten 300-m transects were sampled in each of the three locations. The MNS transects were located between Ramsey Creek and Channel Marker 1A in Zone 1 (Fig. 5-1). The REF transects were located between Channel Marker 7 and Channel Marker 9 in lower Zone 3, and the MSS transects were located between Channel Marker 14 and the NC Highway 150 Bridge in Zone 4. All transects were originally selected to include the various types of fish habitat in Lake Norman that could be effectively sampled. The only areas excluded were shallow flats where the boat could not access the area within 3-4 m of the shoreline. All sampling was conducted during daylight and when water temperatures generally ranged from 15 to 20 °C. Except for largemouth bass, all fish collected were identified to species, and total number and total weight were obtained for each species. Individual total lengths (mm) and weights (g) were obtained for all largemouth bass collected.

Mortality surveys for striped bass were conducted from July 5 through September 5. During this period, weekly surveys using a boat were conducted to specifically search for dead or dying striped bass in Zones 1-4. The location of any dead or dying fish was noted along with its total length.

Striped bass for calculations of relative weight (Wr) were collected from gill-net surveys conducted in November and December by the NCWRC and NCSU personnel during their bioenergetics study. Relative weight was calculated using the formula Wr = (W/Ws) x 100 where W = weight of the individual fish (g) and Ws = length-specific mean weight (g) for a fish as predicted by a weight-length equation for striped bass (Anderson and Neumann 1996).

RESULTS AND DISCUSSION

Numbers and biomass of fish collected from Lake Norman in 2002 spring electrofishing surveys varied among sampling locations (Tables 5-2 through 5-4). A total of 1,361 fish (14 species and 1 hybrid complex) weighing 54.9 kg were collected near MNS while 1,776 fish (18 species and 1 hybrid complex) weighing 103.0 kg were collected at the REF area and 1,157 fish (20 species and 1 hybrid complex) weighing 80.4 kg were collected near MSS. Whitefin shiners, spottail shiners, redbreast sunfish, and bluegills dominated all samples numerically, while common carp, redbreast sunfish, bluegills, and largemouth bass dominated gravimetrically.

Numbers of fish collected in 2002 were highest at the REF location, intermediate at the MNS location, and lowest at the MSS location. However, fish biomass was highest at the REF location, intermediate at the MSS location, and lowest at the MNS location. While numbers of fish have varied considerably among locations and years, fish biomass has remained relatively stable (Fig. 5-2). Fish biomass has always been highest at the MSS or REF locations and lowest at the MNS location. Historically, Lake Norman exhibited spatial heterogeneity in its fish populations with uplake areas generally supporting more fish than downlake areas (Siler et al. 1986). Siler et al. (1986) indicated that this heterogeneity was related to higher nutrient levels uplake than downlake. Our data indicates that this spatial heterogeneity may still be characteristic of fish populations in Lake Norman and that lower nutrients downlake may explain the consistently low fish biomass estimates collected at the MNS location.

Total numbers of fish collected near MNS were greater in 2002 than in 2001 (Fig. 5-2) and were primarily due to increased catches of spottail shiners, redbreast sunfish, and bluegills in 2002. However, fish biomass was similar in both years (Fig. 5-2). Total numbers of fish collected at the REF location were somewhat similar in 2001 and 2002, but biomass increased from 2001 to 2002 (Fig. 5-2) due to increased catches of redbreast sunfish and larger largemouth bass. Both total numbers and biomass of fish collected near the MSS declined from 2001 to 2002 (Fig. 5-2). Declines in fish numbers at this location were related to fewer whitefin and spottail shiners being collected in 2002, and declines in biomass were related to fewer large common carp being collected. Even with the increases and decreases noted in the total numbers and biomass of fish at all locations from 2001 to 2002, these values in 2002 continued to be within the ranges observed here since this sampling program was implemented in 1993, and no overall annual trends in abundance were evident at any sampling location.

Mortality surveys for striped bass in Lake Norman resulted in few fish in 2002 (Table 5-5). Only 6 dead fish (ranging in length from 450 mm to 550 mm) were observed in 2002 compared to 18 in 2001 (Duke Power 2003). Four of these fish were found near the MNS, and the remaining two were from uplake locations.

Twenty-three striped bass were collected in November and December 2002 for Wr evaluations. Mean Wr was 81 and ranged from 65 to 95 (Fig. 5-3). Fewer striped bass were collected for evaluation in 2002, and Wr values appeared to be somewhat higher in 2002 than in 2001. In 2002, 57% of the striped bass had Wr's ≥80 compared to only 38% in 2001 (Duke Power 2003). However, too few fish were collected in 2002 to determine if this was a significant improvement. Low Wr's in striped bass ≥450 mm that were collected in 2002 indicated that these fish continued to be stressed during summer.

<u>FUTURE FISH STUDIES</u>

- Continue the spring electrofishing program annually and evaluate growth rates of largemouth bass

- Continue the September hydroacoustic/purse seine forage population assessment and implement a small mesh gill-net sampling program to evaluate forage fish abundance in the main tributary arms
- Continue striped bass mortality monitoring throughout the summer
- Continue the cooperative striped bass study with NCWRC to evaluate striped bass growth and condition as a function of stocking rates, forage availability, and summer striped bass habitat
- Implement a cooperative trapnetting program with NCWRC to evaluate black crappie abundance and age composition

The future studies/activities outlined above are subject to revision, based on an annual review of the data submitted to date and a re-evaluation of the McGuire Maintenance Monitoring Program by the NCWRC.

