Duke Energy Corporation
McGuire Nuclear Station
12700 Hagers Ferry Road
Huntersville, NC 28078-9340
(704) 875-4800 OFFICE
(704) 875-4809 FAX

H. B. Barron
Vice President

January 8, 2002

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

Subject: McGuire Nuclear Station
Docket Nos. 50-369, 50-370

Please find attached a copy of the annual "Lake Norman Maintenance Monitoring Program: 2000 Summary," as required by the National Pollutant Discharge Elimination System (NPDES) permit NC0024392. The report includes detailed results and data comparable to that of previous years. The report was submitted to the North Carolina Department of Environment and Natural Resources on December 18, 2001.

Any questions regarding this submittal should be directed to Kay Crane, McGuire Regulatory Compliance at (704) 875-4306.

H B Barron

H. B. Barron

C001

cc: Mr. R. E. Martin, Project Manager
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Luis Reyes, Regional Administrator
U.S. Nuclear Regulatory Commission
Region II
Atlanta Federal Center
61 Forsyth St., SW, Suite 23T85
Atlanta, Georgia 30303

Mr. Scott Shaeffer
Senior Resident Inspector
McGuire Nuclear Station

LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2000 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

Duke Power A Duke Energy Company

December 2001

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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 2000.

McGUIRE NUCLEAR STATION OPERATION

The monthly average capacity factor for MNS was 100.8 %, 92.1 %, and 52.0 % during July, August, and September of 2000, respectively. 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 97.9°F (36.6°C) for July, 96.3°F (35.7°C) for August, and 91.3°F (32.9°C) for September 2000. The low-level intake pumps of MNS were not operated to provide additional cooling in 2000. 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 DO data collected in 2000 were similar to those observed historically. Temperature and DO data collected in 2000 were within the range of previously measured values.

Reservoir-wide isotherm and isopleth information for 2000, 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 2000 was generally similar to historical conditions. All chemical parameters measured in 2000 were within the concentration ranges previously reported for the lake during both MNS preoperational and operational years. As has been observed historically, manganese concentrations in the bottom waters in the summer and fall of 2000 often exceeded the NC

water quality standard. This is characteristic of waterbodies that experience hypolimnetic deoxygenation during the summer.

PHYTOPLANKTON

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

In 2000 lake-wide mean chlorophyll *a* concentrations were all within ranges of those observed during previous years of the program. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. In most cases, total phytoplankton densities and biovolumes observed in 2000 were higher than those observed during 1999, and standing crops were generally within ranges established over previous years.

The proportions of ash-free dry weights to dry weights in 2000 were slightly higher than those of 1999, indicating little change in organic/inorganic inputs into Lake Norman. Diversity, or numbers of taxa, of phytoplankton had increased since 1999, and the total number of individual taxa was the highest yet recorded. The phytoplankton index (Myxophycean) tended to confirm the characterization of Lake Norman as oligo-mesotrophic. The annual index for 2000 was higher than that of 1999, and was at the lower end of the intermediate range.

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 2000, were likely due to environmental factors and appears not to be related to plant operations.

Epilimnetic zooplankton densities during all but May of 2000 were within ranges of those observed in previous years. The epilimnetic densities at Locations 2.0 and 5.0 in May 2000 were the highest recorded from these locations for this month, and may have represented a response to comparatively high phytoplankton standing crops in the Mixing Zone at that time.

One hundred and eight zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (fifty-one were identified during 2000). No previously unreported taxa were identified during 2000.

FISHERIES

In accordance with the Lake Norman Maintenance Monitoring Program for the NPDES permit for MNS, specific fish monitoring programs were coordinated with the North Carolina Wildlife Resources Commission (NCWRC) and continued during 2000. General monitoring of Lake Norman and specific monitoring of the MNS mixing zone for striped bass mortalities during the summer of 2000, yielded one mortality within the mixing zone and six mortalities in the main channel outside the mixing zone.

Spring shoreline electrofishing of Lake Norman yielded variable catches for the three areas sampled; the MNS mixing zone area, a mid-lake reference area, and the MSS mixing zone area. The total number of taxa collected was similar for all three areas.

During July 2000, forage fish densities in the six zones of Lake Norman ranged from 6,036 to 18,622 fish/ha. The estimated population was approximately 116 million fish. Purse seine sampling indicated that these fish were 96.24% threadfin shad, 3.26% alewives, and 0.50% gizzard shad.

September 2000 forage fish densities ranged from a low of 2,112 (Zone 6) to a high of 6,482 (Zone 2) and did not demonstrate the same fish distribution trend seen in July. The estimated forage population was approximately 63 million fish. Purse seine sampling indicated that these fish were 87.40% threadfin shad, 12.37% alewives, and 0.22% gizzard shad.

During November 2000, forage fish densities in the six zones of Lake Norman ranged from 579 to 2,294 fish/ha. The estimated forage population was approximately 24 million fish. No purse seine data were available for length frequency distributions or speciation of this population estimate.

Gillnetting for shad and alewives (forage species), collected jointly by NCWRC and Duke in November 2000 yielded a total of 330 fish from 14 net nights of sampling in three zones of Lake Norman. All three forage species (gizzard shad, threadfin shad, and alewives) were

collected from Zones 3 and 5, while only threadfin shad and alewives were collected from Zone 4.

Fisheries data to date indicate that the Lake Norman fishery is consistent with the trophic status and productivity of the reservoir. However, one aspect of the Lake Norman fishery that warrants close monitoring in the future is the composition of forage populations. The introduction of alewives by fishermen over the past several years could have a dramatic impact on lake-wide forage populations and game species.

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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 2000.

OPERATIONAL DATA FOR 2000

The monthly average capacity factor for MNS was 100.8 %, 92.1 %, and 52.0 % during July, August, and September of 2000, 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 97.9°F (36.6°C) for July, 96.3°F (35.7°C) for August, and 91.3°F (32.9°C) for September 2000. The low-level intake pumps of MNS were not operated to provide additional cooling in 2000. 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 2000.

Month	CAPACITY FACTOR (%) Unit 1 Average	Unit 2 Average	Station Average	NPDES DISCHARGE TEMPERATURE Monthly Average °F	°C
January	105.6	99.0	102.3	69.2	20.7
February	106.0	87.8	96.9	65.6	18.7
March	105.7	105.3	105.5	73.9	23.3
April	105.4	105.0	105.2	77.3	25.2
May	96.6	104.2	100.4	83.2	28.4
June	102.6	102.8	102.7	92.4	33.6
July	101.5	100.1	100.8	97.9	36.6
August	101.3	82.9	92.1	96.3	35.7
September	102.7	1.3	52.0	91.3	32.9
October	103.6	57.2	80.4	84.0	28.9
November	104.7	97.7	101.2	79.1	26.2
December	105.5	105.1	105.3	70.6	21.4

CHAPTER 2
WATER CHEMISTRY

INTRODUCTION

The objectives of the water chemistry portion of the Lake Norman Maintenance Monitoring Program are to:

1. Maintain continuity in Lake Norman's chemical data base to allow detection of 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 from other hydropower reservoirs and cooling impoundments in the Southeast.

This year's report focuses primarily on 1999 and 2000. Where appropriate, reference to pre-1999 data will be made by citing reports previously submitted to the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR).

METHODS AND MATERIALS

The water chemistry monitoring program, including sample variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1, whereas specific chemical methodologies, along with the appropriate references are presented in Table 2-2. 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). The first method involved partitioning the reservoir into mixing, background, and discharge zones, 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 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; 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 (mg/cm^2 or mg/L) content of the reservoir were calculated according to Hutchinson (1957), using the following equation:

$$Lt = A_0^{-1} \bullet \int_{zm}^{zo} TO \bullet Az \bullet dz$$

Where;

Lt = reservoir heat ($Kcal/cm^2$) or oxygen (mg/cm^2) content
A_0 = surface area of reservoir (cm^2)
TO = mean temperature (° C) or oxygen content of layer z
Az = area (cm^2) at depth z
dz = depth interval (cm)
zo = surface
zm = maximum depth

RESULTS AND DISCUSSION

Precipitation Amount

Total annual precipitation in the vicinity of MNS in 2000 totaled 33.68 inches (Figure 2-2); this was similar to that observed in 1999 (35.21 inches), but appreciably less than measured in the 1997 (48.0 inches). The highest total monthly rainfall in 2000 occurred in September with a value of 7.60 inches.

Temperature and Dissolved Oxygen

Water temperatures measured in 2000 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3, 2-4). 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 2000 were generally similar to corresponding measurements in 1999, except in early February when year 2000 temperatures averaged about 3 C cooler throughout the entire water column than observed in 1999 (Figure 2-3, 2-4). Interannual variability in water

temperatures during the spring, summer, and fall months was observed in both the mixing and background zones, but these conditions were well within the observed historical variability and were not considered of biological significance (DPC 1985, 1989, 1991, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000).

Temperature data at the discharge location in 2000 were generally similar to 1999 (Figure 2-5) and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000). The warmest discharge temperature of 2000 occurred in August and measured 34.7 °C, or 3.7 °C cooler than measured in August 1999 (DPC 2000).

Seasonal and spatial patterns of DO in 2000 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). Winter and early-spring DO values in 2000 were generally equal to or higher in the mixing zone, and lower in the background zone, than measured in 1999. These trends appear to be related to the cooler temperatures in the mixing zone, and warmer temperatures in the background zone measured in 2000 versus 1999. The cooler water temperatures would be expected to exhibit a higher oxygen content because of the direct effect of temperature on oxygen solubility, and indirectly via an enhanced convective mixing regime, which would promote reaeration.

Spring and summer DO values in 2000 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 1999 and earlier years (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1998, 1999, 2000). DO values during the spring and summer of 2000 generally averaged 1-2 mg/L less throughout the water column than measured in 1999; the lone exception to this was observed in June when DO values were slightly higher than measured in 1999. All dissolved oxygen values recorded in 2000 were well within the historical range (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000).

Considerable differences were observed between 1999 and 2000 fall and early-winter DO values in both the mixing and background zones, especially in the metalimnion and hypolimnion during November (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. Interannual differences in DO are common in Southeastern reservoirs, particularly during the stratified period, and can reflect yearly differences in hydrological, meteorological, and limnological forcing variables (Cole and Hannon 1985; Petts 1984).

The seasonal pattern of DO in 2000 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 2000 (5.4 mg/L) occurred in August, concurrent 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 2000 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 2000 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 1999 and 2000 are found in Table 2-3. Annual minimum heat content for the entire water column in 2000 (8.07 Kcal/cm^2; 7.9 °C) occurred in early February, whereas the maximum heat content (27.44 Kcal/cm^2; 27.19 °C) occurred in mid-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 February and measured 4.3 Kcal/cm^2 (6.6 °C), whereas the maximum occurred in early September and measured 15.46 Kcal/cm^2 (23.8°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 0.099 $Kcal/cm^2/day$ versus 0.053 $Kcal/cm^2/day$ for the hypolimnion. The 2000 heat content and heating rate data were slightly lower than measured in 1999, but similar to earlier years (DPC 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000).

The seasonal oxygen content and percent saturation of the whole water column, and the hypolimnion, are depicted for 2000 in Figure 2-10b. Additional oxygen data can be found in Table 2-4 which presents the 2000 AHOD for Lake Norman and similar estimates for 18 TVA reservoirs. Reservoir oxygen content was greatest in mid-winter when DO content measured 10.5 mg/L for the whole water column and 10.6 mg/L for the hypolimnion. Percent saturation values at this time approached 89% for the entire water column and 87% 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 4.73 mg/L (62% saturation), whereas the minimum for the hypolimnion was 0.66 mg/L (7.7% saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.033 $mg/cm^2/day$ (0.059 mg/L/day) (Figure 2-10b), and is similar to that measured in 1999 (DPC 2000).

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 0.033 $mg/cm^2/day$ for 2000. The oxygen based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 2000 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 1999

through mid-June 2000. Beginning in July 2000, 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 thin layer located in the metalimnion and a small zone of refuge in the upper, riverine portion of the reservoir, near the confluence of Lyles Creek with Lake Norman. Habitat measured in the upper reaches of the reservoir at this time 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 2000 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).

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 2000, ranging from 0.75 to 3.47 NTUs (Table 2-5). Bottom turbidity values were also relatively low over the study period, ranging from 0.93 to 33.4 NTUs (Table 2-5). These values were similar to those measured in 1999 (Table 2-5), and well within the historic range (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000).

Specific conductance in Lake Norman in 2000 ranged from 56.7 to 107.5 umho/cm, and was similar to that observed in 1999 (Table 2-5), and historically (DPC 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000). Specific conductance values in surface and bottom waters were generally similar throughout the year except during the period of thermal stratification. 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 2000, pH and alkalinity values were similar among MNS discharge, mixing and background zones (Table 2-5); they were also similar to values measured in 1999 (Table 2-5) and historically (DPC 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000). Individual pH values in 2000 ranged from 6.1 to 7.4, whereas alkalinity ranged from 15.0 to 32.0 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 2000 was similar to that reported for 1999 (Table 2-5) and previously (DPC 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000). 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 are provided in Table 2-5. Overall, nitrogen and phosphorus levels in 2000 were similar to those measured in 1999 and historically (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000). The lone exception to this pattern was total phosphorus. Total phosphorus concentrations in 2000 averaged about double that measured in 1999 for each of the zones investigated, but were well within the historical range (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000) (Table 2-5).

Metals

Metal concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 2000 were similar to that measured in 1999 (Table 2-5) and historically (DPC 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000). Iron concentrations near the surface were generally low (≤ 0.1 mg/L) during 2000, whereas iron levels near the bottom 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 1999 and 2000, 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). Heavy metal concentrations in Lake Norman never approached NC water quality standards, and there were no appreciable differences between 1999 and 2000.

FUTURE WATER CHEMISTRY STUDIES

No changes are planned for the Water Chemistry portion of the Lake Norman maintenance monitoring program during 2001or 2002.

SUMMARY

Temporal and spatial trends in water temperature and DO data collected in 2000 were similar to those observed historically. Temperature and DO data collected in 2000 were within the range of previously measured values.

Reservoir-wide isotherm and isopleth information for 2000, 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 2000 was generally similar to historical conditions. All chemical parameters measured in 2000 were within the concentration ranges previously reported for the lake during both MNS preoperational and operational years. As has been observed historically, manganese concentrations in the bottom waters in the summer and fall of 2000 often exceeded the NC water quality standard. 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.

2000 McGUIRE NPDES SAMPLING PROGRAM

PARAMETERS	LOCATIONS	1.0	2.0	4.0	5.0	8.0	9.5	11.0	13.0	14.0	15.0	15.9	62.0	69.0	72.0	80.0	16.0
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
	SAM CODE						IN-SITU ANALYSIS										
Temperature	Hydrolab																
Dissolved Oxygen	Hydrolab	ıly at the above locations at 1m intervals from 0.3m to 1m above bottom.															
pH	Hydrolab	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
Cadmium	HGA-CD		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Copper	HGA-CU		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Lead	HGA-PB		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 Solid:	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. Water chemistry methods and analyte detection limits for the McGuire Nuclear Station NPDES long-term maintenance program for Lake Norman.

Variables	Method	Preservation	Detection Limit
Alkalinity, total	Electrometric titration to a pH of 5.1[2]	4°C	$1 mg\text{-}CaCO3 \cdot l^{-1}$ *
Aluminum	Atomic emission/ICP-direct injecition[2]	0.5% HNO_3	$0.3 mg \cdot l^{-1}$
Ammonium	Automated phenate[1]	4°C	$0.050 mg \cdot l^{-1}$
Cadmium	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	$0.1 \mu g \cdot l^{-1}$
Calcium	Atomic emission/ICP-direct injecition[2]	0.5% HNO_3	$0.04 mg \cdot l^{-1}$
Chloride	Automated ferricyanide[1]	4°C	$1.0 mg \cdot l^{-1}$
Conductance, specific	Temperature compensated nickel electrode[1]	In-situ	$1 \mu mho \cdot cm^{-1}$ *
Copper	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	$0.5 \mu g \cdot l^{-1}$
Fluoride	Potentiometric[2]	4°C	$0.10 mg \cdot l^{-1}$
Iron	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	$0.1 mg \cdot l^{-1}$
Lead	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	$2.0 \mu g \cdot l^{-1}$
Magnesium	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	$0.001 mg \cdot l^{-1}$
Manganese	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	$0.003 mg \cdot l^{-1}$
Nitrite-Nitrate	Automated cadmium reduction[1]	4°C	$0.050 mg \cdot l^{-1}$
Orthophosphate	Automated ascorbic acid reduction[1]	4°C	$0.005 mg \cdot l^{-1}$
Oxygen, dissolved	Temperature compensated polarographic cell[1]	In-situ	$0.1 mg \cdot l^{-1}$
pH	Temperature compensated glass electrode[1]	In-situ	0.1 std. units*
Phosphorus, total	Persulfate digestion followed by automated ascorbic acid reduction[1]	4°C	$0.005 mg \cdot l^{-1}$ ** $0.015 mg \cdot l^{-1}$ **
Potassium	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	$0.1 mg \cdot l^{-1}$
Silica	Automated molydosilicate[1]	4°C	$0.5 mg \cdot l^{-1}$
Sodium	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	$0.3 mg \cdot l^{-1}$
Sulfate	Turbidimetric, using a spectrophotometer[3]	4°C	$1.0 mg \cdot l^{-1}$
Temperature	Thermistor/thermometer[1]	In-situ	0.1°C*
Turbidity	Nephelometric turbidity[1]	4°C	1 NTU*
Zinc	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	$4 \mu g \cdot l^{-1}$

[1]United States Environmental Protection Agency 1979. Methods for chemical analysis of water and wastes. Environmental Monitoring and Support Laboratory. Cincinnati, OH.
[2]USEPA. 1982
[3]USEPA. 1984
*Instrument sensitivity used instead of detection limit.
**Detection limit changed during 1989.

Table 2-3. Heat content calculations for the thermal regime in Lake Norman for 1999 and 2000.

	1999	2000
Maximum areal heat content (g cal/cm^2)	28,371	27,434
Minimum areal heat content (g cal/cm^2)	10,293	8066
Maximum hypolimnetic (below 11.5 m) areal heat content (g cal/cm^2)	15,649	15,459
Birgean heat budget (g cal/cm^2)	18,079	19,368
Epilimnion (above 11.5 m) heating rate (°C /day)	0.094	0.106
Hypolimnion (below 11.5 m) heating rate (°C /day)	0.085	0.082

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 (2000)	0.033	5.2	2.45	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 1999 and 2000. Values less than detection were assumed to be the detection limit for calculating a mean.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				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:	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99
Turbidity (ntu)																						
Feb	3.27	1.87	4.53	6.24	3.13	1.57	3.00	8.17	3.47	1.76	1.68	1.78	3.96	4.29	3.62	1.63	33.4	7.69	3.15	1.74	4.08	12.20
May	1.22	1.77	1.22	12.50	0.98	2.04	0.93	2.88	0.95	2.61	0.88	2.32	1.16	3.28	0.75	2.16	1.82	3.22	0.97	2.88	2.49	3.33
Aug	1.04	1.71	3.47	5.24	1.33	2.14	2.24	2.83	0.88	1.50	1.57	1.47	9.23	2.73	1.55	1.63	4.92	2.79	1.61	1.99	5.9	2.62
Nov	0.97	1.85	6.9	3.76	1.04	2.01	7.36	5.75	1.53	2.65	1.04	2.23	3.77	4.25	1.07	2.13	8.32	4.25	1.60	2.19	2.87	12.00
Annual Mean	1.63	1.80	4.02	6.9	1.62	1.9	3.38	4.9	1.71	2.1	1.29	2.0	4.53	3.6	1.75	1.9	12.12	4.5	1.83	2.2	3.84	7.5
Specific Conductance (umho/cm)																						
Feb	57.1	52	57.0	68	57.1	51	56.9	61	58.1	53	57.8	52	57.0	53	57.2	51	56.7	67	60.4	53	59.5	66
May	58.5	60	58.7	95	60.2	60	59.3	59	60.6	60	60.3	60	59.8	59	61.7	60	61.3	59	60.7	60	62.9	66
Aug	64.0	60	74.0	66	64.0	60	77.0	64	65.0	60	64.0	60	75.0	63	64.0	60	70.0	63	63.0	61	74.0	61
Nov	64.0	64	107.6	105	64.2	64	105.1	79	66.7	64	66.6	64	67.4	63	65.6	63	92.3	63	66.5	64	73.3	65
Annual Mean	60.9	59.0	74.3	83.5	61.4	58.8	74.6	65.8	62.6	59.3	62.2	59.0	64.8	59.5	62.1	58.5	70.1	63.0	62.7	59.5	67.4	64.5
pH (units)																						
Feb	6.5	6.3	6.6	6.3	7.0	6.6	6.7	6.3	7.2	6.6	7.0	6.7	6.6	6.4	7.0	6.7	6.8	6.5	7.0	6.7	6.8	6.5
May	6.9	6.3	6.1	6.2	6.8	6.5	6.1	6.5	6.9	6.5	7.1	6.6	6.3	6.7	6.9	6.7	6.2	6.5	7.1	6.7	6.2	6.4
Aug	7.2	7.1	6.2	6.3	7.4	7.2	6.3	6.2	6.8	6.8	7.0	7.0	6.4	6.1	7.1	7.9	6.2	6.2	6.6	8.0	6.2	6.2
Nov	7.0	6.6	6.8	6.6	7.1	6.8	6.8	6.5	7.1	6.8	7.1	6.9	6.6	6.7	7.2	7.0	6.7	6.8	7.0	7.0	6.6	6.5
Annual Mean	6.91	6.55	6.43	6.32	7.07	6.75	6.48	6.38	6.99	6.68	7.04	6.79	6.46	6.47	7.04	7.07	6.46	6.48	6.92	7.11	6.47	6.39
Alkalinity (mg CaCO3/l)																						
Feb	15.5	13.0	16.0	13.0	16.5	13.0	15.5	13.5	16.0	13.0	16.0	13.0	15.5	13.5	16.0	12.5	15.5	13.5	15.5	13.5	15.5	12.5
May	15.5	14.5	15.5	14.0	15.0	14.0	15.5	14.0	15.0	14.0	15.5	13.5	15.5	14.0	15.0	13.5	15.0	14.0	15.0	13.5	15.5	14.0
Aug	16.5	15.0	17.0	17.5	16.5	14.5	17.5	14.5	16.0	14.5	17.0	14.5	23.5	15.5	16.5	14.5	20.0	17.0	16.5	14.0	22.0	16.0
Nov	17.0	16.0	32.0	16.5	17.0	16.0	34.5	16.0	17.0	16.0	17.0	16.0	17.0	16.0	17.0	15.5	30.0	15.5	16.5	15.5	18.5	15.5
Annual Mean	16.14	14.64	20.14	15.26	16.26	14.39	20.77	14.51	16.01	14.39	16.39	14.26	17.89	14.76	16.14	14.01	20.14	15.01	15.89	14.14	17.89	14.51
Chloride (mg/l)																						
Feb	5.5	4.9	5.6	5.2	5.6	5.1	5.5	5.5	5.7	4.9	5.6	4.8	5.5	5.0	5.8	4.8	5.7	5.8	6.1	4.9	5.8	6.3
May	5.8	5.1	5.7	5.2	5.6	5.0	5.8	5.1	5.8	5.1	5.8	5.1	5.8	5.1	5.7	5.1	5.7	5.2	5.6	5.2	5.7	5.0
Aug	5.7	5.0	5.9	4.8	5.6	4.9	5.8	4.9	5.7	4.9	5.6	4.9	5.6	4.9	5.7	4.9	5.7	4.7	5.7	4.9	6.0	4.8
Nov	5.6	5.0	5.9	5.0	5.7	5.0	6.0	5.0	5.7	5.0	5.8	4.9	5.7	4.9	5.6	5.0	5.8	5.0	5.6	5.0	5.6	5.4
Annual Mean	5.65	5.00	5.78	5.05	5.63	5.00	5.78	5.13	5.73	4.98	5.70	4.93	5.65	4.98	5.70	4.95	5.73	5.18	5.75	5.00	5.78	5.38
Sulfate (mg/l)																						
Feb	5.45	NS	5.76	NS	5.46	4.5	5.46	5.0	5.48	4.4	5.48	NS	5.44	NS	5.53	4.3	5.46	5.3	5.97	NS	5.88	NS
May	5.94	NS	5.98	NS	6.03	8.7	5.96	8.2	6.21	8.2	6.04	NS	5.95	NS	6.80	9.1	5.92	8.0	6.13	NS	5.96	NS
Aug	6.22	NS	5.95	NS	6.24	6.5	5.75	NS	6.22	8.6	6.22	NS	5.31	NS	7.50	9.6	5.59	NS	6.23	NS	5.47	NS
Nov	6.15	NS	3.78	NS	6.14	7.7	16.5	8.2	6.13	6.8	6.06	NS	6.01	NS	7.00	7.5	3.96	7.2	6.23	NS	6.13	NS
Annual Mean	5.94		5.37		5.97	6.85	8.43	7.13	6.01	7.00	5.95		5.68		6.71	7.63	5.23	6.83	6.14		5.86	
Calcium (mg/l)																						
Feb	2.83	2.71	2.79	2.67	2.95	2.75	3.01	2.72	2.86	2.72	2.88	2.73	2.95	2.69	2.79	2.75	2.89	2.70	2.69	2.76	2.91	2.84
May	3.05	2.86	3.09	2.95	2.91	2.87	2.89	2.92	2.93	2.88	2.99	2.87	3.03	2.86	2.62	2.89	3.05	2.97	3.06	3.10	3.20	3.04
Aug	3.15	3.01	3.37	3.33	3.14	3.02	3.46	3.21	3.16	2.99	3.12	3.00	3.57	3.15	3.11	2.99	3.40	3.29	3.21	3.05	3.65	3.26
Nov	3.29	3.11	4.03	3.17	3.21	3.13	4.11	3.15	3.22	3.12	3.22	3.17	3.25	3.14	3.22	3.14	4.02	3.16	3.19	2.97	3.07	2.68
Annual Mean	3.08	2.92	3.32	3.03	3.05	2.94	3.37	3.00	3.04	2.93	3.05	2.94	3.20	2.96	2.94	2.94	3.34	3.03	3.04	2.97	3.21	2.95
Magnesium (mg/l)																						
Feb	1.43	1.33	1.42	1.32	1.46	1.35	1.51	1.36	1.44	1.33	1.45	1.33	1.48	1.33	1.41	1.35	1.44	1.33	1.38	1.34	1.48	1.35
May	1.52	1.38	1.53	1.42	1.45	1.38	1.45	1.39	1.46	1.38	1.46	1.38	1.51	1.38	1.33	1.38	1.49	1.41	1.43	1.40	1.51	1.41
Aug	1.54	1.45	1.57	1.55	1.53	1.44	1.62	1.50	1.53	1.42	1.52	1.44	1.65	1.48	1.52	1.44	1.54	1.52	1.51	1.46	1.62	1.50
Nov	1.62	1.53	1.76	1.55	1.59	1.52	1.78	1.52	1.59	1.53	1.60	1.55	1.60	1.53	1.59	1.53	1.76	1.56	1.59	1.52	1.57	1.49
Annual Mean	1.53	1.42	1.57	1.46	1.51	1.42	1.59	1.44	1.50	1.41	1.51	1.43	1.56	1.43	1.46	1.42	1.56	1.45	1.48	1.43	1.55	1.44

NS = Not Sampled

Table 2-5. (Continued)

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				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:	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99
Potassium (mg/l)																						
Feb	1.67	1.62	1.67	1.63	1.75	1.66	1.82	1.74	1.72	1.64	1.72	1.62	1.78	1.62	1.66	1.69	1.65	1.70	1.63	1.69	1.82	1.70
May	1.91	1.50	1.85	1.67	1.76	1.56	1.74	1.60	1.77	1.59	1.95	1.58	1.82	1.56	1.59	1.65	1.88	1.58	1.73	1.45	1.86	1.49
Aug	1.71	1.61	1.79	1.67	1.82	1.59	1.74	1.60	1.76	1.58	1.73	1.57	1.86	1.59	1.83	1.58	1.65	1.59	1.73	1.58	1.80	1.57
Nov	1.85	1.73	1.92	1.85	1.82	1.83	1.99	1.85	1.84	1.81	1.85	1.86	1.82	1.80	1.80	1.82	1.91	1.86	1.85	1.85	1.84	1.90
Annual Mean	1.79	1.62	1.81	1.68	1.79	1.66	1.82	1.70	1.77	1.66	1.81	1.66	1.82	1.64	1.72	1.66	1.77	1.68	1.74	1.64	1.83	1.67
Sodium (mg/l)																						
Feb	6.43	5.64	6.27	5.98	7.33	5.80	6.99	6.52	6.57	5.63	6.34	5.51	6.62	5.77	6.40	5.87	6.55	6.74	7.16	6.18	7.41	7.02
May	6.72	6.18	6.79	6.27	6.37	6.02	6.31	6.47	6.58	6.16	6.45	5.89	6.36	6.18	5.82	6.24	6.69	6.35	6.08	6.33	6.57	6.40
Aug	7.12	6.12	6.43	6.19	6.84	5.84	7.30	5.84	6.93	6.35	7.12	5.54	6.76	5.83	7.19	6.02	6.76	5.66	7.06	6.04	6.72	5.87
Nov	6.46	5.63	6.19	6.43	6.61	6.21	6.26	6.07	6.40	6.41	6.40	6.37	6.37	6.18	6.46	6.48	6.06	6.07	6.50	6.28	6.87	7.08
Annual Mean	6.68	5.89	6.42	6.22	6.79	5.97	6.72	6.23	6.62	6.14	6.58	5.83	6.50	5.99	6.47	6.15	6.62	6.21	6.70	6.21	6.84	6.59
Aluminum (mg/l)																						
Feb	0.12	0.05	0.125	0.10	0.127	0.10	0.134	0.16	0.129	0.09	0.148	0.08	0.121	0.12	0.14	0.11	0.236	0.14	0.124	0.11	0.159	0.23
May	0.08	0.05	0.068	0.26	0.061	0.13	0.061	0.13	0.081	0.13	0.077	0.11	0.076	0.12	0.068	0.13	0.086	0.18	0.086	0.11	0.112	0.12
Aug	0.062	0.05	0.113	0.19	0.094	0.07	0.131	0.16	0.087	0.09	0.1	0.08	0.15	0.12	0.109	0.10	0.118	0.15	0.098	0.11	0.147	0.15
Nov	0.05	0.05	0.08	0.20	0.05	0.14	0.08	0.21	0.05	0.15	0.05	0.16	0.05	0.18	0.05	0.16	0.06	0.19	0.05	0.16	0.05	0.33
Annual Mean	0.08	0.05	0.0963	0.19	0.083	0.11	0.1008	0.17	0.0868	0.11	0.0938	0.11	0.0993	0.14	0.0918	0.12	0.124	0.17	0.0895	0.12	0.117	0.21
Iron (mg/l)																						
Feb	0.019	0.029	0.026	0.098	0.021	0.031	0.037	0.145	0.021	0.030	0.020	0.032	0.027	0.084	0.020	0.024	0.211	0.121	0.024	0.038	0.069	0.366
May	0.027	0.041	0.040	0.369	0.019	0.037	0.020	0.039	0.017	0.032	0.022	0.027	0.051	0.041	0.010	0.028	0.027	0.066	0.024	0.054	0.063	0.082
Aug	0.030	0.048	0.068	0.309	0.028	0.038	0.055	0.142	0.030	0.041	0.023	0.035	0.756	0.105	0.033	0.037	0.266	0.163	0.029	0.035	0.450	0.106
Nov	0.033	0.035	1.281	0.147	0.039	0.043	3.218	0.127	0.052	0.048	0.041	0.044	0.129	0.113	0.029	0.038	1.960	0.071	0.053	0.057	0.161	0.386
Annual Mean	0.027	0.038	0.354	0.231	0.027	0.037	0.833	0.113	0.030	0.038	0.027	0.035	0.241	0.086	0.023	0.032	0.616	0.103	0.033	0.046	0.186	0.235
Manganese (mg/l)																						
Feb	0.01	0.02	0.02	0.06	0.01	0.01	0.01	0.08	0.01	0.01	0.01	0.01	0.02	0.04	0.01	0.01	0.06	0.07	0.01	0.01	0.02	0.09
May	0.01	0.01	0.02	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.04	0.05
Aug	0.02	0.02	0.31	1.30	0.02	0.02	1.18	0.75	0.02	0.02	0.02	0.02	2.47	0.45	0.02	0.01	0.87	0.32	0.01	0.03	2.20	0.69
Nov	0.04	0.04	5.18	0.29	0.05	0.04	5.15	0.13	0.07	0.04	0.07	0.04	0.42	0.09	0.03	0.03	3.72	0.03	0.07	0.02	1.19	0.35
Annual Mean	0.02	0.02	1.38	0.43	0.02	0.02	1.59	0.24	0.03	0.02	0.03	0.02	0.73	0.15	0.01	0.02	1.17	0.11	0.02	0.02	0.86	0.29
Cadmium (ug/l)																						
Feb	0.5	NS	0.5	NS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	NS	0.5	NS	0.5	0.5	0.5	0.5	0.5	NS	0.5	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	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
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		0.5	
Copper (ug/l)																						
Feb	2.00	NS	2	NS	2	2.0	2	4.8	2	2.0	2	NS	2	NS	2	2.0	4.89	2.0	2.83	NS	2.58	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	2.0	NS	5.0	NS	2.3	NS	2.1	NS	2.0	NS	2.0	NS	2.0	NS	2.0	NS	2.0	NS	2.0	NS	2.0	NS
Nov	2.1	NS	2.2	NS	2.0	NS	2.0	NS	2.0	NS	2.0	NS	2.3	NS	2.0	NS	2.0	NS	3.1	NS	2.1	NS
Annual Mean					2.1	2.0	2.0	4.8	2.0	2.0					2.0	2.0	3.0	2.0				
Lead (ug/l)																						
Feb	2	NS	2	NS	2	2	2	2	2	2	2	NS	2	NS	2	2	2	2	2	NS	2	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	NS	2	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				Mixing Zone 2.0				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	
YEAR:	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99	2000	99
Zinc (ug/l)																						
Feb	5	5	8	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5
May	5	5	5	5	5	5	5	5	5	5	9	5	5	5	5	5	5	5	5	5	5	5
Aug	5	7	12	5	5	5	5	19	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Nov	5	5	9	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Annual Mean	5.0	5.5	8.5	5.0	5.0	5.0	5.0	8.5	5.0	5.0	6.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.3	5.0
Nitrate (ug/l)																						
Feb	100	160	100	190	100	170	100	190	100	170	100	170	100	180	100	160	90	240	160	180	150	290
May	160	220	240	270	160	220	240	240	160	230	160	220	220	220	160	220	220	290	190	290	260	330
Aug	20	100	290	320	20	100	240	60	60	120	40	120	30	260	30	60	180	320	20	20	140	330
Nov	70	70	20	50	70	70	20	50	70	70	80	60	180	60	60	70	20	50	120	120	210	110
Annual Mean	87.5	137.5	162.5	207.5	87.5	140.0	150.0	135.0	97.5	147.5	95.0	142.5	132.5	180.0	87.5	127.5	127.5	225.0	122.5	152.5	190.0	265.0
Ammonia (ug/l)																						
Feb	20	30	20	80	20	30	20	80	20	40	20	30	20	60	20	30	20	80	40	40	40	100
May	20	20	20	20	20	20	20	20	20	30	20	20	20	20	20	20	20	20	20	20	20	20
Aug	20	20	20	20	20	20	50	20	20	20	20	20	180	20	20	20	60	20	20	20	100	20
Nov	20	30	580	70	20	30	730	40	20	30	20	20	20	40	20	20	610	20	70	20	80	3100
Annual Mean	20.0	25.0	155.0	47.5	20.0	25.0	205.0	40.0	20.0	30.0	20.0	22.5	60.0	35.0	20.0	22.5	177.5	35.0	37.5	25.0	60.0	810.0
Total Phosphorous (ug/l)																						
Feb	7	5	7	11	6	5	8	14	26	9	31	9	6	7	17	5	7	10	9	5	7	26
May	9	7	11	10	7	5	6	8	6	8	8	6	8	6	7	5	7	6	10	8	10	8
Aug	23	7	16	9	18	7	9	6	26	6	10	7	20	8	10	7	11	6	18	7	29	8
Nov	13	5	14	5	8	5	14	5	9	5	159	5	11	7	10	6	24	8	17	5	26	12
Annual Mean	13.0	6.0	12.0	8.8	9.8	5.5	9.3	8.3	16.8	7.0	52.0	6.8	11.3	7.0	11.0	5.8	12.3	7.5	13.5	6.3	18.0	13.5
Orthophosphate (ug/l)																						
Feb	5	5	5	6	5	5	5	10	5	6	5	5	5	5	5	5	5	6	5	5	5	9
May	5	5	5	5	5	5	5	5	5	5	6	5	6	5	14	5	6	5	5	5	6	5
Aug	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Nov	5	5	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Annual Mean	5.0	5.0	5.0	5.3	5.0	5.0	5.3	6	5.0	5	5.3	5	5.3	5	7.3	5	5.0	5	5.0	5	5.3	6
Silica (mg/l)																						
Feb	3.3	3.6	3.2	4.0	3.2	3.6	3.3	4.1	3.2	3.6	3.2	3.6	3.2	3.9	3.3	3.6	3.1	4.5	4.1	3.7	4.0	4.8
May	3.4	4.0	4.0	4.5	3.5	4.1	4.0	4.2	3.6	4.1	3.5	4.1	3.9	4.2	3.5	4.2	3.9	4.6	3.4	4.9	4.3	4.9
Aug	2.0	3.9	4.6	5.0	2.0	3.9	4.6	4.8	2.2	3.9	2.1	3.9	4.2	4.4	2.0	3.9	4.2	4.8	2.1	4.2	4.5	4.6
Nov	2.7	4.4	5.3	4.3	2.7	4.3	5.8	4.2	2.7	4.3	2.7	4.3	3.2	4.3	2.6	4.3	5.1	4.1	3.3	4.4	4.4	5.2
Annual Mean	2.9	4.0	4.3	4.6	2.9	4.0	4.4	4.3	2.9	4.0	2.9	4.0	3.6	4.2	2.9	4.0	4.1	4.6	3.2	4.3	4.3	4.9

