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Lake Norman Maintenance Monitoring Program:
2007 Summary

Please find attached a copy of the annual "Lake Norman Maintenance Monitoring Program: 2007 Summary," as required by the National Pollutant Discharge Elimination System (NPDES) permit NC0024392. This 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 February 1, 2009.

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LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2007 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

Principal Investigators:

Michael A. Abney
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William J. Foris

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EXECUTIVE SUMMARY

In accordance with National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS), the Lake Norman Maintenance Monitoring Program continued during 2007. Overall, no obvious long-term impacts of station operations were observed in water quality or phytoplankton, zooplankton, and fish communities. The 2007 station operation data are summarized and continue to demonstrate compliance with thermal limits and cool water requirements.

The monthly average capacity factors for MNS in 2007 were 101.9, 101.4, and 101.6% during July, August, and September, respectively. The average monthly discharge temperature was 97.2 °F (36.2 °C) for July, 98.8 °F (37.1 °C) for August, and 97.9 °F (36.6 °C) for September 2007, below the 99.0 °F (37.2 °C) thermal limit for these months. The volume of cool water in Lake Norman in 2007 was adequate to comply with both the Nuclear Regulatory Commission Technical Specification requirements and the NPDES discharge water temperature limits. Annual precipitation in the vicinity of MNS in 2007 totaled 78.2 cm and was the third lowest measurement reported over the period 1975 – 2007, with lower values being recorded only in 1981 (64.4 cm) and 1986 (76.5 cm). Air temperatures near the MNS in 2007 were warmer than both 2006 and the long-term mean for the months of March, August, September, and October.

Temporal and spatial trends in water temperature and DO in 2007 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2007 for the months of January, March, and April ranged from 0.1 to 3.8 °C warmer than measured in 2006 in both the mixing and background zones, whereas 2007 February temperatures were as much as 2.2 °C cooler than observed in 2006. These interannual differences in water temperatures paralleled differences exhibited in monthly air temperature data, but with about a one-month lag. Reduced operations of Unit 1 at MNS in March and April 2007 also contributed to these interannual differences during the winter and early spring.

Summer water temperatures in 2007 were generally similar to those observed in 2006 in both zones, with one notable exception. Surface water temperatures in the mixing zone in June 2007 were up to 2.7 °C cooler than observed in 2006, and appeared to be related primarily to reduced operations of Unit 1 rather than to interannual differences in air temperature. Late summer, fall, and early winter water temperatures in 2007 were consistently warmer in both zones than those measured in 2006, and followed the trend exhibited in air temperatures. The most striking differences were observed in the mixing zone in November when 2007 temperatures were as much as 4.4 °C warmer than measured in 2006. Temperatures at the discharge location in 2007 were generally similar to 2006 and historical data. Temperatures in 2007 were slightly cooler in the spring, and warmer in the fall than observed in 2006. The warmest discharge temperature of 2007 at Location 4 (37.8 °C) occurred in September and was identical to the maximum measured in 2006.

Seasonal and spatial patterns of DO in 2007 were reflective of the patterns exhibited for temperature, i.e., generally similar in both the mixing and background zones. Winter and spring DO values in 2007 were either equal to or slightly lower, in both the background and mixing zones, than measured in 2006 and appeared to be related predominantly to the differences in water column temperatures in 2007 versus 2006. Summer DO values in 2007 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6.0 to 8.0 mg/L in surface waters to lows of 0.0 to 2.0 mg/L in bottom waters. This pattern is similar to that measured in 2006 and earlier years. All dissolved oxygen values recorded in 2007 during this period were within the historical range. Considerable differences were observed between 2007 and 2006 late summer and fall DO values in both the mixing and background zone, especially in the metalimnion and hypolimnion during the months of September, October, and November. The 2007 late summer and autumn DO data indicated that fall convective reaeration proceeded slower and was less complete throughout the water column than observed in the corresponding months in 2006. Consequently, 2007 DO levels in either a portion or all of the water column were less than observed in 2006. The seasonal pattern of DO in 2007 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. Fall DO levels in 2007 at Location 4.0 were slightly lower than observed in 2006 due to warmer temperatures. The lowest DO concentration measured at the discharge location in 2007 (5.5 mg/L) occurred in September and was identical to that measured in August, 2006; it was also 1.4 mg/L higher than the historical minimum measured in August 2003 (4.1 mg/L).

Reservoir-wide isotherm and isopleth information for 2007, 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. Suitable pelagic habitat conditions for adult striped bass in 2007 were most recently similar to conditions measured in

2006 when habitat elimination was observed for a period of about 50 to 60 days during the summer. Observed striped bass mortalities in 2007 totaled thirteen fish.

All chemical parameters measured in 2007 were similar to 2006 and within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Specific conductance and nutrient values and all concentrations of cations and anions were low. Concentrations of metals were also low and often below analytical reporting limits. All values reported for cadmium, lead, zinc, and copper in 2007 were below the State water quality standard or action level for each of these metals. Manganese and iron concentrations in the surface and bottom waters were generally low in 2007, except during summer and fall when bottom waters became anoxic, thereby creating a chemical environment conducive for the release of these species into the water column. Only one iron value recorded in the bottom waters at Location 5.0 in August, exceeded the State action level of 1.0 mg/L. Manganese levels, however, exceeded the State action level (200 µg/L) in the bottom waters at various locations throughout the lake in the summer and fall. This phenomenon, i.e., the release of iron and manganese from bottom sediments into the water column, in response to low oxygen levels, is common in stratified waterbodies.

Chlorophyll concentrations were generally within historical ranges during 2007. Several record low chlorophyll concentrations were recorded in November. Lake-wide mean chlorophyll increased from February through August, then declined to the annual minimum in November. Maximum chlorophyll concentrations were typically observed up-lake at Location 69.0, while minimum chlorophyll concentrations were recorded from down-lake at Locations 2.0 through 9.5. The highest chlorophyll value in 2007 (13.66 µg/L) was well below the NC State Water Quality standard of 40 µg/L.

Phytoplankton densities and biovolumes were generally higher in 2007 than in 2006. Higher standing crops were usually observed at up-lake locations, while lower values were noted down-lake. Standing crop values were lower than the NC guidelines for algae blooms

Seston dry and ash-free weights were most often lower in 2007 than in 2006. Down-lake to up-lake differences were apparent during all quarters. Maximum dry and ash-free weights were generally observed at Location 69.0, while minimum values occurred at Locations 2.0 through 8.0.

Secchi depths reflected suspended solids, with shallow depths related to high dry weights. The lake-wide mean secchi depth was slightly higher in 2007 than in 2006 and within historical ranges observed since 1992.

Diversity of phytoplankton taxa in 2007 was the highest recorded since the beginning of this monitoring program. The taxonomic composition during 2007 was similar to many previous years. Cryptophytes were dominant in February, while diatoms were dominant during May and November. Green algae were dominant during August. Blue-green algae were slightly more abundant in 2007 than in 2006, however, their contribution to total densities was rarely over 3%.

The cryptophyte *Rhodomonas minuta* was the most abundant alga each year of the Lake Norman Maintenance Monitoring Program. The diatom *Fragillaria crotonensis* was the most abundant diatom in May, while *Tabellaria fenestrata* and *Melosira ambigua* were dominant in November. The small desmid, *Cosmarium asphearosporum* var. *strigosum* was dominant in August 2007. These taxa have been common and abundant throughout the program.

Maximum zooplankton densities occurred most often in the spring of 2007. Minimum zooplankton densities were generally noted in the fall. Epilimnetic densities were higher than whole-column densities as in previous years. Mean zooplankton densities were usually higher among background locations than among mixing zone locations in 2007. Spatial trends of zooplankton population densities increased from down-lake to up-lake locations. A year-to-year spring trend of increasing zooplankton densities among mixing zone locations was observed from around 1997 through 2005. Densities at these locations declined sharply in 2006 followed by an increase in 2007. Long-term trends showed much higher year-to-year variability at background locations than at mixing zone locations.

Epilimnetic zooplankton densities were generally within the ranges of densities observed in previous years. Record high densities were observed during winter at Location 15.9 and summer at Location 9.5.

Since the Lake Norman Maintenance Monitoring Program began in 1987, 123 zooplankton taxa have been observed in samples. Of these, 49 were identified in 2007. Additionally, two previously unreported taxa were identified during 2007.

Overall relative abundance of copepods decreased from 2006 to 2007. Copepods were dominant in only three samples. Cladocerans were dominant in two samples and rotifers were dominant in all other samples. The relative abundance of microcrustaceans increased slightly in the epilimnion of the mixing zone, although they decreased among whole-column samples since 2006. At background locations, relative abundances of microcrustaceans in 2007 were similar to those of 2006. Historically, copepods and rotifers have most often shown annual peaks in the spring, while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms. Adults rarely accounted for more than 7% of zooplankton densities. As in previous years, the most important adult copepod was *Tropocyclops*. *Bosmina* was the dominant cladoceran, as in most previous years of the program. *Bosminopsis* dominated several cladoceran populations during the summer. The most abundant rotifers observed in 2007, as in many previous years, were *Plyarthra*, *Keratella*, and *Ptygura*. *Conochilus*, *Asplanchna*, and *Syncheata* were also important among rotifer populations.

In accordance with the Lake Norman Maintenance Monitoring Program fish monitoring programs continued during 2007. Spring electrofishing indicated that numbers and biomass of fish in 2007 were generally similar to those noted since 1993. Additionally, electrofishing indicated that 12 to 20 fish species and two hybrid complexes comprised fish populations in the three sampling areas. Largemouth bass numbers and biomass continue to decline, and the 2007 numbers and biomass were some of the lowest recorded since sampling began in 1993. While displacement of largemouth bass since the introduction of spotted bass in the lower lake is apparent, the direct effect on largemouth bass recruitment is indeterminate, possibly due to confounding effects of other introductions including alewife and white perch. During 2007, the number of summer striped bass mortalities (13) and winter mean relative weight (79.5) were similar to those of previous years. Hydroacoustic sampling estimated the 2007 forage fish population at approximately 72 million. This is comparable to previous years. After an increase in 2006, purse seine sampling indicated a decrease in the percentage of alewives in 2007 to the lowest percent composition since their 1999 introduction. Threadfin shad lengths remained at pre-alewife introduction sizes.

Lake Norman Maintenance Monitoring results from 2007 are consistent with results from previous years. No obvious short-term or long-term impacts were observed in water quality or biota of Lake Norman.

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CHAPTER 1

MCGUIRE NUCLEAR STATION

INTRODUCTION

The following annual report was prepared for the McGuire Nuclear Station (MNS) National Pollutant Discharge Elimination System (NPDES) permit # NC0024392 issued by North Carolina Department of Environment and Natural Resources (NCDENR). This report summarizes environmental monitoring of Lake Norman during 2007.

OPERATIONAL DATA FOR 2007

Station operational data for 2007 are listed in Table 1-1. Operational maintenance was performed on Unit 1 during the period March – April. The monthly average capacity factors for MNS were 101.9, 101.4, and 101.6% during July, August, and September, respectively. These are the months when conservation of cool water is most critical and compliance with discharge temperatures is most challenging. These three months are also when 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 97.2 °F (36.2 °C) for July, 98.8 °F (37.1 °C) for August, and 97.9 °F (36.6 °C) for September 2007. 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 MNS during 2007.

	MONTHLY AVERAGE CAPACITY FACTORS (%)			MONTHLY AVERAGE NPDES DISCHARGE TEMPERATURES	
Month	Unit 1	Unit 2	Station	°F	°C
January	105.1	105.7	105.4	71.4	21.9
February	105.0	105.7	105.3	67.9	19.9
March	30.5	98.5	64.5	70.1	21.2
April	0.0	105.4	52.4	72.8	22.7
May	1.7	104.5	53.1	76.6	24.8
June	96.4	103.6	100.0	91.8	33.2
July	101.6	102.3	101.9	97.2	36.2
August	101.5	101.4	101.4	98.8	37.1
September	101.4	101.8	101.6	97.9	36.6
October	102.7	103.0	102.9	92.2	33.4
November	104.5	104.5	104.5	80.7	27.1
December	105.0	105.2	105.1	75.9	24.4
Average	79.4	103.4	91.4	82.8	28.2

CHAPTER 2

WATER CHEMISTRY

INTRODUCTION

The objectives of the water chemistry portion of the MNS NPDES Maintenance Monitoring Program are to:

1. maintain continuity in the chemical data base of Lake Norman to allow detection of any substantial 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 2006 and 2007. Where appropriate, reference to pre-2006 data will be made by citing reports previously submitted to the NCDENR.

METHODS AND MATERIALS

The complete water chemistry monitoring program for 2007, including specific variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1. 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 2006) starting at the lake surface (0.3 m) and continuing at one-meter intervals to 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 data validation, converted to spreadsheet format for archive.

Water samples for laboratory analysis were collected with a Kemmerer or Van Dorn water bottle at the surface (0.3 m), 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 rinsed in the field with lake water just prior to obtaining a sample. Samples requiring acidification, but no filtration, were placed directly in pre-acidified high density polyethylene (HDPE) bottles. Samples requiring filtration were first processed in the field by filtering through a 0.45-μm filter (Gelman AquaPrep 600 Series Capsule) which was rinsed with 500 mL of sample water, and then placed in pre-acidified HDPE bottles (Table 2-1). Upon collection, all water samples were immediately stored in the dark, and on ice, to minimize the possibility of physical, chemical, or microbial transformation.

Analytical methods, reporting limits and sample preservation techniques employed were identical to those used in 2006, and are summarized in Table 2-2. All laboratory water quality analyses were performed by the Duke Energy analytical laboratory located in Huntersville, NC. This laboratory is certified to perform analytical assessments for inorganic and organic parameters in North Carolina (North Carolina DWQ Laboratory Certification program, certificate number 248), South Carolina (South Carolina Department of Health and Environmental Control, certificate number 99005), and New York (New York Department of Health, certificate number 11717).

A comprehensive Quality Assurance/Quality Control Program (QA/QCP) is fundamental to the collection, reporting, and interpretation of water quality data, and most investigators implement some type of QA/QCP to identify, quantify, and document bias and variability in data resulting from the collection, processing, shipping, handling and analysis of samples by field and laboratory personnel. Both the United States Environmental Protection Agency (USEPA 1998a, b) and the United States Geological Survey (USGS 1998, 2002) require that any agency-funded project have an approved quality assurance program, and that this program incorporate both a field and laboratory component. USGS also requires that any agency funded study that includes laboratory assessments must also participate in their Standard Reference Program (SRP). This program was originally developed by USGS in the 1960's and currently involves analysis by participating laboratories of standards (blind unknowns) created by the agency on a biannual schedule (USGS 2002).

The QA/QCP employed for this study followed the recommendation of the USEPA and USGS, and included both a field and laboratory component. Field blanks, i.e. Milli-Q water placed in sample bottles, were subjected to the same sample collection and handling procedures, including filtration, applied to actual samples. Periodically, samples were also split prior to submitting to the laboratory for analysis with the goal of quantifying intra-sample analytical variability. The laboratory QA/QCP involved a variety of techniques commonly used in analytical chemistry and included reagent blanks, spikes, replicates, and performance samples. To supplement this program, additional performance samples were run on the major ions and nutrients. Beginning in 2005, standards were purchased from the USGS, through the agency's SRS program, and submitted biannually to Duke's laboratory to serve as a "double blind" assessment of analytical performance. These standards allowed quantification of the uncertainty of the analytical results against known values that were within the same concentration matrix as actual samples. The goal of this effort is to assemble analytical uncertainty data for chemical analytes which can be incorporated into statistical analyses assessing trends in time or space.

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 results were reported to be 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, Duke Power, and Duke Energy studies on the lake (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; and Duke Energy 2006, 2007). 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 (Figure 2-1). 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 striped bass habitat. Several quantitative calculations were also performed on the *in situ* 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:

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

where;

Lt = reservoir heat (Kcal/cm^2) or oxygen (mg/cm^2) content
A_o = surface area of reservoir (cm^2)
TO = mean temperature (°C) or oxygen content (mg/L) of layer z
Az = area (cm^2) at depth z
dz = depth interval (cm)
z_o = surface
z_m = maximum depth (m)

Precipitation and air temperature data were obtained from a meteorological monitoring site established near MNS in 1975. These data are employed principally by Duke Energy as input variables into meteorological modeling studies as required by the Nuclear Regulatory Commission to address safety issues associated with potential radiological releases into the atmosphere by MNS (Duke Power 2004b). 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 Energy-Carolinas Fossil/Hydro Generation, which monitors these metrics hourly.

RESULTS AND DISCUSSION

Precipitation and Air Temperature

Annual precipitation in the vicinity of MNS in 2007 totaled 78.2 cm (Figures 2-2a, b) or 26.8 cm less than observed in 2006 (105.0 cm), and 39.4 cm less than the long-term precipitation average for this area (117.6 cm), based on Charlotte, NC airport data. Annual precipitation totals for 2007 measured at the MNS site were also the third lowest over the period 1975 – 2007 with lower values being recorded only in 1981 (64. 4 cm) and 1986 (76.5 cm). Monthly rainfall in 2007 was greatest in March with 10.57 cm, and the least in November with 1.98 cm.

Duke Energy reported that air temperatures near the McGuire Nuclear Station in 2007 were generally warmer than the long-term mean, based on monthly average data (Duke Energy 2006). Monthly mean air temperatures in 2007 near the nuclear facility were warmer than both 2006 and the long-term mean for the months of March, August, September and October (Figure 2-2c). The temporal differences were most pronounced in September and October

2007 when temperatures averaged 2.8 and 4.1 °C warmer, respectively, than recorded in 2006.

Temperature and Dissolved Oxygen

Water temperatures measured in 2007 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3 and 2-4), as they did in 2006. 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. When between-zone differences in temperatures are observed, they occur predominately during the cooling period, and can be traced to the influence of the thermal discharge at MNS. Additionally, interannual differences in water temperatures in Lake Norman, particularly in surface waters in the background zone, typically parallel differences in air temperatures but with a one-month lag time (Duke Power 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

Water temperatures in 2007 for the months of January, March, and April ranged from 0.1 to 3.8 °C warmer than measured in 2006, whereas 2007 February temperatures were as much as 2.2 °C cooler than observed in 2006 (Figures 2-3 and 2-4). These interannual differences in water temperatures paralleled differences in air temperatures (Figure 2-2c), but because lake sampling is generally performed in the first week of each month, the observed data reflects the cumulative influences of meteorology and hydrology during the previous month. Reduced operations of Unit 1 in March 2007 (Table 1-1) undoubtedly also contributed to slightly cooler temperatures in April 2007. Minimum water temperatures in 2007 were recorded in early February and ranged from 7.5 °C to 10.8 °C in the background zone and from 8.0 °C to 13.1 °C in the mixing zone. Minimum water temperatures measured in 2007 were within the observed historical range (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

Summer (June, July, and August) water temperatures in 2007 were generally similar to those observed in 2006 in both zones, with one notable exception. Surface water temperatures in the mixing zone in June 2007 were as much as 2.7 °C cooler than observed in 2006, and appeared to be related primarily to reduced operations of Unit 1 (Table 1-1) rather than to interannual differences in air temperatures (Figure 2-2c).

Late-summer, fall and early winter water temperatures (September, October, November, and December) in 2007 were consistently warmer in both zones than those measured in 2006, and followed the trend exhibited in air temperatures (Figures 2-2c, 2-3). The most striking differences were observed in the mixing zone in November when 2007 temperatures were as much as 4.4 °C warmer than measured in 2006. Interannual differences in December temperature profiles were minimal.

Temperatures at the discharge location in 2007 were generally similar to 2006 (Figure 2-5) and historical data (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). Temperatures in 2007 were slightly cooler in the spring (March temperatures were taken during a station outage), and warmer in the fall, than observed in 2006. The warmest discharge temperature of 2007 at Location 4 (37.8 °C) occurred in September and was identical to the maximum measured in 2006.

Seasonal and spatial patterns of DO in 2007 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 DO patterns between zones has been a dominant feature of the oxygen regime in Lake Norman since MNS began operations in 1983.

Winter and spring DO values in 2007 were generally equal to or slightly lower, in both the background and mixing zones, than measured in 2006, except in February when 2007 DO values ranged from 0.4 to 1.2 mg/L higher than in 2006 (Figures 2-6 and 2-7). The interannual differences in DO values measured during this period appear to be related predominantly to the differences in water column temperatures in 2007 versus 2006. 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. Conversely, cooler water column temperatures, as measured in February 2007, would be expected to exhibit higher oxygen values because of increased oxygen solubility, and an enhanced convective mixing regime which would promote water column reaeration.

Summer DO values in 2007 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6.0 to 8.0 mg/L in surface waters to lows of 0.0 to 2.0 mg/L in bottom waters. This pattern is similar to that measured in 2006 and earlier years (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). Unlike most previous years, summer DO profiles in 2007 and 2006 were remarkably similar throughout the water column in both zones, suggesting that those physical and metabolic processes that influence DO within the reservoir were proceeding at about the same rates in 2007 and 2006. All dissolved oxygen values recorded in 2007 during this period were within the historical range.

Considerable differences were observed between 2007 and 2006 late summer and 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 DO levels during the cooling season are common in Catawba River reservoirs and can be explained by the effects of variable weather patterns on water column cooling (heat loss) rates and mixing. Warmer air temperatures delay water column cooling which, in turn, delays the onset of convective mixing of the water column and the resultant reaeration of the metalimnion and hypolimnion. Conversely, cooler air temperatures increase the rate and magnitude of water column heat loss, thereby promoting convective mixing and resulting in higher DO values earlier in the year.

The 2007 late summer and autumn DO data indicate that fall convective reaeration proceeded slower and was less complete throughout the water column than observed in corresponding months in 2006. Consequently, 2007 DO levels in either a portion or all of the water were less than observed in 2006. These between-year differences in DO corresponded strongly with the degree of thermal stratification which, as discussed earlier, correlated with interannual differences in air temperatures (Figures 2-2c, 2-3, and 2-4). 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 Hannan 1985; Petts, 1984).

The seasonal pattern of DO in 2007 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). Fall DO levels in 2007 at location 4.0 were slightly lower than observed in 2006 due to warmer temperatures. The lowest DO concentration measured at the discharge location in 2007 (5.5 mg/L) occurred in September, and was identical to that measured in August, 2006; it was also 1.4 mg/L higher than the historical minimum, measured in August 2003 (4.1 mg/L).

Reservoir-Wide Temperature and Dissolved Oxygen

The monthly reservoir-wide temperature and DO data for 2007 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 Hannan 1985; Hannan et al. 1979; Petts 1984). Detailed discussions on the seasonal and spatial dynamics of temperature and dissolved oxygen during both the cooling and heating periods in Lake Norman have been presented previously (Duke Power Company 1992, 1993, 1994, 1995, 1996).

The seasonal heat content of both the entire water column and the hypolimnion for Lake Norman in 2007 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 2006 and 2007 is presented in Table 2-3. Annual minimum heat content for the entire water column in 2007 (8.88 Kcal/cm^2; 8.92 °C) occurred in early February, whereas the maximum heat content (28.79 Kcal/cm^2; 28.98 °C) occurred in late August. Heat content of the hypolimnion exhibited a somewhat different temporal trend as that observed for the entire water column. Annual minimum hypolimnetic heat content also occurred in early February and measured 4.77 Kcal/cm^2 (7.53 °C), but the maximum occurred in early September and measured 15.77 Kcal/cm^2 (25.04 °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 epilimnion equaled 0.110 °C/day and 0.089 °C/day for the hypolimnion; both rates were slightly greater than observed in 2006 (Table 2-3). The 2007 heat content and heating rate data for Lake Norman were generally similar to that observed in previous years (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

The seasonal oxygen content and percent saturation of the whole water column, and the hypolimnion, are depicted for 2007 in Figure 2-10b. Additional oxygen data can be found in Table 2-4 which presents the 2006 AHOD for Lake Norman and similar earlier estimates for 18 Tennessee Valley Authority (TVA) reservoirs. Reservoir oxygen content was greatest in mid-winter when DO content measured 10.4 mg/L for the whole water column and 10.3 mg/L for the hypolimnion. Percent saturation values at this time approached 90% for the entire water column and 86% 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 late summer. Minimum summer volume-weighted DO values for the entire water column measured 3.9 mg/L (52% saturation), whereas the minimum for the hypolimnion was 0.18 mg/L (2.2% saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.039 $mg/cm^2/day$ (0.061 mg/L/day) (Figure 2-10b), and is similar to that measured in 2006 (Duke Energy 2007).

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 0.039 $mg/cm^2/day$ for 2007. The oxygen-based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 2007 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 2006 through early July 2007. Beginning in late June 2007, 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. These conditions were similar to those observed in most previous years except that in 2007 no habitat existed in the upper, riverine segments of the reservoir. Historically, a small, but spatially variable zone of habitat is typically observed near and upstream of the confluence of Lyles Creek with Lake Norman. Habitat measured in the upper reaches of the reservoir appears to be influenced by both inflow from Lyles Creek and discharges from Lookout Shoals Hydroelectric facility, which generally are somewhat cooler than ambient conditions in Lake Norman. Upon entering Lake Norman, this water mixes with ambient waters and then proceeds as a subsurface underflow as it migrates downriver (Ford 1985).

An additional refuge was also observed in the metalimnion and hypolimnion near the Cowans Ford dam during this period, but this lasted only until 23 July when dissolved oxygen was reduced to < 2.0 mg/L by microbial demands, thereby eliminating suitable habitat in the lower portion of the reservoir. Summer-time habitat conditions for adult striped bass in 2007 were more severe than 2004 when the largest striped bass die-off ever was observed in the reservoir (2610 fish). Conditions in 2007 were most recently similar to those measured in 2006 when habitat elimination was observed for a period of about 50 to 60 days. Observed striped bass mortalities in 2007 totaled thirteen fish (Chapter 5).