SUMMARY

In accordance with the Lake Norman Maintenance Monitoring Program for the NPDES permit for MNS, specific fish monitoring programs were coordinated with the NCWRC and continued during 2002. Spring electrofishing indicated that 14 to 20 species of fish and 1 hybrid complex composed fish populations in the 3 sampling locations, and that numbers and biomass of fish in 2002 were generally similar to those previously noted at these locations since 1993. Few dead striped bass were noted during the summer survey period indicating no major die-offs occurred. Relative weight of Lake Norman striped bass in November and December may have improved somewhat in 2002 over that noted in 2001, but large striped bass continued to exhibit low Wr's at this time of the year.

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Duke Power. 2003. Lake Norman maintenance monitoring program: 2001 summary. Duke Power, Charlotte, North Carolina.

Siler, J. R., W. J. Foris, and M. C. McInery. 1986. Spatial heterogeneity in fish parameters within a reservoir. Pages 122-136 *in* G. E. Hall and M. J. Van Den Avyle, editors. Reservoir Fisheries Management: Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland.

Table 5-1. Common and scientific names of fish collected from Lake Norman.

Common name	Scientific name
Longnose gar	*Lepisosteus osseus*
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorosoma petenense*
Hybrid shad	*Dorosoma* hybrid
Greenfin shiner	*Cyprinella chloristia*
Whitefin shiner	*Cyprinella nivea*
Common carp	*Cyprinus carpio*
Spottail shiner	*Notropis hudsonius*
Quillback	*Carpiodes cyprinus*
Shorthead redhorse	*Moxostoma macrolepidotum*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
White perch	*Morone americana*
Striped bass	*Morone saxatilis*
Redbreast sunfish	*Lepomis auritus*
Pumpkinseed	*Lepomis gibbosus*
Warmouth	*Lepomis gulosus*
Bluegill	*Lepomis macrochirus*
Redear sunfish	*Lepomis microlophus*
Hybrid sunfish	*Lepomis* hybrid
Spotted bass	*Micropterus punctulatus*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*

Table 5-2. Numbers and biomass of fish collected from 10 transects near the McGuire Nuclear Station, April 2002.

	Transects																					
	1		2		3		4		5		6		7		8		9		10		All	
Taxa	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg
Longnose gar															1	2.021					1	2.021
Gizzard shad	1	0.465													3	1.242					4	1.707
Greenfin shiner			2	0.005					3	0.010	10	0.024			17	0.049	7	0.017	7	0.022	46	0.127
Whitefin shiner			2	0.009	2	0.010			4	0.008	41	0.107	4	0.018	67	0.202	27	0.063	24	0.109	171	0.526
Common carp	1	1.115	1	2.109									1	1.928	4	7.604	4	5.270	1	1.665	12	19.691
Spottail shiner					2	0.014					72	0.362	1	0.007	16	0.077	7	0.034	37	0.215	135	0.709
Channel catfish	1	0.458													1	0.156					2	0.614
Redbreast sunfish	42	0.379	53	0.518	22	0.240	50	0.561	3	0.047	25	0.457	11	0.246	20	0.262	3	0.023	1	0.012	230	2.745
Warmouth					1	0.009	2	0.008							1	0.013	2	0.016	1	0.008	7	0.054
Bluegill	28	0.232	107	0.794	70	0.683	118	0.985	12	0.121	2	0.028	8	0.101	21	0.162	25	0.141	10	0.100	401	3.347
Redear sunfish	22	0.360	54	0.650	51	0.514	93	1.457	1	0.024	1	0.003	3	0.014	11	0.247	8	0.264	2	0.132	246	3.665
Hybrid sunfish	2	0.012	7	0.078	3	0.043	8	0.155	2	0.043	1	0.005	2	0.057	3	0.150	1	0.011			29	0.554
Spotted bass	3	0.870			2	0.077	1	0.027			2	0.143	1	0.038	6	0.744	1	0.495	5	1.453	21	3.847
Largemouth bass	11	3.709	17	3.293	12	3.619	5	1.474					2	0.125	1	0.405	5	1.892	2	0.739	55	15.256
Yellow perch																			1	0.011	1	0.011
All	111	7.600	243	7.456	165	5.209	277	4.667	25	0.253	154	1.129	33	2.534	172	13.334	90	8.226	91	4.466	1361	54.874

Table 5-3. Numbers and biomass of fish collected from 10 transects in a reference area between the McGuire Nuclear Station and Marshall Steam Station, April 2002.