NS = Not Sampled

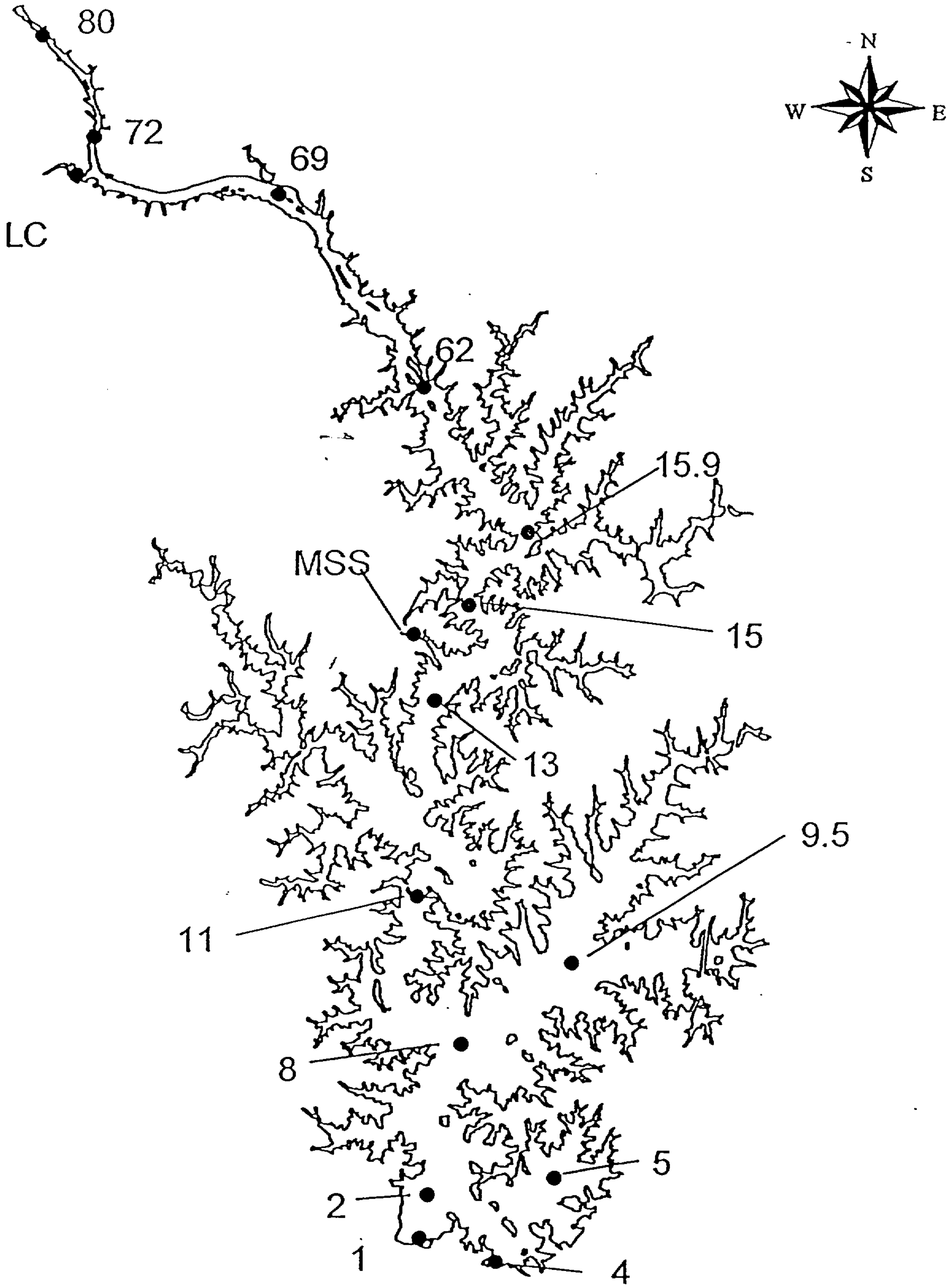

Figure 2-1 Map of sampling locations on Lake Norman

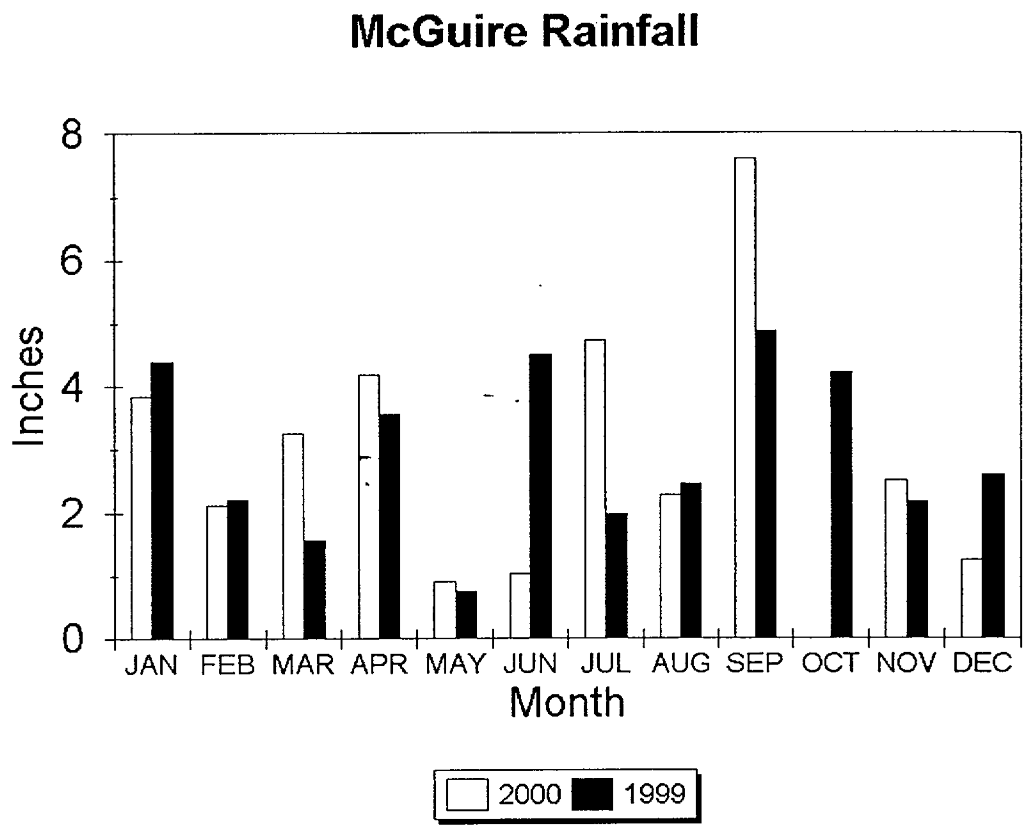

Figure 2-2. Monthly precipitation in the vicinity of McGuire Nuclear Station.

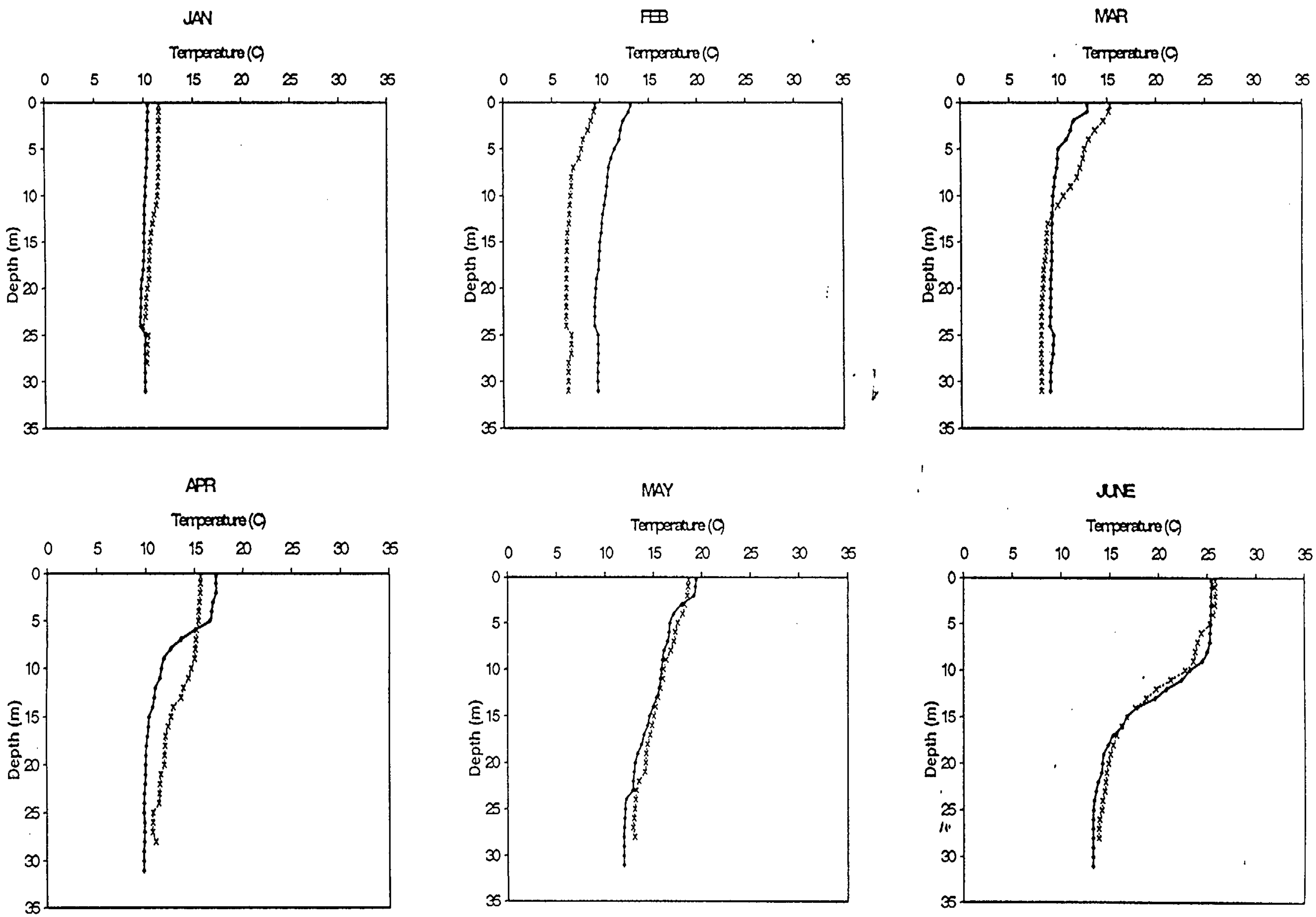

Figure 2-3. Monthly mean temperature profiles for the McGuire Nuclear Station background zone in 1999 (♦♦) and 2000 (××).

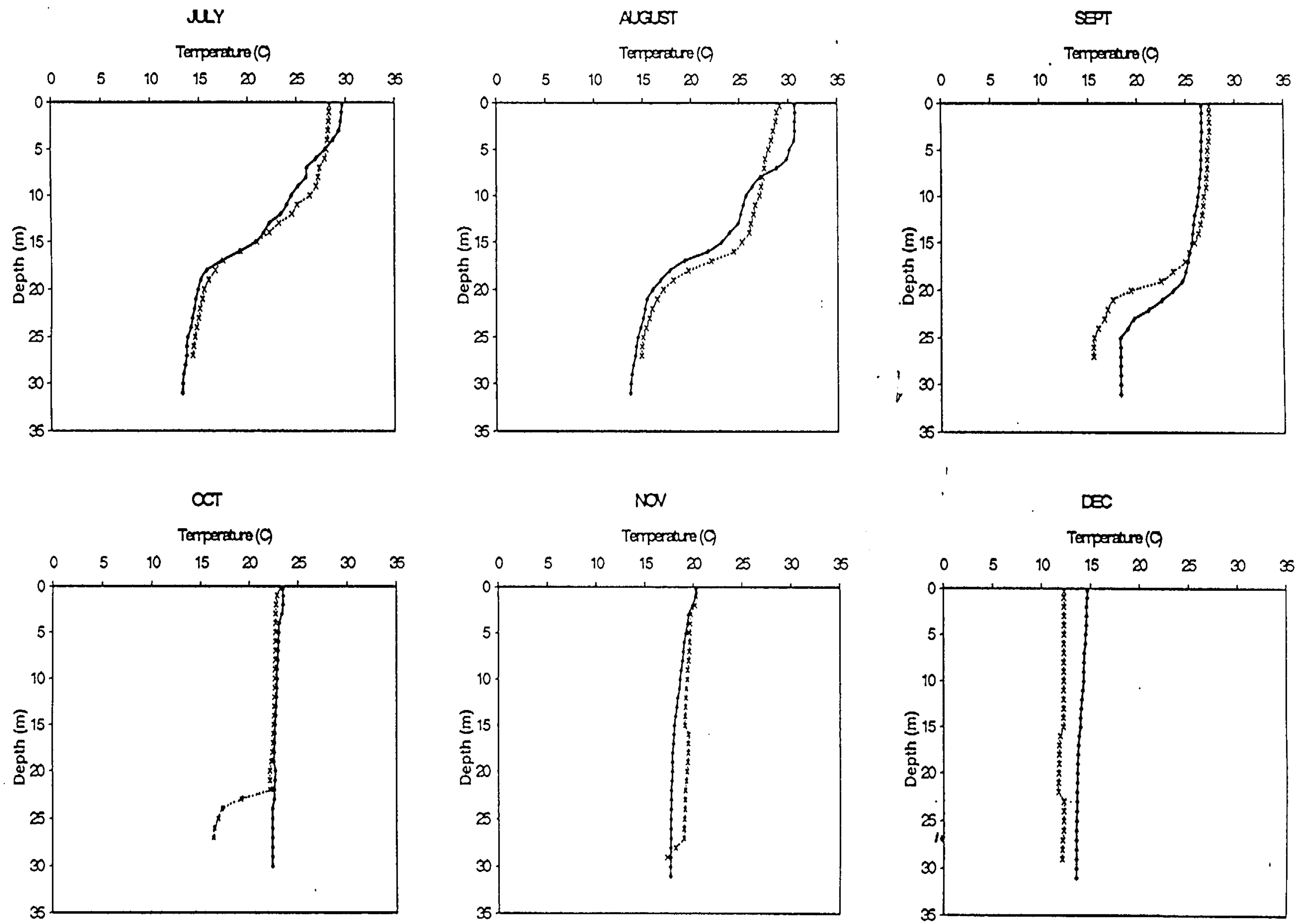

Figure 2-3. (con't).

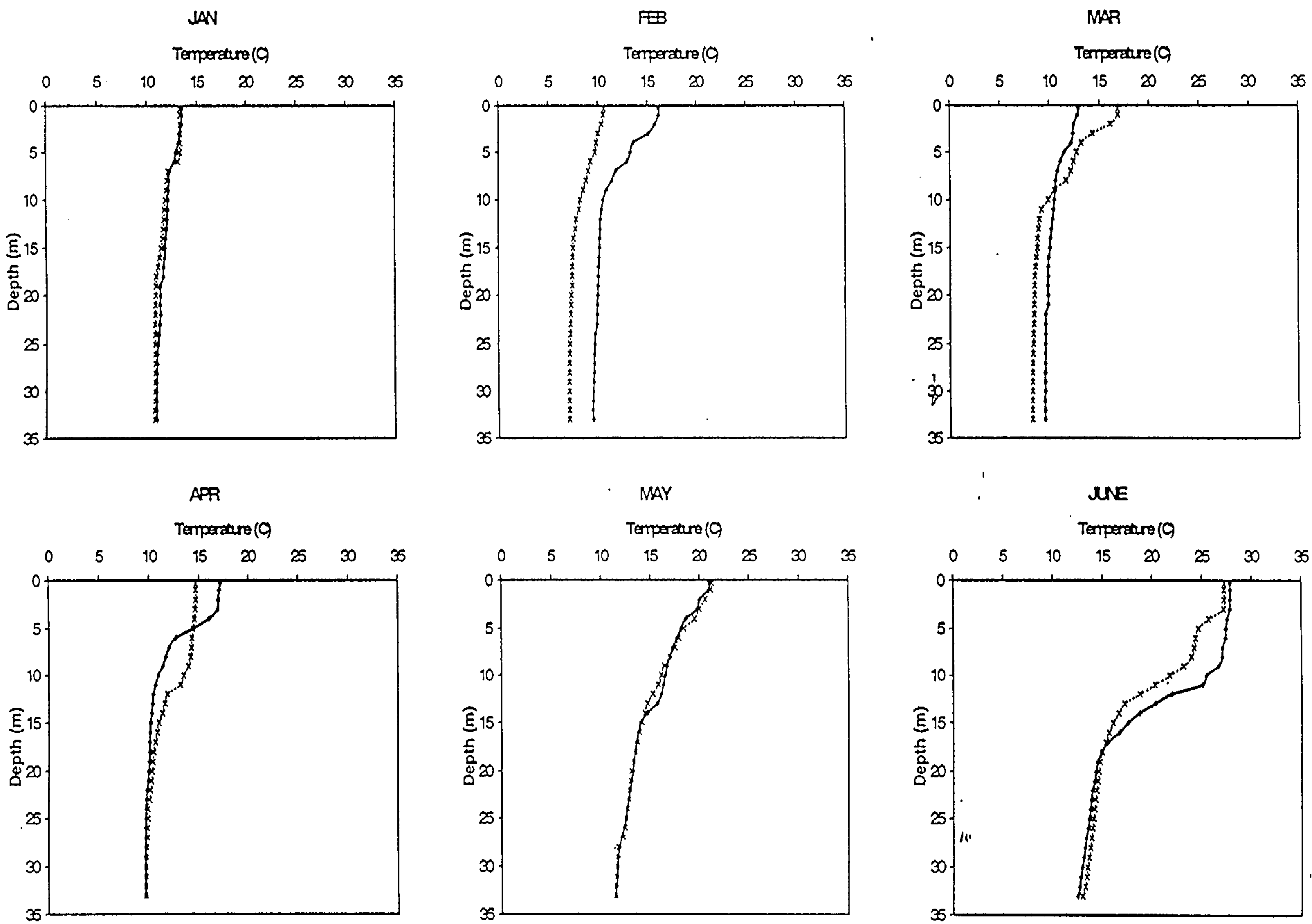

Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 1999 (♦♦) and 2000 (××).

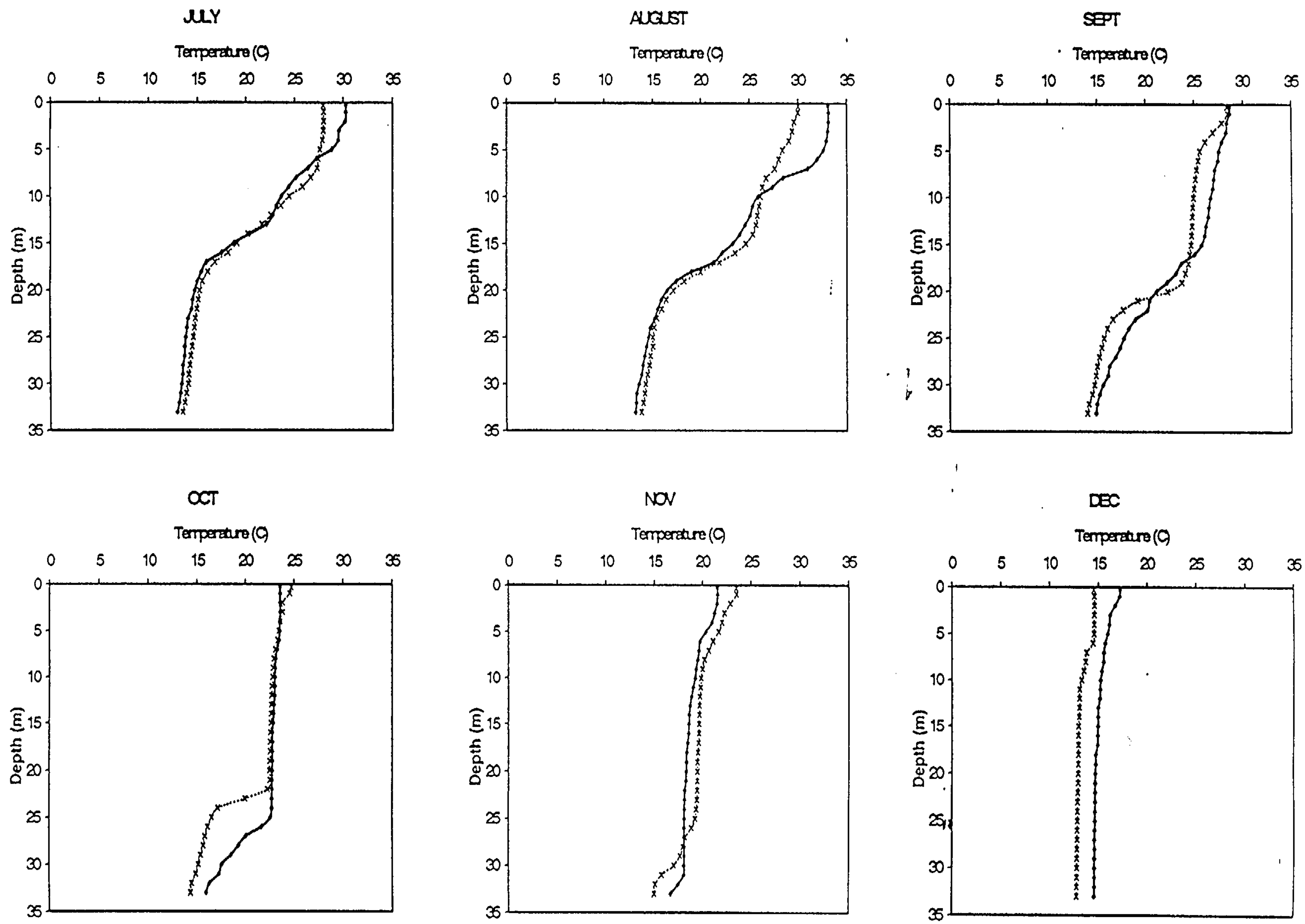

Figure 2-4. (con't).

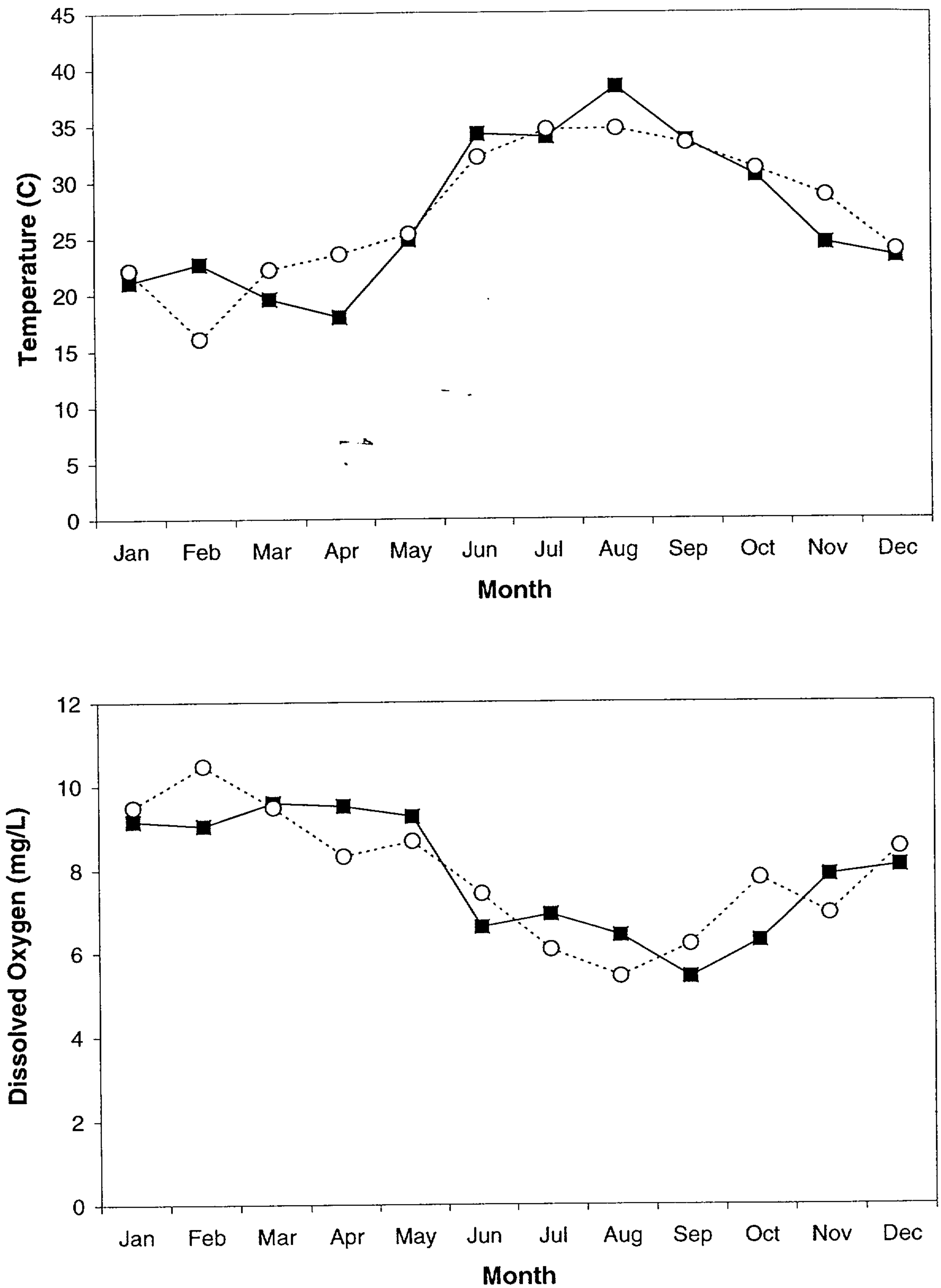

Figure 2-5. Monthly surface (0.3m) temperature and dissolved oxygen data at the discharge location (loc. 4.0) in 2000 (○) and 1999 (■).

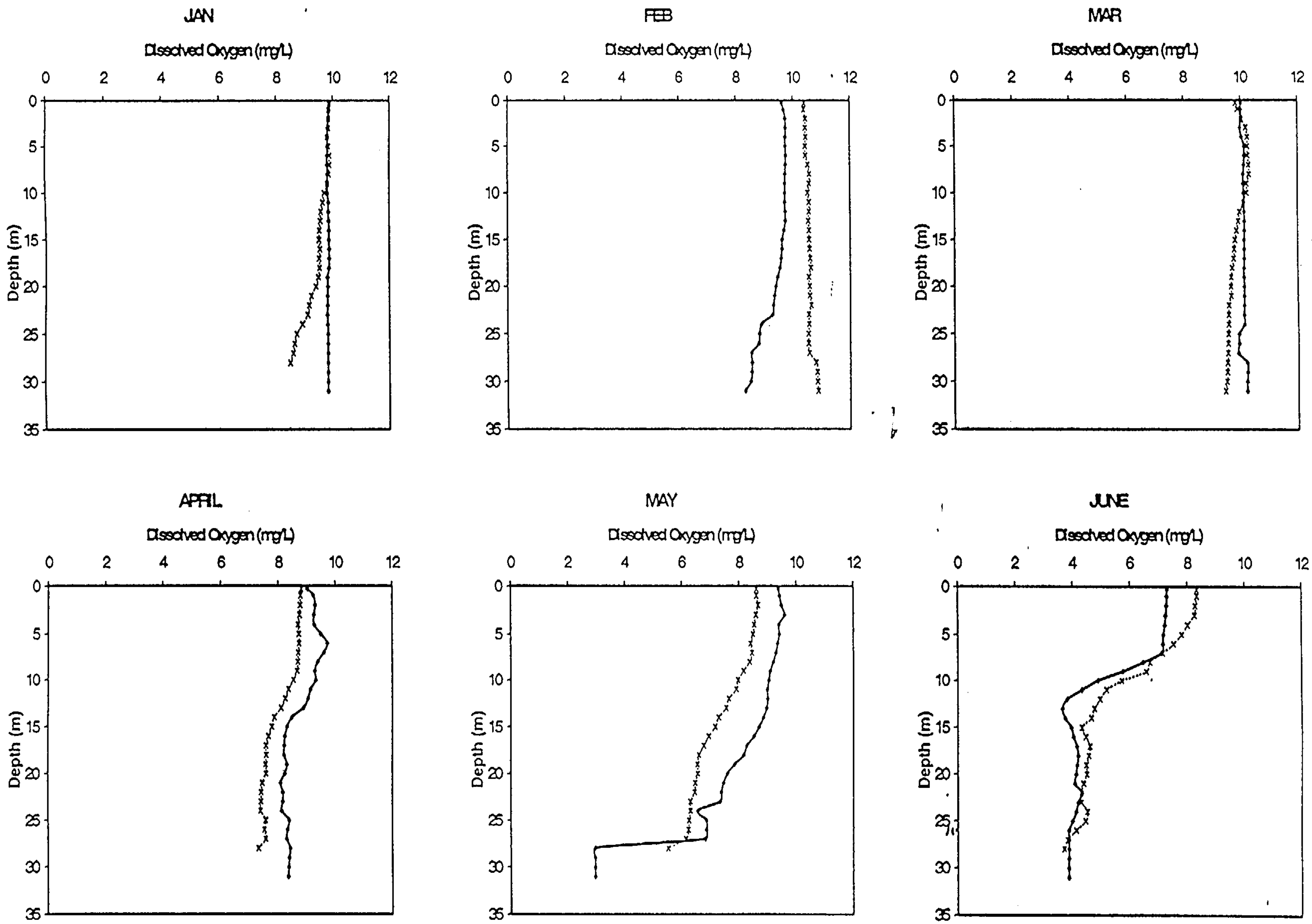

Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 1999 (♦ ♦) and 2000 (××).

