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Subject: McGuire Nuclear Station
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Please find attached a copy of the annual "Lake Norman Maintenance Monitoring Program: 2004 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 January 12, 2006.

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

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IE25

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LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2004 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

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December 2005

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EXECUTIVE SUMMARY

As required by the National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 2004.

McGUIRE NUCLEAR STATION OPERATION

The monthly average capacity factor for MNS was 101.3 %, 101.2 %, and 101.9 % during July, August, and September of 2004, respectively (Table 1-1). These are the months when conservation of cool water and discharge temperatures are most critical and the thermal limit for MNS increases from a monthly average of 95.0 °F (35.0 °C) to 99.0 °F (37.2 °C). The average monthly discharge temperature was 97.7 °F (36.5 °C) for July, 97.6 °F (36.4 °C) for August, and 94.2 °F (34.6 °C) for September 2004. 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 2004 totaled 44.6 inches or 17.1 inches less than observed in 2003, but similar to the long-term precipitation average for this area (46.3 inches). Air temperatures in 2004 were generally warmer than measured in 2003, as well as the long-term mean. The most pronounced differences occurred in May when 2004 temperatures averaged 3.5 °C warmer than 2003, and 2.6 °C warmer than the long-term average.

Temporal and spatial trends in water temperature and DO in 2004 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2004 were generally warmer than observed in 2003 in both the mixing and background zones. Winter temperatures averaged about 0.3 °C warmer throughout the water column in 2004 versus 2003. Summer temperatures averaged about 2 to 3 °C warmer in 2004 versus 2003, with the primary differences observed in the upper 10 m of the water column. Interannual differences in water temperatures, especially in the surface waters, typically paralleled differences exhibited in air temperatures between 2004 and 2003.

Reservoir-wide isotherm and isopleth information for 2004, 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 2004 was generally similar in distribution and amount to historical conditions observed annually since 1983. Despite similarities in habitat conditions to previous years, the largest striped bass die-off ever observed in the reservoir (2599 fish) occurred in the summer of 2004.

All chemical parameters measured in 2004 were within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Concentrations of metals in 2004 were also low, and often below the analytical reporting limits. Manganese and iron concentrations in the surface and bottom waters were generally low in 2004, 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. In contrast to previous years, at no time during 2004 did iron concentrations exceed NC's water quality standard (1.0 mg/L). Manganese levels, however, did exceed the State standard (200 ug/L) in the bottom waters throughout the lake in the summer and fall, and are characteristic of historical conditions.

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 2004 lake-wide mean chlorophyll *a* concentrations were generally in the mesotrophic range with the exception of May, when chlorophyll concentrations averaged in the oligotrophic range. Chlorophyll concentrations during 2004 were generally within the same ranges as those of 2003. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. The highest chlorophyll value recorded in 2004, 10.57 ug/L, was well below the NC State Water Quality standard of 40 ug/L.

In most cases, total phytoplankton densities and biovolumes observed in 2004 were higher than those observed during 2003, and standing crops were within ranges established over previous years. Phytoplankton densities and biovolumes during 2004 never exceeded the NC

guidelines for algae blooms. Standing crop values in excess of bloom guidelines have been recorded during six previous years of the Program. As in past years, high standing crops were usually observed at up-lake locations; while comparatively low values were noted down-lake.

Seston dry and ash-free weights were more often higher in 2004 than in 2003, and down-lake to up-lake differences were apparent most of the time. The proportions of ash-free dry weights to dry weights in 2004 were higher than those of 2003, indicating an increase in organic composition among 2004 samples.

Secchi depths reflected suspended solids, with shallow depths related to high dry weights. The lake-wide mean secchi depth in 2004 was slightly higher than in 2003 and was within historical ranges recorded since 1992.

Diversity, or numbers of taxa, of phytoplankton had decreased since 2003, when the total number of individual taxa was the highest yet recorded. The taxononic composition of phytoplankton communities during 2004 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 2004 than during 2003; however, their contribution to total densities rarely 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 2004. All of these taxa have been common and abundant throughout the Maintenance Monitoring Program.

The phytoplankton index (Myxophycean) characterized Lake Norman as oligotrophic during 2004, and was slightly higher than the annual index for 2003. Quarterly index values decreased from the highest in February to the lowest in November. Quarterly values did not reflect maximum and minimum chlorophyll concentrations and phytoplankton standing crops. Location index values tended to reflect increases in chlorophyll and phytoplankton standing crops from down-lake to mid-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 2004, and no impacts of plant operations were observed.

Maximum zooplankton densities occurred in May at three locations and in February at two other locations. 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 2004. In the Mixing Zone, a long term trend of increasing year-to-year densities was observed for May. In addition, long term trends showed much higher year-to-year variability at Background Locations than at Mixing Zone Locations.

One hundred and seventeen zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (Fifty-two were identified during 2004). Four previously unreported taxa (three cladocerans and one rotifer) were identified during 2004.

Overall relative abundance of copepods in 2004 had decreased since 2003, and they were dominant in ten samples collected during August and November. Cladocerans were dominant in only two samples in August, while rotifers were dominant in 70% of all samples. Overall, the relative abundance of rotifers had increased since 2003, and their relative abundances were somewhat similar to those of 1995. 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 copepod was *Tropocyclops*, as was the case in previous years. *Bosmina* was the predominant cladoceran, as has also been the case in most previous years of the Program. *Bosminopsis* dominated most cladoceran populations in August. The most abundant rotifers observed in 2004, as in many previous years, were *Polyarthra*, *Conochilus*, and *Karetella*, while *Asplanchna* and *Syncheata* were occasionally important among rotifer populations.

FISHERIES

In accordance with the Lake Norman Maintenance Monitoring Program for the NPDES permit for MNS, specific fish monitoring programs were coordinated with the NCWRC and continued during 2004. Spring electrofishing indicated that 17 to 21 species of fish and 2 hybrid complexes comprised fish populations in the 3 sampling areas, and numbers and biomass of fish in 2004 were generally similar to those noted since 1993. Declines in largemouth bass numbers, which were first observed in 2000, appear to be an exception.

In 2004, considerable striped bass mortality was observed during summer in Lake Norman and this mortality appeared to be related to a combination of unique events triggered by an unusually warm May and the abundance of prey in the hypolimnion. Mean W_r for Lake Norman striped bass collected in November and December 2004 was similar to that observed previously and indicated little change in the overall condition of this fish.

Trapnetting indicated little change in the crappie populations in Lake Norman in 2003-2004. Hydroacoustic and purse seine sampling indicated that there was a decline in the number of prey fish and a change in species composition from 2003 to 2004.

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CHAPTER 1

McGUIRE NUCLEAR STATION OPERATION

INTRODUCTION

As required by the National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS) issued by the North Carolina Department of Environment and Natural Resources (NCDENR), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 2004.

OPERATIONAL DATA FOR 2004

The monthly average capacity factor for MNS was 101.3 %, 101.2 %, and 101.9 % during July, August, and September of 2004, respectively (Table 1-1). These are the months when conservation of cool water and discharge temperatures are most critical and the thermal limit for MNS increases from a monthly average of 95.0 °F (35.0 °C) to 99.0 °F (37.2 °C). The average monthly discharge temperature was 97.7 °F (36.5 °C) for July, 97.6 °F (36.4 °C) for August, and 94.2 °F (34.6 °C) for September 2004. 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 2004.

	MONTHLY AVERAGE CAPACITY FACTORS (%)			MONTHLY AVERAGE NPDES DISCHARGE TEMPERATURES	
Month	**Unit 1**	**Unit 2**	**Station**	**°F**	**°C**
January	105.1	105.1	**105.1**	68.0	20.0
February	105.1	104.9	**105.0**	67.5	19.7
March	16.7	104.8	**60.8**	67.9	19.9
April	61.1	104.3	**82.7**	73.3	22.9
May	103.9	103.7	**103.8**	84.0	28.9
June	102.2	102.3	**102.3**	93.1	33.9
July	101.3	101.3	**101.3**	97.7	36.5
August	101.3	101.0	**101.2**	97.6	36.4
September	101.9	102.0	**101.9**	94.2	34.6
October	55.7	103.3	**79.5**	84.2	29.0
November	64.7	104.0	**84.4**	78.1	25.6
December	105.1	104.6	**104.9**	75.2	24.0
Averages	**85.3**	**103.4**	**94.4**	**81.7**	**27.6**

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 2003 and 2004. Where appropriate, reference to pre-2003 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 2004, 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, 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 Duke Power Company (DPC), and Duke Power (DP) studies on the lake (DPC 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 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. The data 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 2004 totaled 44.6 inches (Figures 2-2a, b) or 17.1 inches less than observed in 2003 (61.7 inches), but similar to the long-term precipitation average for this area (46.3 inches), based on Charlotte, NC airport data. In 2003, greater than 80% of the yearly rainfall occurred over the first eight months of the year. In contrast, greater than 80% of the yearly rainfall in 2004 occurred over the last eight months of the year. The highest total monthly rainfall in 2004 occurred in September (7.73 inches), in concert with the occurrence of Hurricanes Frances and Ivan, both of which bypassed the greater Charlotte area but exerted a considerable effect on the North Carolina mountains and foothills.

Air temperatures in 2004 were generally warmer than measured in 2003, and the long-term mean, based on monthly average data (Figure 2-2c). The temporal difference was most pronounced in May when 2004 temperatures averaged 3.5 °C warmer than 2003, and 2.6 °C warmer than the long-term average.

Temperature and Dissolved Oxygen

Water temperatures measured in 2004 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3 and 2-4), as they did in 2003. 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 2004 were generally warmer than those observed in 2003 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 2004 were recorded in early February and ranged from 6.6 °C to 8.0 °C in the background zone, and from 7.4 °C to 13.1 °C in the mixing zone. The average minimum temperature in 2004 was about 0.3 °C warmer than that observed in 2003, and corresponded closely with the between-year difference in mean winter air temperature. Minimum water temperatures measured in 2004 were within the observed historical variability (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004).

Spring and summer water temperatures in 2004 ranged from about 1 to 5 °C warmer, on the average, than observed in 2003, 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 both the mixing and background zones. Water temperatures in this portion of the water column ranged from 3.8 to 6.2 °C warmer in 2004 than 2003, and can be traced to the antecedent May air temperatures, which were the warmest recorded over the last 40 years (unpublished data, Charlotte airport). Maximum August surface water temperatures were also greater in 2004 than 2003 with interannual differences observed within each zone. The maximum surface temperature in the background zone in 2004 was 29.7 °C, whereas in 2003 the corresponding maximum temperature was 28.5 °C, or almost 1.2 °C cooler. Similarly, the maximum August surface temperature in the mixing zone in 2004 was 30.8 °C compared to a maximum of 29.1 °C in 2003. Minimal differences in hypolimnetic (below 20m) temperatures were observed between 2004 and 2003 during the summer; the lone exception was in September when the deeper waters were warmer (and the surface waters were cooler) than observed in 2003, especially in the background zone. These thermal differences can be explained by differential cooling of the water column in 2004 versus 2003, in response to lower air temperatures in the preceding month of August (Figure 2-2c).

Fall and early winter water temperatures (October, November and December) in 2004 were generally similar to those measured in 2003, and followed the trend exhibited in air temperatures (Figure 2-3) Some differences were observed between years, and in certain portions of the water column, but overall cooling of the water column proceeded at a similar rate in 2004 and 2003.

Temperature data at the discharge location in 2004 were generally similar to 2003 (Figure 2-5) and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Temperatures in 2004 were typically equal to or cooler (by a maximum of 6.1 °C) in the spring, and warmer (by a maximum of 3.7 °C) in the summer and fall, than observed in 2003. The warmest discharge temperature of 2004 at Location 4 occurred in August and measured 38.8 °C, or 3.7 °C warmer than measured in August, 2003 (DP 2004).

Seasonal and spatial patterns of DO in 2004 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 DO 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 2004 were generally equal to or slightly lower, in both the background and mixing zones, than measured in 2003, except in January in the background zone which exhibited slightly higher oxygen concentrations in 2004 versus 2003 (Figures 2-6 and 2-7). The interannual differences in DO values measured during this period appeared to be related predominantly to the warmer water column temperatures in 2004 versus 2003. Warmer water would be expected to exhibit a lesser oxygen content because of the direct effect of temperature on oxygen solubility, which is an inverse relationship, and indirectly via a restricted convective mixing regime which would limit water column reaeration. February and March 2004 DO concentrations were about equal to or 0.5 mg/L less throughout the water column than measured in 2003.

Spring and summer DO values in 2004 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 2003 and earlier years (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Epilimnetic and metalimnetic DO

values during the spring and summer of 2004 were typically slightly lower than measured at similar depths in 2003, especially in the background zone, although exceptions to this were observed in both zones. In both the mixing and background zones, August, 2004 DO concentrations in the waters above 10m were considerably higher than measured in 2003 even though temperatures were warmer. Hypolimnetic DO values measured during this period were also either equal to or slightly greater than measured in 2003 in both the mixing and background zones. All dissolved oxygen values recorded in 2004 were within the historical range (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004).

Considerable differences were observed between 2004 and 2003 fall DO values in both the mixing and background zone, especially in the metalimnion and hypolimnion during the months of September, October 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 2004 autumn DO data indicate that fall reaeration proceeded faster and was more complete throughout the water column than observed in the corresponding months in 2003. Consequently, DO levels in these months in 2004 were higher than observed in 2003. 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 2004 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 2004 (5.55 mg/L) occurred in July and August, and was 1.45 mg/L higher than measured in August 2003 (4.1 mg/L) and similar to 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 DO data for 2004 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 2004 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 2003 and 2004 is found in Table 2-3. Annual minimum heat content for the entire water column in 2004 (7.92 Kcal/cm^2; 8.0 °C) occurred in early February, whereas the maximum heat content (29.72 Kcal/cm^2; 28.99 °C) occurred in early July. Heat content of the hypolimnion exhibited a somewhat different temporal trend as that observed for the entire water column. Annual minimum hypolimnetic heat content occurred in early February and measured 4.40 Kcal/cm^2 (7.0 °C), whereas the maximum occurred in mid-September and measured 16.18 Kcal/cm^2 (23.6 °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 0.118 Kcal/cm^2/day and 0.054 Kcal/cm^2/day for the hypolimnion. The 2004 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, 2002, 2003, 2004).

The seasonal oxygen content and percent saturation of the whole water column, and the hypolimnion, are depicted for 2004 in Figure 2-10b. Additional oxygen data can be found in Table 2-4 which presents the 2004 AHOD for Lake Norman and similar estimates for 18 Tennessee Valley Authority (TVA) reservoirs. Reservoir oxygen content was greatest in mid-winter when DO content measured 10.9 mg/L for both the whole water column and the hypolimnion. Percent saturation values at this time approached 98 % for the entire water column and 94 % 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 decline linearly until reaching a minimum in mid summer. Minimum summer volume-weighted DO values for the entire water column measured 4.6 mg/L (60 % saturation),

whereas the minimum for the hypolimnion was 0.3 mg/L (3.8 % saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.046 $mg/cm^2/day$ (0.058 mg/L/day) (Figure 2-10b), and is similar to that measured in 2003 (DP 2004).

Hutchinson (1938, 1957) proposed that the decrease of DO 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 0.046 $mg/cm^2/day$ for 2004. The oxygen based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 2004 AHOD value is also similar to that found in other Southeastern reservoirs of comparable depth, chlorophyll *a* status, and secchi depth (Table 2-4).

Striped Bass Habitat

Suitable pelagic habitat for adult striped bass, defined as that layer of water with temperatures $\leq$ 26 °C and DO levels $\geq$ 2.0 mg/L, was found lake-wide from mid September 2003 through early July 2004. Beginning in mid June 2004, habitat reduction proceeded rapidly throughout the reservoir both as a result of deepening of the 26 °C isotherm and metalimnetic and hypolimnetic deoxygenation (Figure 2-11). Habitat reduction was most severe from mid July through early September when no suitable habitat was observed in the reservoir except for a small, but variable, zone of refuge in the upper, riverine portion of the reservoir, near the confluence of Lyles Creek with Lake Norman. Habitat measured in the upper reaches of the reservoir 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).

A secondary temporary refuge was also observed in the hypolimnion near the dam during this period, but this lasted only until late July when dissolved oxygen was reduced to < 2.0 mg/l by microbial demands. The reservoir was completely devoid of habitat for adult striped bass from 27 July to 9 August, or about two weeks. These habitat conditions were

marginally better than observed in most previous years, including 2003 which exhibited complete habitat elimination for a period of about 30-35 days.

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 2004 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, 2002, 2003, 2004). However, despite overall similarities in the pattern, rate, and extent of habitat depletion in 2004 versus previous years, a significant die-off of striped bass (2610 fish) was observed in 2004. A detailed account of this phenomenon is found in Chapter 5.

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 2004, ranging from 1.0 to 3.4 NTU's (Table 2-5). Bottom turbidity values were also relatively low over the study period, ranging from 0.9 to 7.5 NTU's (Table 2-5). Turbidity values observed in 2004, as a whole, were slightly lower than measured in 2003 (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, 2004).

Specific conductance in Lake Norman in 2004 ranged from 50 to 100 umho/cm, and was generally similar to that observed in 2003 (Table 2-5), and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Lake-wide, mean conductance values in 2004 were similar to those measured in 2003, but were about 10 umhos/cm lower than observed in 2002. Differences were most pronounced in the surface waters during the summer with mean conductance values averaging almost 20 umhos/cm (about 30 %) less in 2004 and 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 and 2004. 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 2004 were generally similar throughout the year except during the period of intense thermal stratification, i.e., August through 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 2004, 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 2003 (Table 2-5), and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Alkalinity values were also similar between years. Individual pH values in 2004 ranged from 6.1 to 8.0, whereas alkalinity ranged from 12.5 to 36 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 2004 was generally similar to that reported for 2003 (Table 2-5) and previously (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Concentrations of several constituents, most notably calcium and potassium, and to a lesser extent chloride, magnesium, and sodium, were however, consistently less in 2004 than 2003, but these differences were not statistically significant and values were within historical ranges.

Nutrients

Nutrient concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 2004 and 2003 are provided in Table 2-5. Overall, nutrient concentrations in 2004 were well within historical ranges (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Nitrogen and phosphorus levels in 2004 were low and generally similar to those measured in 2003 (DP 2004). Total phosphorus and ortho-phosphorus concentrations were typically measured at or below the analytical reporting limits for these constituents, i.e., 10 ug/L and 5 ug/L, respectively. For total phosphorus, only three of the forty samples analyzed exceeded a concentration greater than 10 ug/L, and the highest concentration measured was 12 ug/L. For ortho-phosphorus eight of forty samples exceeded 5 ug/L, and the highest concentration measured was 13 ug/L in the bottom waters of the mixing zone in November. 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 ($p< 0.05$). Spatial variability in various chemical constituents, especially nutrient concentrations, is common in long, deep reservoirs (Soballe et al. 1992).

Nitrite-nitrate concentrations were consistently lower at all locations in 2004 compared to 2003 (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, 2002, 2003, 2004). The lower values measured in 2004 compared to 2003 were probably related primarily to interannual differences in precipitation inputs (Figure 2-2a). 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).

Metals

Metal concentrations in the discharge, mixing, and mid lake background zones of Lake Norman for 2004 were similar to those measured in 2003 (Table 2-5) and historically (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004). Iron concentrations in surface and bottom waters were generally low (≤ 0.2 mg/L) during 2004, the lone exception being a 0.63 mg/L value measured in the bottom waters at Location 5 in August. Nowhere in the reservoir in 2004 did iron concentrations exceed NC's water quality standard (NCDENR 2004) for this

constituent (1.0 mg/L), which is unusual. Typically, iron concentrations increase in the bottom waters during the late summer, and early fall, in response to changing redox conditions (see below). It's unclear why this phenomenon was not as prevalent in 2004 as in previous years.

Similarly, manganese concentrations in the surface and bottom waters were generally low (≤ 100 ug/L) in 2004, except during the summer and fall when bottom waters were anoxic (Table 2-5). This phenomenon, i.e., the release of manganese (and iron) from bottom sediments in response to low redox conditions (low oxygen levels), is common in stratified waterbodies (Stumm and Morgan 1970, Wetzel 1975). Manganese concentrations in the bottom waters rose above NC's water quality standard (NCDENR 2004) for this constituent, i.e., 200 ug/L, at various locations throughout the lake in summer and fall in 2004, and is characteristic of historical conditions (DPC 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; DP 1998, 1999, 2000, 2001, 2002, 2003, 2004).

Concentrations of other metals in 2004 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. All copper concentrations were less than 3 ug/L, and well below the NC standard of 7 ug/L (NCDENR 2004).

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 2004 totaled 44.6 inches or 17.1 inches less than observed in 2003, but similar to the long-term precipitation average for this area (46.3 inches). Air temperatures in 2004 were generally warmer than measured in 2003, as well as the long-term mean. The most pronounced differences occurred in May when 2004 temperatures averaged 3.5 °C warmer than 2003, and 2.6 °C warmer than the long-term average.

Temporal and spatial trends in water temperature and DO in 2004 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2004 were generally warmer than observed in 2003 in both the mixing and background zones. Winter temperatures averaged about 0.3 °C warmer throughout the water column in 2004 versus 2003. Summer temperatures averaged about 2 to 3 °C warmer in 2004 versus 2003, with the primary differences observed in the upper 10 m of the water column. Minimal differences in hypolimnetic (below 20 m) temperatures were observed between 2004 and 2003 during the summer; the lone exception was in September when the lower waters were warmer than observed in 2003, especially in the background zone. These thermal differences can be explained by differential cooling of the water column in 2004 versus 2003, in response to lower air temperatures in the preceding month of August. Interannual differences in water temperatures, especially in the surface waters, typically paralleled differences exhibited in air temperatures between 2004 and 2003.

Winter and early spring DO values in 2004 were generally equal to or slightly lower, in both the background and mixing zones, than measured in 2003, except in January in the background zone which exhibited slightly higher oxygen concentrations in 2004 versus 2003. The interannual differences in DO values measured during this period appeared to be related predominantly to the warmer water column temperatures in 2004 versus 2003.

Spring and summer DO values in 2004 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 observed in 2003 and earlier years. Epilimnetic and metalimnetic DO values during the spring and summer of 2004 were typically slightly lower than measured at similar depths in 2003, especially in the background zone, although exceptions to this were observed in August in both zones. Summer hypolimnetic DO values were also either equal to or slightly greater than measured in 2003 in both the mixing and background zones. All DO values recorded in 2004 were within historical ranges.

Reservoir-wide isotherm and isopleth information for 2004, 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 2004 was generally similar in distribution and amount to historical conditions observed annually since 1983. Despite

similarities in habitat conditions to previous years, the largest striped bass die-off ever observed in the reservoir (2599 fish) occurred in the summer of 2004.

All chemical parameters measured in 2004 were within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Specific conductance values in 2004 were slightly lower than measured in 2003, a high-water year, as were concentrations of nitrite-nitrate nitrogen, calcium and potassium, and to a lesser extent, chloride, magnesium and sodium. Ammonia, ortho-phosphorus, and total phosphorus values were low in 2004 and similar to 2003.

Concentrations of metals in 2004 were also low, and often below the analytical reporting limits. Values for cadmium, lead and zinc were reported as either equal to or below the reporting limit. Copper concentrations were generally less then 3 ug/L, and well below the NC standard of 7 ug/L.

Manganese and iron concentrations in the surface and bottom waters were generally low in 2004, 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. In contrast to previous years, at no time during 2004 did iron concentrations exceed NC's water quality standard (1.0 mg/L). Manganese levels, however, did exceed the State standard (200 ug/L) in the bottom waters throughout the lake in the summer and fall, and are characteristic of historical conditions.

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

2004 McGUIRE NPDES SAMPLING PROGRAM

PARAMETERS	LOCATIONS	1	2	4	5	8	9.5	11	13	14	15	15.9	62	69	72	80	16
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
IN-SITU ANALYSIS																	
Temperature	Hydrolab																
Dissolved Oxygen	Hydrolab	In-situ measurements are collected monthly at the above locations at 1m intervals from 0.3m to 1m above bottom.															
pH	Hydrolab	Measurements are taken weekly from July-August for striped bass habitat.															
Conductivity	Hydrolab																
NUTRIENT ANALYSES																	
Ammonia	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Nitrate+Nitrite	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Orthophosphate	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Total Phosphorus	AA-TP,DG-P	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Silica	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cl	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
TKN	AA-TKN	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B		Q/T,B		Q/T,B			
Total Organic Carbon	TOC		Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B			Q/T							
Dissolved organic carbon	DOC		Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B			Q/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	306-K	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sodium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Zinc	ICP-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 1995

Table 2-3. Heat content calculations for the thermal regime in Lake Norman for 2003 and 2004.

	2003	2004
Maximum Areal Heat Content (g-cal/cm^2)	28,176	29,718
Minimum Areal Heat Content (g cal/cm^2)	8,864	7,921
Birgean Heat Budget (g cal/ cm^2)	19,312	21,797
Epilimnion (above 11.5 m) Heating Rate (°C /day)	0.096	0.122
Hypolimnion (below 11.5 m) Heating Rate (°C /day)	0.072	0.076

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 (2004)	0.046	5.5	2.2	10.3
TVA [a]				
Mainstem				
Kentucky	0.012	9.1	1.0	5.0
Pickwick	0.010	3.9	0.9	6.5
Wilson	0.028	5.9	1.4	12.3
Wheelee	0.012	4.4		5.3
Guntersville	0.007	4.8	1.1	5.3
Nickajack	0.016	2.8	1.1	6.8
Chickamauga	0.008	3.0	1.1	5.0
Watts Bar	0.012	6.2	1.0	7.3
Fort London	0.023	5.9	0.9	7.3
Tributary				
Chatuge	0.041	5.5	2.7	9.5
Cherokee	0.078	10.9	1.7	13.9
Douglas	0.046	6.3	1.6	10.7
Fontana	0.113	4.1	2.6	37.8
Hiwassee	0.061	5.0	2.4	20.2
Norris	0.058	2.1	3.9	16.3
South Holston	0.070	6.5	2.6	23.4
Tims Ford	0.059	6.1	2.4	14.9
Watauga	0.066	2.9	2.7	24.5

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

Table 2-5. Quarterly surface (0.3 m) and bottom (bottom minus 1 m) water chemistry for the MNS discharge, mixing zone, and background locations on Lake Norman during 2003 and 2004. Values less than detection were assumed to be equal to 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:	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003
Turbidity (ntu)																						
Feb	2.81	2.69	2.39	2.61	3.12	2.51	1.94	2.65	NS	2.11	2.12	2.03	1.61	2.23	2.02	2.67	3.51	2.56	3.36	4.76	3.36	3.88
May	1.50	4.04	1.52	7.41	NS	5.58	NS	7.32	1.02	8.49	1.38	6.11	NS	7.48	1.25	3.61	1.31	11.00	1.28	2.35	0.94	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	2.14	2.56	2.32	4.0	2.58	2.8	2.57	3.5	1.82	3.5	1.99	2.8	4.26	6.1	1.83	2.3	3.40	6.1	2.52	2.6	3.31	7.9
Specific Conductance (umho/cm)																						
Feb	52.0	71	51.0	70	52	71	50	70	53	73	52	71	51.0	70	51	70	50	70	51	67	50	68
May	53.0	60	53	62	57	60	53	62	58	59	57	59	54	61	56	60	54	59	58	58	55	54
Aug	63.0	55	59.0	65	62.0	54	60.0	66	64.0	54	62.0	54	66.0	67	60.0	54	58.0	62	62.0	54	59.0	64
Nov	56.0	55	99.0	95	56.0	54	100.0	97	58.0	55	57.0	55	58.0	58	56.0	53	98.0	54	52.0	53	52.0	52.0
Annual Mean	56.0	60.3	65.5	73.0	56.8	59.8	65.8	73.8	58.3	60.3	57.0	59.8	57.3	64.0	55.8	59.3	65.0	61.3	55.8	58.0	54.0	59.5
pH (units)																						
Feb	7.0	6.7	7.0	7.0	7.3	7.2	7.1	7.1	7.3	7.1	7.4	7.2	7.1	7.2	7.4	7.3	7.2	7.2	7.3	7.3	7.1	7.2
May	7.2	6.7	6.3	6.5	7.4	6.9	6.6	6.6	7.3	6.8	7.4	6.9	6.6	6.6	7.7	7.2	6.6	6.6	7.7	7.3	6.7	6.5
Aug	7.3	7.1	6.0	6.3	7.4	6.9	6.1	6.3	7.1	6.6	7.3	6.8	6.3	6.5	8.0	7.1	6.1	6.4	7.1	7.3	6.1	6.4
Nov	6.5	6.8	6.8	6.6	NS	6.8	NS	6.7	6.9	6.7	7.0	6.9	6.7	6.6	7.0	6.8	6.9	6.5	7.0	7.2	6.7	6.5
Annual Mean	7.00	6.53	6.53	6.60	7.37	6.95	6.60	6.69	7.15	7.10	7.28	6.95	6.68	6.73	7.53	7.10	6.70	6.67	7.28	7.28	6.65	6.64
Alkalinity (mg CaCO3/l)																						
Feb	13.5	16.5	13.0	16.5	13.0	16.5	13.0	16.5	NS	16.5	13.0	16.5	13.0	16.5	13.0	16.0	13.0	16.5	13.0	15.0	13.0	15.5
May	13.5	13.5	13.5	13.0	NS	13.5	NS	14.0	14.0	13.0	13.5	13.0	NS	14.0	13.0	13.5	13.5	13.5	14.0	12.0	13.0	12.0
Aug	15.0	13.0	14.5	14.0	15.0	13.0	14.5	14.0	14.5	13.0	15.0	13.0	20.0	17.5	15.0	13.0	14.5	14.5	15.0	13.5	15.0	14.5
Nov	13.0	14.5	36.0	20.5	13.5	14.5	35.5	29.0	13.5	14.0	13.0	14.5	14.0	16.5	13.0	14.5	15.0	15.5	12.0	14.0	12.5	14.5
Annual Mean	13.8	14.4	19.3	16.0	13.8	14.4	21.0	18.4	14.0	14.1	13.6	14.3	15.7	16.1	13.5	14.3	14.0	15.0	13.5	13.6	13.4	14.1
Chloride (mg/l)																						
Feb	4.0	6.9	4.2	6.6	4.1	6.7	4.0	7.0	NS	6.7	3.9	6.7	4.1	6.6	4.1	6.8	4.0	6.9	4.3	6.2	4.1	6.1
May	4.5	5.4	4.5	5.9	NS	5.4	NS	5.8	4.8	5.2	4.6	5.4	NS	5.7	4.6	5.3	4.6	5.5	5.2	5.2	4.6	4.9
Aug	5.3	4.0	4.8	4.7	5.3	3.9	4.7	4.9	5.4	3.9	5.3	4.0	5.2	4.4	5.4	3.9	4.9	4.8	5.4	4.1	4.8	4.7
Nov	4.6	3.9	4.7	4.0	4.5	3.9	4.8	4.6	4.4	3.8	4.4	3.8	4.6	3.8	4.5	4.0	4.5	3.9	4.1	3.9	4.1	3.9
Annual Mean	4.6	5.1	4.6	5.3	4.6	5.0	4.5	5.6	4.9	4.9	4.6	5.0	4.6	5.1	4.7	5.0	4.5	5.3	4.8	4.9	4.4	4.9
Sulfate (mg/l)																						
Feb	NS	NS	NS	NS	5.0	5.8	4.7	7.2	NS	7.1	NS	NS	NS	NS	4.7	7.3	4.8	7.2	NS	NS	6.7	NS
May	NS	NS	NS	NS	NS	6.1	NS	6.3	5.1	5.8	NS	NS	NS	NS	5.1	6.0	5.0	6.0	NS	NS	NS	NS
Aug	NS	NS	NS	NS	4.6	4.8	4.7	5.6	4.7	4.6	NS	NS	NS	NS	4.6	4.9	4.7	5.4	NS	NS	NS	NS
Nov	NS	NS	NS	NS	4.5	4.8	3.2	3.3	4.5	4.8	NS	NS	NS	NS	4.5	4.8	4.4	4.2	NS	NS	NS	NS
Annual Mean	NA	NS	NA	NA	4.7	5.4	4.2	5.6	4.8	5.6	NA	NA	NA	NA	4.7	5.8	4.7	5.7	NA	NA	6.7	NA
Calcium (mg/l)																						
Feb	3.12	3.44	3.09	3.43	3.15	3.48	3.10	3.45	NS	3.48	3.09	3.46	3.09	3.46	3.06	3.49	3.12	3.47	2.94	3.67	2.89	3.65
May	2.92	4.62	3.07	4.37	NS	4.11	NS	4.61	3.02	4.18	3.65	3.78	NS	4.42	3.47	3.89	3.24	3.90	3.29	3.38	3.16	3.96
Aug	2.69	4.05	2.97	4.17	2.71	4.07	2.92	3.74	2.73	2.98	2.77	3.22	3.67	5.03	2.73	3.09	3.06	4.07	3.27	4.46	3.15	4.74
Nov	2.99	3.54	4.18	3.84	2.98	3.53	4.10	4.26	3.00	3.48	2.98	3.48	3.03	3.52	2.97	3.46	3.04	3.15	2.78	3.43	2.84	3.10
Annual Mean	2.93	3.91	3.33	3.95	2.95	3.80	3.37	4.02	2.92	3.53	3.12	3.49	3.26	4.11	3.06	3.48	3.12	3.65	3.07	3.74	3.01	3.86
Magnesium (mg/l)																						
Feb	1.39	1.60	1.37	1.61	1.40	1.60	1.38	1.61	NS	1.62	1.39	1.60	1.39	1.60	1.38	1.60	1.40	1.61	1.33	1.52	1.33	1.55
May	1.37	1.75	1.44	1.70	NS	1.59	NS	1.77	1.41	1.60	1.56	1.52	NS	1.72	1.55	1.58	1.48	1,61	1.45	1.45	1.42	1.56
Aug	1.48	1.63	1.55	1.63	1.49	1.59	1.53	1.57	1.49	1.37	1.51	1.43	1.75	1.82	1.48	1.42	1.57	1.66	1.65	1.73	1.62	1.85
Nov	1.33	1.50	1.68	1.56	1.35	1.49	1.66	1.64	1.34	1.49	1.34	1.49	1.35	1.50	1.34	1.47	1.35	1.43	1.25	1.47	1.25	1.42
Annual Mean	1.39	1.62	1.51	1.63	1.41	1.57	1.52	1.65	1.41	1.52	1.45	1.51	1.50	1.66	1.44	1.52	1.45	1.57	1.42	1.54	1.41	1.60

NS = Not Sampled; NA= Not applicable

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:	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003
Potassium (mg/l)																						
Feb	1.59	2.12	1.57	2.08	1.62	2.09	1.60	2.13	NS	2.29	1.57	2.06	1.59	2.15	1.57	2.16	1.60	2.12	1.46	1.98	1.46	2.14
May	1.63	1.82	1.57	1.94	NS	1.78	NS	1.90	1.58	1.83	1.59	1.75	NS	1.80	1.57	1.76	1.59	1.83	1.53	1.74	1.54	1.75
Aug	1.67	1.81	1.62	1.86	1.60	1.76	1.61	1.85	1.64	1.71	1.64	1.69	1.70	1.88	1.61	1.74	1.64	1.83	1.62	1.74	1.62	1.86
Nov	1.62	1.74	1.68	1.76	1.59	1.72	1.72	1.81	1.59	1.67	1.61	1.68	1.57	1.73	1.66	1.71	1.62	1.59	1.63	1.69	1.59	1.66
Annual Mean	1.63	1.87	1.61	1.91	1.60	1.84	1.64	1.92	1.60	1.88	1.60	1.80	1.62	1.89	1.60	1.84	1.61	1.84	1.56	1.79	1.55	1.85
Sodium (mg/l)																						
Feb	4.27	7.73	4.28	7.73	4.25	7.90	4.32	7.98	NS	8.26	4.24	8.25	4.22	7.84	4.25	7.73	4.22	7.89	4.43	7.00	4.39	7.58
May	4.53	5.00	4.49	5.24	NS	5.06	NS	5.78	4.61	5.02	4.59	4.57	NS	5.40	4.68	4.83	4.61	5.16	4.98	4.64	4.67	3.63
Aug	5.22	4.20	4.73	5.14	5.17	4.14	4.66	5.11	5.21	4.06	5.22	4.13	4.89	4.59	5.09	4.16	4.75	5.10	5.28	4.14	4.77	4.90
Nov	4.62	4.03	4.89	4.17	4.61	3.98	4.81	4.50	4.63	3.96	4.60	3.94	4.62	3.94	5.19	3.94	4.49	4.10	4.08	3.94	4.07	4.09
Annual Mean	4.66	5.24	4.60	5.57	4.68	5.27	4.60	5.84	4.82	5.33	4.66	5.22	4.58	5.44	4.80	5.17	4.52	5.56	4.69	4.93	4.48	5.05
Aluminum (mg/l)																						
Feb	0.050	0.101	0.098	0.111	0.088	0.098	0.099	0.116	NS	0.096	0.094	0.088	0.113	0.109	0.080	0.099	0.176	0.116	0.132	0.164	0.140	0.173
May	0.050	0.286	0.050	0.442	NS	0.349	NS	0.470	0.050	0.509	0.050	0.311	NS	0.430	0.050	0.229	0.093	0.692	0.057	0.206	0.063	1.281
Aug	0.050	0.055	0.050	0.109	0.050	0.054	0.050	0.112	0.050	0.050	0.050	0.050	0.050	0.136	0.050	0.050	0.050	0.225	0.050	0.050	0.066	0.118
Nov	0.109	0.055	0.066	0.055	0.108	0.050	0.076	0.050	0.100	0.052	0.103	0.056	0.173	0.200	0.102	0.062	0.199	0.194	0.122	0.053	0.066	0.366
Annual Mean	0.065	0.179	0.066	0.179	0.082	0.138	0.075	0.187	0.067	0.177	0.074	0.126	0.112	0.219	0.071	0.110	0.130	0.307	0.090	0.118	0.084	0.485
Iron (mg/l)																						
Feb	0.088	0.108	0.150	0.125	0.106	0.110	0.127	0.134	NS	0.107	0.106	0.102	0.149	0.121	0.087	0.105	0.240	0.130	0.149	0.193	0.151	0.218
May	0.059	0.320	0.061	0.450	NS	0.365	NS	0.456	0.060	0.495	0.045	0.324	NS	0.450	0.040	0.256	0.141	0.683	0.080	0.243	0.100	1.106
Aug	0.044	0.062	0.051	0.116	0.037	0.061	0.046	0.120	0.031	0.062	0.030	0.081	0.625	0.732	0.043	0.059	0.046	0.307	0.088	0.048	0.046	0.167
Nov	0.126	0.089	0.055	0.218	0.120	0.082	0.072	1.493	0.131	0.092	0.107	0.091	0.206	0.413	0.132	0.080	0.291	0.471	0.162	0.075	0.079	0.583
Annual Mean	0.079	0.145	0.079	0.227	0.088	0.155	0.082	0.551	0.074	0.189	0.072	0.150	0.327	0.429	0.076	0.125	0.180	0.398	0.120	0.140	0.094	0.519
Manganese (ug/l)																						
Feb	14	10	22	10	14	10	19	13	NS	10	14	10	22	13	11	8	22	10	20	14	21	18
May	12	7	24	19	NS	11	NS	20	8	13	7	11	NS	28	6	6	30	23	11	6	21	47
Aug	23	17	481	441	24	24	245	505	34	48	30	34	1906	1191	14	21	549	1379	108	18	663	1219
Nov	117	53	8694	2251	94	60	8500	4719	262	90	125	65	438	838	60	41	985	499	55	28	284	315
Annual Mean	42	22	2305	680	44	26	2922	1314	101	40	44	30	789	518	23	19	396	478	48	16	247	400
Cadmium (ug/l)																						
Feb	NS	NS	NS	NS	0.5	0.5	0.5	0.5	NS	0.5	NS	NS	NS	NS	0.5	0.5	0.5	0.5	NS	NS	NS	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	0.5	NS	NS	NS	NS	NS	0.5	NS	0.5	NS	NS	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	NS	NS	NS	NS	0.5	NS	0.5	NS	0.5	NS	NS	NS	NS	NS	0.5	NS	0.5	NS	NS	NS	NS	NS
Annual Mean	NA	NA	NA	NA	0.5	0.5	0.5	0.5	0.5	0.5	NA	NA	NA	NA	0.5	0.5	0.5	0.5	NA	NA	NA	NA
Copper (ug/l)																						
Feb	NS	NS	NS	NS	2.3	2.0	2.4	2.0	NS	2.0	NS	NS	NS	NS	2.0	2.0	2.4	2.0	NS	NS	NS	NS
May	NS	NS	NS	NS	2.6	2.9	NS	2.5	2.6	13.8	NS	NS	NS	NS	2.8	2.2	2.6	2.2	NS	NS	NS	NS
Aug	NS	NS	NS	NS	2.3	2.4	2.1	2.3	2.4	2.7	NS	NS	NS	NS	2.6	2.6	2.0	2.7	NS	NS	NS	NS
Nov	NS	NS	NS	NS	2.0	2.0	2.0	2.0	2.0	2.0	NS	NS	NS	NS	2.1	2.0	2.0	2.1	NS	NS	NS	NS
Annual Mean	NA	NA	NA	NA	2.3	2.3	2.2	2.2	2.3	5.1	NA	NA	NA	NA	2.4	2.2	2.3	2.3	NA	NA	NA	NA
Lead (ug/l)																						
Feb	NS	NS	NS	NS	2.0	2.0	2.0	2.0	NS	2.0	NS	NS	NS	NS	2.0	2.3	2.0	2.0	NS	NS	NS	NS
May	NS	NS	NS	NS	2.0	2.0	NS	2.0	2.0	2.0	NS	NS	NS	NS	2.0	2.0	2.0	2.0	NS	NS	NS	NS
Aug	NS	NS	NS	NS	2.0	2.0	2.0	2.0	2.0	2.0	NS	NS	NS	NS	2.0	2.0	2.0	2.0	NS	NS	NS	NS
Nov	NS	NS	NS	NS	2.0	2.0	2.0	2.0	2.0	2.0	NS	NS	NS	NS	2.0	2.0	2.0	2.0	NS	NS	NS	NS
Annual Mean	NA	NA	NA	NA	2.0	2.0	2.0	2.0	2.0	2.0	NA	NA	NA	NA	2.0	2.1	2.0	2.0	NA	NA	NA	NA

