Duke Power
A Duke Energy Company

GARY R. PETERSON
Vice President
McGuire Nuclear Station

Duke Power
MG01VP / 12700 Hagers Ferry Road
Huntersville, NC 28078-9340

704 875 5333
704 875 4809 fax
grpeters@duke-energy.com

January 4, 2005

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: 2003 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 14, 2004.

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

Gary R. Peterson

Gary R. Peterson

A001

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

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

Mr. Joe Brady
Senior Resident Inspector
McGuire Nuclear Station

Duke Power
A Duke Energy Company

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

December 14, 2004

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

Subject: McGuire Nuclear Station
Lake Norman Environmental Monitoring Program: 2003 Summary Report

Certified: 7004 2510 0000 4520 5324

Dear Ms. Sullins:

Enclosed are three copies of the annual Lake Norman Environmental Monitoring Program: 2003 Summary Report, as required by NPDES permit NC0024392 for McGuire Nuclear Station. Fishery studies continue to be coordinated with the Division of Inland Fisheries of the North Carolina Wildlife Resource Commission to address Lake Norman fishery management concerns.

Results of the 2003 data were comparable with that of previous years.

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

Sincerely,

Gary R. Peterson

Gary Peterson
McGuire Site Vice President

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

bc w/attch:	Record No. MN-004775		
	John Derwort	MG03A3	
	Bill Foris	MG03A3	
	Duane Harrell	MG03A3	
	John Williamson	MG01EM	five copies (four for NRC)
	Bob Caccia	EC12A	

LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2003 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

Duke Power A Duke Energy Company

December 2004

LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2003 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

Duke Power A Duke Energy Company

December 2004

TABLE OF CONTENTS

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 2003.

McGUIRE NUCLEAR STATION OPERATION

The monthly average capacity factor for MNS was 101.4 %, 100.3 %, and 58.2 % during July, August, and September of 2003, 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 93.0 °F (33.9 °C) for July, 96.7 °F (35.9 °C) for August, and 91.9 °F (33.3 °C) for September 2003. 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

Annual precipitation in the vicinity of MNS in 2003 totaled 61.7 inches, and was the highest value recorded since measurements were initiated at this site in 1975. The 2003 total was approximately 22 inches greater than observed in 2002 and about 15 inches greater than the long-term average. Winter and summer air temperatures in 2003 were generally cooler than both 2002, and historical conditions, whereas autumn temperatures were about average.

Temporal and spatial trends in water temperature and dissolved oxygen (DO) in 2003 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2003 were generally cooler than observed in 2002 in both the mixing and background zones, except in the fall when temperatures were slightly warmer than measured in 2002. Interannual differences in water temperatures, especially in the surface waters, typically paralleled differences exhibited in air temperatures between 2002 and 2003.

Reservoir-wide isotherm and isopleth information for 2003, 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 2003 was generally similar to historical conditions although, unlike most other years, a complete elimination of habitat in the reservoir was not observed in 2003. No significant mortalities of striped bass were observed during the summer of 2003.

All chemical parameters measured in 2003 were within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Concentrations of metals in 2003 were low, and often below the analytical reporting limit for a specific constituent.

PHYTOPLANKTON

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

In 2003 lake-wide mean chlorophyll *a* concentrations were generally in the mid to high range in February, the low range in May, the low to mid range in August, and the mid range in November. Chlorophyll concentrations during 2003 were most often higher than those of 2002. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. The highest chlorophyll value recorded in 2003, 28.84 ug/l, was below the NC State Water Quality standard of 40 ug/l.

In most cases, total phytoplankton densities and biovolumes observed in 2003 were higher than those observed during 2002, and standing crops were within ranges established over previous years. As in past years, high standing crops were usually observed at up-lake locations; while comparatively low values were noted down-lake. The notable exception was in May. Depressed algae concentrations at up-lake locations in May, 2003 were probably due to near record rainfall during that month and the preceding month, which resulted in heavy washout in the up-lake, transitional areas.

Seston dry weights were more often lower in 2003 than in 2002, and down-lake to up-lake differences were apparent most of the time. Conversely, ash-free dry weights were usually higher in 2003 than in 2002. The proportions of ash-free dry weights to dry weights in 2003 were considerably higher than those of 2002, indicating a decrease in organic composition among 2003 samples.

Secchi depths reflected suspended solids, with shallow depths related to high dry weights. The lake-wide mean secchi depth in 2003 was lower than in 2002 and was within historical ranges recorded since 1992. Lower secchi depths during 2003 were likely due to much higher rainfall than in 2002.

Diversity, or numbers of taxa, of phytoplankton had increased since 2002, and the total number of individual taxa was the highest yet recorded. The taxononic composition of phytoplankton communities during 2003 was similar to those of many previous years. Cryptophytes were dominant in February, while diatoms were dominant during May and November. Green algae dominated phytoplankton assemblages during August. Blue-green algae were slightly more abundant during 2003 than during 2002; however, their contribution to total densities never exceeded 5 %.

The most abundant alga, on an annual basis, was the cryptophyte *Rhodomonas minuta*. Common and abundant diatoms were *Fragillaria crotonensis* in May, and *Tabellaria fenestrata* in November. The small desmid, *Cosmarium asphearosporum* var. *strigosum* was dominant in August 2003. All of these taxa have been common and abundant throughout the Maintenance Monitoring Program.

The phytoplankton index (Myxophycean) characterized Lake Norman as oligotrophic during 2003, and was the next to lowest annual index value recorded. Quarterly index values decreased from the highest in February to the lowest in May then increased through August and November. Quarterly values did reflect maximum and minimum chlorophyll concentrations and phytoplankton standing crops. Location values tended to reflect decreases in phytoplankton standing crops from down-lake to mid-lake, and increases from mid-lake to up-lake.

ZOOPLANKTON

Lake Norman continues to support a highly diverse and viable zooplankton community. Zooplankton densities, as well as seasonal and spatial trends were generally consistent with historical precedent during 2003, and no impacts of plant operations were observed.

Minimum zooplankton densities were most often noted in August. 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 2003, 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 were generally within ranges of those observed in previous years. The one exception was the record high density for August at Location 15.9.

One hundred and thirteen zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (Fifty-two were identified during 2003). Four previously unreported taxa (three cladocerans and one rotifer) were identified during 2003.

Overall relative abundance of copepods in 2003 had increased substantially since 2002, and they were dominant in samples collected during all four quarters. Cladocerans were dominant in only one sample in February, while rotifers were dominant in 65% of all samples. Overall, the relative abundance of rotifers had decreased considerably since 2002, and their relative abundances were somewhat similar to years between 1996 and 2001. Historically, copepods and rotifers have most often shown annual peaks in May; while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms with adults rarely accounting for more than 10% 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. The most abundant rotifers observed in 2003, as in many previous years, were *Polyarthra*, *Conochilus*, and *Karetella*, while *Syncheata* was occasionally important among rotifer populations.

FISHERIES

In accordance with the Lake Norman Maintenance Monitoring Program for the NPDES permit for MNS, specific fish monitoring programs were coordinated with the North Carolina Wildlife Resources Commission (NCWRC) and continued during 2003. Spring electrofishing indicated that 14 to 24 species of fish and 2 hybrid complexes comprised fish populations in the 3 sampling locations, and that numbers and biomass of fish in 2003 were generally similar to those previously noted since 1993.

Few dead striped bass were observed during the summer survey period, indicating no major die-offs occurred in 2003. Mean relative weight (Wr) for Lake Norman striped bass collected in November and December was similar to that observed previously and indicated little change in the overall condition of this fish.

Small-mesh gillnetting and hydroacoustic sampling indicated that prey fish are distributed throughout the lake and pelagic populations were similar to those noted in Lake Norman since 1997.

LIST OF TABLES

LIST OF FIGURES

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 (NCDENR), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 2003.

OPERATIONAL DATA FOR 2003

The monthly average capacity factor for MNS was 101.4 %, 100.3 %, and 58.2 % during July, August, and September of 2003, 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 93.0 °F (33.9 °C) for July, 96.7 °F (35.9 °C) for August, and 91.9 °F (33.3 °C) for September 2003. 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 (%) and monthly average discharge water temperatures for McGuire Nuclear Station during 2003.

	MONTHLY AVERAGE CAPACITY FACTORS (%)			MONTHLY AVERAGE NPDES DISCHARGE TEMPERATURES	
Month	**Unit 1**	**Unit 2**	**Station**	**°F**	**°C**
January	103.2	101.8	**102.5**	65.8	18.8
February	105.3	105.1	**105.2**	65.3	18.5
March	105.3	103.5	**104.4**	70.4	21.3
April	103.1	104.7	**103.9**	75.1	23.9
May	103.3	101.4	**102.3**	79.7	26.5
June	102.6	102.9	**102.8**	86.8	30.4
July	101.3	101.6	**101.4**	93.0	33.9
August	99.7	100.8	**100.3**	96.7	35.9
September	100.8	15.7	**58.2**	91.9	33.3
October	102.0	77.3	**89.6**	84.5	29.2
November	103.3	104.3	**103.8**	80.6	27.0
December	10408	104.9	**104.9**	71.0	21.7
Averages	**102.9**	**93.7**	**98.3**		

CHAPTER 2

WATER CHEMISTRY

INTRODUCTION

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

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

This report focuses primarily on 2002 and 2003. Where appropriate, reference to pre-2002 data will be made by citing reports previously submitted to the North Carolina Department of Environment and Natural Resources (NCDENR).

METHODS AND MATERIALS

The complete water chemistry monitoring program for 2003, including specific variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1, whereas specific chemical methods and associated analytical reporting limits, along with the appropriate references, are presented in Table 2-2. Measurements of temperature, dissolved oxygen (DO), DO saturation, pH, and specific conductance were taken, in situ, throughout the water column at each location with a Hydrolab Data-Sonde (Hydrolab 1986) starting at the lake's surface (0.3m) and continuing at 1m intervals to one meter above lake bottom. Pre and post-calibration procedures associated with operation of the Hydrolab were strictly followed, and documented in hard-copy format. Hydrolab data were captured and stored electronically, and following a data validation step, converted to spreadsheet format for permanent filing.

Water samples for laboratory analysis were collected with a Kemmerer water bottle at the surface (0.3m), and from one meter above bottom, where specified (Table 2-1). Samples not requiring filtration were placed directly in single-use polyethylene terephthalate (PET) bottles which were pre-rinsed in the field with lake-water just prior to obtaining a sample. Samples for the analysis of soluble nutrients (orthophosphate, nitrite-nitrate, and ammonia) were processed in the field by filtering a known volume of water through a 0.45um glass-fiber filter which was pre-rinsed in the field with a 100 mL portion of the filtrate. Upon collection, all water samples were immediately preserved, and stored in the dark and on ice, to minimize the possibility of physical, chemical or microbial transformation.

Water quality data were subjected to various graphical and statistical techniques in an attempt to describe spatial and temporal trends within the lake, and interrelationships among constituents. Whenever analytical values were obtained that were equal to or less than the method reporting limit, these values were set equal to the reporting limit for statistical purposes. Data were analyzed using two approaches, both of which were consistent with earlier studies (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). The first method involved partitioning the reservoir into mixing, background, and discharge zones, consolidating the data into these sub-sets, and making comparisons among zones and years. In this report, the discharge includes only Location 4; the mixing zone, Locations 1 and 5; the background zone includes Locations 8, 11, and 15. The second approach, applied primarily to the in-situ data, emphasized a much broader lake-wide investigation and encompassed the plotting of monthly isotherms and isopleths, and summer-time striped bass habitat. Several quantitative calculations were also performed on the in-situ Hydrolab data; these included the calculation of the areal hypolimnetic oxygen deficit (AHOD), maximum whole-water column and hypolimnion oxygen content, maximum whole-water column and hypolimnion heat content, mean epilimnion and hypolimnion heating rates over the stratified period, and the Birgean heat budget.

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

$$Lt = A_0^{-1} \bullet \int_{z_0}^{z_m} TO \bullet Az \bullet dz$$

where;

Lt = reservoir heat ($Kcal/cm^2$) or oxygen (mg/cm^2) content
Ao = 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)
z_o = surface
z_m = maximum depth

Precipitation and air temperature data were obtained from a meteorological monitoring site established in lower Lake Norman, near MNS, in 1975. These data are employed principally by Duke Power as input variables into meteorological modeling studies to address safety issues associated with potential radiological releases into the atmosphere by MNS (Duke Energy Company 2004), as required by the Nuclear Regulatory Commission, but also serve to document localized temporal trends in air temperatures and rainfall patterns. Data on lake level and hydroelectric flows were obtained from Duke Power's Fossil/Hydroelectric Department, which monitors these metrics hourly.

RESULTS AND DISCUSSION

Precipitation and Air Temperature

Annual precipitation in the vicinity of MNS in 2003 totaled 61.7 inches (Figures 2-2a, b), and was the highest value recorded since measurements were initiated at this site in 1975. The 2003 total was also almost 22 inches greater than observed in 2002 (39.8 inches) and about 15 inches greater than the long-term precipitation average for this area (46.3 inches), based on Charlotte, NC airport data. Approximately 80% of the yearly rainfall in 2003 occurred over the first seven months of the year. The highest total monthly rainfall in 2003 occurred in April with a value of 10.6 inches, whereas the lowest (0 inches) was recorded in December.

Air temperatures in 2003 were generally cooler than both those of 2002, and the long-term mean, based on monthly average data (Figure 2-2c). Differences were most pronounced in the summer and winter when 2003 temperatures ranged from 2.4 °C to 3.5 °C less, respectively, than observed in 2002. In contrast, November temperatures in 2003 were 2.8 °C warmer than the long-term average, and 3.7 °C warmer than those observed in 2002.

Temperature and Dissolved Oxygen

Water temperatures measured in 2003 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3 and 2-4), as they did in 2002. 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 2003 were generally cooler than those observed in 2002 in both the mixing and background zone, and paralleled interannual differences exhibited in air temperatures (Figures 2-2c, 2-3, and 2-4). Minimum water temperatures in 2003 were recorded in early February and ranged from 6.9 °C to 7.8 °C in the background zone, and from 7.0 °C to 11.3 °C in the mixing zone. The average minimum temperature in 2003 was about 2.5 °C cooler than that observed in 2002, and corresponded closely with the between-year difference in mean winter air temperature of 2.6 °C. Minimum water temperatures measured in 2003 were within the observed historical variability (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004).

Summer and early fall water temperatures in 2003 were 2 to 3°C cooler, on the average, than observed in 2002, with the primary differences occurring in the upper 10m of the water column (Figure 2-3, 2-4). The greatest between-year variability in summer water temperature was observed in June in the upper 5m of the water column. Water temperatures in this portion of the water column averaged approximately 4 °C less in 2003 than 2002. Maximum surface water temperatures were also less in 2003 than 2002 with interannual differences observed within each zone. The maximum surface temperature in the background zone in 2003 was 30.4 °C, whereas in 2002 the corresponding maximum temperature was 31.7 °C, or almost 1.3 °C warmer. Similarly, the maximum surface temperature in the mixing zone in 2003 was 30.4 °C compared to a maximum of 34.0 °C in 2002. Minimal differences in hypolimnetic (below 20m) temperatures were observed between 2003 and 2002.

In contrast to the first 10 months of the year, late fall and early winter water temperatures (November and December) in 2003 were warmer than measured in 2002, and followed the trend exhibited in air temperatures. Water temperatures in December 2003 averaged approximately 4.5 °C warmer throughout the water column in both zones than observed in December 2002, a difference similar to the 3.7 °C interannual difference in November air temperature.

Temperature data at the discharge location in 2003 were generally similar to 2002 (Figure 2-5) and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). Temperature data for the period January to August were typically cooler than observed in 2002, whereas fall temperatures were about the same or slightly warmer. The warmest discharge temperature of 2003 at Location 4 occurred in August and measured 35.1 °C, or 3.4 °C cooler than measured in August, 2002 (DP 2004).

Seasonal and spatial patterns of DO in 2003 were reflective of the patterns exhibited for temperature, i.e., generally similar in both the mixing and background zones (Figures 2-6 and 2-7). As observed with water column temperatures, this similarity in dissolved oxygen patterns between zones has been a dominant feature of the oxygen regime in Lake Norman since MNS began operations in 1983.

Winter and early spring DO values in 2003 were generally higher, in both the background and mixing zone, than measured in 2002, except in January which exhibited slightly lower oxygen concentrations in 2003 versus 2002 (Figures 2-6 and 2-7). The higher values measured during this period in 2003 appeared to be related predominantly to cooler water column temperatures. Cooler water would be expected to exhibit a greater oxygen content because of the direct effect of temperature on oxygen solubility, which is an inverse relationship, and indirectly via an enhanced convective mixing regime which would promote water column reaeration. February and March 2003 DO concentrations averaged approximately 1.5, and 1.8 mg/L higher throughout the water column, respectively, than measured in 2002.

Spring and summer DO values in 2003 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6 to 8 mg/L in surface waters to lows of 0 to 2 mg/L in bottom waters. This pattern is similar to that measured in 2002 and earlier years (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). Metalimnetic and hypolimnetic DO values during the spring and summer of 2003 generally ranged from 0.1 to 2.5 mg/L lower than measured in 2002, although exceptions to this were observed in July and August when DO values were slightly higher than measured in 2002. Surface oxygen values in 2003 were generally equal to or less than measured in 2002 except in July in the background zone where DO concentrations were about 1 mg/L higher than 2002. All dissolved oxygen values recorded in 2003 were within the historical range (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004).

Considerable differences were observed between 2002 and 2003 fall and early winter DO values in both the mixing and background zone, especially in the metalimnion and hypolimnion during the months of September and November (Figures 2-6 and 2-7). These interannual differences in autumn 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 earlier in the year. The 2003 September and November DO data indicate that fall reaeration proceeded slower and was less complete than observed in the corresponding months in 2002. Consequently, DO levels in these months in 2003 were less than observed in 2002. Interannual differences in DO patterns are common not only within the Catawba River Basin, but throughout Southeastern reservoirs, and can reflect yearly differences in hydrologic, meteorologic, and limnologic forcing variables (Cole and Hannon 1985; Petts, 1984).

The seasonal pattern of DO in 2003 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 2003 (4.1 mg/L) occurred in August, and was slightly lower than DO levels measured in August 2002 (5.4 mg/L), and August 2001 (5.5 mg/L).

Reservoir-wide Temperature and Dissolved Oxygen

The monthly reservoir-wide temperature and dissolved oxygen data for 2003 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 2003 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 2002 and 2003 are found in Table 2-3. Annual minimum heat content for the entire water column in 2003 (8.86 Kcal/cm^2; 10.2 °C) occurred in early February, whereas the maximum heat content (28.18 Kcal/cm^2; 27.5 °C) occurred in early September. Heat content of the hypolimnion exhibited a similar temporal trend as that observed for the entire water column. Annual minimum hypolimnetic heat content occurred in early February and measured 5.03 Kcal/cm^2 (8.7 °C), whereas the maximum occurred in early September and measured 15.39 Kcal/cm^2 (26.4 °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 equaled 0.092 Kcal/cm^2/day and 0.048 Kcal/cm^2/day for the hypolimnion. The 2003 heat content and heating rate data were similar to that observed in previous years (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004).

The seasonal oxygen content and percent saturation of the whole water column, and the hypolimnion, are depicted for 2003 in Figure 2-10b. Additional oxygen data can be found in Table 2-4 which presents the 2003 AHOD for Lake Norman and similar estimates for 18 TVA reservoirs. Reservoir oxygen content was greatest in mid-winter when DO content measured 11.3 mg/L for both the whole water column and the hypolimnion. Percent saturation values at this time approached 102 % for the entire water column and 97 % 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 4.2 mg/L (54 % saturation), whereas the minimum for the hypolimnion was 0.7 mg/L (8.3 % saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.044 mg/cm^2/day (0.066 mg/L/day) (Figure 2-10b), and is similar to that measured in 2002 (DP 2004).

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 AHODs 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 0.044 mg/cm^2/day for 2003. The oxygen based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 2003 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 ≤ 26 °C and DO levels ≥ 2.0 mg/L, was found lake-wide from October 2002 through mid July 2003. Beginning in mid July 2003, 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 although, unlike most other years, a complete elimination of habitat was not observed in 2003. Habitat was observed to be restricted most severely in the middle and lower portions of the reservoir during the summer; however, a zone of suitable habitat was observed in the upper, riverine segments of the reservoir, immediately downstream from the confluence of Lyles Creek with Lake Norman. Habitat measured in the upper reaches of the reservoir appeared to be influenced by both inflow from Lyles Creek and discharges from Lookout Shoals Hydroelectric facility, which were somewhat cooler than ambient conditions in Lake Norman. Upon entering Lake Norman, this water apparently mixes and then proceeds as a subsurface underflow as it migrates downriver (Ford 1985).

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 2003 was generally similar to that previously reported in Lake Norman, and many other Southeastern reservoirs (Coutant 1985, Matthews et al. 1985, DPC 1992, 1993, 1994, 1995, 1996, 1997, DP 1998, 1999, 2000, 2001, 2003, 2004). No significant mortalities of large striped bass were observed in 2003; a few dead fish (<10) were found over the summer period, but these appeared to be the result of other causes, e.g., hooking mortalities, which are common throughout the Southeast.

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 2003, ranging from 1.05 to 8.49 ntu's (Table 2-5). Bottom turbidity values were also relatively low over the study period, ranging from 1.88 to 18.30 NTUs with the highest values generally found in the mid lake background locations (Table 2-5). Turbidity values observed in 2003, as a whole, were slightly higher than measured in 2002 (Table 2-5), but well within the historical range (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003).

Specific conductance in Lake Norman in 2003 ranged from 52 to 97 umho/cm, and was generally similar to that observed in 2002 (Table 2-5), and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). Lake-wide, mean conductance values in 2003 were, however, about 10 umhos/cm lower than observed in 2002, but similar to values observed in 2001. Differences were most pronounced in the surface waters during the summer with mean conductance values averaging almost 20 umhos/cm (about 30 %) less in 2003 than 2002. These differences appear to have been related to interannual variability in watershed precipitation totals (Figures 2-2a & 2-2b) and the corresponding influence on reservoir water level (Figure 2-12) and volume, as well as inflow and outflow rates. Precipitation totals for the Lake Norman watershed, as recorded at MNS, were considerably less in 2002 than 2003, as discussed above, and differences between these two years were most pronounced during the first nine months of the year. In 2002 approximately 24.0 inches of rain was measured during the period January through September, whereas in 2003 a total of 58.64 inches was recorded for the same period. Reduced levels of precipitation inputs within the watershed would be expected to result in less sub-surface and overland runoff to adjacent streams and lakes. Reduced stream inflows and lake levels would, in turn, concentrate chemical constituents within the water column. Conversely, increases in stream inflows and lake levels would be expected to result in an initial increase in some constituents as material is transported from the terrestrial environment to the adjacent aquatic ecosystem, followed by a decrease in constituent concentration due to dilution associated with additional increases in water volume and corresponding movement through the system (Gray 1970, Kazmann 1988).

Specific conductance values in surface and bottom waters in 2003 were generally similar throughout the year except during the period of intense thermal stratification, i.e., August and November when an increase in bottom conductance values was observed. These 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 extensive hypolimnetic oxygen depletion (Hutchinson 1957, Wetzel 1975).

pH and Alkalinity

During 2003, pH and alkalinity values were similar among MNS discharge, mixing and background zones (Table 2-5). Values of pH were also generally similar to values measured in 2002 (Table 2-5), and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). Alkalinity values, on the other hand, were slightly lower throughout the lake in 2003 as compared to 2002, and this difference may have been related to the precipitation and lake hydrology differences between the two years, and the corresponding influence on constituent concentration, as discussed above for specific conductance. Individual pH values in 2003 ranged from 6.3 to 7.3 su, whereas alkalinity ranged from 12 to 29 mg/L, expressed as $CaCO_3$.

Major Cations and Anions

The concentrations of major ionic species in the MNS discharge, mixing, and mid-lake background zones are provided in Table 2-5. Lake-wide, the major cations were sodium, calcium, magnesium, and potassium, whereas the major anions were bicarbonate, sulfate, and chloride. The overall ionic composition of Lake Norman during 2003 was generally similar to that reported for 2002 (Table 2-5) and previously (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). It was noted in last year's report (DP 2004) that the concentrations of several constituents, most notably chloride and sodium, were found to be from 30 to 50 % higher in 2002 than in 2001. The higher values in 2002 were attributed to precipitation and lake hydrology differences between the two years, and the corresponding influence on constituent concentration, as discussed above for specific conductance. Similarly, the lower concentration values measured in 2003, compared to 2002, are believed to be a dilution effect related to the influence of these physical processes, i.e., precipitation, lake level, and inflow and outflow rates on constituent concentrations.

Nutrients

Nutrient concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 2002 and 2003 are provided in Table 2-5. Overall, nutrient concentrations in 2003 were well within historical ranges (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). Nitrogen and phosphorus levels in 2003 were low and generally similar, with some exceptions, most notably in nitrite-nitrate levels, to those measured in 2002 (DP 2004). Total phosphorus and ortho-phosphorus concentrations were typically measured at or below the analytical detection limits for these constituents, i.e., 10 ug/L and 5 ug/L, respectively. For total phosphorus, only three of forty-four samples exceeded a concentration measurement greater than 20 ug/L, whereas for ortho-phoshorus only two samples exceeded 20 ug/L, and all these instances were observed in May samples. Nutrients were generally higher in the upper portions of the reservoir compared to the lower sections, but the differences were slight and not statistically significant. Spatial variability in various chemical constituents, especially nutrient concentrations, is common in long, deep reservoirs (Soballe et al. 1992).

Nitrite-nitrate concentrations were consistently higher at all locations in 2003 compared to 2002 (Table 2-5), but similar to historical values (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). The lower values measured in 2002 compared to 2003, and historical conditions, were probably related to a combination of below average precipitation inputs, especially during the summer months, and algal uptake. Nitrate-nitrite concentrations in atmospheric precipitation in this portion of North America typically range from about 600 to 1000 ug/L; consequently, rainfall serves as a significant source of nitrogen to aquatic ecosystems in the Southeast both in the form of direct and indirect inputs (Langmuir 1997). Unusually low levels of nitrate-nitrite nitrogen in Lake Norman during the summer of 2002 were also reported by NCDENR (NCDENR 2003), and Mecklenburg County Department of Environmental Protection (MCDEP 2003).

Metals

Metal concentrations in the discharge, mixing, and mid lake background zones of Lake Norman for 2003 were similar to that measured in 2002 (Table 2-5) and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004). Iron concentrations in the surface waters were generally low (≤ 0.1 mg/L) during 2003, although values ranging from 0.2 to 1.1 mg/L were observed throughout the lake in May. These values were about double to almost ten times greater than observed in May, 2002 and were presumably the result of the interannual differences in precipitation totals and watershed inflows during the preceding months (February, March and April) of 2003 versus 2002 (Figure 2-2b). Higher inflows would be expected to import greater amounts of dissolved and particulate material from the watershed into the reservoir, resulting in elevated levels of certain constituents, especially those associated with suspended organic and inorganic particulate matter. Other variables that illustrated a similar temporal trend included turbidity, total phosphorus, ortho-phosphorus, aluminum, and copper (Table 2-5). The highest iron value reported in 2003 was 1.49 mg/L and was observed in November in the bottoms waters at Location 2, just before lake turnover.

Similarly, manganese concentrations in the surface and bottom waters were generally low (≤ 0.1 mg/L) in both 2002 and 2003, 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 (Stumm and Morgan 1970, Wetzel 1975). Manganese and iron concentrations in the bottom waters rose above NC water quality standards for these two constituents, i.e., 0.2 mg/L and 1.0 mg/L, respectively, at various locations throughout the lake in summer and fall of both years, and is characteristic of historical conditions (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2003, 2004).

Concentrations of other metals in 2003 were typically low, and often below the analytical reporting limit for the specific constituent (Table 2-5). All values for cadmium, lead and zinc were reported as either equal to or below each constituent's reporting limit, and no NC water quality standard was exceeded. Zinc values appeared to be higher in 2003 than 2002, but these differences can be attributed to the analytical reporting limit for that year. In year 2002 the reporting limit for zinc was 5 ug/L, whereas in 2003 the reporting limit was increased to 20 ug/L due to a change in the analytical method. Copper concentrations were generally less than 3 ug/L, and well below the NC standard of 7 ug/L. The lone exception to this occurred in May at the discharge site where a value of 13.8 ug/L was recorded.

FUTURE STUDIES

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

SUMMARY

Annual precipitation in the vicinity of MNS in 2003 totaled 61.7 inches, and was the highest value recorded since measurements were initiated at this site in 1975. The 2003 total was approximately 22 inches greater than observed in 2002 and about 15 inches greater than the long-term average. Winter and summer air temperatures in 2003 were generally cooler than both 2002, and historical conditions, whereas autumn temperatures were about average.

Temporal and spatial trends in water temperature and DO in 2003 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2003 were generally cooler than observed in 2002 in both the mixing and background zones, except in the fall when temperatures were slightly warmer than measured in 2002. Interannual differences in water temperatures, especially in the surface waters, typically paralleled differences exhibited in air temperatures between 2002 and 2003.

Winter and early spring DO values in 2003 were generally higher, in both the background and mixing zone, than measured in 2002, except in January which exhibited slightly lower oxygen concentrations in 2003 versus 2002. The higher values measured in 2003 appeared to be related predominantly to cooler water column temperatures. Spring and summer DO values in 2003 were highly variable throughout the water column in both zones, which is similar to that measured in 2002 and earlier years. Metalimnetic and hypolimnetic DO values during the spring and summer of 2003 generally ranged from 0.1 to 2.5 mg/L lower than measured in 2002. Autumn DO levels in 2003 were generally lower than observed in 2002 due primarily to warmer air temperatures which delayed water column cooling and reaeration relative to 2002. All dissolved oxygen values recorded in 2003 were within the historical range.

Reservoir-wide isotherm and isopleth information for 2003, 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 2003 was generally similar to historical conditions although, unlike most other years, a complete elimination of habitat in the reservoir was not observed in 2003. No significant mortalities of striped bass were observed during the summer of 2003.

All chemical parameters measured in 2003 were within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Specific conductance values in 2003 were slightly lower than measured in 2002, a low-water year, as were chloride, magnesium, and sodium. Ammonia, ortho-phosphorus, and total phosphorus values were low and similar to 2002, whereas nitrite-nitrate concentrations were higher than in 2002, but similar to historical averages.

Concentrations of metals in 2003 were low, and often below the analytical reporting limit for a specific constituent. Values for cadmium, lead and zinc were reported as either equal to or below the reporting limit. Copper concentrations were generally less than 3 ug/L, and well below the NC standard of 7 ug/L. The lone exception to this occurred in May at the discharge site where a value of 13.8 ug/L was recorded.

Manganese and iron concentrations in the surface and bottom waters were generally low in 2003, except during the summer and fall when bottom waters became anoxic, and the release of soluble forms of these metals into the water column was observed. Manganese and iron concentrations rose above the NC's water quality standards for these two constituents, i.e., 0.2 and 1.0 mg/l, respectively, in the bottom waters at various locations throughout the lake in summer and fall of both years, and is characteristic of historical conditions.

LITERATURE CITED

American Public Health Association (APHA). 1995. Standard Methods for the Examination of Water and Wastewater. 19th Edition. APHA, Washington, DC.

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. Trans. Amer. Fisher. Soc. 114:31-61.

Cole, T. M. and H. H. Hannon. 1985. Dissolved oxygen dynamics. In: Reservoir Limnology: Ecological Perspectives. K. W. Thornton, B. L. Kimmel and F. E. Payne editors. John Wiley & Sons. NY.

Duke Power Company. 1985. McGuire Nuclear Station, 316(a) Demonstration. Duke Power Company, Charlotte, NC.

Duke Power Company. 1987. Lake Norman maintenance monitoring program: 1986 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1988a. Lake Norman maintenance monitoring program: 1987 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1988b. Mathematical modeling of McGuire Nuclear Station thermal discharges. Duke Power Company, Charlotte, NC.

Duke Power Company. 1989. Lake Norman maintenance monitoring program: 1988 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1990. Lake Norman maintenance monitoring program: 1989 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1991. Lake Norman maintenance monitoring program: 1990 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1992. Lake Norman maintenance monitoring program: 1991 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1993. Lake Norman maintenance monitoring program: 1992 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1994. Lake Norman maintenance monitoring program: 1993 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1995. Lake Norman maintenance monitoring program: 1994 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1996. Lake Norman maintenance monitoring program: 1995 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1997. Lake Norman maintenance monitoring program: 1996 summary. Duke Power Company, Charlotte, NC.

Duke Power. 1998. Lake Norman maintenance monitoring program: 1997 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 1999. Lake Norman maintenance monitoring program: 1998 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2000. Lake Norman maintenance monitoring program: 1999 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2001. Lake Norman maintenance monitoring program: 2000 Summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2003. Lake Norman maintenance monitoring program: 2001 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2004. Lake Norman maintenance monitoring program: 2002 summary. Duke Energy Company, Charlotte, NC.

Duke Energy Company. 2004. McGuire Nuclear Station. Updated final safety analysis report. Duke Energy Company, Charlotte, NC.

Ford, D. E. 1985. Reservoir transport processes. In: Reservoir Limnology: Ecological Perspectives. K. W. Thornton, B. L. Kimmel and F. E. Payne editors. John Wiley & Sons. NY.

Gray, D. M. 1970. Handbook on the principles of hydrology. Water Information Center, Inc., National Research Council of Canada.

Hannan, H. H., I. R. Fuchs and D. C. Whittenburg. 1979 Spatial and temporal patterns of temperature, alkalinity, dissolved oxygen and conductivity in an oligo-mesotrophic, deep-storage reservoir in Central Texas. Hydrobilologia 51 (30); 209-221.

Higgins, J. M. and B. R. Kim. 1981. Phosphorus retention models for Tennessee Valley Authority reservoirs. Water Resour. Res., 17:571-576.

Higgins, J. M., W. L. Poppe, and M. L. Iwanski. 1980. Eutrophication analysis of TVA reservoirs. In Surface Water Impoundments. H. G. Stefan, Ed. Am. Soc. Civ. Eng., NY, pages 412-423.

Hutchinson, G. E. 1938. Chemical stratification and lake morphometry. Proc. Nat. Acad. Sci., 24:63-69.

Hutchinson, G. E. 1957. A Treatise on Limnology, Volume I Geography, Physics and Chemistry. John Wiley & Sons, NY.

Hydrolab Corporation. 1986. Instructions for operating the Hydrolab Surveyor Datasonde. Austin, TX. 105p.

Kazmann, R. G. 1988. Modern hydrology. The National Water Well Association. Dublin, Ohio.

Langmuir, D. 1997. Aqueous environmental geochemistry. Prentice-Hall, Inc. Simon and Schuster/ A Viacom company. Upper Saddle River, New Jersey 07458.

Matthews, W. J., L. G. Hill, D. R. Edds, and F. P. Gelwick. 1980. Influence of water quality and season on habitat use by striped bass in a large southwestern reservoir. Transactions of the American Fisheries Society 118: 243-250.

Mecklenburg County Department of Environmental Protection. 2003. Lake monitoring data summary for 2001-2002.

Mortimer, C. H. 1941. The exchange of dissolved substances between mud and water in lakes (Parts I and II). J. Ecol., 29:280-329.

NCDENR. 2003. Basinwide assessment report; Catawba River Basin. North Carolina Department of Environment and Natural Resources Division of Water Quality. 203pp.

Petts G. E., 1984. Impounded Rivers: Perspectives For Ecological Management. John Wiley and Sons. New York. 326pp.

Soballe, D. M., B. L. Kimmel, R.H. Kennedy, and R. F. Gaugish. 1992. Reservoirs. In: Biodiversity of the southeastern United States aquatic communities. John Wiley & Sons, Inc. New York.

Stumm, W. and J. J. Morgan. 1970. Aquatic chemistry: an introduction emphasizing chemical equilibria in natural waters. Wiley and Sons, Inc. New York, NY 583pp.

U.S. Environmental Protection Agency (USEPA). 1983. Methods for the Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Lab. Office of Research and Development, Cincinnati,

Wetzel, R. G. 1975. Limnology. W. B. Saunders Company, Philadelphia Pennsylvania, 743pp.

Table 2.1 Water chemistry program for the McGuire Nuclear Station NPDES maintenance monitoring program on Lake Norman.

2003 McGUIRE NPDES SAMPLING PROGRAM

PARAMETERS	LOCATIONS	1	2	4	5	8	9.5	11	13	14	15	15.9	62	69	72	80	16
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
IN-SITU ANALYSIS																	
	Method																
Temperature	Hydrolab																
Dissolved Oxygen	Hydrolab	In-situ measurements are collected monthly at the above locations at 1m intervals from 0.3m to 1m above bottom.															
pH	Hydrolab	Measurements are taken weekly from July-August for striped bass habitat.															
Conductivity	Hydrolab																
NUTRIENT ANALYSES																	
Ammonia	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Nitrate+Nitrite	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Orthophosphate	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Total Phosphorus	AA-TP,DG-P	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Silica	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cl	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
TKN	AA-TKN	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B		Q/T,B		Q/T,B			S/T
Total Organic Carbon	TOC		Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B			Q/T							S/T
Dissolved organic carbon	DOC		Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B			Q/T							S/T
ELEMENTAL ANALYSES																	
Aluminum	ICP-MS-D	Q/T,B	S/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
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-MS-D	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-MS-D	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	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
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-MS-D	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cadminum	ICP-MS-D		Q/T,B	Q/T		Q/T,B	Q/T,B			Q/T		Q/T,B					S/T
Copper (Total Recoverabl	ICP-MS-D		Q/T,B	Q/T		Q/T,B	Q/T,B			Q/T		Q/T,B					S/T
Copper (Dissolved)	ICP-MS		Q/T,B	Q/T		Q/T,B	Q/T,B			Q/T		Q/T,B					S/T
Lead	ICP-MS-D		Q/T,B	Q/T		Q/T,B	Q/T,B			Q/T		Q/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		Q/T,B	Q/T		Q/T,B				Q/T		Q/T,B					S/T
Total Solids	S-TSE		Q/T,B	Q/T		Q/T,B				Q/T		Q/T,B					S/T
Total Suspended Solids	S-TSSE		Q/T,B	Q/T		Q/T,B				Q/T		Q/T,B					S/T

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

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

Parameter	Method (EPA/APHA)	Preservation	Reporting Limit
Alkalinity, Total	Total inflection point, EPA 310.1	4 C	0.01 meq/L
Aluminum	ICP, EPA 200.7	0.5% HNO_3	0.05 mg/L
Cadmium, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	0.5 ug/L
Calcium	ICP, EPA 200.7	0.5% HNO_3	30 ug/L
Chloride	Colorimetric, EPA 325.2	4 C	1.0 mg/L
Copper, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 ug/L
Copper, Dissolved	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 ug/L
Iron, Total Recoverable	ICP, EPA 200.7	0.5% HNO_3	10 ug/L
Lead, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 ug/L
Magnesium	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	30 ug/L
Manganese, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	1.0 ug/L
Nitrogen, Ammonia	Colorimetric, EPA 350.1	4 C	20 ug/L
Nitrogen, Nitrite + Nitrate	Colorimetric, EPA 353.2	4 C	20 ug/L
Nitrogen, Total Kjeldahl	Colorimetric, EPA 351.2	4 C	100 ug/L
Phosphorus, Orthophosphorus	Colorimetric, EPA 365.1	4 C	5 ug/L
Organic Carbon, Total	EPA 415.1	0.5% H_2SO_4	0.1 mg/L
Organic Carbon, Dissolved	EPA 415.1	0.5% H_2SO_4	0.1 mg/L
Phosphorus, Total	Colorimetric, EPA 365.1	4 C	10 ug/L
Potassium	ICP, EPA 200.7	0.5% HNO_3	250 ug/L
Silica	APHA 4500Si-F	0.5% HNO_3	500 ug/L
Sodium	Atomic emission/ICP, EPA 200.7	0.5% HNO_3	1.5 mg/L
Solids, Total	Gravimetric, EPA 160.2	4 C	0.1 mg/L
Solids, Total Suspended	Gravimetric, EPA 160.2	4 C	0.1 mg/L
Sulfate	Ion Chromatography	4 C	0.1 mg/L
Turbidity	Turbidimetric, EPA 180.1	4 C	0.05 NTU
Zinc, Total Recoverable	ICP, EPA 200.8	0.5% HNO_3	20 ug/L

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

Table 2-3. Heat content calculations for the thermal regime in Lake Norman for 2002 and 2003.