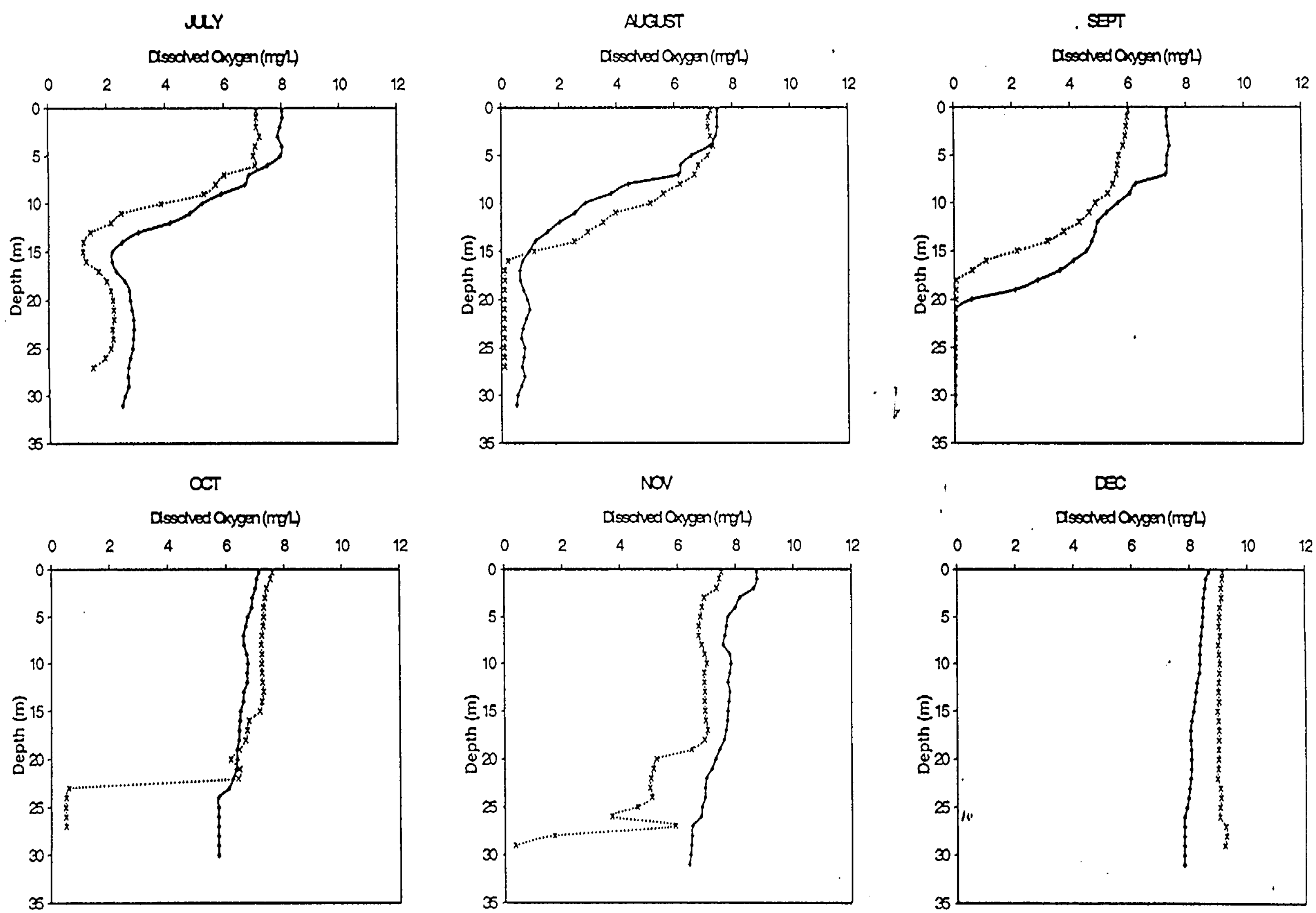

Figure 2-6. (con't).

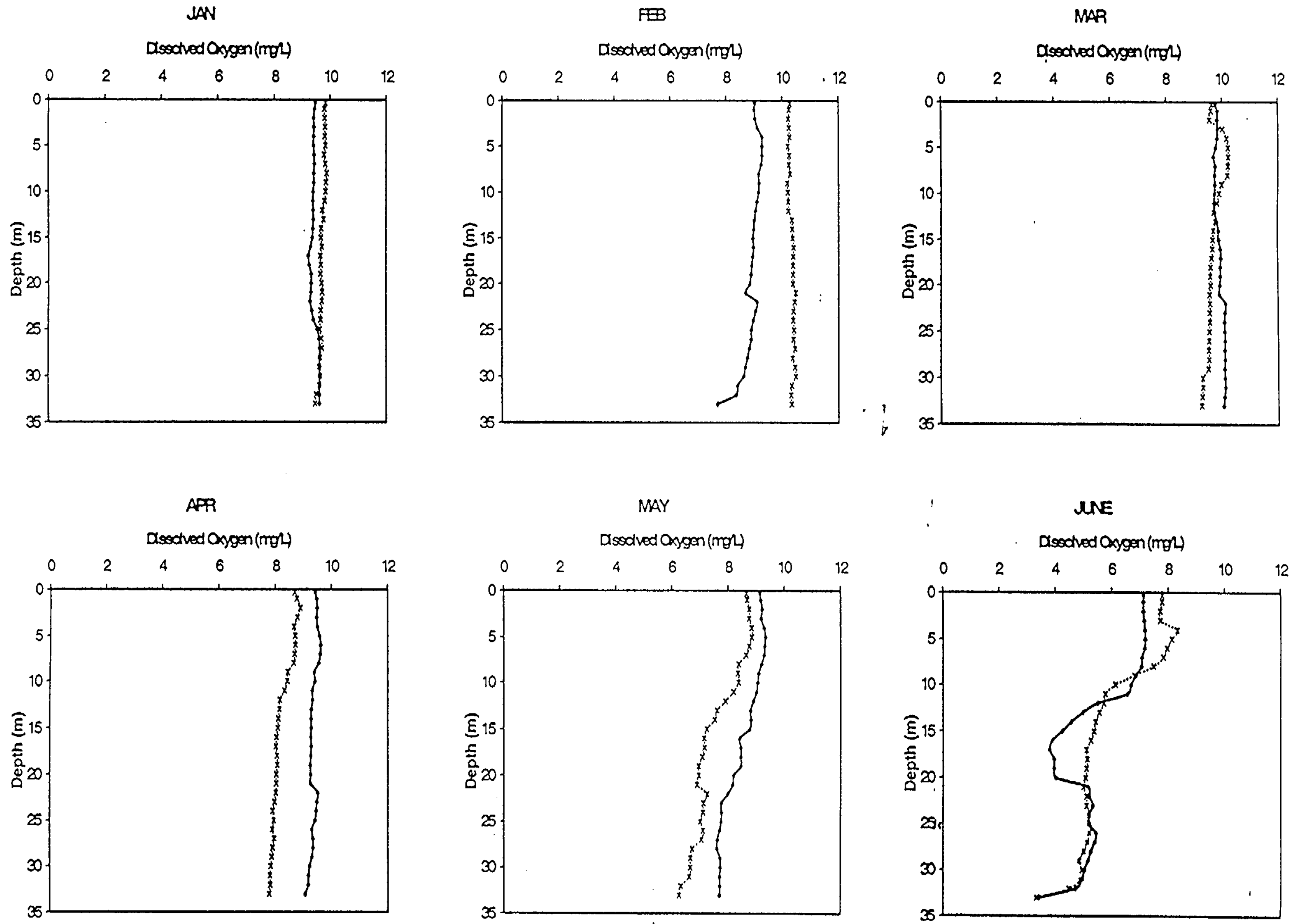

Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 1999 (♦ ♦) and 2000 (××).

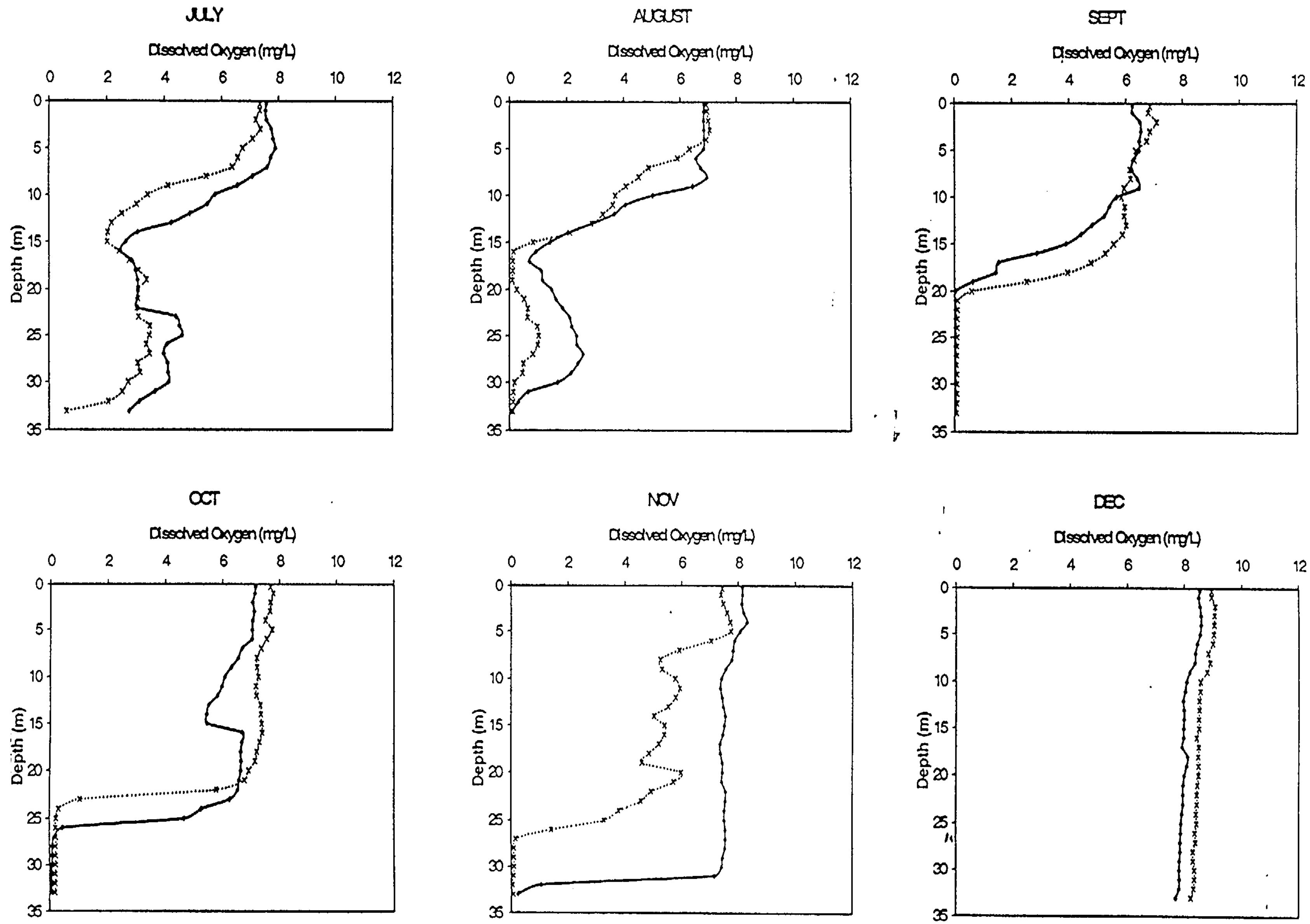

Figure 2-7. (con't).

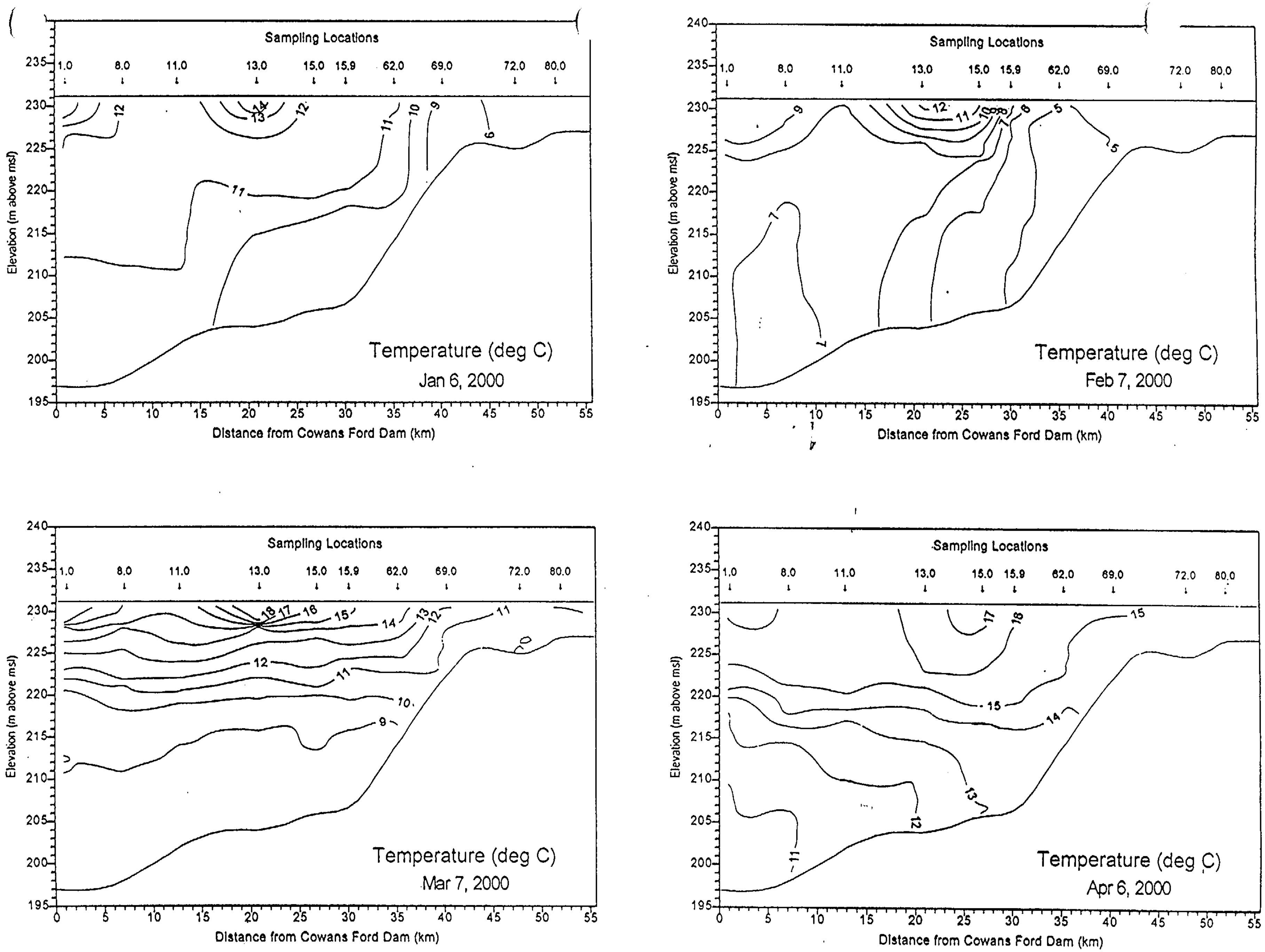

Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 2000.

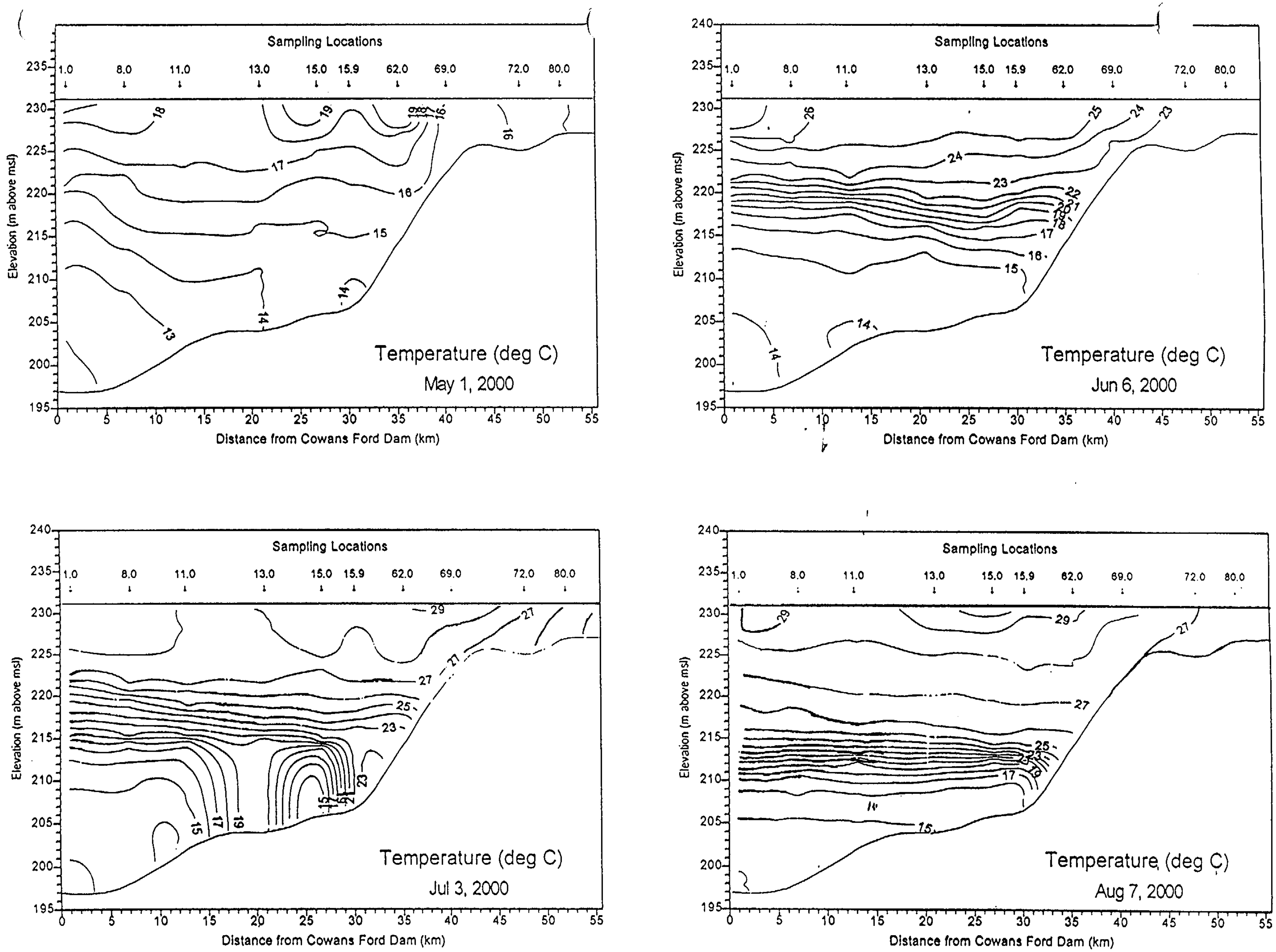

Figure 2-8. Continued.

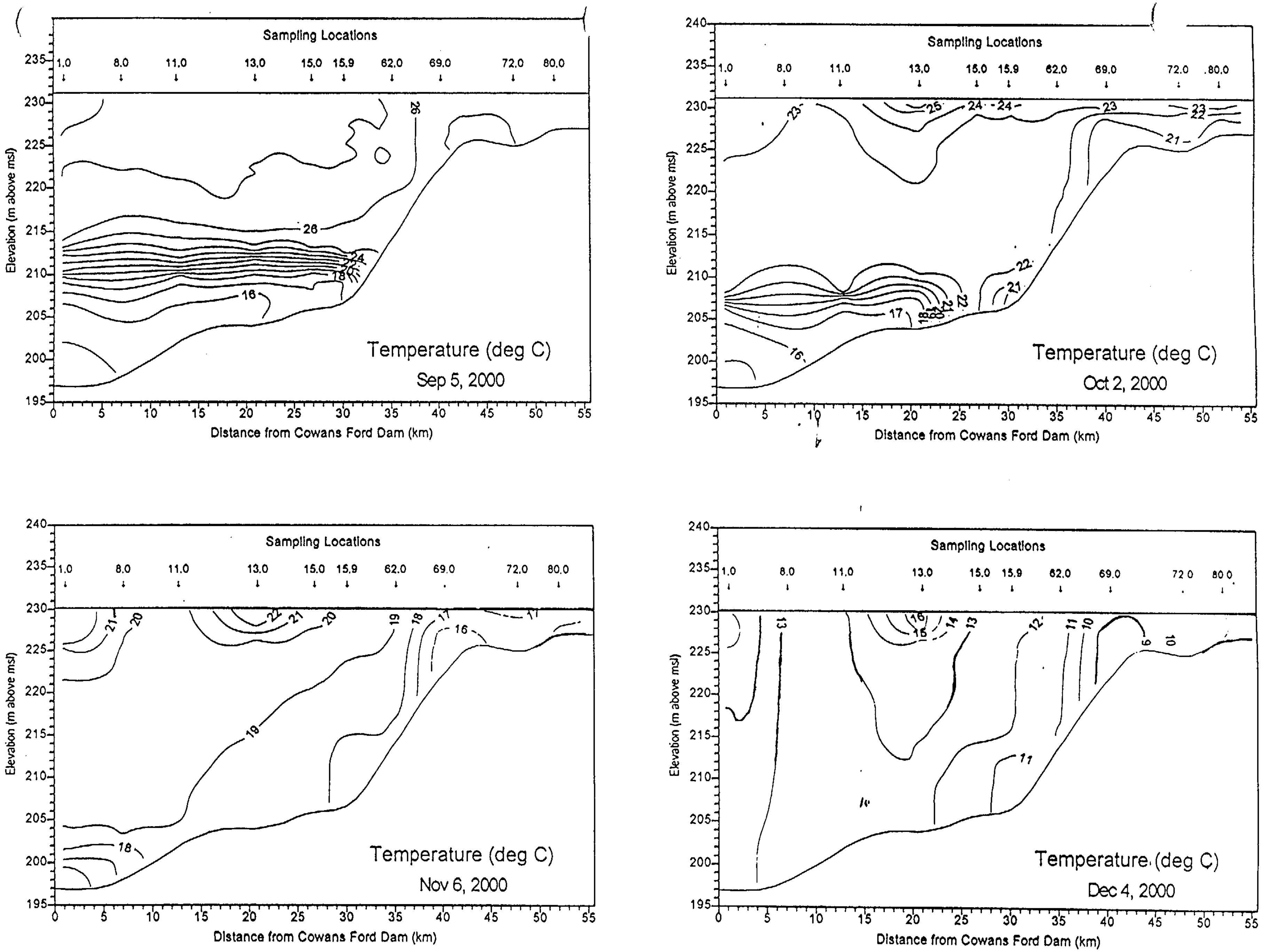

Figure 2-8. Continued.

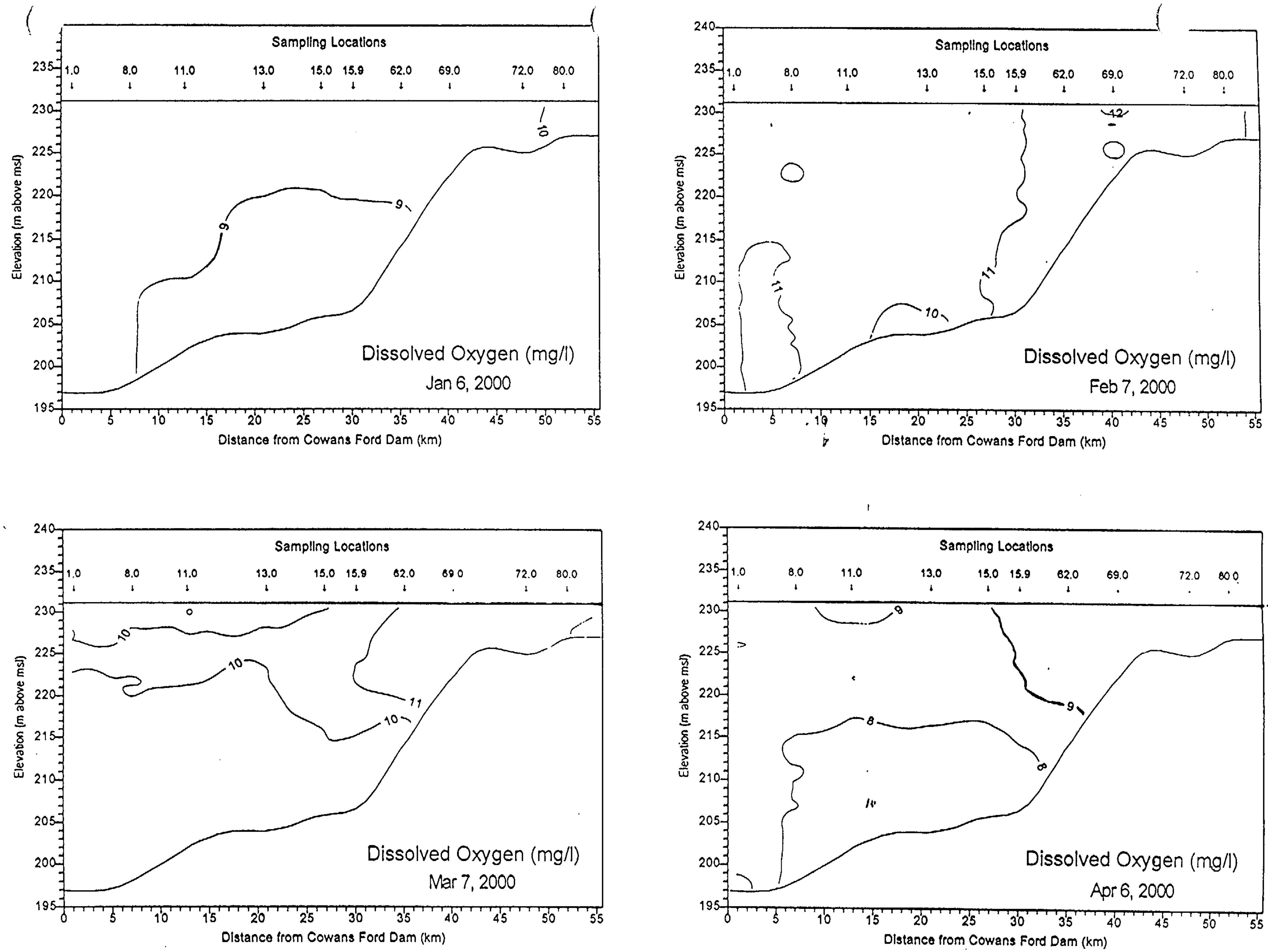

Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 2000.

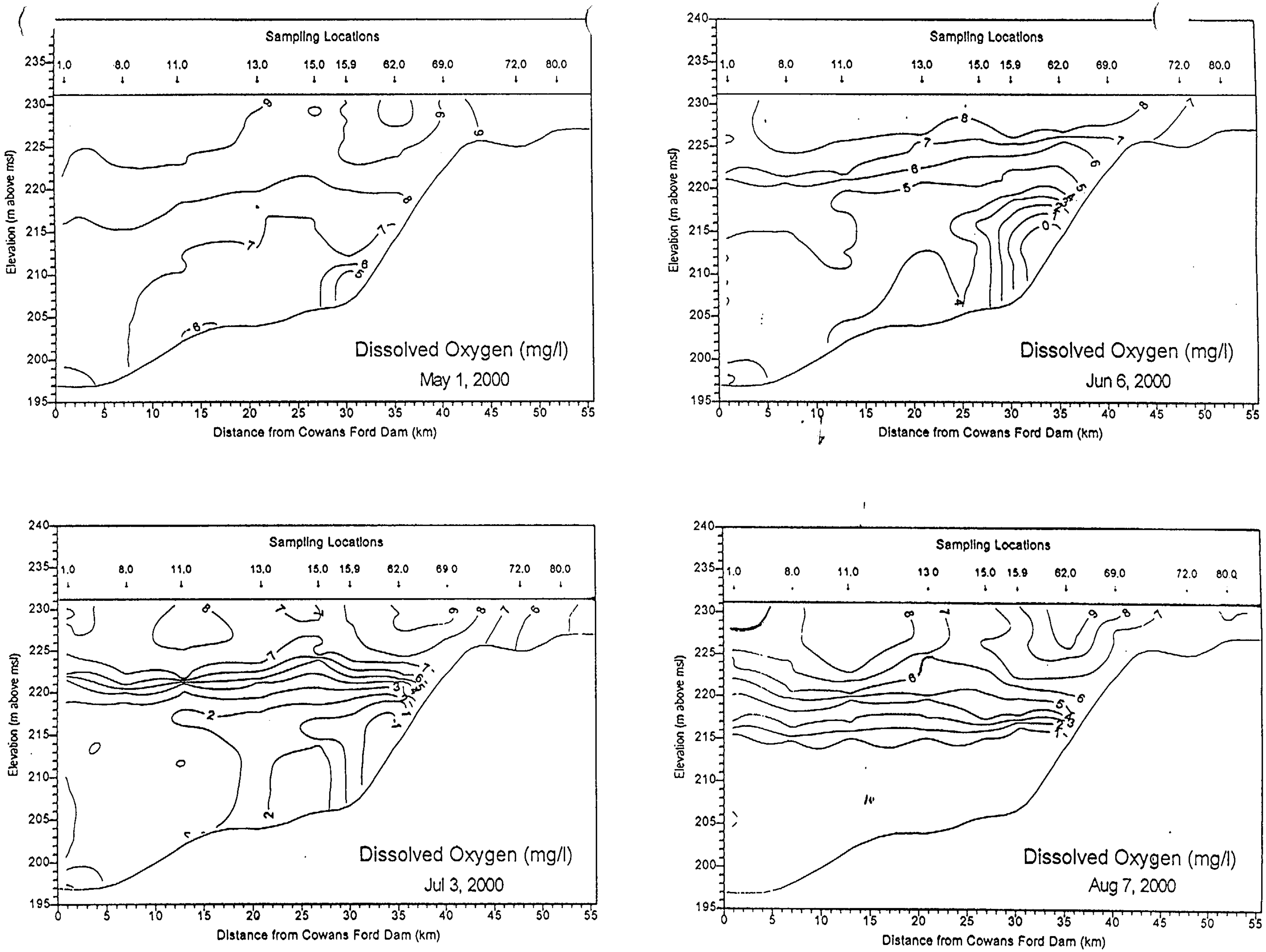

Figure 2-9. Continued.

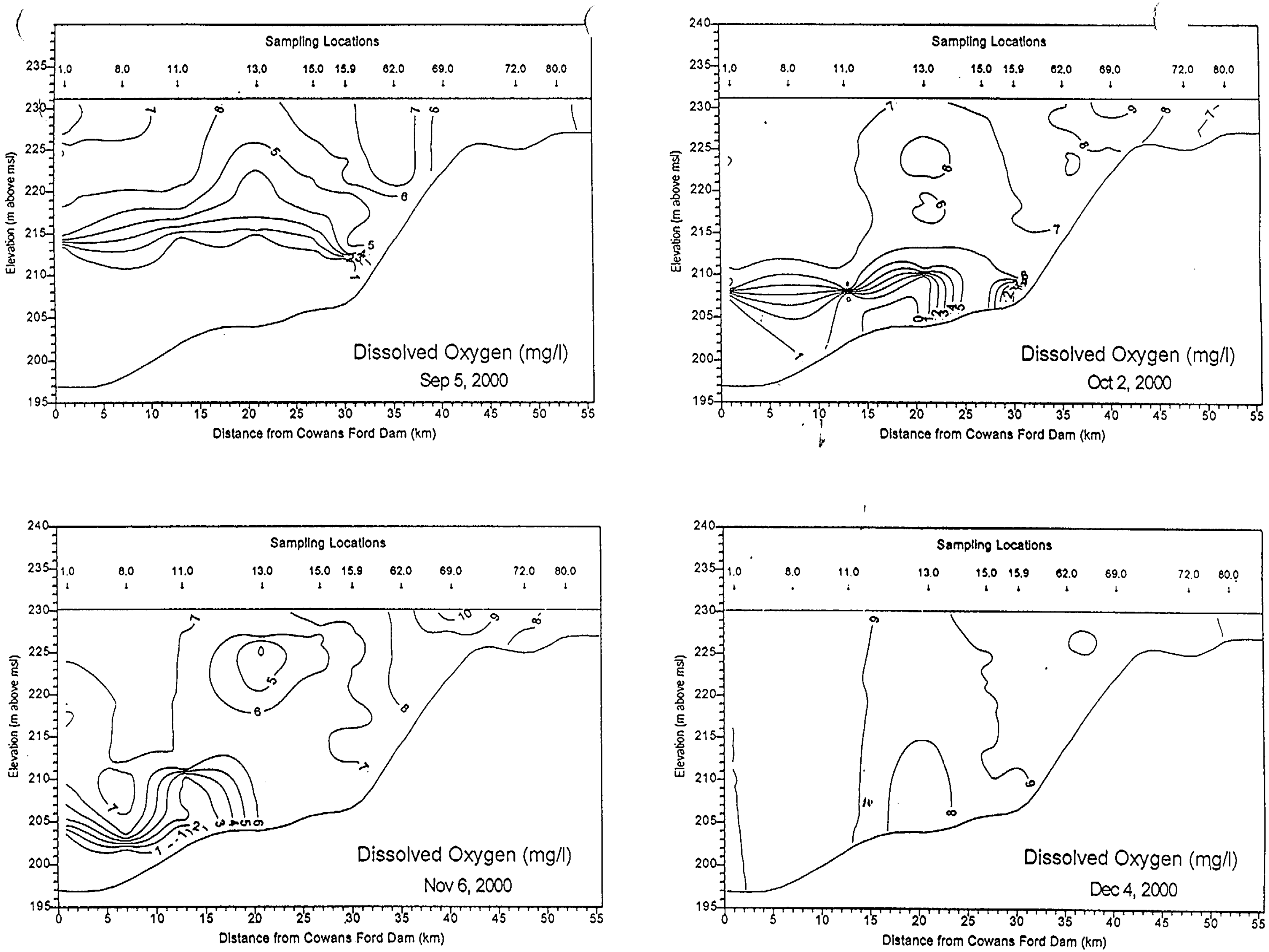

Figure 2-9. Continued.