	Transects																					
	1		2		3		4		5		6		7		8		9		10		All	
Taxa	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg
Longnose gar													1	1.803							1	1.803
Alewife							27	0.241	1	0.009	17	0.156									45	0.406
Gizzard shad	1	0.555			4	1.828	9	3.897	7	3.136	3	1.110	4	1.798					1	0.632	29	12.956
Greenfin shiner			21	0.068	1	0.002	5	0.013	4	0.005					3	0.010	37	0.088			71	0.186
Whitefin shiner	42	0.108	20	0.070	93	0.299	45	0.142	25	0.063	24	0.081	27	0.102	27	0.075	57	0.168	28	0.115	388	1.223
Common carp	2	3.070			1	2.110	2	3.708	2	4.548					1	1.202			2	3.425	10	18.063
Spottail shiner	2	0.012	4	0.018	17	0.075	29	0.148	3	0.011	1	0.006			1	0.006	55	0.258	3	0.017	115	0.551
Quillback															1	1.010					1	1.010
Channel catfish							1	0.273									1	1.155			2	1.428
Flathead catfish	1	0.482	1	0.910	1	0.094			1	22.700											4	24.186
White perch											1	0.223									1	0.223
Redbreast sunfish	23	0.265	68	0.900	61	0.769	14	0.286	12	0.301	3	0.067	8	0.242	30	3.550	37	0.611	52	0.704	308	7.695
Warmouth	5	0.070			2	0.013	1	0.008			1	0.004			4	0.092	1	0.002			14	0.189
Bluegill	81	0.742	72	0.679	143	1.315	25	0.360	40	0.586	5	0.045	28	0.408	44	0.435	95	1.088	45	0.460	578	6.118
Redear sunfish	18	0.520	16	0.146	10	0.135			11	0.325			10	0.612	10	0.362	4	0.121	6	0.082	85	2.303
Hybrid sunfish	2	0.023	3	0.015	5	0.158	4	0.091	5	0.084	1	0.042	3	0.087	4	0.064	7	0.221	3	0.070	37	0.855
Spotted bass					2	0.169			1	0.487											3	0.656
Largemouth bass	11	3.116	10	3.137	9	2.311	10	1.655	6	1.535			12	3.790	10	2.279	4	1.956	5	1.337	77	21.116
Black crappie							1	0.008					6	2.007							7	2.015
All	188	8.963	215	5.943	349	9.278	173	10.830	118	33.790	56	1.734	99	10.849	135	9.085	298	5.668	145	6.842	1776	102.982

Table 5-4. Numbers and biomass of fish collected from 10 transects near the Marshall Steam Station, April 2002.

	Transects																					
	1		2		3		4		5		6		7		8		9		10		All	
Taxa	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg	N	Kg
Alewife																			3	0.027	3	0.027
Gizzard shad							4	1.435							1	0.532			1	0.368	6	2.335
Threadfin shad																			1	0.004	1	0.004
Greenfin shiner							3	0.009	1	0.004			5	0.018					1	0.002	10	0.033
Whitefin shiner			17	0.080	2	0.006	30	0.159	10	0.041	8	0.030	113	0.455			22	0.108	68	0.303	270	1.182
Common carp	2	3.667					1	1.413					1	1.345	3	7.168	4	6.900			11	20.493
Spottail shiner			4	0.027			7	0.036	1	0.006			1	0.006	1	0.007	2	0.011	10	0.066	26	0.159
Quillback															2	2.480					2	2.480
Shorthead redhorse			1	0.239			1	0.280													2	0.519
Channel catfish					1	0.234															1	0.234
Flathead catfish					1	0.113															1	0.113
White perch																			1	0.200	1	0.200
Redbreast sunfish			1	0.090	19	0.621	9	0.094	16	0.311	2	0.187	24	0.520	36	0.627	38	0.553	17	0.312	162	3.315
Pumpkinseed	4	0.140																			4	0.140
Warmouth					4	0.039			2	0.046					4	0.042	2	0.010			12	0.137
Bluegill	2	0.043	4	0.284	72	1.021	80	0.672	64	0.809	5	0.173	30	0.280	98	0.950	46	0.555	22	0.310	423	5.097
Redear sunfish	6	0.496	7	0.538	8	0.760	32	0.916	8	0.550			4	0.507	2	0.133	4	0.391	7	0.940	78	5.231
Hybrid sunfish	2	0.118	1	0.139	4	0.098			8	0.216	2	0.147	3	0.068	7	0.109	2	0.010	1	0.010	30	0.915
Largemouth bass	7	1.981	11	4.829	14	6.628	16	6.427	3	2.616	15	3.781	2	0.095	10	2.335	16	4.758	15	3.761	109	37.211
Black crappie															1	0.500					1	0.500
Yellow perch							1	0.011			3	0.048									4	0.059
All	23	6.445	46	6.226	125	9.520	184	11.452	113	4.599	35	4.366	183	3.294	165	14.883	136	13.296	147	6.303	1157	80.384

Table 5-5. Dead or dying striped bass observed in Lake Norman, July-September 2002.