	2002	2003
Maximum Areal Heat Content (g-cal/cm^2)	28,252	28,176
Minimum Areal Heat Content (g cal/cm^2)	10,042	8,864
Birgean Heat Budget (g cal/ cm^2)	18,210	19,312
Epilimnion (above 11.5 m) Heating Rate (°C /day)	0.113	0.096
Hypolimnion (below 11.5 m) Heating Rate (°C /day)	0.066	0.072

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 (2003)	0.044	5.3	2.5	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 2002 and 2003. Values less than detection were assumed to be the detection limit for calculating a mean.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Turbidity (ntu)																						
Feb	3.75	2.69	6.30	2.61	3.63	2.51	3.39	2.65	3.29	2.11	4	2.03	5.53	2.23	5.06	2.67	6.77	2.56	4.08	4.76	7.86	3.88
May	1.59	4.04	3.50	7.41	1.02	5.58	2.41	7.32	1.48	8.49	1.43	6.11	2.53	7.48	1.53	3.61	2.8	11.00	2.19	2.35	NS	18.30
Aug	1.45	1.96	2.57	3.90	1.5	1.84	2.09	2.20	1.4	2.03	1.46	2.04	3.63	10.40	1.32	1.82	2.99	6.64	2.11	2.03	2.49	4.38
Nov	2.80	1.56	2.8	2.01	3.13	1.43	3.69	1.88	3.05	1.40	2.98	1.18	7.53	4.25	2.72	1.05	5.77	4.15	3.32	1.25	6.46	5.06
Annual Mean	2.40	2.56	3.79	4.0	2.32	2.8	2.90	3.5	2.31	3.5	2.47	2.8	4.81	6.1	2.66	2.3	4.58	6.1	2.93	2.6	5.60	7.9
Specific Conductance (umho/cm)																						
Feb	72.0	71	71.0	70	72	71	71	70	74	73	73	71	71.0	70	70	70	70	70	70	67	69	68
May	75.0	60	73	62	74	60	73	62	75	59	75	59	73	61	74	60	73	59	72	58	72	54
Aug	77.0	55	78.0	65	75.0	54	79.0	66	74.0	54	75.0	54	81.0	67	75.0	54	77.0	62	74.0	54	79.0	64
Nov	74.0	55	110.0	95	74.0	54	77.0	97	74.0	55	74.0	55	74.0	58	74.0	53	72.0	54	73.0	53	73.0	52.0
Annual Mean	74.5	60.3	83.0	73.0	73.8	59.8	75.0	73.8	74.3	60.3	74.3	59.8	74.8	64.0	73.3	59.3	73.0	61.3	72.3	58.0	73.3	59.5
pH (units)																						
Feb	7.0	6.7	6.7	7.0	7.2	7.2	6.8	7.1	7.2	7.1	7.2	7.2	6.9	7.2	6.4	7.3	6.7	7.2	6.6	7.3	6.6	7.2
May	6.9	6.7	6.6	6.5	7.1	6.9	6.6	6.6	7.0	6.8	7.1	6.9	6.8	6.6	7.3	7.2	6.6	6.6	7.2	7.3	6.6	6.5
Aug	7.1	7.1	6.3	6.3	7.4	6.9	6.4	6.3	7.1	6.6	7.2	6.8	6.6	6.5	6.9	7.1	6.2	6.4	7.7	7.3	6.3	6.4
Nov	6.6	6.8	6.8	6.6	7.1	6.8	6.9	6.7	7.0	6.7	7.0	6.9	6.9	6.6	7.1	6.8	7.1	6.5	7.1	7.2	7.0	6.5
Annual Mean	6.90	6.60	6.60	6.60	7.20	6.95	6.68	6.69	7.07	7.10	7.13	6.95	6.80	6.73	6.93	7.10	6.66	6.67	7.15	7.28	6.63	6.64
Alkalinity (mg CaCO3/l)																						
Feb	20.0	16.5	19.5	16.5	19.5	16.5	19.5	16.5	19.5	16.5	19.5	16.5	19.5	16.5	19.5	16.0	19.0	16.5	19.0	15.0	18.5	15.5
May	16.5	13.5	17.0	13.0	17.0	13.5	16.5	14.0	17.0	13.0	17.0	13.0	17.0	14.0	17.0	13.5	17.0	13.5	16.0	12.0	NA	12.0
Aug	17.5	13.0	18.0	14.0	18.0	13.0	18.0	14.0	17.5	13.0	17.5	13.0	22.0	17.5	17.5	13.0	18.0	14.5	17.5	13.5	19.5	14.5
Nov	19.0	14.5	19.0	20.5	18.5	14.5	20.0	29.0	18.5	14.0	18.5	14.5	19.0	16.5	18.0	14.5	18.0	15.5	18.5	14.0	18.0	14.5
Annual Mean	18.25	14.38	18.38	16.00	18.25	14.38	18.50	18.38	18.13	14.13	18.13	14.25	19.38	16.13	18.00	14.25	18.00	15.00	17.75	13.63	18.67	14.13
Chloride (mg/l)																						
Feb	7.3	6.9	6.9	6.6	6.6	6.7	6.8	7.0	6.9	6.7	6.6	6.7	6.7	6.6	6.6	6.8	6.4	6.9	6.9	6.2	6.9	6.1
May	6.7	5.4	6.6	5.9	6.6	5.4	6.4	5.8	6.5	5.2	6.6	5.4	6.4	5.7	6.5	5.3	6.4	5.5	6.6	5.2	NS	4.9
Aug	7.0	4.0	6.7	4.7	7.1	3.9	6.7	4.9	7.0	3.9	7.0	4.0	6.8	4.4	7.1	3.9	6.8	4.8	7.0	4.1	6.9	4.7
Nov	7.2	3.9	NS	4.0	7.5	3.9	7.3	4.6	7.4	3.8	7.4	3.8	7.4	3.8	7.3	4.0	7.5	3.9	7.2	3.9	7.3	3.9
Annual Mean	7.05	5.05	6.73	5.30	6.95	4.98	6.80	5.58	6.95	4.90	6.90	4.98	6.83	5.13	6.88	5.00	6.78	5.28	6.93	4.85	7.03	4.90
Sulfate (mg/l)																						
Feb	6.05	NS	6.72	NS	NS	5.8	NS	7.2	6.67	7.1	6.8	NS	6.74	NS	NS	7.3	6	7.2	6.69	NS	6.66	NS
May	5.32	NS	5.86	NS	5.59	6.1	5.78	6.3	7.3	5.8	6.03	NS	5.37	NS	4.78	6.0	5.8	6.0	5.32	NS	NS	NS
Aug	6.40	NS	NS	NS	NS	4.8	NS	5.6	6.24	4.6	6.09	NS	6.30	NS	6.24	4.9	14.44	5.4	5.93	NS	6.24	NS
Nov	6.80	NS	6.80	NS	6.77	4.8	6.6	3.3	6.99	4.8	6.75	NS	6.74	NS	6.82	4.8	6.92	4.2	6.59	NS	6.62	NS
Annual Mean	6.14	NS	6.46	NS	6.18	5.38	6.17	5.60	6.80	5.58	6.42	NS	6.29	NS	5.95	5.75	8.29	5.70	6.14		5.86	
Calcium (mg/l)																						
Feb	3.25	3.44	3.05	3.43	2.92	3.48	3.62	3.45	3.26	3.48	3.34	3.46	3.15	3.46	3.05	3.49	3.07	3.47	3.20	3.67	2.89	3.65
May	3.28	4.62	3.31	4.37	3.26	4.11	3.29	4.61	3.26	4.18	3.29	3.78	3.31	4.42	3.24	3.89	3.29	3.90	3.36	3.38	NS	3.96
Aug	3.53	4.05	3.75	4.17	3.52	4.07	3.82	3.74	3.52	2.98	3.52	3.22	3.96	5.03	3.49	3.09	3.82	4.07	3.59	4.46	3.95	4.74
Nov	3.41	3.54	3.41	3.84	3.46	3.53	3.51	4.26	3.43	3.48	3.44	3.48	3.43	3.52	3.45	3.46	3.40	3.15	3.51	3.43	3.52	3.10
Annual Mean	3.37	3.91	3.38	3.95	3.29	3.80	3.56	4.02	3.37	3.53	3.40	3.49	3.46	4.11	3.31	3.48	3.40	3.65	3.42	3.74	3.45	3.86
Magnesium (mg/l)																						
Feb	1.57	1.60	1.58	1.61	1.54	1.60	1.77	1.61	1.67	1.62	1.57	1.60	1.60	1.60	1.55	1.60	1.55	1.61	1.60	1.52	1.47	1.55
May	1.55	1.75	1.57	1.70	1.55	1.59	1.56	1.77	1.57	1.60	1.56	1.52	1.56	1.72	1.55	1.58	1.55	1.61	1.51	1.45	NS	1.56
Aug	1.67	1.63	1.70	1.63	1.68	1.59	1.71	1.57	1.65	1.37	1.65	1.43	1.78	1.82	1.65	1.42	1.74	1.66	1.65	1.73	1.79	1.85
Nov	1.72	1.50	1.72	1.56	1.72	1.49	1.74	1.64	1.72	1.49	1.74	1.49	1.72	1.50	1.73	1.47	1.70	1.43	1.70	1.47	1.70	1.42
Annual Mean	1.63	1.62	1.64	1.63	1.62	1.57	1.70	1.65	1.65	1.52	1.63	1.51	1.67	1.66	1.62	1.52	1.64	1.57	1.62	1.54	1.65	1.60

NS = Not Sampled

Table 2-5. (Continued)

LOCATION:	Mixing Zone 1.0				Mixing Zone 2				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Potassium (mg/l)																						
Feb	1.80	2.12	1.77	2.08	1.85	2.09	1.86	2.13	1.80	2.29	1.80	2.06	1.83	2.15	1.87	2.16	1.84	2.12	1.80	1.98	1.75	2.14
May	1.91	1.82	1.96	1.94	1.94	1.78	1.91	1.90	1.89	1.83	1.93	1.75	1.90	1.80	1.88	1.76	1.91	1.83	1.83	1.74	NS	1.75
Aug	2.11	1.81	2.11	1.86	2.11	1.76	2.07	1.85	2.03	1.71	2.05	1.69	2.11	1.88	2.00	1.74	2.08	1.83	2.04	1.74	2.07	1.86
Nov	2.12	1.74	2.12	1.76	2.18	1.72	2.23	1.81	2.17	1.67	2.22	1.68	2.17	1.73	2.14	1.71	2.16	1.59	2.12	1.69	2.10	1.66
Annual Mean	1.99	1.87	1.99	1.91	2.02	1.84	2.02	1.92	1.97	1.88	2.00	1.80	2.00	1.89	1.97	1.84	2.00	1.84	1.95	1.79	1.97	1.85
Sodium (mg/l)																						
Feb	7.08	7.73	7.82	7.73	8.03	7.90	7.54	7.98	8.08	8.26	7.29	8.25	8.05	7.84	7.83	7.73	7.62	7.89	7.75	7.00	7.91	7.58
May	7.81	5.00	8.11	5.24	7.90	5.06	7.93	5.78	7.80	5.02	7.71	4.57	7.57	5.40	8.03	4.83	7.71	5.16	7.95	4.64	NS	3.63
Aug	8.28	4.20	7.94	5.14	8.31	4.14	8.05	5.11	7.85	4.06	8.18	4.13	7.83	4.59	8.05	4.16	7.90	5.10	8.41	4.14	8	4.90
Nov	7.16	4.03	7.16	4.17	7.72	3.98	7.65	4.50	7.15	3.96	7.77	3.94	7.58	3.94	7.55	3.94	7.27	4.10	8.03	3.94	7.76	4.09
Annual Mean	7.58	5.24	7.76	5.57	7.99	5.27	7.79	5.84	7.72	5.33	7.74	5.22	7.76	5.44	7.87	5.17	7.63	5.56	8.04	4.93	7.89	5.05
Aluminum (mg/l)																						
Feb	0.092	0.101	0.142	0.111	0.080	0.098	0.151	0.116	0.087	0.096	0.101	0.088	0.163	0.109	0.085	0.099	0.172	0.116	0.135	0.164	0.311	0.173
May	0.050	0.286	0.065	0.442	0.050	0.349	0.051	0.470	0.05	0.509	0.050	0.311	0.063	0.430	0.050	0.229	0.063	0.692	0.050	0.206	NS	1.281
Aug	0.050	0.055	0.060	0.109	0.050	0.054	0.050	0.112	0.05	0.050	0.050	0.050	0.107	0.136	0.050	0.050	0.070	0.225	0.050	0.050	0.066	0.118
Nov	0.076	0.055	0.076	0.055	0.089	0.050	0.082	0.050	0.095	0.052	0.087	0.056	0.240	0.200	0.067	0.062	0.188	0.194	0.106	0.053	0.237	0.366
Annual Mean	0.07	0.18	0.086	0.18	0.067	0.14	0.084	0.187	0.071	0.18	0.072	0.13	0.143	0.22	0.063	0.11	0.123	0.31	0.085	0.12	0.205	0.48
Iron (mg/l)																						
Feb	0.108	0.108	0.198	0.125	0.113	0.110	0.205	0.134	0.103	0.107	0.137	0.102	0.245	0.121	0.121	0.105	0.270	0.130	0.185	0.193	0.452	0.218
May	0.052	0.320	0.117	0.450	0.044	0.365	0.098	0.456	0.041	0.495	0.034	0.324	0.115	0.450	0.056	0.256	0.122	0.683	0.103	0.243	NS	1.106
Aug	0.066	0.062	0.119	0.116	0.062	0.061	0.086	0.120	0.061	0.062	0.064	0.081	0.239	0.732	0.049	0.059	0.143	0.307	0.063	0.048	0.142	0.167
Nov	0.107	0.089	0.107	0.218	0.125	0.082	0.211	1.493	0.138	0.092	0.133	0.091	0.385	0.413	0.101	0.080	0.255	0.471	0.141	0.075	0.309	0.583
Annual Mean	0.083	0.145	0.135	0.227	0.086	0.155	0.150	0.551	0.086	0.189	0.092	0.150	0.246	0.429	0.082	0.125	0.198	0.398	0.123	0.140	0.301	0.519
Manganese (mg/l)																						
Feb	0.01	0.01	0.05	0.01	0.01	0.01	0.05	0.02	0.01	0.01	NS	0.01	0.05	0.01	0.02	0.01	NS	0.01	0.02	0.01	0.05	0.02
May	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.04	0.03	0.01	0.01	0.03	0.02	0.01	0.01	NS	0.05
Aug	0.02	0.02	NS	0.44	0.02	0.02	0.52	0.51	0.02	0.05	0.02	0.03	1.76	1.19	0.01	0.02	0.63	1.40	0.03	0.02	1.22	1.22
Nov	0.11	0.05	0.11	2.25	0.09	0.06	0.64	4.72	0.13	0.09	0.12	0.06	0.33	0.84	0.08	0.04	0.03	0.50	0.05	0.03	0.08	0.32
Annual Mean	0.04	0.02	0.06	0.68	0.03	0.02	0.31	1.32	0.04	0.04	0.05	0.03	0.54	0.52	0.03	0.02	0.23	0.48	0.03	0.02	0.45	0.40
Cadmium (ug/l)																						
Feb	NS	NS	NS	NS	0.5	0.5	0.5	0.5	0.5	0.5	NS	NS	NS	NS	0.5	0.5	0.5	0.5	NS	NS	NS	NS
May	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	NS	NS
Aug	NS	NS	NS	NS	0.5	0.5	0.5	0.5	0.5	0.5	NS	NS	NS	NS	0.5	0.5	0.5	0.5	NS	NS	NS	NS
Nov	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS	0.5	NS
Annual Mean	0.5	NS	0.5	NS	0.5	NS	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
Copper (ug/l)																						
Feb	NS	NS	NS	NS	2.0	2.0	2.1	2.0	2.0	2.0	NS	NS	NS	NS	2.0	2.0	2.5	2.0	2.4	NS	NS	NS
May	6.8	NS	3.0	NS	2.4	2.9	2.3	2.5	2.2	13.8	2.3	NS	4.5	NS	2.2	2.2	2.3	2.2	3.3	NS	NS	NS
Aug	NS	NS	NS	NS	2.8	2.4	2.3	2.3	2.3	2.7	NS	NS	NS	NS	2.5	2.6	2.2	2.7	NS	NS	NS	NS
Nov	2.0	NS	2.0	NS	2.2	2.0	2.3	2.0	2.3	2.0	2.0	NS	2.4	NS	2.3	2.0	2.4	2.1	3.1	NS	3.1	NS
Annual Mean	4.4	NS	2.5	NS	2.3	2.3	2.2	2.2	2.2	5.1	2.0	NS	2.1		2.2	2.2	2.3	2.3	2.9	NS	3.1	NS
Lead (ug/l)																						
Feb	NS	NS	NS	NS	2	2	2	2	2	2	NS	NS	NS	NS	2	2	2	2	2	NS	NS	NS
May	2	NS	2	NS	2	2	2	2	2	2	2	NS	2	NS	2	2	2	2	2	NS	NS	NS
Aug	NS	NS	NS	NS	2	2	2	2	2	2	NS	NS	NS	NS	2	2	2	2	NS	NS	NS	NS
Nov	2	NS	2	NS	2	2	2	2	2	2	2	NS	2	NS	2	2	2	2	2	NS	2	NS
Annual Mean	2	NS	2	NS	2	2	2	2	2	2	2	NS	2	NS	2	2	2	2	2	NS	2	NS

NS = Not sampled

Table 2-5. (Continued)

	Mixing Zone				Mixing Zone				MNS Discharge		Mixing Zone				Background				Background			
LOCATION:	1.0				Mi 2				4.0		5.0				8.0				11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Zinc (ug/l)																						
Feb	5	20	5	20	5	25	5	20	5	20	6	20	5	20	7	20	5	20	5	20	10	20
May	5	20	5	20	5	20	5	20	5	20	9	20	5	20	5	20	5	20	5	20	NS	20
Aug	5	20	8	20	5	20	5	20	5	20	5	20	5	20	5	20	5	20	6	20	5	20
Nov	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Annual Mean	8.8	20.0	9.5	20.0	8.8	21.3	8.8	20.0	8.8	20.0	10.0	20.0	8.8	20.0	9.3	20.0	8.8	20.0	9.0	20.0	11.7	20.0
Nitrite-Nitrate (ug/l)																						
Feb	110	210	120	220	110	280	130	230	120	230	110	220	120	230	120	420	130	390	150	350	220	350
May	120	350	170	410	130	340	170	410	130	370	130	340	160	410	120	300	190	430	150	260	NS	460
Aug	20	180	170	450	20	200	160	450	20	230	20	220	90	180	20	180	150	420	20	110	160	410
Nov	50	110	50	50	60	110	50	20	60	120	60	110	50	90	60	110	70	140	140	120	140	150
Annual Mean	75.0	212.5	127.5	282.5	80.0	232.5	127.5	277.5	82.5	237.5	80.0	222.5	105.0	227.5	80.0	252.5	135.0	345.0	115.0	210.0	173.3	342.5
Ammonia (ug/l)																						
Feb	20	20	40	30	20	20	50	30	30	20	20	20	40	20	20	30	190	30	40	30	50	30
May	20	40	20	20	20	40	20	20	20	50	20	40	20	20	20	30	20	20	20	30	NS	90
Aug	20	20	20	20	20	20	40	20	20	20	20	20	80	130	20	20	60	20	20	20	50	20
Nov	60	60	60	280	60	70	110	490	60	80	60	50	80	190	60	70	50	190	50	20	60	140
Annual Mean	30.0	35.0	35.0	87.5	30.0	37.5	55.0	140.0	32.5	42.5	30.0	32.5	55.0	90.0	30.0	37.5	80.0	65.0	32.5	25.0	53.3	70.0
Total Phosphorous (ug/l)																						
Feb	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	16	10
May	10	11	10	12	10	11	10	15	10	58	10	14	26	14	18	17	10	24	10	13	NS	34
Aug	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	10	10	10	10
Nov	10	11	10	16	10	10	22	14	10	17	10	10	10	18	10	10	10	16	10	19	10	19
Annual Mean	10.0	10.5	10.0	12.0	10.0	10.3	13.0	12.3	10.0	23.8	10.0	11.0	14.0	13.0	12.0	11.8	10.0	15.3	10.0	13.0	12.0	18.3
Orthophosphate (ug/l)																						
Feb	5	5	5	5	6	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
May	5	5	5	6	5	5	5	7	5	49	5	7	14	31	5	9	5	5	5	17	NS	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	13	5	5	7	5	5	5	5	5	5	5	5	5	5	5	6
Annual Mean	5.0	5.0	5.0	5.3	5.3	4.3	7.0	6	5.0	17	5.0	6	7.3	12	5.0	6	5.0	5	5.0	8.0	5.0	5
Silica (mg/l)																						
Feb	3.2	4.1	3.4	4.1	3.3	4.1	3.5	4.1	3.3	4.1	3.3	4.1	3.4	4.1	3.3	4.1	3.5	4.1	3.6	4.5	3.8	4.4
May	3.4	3.8	3.8	4.3	3.4	3.9	3.8	4.3	3.4	4.0	3.4	3.9	4.0	4.3	3.3	3.8	3.9	4.3	3.8	3.4	NS	4.2
Aug	3.0	2.7	4.3	4.7	3.0	3.0	4.4	4.8	3.0	3.3	3.0	3.1	4.4	4.5	3.0	2.8	4.3	4.9	3.2	2.7	4.4	4.7
Nov	4.3	4.0	4.3	4.5	4.5	4.0	4.5	5.1	4.4	4.1	4.5	4.0	4.5	4.3	4.4	4.0	4.3	5.4	4.8	4.3	4.8	5.4
Annual Mean	3.5	3.7	4.0	4.4	3.6	3.8	4.1	4.6	3.5	3.9	3.6	3.8	4.1	4.3	3.5	3.7	4.0	4.7	3.9	3.7	4.3	4.7

NS = Not Sampled

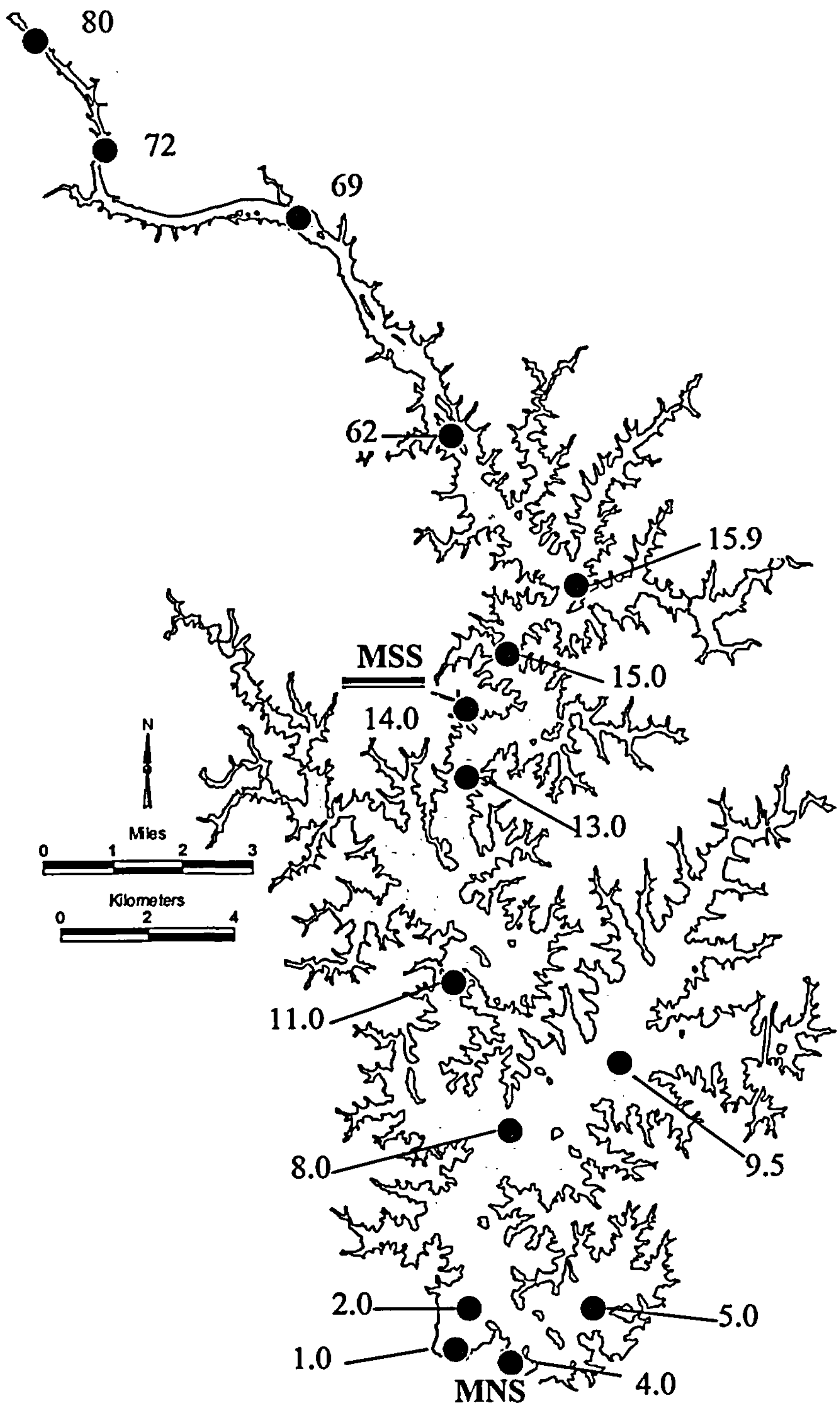


Figure 2-1. Water quality sampling locations (numbered) for Lake Norman. Approximate locations of Marshall Steam Station (MSS), and McGuire Nuclear Station (MNS) are also shown.

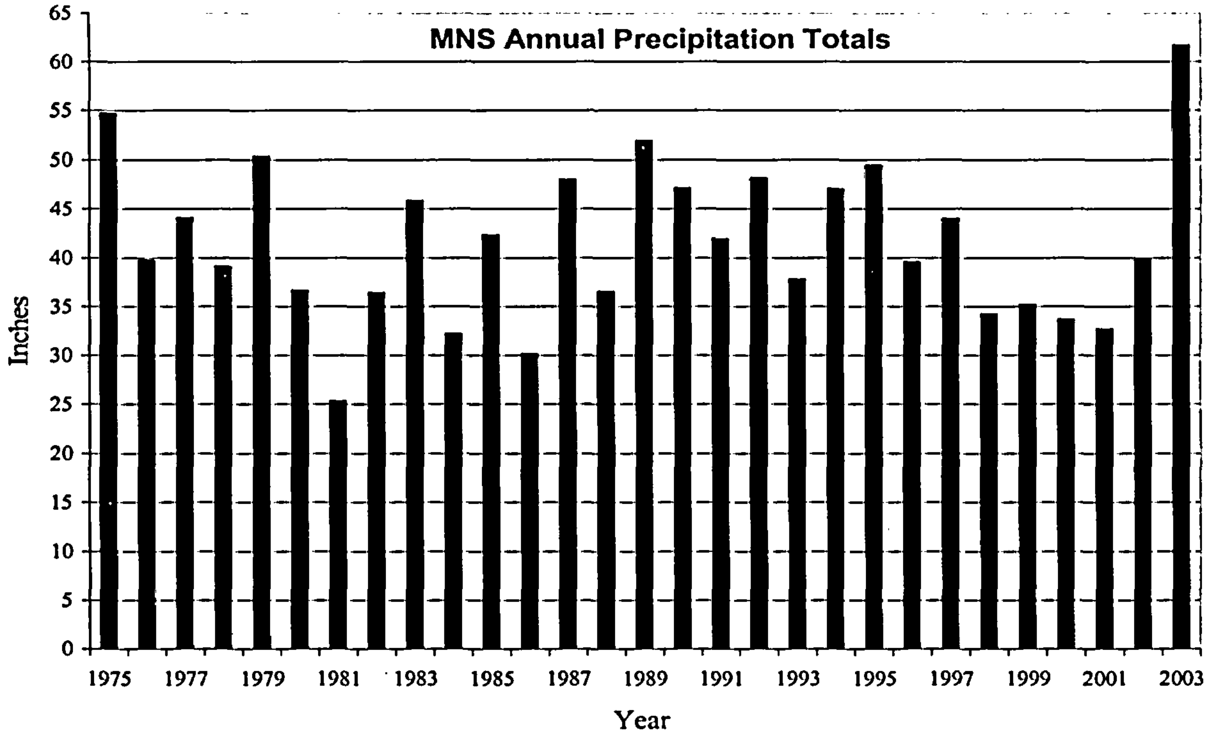


Figure 2-2a. Annual precipitation totals in the vicinity of McGuire Nuclear Station (MNS).

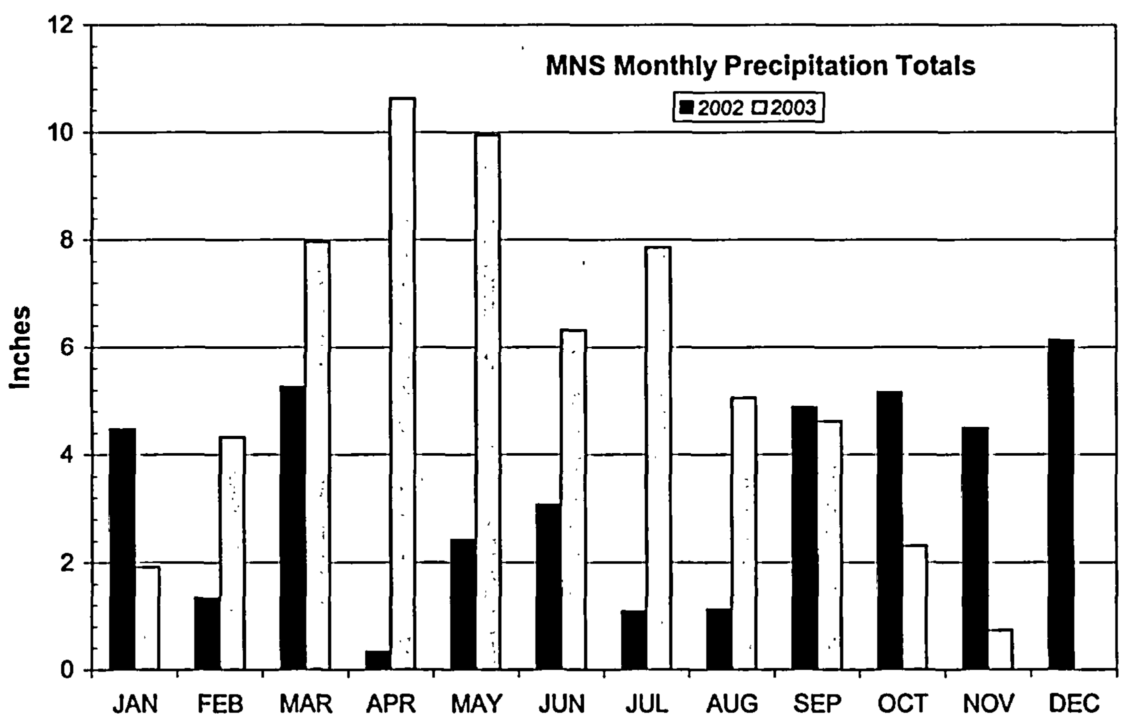


Figure 2-2b. Monthly precipitation totals in the vicinity of McGuire Nuclear Station (MNS)

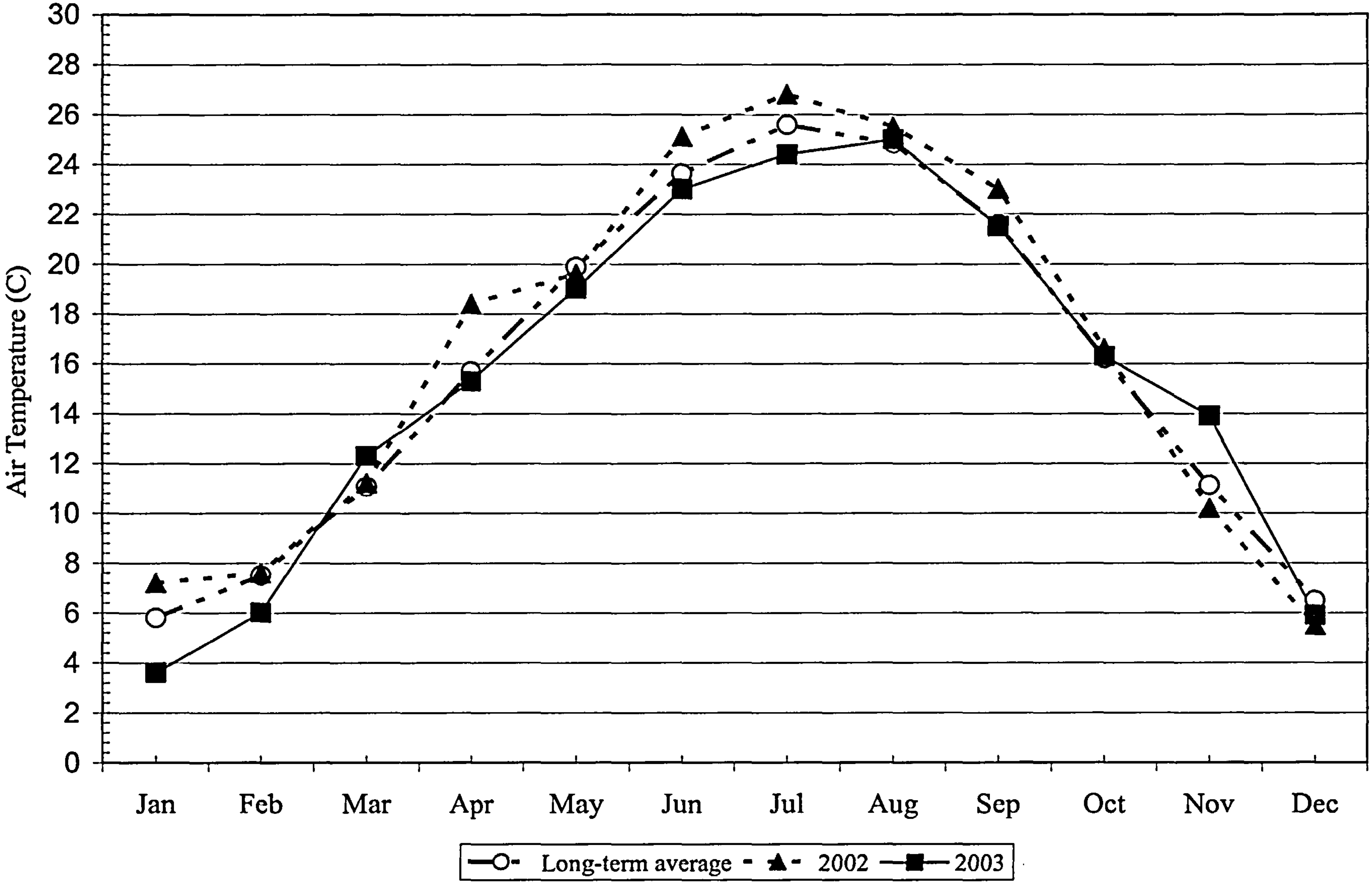


Figure 2-2c. Mean monthly air temperatures recorded at MNS beginning in 1989. Data are complied from average daily temperatures which, in turn, were created from hourly measurements.

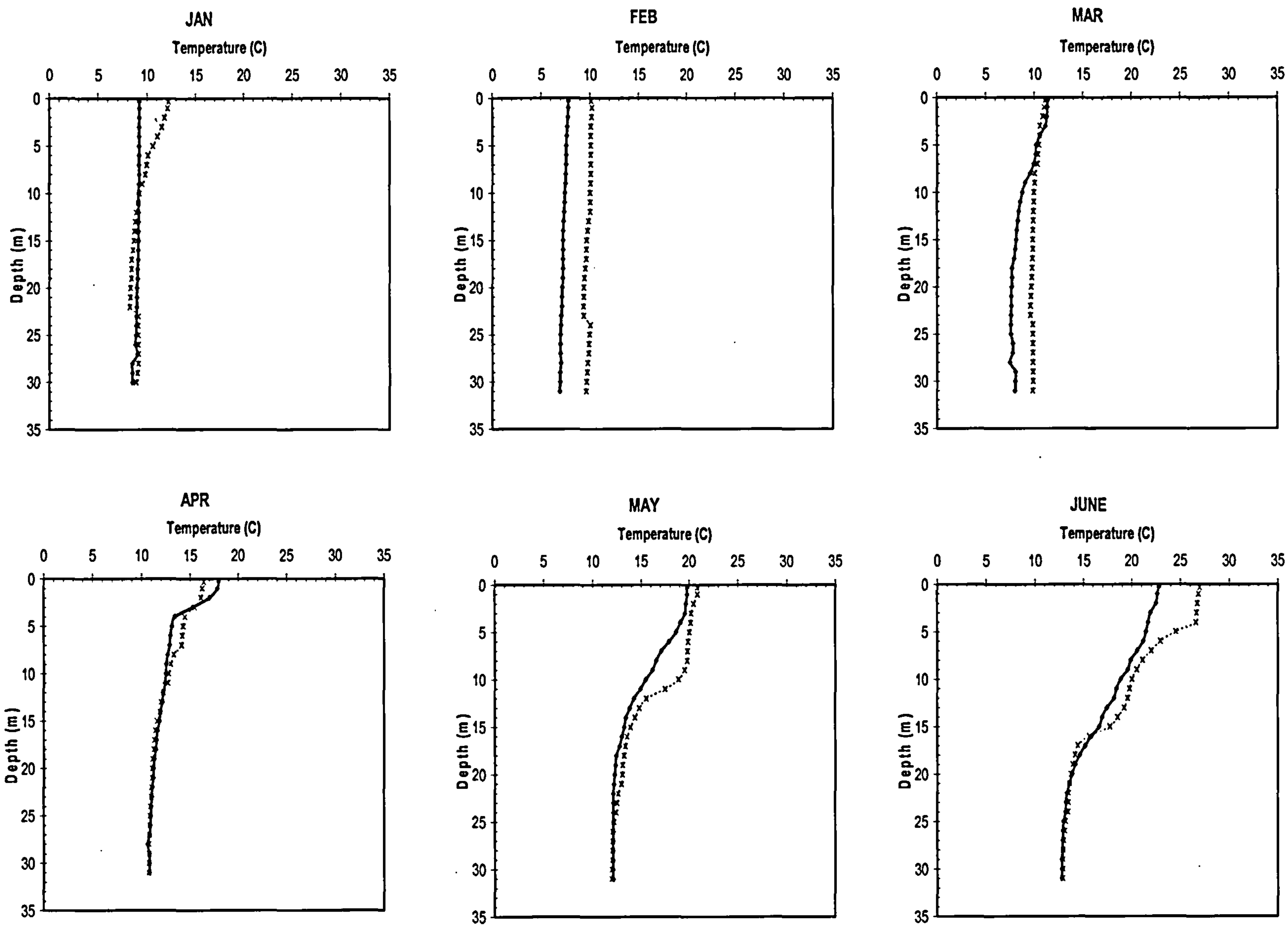


Figure 2-3. Monthly mean temperature profiles for the McGuire Nuclear Station background zone in 2002 (××) and 2003 (♦♦).

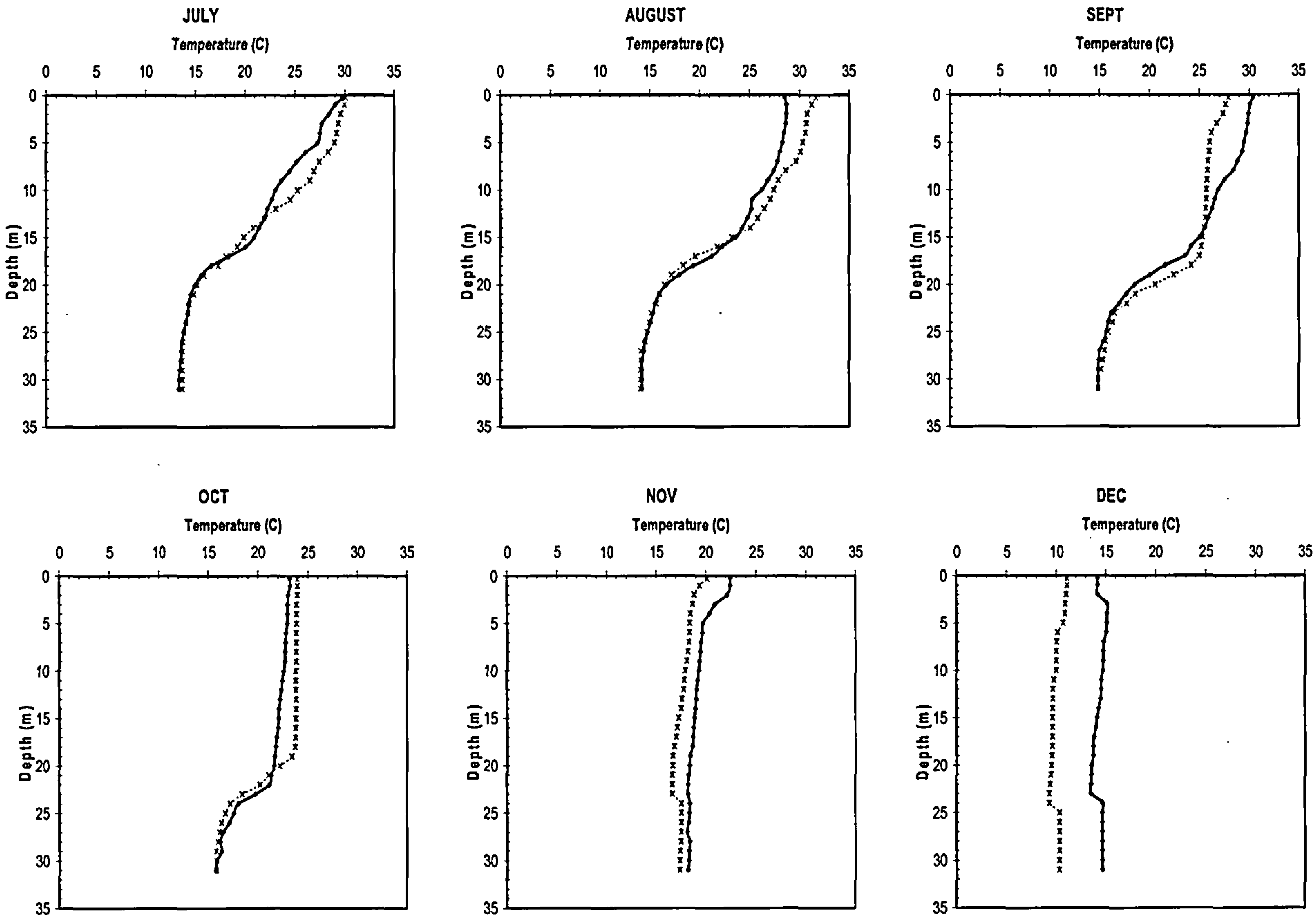


Figure 2-3. (con't).

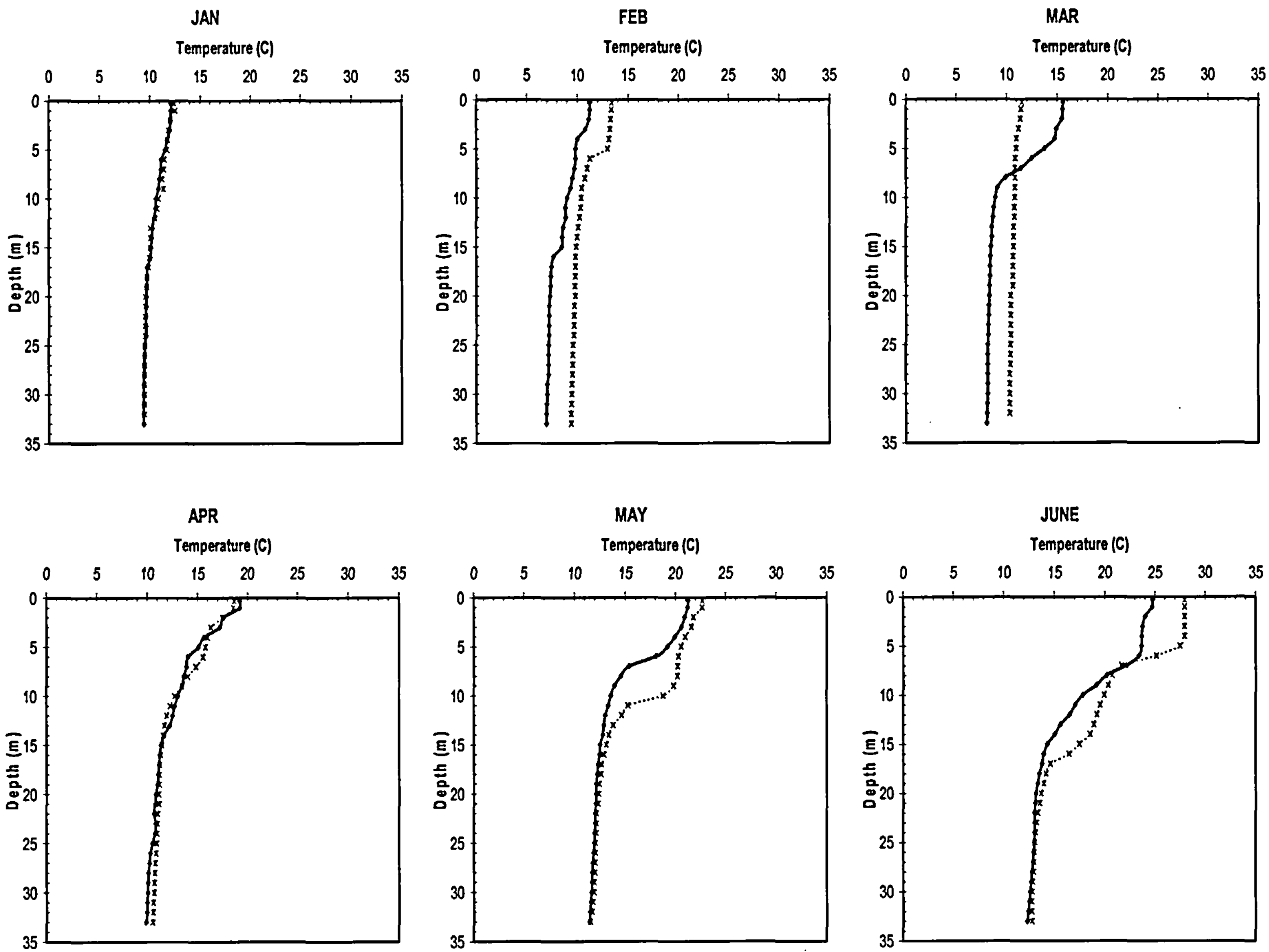


Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 2002 (××) and 2003 (♦♦).