NS = Not Sampled; NA= Not Applicable

Table 2-5. (Continued)

LOCATION:	Mixing Zone 1.0				Mixing Zone Mi 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:	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003
Zinc (ug/l)																						
Feb	20	20	20	20	20	25	30	20	NS	20	20	20	20	20	20	20	20	20	20	20	20	20
May	20	20	20	20	NS	20	NS	20	20	20	20	20	NS	20	20	20	20	20	20	20	20	20
Aug	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Nov	20	20	20	20	20	20	20	20	20	20	20	20	20	20	27	20	20	20	20	20	20	20
Annual Mean	20.0	20.0	20.0	20.0	20.0	21.3	23.3	20.0	20.0	20.0	20.0	20.0	20.0	20.0	21.8	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Nitrite-Nitrate (ug/l)																						
Feb	200	210	210	220	200	280	220	230	NS	230	200	220	200	230	200	420	200	390	250	350	240	350
May	210	350	250	410	NS	340	NS	410	210	370	220	340	NS	410	190	300	260	430	220	260	270	460
Aug	90	180	330	450	70	200	340	450	90	230	110	220	340	180	40	180	340	420	100	110	310	410
Nov	180	110	20	50	190	110	20	20	190	120	190	110	170	90	190	110	180	140	220	120	220	150
Annual Mean	170.0	212.5	202.5	282.5	153.3	232.5	193.3	277.5	163.3	237.5	180.0	222.5	236.7	227.5	155.0	252.5	245.0	345.0	197.5	210.0	260.0	342.5
Ammonia (ug/l)																						
Feb	30	20	50	30	40	20	40	30	NS	20	40	20	40	20	40	30	30	30	20	30	30	30
May	20	40	50	20	NS	40	NS	20	30	50	20	40	NS	20	20	30	70	20	30	30	70	90
Aug	20	20	30	20	20	20	20	20	20	20	20	20	90	130	20	20	20	20	20	20	20	20
Nov	80	60	540	280	70	70	570	490	70	80	70	50	100	190	50	70	140	190	90	20	110	140
Annual Mean	37.5	35.0	167.5	87.5	43.3	37.5	210.0	140.0	40.0	42.5	37.5	32.5	76.7	90.0	32.5	37.5	65.0	65.0	40.0	25.0	57.5	70.0
Total Phosphorous (ug/l)																						
Feb	10	10	10	10	10	10	10	10	NS	10	10	10	10	10	10	10	10	10	10	10	10	10
May	11	11	10	12	NS	11	NS	15	10	58	10	14	NS	14	10	17	10	24	12	13	10	34
Aug	7	10	5	10	8	10	6	10	11	10	5	10	8	10	5	10	10	11	5	10	6	10
Nov	5	11	5	16	5	10	7	14	7	17	5	10	7	18	5	10	7	16	5	19	5	19
Annual Mean	8.3	10.5	7.5	12.0	7.7	10.3	7.7	12.3	9.3	23.8	7.5	11.0	8.3	13.0	7.5	11.8	9.3	15.3	8.0	13.0	7.8	18.3
Orthophosphate (ug/l)																						
Feb	5	5	5	5	5	2	5	5	NS	5	5	5	5	5	5	5	5	5	5	5	5	5
May	6	5	9	6	NS	5	NS	7	9	49	8	7	NS	31	9	9	5	5	10	17	9	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	5.3	5.0	6.0	5.3	5.0	4.3	7.7	6	6.3	17	5.8	6	5.0	12	6.0	6	5.0	5	6.3	8.0	6.0	5
Silicon (mg/l)																						
Feb	4.9	4.1	5.0	4.1	5.0	4.1	5.2	4.1	NS	4.1	5.0	4.1	4.8	4.1	5.0	4.1	5.0	4.1	5.1	4.5	5.1	4.4
May	4.3	3.8	4.9	4.3	NS	3.9	NS	4.3	4.4	4.0	4.3	3.9	NS	4.3	4.2	3.8	5.0	4.3	3.9	3.4	4.9	4.2
Aug	3.8	2.7	5.4	4.7	3.8	3.0	5.4	4.8	3.9	3.3	3.8	3.1	5.2	4.5	3.7	2.8	5.4	4.9	4.2	2.7	5.4	4.7
Nov	4.2	4.0	5.6	4.5	4.3	4.0	5.6	5.1	4.3	4.1	4.3	4.0	4.4	4.3	4.3	4.0	4.4	5.4	4.4	4.3	4.6	5.4
Annual Mean	4.3	3.7	5.2	4.4	4.4	3.8	5.4	4.6	4.2	3.9	4.4	3.8	4.8	4.3	4.3	3.7	5.0	4.7	4.4	3.7	5.0	4.7

NS = Not Sampled; NA= Not Applicable

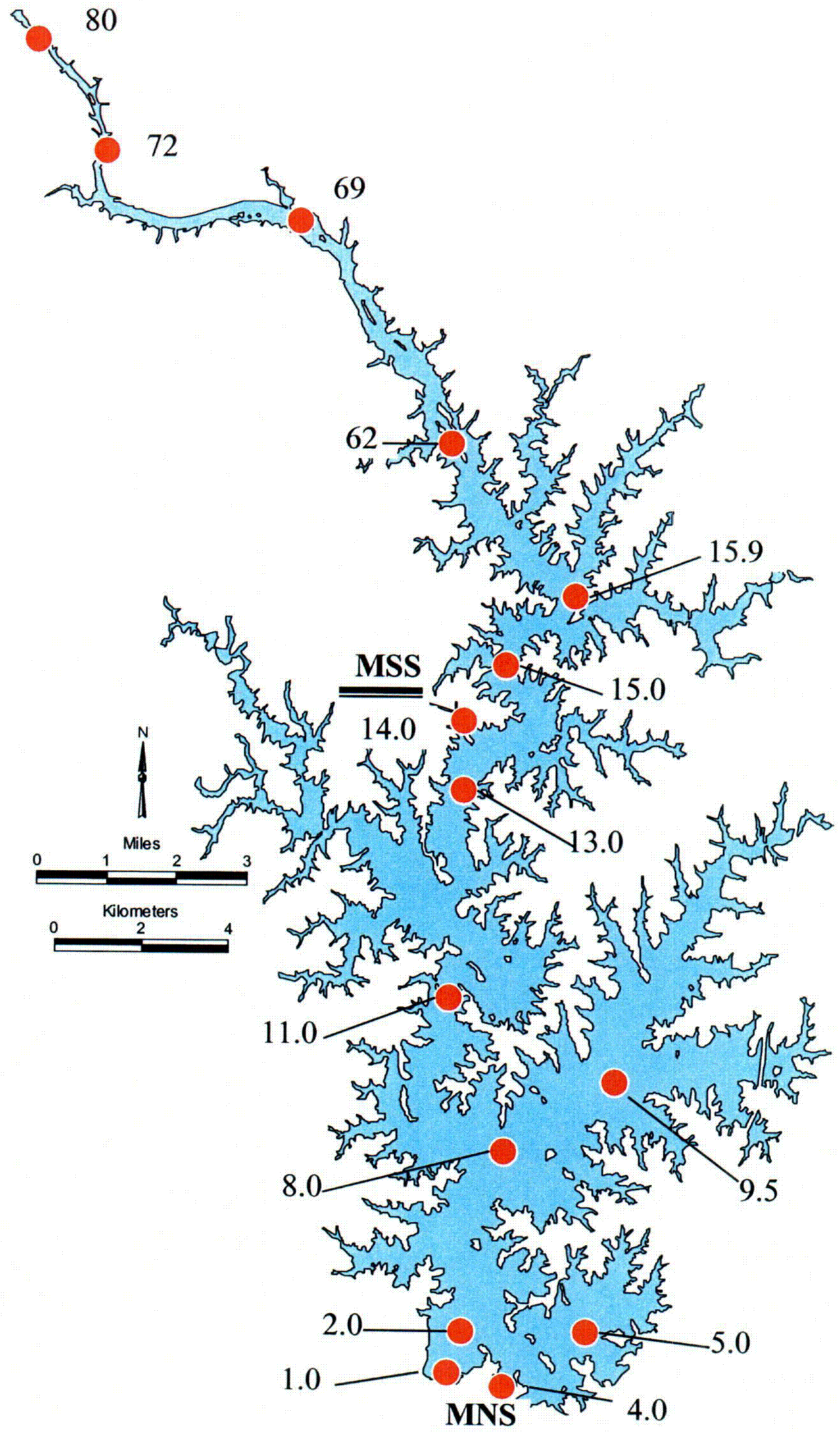


Figure 2-1. Water quality sampling locations (numbered) for Lake Norman. Approximate locations of Marshall Steam Station (MSS), and McGuire Nuclear Station (MNS) are also shown.

c01

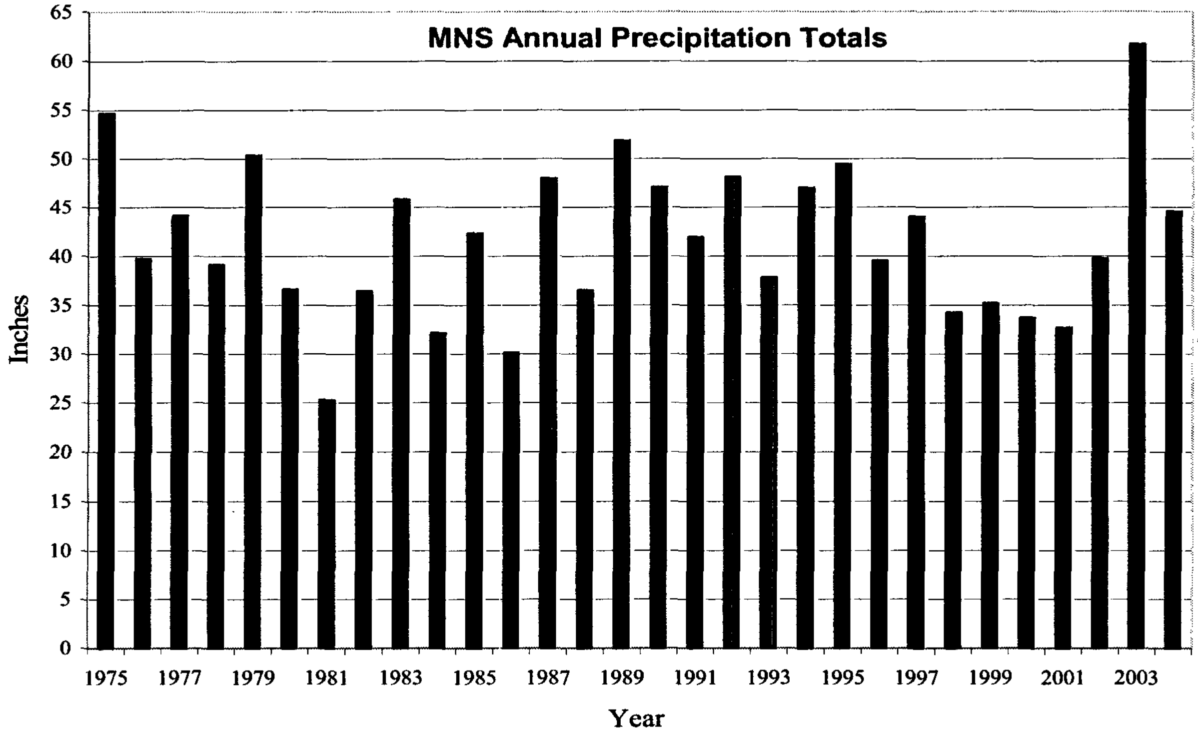


Figure 2-2a. Annual precipitation totals in the vicinity of McGuire Nuclear Station (MNS).

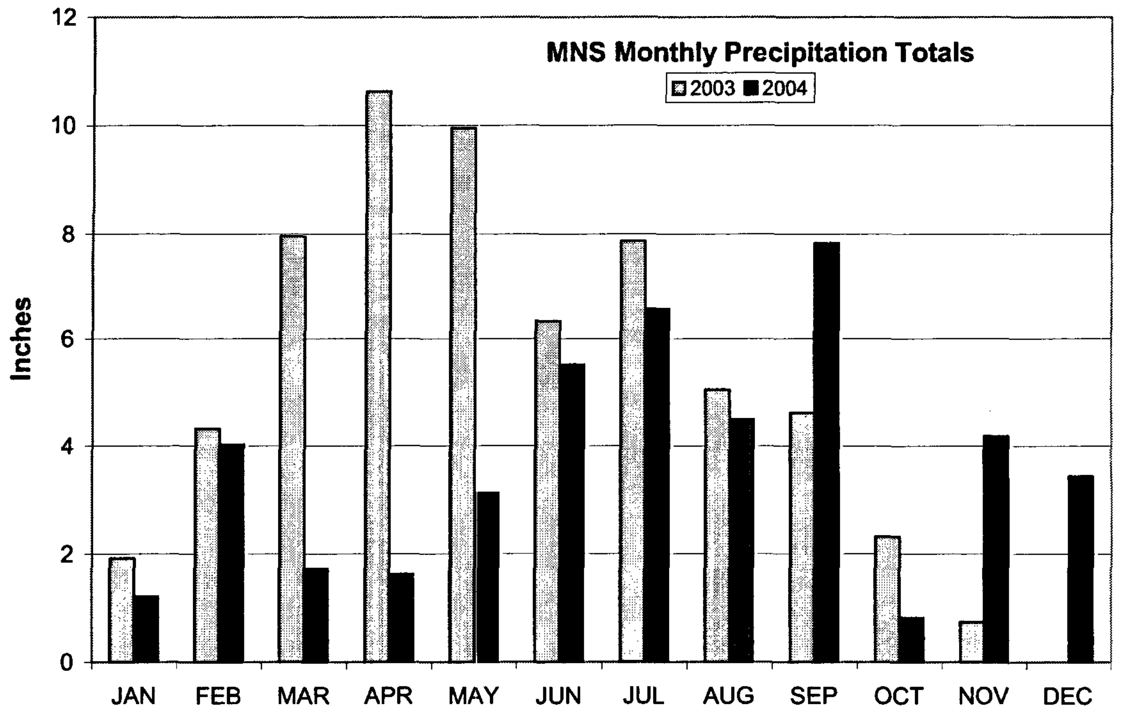


Figure 2-2b. Monthly precipitation totals in the vicinity of McGuire Nuclear Station (MNS)

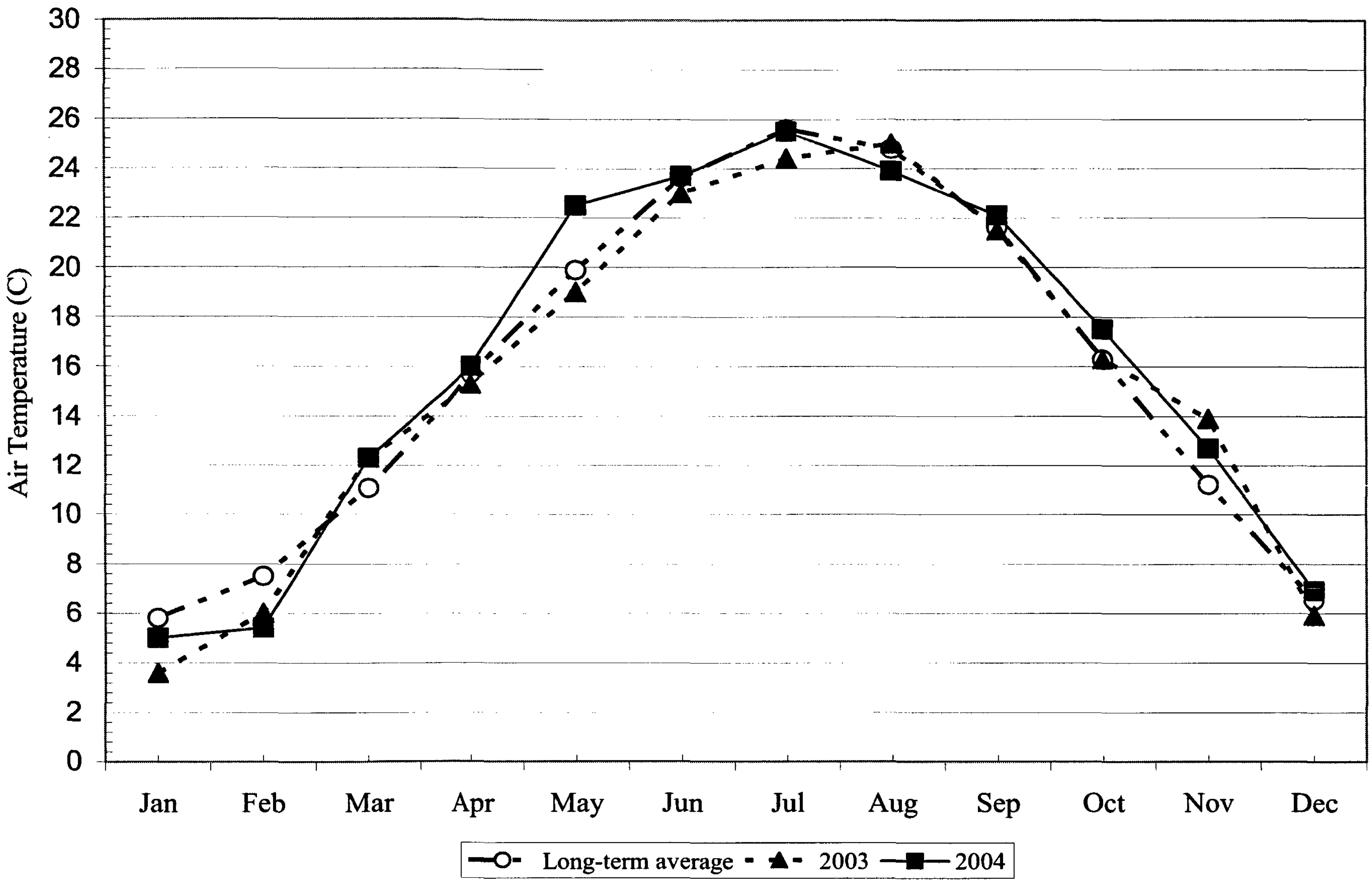


Figure 2-2c. Mean monthly air temperatures recorded at MNS beginning in 1989. Data are complied from average daily temperatures which, in turn, were created from hourly measurements.

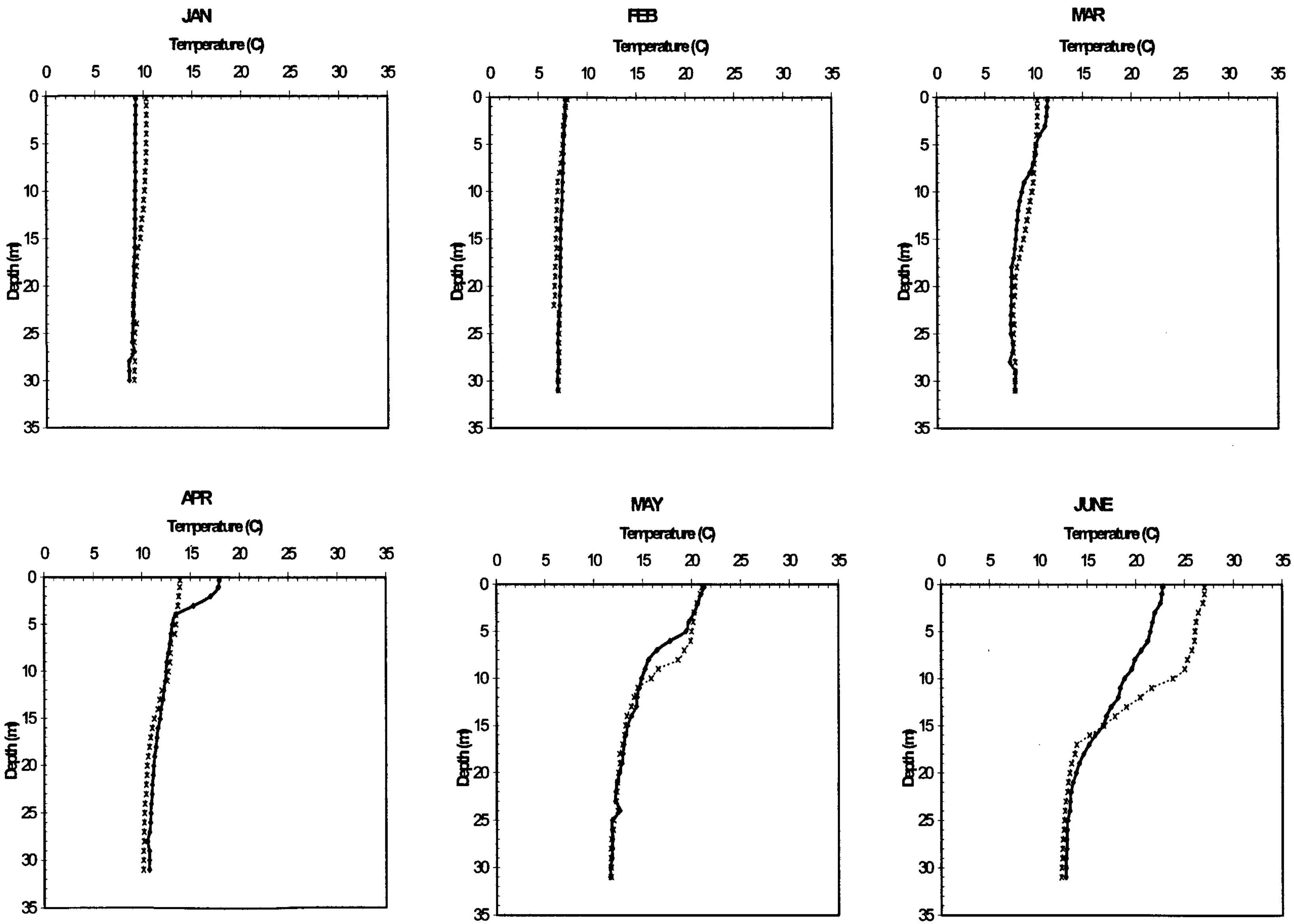


Figure 2-3. Monthly mean temperature profiles for the McGuire Nuclear Station background zone in 2004 (××) and 2003 (♦♦).

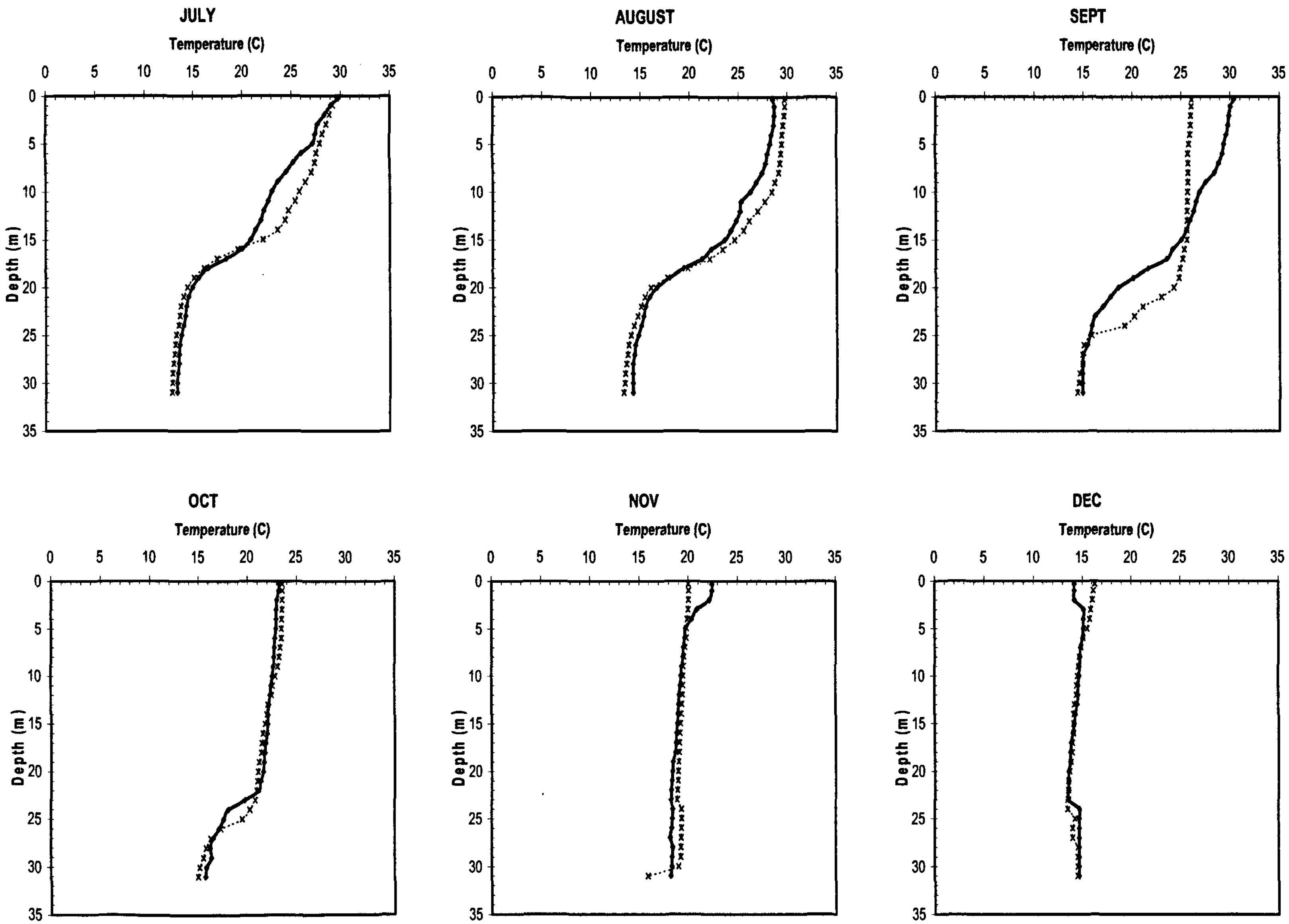


Figure 2-3. (Continued).

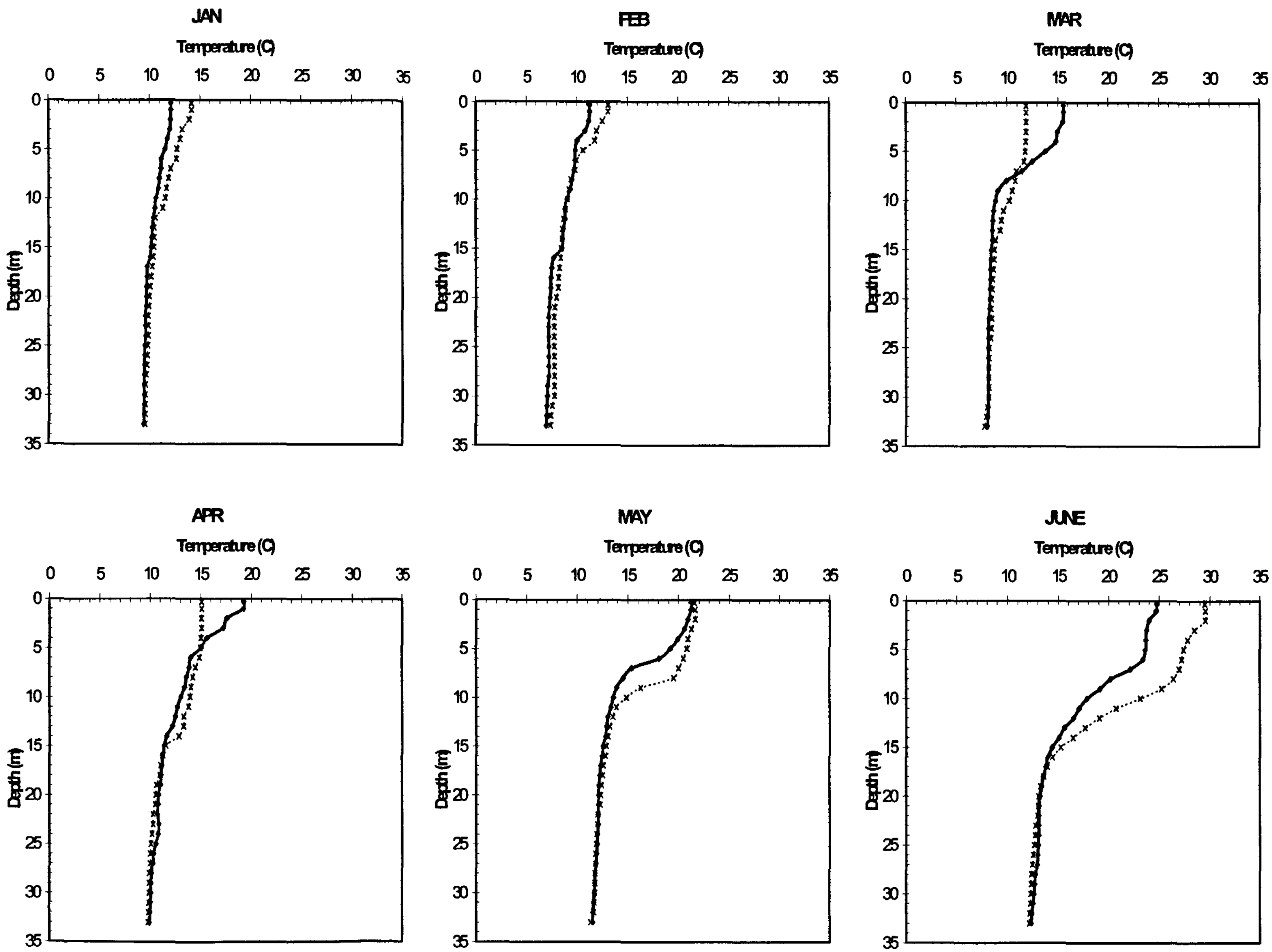


Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 2004 (××) and 2003 (♦♦).

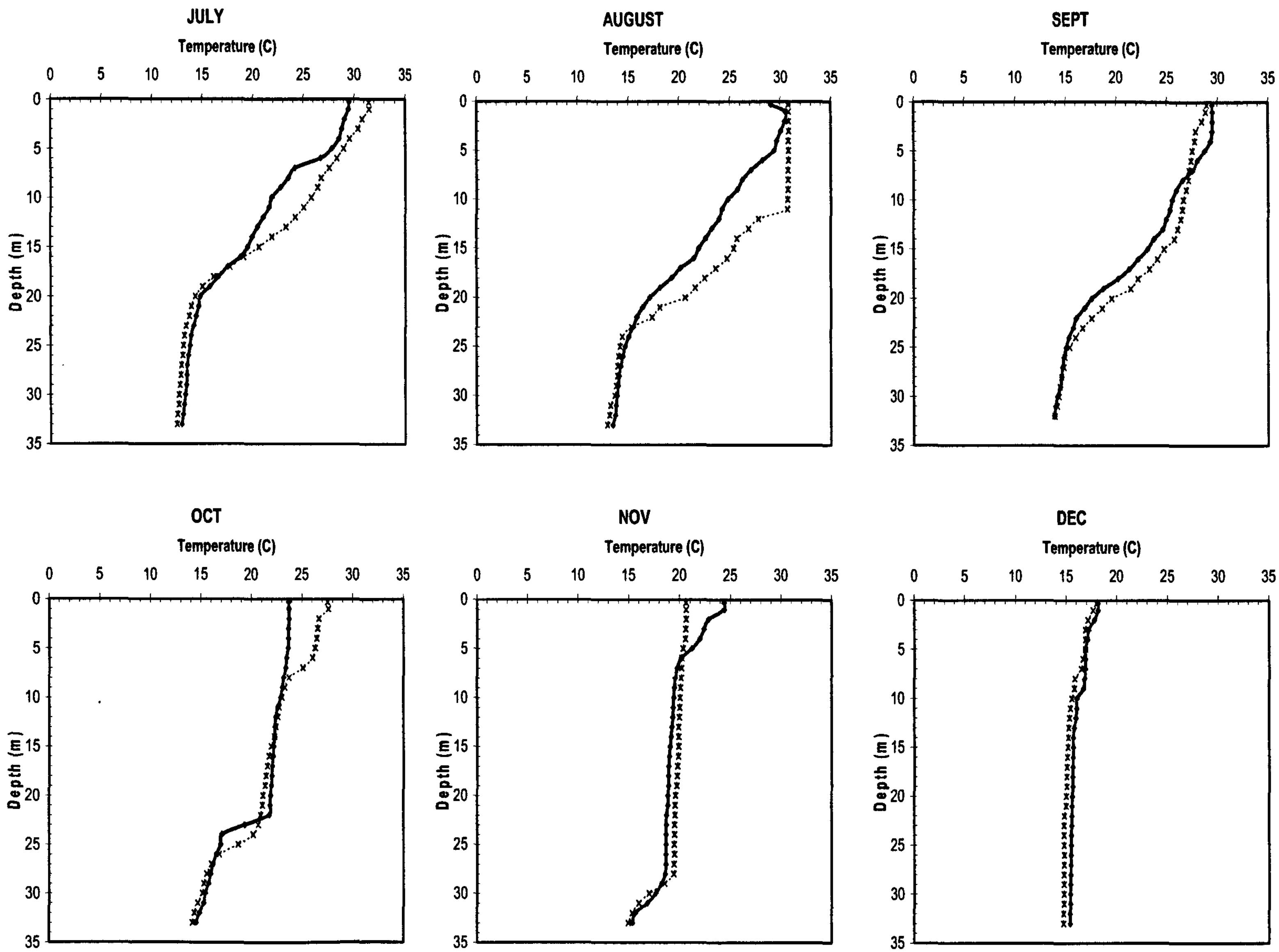
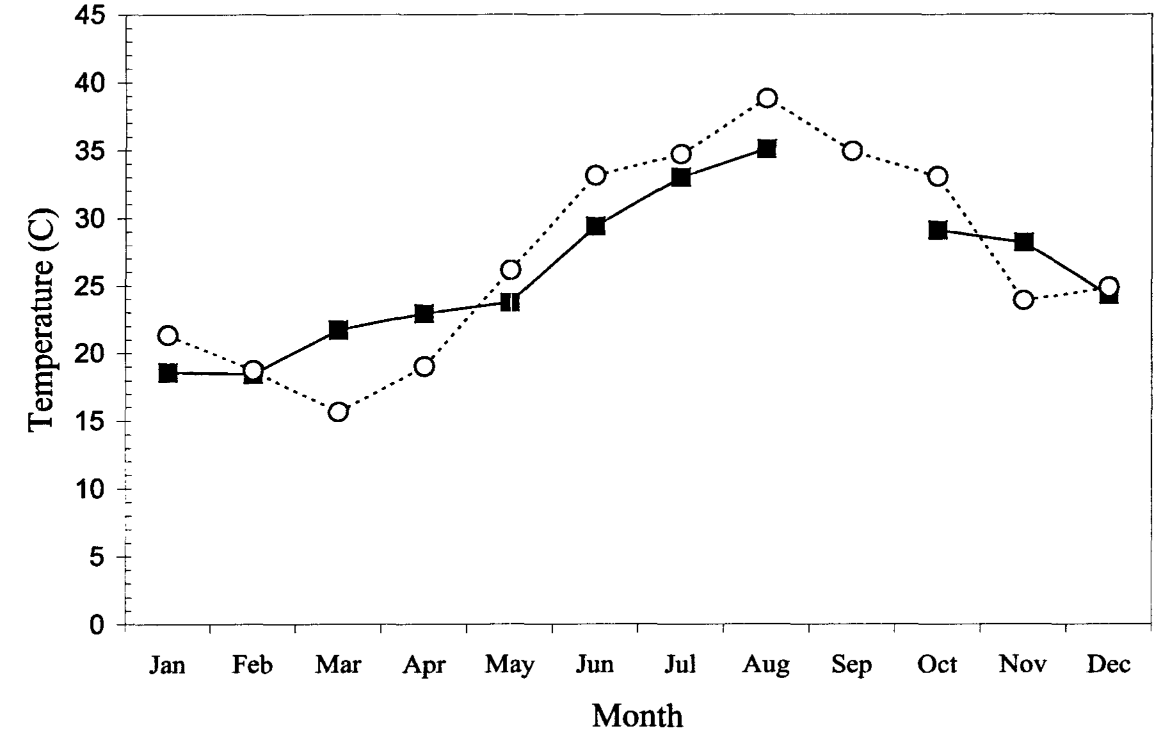


Figure 2-4. (Continued).