Date	Location	Length (mm)	Number
July 17	Channel Marker 2	520	1
July 25	Channel Marker 6	545	1
August 02	Cowan's Ford Dam	550	1
August 09	Channel Marker 3	530	1
August 22	Channel Marker 6	465	1
August 30	Cowan's Ford Dam	450	1

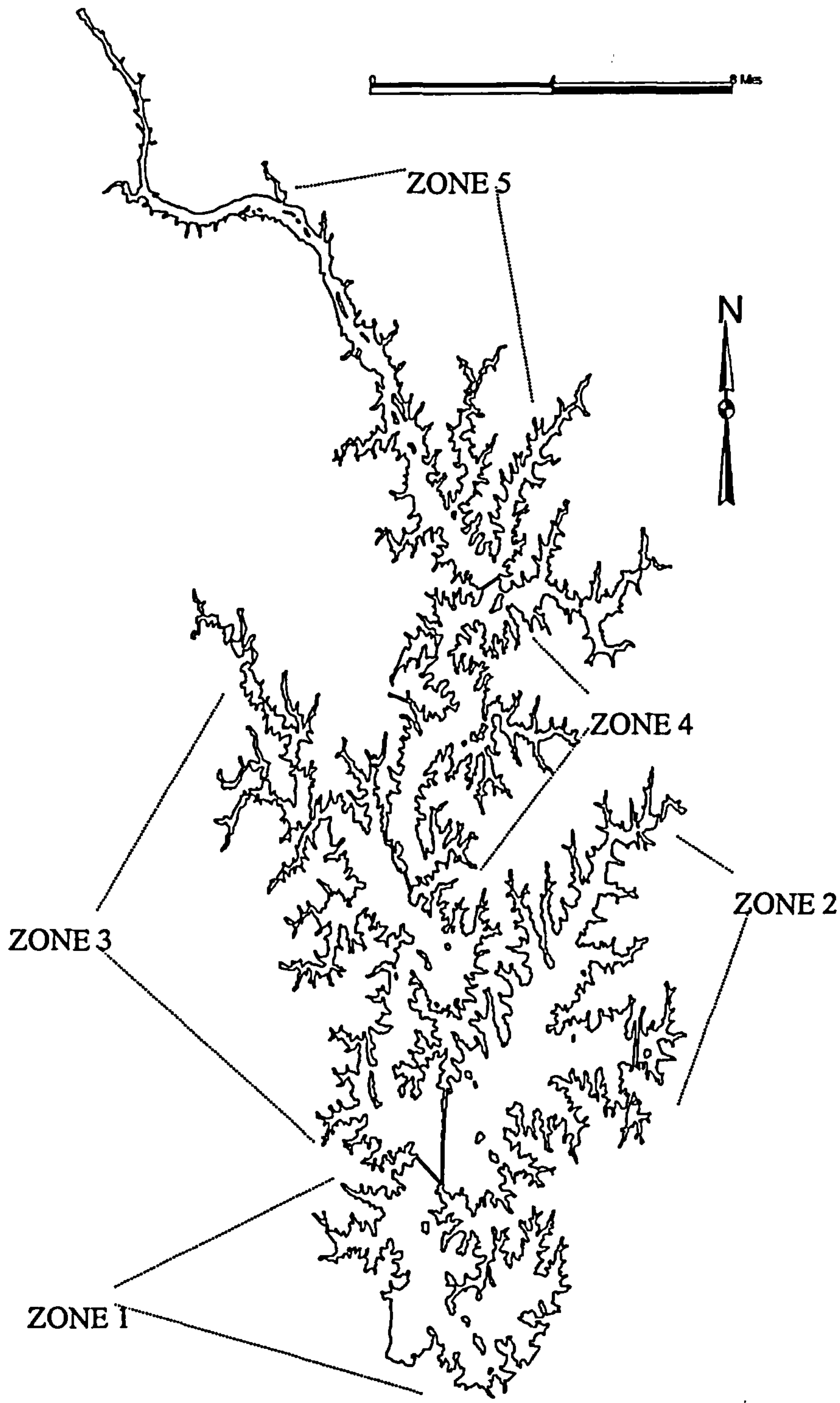
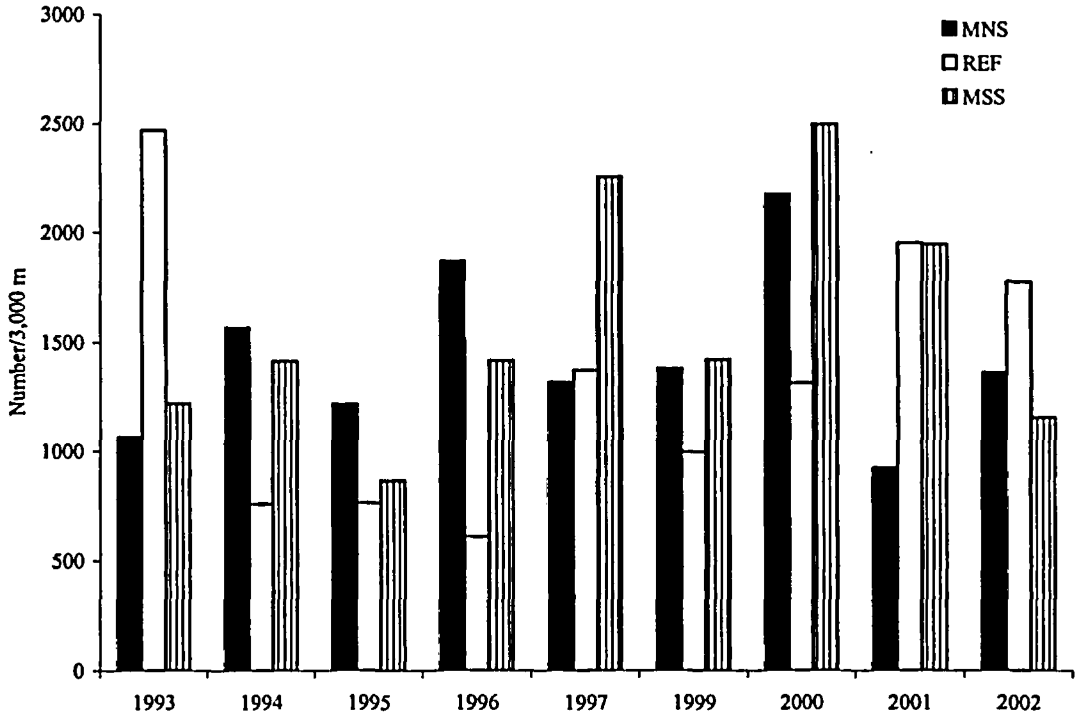