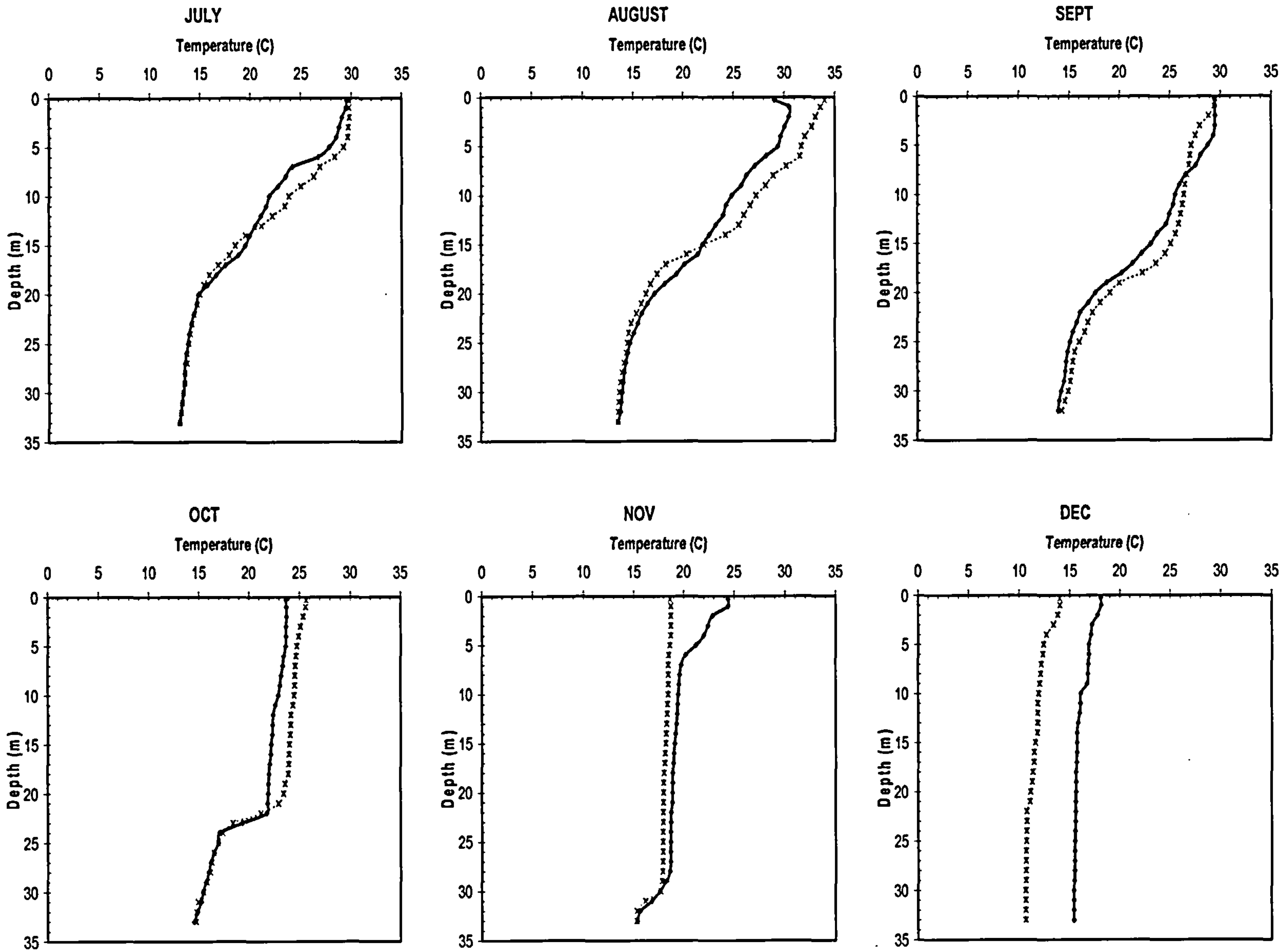


Figure 2-4. (con't).

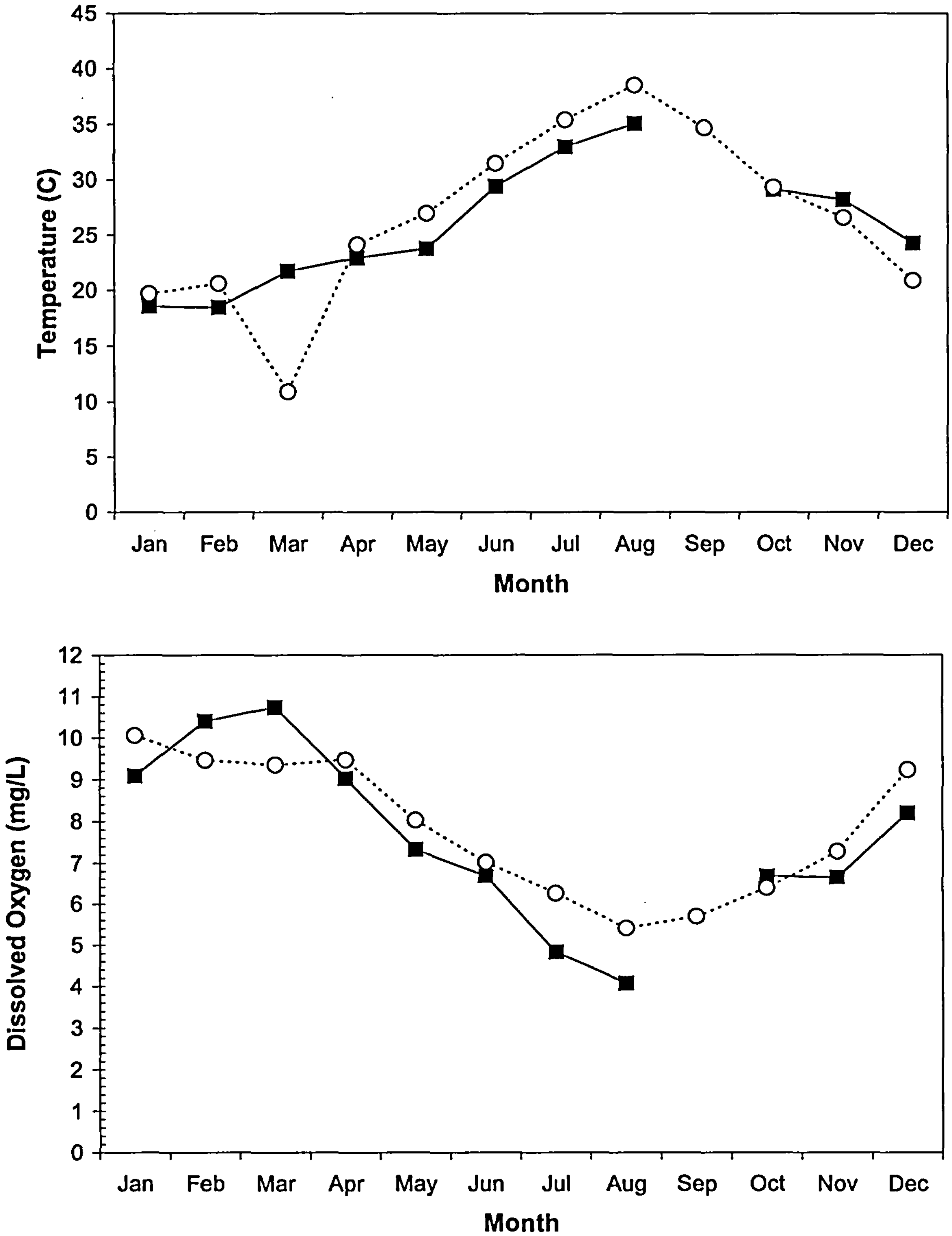


Figure 2-5. Monthly surface (0.3m) temperature and dissolved oxygen data at the discharge location (loc. 4.0) in 2002 (O) and 2003 (■). September 2003 data are missing.

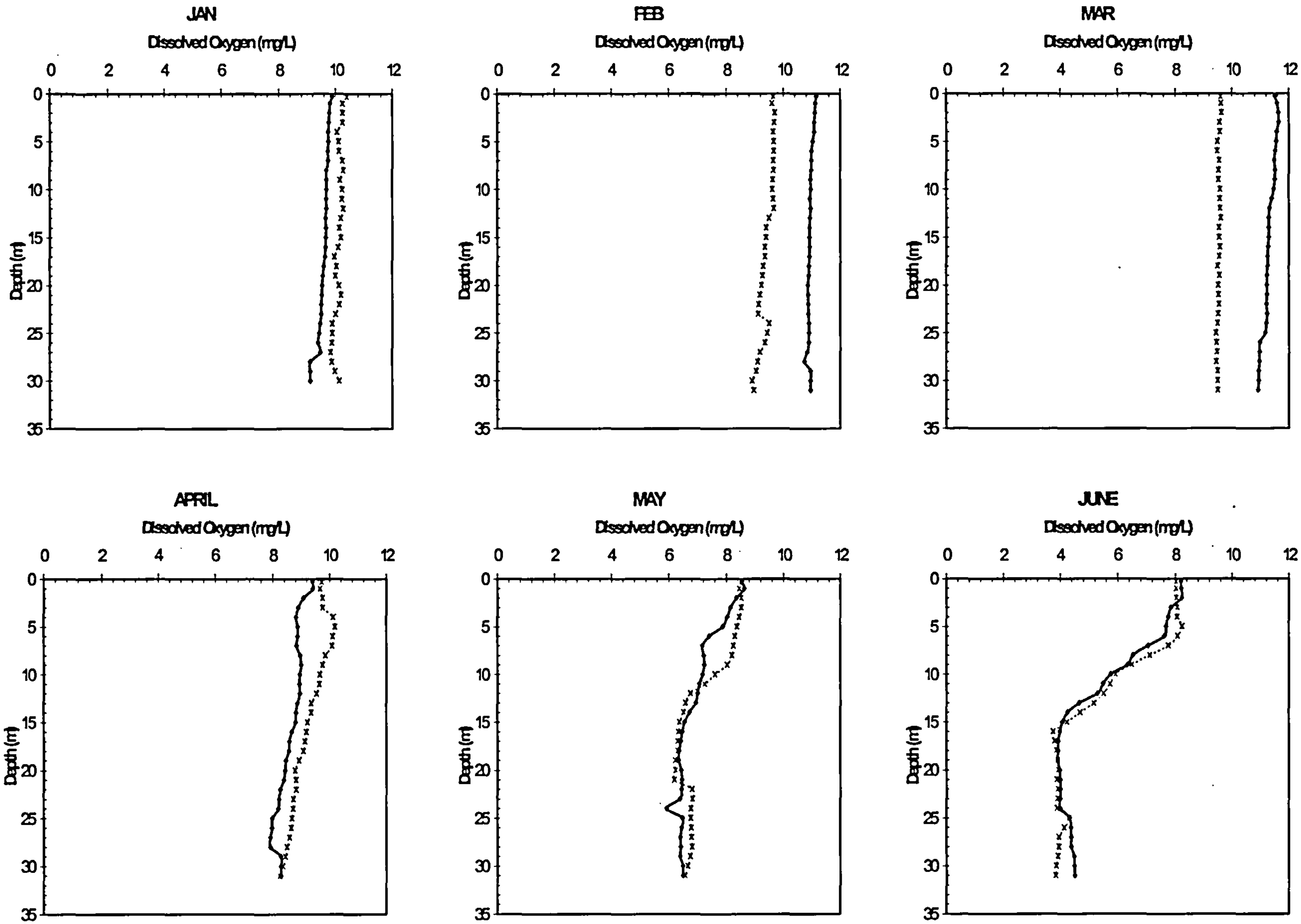


Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 2002 (××) and 2003 (♦♦).

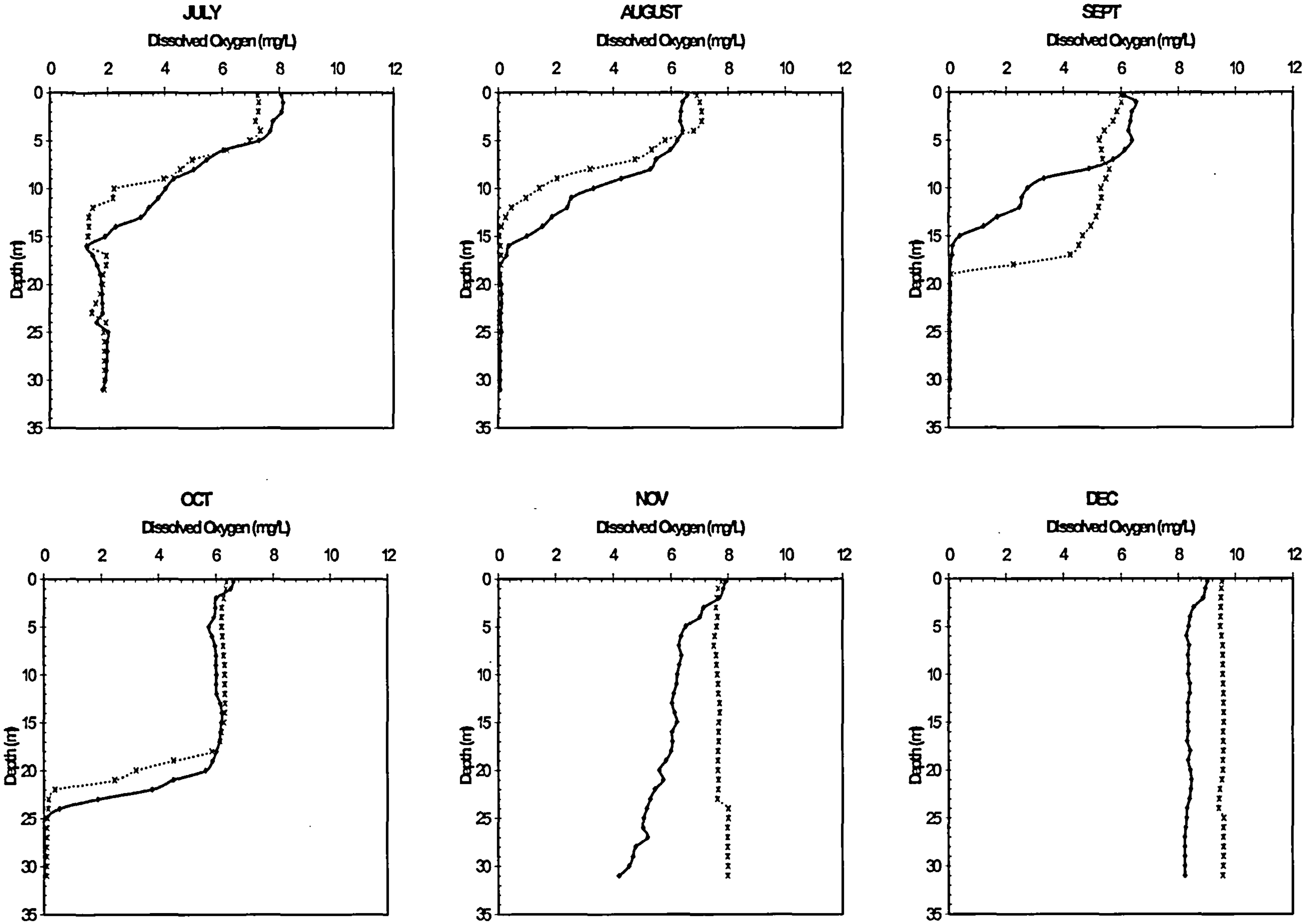


Figure 2-6. (con't).

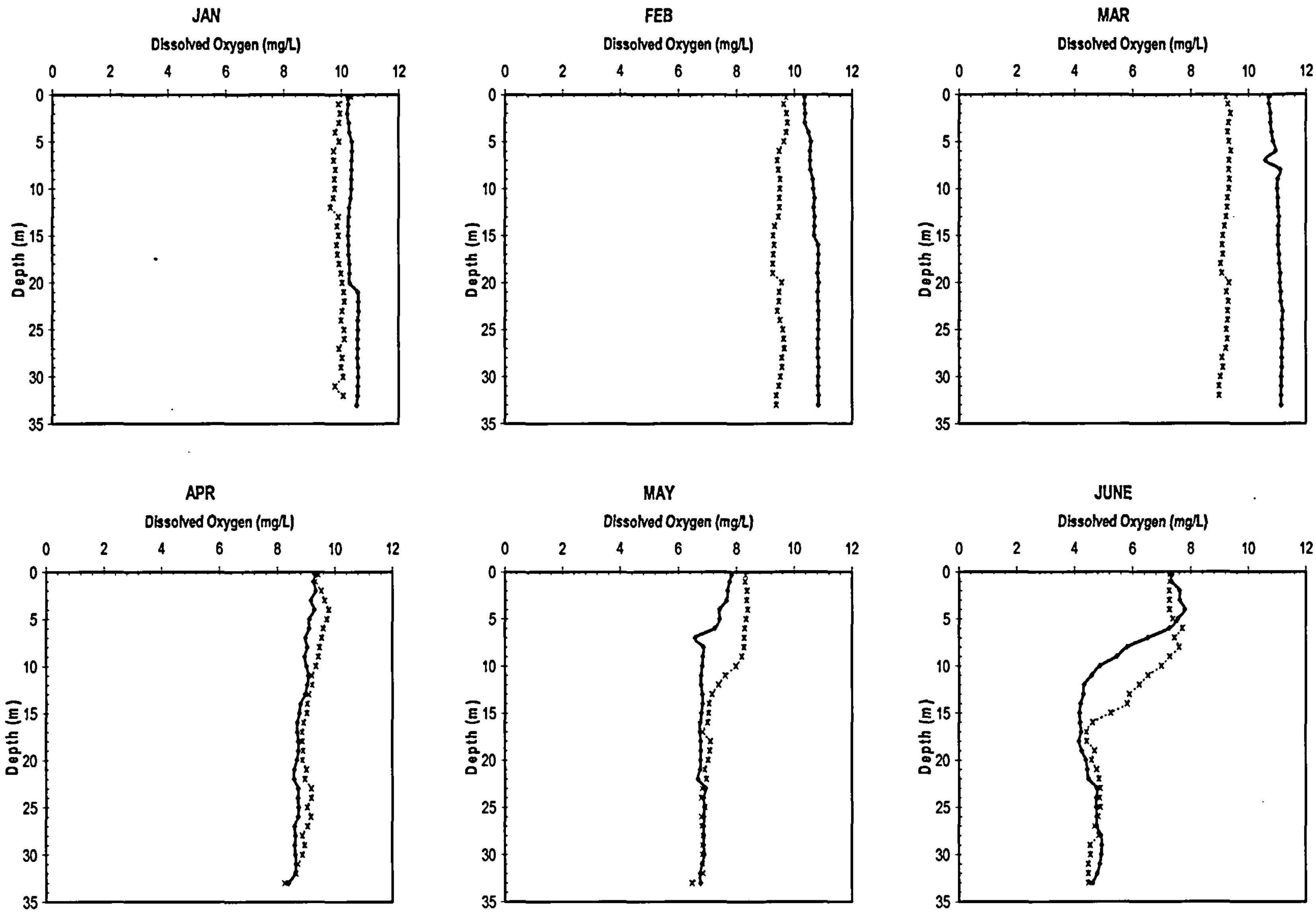


Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 2002 (××) and 2003 (♦♦).

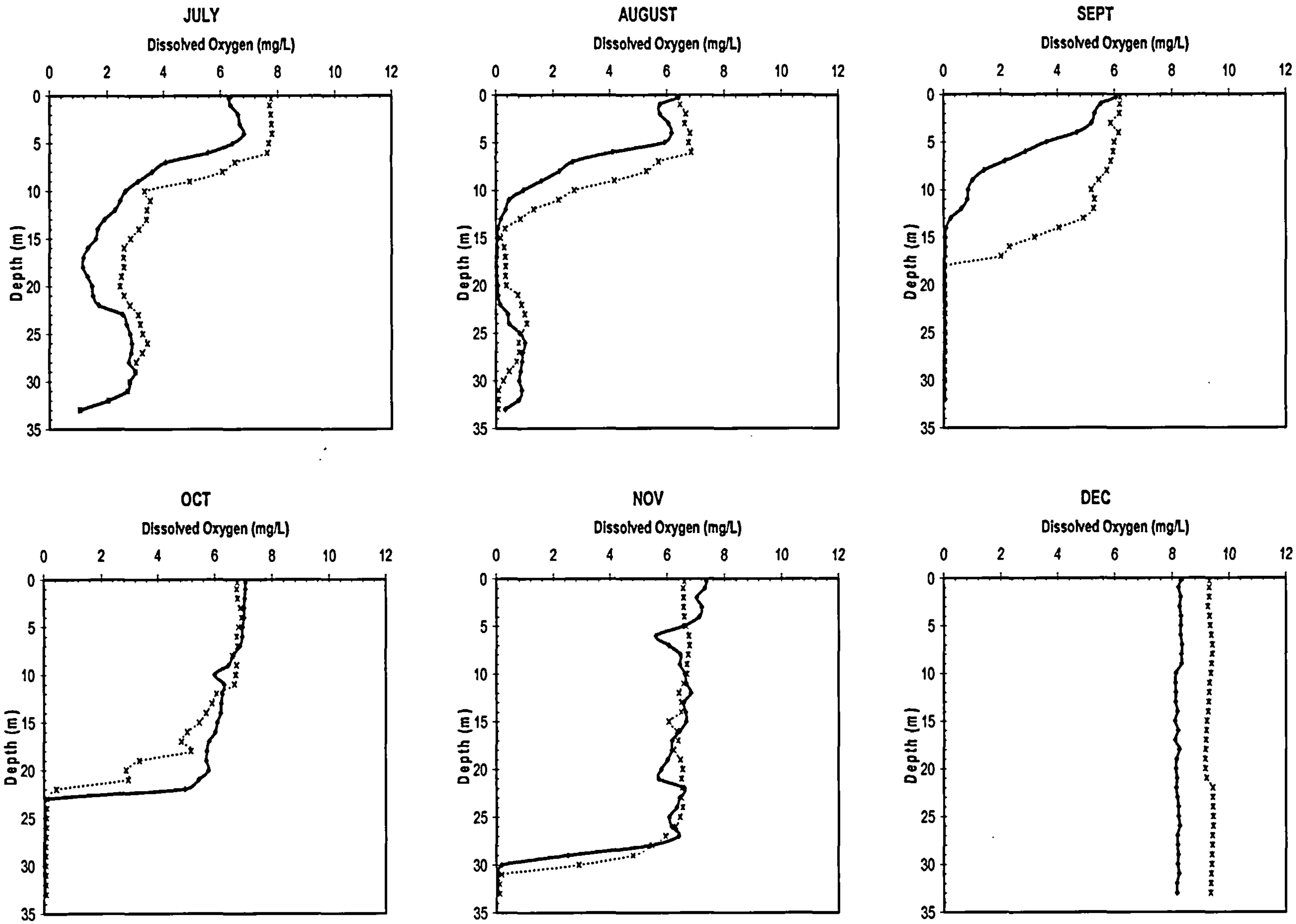


Figure 2-7. (con't).

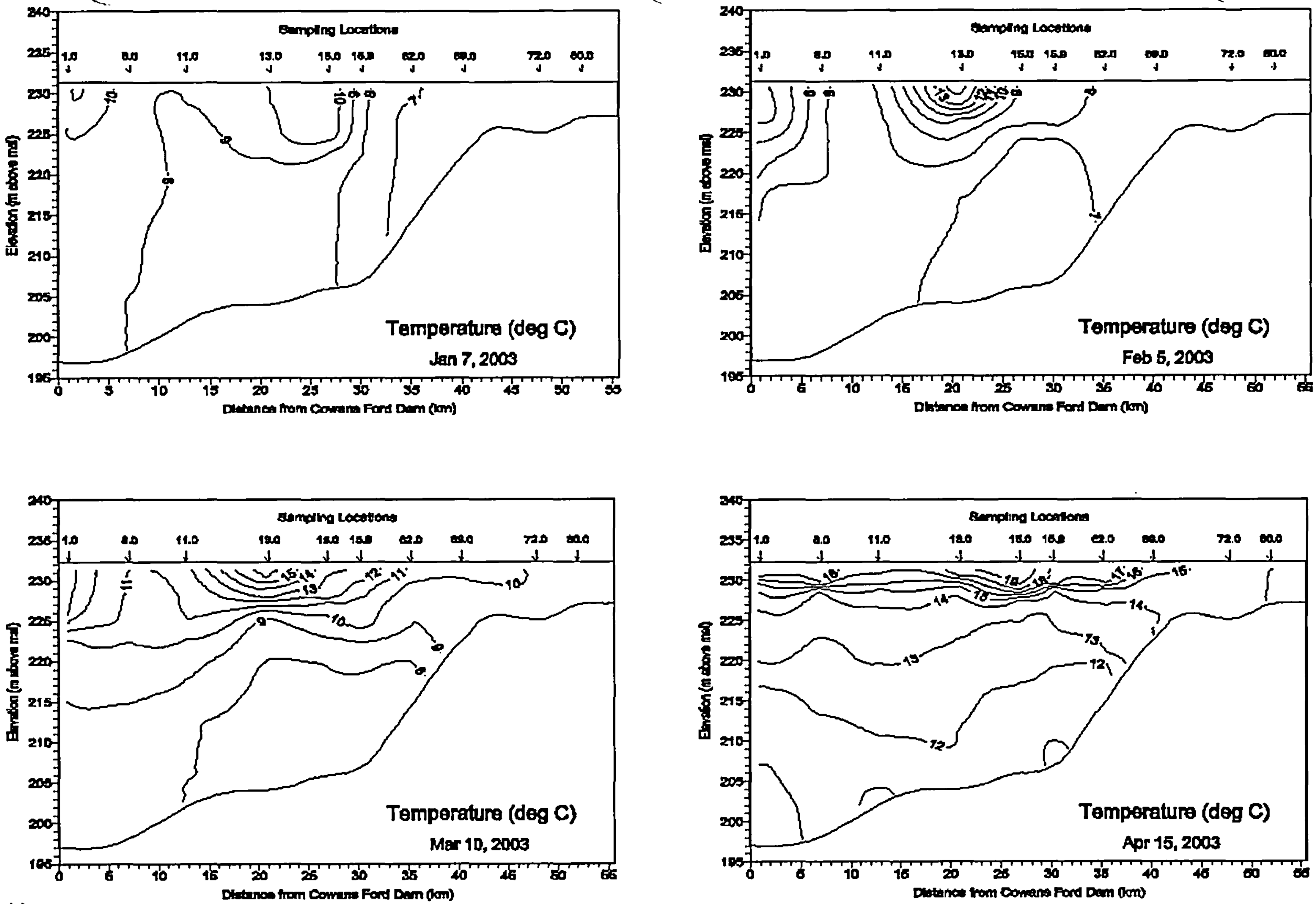


Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 2003.

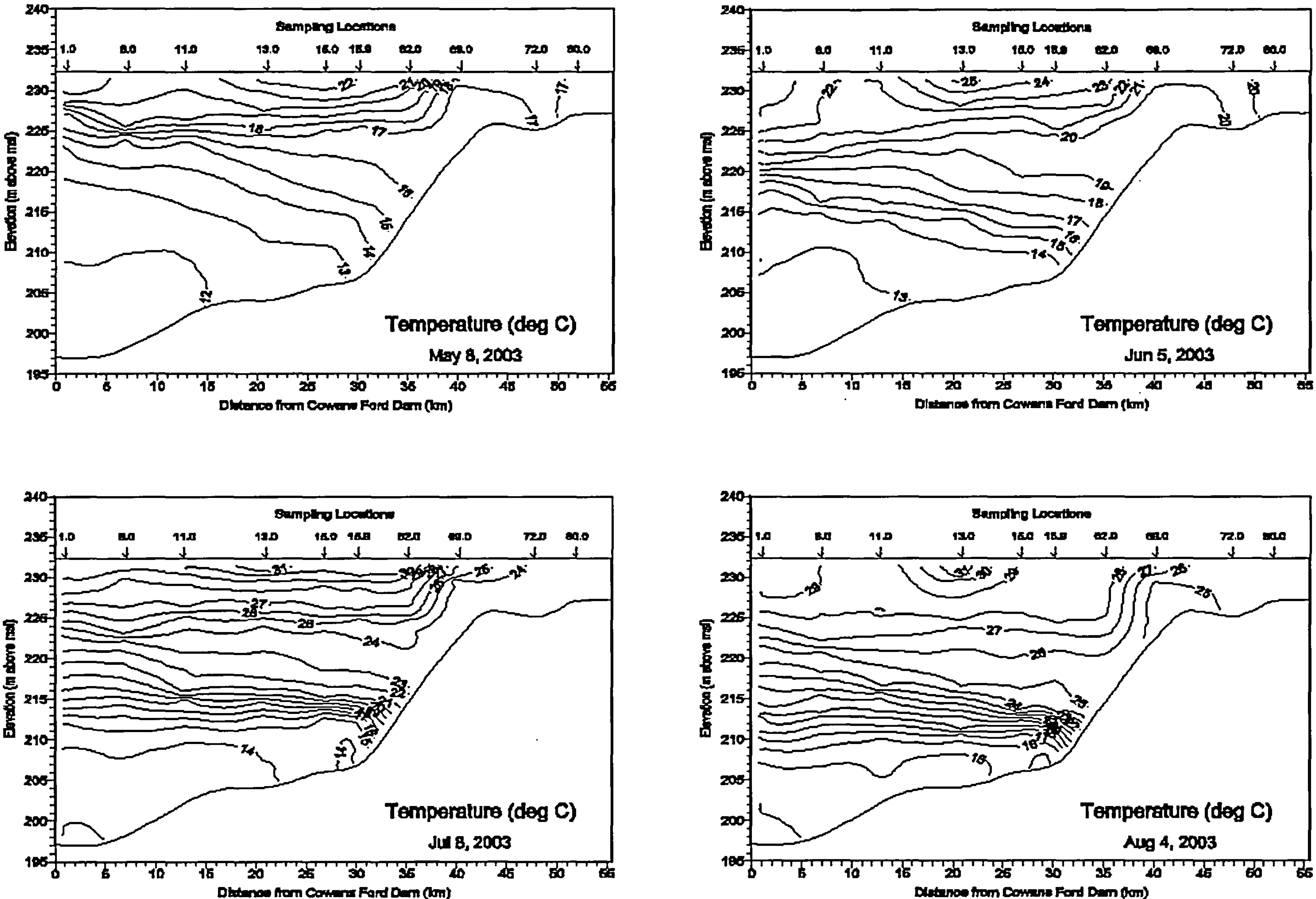


Figure 2-8. Continued.

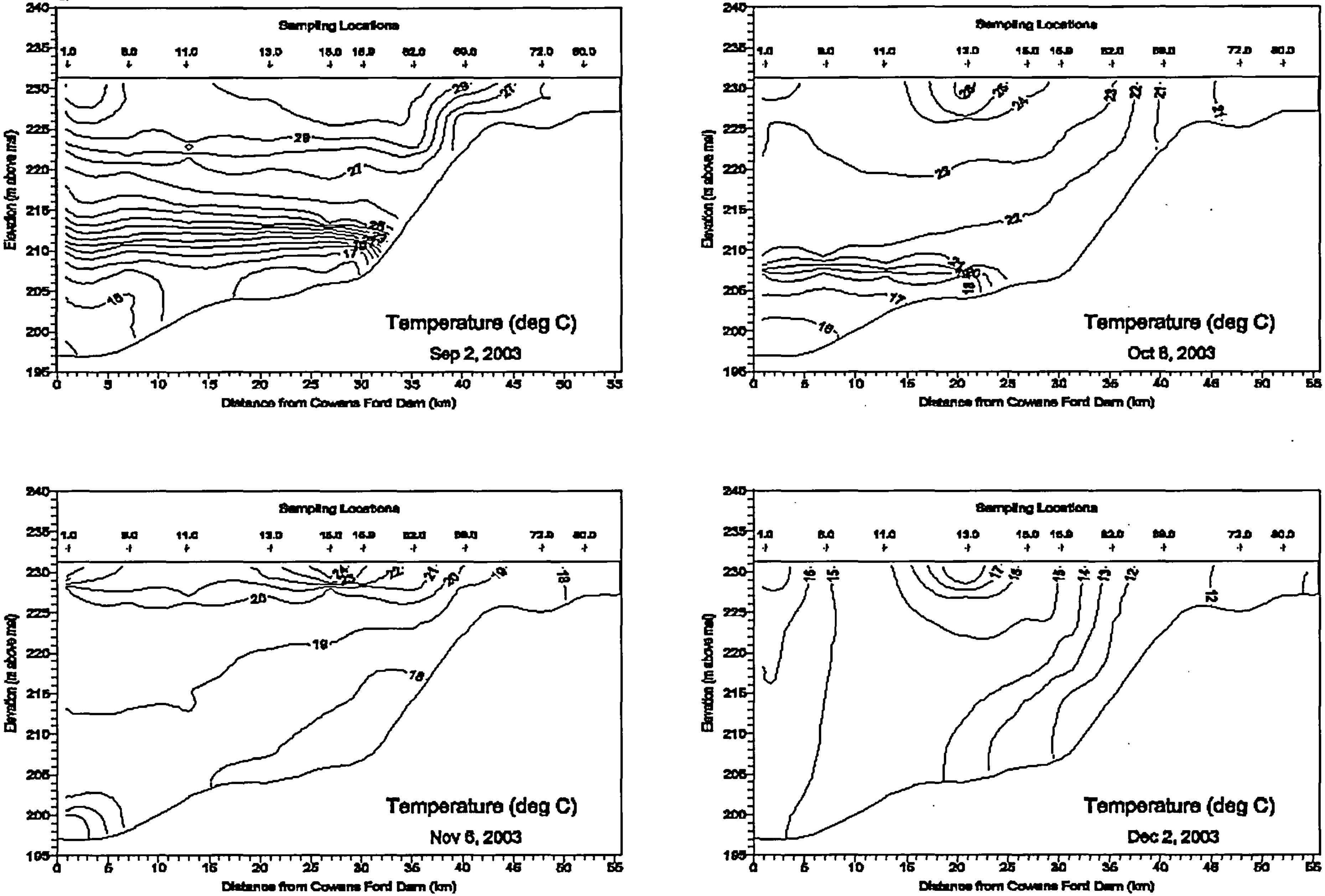


Figure 2-8. Continued.

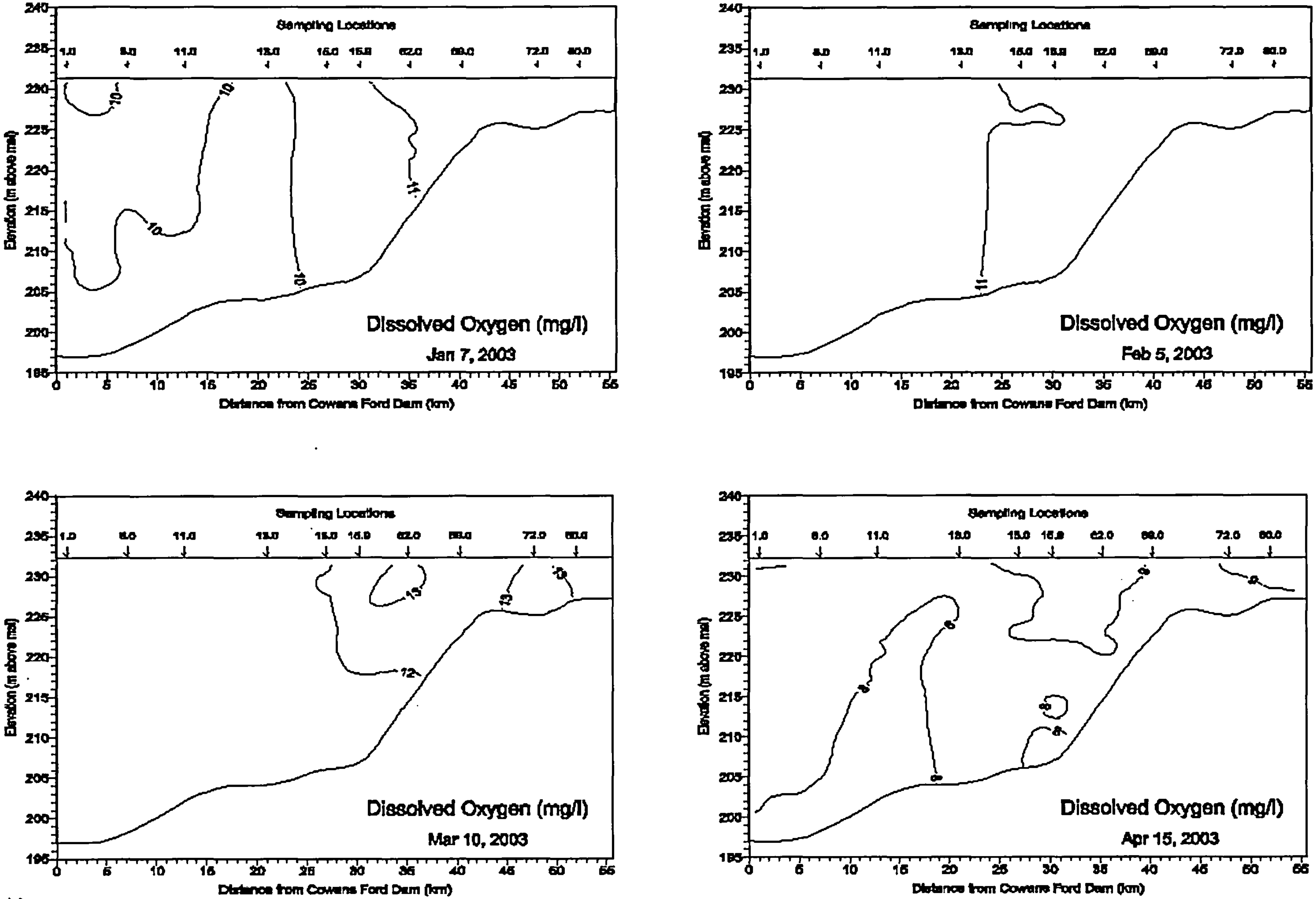


Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 2003.

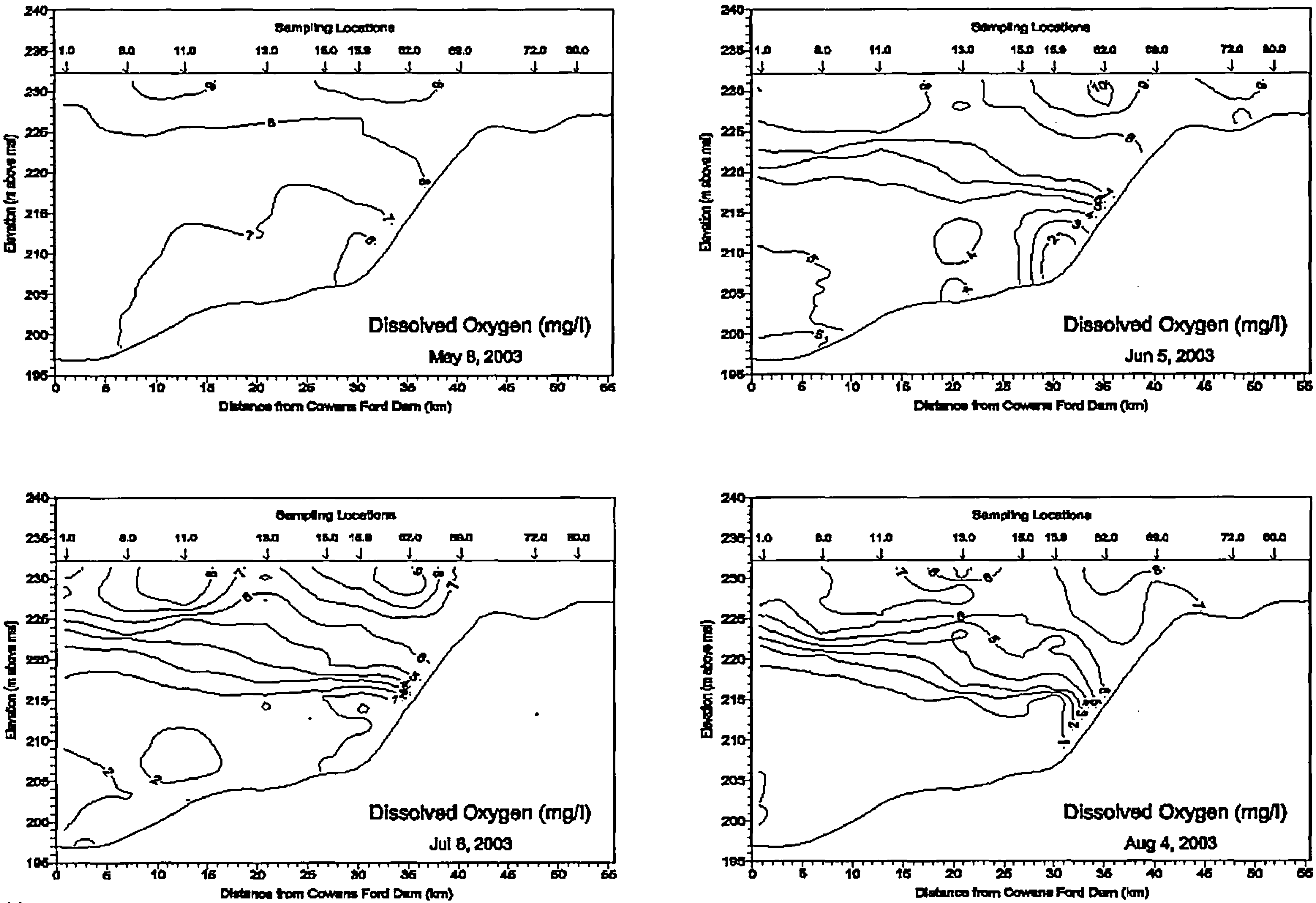


Figure 2-9. Continued.