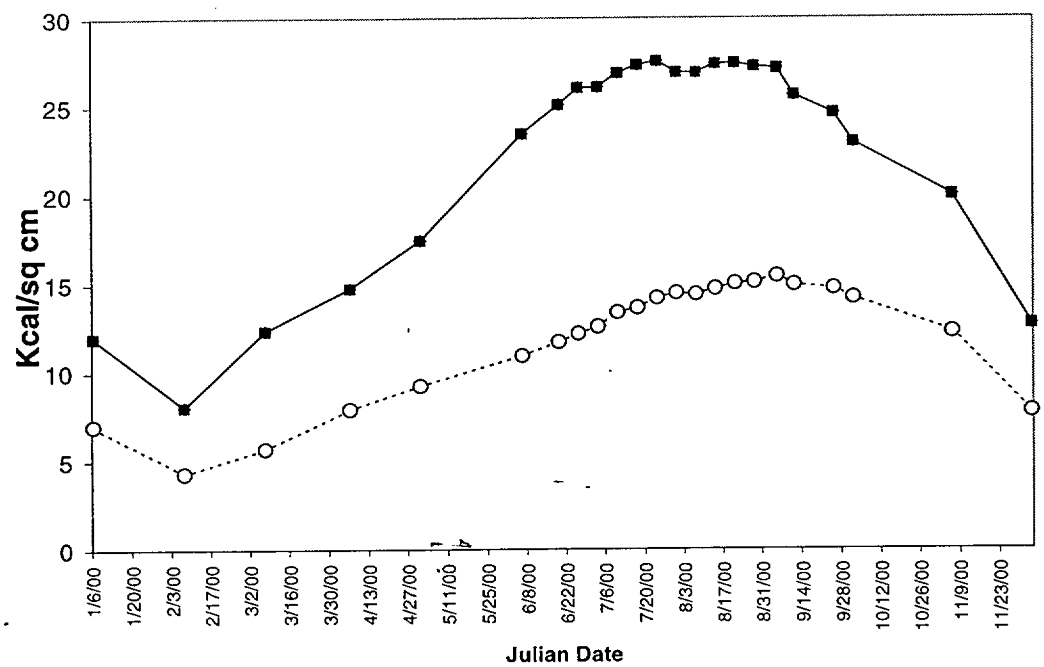

Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (O) in Lake Norman in 2000.

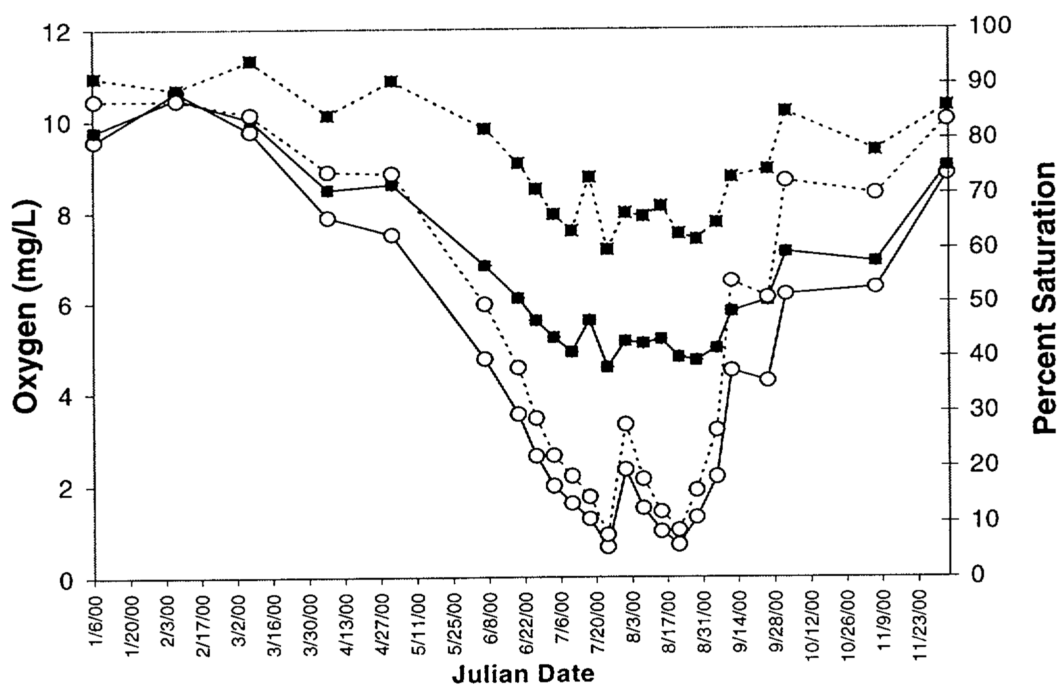

Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (O) of Lake Norman in 2000.

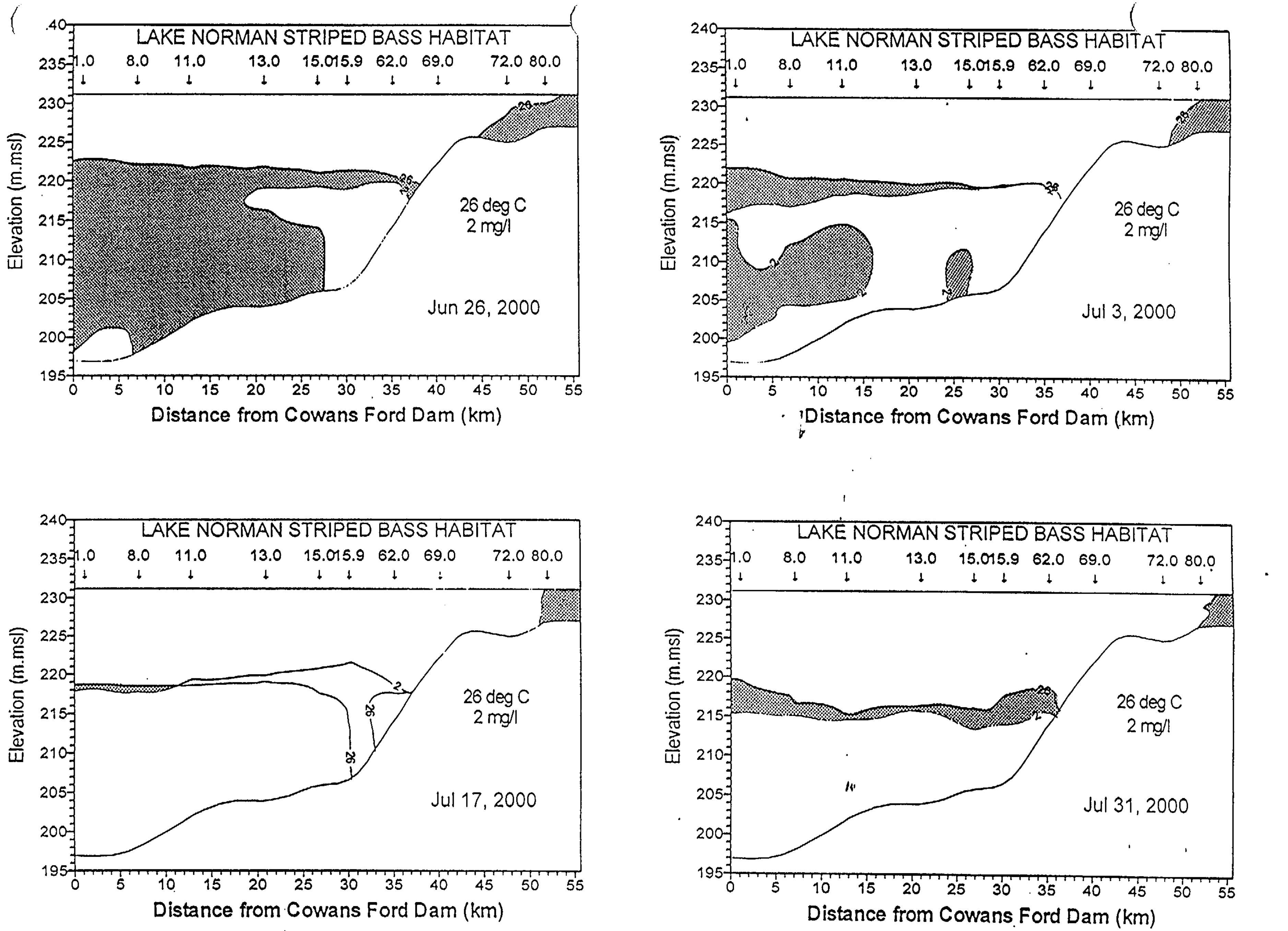

Figure 2-11. Striped bass habitat (temperatures ≤ 26 C and dissolved oxygen ≥ 2.0 mg/L in Lake Norman in June, July, August, and September 2000.

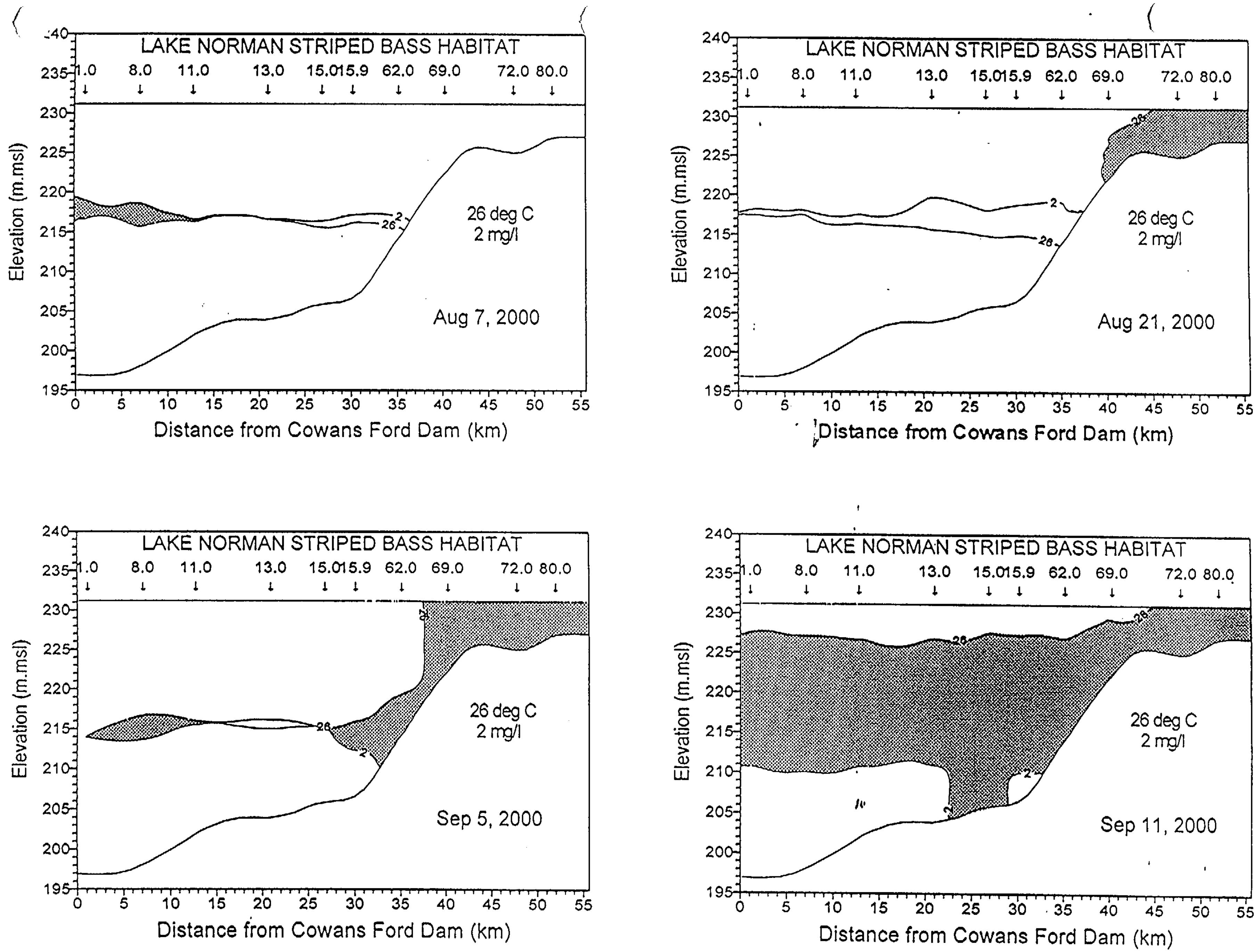

Figure 2-11. Continued.

CHAPTER 3
PHYTOPLANKTON

INTRODUCTION

Phytoplankton standing crop parameters were monitored in 2000 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, and November 2000) 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 Company 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 3 February, 24 May, 29 August, and 10 November 2000. 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 methods, 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 2000 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 2.04 ug/l at Location 13.0 in February, to a high of 26.43 ug/l at Location 15.9 in May (Table 3-1, Figure 3-1). All values were well below the North Carolina water quality standard of 40 ug/l (NCDEHNR 1991). Lake-wide mean chlorophyll concentrations were within ranges of those recorded in previous years (Figure 3-2). The seasonal trend in 2000 of minimum values in February, increasing to maximum values in May, then declining values from August to November has never been observed during the course of the Lake Norman Maintenance Monitoring Study. Although Lake Norman continues to be primarily in the mesotrophic range, the lake-wide mean in February was in the oligotrophic range (<4 ug/l), while the lake-wide mean in May was in the eutrophic range (>12 ug/l). Lake-wide quarterly mean concentrations below 4 ug/l have been recorded on eight previous occasions, while a concentration of greater than 12 ug/l was only recorded once before, in May 1997.

During 2000 chlorophyll *a* concentrations showed considerable spatial variability. Maximum concentrations were observed at Location 15.9 during May and November, at Location 9.5 in February, and at Location 69.0 in August (Table 3-2). Minimum concentrations occurred at Location 13.0 in February, at Location 9.5 in May and August, and at Location 2.0 in November. The trend of increasing chlorophyll concentrations from down-lake to up-lake, which had been observed in 1994 and some previous years (Duke Power Company 1995), was apparent during all but February (Table 3-1, Figure 3-1). A consistent pattern of increasing values from down-lake to up-lake has not been observed

since 1994. Locations 15.9 (uplake, above Plant Marshall) and 69.0 (the uppermost riverine locations) had significantly higher chlorophyll values than mixing zone locations during all sample periods except February (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 2000) have varied considerably. During February 2000, all locations had chlorophyll concentrations in the low range (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 1997. All but Locations 13.0 and 69.0 had higher chlorophyll concentrations in February 2000 than in February 1999.

During May 2000, chlorophyll concentrations at Locations 2.0 through 9.5 were in the intermediate to high range. Chlorophyll concentrations at Locations 11.0 through 69.0 were in the high range for May. In fact, the chlorophyll concentration at Location 15.9 was the highest ever observed for May (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 1996. All locations had higher chlorophyll concentrations in May 2000 than during this period last year.

August 2000 chlorophyll concentrations at all but Locations 8.0 and 9.5 were in the high range, while concentrations at 8.0 and 9.5 were in the low to intermediate range (Figure 3-3). 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 1993. Locations 11.0, 13.0, and

69.0 had higher August concentrations in 2000 than in 1999, while concentrations at all other locations were lower than last year.

In November 2000, chlorophyll concentrations were in the low range at Locations 2.0 through 11.0. At Locations 13.0 through 69.0 November 2000 chlorophyll concentrations were in the intermediate range (Figure 3-3). 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. All but Location 69.0 had lower November values in 2000 than in 1999.

Total Abundance

Density and biovolume are measurements of phytoplankton abundance. The lowest density during 2000 occurred at Location 2.0 in November (867 units/ml), and the lowest biovolume (267 mm^3/m^3) occurred at Location 11.0 during February (Table 3-3, Figure 3-1). The maximum density (15,924 units/ml) and biovolume (14,358 mm^3/m^3) were observed at Location 15.9 in May. Phytoplankton standing crops during February and May 2000 were generally higher than those of February and May 1999, while August and November standing crops were most often lower than in those periods of 1999 (Duke Power Company 2000). The phytoplankton density at Location 15.9 in May 2000 exceeded the NC state guideline for algae blooms of 10,000 units/ml. The biovolumes at Locations 11.0 and 15.9 during May 2000 also exceeded the NC guideline of 5,000 mm^3/m^3 biovolume (NCDEHNR 1991). Densities and biovolumes in excess of NC guidelines were recorded in 1987, 1989, 1997 and 1998 (Duke Power Company 1988, 1990, 1998, 1999).

Total densities at locations in the mixing zone during 2000 were within the same statistical ranges during all sampling periods but February (Table 3-4). In May and November, Location 15.9 had significantly higher densities than both mixing zone locations. During February, Location 9.5 had the maximum density, and was in the same statistical range as Location 15.9. In August, Location 15.9 had the highest density, but its statistical range overlapped that of the mixing zone locations. During May, and to a lesser extent in August, and November, phytoplankton densities showed a spatial trend, similar to that of chlorophyll, that is lower values at down-lake locations versus up-lake locations. During February, no such pattern was observed.

Seston

Seston dry weights represent a combination of algal matter, and other organic and inorganic material. Dry weights during 2000 were most often higher than those of 1999. Location 69.0, the uppermost riverine location, had the highest seston dry weights during all sample periods except February, when the maximum dry weight was observed at Location 13.0 (Table 3-5). A pattern of increasing values from down-lake to up-lake was observed in all but February, when no spatial trend was observed (Figure 3-1). Statistically, Location 69.0 had significantly higher values than other locations in May and August. During February and November, statistical differences were nonexistent or minimal. From 1995 through 1997 seston dry weights had been increasing (Duke Power Company 1998). Values since 1998 represented a reversal of this trend, and were in the low range at most locations during 1999 and 2000 (Duke Power Company 2000).

Seston ash-free dry weights represent organic material and may reflect trends of algal standing crops. In most cases, relationships between ash-free dry weights and chlorophyll concentrations/standing crops were not very apparent. In some cases, this relationship held true in 2000; most notably at Locations 9.5 and 69.0, which had the highest ash-free dry weights, as well as maximum chlorophyll values during May and August 2000 (Tables 3-1, 3-2, and 3-5). Locations 9.5 and 15.9, which had comparatively high ash-free dry weights in February, May, and August, also had seasonal maximum density values during these periods (Tables 3-4 and 3-5). During all sampling periods, little or no statistical differences were observed. The proportions of ash free dry weights to dry weights during 2000 were slightly higher than in 1999, indicating a very small increase in inorganic inputs during 2000. Between 1994 and 1997 a trend of declining organic/inorganic ratios was observed (Duke Power Company 1995, 1996, 1997, 1998).

Secchi Depths

Secchi depth is a measure of light penetration. Secchi depths were often inversely related to 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 1.12 m at Location 69.0 in November, to 2.88 m at Location 2.0 in May (Table 3-1). The lake-wide mean secchi depth during 2000 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 Company 1993, 1994, 1995, 1996, 1997, 1998, 1999).

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 also true in 2000. Nine classes comprising 81 genera and 172 species, varieties, and forms of phytoplankton were identified in samples collected during 2000, as compared to 76 genera and 135 lower taxa identified in 1999 (Table 3-6). The 2000 total was the highest number of individual taxa recorded since monitoring began in 1987. Twenty-four taxa previously unrecorded during the Maintenance Monitoring Program were identified during 2000.

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.

Diatoms (Bacillariophyceae) dominated densities at Locations 2.0, 5.0, and 9.5 in February 2000, and were the most abundant forms at all locations in May 2000 (Table 3-7, Figures 3-4 through 3-8). Cryptophytes (Cryptophyceae) were dominant at Locations 11.0 and 15.9 in February. 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 Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999). The most abundant diatoms during February were *Cyclotella comta* (Location 2.0), *Melosira ambigua* (Location 5.0), and *Tabellaria fenestrata* (Location 9.5). During May, the most abundant diatom was *Fragillaria crotonensis*. All of these species have been common and abundant at various times throughout the course of the program. The most abundant cryptophyte was the small flagellate, *Rhodomonas minuta* (Table 3-7). This species has been one of the most common and abundant forms observed in February 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, this taxon'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 2000 diatoms dominated densities at all locations (Figures 3-4 through 3-8). The most abundant diatom in August was the small pennate, *Anomoeoneis vitrea* (Table 3-7). This same pattern was observed in August 1999, which was the first time diatoms had ever dominated summer samples. 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. This pattern of diatom dominance in August of both 1999 and 2000 was lake-wide, and not associated specifically with locations in the vicinity of MNS or Marshall Steam Station (MSS). *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 deepest and next deepest secchi depths were recorded for 1999 and 2000, respectively), extended periods of low water due to draw-down, shifts in nutrient inputs and concentrations, and macrophyte control procedures upstream (Duke Power Company 2000). Whatever the cause, the phenomenon was lake-wide, and not localized near MNS or MSS; therefore, it was most likely due to a combination of unusual environmental factors, and not station operations.

During November 2000, densities at Locations 2.0, 9.5, and 11.0 were dominated by diatoms, while cryptophytes were most abundant at Locations 5.0 and 15.9 (Figures 3-4 through 3-8). The dominant species at all locations was the small cryptophyte *Rhodomonas minuta* (Table 3-7). During 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 2000 samples. Although their overall contribution to phytoplankton densities was higher than in 1999, densities of blue-greens seldom exceeded 6% of totals. The highest percent composition of Myxophyceae (6.7%) during all sampling periods in 2000 occurred at Location 5.0 in August. Prior to 1991, blue-green algae were often

dominant at up-lake locations during the summer (Duke Power Company 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 of 2000, and for each location during 2000 (Figure 3-9).

For the most part, the long term annual Myxophycean index values confirmed that Lake Norman has been 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, and 1998; and in the low, or oligotrophic, range in 1988, 1995, 1997, and 1999. The index for 2000 was higher than that of 1999, and fell in the lower mesotrophic range.

The highest index value among sample periods of 2000 was observed in February, and the lowest index value occurred in August (Figure 3-9). This did not reflect chlorophyll concentrations observed throughout the lake during 2000. The index values for locations during 2000 showed low values at Locations 2.0 through 9.5, with values in the high range at Locations 11.0 and 15.9. This tended to reflect the pattern of increasing algae concentrations from down-lake to up-lake locations observed during May, August, and November 2000. Last year, this pattern of increasing trophic state from down-lake to up-lake locations was not as obvious (Duke Power Company 2000).

FUTURE STUDIES

No changes are planned for the phytoplankton portion of the Lake Norman Maintenance Monitoring Program during 2000.

SUMMARY

In 2000 lake-wide mean chlorophyll *a* concentrations were all within ranges of those observed during previous years of the program. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. The lake-wide chlorophyll mean chlorophyll in February increased from the annual minimum to the annual maximum in May, and then declined through November. This seasonal pattern had never been recorded during the Maintenance Monitoring Program. Considerable spatial variability was observed in 2000, however, maximum chlorophyll concentrations were most often observed up-lake; while comparatively low chlorophyll concentrations were recorded from mixing zone locations. The 2000 maximum chlorophyll value of 26.43 ug/l was well below the NC State Water Quality standard of 40 ug/l.

In most cases, total phytoplankton densities and biovolumes observed in 2000 were higher than those observed during 1999, and standing crops were generally within ranges established over previous years. The maximum density at Location 15.9 in May, and the biovolumes at Locations 11.0 and 15.9 that same month exceeded NC guidelines for algae blooms. Standing crop values in excess of bloom guidelines have been recorded during four 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 and ash free dry weights were generally higher in 2000 than in 1999, and down-lake to up-lake differences were apparent most of the time. Maximum dry and ash-free dry weights were most often observed at Locations 13 through 69.0, while minima were most often noted at Locations 2.0 through 11.0. The proportions of ash-free dry weights to dry weights in 2000 were slightly higher than those of 1999, indicating little change in organic/inorganic inputs into Lake Norman.

Secchi depths reflected suspended solids values, with shallow depths related to high dry weights. The lake-wide mean secchi depth in 2000 was the second deepest recorded since measurements were first reported in 1992. The greatest annual mean lake-wide secchi depth was recorded for 1999.

Diversity, or numbers of taxa, of phytoplankton had increased since 1999, and the total number of individual taxa was the highest yet recorded. The taxonomic composition of phytoplankton communities during February, May, and November was similar to those of previous years. Diatoms were dominant at most locations during all sampling periods. 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 2000. During most previous August periods, green algae (and occasionally blue-green algae) dominated the phytoplankton. This shift was likely the result of a variety of unusual environmental factors, and not related to station operations. Blue-green algae were somewhat more abundant during 2000 than 1999; however their contribution to total densities seldom exceeded 6%.

The most abundant alga, on an annual basis, was the cryptophyte *Rhodomonas minuta*. Common and abundant diatoms were *Cyclotella comta, Melosira ambigua*, and *Tabellaria fenestrata* in February; *Fragillaria crotonensis in* May; *Anomoeneis vitrea* during August, and *T. fenestrata* in November. All of these taxa, except *A. vitrea*, have been common and abundant throughout the Maintenance Monitoring Program. *A. vitrea* was found to be a major contributor to periphyton communities on natural substrates during studies conducted from 1974 through 1977.

The phytoplankton index (Myxophycean) tended to confirm the characterization of Lake Norman as oligo-mesotrophic. The annual index for 2000 was higher than that of 1999, and was at the lower end of the intermediate range. Quarterly index values declined from February to August, and then increased in November. Quarterly values did not reflect seasonal changes in phytoplankton standing crops. Location values tended to reflect increases in phytoplankton standing crops from down-lake to up-lake.

Lake Norman continues to support highly viable 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 (0.3, 4 and 8m depths) and secchi depths (m) observed in Lake Norman, NC, in 2000.

Chlorophyll *a*

Location	FEB	MAY	AUG	NOV
2.0	3.36	8.25	6.07	2.26
5.0	3.05	7.20	6.20	3.06
8.0	3.71	7.48	5.68	3.23
9.5	4.92	7.02	5.31	3.50
11.0	2.62	14.95	10.26	3.99
13.0	2.04	16.02	6.53	5.51
15.9	3.76	26.43	10.08	8.92
69.0	2.52	10.41	15.48	5.05

Secchi depths

Location	FEB	MAY	AUG	NOV
2.0	2.30	2.88	2.35	2.00
5.0	2.20	2.28	2.40	1.80
8.0	2.50	2.49	2.85	2.15
9.5	2.00	2.04	2.81	2.30
11.0	2.40	1.72	2.34	2.40
13.0	2.10	1.68	1.79	1.55
15.9	2.30	1.76	2.45	1.90
69.0	2.30	1.53	1.50	1.12

Table 3-2. Duncan's multiple Range Test on chlorophyll *a* concentrations in Lake Norman, NC, during 2000.

February	Location	**13.0**	**69.0**	**11.0**	**5.0**	**2.0**	**8.0**	**15.9**	**9.5**
	Mean	2.04	2.52	2.62	3.05	3.36	3.71	3.76	4.92
May	Location	**9.5**	**5.0**	**8.0**	**2.0**	**69.0**	**11.0**	**13.0**	**15.9**
	Mean	7.02	7.20	7.48	8.25	10.41	14.95	16.02	26.43
August	Location	**9.5**	**8.0**	**2.0**	**5.0**	**13.0**	**15.9**	**11.0**	**69.0**
	Mean	5.31	5.68	6.07	6.20	6.53	10.07	10.26	15.49
November	Location	**2.0**	**5.0**	**8.0**	**9.5**	**11.0**	**69.0**	**13.0**	**15.9**
	Mean	2.58	2.71	2.87	3.42	3.74	3.92	6.02	6.93

Table 3-3. Total mean phytoplankton densities and biovolumes from samples collected in Lake Norman, NC, during 2000.

Density (units/ml)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	1090	1060	1488	1039	1450	1225
MAY	3426	3030	4230	7616	15924	6845
AUG	2632	2694	2246	3149	3463	2836
NOV	867	981	1106	1245	2493	1338

Biovolume (mm^3/m^3)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	974	833	1778	267	947	960
MAY	3343	3121	4208	7056	14358	6417
AUG	1807	2096	1795	2731	2533	2192
NOV	566	658	741	878	2065	982

Table 3-4. Duncan's multiple Range Test on phytoplankton densities in Lake Norman, NC, during 2000.

February	Location	**11.0**	**5.0**	**2.0**	**15.9**	**9.5**
	Mean	1040	1060	1090	1450	1487
May	Location	**5.0**	**2.0**	**9.5**	**11.0**	**15.9**
	Mean	3030	3426	4230	7616	15924
August	Location	**9.5**	**2.0**	**5.0**	**11.0**	**15.9**
	Mean	2246	2632	2694	3149	3463
November	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Mean	867	980	1106	1244	2493

Table 3-5. Duncan's multiple Range Test on dry and ash free dry weights (mg/l) in Lake Norman, NC during 2000.

DRY WEIGHT

February	Location	**11.0**	**2.0**	**9.5**	**5.0**	**69.0**	**15.9**	**8.0**	**13.0**
	Mean	0.86	1.39	1.41	1.44	1.51	1.55	1.57	1.58
May	Location	**5.0**	**8.0**	**9.5**	**2.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	1.99	2.24	2.32	2.35	3.09	3.86	4.48	9.40
August	Location	**8.0**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	1.28	1.33	1.52	1.90	1.97	2.07	2.18	3.05
November	Location	**11.0**	**8.0**	**5.0**	**2.0**	**15.9**	**9.5**	**13.0**	**69.0**
	Mean	1.33	1.47	1.84	1.93	2.01	2.52	3.04	5.06

ASH FREE DRY WEIGHT

February	Location	**13.0**	**11.0**	**8.0**	**69.0**	**5.0**	**15.9**	**2.0**	**9.5**
	Mean	0.84	0.84	0.93	1.07	1.09	1.21	1.24	1.30
May	Location	**5.0**	**9.5**	**2.0**	**8.0**	**13.0**	**11.0**	**15.9**	**69.0**
	Mean	1.57	1.77	1.91	1.96	2.34	2.49	2.67	3.05
August	Location	**2.0**	**13.0**	**8.0**	**9.5**	**5.0**	**11.0**	**15.9**	**69.0**
	Mean	1.01	1.22	1.27	1.32	1.39	1.61	1.96	2.47
November	Location	**11.0**	**15.9**	**9.5**	**5.0**	**2.0**	**8.0**	**69.0**	**13.0**
	Mean	1.30	0.68	0.79	0.92	1.23	1.48	1.51	1.53

Table 3-6. Phytoplankton taxa identified in quarterly samples collected in Lake Norman from August 1987 to November 2000.