Physicochemical habitat 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 2007 was generally similar to that previously reported in Lake Norman, and many other Southeastern reservoirs (Coutant 1985; Matthews et al. 1985; Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 2007, ranging from 0.95 to 5.60 NTU's (Table 2-5). Bottom turbidity values were also low over the 2007 study period, ranging from 1.0 to 8.4 NTU's (Table 2-5). Turbidity values observed in 2007 were within the historical range (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

Specific conductance in Lake Norman in 2007 ranged from 51 to 105 umho/cm, and was generally similar to that observed in 2006 (Table 2-5), and historically (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). Specific conductance values in surface and bottom waters in 2007 were similar throughout the year except during the period of intense thermal stratification, i.e., August and November, when an increase in bottom conductance values was observed at locations within the mixing and background zones. 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), and is an annually recurring phenomenon in Lake Norman.

pH and Alkalinity

During 2007, 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 2007 (Table 2-5), and historically (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). Values of pH in 2007 ranged from 7.2 to 8.2 in surface waters, and from 6.0 to 7.9 in bottom waters. Alkalinity values in 2007 ranged from 13.0 to 16.0 mg/L, expressed as $CaCO_3$, in surface waters and from 11.5 to 22.5 mg/L in bottom waters.

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 2007 was generally similar to that reported for 2006 (Table 2-5) and previously (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

Nutrients

Nutrient concentrations in the discharge, mixing, and mid lake background zones of Lake Norman for 2006 and 2007 are provided in Table 2-5. Overall, nutrient concentrations in 2007 were well within historical ranges (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). Nitrogen and phosphorus levels in 2007 were low and generally similar to those measured in 2006 (Duke Energy 2006). Historic total phosphorus (TP) and ortho-phosphorus (OP) concentrations were typically measured at or below the analytical reporting limits (ARL) for these constituents, i.e., 5 µg/L. For total phosphorus, all 44 samples analyzed in 2007 exceeded the ARL, but most measurements (40 of 44) were ≤ 10 µg/L. The maximum TP value reported in 2007 was 114 µg/L and was observed at the bottom at Location 2.0. Similarly, almost all measurements of OP (43 of 44) were recorded as ≤ 5 µg/L, the lone exception being a value of 13 µg/L reported at the bottom depth at Location 2.0. Nutrients in 2007 were generally somewhat higher uplake than downlake, 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 and ammonia nitrogen concentrations were low at all locations sampled in 2007 (Table 2-5), and also were generally similar to 2006 and historical values (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007).

Metals

Metal concentrations in the discharge, mixing, and mid lake background zones of Lake Norman for 2007 were similar to those measured in 2006 (Table 2-5) and historically (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). Iron concentrations in surface and bottom waters were generally low (≤ 0.4 mg/L) during 2007, the lone exceptions being a 0.82-mg/L value measured in the bottom waters at Location 2.0 in November, and a 1.26-mg/L value measured at the bottom depth at Location 5.0 in August. This latter value is the only instance in 2007 that an iron measurement exceeded the North Carolina water quality action level for iron (1.0 mg/L; NCDENR 2004).

Similarly, manganese concentrations in the surface and bottom waters were generally low (≤ 100 µg/L) in 2007, except during the summer and fall when bottom waters were anoxic (Table 2-5). Manganese concentrations in the bottom waters rose above the State water quality action level for this constituent (200 µg/L; NCDENR 2004) at various locations throughout the lake in summer and fall of 2007, and were characteristic of historical conditions (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). 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).

Concentrations of other metals in 2007 were typically low, and often below the analytical reporting limit for the specific constituent (Table 2-5). These findings are similar to those observed for earlier years (Duke Power Company 1985, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007). All values for cadmium and lead were reported as either equal to or below the ARL with the lone exception being a lead value of 3.4 µg/L measured at the bottom depth at Location 2.0 in February. Zinc values were consistently above the ARL and ranged from < 1.0 µg/L to 24.9 µg/L; this maximum was measured at the bottom depth at Location 2.0 in February. All copper concentrations, measured as total recoverable copper, were less than 4 µg/L, and over half (24 of 44) of the values were less than the ARL. The maximum copper concentration recorded in 2007 (3.13 µg/L) was measured in the surface waters (0.3 m) at Location 11.0 in May. All values reported for cadmium, lead, zinc, and copper in 2007 were below the State action level for each of these metals (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 2007 totaled 78.2 cm and was the third lowest measurement reported over the period 1975 – 2007, with lower values being recorded only in 1981 (64.4 cm) and 1986 (76.5 cm). Air temperatures near the McGuire Nuclear Station in 2007 were warmer than both 2006 and the long-term mean for the months of March, August, September and October. The temporal differences were most pronounced in September and October 2007 when temperatures averaged 2.8 and 4.1 °C warmer, respectively, than recorded in 2006.

Temporal and spatial trends in water temperature and DO in 2007 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2007 for the months of January, March, and April ranged from 0.1 to 3.8 °C warmer than measured in 2006 in both the mixing and background zones, whereas 2007 February temperatures were as much as 2.2 °C cooler than observed in 2006. These interannual differences in water temperatures paralleled differences exhibited in monthly air temperature data but with about a one month lag. Reduced operations of Unit 1 at MNS in

March and April 2007 also undoubtedly contributed to these interannual differences during the winter and early spring.

Summer (June, July, and August) water temperatures in 2007 were generally similar to those observed in 2006 in both zones, with one notable exception. Surface water temperatures in the mixing zone in June 2007 were up to 2.7 °C cooler than observed in 2006, and appeared to be related primarily to reduced operations of Unit 1 rather than to interannual differences in air temperature. Late-summer, fall, and early winter water temperatures (September, October, November, and December) in 2007 were consistently warmer in both zones than those measured in 2006, and followed the trend exhibited in air temperatures. The most striking differences were observed in the mixing zone in November when 2007 temperatures were as much as 4.4 °C warmer than measured in 2006.

Temperatures at the discharge location in 2007 were generally similar to 2006 (Figure 2-5) and historical data. Temperatures in 2007 were slightly cooler in the spring (March temperatures were taken during a station outage), and warmer in the fall than observed in 2006. The warmest discharge temperature of 2007 at Location 4 (37.8 °C) occurred in September and was identical to the maximum measured in 2006.

Seasonal and spatial patterns of DO in 2007 were reflective of the patterns exhibited for temperature, i.e., generally similar in both the mixing and background zones. Winter and spring DO values in 2007 were generally equal to or slightly lower, in both the background and mixing zones, than measured in 2006, except in February when 2007 DO values ranged from 0.4 to 1.2 mg/L higher than in 2006. The interannual differences in DO values measured during this period appeared to be related predominantly to the differences in water column temperatures in 2007 versus 2006. Summer DO values in 2007 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6.0 to 8.0 mg/L in surface waters to lows of 0.0 to 2.0 mg/L in bottom waters. This pattern is similar to that measured in 2006 and earlier years. Unlike most previous years, summer DO profiles in 2007 and 2006 were remarkably similar throughout the water column in both zones, suggesting that those physical and metabolic processes that influence DO within the reservoir were proceeding at about the same rates in 2007 and 2006. All dissolved oxygen values recorded in 2007 during this period were within the historical range.

Considerable differences were observed between 2007 and 2006 late summer and fall DO values in both the mixing and background zone, especially in the metalimnion and hypolimnion during the months of September, October, and November. The 2007 late summer and autumn DO data indicated that fall convective reaeration proceeded slower and was less complete throughout the water column than observed in the corresponding months in 2006. Consequently, 2007 DO levels in either a portion or all of the water column were less than observed in 2006. These between-year differences in DO corresponded strongly with the degree of thermal stratification and interannual differences in air temperatures.

The seasonal pattern of DO in 2007 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. Fall DO levels in 2007 at location 4.0 were slightly lower than observed in 2006 due to warmer temperatures. The lowest DO concentration measured at the discharge location in 2007 (5.5 mg/L) occurred in September, and was identical to that measured in August, 2006; it was also 1.4 mg/L higher than the historical minimum, measured in August 2003 (4.1 mg/L).

Reservoir-wide isotherm and isopleth information for 2007, 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. Suitable pelagic habitat for adult striped bass, defined as that layer of water with temperatures ≤ 26 °C and DO levels ≥ 2.0 mg/L, was found lake-wide from mid September 2006 through early July 2007. Beginning in late June 2007, habitat reduction proceeded rapidly throughout the reservoir both as a result of deepening of the 26 °C isotherm and metalimnetic and hypolimnetic deoxygenation. Habitat reduction was most severe from mid July through early September when no suitable habitat was observed in the reservoir. Summer 2007 habitat conditions were most recently similar to those measured in 2006 when habitat elimination was observed for a period of about 50 to 60 days. Observed striped bass mortalities in 2007 totaled thirteen fish.

All chemical parameters measured in 2007 were similar to 2006, and within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Specific conductance values, and all concentrations of cation and anion species measured, were low. Nutrient concentrations were also low with most values reported close to or below the analytical reporting limit for that test. Concentrations of metals in 2007 were low, and often below the analytical reporting limits. All values reported for cadmium, lead, zinc, and copper in 2007 were below the State water quality standard or action level for each of these metals.

Iron concentrations in surface and bottom waters were generally low (≤ 0.40 mg/L) during 2007, the only exceptions being a 0.82-mg/L value measured in the bottom waters at Location 2.0 in November, and a 1.26-mg/L value measured at the bottom depth at Location 5.0 in August. This latter value is the only instance in 2007 that an iron measurement exceeded the North Carolina water quality action level for iron (1.0 mg/L). Similarly, manganese concentrations were generally low (≤ 100 μg/L) in 2007, except during the summer and fall when bottom waters were anoxic. Manganese concentrations in the bottom waters rose above the State water quality standard for this constituent (200 μg/L) at various locations throughout the lake in summer and fall of 2007, and were characteristic of historical conditions. 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.

Table 2-1. Water chemistry program for the McGuire Nuclear Station NPDES Maintenance Monitoring Program on Lake Norman.

		2007 McGUIRE NPDES SAMPLING PROGRAM															
PARAMETERS	LOCATIONS	1	2	4	5	8	9.5	11	13	14	15	15.9	62	69	72	80	16
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
IN-SITU ANALYSIS																	
	Method																
Temperature	Hydrolab																
Dissolved Oxygen	Hydrolab	In-situ measurements are collected monthly at the above locations at 1m intervals from 0.3m to 1m above bottom.															
pH	Hydrolab	Measurements are taken weekly from July-August for striped bass habitat.															
Conductivity	Hydrolab																
NUTRIENT ANALYSES																	
Ammonia	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B		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		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		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		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		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		Q/T,B			S/T
TKN	AA-TKN	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		Q/T,B			S/T
Total Organic Carbon	TOC	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		Q/T,B			S/T
Dissolved organic carbon	DOC	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		Q/T,B			S/T
ELEMENTAL ANALYSES																	
Aluminum	ICP-MS-D	Q/T,B	S/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B		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		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		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		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		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		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		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		Q/T,B			S/T
Arsenic	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		Q/T,B			S/T
Cadminum	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		Q/T,B			S/T
Copper (Total Recoverable)	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		Q/T,B			S/T
Copper (Dissolved)	ICP-MS	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		Q/T,B			S/T
Lead	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		Q/T,B			S/T
Selenium	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		Q/T,B			S/T
ADDITIONAL ANALYSES																	
Hardness		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		Q/T,B			S/T
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		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		Q/T,B			S/T
Sulfate	UV_SO4	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		Q/T,B			S/T
Total Solids	S-TSE	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		Q/T,B			S/T
Total Suspended Solids	S-TSSE	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		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 µg/L/1.0 µg/L [a]
Calcium	ICP, EPA 200.7	0.5% HNO_3	30 µg/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 µg/L
Copper, Dissolved	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 µg/L
Iron, Total Recoverable	ICP, EPA 200.7	0.5% HNO_3	10 µg/L
Lead, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	2.0 µg/L
Magnesium	Atomic Emission/ICP, EPA 200.7	0.5% HNO_3	30 µg/L
Manganese, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	1.0 µg/L
Nitrogen, Ammonia	Colorimetric, EPA 350.1	0.5% H_2SO_4	20 µg/L
Nitrogen, Nitrite + Nitrate	Colorimetric, EPA 353.2	0.5% H_2SO_4	20 µg/L
Nitrogen, Total Kjeldahl	Colorimetric, EPA 351.2	0.5% H_2SO_4	100 µg/L
Phosphorus, Orthophosphorus	Colorimetric, EPA 365.1	4 °C	5 µg/L
Phosphorus, Total	Colorimetric, EPA 365.1	0.5% H_2SO_4	5 µg/L
Potassium	ICP, EPA 200.7	0.5% HNO_3	250 µg/L
Silica	APHA 4500Si-F	0.5% HNO_3	500 µg/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	0.5% H_2SO_4	0.05 NTU
Zinc, Total Recoverable	ICP Mass Spectroscopy, EPA 200.8	0.5% HNO_3	1 µg/L

References: USEPA 1983, and APHA 1995

a- Reporting limit for May samples

Table 2-3. Heat content calculations for the thermal regime in Lake Norman for 2006 and 2007.

	2006	2007
Maximum Areal Heat Content (g·cal/cm^2)	28,880	28,787
Minimum Areal Heat Content (g·cal/cm^2)	10,846	8,882
Birgean Heat Budget (g·cal/ cm^2)	18,034	19,905
Epilimnion (above 11.5 m) Heating Rate (°C /day)	0.091	0.110
Hypolimnion (below 11.5 m) Heating Rate (°C /day)	0.068	0.089

Table 2-4. A comparison of areal hypolimnetic oxygen deficits (AHOD), summer chlorophyll *a* (Chl *a*), Secchi depth, 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	0.039	4.5	1.7	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 McGuire Nuclear Station discharge, mixing zone, and background locations on Lake Norman during 2006 and 2007. 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:	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Turbidity (NTU)																						
Feb	NA	2.3	NA	2.30	NA	2.70	NA	3.60	NA	2.70	NA	2.40	NA	2.90	1.6	2.20	2.3	3.50	2.2	5.60	2.8	5.70
May	1.10	2.0	0.98	1.30	1.2	1.30	1	1.50	1.2	1.50	1.3	1.00	1.2	1.10	1.4	0.95	1.1	1.60	1.1	1.20	1.5	1.60
Aug	10.00	1.3	20.00	1.00	9.8	1.40	18	1.00	22	1.50	9.8	1.40	9	8.40	1.4	1.30	1.7	1.60	1.9	1.40	1.8	1.60
Nov	2.00	2.6	3.3	3.40	2.40	2.70	2.70	4.30	3.70	2.70	5.30	2.80	4.90	4.30	2.30	1.70	6.50	3.00	3.70	3.10	7.00	3.40
Annual Mean	4.37	2.05	8.09	2.0	4.47	2.0	7.23	2.6	8.97	2.1	5.47	1.9	5.03	4.2	1.68	1.5	2.90	2.4	2.23	2.8	3.28	3.1
Specific Conductance (umho/cm)																						
Feb	53.0	53.8	52.9	52.6	53.3	53.8	53.1	53.1	53.7	54.7	53.4	54.3	52.6	53.2	52.6	53.8	53.1	53.8	53.1	51.5	53.2	51.4
May	53.9	55.8	53.5	55.2	53.9	55.7	53.2	55	54.4	56.3	54.2	56	53.1	54.7	53.2	55.9	53.3	55.1	53.5	56.6	53.4	55.2
Aug	57.7	61.1	62.6	73.9	58.2	60.9	67.4	71.2	58.4	61	58.2	61	65.9	68.9	58.0	61.1	59.9	65.6	58.2	64.3	64.1	68
Nov	57.7	64.8	57.8	104.7	57.8	64.9	57.7	67.2	58.5	65.7	58.0	65.3	58.3	65.3	58.0	64.5	57.8	64.4	56.6	69.1	56.7	69.2
Annual Mean	55.6	58.9	56.7	71.6	55.8	58.8	57.9	61.6	56.3	59.4	56.0	59.2	57.5	60.5	55.5	58.8	56.0	59.7	55.4	60.4	56.9	61.0
pH (units)																						
Feb	7.2	7.3	7.0	6.7	7.3	7.3	7.0	7.1	7.3	7.3	7.4	7.4	7.1	7.5	7.1	7.4	6.8	7.3	7.0	7.3	6.8	7.1
May	7.4	7.2	6.5	6.8	7.4	7.5	6.6	6.5	7.3	7.4	7.4	7.4	7.0	6.5	7.8	7.6	6.7	6.5	7.5	7.5	6.5	6.5
Aug	7.6	7.6	6.2	6.0	7.6	7.4	6.4	6.0	7.1	7.2	7.3	7.5	6.4	6.5	7.7	8.2	6.2	6.5	7.9	7.9	6.3	6.5
Nov	7.3	7.4	7.0	7.1	7.3	7.5	7.2	7.3	7.5	7.4	7.5	7.4	7.4	7.4	7.5	7.6	7.5	7.6	7.3	7.6	7.3	7.4
Annual Mean	7.37	6.66	6.66	6.65	7.37	7.43	6.80	6.73	7.29	7.10	7.39	7.43	6.96	6.98	7.52	7.70	6.79	6.98	7.42	7.58	6.73	6.88
Alkalinity (mg CaCO3/L)																						
Feb	12.5	13.5	12.0	13.5	11.5	14.0	12.5	13.5	12.5	13.5	12.0	14.0	12.0	13.5	12.5	14.0	12.5	14.0	12.0	13.0	12.5	13.0
May	12.0	13.5	12.0	14.0	12.5	13.5	12.5	13.5	13.0	13.5	12.5	14.0	12.5	13.5	12.0	13.5	12.5	13.5	12.5	13.5	12.5	13.5
Aug	14.0	15.0	15.5	15.5	14.0	15.0	16.0	16.0	14.0	15.0	14.0	15.0	19.5	22.5	14.0	15.0	15.5	19.0	14.5	15.5	17.5	19.0
Nov	14.5	16.0	15.0	17.0	15.0	16.0	15.0	20.0	14.5	16.5	15.0	16.0	13.0	16.5	14.5	15.5	15.0	11.5	14.5	16.0	14.5	16.0
Annual Mean	13.3	14.5	13.6	15.0	13.3	14.6	14.0	15.8	13.5	14.6	13.4	14.8	14.3	16.5	13.3	14.5	13.9	14.5	13.4	14.5	14.3	15.4
Chloride (mg/L)																						
Feb	4.5	4.6	4.6	4.7	4.4	4.6	4.4	4.6	4.5	4.5	4.3	4.7	4.5	4.5	4.4	4.7	4.6	4.7	4.5	4.5	4.7	4.6
May	4.8	5.1	4.8	4.7	4.7	4.9	4.9	4.8	4.8	5.0	4.8	4.8	4.8	4.8	4.9	5.1	4.7	5.1	4.8	5.3	4.6	5.3
Aug	4.6	5.4	4.4	4.8	4.6	5.4	4.1	4.7	4.6	5.4	4.5	5.2	4.4	5.0	4.5	5.3	4.9	4.9	4.7	5.9	4.2	4.6
Nov	5.0	6.6	5.0	6.5	4.9	6.5	4.9	6.3	5.0	6.5	5.0	6.7	5.0	6.5	5.0	6.7	5.1	6.6	5.1	7.6	5.1	7.6
Annual Mean	4.7	5.4	4.7	5.2	4.7	5.4	4.6	5.1	4.7	5.4	4.7	5.4	4.7	5.2	4.7	5.5	4.8	5.3	4.8	5.8	4.7	5.5
Sulfate (mg/L)																						
Feb	4.3	3.8	4.3	3.6	4.4	3.6	4.2	3.9	4.3	3.6	4.3	3.7	5.1	3.7	4.3	3.7	4.2	3.7	4.4	3.6	4.2	3.8
May	4.7	4.2	4.7	4.2	4.7	4.2	4.7	4.1	4.7	4.2	4.7	4.2	4.7	4.2	4.7	4.2	4.6	4.2	4.6	4.1	4.4	4.1
Aug	4.2	4.8	4.0	4.3	4.2	4.5	4.0	4.3	4.2	4.6	4.2	4.6	3.8	3.8	4.2	4.5	3.7	4.2	4.1	4.5	3.9	4.1
Nov	4.1	4.5	4.0	4.4	4.2	4.6	4.2	3.9	4.1	4.5	4.1	4.6	5.0	4.6	4.2	4.7	4.1	9.6	4.0	4.8	4.0	4.8
Annual Mean	4.3	4.3	4.3	4.1	4.3	4.2	4.3	4.1	4.3	4.2	4.3	4.3	4.6	4.1	4.4	4.3	4.1	5.4	4.2	4.3	6.7	4.2
Calcium (mg/L)																						
Feb	2.96	3.23	2.96	3.21	2.95	3.23	2.94	3.26	2.97	3.19	2.96	3.18	2.97	3.22	2.97	3.19	3.02	3.18	3.07	3.52	3.15	3.41
May	3.02	3.44	3.05	3.43	3.02	3.50	3.04	3.44	3.01	3.47	3.00	3.42	3.02	3.40	3.00	3.49	3.09	3.60	3.08	3.92	3.17	3.83
Aug	3.08	3.76	3.43	3.90	3.10	3.78	3.51	3.93	3.12	3.77	3.11	3.78	3.64	4.26	3.11	3.82	3.49	3.97	3.18	4.14	3.54	4.03
Nov	3.17	4.10	3.11	4.13	3.17	4.09	3.17	4.23	3.16	4.11	3.15	4.11	3.14	4.07	3.15	4.11	3.08	4.09	3.02	4.44	3.06	4.44
Annual Mean	3.06	3.63	3.14	3.67	3.06	3.65	3.17	3.72	3.07	3.64	3.06	3.62	3.19	3.74	3.06	3.65	3.17	3.71	3.09	4.01	3.23	3.93
Magnesium (mg/L)																						
Feb	1.51	1.66	1.51	1.65	1.51	1.65	1.49	1.64	1.52	1.64	1.52	1.65	1.52	1.65	1.52	1.65	1.51	1.66	1.51	1.63	1.50	1.61
May	1.48	1.64	1.48	1.64	1.47	1.64	1.48	1.64	1.48	1.65	1.47	1.65	1.48	1.63	1.47	1.67	1.48	1.67	1.47	1.74	1.49	1.74
Aug	1.58	1.89	1.61	1.81	1.59	1.90	1.64	1.84	1.59	1.89	1.58	1.89	1.69	1.94	1.58	1.89	1.64	1.87	1.59	2.06	1.65	1.88
Nov	1.71	2.06	1.70	2.05	1.71	2.05	1.71	2.06	1.70	2.06	1.71	2.06	1.70	2.05	1.71	2.08	1.71	2.06	1.69	2.22	1.71	2.22
Annual Mean	1.57	1.81	1.58	1.79	1.57	1.81	1.58	1.80	1.57	1.81	1.57	1.81	1.60	1.82	1.57	1.82	1.59	1.82	1.57	1.91	1.59	1.86

NS = Not Sampled: NA= Not Applicable; FQC = Failed Quality Control

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:	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Potassium (mg/L)																						
Feb	1.79	1.89	1.80	1.91	1.80	1.91	1.78	2.10	1.82	1.88	1.83	1.89	1.79	1.89	1.80	1.93	1.75	1.89	1.75	1.84	1.67	1.84
May	1.70	1.78	1.71	1.84	1.69	1.83	1.69	1.80	1.67	1.81	1.69	1.81	1.71	1.76	1.69	1.75	1.66	1.72	1.63	1.65	1.61	1.66
Aug	1.72	1.87	1.73	1.88	1.70	1.90	1.73	1.88	1.72	1.88	1.72	1.87	1.76	1.94	1.72	1.92	1.71	1.89	1.68	1.86	1.73	1.90
Nov	1.87	1.93	1.89	1.90	1.86	1.94	1.87	1.93	1.86	1.92	1.87	1.91	1.87	1.88	1.89	1.92	1.91	1.90	1.95	1.89	1.95	1.91
Annual Mean	1.77	1.87	1.78	1.88	1.76	1.90	1.77	1.93	1.77	1.87	1.78	1.87	1.78	1.87	1.78	1.88	1.76	1.85	1.75	1.81	1.74	1.83
Sodium (mg/L)																						
Feb	4.65	5.00	4.66	5.03	4.63	5.03	4.60	4.90	4.67	4.94	4.66	4.96	4.64	4.93	4.64	4.03	4.67	5.04	4.69	4.21	4.62	4.41
May	4.51	4.49	4.49	4.47	4.51	4.51	4.48	4.52	4.49	4.49	4.51	4.51	4.57	4.48	4.51	4.41	4.46	4.33	4.5	4.21	4.42	4.19
Aug	4.84	4.71	4.53	4.52	4.85	4.71	4.53	4.48	4.82	4.68	4.83	4.67	4.61	4.56	4.82	4.75	4.56	4.48	4.38	4.73	4.54	4.51
Nov	5.27	4.75	5.27	4.73	5.24	4.75	5.26	4.73	5.27	4.78	5.26	4.76	5.25	4.71	5.26	4.82	5.28	4.76	5.36	5.08	5.38	5.04
Annual Mean	4.81	4.74	4.74	4.69	4.81	4.75	4.72	4.66	4.81	4.72	4.81	4.73	4.77	4.67	4.81	4.50	4.74	4.65	4.73	4.56	4.74	4.54
Aluminum (mg/L)																						
Feb	0.050	0.066	0.056	0.070	0.050	0.075	0.050	0.118	0.050	0.082	0.050	0.073	0.060	0.088	0.050	0.077	0.057	0.083	0.050	0.145	0.050	0.157
May	0.055	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.051	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.057	0.050	0.054
Aug	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Nov	0.050	0.068	0.050	0.077	0.050	0.060	0.050	0.050	0.050	0.067	0.050	0.070	0.050	0.055	0.050	0.060	0.050	0.062	0.050	0.064	0.050	0.069
Annual Mean	0.051	0.062	0.052	0.062	0.050	0.059	0.050	0.067	0.050	0.062	0.050	0.061	0.053	0.061	0.050	0.059	0.052	0.061	0.050	0.079	0.050	0.083
Iron (mg/L)																						
Feb	0.118	0.110	0.245	0.110	0.124	0.120	0.237	0.240	0.138	0.130	0.123	0.110	0.315	0.170	0.132	0.090	0.281	0.160	0.202	0.300	0.278	0.320
May	0.050	0.060	0.077	0.070	0.061	0.060	0.074	0.080	0.054	0.090	0.061	0.090	0.064	0.070	0.051	0.040	0.106	0.070	0.049	0.050	0.142	0.080
Aug	0.040	0.050	0.063	0.060	0.036	0.050	0.260	0.060	0.049	0.040	0.042	0.040	0.556	1.260	0.032	0.050	0.098	0.090	0.052	0.040	0.110	0.250
Nov	0.115	0.160	0.201	0.370	0.121	0.170	0.119	0.820	0.113	0.190	0.106	0.170	0.232	0.250	0.087	0.160	0.318	0.360	0.147	0.180	0.324	0.250
Annual Mean	0.081	0.095	0.147	0.153	0.086	0.100	0.173	0.300	0.089	0.113	0.083	0.103	0.292	0.438	0.076	0.085	0.201	0.170	0.113	0.143	0.214	0.225
Manganese (ug/L)																						
Feb	17	12	51	12	18	14	71	82	17	15	17	14	48	25	14	11	42	13	28	26	57	28
May	9	5	33	9	8	6	33	7	8	6	8	7	9	8	6	5	30	6	8	11	54	12
Aug	23	17	1079	493	23	28	1584	979	48	36	34	30	2038	2542	20	16	838	1698	33	47	1550	1550
Nov	44	138	54	552	43	142	42	1324	41	253	45	163	89	245	31	58	55	87	56	74	101	92
Annual Mean	23	43	304	267	23	48	433	598	29	78	26	54	546	705	18	23	241	451	31	40	441	421
Cadmium (ug/L)																						
Feb	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
May	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
Aug	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Nov	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Mean	0.5	0.6	0.5	0.6	0.5	0.625	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6
Copper (ug/L)																						
Feb	2.0	2.0	2.1	2.0	2.0	2.0	2.2	2.6	2.0	2.0	2.5	2.0	2.1	2.1	2.0	2.0	2.1	2.0	2.5	3.0	2.1	2.6
May	2.0	2.2	2.1	2.4	2.0	2.3	2.0	2.3	2.0	2.8	2.0	2.3	2.0	2.4	2.0	2.5	2.0	2.5	2.5	3.1	2.0	3.0
Aug	2.1	2.0	2.0	2.0	2.1	2.0	2.0	2.0	2.1	2.0	2.2	2.0	2.0	2.0	2.0	2.1	2.0	2.0	2.8	2.2	2.0	2.0
Nov	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.8	2.2	2.8	2.3
Annual Mean	2.0	2.1	2.1	2.1	2.0	2.1	2.1	2.2	2.0	2.2	2.2	2.1	2.0	2.1	2.0	2.2	2.0	2.1	2.7	2.6	2.2	2.5
Lead (ug/L)																						
Feb	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
May	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Aug	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Nov	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Annual Mean	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