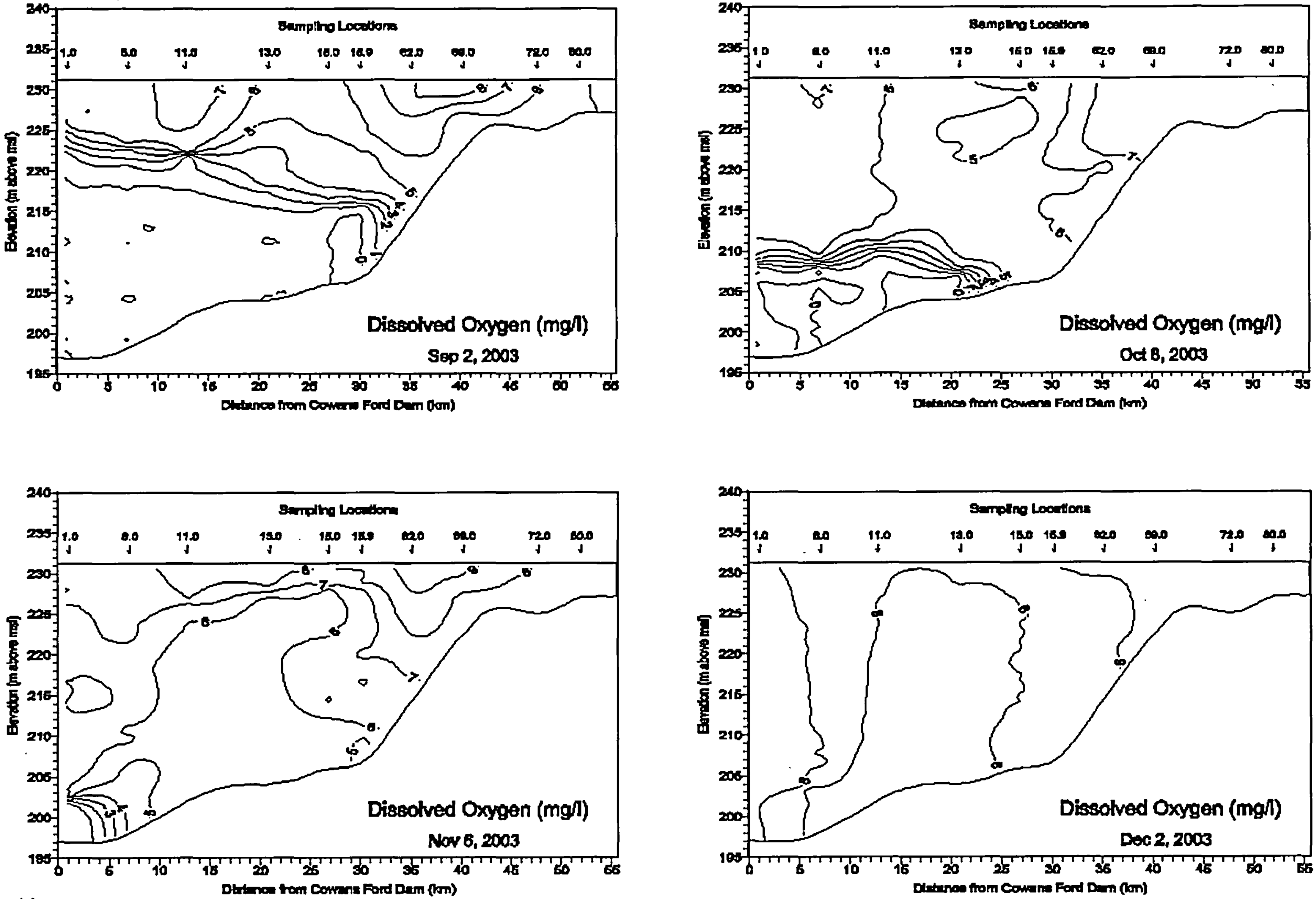


Figure 2-9. Continued.

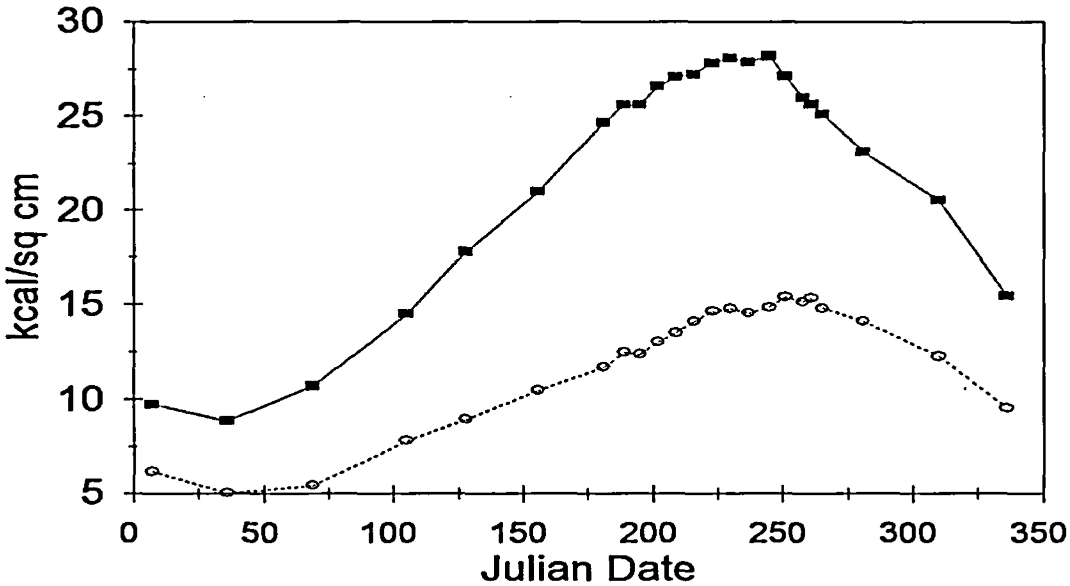


Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (○) in Lake Norman in 2003.

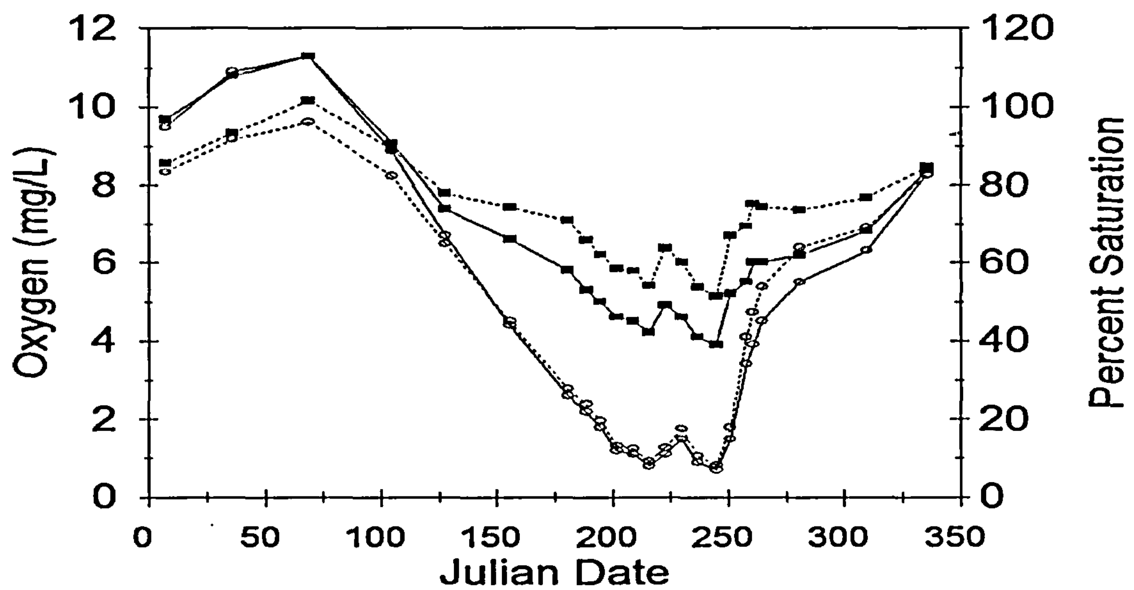


Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (○) of Lake Norman in 2003.

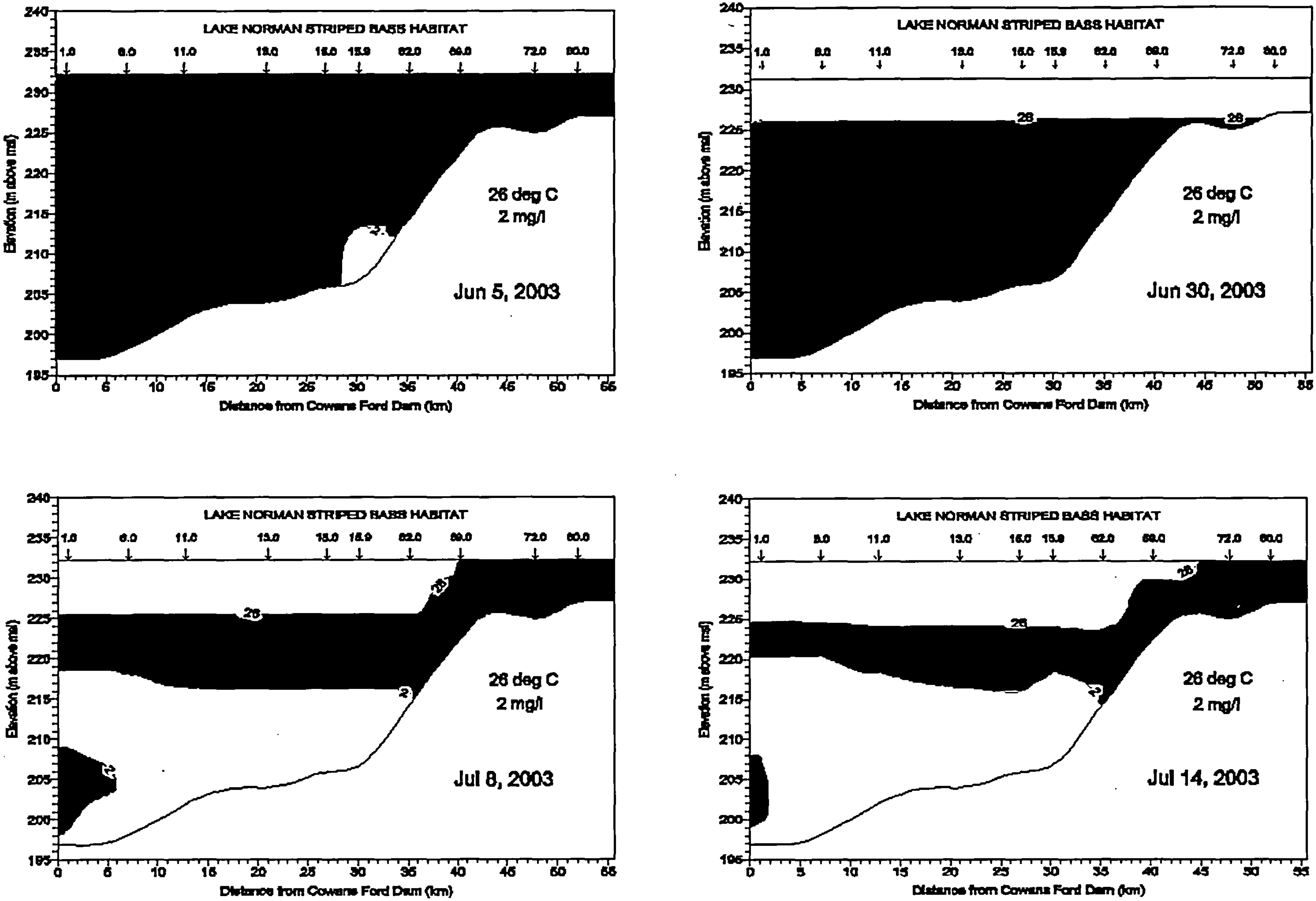


Figure 2-11. Striped bass habitat (temperatures ≤20 °C and dissolved oxygen ≥2 mg/L) in Lake Norman, summer 2003.

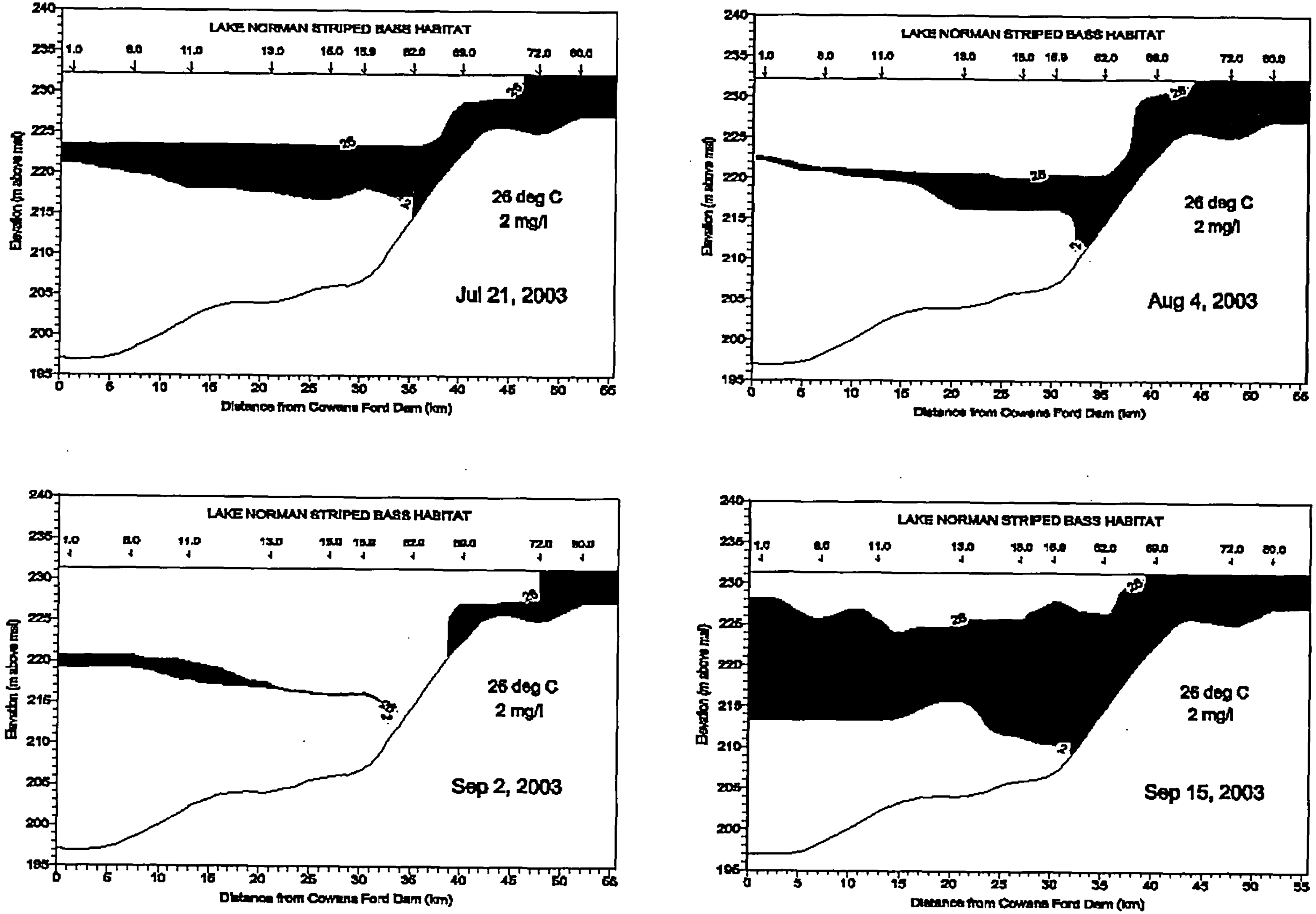


Figure 2-11. Continued.

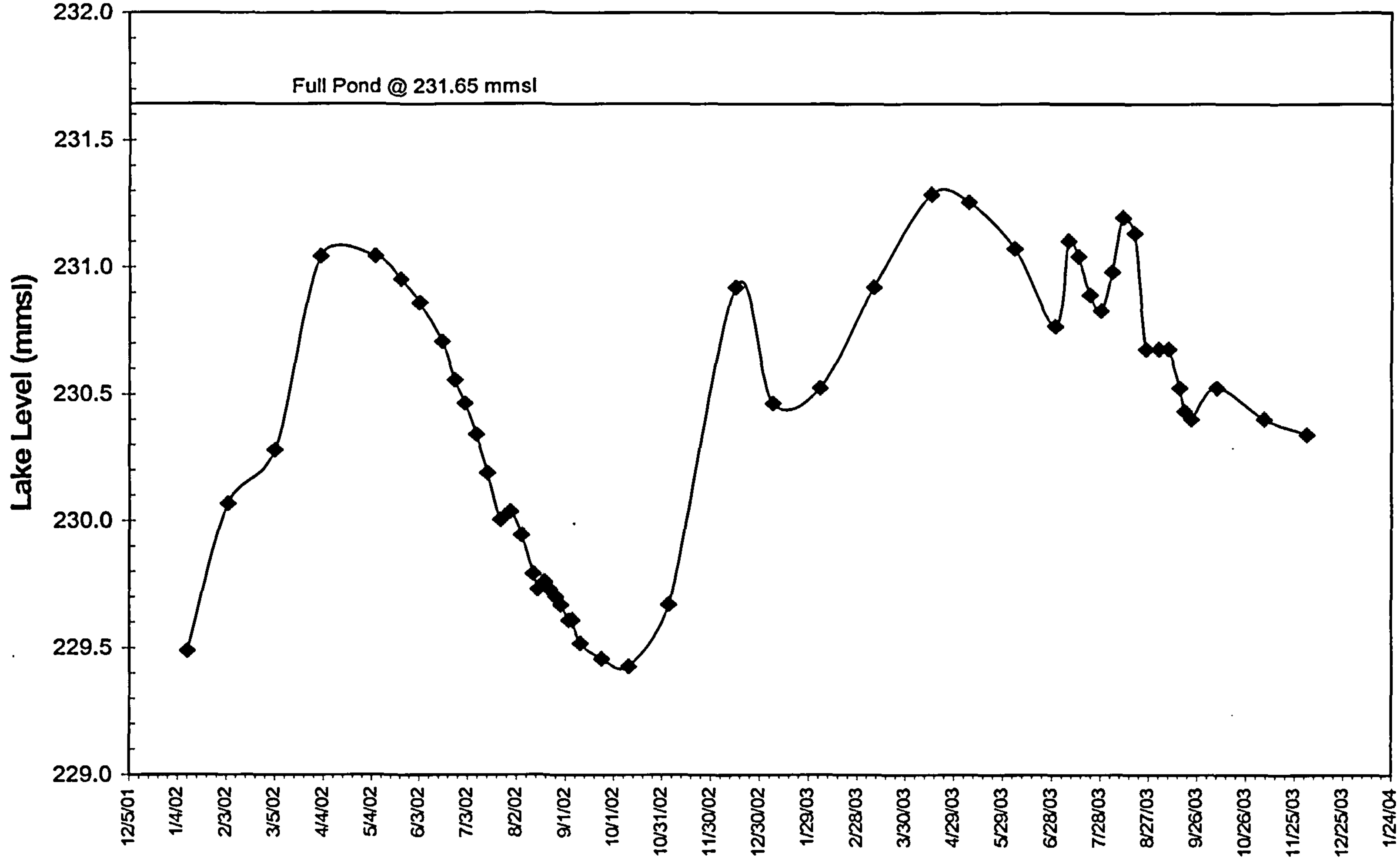


Figure 2-12. Lake Norman lake levels, expressed in meters above mean sea level (mmsl), for 2002 and 2003. Lake level data corresponds to the water quality sampling dates over this time period

CHAPTER 3

PHYTOPLANKTON

INTRODUCTION

Phytoplankton standing crop parameters were monitored in 2003 in accordance with the NPDES permit for McGuire Nuclear Station (MNS). The objectives of the phytoplankton section of 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 2003) 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 (low to intermediate productivity) 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 (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 in February, May, August, and November 2003. Secchi depths were recorded from all sampling locations. Phytoplankton density, biovolume, and taxonomic composition were determined for samples collected at Locations 2.0, 5.0, 9.5, 11.0, and 15.9; chlorophyll *a* concentrations and seston dry and ash-free dry weights were determined for samples from all locations. Chlorophyll *a* and total phytoplankton densities and biovolumes were used in determining phytoplankton standing crop. Field sampling and laboratory methods used for chlorophyll *a*, seston dry weights and population identification and enumeration were identical to those used by Rodriguez (1982). Data collected in 2003 were compared with corresponding data from quarterly monitoring beginning in August 1987.

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

RESULTS AND DISCUSSION

Standing Crop

Chlorophyll a

Chlorophyll *a* concentrations (mean of two replicate composites) ranged from a low of 1.26 ug/L at Location 69.0 in May, to a high of 28.84 ug/L at Location 15.9 in February (Table 3-1, Figure 3-1). All values were below the North Carolina water quality standard of 40 ug/L (NCDEHNR 1991). Lake-wide mean chlorophyll concentrations during all sampling periods were within ranges of those reported in previous years (Figure 3-2). The seasonal trend in 2003 of the annual high in February, declining to the yearly minimum in May, increasing values through August, then a decline through November, has never been observed during the course of the Lake Norman Maintenance Monitoring Study. Based on quarterly mean chlorophyll concentrations, the trophic level of Lake Norman was in the high mesotrophic range during February, in the oligotrophic (low) range in May, and in the low mesotrophic range in August and November 2003. Nearly 48% of individual chlorophyll values were less than 4 ug/L (oligotrophic), while one-half of the concentrations were between 4 and 12 ug/L (mesotrophic). Only two values were greater than 12 ug/L (eutrophic). Lake-wide quarterly mean concentrations of below 4 ug/L have been recorded on nine previous occasions, while lake-wide mean concentrations of greater than 12 ug/L were only recorded during May of 1997 and 2000 (Duke Power 2001).

During 2003 chlorophyll *a* concentrations showed a high degree of spatial variability. Maximum concentrations were observed at Location 15.9 during February and November, at Location 9.5 in May, and at Location 69.0 in August. Minimum concentrations occurred at Location 5.0 in February, Location 69.0 in May, Location 8.0 in August, and Location 2.0 in

November (Table 3-2). The trend of increasing chlorophyll concentrations from down-lake to up-lake, which had been observed during most quarters of 2000 through 2002, was apparent in varying degrees during most quarters of 2003 (Table 3-1, Figure 3-1). Locations 15.9 (up-lake, above Plant Marshall) and 69.0 (the uppermost riverine location) had significantly higher chlorophyll values than Mixing Zone locations during all sample periods except May, when concentrations at Locations 15.9 and 69.0 were significantly lower than all other locations (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, as was the case in April and May when monthly rainfall averages peaked, 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 2003) have varied considerably, resulting in moderate to wide historical ranges. During February 2003, Locations 2.0 through 9.5 had chlorophyll concentrations in the mid range, while chlorophyll concentrations at Locations 11.0 and 69.0 were in the low range. Chlorophyll values at Locations 13.0 and 15.9 in February were the highest long term February concentrations reported for these locations (Figure 3-3). Long term February peaks at locations 2.0 through 9.5 occurred in 1996, while the long term February peak at Location 11.0 was observed in 1991. The highest February value at location 69.0 occurred in 2001. All but Locations 5.0 and 69.0 had higher chlorophyll concentrations in February 2003 than in February 2002 (Duke Power 2004).

During May and August, chlorophyll concentrations at Lake Norman locations were lower than normal, and two record low concentrations were recorded for May at Locations 15.9 and 69.0 (Figure 3-3). May 2003 chlorophyll concentrations at Locations 2.0 through 9.5 were higher than those of 2002, while May 2003 concentrations at Locations 11.0 through 69.0 were lower than those of last year (Duke Power 2004). Long term May peaks at Locations 2.0 and 9.5 occurred in 1992; at Location 5.0 in 1991; at Locations 8.0, 11.0, and 13.0 in 1997; and at Location 69.0 in 2001.

Long term August peaks in the Mixing Zone were observed in 1998, while year-to-year maxima at Locations 8.0 and 9.5 occurred in 1993. Long term August peaks at Locations 11.0 and 13.0 were observed in 1991 and 1993, respectively. The highest August chlorophyll concentration from Location 15.9 was observed in 1998, while Location 69.0 experienced its long term August peak in 2001. Locations 2.0 through 9.5, and 15.9 had higher values in August 2003 than in August 2002, while values at the other three locations (11.0, 13.0, and 69.0) were lower than in August of last year (Duke Power 2004).

During November 2003 Locations 2.0 and 5.0 were in the low range for that month, while Locations 9.5 through 15.9 were in the mid range for November. The November 2003 chlorophyll concentration from Location 69.0 was the third highest November value on record. 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 November 2003 chlorophyll concentrations were higher than during November 2002 (Duke Power 2004).

Total Abundance

Density and biovolume are measurements of phytoplankton abundance. The lowest density (729 units/ml) and biovolume (258 mm^3/m^3) during 2003 occurred at Location 5.0 in February (Table 3-3, Figure 3-1). The maximum density (6,130 units/ml) and biovolume (5,379 mm^3/m^3) were also observed in February at Location 15.9. As with chlorophyll concentrations, most standing crop values during 2003 were higher than those of 2002 (Duke Power 2004). Phytoplankton densities during 2003 never exceeded the NC guideline for algae blooms of 10,000 units/ml. However, the biovolume from Location 15.9 in February exceeded the NC guideline of 5,000 mm^3/m^3 (NCDEHNR 1991). Densities and biovolumes in excess of NC guidelines were recorded in 1987, 1989, 1997, 1998, and 2000 (Duke Power Company 1988, 1990; Duke Power 1998, 1999, 2001).

Total densities at locations in the Mixing Zone during 2003 were within the same statistical ranges during all sampling periods but May (Table 3-4). Location 15.9 had significantly higher densities than all other locations during all but May when the density at this location was significantly lower than at all other locations. During all but May, phytoplankton densities showed a spatial trend similar to that of chlorophyll; that is lower values at down-lake locations versus up-lake locations.

Extremely low chlorophyll concentrations and algae standing crops in May, particularly at up-lake locations, were likely due to very high rainfall and subsequent runoff during the spring of 2003. According to MNS rainfall data, April and May had the highest and second highest rainfall totals, respectively, of 2003. The combined total rainfall during these months of 2003 was nearly 7.5 times higher than during these same periods of 2002. This situation would have resulted in considerable wash-out at up-lake locations, and severe depression of algae concentrations.

Seston

Seston dry weights represent a combination of algal matter, and other organic and inorganic material. Dry weights during February and November 2003 were consistently lower than those February and November 2002, while dry weights in May and August were most often higher in 2003 than during these months of 2002. A general pattern of increasing values from down-lake to up-lake was observed in all quarters to some extent (Figure 3-1). Statistically, Location 69.0 had significantly higher values than other locations during all quarters of 2003 (Table 3-5). From 1995 through 1997 seston dry weights had been increasing (Duke Power 1998). Values since 1998 represented a reversal of this trend, and were in the low range at most locations during 1999 through 2002 (Duke Power 2004). Low dry weights during these years were likely a result of prolonged drought conditions.

Seston ash-free dry weights represent organic material and may reflect trends of algal standing crops. This relationship seldom held true in 2003. Location 69.0 had significantly higher ash-free dry weights than other locations throughout 2003 (Table 3-5). Ash-free dry weights during 2003 were generally higher than in 2002. The proportions of ash free dry weights to dry weights during 2003 were considerably higher than in 2002 and 2001, indicating lower organic composition among samples in 2003 as compared to previous years. Between 1994 and 1997 a trend of declining organic/inorganic ratios was observed (Duke Power Company 1995, 1996, 1997; Duke Power 1998, 2001, 2003, 2004).

Secchi Depths

Secchi depth is a measure of light penetration. Secchi depths were often the inverse of suspended sediment (seston dry weight), with the shallowest depths at Locations 13.0 through 69.0 and deepest from Locations 9.5 through 2.0 down-lake. Depths ranged from 0.50 m at Location 13.0 in May, to 3.10 m at Location 8.0 in February (Table 3-1). The lake-wide mean secchi depth during 2003 was lower than in 2002, and was within historical ranges for the years 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; Duke Power 1998, 1999, 2000, 2001, 2003). Lower secchi depths were likely due to much higher rainfall during 2003 as compared to the previous four years.

Community Composition

One indication of "balanced indigenous populations" in a reservoir is the diversity, or number of taxa observed over time. Lake Norman typically supports a rich community of phytoplankton species. This was certainly true in 2003. Ten classes comprising 95 genera and 214 species, varieties, and forms of phytoplankton were identified in samples collected during 2003, as compared to 89 genera and 208 lower taxa identified in 2002 (Table 3-6). The 2003 total represented the highest number of individual taxa recorded in any year since monitoring began in 1987. Eighteen taxa previously unrecorded during the Maintenance Monitoring Program were identified during 2003.

Species Composition and Seasonal Succession

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

During February 2003, cryptophytes (Cryptophyceae) dominated densities at all locations (Table 3-7, Figures 3-4 through 3-8). During most previous years, cryptophytes, and occasionally diatoms, dominated February phytoplankton samples in Lake Norman. The most abundant cryptophyte during February 2003 was the small flagellate *Rhodomonas minuta*. *R. minuta* has been one of the most common and abundant forms observed in Lake Norman samples since monitoring began in 1987. Cryptophytes are characterized as light limited, often found deeper in the water column, or near surface under low light conditions, which are common during winter (Lee 1989). In addition, *R. minuta*'s small size and high surface to volume ratio would allow for more efficient nutrient uptake during periods of limited nutrient availability (Harris 1978).

In May, diatoms (Bacillariophyceae) were dominant at all locations. The most abundant diatom was the pennate, *Fragillaria crotonensis*. 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; Duke Power 1998, 1999, 2000, 2001, 2003, 2004).

During August 2003 green algae (Chlorophyceae) dominated densities at all locations (Figures 3-4 through 3-8). The most abundant green alga was the small desmid, *Cosmarium asphearosporum* var. *strigosum* (Table 3-7). During August periods of the Lake Norman study prior to 1999, green algae, with blue-green algae (Myxophyceae) as occasional dominants or co-dominants, were the primary constituents of summer phytoplankton assemblages, and the predominant green alga was also *C. asphearosporum* var. *strigosum*. During August periods of 1999 through 2001, Lake Norman phytoplankton assemblages were dominated by diatoms, primarily the small pennate *Anomoeoneis vitrea*. *A. vitrea* has been described as typically periphytic, and widely distributed in freshwater habitats. It 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 earlier reports, and included deeper light penetration (the three deepest lake-wide secchi depths were recorded from 1999 through 2001), extended periods of low water due to draw-down, shifts in nutrient inputs and concentrations, and macrophyte control procedures upstream (Duke Power 2000, 2001, 2003). Whatever the cause, the phenomenon was lake-wide, and not localized near MNS or Plant Marshall; therefore, it was most likely due to a combination of environmental factors, and not station operations.

During November 2003, densities at all locations were again dominated by diatoms (Figures 3-4 through 3-8). The dominant species was the pennate diatom *Tabellaria fenestrata* (Table 3-7). During the November quarters of previous years diatoms have been dominant on most occasions, with occasional dominance by cryptophytes.

Blue-green algae, which are often implicated in nuisance blooms, were never abundant in 2003 samples. Their overall contribution to phytoplankton densities was slightly higher than in 2002; however, densities of blue-greens never exceeded 5% of totals. The highest percent composition of Myxophyceae (4.8%) during all sampling periods in 2003 occurred at Location 9.5 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, and for each location during 2003 (Figure 3-9).

For the most part, the long term annual Myxophycean index values confirmed that Lake Norman has been primarily in the oligo-mesotrophic range since 1988 (Figure 3-9). Values were in the high, or eutrophic, range in 1989, 1990, and 1992; in the intermediate, or mesotrophic, range in 1991, 1993, 1994, 1996, 1998, 2000, and 2001; and in the low, or oligotrophic, range in 1988, 1995, 1997, 1999, and 2002. The index for 2003 fell into the oligotrophic range, and was the next to lowest annual index value recorded during the Maintenance Monitoring Program.

The highest index value among sample periods of 2003 was observed in February, and the lowest index value occurred in May (Figure 3-9). The index did reflect seasonal chlorophyll concentrations, since the maximum lake-wide chlorophyll concentration occurred in February, with the annual minimum observed in May. The index values for locations during 2003 showed a gradual decline in values from Locations 2.0 through 9.5, with values increasing from Locations 9.5 through 11.0, which had the maximum index value. The index value at Location 15.9 was lower than that of Location 11.0. This trend was similar to that of 2002 (Duke Power 2004).

FUTURE STUDIES

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

SUMMARY

In 2003 lake-wide mean chlorophyll *a* concentrations were generally in the mid to high range in February, the low range in May, the low to mid range in August, and the mid range in November. Chlorophyll concentrations during 2003 were most often higher than those of 2002. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. Lake-wide mean chlorophyll declined from the annual peak in February to the annual minimum in May, increased in August, then declined slightly in November. Some spatial variability was observed in 2003; however, maximum chlorophyll concentrations were most often observed up-lake, while comparatively low chlorophyll concentrations were recorded from Mixing Zone and mid lake locations. Location 15.9, the location upstream of Plant Marshall, demonstrated maximum chlorophyll concentrations in February and November of 2003, but had the lowest chlorophyll value in May. The highest chlorophyll value recorded in 2003, 28.84 ug/l, was below the NC State Water Quality standard of 40 ug/l.

In most cases, total phytoplankton densities and biovolumes observed in 2003 were higher than those observed during 2002, and standing crops were within ranges established over previous years. Phytoplankton densities during 2003 never exceeded the NC guideline for algae blooms; however, the biovolume at Location 15.9 in February was slightly higher than the NC guideline. Standing crop values in excess of bloom guidelines have been recorded during five previous years of the Program. As in past years, high standing crops were usually observed at up-lake locations; while comparatively low values were noted down-lake. The notable exception was in May. Depressed algae concentrations at up-lake locations in May, 2003 were probably due to near record rainfall during that month and the preceding month, which resulted in heavy washout in the up-lake, transitional areas.

Seston dry weights were more often lower in 2003 than in 2002, and down-lake to up-lake differences were apparent most of the time. Conversely, ash-free dry weights were usually higher in 2003 than in 2002. Maximum dry and ash-free dry weights were observed at

Location 69.0, while low values were most often noted at Locations 2.0 through 11.0. The proportions of ash-free dry weights to dry weights in 2003 were considerably higher than those of 2002, indicating a decrease in organic composition among 2003 samples.

Secchi depths reflected suspended solids, with shallow depths related to high dry weights. The lake-wide mean secchi depth in 2003 was lower than in 2002 and was within historical ranges recorded since 1992. Lower secchi depths during 2003 were likely due to much higher rainfall than in 2002.

Diversity, or numbers of taxa, of phytoplankton had increased since 2002, and the total number of individual taxa was the highest yet recorded. The taxononic composition of phytoplankton communities during 2003 was similar to those of many previous years. Cryptophytes were dominant in February, while diatoms were dominant during May and November. Green algae dominated phytoplankton assemblages during August. Blue-green algae were slightly more abundant during 2003 than during 2002; however, their contribution to total densities never exceeded 5 %.

The most abundant alga, on an annual basis, was the cryptophyte *Rhodomonas minuta*. Common and abundant diatoms were *Fragillaria crotonensis* in May, and *Tabellaria fenestrata* in November. The small desmid, *Cosmarium asphearosporum* var. *strigosum* was dominant in August 2003. All of these taxa have been common and abundant throughout the Maintenance Monitoring Program.

The phytoplankton index (Myxophycean) characterized Lake Norman as oligotrophic during 2003, and was the next to lowest annual index value recorded. Quarterly index values decreased from the highest in February to the lowest in May then increased through August and November. Quarterly values did reflect maximum and minimum chlorophyll concentrations and phytoplankton standing crops. Location values tended to reflect decreases in phytoplankton standing crops from down-lake to mid-lake, and increases from mid-lake to up-lake.

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

LITERATURE CITED

Derwort, J. E. 1982. Periphyton, p 279-314. In J. E. Hogan and W. D. Adair (ed.). Lake Norman Summary, vol. II. Duke power Company, Technical Report DUKE PWR/82-02. Duke Power Company, Production Support Department, Production Environmental Services, Huntersville, NC.

Duke Power Company. 1976. McGuire Nuclear Station, Units 1 and 2, Environmental Report, Operating License Stage. 6th rev. Volume 2. Duke Power Company, Charlotte, NC.

Duke Power Company. 1985. McGuire Nuclear Station, 316(a) Demonstration. Duke Power Company, Charlotte, NC.

Duke Power Company. 1988. Lake Norman maintenance monitoring program: 1987 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1989. Lake Norman maintenance monitoring program: 1988 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1990. Lake Norman maintenance monitoring program: 1989 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1991. Lake Norman maintenance monitoring program: 1990 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1992. Lake Norman maintenance monitoring program: 1991 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1993. Lake Norman maintenance monitoring program: 1992 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1994. Lake Norman maintenance monitoring program: 1993 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1995. Lake Norman maintenance monitoring program: 1994 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1996. Lake Norman maintenance monitoring program: 1995 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1997. Lake Norman maintenance monitoring program: 1996 summary. Duke Power Company, Charlotte, NC.

Duke Power. 1998. Lake Norman maintenance monitoring program: 1997 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 1999. Lake Norman maintenance monitoring program: 1998 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2000. Lake Norman maintenance monitoring program: 1999 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2001. Lake Norman maintenance monitoring program: 2000 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2003. Lake Norman maintenance monitoring program: 2001 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2004. Lake Norman maintenance monitoring program: 2002 summary. Duke Energy Company, Charlotte, NC.

Harris, G. P. 1978. Photosynthesis, productivity and growth: the physiological ecology of phytoplankton. Arch. Hydrobiol. Beih. Ergeb. Limnol. 10: 1-171.

Hutchinson, G. E. 1967. A Treatise on Limnology, Vol. II. Introduction to the limonplankton. John Wiley and Sons, New York, NY.

Lee, R. E. 1989. Phycology (2nd. Ed.). Cambridge University Press. 40 West 20th. St., New York, NY.

Menhinick, E. F. and L. D. Jensen. 1974. Plankton populations, p. 120-138 In L. D. Jensen (ed.). Environmental responses to thermal discharges from Marshall Steam Station, Lake Norman, NC. Electric Power Research Institute, Cooling Water Discharge Project (RP-49) Report No. 11. Johns Hopkins Univ., Baltimore MD.

North Carolina Department of Environment, Health and Natural Resources, Division of Environmental Management (DEM), Water Quality Section. 1991. 1990 Algal Bloom Report.

Nygaard, G. 1949. Hydrological studies of some Danish pond and lakes II. K. danske Vilensk. Selsk. Biol. Skr.

Rodriguez, M. S. 1982. Phytoplankton, p. 154-260 In J. E. Hogan and W. D. Adair (eds.). Lake Norman summary. Technical Report DUKEPWR/82-02 Duke Power Company, Charlotte, NC.

Thornton, K. W., B. L. Kimmel, F. E. Payne. 1990. Reservoir Limnology. John Wiley and Sons, Inc. N. Y.

Table 3-1. Mean chlorophyll *a* concentrations (ug/L) in composite samples and secchi depths (m) observed in Lake Norman, NC, in 2003.

Chlorophyll *a*

Location	FEB	MAY	AUG	NOV
2.0	3.52	1.82	4.24	2.34
5.0	3.02	2.39	4.30	2.70
8.0	3.76	3.43	3.58	4.44
9.5	4.03	3.60	4.85	4.70
11.0	9.59	2.44	4.67	4.38
13.0	14.50	2.79	4.23	6.18
15.9	28.84	1.36	8.14	9.38
69.0	8.70	1.26	8.60	6.70

Secchi depths

Location	FEB	MAY	AUG	NOV
2.0	2.47	1.21	3.00	2.44
5.0	2.90	1.10	2.69	2.80
8.0	3.10	1.50	2.81	2.46
9.5	2.71	1.96	2.69	2.43
11.0	2.00	2.00	2.89	2.26
13.0	1.91	0.50	1.30	1.08
15.9	1.76	1.00	1.85	1.62
69.0	0.79	0.60	0.90	1.20

Table 3-2. Duncan's multiple Range Test on chlorophyll *a* concentrations (ug/L) in Lake Norman, NC, during 2003.

February	Location	**5.0**	**2.0**	**8.0**	**9.5**	**69.0**	**11.0**	**13.0**	**15.9**
	Mean	3.02	3.52	3.76	4.03	8.70	9.59	14.50	28.84
May	Location	**69.0**	**15.9**	**2.0**	**5.0**	**8.0**	**11.0**	**13.0**	**9.5**
	Mean	1.26	1.36	1.82	2.39	2.43	2.44	2.79	3.60
August	Location	**8.0**	**13.0**	**2.0**	**5.0**	**11.0**	**9.5**	**15.9**	**69.0**
	Mean	3.58	4.23	4.24	4.30	4.67	4.85	8.14	8.60
November	Location	**2.0**	**5.0**	**11.0**	**8.0**	**9.5**	**13.0**	**69.0**	**15.9**
	Mean	3.34	3.46	4.47	4.71	5.72	8.10	8.21	9.54

Table 3-3. Total mean phytoplankton densities and biovolumes from samples collected in Lake Norman, NC, during 2003.

Density (units/ml)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	829	729	1046	2893	6130	2325
MAY	1160	1388	1959	1468	954	1386
AUG	1931	1951	2496	2304	3410	2418
NOV	771	996	1474	1695	2879	1563

Biovolume (mm^3/m^3)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	361	296	552	2396	5374	1796
MAY	577	690	1502	848	647	853
AUG	1188	1238	1813	1492	2161	1578
NOV	567	922	1230	1131	3027	1375

Table 3-4. Duncan's multiple Range Test on phytoplankton densities (units/ml) in Lake Norman, NC, during 2003.

February	Location	**5.0**	**2.0**	**9.5**	**11.0**	**15.9**
	Mean	729	829	1046	2893	6130
May	Location	**15.9**	**2.0**	**5.0**	**11.0**	**9.5**
	Mean	954	1160	1388	1468	1959
August	Location	**2.0**	**5.0**	**11.0**	**9.5**	**15.9**
	Mean	1931	1951	2304	2496	3410
November	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Mean	771	996	1474	1695	2879

Table 3-5. Duncan's multiple Range Test on dry and ash free dry weights (mg/L) in Lake Norman, NC during 2003.

DRY WEIGHT

February	Location	**9.5**	**8.0**	**2.0**	**5.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	0.74	0.94	0.98	1.04	1.74	2.06	2.35	3.98
May	Location	**9.5**	**2.0**	**5.0**	**8.0**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	1.44	1.47	2.02	2.14	2.53	5.66	5.74	9.30
August	Location	**9.5**	**5.0**	**8.0**	**11.0**	**15.9**	**13.0**	**2.0**	**69.0**
	Mean	1.70	1.72	1.73	1.77	2.20	2.22	2.28	11.98
November	Location	**2.0**	**8.0**	**13.0**	**11.0**	**5.0**	**9.5**	**15.9**	**69.0**
	Mean	0.97	1.08	1.18	1.33	1.44	1.50	1.51	4.65

ASH FREE DRY WEIGHT

February	Location	**9.5**	**8.0**	**2.0**	**5.0**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	0.35	0.44	0.47	0.58	0.74	1.22	1.24	2.98
May	Location	**8.0**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	0.64	0.98	0.98	1.58	1.89	4.56	4.74	7.87
August	Location	**8.0**	**11.0**	**5.0**	**9.5**	**2.0**	**15.9**	**13.0**	**69.0**
	Mean	0.54	0.61	0.64	0.66	0.99	1.14	1.19	8.78
November	Location	**8.0**	**2.0**	**13.0**	**15.9**	**11.0**	**9.5**	**5.0**	**69.0**
	Mean	0.32	0.44	0.49	0.54	0.56	0.62	0.68	2.53

Table 3-6. Phytoplankton taxa identified in quarterly samples collected in Lake Norman from February 1989 to November 2003.