TAXON	87	88	89	90	91	92	93	94	95	96	97	98	99	00
CLASS: CHLOROPHYCEAE														
Acanthospaera 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
A. convolutus Corda														X
A. falcatus (Corda) Ralfs	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				X			
A. spp. Corda					X		X							
Arthrodesmus convergens Ehrenberg									X					
A. incus (Breb.) Hassall		X			X				X			X		
A. subulatus Kutzing										X	X	X		X
A. spp. Ehrenberg							X	X						
Asterococcus limneticus G. M. Smith				X	X	X	X	X					X	
Botryococcus braunii Kutzing					X	X								
Carteria frtzschii Takeda	X	X												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
Chlorella vulgaris Beyerink											X			
Chlorogonium euchlorum Ehrenberg	X			X						X	X			X
C. spirale Scherffel & Pascher								X	X					
Closteriopsis longissima West & West	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Closterium cornu Ehrenberg													X	
C. gracile Brebisson										X				
C. incurvum Brebisson	X	X						X	X	X	X	X	X	X
C. tumidum Johnson														X
C. spp. Nitzsch			X	X	X		X							
Coccomonas orbicularis Stein												X		
Coelastrum cambricum Archer	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
C. proboscideum Bohlin					X									
C. spp. Nageli				X	X									
Cosmarium agulosum v. *concinnum* (Rab) W&W	X													X
C. asphaerosporum v. *strigosum* Nord.	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
C. contractum Kirchner	X				X			X	X	X	X	X	X	X
C. moniliforme (Turp.) Ralfs														X
C. phaseolus f. *minor* Boldt.											X	X		X
C. pokornyanum (Grun.) W. & G.S. West												X		
C. polygonum (Nag.) Archer	X								X	X	X	X	X	X
C. regnellii Wille	X						X			X	X	X	X	X
C. regnesi Schmidle					X	X	X							
C. tenue Archer	X	X							X	X	X	X	X	X
C. tinctum Ralfs	X	X					X	X	X	X	X	X	X	X
C. tinctum v. *subretusum* Messik.														X
C. tinctum v. *tumidum* Borge.											X		X	X
C. spp. Corda	X	X	X	X	X	X	X	X						
Crucigenia crucifera (Wolle) Collins	X	X		X	X				X	X	X	X	X	X
C. fenestrata Schmidle					X									
C. irregularis Wille		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
Dictyospaerium ehrenbergianum Nageli	X	X												X
D. pulchellum Wood	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
Euastrum denticulatum (Kirch.) Gay									X	X	X	X	X	X
E. spp. Ehrenberg		X		X		X	X							
Eudorina elegans Ehrenberg		X								X				
Franceia droescheri (Lemm.) G. M. Smith	X	X							X	X	X	X	X	X
F. ovalis (France) Lemm.		X	X	X	X	X	X	X						X
Gloeocystis botryoides (Kutz.) Nageli	X													X
G. gigas Kutzing	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
G. vesciculosa Naegeli												X		
G. spp. Nageli	X	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
Gonium pectorale Mueller												X		
G. sociale (Duj.) Warming		X							X			X	X	
Kirchneriella contorta (Schmidle) Bohlin		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
K. lunaris v. *irregularis* G.M. Smith														X
K. obesa W. West		X	X	X	X	X	X	X						

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
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
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
M. spp. Agardh		X				X	X	X						
Nephrocytium agardhianum Nageli		X			X									
N. limneticum (G.M. Smith) G.M. Smith	X	X											X	
Oocystis borgii Snow												X	X	X
O. ellyptica W. West		X										X		
O. lacustris Chodat		X												
O. parva West & West	X	X	X	X					X	X	X	X	X	X
O. pusilla Hansgirg			X	X			X	X	X	X	X	X	X	X
O. pyriformis Prescott												X		
O. spp. Nageli				X										
Pandorina charkowiensis Kprshikov	X													
P. morum Bory			X	X		X	X							
Pediastrum biradiatum Meyen	X													
P. duplex Meyen	X	X		X	X		X		X	X	X		X	X
P. duplex v. *gracillimum* West and West											X	X		
P. tetras v. *tetroadon* (Corda) Rabenhorst	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			
Q. lacustris (Chodat) G. M. Smith		X												
Scenedesmus abundans (Kirchner) Chodat	X	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								X					
S. acuminatus (Lagerheim) Chodat	X					X	X	X	X	X		X	X	X
S. armatus v. *bicaudatus* (Gug.-Prin.)Chod	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
S. bijuga v. *alterans* (Reinsch) Hansg.	X													
S. brasiliensis Bohlin									X	X	X	X	X	X
S. denticulatus Lagerheim	X	X	X	X	X	X	X	X	X	X		X	X	X

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
S. dimorphus (Turp.) Kutzing	X			X		X	X	X			X	X	X	X
S. incrassulatus G. M. Smith	X													
S. quadricauda (Turp.) Brebisson	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. smithii Teiling										X				
S. spp. Meyen			X	X	X	X	X	X						
Schizochlamys compacta Prescott										X		X		X
S. gelatinosa A. Braun														X
Schoederia setigera (Schroed.) Lemm.		X			X									
Selenastrum gracile Reinsch					X					X				
S. minutum (Nageli) Collins	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) Schmidle											X			
Sphaerocystis schoeteri Chodat	X	X		X					X			X	X	X
Sphaerozosma granulatum Roy & Bliss	X	X												
Stauastrum americanum (W&W) G. Sm.	X	X							X	X	X	X	X	X
S. apiculatum Brebisson	X										X	X	X	X
S. brachiatum Ralfs											X	X	X	
S. brevispinum Brebisson	X											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
S. cuspidatum Brebisson	X										X	X	X	X
S. dejectum Brebisson	X	X	X	X	X	X		X						X
S. dickeii v. *maximum* West & West		X												
S. gladiosum Turner							X							
S. leptocladum v. *sinuatum* Wolle	X				X									
S. manfeldtii v. *fluminense* Schumacher		X		X	X			X	X		X	X		X
S. megacanthum Lundell	X	X					X	X						
S. ophiura v. *cambricum* (Lund) W. & W.														X
S. orbiculare Ralfs								X						
S. paradoxum Meyen			X	X	X	X	X	X				X	X	
S. paradoxum v. *cingulum* West & West	X													
S. paradoxum v. *parvum* W. West	X											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
S. turgescens de Not.	X	X												
S. spp. Meyen			X	X	X	X		X						
Tetraedron bifurcatum v. *minor* Prescott										X				
T. caudatum (Corda) Hansgirg	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							

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
T. minmum (Braun) Hansgirg	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				
T. planktonicum G. M. Smith												X		X
T. pentaedricum West & West			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
T. trigonum v. *gracile* (Reinsch) DeToni						X				X				X
T. spp. Kutzing		X		X			X							
Tetraspora lamellosa Prescott														X
T. spp. Link							X	X						
Tetrastrum heteracanthum (Nordst.) Chod.				X										
Treubaria setigerum (Archer) G. M. Smith	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Westella botryoides (West & West) Wilde.												X		X
W. linearis G. M. Smith		X										X		X
Xanthidium spp. Ehrenberg								X						
CLASS: BACILLARIOPHYCEAE														
Achnanthes microcephala Kutzing	X		X	X					X	X	X	X	X	X
A. spp. Bory	X	X	X	X	X	X	X	X		X				
Anomoeoneis vitrea (Grunow) Ross		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
Attheya zachariasi J. Brun	X	X	X	X	X		X	X	X	X	X	X	X	X
Cocconeis placentula Ehrenberg	X	X										X	X	
C. spp. Ehrenberg								X						
Cyclotella comta (Ehrenberg) Kutzing			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
C. pseudostelligera Hustedt	X													
C. stelligera Cleve & Grunow	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	
C. tumida (Breb.) van Huerck								X						
C. turgida (Gregory) Cleve		X												
C. spp. Agardh		X			X									
Denticula thermalis Kuetzing												X		
Diploneis spp. Ehrenberg				X										

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Eunotia flexuosa v. *eurycephala* Grun.														X
E. zasuminensis (Cab.) Koerner			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
Frustulia rhomboides (Ehr.) de Toni	X	X												
Gomphonema spp. Agardh					X			X						
Melosira ambigua (Grun.) O. Muller	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. distans (Ehr.) Kutzing		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
M. italica (Ehr.) Kutzing	X	X												
M. varians Agardh						X	X					X		
M. spp. Agardh	X	X	X	X	X	X	X	X		X			X	
Navicula cryptocephala Kutzing				X						X	X			
N. exigua (Gregory) O. Muller									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
N. agnita Hustedt		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
N. linearis W. Smith														X
N. palea (Kutzing) W. Smith	X	X						X	X	X	X	X		
N. sublinearis Hustedt	X									X		X		
N. spp. Hassall	X	X	X	X	X	X	X	X						
Pinnularia spp. Ehrenberg							X							
Rhizosolenia spp. Ehrenberg	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	X		
Surirella linearis v. *constricta* (Ehr.) Grun.												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
S. planktonica Ehrenberg	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
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	X						
Tabellaria fenestrata (Lyngb) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. flocculosa (Roth.) Kutzing	X	X		X				X						X

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
CLASS: CHRYSOPHYCEAE														
Aulomonas purdyii Lackey		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		
Chrysosphaerella solitaria Lauterb.					X	X	X	X	X	X	X	X	X	X
Codomonas annulata Lackey										X	X	X	X	X
Dinobryon bavaricum Imhof	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. cylindricum Imhof				X	X	X	X	X		X		X		
D. divergens Imhof			X	X		X	X	X	X	X			X	
D. sertularia Ehrenberg		X							X					X
D. spp. Ehrenberg		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
Kephyrion littorale Lund												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
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
M. globosa Schiller				X								X		X
M. producta Iwanoff														X
M. pseudocoronata Prescott		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
M. spp. Perty	X	X	X	X	X	X	X	X						X
Ochromonas granularis Doflein												X	X	X
O. mutabilis Klebs														X
O. spp. Wyss	X	X	X					X	X	X	X	X	X	X
Pseudokephyrion schilleri Conrad												X	X	
P. tintinabulum Conrad												X		
Rhizochrisis polymorpha Naumann													X	X
R. spp. Pascher		X			X									
Salpingoeca frequentissima (Zachary) Lemm.												X	X	X
Stelexomonas dichotoma Lackey		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
S. uvella Ehrenberg		X	X	X	X		X	X						
S. spp. Ehrenberg			X	X	X	X	X	X						
Uroglenopsis americana (Caulk.) Lemm.		X							X	X	X		X	

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
CLASS: HAPTOPHYCEAE														
Chrysochromulina parva Lackey	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: XANTHOPHYCEAE														
Characiopsis dubia Pascher									X	X		X	X	X
Dichotomococcus curvata Korschikov	X													
Ophiocytium caoitatum v. *longisp.* (M) Lem							X	X						
CLASS: CRYPTOPHYCEAE														
Cryptomonas erosa Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. erosa v. *reflexa* Marsson				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
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
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
CLASS: MYXOPHYCEAE														
Agmenellum quadriduplicatum Brebisson						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	
A. wisconsinense Prescott	X	X							X	X	X	X	X	X
A. spp. Bory		X	X	X	X	X	X	X		X			X	
Anacystis incerta (Lemm.) Druet & Daily			X	X	X	X	X	X				X		X
A. spp. Meneghini	X													
Chroococcus dispersus (Keissl.) Lemm.												X		X
C. limneticus Lemmermann	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
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						

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
L. ochracea (Kutz.) Thuret														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
Merismopedia tenuissima Lemmermann												X		
Microcystis aeruginosa Kutz. *emend* Elen.	X		X	X	X	X	X	X	X	X		X	X	X
Oscillatoria geminata Meneghini	X	X		X					X	X	X	X	X	X
O. limnetica Lemmermann		X							X	X	X	X	X	X
O. splendida Greville									X	X		X		
O. subtilissima Kutz.														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	
Rhabdoderma sigmoidea Schm. & Lautrb.			X											
Synecococcus lineare (Sch. & Laut.) Kom.				X	X	X	X	X	X	X		X	X	X
CLASS: EUGLENOPHYCEAE														
Euglena acus Ehrenberg				X									X	
E. minuta Prescott			X											X
E. polymorpha Dangeard										X				
E. spp. Ehrenberg		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 (Stok.) Defl.		X												
T. hispida (Perty) Stein							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	X
Glenodinium borgei (Lemm.) Schiller	X	X								X				
G. gymnodinium Penard			X	X	X	X	X				X			
G. palustre (Lemm.) Schiller	X													
G. penardiforme (linde.) Schiller													X	X

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98	99	00
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
Peridinium aciculiferum Lemmermann		X												
P. inconspicuum Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. intermedium Playfair												X	X	X
P. pusillum (Lenard) Lemmermann	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
P. spp. Ehrenberg	X			X	X	X	X	X						
CLASS: CHLOROMONADOPHYCEAE														
Gonyostomum depresseum Lauterborne		X							X			X	X	
G. semen (Ehrenberg) Diesing				X										
G. spp. Diesing	X	X		X				X						

Table 3-7. Dominant classes and species of Phytoplankton, and their percent composition (in parenthesis) at Lake Norman locations during each sampling period of 2000.

LOC	FEBRUARY	MAY
2.0	BACILLARIOPHYCEAE (61.9) *Cyclotella comta* (25.4)	BACILLARIOPHYCEAE (76.7) *T. fenestrata* (25.3)
5.0	BACILLARIOPHYCEAE (48.7) *Melosira ambigua* (19.0)	BACILLARIOPHYCEAE (85.1) *Fragillaria crotonensis* (25.1)
9.5	BACILLARIOPHYCEAE (75.2) *Tabellaria fenestrata* (31.0)	BACILLARIOPHYCEAE (78.2) *F. crotonensis* (27.9)
11.0	CRYPTOPHYCEAEA (72.6) *Rhodomonas minuta* (67.7)	BACILLARIOPHYCEAE (87.1) *F. crotonensis* (48.3)
15.9	CRYPTOPHYCEAE (40.2) *R. minuta* (34.7)	BACILLARIOPHYCEAE (93.0) *F. crotonensis* (63.2)
	AUGUST	NOVEMBER
2.0	BACILLARIOPHYCEAE (42.2) *Anomoeoneis vitrea* (34.1)	BACILLARIOPHYCEAE (40.1) *R. minuta* (30.4)
5.0	BACILLARIOPHYCEAE (44.0) *A. vitrea* (34.2)	CRYPTOPHYCEAE (39.7) *R. minuta* (34.2)
9.5	BACILLARIOPHYCEAE (47.0) *A. vitrea* (31.0)	BACILLARIOPHYCEAE (41.3) *R. minuta* (29.9)
11.0	BACILLARIOPHYCEAE (42.7) *A. vitrea* (21.0)	BACILLARIOPHYCEAE (36.0) *R. minuta* (30.8)
15.9	BACILLARIOPHYCEAE (34.1) *A. vitrea* (9.8)	CRYPTOPHYCEAE (37.5) *R. minuta* (28.2)

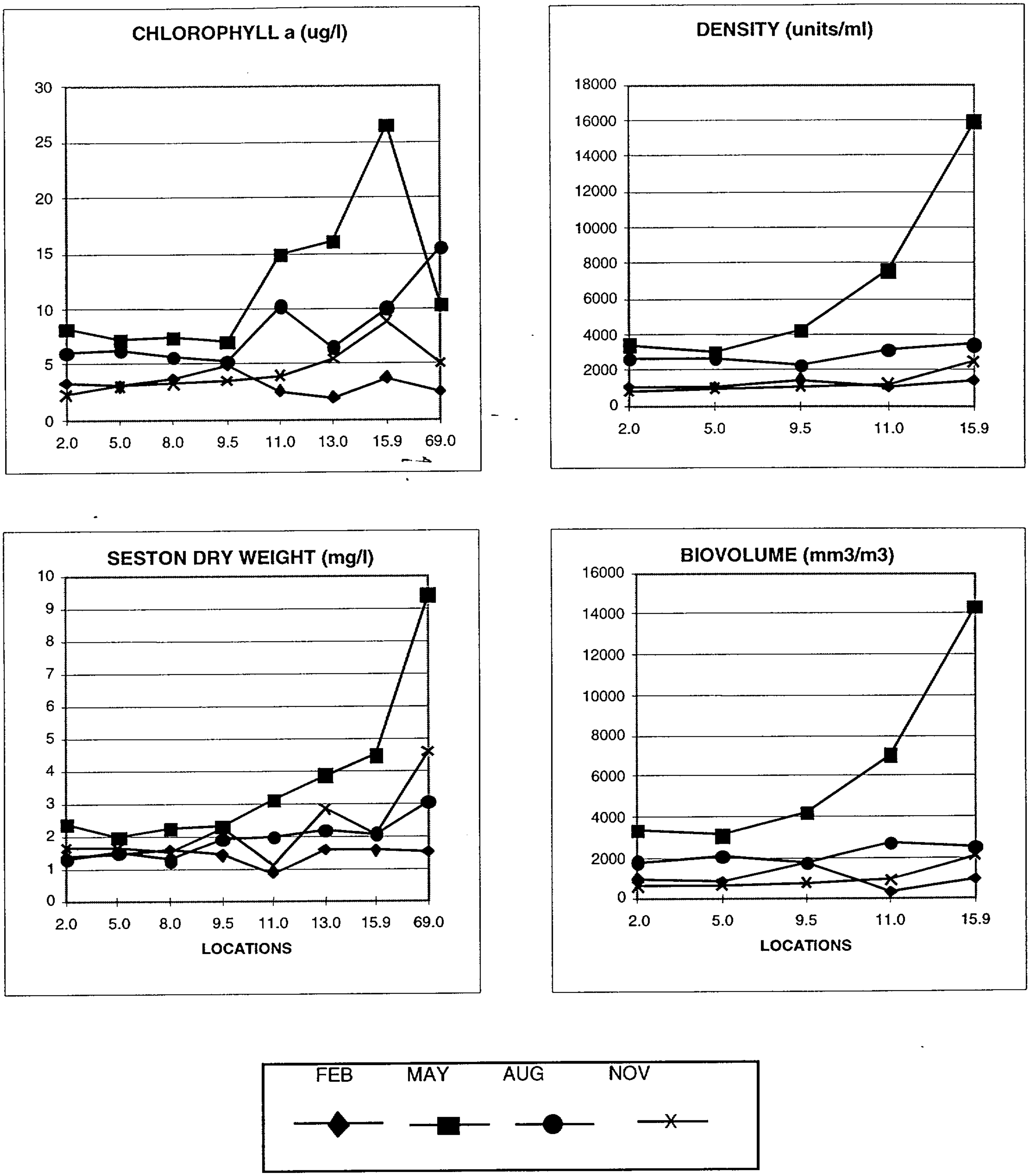


Figure 3-1. Phytoplankton chlorophyll *a*, densities, and biovolumes; and seston weights at locations in Lake Norman, NC, in February, May, August, and November 2000.

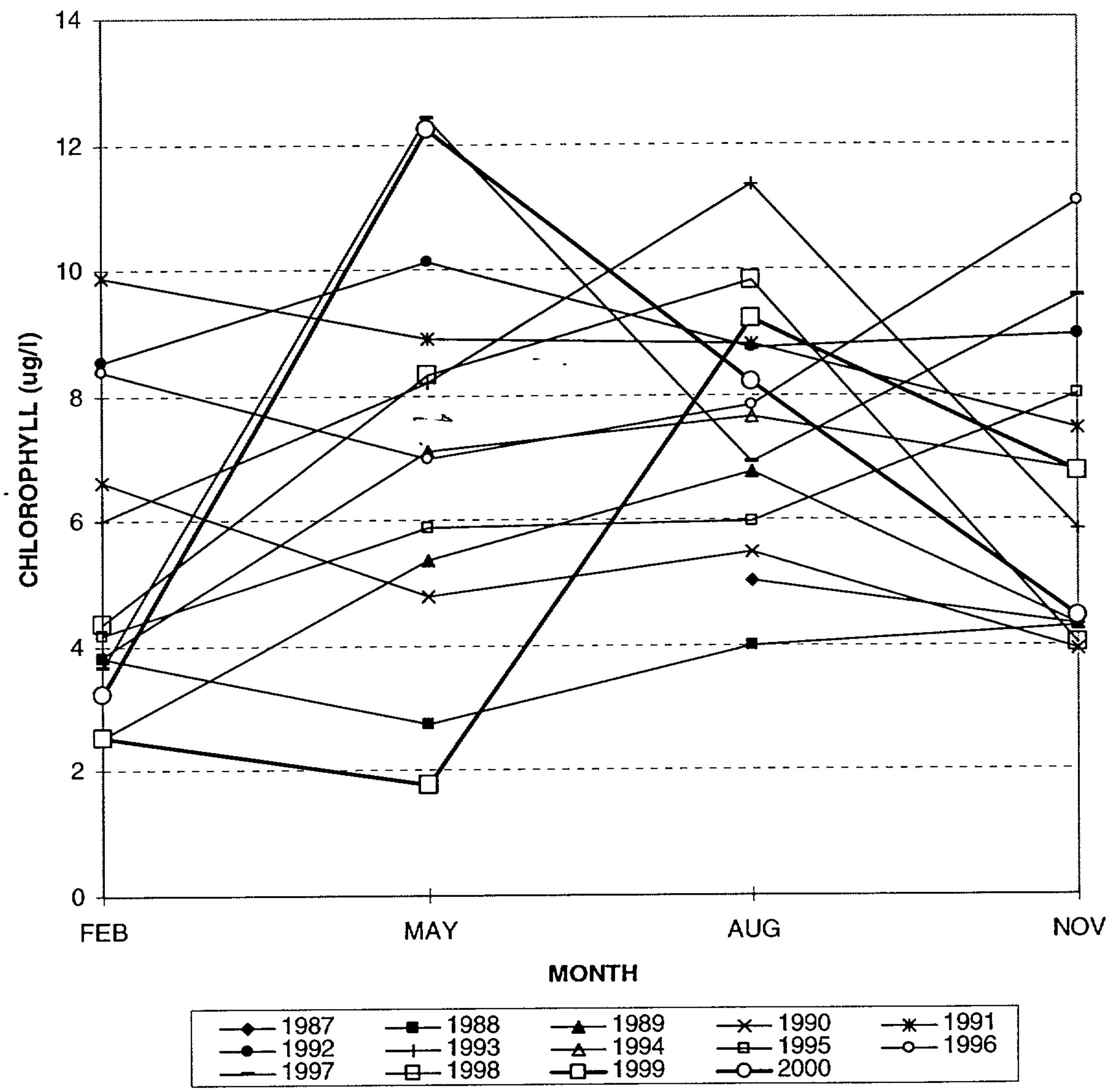


Figure 3-2. Phytoplankton chlorophyll *a* annual lake means from all locations in Lake Norman, NC, for each quarter since August 1987.

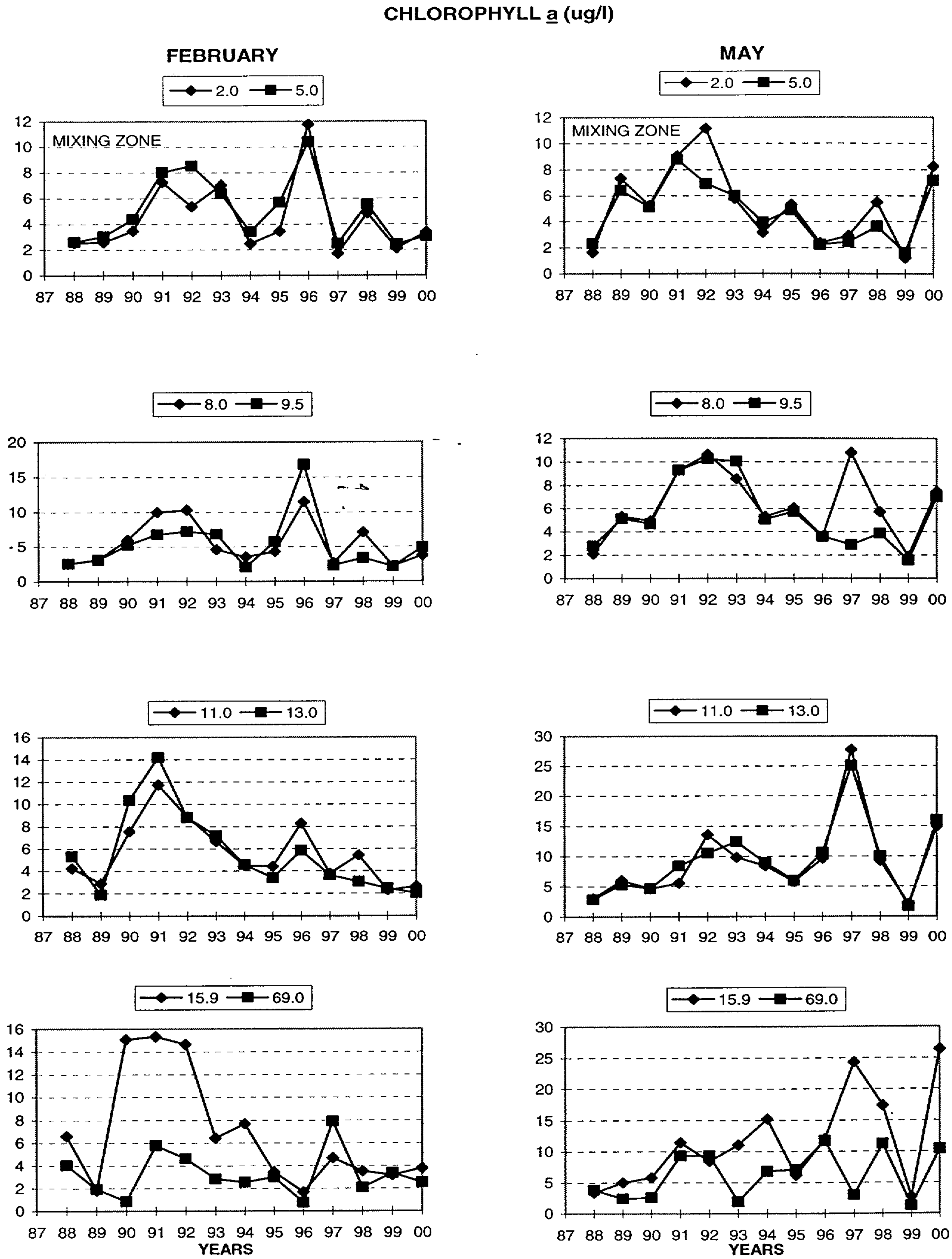


Figure 3-3. Phytoplankton chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from August 1987 through November 2000.

CHLOROPHYLL a (ug/l)

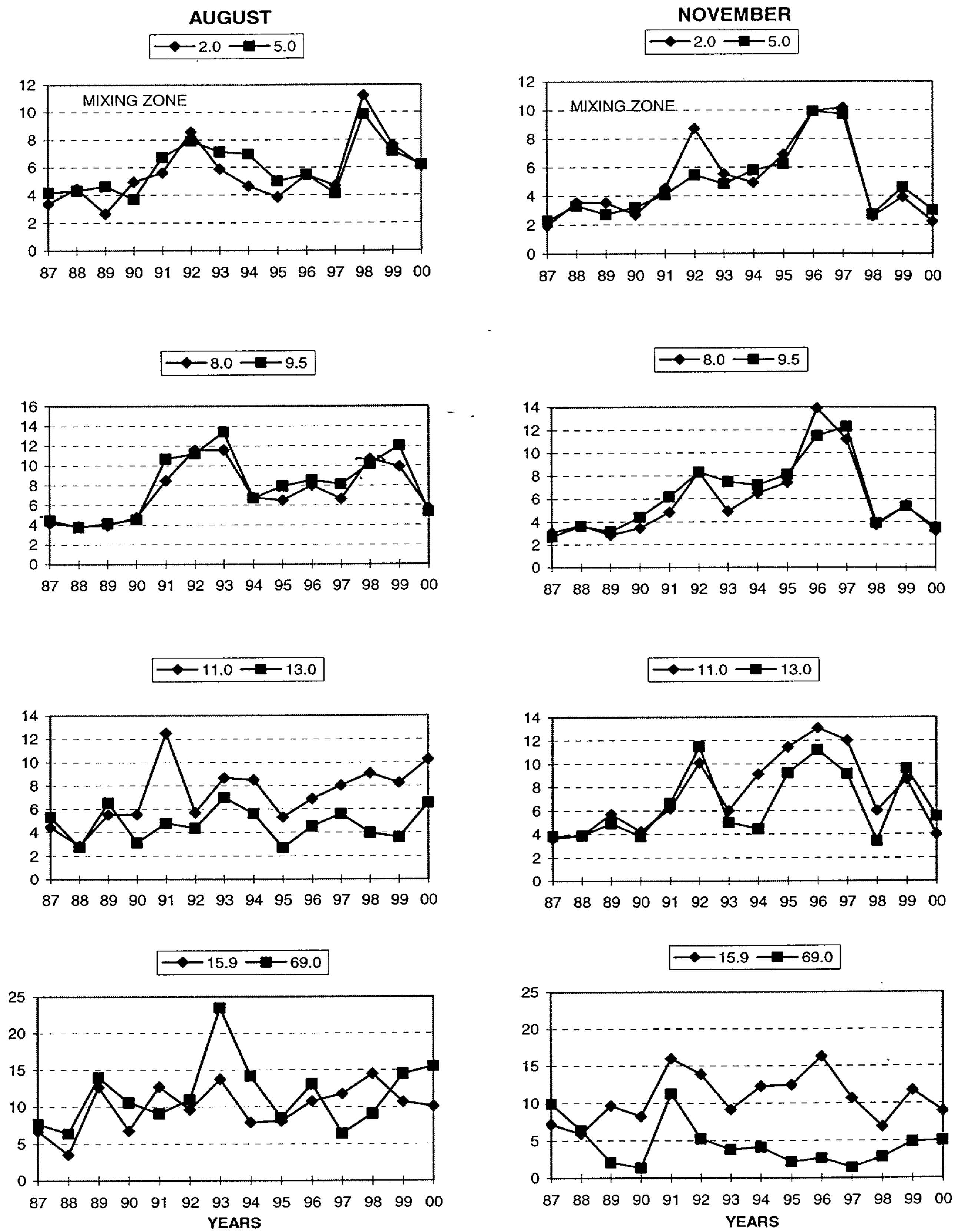
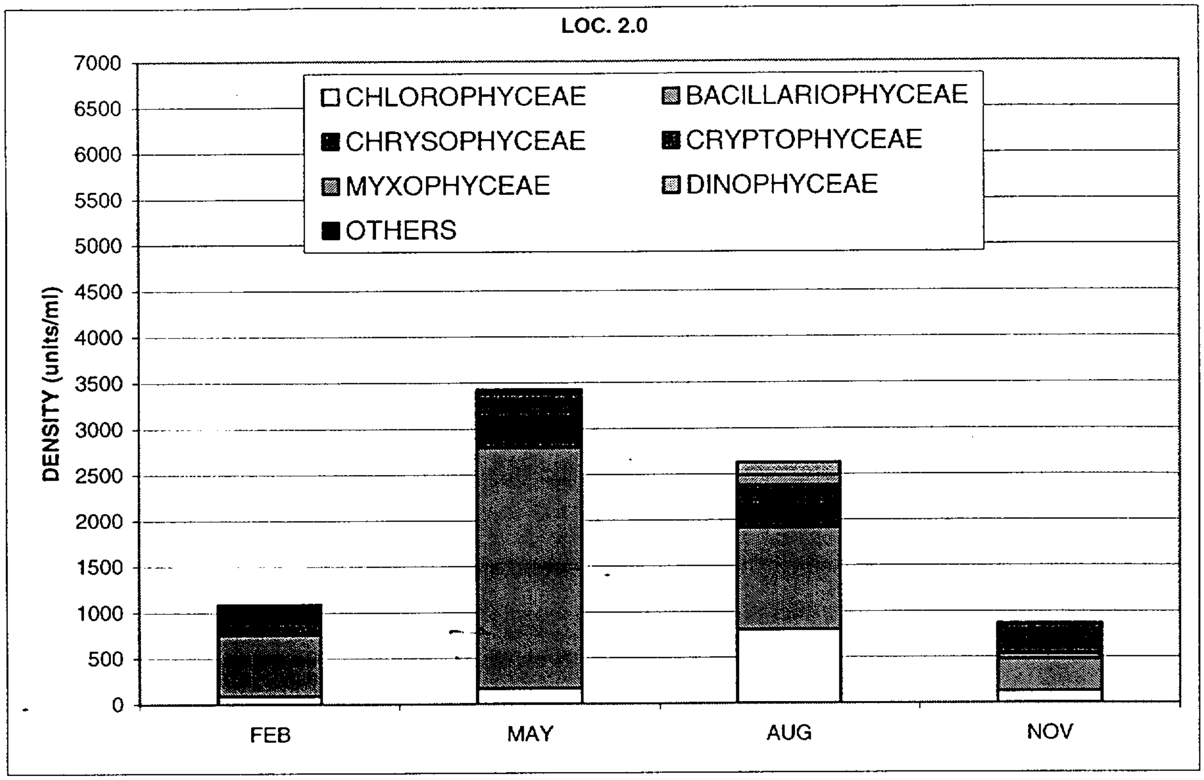


Figure 3-3 (continued).



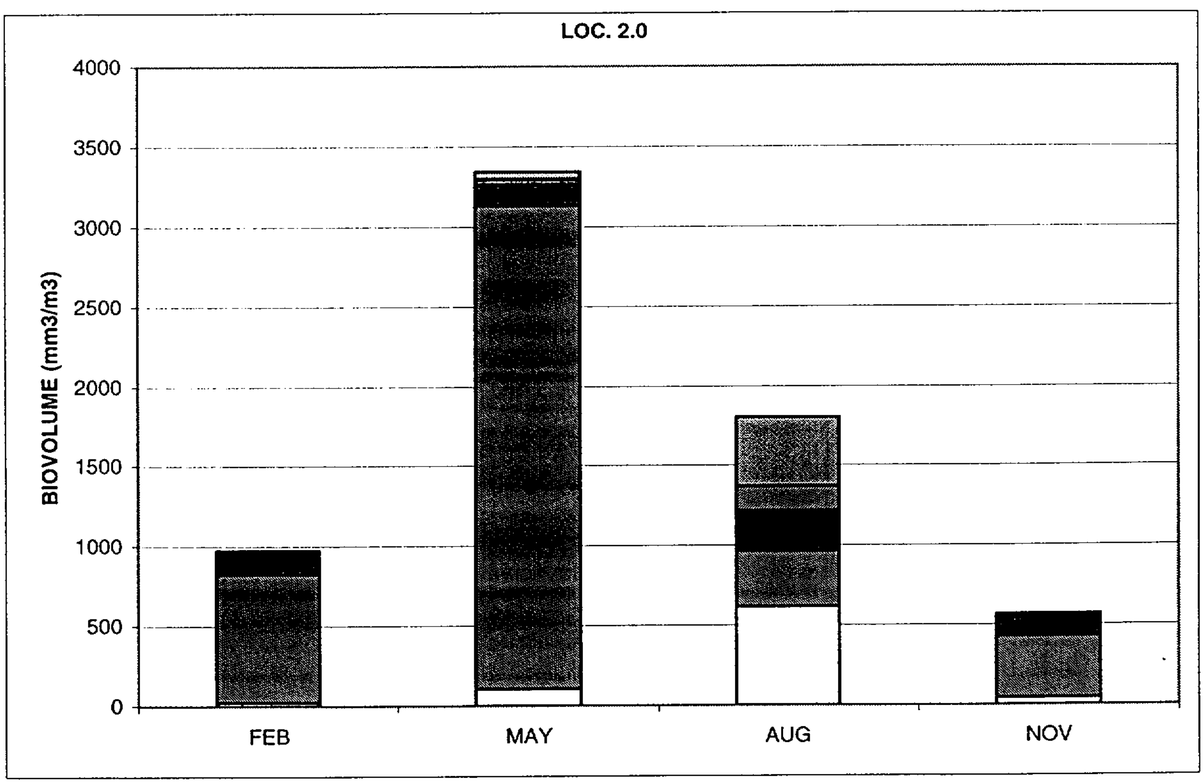
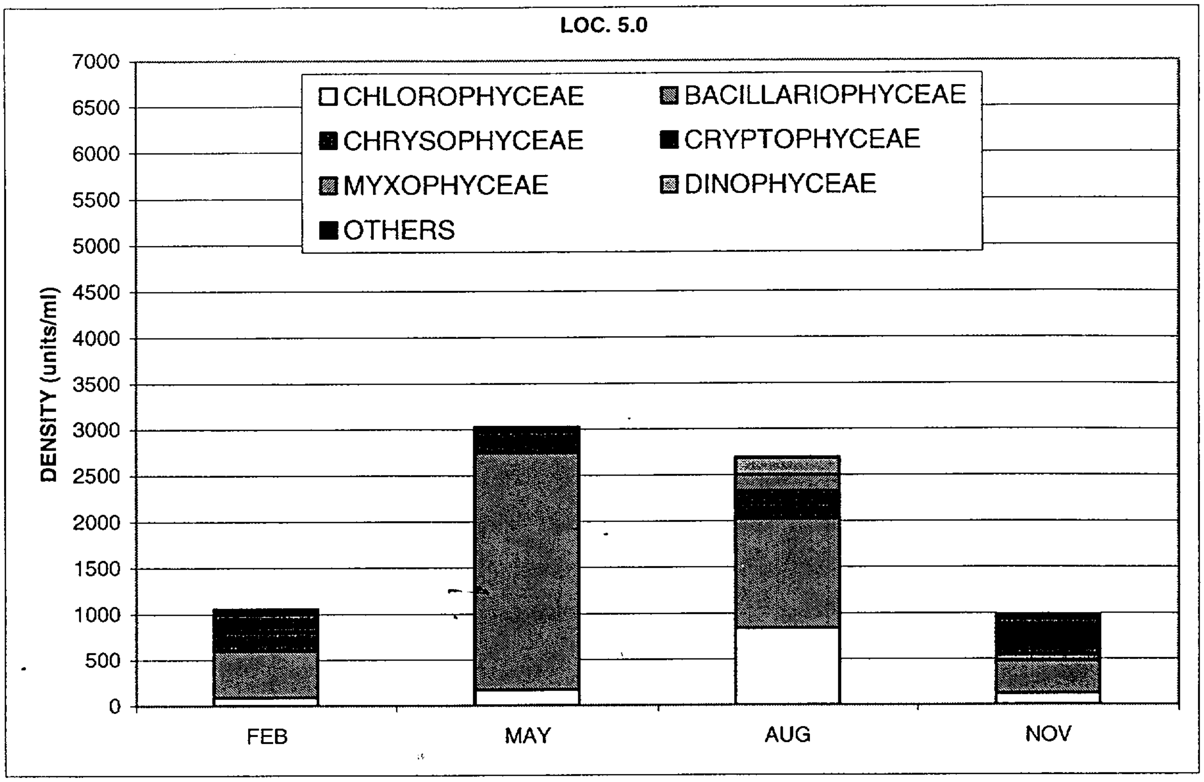


Figure 3-4. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 2.0 in Lake Norman, NC, during 2000.