NS = Not Sampled: NA= Not Applicable; FQC = Failed Quality Control

Table 2-5 (Continued)

	Mixing Zone				Mixing Zone				MNS Discharge		Mixing Zone				Background				Background			
LOCATION:	1.0				2.0				4.0		5.0				8.0				11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Zinc (ug/L)																						
Feb	1.0	1.4	1.0	1.6	1.0	1.0	1.0	24.9	1.4	1.3	1.0	1.4	1.0	5.4	1.0	2.8	4.1	2.5	1.1	2.4	1.1	3.6
May	1.0	6.3	1.0	10.2	1.0	10.9	1.0	5.2	1.0	6.9	1.0	4.7	1.0	6.5	1.0	4.6	1.0	4.4	5.6	6.5	1.0	5.0
Aug	1.8	2.1	1.1	2.6	1.4	1.4	1.0	1.9	1.0	1.0	1.0	1.3	1.0	2.2	1.2	2.8	1.0	2.1	2.7	1.6	1.0	1.8
Nov	4.7	1.7	1.1	1.6	2.0	1.3	1.0	1.4	1.0	1.7	1.0	1.0	1.0	2.4	1.0	2.4	1.0	1.8	1.0	1.8	1.2	1.8
Annual Mean	2.1	2.9	1.1	4.0	1.4	3.7	1.0	8.4	1.1	2.7	1.0	2.1	1.0	4.1	1.0	3.2	1.8	2.7	2.6	3.1	1.1	3.1
Nitrite-Nitrate (ug/L)																						
Feb	200	160	230	170	210	180	220	190	200	200	200	160	210	170	210	160	240	160	260	290	310	350
May	200	190	290	190	210	190	280	200	210	190	210	190	210	190	190	200	290	210	190	230	290	240
Aug	50	70	530	440	60	180	240	450	110	150	90	170	120	450	50	190	220	330	40	210	200	350
Nov	150	130	300	570	90	120	140	80	180	100	120	130	110	120	130	130	140	230	160	260	390	290
Annual Mean	150.0	137.5	337.5	342.5	142.5	167.5	220.0	230.0	175.0	160.0	155.0	162.5	162.5	232.5	145.0	170.0	222.5	232.5	162.5	247.5	297.5	307.5
Ammonia (ug/L)																						
Feb	120	42	140	40	84	37	110	54	87	69	86	72	120	57	110	38	98	50	85	46	100	58
May	35	20	40	24	30	23	38	20	35	29	31	20	28	25	24	29	45	20	35	21	56	20
Aug	90	20	150	39	80	25	170	68	92	31	90	29	200	180	84	28	120	98	100	43	140	110
Nov	65	92	65	120	65	93	63	220	63	100	69	94	69	110	60	79	56	78	56	60	73	85
Annual Mean	77.5	43.5	98.8	55.8	64.8	44.5	95.3	90.5	69.3	57.3	69.0	53.8	104.3	93.0	69.5	43.5	79.8	61.5	69.0	42.5	92.3	68.3
Total Phosphorous (ug/L)																						
Feb	7	9	9	8	8	10	9	114	8	9	8	8	10	11	9	9	9	9	10	17	14	14
May	8	7	8	6	8	7	7	7	7	7	7	7	7	7	7	6	8	9	7	7	9	7
Aug	7	7	8	10	7	8	10	7	7	7	7	7	8	7	7	8	7	7	8	8	8	8
Nov	8	7	11	7	9	7	9	8	9	8	8	7	9	8	8	7	12	9	10	9	15	9
Annual Mean	7.5	7.5	9.0	7.8	8.0	8.0	8.8	34.0	7.8	7.8	7.5	7.3	8.5	8.3	7.8	7.5	9.0	8.5	8.8	10.3	11.5	9.5
Orthophosphate (ug/L)																						
Feb	5	5	5	5	5	5	5	13	5	5	5	5	5	5	5	5	5	5	5	5	5	5
May	5	5	5	5	5	5	5	5	9	5	5	5	5	5	5	5	5	5	5	5	6	5
Aug	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Nov	5	5	5	5	5	5	13	5	5	5	5	5	6	5	5	5	5	5	5	5	5	5
Annual Mean	5.0	5.0	5.0	5.0	5.0	5.0	7.0	7	6.0	5	5.0	5	5.3	5	5.0	5	5.0	5	5.0	5.0	5.3	5
Silicon (mg/L)																						
Feb	4.6	4.2	4.6	3.9	4.6	4.0	4.6	4.0	4.5	4.0	4.5	4.0	4.6	4.1	4.5	4.0	4.6	3.7	4.4	4.8	4.6	4.7
May	4.5	4.2	4.8	4.7	4.5	4.2	4.8	4.6	4.5	4.3	4.4	4.0	4.5	4.0	4.4	3.9	4.9	3.7	4.2	3.6	4.8	3.6
Aug	4.0	3.8	5.5	5.0	4.1	3.7	5.5	5.2	4.1	3.7	4.1	3.7	5.4	5.4	4.1	3.6	5.4	5.1	4.1	3.9	5.3	5.1
Nov	4.6	4.6	4.4	4.9	4.4	4.7	4.4	5.0	4.4	4.7	4.4	4.7	4.5	4.7	4.4	4.6	4.3	4.6	4.6	5.1	4.5	5.1
Annual Mean	4.4	4.2	4.8	4.6	4.4	4.2	4.8	4.7	4.4	4.2	4.4	4.1	4.8	4.6	4.4	4.0	4.8	4.3	4.3	4.4	4.8	4.6

NS = Not Sampled: NA= Not Applicable; FQC = Failed Quality Control

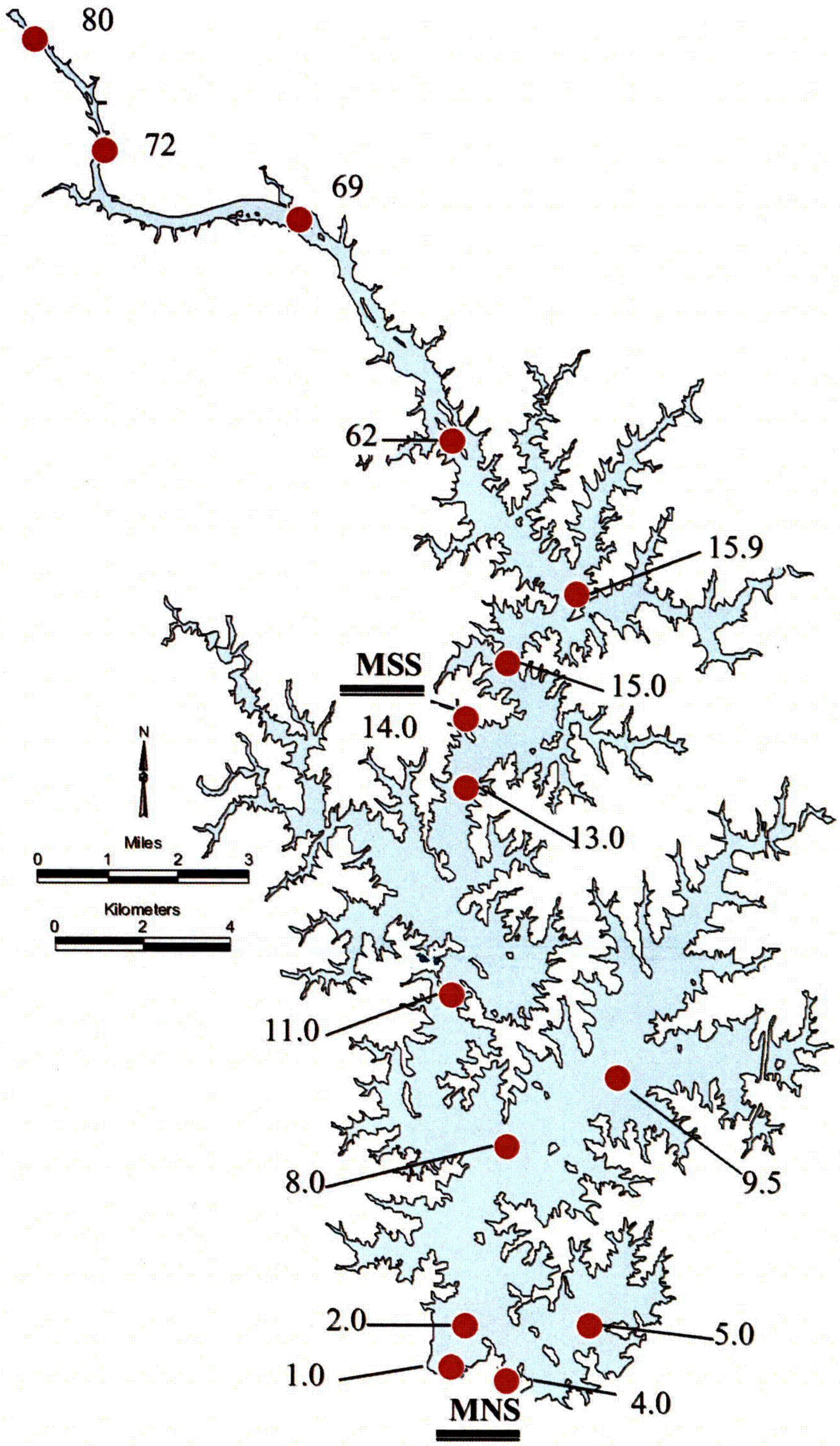


Figure 2-1. Water quality sampling locations (numbered) for Lake Norman. Approximate locations of Marshall Steam Station, and McGuire Nuclear Station are also shown.

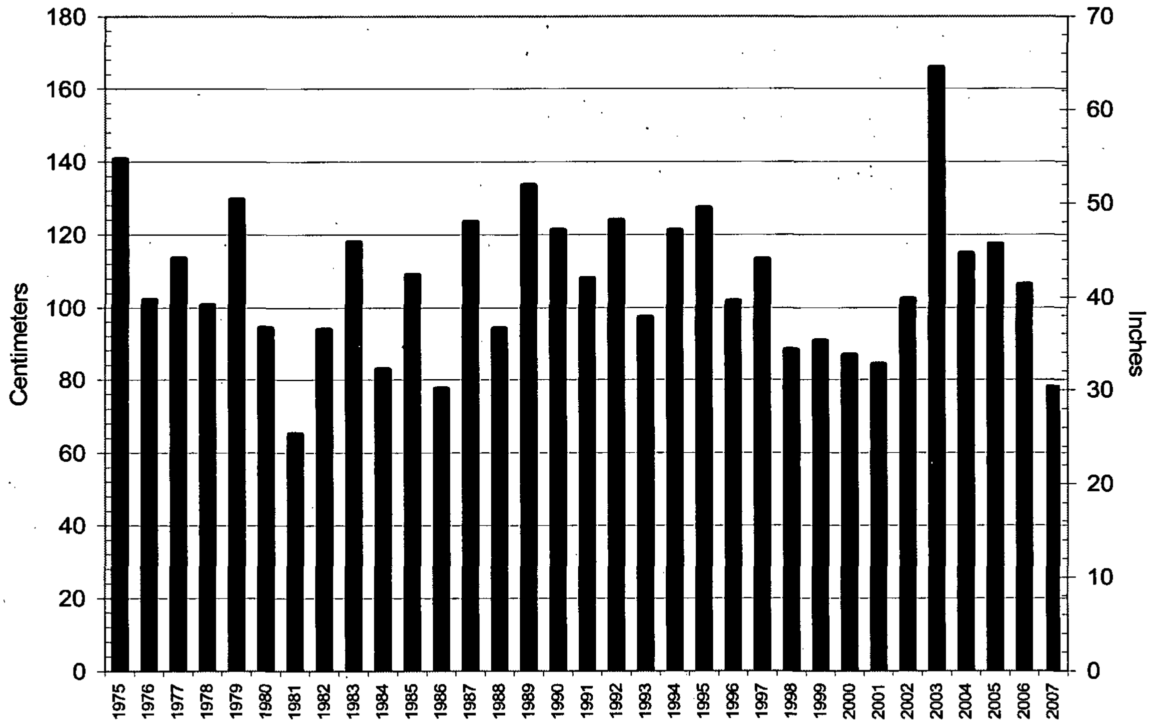


Figure 2-2a. Annual precipitation totals in the vicinity of McGuire Nuclear Station.

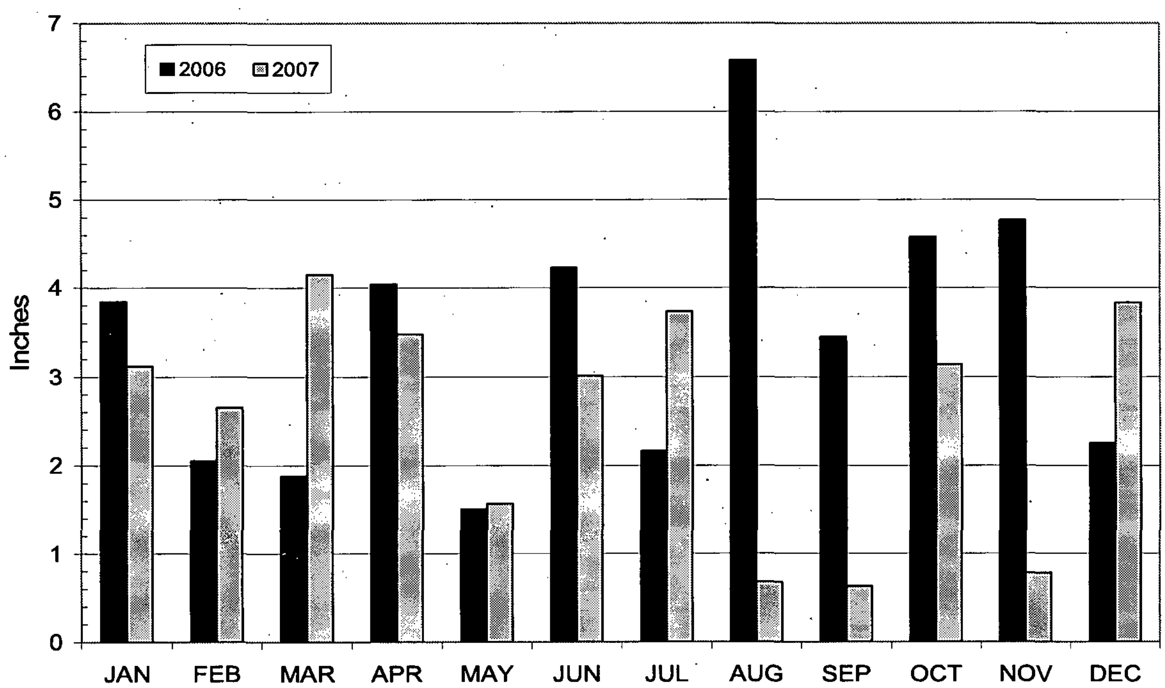


Figure 2-2b. Monthly precipitation totals in the vicinity of McGuire Nuclear Station in 2006 and 2007.

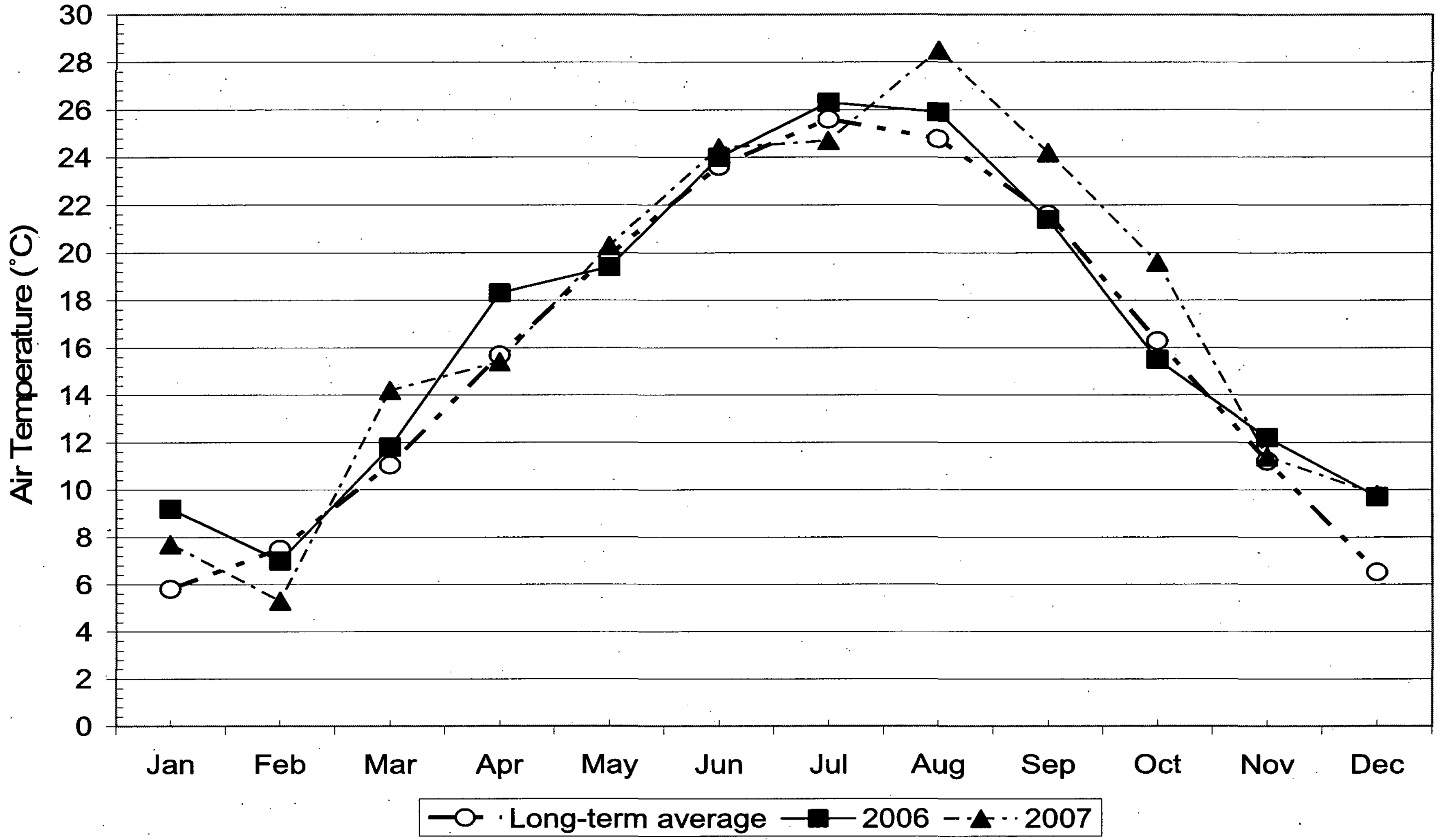


Figure 2-2c. Mean monthly air temperatures recorded at McGuire Nuclear Station beginning in 1989. Data were complied from average daily temperatures which, in turn, were created from hourly measurements.

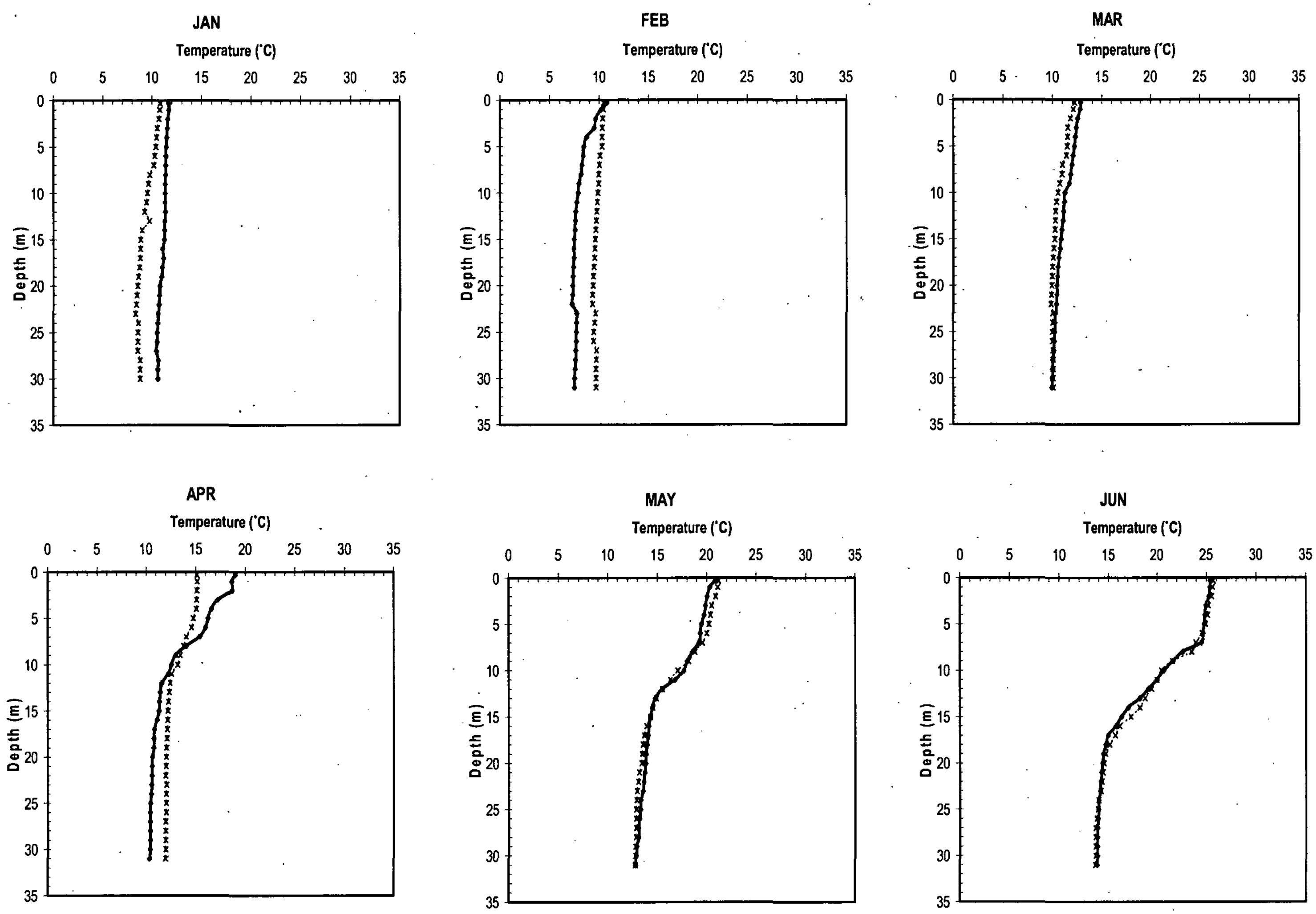


Figure 2-3. Monthly mean temperature profiles for the McGuire Nuclear Station background zone in 2006 (♦♦) and 2007 (xx).