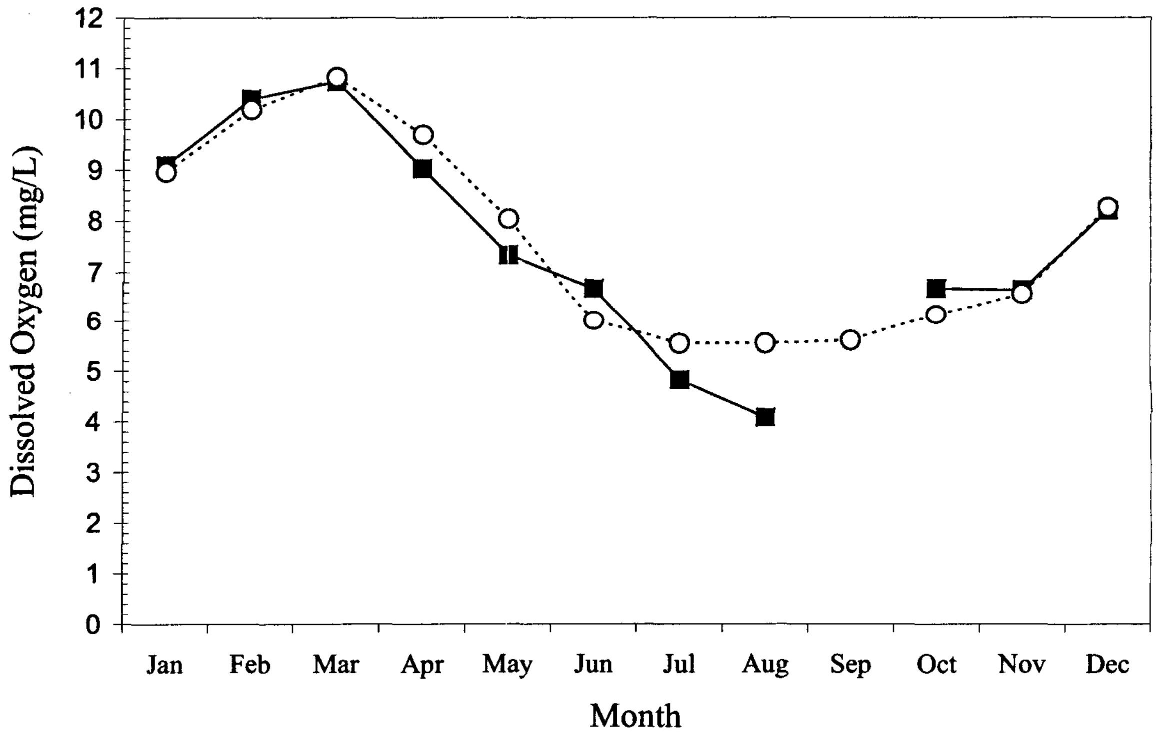


Figure 2-5. Monthly surface (0.3m) temperature and dissolved oxygen data at the discharge location (loc. 4.0) in 2004 (○) and 2003 (■). September 2003 data are missing.

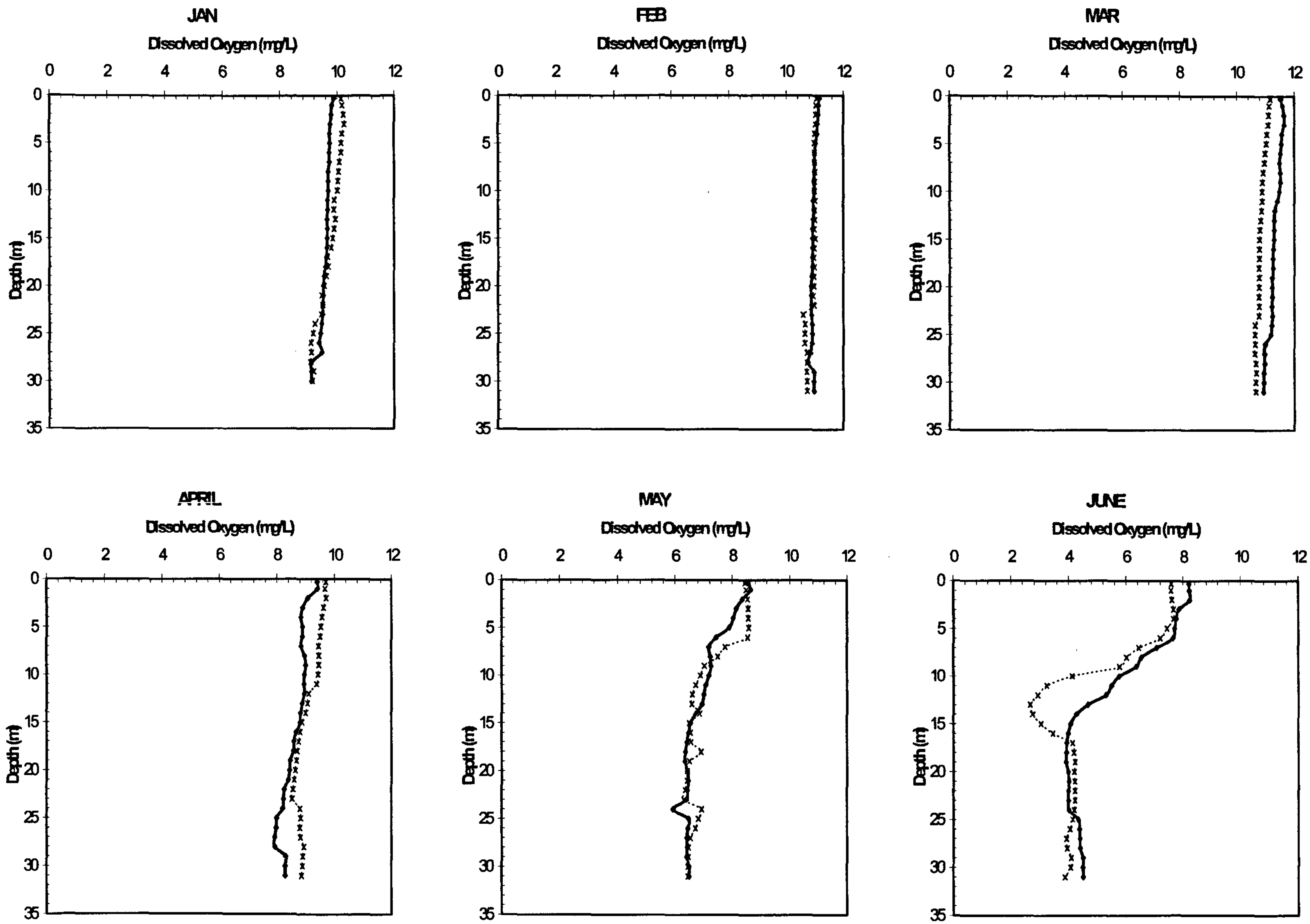


Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 2004 (××) and 2003 (♦♦).

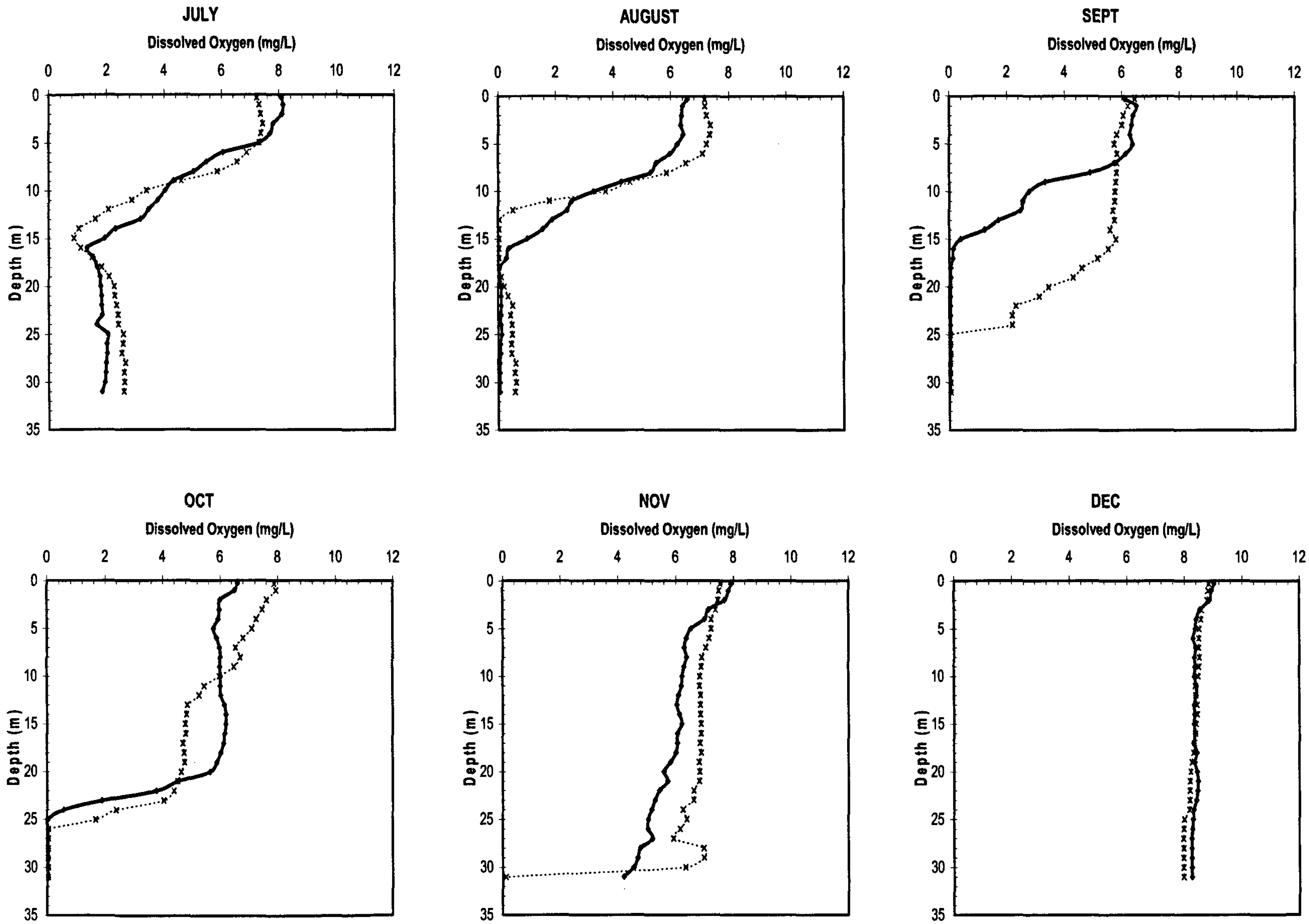


Figure 2-6. (Continued).

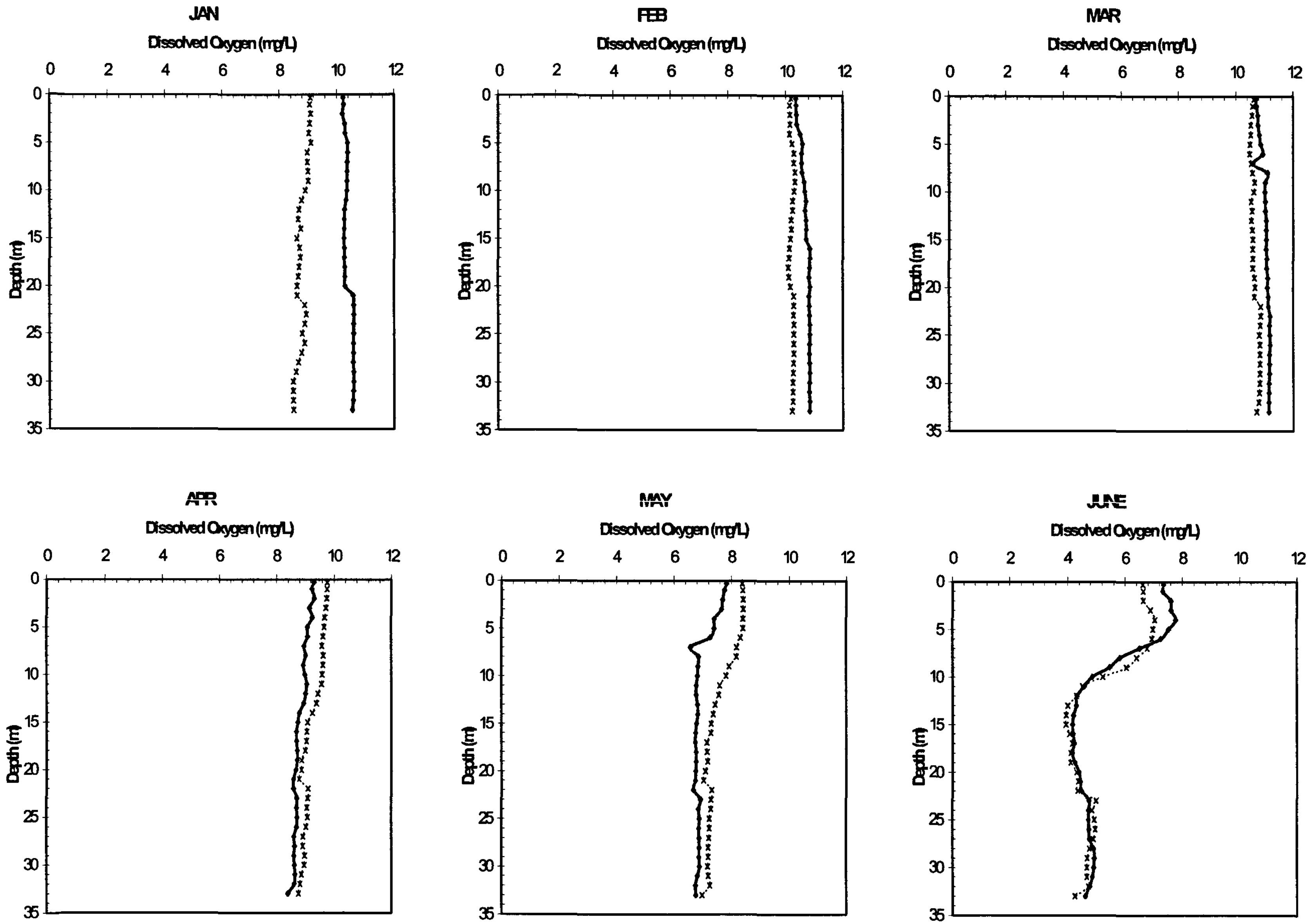


Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 2004 (××) and 2003 (♦♦).

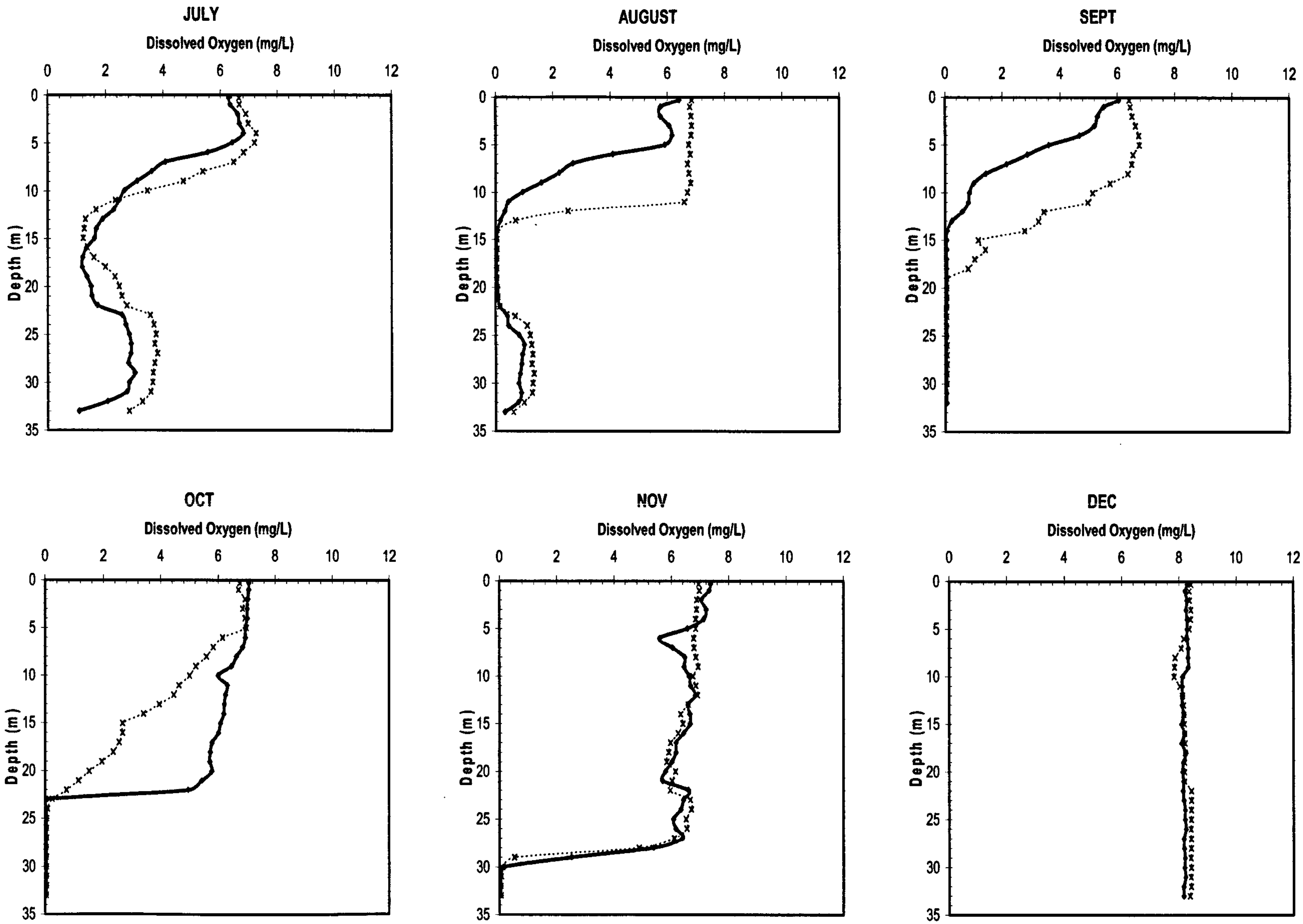


Figure 2-7. (Continued).

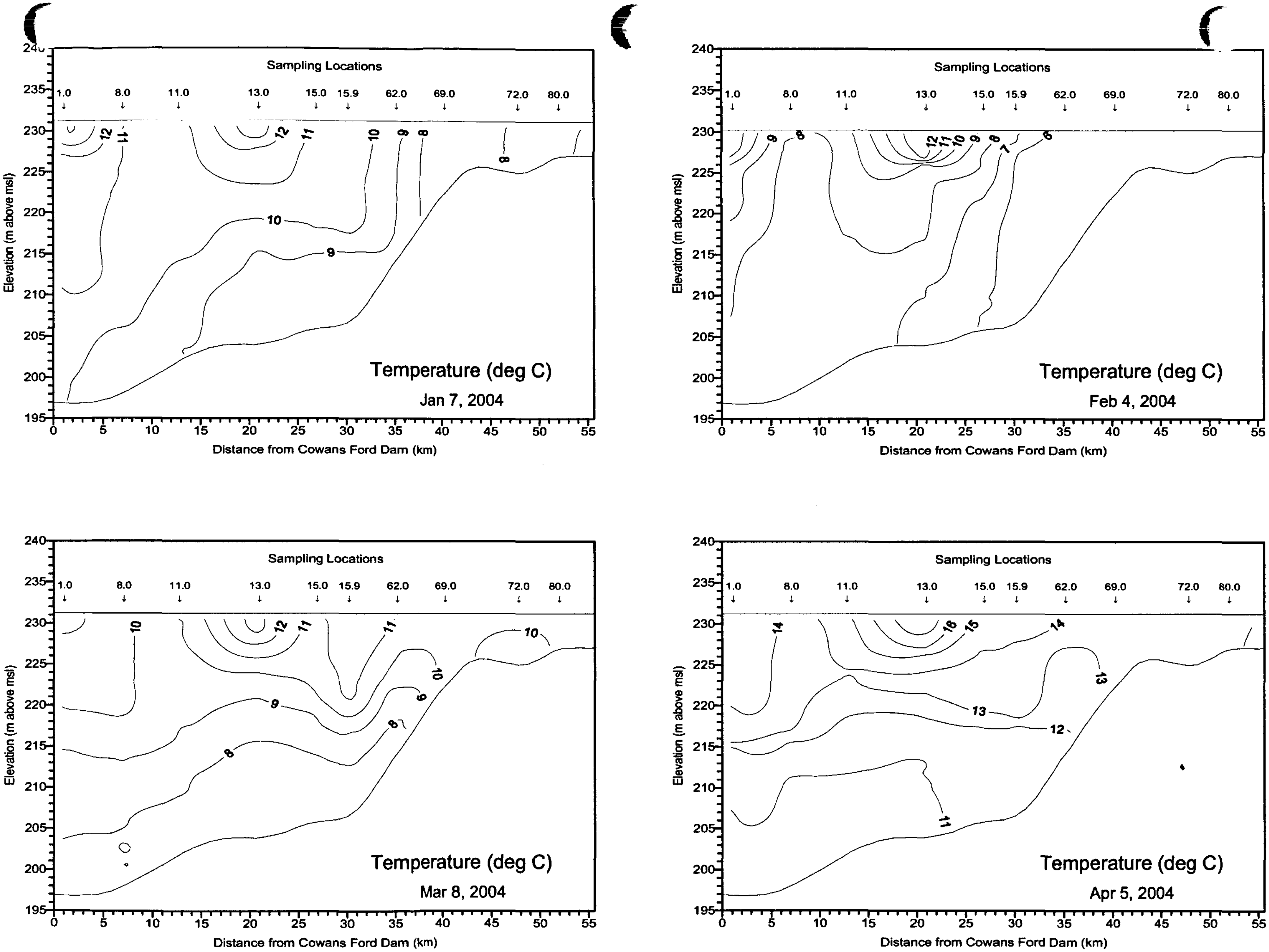


Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 2004.

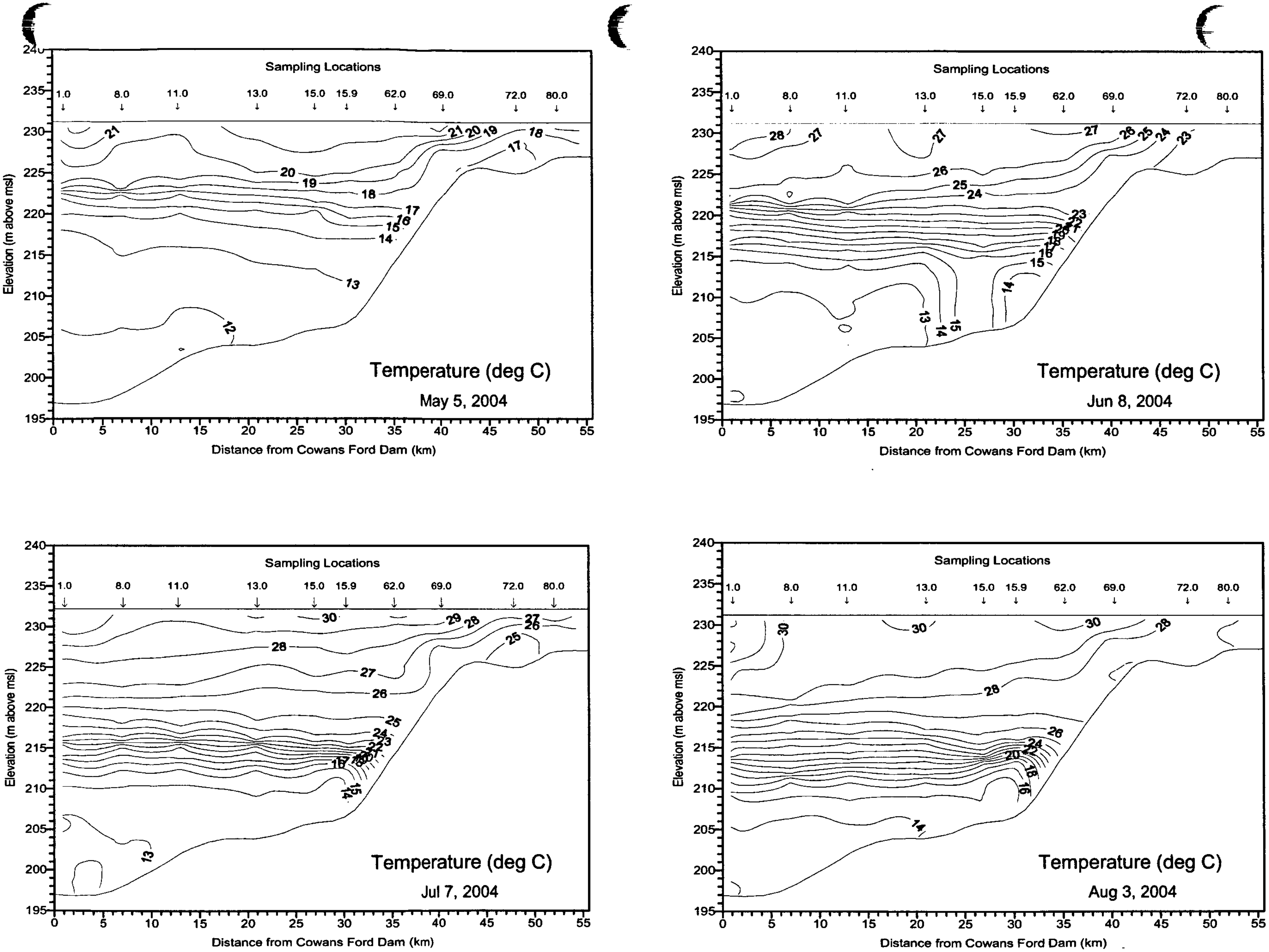


Figure 2-8. (Continued).

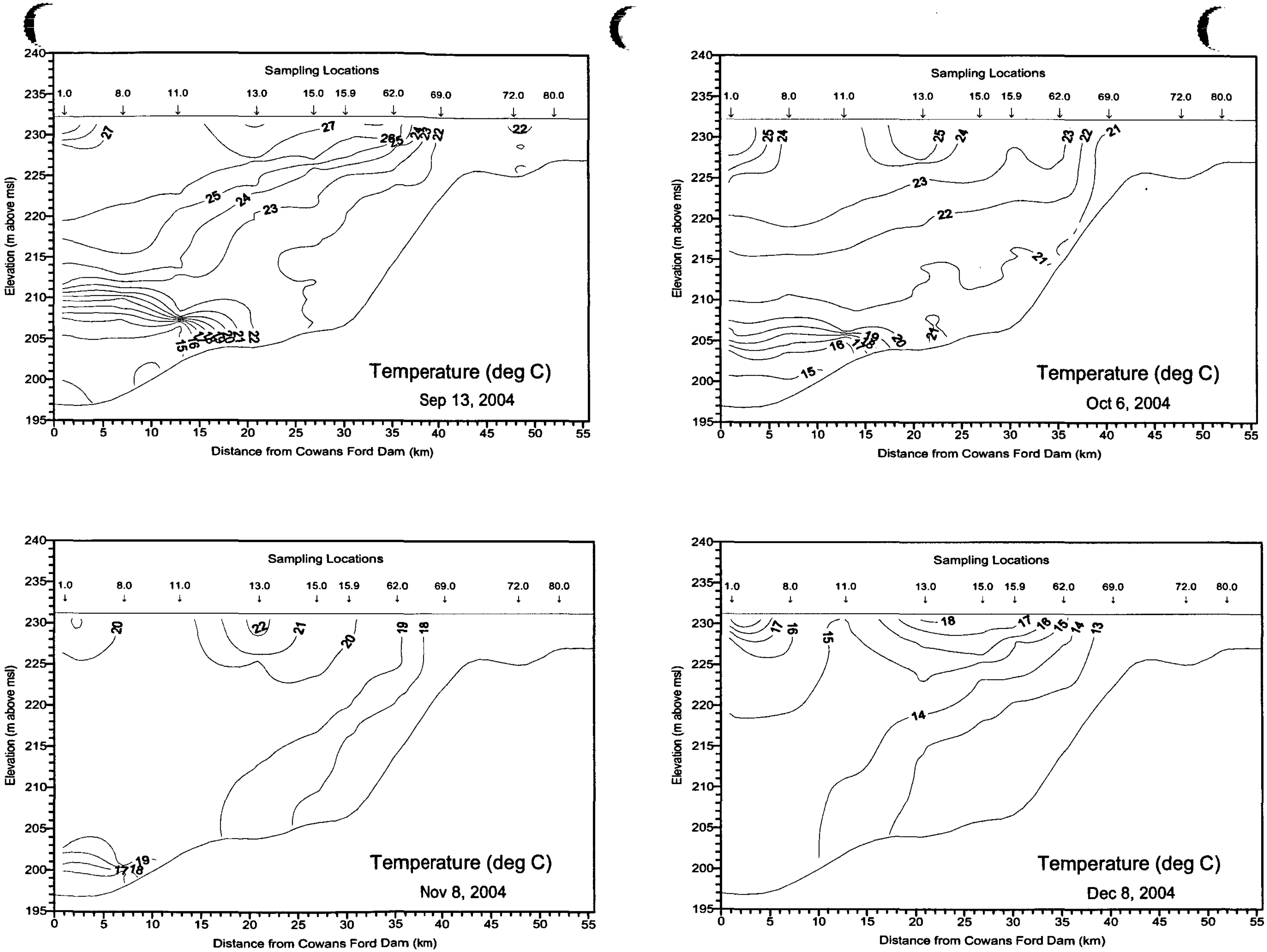


Figure 2-8. (Continued).

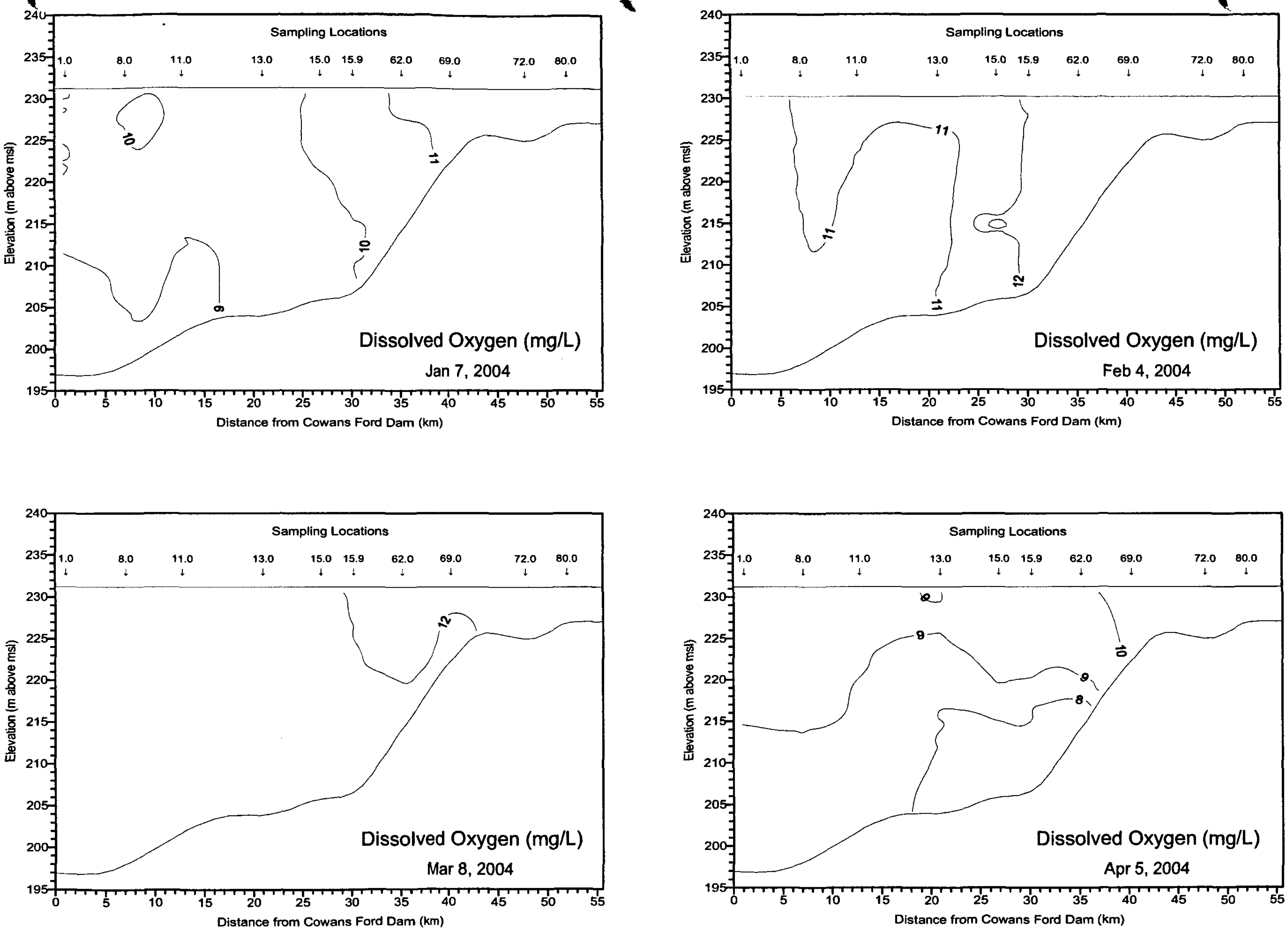


Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 2004.

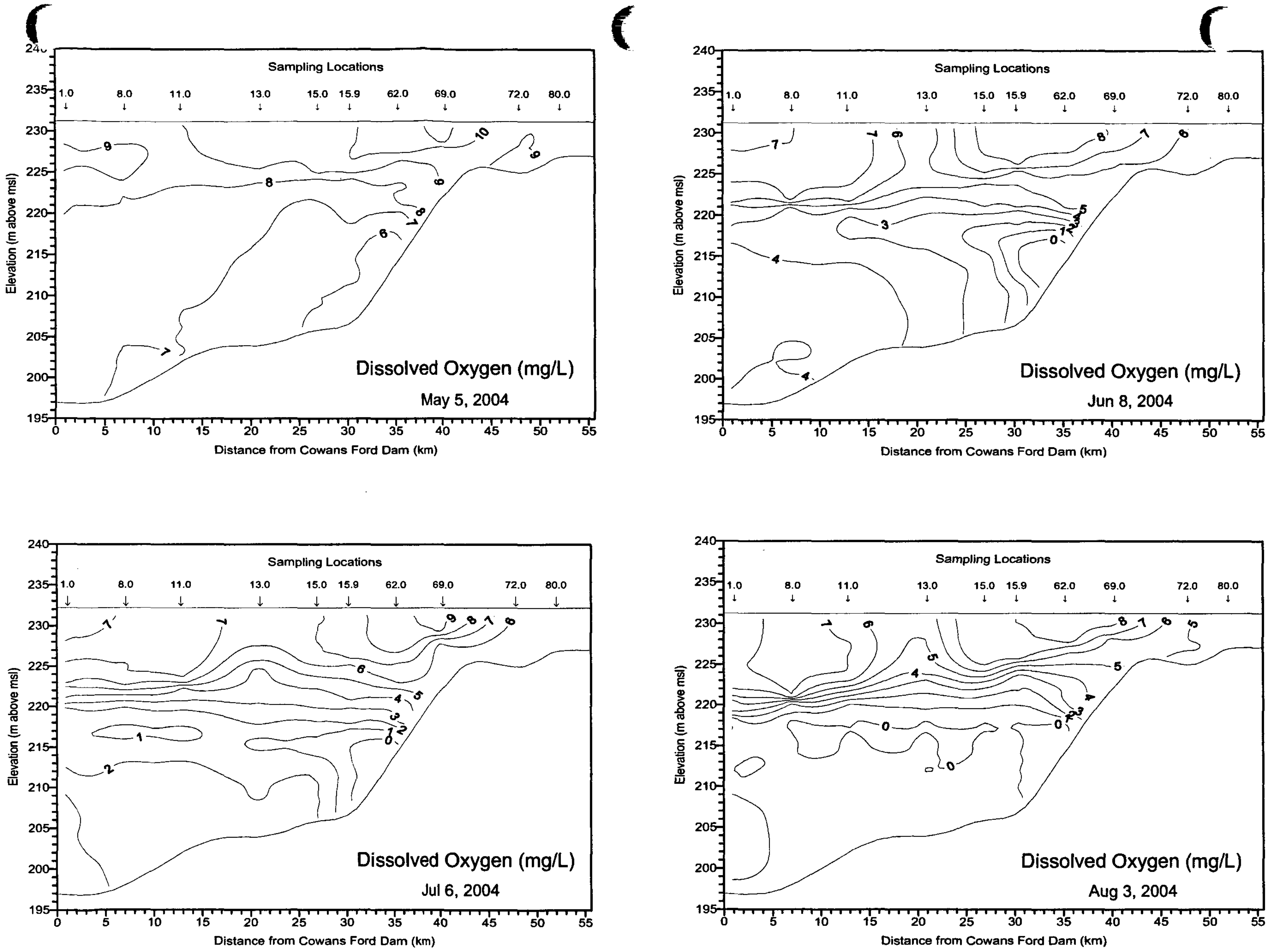


Figure 2-9. (Continued).