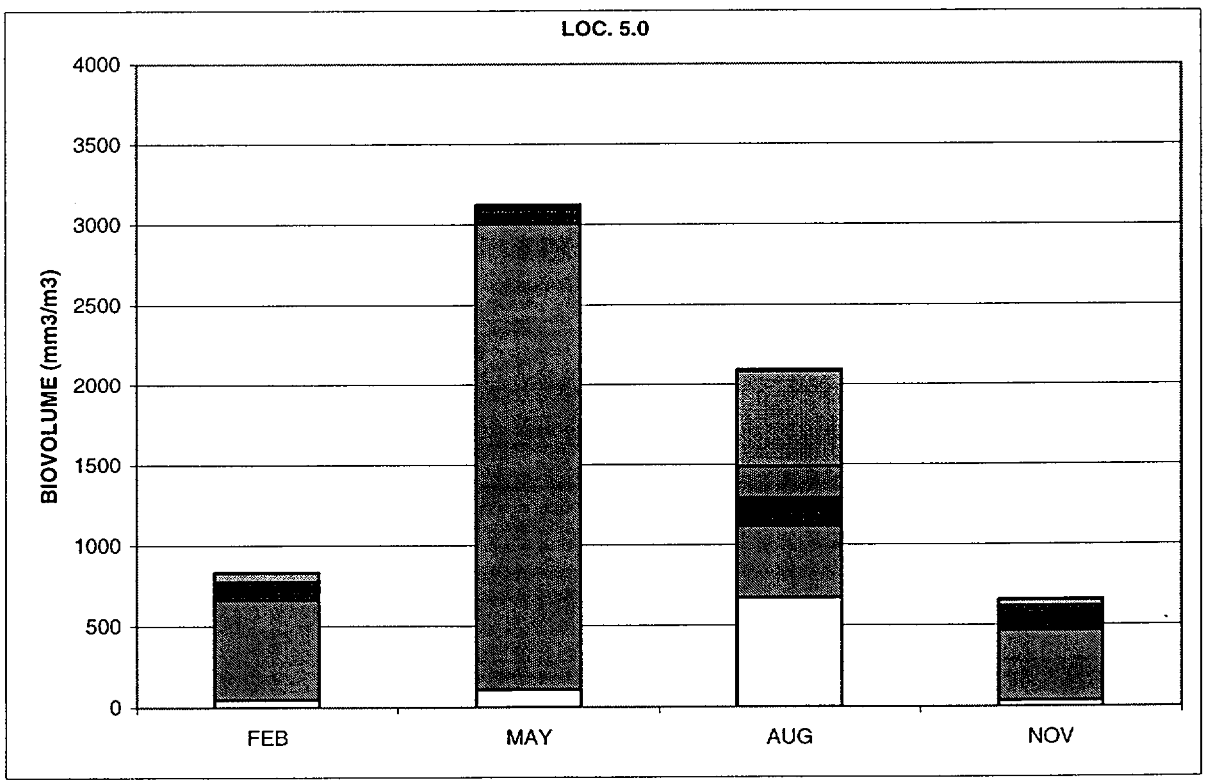


Figure 3-5. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 5.0 in Lake Norman, NC, during 2000.

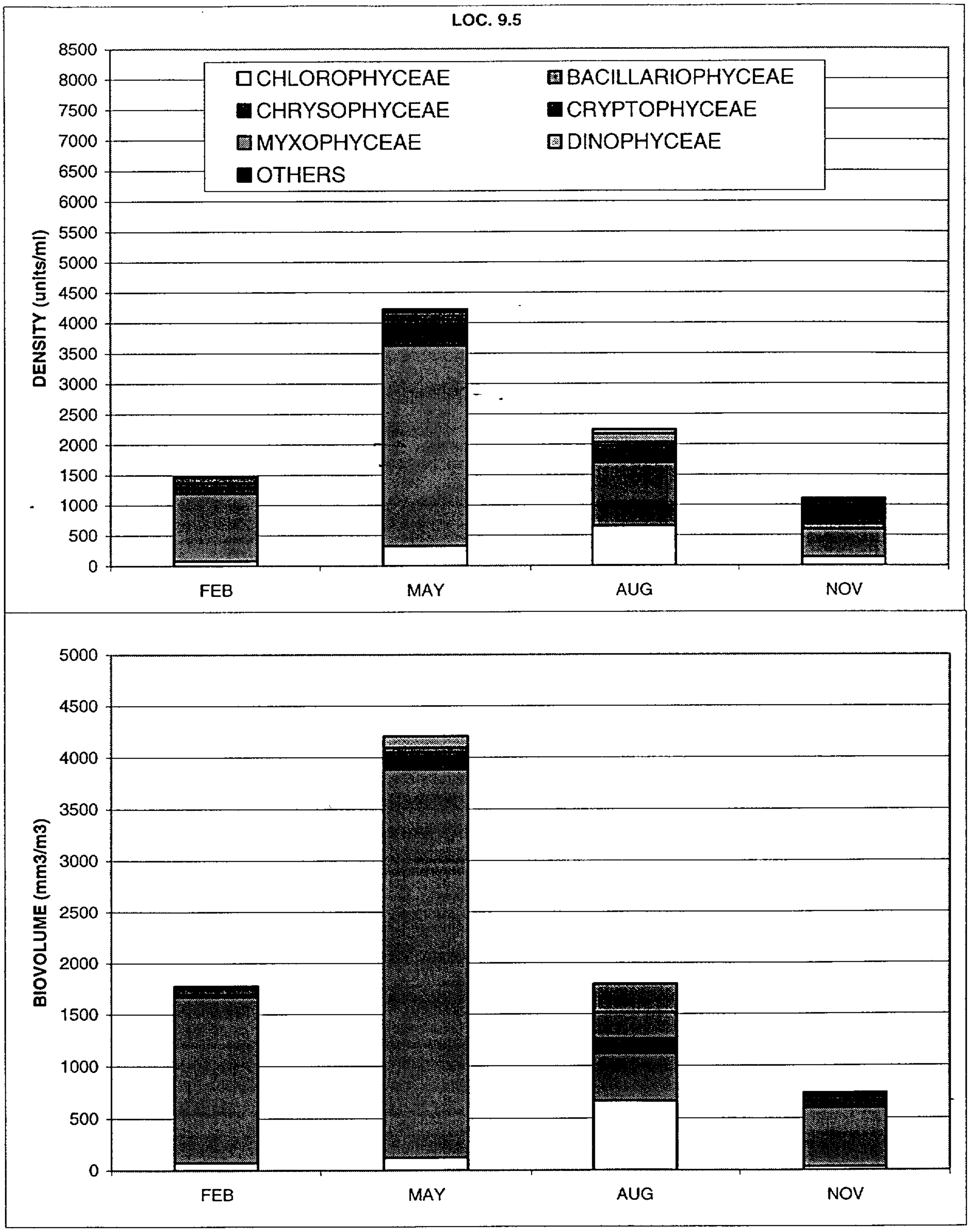


Figure 3-6. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC, during 2000.

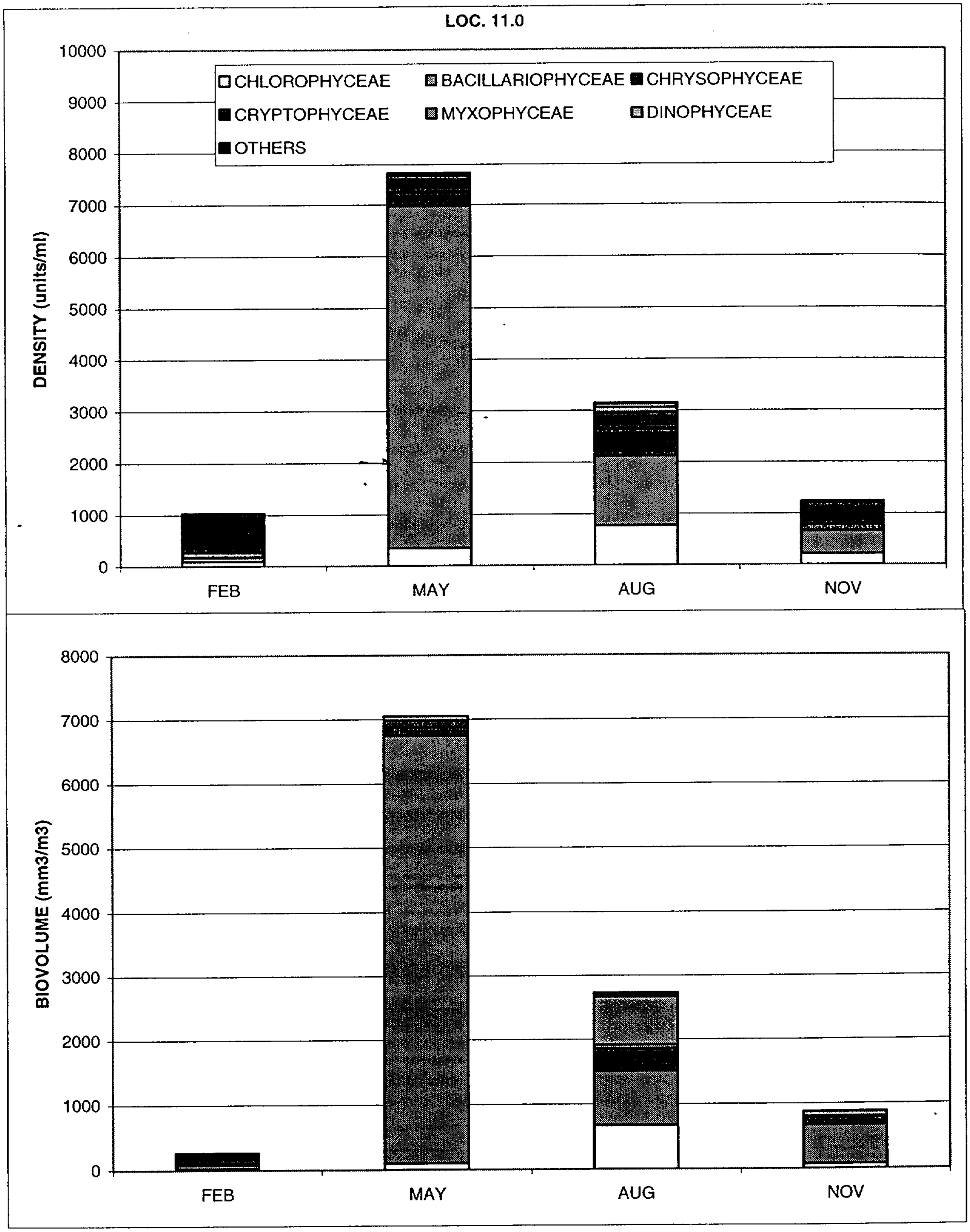


Figure 3-7. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC, during 2000.

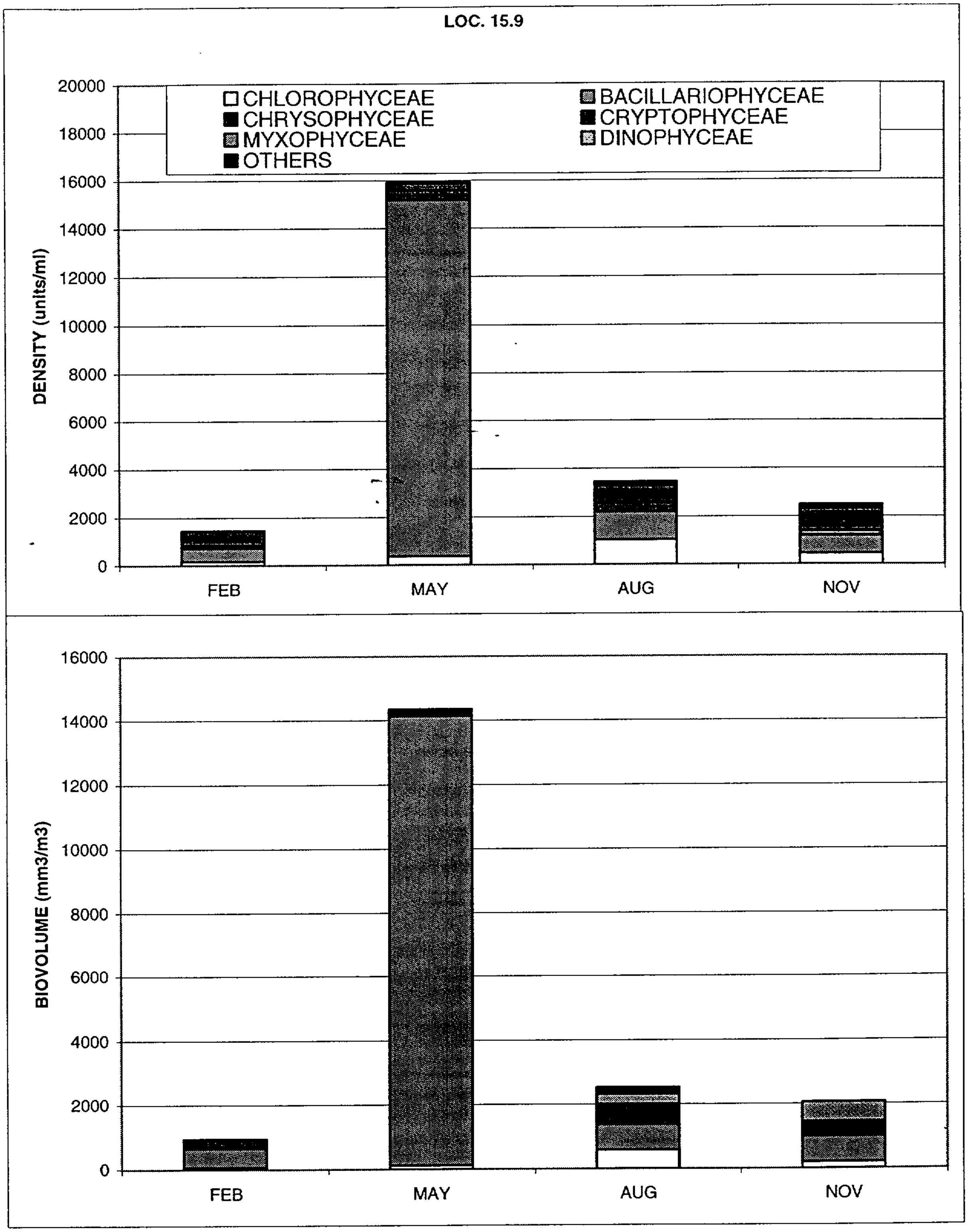


Figure 3-8. Class composition (density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC, during 2000.

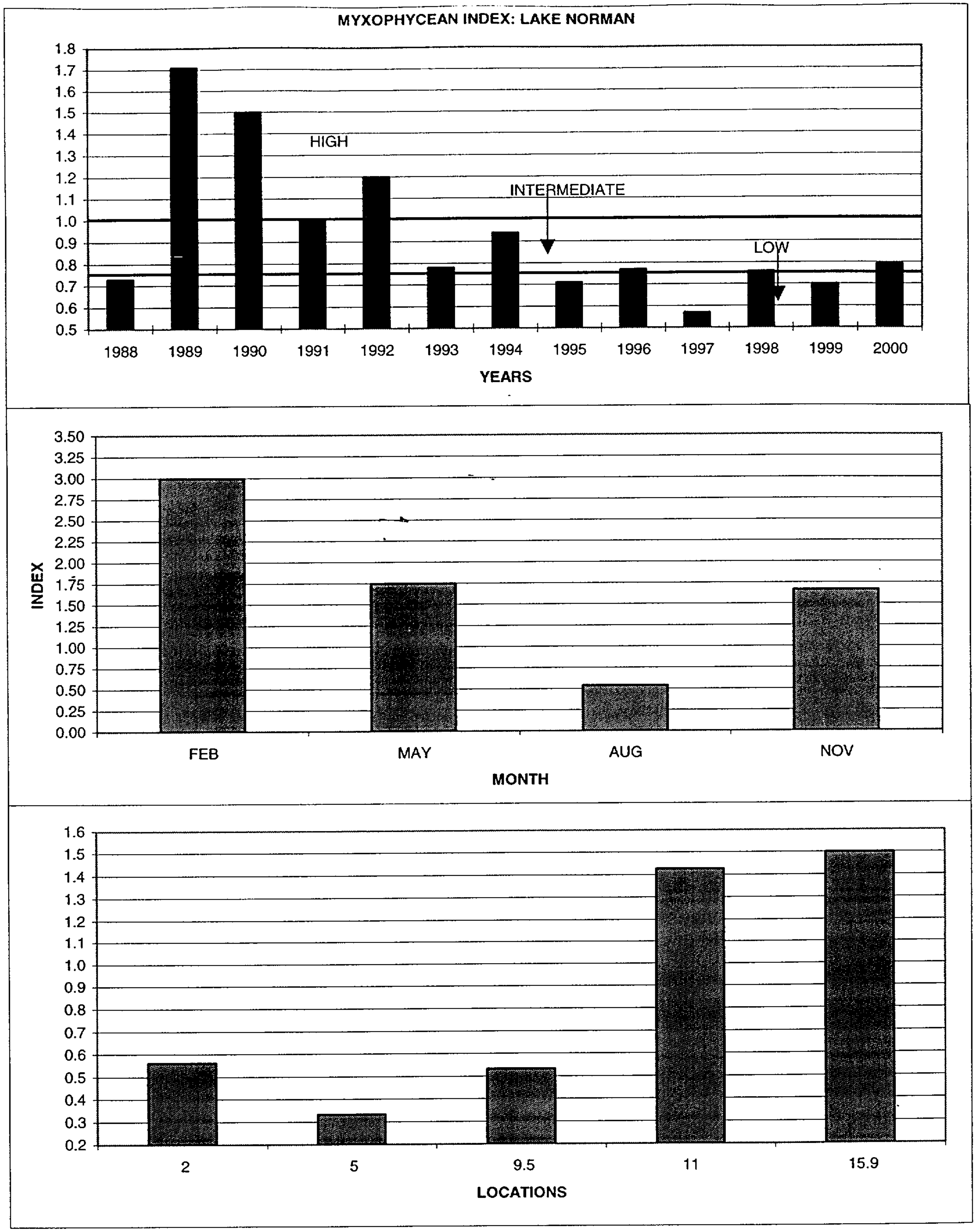


Figure 3-9. Myxophycean index values by year (top), each season in 2000 (mid), and each location in Lake Norman, NC, during 2000.

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 2000) with historical data collected during the period 1987-1999.

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 Company 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 3 February, 24 May, 29 August, and 10 November 2000 (Note: due to loss of mooring buoys and high winds, 10-m to surface samples were not collected at Location 5.0 in February and Location 15.9 in August; and bottom to surface net samples were not collected at Locations 5.0 and 9.5 in February and Location 15.9 in August). 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 2000 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 2000, some degree of seasonal variability was observed in epilimnetic samples. Total zooplankton densities in all epilimnetic samples were highest in May (Table 4-1, Figure 4-1). The lowest epilimnetic densities at Locations 2.0, 5.0, and 15.9 occurred in November, while annual minimum densities at Locations 9.5 and 11.0 were observed in February. Epilimnetic densities ranged from a low of 24,000/m^3 at Location 2.0 in November, to a high of 361,400/m^3 at Location 15.9 in May. In the whole column samples, maximum densities at all but Location 11.0, which had its highest density in August, were observed in May. Minimum densities were observed in November at all but Location 9.5, which had its lowest density in August. Whole column densities ranged from 34,400/m^3 at Location 2.0 in February, to 178,300/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 2000, as has been the case in previous years (Duke Power Company 2000). 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 down-lake to up-lake was observed during 2000 (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 all but August, when Location 11.0 demonstrated the significant maximum (Table 4-2). Note that during August

Location 15.9 was not sampled. In most previous years of the Program, Background Locations had higher mean densities than Mixing Zone locations (Duke Power Company 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999).

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 2000 (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).

Epilimnetic zooplankton densities during all but May of 2000 were within the seasonal ranges of those observed during previous years of the Program. The mean epilimnetic zooplankton densities at Locations 2.0 and 5.0 in May 2000 were the highest May values yet observed for these locations. These high epilimnetic zooplankton concentrations may have been a response to comparatively high phytoplankton concentrations in this part of the lake during May 2000 (Chapter 3). The highest February densities recorded during the Program at Locations 5.0 and 9.5 occurred in 1995, and in 1996 at Locations 2.0 and 11.0 (Figure 4-2). The long-term February maximum at Location 15.9 was observed in 1992. Long-term maximum densities for May occurred at Location 11.0 in 1995, and at Locations 9.5 and 15.9 in 1988. 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 eight 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 2000, compared to fifty-two taxa recorded during 1999 (Duke Power Company 2000). No previously unreported taxa were identified in 2000.

Copepods were dominant most often during 2000 (Table 4-1, Figures 4-4 and 4-5). These microcrustaceans were dominant at Location 15.9 in February, at Locations 2.0 (whole column), 5.0, and 15.9 (epilimnion) in May, at all locations in August, and at Locations 2.0, 5.0 (whole column) and 11.0 in November. Cladocerans were dominant at Location 2.0 (whole column) in February, and Location 9.5 in November. Rotifers dominated zooplankton at Locations 2.0 (epilimnion), 9.5, and 11.0 in February, at Locations 2.0 (epilimnion), 9.5, 11.0, and 15.9 (whole column) in May, and at Locations 5.0 (epilimnion) and 15.9 in November. Microcrustaceans remained dominant in all areas of the lake during 2000 (Figures 4-6 through 4-8). Compared with 1999, the percent composition of microcrustaceans had increased in lake-wide and Background epilimnetic samples, and in Mixing Zone whole column samples. Their relative abundance had declined slightly in Lake-wide and Background whole column samples since last year. During most years of the Program, microcrustaceans dominated Mixing Zone samples, but were less important among Background locations.

Copepoda

Copepod populations were consistently dominated by immature forms (primarily nauplii) during 2000, as has always been the case. Adult copepods seldom constituted more than 8% of the total zooplankton density at any location during 2000. *Tropocyclops* and *Epischura* were often important constituents of adult populations; while *Mesocyclops* were occasionally important (Table 4-4).

Copepods tended to be more abundant, if not dominant, at Background Locations than at Mixing Zone Locations during 2000, and their densities peaked in May at both Mixing Zone and Background Locations. In fact, the mean copepod density for Background Locations in May was the highest yet observed (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 2000 samples, as has been the case in most previous studies (Duke Power Company 2000, 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 at several locations in February and November. *Diaphanosoma* and *Bosminopsis* were also important among cladocerans (Table 4-4). During May, *Diaphanosoma* dominated cladoceran populations in all but the whole column sample from Location 5.0. *Bosminopsis* dominated cladoceran populations at Location 5.0 (whole column) in May and in both sets of samples from this location in August. *Bosminopsis* expressed lower dominance during August 2000 as compared to August 1999, however, similar patterns of *Diaphanosoma-Bosminopsis* dominance have been observed in past years of the Program (Duke Power Company 2000).

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

Rotifera

Keratella was the most abundant rotifer in 2000 samples. This taxon dominated most rotifer populations in May (Table 4-4). *Keratella* also dominated rotifer populations at Locations 2.0, 15.9 (epilimnion), and 11.0 in November. *Polyarthra* was dominant in most August samples, as well as at Locations 2.0, and 11.0 (whole column) in May and whole column samples from Locations 5.0 and 15.9 in November. *Conochilus* dominated rotifer populations at Location 11.0 in February, and Locations 2.0 (epilimnion) and 15.9 (whole column) in November. *Kellicottia* dominated rotifer densities at most Locations in February. *Asplanchna* was the dominant rotifer in samples from Location 11.0 in August, while *Trichocerca* was the dominant rotifer at Location 9.5 (whole column) in August. All of these taxa have been identified as important constituents of rotifer populations, as

well as zooplankton communities, in previous studies (Duke Power Company 2000; 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 Company 1989, 1990). During 2000, peak densities at all locations were observed in May.

FUTURE STUDIES

No changes are planned for the zooplankton portion of the Lake Norman Maintenance Monitoring Program in 2001 and 2002.

SUMMARY

Maximum epilimnetic zooplankton densities occurred in May, while minimum values were recorded in February (Locations 9.5, and 11.0), and November (Locations 2.0 and 15.9). In most whole column samples, maximum densities also occurred in May, with minimum values most often observed in November. 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 2000, 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 during all but May of 2000 were within ranges of those observed in previous years. The epilimnetic densities at Locations 2.0 and 5.0 in May 2000 were the highest recorded from these locations for this month, and may have represented a response to comparatively high phytoplankton standing crops in the Mixing Zone at that time.

One hundred and eight zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (fifty-one were identified during 2000). No previously unreported taxa were identified during 2000.

Copepods dominated zooplankton standing crops most often during 2000. Overall relative abundance of copepods in 2000 had increased slightly since 1999. Cladocerans were occasionally dominant in February and November, while rotifers were dominant in most samples in February and May. Overall, the relative abundance of rotifers had decreased since 1999. 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 seldom 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. *Diaphanosoma* and *Bosminopsis* dominated cladoceran populations in May. The most abundant rotifers observed in 2000, as in previous years, were *Keratella* and *Polyarthra*, while *Conochilus* and *Kellicottia* were occasionally important among rotifer populations in February and November.

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 2000, 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 2000.

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
2/3/00	10-S	COPEPODA	7.9		11.7	27.6	74.6
			(17.4)		(31.3)	(38.8)	(47.5)
		CLADOCERA	15.3		11.8	12.0	31.1
			(33.7)		(31.6)	(17.0)	(19.8)
		ROTIFERA	22.2		13.8	31.3	51.2
			(48.9)		(37.0)	(44.2)	(32.7)
		TOTAL	**45.4**	**NS**	**32.3**	**70.9**	**156.9**
	B-S						
	depth (m)						
	of tow	COPEPODA	12.2			29.7	56.2
	for each		(22.5)			(39.3)	(47.2)
	Location	CLADOCERA	21.9			13.3	27.7
	2.0=30		(40.4)			(17.6)	(23.3)
	5.0=17	ROTIFERA	20.2			32.5	35.0
	9.5=21		(37.1)			(43.1)	(29.5)
	11.0=25						
	15.9=20	**TOTAL**	**54.3**	**NS**	**NS**	**75.5**	**118.9**
5/24/00	10-S	COPEPODA	46.0	42.0	64.7	61.6	168.7
			(37.3)	(37.1)	(36.7)	(29.9)	(46.7)
		CLADOCERA	24.7	30.6	22.8	37.4	45.3
			(20.0)	(27.1)	(12.9)	(18.2)	(12.5)
		ROTIFERA	52.6	40.5	88.6	106.9	147.4
			(42.7)	(35.8)	(50.3)	(51.9)	(40.8)
		TOTAL	**123.3**	**113.1**	**176.1**	**206.0**	**361.4**
	B-S						
	depth (m)						
	of tow	COPEPODA	29.0	26.8	50.2	17.7	78.6
	for each		(49.2)	(46.9)	(41.1)	(21.7)	(44.1)
	Location	CLADOCERA	8.1	17.4	10.8	15.8	19.6
	2.0=30		(13.8)	(22.2)	(8.9)	(19.4)	(11.0)
	5.0=NS	ROTIFERA	21.8	24.2	61.0	48.0	80.1
	9.5=21		(37.0)	(30.8)	(50.0)	(58.9)	(44.9)
	11.0=25						
	15.9=20	**TOTAL**	**58.8**	**78.4**	**122.0**	**81.6**	**178.3**

Table 4-1 (continued).

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
8/29/00	10-S	COPEPODA	45.7	41.8	32.3	53.4	
			(62.1)	(61.8)	(43.0)	(43.2)	
		CLADOCERA	19.8	11.9	26.7	27.3	
			(27.0)	(17.6)	(35.5)	(22.1)	
		ROTIFERA	8.0	13.9	16.2	42.9	
			(10.9)	(20.6)	(21.5)	(34.7)	
		TOTAL	**73.6**	**67.7**	**75.2**	**123.6**	**NS**
	B-S						
	depth (m)						
	of tow	COPEPODA	29.6	39.9	26.3	41.8	
	for each		(61.2)	(63.8)	(47.9)	(50.8)	
	Location	CLADOCERA	15.9	11.3	18.7	17.0	
	2.0=30		(33.0)	(18.0)	(34.0)	(20.7)	
	5.0=NS	ROTIFERA	2.8	11.4	9.9	23.4	
	9.5=19		(5.8)	(18.2)	(18.0)	(28.5)	
	11.0=25						
	15.9=18	**TOTAL**	**48.3**	**62.6**	**54.9**	**82.2**	**NA**
11/10/00	10-S	COPEPODA	10.6	13.4	26.3	45.2	30.5
			(44.2)	(28.3)	(25.8)	(45.3)	(25.0)
		CLADOCERA	9.6	16.5	47.0	18.5	4.6
			(39.8)	(35.0)	(46.1)	(18.6)	(3.8)
		ROTIFERA	3.8	17.3	28.7	36.1	86.9
			(16.0)	(36.6)	(28.2)	(36.2)	(71.2)
		TOTAL	**24.0**	**47.3**	**102.0**	**99.7**	**122.0**
	B-S						
	depth (m)						
	of tow	COPEPODA	19.3	16.7	30.6	45.3	28.8
	for each		(56.1)	(36.6)	(29.2)	(60.6)	(28.4)
	Location	CLADOCERA	10.2	13.0	40.2	12.5	4.5
	2.0=30		(29.8)	(28.7)	(38.3)	(16.8)	(4.4)
	5.0=NS	ROTIFERA	4.8	15.8	34.1	16.9	68.2
	9.5=20		(14.0)	(34.7)	(32.5)	(22.6)	(67.2)
	11.0=24						
	15.9=NS	**TOTAL**	**34.4**	**45.5**	**104.9**	**74.7**	**101.5**

NS= Sample not collected due to high winds, or no mooring buoy.

Table 4-2. Duncan's Multiple Range Test on epilimnetic zooplankton densities (no. X 1000/m^3) in Lake Norman, NC during 2000.

February	Location	**5.0**	**9.5**	**2.0**	**11.0**	**15.9***
	Mean	NS	37.3	45.4	70.9	156.9
May	Location	**5.0**	**2:0**	**9.5**	**11.0**	**15.9**
	Mean	113.1	123.3	176.1	206.0	361.4
August	Location	**15.9**	**5.0**	**2.0**	**9.5**	**11.0**
	Mean	NS	67.7	73.6	75.2	123.6
November	Location	**2.0**	**5.0**	**11.0**	**9.5**	**15.9**
	Mean	24.0	47.3	99.7	102.0	122.3

NS = not sampled

* = only one replicate

Table 4-3. Zooplankton taxa identified from samples collected quarterly on Lake Norman from 1988 through 2000.

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00
COPEPODA													
Cyclops thomasi Forbes	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		
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
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
Epishura fluviatilis Herrick								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
M. spp. Sars	X	X		X	X	X	X	X	X	X			
Tropocyclops prasinus (Fischer)	X	X	X					X	X	X	X	X	X
T. spp.	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
Cyclopoid copepodites	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
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
B. spp. Baird	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
Ceriodaphnia lacustris Birge				X						X	X	X	X
C. spp. Dana	X	X	X	X	X	X	X	X	X	X	X	X	X
Chydorus spp. Leach				X		X	X	X	X	X		X	
Daphnia ambigua Scourfield	X	X	X						X	X	X	X	
D. catawba Coker									X	X			
D. galeata Sars									X				
D. laevis Birge									X				
D. longiremis Sars									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
D. pulex (de Geer)									X	X			

Table 4-3 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00
CLADOCERA (continued)													
D. pulicaria Sars									X	X			
D. retrocurva Forbes									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
Diaphanosoma brachyurum (Lievin)										X	X	X	X
D. spp. Fischer	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
H. gibberum Zaddach			X							X	X		
H. spp. Stingelin	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
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
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	
C. spp. Lauterborne	X	X	X	X	X	X	X	X	X				
Collotheca balatonica Harring									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
Colurella spp. Bory de St. Vincent									X				
Conochiloides dossuarius Hudson										X	X	X	X
C. spp. Hlava	X	X	X	X	X	X	X	X	X	X			
Conochilus unicornis (Rousselet)	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
ROTIFER (continued)													
C. spp. Hlava	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
G. spp. Imhof	X	X	X		X	X	X	X	X	X	X		
Hexarthra mira Hudson										X	X	X	X
H. spp. Schmada	X	X	X	X	X	X	X	X	X	X			
Kellicottia bostoniensis (Rousselet)	X	X	X				X	X	X	X	X	X	X
K. longispina Kellicott										X	X	X	X
K. spp. Rousselet	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
Lecane spp. Nitzsch	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
Monostyla stenroosi (Meissener)	X		X										
M. spp. Ehrenberg	X	X	X				X	X	X		X		
Notholca spp. Gosse							X		X		X		
Ploeosoma hudsonii Brauer				X			X	X	X	X	X	X	X
P. truncatum (Levander)	X	X	X				X	X	X	X	X	X	X
P. spp. Herrick	X	X	X	X	X	X	X	X	X		X		
Polyarthra euryptera (Weirzeijski)	X	X	X								X		
P. major Burckhart										X		X	X
P. vulgaris Carlin	X	X	X							X		X	X
P. spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X
Pompholyx spp. Gosse									X				
Ptygura libra Meyers										X	X		X
P. spp. Ehrenberg	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
Trichocerca capucina (Weireijski)	X	X	X				X	X	X	X	X		
T. cylindrica (Imhof)	X	X	X					X	X	X	X	X	X
T. longiseta Schrank										X			
T. multicrinis (Kellicott)											X	X	X
T. porcellus (Gosse)								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
Trichotria spp. Bory de St. Vincent									X				

Table 4-3 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00
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	
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 2000.