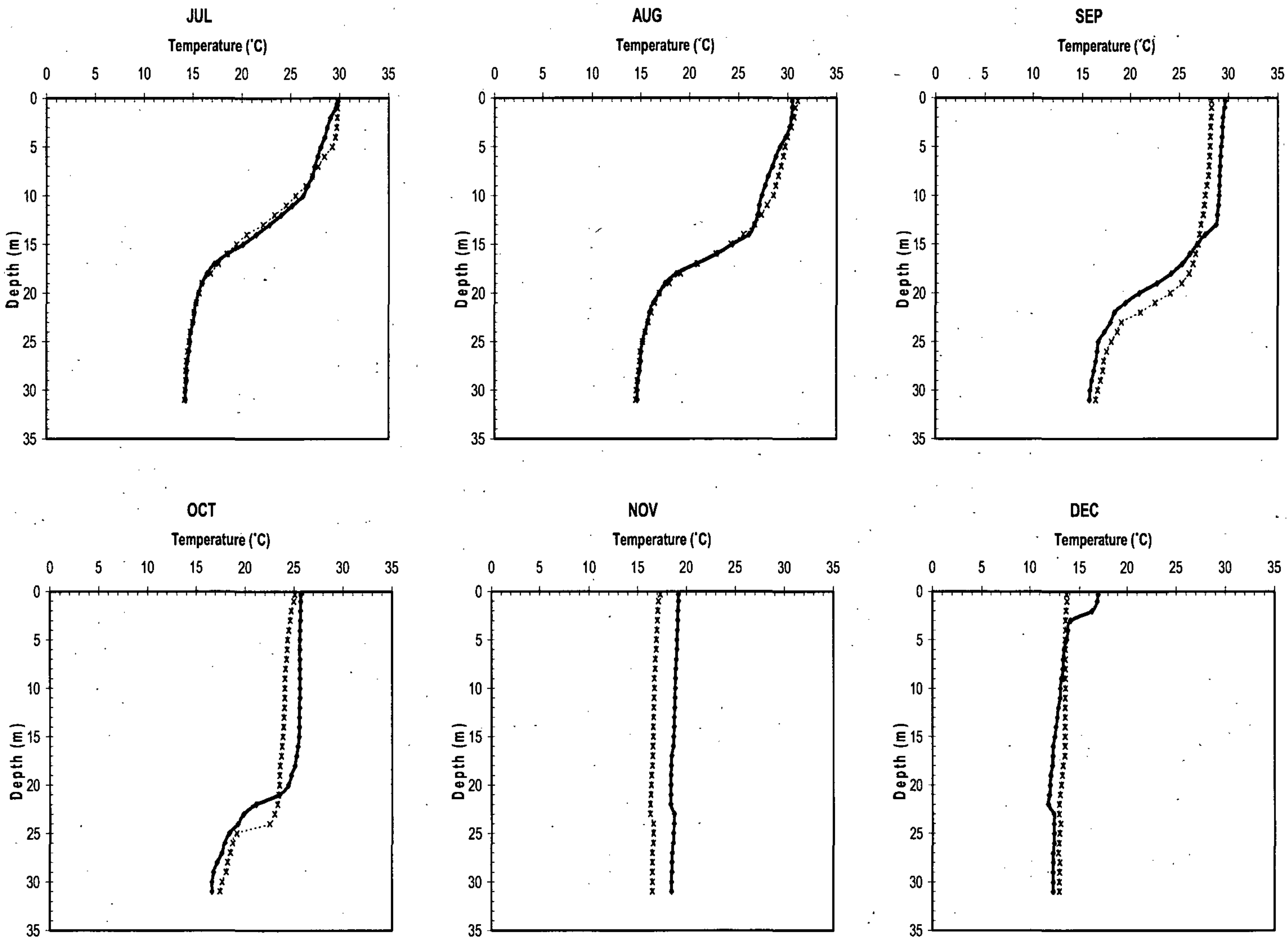


Figure 2-3. (Continued).

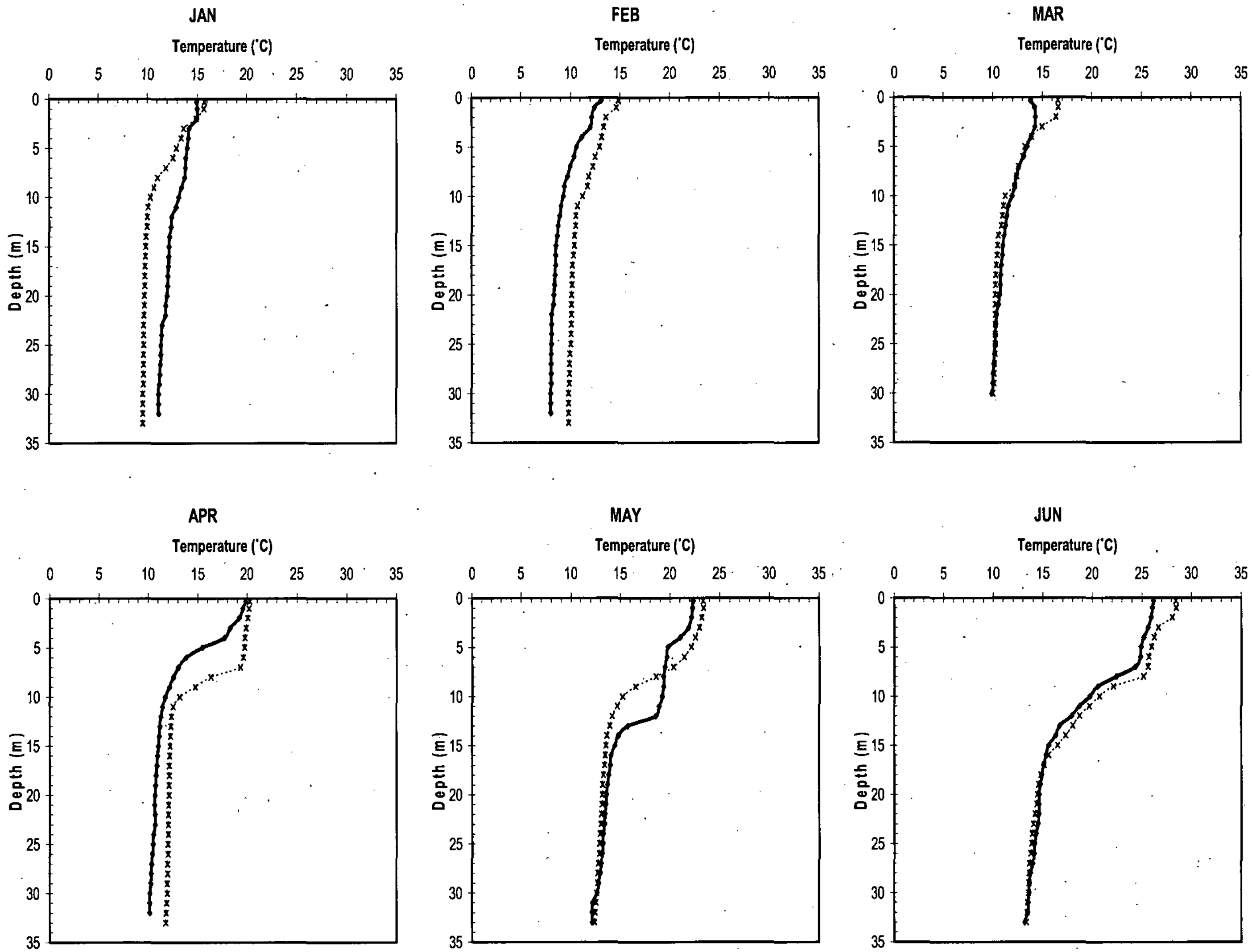


Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 2006 (♦♦) and 2007 (xx).

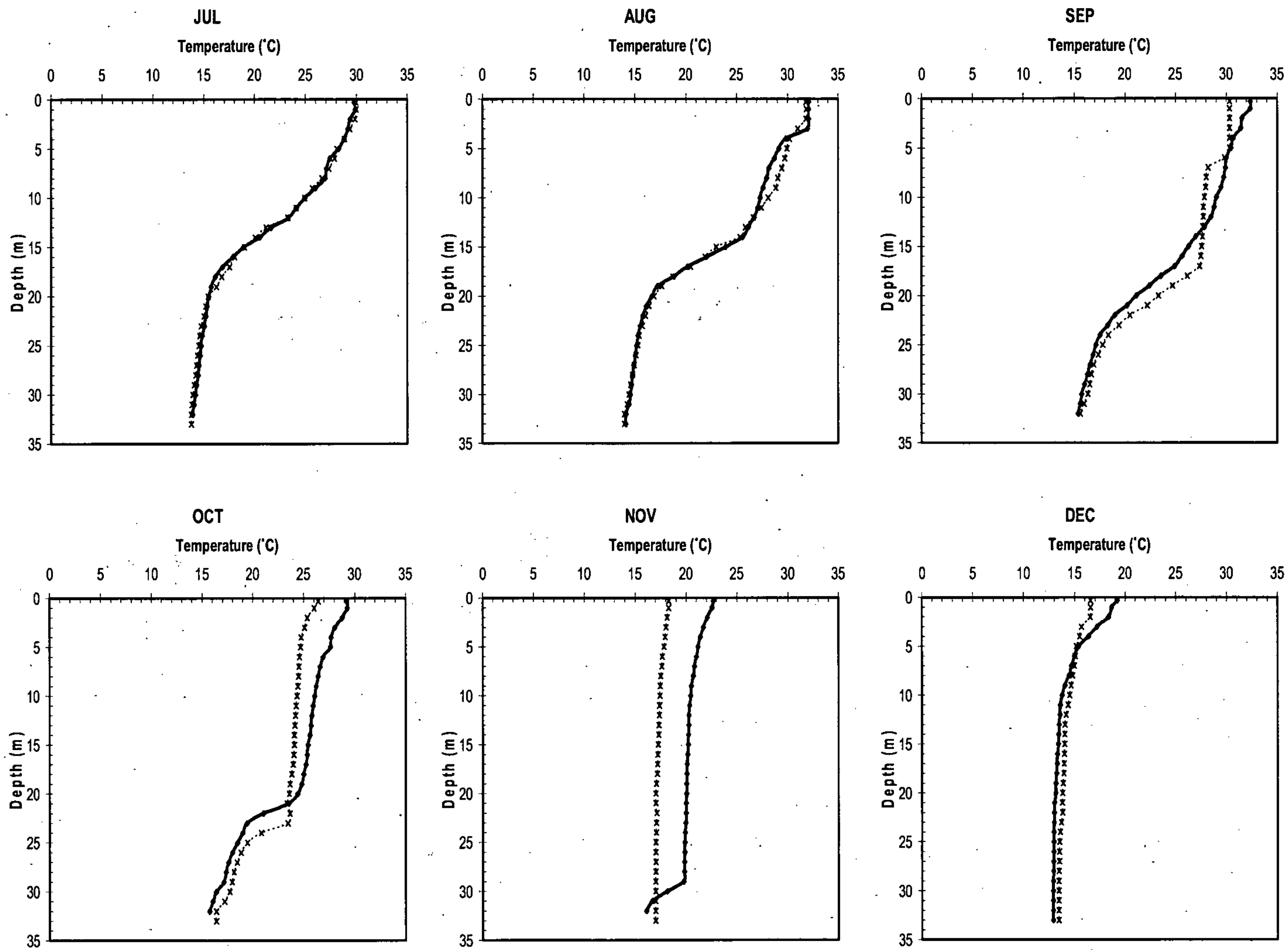


Figure 2-4. (Continued).

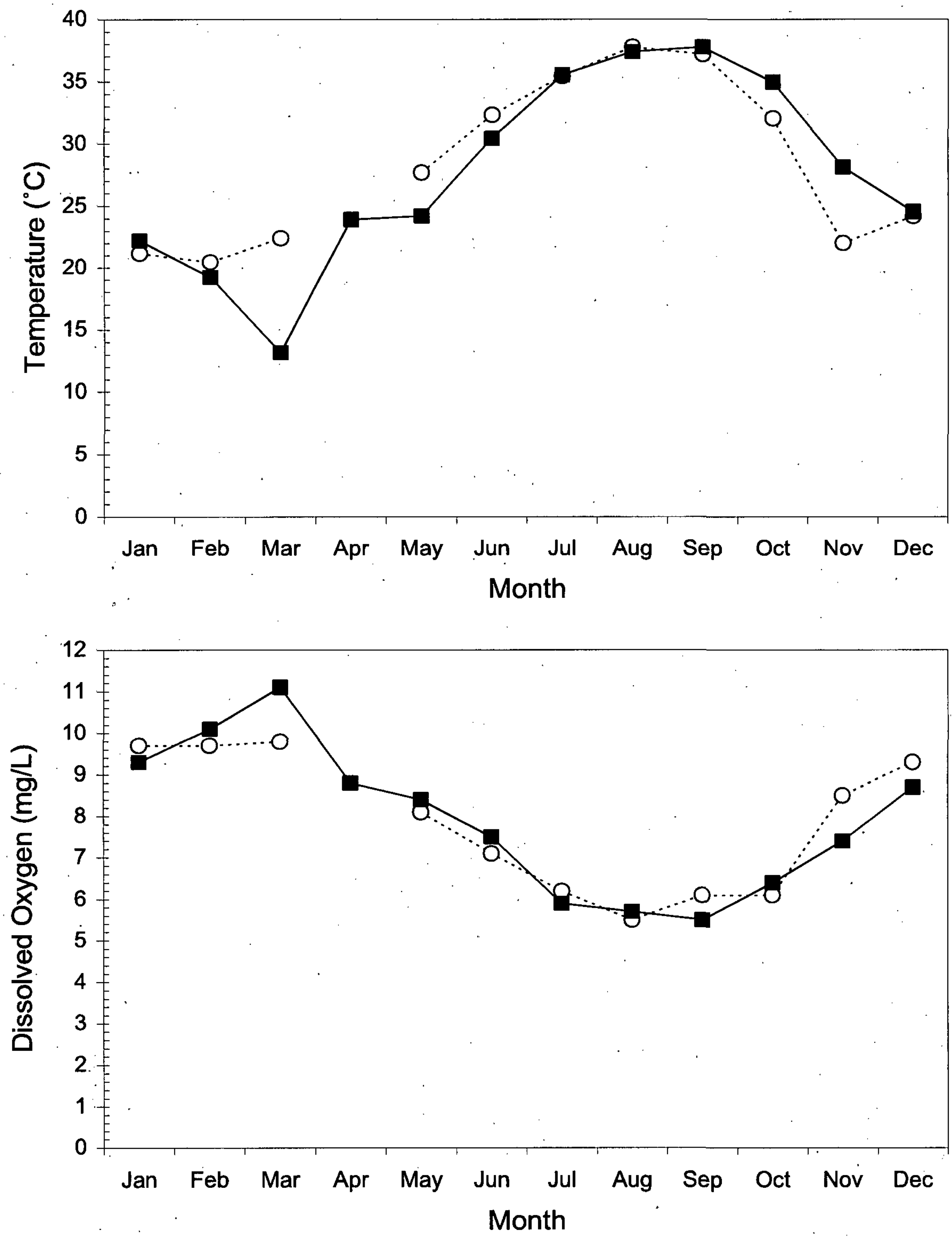


Figure 2-5. Monthly surface (0.3m) temperature and dissolved oxygen data at the discharge location (Location 4.0) in 2006 (■) and 2007 (O).

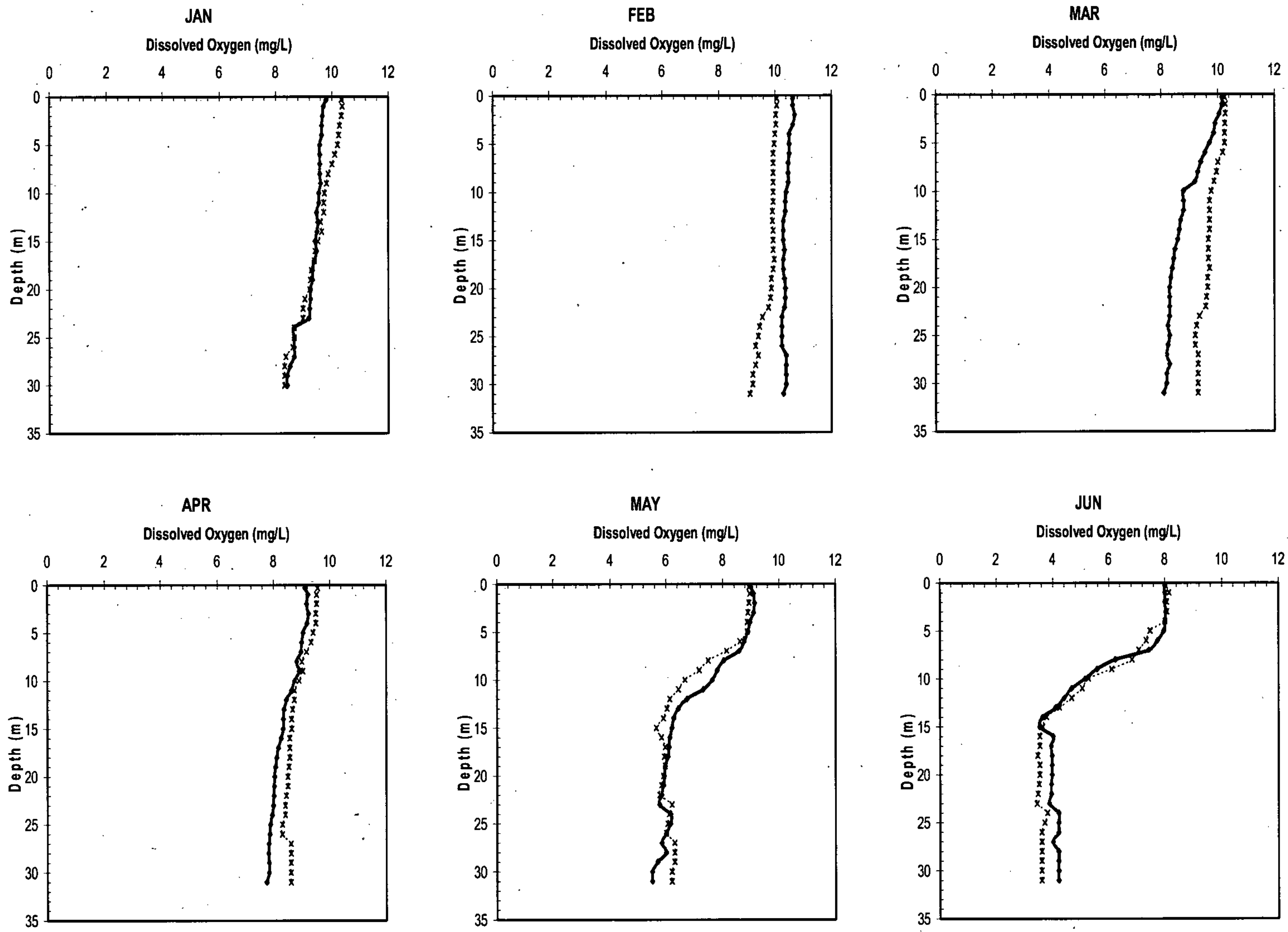


Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 2006 (××) and 2007 (♦ ♦).

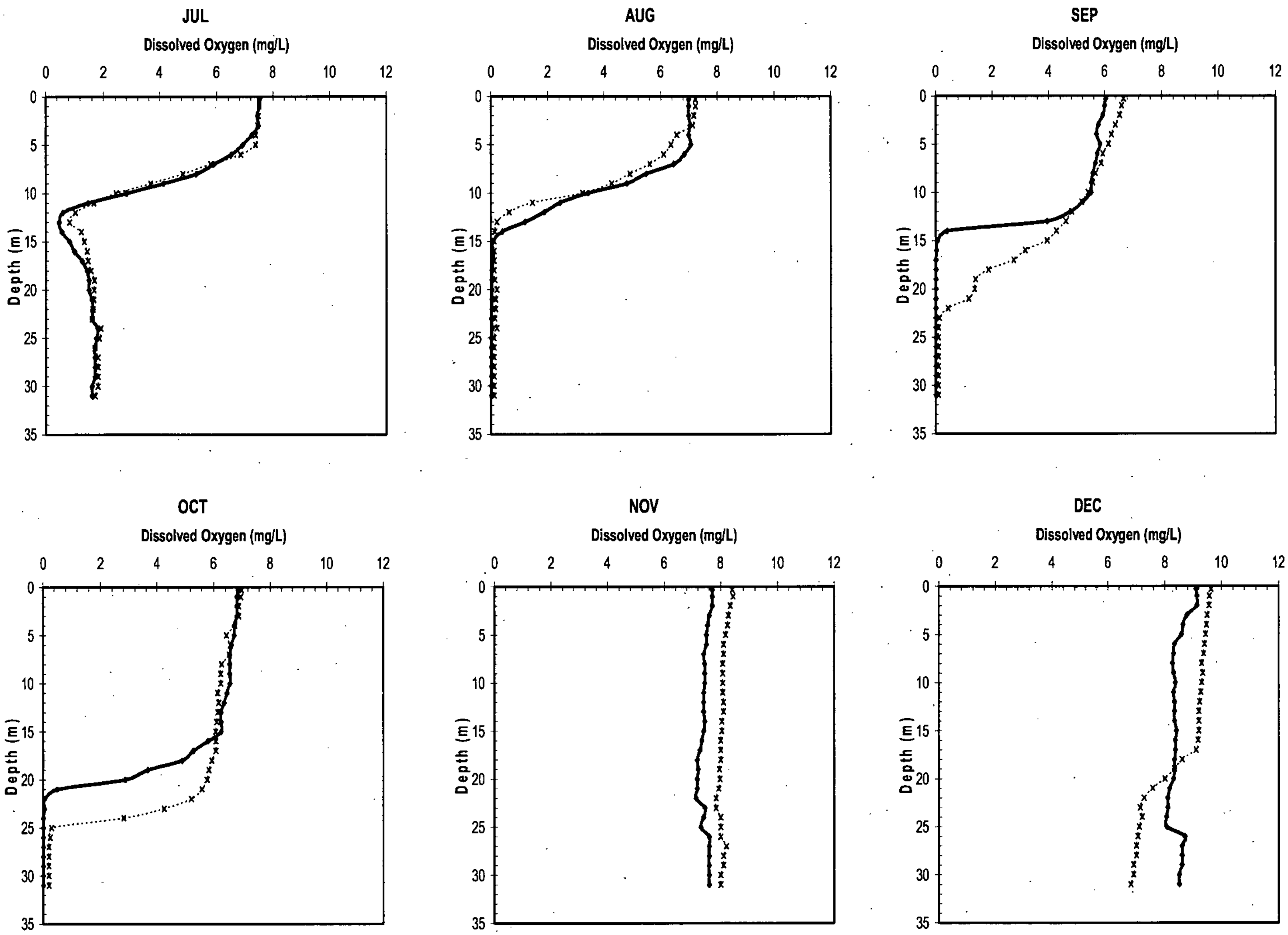


Figure 2-6. (Continued).

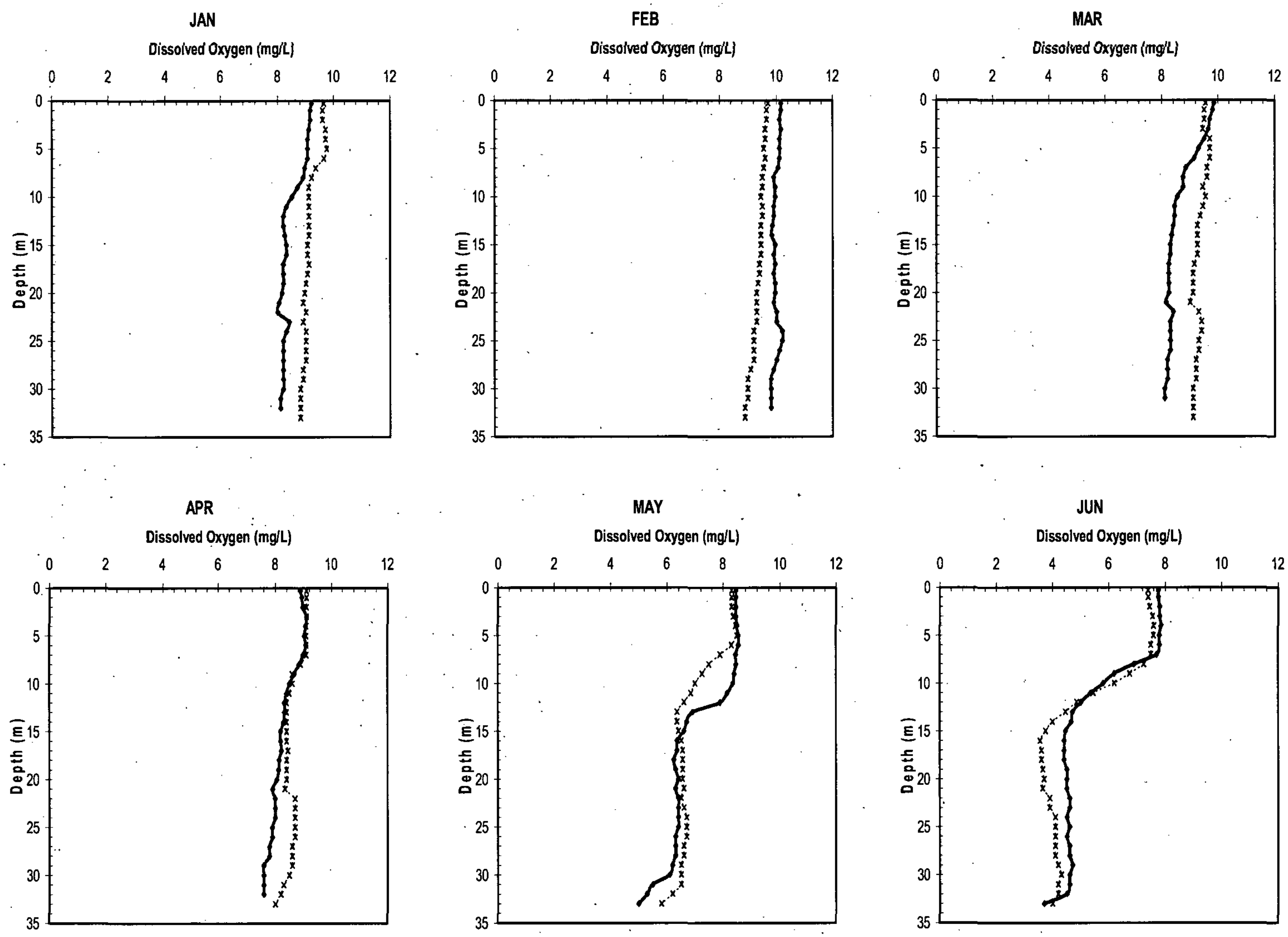


Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 2006 (××) and 2007 (♦ ♦).