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
CLASS: CHLOROPHYCEAE															
Acanthosphaera zachariasi Lemm.		X	X		X										
Actidesmium hookeri Reinsch					X										
Actinastrum hantzchii Lagerheim		X	X	X	X	X								X	
Ankistrodesmus braunii (Naeg) Brunn							X	X	X	X	X	X	X	X	X
A. convolutus Corda												X			
A. falcatus (Corda) Ralfs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
A. fusiformis Corda sensu Korsch.	X	X	X	X	X	X									
A. nannoselene Skuja												X			
A. spiralis (Turner) Lemm.	X	X	X		X				X						
A. spp. Corda			X		X										
Arthrodesmus convergens Ehrenberg							X							X	X
A. incus (Breb.) Hassall			X				X			X			X	X	X
A. octocornis														X	X
A. subulatus Kutzing								X	X	X		X	X	X	X
A. spp. Ehrenberg					X	X									
Asterococcus limneticus G. M. Smith		X	X	X	X	X					X			X	X
Botryococcus braunii Kutzing			X	X											
Carteria frtzschii Takeda												X			X
C. globosa Korsch														X	
C. spp. Diesing		X		X	X				X						X
Characium limneticum Lemmerman															X
C. spp. Braun	X														
Chlamydomonas spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chlorella vulgaris Beyerink									X						
Chlorogonium euchlorum Ehrenberg		X						X	X			X			
C. spirale Scherffel & Pascher						X	X								
Closteriopsis longissima W. & W.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Closterium cornu Ehrenberg											X			X	
C. gracile Brebisson								X							
C. incurvum Brebisson						X	X	X	X	X	X	X	X	X	X
C. tumidum Johnson												X			
C. spp. Nitzsch	X	X	X		X										
Coccomonas orbicularis Stein										X				X	
Coelastrum cambricum Archer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. microporum Nageli							X	X		X		X			X
C. reticulatum (Dang.) Sinn.											X				
C. sphaericum Nageli		X	X			X		X			X	X	X	X	X
C. proboscideum Bohlin			X												
C. spp. Nageli		X	X												
Cosmarium angulosum v. *concin.* (Rab) W&W												X		X	
C. asphaerosporum v. *strigosum* Nord.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. contractum Kirchner			X			X	X	X	X	X	X	X	X	X	X
C. moniliforme (Turp.) Ralfs												X			X
C. notabile															X
C. phaseolus f. *minor* Boldt.									X	X		X		X	

Table 3-6 (continued).

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
C. pokornyanum (Grun.) W. & G.S. West										X				X	
C. polygonum (Nag.) Archer							X	X	X	X	X	X	X	X	X
C. raciborskii Lagerheim														X	
C. regnellii Wille					X			X	X	X	X	X	X	X	X
C. regnesi Schmidle			X	X	X									X	
C. subreniforme Nordstedt														X	
C. tenue Archer							X	X	X	X	X	X	X	X	X
C. tinctum Ralfs					X	X	X	X	X	X	X	X	X	X	X
C. tinctum v. *subretusum* Messik.												X			
C. tinctum v. *tumidum* Borge.									X		X	X	X	X	X
C. trilobatum v. *depressum* Printz														X	
C. tumidum Borge														X	
C. spp. Corda	X	X	X	X	X	X									
Crucigenia apiculata (Lemm.) Schmidl														X	X
C. crucifera (Wolle) Collins		X	X				X	X	X	X	X	X	X	X	X
C. fenestrata Schmidle			X											X	X
C. irregularis Wille				X	X	X		X		X		X		X	X
C. rectangularis (A. Braun) Gay										X					
C. tetrapedia (Kirch.) West & West	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dictyospaerium ehrenbergianum Nageli												X		X	X
D. pulchellum Wood	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dimorphococcus spp. Braun		X													
Elakatothrix gelatinosa Wille	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Errerella bornheimiensis Conrad														X	X
Euastrum ansatum v. *dideltiforme* Ducel.														X	
E. banal (Turp.) Ehrenberg														X	
E. denticulatum (Kirch.) Gay							X	X	X	X	X	X	X	X	X
E. elegans Kutzing															X
E. spp. Ehrenberg		X		X	X										
Eudorina elegans Ehrenberg								X						X	X
Franceia droescheri (Lemm.) G. M. Sm.							X	X	X	X	X	X	X	X	X
F. ovalis (France) Lemm.	X	X	X	X	X	X						X		X	X
F. tuberculata G. M. Smith															X
Gloeocystis botryoides (Kutz.) Nageli												X			X
G. gigas Kutzing	X							X	X	X	X	X	X	X	X
G. major Gerneck *ex.* Lemmermann										X					
G. planktonica (West & West) Lemm.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
G. vesciculosa Naegeli										X				X	X
G. spp. Nageli	X	X	X	X	X	X									
Golenkinia paucispina West & West														X	X
G. radiata Chodat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gonium pectorale Mueller										X				X	
G. sociale (Duj.) Warming							X			X	X			X	X
Kirchneriella contorta (Schmidle) Bohlin	X	X	X	X	X	X				X				X	X
K. elongata G.M. Smith												X			X
K. lunaris (Kirch.) Mobius	X		X												X
K. lunaris v. *dianae* Bohlin	X								X			X		X	X
K. lunaris v. *irregularis* G.M. Smith												X			X

Table 3-6 (continued)

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
K. obesa W. West	X	X	X	X	X	X									
K. subsolitaria G. S. West							X	X	X	X	X	X		X	X
K. spp. Schmidle							X	X	X					X	
Lagerheimia ciliata (Lag.) Chodat														X	
L. citriformis (Snow) G. M. Smith									X						
L. longiseta (Lemmermann) Printz														X	X
L. quadriseta (Lemm.) G. M. Smith	X	X	X	X											
L. subsala Lemmerman		X	X	X	X	X		X	X	X		X		X	X
Mesostigma viride Lauterborne							X	X	X	X	X	X		X	X
Micractinium pusillum Fresen.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Monoraphidium contortum Thuret	X		X	X	X	X									
M. pusillum Printz	X		X	X	X	X									
Mougeitia elegantula Whittrock							X	X	X	X	X	X	X	X	X
M. spp. Agardh				X	X	X									
Nephrocytium agardhianum Nageli			X											X	X
N. limneticum (G.M. Smith) G.M. Smith											X			X	
Oocystis borgii Snow										X	X	X		X	X
O. ellyptica W. West										X				X	X
O. lacustris Chodat [1]															X
O. parva West & West	X	X					X	X	X	X	X	X	X	X	X
O. pusilla Hansgirg	X	X			X	X	X	X	X	X	X	X	X	X	X
O. pyriformis Prescott										X				X	
O. solitaria Wittrock															X
O. spp. Nageli		X													
Pandorina charkowiensis Kprshikov [1]															
P. morum Bory	X	X		X	X										X
Pediastrum biradiatum Meyen [1]															
P. duplex v. *clatheatum* (A. Braun) Lag.														X	
P. duplex Meyen		X	X		X		X	X	X		X	X	X	X	X
P. duplex v. *gracillimum* West and West									X	X				X	X
P. tetras v. *tetroadon* (Corda) Rabenhorst	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Meyen		X	X												
Planktosphaeria gelatinosa G. M. Smith							X							X	
Quadrigula closterioides (Bohlin) Printz			X					X	X				X	X	X
Q. lacustris (Chodat) G. M. Smith														X	X
Scenedesmus abundans (Kirchner) Chodat	X	X													X
S. abundans v. *asymetrica* (Schr.) G. Sm.	X	X	X	X	X	X		X	X			X		X	X
S. abundans v. *brevicauda* G. M. Smith							X								X
S. acuminatus (Lagerheim) Chodat				X	X	X	X	X		X	X	X	X	X	X
S. armatus v. *bicaudatus* (Gug.-Pr..)Chod		X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. bijuga (Turp.) Lagerheim	X	X			X	X	X	X	X	X	X	X	X	X	X
S. bijuga v. *alterans* (Reinsch) Hansg.[1]															
S. brasiliensis Bohlin							X	X	X	X	X	X	X	X	X
S. denticulatus Lagerheim	X	X	X	X	X	X	X	X		X	X	X	X	X	X
S. denticulatus v. *recurvatus* Schumacher															X
S. dimorphus (Turp.) Kutzing		X		X	X	X			X	X	X	X		X	X
S. incrassulatus G. M. Smith [1]															
S. parisiensis Chodat															X
S. quadricauda (Turp.) Brebisson	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. smithii Teiling								X						X	X

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
S. spp. Meyen	X	X	X	X	X	X									
Schizochlamys compacta Prescott								X		X		X		X	
S. gelatinosa A. Braun												X		X	
Schoederia setigera (Schroed.) Lemm.			X											X	
Selenastrum gracile Reinsch			X					X						X	
S. minutum (Nageli) Collins	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. westii G. M. Smith				X			X	X		X	X			X	X
Sorastrum americanum (Bohlin) Schm.									X						
Sphaerocystis schoeteri Chodat		X					X			X	X	X		X	X
Sphaerozosma granulatum Roy & Bl. [1]															
Stauastrum americanum (W&W) G. Sm.							X	X	X	X	X	X	X	X	X
S. apiculatum Brebisson									X	X	X	X	X	X	X
S. brachiatum Ralfs									X	X	X			X	X
S. brevispinum Brebisson										X					
S. chaetocerus (Schoed.) G. M. Smith				X	X	X									
S. curvatum W. West		X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. cuspidatum Brebisson									X	X	X	X	X	X	X
S. dejectum Brebisson	X	X	X	X		X						X			
S. dickeii v. *maximum* West & West [1]															
S. dickeii v. *rhomboidium* W.& G.S. West														X	
S. gladiosum Turner					X										
S. leptocladum v. *sinuatum* Wolle			X												
S. manfeldtii v. *fluminense* Schumacher		X	X			X	X		X	X		X		X	X
S. megacanthum Lundell					X	X									X
S. ophiura v. *cambricum* (Lund) W. & W.												X			
S. orbiculare Ralfs						X								X	
S. paradoxum Meyen	X	X	X	X	X	X				X	X				
S. paradoxum v. *cingulum* W. & W. [1]															
S. paradoxum v. *parvum* W. West										X				X	X
S. pentacerum (Wolle) G. M. Smith														X	
S. subcruciatum Cook & Wille							X		X	X	X	X		X	X
S. tetracerum Ralfs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. turgescens de Not.															
S. vestitum Ralfs														X	X
S. spp. Meyen	X	X	X	X		X									
Stichococcus scopulinus Hazen														X	
Stigeoclonium spp. Kutzing													X		
Tetraedron arthrodesmiforme (W.) Wol.														X	X
Tetraedron bifurcatum v. *minor* Prescott								X							
T. caudatum (Corda) Hansgirg	X	X		X		X		X	X	X	X	X	X	X	X
T. limneticum Borge				X											
T. lobulatum (Naeg.) Hansgirg												X			
T. lobulatum v. *crassum* Prescott					X										
T. minmum (Braun) Hansgirg	X	X				X	X	X		X	X	X	X	X	X
T. muticum (Braun) Hansgirg			X	X	X	X	X	X		X					
T. obesum (W & W) Wille *ex* Brunnthaler								X							

Table 3-6 (continued)

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
T. pentaedricum West & West	X					X									
T. planktonicum G. M. Smith										X		X		X	X
T. regulare Kutzing			X	X	X	X									
T. regulare v. *bifurcatum* Wille										X					
T. regulare v. *incus* Teiling	X				X										
T. trigonum (Nageli) Hansgirg		X	X		X			X	X	X		X	X	X	X
T. trigonum v. *gracile* (Reinsch) DeToni				X				X				X			
T. spp. Kutzing		X			X										
Tetrallantos lagerheimii Teiling													X		X
Tetraspora lamellosa Prescott												X			
T. spp. Link					X	X									
Tetrastrum heteracanthum (Nor.) Chod.		X												X	
T. staurogeniforme (Schroeder) Lemm.															X
Treubaria setigerum (Archer) G. M. Sm.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Westella botryoides (W. & W.) Wilde.										X		X			
W. linearis G. M. Smith										X		X			X
Xanthidium critatatum v. *uncinatum* Breb.														X	
X. spp. Ehrenberg						X								X	
CLASS: BACILLARIOPHYCEAE															
Achnanthes lanceolata Breb.														X	
A. microcephala Kutzing	X	X					X	X	X	X	X	X	X	X	X
A. spp. Bory	X	X	X	X	X	X		X							
Amphiphora ornate Bailey														X	
Anomoeoneis vitrea (Grunow) Ross		X				X	X	X		X	X	X	X	X	X
A. spp. Pfitzer						X									
Asterionella formosa Hassall	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Attheya zachariasi J. Brun	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Cocconeis placentula Ehrenberg										X	X				X
C. spp. Ehrenberg						X									
Cyclotella comta (Ehrenberg) Kutzing	X					X	X	X	X	X	X	X	X	X	X
C. glomerata Bachmann							X	X	X	X	X				X
C. meneghiniana Kutzing	X					X	X	X	X	X	X	X		X	X
C. pseudostelligera Hustedt [1]															
C. stelligera Cleve & Grunow		X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Kutzing	X	X													
Cymbella affinis Kutzing												X			X
C. gracilis (Rabh.) Cleve															X
C. minuta (Bliesch & Rabn.) Reim.		X		X	X		X	X		X	X			X	X
C. tumida (Breb.) van Huerck						X									
C. turgida (Gregory) Cleve [1]															
C. spp. Agardh			X												
Denticula elegans Kutzing														X	
D. thermalis Kutzing										X				X	
Diploneis spp. Ehrenberg		X													
Eunotia flexuosa v. *eurycephala* Grun.												X			
E. zasuminensis (Cab.) Koerner	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Fragilaria crotonensis Kitton		X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3-6 (continued)

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Frustulia rhomboides (Her.) de Toni[1]															
F. rhomboides v. *saxonica* (Rabh.) de T.															X
Gomphonema angustatum (Kutz.) Rabh.														X	
G. parvulum Kutz.														X	X
G. spp. Agardh			X			X									
Melosira ambigua (Grun.) O. Muller	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. distans (Her.) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. granulata (Ehr.) Ralfs		X	X		X										
M. granulata v. *angustissima* O. Muller	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. italica (Ehr.) Kutzing [1]															
M. varians Agardh				X	X					X					
M. spp. Agardh	X	X	X	X	X	X		X			X		X	X	X
Meridion circulare Agardh														X	
Navicula cryptocephala Kutzing		X						X	X					X	
N. exigua (Gregory) O. Muller							X							X	
N. exigua v. *capitata* Patrick								X							
N. radiosa Kutz.															X
N. radiosa v. *tenella* (Breb.) Grun.															X
N. subtilissima Cleve							X					X			X
N. spp. Bory	X	X	X	X	X	X									
Nitzschia acicularis W. Smith		X	X	X	X			X	X	X	X	X	X	X	X
N. agnita Hustedt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. holsatica Hustedt	X	X	X				X		X	X	X	X	X	X	X
N. linearis W. Smith												X			
N. palea (Kutzing) W. Smith						X	X	X	X	X				X	
N. sublinearis Hustedt								X		X			X	X	
N. spp. Hassall	X	X	X	X	X	X								X	
Pinnularia spp. Ehrenberg					X									X	
Rhizosolenia spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Skeletonema potemos (Weber) Hilse					X		X	X		X	X	X		X	X
Stephanodiscus spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X					X
Surirella angustata Kutz.															X
S. linearis v. *constricta* (Ehr.) Gr0.										X					
Synedra actinastroides Lemmerman						X									
S. acus Kutzing					X	X			X	X		X		X	X
S. delicatissima Lewis				X	X	X									
S. filiformis v. *exilis* Cleve-Euler										X		X	X	X	X
S. planktonica Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. rumpens Kutzing							X	X	X	X	X	X	X	X	X
S. rumpens v. *fragilarioides* Grunow [1]															
S. rumpens v. *scotica* Grunow [1]															
S. ulna (Nitzsch) Ehrenberg			X				X	X	X	X	X	X		X	X
S. spp. Ehrenberg	X	X	X	X	X	X									
Tabellaria fenestrata (Lyngb) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. flocculosa (Roth.) Kutzing		X				X						X			
CLASS: CHRYSOPHYCEAE															
Aulomonas purdyii Lackey						X	X	X	X	X	X	X		X	X
Bicoeca petiolatum (Stien) Pringsheim									X	X					

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Calycomonas pascheri (Van Goor) Lund							X					X			X
Chromulina spp. Chien.										X				X	X
Chrysococcus rufescens Klebs															X
Chrysosphaerella solitaria Lauterb.			X	X	X	X	X	X	X	X	X	X	X	X	X
Codomonas annulata Lackey								X	X	X	X	X	X		X
Dinobryon bavaricum Imhof	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. cylindricum Imhof		X	X	X	X	X		X		X				X	X
D. divergens Imhof	X	X		X	X	X	X	X			X			X	X
D. sertularia Ehrenberg							X					X		X	X
D. spp. Ehrenberg	X	X	X				X	X	X	X	X	X	X	X	X
Domatomococcus cylindricum Lackey										X	X				X
Erkinia subaequicilliata Skuja	X	X				X	X	X	X	X	X	X	X	X	X
Kephyrion campanuliforme Conrad															X
K. littorale Lund										X				X	X
K. petasatum Conrad															X
K. rubi-claustri Conrad														X	X
K. skujae Ettl [1]															
K. spp. Pascher	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mallomonas acaroides Perty						X									
M. akrokomos (Naumann) Krieger		X								X	X	X			X
M. allorgii (Defl.) Conrad															X
M. alpina Pascher										X		X			
M. caudata Conrad	X	X	X	X	X	X	X				X	X	X	X	X
M. globosa Schiller		X								X		X	X	X	X
M. producta Iwanoff												X		X	X
M. pseudocoronata Prescott	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. tonsurata Teiling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. spp. Perty	X	X	X	X	X	X						X			
Ochromonas granularis Doflein										X	X	X	X	X	X
O. mutabilis Klebs												X			
O. spp. Wyss	X					X	X	X	X	X	X	X	X	X	X
Pseudokephyrion schilleri Conrad										X	X		X	X	X
P. tintinabulum Conrad										X					
P. spp. Pascher															X
Rhizochrisis polymorpha Naumann											X	X	X	X	X
R. spp. Pascher			X												
Salpingoeca frequentissima (Zach.) Lem.										X	X	X			X
Stelexomonas dichotoma Lackey	X	X	X	X	X	X	X	X	X	X		X		X	X
Stokesiella epipyxis Pascher									X	X	X				
Synura spinosa Korschikov		X					X	X	X	X	X	X	X	X	X
S. uvella Ehrenberg	X	X	X		X	X							X		
S. spp. Ehrenberg	X	X	X	X	X	X									
Uroglenopsis americana (Caulk.) Lemm.							X	X	X		X				
CLASS: HAPTOPHYCEAE															
Chrysochromulina parva Lackey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: XANTHOPHYCEAE															
Characiopsis acuta Pascher															X

Table 3-6 (continued)

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
C. dubia Pascher							X	X		X	X	X	X	X	X
Dichotomococcus curvata Korschikov [1]															
Ophiocytium caoitatum v. *longisp.* (M) L.					X	X									X
Stipitococcus vas Pascher															X
CLASS: CRYPTOPHYCEAE															
Cryptomonas erosa Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. erosa v. *reflexa* Marsson		X								X	X	X	X	X	X
C. gracilia Skuja												X			
C. marsonii Skuja	X	X	X	X	X	X									X
C. obovata Skuja															X
C. ovata Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. phaseolus Skuja	X	X	X	X	X	X									
C. reflexa Skuja	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Ehrenberg	X	X	X	X	X	X									
Rhodomonas minuta Skuja	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: MYXOPHYCEAE															
Agmenellum quadriduplicatum Brebisson				X	X	X	X		X	X	X	X	X	X	X
A. thermale Drouet and Daily															X
Anabaena catenula (Kutzing) Born.									X	X					
A. inaequalis (Kutz.) Born.												X			
A. scheremetievi Elenkin									X	X	X		X		
A. wisconsinense Prescott							X	X	X	X	X	X	X	X	X
A. spp. Bory	X	X	X	X	X	X		X			X		X	X	
Anacystis incerta (Lemm.) Druet & Daily	X	X	X	X	X	X				X		X	X		
A. spp. Meneghini [1]															
Chroococcus dispersus (Keissl.) Lemm.										X		X			
C. limneticus Lemmermann		X							X	X	X	X	X	X	X
C. minor Kutzing														X	X
C. turgidus (Kutz.) Lemmermann			X		X										
C. spp. Nageli	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coelosphaerium kuetzingiana Nageli		X													
Dactylococcopsis irregularis Hansgirg		X	X			X									X
D. rupestris Hansgirg												X			
D. smithii Chodat and Chodat									X	X		X			X
D. spp. Hansgirg												X			
Gomphospaeria lacustris Chodat	X	X	X	X	X	X									
Lyngbya contorta Lemmermann			X	X											
L. limnetica Lemmermann	X	X	X	X	X	X									
L. ochracea (Kutz.) Thuret												X		X	
L. subtilis W. West	X	X	X	X		X									
L. spp. Agardh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Merismopedia tenuissima Lemmermann										X					
Microcystis aeruginosa Kutz. *emend* Elen.	X	X	X	X	X	X	X	X		X	X	X	X		
Oscillatoria amphibia Agardh														X	X
O. geminata Meneghini		X					X	X	X	X	X	X	X	X	X
O. limnetica Lemmermann							X	X	X	X	X	X	X	X	X
O. splendida Greville							X	X		X				X	

Table 3-6 (continued)

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
O. subtilissima Kutz.												X	X	X	X
O. spp. Vaucher	X					X							X		X
Phormidium angustissimum West & West	X	X	X			X									
P. spp. Kutzing	X	X			X	X									
Raphidiopsis curvata Fritsch & Rich				X		X	X	X	X	X	X	X		X	
R. mediterranea Skuja											X				
Rhabdoderma sigmoidea Schm. & Lautrb.	X														
Spirulina subsala Oersted														X	
Synecococcus lineare (Sch. & Lt.) Kom.		X	X	X	X	X	X	X		X	X	X	X		X
CLASS: EUGLENOPHYCEAE															
Euglena acus Ehrenberg		X									X				
E. minuta Prescott	X											X		X	
E. polymorpha Dangeard								X					X	X	
E. proxima Dangeard															X
E. spp. Ehrenberg	X	X	X		X	X	X	X		X	X		X		
Lepocinclus glabra Drezepolski															X
L. (Ehr.) Lemm.												X			
L. spp. Perty										X					
Phacus cuvicauda Swirenko												X			
P. longicauda (Ehr.) Dujardin												X			
P. orbicularis Hubner				X											
P. tortus (Lemm.) Skvortzow	X	X		X											
P. spp. Dujardin	X														
Trachelomonas acanthostoma (Stk.) Defl.													X		
T. ensifera Daday															X
T. hispida (Perty) Stein					X		X				X		X	X	X
T. pulcherrima Playfair 1															
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			
Glenodinium borgei (Lemm.) Schiller								X							
G. gymnodinium Penard	X	X	X	X	X				X						
G. palustre (Lemm.) Schiller															
G. penardiforme (linde.) Schiller											X	X			
G. quadridens (Stein) Schiller		X				X									
G. spp. (Ehrenberg) Stein			X			X									
Gymnodinium aeruginosum Stein										X	X	X			X
G. spp. (Stein) Kofoid & Swezy		X	X	X	X	X	X		X	X		X	X	X	X
Peridinium aciculiferum Lemmermann 1															
P. inconspicuum Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. cinctum (Muller) Ehrenberg														X	
P. intermedium Playfair										X	X	X	X	X	X
P. pusillum (Lenard) Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. umbonatum Stein				X	X	X									
P. wisconsinense Eddy		X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Ehrenberg		X	X	X	X	X									

Table 3-6 (continued)

TAXON	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
CLASS: CHLOROMONADOPHYCEAE															
Gonyostomum depresseum Lauterborne							X			X	X			X	X
G. semen (Ehrenberg) Diesing		X													
G. spp. Diesing		X				X									

1 = taxa found during 1987-88 only

Table 3-7. Dominant classes, their most abundant species, and their percent composition (in parenthesis) at Lake Norman locations during each sampling period of 2003.

LOC	FEBRUARY	MAY
2.0	CRYPTOPHYCEAE (42.5)	BACILLARIOPHYCEAE (43.0)
	Rhodomonas minuta (38.6)	*Fragillaria crotonensis* (35.1)
5.0	CRYPTOPHYCEAE (48.4)	BACILLARIOPHYCEAE (44.4)
	R. minuta (37.9)	*F. crotonensis* (32.2)
9.5	CRYPTOPHYCEAE (45.6)	BACILLARIOPHYCEAE (44.6)
	R. minuta (36.0)	*F. crotonensis* (29.4)
11.0	CRYPTOPHYCEAE (50.7)	BACILLARIOPHYCEAE (54.4)
	R. minuta (38.5)	*F. crotonensis* (39.0)
15.9	CRYPTOPHYCEAE (38.1)	BACILLARIOPHYCEAE (64.9)
	R. minumta (27.3)	*F. crotonensis* (45.4)
	AUGUST	NOVEMBER
2.0	CHLOROPHYCEAE (43.6)	BACILLARIOPHYCEAE (33.2)
	Cosmarium asphear. strig. (22.8)	*Tabellaria. fenestrata* (17.4)
5.0	CHLOROPHYCEAE (57.7)	BACILLARIOPHYCEAE (42.5)
	C. asphearosporum strig. (20.1)	*T. fenestrata* (21.3)
9.5	CHLOROPHYCEAE (58.7)	BACILLARIOPHYCEAE (42.9)
	C. asphearosporum strig. (20.9)	*T. fenestrata* (22.8)
11.0	CHLOROPHYCEAE (51.1)	BACILLARIOPHYCEAE (32.6)
	C. asphearosporum strig. (24.3)	*T. fenetrata* (16.5)
15.9	CHLOROPHYCEAE (51.9)	BACILLARIOPHYCEAE (34.0)
	C. asphearosporum strig. (20.5)	*T. fenestrata* (7.9)

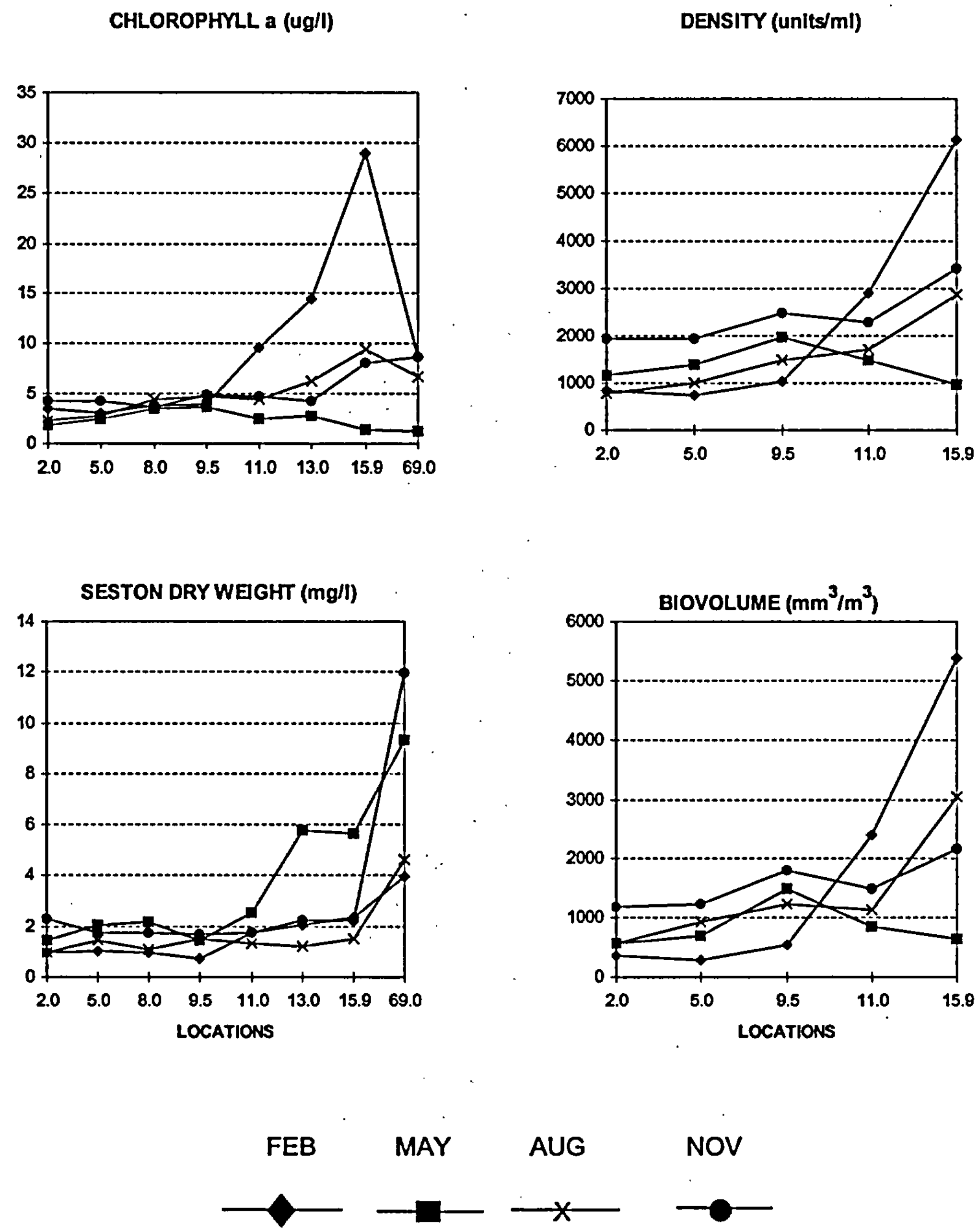


Figure 3-1. Phytoplankton chlorophyll *a*, densities, and biovolumes; and seston weights at locations in Lake Norman, NC, in February, May, August, and November 2003.

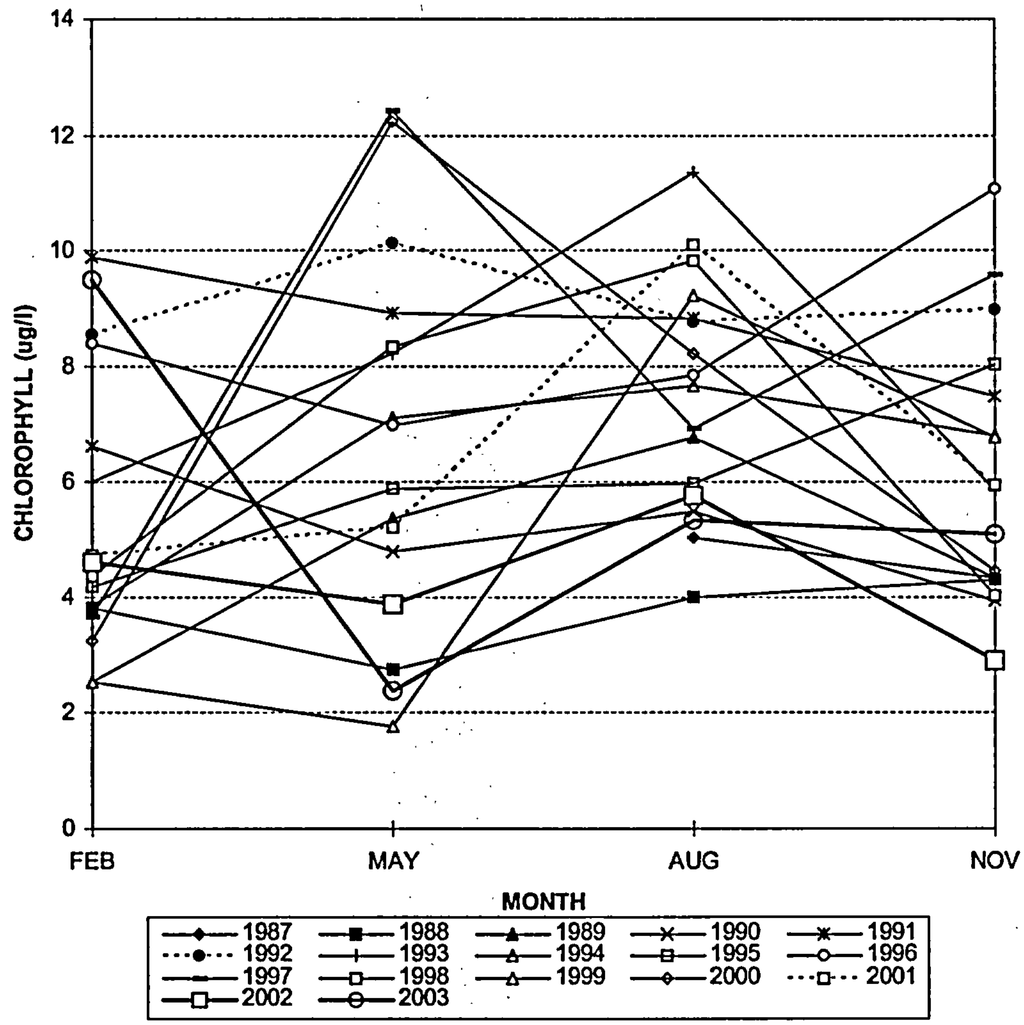


Figure 3-2. Phytoplankton chlorophyll *a* annual lake means from all locations in Lake Norman, NC, for each quarter since August 1987.

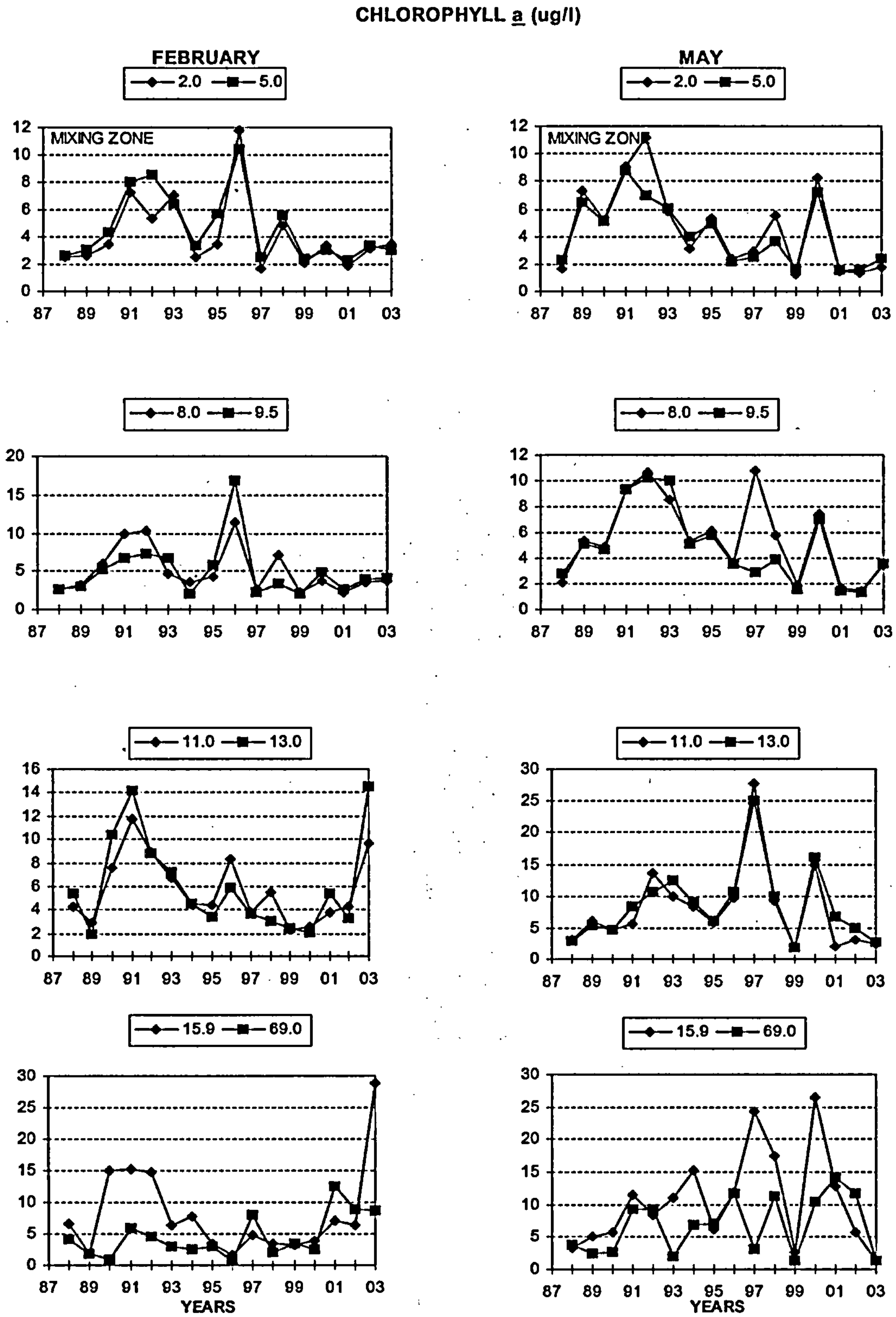


Figure 3-3. Phytoplankton chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from August 1987 through November 2003.

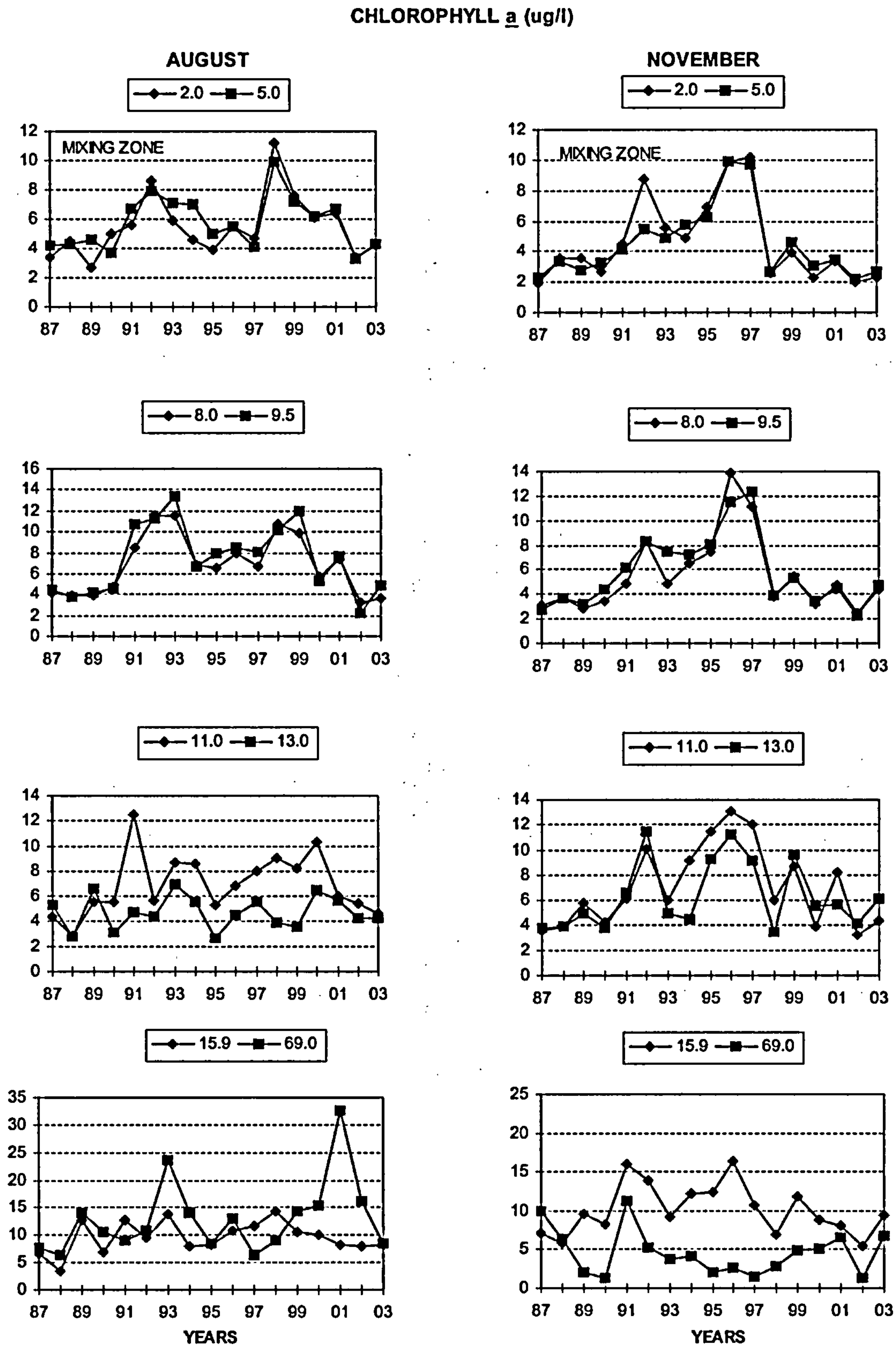
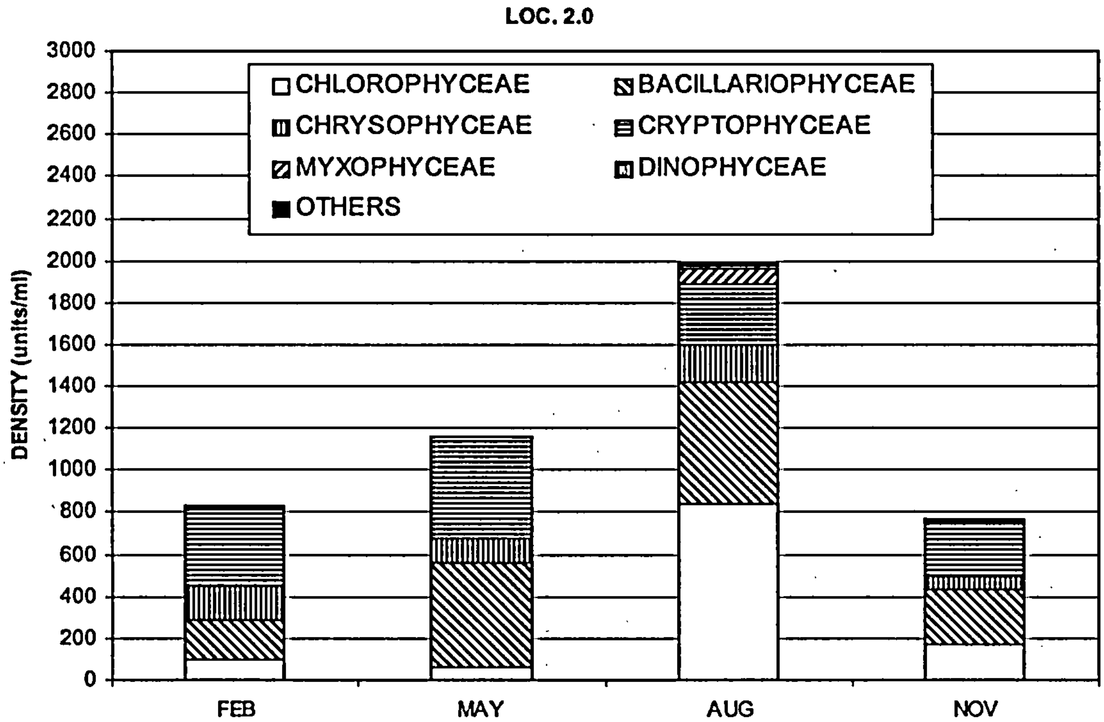


Figure 3-3 (continued).