Figure 5-1. Sampling zones on Lake Norman, North Carolina.

Figure 5-2. Numbers and biomass of fish collected from three areas of Lake Norman, 1993-2002.



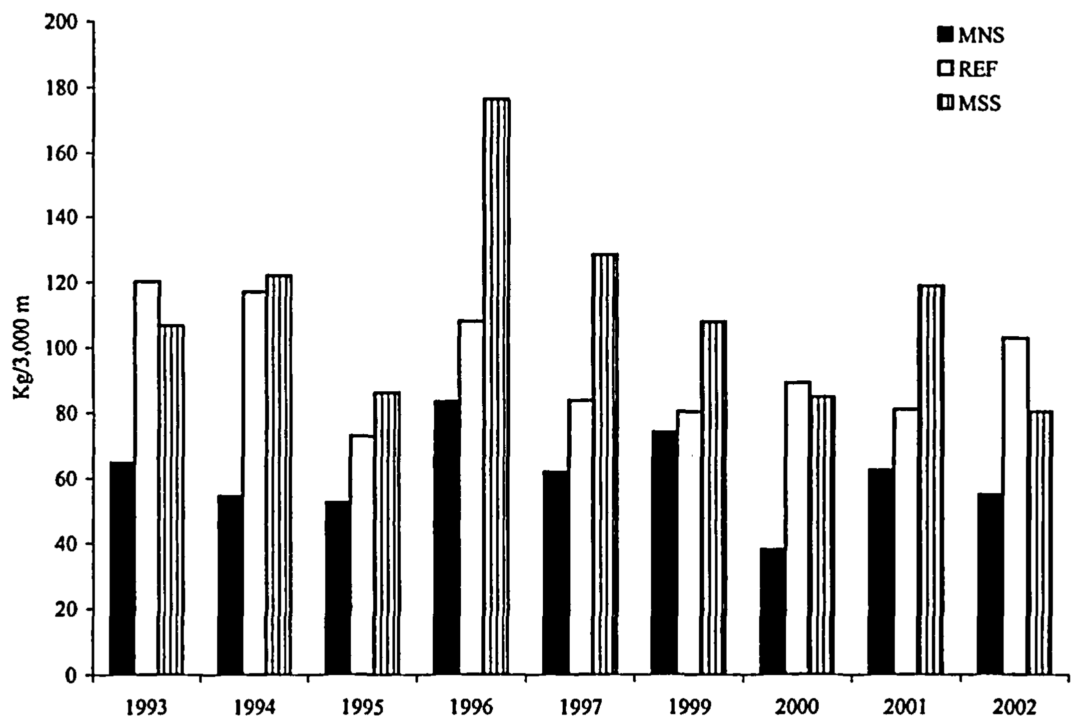
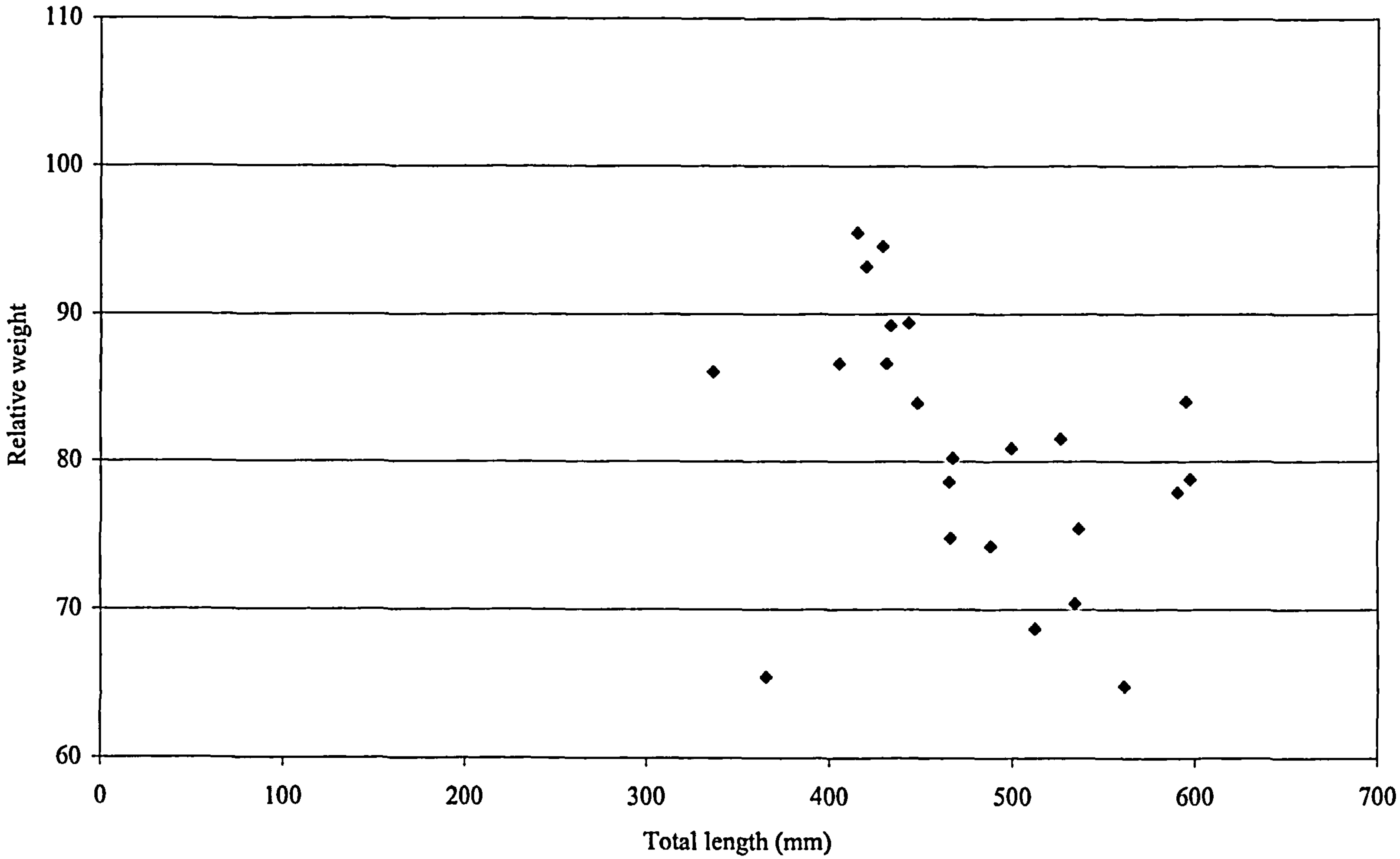