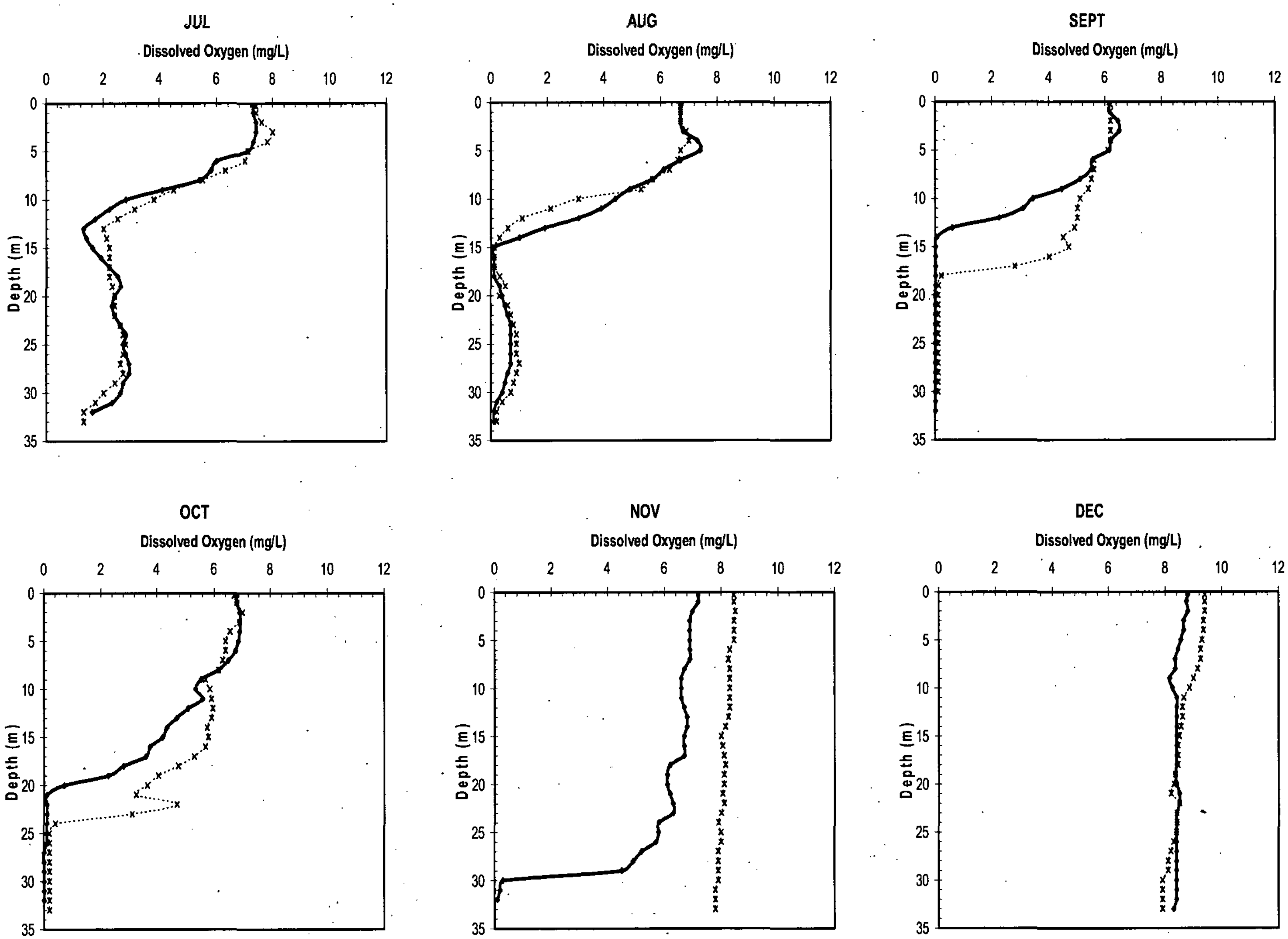


Figure 2-7. (Continued).

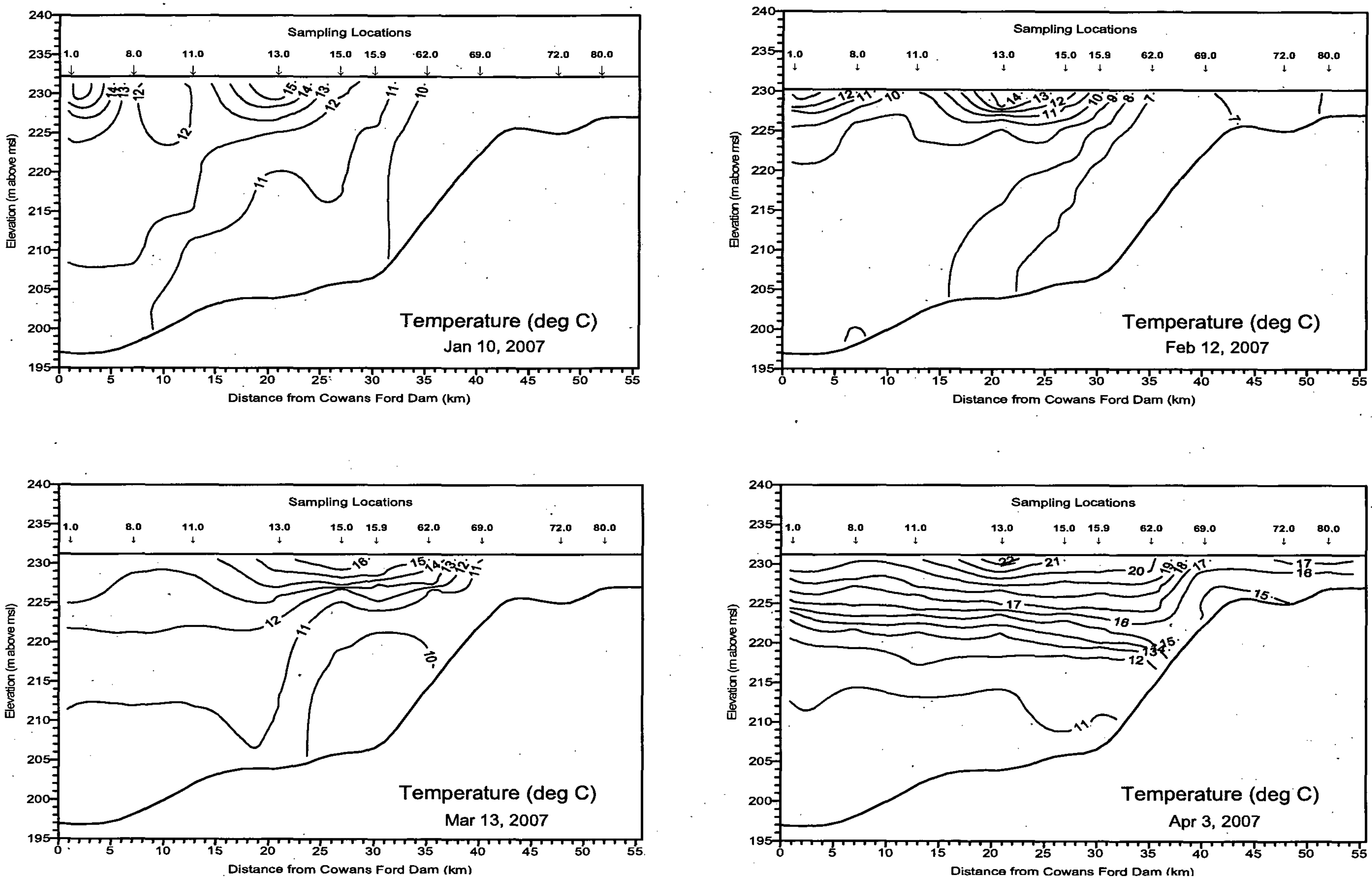


Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 2007.

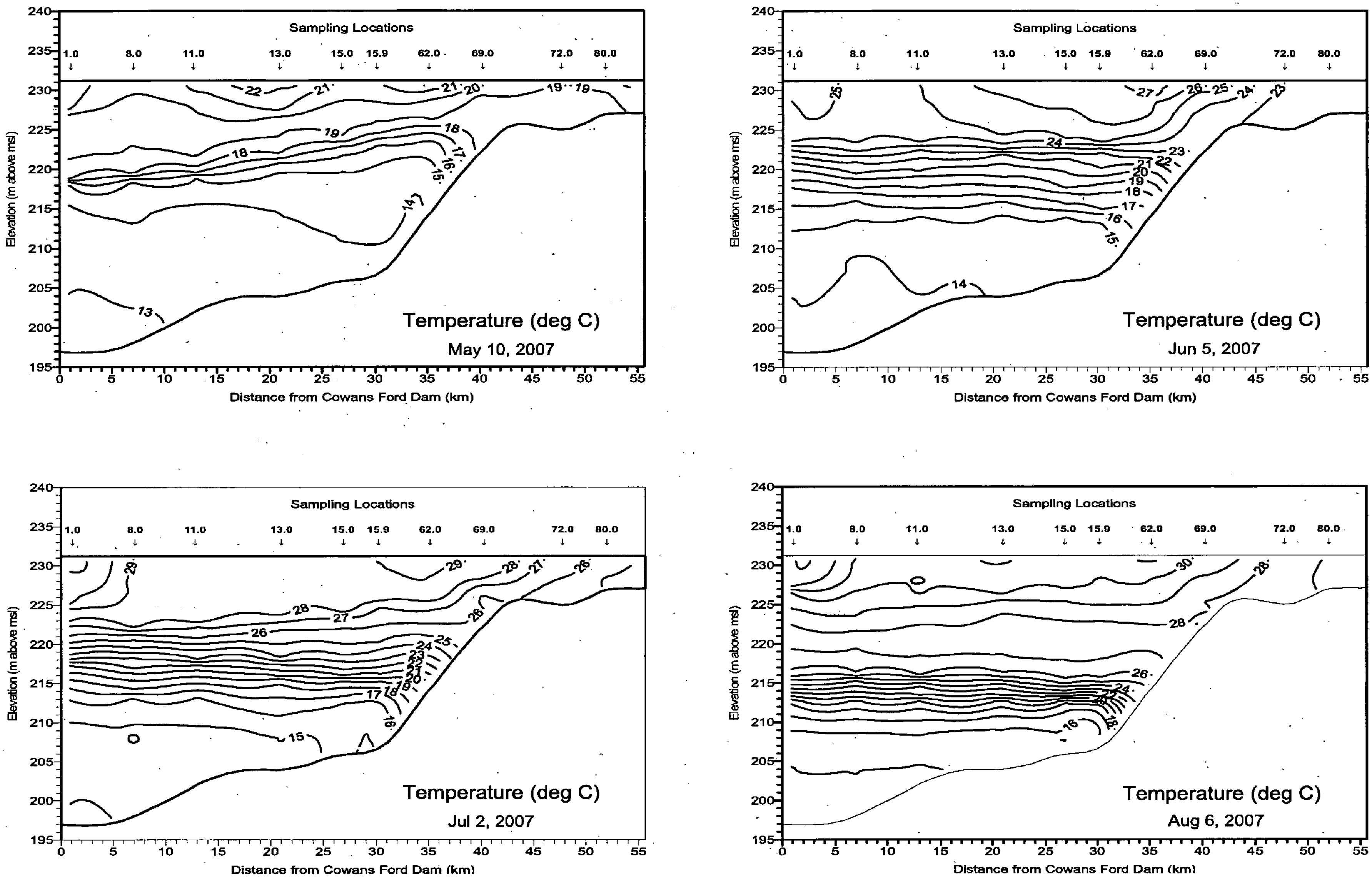


Figure 2-8. (Continued).

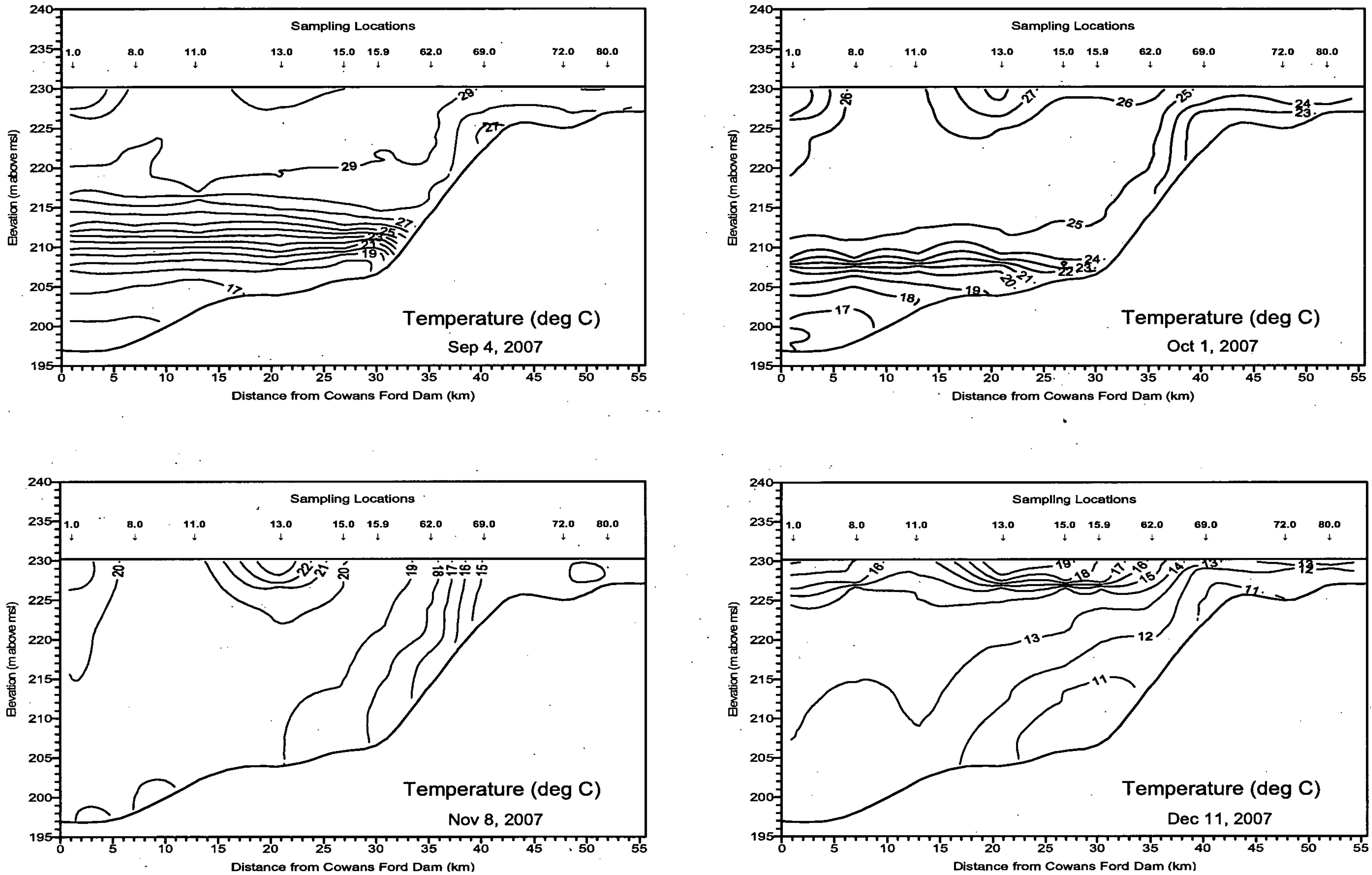


Figure 2-8. (Continued).

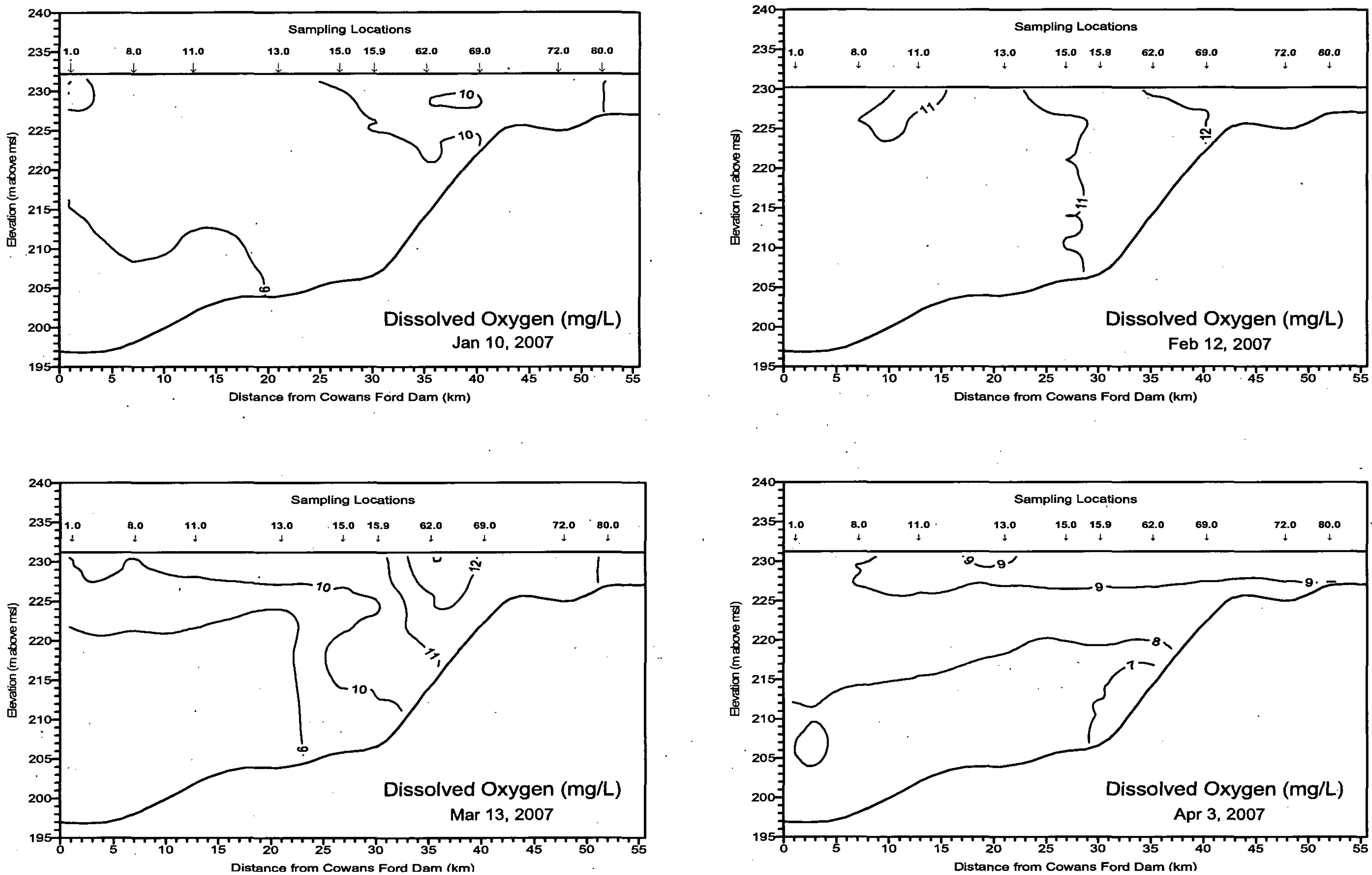


Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 2007.

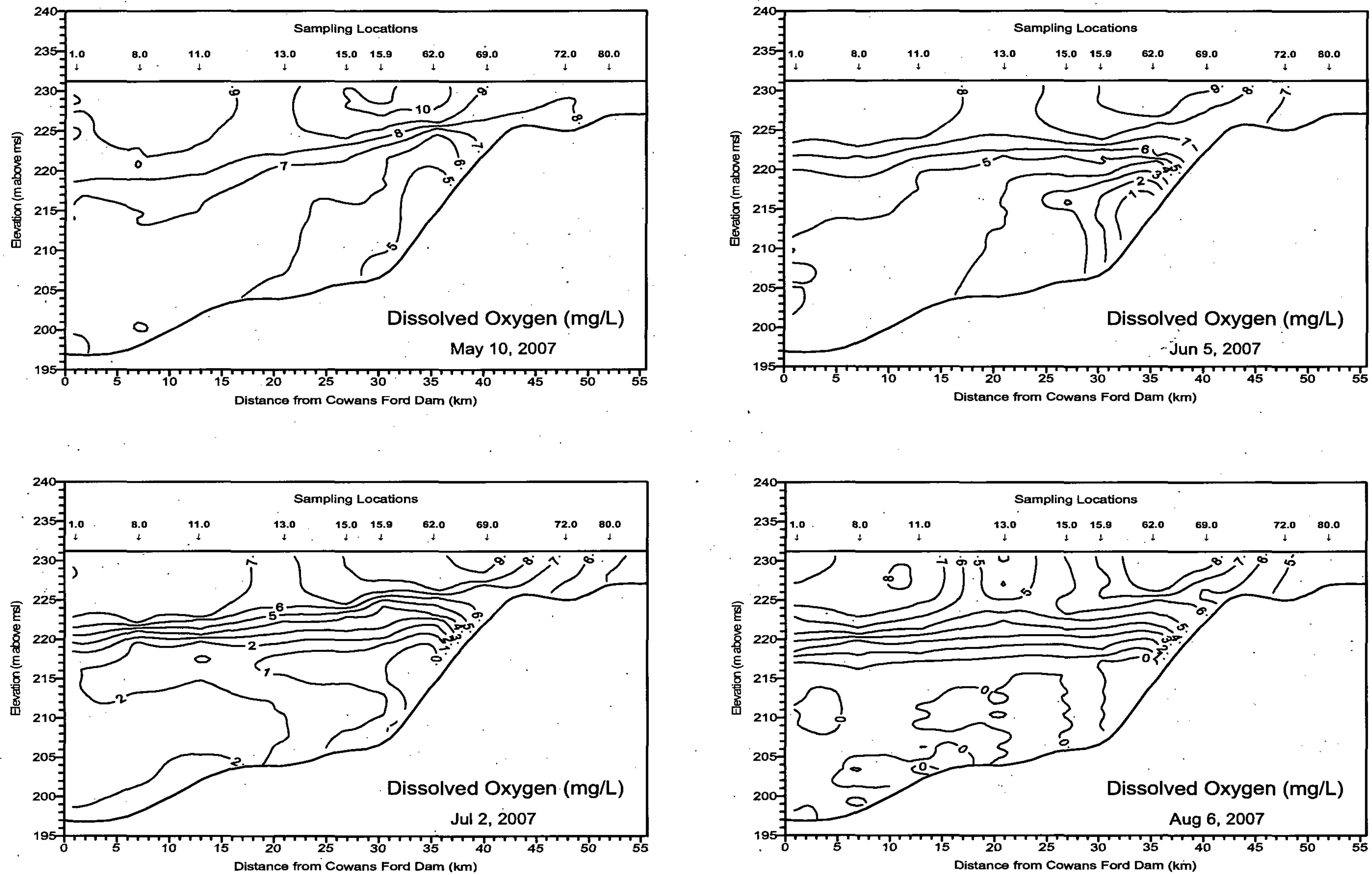


Figure 2-9. (Continued).

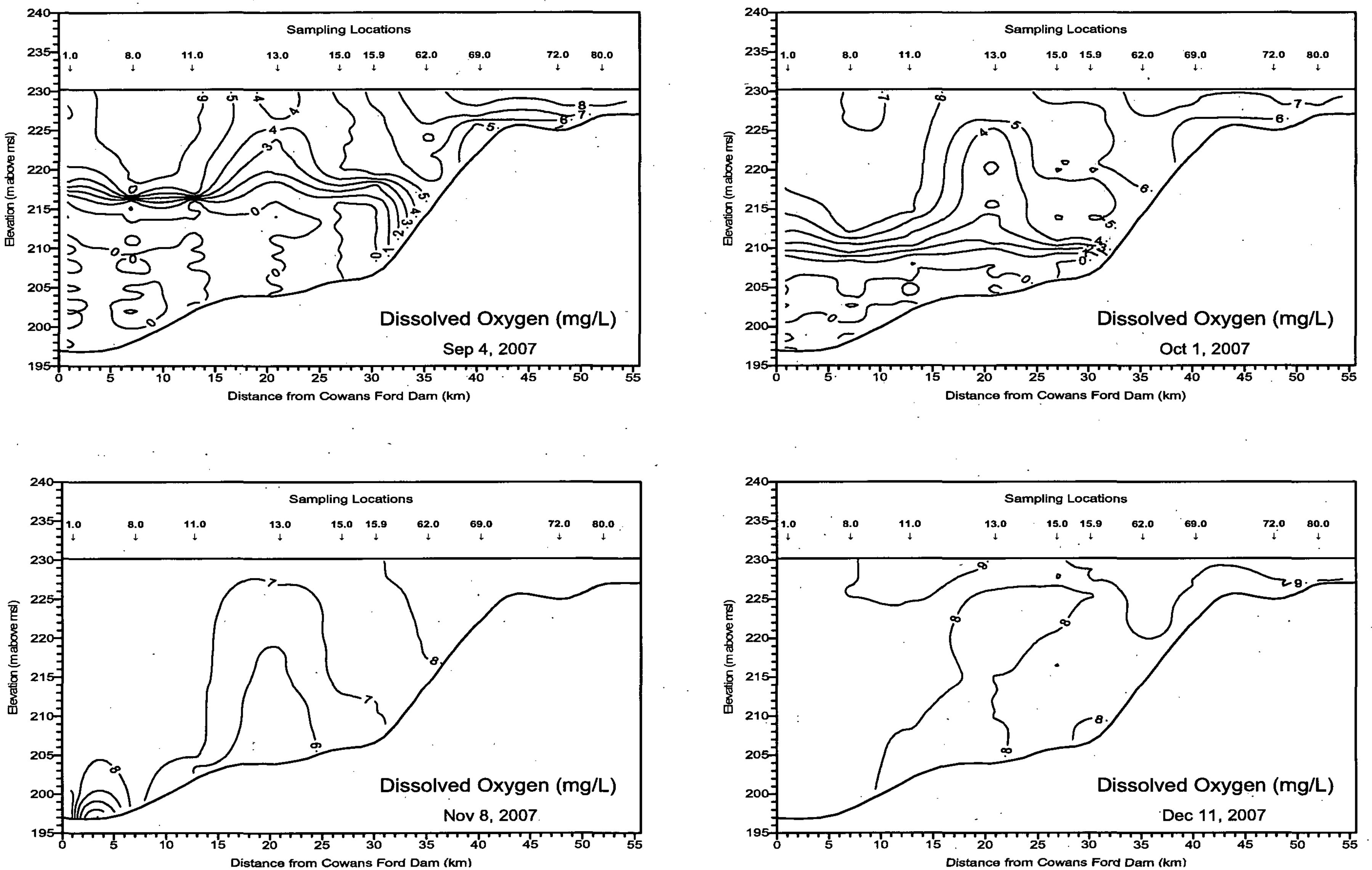


Figure 2-9. (Continued).