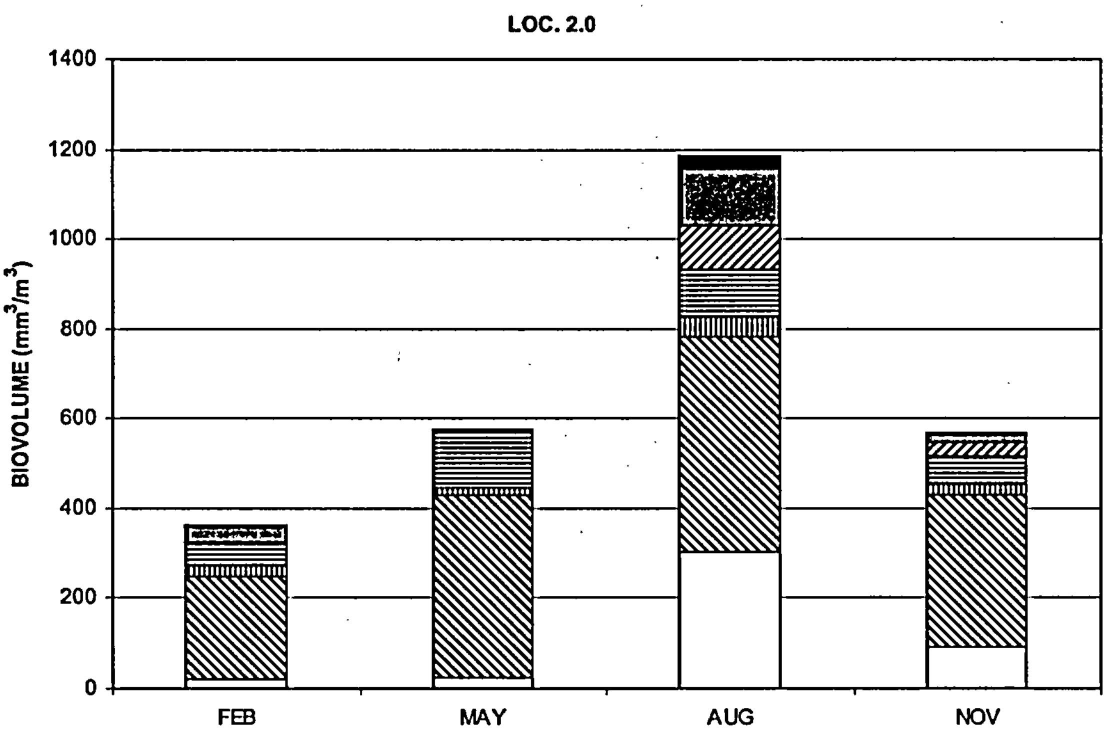
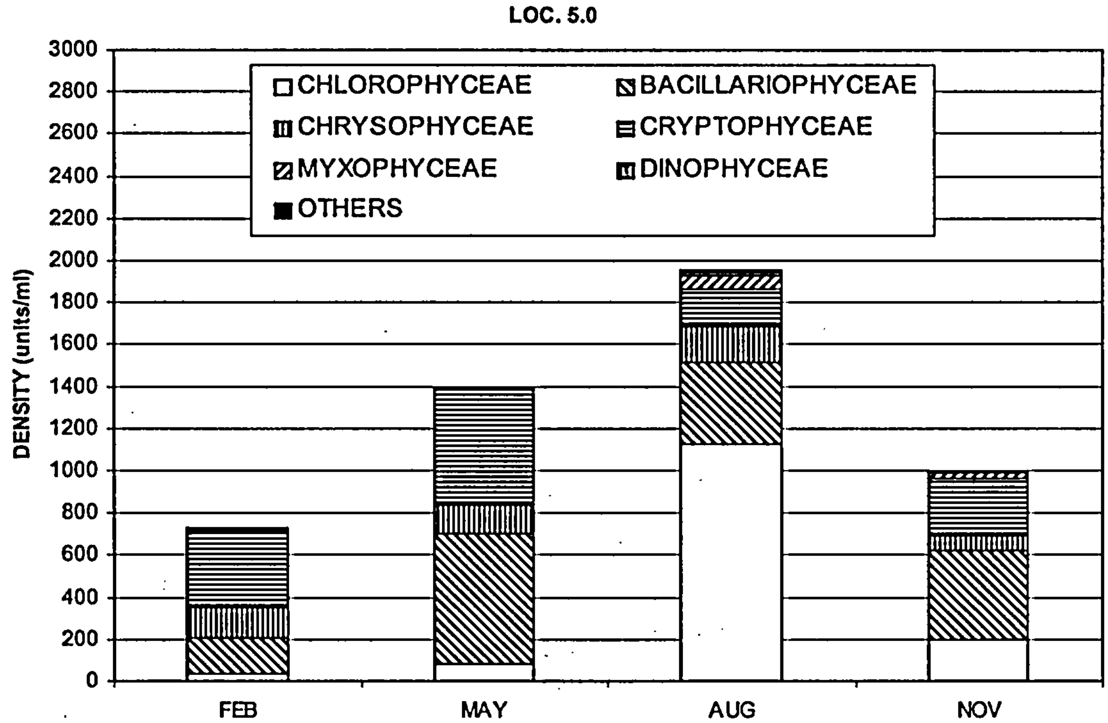


Figure 3-4. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 2.0 in Lake Norman, NC, during 2003.



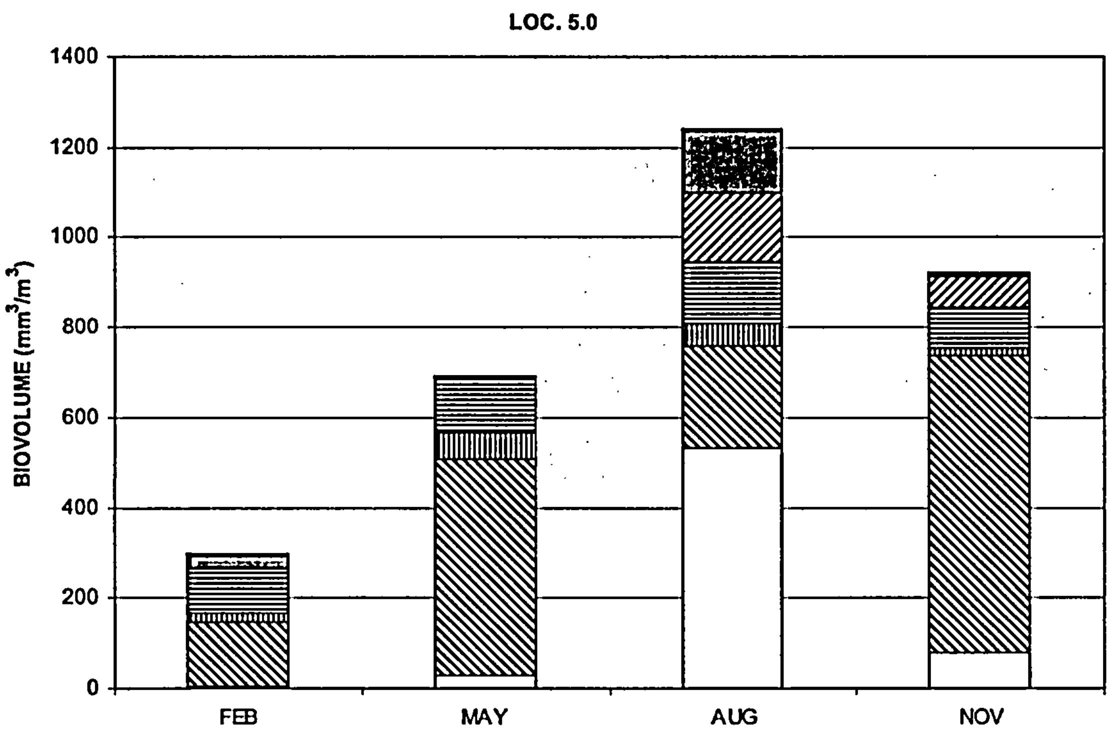


Figure 3-5. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 5.0 in Lake Norman, NC, during 2003.

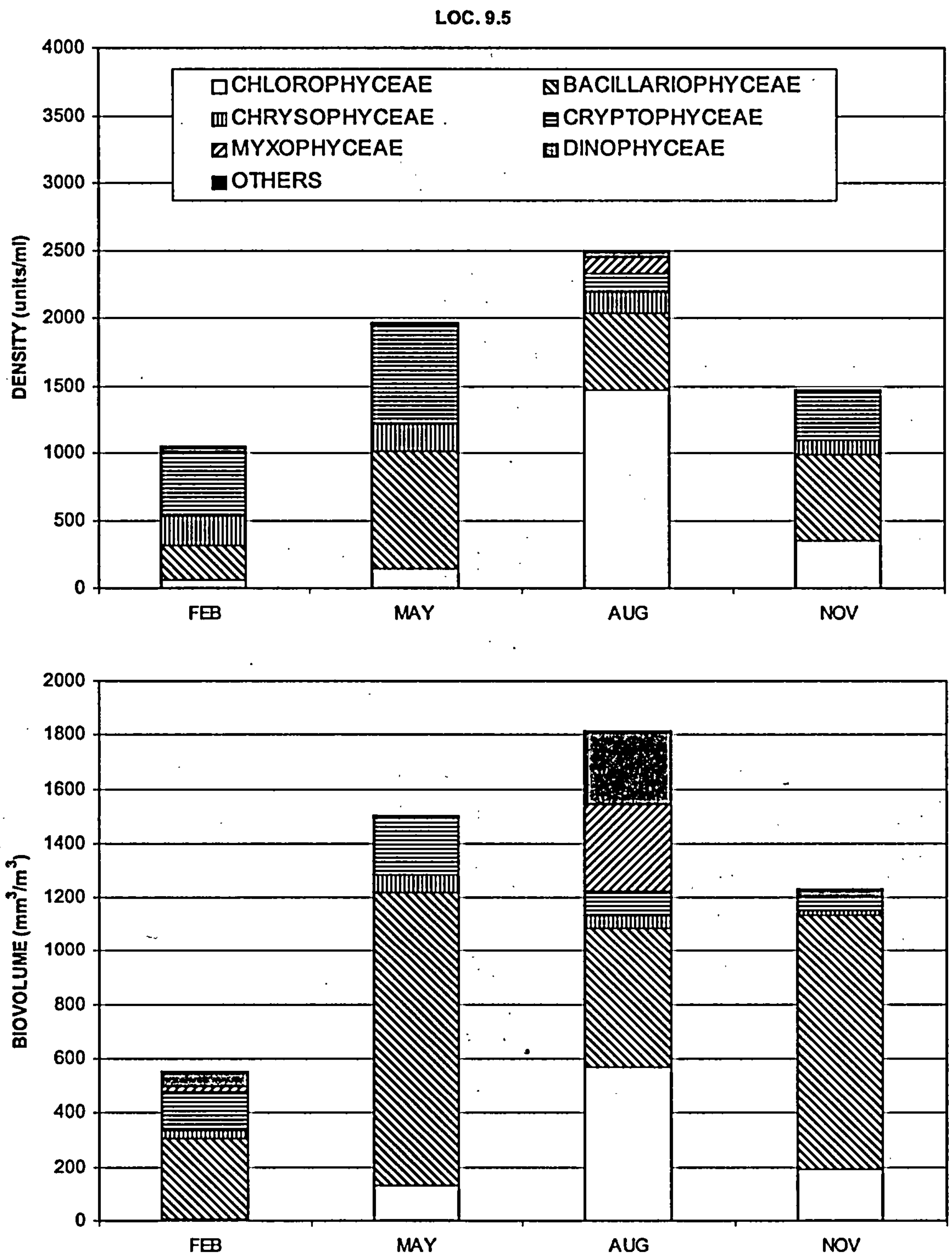


Figure 3-6. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC, during 2003.

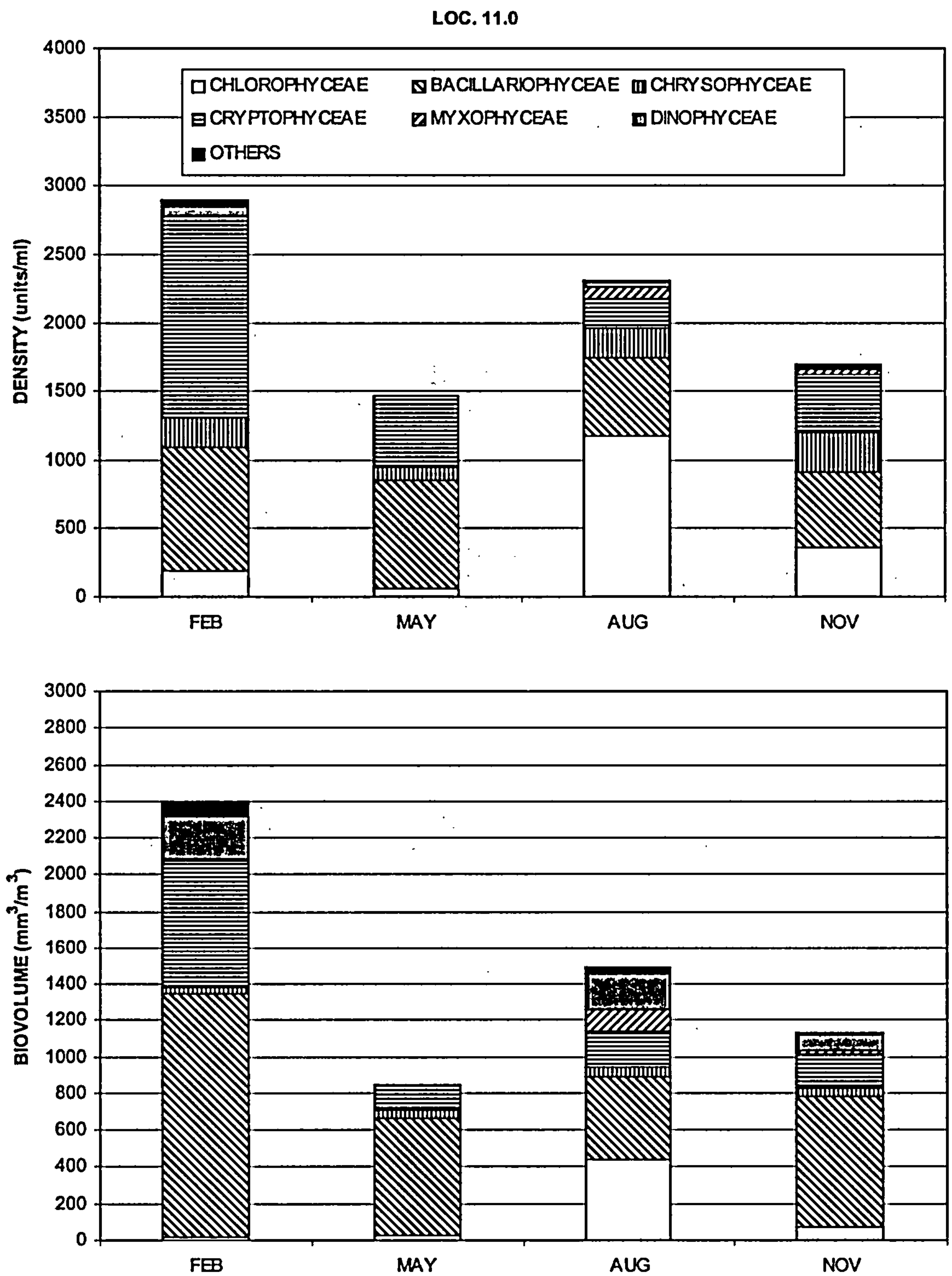


Figure 3-7. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC, during 2003

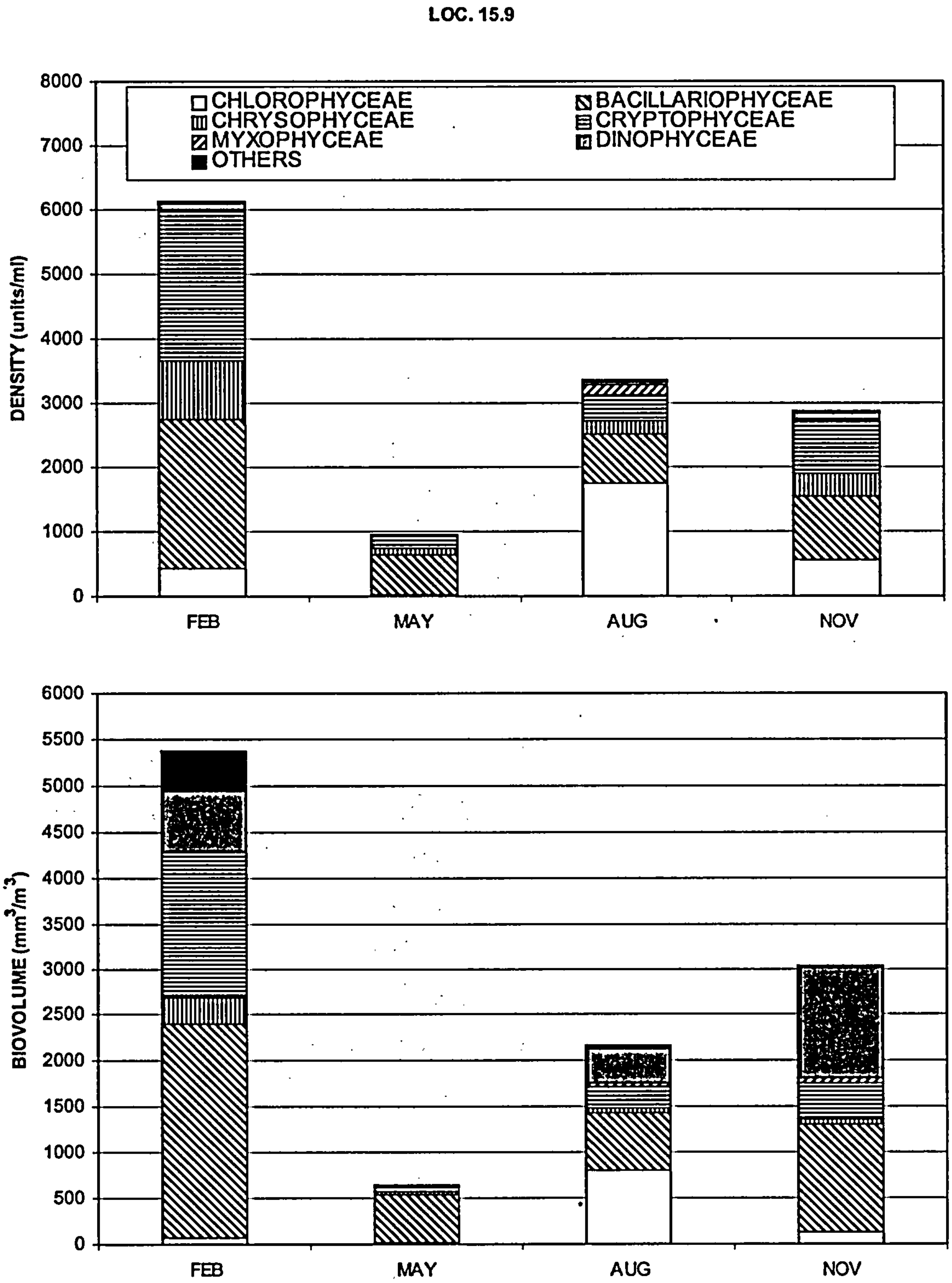


Figure 3-8. Class composition (density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC, during 2003.

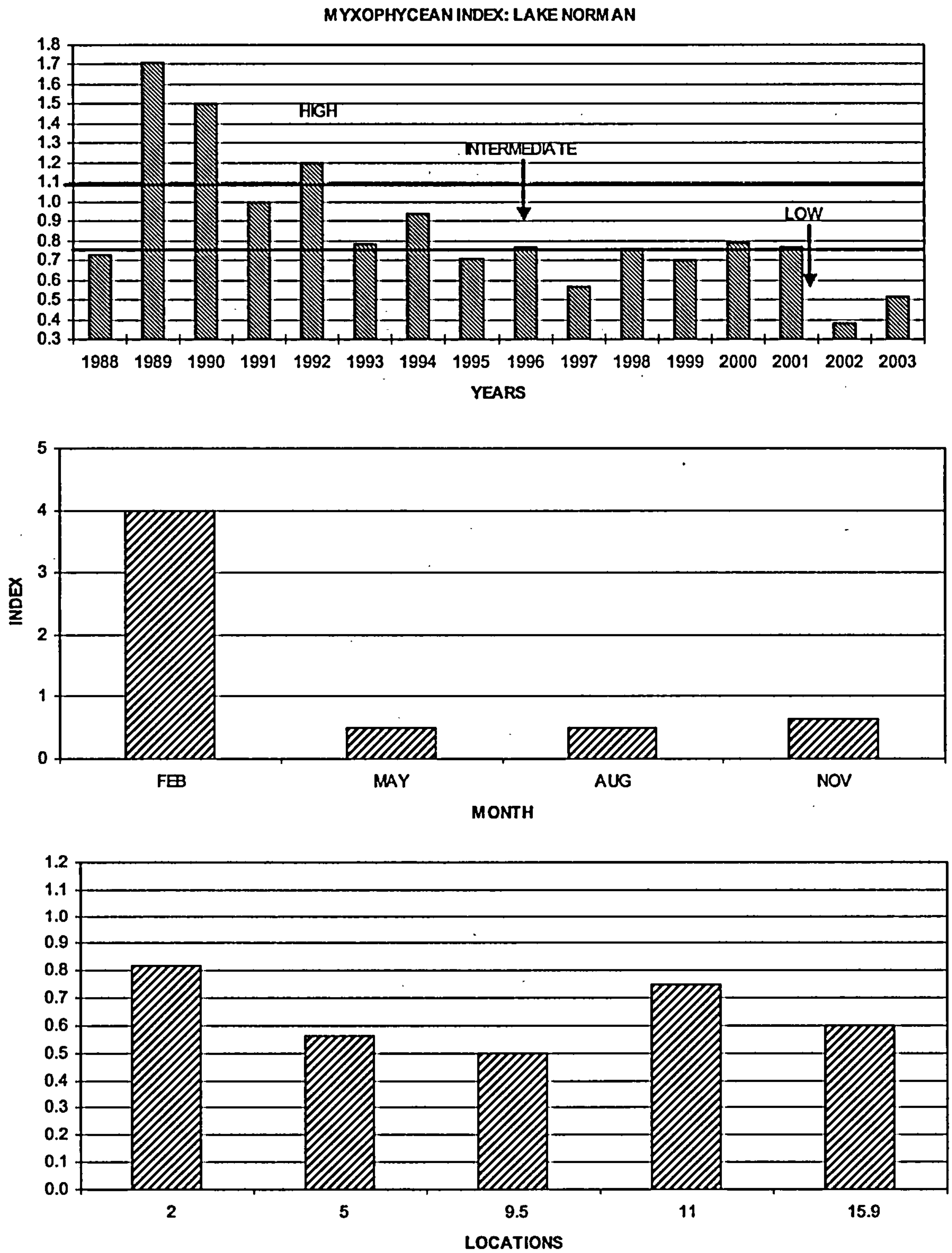


Figure 3-9. Myxophycean index values by year (top), each quarter in 2002 (mid), and each location in Lake Norman, NC, during 2003.

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 2003) with historical data collected during the period 1987-2002.

Previous studies of Lake Norman zooplankton populations, using monthly data, have demonstrated a bimodal seasonal distribution with highest values generally occurring in the spring, and a less pronounced fall peak. Considerable spatial and year-to-year variability has been observed in zooplankton abundance in Lake Norman (Duke Power 1976, 1985; Hamme 1982; Menhinick and Jensen 1974). Since quarterly sampling was initiated in August 1987, clear cut bimodal seasonal distribution has been less apparent due to lack of transitional data between quarters.

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 5 February, 21 May, 26 August, and 3 November 2003. For discussion purposes the 10 m to surface tow samples are called <u>epilimnetic samples</u> and the bottom to surface net tow samples are called <u>whole column samples</u>. 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 2003 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 2003, typical seasonal variability was observed in epilimnetic samples. Maximum epilimnetic densities were highest in May at Locations 2.0 through 9.5 and in November at Locations 11.0 and 15.9 (Table 4-1, Figure 4-1). The lowest epilimnetic densities at Locations 2.0, 9.5, and 11.0 occurred in August, while annual minimum densities at Locations 5.0 and 15.9 were observed in November. Epilimnetic densities ranged from a low of 27,713/m^3 at Location 5.0 in November, to a high of 266,226/m^3 at Location 15.9, also in November. Maximum densities in the whole column samples were also observed in May at Locations 2.0 through 9.5, while maxima at Locations 11.0 and 15.9 were recorded in February and November, respectively. Minimum whole column densities were observed at all but Location 5.0 in August, while the minimum at location 5.0 occurred in November. Whole column densities ranged from 22,569/m^3 at Location 2.0 in August, to 206,741/m^3 at Location 15.9 in November.

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 2003, as has been the case in previous years (Duke Power 2004). This is related to the ability of zooplankton to orient vertically in the water column in response to physical and chemical gradients and the distribution of food sources, primarily phytoplankton, which are generally most abundant in the euphotic zone (Hutchinson 1967).

Although spatial distribution varied among locations from season to season, a general pattern of increasing values from Mixing Zone to Background Locations was observed during 2003 (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 during all sampling periods (Table

4-2). 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; Duke Power 1998, 1999, 2000, 2001, 2003, 2004).

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 2003 (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 2003 were generally within historical ranges during each quarter (Figure 4-3). The only exception was the density at Location 15.9 in August, which was the highest August density reported for this location. Phytoplankton standing crops during 2003 also fell within historical ranges on most occasions (Chapter 3).

The highest February densities recorded from Locations 5.0 and 9.5 occurred in 1995, while Locations 2.0 and 11.0 experienced February maxima in 1996 (Figure 4-2). The long term February maximum at Location 15.9 was observed in 1992. Long term maximum densities for May occurred at Locations 2.0 and 9.5 in 2000, while the highest May values at Locations 5.0, 11.0, and 15.9 occurred in May 2002. Long term August maxima occurred in 1988 at all but Location 15.9, which had its highest August value in 2003 (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 striking, 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 thirteen zooplankton taxa have been identified since the Lake Norman Maintenance Monitoring Program began in August 1987 (Table 4-3). Fifty-two taxa were identified during 2003, as compared to fifty-one taxa recorded during 2002 (Duke Power 2004). Four previously unreported taxa were identified in 2003: Three cladocerans (*Monospilus dispar, Pleuroxus hamularis* and *P* spp.) and one rotifer (*Brachionus bidentata*) were added to the taxa list.

Copepods, which were most often dominant during 2001, showed a significant decline in relative abundance during 2002, when they were dominant in only seven August samples. During 2003, copepods rebounded considerably, and were dominant in thirteen zooplankton samples collected during all four quarters (Table 4-1, Figures 4-4 and 4-5). Copepods were dominant in epilimnetic samples from Location 9.5 in February, and Locations 2.0 and 5.0 in November. They dominated whole column samples at Locations 2.0 and 9.5 in February, Locations 5.0 through 11.0 in May, Locations 2.0 through 9.5 in August, and Locations 2.0 and 5.0 in November. Cladocerans, always the least abundant forms in Lake Norman, were dominant in only one sample, Location 2.0 (epilimnion), in February. Rotifers were dominant in 65% of all zooplankton samples collected during 2003. During most years of the Program, microcrustaceans dominated Mixing Zone samples, but were considerably less important among Background Locations (Figures 4-6 through 4-8). From 1995 through 1998, a trend of increasing relative abundance among microcrustaceans was observed throughout Lake Norman. Since 2000, this trend has reversed, with a subsequent increase in relative abundances of rotifers to the extent that taxonomic composition in 2002 was similar to that found during years prior to 1995. During 2003, microcrustaceans increased in relative abundance in all areas except Background Locations, where whole column samples showed a decline in relative abundance of microcrustaceans.

Copepoda

Copepod populations were consistently dominated by immature forms (primarily nauplii) during 2003, as has always been the case. Adult copepods rarely constituted more than 10% of the total zooplankton density at any location. *Tropocyclops* and *Epischura* were the most important constituents of adult populations in epilimnetic samples, while *Tropocyclops* and *Mesocyclops* were principal components of adult populations in whole column samples (Table 4-4). This was also the case in previous years (Duke Power 2004).

Copepods tended to be more abundant, if not dominant, at Background Locations than at Mixing Zone Locations during 2003, and their densities peaked in May at both Mixing Zone and Background Locations. Copepods showed similar spatial and seasonal trends during 2002 (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 2003 samples, as has been the case in most previous studies (Duke Power 2004, Hamme 1982). *Bosmina* often comprised greater than 5% of the total zooplankton densities in both epilimnetic and whole column samples, and was the dominant zooplankter in several samples from February and November (Table 4-4). *Bosminopsis* was also important among cladocerans in August when it dominated cladoceran populations at most locations. *Bosminopsis* expressed somewhat higher dominance during August 2003 as compared to August 2002. During May, *Diaphanosoma* dominated cladoceran populations at all but Location 15.9, where *Daphnia* was the dominant cladoceran in both epilimnetic and whole column samples. Similar patterns of *Bosminopsis-Diaphanosoma* dominance have been observed in past years of the Program (Duke Power 2004).

Long-term seasonal trends of cladoceran densities were variable: From 1990 to 1993, peak densities occurred in February; while in 1994, 1995, 1997, and 2000, maxima were recorded in May (Figure 4-5). During 1996, 1999, and 2002, peak cladoceran densities occurred in May in the Mixing Zone, and in August among Background Locations. Maximum cladoceran densities in 1998 occurred in August. In 2001, maximum cladoceran densities in the Mixing Zone occurred in February, while Background Locations showed peaks in November. During 2003, maximum densities at Background Locations occurred in August, while peaks in the Mixing Zone were observed in November. Spatially, cladocerans were generally more numerous at Background Locations than at other locations (Table 4-1, Figures 4-4 and 4-5).

Rotifera

Polyarthra was the most abundant rotifer in 2003 samples (Table 4-4). This taxon dominated rotifer populations at Locations 2.0 (epilimnion), 9.5, and 15.9 (whole column) in February;

was dominant at all locations in May, and in whole coumn samples from Locations 2.0 and 5.0 in August. In November, *Polyarthra* was the dominant rotifer at all but Locations 5.0 (epilimnion) and 15.9. *Conochilus* dominated rotifer populations at Locations 2.0 (epilimnion), 9.5, 11.0 and 15.9 (epilimnion) in August. *Keratella* was the dominant rotifer at Locations 2.0 (whole column), and 11.0 in February; and at Locations 5.0 (epilimnion) and 15.9 (whole column) in August and November. *Synchaeta* was the dominant rotifer at Location 5.0 in February, while *Asplanchna* was the dominant rotifer at Location 15.9 (epilimnion) in February. All of these taxa have been identified as important constituents of rotifer populations, as well as zooplankton communities, in previous studies (Duke Power 2004; Hamme 1982).

Long term tracking of rotifer populations indicated high year-to-year seasonal variability. Peak densities have most often occurred in February and May, with an occasional peak in August (Figure 4-5, Duke Power 1989, 2002, 2003). During 2003, peak densities were observed in May at Mixing Zone Locations and in November at Background Locations.

FUTURE STUDIES

No changes are planned for the zooplankton portion of the Lake Norman Maintenance Monitoring Program in 2005.

SUMMARY

Maximum epilimnetic and whole column zooplankton densities occurred in May at Locations 2.0 through 9.5, while maximum epilimnetic densities at Locations 11.0 and 15.9 were observed in November. Maximum whole column densities at Locations 11.0 and 15.9 were observed in February and November, respectively. Minimum zooplankton densities were most often noted in August. 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 2003, 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 were generally within ranges of those observed in previous years. The one exception was the record high density for August at Location 15.9.

One hundred and thirteen zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (Fifty-two were identified during 2003). Four previously unreported taxa (three cladocerans and one rotifer) were identified during 2003.

Overall relative abundance of copepods in 2003 had increased substantially since 2002, and they were dominant in samples collected during all four quarters. Cladocerans were dominant in only one sample in February, while rotifers were dominant in 65% of all samples. Overall, the relative abundance of rotifers had decreased considerably since 2002, and their relative abundances were somewhat similar to years between 1996 and 2001. Historically, copepods and rotifers have most often shown annual peaks in May; while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms with adults rarely accounting for more than 10% of zooplankton densities. The most important adult copepods were *Tropocyclops*, *Epischura*, and *Mesocyclops* as was the case in previous years. *Bosmina* was the predominant cladoceran, as has also been the case in most previous years of the Program. *Bosminopsis* dominated most cladoceran populations in August, while *Diaphanosoma* was the predominant cladoceran in May. The most abundant rotifers observed in 2003, as in many previous years, were *Polyarthra*, *Conochilus*, and *Karetella*, while *Syncheata* was occasionally important among rotifer populations.

Lake Norman continues to support a highly diverse and viable zooplankton community. Zooplankton densities, as well as seasonal and spatial trends were generally consistent with historical precedent during 2003, and no impacts of plant operations were observed.

LITERATURE CITED

Duke Power Company. 1976. McGuire Nuclear Station, Units 1 and 2, Environmental Report, Operating License Stage. 6th rev. Volume 2. Duke Power Company, Charlotte, NC.

Duke Power Company. 1985. McGuire Nuclear Station, 316(a) Demonstration. Duke Power Company, Charlotte, NC.

Duke Power Company. 1988. Lake Norman maintenance monitoring program: 1987 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1989. Lake Norman maintenance monitoring program: 1988 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1990. Lake Norman maintenance monitoring program: 1989 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1991. Lake Norman maintenance monitoring program: 1990 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1992. Lake Norman maintenance monitoring program: 1991 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1993. Lake Norman maintenance monitoring program: 1992 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1994. Lake Norman maintenance monitoring program: 1993 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1995. Lake Norman maintenance monitoring program: 1994 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1996. Lake Norman maintenance monitoring program: 1995 summary. Duke Power Company, Charlotte, NC.

Duke Power Company. 1997. Lake Norman maintenance monitoring program: 1996 summary. Duke Power Company, Charlotte, NC.

Duke Power. 1998. Lake Norman maintenance monitoring program: 1997 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 1999. Lake Norman maintenance monitoring program: 1998 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2000. Lake Norman maintenance monitoring program: 1999 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2001. Lake Norman maintenance monitoring program: 2000 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2003. Lake Norman maintenance monitoring program: 2001 summary. Duke Energy Company, Charlotte, NC.

Duke Power. 2004. Lake Norman maintenance monitoring program: 2002 summary. Duke Energy Company, Charlotte, NC.

Hamme, R. E. 1982. Zooplankton, In J. E. Hogan and W. D. Adair (eds.). Lake Norman Summary, Technical Report DUKEPWR/82-02. p. 323-353, Duke Power Company, Charlotte, NC. 460 p.

Hutchinson, G. E. 1967. A Treatise on Limnology. Vol. II. Introduction to Lake Biology and the Limnoplankton. John Wiley and Sons, Inc. N. Y. 1115 pp.

Menhinick, E. F. and L. D. Jensen. 1974. Plankton populations. In L. D. Jensen (ed.). Environmental responses to thermal discharges from Marshall Steam Station, Lake Norman, North Carolina. Electric Power Research Institute, Cooling Water Discharge Research Project (RP-49) Report No. 11., p. 120-138, Johns Hopkins University, Baltimore, MD 235 p.

Thornton, K. W., B. L. Kimmel, F. E. Payne. 1990. Reservoir Limnology. John Wiley and Sons, Inc. New York, NY.

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 2003.

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
2/5/03	10-S	COPEPODA	17.0	13.0	40.3	39.0	23.9
			(34.0)	(31.1)	(54.1)	(29.4)	(17.0)
		CLADOCERA	17.2	6.6	25.1	20.6	9.3
			(34.4)	(15.7)	(33.6)	(15.6)	(6.6)
		ROTIFERA	15.8	22.2	9.2	72.8	107.0
			(31.6)	(53.2)	(12.3)	(55.0)	(76.4)
		TOTAL	**50.0**	**41.8**	**74.6**	**132.4**	**140.2**
	B-S						
	Depth (m)						
	of tow	COPEPODA	15.9	10.2	31.1	45.2	28.3
	For each		(38.7)	(32.0)	(58.4)	(39.9)	(21.3)
	Location	CLADOCERA	13.7	6.3	13.2	21.9	14.9
	2.0=29		(33.4)	(19.7)	(24.9)	(14.5)	(11.2)
	5.0=18	ROTIFERA	11.4	15.4	8.9	84.0	89.4
	9.5=20		(27.9)	(48.3)	(16.7)	(55.6)	(67.5)
	11.0=24						
	15.9=20	**TOTAL**	**41.1**	**31.9**	**53.2**	**151.1**	**132.6**
5/21/03	10-S	COPEPODA	48.3	26.4	38.5	37.2	41.3
			(40.6)	(37.0)	(34.1)	(37.2)	(32.1)
		CLADOCERA	17.2	7.5	24.0	22.9	3.8
			(14.4)	(10.6)	(21.3)	(22.9)	(2.9)
		ROTIFERA	53.7	37.4	50.4	39.9	83.7
			(45.0)	(52.4)	(44.6)	(39.9)	(65.0)
		TOTAL	**119.2**	**71.3**	**112.9**	**100.0**	**128.8**
	B-S						
	Depth (m)						
	of tow	COPEPODA	22.4	22.7	31.4	19.0	35.7
	for each		(38.8)	(43.7)	(39.9)	(39.3)	(31.6)
	Location	CLADOCERA	10.9	7.5	19.5	11.8	3.6
	2.0=30		(18.9)	(14.4)	(24.7)	(24.3)	(3.2)
	5.0=20	ROTIFERA	24.5	21.8	27.9	17.6	73.8
	9.5=20		(42.3)	(41.9)	(35.4)	(36.4)	(65.2)
	11.0=25						
	15.9=20	**TOTAL**	**57.8**	**52.0**	**78.8**	**48.4**	**113.1**

Table 4-1 (continued).

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
8/26/03	10-S	COPEPODA	17.0	21.0	18.6	18.8	64.9
			(43.3)	(38.3)	(26.7)	(26.2)	(25.7)
		CLADOCERA	4.7	11.0	16.6	13.2	77.8
			(12.0)	(20.2)	(23.9)	(18.4)	(30.8)
		ROTIFERA	17.6	22.8	34.4	39.6	109.4
			(44.7)	(41.5)	(49.4)	(55.4)	(43.4)
		TOTAL	**39.3**	**54.8**	**69.6**	**71.6**	**252.1**
	B-S depth (m) of tow for each Location 2.0=30 5.0=19 9.5=20 11.0=21 15.9=20	COPEPODA	13.1	17.2	23.4	18.3	24.0
			(58.2)	(48.7)	(44.9)	(38.2)	(32.7)
		CLADOCERA	1.9	6.0	7.5	8.8	23.9
			(8.4)	(17.1)	(14.3)	(18.5)	(32.7)
		ROTIFERA	7.5	12.1	21.1	20.7	25.3
			(33.4)	(34.2)	(40.5)	(43.3)	(34.6)
		TOTAL	**22.5**	**35.3**	**52.0***	**47.8**	**73.2**
11/4/02	10-S	COPEPODA	20.6	11.1	20.9	14.7	47.1
			(37.6)	(40.0)	(22.5)	(10.5)	(17.7)
		CLADOCERA	20.4	8.6	9.2	12.8	6.0
			(37.3)	(31.0)	(9.9)	(9.2)	(2.3)
		ROTIFERA	13.7	8.0	62.8	112.1	213.2
			(25.1)	(29.0)	(67.6)	(80.3)	(80.0)
		TOTAL	**54.7**	**27.7**	**92.9**	**139.6**	**266.3**
	B-S depth (m) of tow for each Location 2.0=29 5.0=18 9.5=20 11.0=18 15.9=20	COPEPODA	12.0	11.1	16.1	19.8	46.7
			(48.9)	(38.1)	(26.7)	(21.5)	(22.6)
		CLADOCERA	8.2	10.1	6.4	15.6	13.7
			(33.6)	(34.8)	(10.5)	(17.0)	(6.6)
		ROTIFERA	4.3	7.9	38.1	56.5	146.3
			(17.5)	(27.1)	(62.8)	(61.5)	(70.8)
		TOTAL	**24.5**	**29.1**	**60.6**	**91.9**	**206.7**

*= Ostracoda observed in sample (108/m^3, 0.21%).
NS = No sample data available

Table 4-2. Duncan's Multiple Range Test on epilimnetic zooplankton densities (no. X 1000/m^3) in Lake Norman, NC during 2003.

February	Location	**5.0**	**2.0**	**9.5**	**11.0**	**15.9**
	Mean	41.7	50.0	74.6	132.4	140.2
May	Location	**5.0**	**11.0**	**9.5**	**2.0**	**15.9**
	Mean	71.3	100.1	112.9	119.2	128.8
August	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Mean	39.3	54.8	69.6	71.6	126.1
November	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Mean	27.3	27.7	92.9	139.7	266.2

Table 4-3. Zooplankton taxa identified from samples collected quarterly on Lake Norman from 1988 through 2003.