Figure 5-3. Relative weights of striped bass collected from Lake Norman, November-December 2002.



Attachment 1:

Lake Norman Hydroacoustic and Purse Seine Data: 2002

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of forage fish population parameters was conducted in 2002. This monitoring included a mobile hydroacoustic survey to estimate forage fish density and population size. Purse seine sampling was also employed to determine species composition and size distribution for target strength evaluation. A joint Duke Power / North Carolina Wildlife Resources Commission / North Carolina State University study to evaluate striped bass bioenergetics in Lakes Norman and Badin necessitated two additional hydroacoustic assessments and purse seine samples in 2002.

METHODS AND MATERIALS

Three mobile hydroacoustic surveys of the entire lake were conducted on July 1 and 2, (Bioenergetics Study), September 17 and 18 (MNS NPDES), and December 11 and 12 (Bioenergetics Study) to estimate forage fish populations. Hydroacoustic surveys employed multiplexing, side-scan and down-looking transducers to detect surface-oriented fish and deeper fish (from 2.0 m below the water surface to the bottom), respectively. Both transducers were capable of determining target strength directly by measuring fish position relative to the acoustic axis. The lake was divided into five zones (Figure 5-1) due to its large size, spatial heterogeneity, and multiple power generation facilities (drought conditions and resulting low water levels in 2002 prevented the assessment of the uppermost zone (Zone 6) in Lake Norman).

Purse seine samples were collected on June 25, September 16, and December 9, 2002 from the lower (main channel near Marker 1), mid (mouth of Davidson Creek), and uplake (just downlake of Lake Norman (Duke Power) State Park) areas of the reservoir. The purse seine measured 118 x 9 m (400 x 30 ft) with a mesh size of 4.8-mm (3/16 in). A subsample of forage fish collected from each area was used to determine taxa composition and size distribution.

RESULTS AND DISCUSSION

Forage fish densities in the five zones of Lake Norman ranged from 5,068 to 12,580 fish/ha in July 2002 (Table 1). Forage fish densities were highest uplake (Zone 5) and lowest downlake. The estimated lakewide population was approximately 103 million fish. Purse seine sampling indicated that these fish were 74.75% threadfin shad and 25.25% alewives. The length frequency distribution indicated that threadfin shad comprised two peaks; a lower one with a 45-mm modal length and an upper with a modal length of 100 mm. Alewives dominated a wide size range of individuals that were most numerous between 45 and 80 mm (Figure 1).

September 2002 forage fish densities ranged from a low of 3,228 (Zone 4) to a high of 9,363 (Zone 5). The estimated lakewide forage population was approximately 74 million fish. Purse seine sampling indicated that these fish were 70.27% threadfin shad and 29.73% alewives. The length frequency distribution indicated a bimodal forage fish population with the lower modal length of approximately 45 mm, representing threadfin shad, and the upper mode comprised of alewives with a 70-mm modal length (Figure 2).