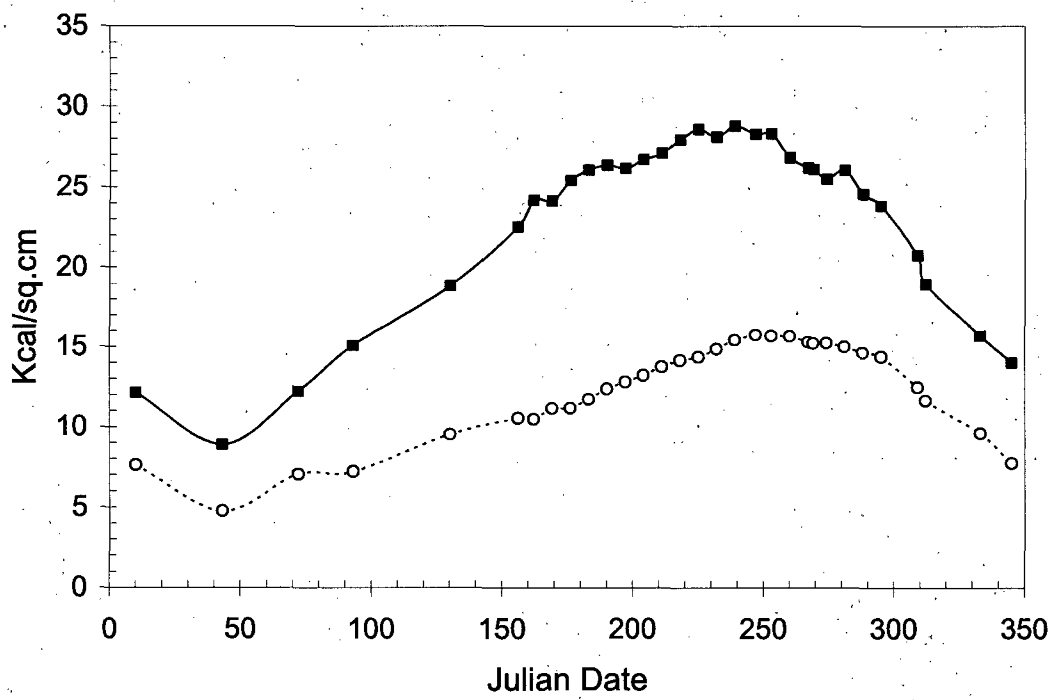


Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (○) in Lake Norman in 2007.

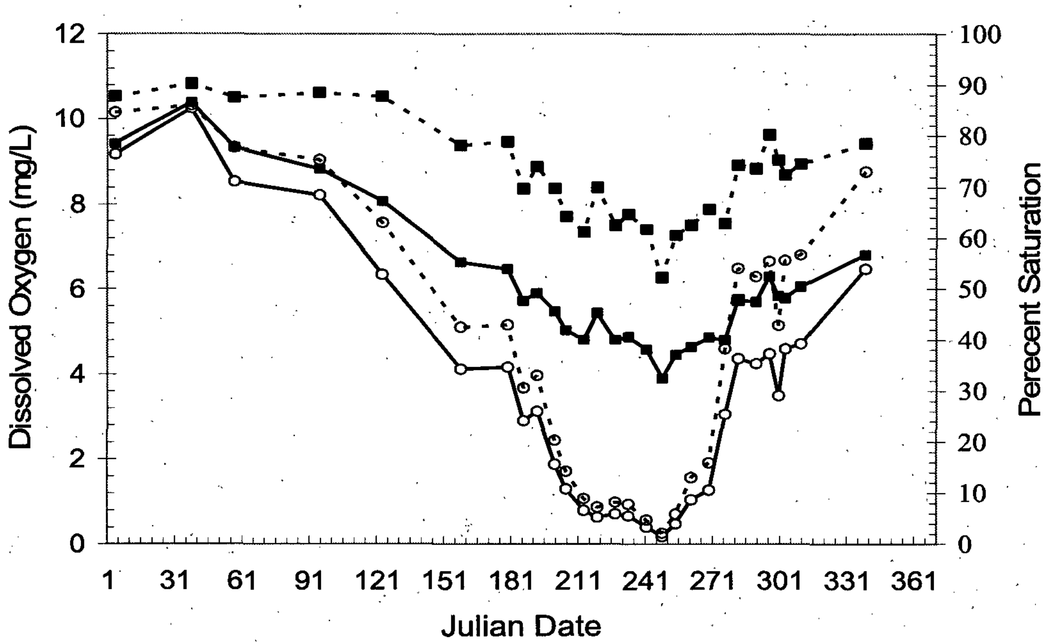


Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (○) of Lake Norman in 2007.

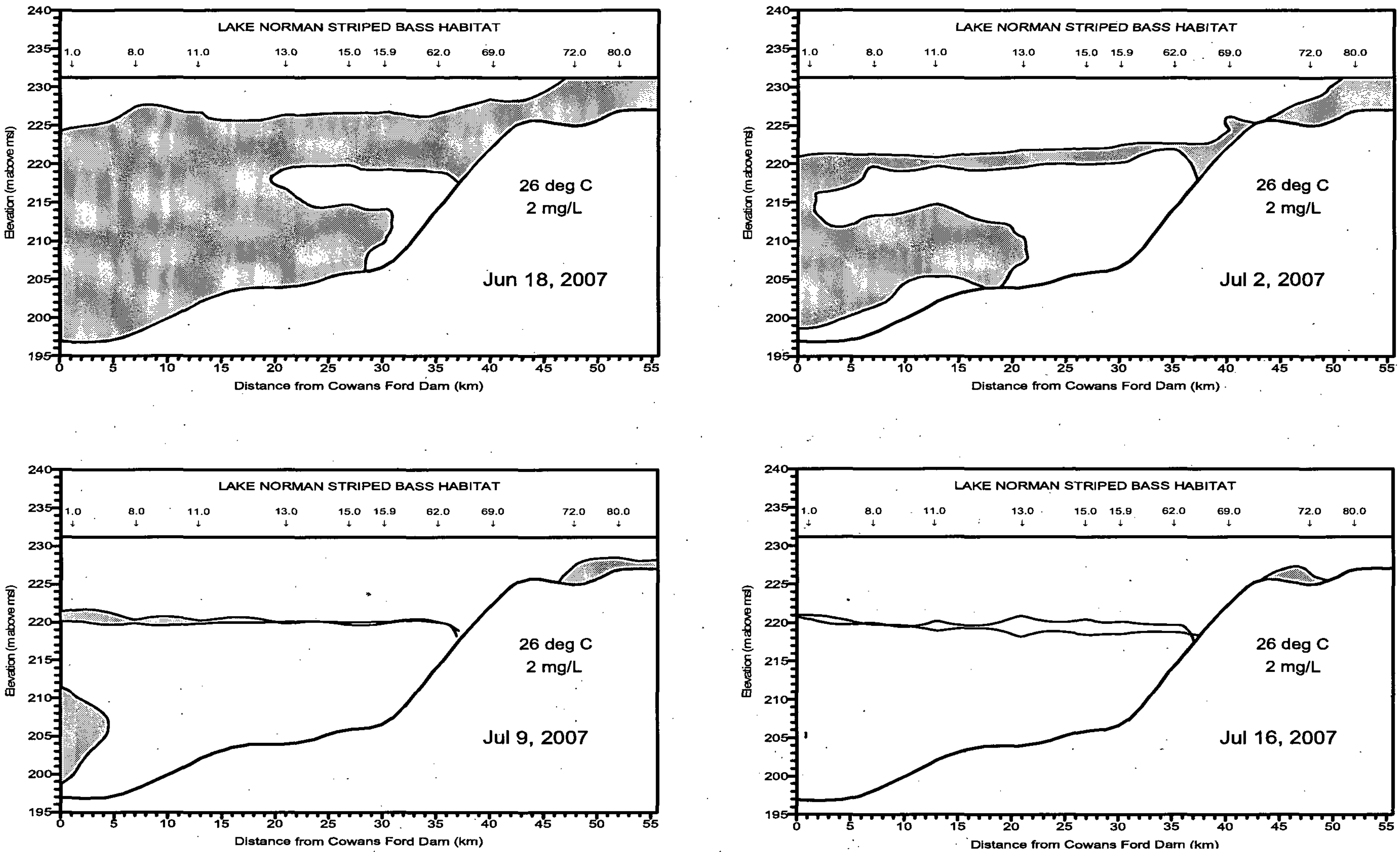


Figure 2-11. Striped bass habitat (shaded areas; temperatures ≤ 26 °C and dissolved oxygen ≥ 2 mg/L) in Lake Norman in June, July, August, September, and October 2007.

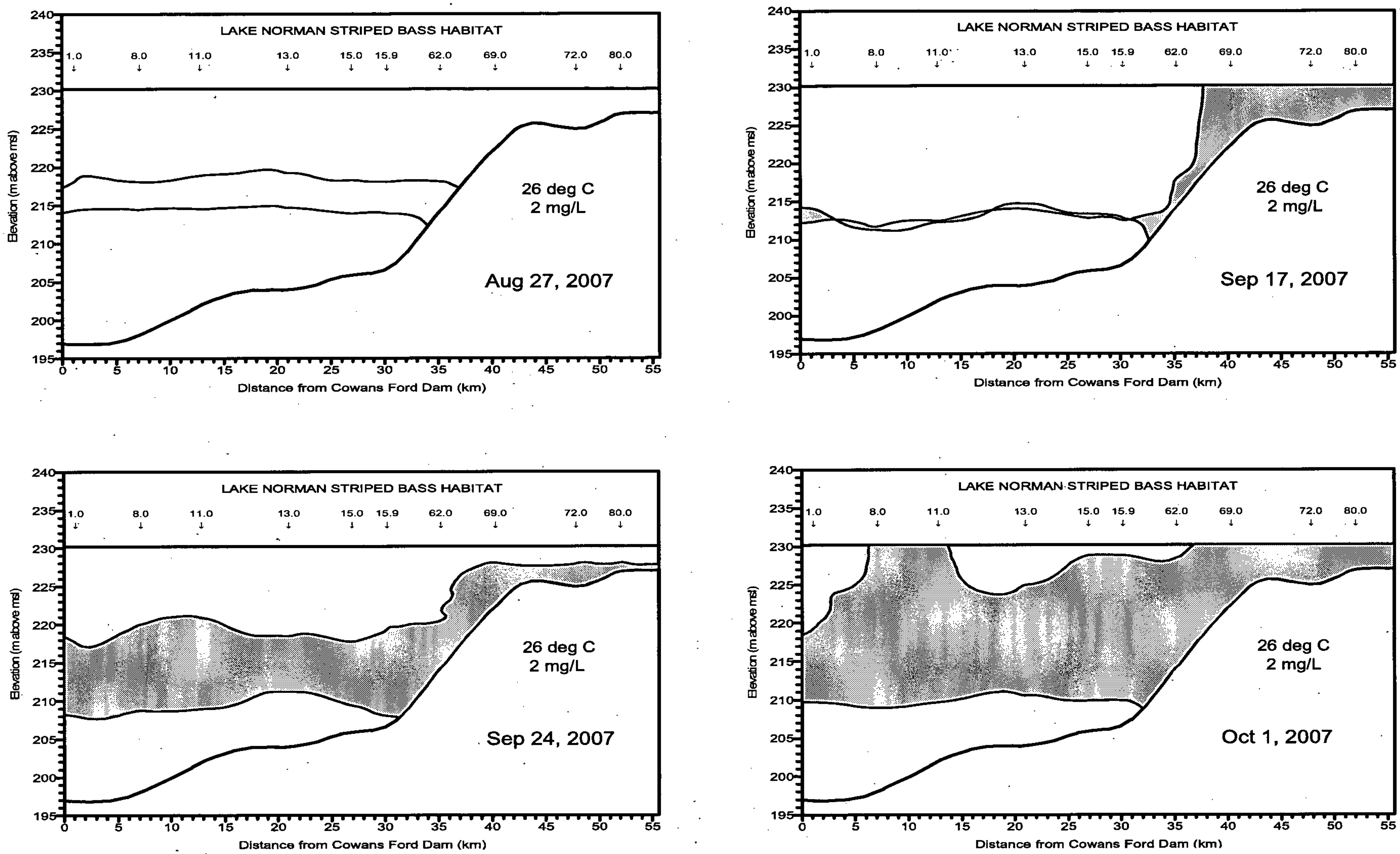


Figure 2-11. (Continued).

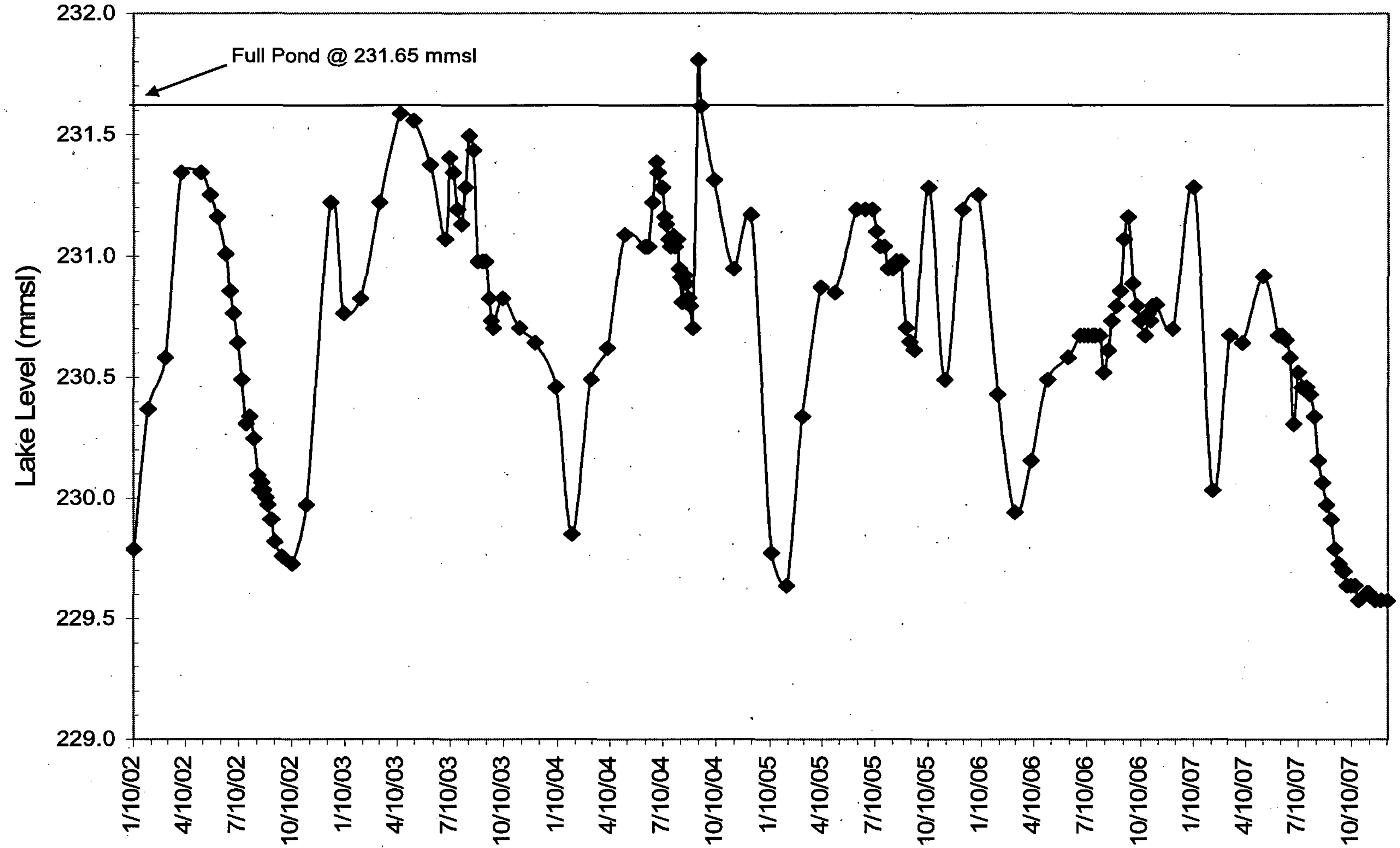


Figure 2-12. Lake Norman lake levels, expressed in meters above mean sea level (mmsl) for 2002, 2003, 2004, 2005, 2006, and 2007. Lake level data correspond to the water quality sampling dates over this time period.

CHAPTER 3

PHYTOPLANKTON

INTRODUCTION

Phytoplankton standing crop parameters were monitored in 2007 in accordance with the NPDES permit for McGuire Nuclear Station (MNS). The objectives of the phytoplankton study 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 current study with data collected in prior study years.

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 (Duke Energy 2007).

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 locations, except Location 69.0, where grabs were taken at 0.3, 3.0, and 6.0 m due to the depth. Grab samples were composited for each location. Sampling was conducted in February, May, August, and November 2007. Secchi depths were recorded from all sampling locations. As in previous years and based on the original design study (Duke Power Company 1988), 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 2006 were compared with corresponding data from quarterly monitoring beginning in August 1987.

RESULTS AND DISCUSSION

Standing Crop

Chlorophyll a

Chlorophyll *a* concentrations (mean of two replicate composites) ranged from a low of 1.96 µg/L at Location 8.0 in November, to a high of 13.66 µg/L at Location 69.0 in August (Table 3-1, Figure 3-1). All values were below the North Carolina water quality standard of 40 µg/L (NCDENR 1991). Lake-wide mean chlorophyll concentrations were within ranges of those reported in previous years, but were all below the long-term lake-wide means (Figure 3-2). Seasonally, chlorophyll concentrations increased from February through May to the annual maximum in August then declined to the annual lake-wide minimum in November. Based on quarterly mean chlorophyll concentrations, the trophic level of Lake Norman was in the oligotrophic (low) range during February and November and in the mesotrophic (intermediate) range in May and August 2007. Over 59% of the mean chlorophyll *a* values were less than 4 µg/L (oligotrophic), while all but one of the remaining chlorophyll *a* values were between 4 and 12 µg/L (mesotrophic). The chlorophyll concentration from Location 69.0 in August was the only one greater than 12 µg/L (eutrophic, or high range). Historically, quarterly mean concentrations of below 4 µg/L have been recorded on fourteen previous occasions, while lake-wide mean concentrations of greater than 12 µg/L were only recorded during May of 1997 and 2000 (Duke Power 1998, 2001; Duke Energy 2007).

During 2007 chlorophyll *a* concentrations showed typical spatial variability. Maximum concentrations among sampling locations were observed at Location 69.0 (furthest up-lake) during all sampling periods, while minimum concentrations occurred at Location 9.5 in February, Location 2.0 in May, Location 5.0 in August, and Location 8.0 in November (Table 3-1). The trend of increasing chlorophyll concentrations from down-lake to up-lake, which had been observed during many previous years, was apparent to some extent during all sampling periods (Table 3-1, Figure 3-1).

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 resulting in higher retention time. However, 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 many previous years, as opposed to Locations 2.0 and 5.0 which have usually shown similar concentrations during sampling periods.

Mean quarterly chlorophyll concentrations during the period of record (August 1987 – November 2007) have varied considerably, resulting in moderate to wide historical ranges. During February 2007, chlorophyll values at all but Location 69.0 were lower than in previous February periods, while the value at Location 69.0 was higher than average (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. Long-term maxima at Locations 13.0 and 15.9 occurred in 2003. The highest February value at location 69.0 occurred in 2001. All locations had higher chlorophyll concentrations in February 2007 than in February 2006 (Duke Energy 2007).

During May, mean chlorophyll concentrations at Locations 2.0 and 5.0 were in the mid historical range, while concentrations at Locations 8.0 through 15.9 were in the low range. The concentration at Location 69.0 was once again in the high range (Figure 3-3). Long-term May peaks at Locations 2.0 and 9.5 occurred in 1992; at Location 5.0 in 1991; at Locations 8.0, 11.0, and 13.0 in 1997; at Location 15.9 in 2000; and at Location 69.0 in 2001. May 2007 mean chlorophyll concentrations at all but Location 13.0 were higher than those of 2006 (Duke Energy 2007).

Although the lake-wide mean chlorophyll concentration in August 2007 was the highest of the four sampling periods, mean chlorophyll concentrations at all but Location 69.0 were in the low historical range, with Location 69.0 having a concentration in the high range (Figures 3-2 and 3-4). Long-term August peaks at Locations 2.0 and 5.0 were observed in 1998, while

August peaks 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. Mean chlorophyll concentrations for August 2007 were higher than those of August 2006 at all but Location 5.0 (Duke Energy 2007).

The lake-wide mean chlorophyll concentration in November 2007 was the lowest among all four sampling periods (Figure 3-2). Chlorophyll concentrations at all but Location 69.0 were in the low historical range and concentrations from Locations 5.0, 8.0, 9.5, and 15.9 were the lowest November concentrations recorded from these locations (Figure 3-4). As was the case during the previous sampling periods, the chlorophyll concentration at Location 69.0 was in the high historical range. Long-term November peaks at Locations 5.0 and 8.0 occurred in 2006, while November maxima at Locations 11.0 and 15.9 occurred in 1996. The highest November value at Location 13.0 was recorded for 1992, while the 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 2007 chlorophyll concentrations at all but Location 69.0 were lower than during November 2006 (Duke Energy 2007).

Total Abundance

Density and biovolume are measurements of phytoplankton standing crops. In most cases, standing crop parameters mirror the temporal trends of chlorophyll concentrations. During 2007, mean seasonal standing crops increased from the annual minimum in February through to the annual peak in August then declined through November. The lowest density (761 units/mL) and biovolume (551 mm^3/m^3) occurred at Location 9.5 in February (Table 3-2, Figure 3-1). The maximum density (6,232 units/mL) and biovolume (4,860 mm^3/m^3) were observed at Location 15.9 in August. Most standing crop values during February, May, and August 2007 were higher than those of 2006, while values from November 2007 were lower than in November of the previous year (Duke Energy 2007). Phytoplankton densities during 2007 never exceeded the NC guidelines for algae blooms of 10,000 units/mL density and 5,000 mm^3/m^3 for biovolume (NCDENR 1991). Densities or biovolumes in excess of NC guidelines were recorded in 1987, 1989, 1997, 1998, 2000, 2003, and 2006 (Duke Power Company 1988, 1990; Duke Power 1998, 1999, 2001, 2004a; Duke Energy 2007). During all sampling periods phytoplankton densities and biovolumes demonstrated a spatial trend similar to that of chlorophyll; that is, lower values at down-lake locations verses up-lake locations (Table 3-2, Figure 3-1).

Seston

Seston dry weights represent a combination of algal matter and other organic and inorganic material. Dry weights during 2007 were most often lower than those of 2006. As was observed with chlorophylls and algal standing crops, a general pattern of increasing values from down-lake to up-lake was observed during 2007 (Table 3-3 and Figure 3-1). 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 resulting in low sedimentation from runoff (Figure 2-2a). From 2002 through 2006, dry weights gradually increased throughout the lake, followed by a dramatic decline in 2007. The lake-wide average dry weight in 2007 was the lowest since dry weights were recorded in 1988. These exceptionally low values were likely due to severe drought conditions throughout the watershed during 2007.

Seston ash-free dry weights represent organic material and may reflect trends of chlorophyll *a*. This relationship held true for the most part during 2007, especially with respect to increasing values from down-lake to up-lake areas, as was the case with chlorophyll concentrations and standing crop values (Tables 3-1 through 3-3).

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 1.10 m at Location 13.0 in February and 69.0 in August, to 3.7 m at Location 8.0 in May (Table 3-1). The lake-wide mean Secchi depth during 2007 was slightly higher than in 2006 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 (2.26 m) (Duke Power 2000).

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 2007. Ten classes comprising 98 genera and 257 species, varieties, and forms of phytoplankton were identified in samples collected during 2007, as compared to 91 genera and 243 lower taxa identified in 2006 (Table 3-4). The 2007 total represented the highest number of taxa recorded in any year since monitoring began in 1987 (Duke Energy 2007). Fifteen taxa previously unrecorded during the Maintenance Monitoring program were identified during 2007.

Species Composition and Seasonal Succession

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

During February 2007, cryptophytes (Cryptophyceae) dominated densities at all locations (Table 3-5, 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 2007 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, and are often found deeper in the water column or near surface under low light conditions, which are common during winter (Lee 1989).

In May, diatoms (Bacillariophyceae) were dominant at all locations (Table 3-5, Figures 3-5 through 3-9). The most abundant diatom at all locations 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, 2004a, 2005; Duke Energy 2006, 2007).

During August 2007, 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 and was identified 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 drawdown, and shifts in nutrient inputs and concentrations (Duke Power 2000, 2001, 2002). Whatever the cause, the phenomenon was lake-wide and not localized near MNS or Marshall Steam Station (MSS), therefore, it was most likely due to a combination of environmental factors, and not station operations. Since 2002, taxonomic composition during the summer has shifted back to green algae predominance (Duke Power 2003, 2004a, 2005, Duke Energy 2006, 2007).

During November 2007, densities at all locations were again dominated by diatoms. The most abundant species at Locations 2.0, 11.0, and 15.9 was the pennate diatom, *Tabellaria fenestrata* (Table 3-5, Figures 3-5 through 3-9). At Locations 5.0 and 9.5, the most abundant diatom was the centrate, *Melosira ambigua.* These diatoms have been among the most common and abundant forms found in Lake Norman throughout the Lake Norman Maintenance Monitoring program.

Blue-green algae, which are often implicated in nuisance blooms, were never abundant in 2007 samples (Duke Energy 2007). Their overall contribution to phytoplankton densities was slightly higher than in 2006, but densities seldom exceeded 3% of totals. Prior to 1991, blue-green algae were often dominant at up-lake locations during the summer (Duke Power Company 1988, 1989, 1990, 1991, 1992).

FUTURE STUDIES

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

SUMMARY

Lake Norman continues to be classified as oligo-mesotrophic based on long-term, annual mean chlorophyll concentrations. Chlorophyll concentrations during 2007 were most often within historical ranges, however, several record low chlorophyll concentrations were recorded in November. Lake-wide mean chlorophyll increased from February through August then declined to the annual minimum in November. Some spatial variability was observed in 2007, however, maximum chlorophyll concentrations were typically observed up-lake at Location 69.0, while minimum chlorophyll concentrations were recorded from down-lake at Locations 2.0 through 9.5. The highest chlorophyll value recorded in 2007, 13.66 μg/L, was well below the NC State Water Quality standard of 40 μg/L.

Phytoplankton densities and biovolumes during 2007 were generally higher than in 2006. Phytoplankton densities during 2007 never exceeded the NC guidelines for algae blooms. Standing crop values in excess of bloom guidelines have been recorded during seven previous years of the program. As in past years, higher standing crops were usually observed at up-lake locations, while comparatively lower values were noted down-lake.

Seston dry and ash-free weights were most often lower in 2007 than in 2006 and down-lake to up-lake differences were apparent during all quarters. Maximum dry and ash-free weights were generally observed at Location 69.0. Minimum values were noted at Locations 2.0 through 9.5.

Secchi depths reflected suspended solids with shallow depths related to high dry weights. The lake-wide mean Secchi depth in 2007 was slightly higher than in 2006 and was within historical ranges recorded since 1992.