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
COPEPODA																
Cyclops thomasi Forbes	X	X	X				X	X		X	X	X	X	X	X	X
C. vernalis Fischer									X							
C. spp. O. F. Muller	X	X	X	X	X	X	X	X	X	X	X			X	X	X
Diaptomus birgei Marsh	X	X	X	X		X							X			
D. mississippiensis Marsh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. pallidus Herick		X	X			X		X	X	X		X				X
D. reighardi Marsh												X				
D. spp. Marsh	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Epishura fluviatilis Herrick								X	X	X	X	X	X	X	X	X
Ergasilus spp.									X							
Eucyclops agilis (Koch)											X					
Mesocyclops edax (S. A. Forbes)	X	X	X				X	X	X	X	X	X	X	X	X	X
M. spp. Sars	X	X		X	X	X	X	X	X	X				X	X	X
Tropocyclops prasinus (Fischer)	X	X	X					X	X	X	X	X	X	X	X	X
T. spp.	X	X	X	X	X	X	X	X	X	X				X	X	
Calanoid copepodites	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyclopoid copepodites	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Harpacticoidea					X	X			X							
Nauplii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Parasitic copepods												X				
CLADOCERA																
Alona spp.Baird									X	X						
Alonella spp. (Birge)							X					X				
Bosmina longirostris (O. F. M.)	X	X	X			X				X	X	X	X	X	X	X
B. spp. Baird	X	X		X	X	X	X	X	X	X	X		X	X	X	
Bosminopsis dietersi Richard	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ceriodaphnia lacustris Birge				X						X	X	X	X	X		X
C. spp. Dana	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chydorus spp. Leach				X		X	X	X	X	X		X		X	X	
Daphnia ambigua Scourfield	X	X	X						X	X	X	X		X		
D. catawba Coker									X	X				X		
D. galeata Sars									X							
D. laevis Birge									X							X
D. longiremis Sars									X	X			X	X		X
D. lumholzi Sars				X		X	X	X	X		X	X	X			
D. mendotae (Sars) Birge										X	X	X	X			X
D. parvula Fordyce	X	X	X					X	X	X	X	X	X	X	X	X
D. pulex (de Geer)									X	X						
D. pulicaria Sars									X	X						
D. retrocurva Forbes									X	X	X	X	X		X	X
D. schodleri Sars									X							
D. spp. Mullen	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Diaphanosoma brachyurum (Lievin)										X	X	X	X	X	X	X

Table 4-3 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
D. spp. Fischer	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Eubosmina spp. (Baird)				X												
Holopedium amazonicum Stinge.	X	X	X							X	X	X	X	X	X	
H. gibberum Zaddach			X							X	X					
H. spp. Stingelin	X	X		X	X	X	X	X	X	X			X	X	X	X
Ilyocryptus sordidus (Lieven)	X	X	X													
I. spinifer Herrick												X				
I. spp. Sars					X	X	X				X		X			
Latona setifera (O.F. Muller)				X												
Leptodora kindtii (Focke)	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Leydigia spp. Freyberg						X	X	X	X	X						X
Moina spp. Baird				X												
Monospilus dispar Sars																X
Pleuroxus hamulatus Birge																X
P. spp. Baird																X
Sida crystallina O. F. Muller	X		X	X	X											
Simocephalus expinosus					X											
Simocephalus spp. Schodler												X				
ROTIFERA																
Anuraeopsis spp. Lauterborne	X	X	X	X	X	X		X		X		X				
Asplanchna brightwelli Gosse											X		X			
A. priodonta Gosse											X	X	X			
A. spp. Gosse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brachionus caudata Barr. & Daday	X	X	X													
B. bidentata Anderson																X
B. havanensis Rousselet	X	X	X							X						
B. patulus O. F. Muller	X	X	X								X					
B. spp. Pallas				X		X		X	X		X					
Chromogaster ovalis (Bergendel)										X	X	X		X		
C. spp. Lauterborne	X	X	X	X	X	X	X	X	X							
Collotheca balatonica Harring									X	X	X	X	X		X	X
C. mutabilis (Hudson)									X	X	X	X	X			X
C. spp. Harring	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Colurella spp. Bory de St. Vincent									X							
Conochiloides dossuarius Hudson										X	X	X	X	X	X	X
C. spp. Hlava	X	X	X	X	X	X	X	X	X	X				X		X
Conochilus unicornis (Rousselet)	X	X	X							X	X	X	X	X	X	X
C. spp. Hlava	X	X	X	X	X	X	X	X	X	X				X	X	
Filinia spp. Bory de St. Vincent						X	X				X					
Gastropus stylifer Imhof											X	X	X	X		
G. spp. Imhof	X	X	X		X	X	X	X	X	X	X			X		
Hexarthra mira Hudson										X	X	X	X		X	
H. spp. Schmada	X	X	X	X	X	X	X	X	X	X				X		
Kellicottia bostoniensis (Rousselet)	X	X	X				X	X	X	X	X	X	X	X	X	X
K. longispina Kellicott										X	X	X	X	X	X	X
K. spp. Rousselet	X	X	X	X	X	X	X	X	X	X				X	X	X
Keratella cochlearis												X	X			
K. taurocephala Myers										X		X				

Table 4-3 (continued)

TAXON	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
K. spp. Bory de St. Vincent	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Lecane spp. Nitzsch	X	X	X		X		X	X		X	X		X		X	X
Macrochaetus subquadratus Perty										X	X					
M. spp. Perty	X	X	X	X		X			X			X	X		X	
Monostyla stenroosi (Meissener)	X		X													
M. spp. Ehrenberg	X	X	X				X	X	X		X					X
Notholca spp. Gosse							X		X		X					
Platyias patulus Harring															X	
Ploeosoma hudsonii Brauer				X			X	X	X	X	X	X	X	X	X	X
P. truncatum (Levander)	X	X	X				X	X	X	X	X	X	X	X	X	X
P. spp. Herrick	X	X	X	X	X	X	X	X	X		X			X		
Polyarthra euryptera (Weirzeijski)	X	X	X								X					
P. major Burckhart										X		X	X		X	X
P. vulgaris Carlin	X	X	X							X		X	X	X	X	X
P. spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pompholyx spp. Gosse									X							
Ptygura libra Meyers										X	X		X		X	X
P. spp. Ehrenberg	X	X	X		X	X	X	X	X	X					X	X
Synchaeta spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichocerca capucina (Weireijski)	X	X	X				X	X	X	X	X				X	
T. cylindrica (Imhof)	X	X	X					X	X	X	X	X	X		X	X
T. longiseta Schrank										X						
T. multicrinis (Kellicott)											X	X	X		X	X
T. porcellus (Gosse)								X	X	X		X	X		X	
T. pusilla Jennings										X						
T. similis Lamark								X								
T. spp. Lamark	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichotria spp. Bory de St. Vincent									X						X	
ROTIFERA (continued)																
Unidentified Bdelloida	X	X	X		X	X	X			X	X	X				
Unidentified Rotifera				X	X	X	X	X	X	X	X	X	X			
INSECTA																
Chaoborus spp. Lichtenstein	X	X	X	X	X	X					X	X		X	X	
OSTRACODA (unidentified)											X					X

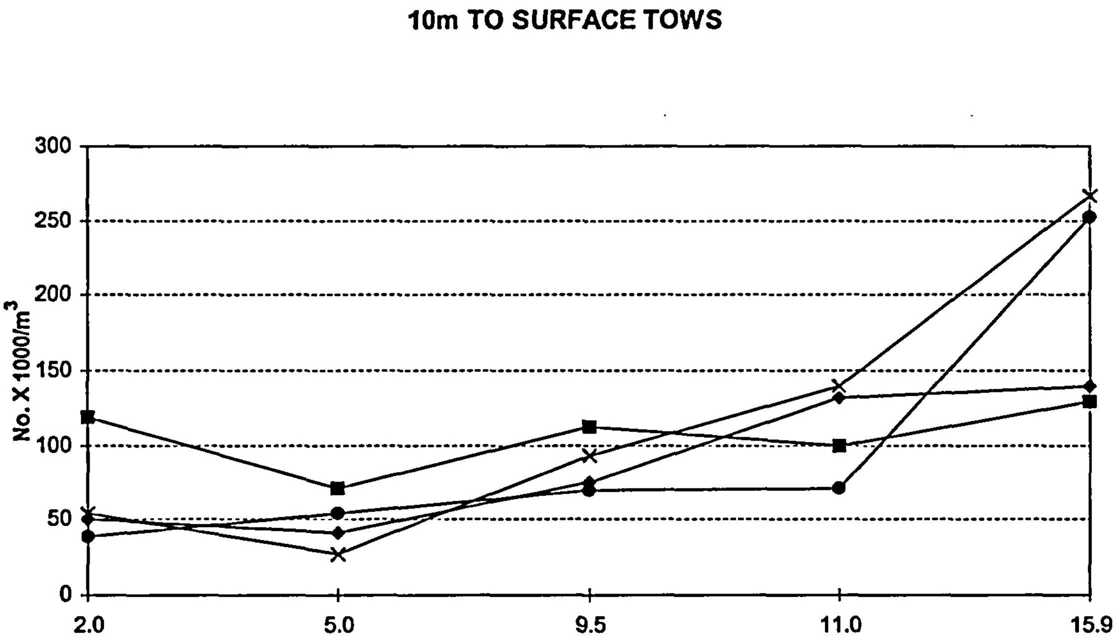
Table 4-4. Dominant taxa among copepods (adults), cladocerans, and rotifers, and their percent composition (in parentheses) of copepod, cladoceran and rotifer densities in Lake Norman samples during 2003.

	FEBRUARY	MAY	AUGUST	NOVEMBER
		COPEPODA	EPILIMNION	
2.0	*Epishura* (3.3)*	*Epishura* (2.7)	*Tropocyclops* (3.4)*	*Tropocyclops* (10.3)
5.0	*Epish./Tropocy* (2.0 ea.)	*Epish./Tropocy* (3.0 ea.)	*Tropocyclops* (11.8)	*Mesocyclops* (1.3)
9.5	*Epishura* (6.6)	*Mesocyclops* (1.4)	*Tropocyclops* (4.0)	*Tropocyclops* (2.6)
11.0	*Tropocyclops* (1.3)	*Mesocyclops* (11.2)	*Tropocyclops* (6.4)*	*Tropocyclops* (2.8)
15.9	*Cyclops/Tropo* (1.3 ea.)	*Cyclops* (5.3)	*Tropocyclops* (2.4)	*Tropocyclops* (6.8)*
		COPEPODA	WHOLE COLUMN	
2.0	*Cyclops* (2.8)	*Mesocyclops* (5.2)	*Tropocyclops* (12.1)	*Tropocyclops* (6.7)
5.0	*Tropocyclops* (8.1)	*Epishura* (6.9)	*Tropocyclops* (11.5)	*Tropocyclops* (7.6)
9.5	*Epishura* (6.4)	*Mesocyclops* (10.7)	*Tropocyclops* (13.0)	*Tropocyclops* (5.2)
11.0	*Cyclops* (2.5)	*Mesocyclops* (12.0)	*Tropocyclops* (4.5)	*Mesocyclops* (9.2)
15.9	*Cyclops* (2.5)	*Mesocyclops* (5.3)	*Tropocyclops* (2.1)	*Tropocyclops* (4.2)*
		CLADOCERA	EPILIMNION	
2.0	*Bosmina* (99.2)	*Diaphanosoma* (80.9)	*Bosminopsis* (84.6)	*Bosmina* (87.9)
5.0	*Bosmina* (98.0)	*Diaphanosoma* (82.9)	*Bosminopsis* (96.6)	*Bosmina* (83.4)
9.5	*Bosmina* (90.0)	*Diaphanosoma* (81.2)	*Bosminopsis* (70.4)	*Bosmina* (88.2)
11.0	*Bosmina* (95.1)	*Diaphanosoma* (71.7)	*Bosminopsis* (83.1)	*Bosmina* (75.7)
15.9	*Bosmina* (100.0)	*Daphnia* (39.7)	*Bosminopsis* (81.8)	*Bosmina* (94.2)
		CLADOCERA	WHOLE COLUMN	
2.0	*Bosmina* (98.2)	*Diaphanosoma* (91.1)	*Bosminopsis* (62.8)	*Bosmina* (72.4)
5.0	*Bosmina* (96.8)	*Diaphanosoma* (98.1)	*Bosmina* (55.0)	*Bosmina* (58.3)
9.5	*Bosmina* (92.1)	*Diaphanosoma* (81.8)	*Bosminopsis* (66.6)	*Bosmina* (80.6)
11.0	*Bosmina* (92.4)	*Diaphanosoma* (53.2)	*Bosminopsis* (54.3)	*Diaphanosoma* (44.7)
15.9	*Bosmina* (97.5)	*Daphnia* (41.3)	*Bosminopsis* (69.9)	*Bosmina* (80.0)

Table 4-4 (continued)

	FEBRUARY	MAY	AUGUST	NOVEMBER
		ROTIFERA	**EPILIMNION**	
2.0	*Polyarthra* (44.1)	*Polyarthra* (92.4)	*Conochilus* (37.7)	*Polyarthra* (55.4)
5.0	*Synchaeta* (66.5)	*Polyarthra* (96.6)	*Keratella* (26.6)	*Keratella* (41.2)
9.5	*Polyarthra* (47.3)	*Polyarthra* (93.7)	*Conochilus* (41.4)	*Polyarthra* (67.6)
11.0	*Keratella* (45.4)	*Polyarthra* (90.1)	*Conochilus* (35.8)	*Polyarthra* (53.0)
15.9	*Asplanchna* (32.7)	*Polyarthra* (43.0)	*Conochilus* (38.0)	*Keratella* (65.6)
		ROTIFERA	**WHOLE COLUMN**	
2.0	*Keratella* (45.2)	*Polyarthra* (93.4)	*Polyarthra* (40.2)	*Polyarthra* (48.4)
5.0	*Synchaeta* (62.8)	*Polyarthra* (94.1)	*Polyarthra* (29.7)	*Polyarthra* (35.8)
9.5	*Polyarthra* (45.2)	*Polyarthra* (90.1)	*Conochilus* (33.9)	*Polyarthra* (59.5)
11.0	*Keratella* (65.9)	*Polyarthra* (82.5)	*Conochilus* (29.4)	*Polyarthra* (45.3)
15.9	*Polyarthra* (33.7)	*Polyarthra* (40.5)	*Keratella* (34.9)	*Keratella* (54.7)

* = Only adults present in samples.



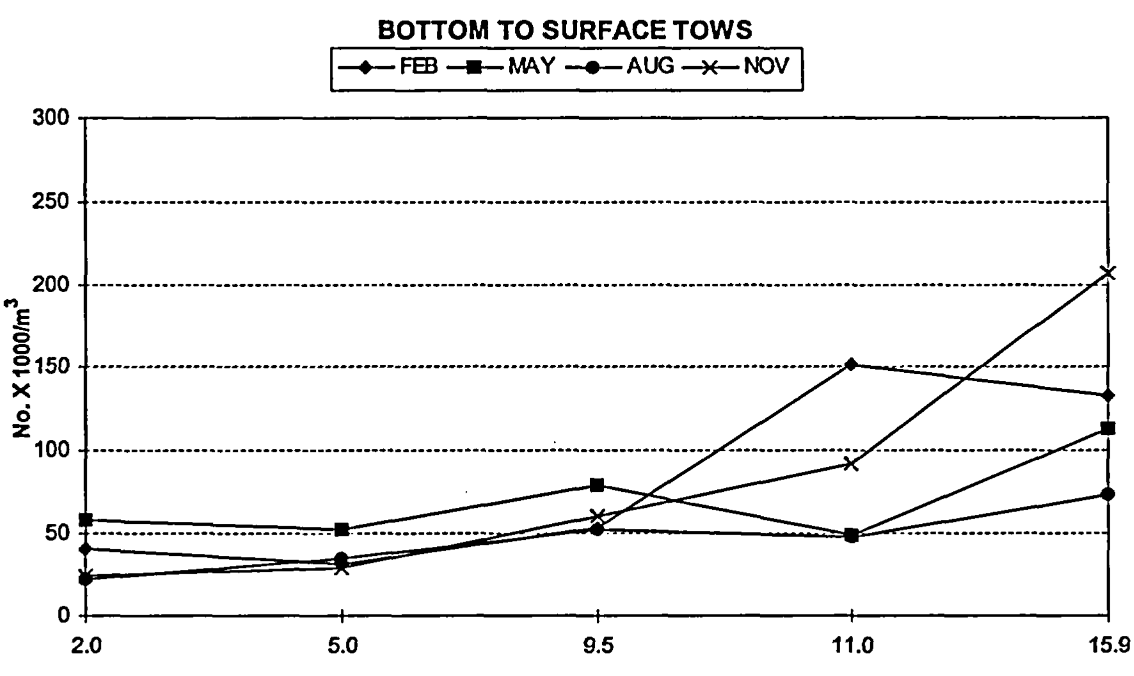


Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman, NC, in 2003.

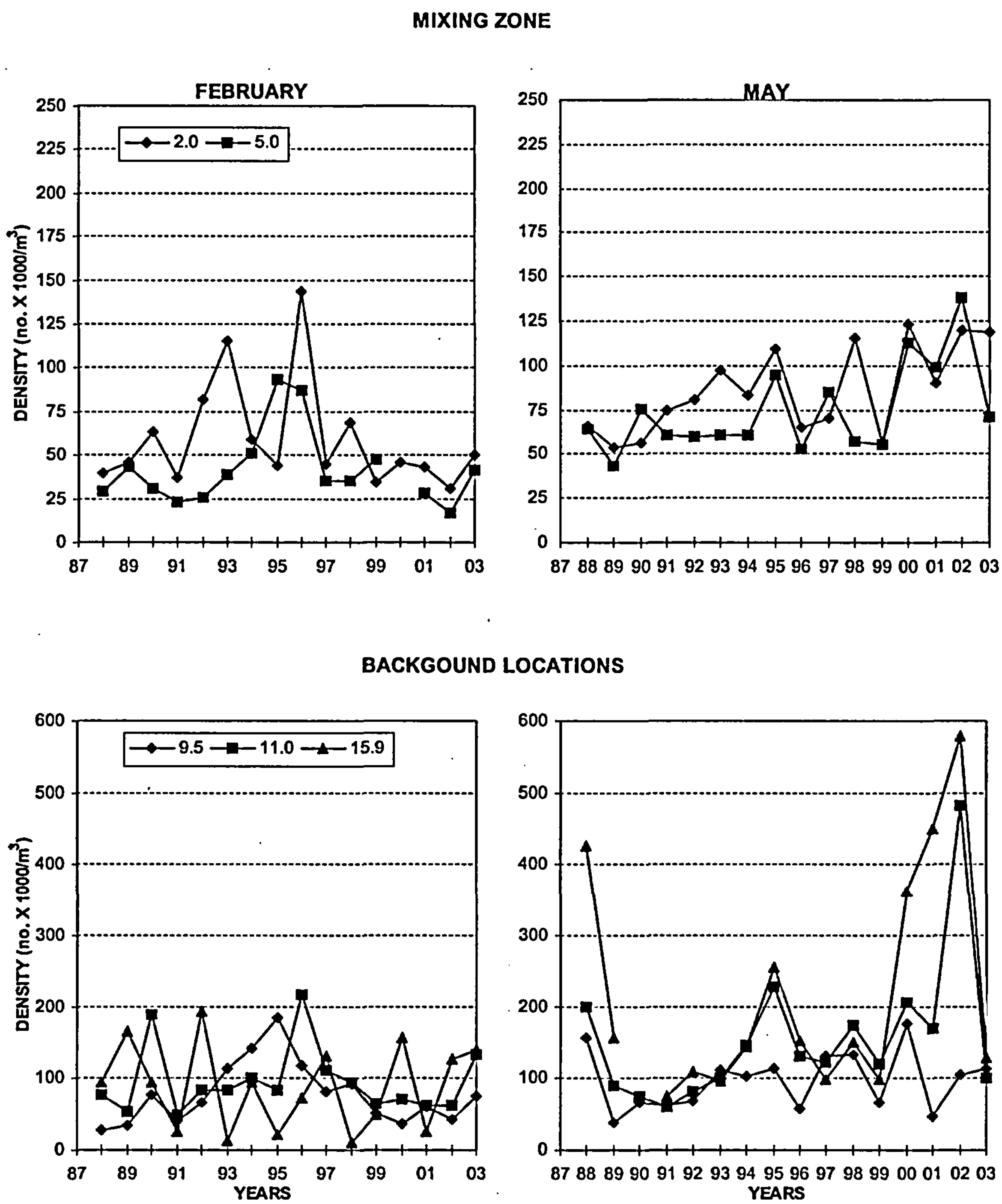


Figure 4-2. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in February and May of 1988 through 2003.

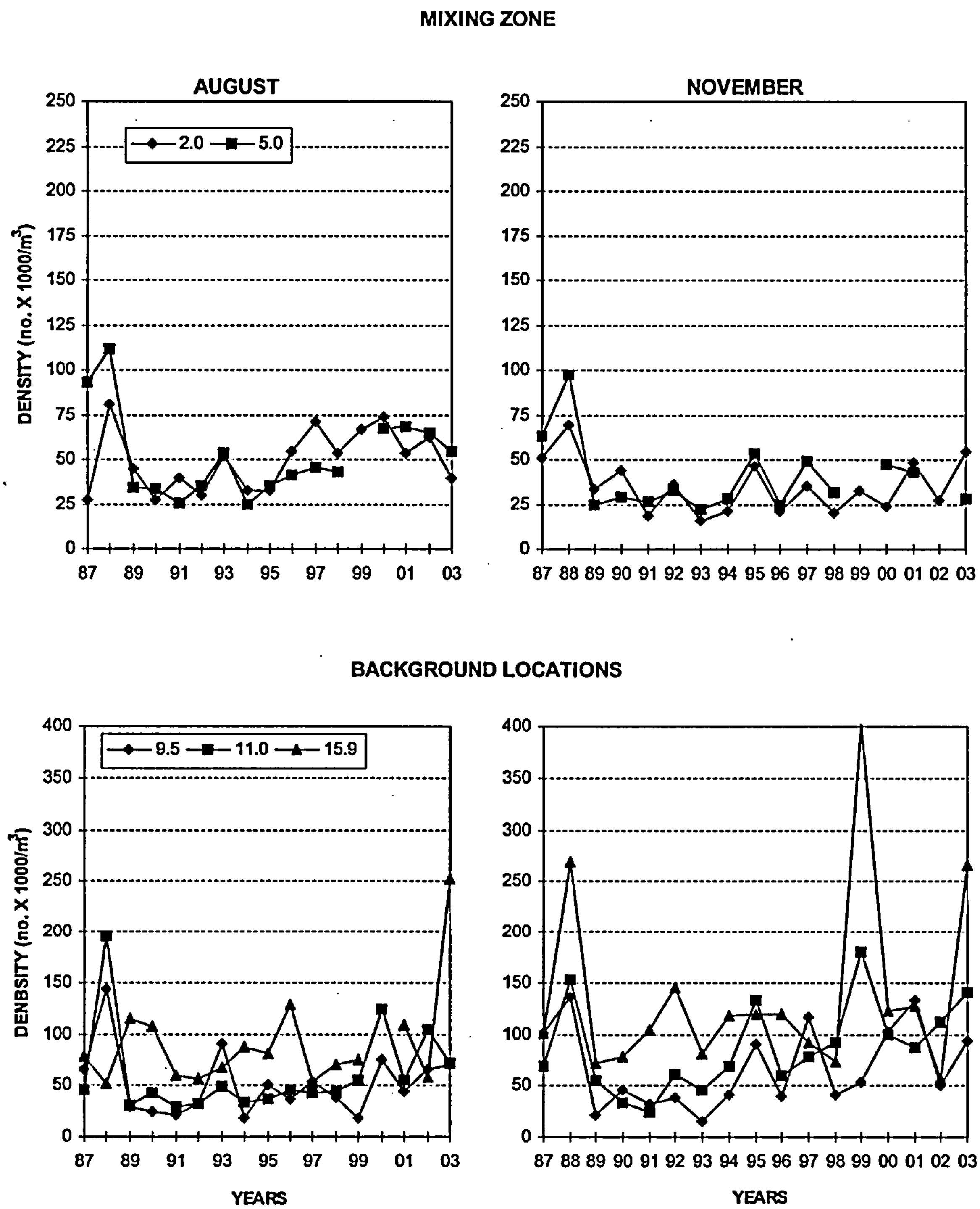


Figure 4-3. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in August and November of 1987 through 2003.

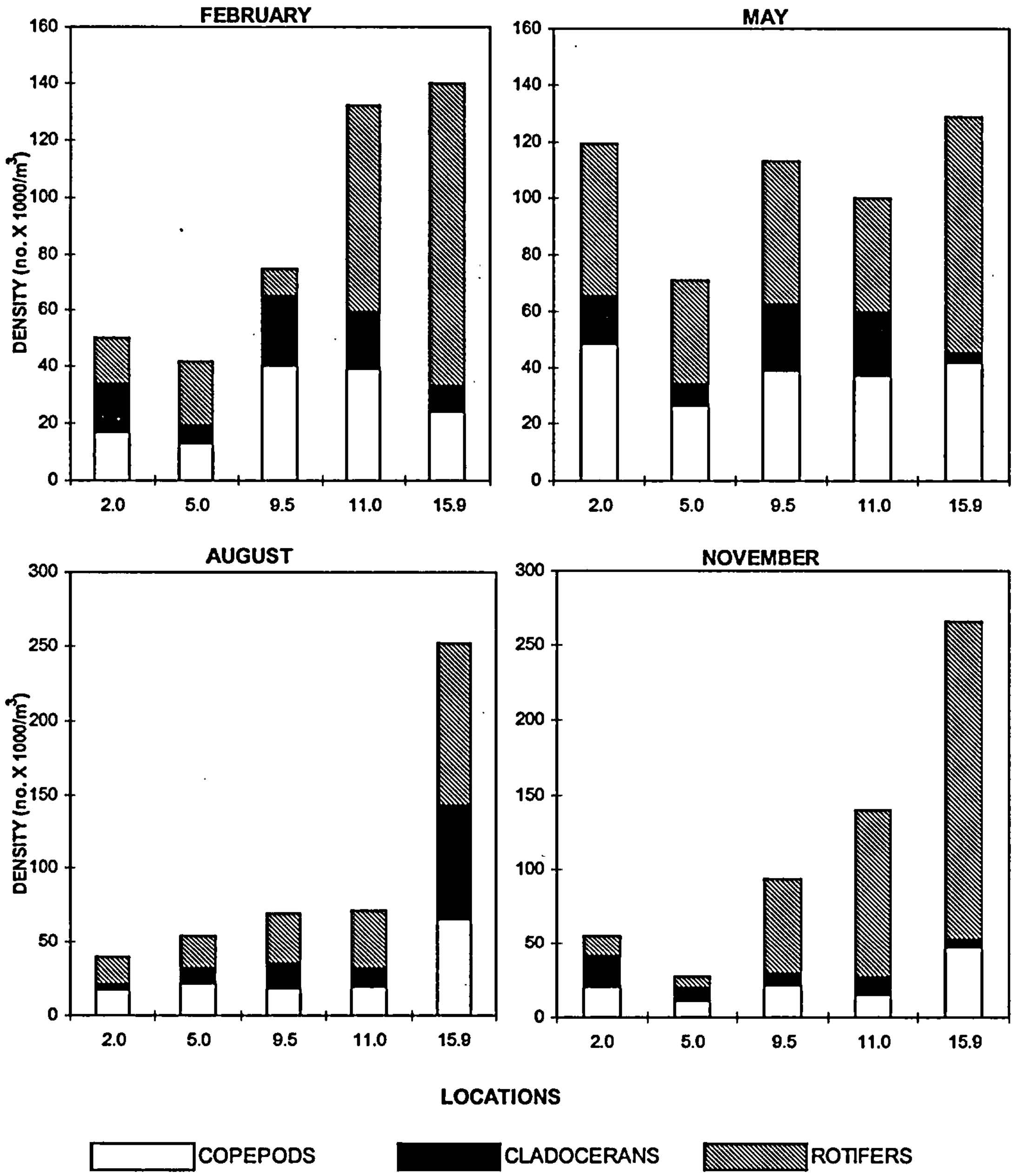


Figure 4-4. Zooplankton community composition by month for epilimnetic samples collected in Lake Norman, NC, in 2003.

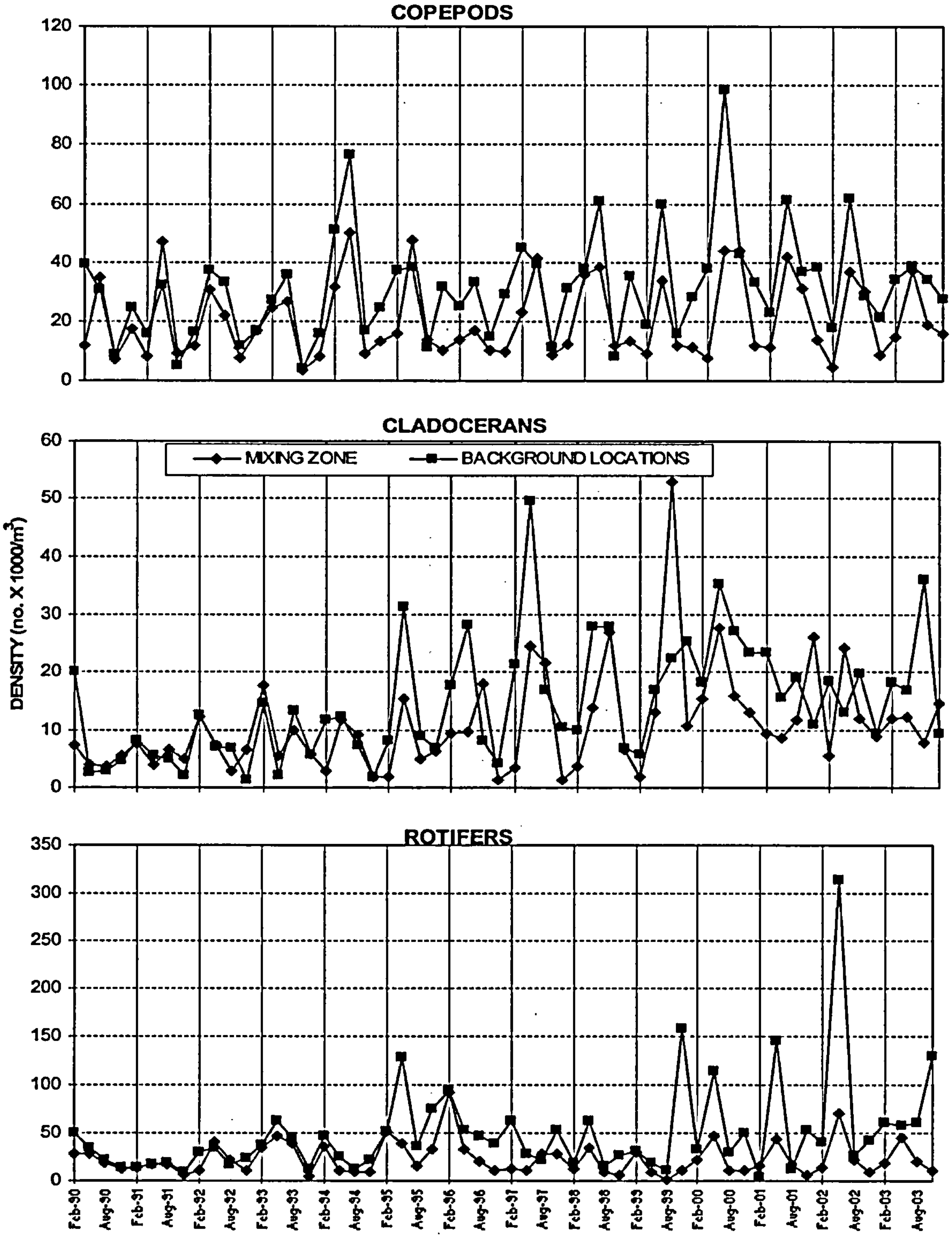


Figure 4-5. Zooplankton composition by quarter for epimlimnetic samples collected in Lake Norman, NC, from 1990 through 2003.

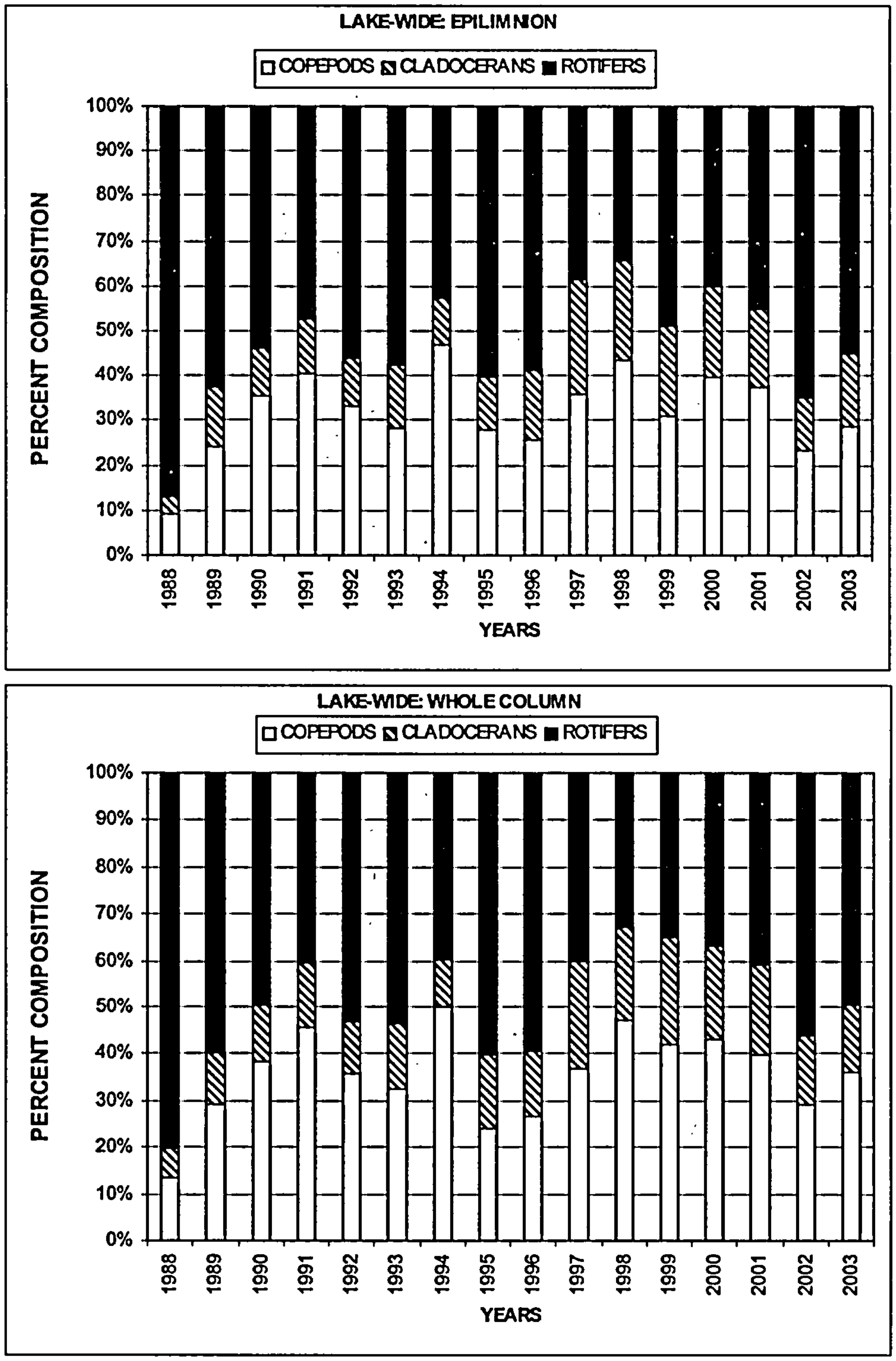
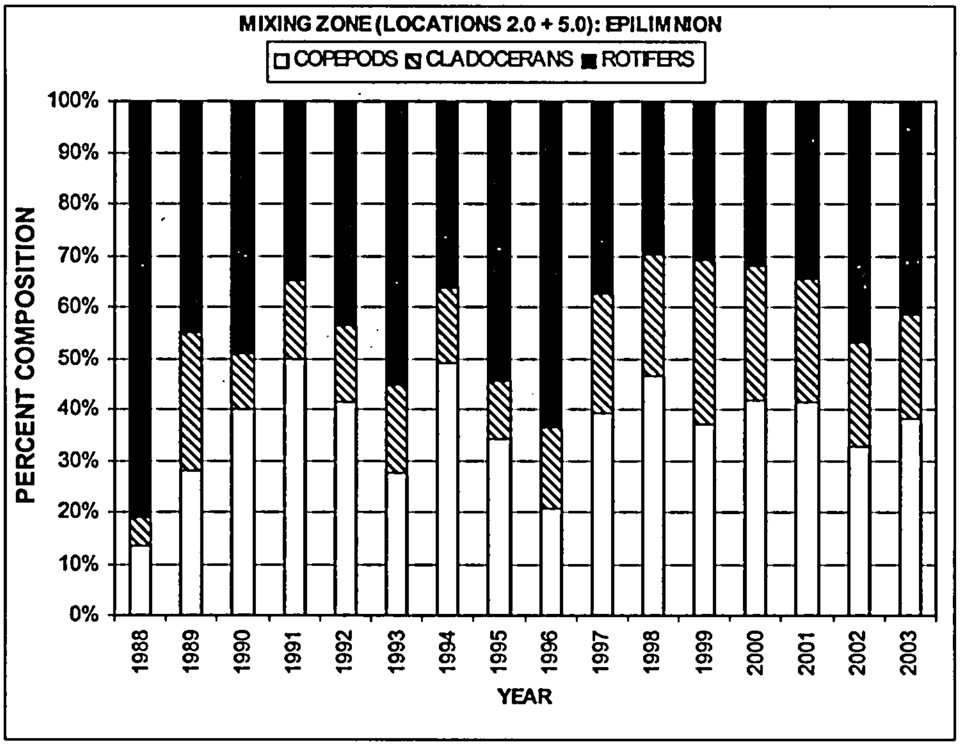


Figure 4-6. Annual lake-wide percent composition of major zooplankton taxonomic groups from 1988 through 2003 (Note: Does not include Location 5.0 in November 2002).



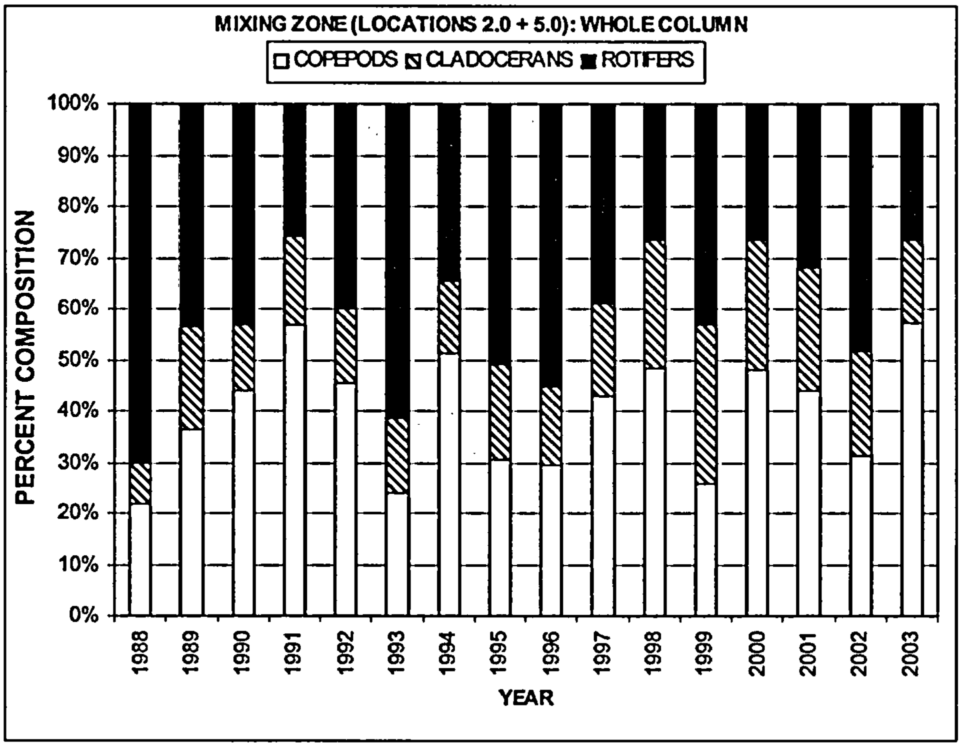


Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from Mixing Zone Locations: 1988 through 2003 (Note: Does not include Location 5.0 in November 2002).

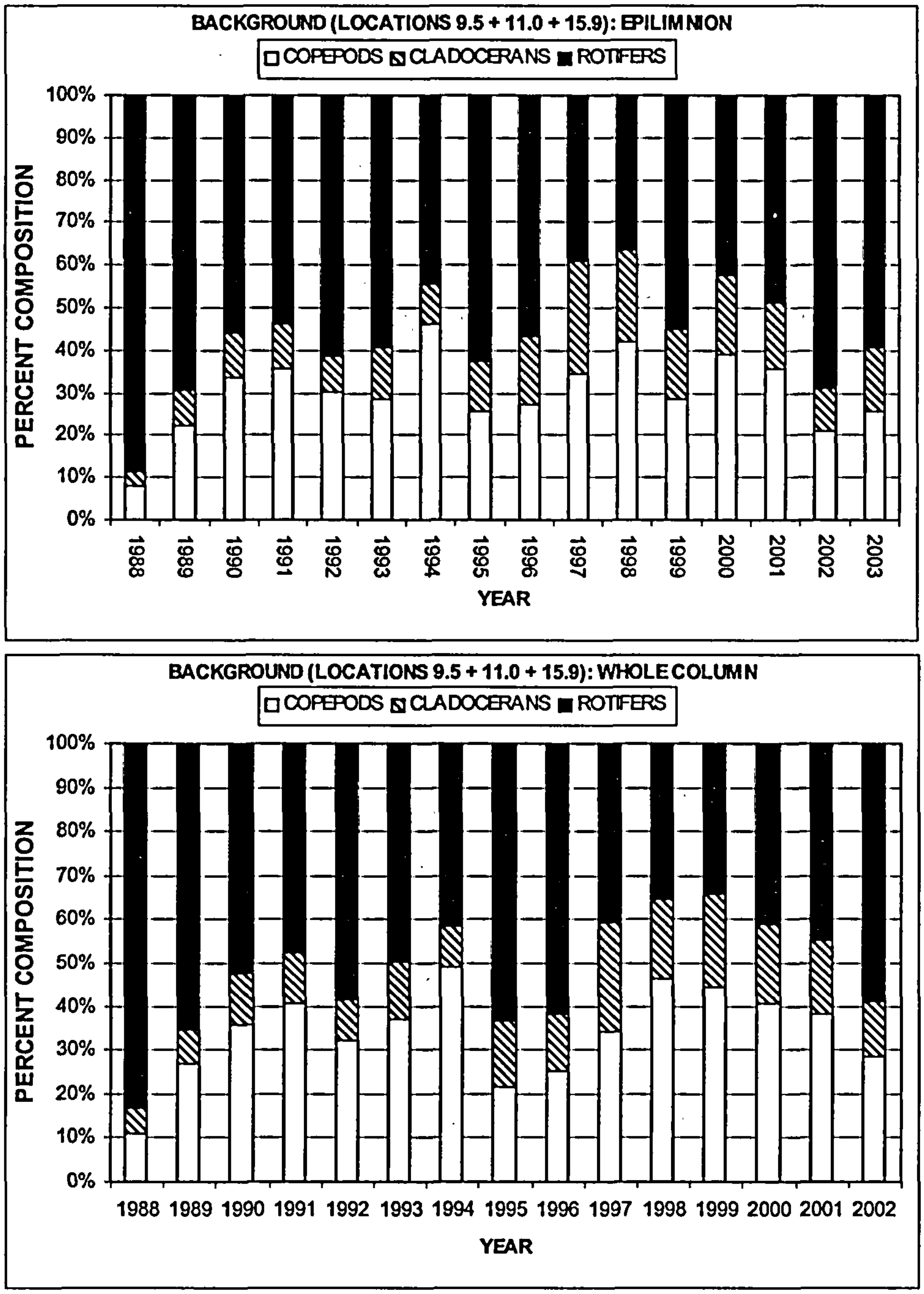


Figure 4-8. Annual percent composition of major zooplankton taxonomic groups from Background Locations: 1988 through 2003.

CHAPTER 5

FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters continued during 2003. The components of this portion of the Lake Norman Maintenance Monitoring Program were to continue:

1. spring electrofishing surveys of littoral fish populations with emphasis on age, growth and relative weight (Wr) of largemouth bass (scientific names of fish mentioned in this chapter are listed in Table 5-1);
2. summer striped bass mortality monitoring;
3. cooperative striped bass study with the North Carolina Wildlife Resources Commission (NCWRC) with emphasis on age, growth and Wr;
4. cooperative trap-net surveys with NCWRC for white crappies and black crappies, with emphasis on age and growth;
5. small mesh gill-net surveys to determine prey fish abundance and size distributions in tributary arms;
6. fall hydroacoustic and purse seine surveys of pelagic prey fish to determine their abundance and species composition.

METHODS AND MATERIALS

Spring electrofishing surveys were conducted in April at three locations: (1) near the Marshall Steam Station (MSS) in Zone 4, (2) a reference (REF) area located between MNS and MSS in Zone 3 and (3) near the MNS in Zone 1 (Fig. 5-1). The locations sampled in 2003 were the same sampled since implementation of this sampling program in 1993 and consisted of ten 300-m transects in each location. All transects include the various types of fish habitat in Lake Norman. 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, when water temperatures generally ranged from 59 to 68 °F (15 to 20 °C). All stunned fish collected were identified to species and, except for largemouth bass and spotted bass, were counted and weighed (g) in aggregate by taxon. Individual total lengths (mm) and weights were obtained for all largemouth bass and spotted bass collected. Sagittal otoliths were removed from all largemouth bass and sectioned for age determination (Devries and Frie 1996). Growth rates were calculated as the mean length for all fish of the same age. Relative weight was calculated for all largemouth bass ≥ 150 mm, using the formula Wr = (W/Ws) x 100, where W = weight of the individual fish (g) and Ws = length-specific mean weight (g) for a fish as predicted by a weight-length equation for that fish (Anderson and Neumann 1996).

Mortality surveys for striped bass were conducted weekly from July 3 through September 5. Roving surveys were conducted to specifically search for dead or dying striped bass in Zones 1-4. The location of each dead or dying fish was noted along with its total length.

Striped bass for age, growth and Wr calculations were collected at a local fishing tournament in late November and gill-net surveys conducted in early December by NCWRC and Duke Power (DP) personnel. Individual total lengths and weights were obtained, and sagittal otoliths were removed from each striped bass. Age, growth and Wr were determined for these striped bass as described earlier for largemouth bass.