Forage fish densities in the five zones of Lake Norman ranged from 1,413 to 2,172 fish/ha in December 2002. There were considerably fewer fish in the uplake zones compared to July and September estimates; densities were fairly homogeneous throughout the lake. The estimated forage population was approximately 25 million fish. Purse seine sampling indicated that these fish were 75.26% threadfin shad, 24.55% alewives, and 0.19% hybrid shad. The length frequency distribution indicated that threadfin shad dominated a large skewed size class of forage fish with a modal length of approximately 60 mm and lower numbers of larger individuals. Alewives occupied a larger size class with a modal length of approximately 85 mm (Figure 3).

Open water purse seine samples have undergone a dramatic shift in recent years. From 1993 through 1999, when the first alewife was collected, purse seine samples were totally composed of small threadfin shad (typically ≤55 mm). From 2000 through 2002 the open water forage fish community has shown increasing contributions from alewives (now ~25% of the community) and a concurrent wider size range of individuals. The average size of the young-of-the-year threadfin shad and alewives does increase throughout the year. The 2002 population estimates demonstrated a steady decline from the first sample (July) through the last (December) similar to the trend seen in 2000. It appears that natural mortality resulted in the steady decline of forage fish numbers throughout the year. Fishing mortality, resulting from bait collection, probably represents a very small proportion of the total mortality for forage fish. Lakewide population estimates in September 2002 were similar to values measured from 1997 to 2001.

Table 1. Lake Norman forage fish densities and population estimates by zone, and lakewide populations estimates and 95% confidence limits from three hydroacoustic samples in 2002.

	Density (no/hectare)			Population Estimate		
Zone	July	September	December	July	September	December
1	5,068	3,289	1,413	11,560,108	7,502,209	3,223,053
2	5,093	3,785	2,146	15,697,135	11,665,749	6,614,187
3	8,166	7,679	2,172	28,217,776	26,534,938	7,505,389
4	12,243	3,228	1,497	15,071,133	3,973,668	1,842,807
5	12,580	9,363	2,147	32,506,720	24,193,992	5,547,848
Total				103,052,873	73,870,556	24,733,284
95% LCL				95,065,240	67,453,128	21,081,450
95% UCL				111,040,506	80,287,983	28,385,118

*Zones 5 and 6 were combined for one density and one population estimate due to low water levels in Zone 6.

Figure 1. Lake Norman (combined) forage fish – June 2002. Data from the Davidson Creek sample has not been processed by NCSU.