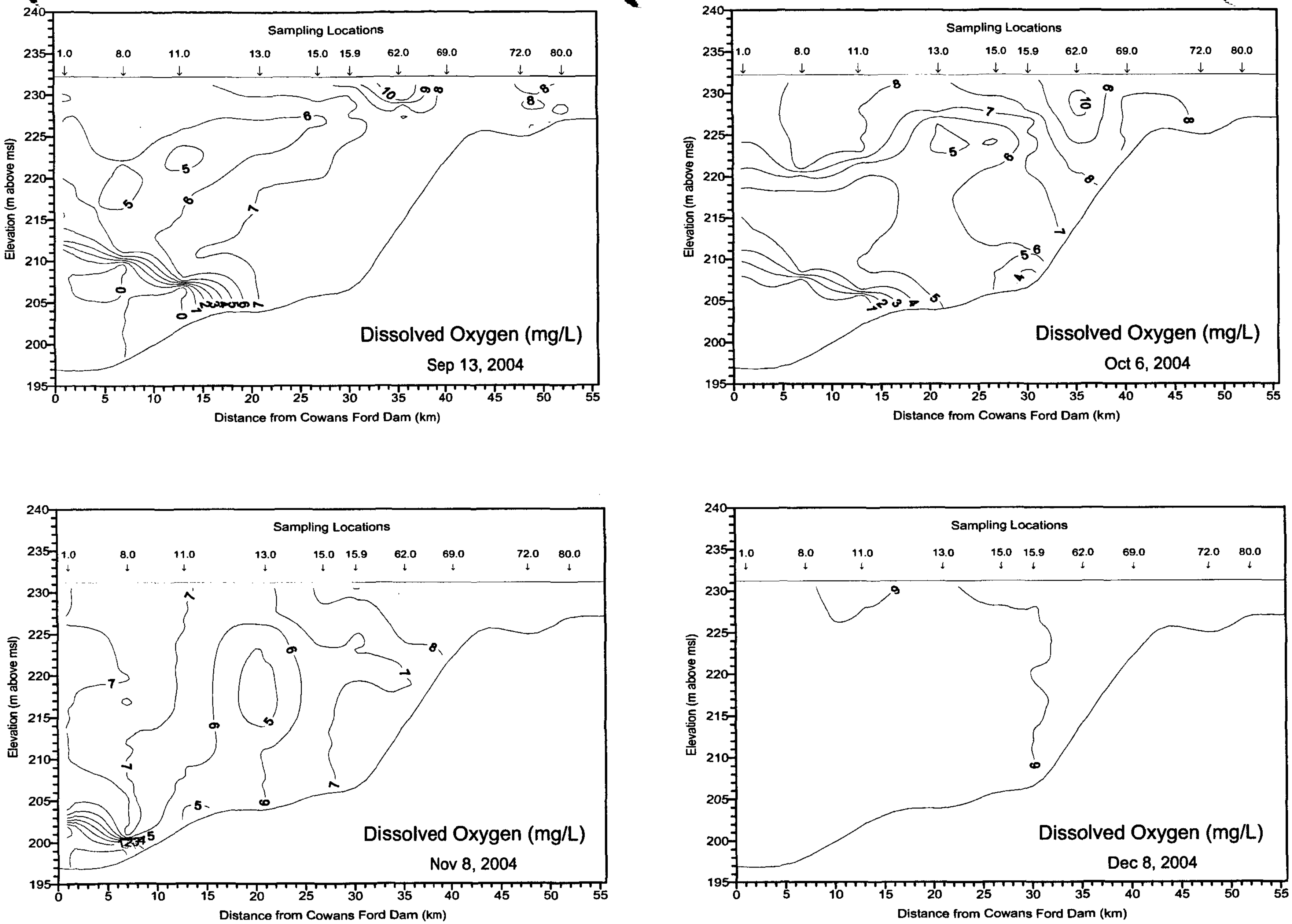


Figure 2-9. (Continued).

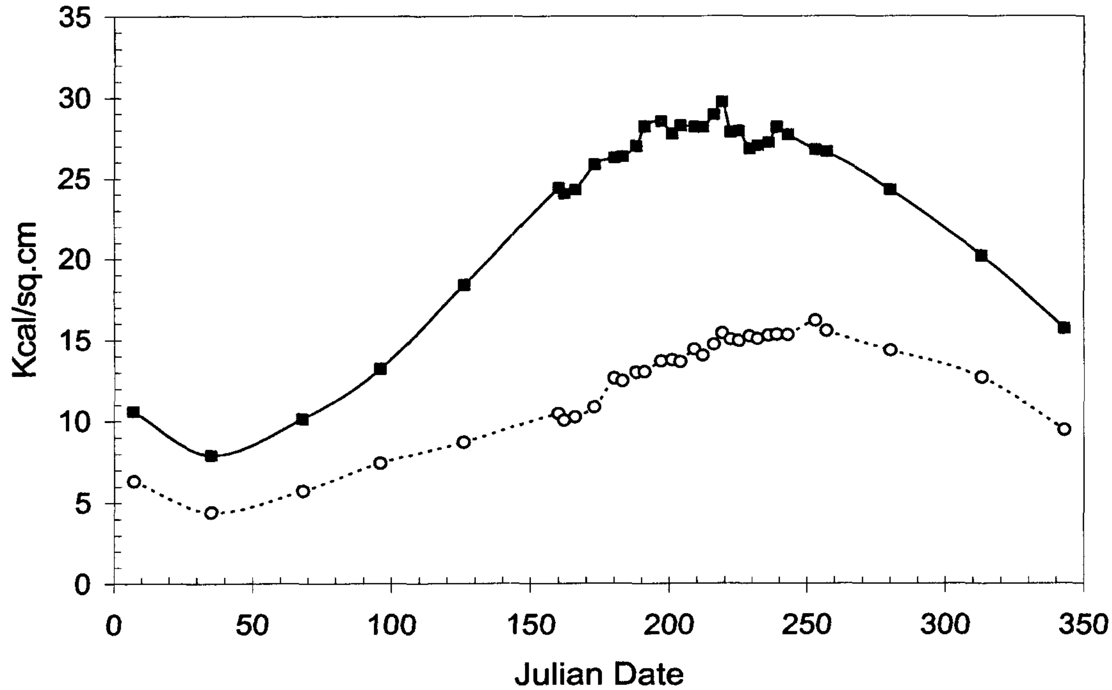


Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (○) in Lake Norman in 2004.

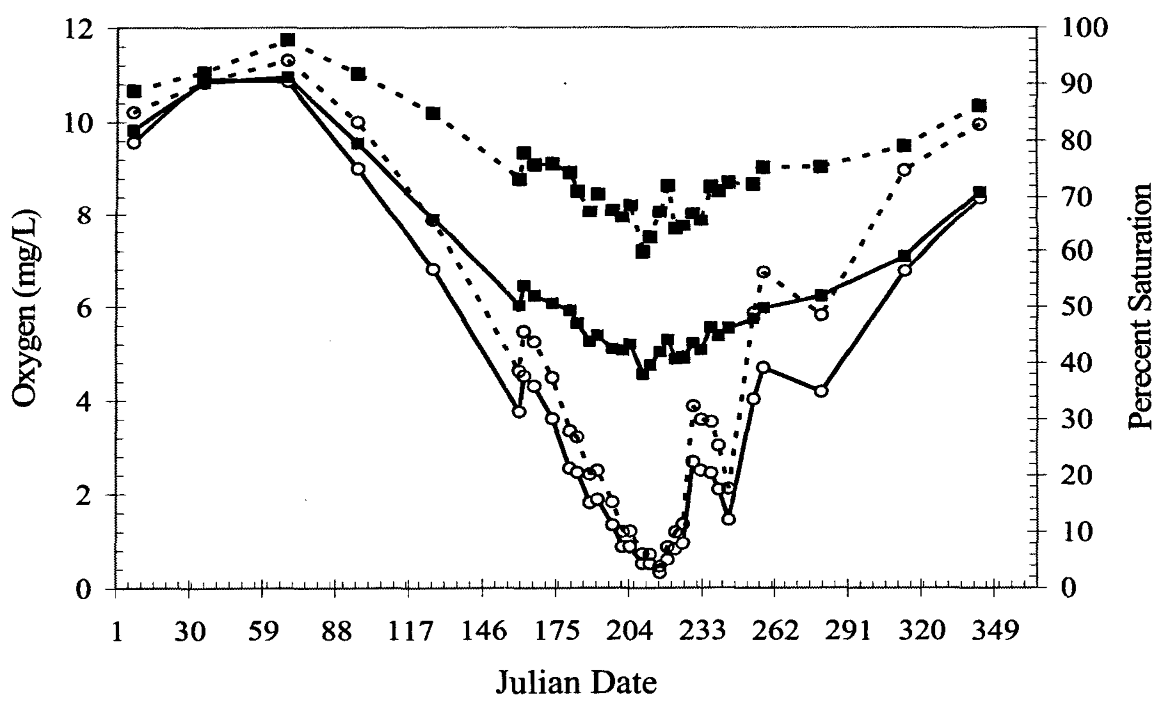


Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (○) of Lake Norman in 2004.

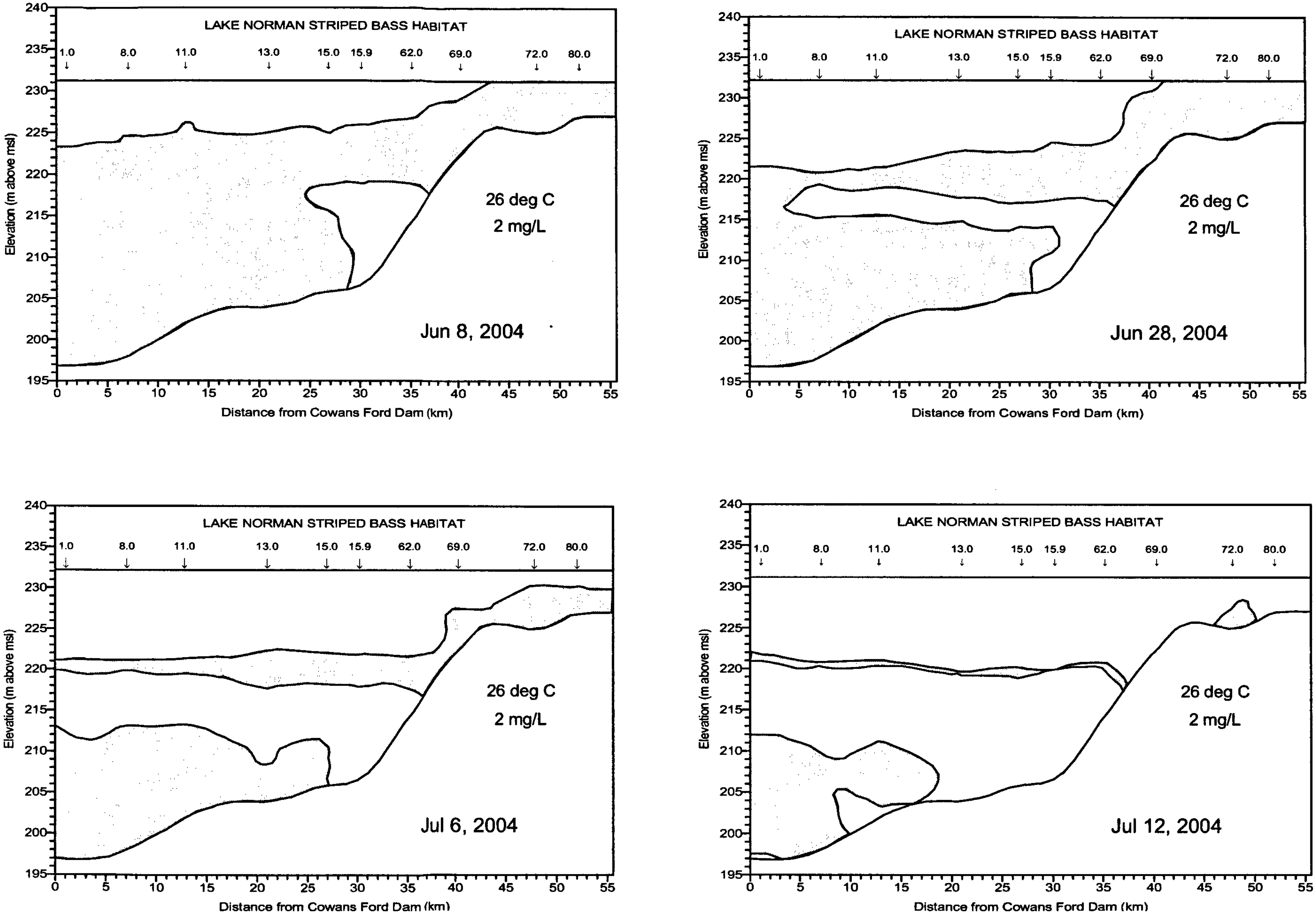


Figure 2-11. Striped bass habitat (temperatures ≤ 26 °C and dissolved oxygen ≥ 2 mg/L) in Lake Norman, summer 2004.

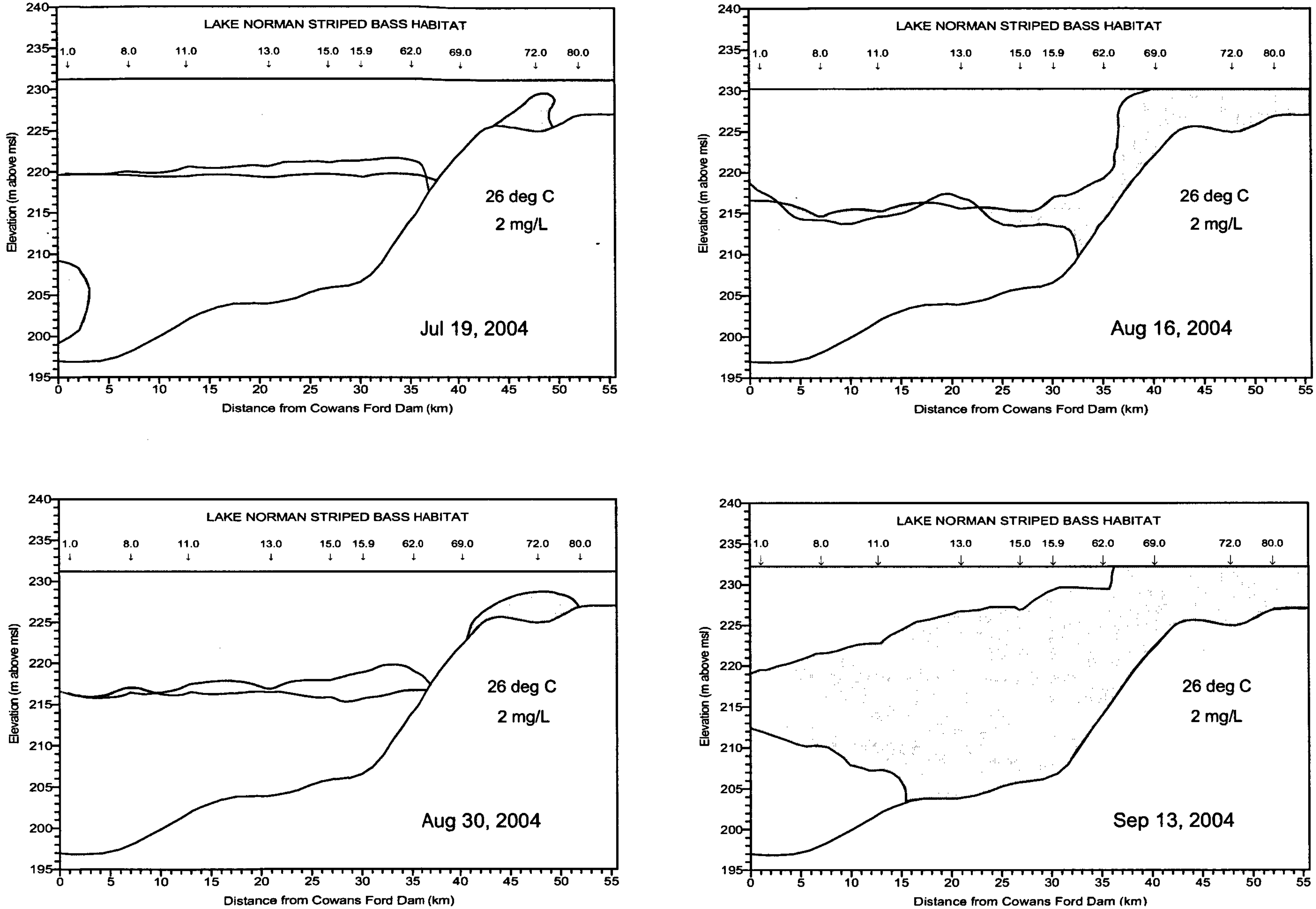


Figure 2-11. (Continued).

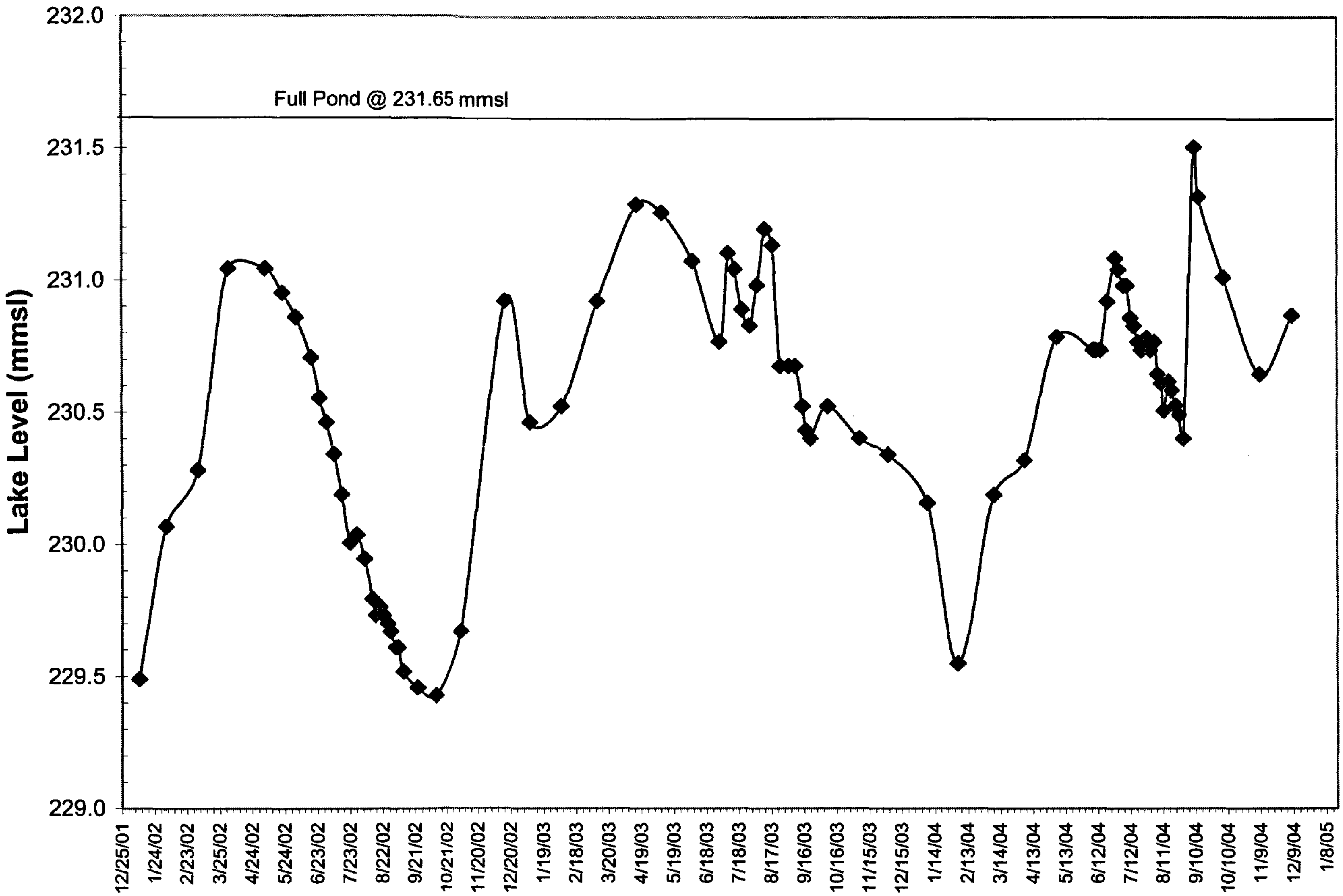


Figure 2-12. Lake Norman lake levels, expressed in meters above mean sea level (mmsl) for 2002, 2003 and 2004. Lake level data correspond to the water quality sampling dates over this time period.

CHAPTER 3

PHYTOPLANKTON

INTRODUCTION

Phytoplankton standing crop parameters were monitored in 2004 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 2004) with 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 confirmed 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 depth. Sampling was conducted in February, May, August, and November 2004. 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 2004 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 0.97 ug/L at Location 2.0 in May, to a high of 10.57 ug/L at Location 15.9 in November (Table 3-1, Figure 3-1). All values were below the North Carolina water quality standard of 40 ug/L (NCDENR 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 2004 of the annual low in May, increasing to the yearly maximum in August, was also recorded from 1999 (Duke Power 2000). Based on quarterly mean chlorophyll concentrations, the trophic level of Lake Norman was in the mesotrophic (intermediate) range during February, in the oligotrophic (low) range in May, and in the mesotrophic range in August and November 2004. Nearly 47% of individual chlorophyll values were less than 4 ug/L (oligotrophic) while all of the remaining chlorophyll concentrations were between 4 and 12 ug/L (mesotrophic). No chlorophyll sample exceeded 12 ug/L (eutrophic or high range). Lake-wide quarterly mean concentrations of below 4 ug/L have been recorded on ten 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 2004 chlorophyll *a* concentrations showed a certain degree of spatial variability. Maximum concentrations were observed at Location 69.0 during February, May, and August, and at Location 15.9 in November. Minimum concentrations occurred at Location 9.5 in February, Location 2.0 in May and August, and Location 8.0 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 2003, was apparent in varying degrees during most quarters of 2004 (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 (2.0 and 5.0) during all sample periods (Table 3-2). Flow in the riverine zone of a reservoir is subject to wide fluctuations depending, ultimately, on meteorological conditions (Thornton, *et* al. 1990), although influences may be moderated due to upstream dams. During periods of high flow, algal production and standing crop would be depressed, due in great part, to washout. Conversely, production and standing crop would increase during periods of low flow and high retention time. Over long periods of low flow, production and standing crop would gradually decline once more. These conditions result in the comparatively 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 usually similar during each sampling period.

Average quarterly chlorophyll concentrations during the period of record (August 1987 – November 2004) have varied considerably, resulting in moderate to wide historical ranges. During February 2004, Locations 2.0 through 8.0, and 11.0 and 13.0 had chlorophyll concentrations in the mid range, while chlorophyll concentrations at Locations 15.9 and 69.0 were in the high range for this month. The mean chlorophyll concentration at Locations 9.5 was in the low range (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. Locations 5.0 and 8.0 had higher chlorophyll concentrations in February 2004 than in February 2003, while all other locations had lower concentrations than in February of the previous year (Duke Power 2004).

During May chlorophyll concentrations at Lake Norman locations were lower than normal, and five record low concentrations were recorded for May at Locations 2.0 through 11.0 (Figure 3-3). May 2004 chlorophyll concentrations at Locations 13.0 through 69.0 were higher than those of 2003 (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.

August chlorophyll concentrations at Locations 5.0 through 9.5, 13.0 and 69.0 were in the mid range for that time of year, while concentrations at Locations 2.0, 11.0 and 15.9 were in the low range for August (Figure 3-4). 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. All but Location 2.0 had higher chlorophyll concentrations in August 2004 than in August of the previous year (Duke Power 2004).

During November 2004 Locations 2.0 through 9.5 had chlorophyll concentrations in the low range for that month, while Locations 11.0 through 69.0 were in the mid range for November (Figure 3-4). 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. November 2004 chlorophyll concentrations at Locations 2.0, 11.0, and 15.9 were higher than during November 2003, while values at the other locations were lower than in November of the previous year (Duke Power 2004).

Total Abundance

Density and biovolume are measurements of phytoplankton abundance. The lowest density (777 units/ml) and biovolume (145 mm^3/m^3) during 2004 occurred at Location 9.5 in February (Table 3-3, Figure 3-1). The maximum density (7,200 units/ml) was observed at Location 15.9 in August and the highest biovolume (4,101 mm^3/m^3) was recorded from this same location in November. Standing crop values during 2004 were most often higher than those of 2003 (Duke Power 2004). Phytoplankton densities and biovolumes during 2004 never exceeded the NC guideline for algae blooms of 10,000 units/ml density or 5,000 mm^3/m^3 biovolume (NCDEHNR 1991). Densities and biovolumes in excess of NC guidelines were recorded in 1987, 1989, 1997, 1998, 2000, and 2003 (Duke Power Company 1988, 1990; Duke Power 1998, 1999, 2001, 2004).

Total densities at locations in the Mixing Zone during 2004 were within the same statistical ranges during all sampling periods, and location 15.9 had significantly higher densities than all other locations during 2004 (Table 3-4). During most sampling periods phytoplankton densities showed a spatial trend similar to that of chlorophyll; that is lower values at down-lake locations versus up-lake locations.

Low chlorophyll concentrations and algae standing crops in May, particularly at down-lake locations, may have been due to a combination of factors. Rainfall was well below normal during the months preceding May sampling, according to MNS rainfall data. Low rainfall and subsequent runoff would have caused a depression in nutrients available to algae further down-lake. In addition, zooplankton densities in May were the highest recorded during 2004 (Chapter 4). High zooplankton densities would have resulted in increased predation on available phytoplankton throughout the lake.

Seston

Seston dry weights represent a combination of algal matter, and other organic and inorganic material. Dry weights during all but May 2004 were generally higher than those of 2003, while dry weights in May were consistently lower than in the previous year. A general pattern of increasing values from down-lake to up-lake was observed in all quarters to varying extents (Figure 3-1). Statistically, Location 69.0 had significantly higher values than other locations during all quarters of 2004 (Table 3-5). From 1995 through 1997 seston dry weights had been increasing (Duke Power 1998). Values from 1998 through 2001 represented a reversal of this trend, and were in the low range at most locations during 1999 through 2001 (Duke Power 2002). Low dry weights during these years were likely a result of prolonged drought conditions. Since 2002, dry weights have gradually increased throughout the lake.

Seston ash-free dry weights represent organic material and may reflect trends of algal standing crops. This relationship seldom held true in 2004 as evidenced by a comparison of spatial distributions of ash-free dry weights and chlorophyll concentrations (Tables 3-2 and 3-5). The only near consistent relationship was at Location 69.0 where both maximum chlorophyll concentrations and ash-free dry weights were recorded in all but November. Location 69.0 had significantly higher ash-free dry weights than other locations in all but May, when Location 69.0 demonstrated the highest ash-free dry weight, but the value was not significantly higher than most other locations (Table 3-5). The proportions of organic material among solids during 2004 were higher than in 2003. From 1996 through 2001 there was a trend of decreasing ash-free dry weight to dry weight ratios, followed by a trend of increasing ratios through 2004, indicating higher organic contributions to total solids from 2002 through 2004 (Duke Power Company 1997; Duke Power 1998, 1999, 2000, 2001, 2002, 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 0.55 m at Location 69.0 in February, to 3.37 m at Location 5.0 in May (Table 3-1). The lake-wide mean secchi depth during 2004 was higher than in 2003, and was within historical ranges for the years since measurements were first reported in 1992. The deepest lake-wide mean secchi depth was recorded for 1999 (Duke Power Company 1993, 1994, 1995, 1996, 1997; Duke Power 1998, 1999, 2000, 2001, 2002, 2003, 2004). Higher secchi depths during 2004 as compared to 2003 were likely due to less rainfall and resultant lower turbidity during 2004.

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 2004. Ten classes comprising 90 genera and 210 species, varieties, and forms of phytoplankton were identified in samples collected during 2004, as compared to 95 genera and 214 lower taxa identified in 2003 (Table 3-6). The 2003 total represented the highest number of individual taxa recorded in any year since monitoring began in 1987 (Duke Power 2004). Thirteen taxa previously unrecorded during the Maintenance Monitoring Program were identified during 2004.

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 2004, cryptophytes (Cryptophyceae) dominated densities at all locations (Table 3-7, Figures 3-5 through 3-9). During most previous years, cryptophytes, and occasionally diatoms, dominated February phytoplankton samples in Lake Norman. The most abundant cryptophyte during February 2004 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 (Figures 3-5 through 3-9). 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, 2002, 2003, 2004).

During August 2004 green algae (Chlorophyceae) dominated densities at all locations (Figures 3-5 through 3-9). 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* (Duke Power Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997; Duke Power 1998, 1999). During August periods of 1999 through 2001, Lake Norman phytoplankton assemblages were dominated by diatoms, primarily the small pennate *Anomoeoneis vitrea* (Duke Power 2000, 2001, 2002). *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, 2002). 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. Since 2002, taxonomic composition has shifted back to green algae predominance (Duke Power 2003, 2004).

During November 2004, densities at all locations were again dominated by diatoms (Figures 3-5 through 3-9). 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 2004 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 (6.3%) during all sampling periods in 2004 occurred at Location 11.0 in February. Prior to 1991, blue-green algae were often dominant at up-lake locations during the summer (Duke Power Company 1988, 1989, 1990, 1991, 1992).

Phytoplankton index

Phytoplankton indexes have been used with varying degrees of success ever since the concept was formalized by Kolkwitz and Marsson in 1902 (Hutchinson 1967). Nygaard (1949) proposed a series of indexes based on the number of species in certain taxonomic categories (Divisions, Classes, and Orders). The Myxophycean index was selected to help determine long term changes in the trophic status of Lake Norman. This index is a ratio of the number of blue-green algae taxa to desmid taxa, and was designed to reflect the "potential" trophic status as opposed to chlorophyll, which gives an "instantaneous" view of phytoplankton concentrations. The index was calculated on an annual basis for the entire lake, for each sampling period of 2004, and for each location during 2004 (Figure 3-10).

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 3-10). 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, 2002, and 2003. The index for 2004 fell into the oligotrophic range, and was slightly higher than in 2003. The lowest annual index value recorded during the Maintenance Monitoring Program occurred during 2002.

The highest index value among sample periods of 2004 was observed in February, and the lowest index value occurred in November (Figure 3-10). The index did not reflect seasonal chlorophyll concentrations, since the maximum lake-wide chlorophyll concentration occurred in August, with the annual minimum observed in May. The index values for locations during 2004 showed a general increase from down-lake to up-lake locations. This spatial trend was similar to those observed for chlorophyll and standing crop values.

FUTURE STUDIES

No changes are planned for the phytoplankton portion of the Lake Norman Maintenance Monitoring Program during 2005.

SUMMARY

In 2004 lake-wide mean chlorophyll *a* concentrations were generally in the mesotrophic range with the exception of May, when chlorophyll concentrations averaged in the oligotrophic range. Chlorophyll concentrations during 2004 were generally within the same ranges as those of 2003. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. Lake-wide mean chlorophyll declined from February to the annual minimum in May, increased to the yearly maximum in August, then declined slightly in November. Some spatial variability was observed in 2004; however, maximum chlorophyll concentrations were most often observed up-lake, while comparatively low chlorophyll concentrations were recorded from Mixing Zone and mid lake locations. Location 69.0, the location furthest upstream, demonstrated maximum chlorophyll concentrations in all but November of 2004, when Location 15.9 had the highest concentration. The highest chlorophyll value recorded in 2004, 10.57 ug/L, was well below the NC State Water Quality standard of 40 ug/L.

In most cases, total phytoplankton densities and biovolumes observed in 2004 were higher than those observed during 2003, and standing crops were within ranges established over previous years. Phytoplankton densities and biovolumes during 2004 never exceeded the NC guidelines for algae blooms. Standing crop values in excess of bloom guidelines have been recorded during six previous years of the Program. As in past years, high standing crops were usually observed at up-lake locations; while comparatively low values were noted down-lake.

Seston dry and ash-free weights were more often higher in 2004 than in 2003, and down-lake to up-lake differences were apparent most of the time. Maximum dry and ash-free weights were always observed at Location 69.0. Minimum values were most often noted at Locations 2.0 through 8.0. The proportions of ash-free dry weights to dry weights in 2004 were higher than those of 2003, indicating an increase in organic composition among 2004 samples.

Secchi depths reflected suspended solids, with shallow depths related to high dry weights. The lake-wide mean secchi depth in 2004 was slightly higher than in 2003 and was within historical ranges recorded since 1992.

Diversity, or numbers of taxa, of phytoplankton had decreased since 2003, when the total number of individual taxa was the highest yet recorded. The taxononic composition of phytoplankton communities during 2004 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 2004 than during 2003; however, their contribution to total densities rarely 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 2004. All of these taxa have been common and abundant throughout the Maintenance Monitoring Program.

The phytoplankton index (Myxophycean) characterized Lake Norman as oligotrophic during 2004, and was slightly higher than the annual index for 2003. Quarterly index values decreased from the highest in February to the lowest in November. Quarterly values did not reflect maximum and minimum chlorophyll concentrations and phytoplankton standing crops. Location index values tended to reflect increases in chlorophyll and phytoplankton standing crops from down-lake to mid-lake.

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

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Table 3-1. Mean chlorophyll *a* concentrations (ug/L) in composite samples and secchi depths (m) observed in Lake Norman, NC, in 2004.

Chlorophyll *a*

Location	FEB	MAY	AUG	NOV
2.0	3.16	0.97	3.79	3.12
5.0	3.56	1.07	5.86	2.82
8.0	3.83	1.16	7.32	2.74
9.5	2.55	1.23	6.81	3.32
11.0	4.86	1.55	4.87	6.41
13.0	5.13	3.58	5.21	6.06
15.9	7.65	3.62	7.40	10.57
69.0	7.91	6.14	9.09	4.28

Secchi depths

Location	FEB	MAY	AUG	NOV
2.0	2.30	3.00	2.10	1.42
5.0	2.45	3.37	1.90	1.42
8.0	2.72	3.00	1.70	1.58
9.5	2.78	3.32	1.51	1.80
11.0	1.80	2.31	1.55	1.66
13.0	1.79	2.10	1.33	1.42
15.9	1.80	2.31	1.95	1.48
69.0	0.55	1.36	1.20	1.19

Table 3-2. Duncan's multiple Range Test on chlorophyll *a* concentrations (ug/L) in Lake Norman, NC, during 2004.

February									
	Location	**9.5**	**2.0**	**5.0**	**8.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Means	2.55	3.16	3.56	3.83	4.86	5.13	7.65	7.92

May									
	Location	**2.0**	**5.0**	**8.0**	**9.5**	**11.0**	**13.0**	**15.9**	**69.0**
	Means	0.97	1.07	1.16	1.23	1.55	3.58	3.62	6.14

August									
	Location	**2.0**	**11.0**	**13.0**	**5.0**	**9.5**	**8.0**	**15.9**	**69.0**
	Means	3.79	4.87	5.21	5.86	6.81	7.32	7.40	9.09

November									
	Location	**8.0**	**5.0**	**2.0**	**9.5**	**69.0**	**13.0**	**11.0**	**15.9**
	Means	2.74	2.82	3.12	3.32	4.28	6.06	6.41	10.57

Table 3-3. Total mean phytoplankton densities and biovolumes from samples collected in Lake Norman, NC, during 2004.

Density (units/ml)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	970	1094	777	1582	3041	1493
MAY	861	953	1120	1132	2004	1214
AUG	3586	3864	5506	3582	7200	4732
NOV	1342	1102	1270	2400	4110	2045

Biovolume (mm^3/m^3)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	316	357	145	812	1637	653
MAY	477	604	692	365	1056	639
AUG	1874	2720	3290	1447	3184	2503
NOV	1228	933	1374	2327	4101	1993

Table 3-4. Duncan's multiple Range Test on phytoplankton densities (units/ml) in Lake Norman, NC, during 2004.

February	Location	**9.5**	**2.0**	**5.0**	**11.0**	**15.9**
	Means	777	970	1094	15.82	3041
May	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Means	861	953	1120	1132	2004
August	Location	**11.0**	**2.0**	**5.0**	**9.5**	**15.9**
	Means	3582	3586	3864	5506	7200
November	Location	**5.0**	**9.5**	**2.0**	**11.0**	**15.9**
	Means	1102	1270	1342	2400	4110

Table 3-5. Duncan's multiple Range Test on dry and ash free dry weights (mg/L) in Lake Norman, NC during 2004.

DRY WEIGHT

February	Location	**5.0**	**2.0**	**9.5**	**8.0**	**13.0**	**11.0**	**15.9**	**69.0**
	Mean	1.11	1.58	1.78	1.84	2.42	2.82	3.52	19.04

May	Location	**2.0**	**5.0**	**8.0**	**9.5**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	0.87	0.98	1.11	1.12	1.38	1.43	1.47	2.16

August	Location	**2.0**	**5.0**	**8.0**	**9.5**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	2.06	2.06	2.27	2.60	2.63	2.72	3.75	9.31

November	Location	**8.0**	**11.0**	**13.0**	**9.5**	**15.9**	**2.0**	**5.0**	**69.0**
	Mean	1.82	2.06	2.64	2.66	2.68	2.93	3.12	3.76

ASH FREE DRY WEIGHT

February	Location	**5.0**	**9.5**	**13.0**	**2.0**	**11.0**	**8.0**	**15.9**	**69.0**
	Mean	0.32	0.44	0.52	0.65	0.89	1.11	2.66	5.16

May	Location	**2.0**	**5.0**	**9.5**	**8.0**	**15.9**	**11.0**	**13**	**69.0**
	Mean	0.32	0.43	0.49	0.51	0.55	0.68	0.78	0.84

August	Location	**13.0**	**11.0**	**8.0**	**15.9**	**9.5**	**5.0**	**2.0**	**69.0**
	Mean	1.13	1.25	1.47	1.55	1.58	1.60	1.75	3.6

November	Location	**13.0**	**11.0**	**15.9**	**9.5**	**8.0**	**5.0**	**2.0**	**69.0**
	Mean	0.56	0.62	0.78	1.26	1.32	1.60	1.75	1.80

Table 3-6. Phytoplankton taxa identified in quarterly samples collected in Lake Norman each year from 1990 to 2004.