Diversity or the number of taxa of phytoplankton in 2007 was the highest yet recorded. The taxonomic composition of phytoplankton communities during 2007 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 2007 than during 2006, but their contribution to total densities seldom exceeded 3%.

The most abundant alga, on an annual basis, was the cryptophyte *R. minuta*. The most abundant diatom in May was *F. crotonensis,* while the most abundant diatoms during November were *T. fenestrata* and *M. ambigua.* The small desmid, *C. asphearosporum* var. *strigosum* was dominant in August 2007. All of these taxa have been common and abundant throughout the Lake Norman Maintenance Monitoring program.

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

Table 3-1. Mean chlorophyll *a* concentrations (µg/L) in composite samples and Secchi depths (m) observed in Lake Norman in 2007.

CHLOROPHYLL *A*

Location	FEB	MAY	AUG	NOV
2.0	2.91	2.94	4.47	2.07
5.0	2.94	3.04	3.60	2.18
8.0	3.58	3.11	4.77	1.96
9.5	2.80	3.26	5.02	2.35
11.0	3.78	3.98	5.35	3.32
13.0	3.94	4.41	4.10	3.43
15.9	4.61	5.46	7.70	3.86
69.0	6.19	10.46	13.66	5.59

SECCHI DEPTHS

Location	FEB	MAY	AUG	OCT*
2.0	2.10	3.20	2.90	2.36
5.0	2.25	2.90	2.40	1.82
8.0	2.60	3.70	2.71	2.26
9.5	2.40	3.10	2.70	2.44
11.0	1.30	2.10	2.35	2.48
13.0	1.10	1.90	1.25	1.50
15.9	1.32	1.20	2.80	1.63
69.0	1.20	1.20	1.10	1.26
Annual mean from all Locations: 2007				2.11
Annual mean from all Locations: 2006				1.94

*Secchi depths were not available for November.

Table 3-2. Mean phytoplankton densities (units/mL) and biovolumes (mm^3/m^3) by location and sample month from samples collected in Lake Norman, NC, during 2007.

Density

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	911	961	761	1,100	1,884	1,123
MAY	1,454	1,566	1,737	2,730	3,181	2,134
AUG	2,800	1,943	2,957	3,385	6,232	3,463
NOV	783	869	970	1,402	1,723	1,149

Biovolume

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	590	551	468	1,395	2,014	1,004
MAY	1,257	1,238	1,366	2,368	2,370	1,720
AUG	1,285	938	1,238	2,540	4,860	2,172
NOV	867	1,373	1,657	1,883	2,799	1,716

Table 3-3. Total mean seston dry and ash free dry weights (mg/L) from samples collected in Lake Norman, NC during 2007.

Dry weights

	Locations								
Month	2.0	5.0	8.0	9.5	11.0	13.0	15.9	69.0	Mean
FEB	0.97	0.99	1.02	0.94	1.46	1.35	1.61	2.37	1.34
MAY	0.58	0.76	0.82	1.01	1.28	0.96	1.01	2.75	1.15
AUG	1.29	1.11	1.23	1.29	1.19	1.87	2.01	2.46	1.55
NOV	1.40	1.48	1.17	1.57	1.81	1.85	1.58	2.78	1.70

Ash free dry weights

Month									
FEB	0.41	0.46	0.48	0.36	0.57	0.61	0.81	0.83	0.56
MAY	0.41	0.46	0.47	0.50	0.60	0.55	0.59	0.86	0.55
AUG	0.86	0.76	0.87	0.86	0.89	0.89	1.36	1.19	0.96
NOV	0.57	0.52	0.33	0.85	0.70	0.65	0.67	1.01	0.66

Table 3-4. Phytoplankton taxa identified in quarterly samples collected in Lake Norman each year from 1992 to 2007.

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
CLASS: CHLOROPHYCEAE																
Acanthosphaera zachariasi Lemm.		X														
Actidesmium hookeri Reinsch		X														
Actinastrum hantzchii Lagerheim	X	X	X								X					
Ankistrodesmus braunii (Naegeli) Brunn				X	X	X	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	X
A. fusiformis Corda sensu Korsch.	X	X	X													
A. nannoselene Skuja									X							
A. spiralis (Turner) Lemm.		X				X										
A. spp. Corda		X														
Arthrodesmus convergens Ehrenberg				X							X	X		X	X	X
A. incus (Breb.) Hassall				X			X			X	X	X	X	X	X	X
A. octocornis Ehrenberg											X	X	X	X		X
A. ralfsii W. West													X	X	X	
A. subulatus Kutzing					X	X	X		X	X	X	X	X	X	X	X
A. validus v. *increassalatus* Scott & Gron.													X			
A. spp. Ehrenberg		X	X													
Asterococcus limneticus G. M. Smith	X	X	X					X			X	X		X	X	X
A. superbus (Cienk.) Scherffel													X			X
Botryococcus braunii Kutzing	X															
Carteria frtzschii Takeda									X			X	X	X	X	X
C. globosa Korsch											X		X		X	
C. spp. Diesing	X	X				X						X				
Characium ambiguum Hermann														X		
C. limneticum Lemmerman												X				
C. spp. Braun [1]																
Chlamydomonas spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chlorella vulgaris Beyerink						X								X	X	
Chlorogonium euchlorum Ehrenberg					X	X			X				X	X	X	X
C. spirale Scherffel & Pascher			X	X									X	X	X	X
Closteriopsis longissima W. & West	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Closterium acutum Breb.															X	X
C. cornu Ehrenberg								X			X					
C. gracile Brebisson					X											X
C. incurvum Brebisson			X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. parvulum Nageli														X		
C. tumidum Johnson									X							
C. spp. Nitzsch		X														
Coccomonas orbicularis Stein							X				X		X	X	X	X
Coelastrum cambricum Archer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. microporum Nageli				X	X		X		X			X		X	X	X
C. proboscideum Bohlin [1]																
C. reticulatum (Dang.) Sinn.								X							X	X
C. sphaericum Nageli			X		X			X	X	X	X	X	X	X	X	X
C. spp. Nageli [1]																
Cosmarium angulosum v. *concin.* (Rab) W&W									X		X		X	X		
C. asphaerosporum v. *strigosum* Nord.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
C. contractum Kirchner			X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. moniliforme (Turp.) Ralfs									X			X		X	X	X
C. notabile Brebisson											X					
C. phaseolus f. *minor* Boldt.					X	X		X		X				X	X	X
C. pokornyanum (Grun.) W. & G.S. West							X				X			X		X
C. polygonum (Nag.) Archer				X	X	X	X	X	X	X	X	X	X	X	X	X
C. raciborskii Lagerheim											X			X	X	X
C. regnellii Wille		X			X	X	X	X	X	X	X	X	X	X	X	X
C. regnesi Schmidle	X	X									X					
C. subreniforme Nordstedt											X			X		X
C. subprotumidum Nordst.															X	
C. tenue Archer				X	X	X	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	X	X	X
C. tinctum v. *subretusum* Messik.									X							
C. tinctum v. *tumidum* Borge.						X		X	X	X	X	X	X	X	X	X
C. trilobatum v. *depressum* Printz											X					
C. tumidum Borge											X					
C. spp. Corda	X	X	X													
Crucigenia apiculata (Lemm.) Schmidl											X	X			X	X
C. crucifera (Wolle) Collins				X	X	X	X	X	X	X	X	X	X	X	X	X
C. fenestrata Schmidle											X	X	X	X	X	X
C. irregularis Wille	X	X	X		X		X		X		X	X	X	X	X	
C. quadrata Morren																X
C. rectangularis (A. Braun) Gay							X								X	
C. tetrapedia (Kirch.) West & West	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dictyospaerium ehrenbergianum Nageli									X		X	X	X	X	X	X
D. pulchellum Wood	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dimorphococcus spp. Braun[1]																
Elakatothrix gelatinosa Wille	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Errerella bornheimiensis Conrad											X	X		X	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	X	X	X
E. elegans Kutzing												X				
E. spp. Ehrenberg	X	X														X
Eudorina elegans Ehrenberg					X						X	X		X	X	
Franceia droescheri (Lemm.) G. M. Sm.				X	X	X	X	X	X	X	X	X	X	X	X	X
F. ovalis (France) Lemm.	X	X	X						X		X	X	X	X	X	X
F. tuberculata G. M. Smith												X				
Gloeocystis botryoides (Kutz.) Nageli									X			X	X		X	X
G. gigas Kutzing					X	X	X	X	X	X	X	X	X	X	X	X
G. major Gerneck *ex.* Lemmermann							X								X	
G. planktonica (West & West) Lemm.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
G. vesciculosa Naegeli							X				X	X	X	X	X	X
G. spp. Nageli	X	X	X													
Golenkinia paucispina West & West											X	X	X	X	X	X
G. radiata Chodat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gonium pectorale Mueller							X				X			X	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
G. sociale (Duj.) Warming				X			X	X			X	X	X	X	X	X
Kirchneriella contorta (Schmidle) Bohlin	X	X	X				X				X	X			X	
K. elongata G.M. Smith									X			X				X
K. lunaris (Kirch.) Mobius												X	X			
K. lunaris v. *dianae* Bohlin						X			X		X	X	X	X	X	X
K. lunaris v. *irregularis* G.M. Smith									X			X				
K. obesa W. West	X	X	X												X	
K. subsolitaria G. S. West				X	X	X	X	X	X		X	X	X	X	X	X
K. spp. Schmidle				X	X	X					X			X	X	
Lagerheimia ciliata (Lagerheim) Chodat											X				X	
L. citriformis (Snow) G. M. Smith						X								X	X	
L. longiseta (Lemmermann) Printz											X	X	X	X		X
L. quadriseta (Lemm.) G. M. Smith	X															
L. subsala Lemmerman	X	X	X		X	X	X		X		X	X	X	X	X	X
Mesostigma viride Lauterborne				X	X	X	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	X
Monoraphidium contortum Thuret	X	X	X													
M. pusillum Printz	X	X	X													
Mougeitia elegantula Whittrock				X	X	X	X	X	X	X	X	X	X	X	X	X
M. spp. Agardh	X	X	X													X
Nephrocytium agardhianum Nageli											X	X	X	X	X	X
N. ecdysiscepanum W. West															X	
N. limneticum (G.M. Smith) G.M. Smith								X			X		X		X	X
N. obesum West & West															X	
Oocystis borgii Snow							X	X	X		X	X		X	X	X
O. ellyptica W. West							X				X	X	X			X
O. lacustris Chodat												X	X	X		X
O. parva West & West				X	X	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	X	X
O. pyriformis Prescott							X				X					
O. solitaria Wittrock												X			X	
O. submarina Lagerheim															X	
O. spp. Nageli[1]																
Pandorina charkowiensis Kprshikov														X	X	
P. morum Bory	X	X										X		X	X	X
Pediastrum biradiatum Meyen														X	X	X
P. duplex Meyen		X		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	X	X	X
P. tetras v. *tetroadon* (Corda) Rabenhorst	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Meyen [1]																
Planktosphaeria gelatinosa G. M. Smith				X							X		X	X		X
Quadrigula closterioides (Bohlin) Printz					X	X				X	X	X	X	X	X	X
Q. lacustris (Chodat) G. M. Smith											X	X	X	X	X	X
Scenedesmus abundans (Kirchner) Chodat												X		X	X	
S. abundans v. *asymetrica* (Schr.) G. Sm.	X	X	X		X	X			X		X	X	X		X	X
S. abundans v. *brevicauda* G. M. Smith				X								X	X			X
S. abundans v. *longicauda* G.M. Smith																X
S. acuminatus (Lagerheim) Chodat	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
S. armatus v. *bicaudatus* (Gug.-Pr..)Chod	X	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	X	X
S. bijuga v. *alterans* (Reinsch) Hansg.													X		X	
S. brasiliensis Bohlin				X	X	X	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	X
S. denticulatus v. *recurvatus* Schumacher												X	X	X	X	X
S. dimorphus (Turp.) Kutzing	X	X	X			X	X	X	X		X	X	X	X	X	X
S. incrassulatus G. M. Smith [1]																
S. opoliensis P. Richter														X		
S. parisiensis Chodat												X		X		
S. quadricauda (Turp.) Brebisson	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. smithii Teiling					X						X	X		X	X	
S. serratus (Corda) Bohlin													X			
S. spp. Meyen	X	X	X													
Schizochlamys compacta Prescott					X		X		X		X		X	X		X
S. gelatinosa A. Braun									X		X		X	X	X	X
Schoederia setigera (Schroed.) Lemm.											X					
Selenastrum bibraianum Reinsch															X	X
S. gracile Reinsch					X						X				X	X
S. minutum (Nageli) Collins	X	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	X	X	X
Sorastrum americanum (Bohlin) Schm.						X									X	
Sphaerocystis schoeteri Chodat				X			X	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	X	X	X
S. apiculatum Brebisson						X	X	X	X	X	X	X	X	X	X	X
S. aspinosum v. *annulatum* W.& G.S.Wst.																X
S. brachiatum Ralfs						X	X	X			X	X	X	X	X	X
S. brevispinum Brebisson							X									
S. chaetocerus (Schoed.) G. M. Smith	X	X	X													
S. capitulum Brebisson															X	
S. curvatum W. West	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. curvatum v. *elongatum* G.M. Smith																X
S. cuspidatum Brebisson						X	X	X	X	X	X	X	X	X	X	X
S. dejectum Brebisson	X		X						X				X			X
S. dickeii v. *maximum* West & West [1]															X	
S. dickeii v. *rhomboidium* W.& G.S. West											X					
S. gladiosum Turner		X														
S. leptocladum Nordstedt														X		
S. leptocladum v. *sinuatum* Wolle [1]																
S. manfeldtii v. *fluminense* Schumacher			X	X		X	X		X		X	X	X	X	X	X
S. megacanthum Lundell		X	X									X	X	X	X	
S. ophiura v. *cambricum* (Lund) W. & W.									X					X		
S. orbiculare Ralfs			X								X					
S. paradoxum Meyen	X	X	X				X	X					X	X	X	X
S. paradoxum v. *cingulum* W. & W.													X	X	X	X
S. paradoxum v. *parvum* W. West							X				X	X	X	X	X	X
S. pentacerum (Wolle) G. M. Smith											X			X	X	
S. subcruciatum Cook & Wille				X		X	X	X	X		X	X	X	X	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
S. tetracerum Ralfs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. turgescens de Not.														X		X
S. vestitum Ralfs											X	X				X
S. spp. Meyen	X		X													
Stichococcus scopulinus Hazen											X					
S. spp. Nageli																X
Stigeoclonium spp. Kutzing										X						X
Tetraedron arthrodesmiforme (W.) Wol.											X	X		X	X	
T. bifurcatum v. *minor* Prescott					X											
T. caudatum (Corda) Hansgirg	X		X		X	X	X	X	X	X	X	X	X	X	X	X
T. limneticum Borge	X															X
T. lobulatum (Naegeli) Hansgirg									X							
T. lobulatum v. *crassum* Prescott		X											X			X
T. minmum (Braun) Hansgirg			X	X	X		X	X	X	X	X	X	X	X	X	X
T. muticum (Braun) Hansgirg	X	X	X	X	X		X									
T. obesum (W & W) Wille *ex* Brunnthaler					X											
T. pentaedricum West & West			X											X	X	X
T. planktonicum G. M. Smith							X		X		X	X	X	X	X	X
T. regulare Kutzing	X	X	X												X	
T. regulare v. *bifurcatum* Wille							X									
T. regulare v. *incus* Teiling		X													X	
T. trigonum (Nageli) Hansgirg		X			X	X	X		X	X	X	X	X	X	X	X
T. trigonum v. *gracile* (Reinsch) DeToni	X				X				X				X		X	
T. spp. Kutzing		X														
Tetrallantos lagerheimii Teiling										X		X	X			X
Tetraspora lamellose 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	X
Westella botryoides (W. & W.) Wilde.							X		X				X	X	X	X
W. linearis G. M. Smith							X		X			X	X	X	X	X
Xanthidium antiloparium v. *floridense* Sc & Gron.															X	
X. cristatatum v. *uncinatum* Breb.											X		X	X	X	X
X. spp. Ehrenberg			X								X					
CLASS: BACILLARIOPHYCEAE																
Achnanthes lanceolata Brebisson											X			X		
A. microcephala Kutzing				X	X	X	X	X	X	X	X	X	X	X	X	X
A. spp. Bory	X	X	X		X								X			
Amphiprora ornate Bailey											X					
Amphora ovalis Kutzing															X	
Anomoeoneis vitrea (Grunow) Ross			X	X	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	X
Attheya zachariasi J. Brun		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cocconeis placentula Ehrenberg							X	X				X				X
C. spp. Ehrenberg			X													
Cyclotella comta (Ehrenberg) Kutzing			X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
C. glomerata Bachmann				X	X	X	X	X				X	X	X	X	X
C. meneghiniana Kutzing			X	X	X	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	X
C. spp. Kutzing[1]																
Cymbella affinis Kutzing									X			X				
C. gracilis (Rabenhorst) Cleve												X	X			
C. minuta (Bliesch & Rabn.) Reim.	X	X		X	X		X	X			X	X	X	X	X	X
C. naviculiformis Auersw. *ex* Heib.																X
C. tumida (Brebison) van Huerck			X													
C. turgida (Gregory) Cleve [1]																
C. spp. Agardh [1]																
Denticula elegans Kutzing											X		X			X
D. thermalis Kutzing							X				X			X		
Diploneis ellyptica (Kutzing) Cleve													X			
D. marginestriata Hustedt																X
D. ovalis (Hilse) Cleve													X			
D. puella (Schum.) Cleve													X			
D. spp. Ehrenberg[1]																
Eunotia flexuosa v. *eurycephala* Grun.									X							
E. zasuminensis (Cab.) Koerner	X	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	X
F. construens (Ehrenberg) Grunow													X			
Frustulia rhomboides (Ehr.) de Toni[1]																
F. rhomboides v. *saxonica* (Rabh.) de T.												X				
Gomphonema angustatum (Kutz.) Rabh.											X					
G. gracile (Her.) Van Huerk																X
G. parvulum Kutz.											X	X			X	X
G. spp. Agardh			X													
Melosira ambigua (Grunow) O. Muller	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. distans (Ehrenberg) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. granulata (Ehrenberg) 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	X
M. italica (Ehrenberg) Kutzing [1]																
M. italica v. *tennuissima* (Grun.) O.Mull															X	
M. varians Agardh	X	X					X							X	X	X
M. spp. Agardh	X	X	X		X			X		X	X	X	X	X	X	X
Meridion circulare Agardh											X					
Navicula cryptocephala Kutzing					X	X					X					
N. exigua (Gregory) O. Muller				X							X		X			
N. exigua v. *capitata* Patrick					X											X
N. radiosa Kutzing												X		X		
N. radiosa v. *tenella* (Breb.) Grun.												X	X		X	X
N. subtilissima Cleve				X					X			X		X	X	X
N. spp. Bory	X	X	X										X			
Nitzschia acicularis W. Smith	X	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	X
N. communis Rabenhorst															X	

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
N. holsatica Hustedt				X		X	X	X	X	X	X	X	X	X	X	X
N. kutzingiana Hilse													X	X		X
N. linearis W. Smith									X					X		X
N. palea (Kutzing) W. Smith			X	X	X	X	X				X		X	X	X	X
N. sublinearis Hustedt					X		X			X	X				X	
N. spp. Hassall	X	X	X								X			X		X
Pinnularia biceps Gregory														X		
P. mesolepta (Her.) W. Smith																X
P. spp. Ehrenberg		X									X			X		X
Rhizosolenia spp. Ehrenberg	X	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		X	X	X
Stephanodiscus astraea (Her.) Grunow														X		X
S. spp. Ehrenberg	X	X	X	X	X	X	X					X	X	X	X	X
Surirella angustata Kutz.												X				
S. linearis v. *constricta* (Her.) Gr.							X									X
S .tenuis Mayer														X		
Synedra actinastroides Lemmerman			X													
S. acus Kutzing		X	X			X	X		X		X	X	X	X	X	X
S. amphicephala Kutzing															X	X
S. delicatissima Lewis	X	X	X													
S. filiformis v. *exilis* Cleve-Euler							X		X	X	X	X	X	X	X	X
S. planktonica Ehrenberg	X	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	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	X	X
S. spp. Ehrenberg	X	X	X													
Tabellaria fenestrata (Lyngb) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. flocculosa (Roth.) Kutzing			X						X				X			X
CLASS: CHRYSOPHYCEAE																
Aulomonas purdyii Lackey		X	X	X	X	X	X	X		X	X		X	X	X	X
Bicoeca petiolatum (Stien) Pringsheim					X	X										
Calycomonas pascheri (Van Goor) Lund				X					X			X				
Centritractus belanophorus Lemm.														X		
Chromulina nebulosa Pascher															X	
C. spp. Chien.							X				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	X	X
Codomonas annulata Lackey					X	X	X	X	X	X		X	X	X	X	X
Dinobryon acuminatum Ruttner																X
D. bavaricum Imhof	X	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	X
D. divergens Imhof	X	X	X	X	X			X			X	X	X	X	X	X
D. pediforme (Lemm.) Syein.															X	
D. sertularia Ehrenberg				X					X		X	X	X	X	X	
D. spp. Ehrenberg				X	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	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
Kephyrion campanuliforme Conrad												X				
K. littorale Lund							X				X	X	X	X	X	X
K. petasatum Conrad												X				
K. rubi-claustri Conrad											X	X	X	X	X	X
K. skujae Ettl [1]																
K. valkanovii Conrad														X	X	
K. spp. Pascher	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mallomonas acaroides Perty			X											X	X	X
M. akrokomos (Naumann) Krieger							X	X	X			X		X	X	X
M. allantoides Perty															X	
M. allorgii (Defl.) Conrad												X				
M. alpina Pascher							X		X							
M. caudata Conrad	X	X	X	X				X	X	X	X	X		X	X	X
M. globosa Schiller							X		X	X	X	X	X	X	X	X
M. producta Iwanoff									X		X	X		X		X
M. pseudocoronata Prescott	X	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	X
M. spp. Perty	X	X	X						X							X
Ochromonas granularis Doflein							X	X	X	X	X	X	X	X	X	X
O. mutabilis Klebs									X						X	X
O. spp. Wyss			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pseudokephyrion concinum (Schill.) Sch.														X		
P. schilleri Conrad							X	X		X	X	X		X		
P. tintinabulum Conrad							X									
P. spp. Pascher												X		X	X	
Rhizochrisis polymorpha Naumann								X	X	X	X	X	X	X	X	X
R. spp. Pascher [1]																
Salpingoeca frequentissima (Zach.) Lem.							X	X	X			X		X		
Stelexomonas dichotoma Lackey	X	X	X	X	X	X	X		X		X	X		X	X	X
Stokesiella epipyxis Pascher						X	X	X							X	
Synura sphagnicola Korschikov													X			
S. spinosa Korschikov				X	X	X	X	X	X	X	X	X	X	X	X	X
S. uvella Ehrenberg		X	X							X					X	
S. spp. Ehrenberg	X	X	X													
Uroglenopsis americana (Caulk.) Lemm.				X	X	X		X								
CLASS: HAPTOPHYCEAE																
Chrysochromulina parva Lackey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: XANTHOPHYCEAE																
Characiopsis acuta Pascher											X			X	X	X
C. cylindrica (Lambert) Lemm.																X
C. dubia Pascher				X	X		X	X	X	X	X	X	X	X	X	X
Dichotomococcus curvata Korschikov [1]																
Ophiocytium capitatum v. *longisp.* (M) L.		X	X									X	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	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
C. erosa v. *reflexa* Marsson							X	X	X	X	X	X	X	X	X	X
C. gracilia Skuja									X							
C. marsonii Skuja	X	X	X									X				X
C. obovata Skuja												X		X	X	
C. ovata Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. phaseolus Skuja	X	X	X													
C. reflexa Skuja	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Ehrenberg	X	X	X													X
Rhodomonas minuta Skuja	X	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	X	X	X
A. thermale Drouet and Daily												X				
Anabaena catenula (Kutzing) Born.						X	X									
A. inaequalis (Kutzing) Born.									X							X
A. scheremetievi Elenkin						X	X	X		X					X	X
A. wisconsinense Prescott				X	X	X	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						
A. spp. Meneghini [1]																
Chroococcus dispersus (Keissl.) Lemm.							X		X							X
C. giganteous W. West															X	
C. limneticus Lemmermann						X	X	X	X	X	X	X		X	X	X
C. minor Kutzing											X	X		X	X	X
C. turgidus (Kutz.) Lemmermann		X														
C. spp. Nageli	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coelosphaerium kuetzingiana Nageli																
C. neagleanum Unger															X	X
Dactylococcopsis irregularis Hansgirg			X									X	X	X		X
D. musicola Hustedt																X
D. raphidiopsis Hansgirg																X
D. rupestris Hansgirg									X							
D. smithii Chodat and Chodat						X	X		X			X	X	X	X	X
D. spp. Hansgirg									X							
Gomphospaeria lacustris Chodat	X	X	X											X		
Lyngbya contorta Lemmermann	X															
L. limnetica Lemmermann	X	X	X													
L. ochracea (Kutzing) Thuret									X		X		X	X		
L. subtilis W. West	X		X													
L. tenue Agardh													X			
L. spp. Agardh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Merismopedia tenuissima Lemmermann							X									
Microcystis aeruginosa Kutzing	X	X	X	X	X		X	X	X	X			X	X	X	X
Oscillatoria amoena (Kutz.) Gomont													X			
O. amphibia Agardh											X	X	X		X	X
O. geminata Meneghini				X	X	X	X	X	X	X	X	X	X	X	X	X
O. limnetica Lemmermann				X	X	X	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	X	X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
O. spp. Vaucher			X							X		X				X
Phormidium angustissimum West & West			X													
P. spp. Kutzing		X	X													
Raphidiopsis curvata Fritsch & Rich	X		X	X	X	X	X	X	X		X		X			X
R. mediterranea Skuja								X								
R. spp. Fritsch & Rich																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			
CLASS: EUGLENOPHYCEAE																
Euglena acus Ehrenberg								X					X	X		
E. deses Ehrenberg														X	X	
E. minuta Prescott									X		X		X	X		X
E. polymorpha Dangeard					X					X	X		X	X		
E. proxima Dangeard												X	X	X	X	
E. spp. Ehrenberg		X	X	X	X		X	X		X			X	X	X	X
Lepocinclus acicularis France															X	
L. acuta Prescott													X			
L. glabra Drezepolski												X				
L. ovum. (Ehr.) Lemm.									X				X			X
L. spp. Perty							X									
Phacus cuvicauda Swirenko									X							
P. longicauda (Her.) Dujardin									X							X
P. orbicularis Hubner	X													X		
P. tortus (Lemm.) Skvortzow	X															
P. triquter Playfair													X			
P. spp. Dujardin 1																
Trachelomonas abrupta (Swir.) Deflandre															X	
T. abrupta v. *minor* Deflan.														X	X	
T. acanthostoma (Stk.) Defl.										X			X	X	X	X
T. ensifera Daday												X				X
T. hispida (Perty) Stein		X		X				X		X	X	X	X	X		X
T. lemmermanii v. *acuminata* Deflandre														X		X
T. pulcherrima Playfair 1																
T. pulcherrima v. *minor* Playfair													X			
T. varians (Lemm.) Deflandre																X
T. volvocina Ehrenberg				X				X		X		X	X	X		X
T. spp. Ehrenberg			X													
CLASS: DINOPHYCEAE																
Ceratium hirundinella (OFM) Schrank	X		X	X		X	X	X	X							
C. hirundinella v. *brachyceras* (Day.) Est.														X		
Glenodinium borgei (Lemm.) Schiller					X											
G. gymnodinium Penard	X	X				X							X		X	X
G. palustre (Lemm.) Schiller																X
G. penardiforme (Linde.) Schiller								X	X				X		X	X
G. quadridens (Stein) Schiller			X												X	X

Table 3-4. (Continued).