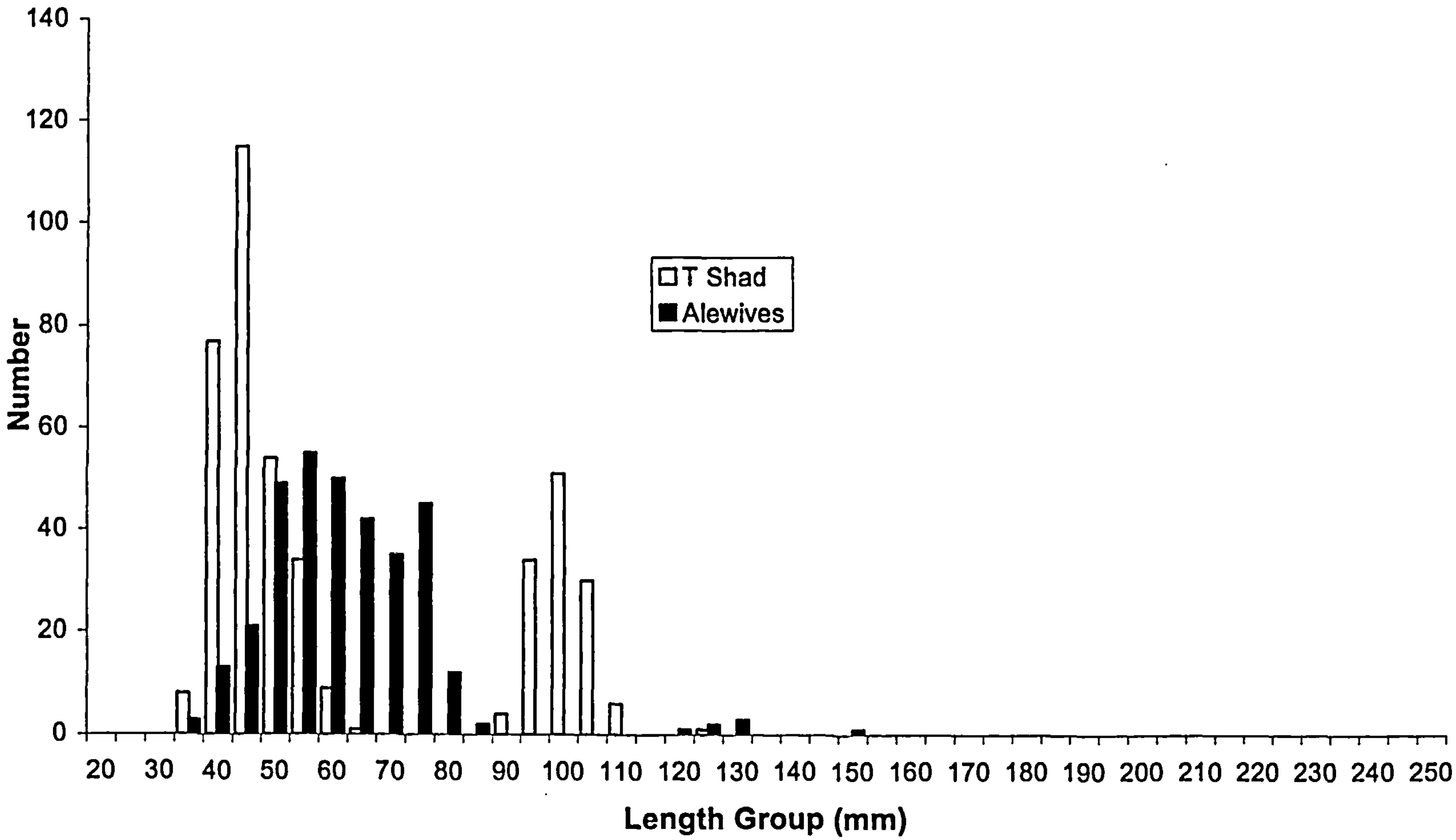


Figure 2. Lake Norman (combined) forage fish – September 2002. Data from the Davidson Creek sample has not been processed by NCSU.

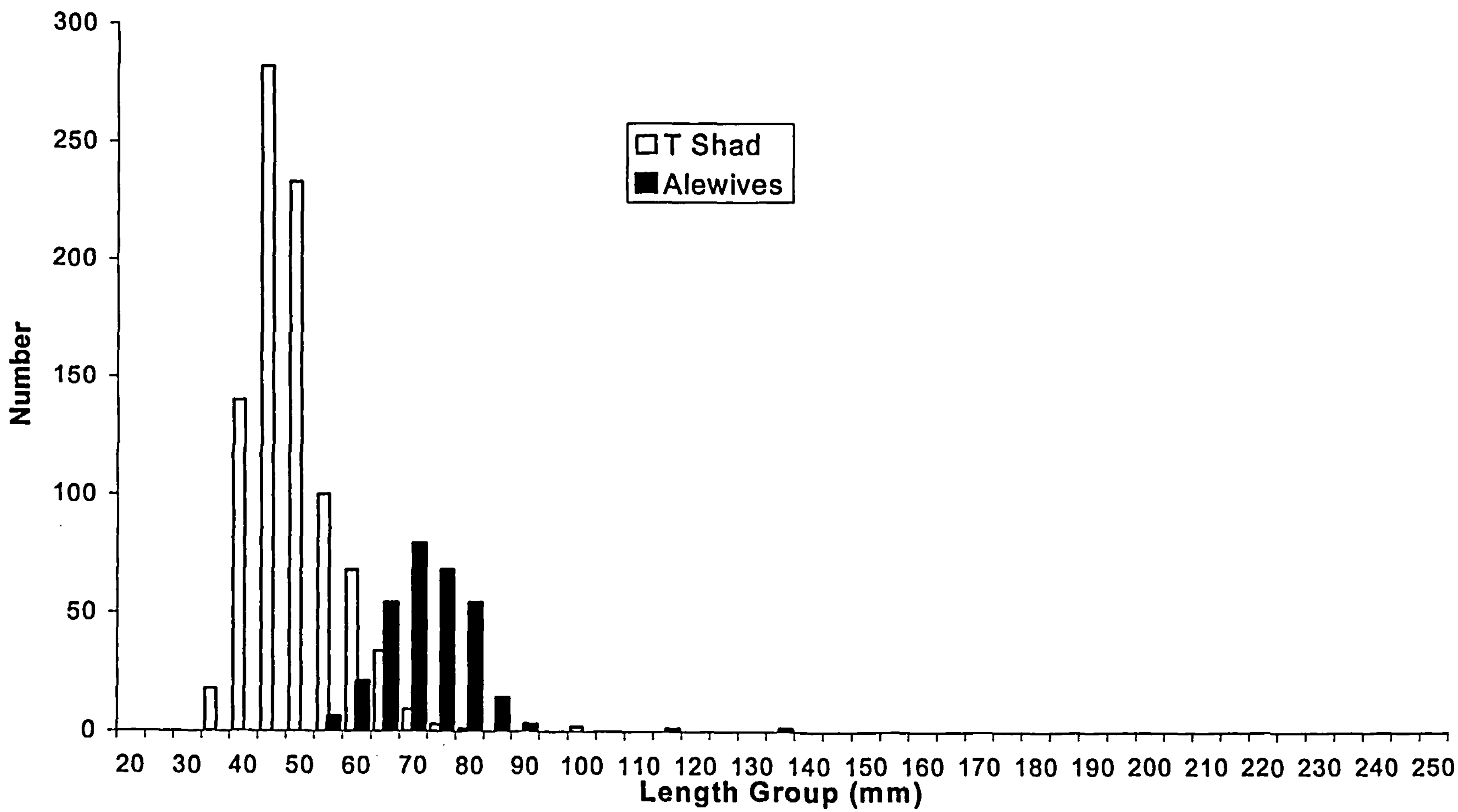


Figure 3. Lake Norman (combined) forage fish – December 2002. Data from the Davidson Creek sample has not been processed by NCSU.