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
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	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										
A. nannoselene Skuja											X				
A. spiralis (Turner) Lemm.	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	X
A. octocornis													X	X	X
A. ralfsii W. West															X
A. subulatus Kutzing							X	X	X		X	X	X	X	X
A. validus v. *increassalatus*															X
A. spp. Ehrenberg				X	X										
Asterococcus limneticus G. M. Smith	X	X	X	X	X					X			X	X	
A. superbus (Cienk.) Scherffel															X
Botryococcus braunii Kutzing		X	X												
Carteria frtzschii Takeda											X			X	X
C. globosa Korsch													X		X
C. spp. Diesing	X		X	X				X						X	
Characium limneticum Lemmerman														X	
C. spp. Braun															
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				X
C. spirale Scherffel & Pascher					X	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	X
C. tumidum Johnson											X				
C. spp. Nitzsch	X	X		X											
Coccomonas orbicularis Stein									X				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	X
C. proboscideum Bohlin		X													
C. spp. Nageli	X	X													
Cosmarium angulosum v. *concin.* (Rab) W&W											X		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	X
C. moniliforme (Turp.) Ralfs											X			X	

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
C. notabile													X		
C. phaseolus f. *minor* Boldt.							X	X		X		X			
C. pokornyanum (Grun.) W. & G.S. West									X				X		
C. polygonum (Nag.) Archer						X	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	X
C. regnesi Schmidle		X	X	X									X		
C. subreniforme Nordstedt													X		
C. tenue Archer						X	X	X	X	X	X	X	X	X	X
C. tinctum Ralfs				X	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	X
C. trilobatum v. *depressum* Printz													X		
C. tumidum Borge													X		
C. spp. Corda	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	X
C. fenestrata Schmidle		X											X	X	X
C. irregularis Wille			X	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	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	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	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	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	X
G. spp. Nageli	X	X	X	X	X										
Golenkinia paucispina West & West													X	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	X
Kirchneriella contorta (Schmidle) Bohlin	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	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
K. obesa W. West	X	X	X	X	X										
K. subsolitaria G. S. West						X	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	X
L. quadriseta (Lemm.) G. M. Smith	X	X	X												
L. subsala Lemmerman	X	X	X	X	X		X	X	X		X		X	X	X
Mesostigma viride Lauterborne						X	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										
M. pusillum Printz		X	X	X	X										
Mougeitia elegantula Whittrock						X	X	X	X	X	X	X	X	X	X
M. spp. Agardh			X	X	X										
Nephrocytium agardhianum Nageli		X											X	X	X
N. limneticum (G.M. Smith) G.M. Smith										X			X		X
Oocystis borgii Snow									X	X	X		X	X	
O. ellyptica W. West									X				X	X	X
O. lacustris Chodat [1]														X	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	
Pediastrum biradiatum Meyen [1]															
P. duplex Meyen	X	X		X		X	X	X		X	X	X	X	X	X
P. duplex v. *clatheatum* (A. Braun) Lag.													X		
P. duplex v. *gracillimum* West and West								X	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		X
Quadrigula closterioides (Bohlin) Printz		X					X	X				X	X	X	X
Q. lacustris (Chodat) G. M. Smith													X	X	X
Scenedesmus abundans (Kirchner) Chodat	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	X
S. acuminatus (Lagerheim) Chodat			X	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	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]															X
S. brasiliensis Bohlin						X	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	X
S. dimorphus (Turp.) Kutzing	X		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	

Table 3-6. (Continued).

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
S. serratus (Corda) Bohlin															X
S. spp. Meyen	X	X	X	X	X										
Schizochlamys compacta Prescott							X		X		X		X		X
S. gelatinosa A. Braun											X		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	X
Sorastrum americanum (Bohlin) Schm.								X							
Sphaerocystis schoeteri Chodat	X					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	X
S. apiculatum Brebisson								X	X	X	X	X	X	X	X
S. brachiatum Ralfs								X	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	X
S. cuspidatum Brebisson								X	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	X
S. megacanthum Lundell				X	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]															X
S. paradoxum v. *parvum* W. West									X				X	X	X
S. pentacerum (Wolle) G. M. Smith													X		
S. subcruciatum Cook & Wille						X		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										
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											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	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
T. pentaedricum West & West					X										
T. planktonicum G. M. Smith									X		X		X	X	X
T. regulare Kutzing		X	X	X	X										
T. regulare v. *bifurcatum* Wille									X						
T. regulare v. *incus* Teiling				X											
T. trigonum (Nageli) Hansgirg	X	X		X			X	X	X		X	X	X	X	X
T. trigonum v. *gracile* (Reinsch) DeToni			X				X				X				X
T. spp. Kutzing	X			X											
Tetrallantos lagerheimii Teiling												X		X	X
Tetraspora lamellosa Prescott											X				
T. spp. Link				X	X										
Tetrastrum heteracanthum (Nor.) Chod.	X												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				X
W. linearis G. M. Smith									X		X			X	X
Xanthidium critatatum v. *uncinatum* Breb.													X		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	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	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	X
C. spp. Kutzing	X														
Cymbella affinis Kutzing											X			X	
C. gracilis (Rabh.) Cleve														X	X
C. minuta (Bliesch & Rabn.) Reim.	X		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		X
D. thermalis Kutzing									X				X		
Diploneis ellyptica (Kutz.) Cleve															X
D. ovalis (Hilse) Cleve															X
D. puella (Schum.) Cleve															X
D. spp. Ehrenberg	X														
Eunotia flexuosa v. *eurycephala* Grun.											X				

Table 3-6. (Continued).

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
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	X
F. construens															X
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		X
N. exigua v. *capitata* Patrick							X								
N. radiosa Kutz.														X	
N. radiosa v. *tenella* (Breb.) Grun.														X	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	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. kutzingiana Hilse															X
N. linearis W. Smith											X				
N. palea (Kutzing) W. Smith					X	X	X	X	X				X		X
N. sublinearis Hustedt							X		X			X	X		
N. spp. Hassall	X	X	X	X	X								X		
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	X
S. delicatissima Lewis			X	X	X										
S. filiformis v. *exilis* Cleve-Euler									X		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	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	X
S. spp. Ehrenberg	X	X	X	X	X										
Tabellaria fenestrata (Lyngb) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. flocculosa (Roth.) Kutzing	X				X						X				X

Table 3-6. (Continued).

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
CLASS: CHRYSOPHYCEAE															
Aulomonas purdyii Lackey				X	X	X	X	X	X	X		X	X		X
Bicoeca petiolatum (Stien) Pringsheim							X	X							
Calycomonas pascheri (Van Goor) Lund						X					X			X	
Chromulina spp. Chien.									X				X	X	X
Chrysococcus rufescens Klebs														X	
Chrysosphaerella solitaria Lauterb.		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Codomonas annulata Lackey							X	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	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	X
K. petasatum Conrad														X	
K. rubi-claustri Conrad													X	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	
M. globosa Schiller	X								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				
Ochromonas granularis Doflein									X	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	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	
Stokesiella epipyxis Pascher								X	X	X					
Synura sphagnicola Korschikov															X
S. spinosa Korschikov	X					X	X	X	X	X	X	X	X	X	X
S. uvella Ehrenberg	X	X		X	X							X			
S. spp. Ehrenberg	X	X	X	X	X										
Uroglenopsis americana (Caulk.) Lemm.						X	X	X		X					

Table 3-6. (Continued).

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
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		
C. dubia Pascher						X	X		X	X	X	X	X	X	X
Dichotomococcus curvata Korschikov [1]															
Ophiocytium caoitatum v. *longisp.* (M) L.				X	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	X
C. gracilia Skuja											X				
C. marsonii Skuja	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										
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										
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	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	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			
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	X
D. rupestris Hansgirg											X				
D. smithii Chodat and Chodat								X	X		X			X	X
D. spp. Hansgirg											X				
Gomphospaeria lacustris Chodat	X	X	X	X	X										
Lyngbya contorta Lemmermann		X	X												
L. limnetica Lemmermann	X	X	X	X	X										
L. ochracea (Kutz.) Thuret											X		X		X
L. subtilis W. West	X	X	X		X										
L. tenue															X
L. spp. Agardh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3-6. (Continued).

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
Merismopedia tenuissima Lemmermann									X						
Microcystis aeruginosa Kutz. *emend* Elen.	X	X	X	X	X	X	X		X	X	X	X			X
Oscillatoria amoena (Kutz.) Gomont															X
O. amphibia Agardh													X	X	X
O. geminata Meneghini	X					X	X	X	X	X	X	X	X	X	X
O. limnetica Lemmermann						X	X	X	X	X	X	X	X	X	X
O. splendida Greville						X	X		X				X		
O. subtilissima Kutz.											X	X	X	X	X
O. spp. Vaucher					X							X		X	
Phormidium angustissimum West & West	X	X			X										
P. spp. Kutzing	X			X	X										
Raphidiopsis curvata Fritsch & Rich			X		X	X	X	X	X	X	X		X		X
R. mediterranea Skuja										X					
Rhabdoderma sigmoidea Schm. & Laut.1															
Spirulina subsala Oersted													X		
Synecococcus lineare (Sch. & Lt.) Kom.	X	X	X	X	X	X	X		X	X	X	X		X	X
CLASS: EUGLENOPHYCEAE															
Euglena acus Ehrenberg	X									X					X
E. minuta Prescott											X		X		X
E. polymorpha Dangeard							X					X	X		X
E. proxima Dangeard														X	X
E. spp. Ehrenberg	X	X		X	X	X	X		X	X		X			X
Lepocinclus acuta															X
L. glabra Drezepolski														X	
L. ovum. (Ehr.) Lemm.											X				X
L. spp. Perty									X						
Phacus cuvicauda Swirenko											X				
P. longicauda (Ehr.) Dujardin											X				
P. orbicularis Hubner			X												
P. tortus (Lemm.) Skvortzow	X		X												
P. triquter Playfair															X
P. spp. Dujardin 1															
Trachelomonas acanthostoma (Stk.) Defl.												X			X
T. ensifera Daday														X	
T. hispida (Perty) Stein				X		X				X		X	X	X	X
T. pulcherrima Playfair 1															
T. pulcherrima v. *minor*															X
T. volvocina Ehrenberg						X				X		X		X	X
T. spp. Ehrenberg	X	X			X										
CLASS: DINOPHYCEAE															
Ceratium hirundinella (OFM) Schrank	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 1															
G. penardiforme (linde.) Schiller										X	X				X
G. quadridens (Stein) Schiller	X				X										
G. spp. (Ehrenberg) Stein		X			X										

Table 3-6. (Continued). page 10 of 10

TAXON	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
Gymnodinium aeruginosum Stein									X	X	X			X	X
G. spp. (Stein) Kofoid & Swezy	X	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	X
P. pusillum (Lenard) Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
P. umbonatum Stein			X	X	X										
P. willei (Huitfeld-Kass															X
P. wisconsinense Eddy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Ehrenberg	X	X	X	X	X										
CLASS: CHLOROMONADOPHYCEAE															
Gonyostomum depresseum Lauterborne						X			X	X			X	X	X
G. semen (Ehrenberg) Diesing	X														
G. spp. Diesing	X				X										

1 = taxa found during 1987-89 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 2004.

LOC	FEBRUARY	MAY
2.0	CRYPTOPHYCEAE (66.1)	BACILLARIOPHYCEAE (70.2)
	Rhodomonas minuta (62.4)	*Fragillaria crotonensis* (52.8)
5.0	CRYPTOPHYCEAE (65.9)	BACILLARIOPHYCEAE (67.9)
	R. minuta (58.2)	*F. crotonensis* (48.3)
9.5	CRYPTOPHYCEAE (55.2)	BACILLARIOPHYCEAE (69.9)
	R. minuta (53.6)	*F. crotonensis* (54.7)
11.0	CRYPTOPHYCEAE (45.3)	BACILLARIOPHYCEAE (57.9)
	R. minuta (40.3)	*F. crotonensis* (42.1)
15.9	CRYPTOPHYCEAE (54.5)	BACILLARIOPHYCEAE (53.8)
	R. minumta (45.7)	*F. crotonensis* (35.6)
	AUGUST	NOVEMBER
2.0	CHLOROPHYCEAE (62.5)	BACILLARIOPHYCEAE (44.2)
	Cosmarium asphear. strig. (39.3)	*Tabellaria. fenestrata* (19.7)
5.0	CHLOROPHYCEAE (67.5)	BACILLARIOPHYCEAE (57.5)
	C. asphearosporum strig. (40.4)	*T. fenestrata* (34.2)
9.5	CHLOROPHYCEAE (67.2)	BACILLARIOPHYCEAE (61.2)
	C. asphearosporum strig. (47.5)	*T. fenestrata* (40.7)
11.0	CHLOROPHYCEAE (62.9)	BACILLARIOPHYCEAE (49.0)
	C. asphearosporum strig. (43.3)	*T. fenetrata* (14.3)
15.9	CHLOROPHYCEAE (65.5)	BACILLARIOPHYCEAE (46.1)
	C. asphearosporum strig. (49.4)	*T. fenestrata* (18.3)

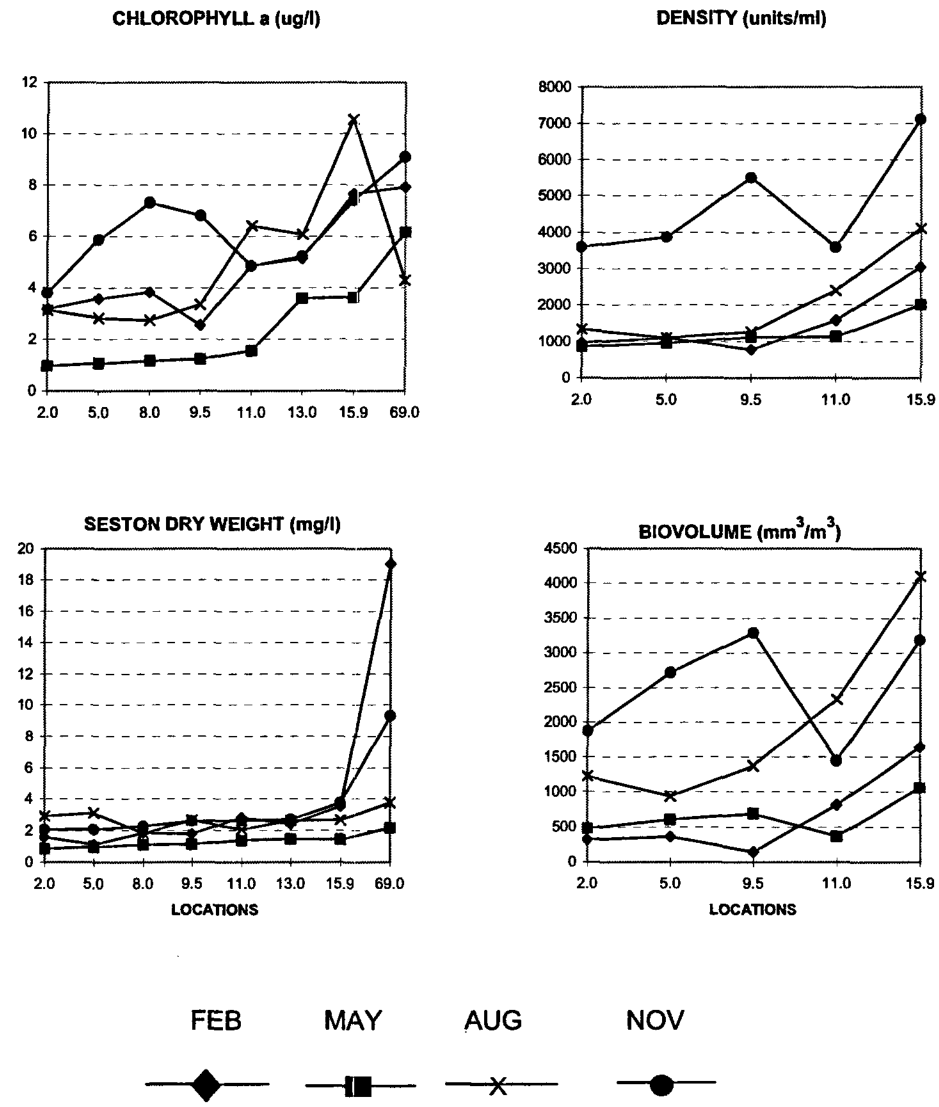

Figure 3-1. Phytoplankton chlorophyll *a*, densities, biovolumes, and seston weights at locations in Lake Norman, NC, in February, May, August, and November 2004.

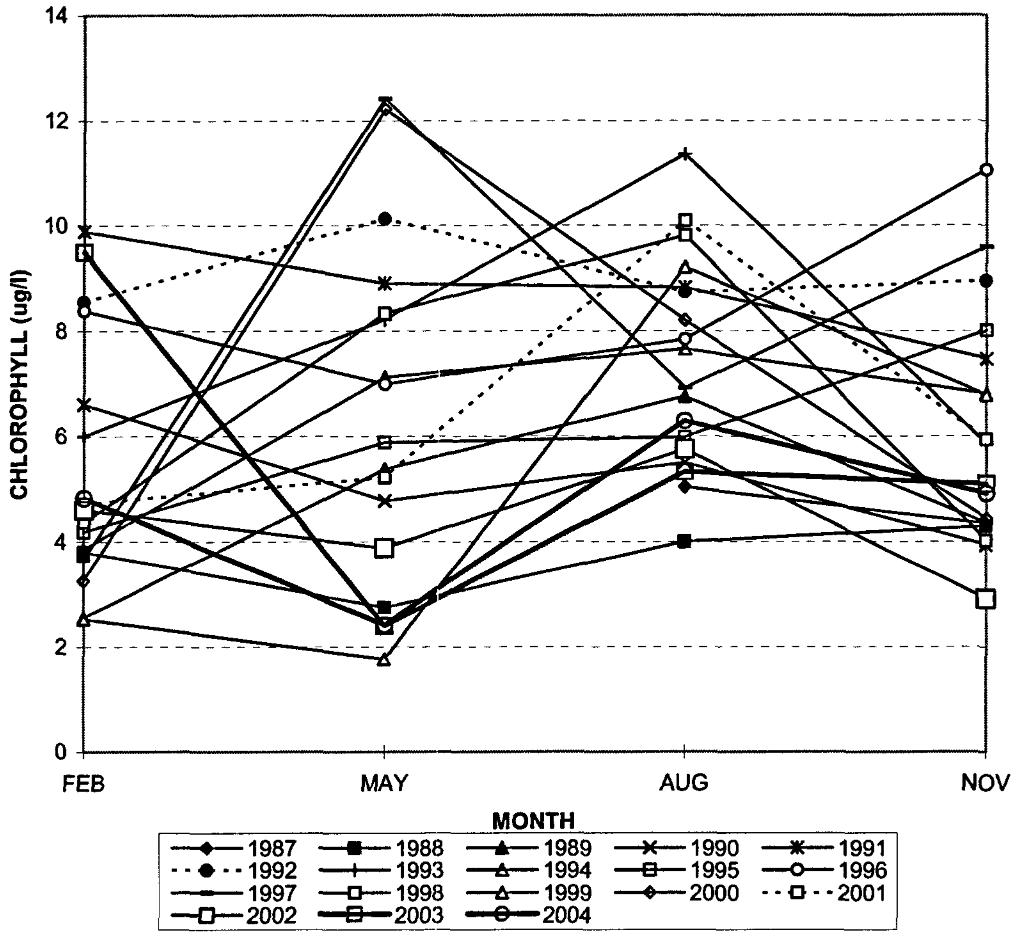

Figure 3-2. Phytoplankton chlorophyll *a* annual lake means from all locations in Lake Norman, NC, for each quarter since August 1987.

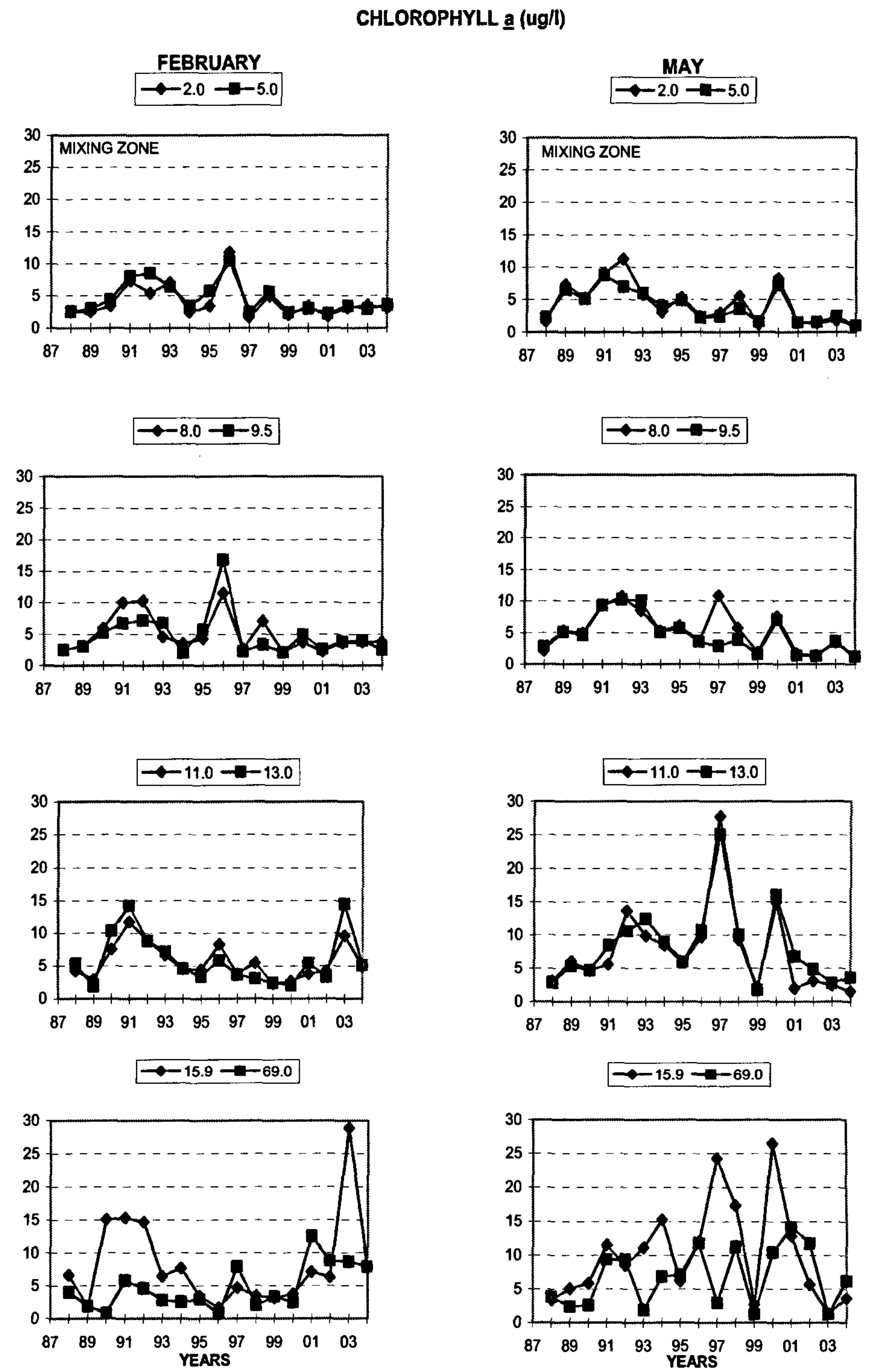

Figure 3-3. Phytoplankton chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from February and May 1988 through 2004.

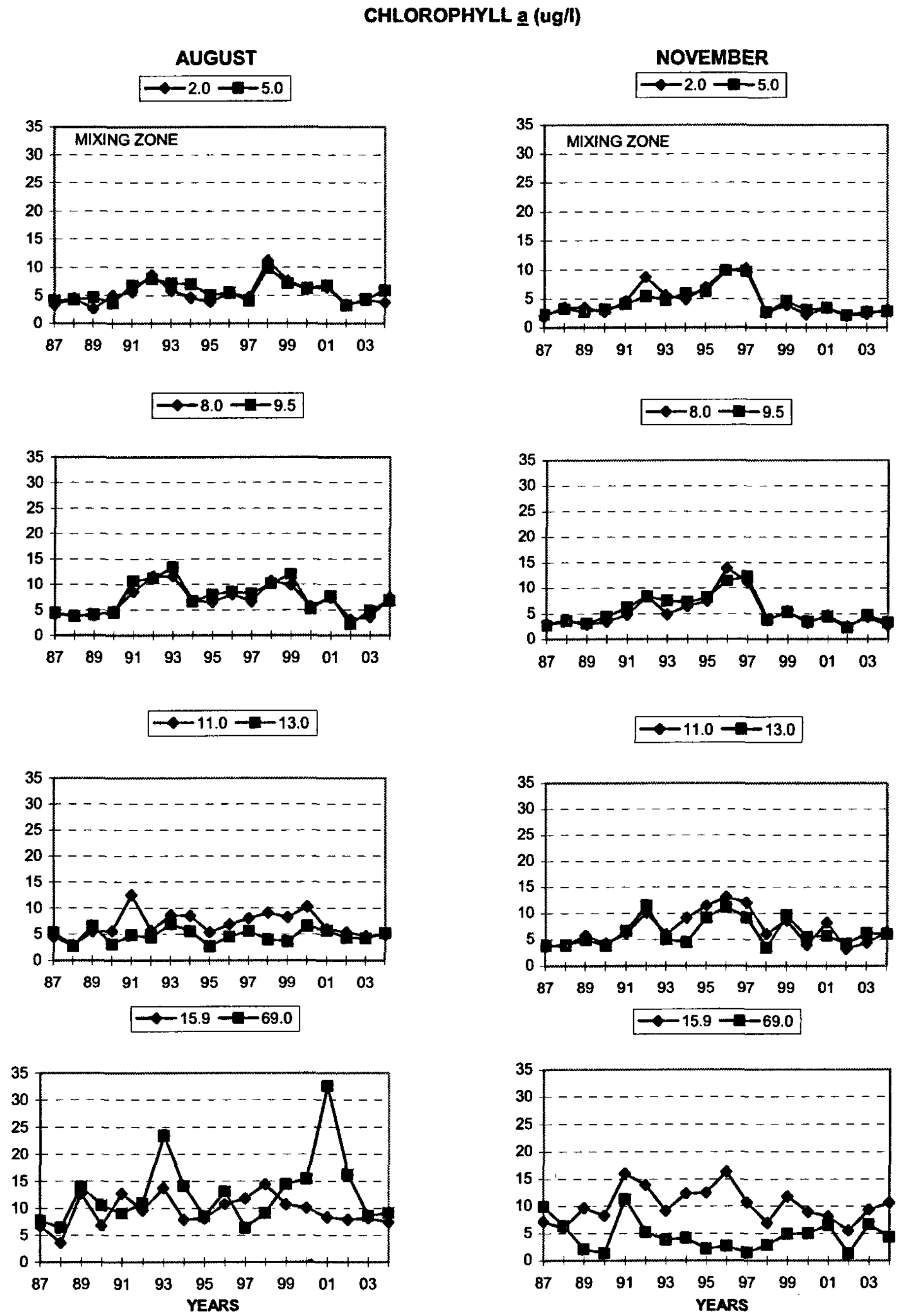

Figure 3-4. Phytoplankton chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from August and November 1987 through 2004.

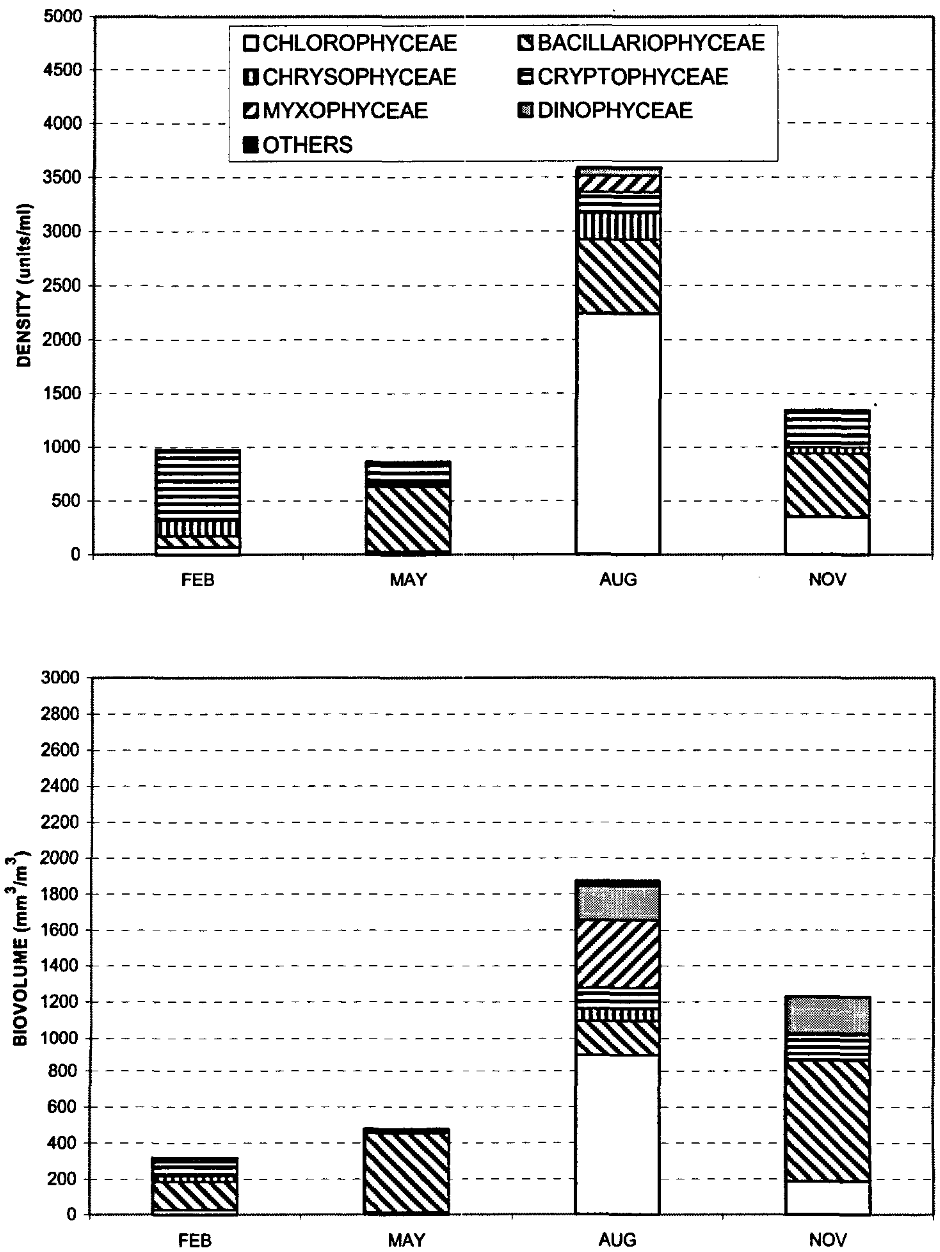

Figure 3-5. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 2.0 in Lake Norman, NC, during 2004.

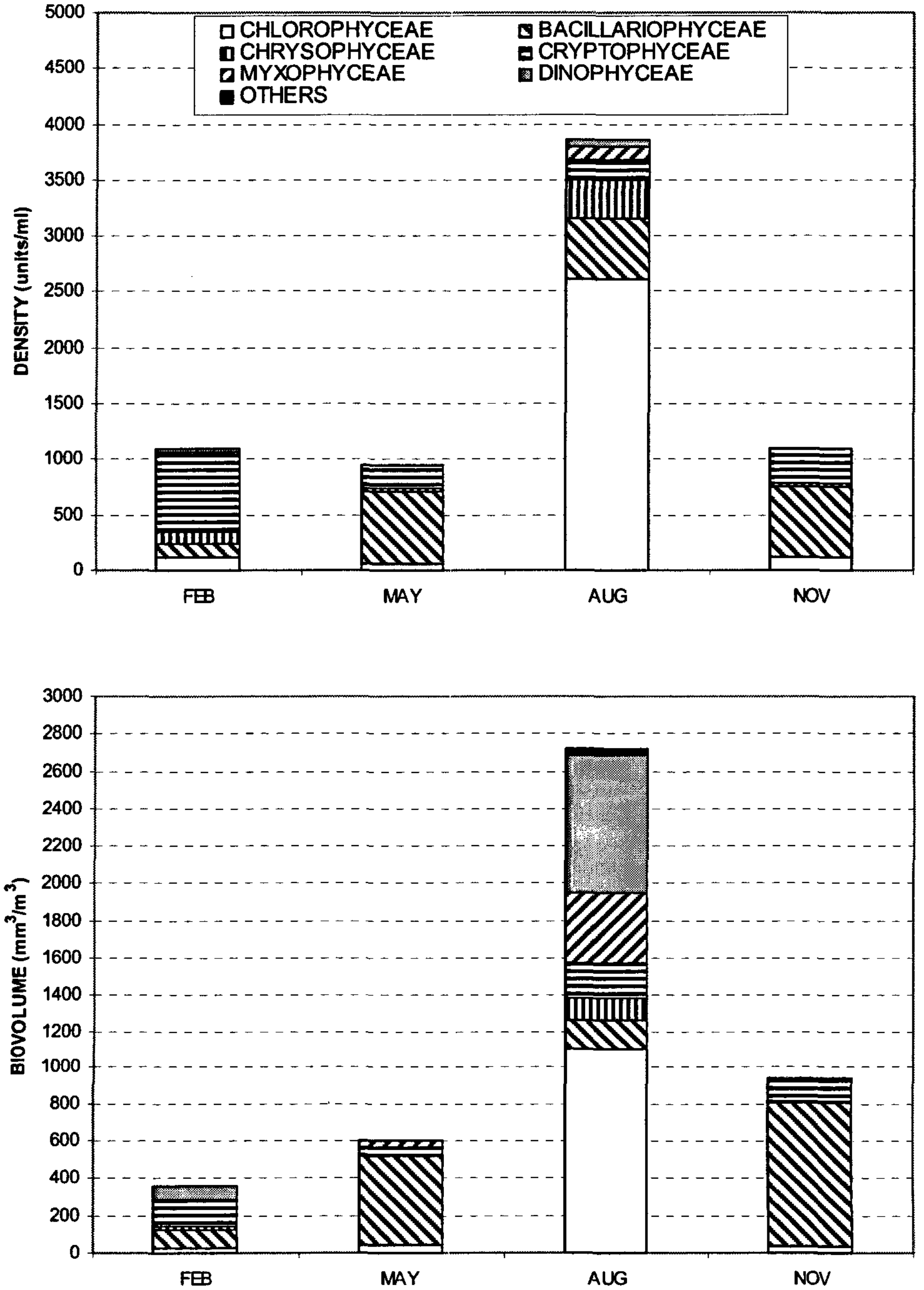

Figure 3-6. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 5.0 in Lake Norman, NC, during 2004.

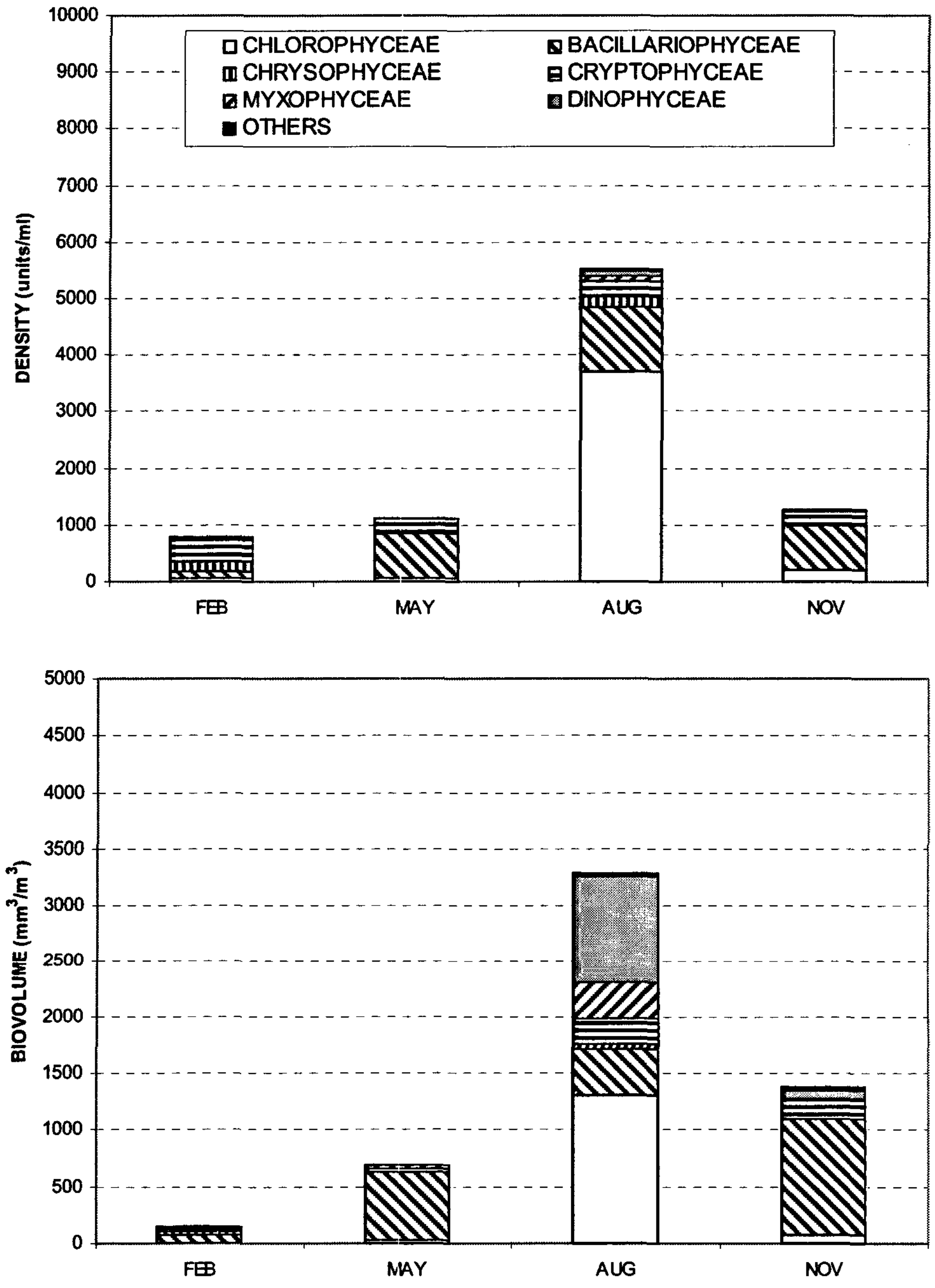

Figure 3-7. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC, during 2004.