	FEBRUARY	MAY	AUGUST	NOVEMBER
		COPEPODA	**EPILIMNION**	
2.0	*Tropocyclops* (1.7)	*Epischura* (1.1)	*Tropocyclops* (8.2)	*Episch.+ Trop* (0.4ea)*
5.0	NOT SAMPLED	*Epischura* (1.3)	*Tropocyclops* (10.9)	*Epischura* (0.8)
9.5	*Mesocyclops* (1.0)	*Epischura* (2.1)	*Tropocyclops* (4.2)*	*Epischura* (1.4)
11.0	*Epischura* (2.6)	*Mesocyclops* (0.6)	*Tropocyclops* (2.5)	*Tropocyclops* (1.5)
15.9	*Epischura* (4.0)	*Mesocyclops* (2.1)	NOT SAMPLED	*Tropocyclops* (0.5)
		COPEPODA	**WHOLE COLUMN**	
2.0	*Tropocyclops* (0.4)	*Mesocyclops* (1.6)	*Tropocyclops* (9.4)	*Epischura* (4.7)
5.0	NOT SAMPLED	*Epischura* (1.5)	*Tropocyclops* (15.3)	*Tropocyclops* (2.2)
9.5	NOT SAMPLED	*Epischura* (1.1)	*Tropocyclops* (4.7)	*Epischura* (2.6)
11.0	*Mesocyclops* (2.2)	*Mesocyclops* (3.1)	*Tropocyclops* (4.3)	*Tropocyclops* (2.5)
15.9	*Cyclops* (2.1)	*Mesocyclops* (3.3)	NOT SAMPLED	*Tropocyclops* (1.2)
		CLADOCERA	**EPILIMNION**	
2.0	*Bosmina* (100.0)	*Diaphanosoma* (67.7)	*Bosmina* (57.0)	*Bosmina* (91.0)
5.0	NOT SAMPLED	*Diophanosoma* (52.1)	*Bosminopsis* (50.2)	*Bosmina* (90.3)
9.5	*Bosmina* (89.9)	*Diaphanosoma* (46.5)	*Bosmina* (51.9)	*Bosmina* (99.3)
11.0	*Bosmina* (70.0)	*Diaphanosoma* (58.1)	*Bosmina* (77.9)	*Bosmina* (91.0)
15.9	*Bosmina* (55.0)	*Diaphanosoma* (55.8)	NOT SAMPLED	*Bosmina* (93.6)
		CLADOCERA	**WHOLE COLUMN**	
2.0	*Bosmina* (97.9)	*Diaphanosoma* (43.2)	*Bosmina* (52.8)	*Bosmina* (66.7)
5.0	NOT SAMPLED	*Bosmina* (42.7)	*Bosminopsis* (47.0)	*Bosmina* (78.6)
9.5	NOT SAMPLED	*Diaphanosoma* (43.8)	*Bosmina* (61.9)	*Bosmina* (98.5)
11.0	*Bosmina* (82.4)	*Diaphanosoma* (68.0)	*Bosmina* (68.3)	*Bosmina* (75.8)
15.9	*Bosmina* (54.5)	*Diaphanosoma* (40.7)	NOT SAMPLED	*Bosmina* (91.0)

Table 4-4 (continued)

	FEBRUARY	MAY	AUGUST	NOVEMBER
		ROTIFERA	**EPILIMNION**	
2.0	*Kellicottia* (39.5)	*Polyarthra* (31.3)	*Polyarthra* (80.5)	*Conochilus* (36.4)
5.0	NOT SAMPLED	*Keratella* (39.4)	*Polyarthra* (74.8)	*Keratella* (30.3)
9.5	*Kellicottia* (25.1)	*Keratella* (61.1)	*Polyarthra* (22.9)	*Conochilus* (56.5)
11.0	*Conochilus* (41.2)	*Keratella* (35.0)	*Asplanchna* (34.3)	*Keratella* (48.7)
15.9	*Kellicottia* (31.8)	*Keratella* (58.1)	NOT SAMPLED	*Keratella* (45.0)
		ROTIFERA	**WHOLE COLUMN**	
2.0	*Kellicottia* (46.6)	*Polyarthra* (39.8)	*Polyarthra* (51.8)	*Kellicottia* (38.9)
5.0	NOT SAMPLED	*Keratella* (52.3)	*Polyarthra* (71.7)	*Polyarthra* (42.4)
9.5	NOT SAMPLED	*Keratella* (63.3)	*Trichocerca* (27.9)	*Conochilus* (57.0)
11.0	*Conochilus* (30.4)	*Polyarthra* (42.1)	*Asplanchna* (37.8)	*Keratella* (45.4)
15.9	*Kellicottia* (31.9)	*Keratella* (65.4)	NOT SAMPLED	*Polyarthra* (42.0)

* = Only adults present in samples.

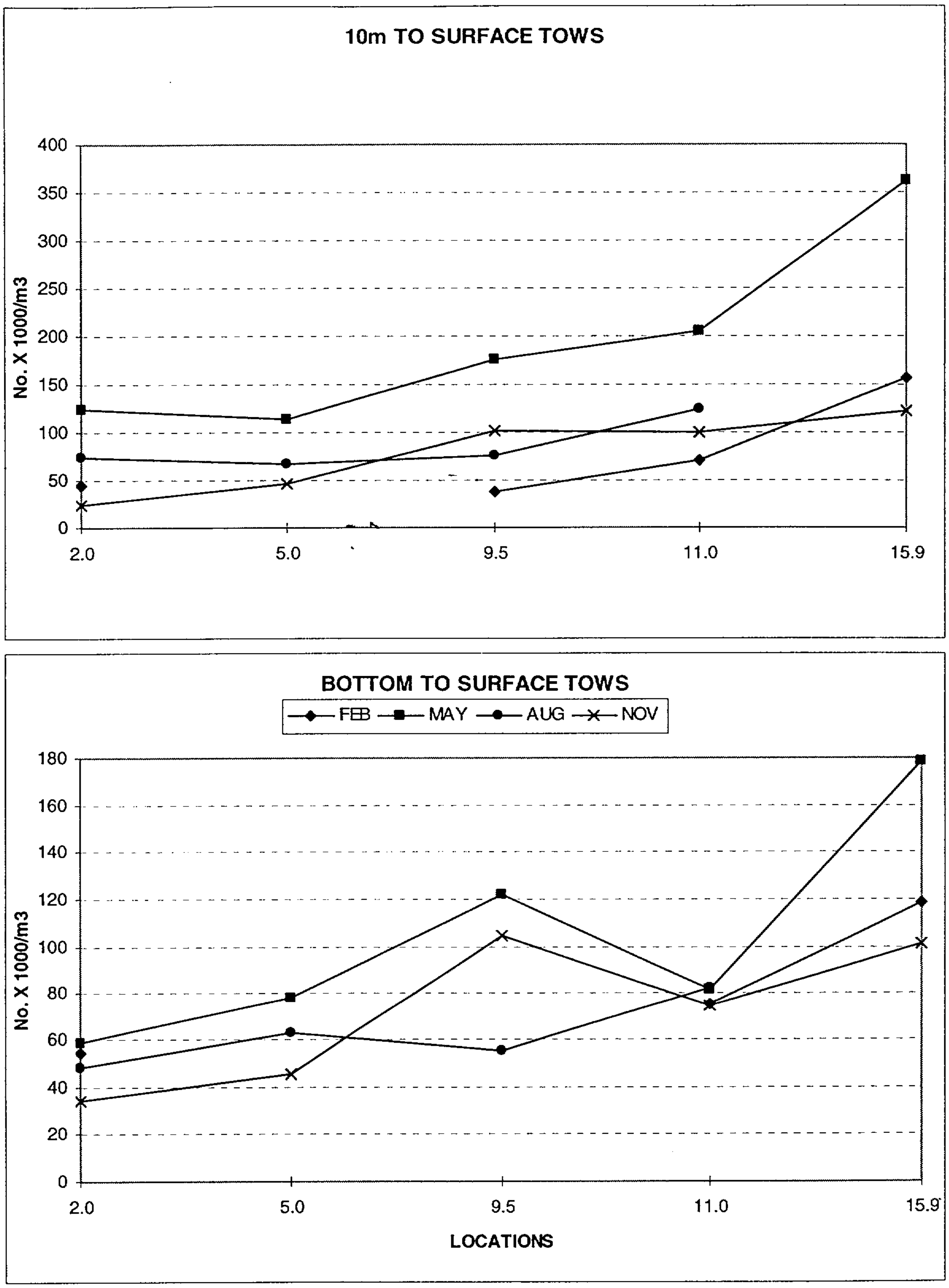
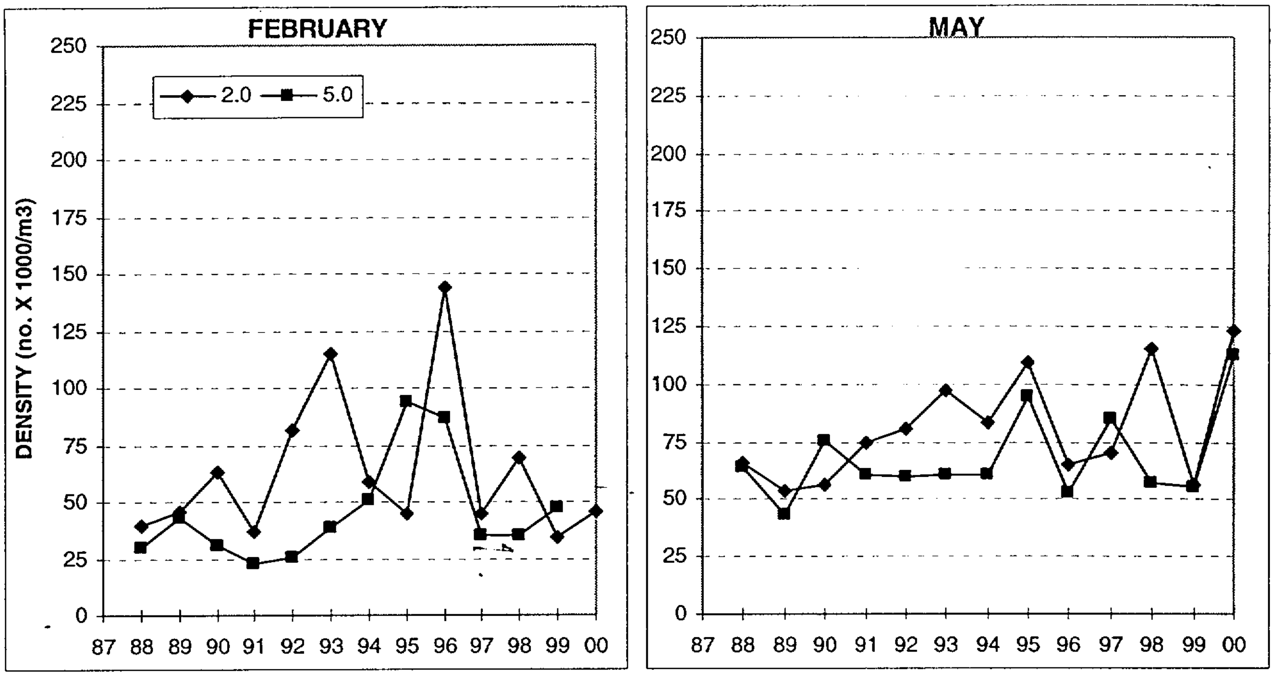


Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman, NC, in 2000.

MIXING ZONE



BACKGOUND LOCATIONS

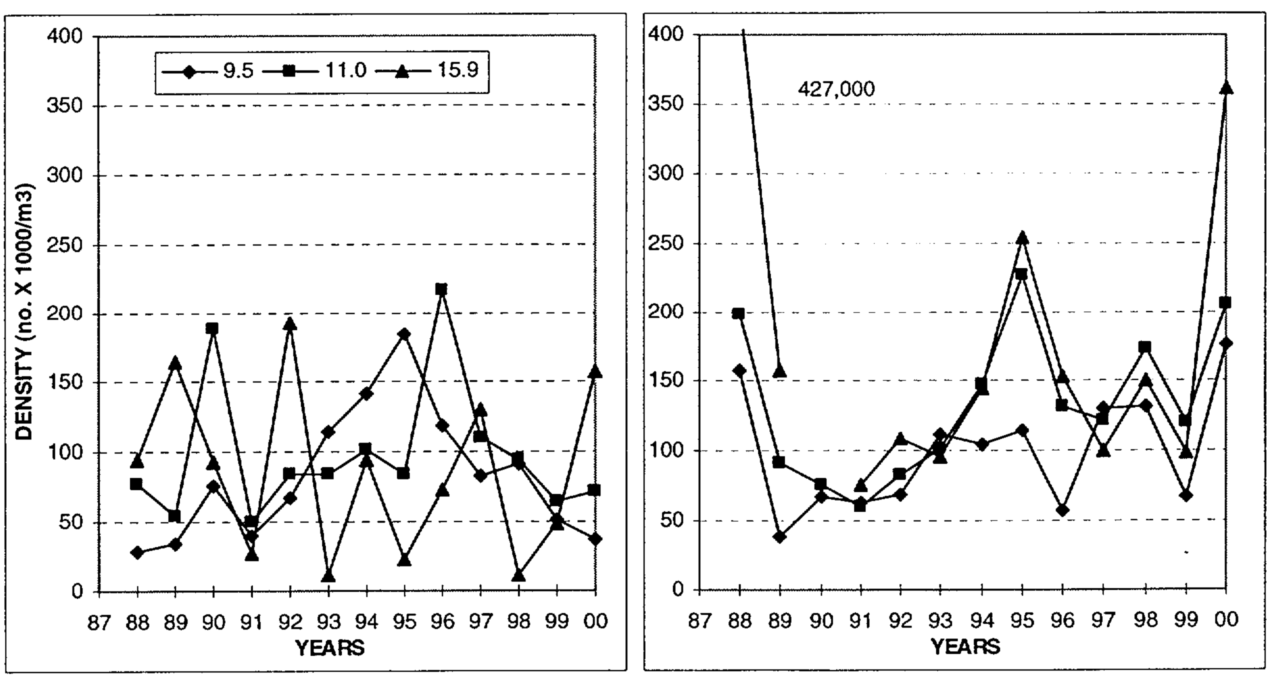


Figure 4-2. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in February and May of 1988 through 2000.

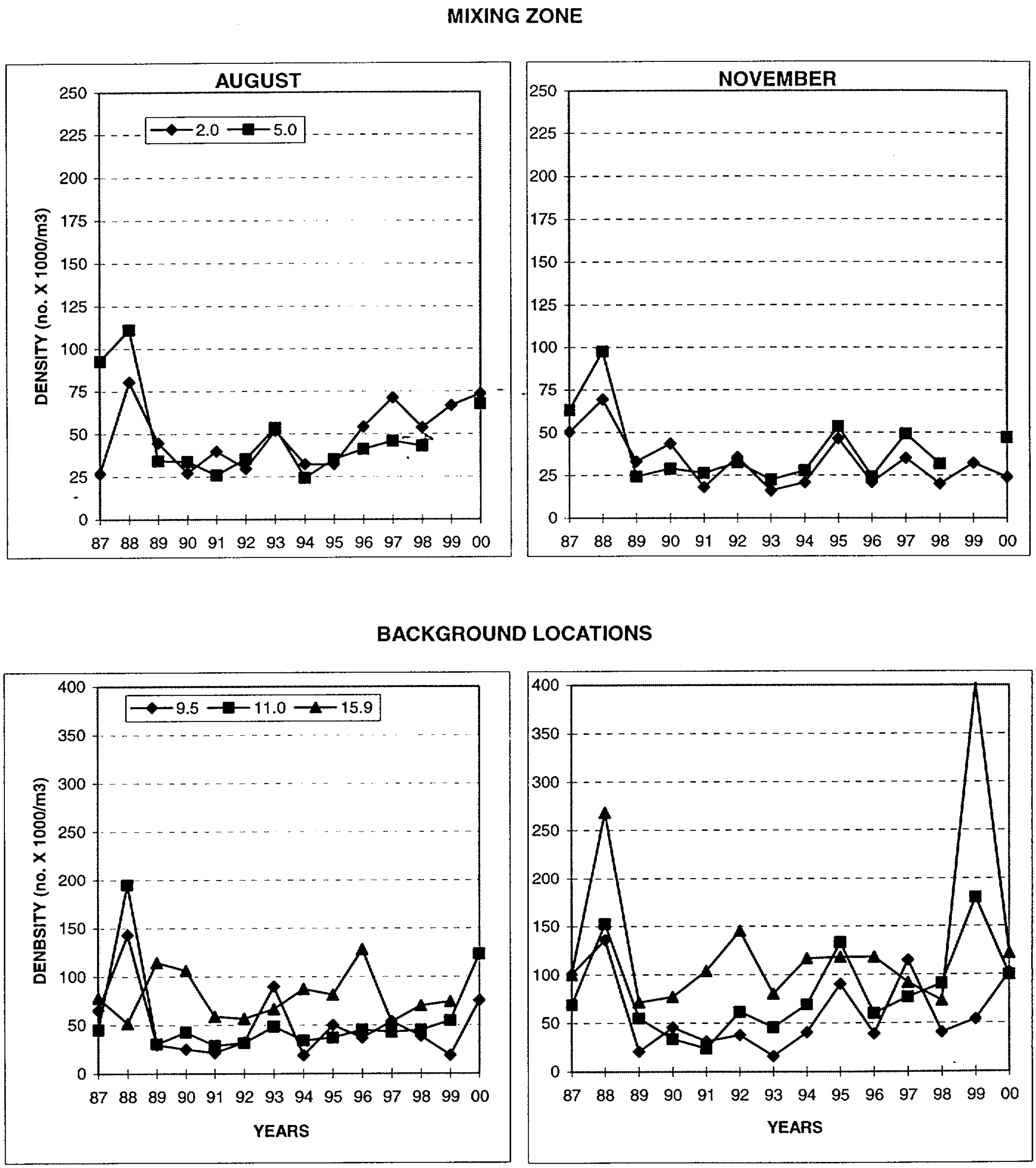


Figure 4-3. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in August and November of 1987 through 2000.

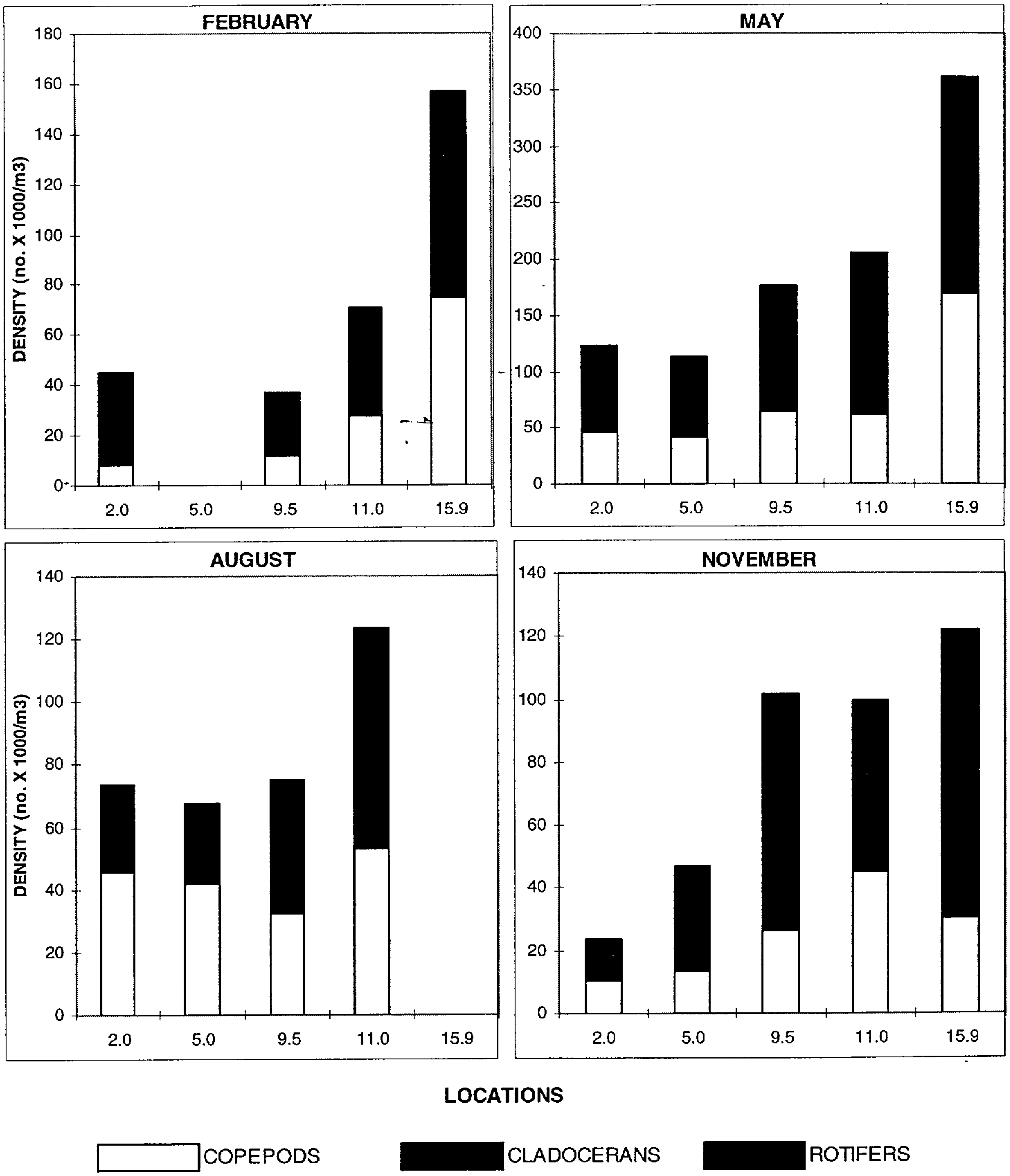


Figure 4-4. Zooplankton community composition by month for epilimnetic samples collected in Lake Norman, NC, in 2000.

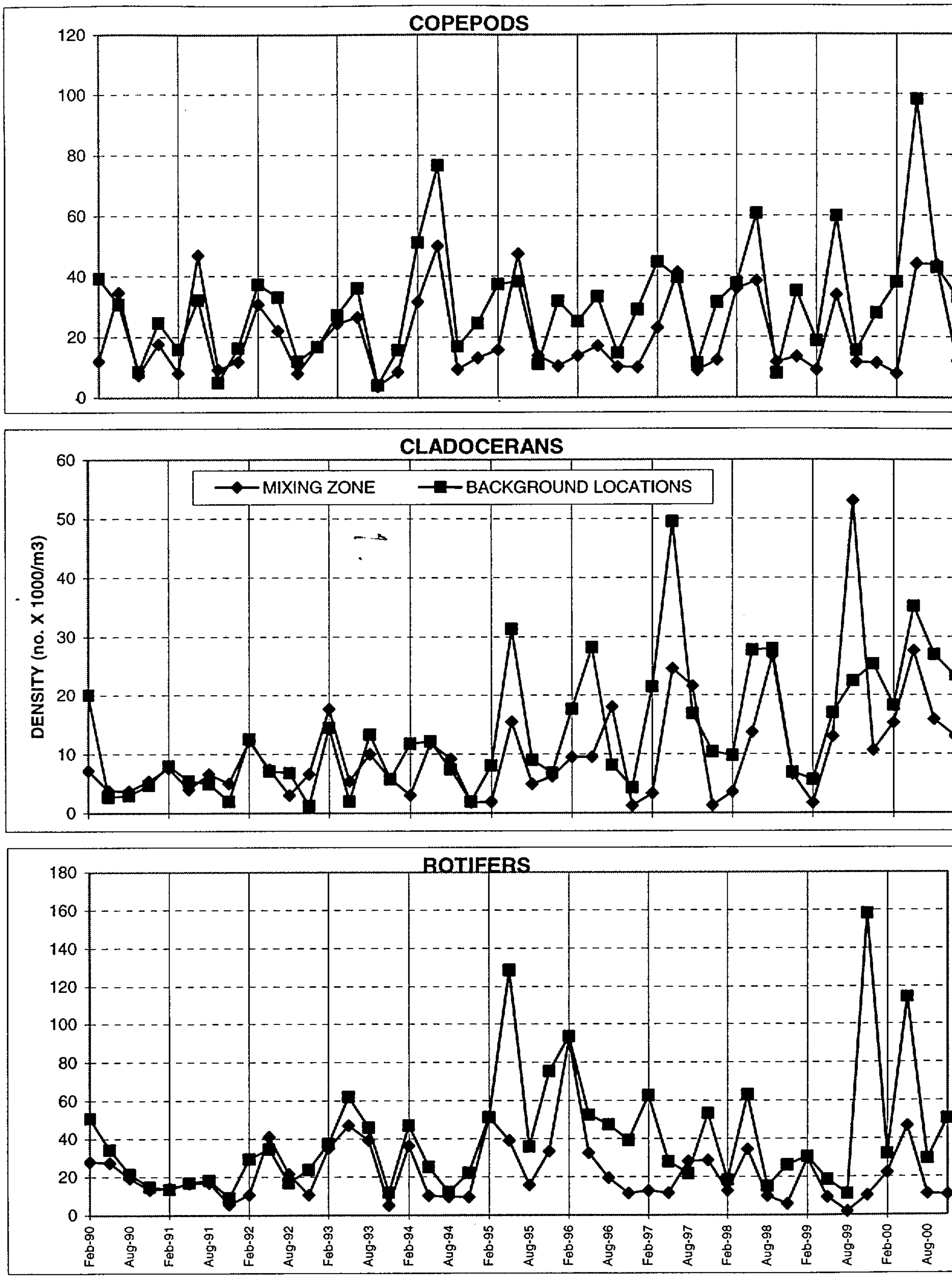


Figure 4-5. Zooplankton composition by quarter for epimlimnetic samples collected in Lake Norman, NC, from 1990 through 2000 (only Location 2.0 represents the MIXING ZONE in February 2000).

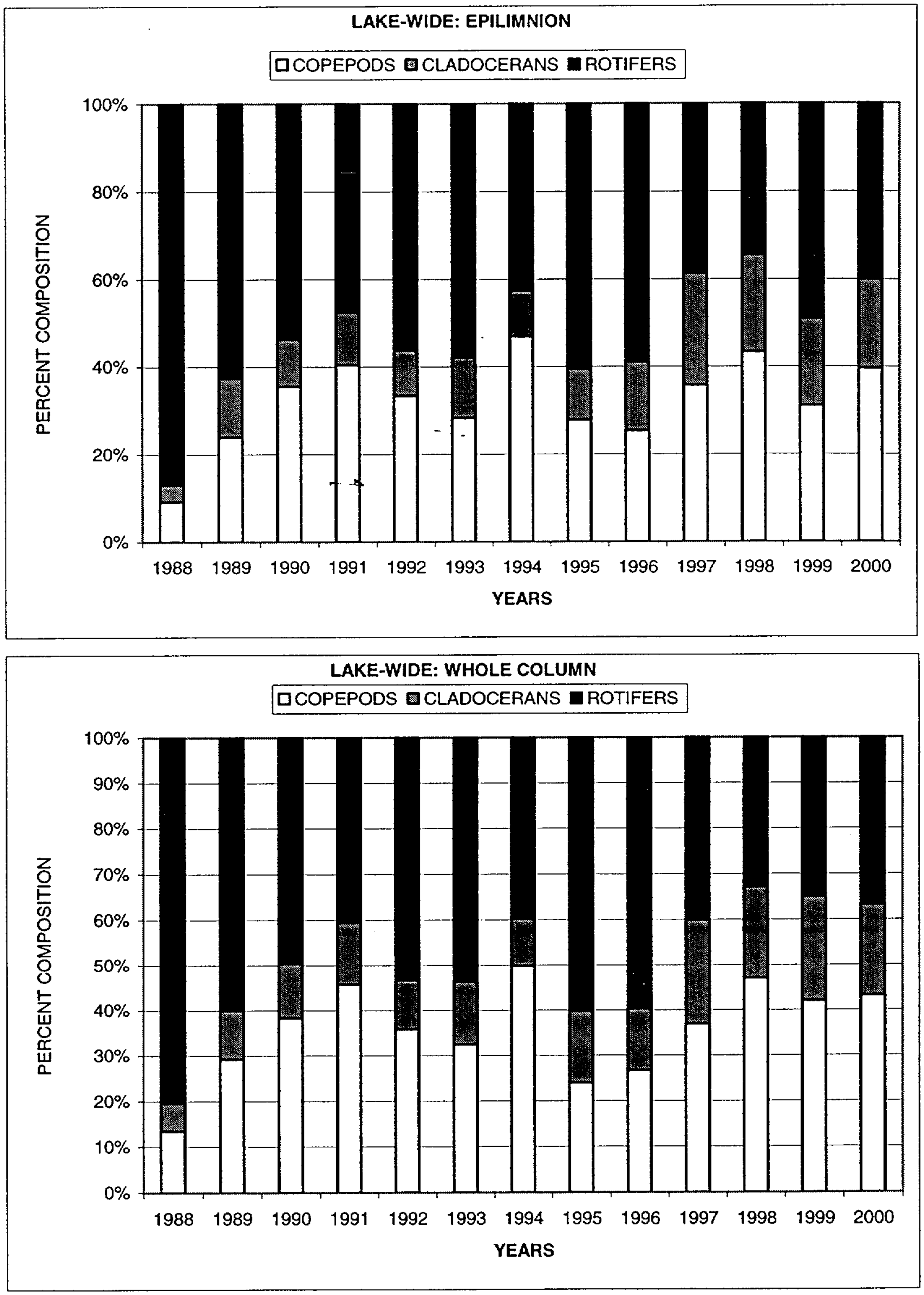
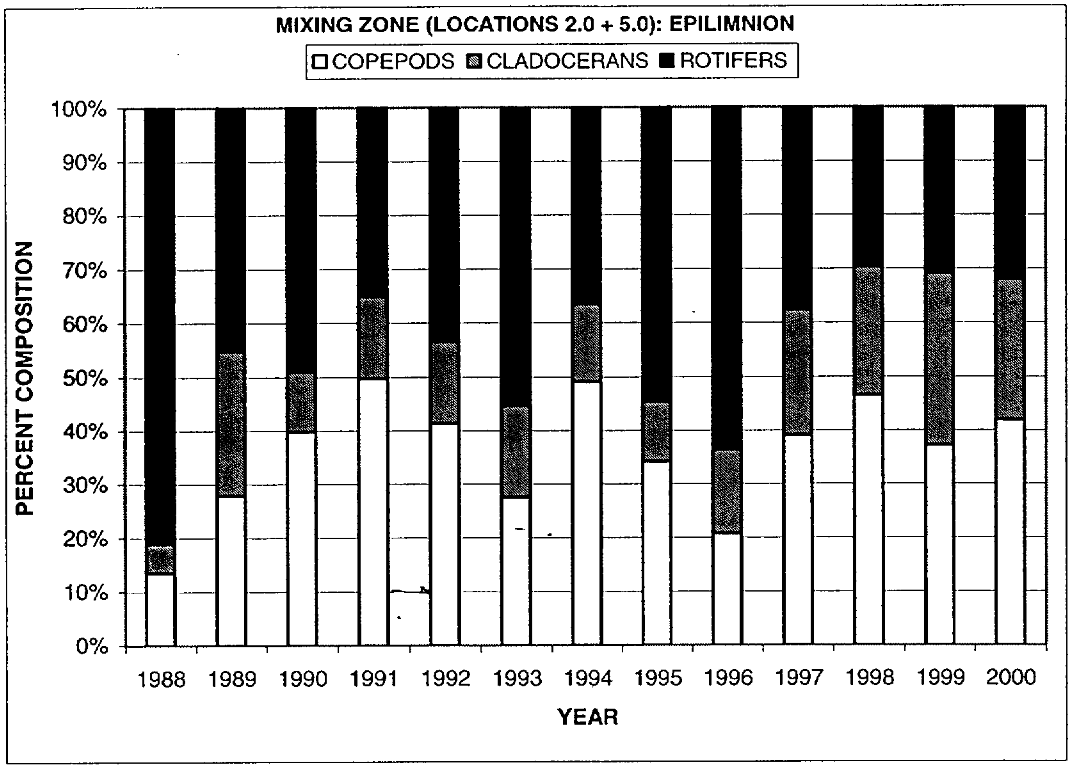


Figure 4-6. Annual lake-wide percent composition of major zooplankton taxonomic groups from 1988 through 2000.