White crappie and black crappie populations in Lake Norman were sampled cooperatively by the NCWRC and DP in late October using trap nets as described by Barwick and Dorsey (2003) for samples collected from this lake in 2001. Total lengths and weights were obtained for all collected white and black crappies, and sagittal otoliths were removed from most fish for age and growth determinations.

Prey fish populations (i.e., alewives, threadfin shad and gizzard shad) inhabiting Lake Norman tributary arms were sampled in September, using small-mesh gill nets. These experimental gill nets were 45.7 m long x 2.7 m deep containing one 7.6-m panel of 10-, 13-, 19-, 25-, 32- and 38-mm mesh (square measure). Six nets were set overnight in uplake (Zone 5), Davidson Creek (Zone 2) and MNS (Zone 1) areas. All fish caught were identified to species, enumerated and measured for total length.

The abundance and distribution of pelagic prey fish in Lake Norman was determined using mobile hydroacoustic techniques (Brandt 1996). This survey of the entire lake was begun on September 9 and completed on September 14, and employed multiplexing, side-scan and down-looking transducers to detect surface-oriented fish and deeper fish (from 2 m below the water surface to the bottom), respectively. Both transducers were capable of determining target strength directly, by measuring fish position relative to the acoustic axis. The lake was divided into six zones (Fig. 5-1), due to its large size, spatial heterogeneity and multiple power generation facilities and estimates were generated by zone. Prey fish abundance was determined for each zone (product of fish density in fish/ha and area of the zone) and summed across all zones to generate a lake-wide estimate of prey fish abundance.

Purse seine samples (one haul from each sampled zone) were collected on September 8 in Zones 1, 2 and 5 in Lake Norman (Fig. 5-1). The purse seine measured 118 m long x 9 m deep with 4.8-mm mesh. A subsample of prey fish collected from each zone was used to determine lake-wide taxa composition and size distributions.

RESULTS AND DISCUSSION

Numbers and biomass of fish collected from Lake Norman in 2003 spring electrofishing surveys varied among sampling locations (Table 5-2). A total of 3,277 fish (24 species and 1 hybrid complex) weighing 387 kg was collected in the MSS area, while 2,349 fish (24 species and 1 hybrid complex) weighing 115 kg were collected in the REF area and 2,640 fish (14 species and 2 hybrid complexes) weighing 57 kg were collected in the MNS area. Greenfin shiners, whitefin shiners, spottail shiners, redbreast sunfish, warmouth, bluegills, redear sunfish, hybrid sunfish and largemouth bass dominated all samples numerically while redbreast sunfish, bluegills and largemouth bass generally dominated all samples gravimetrically.

Numbers of fish collected in the spring of 2003 were highest in the MSS area, intermediate in the MNS area and lowest in the REF area. However, fish biomass was highest in the MSS area, intermediate in the REF area and lowest in the MNS area. Since 1993, numbers of fish collected have varied annually from area to area (Fig. 5-2) with no apparent trend in abundance. On the other hand, biomass has been relatively stable during 1993-2003 and was usually highest in the MSS or REF areas and lowest in the MNS area. The exceptionally high numbers and biomass of common carp collected at the MSS area in 2003 was unusual and greatly inflated overall biomass estimates at this location in 2003. Apparently, common carp spawning was at its peak on the day that this area was sampled, and large numbers of fish were inshore, where they were available to electrofishing. Nevertheless, trends observed in biomass estimates obtained in the electrofishing surveys continue to support the spatial heterogeneity theory advanced by Siler et al. (1986), indicating that fish populations are generally higher in uplake Lake Norman versus downlake, because of higher nutrient levels and resulting productivity uplake.

In 2003, more emphasis was directed to largemouth bass dynamics in Lake Norman than in past years. This was due to observed declines in largemouth bass catch rates in the annual spring electrofishing surveys, especially in the MNS area (Fig. 5-3). The number of largemouth bass collected in 2001 through 2003 was the lowest number collected in any previous three-year period. These declines in largemouth bass catch rates appear to have begun in 2000 and are noticeable in all sampling areas. Even though there has been a decline in largemouth bass catch rates, biomass has remained similar in most areas, with the MNS area being somewhat an exception. Such declines in abundance and not in biomass, indicate that largemouth bass growth rates in Lake Norman have increased in recent years as catch rates declined.

Mean total lengths at age for Lake Norman largemouth bass collected in 2003 are presented in Table 5-3. Mean lengths of fish were generally similar in the MSS and MNS areas at all ages. However, mean lengths calculated for age 1 and age 2 largemouth bass from the REF area were considerably lower than noted in the MSS and MNS areas. Largemouth bass mean lengths for age 3 and older fish were similar in all sampling areas. Comparisons of mean length at age in 2003 with that reported for largemouth bass from comparable areas of Lake Norman in the 1970's (Table 5-4) does indicate that growth may have improved, especially for age 1 and 2 fish. In 2003, size distributions (Fig. 5-4) and Wr's (Fig. 5-5) for largemouth bass in Lake Norman were generally similar in all sampled areas. Declines in largemouth bass recruitment may be responsible for the observed decline in catch rates. It is possible that recent invasions and expanding populations of alewives and white perch have resulted in increased predation on largemouth bass eggs and juveniles (e.g., Kohler and Ney 1980, Madenjian et al. 2000), and resulted in the decline noted in the numbers of largemouth bass in Lake Norman. This decline in largemouth bass numbers may have reduced competition for food among surviving largemouth bass and contributed to their increased growth rates. Relatively high numbers of largemouth bass <150 mm long and slower growth rates in the REF area may indicate somewhat higher recruitment here than in the MSS and MNS areas of Lake Norman.

Striped bass mortality surveys in Lake Norman noted few dead or dying fish in 2003 (Table 5-5). Only 10 dead fish ranging in total length from 345 to 575 mm were observed, and this was comparable to the 6 observed in 2002 (Duke Power 2004). Six of these fish were found in Zone 1, and the remaining fish were from uplake.

One hundred forty-four striped bass were collected in November and December 2003 for age, growth and Wr evaluations (Fig. 5-6). Mean total length at age was 437, 516, 572, 585, 578, 583, 591 and 737 mm at ages 1-7 and at age 9, respectively. Growth of Lake Norman striped bass was slow after age 3 and was associated with the lowest Wr's noted for this species. Progressive declines in Wr were noted annually through age 4 or age 5. Afterwards, Wr improved somewhat in older fish. Overall, mean Wr of all fish in 2003 was 81 (ranged from 56 to 102) and was identical to that noted for Lake Norman striped bass in the fall of 2002 (Duke Power 2004).

Duke Power and the NCWRC collected 348 crappies in 90 trap-net samples from Lake Norman in 2003. All data were sent to the NCWRC for analyses.

In 2003, 2,047 fish were collected in the small-mesh gill nets (Table 5-6). Catches were highest uplake, intermediate in Davidson Creek and lowest downlake. Threadfin shad and white perch dominated the catches in all areas. Alewives were most abundant uplake, with only a few being caught in Davidson Creek, and no alewives were collected downlake. Catches of threadfin shad were similar uplake and in Davidson Creek, and lowest downlake. A few gizzard shad were caught upake and in Davidson Creek, and no gizzard shad were collected downlake. Alewives and gizzard shad were generally most abundant in 70 to 89 mm and 80 to 99 mm size groups, respectively (Fig. 5-7). However, threadfin shad exhibited a bimodal size distribution with peak abundances at 70 to 79 mm and 90 to 109 mm size groups (Fig. 5-6).

Pelagic prey fish densities in Lake Norman's 6 sampling zones ranged from 1,800 to 13,158 fish/ha in September 2003 (Table 5-7). Fish densities were highest in Zone 5, intermediate in Zone 2, similar but lower in Zones 1, 3, and 4 and lowest in Zone 6. The large amount of unsampleable habitat (i.e., shallow water where physical damage to the transducers by collision with the bottom is a high probability) in Zone 6 complicated any discussion of fish densities in this uppermost zone of Lake Norman. The estimated lake-wide population was 85.7 million fish. This population estimate of pelagic prey fish in Lake Norman during September 2003 was similar to estimates obtained here from 1997 to 2002 (64.3 to 91.3 million fish).

Purse seine samples indicated that the pelagic prey fish populations in Lake Norman in 2003 were comprised of 82.6 % threadfin shad, 17.3 % alewives and 0.1 % gizzard shad (Table 5-8). Threadfin shad lengths primarily ranged from 36 to 70 mm while alewife lengths ranged from 36 to 85 mm. The two length frequency distributions overlapped with a modal length between 46 and 50 mm (Figure 5-8). Pelagic prey fish populations in Lake Norman have undergone a dramatic shift in species composition during recent years. From 1993 through 1999, purse seine samples were composed almost entirely of small threadfin shad (typically ≤ 55 mm). Alewives were first collected in purse seine samples in Lake Norman in 1999. From 2000 through 2003, alewives have gradually increased in abundance in the pelagic prey fish community and now comprise about 20% of the population.

FUTURE STUDIES

No changes are planned for the fish portion of the Lake Norman Maintenance Monitoring Program.

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 2003. Spring electrofishing indicated that 14 to 24 species of fish and 2 hybrid complexes comprised fish populations in the 3 sampling locations, and that numbers and biomass of fish in 2003 were generally similar to those previously noted since 1993. Few dead striped bass were observed during the summer survey period, indicating no major die-offs occurred in 2003. Mean Wr for Lake Norman striped bass collected in November and December was similar to that observed previously and indicated little change in the overall condition of this fish. Small-mesh gillnetting and hydroacoustic sampling indicated that prey fish are distributed throughout the lake and pelagic populations were similar to those noted in Lake Norman since 1997.

LITERATURE CITED

Anderson, R. A., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Barwick, B., and L. Dorsey. 2003. Population dynamics of black crappies in Lake Norman. Survey Report, Federal Aid in Fish Restoration Project F-23-S. North Carolina Wildlife Resources Commission, Raleigh, North Carolina.

Brandt, S. B. 1996. Acoustic assessment of fish abundance and distribution. Pages 385-432 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Devries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483-512 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Duke Power. 2004. Lake Norman maintenance monitoring program: 2002 summary. Duke Power, Charlotte, North Carolina.

Kohler, C. C., and J. J. Ney. 1980. Piscivority in a land-locked alewife (*Alosa pseudohargenus*) population. Canadian Journal of Fisheries and Aquatic Sciences 37:1314-1317.

Madenjian, C. P., R. L. Knight, M. T. Bur, and J. L. Forney. 2000. Reduction in recruitment of white bass in Lake Erie after invasion of white perch. Transactions of the American Fisheries Society 129:1340-1353.

Siler, J. R. 1981. Growth of largemouth bass, bluegill, and yellow perch in Lake Norman, North Carolina--A summary of 1975 through 1979 collections. Research Report PES/81-6. Duke Power Company, Huntersville, North Carolina.

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

Table 5-1. Common and scientific names of fish collected in Lake Norman, 2003.

Common name	Scientific name
Longnose gar	*Lepisosteus osseus*
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosome cepedianum*
Threadfin shad	*Dorosoma petenense*
Greenfin shiner	*Cyprinella chloristia*
Whitefin shiner	*Cyprinella nivea*
Common carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Spottail shiner	*Notropis hudsonius*
Quillback	*Carpoides cyprinus*
Notchlip redhorse	*Moxostoma collapsum*
Shorthead redhorse	*Moxostoma macrolepidotum*
Blue catfish	*Ictalurus furcatus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Rainbow trout	*Oncorhynchus mykiss*
White perch	*Morone americana*
White bass	*Morone chrysops*
Striped bass	*Morone saxatilis*
Redbreast sunfish	*Lepomis auritus*
Warmouth	*Lepomis gulosus*
Bluegill	*Lepomis macrochirus*
Redear sunfish	*Lepomis microlophus*
Hybrid sunfish	*Lepomis* hybrid
Spotted bass	*Micropterus punctulatus*
Largemouth bass	*Micropterus salmoides*
Hybrid black bass	*Micropterus* hybrid
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Tessellated darter	*Etheostoma olmstedi*
Yellow perch	*Perca flavescens*

Table 5-2. Numbers and biomass of fish collected from electrofishing ten 300-m transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, April 2003.

	MSS		REF		MNS	
Taxa	N	Kg	N	Kg	N	Kg
Longnose gar	1	2.925				
Alewife	42	0.480	12	0.117		
Gizzard shad	20	7.180	17	8.481	2	0.839
Threadfin shad	774	4.537	58	0.326		
Greenfin shiner	30	0.064	50	0.103	64	0.163
Whitefin shiner	90	0.320	226	0.612	145	0.442
Common carp	141	255.456	18	30.245		
Golden shiner	4	0.010	2	0.002	3	0.010
Spottail shiner	12	0.063	192	1.126	16	0.092
Quillback	1	1.166	2	3.030		
Shorthead redhorse	1	0.378				
Blue catfish	1	0.272	1	0.660		
Channel catfish	24	4.790	18	4.773	11	3.936
Flathead catfish	5	4.853			5	1.021
Rainbow trout			1	0.016		
White perch	101	5.194	3	0.392		
White bass	2	0.830	1	0.420		
Striped bass	2	1.096	2	0.270	1	1.370
Redbreast sunfish	336	6.565	392	7.620	544	9.204
Warmouth	78	0.862	57	0.527	128	1.001
Bluegill	1,151	14.561	837	9.200	1,226	12.433
Redear sunfish	182	7.982	221	6.914	231	5.476
Hybrid sunfish	93	2.248	98	1.990	185	3.700
Spotted bass	15	0.752	9	0.544	54	5.460
Largemouth bass	159	64.469	126	36.879	24	10.712
Hybrid black bass					1	0.960
Black crappie			3	1.120		
Tessellated darter			1	0.001		
Yellow perch	12	0.276	2	0.029		
Total	3,277	387.329	2,349	115.397	2,640	56.819

Table 5-3. Mean total lengths (mm) at age for largemouth bass collected from electrofishing ten transects near the Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, April 2003. Numbers of fish used to compute means are in parentheses.

	Age							
Location	1	2	3	4	5	6	7	8
MSS	216 (45)	317 (17)	349 (13)	378 (10)	386 (8)	394 (1)	377 (1)	
REF	139 (52)	296 (20)	358 (7)	390 (4)	367 (3)	370 (2)	394 (5)	399 (1)
MNS	197 (9)	315 (5)	248 (1)	389 (4)	387 (1)	476 (1)	376 (1)	
Weighted mean	177	307	347	383	381	402	389	399

Table 5-4. Comparisons of mean total lengths (mm) at age for largemouth bass collected from areas near Marshall Steam Station (MSS) and near the present location of McGuire Nuclear Station (MNS). Data from 1971-78 are from Siler (1981).

	Age				
Location (Year)	1	2	3	4	5
MSS (1974-78)	170	266	310	377	
MSS (2003)	216	317	349	378	
MNS (1971-78)	134	257	325	376	475
MNS (2003)	197	315	248	389	387

Table 5-5. Dead or dying striped bass observed in Lake Norman, July-August 2003.

Date	Location	Length (mm)	Number
10-Jul	Zone 4	575	1
24-Jul	Zone 1	526	1
	Zone 1	528	1
30-Jul	Zone 3	560	1
7-Aug	Zone 1	522	1
	Zone 3	490	1
	Zone 3	533	1
	Zone 1	502	1
21-Aug	Zone 1	380	1
28-Aug	Zone 1	345	1

Table 5-6. Numbers of fish collected from six small-mesh gill nets set in uplake, Davidson Creek and downlake areas of Lake Norman, September 2003.

	Area			
Taxa	Uplake	Davidson Creek	Downlake*	All
Longnose gar	3		1	4
Alewife	68	3		71
Gizzard shad	28	31		59
Threadfin shad	342	361	82	785
Common carp	2	1		3
Golden shiner		1		1
Quillback	1			1
Notchlip redhorse	1			1
Shorthead redhorse	10			10
Blue catfish	11	2	16	29
Channel catfish	2	11	17	30
Flathead catfish		1	2	3
White perch	230	276	359	865
Striped bass	14	2	1	17
Warmouth	3	2	6	11
Bluegill	2	7		9
Redear sunfish			2	2
Spotted bass			66	66
Largemouth bass		5	4	9
White crappie	1	2		3
Black crappie	44	12	11	67
Yellow perch			1	1
Total	762	717	568	2,047

*Numbers expanded to account for one net that was lost.

Table 5-7. Prey fish densities (N/ha) and population estimates from hydroacoustic surveys of Lake Norman, September 2003.

Zone	Density	Population estimate
1	4,744	10,821,064
2	7,666	23,627,379
3	4,847	16,748,905
4	4,791	5,897,721
5	13,158	27,710,748
6	1,800	860,400
Lakewide		85,666,217
95% Lower confidence interval		79,459,522
95% Upper confidence interval		91,872,912

Table 5-8. Numbers (N), species composition (%) and modal lengths (mm) of prey fish from purse seine samples collected in Lake Norman during late summer or early fall, 1997-2003.

	Year						
	1997	1998	1999	2000	2001	2002	2003
N	6,711	5,723	5,404	4,265	9,652	10,134	33,660
Species composition							
Threadfin shad	99.99	99.95	99.26	87.4	76.47	74.96	82.59
Gizzard shad	0.01	0.05	0.26	0.22	0.01	0	0.14
Alewife	0	0	0.048	12.37	23.52	25.04	17.27
Threadfin shad modal lengths	41-45	41-45	36-40	51-55	56-60	41-45	46-50

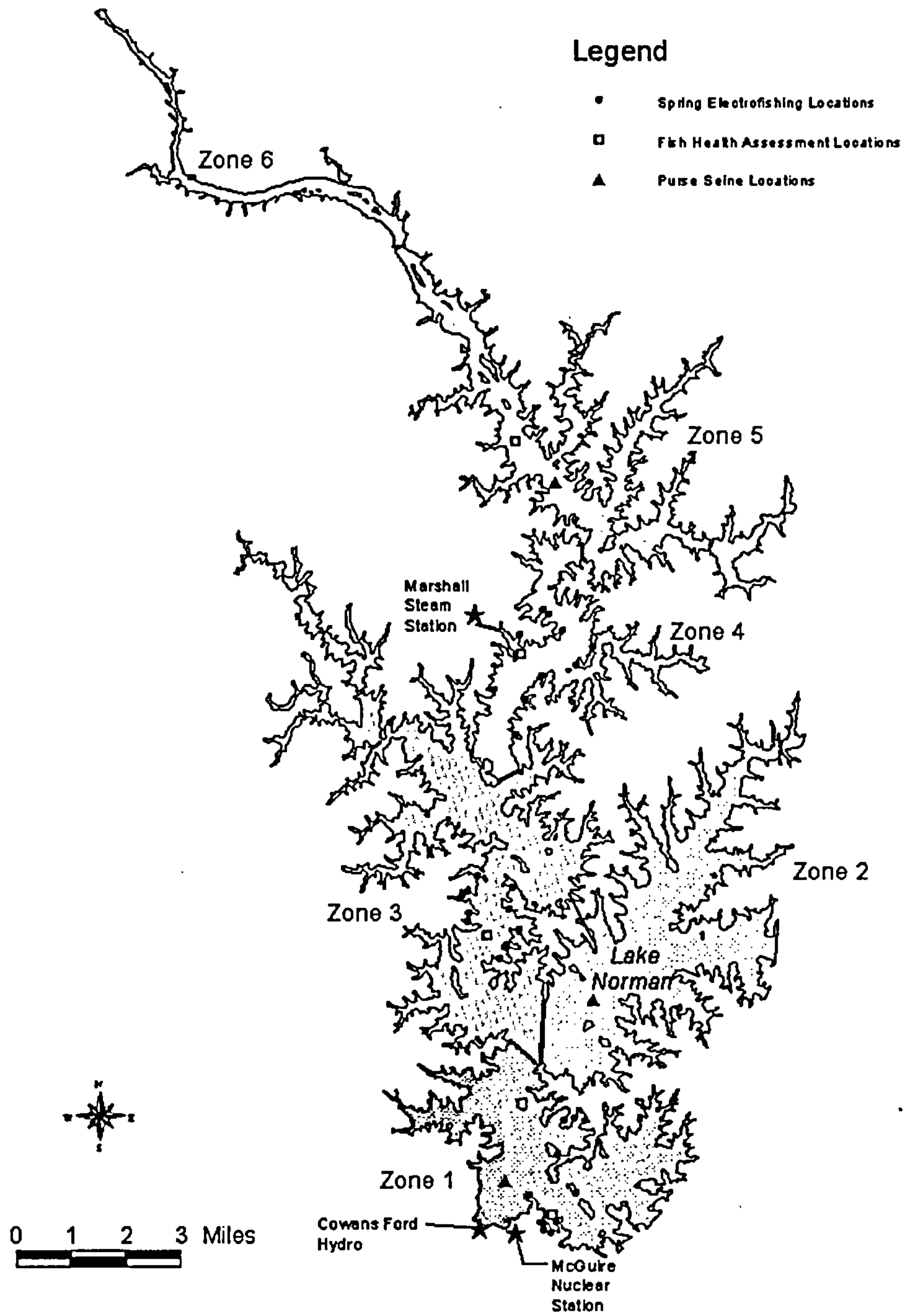
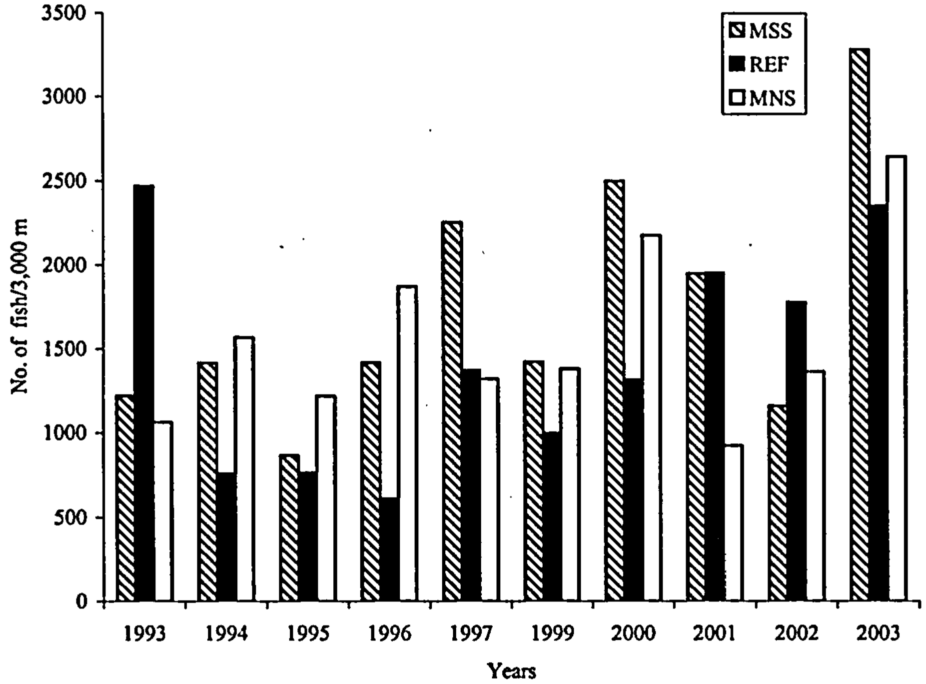


Figure 5-1. Sampling zones on Lake Norman.



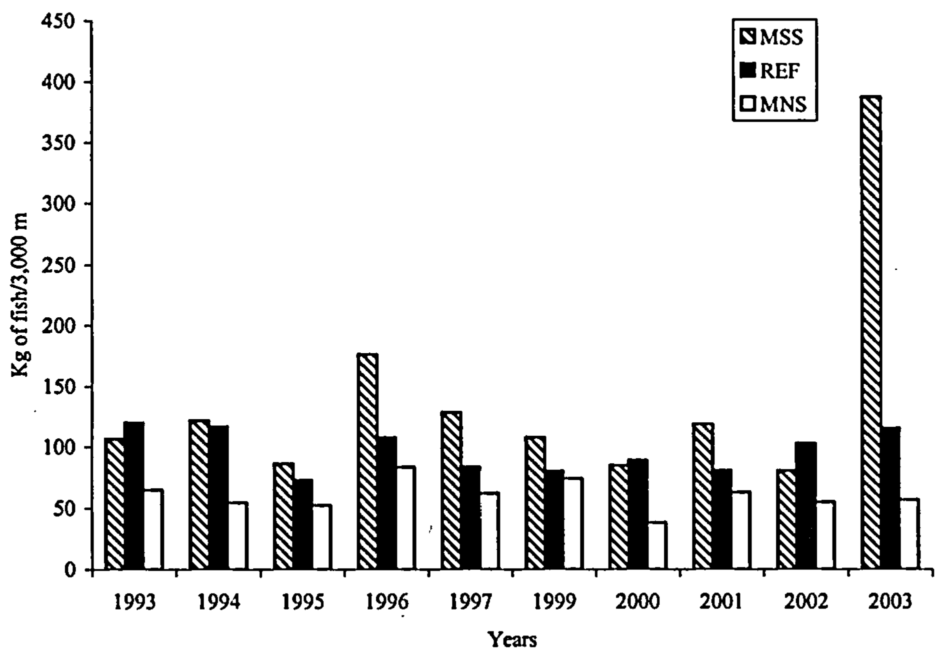


Figure 5-2. Numbers and biomass of fish collected from electrofishing ten 300-m transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, 1993-2003.

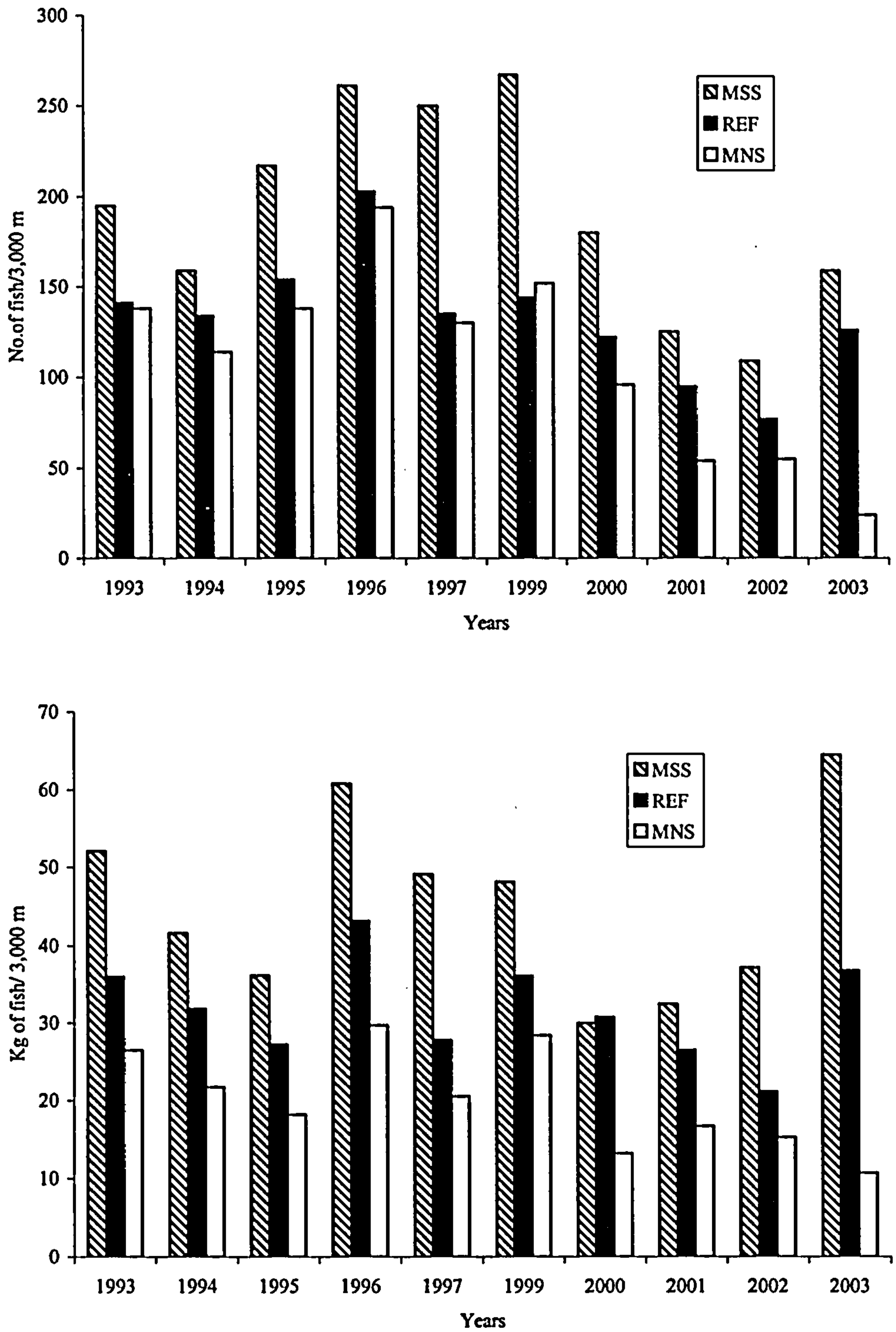


Figure 5-3. Numbers and biomass of largemouth bass collected from electrofishing ten 300-m transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, 1993-2003.

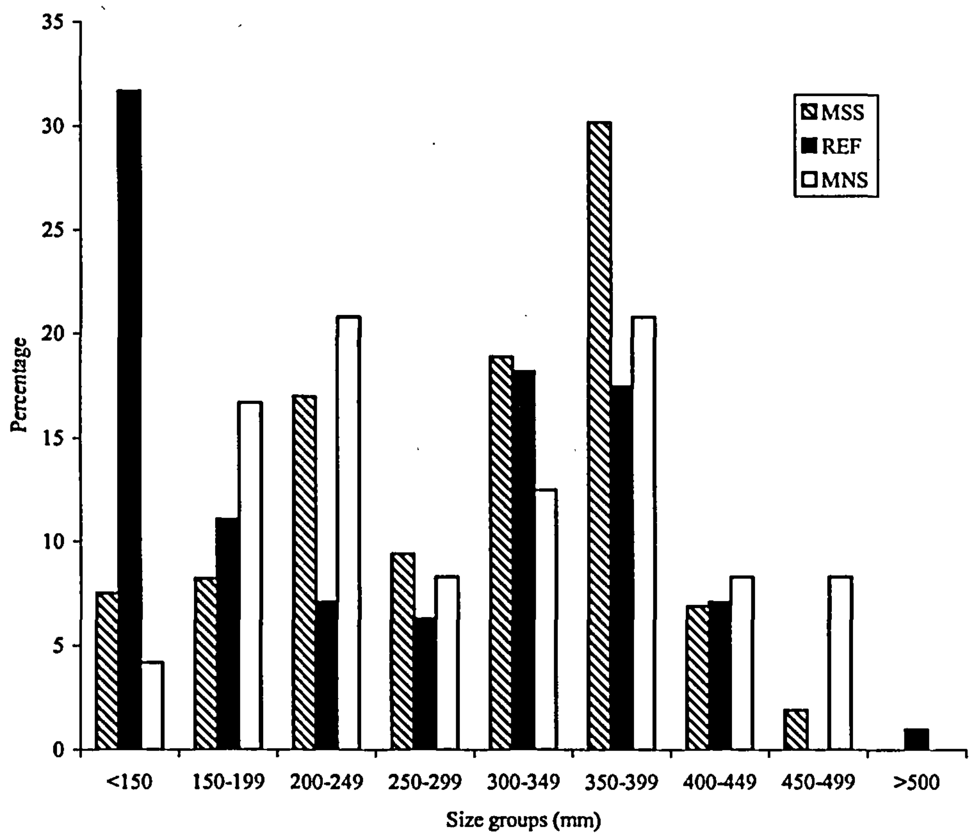


Figure 5-4. Size distributions of largemouth bass collected from electrofishing ten 300- m transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, 2003.

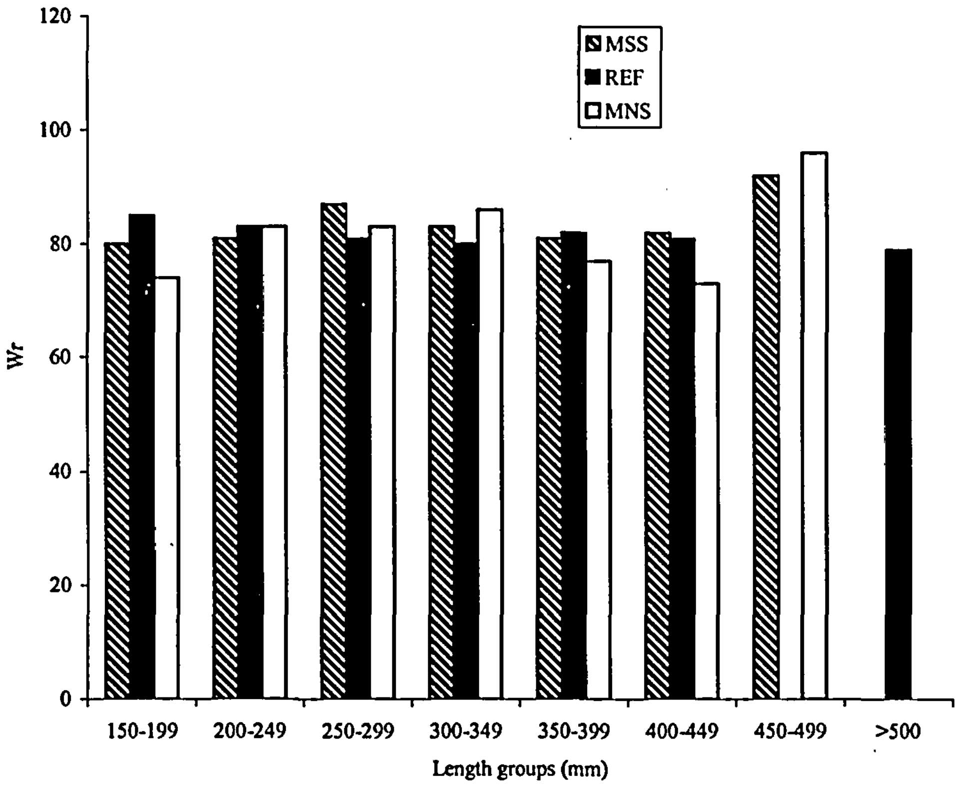


Figure 5-5. Mean relative weights (Wr) for largemouth bass collected from electrofishing ten transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, 2003.

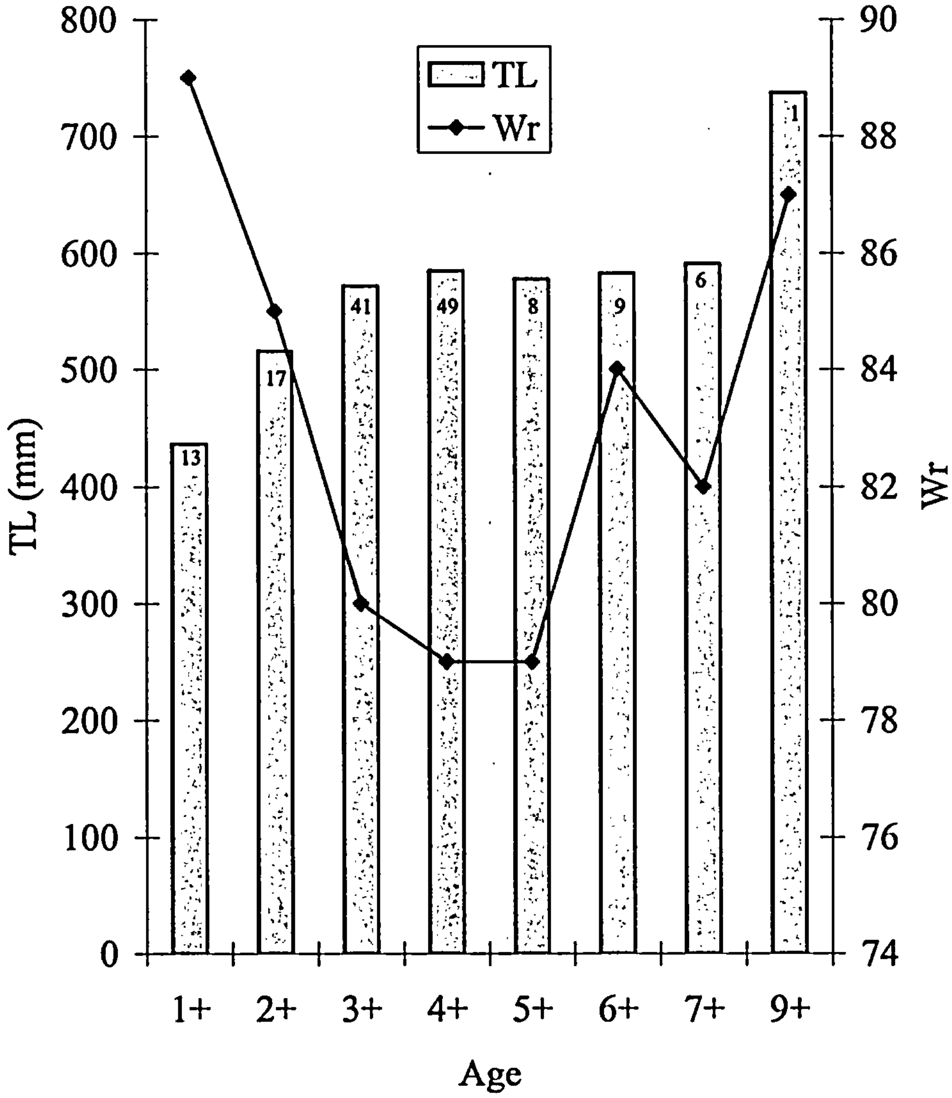


Figure 5-6. Mean total length and mean relative weight (Wr) for striped bass collected from Lake Norman, November-December 2003. Number of fish associated with the mean lengths are inside the bars.

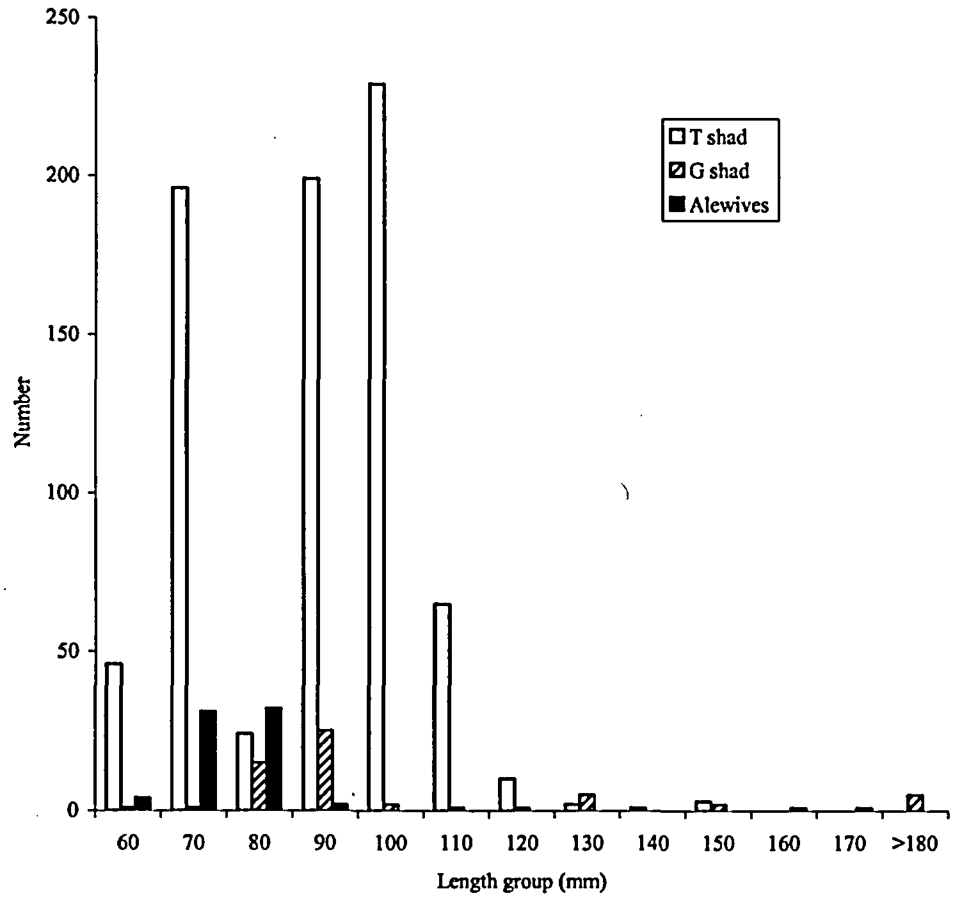


Figure 5-7. Size distributions of threadfin shad (T shad), gizzard shad (G shad) and alewives collected in gill-net surveys of Lake Norman, 2003.

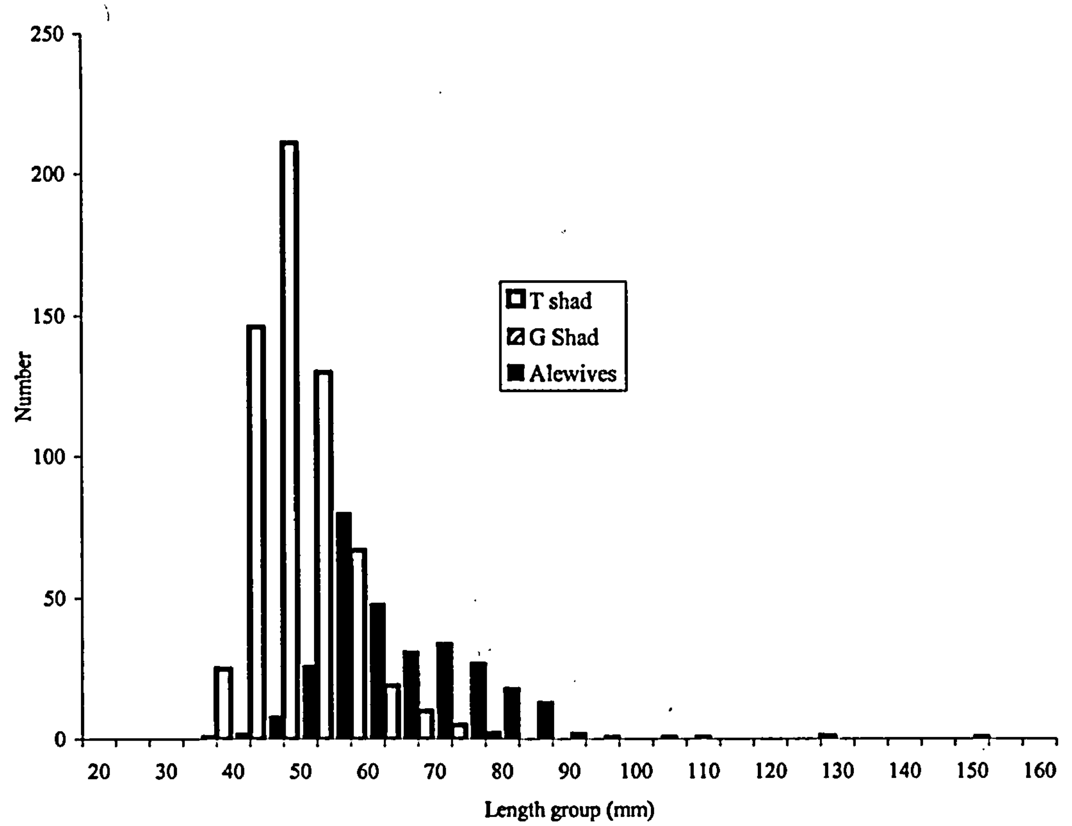


Figure 5-8. Size distributions of threadfin shad (T shad), gizzard shad (G shad) and alewives collected in purse seine surveys of Lake Norman, 2003.