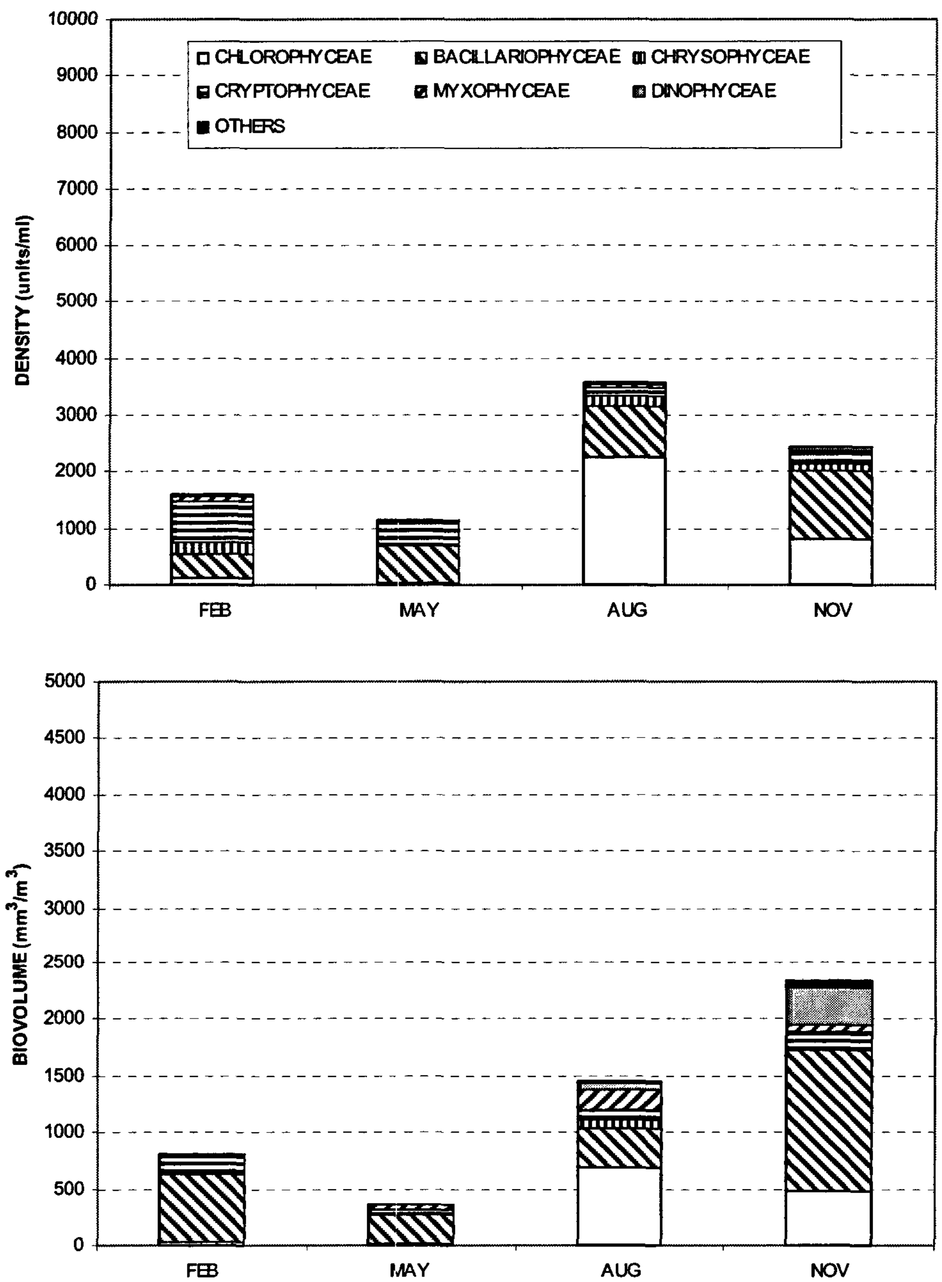

Figure 3-8. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC, during 2004

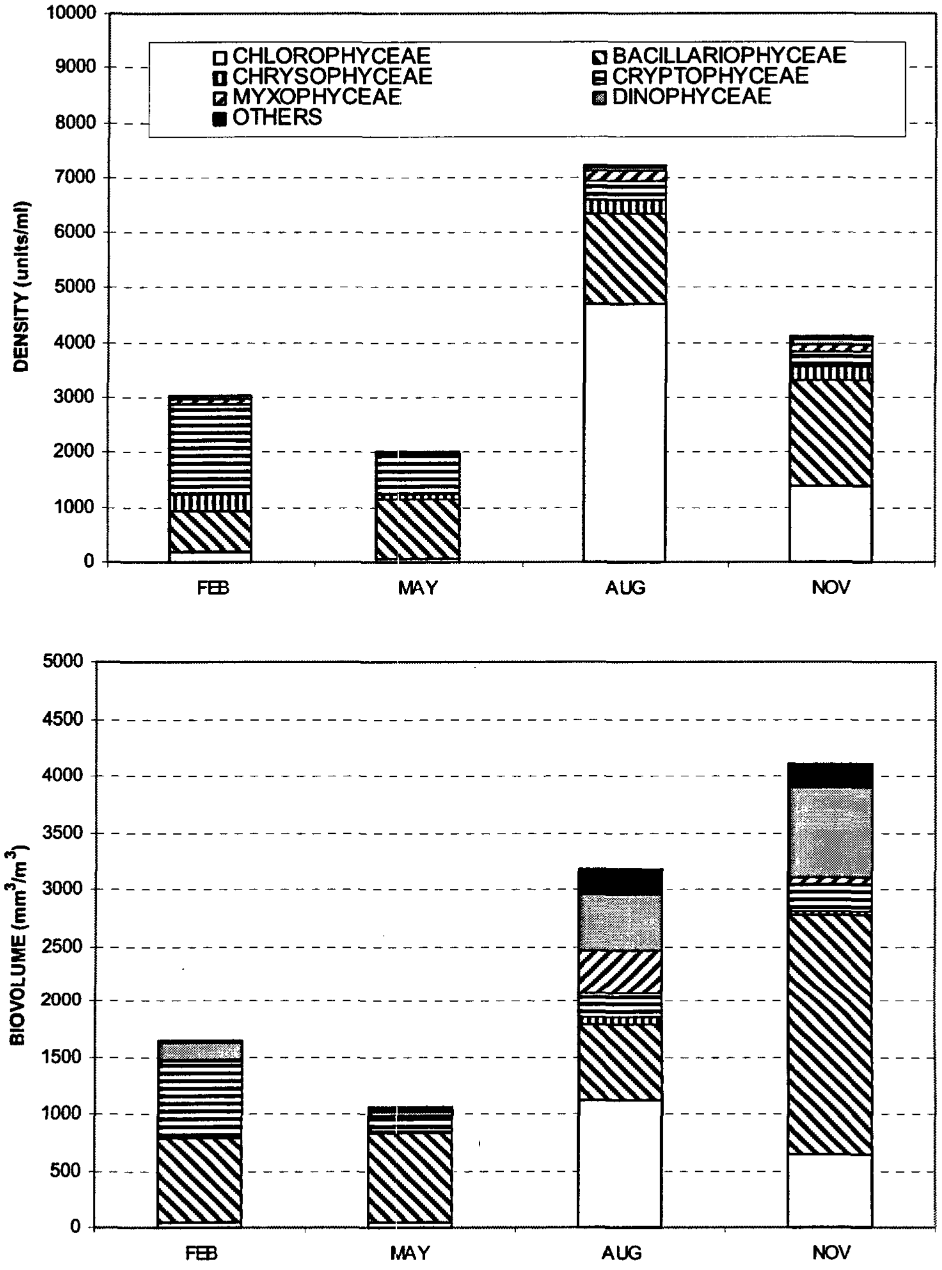

Figure 3-9. Class composition (density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC, during 2004.

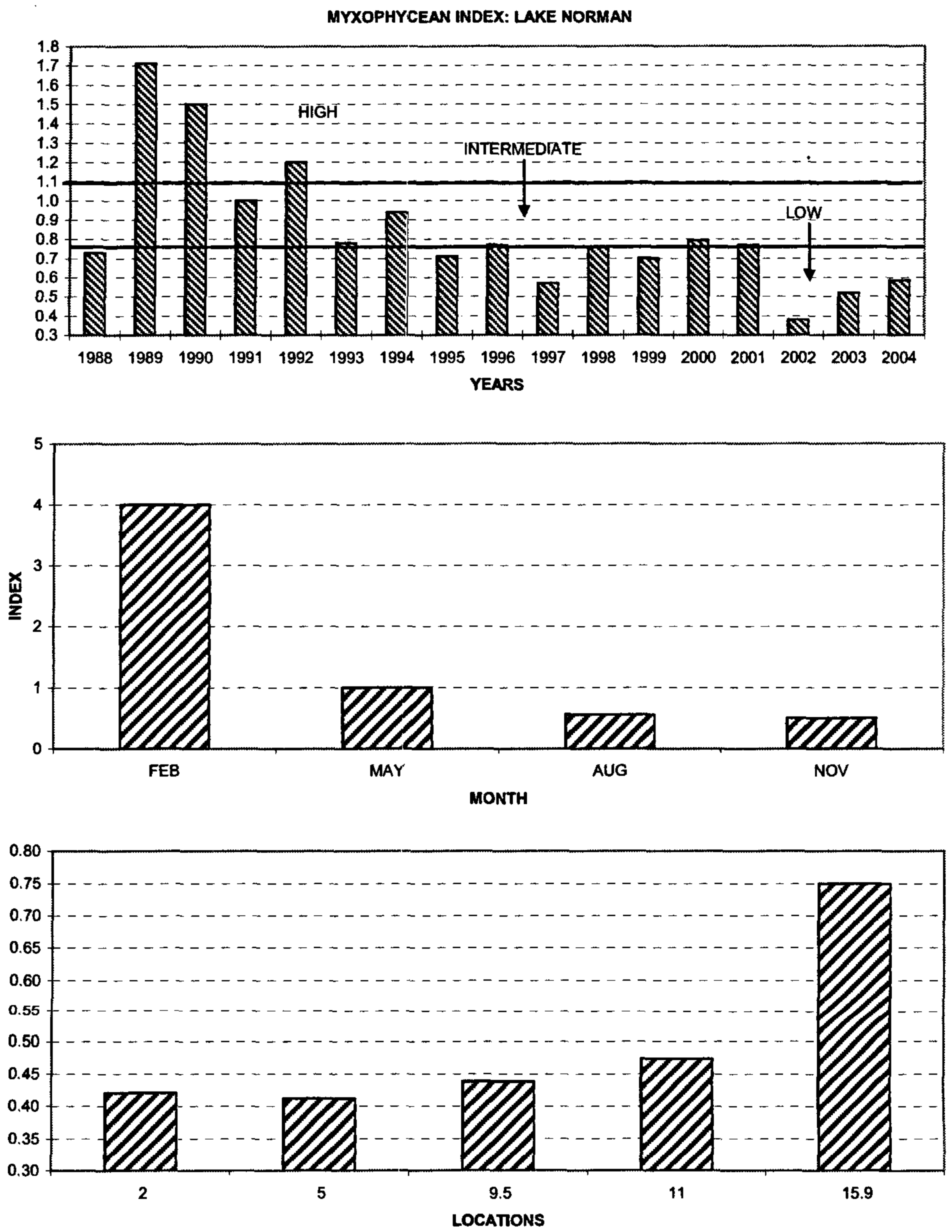

Figure 3-10. Myxophycean index values by year (top), each quarter in 2004 (mid), and each location in Lake Norman, NC, during 2004.

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 2004) with historical data collected during the period 1987-2003.

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) in February, May, August, and November 2004. For discussion purposes the 10 m to surface tow samples are called epilimnetic samples and the bottom to surface net tow samples are called whole column samples. Locations 2.0 and 5.0 are defined as the Mixing Zone and Locations 9.5, 11.0 and 15.9 are defined as Background Locations. Field and laboratory methods for zooplankton standing crop analysis were the same as those reported in Hamme (1982). Zooplankton standing crop data from 2004 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 2004, typical seasonal variability was observed in epilimnetic samples. Maximum epilimnetic densities were observed in May at Locations 2.0, 5.0, and 15.9 and in February at Locations 9.5 and 11.0 (Table 4-1, Figure 4-1). The lowest epilimnetic densities occurred in August at all but Location 15.9 which had its lowest annual density in February. Epilimnetic densities ranged from a low of 29,413/m^3 at Location 2.0 in August, to a high of 359,434/m^3 at Location 15.9 in May. Maximum densities in the whole column samples were also observed in May at Locations 2.0, 5.0 and 15.9, while maxima at Locations 9.5 and 11.0 were recorded in February. Minimum whole column densities were observed at all Locations in August. Whole column densities ranged from 19,381/m^3 at Location 2.0 in August, to 186,346/m^3 at Location 15.9 in May.

Historically, maximum epilimnetic zooplankton densities at Lake Norman locations have most often been observed in May, with annual peaks observed in February about 25% of the time. Annual maxima have only occasionally been recorded for August and November (Duke Power 2004).

Total zooplankton densities were consistently higher in epilimnetic samples than in whole column samples during 2004, 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 lower average densities from the Mixing Zone as compared to Background Locations was observed during 2004 (Tables 4-1 and 4-2, Figures 4-1 and 4-2). Location 15.9, the uppermost location, had significantly higher densities than Mixing Zone locations during all sampling periods except February (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, 2002, 2003, 2004).

Historically, both seasonal and spatial variability among epilimnetic zooplankton densities have been much higher among Background Locations than among Mixing Zone locations. The uppermost location, 15.9, showed the greatest range of densities during 2004 (Table 4-1, Figures 4-3 and 4-4). 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 2004 were generally within historical ranges during each quarter (Figures 4-3 and 4-4). The exceptions were Location 5.0, which had the highest density yet recorded for February; and Locations 2.0 and 5.0, which had record high densities for May. Phytoplankton chlorophyll concentrations and standing crops during 2004 also fell within historical ranges on most occasions; however, down-lake locations demonstrated historical chlorophyll minima for May, which may indicate an inverse relationship between phytoplankton and zooplankton standing crops over the long term (Chapter 3).

The highest February densities recorded from Locations 2.0 and 11.0 occurred in 1996, while February maxima at Locations 9.5 and 15.9 were recorded for 1995 and 1992, respectively. The February maximum form Location 5.0 occurred in 2004 (Figure 4-3). Long term maximum densities for May at Locations 2.0 and 5.0 were observed in 2004, while the highest May values from Locations 11.0 and 15.9 occurred in 2002. The long term May peak from Location 9.5 was observed in 2000. Long term August maxima occurred in 1988 at all but Location 15.9, which had its highest August value in 2003 (Figure 4-4). 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 shown a moderate degree of year-to-year variability, and the long term trend at Mixing Zone locations has been a gradual increase over the last fifteen years with long term peaks recorded in 2004. 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 4-3 and 4-4).

Community Composition

One hundred and seventeen 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 2004, as compared to fifty-one taxa recorded during 2003 (Duke Power 2004). Four previously unreported taxa were identified in 2004: Three cladocerans (*Disparalona acutirostris, Leydigia acanthoceroides*, and *Oxurella* spp.), and one rotifer (*Anuraeopsis fissa*) 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 (Duke Power 2002, 2003, and 2004). During 2004, copepod dominance and relative abundance declined once more, and these microcrustaceans were dominant in only ten samples collected in August and November (Table 4-1, Figures 4-2 and 4-6 through 4-8). Copepods were dominant in epilimnetic samples from Location 5.0, 11.0, and 15.9 in August; and Location 2.0 in November. They dominated whole column samples at all locations in August and Location 2.0 in November. Cladocerans, always the least abundant forms in Lake Norman, were dominant in only two epilimnetic samples from Locations 2.0 and 9.5 in August. Rotifers were dominant in 70% of all zooplankton samples collected during 2004. During most years of the Program, microcrustaceans (copepods and cladocerans) 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 since 2002 has been similar to that found during 1995. During 2004, microcrustaceans decreased in relative abundance in all areas of Lake Norman.

Copepoda

Copepod populations were consistently dominated by immature forms (primarily nauplii) during 2004, as has always been the case. Adult copepods rarely constituted more than 10% of the total zooplankton density at any location. *Tropocyclops* was the most important constituent of adult populations in both epilimnetic and 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 2004, and their densities peaked in May at both Mixing Zone and Background Locations. Copepods showed similar spatial and seasonal trends during 2003 (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 2004 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 November (Table 4-4). *Bosminopsis* was also important among cladocerans in August when it dominated cladoceran populations at most locations. *Bosminopsis* expressed somewhat lower dominance during August 2004 as compared to August 2003. Similar patterns of *Bosminopsis* 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, 2000, and 2004, 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 well distributed among all locations (Table 4-1, Figures 4-2 and 4-5).

Rotifera

Polyarthra was the most abundant rotifer in 2004 samples (Table 4-4). This taxon dominated rotifer populations in the epilimnion at Locations 2.0 and 9.5; and Location 15.9 (whole column) in February; was dominant at all locations in May, and in whole column samples from Locations 11.0 and 15.9 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, and 9.5; and were dominant in whole column samples at Locations 11.0 and 15.9 in August. *Keratella* was the dominant rotifer at Location 11.0 (epilimnion) in February, Location 5.0 (epilimnion) in August, and Locations 5.0 (epilimnion) and 15.9 in November. *Asplanchna* was the dominant rotifer at Location 15.9 (epilimnion), as well as in whole column samples from Locations 9.5 and 11.0 in February. *Synchaeta* was the dominant rotifer at Location 5.0 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, 2004). During 2004, peak densities were observed in May.

FUTURE STUDIES

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

SUMMARY

Maximum zooplankton densities occurred in May at Locations 2.0, 5.0, and 15.9, while maximum densities at Locations 9.5 and 11.0 were observed in February. 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 2004. In the Mixing Zone, a long term trend of increasing year-to-year densities was observed for

May. 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 exceptions were record high densities for February at Location 5.0, and record high May densities at Locations 2.0, 5.0, and 15.9. Long term May maxima at Locations 2.0 and 5.0 corresponded to record low May phytoplankton chlorophyll concentrations at these locations.

One hundred and seventeen zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (Fifty-two were identified during 2004). Four previously unreported taxa (three cladocerans and one rotifer) were identified during 2004.

Overall relative abundance of copepods in 2004 had decreased since 2003, and they were dominant in ten samples collected during August and November. Cladocerans were dominant in only two samples in August, while rotifers were dominant in 70% of all samples. Overall, the relative abundance of rotifers had increased since 2003, and their relative abundances were somewhat similar to those of 1995. 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 copepod was *Tropocyclops*, as was the case in previous years. *Bosmina* was the predominant cladoceran, as has also been the case in most previous years of the Program. *Bosminopsis* dominated most cladoceran populations in August. The most abundant rotifers observed in 2004, as in many previous years, were *Polyarthra*, *Conochilus*, and *Karetella*, while *Asplanchna* and *Syncheata* were 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 2004, and no impacts of plant operations were observed.

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Table 4-1. Total zooplankton densities (no. X 1000/m^3), 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 2004.

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
2/11/04	10-S	COPEPODA	9.2	6.5	31.3	13.6	19.2
			(16.8)	(6.6)	(25.7)	(8.0)	(22.0)
		CLADOCERA	8.6	5.6	21.1	15.1	11.1
			(15.6)	(5.7)	(17.3)	(8.9)	(12.8)
		ROTIFERA	37.2	85.9	69.4	140.9	56.9
			(67.6)	(87.7)	(57.0)	(83.1)	(65.2)
		TOTAL	**55.0**	**98.0**	**121.8**	**169.6**	**87.2**
	B-S						
	Depth (m)						
	of tow	COPEPODA	7.3	5.8	24.8	13.6	19.7
	For each		(14.7)	(10.6)	(29.5)	(10.5)	(24.7)
	Location	CLADOCERA	10.7	3.3	15.2	17.2	8.0
	2.0=30		(21.5)	(6.1)	(18.1)	(13.2)	(10.1)
	5.0=20	ROTIFERA	31.8	45.7	44.2	99.2	51.8
	9.5=20		(63.8)	(83.3)	(52.5)	(76.3)	(65.2)
	11.0=25						
	15.9=20	**TOTAL**	**49.8**	**54.8**	**84.3**	**130.0**	**79.5**
5/13/04	10-S	COPEPODA	50.8	53.9	34.4	30.9	60.7
			(28.3)	(30.4)	(31.9)	(25.3)	(16.9)
		CLADOCERA	10.8	10.8	4.5	7.6	45.7
			(6.0)	(6.1)	(4.2)	(6.3)	(12.7)
		ROTIFERA	117.9	112.8	69.0	83.3	253.0
			(65.7)	(63.5)	(63.9)	(68.4)	(70.4)
		TOTAL	**179.6**	**177.5**	**108.0**	**121.8**	**359.4**
	B-S						
	Depth (m)						
	Of tow	COPEPODA	24.8	32.8	23.2	20.6	35.4
	for each		(26.9)	(29.6)	(28.5)	(30.0)	(19.0)
	Location	CLADOCERA	17.3	8.9	4.9	3.6	17.1
	2.0=30		(18.8)	(8.0)	(6.0)	(5.2)	(9.2)
	5.0=20	ROTIFERA	50.3	69.1	53.2	44.6	133.8
	9.5=20		(54.3)	(62.4)	(65.5)	(64.8)	(71.8)
	11.0=25						
	15.9=20	**TOTAL**	**92.4**	**110.8**	**81.3**	**68.8**	**186.3**

Table 4-1. (Continued).

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
8/4/04	10-S	COPEPODA	13.4	18.2	9.0	38.7	41.9
			(45.5)	(56.2)	(28.3)	(62.7)	(43.6)
		CLADOCERA	13.4	8.1	17.2	7.2	20.0
			(45.6)	(24.9)	(54.2)	(11.8)	(20.8)
		ROTIFERA	2.6	6.1	5.5	15.7	34.2
			(8.9)	(18.8)	(17.5)	(25.4)	(35.6)
		TOTAL	**29.4**	**32.4**	**31.7**	**61.7***	**96.1**
	B-S						
	Depth(m)						
	of tow	COPEPODA	12.3	15.4	11.8	24.6	29.0
	for each		(63.5)	(65.4)	(43.5)	(71.6)	(47.6)
	Location	CLADOCERA	5.9	4.8	11.5	4.9	10.8
	2.0=30		(30.2)	(20.6)	(42.2)	(14.4)	(17.7)
	5.0=19	ROTIFERA	1.2	3.3	3.8	4.8	21.0
	9.5=20		(6.3)	(14.0)	(14.1)	(14.0)	(34.4)
	11.0=25						
	15.9=21	**TOTAL**	**19.4**	**23.5**	**27.1****	**34.3**	**61.0****
11/30/04	10-S	COPEPODA	13.0	9.1	13.2	26.0	24.8
			(40.5)	(26.3)	(26.0)	(27.8)	(19.6)
		CLADOCERA	6.9	11.9	17.4	11.0	4.2
			(21.5)	(34.1)	(34.2)	(11.7)	(3.3)
		ROTIFERA	12.1	13.8	20.2	56.5	97.5
			(38.0)	(39.6)	(39.8)	(60.4)	(77.1)
		TOTAL	**32.0**	**34.8**	**50.9**	**93.5**	**126.5**
	B-S						
	Depth(m)						
	of tow	COPEPODA	11.0	7.5	14.6	26.5	16.3
	For each		(44.8)	(28.5)	(32.1)	(34.2)	(19.9)
	Location	CLADOCERA	7.0	8.4	9.0	10.3	4.1
	2.0=30		(28.7)	(32.1)	(19.8)	(13.3)	(5.0)
	5.0=20	ROTIFERA	6.5	10.3	21.9	40.7	61.5
	9.5=21		(26.5)	(39.4)	(48.1)	(52.5)	(75.1)
	11.0=25						
	15.9=20	**TOTAL**	**24.5**	**26.2**	**45.6**	**77.6**	**81.9**

* = Ostracoda observed in sample (103/m^3, 0.17%).

** = *Chaoborus* (Insecta) observed in sample at 9.5 (53/m^3, 0.19%), and 15.9 (207/m^3, 0.34%

Table 4-2. Duncan's Multiple Range Test on epilimnetic zooplankton densities (no. X 1000/m^3) in Lake Norman, NC during 2004.

February	Location	**2.0**	**15.9**	**5.0**	**9.5**	**11.0**
	Means	55.0	87.2	98.0	121.8	169.6
May	Location	**9.5**	**11.0**	**5.0**	**2.0**	**15.9**
	Means	108.0	121.8	177.5	179.6	359.4
August	Location	**2.0**	**9.5**	**5.0**	**11.0**	**15.9**
	Means	29.4	31.7	32.4	61.7	96.1
November	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Means	32.0	34.8	50.9	93.5	126.5

Table 4-3. Zooplankton taxa identified from samples collected quarterly on Lake Norman from 1987 through 2004.

TAXON	87-90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
COPEPODA															
Cyclops thomasi Forbes	X				X	X		X	X	X	X	X	X	X	X
C. vernalis Fischer							X								
C. spp. O. F. Muller	X	X	X	X	X	X	X	X	X			X	X	X	
Diaptomus birgei Marsh	X	X		X							X				
D. mississippiensis Marsh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. pallidus Herick	X			X		X	X	X		X				X	
D. reighardi Marsh										X					
D. spp. Marsh	X	X	X	X	X	X	X	X	X	X	X		X	X	
Epishura fluviatilis Herrick						X	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
M. spp. Sars	X	X	X	X	X	X	X	X				X	X	X	
Tropocyclops prasinus (Fischer)	X					X	X	X	X	X	X	X	X	X	X
T. spp. (Fischer)	X	X	X	X	X	X	X	X				X	X		X
Calanoid copepodites	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyclopoid copepodites	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Harpacticoidea			X	X			X								
Nauplii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Parasitic copepods										X					
CLADOCERA															
Alona spp.Baird							X	X							
Alonella spp. (Birge)					X					X					
Bosmina longirostris (O. F. M.)	X			X				X	X	X	X	X	X	X	X
B. spp. Baird	X	X	X	X	X	X	X	X	X		X	X	X		
Bosminopsis dietersi Richard	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ceriodaphnia lacustris Birge		X						X	X	X	X	X		X	X
C. spp. Dana	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		X
Daphnia ambigua Scourfield	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	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
D. pulex (de Geer)							X	X							
D. pulicaria Sars							X	X							
D. retrocurva Forbes							X	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
Diaphanosoma brachyurum (Lievin)								X	X	X	X	X	X	X	X

Table 4-3 (continued)

TAXON	87-90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
D. spp. Fischer	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Disparalona acutirostris (Birge)															X
Eubosmina spp. (Baird)		X													
Holopedium amazonicum Stin..	X							X	X	X	X	X	X		X
H. gibberum Zaddach	X							X	X						
H. spp. Stingelin	X	X	X	X	X	X	X	X			X	X	X	X	
Ilyocryptus sordidus (Lieven)	X														
I. spinifer Herrick										X					
I. spp. Sars			X	X	X				X		X				
Latona setifera (O.F. Muller)		X													
Leptodora kindtii (Focke)	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Leydigia acanthoceroides (Fis.)															X
L. spp. Freyberg				X	X	X	X	X						X	X
Moina spp. Baird		X													
Monospilus dispar Sars														X	
Oxurella spp. (Sars)															X
Pleuroxus hamulatus Birge														X	
P. spp. Baird														X	
Sida crystallina O. F. Muller	X	X	X												
Simocephalus expinosus (Koch)			X												
Simocephalus spp. Schodler										X					
ROTIFERA															
Anuraeopsis fissa (Gosse)															X
A. spp. Lauterborne	X	X	X	X		X		X		X					X
Asplanchna brightwelli Gosse									X		X				
A. priodonta Gosse									X	X	X				X
A. spp. Gosse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brachionus caudata Bar. & Dad.	X														
B. bidentata Anderson														X	
B. havanensis Rousselet	X							X							
B. patulus O. F. Muller	X								X						
B. spp. Pallas		X		X		X	X		X						
Chromogaster ovalis (Berg.)								X	X	X		X			
C. spp. Lauterborne	X	X	X	X	X	X	X								
Collotheca balatonica Harring							X	X	X	X	X		X	X	X
C. mutabilis (Hudson)							X	X	X	X	X			X	X
C. spp. Harring	X	X	X	X	X	X	X	X	X		X	X	X	X	
Colurella spp. Bory de St. Vin.							X								
Conochiloides dossuarius Hud.								X	X	X	X	X	X	X	X
C. spp. Hlava	X	X	X	X	X	X	X	X				X		X	
Conochilus unicornis (Rouss.)	X							X	X	X	X	X	X	X	X
C. spp. Hlava	X	X	X	X	X	X	X	X				X	X		
Filinia spp. Bory de St. Vincent				X	X				X						X
Gastropus stylifer Imhof									X	X	X	X			X
G. spp. Imhof	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			
Kellicottia bostoniensis (Rouss.)	X				X	X	X	X	X	X	X	X	X	X	X
K. longispina Kellicott								X	X	X	X	X	X	X	X

Table 4-3 (continued)

TAXON	87-90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
K. spp. Rousselet	X	X	X	X	X	X	X	X				X	X	X	X
Keratella cochlearis										X	X				X
K. taurocephala Myers								X		X					X
K. spp. Bory de St. Vincent	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	
Macrochaetus subquadratus P.								X	X						
M. spp. Perty	X	X		X			X			X	X		X		
Monostyla stenroosi (Meiss.)	X														
M. spp. Ehrenberg	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	X
P. truncatum (Levander)	X				X	X	X	X	X	X	X	X	X	X	X
P. spp. Herrick	X	X	X	X	X	X	X		X			X			
Polyarthra euryptera (Weir.)	X								X						X
P. major Burckhart								X		X	X		X	X	X
P. vulgaris Carlin	X							X		X	X	X	X	X	X
P. spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pompholyx spp. Gosse							X								
Ptygura libra Meyers								X	X		X		X	X	X
P. spp. Ehrenberg	X		X	X	X	X	X	X					X	X	
Synchaeta spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichocerca capucina (Weir.)	X				X	X	X	X	X				X		
T. cylindrica (Imhof)	X					X	X	X	X	X	X		X	X	X
T. longiseta Schrank								X							
T. multicrinis (Kellicott)									X	X	X		X	X	X
T. porcellus (Gosse)						X	X	X		X	X		X		X
T. pusilla Jennings								X							
T. similis Lamark						X									
T. spp. Lamark	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichotria spp. Bory de St. Vin.							X						X		X
Unidentified Bdelloida	X		X	X	X			X	X	X					X
Unidentified Philodinidae															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
OSTRACODA (unidentified)									X					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 2004.

	FEBRUARY	MAY	AUGUST	NOVEMBER
		COPEPODA	**EPILIMNION**	
2.0	*Tropocyclops* (6.8)*	*Tropocyclops* (4.6)	*Tropocyclops* (4.8)	*Tropocyclops* (7.8)*
5.0	No adults	*Mesocyclops* (7.3.)	*Tropocyclops* (4.6)*	*Tropocyclops* (2.1)
9.5	*Cyclops* (3.0)	*Epishura* (7.5)	*Tropocyclops* (5.3)*	*Tropocyclops* (3.0)
11.0	*Tropocyclops* (5.3)*	*Tropocyclops* (3.5)	*Tropocyclops* (10.4)	*Meso/Tropo* (0.8 ea.)*
15.9	*Tropocyclops* (4.5.)	*Tropocyclops* (3.8)	*Tropocyclops* (13.4)	*Tropocyclops* (1.3)*
		COPEPODA	**WHOLE COLUMN**	
2.0	*Tropocyclops* (7.4)	*Tropocyclops* (3.3)	*Mesocyclops* (11.6)	*Tropocyclops* (6.7)
5.0	*Tropocyclops* (19.3)	*Epishura* (9.0)	*Tropocyclops* (2.8)	*Tropocyclops* (7.3)
9.5	*Tropocyclops* (8.3)	*Tropocyclops* (4.8)	*Tropocyclops* (8.6)	*Tropocyclops* (3.6)
11.0	*Tropocyclops* (4.7)*	*Mesocyclops* (5.6)	*Tropocyclops* (7.7)	*Mesocyclops* (1.9)
15.9	*Cyclops* (2.5)	*Mesocyclops* (4.4)	*Mesocyclops* (4.6)	*Tropocyclops* (3.3)
		CLADOCERA	**EPILIMNION**	
2.0	*Bosmina* (100.0)	*Bosmina* (85.8)	*Bosminopsis* (93.8)	*Bosmina* (96.9)
5.0	*Bosmina* (100.0)	*Bosmina* (86.3)	*Bosminopsis* (90.7)	*Bosmina* (93.6)
9.5	*Bosmina* (100.0)	*Bosmina* (68.7)	*Bosminopsis* (96.5)	*Bosmina* (98.8)
11.0	*Bosmina* (97.5)	*Bosmina* (47.6)	*Bosminopsis* (73.0)	*Bosmina* (99.1)
15.9	*Bosmina* (97.6)	*Daphnia* (60.0)	*Bosmina* (62.1)	*Bosmina* (100.0)
		CLADOCERA	**WHOLE COLUMN**	
2.0	*Bosmina* (98.7)	*Bosmina* (94.1)	*Bosminopsis* (77.2)	*Bosmina* (86.7)
5.0	*Bosmina* (100.0)	*Bosmina* (83.0)	*Bosminopsis* (81.1)	*Bosmina* (89.7)
9.5	*Bosmina* (98.8)	*Bosmina* (84.4)	*Bosminopsis* (85.6)	*Bosmina* (91.1)
11.0	*Bosmina* (97.7)	*Bosmina* (60.0)	*Bosmina* (43.5)	*Bosmina* (88.9)
15.9	*Bosmina* (98.1)	*Daphnia* (46.4)	*Bosmina* (56.7)	*Bosmina* (100.0)

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	*Asplanchna* (47.0)	*Polyarthra* (82.3)	*Conochilus* (51.4)	*Polyarthra* (52.9)
5.0	*Synchaeta* (83.9)	*Polyarthra* (75.2)	*Trichocerca* (46.4)	*Polyarthra* (58.2)
9.5	*Asplanchna* (68.9)	*Polyarthra* (70.1)	*Conochilus* (52.0)	*Polyarthra* (77.2)
11.0	*Asplanchna* (63.5)	*Polyarthra* (52.9)	*Polyarthra* (47.3)	*Polyarthra* (62.9)
15.9	*Polyarthra* (47.9)	*Polyarthra* (75.8)	*Polyarthra* (35.2)	*Keratella* (46.6)

* = Only adults present in samples.

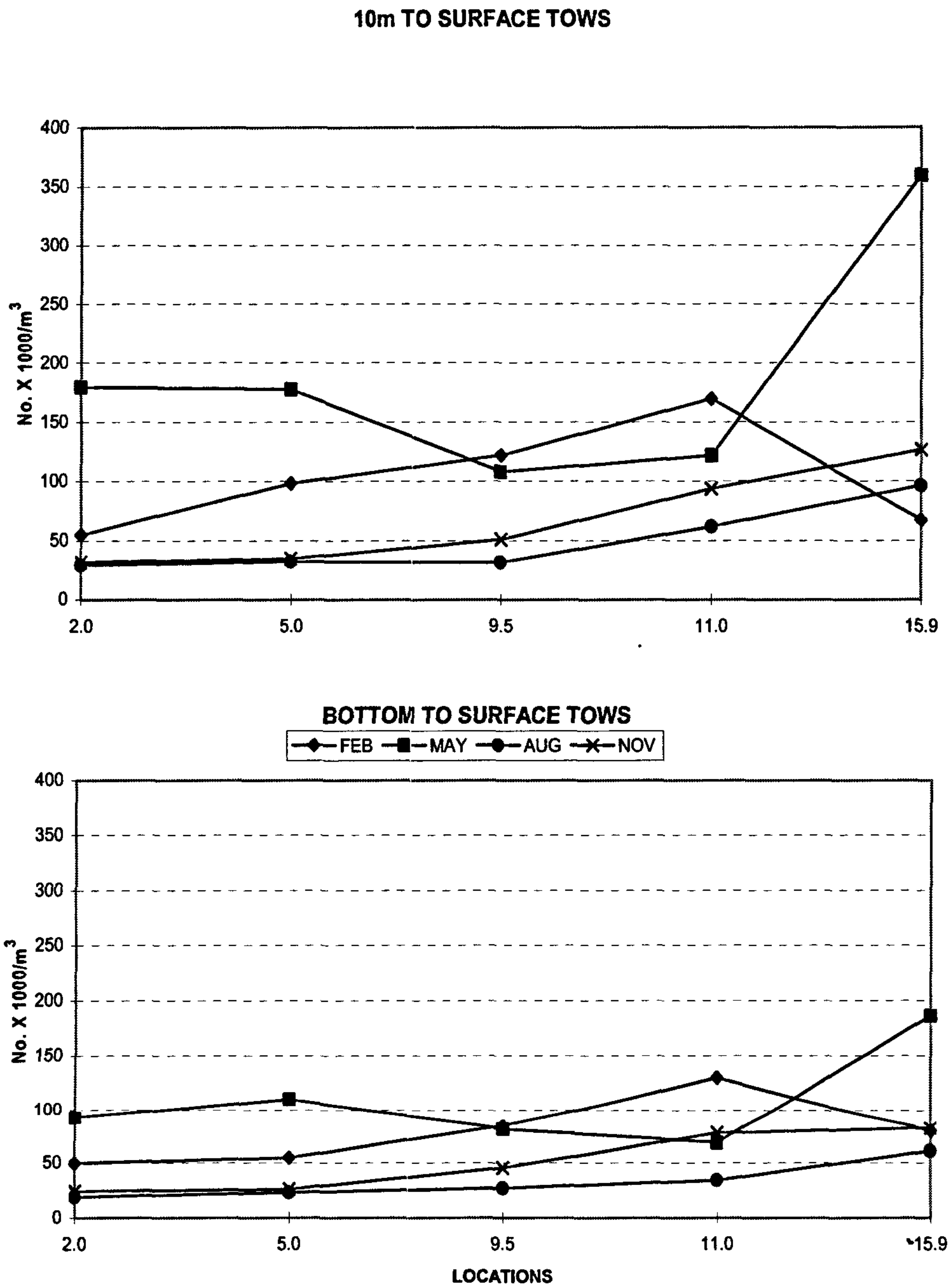

Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman, NC, in 2004.