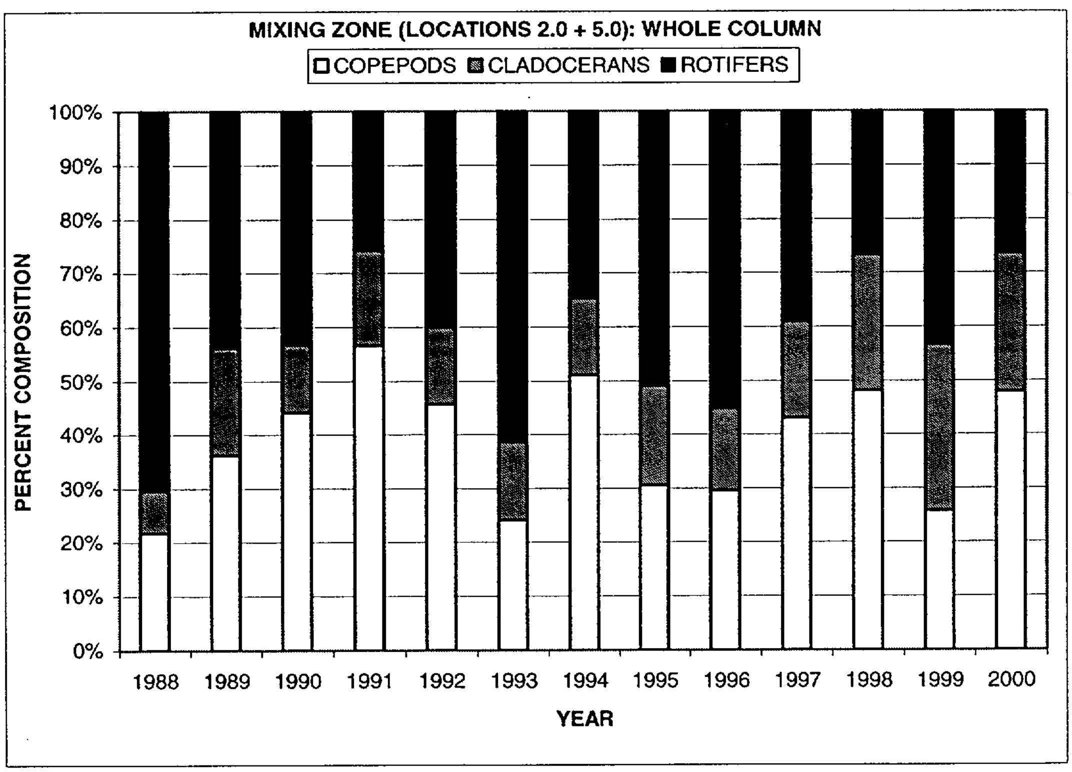
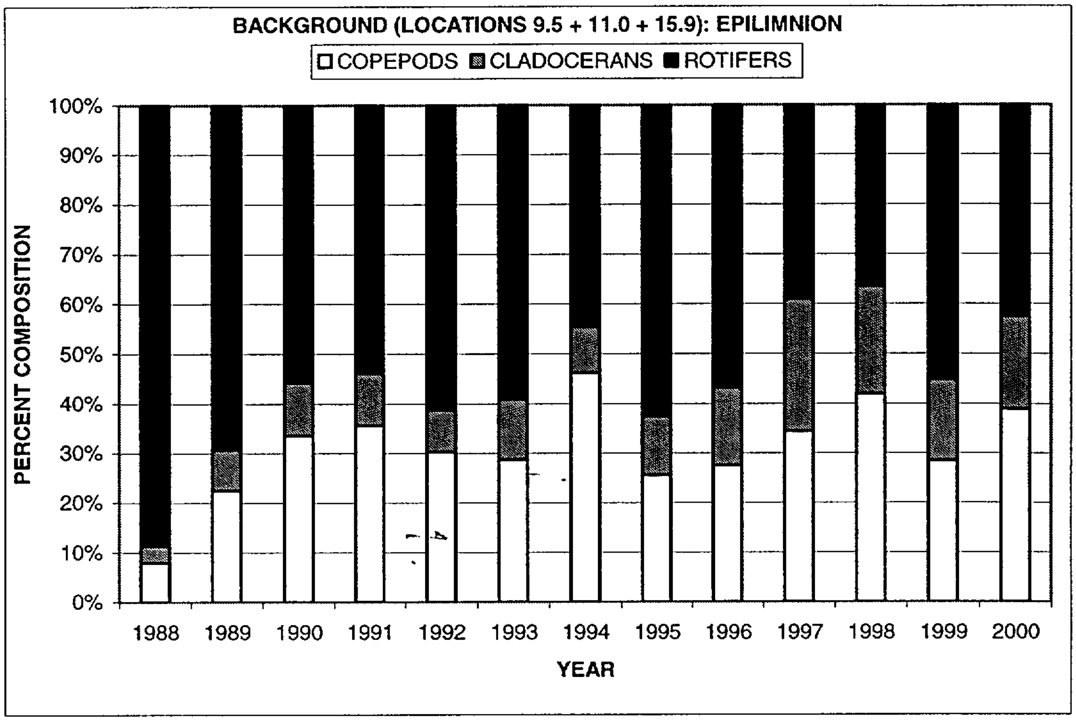


Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from Mixing Zone Locations: 1988 through 2000.



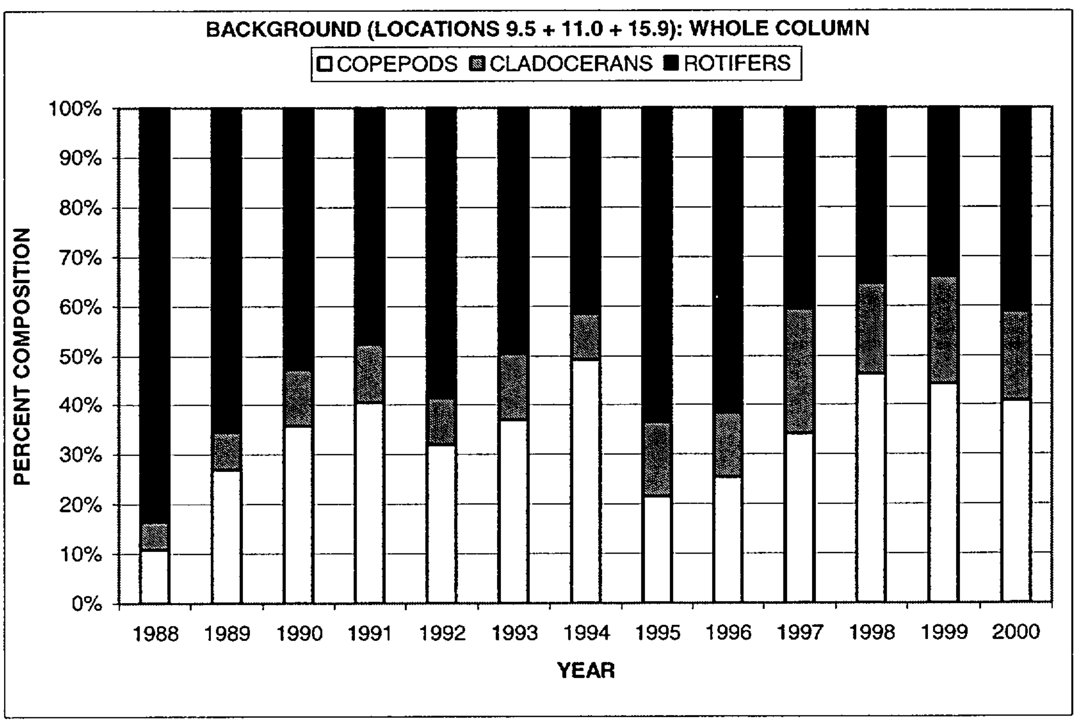


Figure 4-8. Annual percent composition of major zooplankton taxonomic groups from Background Locations: 1988 through 2000.

CHAPTER 5
FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters was continued during 2000. The components of the 2000 fish monitoring program for Lake Norman were to:

1. Continue striped bass mortality monitoring throughout the summer;
2. Continue a 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 in Lake Norman;
3. Continue annual, fall hydroacoustic/purse seine forage population assessments;
4. Assist the NCWRC in shad netting collections to evaluate the taxa composition and size distribution of Lake Norman forage species;
5. Revise annual, spring shoreline electrofishing program to be conducted every 2 years, beginning Spring 1999, with next sample scheduled for Spring 2001;
6. Cooperate with NCWRC on a shoreline plantings demonstration project on Lake Norman;
7. Continue Duke participation on the Lake Norman Advisory Committee and assist the NCWRC in accessing and interpreting relevant Duke data, relative to Committee activities.

METHODS AND MATERIALS

The Spring shoreline electrofishing portion of the MNS maintenance monitoring program was not scheduled to be conducted during 2000, however, shoreline electrofishing of Lake Norman was conducted as part of a watershed program in which all Catawba River reservoirs are sampled every three years. Sampling was conducted on March 27 and April 10-12. The locations sampled were the same locations sampled under the MNS monitoring program; Ten 300-m transects were sampled in each of three areas of Lake Norman (MNS mixing zone, mid-lake reference area, and Marshall Steam Station mixing zone), for a total of 30 transects. The MNS mixing zone transects were located within the area between Ramsey Creek and Channel Marker 1 A. The mid-lake reference transects were located in the area between Channel Marker 7 and Channel Marker 9, while the Marshall Steam Station (MSS) mixing

zone transects were located in the area between Channel Marker 14 and the NC Highway 150 Bridge. All transects were subjectively selected to include the various habitat types that exist in Lake Norman and 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.

The mixing zone was monitored for striped bass mortalities during all summer sampling trips on the lake. Additionally, from July 3 through September 11, weekly surveys were conducted specifically to search for dead or dying striped bass in the main channel areas of the entire lake from Cowan's Ford Dam to uplake of NC Highway 150.

During 2000, no specific sampling for striped bass condition was conducted under the MNS maintenance monitoring program, however, these data were collected as part of the cooperative bioenergetics study being conducted by the NCWRC, North Carolina State University and Duke. Due to the collection of sufficient striped bass data during sampling for the bioenergetics study, no additional data were collected from the December striped bass tournament.

The materials and methods for the purse seine and hydroacoustics sampling on Lake Norman during 2000 are presented in a separate report included as Attachment 1.

Gill netting for shad and alewives was jointly conducted by the NCWRC and Duke during November 6-8, to evaluate the taxa composition and size distribution of Lake Norman forage species. Netting was conducted in creel zones 3, 4, and 5 (Figure 5-1). The number of nets fished by zone were: two shallow and two deep nets in zone 3, one shallow and two deep nets in zone 4 and three shallow and four deep nets in zone 5. Sampling consisted of one overnight net set for each net, for a total sampling effort of 14 net nights. Collected fish were sorted by species and measured for individual total length (mm). Netting data were recorded separately for each net fished.

RESULTS AND DISCUSSION

As in previous years, spring shoreline electrofishing of Lake Norman yielded variable catches among the three areas sampled (Tables 5-1 through 5-3). In the MNS mixing zone area, a total of 2,175 fish were collected, weighing a total of 38.13 kg and representing 17 taxa (Table 5-1). Although the total number of fish and taxa collected during 2000 were higher than 1999 catches from this area (1,379 fish and 14 taxa), the total biomass during 2000 was about half of the 1999 biomass (74.21 kg). This lower biomass is primarily attributable to the absence of carp and lower catches of largemouth bass during 2000. Individual transect catches ranged from a low of 67 fish to a high of 607 fish.

The total catch from the reference area was 1,314 fish, weighing 89.28 kg and representing 16 taxa (Table 5-2). The number of taxa collected from the reference area was the same as during 1999, however the total number and biomass of fish collected during 2000 were higher than those for 1999 (998 fish weighing 80.45 kg). Individual transect catches ranged from 35 to 231 fish.

As in 1999, the highest total catch by number was collected from the MSS mixing zone area (Table 5-3). The total catch was 2,496 fish, weighing 84.93 kg, and representing 17 taxa. The total number of fish collected from this area during 2000 was substantially higher than the 1999 catch (1,421 fish), however, total biomass and number of taxa were slightly lower than during 1999 (107.86 kg and 20 taxa). The 2000 sample did include the collection of an unusual species for Lake Norman. A rainbow trout was collected near the MSS discharge.

General monitoring of Lake Norman and specific monitoring of the MNS mixing zone for striped bass mortalities during the summer of 2000, yielded one mortality within the mixing zone and six mortalities in the main channel outside the mixing zone. The seven observed mortalities ranged in size from 450 mm to 615 mm. Specific observations by date were:

DATE	LOCATION	LENGTH (mm)	NUMBER
July 18	Vicinity of Channel Marker 14	450	1
July 24	Vicinity of Channel Marker 2	519	1
	Vicinity of Channel Marker 16	505	1
August 7	Vicinity of Channel Marker D 3	505	1
August 22	Vicinity of Channel Marker 4	491	1
	Vicinity of Channel Marker 10	580	1
	Vicinity of Channel Marker 13	615	1

Results of the purse seine and hydroacoustics sampling on Lake Norman during 2000 are presented in a separate report included as Attachment 1.

Gillnetting for shad and alewives during 2000 yielded a total of 330 fish from 14 net nights of sampling in three zones of Lake Norman (Table 5-4). Total net catches were highest in Zone 5 (278 fish), followed by Zones 4 (28 fish), and 3 (24 fish), respectively. Species composition in Zones 3 and 5 were similar during 1999 and 2000, with collections of all three forage species (gizzard shad, threadfin shad, and alewives) from each of the two zones. In Zone 4, however, only threadfin shad and alewives were collected during 2000, while only gizzard shad and threadfin shad were collected during 1999. Overall, a comparison of 1999 and 2000 gill net catches suggests a trend of increasing abundance and distribution of alewives within Lake Norman, especially in the upper portion of the reservoir.

FUTURE FISH STUDIES

- Continue striped bass mortality monitoring throughout the summer.
- Continue a 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 in Lake Norman.
- Continue the annual, fall hydroacoustic/purse seine forage population assessment.
- Continue spring electrofishing program on a two-year frequency, with the next sample scheduled for the Spring 2001.
- Repeat late summer purse seine sample and fall small mesh gill net sample to monitor changes in Lake Norman forage population.

- Cover December Striper Swipers tournament to obtain striped bass body condition data.
- Support cooperative NCSU bioenergetics study on Lakes Badin and Norman by assisting in the collection of striped bass, forage, and summer habitat data for Lake Norman, as requested by the NCWRC.
- Assist and support the NCWRC in the evaluation of a shoreline plantings demonstration project begun by the NCWRC and a local fishing club during 2000 in the vicinity of Duke Power State Park.

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 2000. General monitoring of Lake Norman and specific monitoring of the MNS mixing zone for striped bass mortalities during the summer of 2000, yielded one mortality within the mixing zone and six mortalities in the main channel outside the mixing zone.

Spring shoreline electrofishing of Lake Norman yielded variable catches for the three areas sampled; the MNS mixing zone area, a mid-lake reference area, and the MSS mixing zone area. The highest total catch numerically was from the MSS mixing zone area, followed by the MNS mixing zone and mid-lake reference areas, respectively. The highest total catch gravimetrically was from the mid-lake reference area, followed by the MSS and MNS mixing zone areas, respectively. The total number of taxa collected was similar for all three areas.

During July 2000, forage fish densities in the six zones of Lake Norman ranged from 6,036 to 18,622 fish/ha. There appeared to be a trend of more forage fish in uplake regions (Zones 5 & 6) than downlake. The estimated population was approximately 116 million fish. Purse seine sampling indicated that these fish were 96.24% threadfin shad, 3.26% alewives, and 0.50% gizzard shad.

September 2000 forage fish densities ranged from a low of 2,112 (Zone 6) to a high of 6,482 (Zone 2) and did not demonstrate the same fish distribution trend seen in July. The estimated

forage population was approximately 63 million fish. Purse seine sampling indicated that these fish were 87.40% threadfin shad, 12.37% alewives, and 0.22% gizzard shad.

During November 2000, forage fish densities in the six zones of Lake Norman ranged from 579 to 2,294 fish/ha. There appeared to be fewer fish in the uplake zones as lake water temperatures declined. The estimated forage population was approximately 24 million fish. No purse seine data were available for length frequency distributions or speciation of this population estimate.

Gillnetting for shad and alewives yielded a total of 330 fish from 14 net nights of sampling in three zones of Lake Norman. All three forage species (gizzard shad, threadfin shad, and alewives) were collected from Zones 3 and 5, while only threadfin shad and alewives were collected from Zone 4.

Through consultation with the NCWRC, the Lake Norman fisheries program continues to be reviewed and modified annually to address fishery issues. Fisheries data continue to be collected through cooperative monitoring programs with the NCWRC, to allow the Commission's assessment and management of Lake Norman fish populations. Fisheries data to date indicate that the Lake Norman fishery is consistent with the trophic status and productivity of the reservoir. However, one aspect of the Lake Norman fishery that warrants close monitoring in the future is the composition of forage populations. The introduction of alewives by fishermen over the past several years could have a dramatic impact on lake-wide forage populations and game species.

Table 5-1. Numbers and biomass of fish collected from electrofishing ten 300-m transects in the MNS mixing zone of Lake Norman during April 2000.

	Transect																					
	1		2		3		4		5		6		7		8		9		10		ALL	
Species	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG
Gizzard shad	2	0.995	2	0.990			1	0.350					2	0.911	1	0.460					8	3.706
Threadfin shad									11	0.081					10	0.101					21	0.182
Greenfin shiner							2	0.004	2	0.003											4	0.007
Whitefin shiner	18	0.048	18	0.043	1	0.001	30	0.089	10	0.017	111	0.360	26	0.144	47	0.148	27	0.053	108	0.270	396	1.173
Golden shiner											1	0.009									1	0.009
Spottail shiner											2	0.010							11	0.043	13	0.053
Flathead catfish	1	1.530	1	0.115													1	0.008			3	1.653
White bass																			1	0.180	1	0.180
Striped bass							1	0.320			1	1.170									2	1.490
Redbreast sunfish	46	0.525	50	0.650	26	0.295	98	1.070	10	0.072	59	0.740	11	0.288	13	0.355	19	0.320	15	0.205	347	4.520
Green sunfish											8	0.021							1	0.002	9	0.023
Warmouth	10	0.064	7	0.115	4	0.018	12	0.071	2	0.005	3	0.009	1	0.001			11	0.082	1	0.009	51	0.374
Bluegill	62	0.380	167	1.166	106	0.890	339	2.410	25	0.149	29	0.168	4	0.069	9	0.109	81	0.520	116	0.730	938	6.591
Redear sunfish	12	0.240	14	0.280	27	0.295	87	1.260	7	0.460	9	0.049			2	0.085	25	0.085	5	0.125	188	2.879
Hybrid sunfish	5	0.058	19	0.295	16	0.245	26	0.334	1	0.013	3	0.024	8	0.311	1	0.055	9	0.320	7	0.087	95	1.742
Largemouth bass	23	2.803	9	0.842	15	2.150	11	0.908	4	1.070	5	2.067	15	2.172	5	0.330	5	0.597	4	0.268	96	13.207
Black crappie					2	0.340															2	0.340
All	179	6.643	287	4.496	197	4.234	607	6.816	72	1.870	231	4.627	67	3.896	88	1.643	178	1.985	269	1.919	2175	38.129

Table 5-2. Numbers and biomass of fish collected from electrofishing ten 300-m transects in the mid-lake reference area of Lake Norman during March/April 2000.

	Transect																					
	1		2		3		4		5		6		7		8		9		10		ALL	
Species	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG
Gizzard shad	3	1.325			3	1.415	10	3.615	3	1.090					1	0.377			4	1.940	24	9.762
Greenfin shiner	2	0.003													1	0.003	5	0.009	1	0.001	9	0.016
Whitefin shiner	21	0.070	1	0.004			29	0.066	29	0.066	28	0.063	9	0.018	21	0.061	15	0.034	33	0.076	186	0.458
Common carp					1	1.600	4	6.550			2	3.390			1	1.182	2	3.394	1	1.340	11	17.456
Spottail shiner							1	0.004			7	0.028			21	0.077			9	0.037	38	0.146
Swallowtail shiner									1	0.001											1	0.001
Blue catfish															7	10.923					7	10.923
Channel catfish					1	0.250	1	0.455	1	0.210			1	0.215	2	2.279	1	0.162	3	0.711	10	4.282
White bass	1	0.377																			1	0.377
Redbreast sunfish	20	0.454	21	0.605	16	0.345	3	0.028	12	0.350	1	0.081	9	0.235	33	0.477	25	0.395	21	0.722	161	3.692
Warmouth	7	0.054			1	0.001	2	0.004	3	0.125	1	0.007			1	0.001	2	0.003	1	0.001	18	0.196
Bluegill	80	0.786	41	0.655	113	1.280	5	0.070	43	0.320	3	0.053	4	0.105	119	1.175	121	0.730	107	0.715	636	5.889
Redear sunfish	7	0.067	3	0.034	5	0.490	1	0.118	11	0.530	7	0.750	3	0.110	2	0.178	10	0.421	9	0.396	58	3.094
Hybrid sunfish	1	0.078	8	0.315	3	0.067	1	0.034	3	0.081	2	0.170			1	0.063	4	0.210	4	0.207	27	1.225
Largemouth bass	18	5.274	16	3.036	18	4.143	7	2.396	13	1.922	8	1.715	8	2.021	17	4.359	11	2.655	6	3.246	122	30.767
Black crappie													1	0.210	4	0.783					5	0.993
All	160	8.488	90	4.649	161	9.591	64	13.340	119	4.695	59	6.257	35	2.914	231	21.938	196	8.013	199	9.392	1314	89.277

Table 5-3. Numbers and biomass of fish collected from electrofishing ten 300-m transects in the Marshall Steam Station mixing zone area of Lake Norman during April 2000.

	Transect																					
	1		2		3		4		5		6		7		8		9		10		ALL	
Species	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG	N	KG
Gizzard shad							1	0.021	1	0.280							1	0.435			3	0.736
Threadfin shad							14	0.110													14	0.110
Greenfin shiner	2	0.002					3	0.010													5	0.012
Whitefin shiner	45	0.152	8	0.043	28	0.121	6	0.019	85	0.332	1	0.004							229	0.785	402	1.456
Common carp	1	0.920			3	7.235			1	1.650	2	3.185	2	4.855	1	2.220	1	2.170	1	2.015	12	24.250
Spottail shiner	91	0.412			1	0.003			13	0.052							1	0.004	142	0.590	248	1.061
Blue catfish															1	3.280					1	3.280
Channel catfish																	1	0.335			1	0.335
Flathead catfish					1	0.260	1	3.595	1	0.016					1	0.063	2	0.505			6	4.439
Rainbow trout					1	0.009															1	0.009
Redbreast sunfish	29	0.395	27	0.415	48	1.105	12	0.085	21	0.309	1	0.052	19	0.290	34	0.520	71	0.930	34	0.795	296	4.896
Warmouth	4	0.044			13	0.191	6	0.078	14	0.055			4	0.071	2	0.014	4	0.056	3	0.008	50	0.517
Bluegill	105	0.815	99	0.485	215	2.050	128	0.590	257	2.465	6	0.139	58	0.470	125	1.355	72	0.885	78	1.280	1143	10.534
Redear sunfish	7	0.158	4	0.069	11	0.078	15	0.111	13	0.172	1	0.003	14	1.080	2	0.009	6	0.059	1	0.005	74	1.744
Hybrid sunfish	1	0.120	4	0.035	13	0.280	5	0.036	12	0.364	2	0.199	3	0.150	9	0.195	7	0.073	3	0.098	59	1.550
Largemouth bass	19	4.121	14	1.838	24	4.754	11	2.559	20	1.222	15	2.315	13	1.644	18	2.678	23	3.990	23	4.864	180	29.985
Yellow perch							1	0.018													1	0.018
All	304	7.139	156	2.885	358	16.086	203	7.232	438	6.917	28	5.897	113	8.560	193	10.334	189	9.442	514	10.440	2496	84.932

Table 5-4. Comparison of catches from gillnet sampling in three zones of Lake Norman during the fall of 1999 and 2000.

September 20-23, 1999 Sample

Taxa	Zone 3 No.	Zone 3 Length Range (mm)	Zone 4 No.	Zone 4 Length Range (mm)	Zone 5 No.	Zone 5 Length Range (mm)
Gizzard shad	44	84-365	5	279-356	31	183-332
Threadfin shad	60	62-161	8	68-151	219	64-160
Alewife	3	101-118			6	110-193
Total	107		13		256	

November 6-8, 2000 Sample

Taxa	Zone 3 No.	Zone 3 Length Range (mm)	Zone 4 No.	Zone 4 Length Range (mm)	Zone 5 No.	Zone 5 Length Range (mm)
Gizzard shad	3	230-281			11	112-357
Threadfin shad	6	72-163	26	70-178	124	65-157
Alewife	15	102-178	2	102-106	143	89-117
Total	24		28		278	

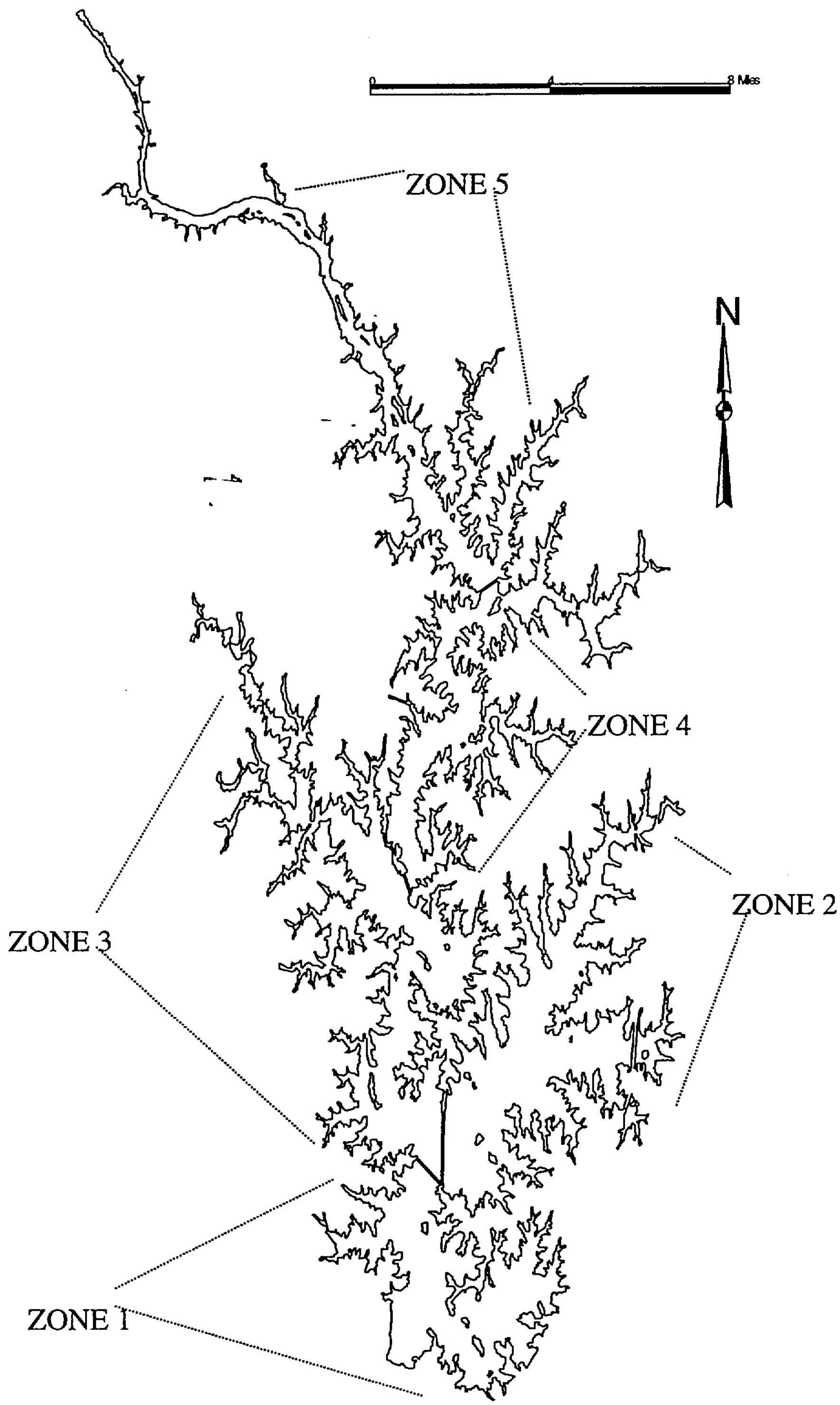


Figure 5-1. Sampling zones on Lake Norman, North Carolina.

Attachment 1:
Hydroacoustic and Purse Seine Data: 2000

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of forage fish population parameters was conducted in 2000. 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 / NCWRC / NCSU study to evaluate striped bass bioenergetics in Lakes Norman and Badin necessitated two additional hydroacoustic assessments and purse seine samples in 2000.

METHODS AND MATERIALS

Three mobile hydroacoustic surveys of the entire lake were conducted on July 13 and 17, (Bioenergetics Study), September 18 and 19 (MNS NPDES), and November 28 and 29 (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 (2.0 m to 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 six zones due to its large size, spatial heterogeneity, and multiple power generation facilities.

Purse seine samples were collected on July 12 and September 18, 2000 from the lower (main channel near Marker 1), mid (mouth of Davidson Creek), and uplake (just downlake of Duke Power State Park) areas of the reservoir. No purse seine sample was collected in November as destruction of the purse seine net on Lake Badin prior to the Lake Norman sample precluded the collection of data. 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 six zones of Lake Norman ranged from 6,036 to 18,622 fish/ha in July 2000 (Table 1). There appeared to be a trend of more forage fish in uplake

regions (Zones 5 & 6) than downlake. The estimated population was approximately 116 million fish. Purse seine sampling indicated that these fish were 96.24% threadfin shad, 3.26% alewives, and 0.50% gizzard shad. The length frequency distribution indicates threadfin shad dominate the lower size classes of forage fish under 100 mm while the alewives occupy the higher size classes (Figure 1).

September 2000 forage fish densities ranged from a low of 2,112 (Zone 6) to a high of 6,482 (Zone 2) and did not demonstrate the same fish distribution trend seen in July. The estimated forage population was approximately 63.2 million fish. Purse seine sampling indicated that these fish were 87.40% threadfin shad, 12.37% alewives, and 0.22% gizzard shad. The length frequency distribution indicates threadfin shad continue to dominate the lower size classes of forage fish with a modal length of approximately 50-55 mm while the alewives occupy the higher size classes (Figure 2).

Forage fish densities in the six zones of Lake Norman ranged from 579 to 2,294 fish/ha in November 2000. There appeared to be fewer fish in the uplake zones and this was thought to be related to downlake movements of fish resulting from declining water temperatures. The estimated forage population was approximately 24.3 million fish. No purse seine data were available for length frequency distributions or speciation of this population estimate.

The 2000 population estimates demonstrated declining population sizes as the year progressed. Natural mortality and predation from Lake Norman's numerous piscivorous species and adult alewives probably contributed to this decline. Population estimates in 2000 are similar to estimates during 1997 – 1999 but are lower than the estimates during 1993 – 1996.

FUTURE FISH STUDIES

- Continue the annual fall hydroacoustic/purse seine forage population assessment.

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 2000.

	Density (no/hectare)			Population Estimate		
Zone	July	September	November	July	September	November
1	6,036	4,455	1,203	13,768,116	10,161,855	2,744,043
2	7,546	6,482	2,294	23,257,527	19,978,172	7,070,337
3	6,509	5,189	2,239	22,491,980	17,930,693	7,736,909
4	7,651	3,953	2,012	9,418,381	4,866,143	2,476,772
5	18,622	4,392	1,876	39,217,932	9,249,552	3,950,856
6	16,367	2,112	579	7,823,426	1,009,536	276,762
Total				115,977,361	63,195,951	24,255,680
95% LCL				103,926,570	59,998,381	21,962,482
95% UCL				128,028,153	66,393,522	26,548,877

Figure 1. Lake Norman (combined) forage fish – July 2000.

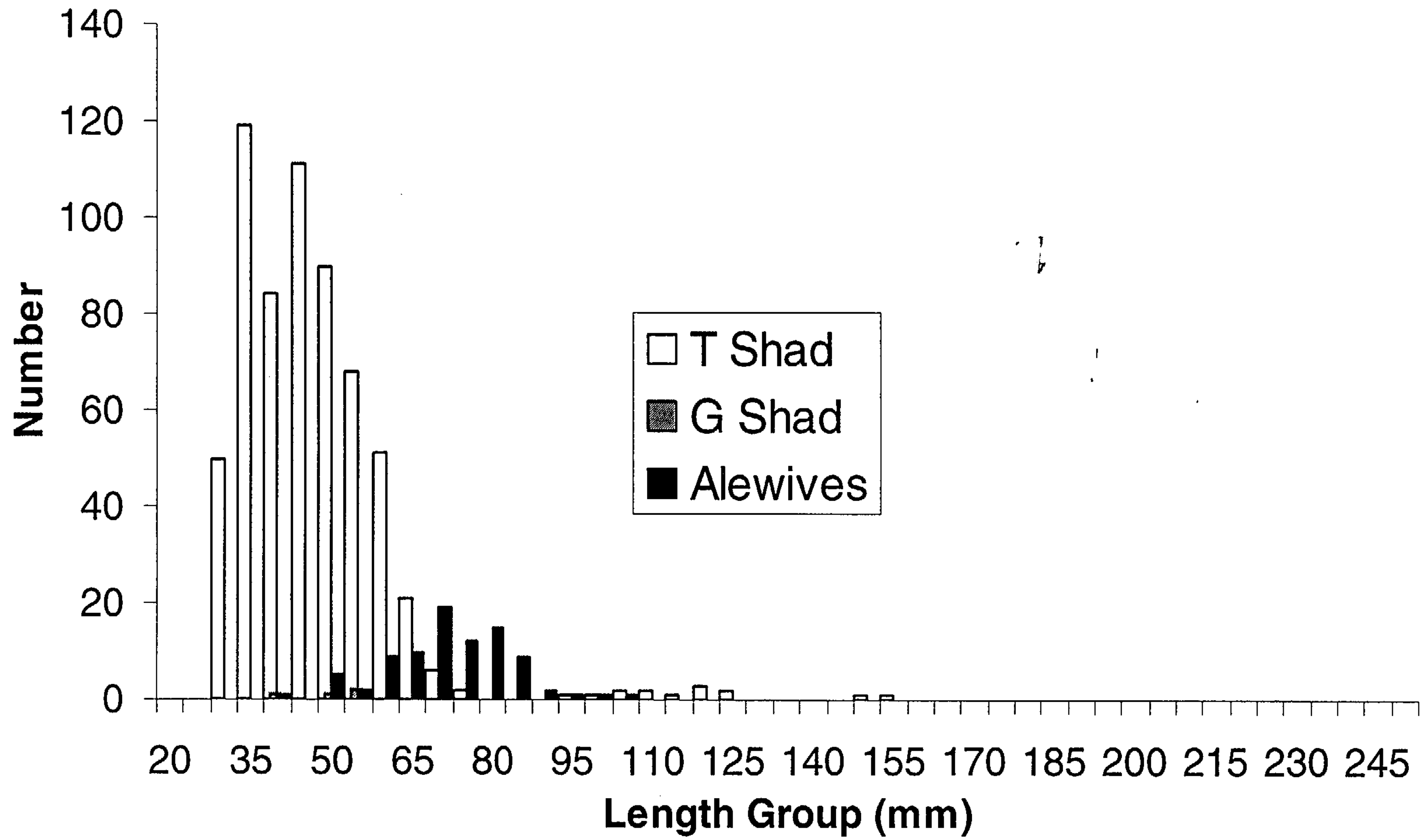


Figure 2. Lake Norman (combined) forage fish – September 2000.