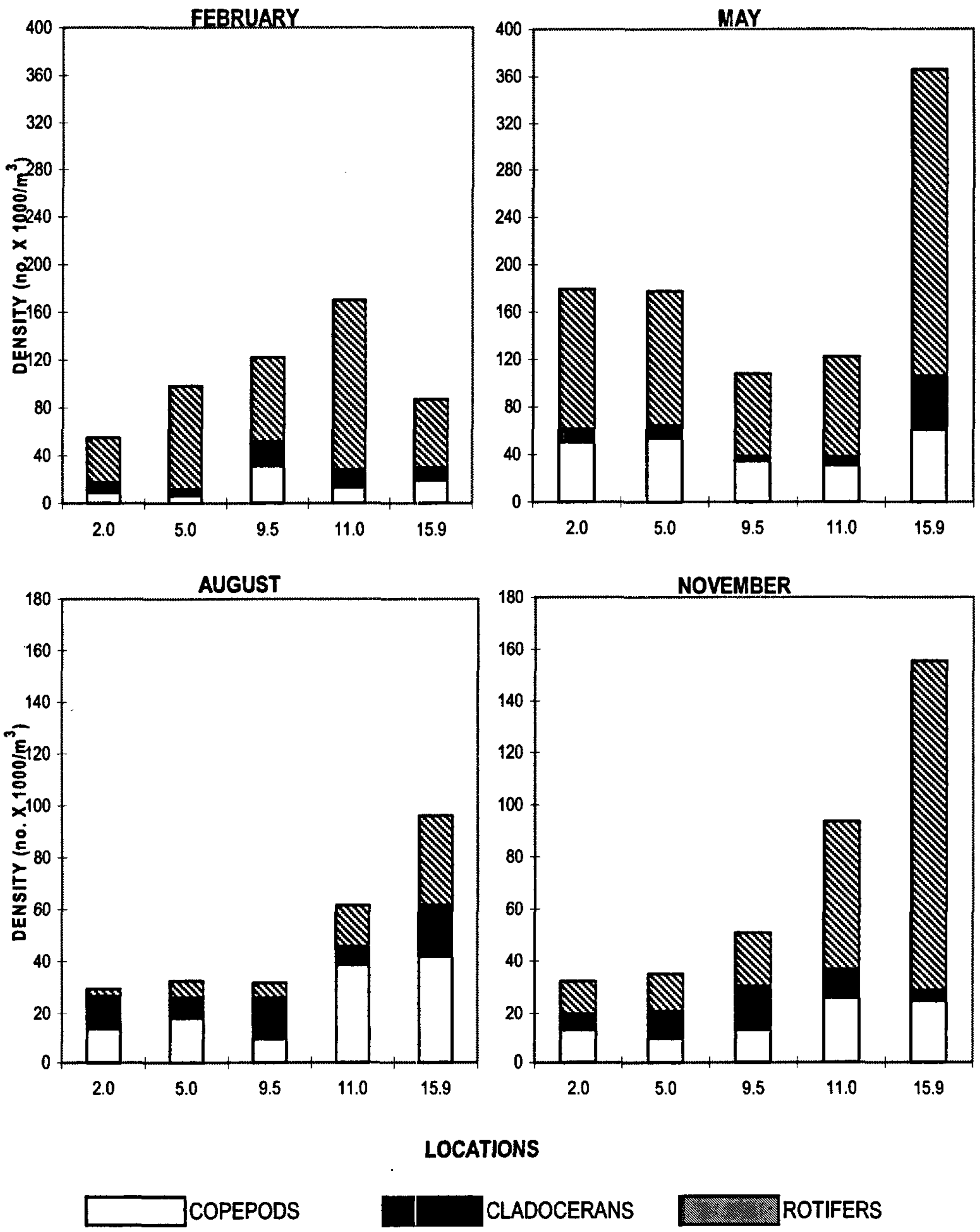

Figure 4-2. Zooplankton community composition by month for epilimnetic samples collected in Lake Norman, NC, in 2004.

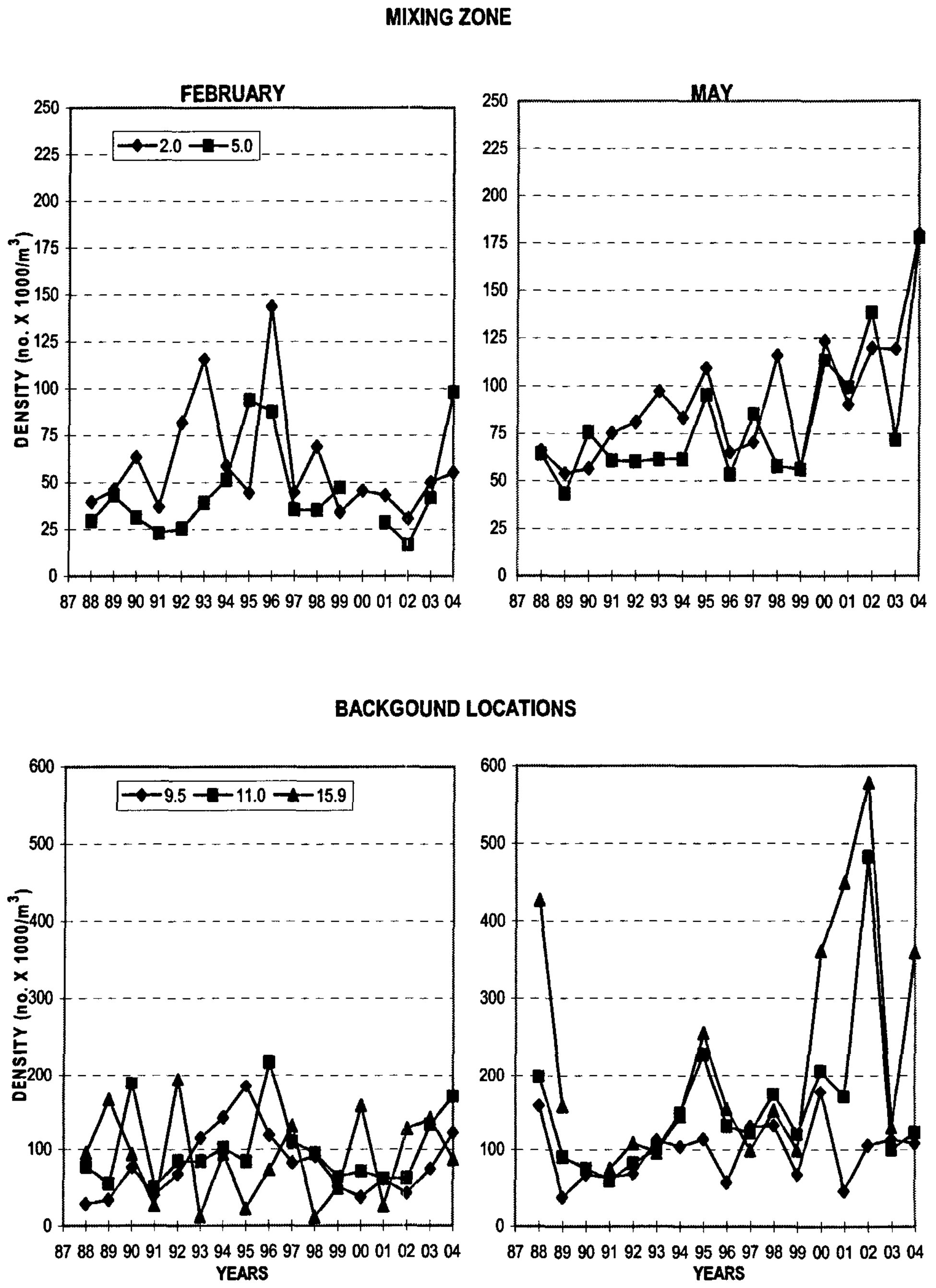

Figure 4-3. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in February and May of 1988 through 2004.

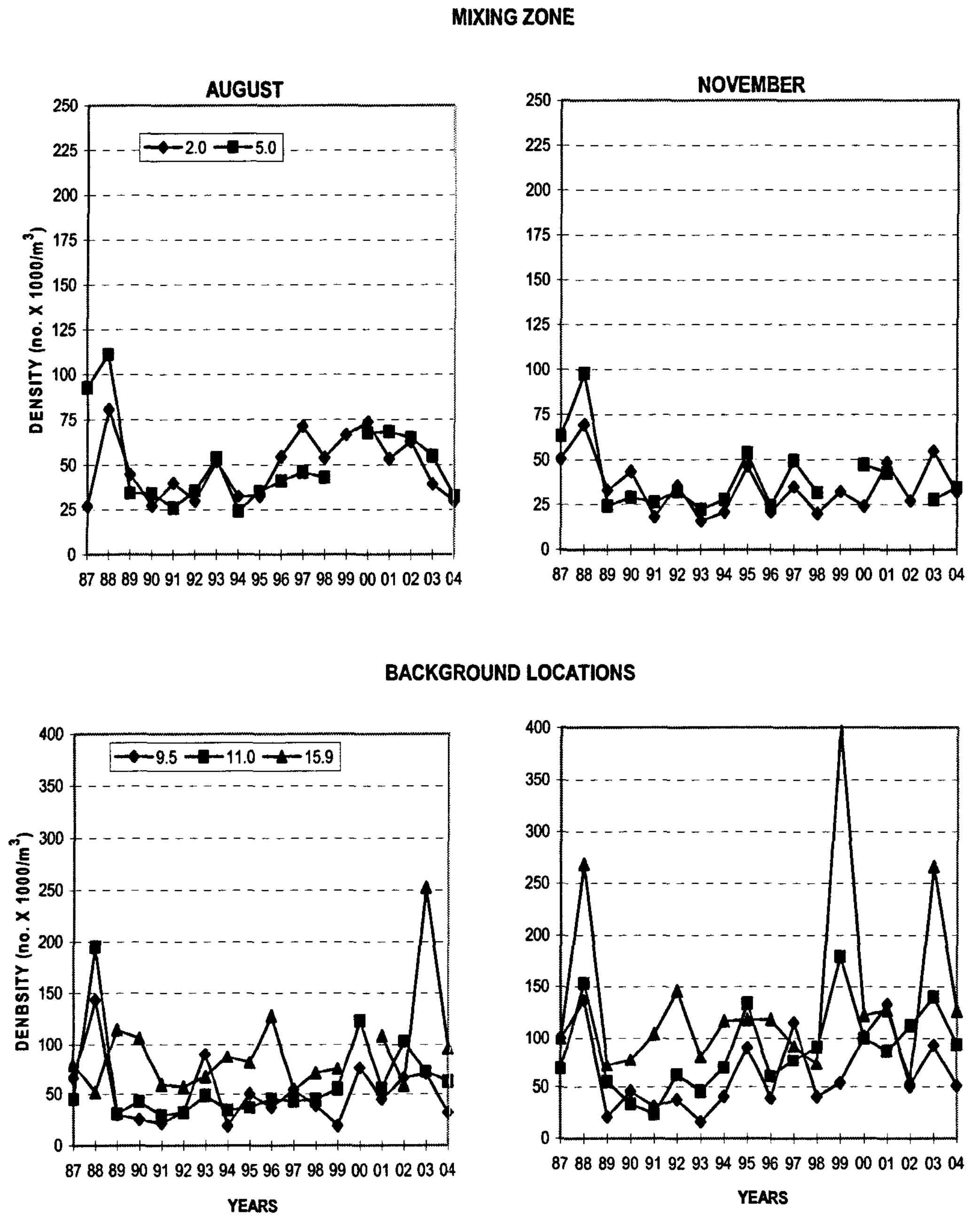

Figure 4-4. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in August and November of 1987 through 2004.

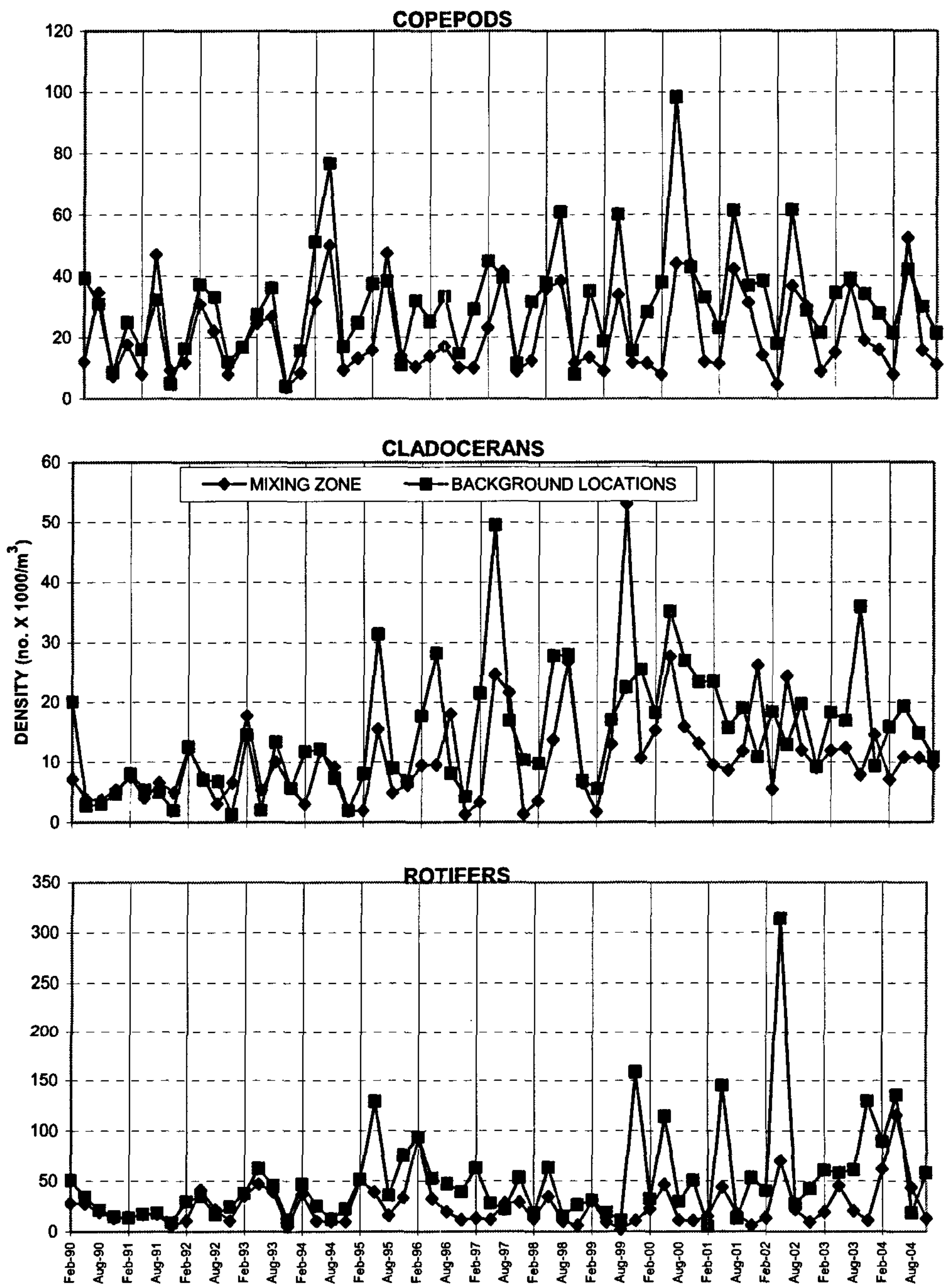

Figure 4-5. Zooplankton composition by quarter for epimlimnetic samples collected in Lake Norman, NC, from 1990 through 2004.

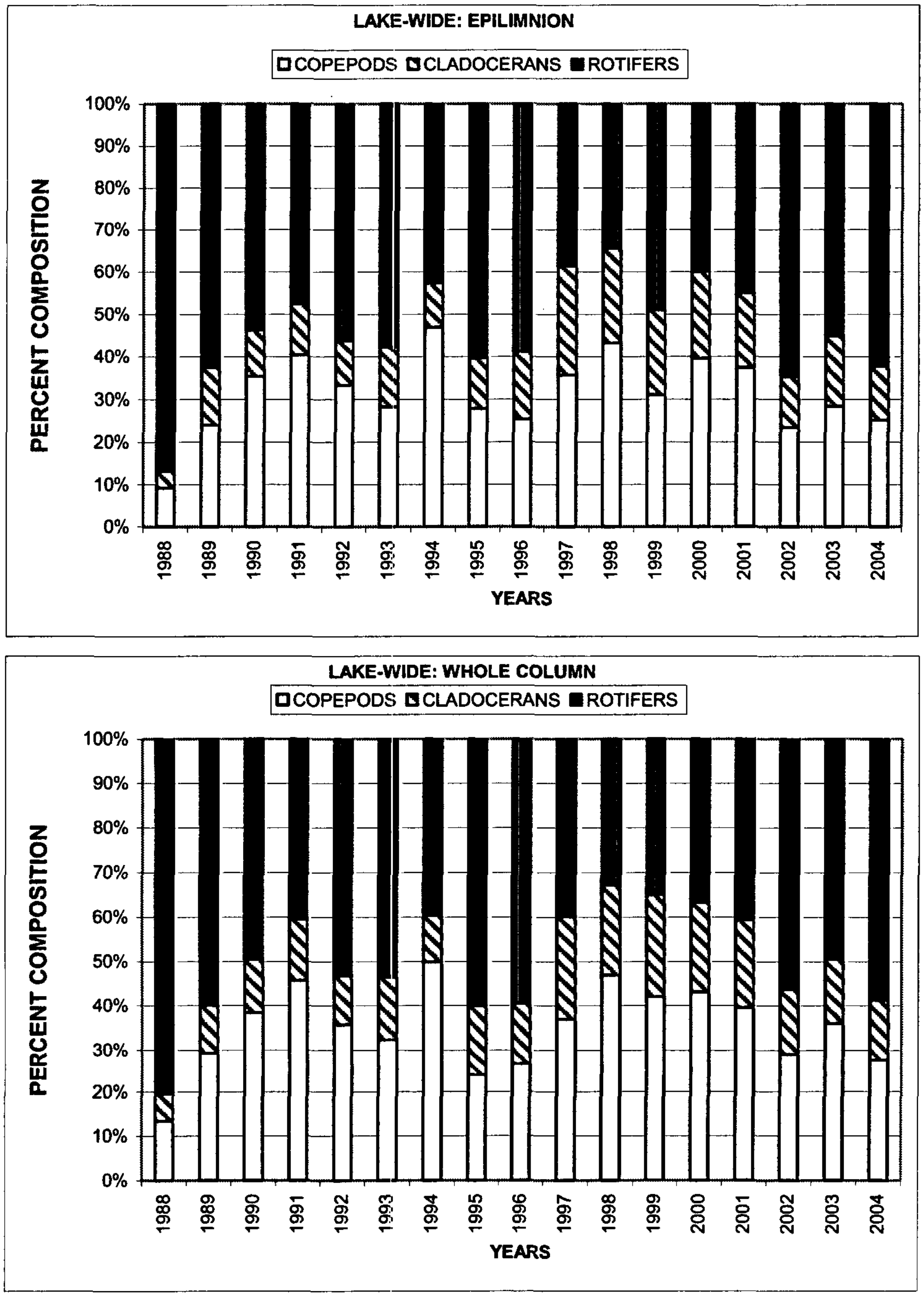

Figure 4-6. Annual lake-wide percent composition of major zooplankton taxonomic groups from 1988 through 2004 (Note: Does not include Location 5.0 in November 2002).

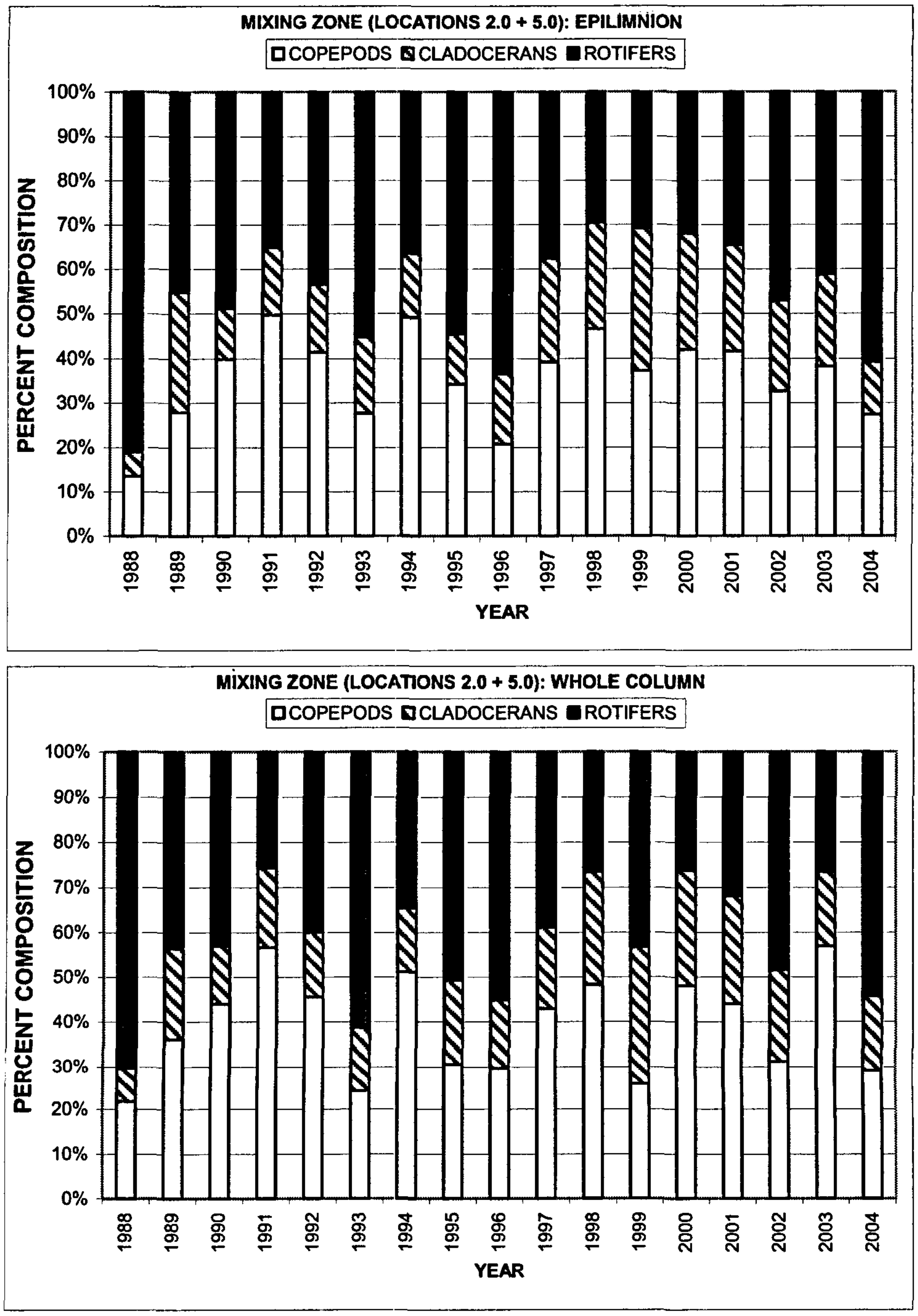

Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from Mixing Zone Locations: 1988 through 2004 (Note: Does not include Location 5.0 in November 2002).

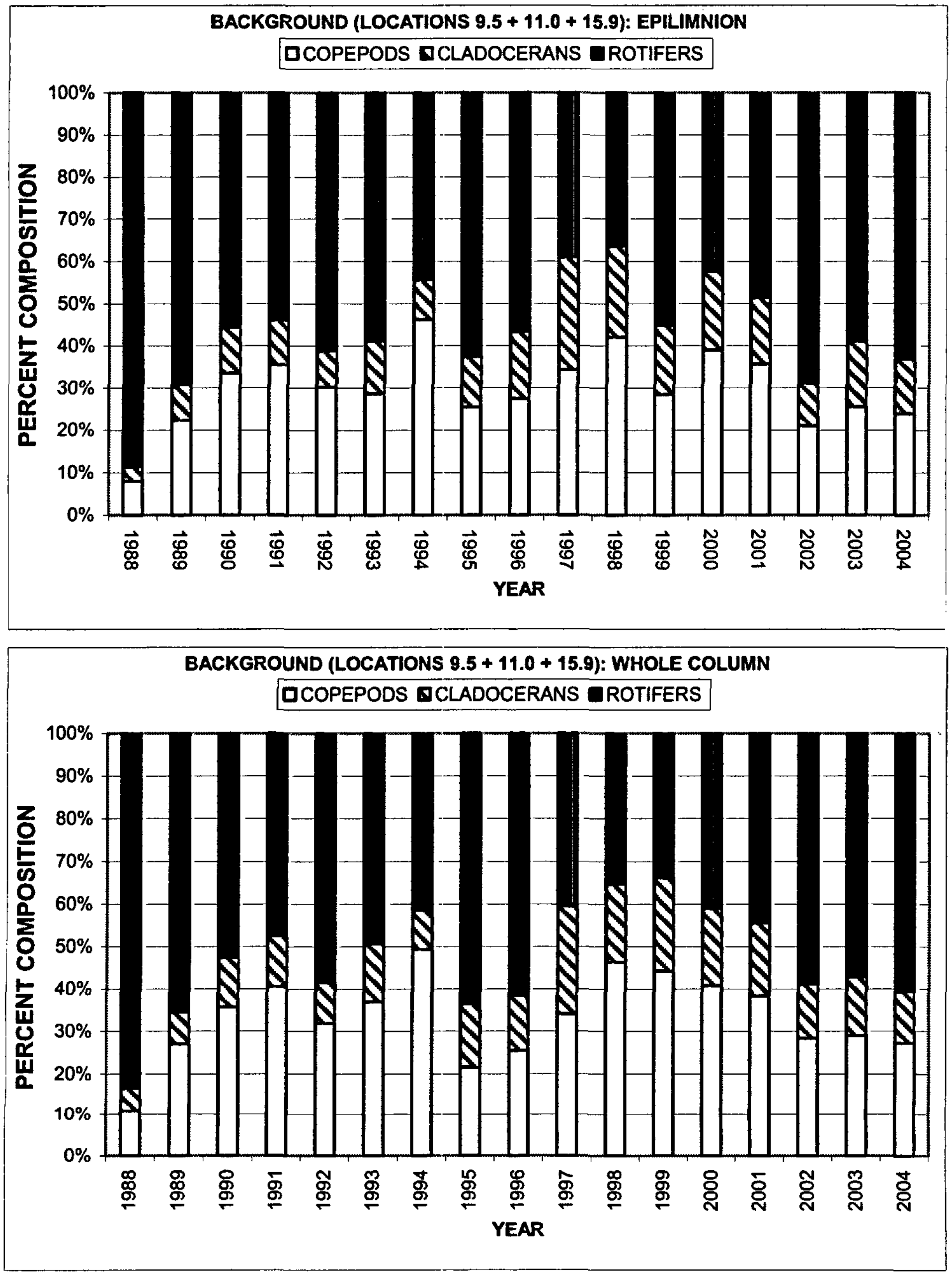

Figure 4-8. Annual percent composition of major zooplankton taxonomic groups from Background Locations: 1988 through 2004.

CHAPTER 5

FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters continued during 2004. 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, size distribution, and relative weight (W_r) 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 W_r;
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 vertical distributions of prey fish in summer;
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 March and 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 (Figure 5-1). The locations sampled in 2004 were the same sampled since implementation of this sampling program in 1993 and consisted of ten 300-m shoreline transects in each location. All transects included the various types of fish habitat found 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 15 to 20 °C (59 to 68 °F). All stunned fish were collected and identified to species. Except for largemouth bass and spotted bass, all other fish 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 $\geq$ 150 mm long, using the formula $W_r = (W/W_s) \times 100$, where W = weight of the individual fish (g) and W_s = 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 from July 1 through August 30. Initially, roving surveys were conducted weekly (as in previous years) to specifically search for dead or dying striped bass in Zones 1-4. After considerable striped bass mortality was noted on July 22 and again on July 27, surveys were conducted every other day until July 30. After this date, daily surveys were implemented and continued through August 13. After August 13, weekly surveys were again conducted through August 30. All dead and dying striped bass were collected during these surveys and their location noted. Measurements for total length were also obtained for a portion of these fish prior to their disposal.

Striped bass for age, growth and W_r 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 W_r were determined for these fish 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 and early November using trap nets as described by Nelson and Dorsey (2005). Total lengths and weights were obtained for all collected white and black crappies and sagittal otoliths were removed for age and growth determinations.

Fish inhabiting Lake Norman's hypolimnion in Zone 1 during July were sampled using small-mesh gill nets that 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) to determine species composition. Four nets were fished in the upper portion of the hypolimnion at a depth of 18.3 m where daytime mobile hydroacoustic samples indicated fish were most abundant (unpublished Duke Power data) and two additional nets were fished on the bottom at a depth of 32.0 m. All nets were set overnight for two consecutive nights, but were retrieved daily, the fish removed and the nets reset. All fish caught were identified to species and enumerated.

The abundance and distribution of pelagic prey fish in Lake Norman was determined using mobile hydroacoustic (Brandt 1996) and purse seine (Hayes et al. 1996) techniques. The mobile hydroacoustic survey of the entire lake was conducted on September 20 and 22 to estimate forage fish populations. Hydroacoustic surveys employed multiplexing, side-scan and down-looking transducers to detect surface-oriented fish and deeper fish (from 2.0 m below the water surface to the bottom), respectively. Both transducers were capable of determining target strength directly by measuring fish position relative to the acoustic axis. The lake was divided into six zones (Figure 5-1) due to its large size, spatial heterogeneity, and multiple power generation facilities.

Purse seine samples were collected on September 21 from the lower (Zone 1), mid (Zone 2), and uplake (Zone 5) areas of the reservoir. The purse seine measured 118 x 9 m with a mesh size of 4.8-mm. A subsample of forage fish collected from each area was used to determine taxa composition and size distribution.

RESULTS AND DISCUSSION

Electrofishing resulted in the collection of 2,449 fish (21 species and 2 hybrid complexes) weighing 143 kg from the MSS area, 2,229 fish (17 species and 2 hybrid complexes) weighing 114 kg from the REF area and 1,772 fish (17 species and 2 hybrid complexes) weighing 74 kg from the MNS area (Table 5-2). A variety of species including whitefin shiners, spottail shiners, redbreast sunfish, warmouth, bluegills, redear sunfish, hybrid sunfish and largemouth bass dominated all samples numerically while common carp, redbreast sunfish, bluegills and largemouth bass dominated all samples gravimetrically. Spotted bass were most abundant (numerically and gravimetrically) in the MNS area, intermediate in abundance in the MSS area and least abundant in the REF area.

Overall, total numbers of fish collected in spring 2004 were highest in the MSS and REF areas, and lowest in the MNS area. Fish biomass at this time was highest in the MSS area, intermediate in the REF area and lowest in the MNS area. Since 1993, the numbers of fish collected in the sampled areas have varied annually (Figure 5-2) with no apparent trend in area catch rates. However, estimates of fish biomass collected annually from 1993 through 2004 have remained generally stable within sampling areas. An exception was noted in 2003 when large numbers of common carp were collected in the MSS area that greatly inflated total fish biomass here over what has been normally observed. Fish biomass noted in

electrofishing samples was generally highest in the MSS area, intermediate in the REF area, and lowest in the MNS area. This trend in fish biomass continued to support the spatial heterogeneity theory noted by Siler et al. (1986) for fish biomass in Lake Norman. They reported that fish biomass was higher uplake than downlake due to higher levels of nutrients and productivity in the uplake area compared to the downlake area.

The dynamics of the largemouth bass population in Lake Norman was investigated in detail during 2004. Starting in 2000, a noticeable decline in the numbers of largemouth bass in electrofishing samples was observed in all areas of Lake Norman (Figure 5-3). The greatest decline in largemouth bass numbers appeared to occur in the MNS area during 2003 and 2004. However, largemouth bass biomass during this same period did not appear to decline simultaneously with declines in largemouth bass numbers in all areas and even increased in some areas in 2003 and 2004 (Figure 5-3).

In 2004, mean lengths of largemouth bass from Lake Norman varied by area (Table 5-3). Mean lengths of age 1 largemouth bass were similar in the MSS and MNS areas and fish in these areas were longer than fish from the REF area. Mean lengths of age 2 largemouth bass were highest in the MSS area, intermediate in the REF area and lowest in the MNS area. By age 3, mean lengths of largemouth bass were highest in the REF area, intermediate in the MSS area and lowest in the MNS area. Mean lengths of age 4 largemouth bass was highest in the REF area and lowest, but similar, in the MSS and MNS areas.

Declines noted in largemouth bass numbers that were associated with stable or increasing biomass estimates may indicate improved growth rates for fish in 2003 and 2004 (Table 5-4). Suspected increases in largemouth bass growth rates in recent years were not readily apparent for age 1 fish, except in those collected from the MSS area for 2003-04 and in the MNS area for 2003 only. There did appear to be some increase in the mean lengths of age 2 and age 3 fish in 2003-04 for most areas when compared to data collected previously (Table 5-4). Mean lengths of age 4 fish in 2003-04 were generally higher in all areas than reported in 1993-94, but not higher than mean lengths reported for the MSS and MNS areas in 1974-78.

In 2004, size distributions of largemouth bass differed somewhat by area (Figure 5-4). The size distributions of largemouth bass collected from the MSS and REF areas were similar with peak numbers occurring at lengths < 150 mm and between 350-399 mm. Even though largemouth bass lengths were somewhat similarly distributed, the numbers of largemouth

bass 350-399 mm long collected in the MSS area exceeded that noted in the REF area. In contrast to that noted in the MSS and REF areas, only a single peak (200-249) was noted in the size distribution of largemouth bass from the MNS area and the numbers of fish collect here were much lower than noted at the two uplake areas.

The size distributions of largemouth bass in 2004 were generally similar in the MSS and the REF areas to those reported in 2003 (Duke Power 2004), but differed from those observed in the MNS area. In 2003, two peaks (one at 200-249 mm and another at 350-399 mm) were noted in the size distribution of largemouth bass collected from the MNS area. In 2004, only one was observed for fish 200-249 mm long.

Mean W_r for largemouth bass collected from Lake Norman varied somewhat among the three sampling areas (Figure 5-5). Overall, mean W_r calculated for fish from the MSS and REF areas were generally similar for most length groups of fish and were higher than that noted for fish collected from the MNS area. This was especially true for the 150-199 mm length group.

Regarding abundance, growth, size distribution and mean W_r for largemouth bass collected from Lake Norman, it appeared that the dynamics of this fish population continued to change in all sampled areas. Compared to 2003, largemouth bass abundance in 2004 was higher in the MSS and REF areas while remaining similar in the MNS area. However, growth rates declined somewhat for age 1 and age 2 fish in all areas from 2003 to 2004. The size distributions of largemouth bass in the MSS and REF areas appeared similar in 2003-04, but larger fish were absent from samples collected in the MNS area in 2004. Mean W_r was generally similar for fish collected in the MSS and REF areas and lower for fish collected in the MNS area. This was especially true for fish in the 150-199 mm length group.

Declines in recruitment resulting from competition with recently stocked species of fish may be impacting the largemouth bass population in Lake Norman. Recent introductions of alewives and white perch may have increased lakewide predation on largemouth bass eggs and juveniles (e.g., Kohler and Ney 1980, Madenjian et al. 2000), and resulted in the changes noted in largemouth bass abundance. A change in largemouth bass abundance may also be reflected in growth rates for this species. A decline in abundance may increase the growth rates of surviving largemouth bass while an increase in abundance may reduce growth. It is difficult to determine if introduction of the spotted bass to Lake Norman has resulted in

competition with the largemouth bass and may have also reduced growth rates and mean W_r primarily in the MNS area where spotted bass were most abundant.

In 2004, a total of 2,610 dead striped bass were collected from surveys conducted between July 1 and August 30 in Lake Norman (Table 5-5). Only 10 dead stripers were collected during a similar period in 2003 (Duke Power 2004). Most of these dead fish were collected in Zone 1 from July 22 through August 13. This kill was reported and investigated by the NCWRC (Waters 2004).

This die-off of striped bass was the largest ever for Lake Norman and coincided with the temporary loss of striped bass habitat near the dam in late July (see Chapter 2). As noted in Chapter 2, habitat conditions were marginally better in 2004 than 2003 when few striped bass died (Duke Power 2004). Thus, this kill was unexpected and may be related to an unusually warm May (Figure 2-2c, Chapter 2) that resulted in higher than normal epilimnetic water temperatures in June and July (Figure 2-3, Chapter 2). For example, it appears that the 26 °C isotherm (upper limit used for striped bass habitat) in July was about 5 m deeper in 2004 than in 2003.

With higher than normal epilimnetic water temperatures in Lake Norman in 2004, striped bass may have migrated earlier and deeper into the metalimnion and hypolimnion of Lake Norman than in previous years. Due to the presence of alewives as a suitable prey in the hypolimnion (see small-mesh netting results in this chapter), striped bass may have remained in the hypolimnion as microbial activity reduced metalimnetic dissolved oxygen concentrations to critical levels (< 2 mg/l). In Lake Norman, metalimnetic dissolved oxygen concentrations are normally reduced prior to hypolimnetic concentrations (Figure 2-6, Chapter 2), thus "trapping" any fish that may be in the hypolimnion at this time. As dissolved oxygen concentrations in the hypolimnion were reduced to < 2.0 mg/l by late July or early August, any striped bass "trapped" there would not have been expected to survive.

Even though similar metalimnetic and hypolimnetic dissolved oxygen conditions have been documented in Lake Norman in previous years, this was the first major kill since 1983 when < 200 fish died (Duke Power unpublished data). We can only assume that in previous years striped bass die-offs did not occur primarily because fish were not forced into the hypolimnion in late spring or early summer due to unusually warm meteorological conditions or if they were forced deeper into the reservoir, they may not have remained there for an extended period of time due to lack of a readily available food source.

Threadfin shad and gizzard shad were the primary prey for striped bass prior to the introduction of alewives into Lake Norman in the late 1990s. Gizzard shad (Coutant 1977) and probably threadfin shad have summer temperature preferences higher than alewives (Colby 1973) and would not be expected to inhabit the hypolimnion of Lake Norman in early summer as do alewives. Without sufficient prey at these deeper depths, the striped bass would not be inclined to remain in the hypolimnion long enough to become "trapped" by natural reductions in metalimnetic dissolved oxygen concentrations. Therefore, kills of the magnitude seen in 2004 would not have been expected prior to alewives becoming established in the lake. The NCWRC did not think that the number of fish killed in 2004 significantly reduced the overall numbers of striped bass in Lake Norman (Christian Waters, personal communication).

One hundred seven striped bass were collected in November and December 2004 for age, growth and W_r evaluations (Figure 5-6). Mean total length at age was 308, 451, 519, 574, 586, 600, 590 and 647 mm at ages 0-7, respectively. Growth of Lake Norman striped bass was slow after age 3 as noted in 2003 (Duke Power 2004). Mean W_r ranged from 67 to 90 and was highest for young fish and lowest for older fish. Overall, mean W_r for all fish in 2004 was 79 and was similar to that (81) noted in 2003 (Duke Power 2004).

Duke Power and the NCWRC collected 258 crappies in 105 trap-net sets from Lake Norman in 2004. These data were summarized by Nelson and Dorsey (2005). They found that mean length, mean total length at age and mean W_r for fish collected in 2004 were similar to that noted for fish collected in comparable sampling in 2003.

A total of 82 fish were collected in small-mesh gillnetting conducted in the hypolimnion of Lake Norman in 2004 (Table 5-6). Alewife (57.3 %) and blue catfish (30.5 %) composed most of the catch. The presence of alewives in the hypolimnion of Lake Norman just prior to the striped bass kill may partially explain why striped bass became "trapped" in the hypolimnion and later died due to the lack of dissolved oxygen.

Forage fish densities in the six zones of Lake Norman ranged from 633 to 6,188 fish/ha in September 2004 (Table 5-7). Forage fish densities were highest in Zones 3 and 4, intermediate in Zone 5, and lowest in Zones 1, 2, and 6. The limited amount of available habitat for sampling (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 population was approximately 47.2 million fish. The lakewide population estimate in September 2004 was below values measured from 1997 to 2003 when estimates ranged from 64.3 to 91.3 million fish (Figure 5-7), but no trends were noted in zonal or lakewide population estimates for pelagic fish surveys conducted in Lake Norman from 1997 through 2004.

Purse seine sampling in 2004 indicated that the forage fish sampled by hydroacoustics were 86.6% threadfin shad, 13.2% alewives, and 0.2% gizzard shad (Table 5-8). Threadfin shad lengths primarily ranged from 36 to 85 mm while alewife lengths ranged from 56 to 85 mm. The two length frequency distributions overlapped with a modal length between 51 and 55 mm (Figure 5-8). Results from purse seining have undergone a dramatic shift in recent years. From 1997 through 1999, purse seine samples were mostly composed of small threadfin shad (typically ≤ 55 mm long). Alewives were first detected in 1999 in low numbers and increased to approximately 25% of the open water forage fish community in 2002 and their presence was accompanied by a concurrent wider size range of individuals with a larger modal length class. The percent contribution from alewives has declined since 2002 and was approximately 13% of the forage fish catch in 2004. However, the concurrent wider size range and larger modal length class of forage individuals has persisted.

FUTURE STUDIES

The only suggested change to the fish portion of the Lake Norman Maintenance Monitoring Program is to discontinue small-mesh gillnetting for fish inhabiting Zone 1 of Lake Norman's hypolimnion.

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 2004. Spring electrofishing indicated that 17 to 21 species of fish and 2 hybrid complexes comprised fish populations in the 3 sampling areas, and numbers and biomass of fish in 2004 were generally similar to those noted since 1993. Declines in largemouth bass numbers, which were first observed in 2000, appear to be an exception.

In 2004, considerable striped bass mortality was observed during summer in Lake Norman and this mortality appeared to be related to a combination of unique events triggered by an unusually warm May and the abundance of prey in the hypolimnion. Mean W_r for Lake Norman striped bass collected in November and December 2004 was similar to that observed previously and indicated little change in the overall condition of this fish.

Trapnetting indicated little change in the crappie populations in Lake Norman in 2003-2004. Hydroacoustic and purse seine sampling indicated that there was a decline in the number of prey fish and a change in species composition from 2003 to 2004.

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Table 5-1. Common and scientific names of fish collected in Lake Norman, 2004.

Common name	Scientific name
Blueback herring	*Alosa aestivalis*
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorosoma petenense*
Goldfish	*Carassius auratus*
Greenfin shiner	*Cyprinella chloristia*
Whitefin shiner	*Cyprinella nivea*
Common carp	*Cyprinus carpio*
Eastern silvery minnow	*Hybognathus regius*
Spottail shiner	*Notropis hudsonius*
Fathead minnow	*Pimephales promelas*
Blue catfish	*Ictalurus furcatus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Striped mullet	*Mugil cephalus*
White perch	*Morone americana*
Striped bass	*Morone saxatilis*
Redbreast sunfish	*Lepomis auritus*
Green sunfish	*Lepomis cyanellus*
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, March and April 2004.

	MSS		REF		MNS	
Taxa	N	Kg	N	Kg	N	Kg
Alewife	1	0.004	47	0.329		
Gizzard shad	3	1.352	1	0.635	1	0.700
Goldfish					1	1.517
Greenfin shiner	4	0.007	4	0.014	4	0.010
Whitefin shiner	68	0.415	145	0.430	110	0.252
Common carp	19	43.111	23	46.592	11	21.159
Eastern silvery minnow	2	0.007				
Spottail shiner	149	1.355	52	0.410	9	0.060
Fathead minnow	1	0.001				
Channel catfish	1	0.128	5	3.126		
Flathead catfish	4	0.768	1	0.133	5	0.416
Striped mullet					1	2.408
White perch	1	0.424				
Redbreast sunfish	523	8.898	497	7.478	288	4.863
Green sunfish	2	0.042			7	0.020
Warmouth	22	0.169	51	0.568	46	0.250
Bluegill	1,202	12.322	1,013	10.710	1,013	14.115
Redear sunfish	150	8.696	153	6.387	94	3.410
Hybrid sunfish	115	2.920	132	2.481	82	1.813
Spotted bass	27	4.079	1	0.014	59	10.691
Largemouth bass	140	56.651	87	30.071	36	11.288
Hybrid black bass	4	0.241	1	0.826	1	0.296
Black crappie	3	1.000	5	3.947	1	0.553
Tessellated darter	2	0.002	1	0.002	3	0.005
Yellow perch	6	0.043	10	0.111		
Total	2,449	142.635	2,229	114.264	1,772	73.826

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, March-April 2004. Numbers of fish used to compute means are in parentheses.

	Age								
Location	1	2	3	4	5	6	7	8	9
MSS	176 (47)	309 (37)	355 (17)	367 (14)	403 (11)	417 (2)	428 (2)	415 (2)	
REF	143 (47)	288 (16)	364 (13)	415 (4)	404 (3)	382 (6)		379 (1)	394 (1)
MNS	170 (50)	276 (18)	335 (9)	370 (14)		356 (1)		414 (1)	
Weighted mean	163	296	353	374	403	387	428	406	394

Table 5-4. Mean total length (mm) at age for largemouth bass collected from an area near the Marshall Steam Station (MSS), from an area (REF) between MSS and the McGuire Nuclear Station (MNS), and from an area near MNS. Data from 1971-78, 1993-94, and 2003 are from Siler (1981), Duke Power unpublished data, and Duke Power (2004), respectively.

	Age			
Location and year	1	2	3	4
MSS 1974-78	170	266	310	377
MSS 1993	170	277	314	338
MSS 1994	164	273	308	332
MSS 2003	216	317	349	378
MSS 2004	176	309	355	367
REF 1993	157	242	279	330
REF 1994	155	279	326	344
REF 2003	139	296	358	390
REF 2004	143	288	364	415
MNS 1971-78	134	257	325	376
MNS 1993	176	256	316	334
MNS 1994	169	256	298	347
MNS 2003	197	315	248	389
MNS 2004	170	276	335	370

Table 5-5. Dead or dying striped bass observed in Lake Norman, July-August 2004.

Dat	Number	Zon	Range in total length
1-Jul	3	1	522-
	1	3	565
	1	4	589
6-Jul	2	4	400-
9-Jul	1	1	592
	1	2	575
	2	4	464-
15-Jul	2	1	558-
	1	3	535
	3	4	508-
22-Jul	10	1	512-
	2	2	520-
	7	3	429-
	4	4	480-
27-Jul	22	1	423-
	10	3	526-
29-Jul	91	1	450-
	1	2	545
30-Jul	204	1	441-
	1	3	540
	1	4	570
31-Jul	90	1	425-
	2	2	455-
	1	3	515
	2	4	558-
1-	72	1	466-
2-	112	1	462-

Table 5-5. Continued.

Date	Number	Zone	Range in total length (mm)
3-Aug	86	1	464-623
	1	4	510
4-Aug	191	1	449-819
5-Aug	200	1	435-650
	2	3	523-540
	1	4	503
6-Aug	206	1	*
	1	2	*
	3	3	*
	3	4	*
7-Aug	318	1	*
8-Aug	479	1	*
9-Aug	166	1	*
10-Aug	197	1	*
	4	2	*
	5	3	*
	1	4	*
11-Aug	53	1	*
12-Aug	22	1	*
13-Aug	11	1	*
20-Aug	5	1	450-500
	1	2	510
	3	3	500-595
	1	4	540
30-Aug	1	4	600

* Length data not collected

Table 5-6. Numbers of fish caught in small-mesh gill nets set in Lake Norman's hypolimnion, July 2004.

	Depth and percent compostion					
Species	Upper	%	Bottom	%	Combined	%
Blueback herring	5	7.6	1	6.2	6	7.3
Alewife	43	65.2	4	25.0	47	57.3
Gizzard shad	1	1.5	0		1	1.2
Blue catfish	14	21.2	11	68.8	25	30.5
White perch	1	1.5	0		1	1.2
Striped bass	2	3.0	0		2	2.4

Table 5-7. Prey fish densities (N/ha) and population estimates from hydroacoustic surveys of Lake Norman, September 2004.

Zone	Density	Population estimate
1	1,811	4,130,891
2	1,752	5,399,839
3	6,188	21,382,758
4	5,717	7,037,627
5	4,235	8,918,910
6	633	302,574
Lakewide		47,172,599
95% Lower confidence interval		43,699,683
95% Upper confidence interval		50,645,514

Table 5-8. Numbers (N), species composition and modal lengths (mm) of prey fish collected in purse seine samples collected in Lake Norman during late summer or fall, 1997-2004.

Year	N	Species composition			Threadfin shad modal length class
		Threadfin	Gizzard	Alewife	
1997	6,711	99.99%	0.01%	0.00%	41-45
1998	5,723	99.95%	0.05%	0.00%	41-45
1999	5,404	99.26%	0.26%	0.48%	36-40
2000	4,265	87.40%	0.22%	12.37%	51-55
2001	9,652	76.47%	0.01%	23.52%	56-60
2002	10,134	74.96%	0.00%	25.04%	41-45
2003	33,660	82.59%	0.14%	17.27%	46-50
2004	21,158	86.55%	0.24%	13.20%	51-55

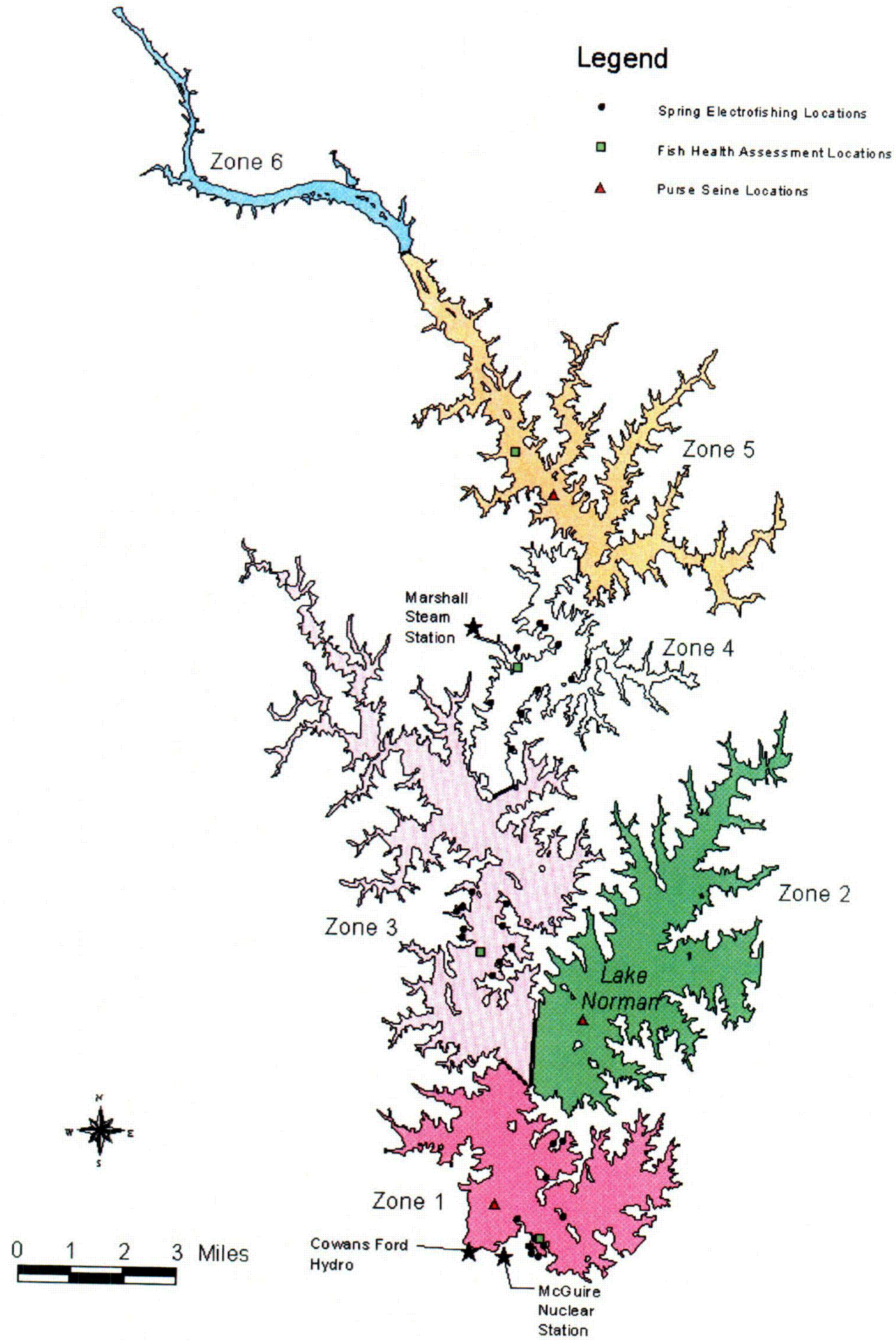
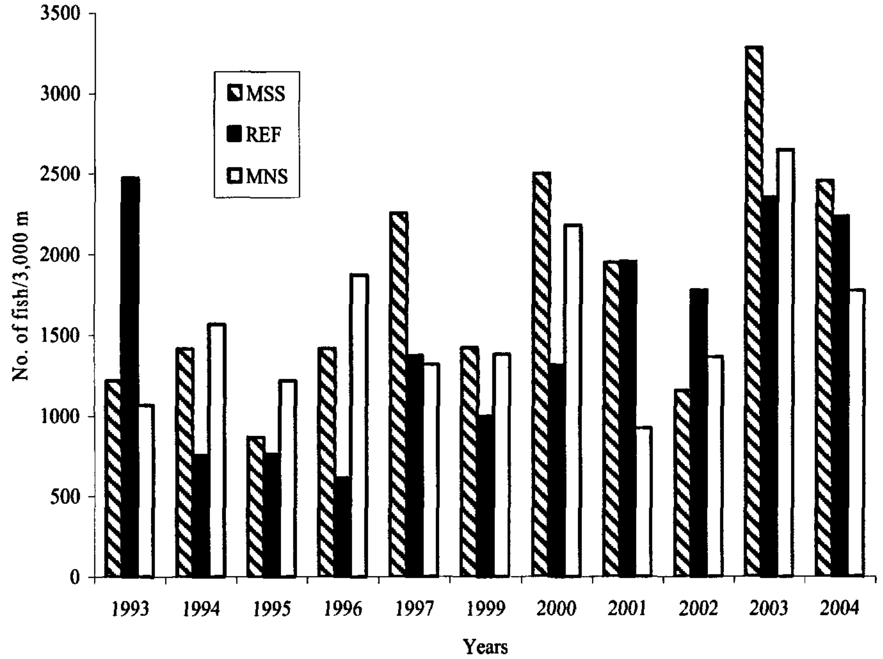


Figure 5-1. Sampling zones in Lake Norman.

C02



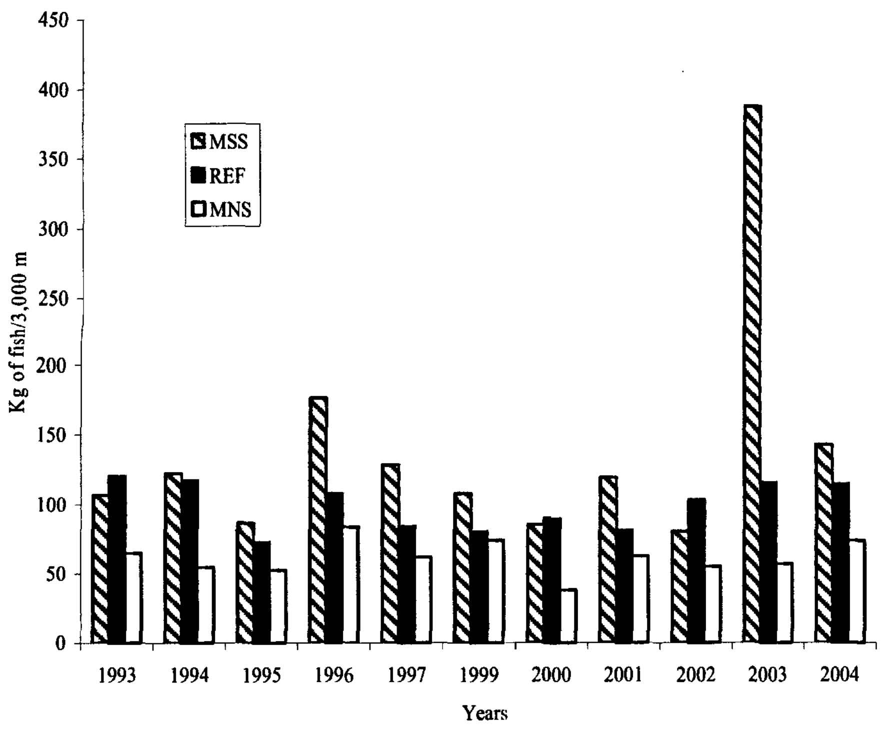


Figure 5-2. Numbers and biomass of fish collected from electrofishing ten 300-m transects near Marshall Steam Station (MSS), a reference (REF) area between MSS and and McGuire Nuclear Station (MNS), and near MNS in Lake Norman, 1993-2004.

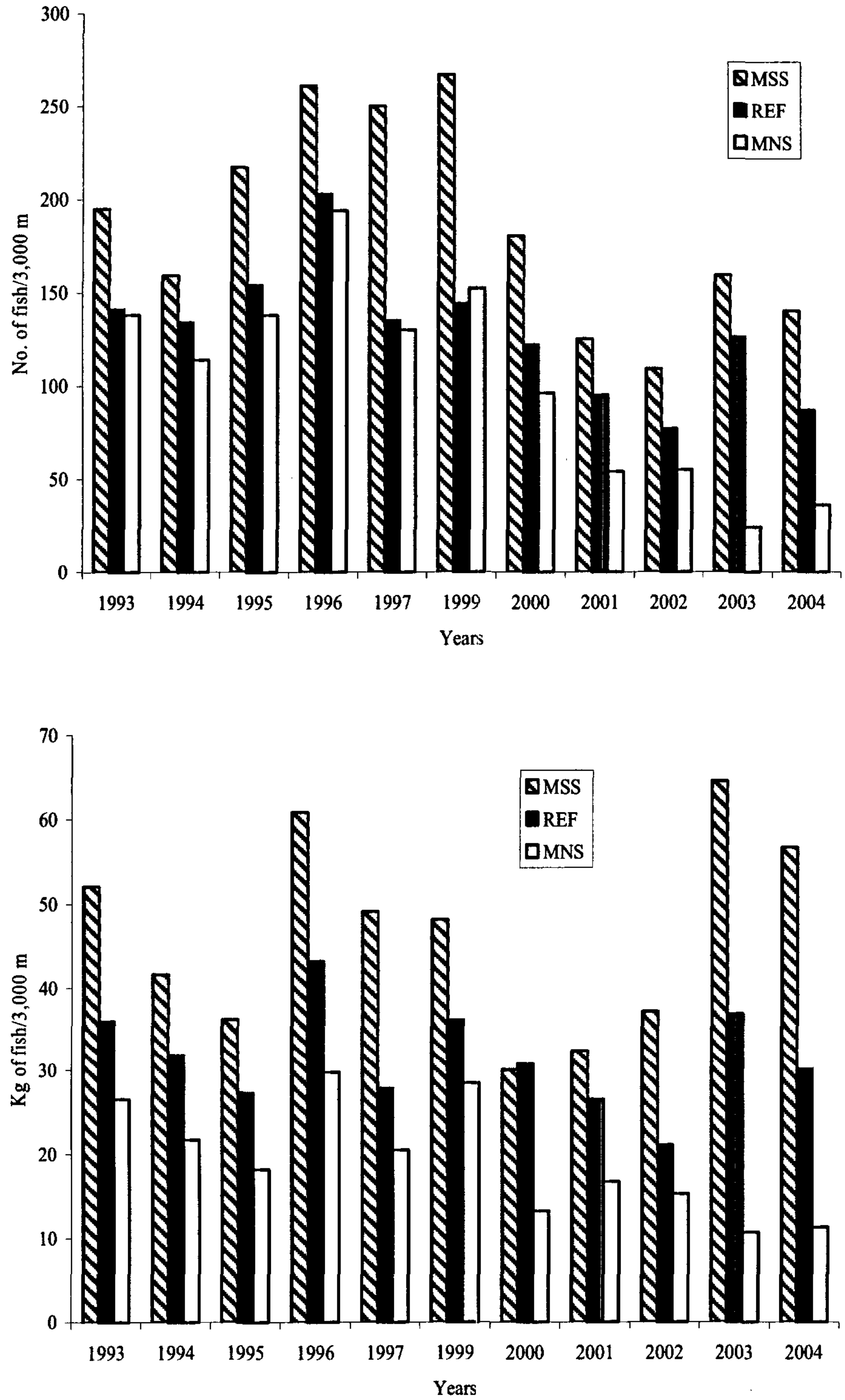


Figure 5-3. Numbers and biomass of largemouth bass collected from electrofishing ten 300-m transects near Marshall Steam Station (MSS), a reference (REF) area between MSS and McGuire Nuclear Station (MNS), and near MNS in Lake Norman, 1993-2004.

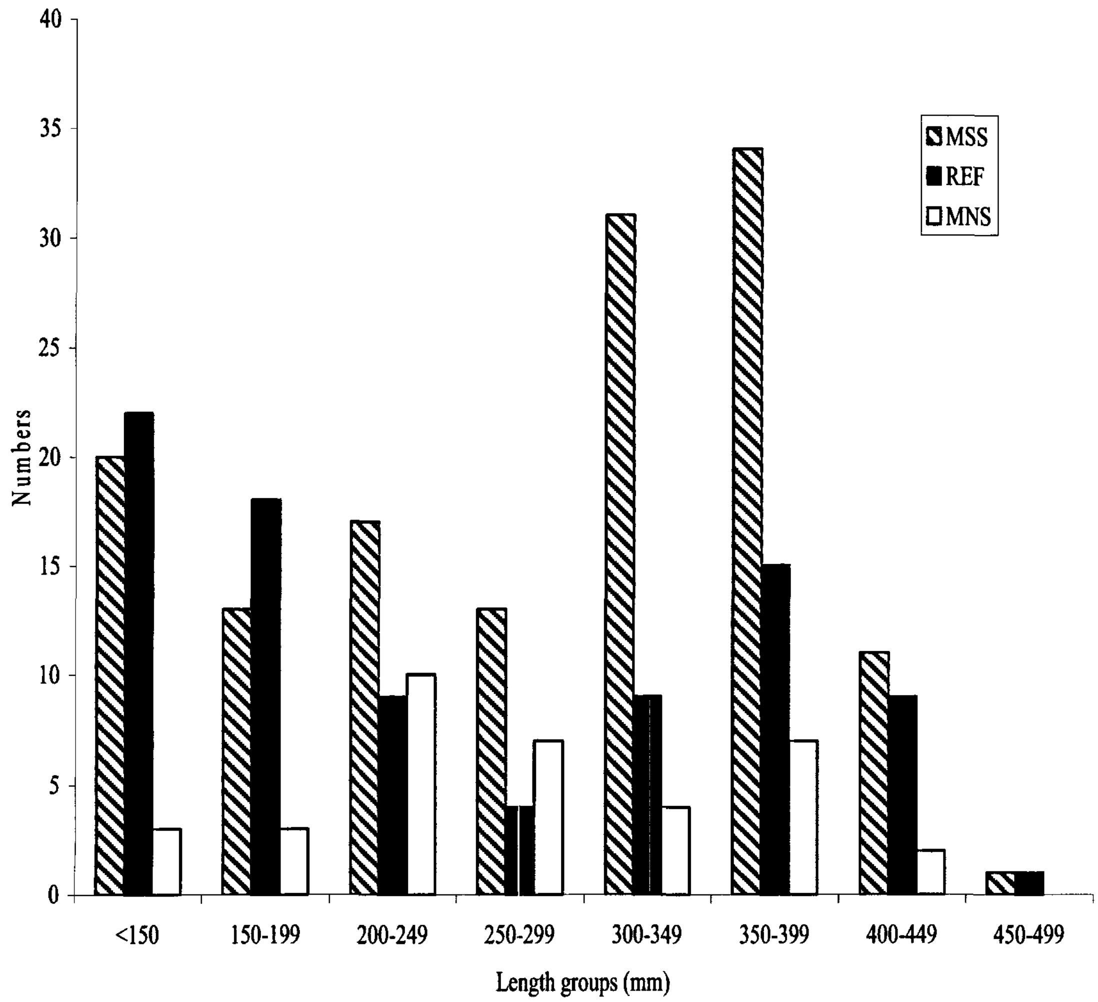


Figure 5-4. Size distribution of largemouth bass collected from electrofishing ten 300-m transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, 2004.

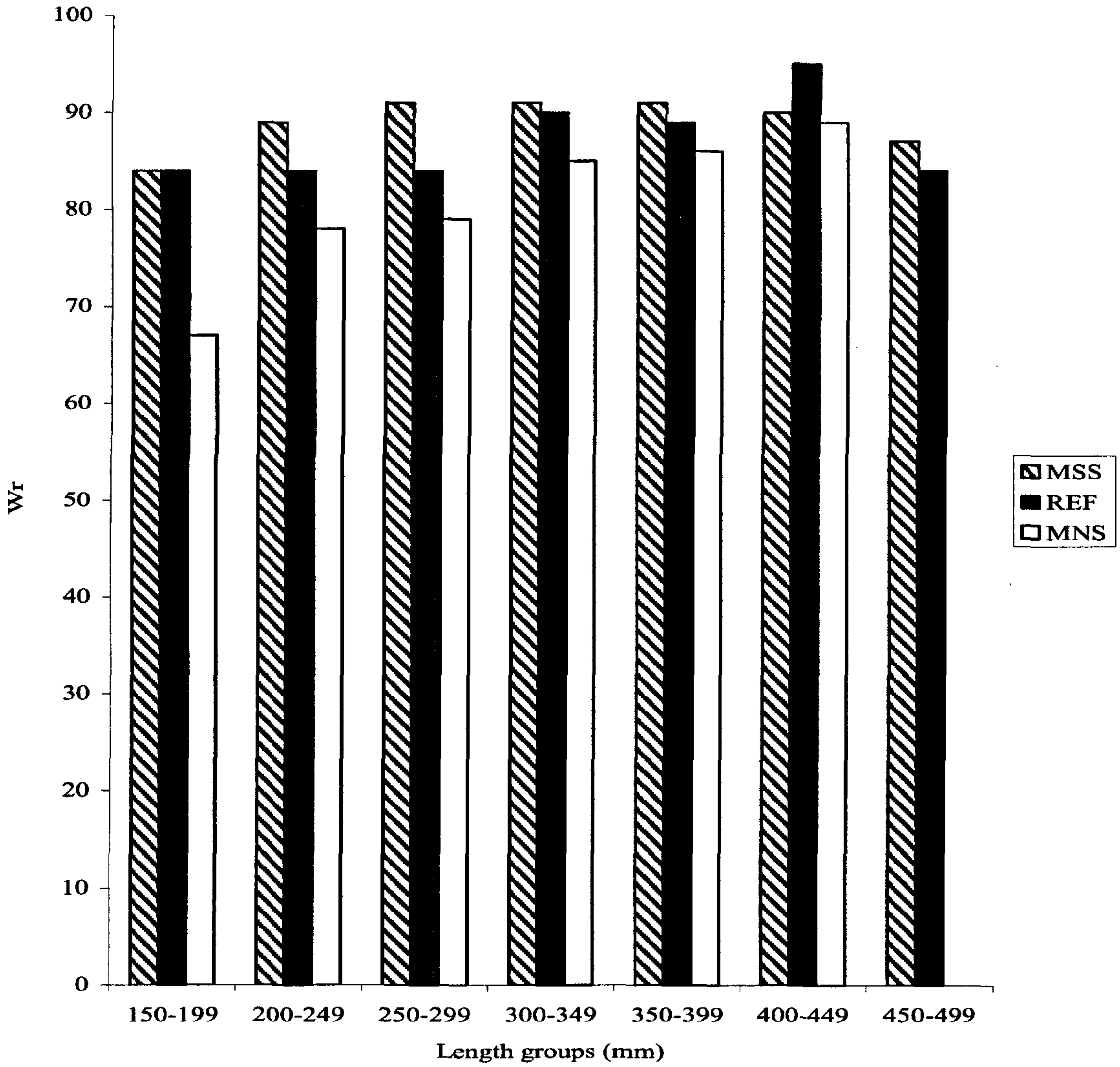


Figure 5-5. Mean relative weight (W_r) for largemouth bass collected from electrofishing ten transects near Marshall Steam Station (MSS), in a reference (REF) area between MSS and McGuire Nuclear Station (MNS) and near MNS in Lake Norman, 2004.

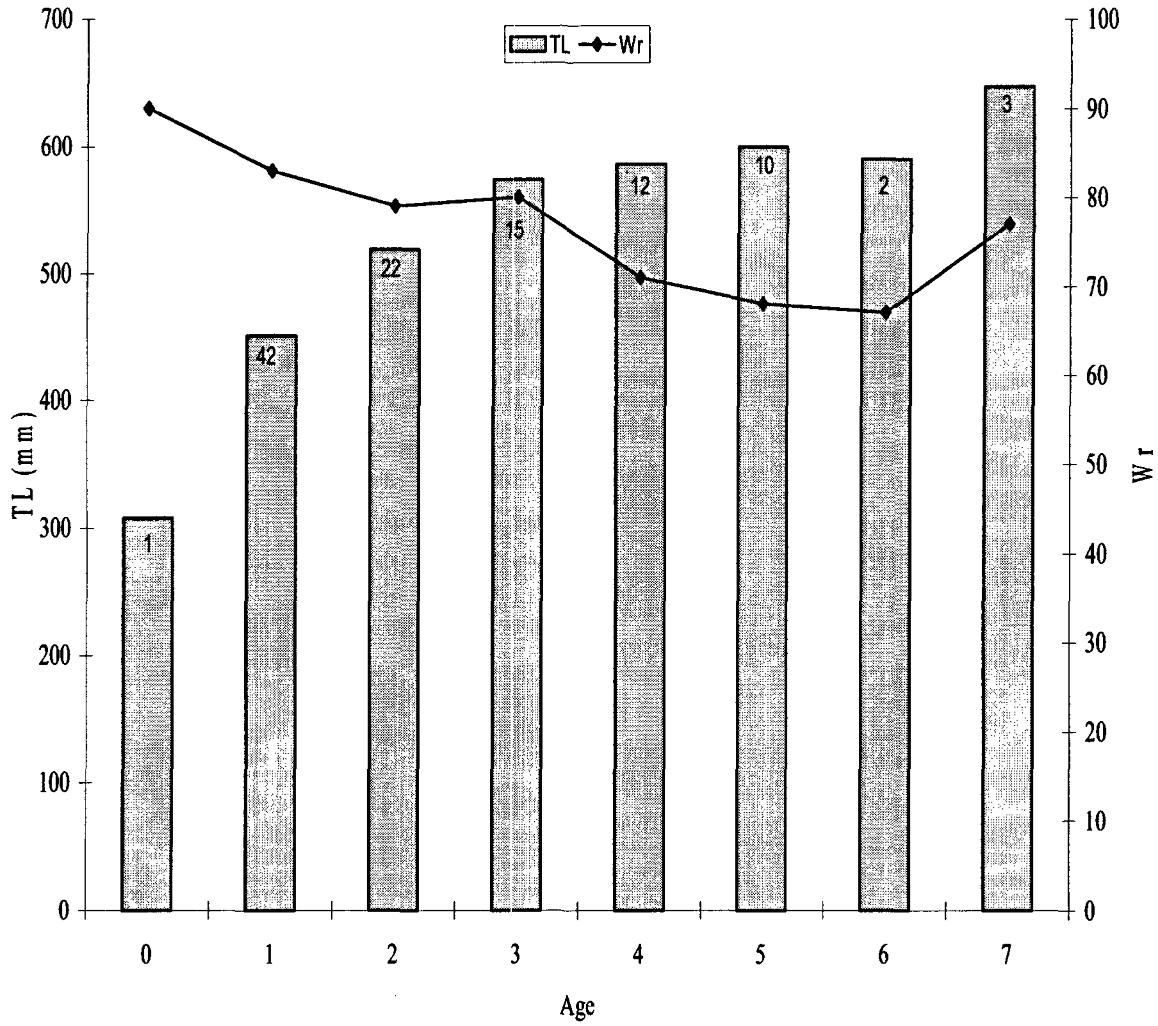


Figure 5-6. Mean total length and mean relative weight (W_r) for striped bass collected from Lake Norman, November-December 2004. Number of fish associated with the mean length are inside the bars.

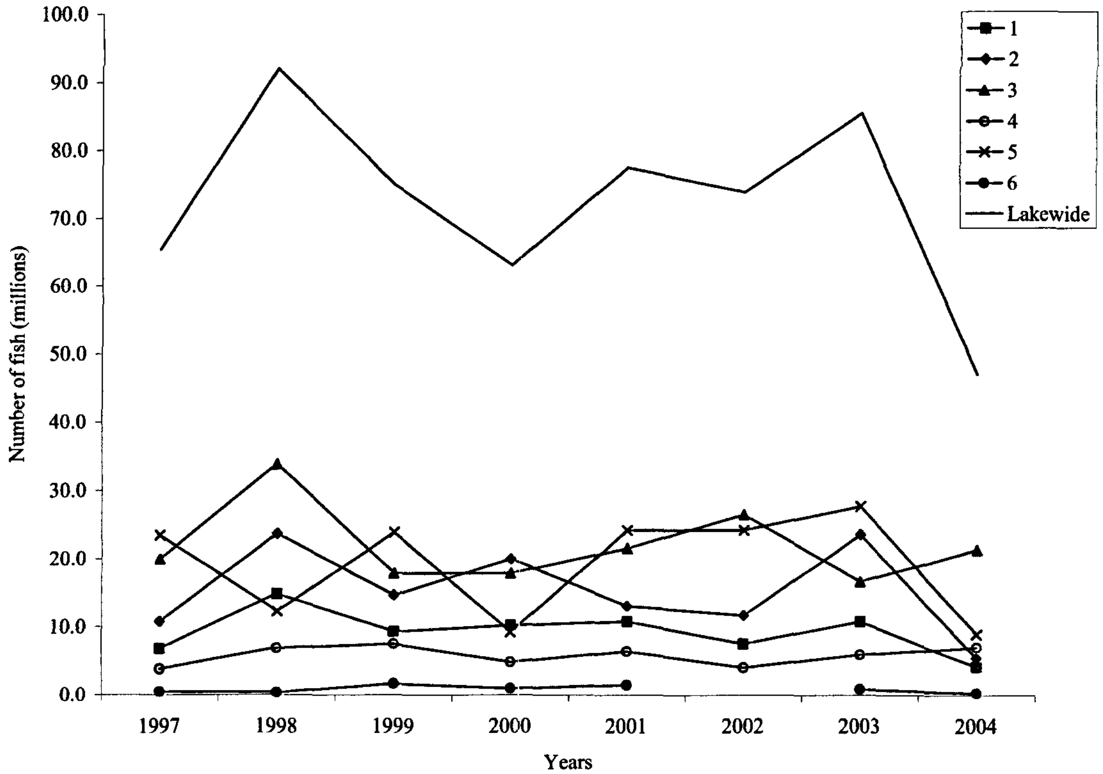


Figure 5-7. Zonal and lakewide population estimates of pelagic fish in Lake Norman.

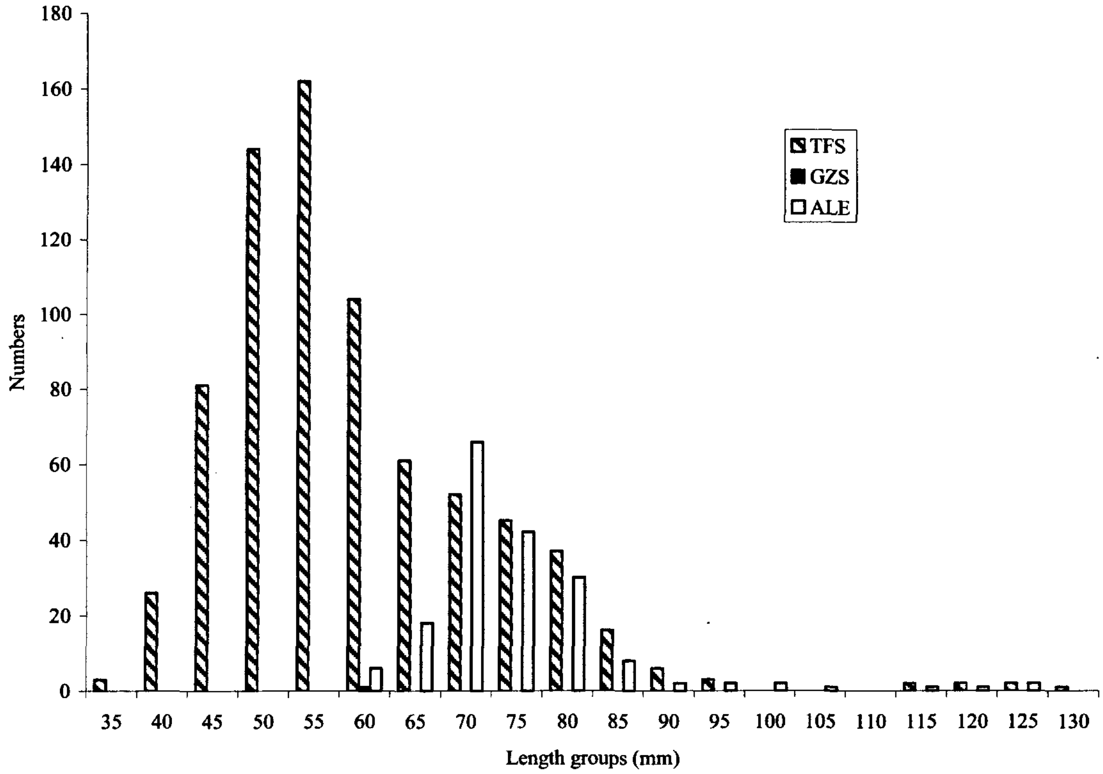


Figure 5-8. Size distributions of threadfin shad (TFS), gizzard shad (GZS) and alewives (ALE) collected in purse seine surveys of Lake Norman, 2004.