TAXON	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
G. spp. (Ehrenberg) Stein			X													
Gymnodinium aeruginosum Stein							X	X	X			X	X	X		X
G. spp. (Stein) Kofoid & Swezy	X	X	X	X		X	X		X	X	X	X	X	X	X	X
Peridinium aciculiferum Lemmermann [1]																
P. cinctum (Muller) Ehrenberg											X				X	
P. inconspicuum Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. intermedium Playfair							X	X	X	X	X	X	X	X	X	X
P. limbatum (Stokes) Lemm.														X		X
P. pusillum (Lenard) Lemmermann	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
P. umbonatum Stein	X	X	X													
P. willei Huitfeld-Kass													X	X	X	
P. wisconsinense Eddy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Ehrenberg	X	X	X													
CLASS: CHLOROMONADOPHYCEAE																
Gonyostomum depresseum Lauterborne				X			X	X			X	X	X	X	X	X
G. spp. Diesing			X													

1 = taxa found during 1987 - 91 only

Table 3-5. Dominant classes, their most abundant species, and their percent composition (in parentheses) at Lake Norman locations during each sampling period of 2007.

LOCATION	FEBRUARY	MAY
2.0	Cryptophyceae (51.7) *Rhodomonas minuta* (45.5)	Bacillariophyceae (77.8) *Fragillaria crotonensis* (42.7)
5.0	Cryptophyceae (52.4) *R. minuta* (48.2)	Bacillariophyceae (63.9) *F. crotonensis* (39.8)
9.5	Cryptophyceae (47.1) *R. minuta* (44.0)	Bacillariophyceae (65.7) *F. crotonensis* (39.9)
11.0	Cryptophyceae (64.6) *R. minuta* (49.0)	Bacillariophyceae (70.4) *F. crotonensis* (34.6)
15.9	Cryptophyceae (64.9) *R. minuta* (45.7)	Bacillariophyceae (64.9) *F. crotonensis* (22.2)
LOCATION	AUGUST	NOVEMBER
2.0	Chlorophyceae (52.2) *Cosmarium asphearosporum* variety *strigosum* (28.5)	Bacillariophyceae (52.7) *Tabellaria fenestrata* (12.3)
5.0	Chlorophyceae (62.7) *C. asphear.* var. *strig.* (34.2)	Bacillariophyceae (65.2) *Melosira ambigua* (28.8)
9.5	Chlorophyceae (61.1) *C. asphear.* var. *strig.* (32.4)	Bacillariophyceae (69.6) *M. ambigua* (28.9)
11.0	Chlorophyceae (59.9) *C. asphear.* var. *strig.* (30.7)	Bacillariophyceae (54.0) *T. fenestrata* (36.0)
15.9	Chlorophyceae (44.2) *C. asphear.* var. *strig.* (24.3)	Bacillariophyceae (55.6) *T. fenestrata* (29.8)

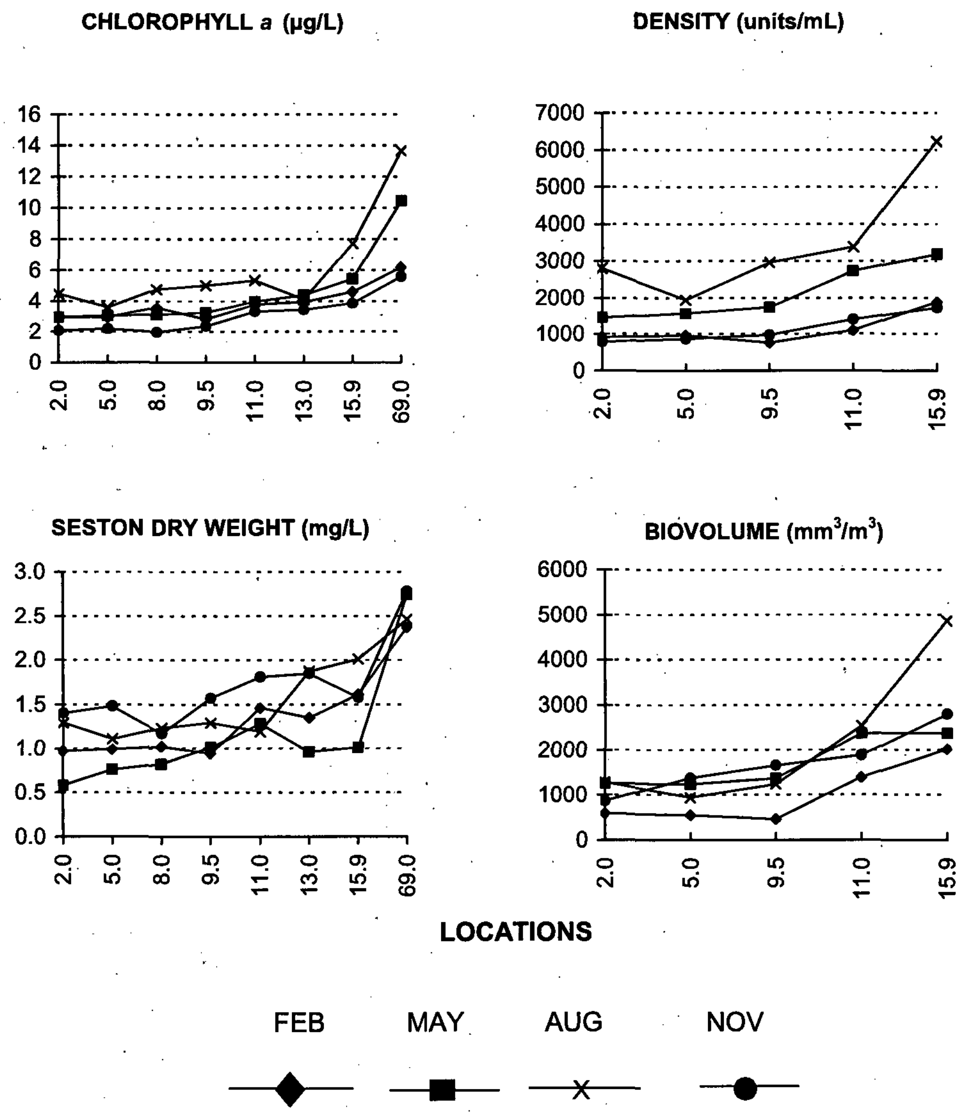


Figure 3-1. Phytoplankton chlorophyll *a*, densities, biovolumes, and seston weights at locations in Lake Norman, NC in February, May, August, and November 2007.

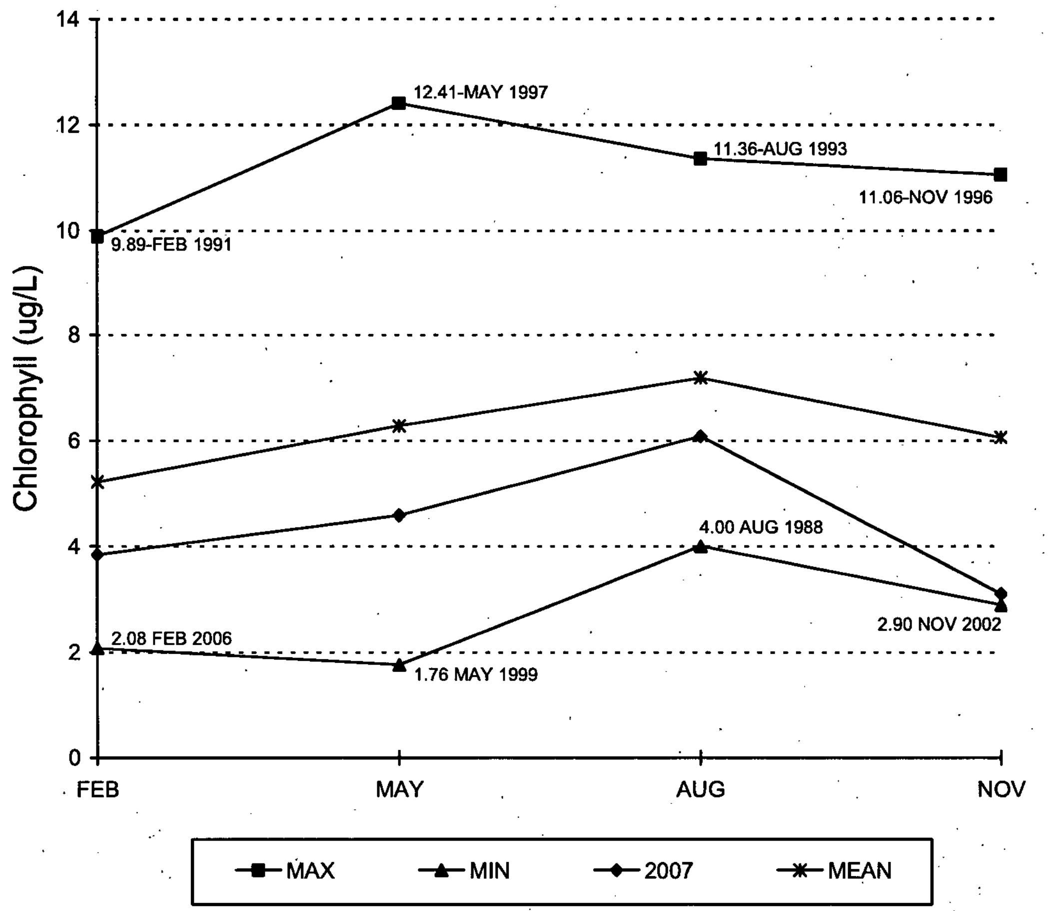


Figure 3-2. Lake Norman phytoplankton chlorophyll *a* seasonal maximum and minimum lake wide means since August 1987 compared with the long term seasonal lake wide means and lake wide means for 2007.

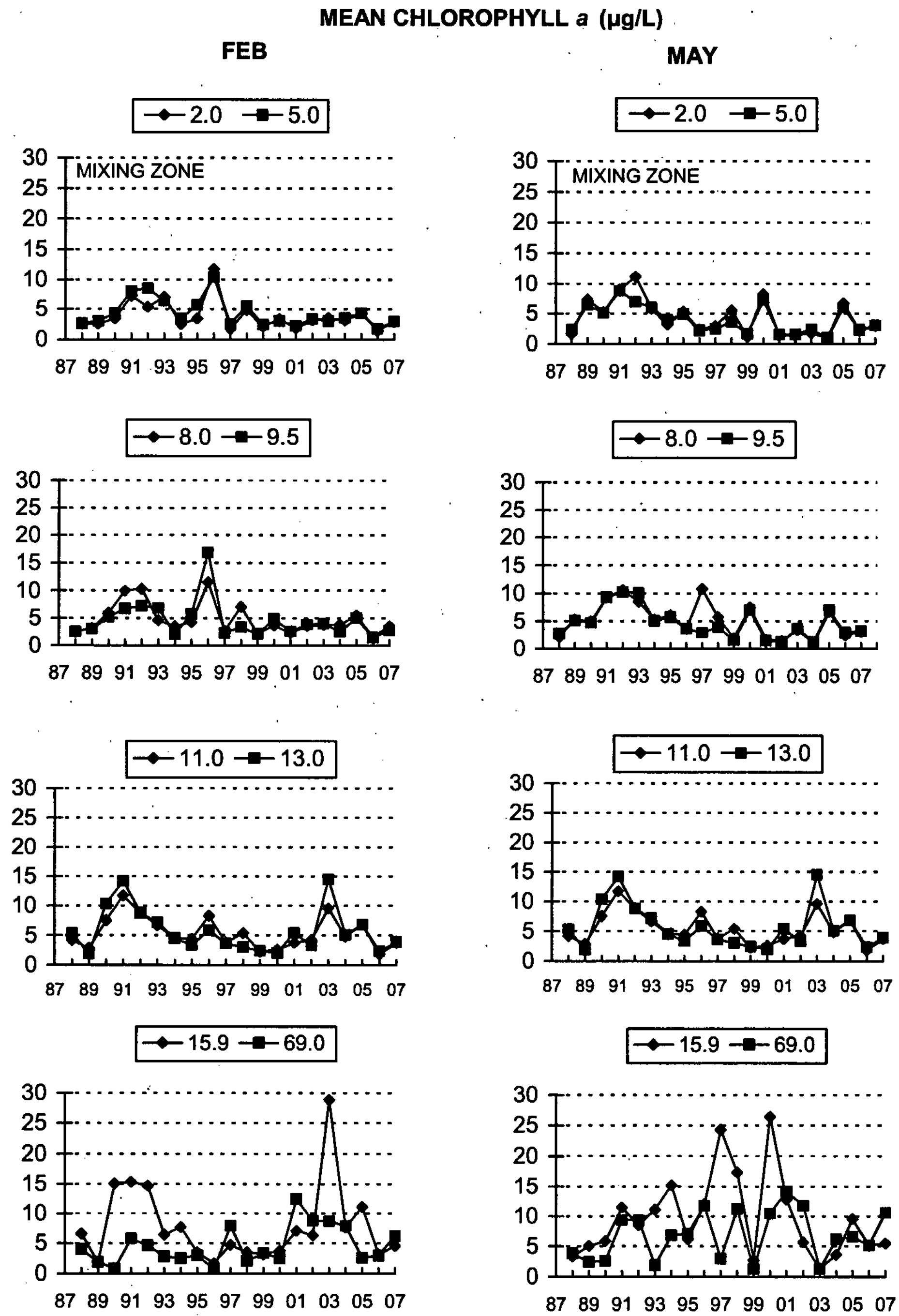


Figure 3-3. Phytoplankton mean chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from February and May 1988 – 2007.

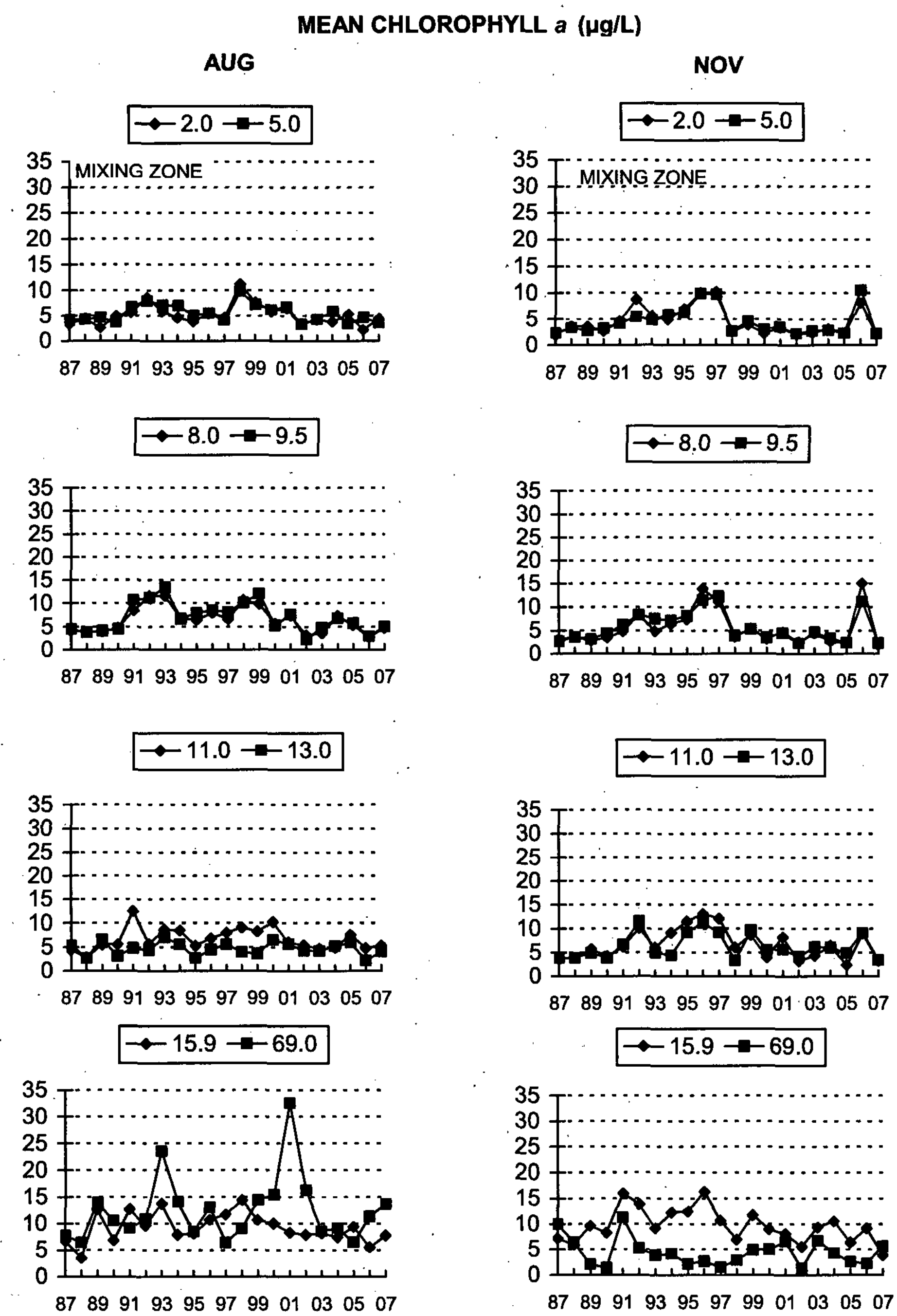


Figure 3-4. Phytoplankton mean chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from August and November 1987 – 2007.

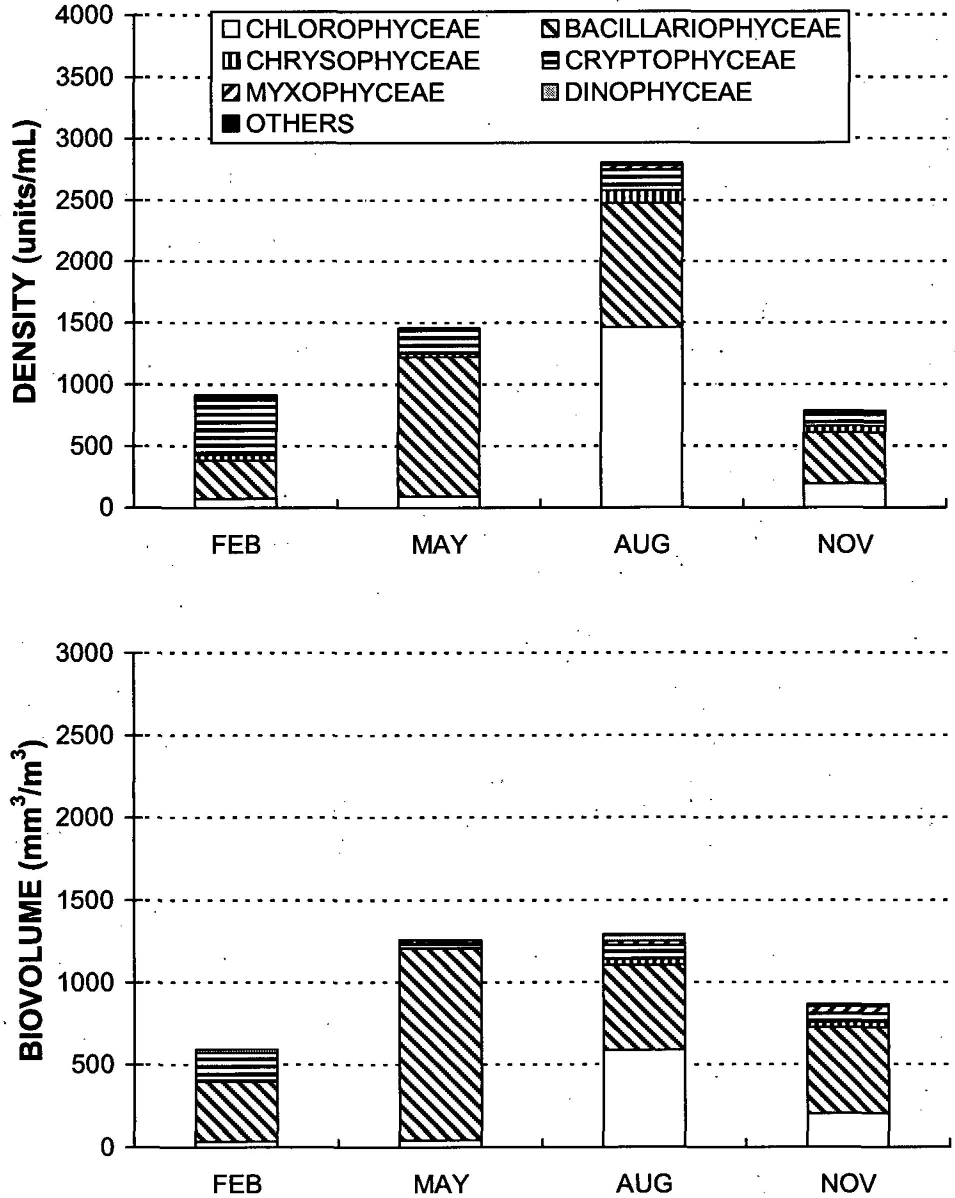


Figure 3-5. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 2.0 in Lake Norman, NC, during 2007.

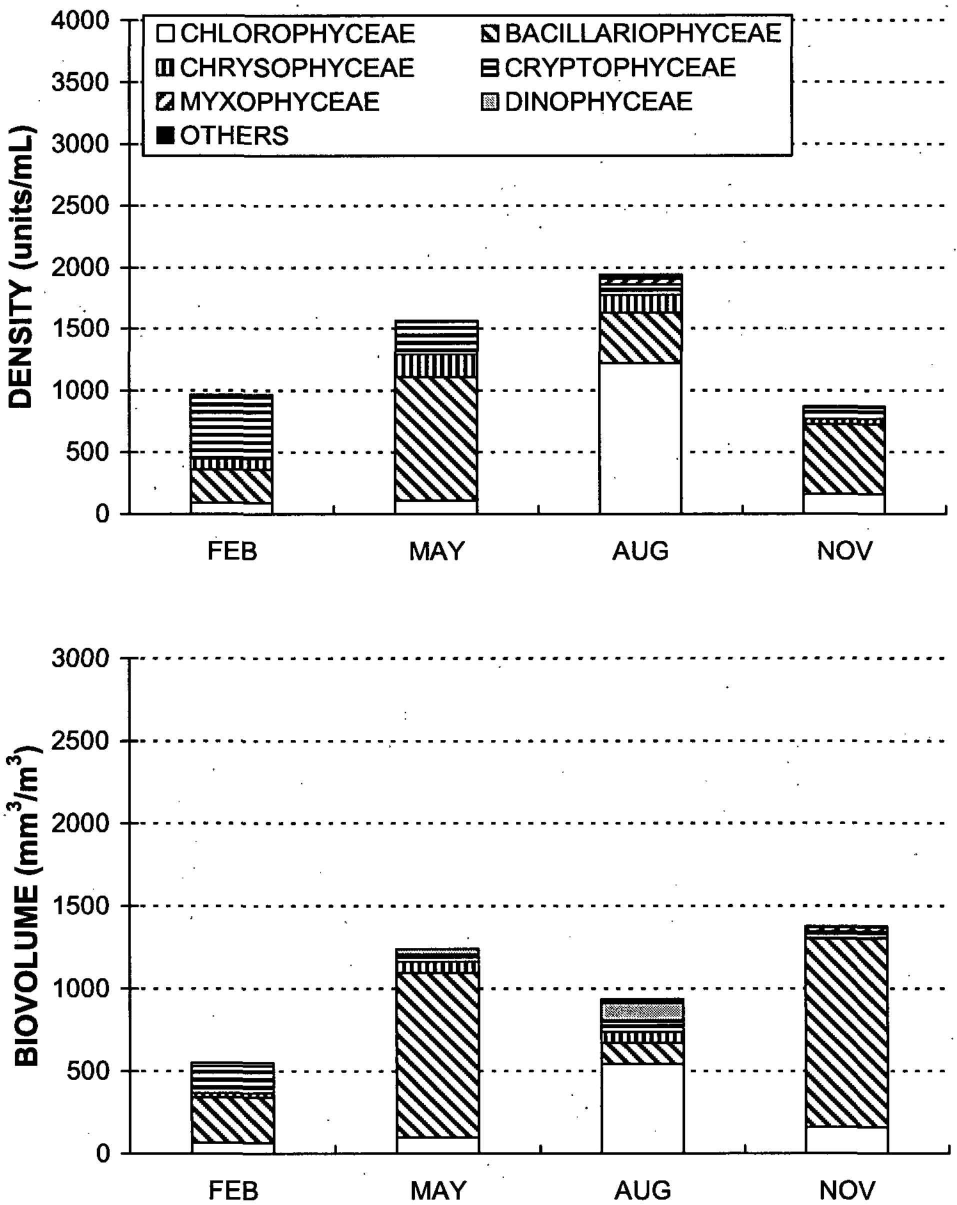


Figure 3-6. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 5.0 in Lake Norman, NC during 2007.

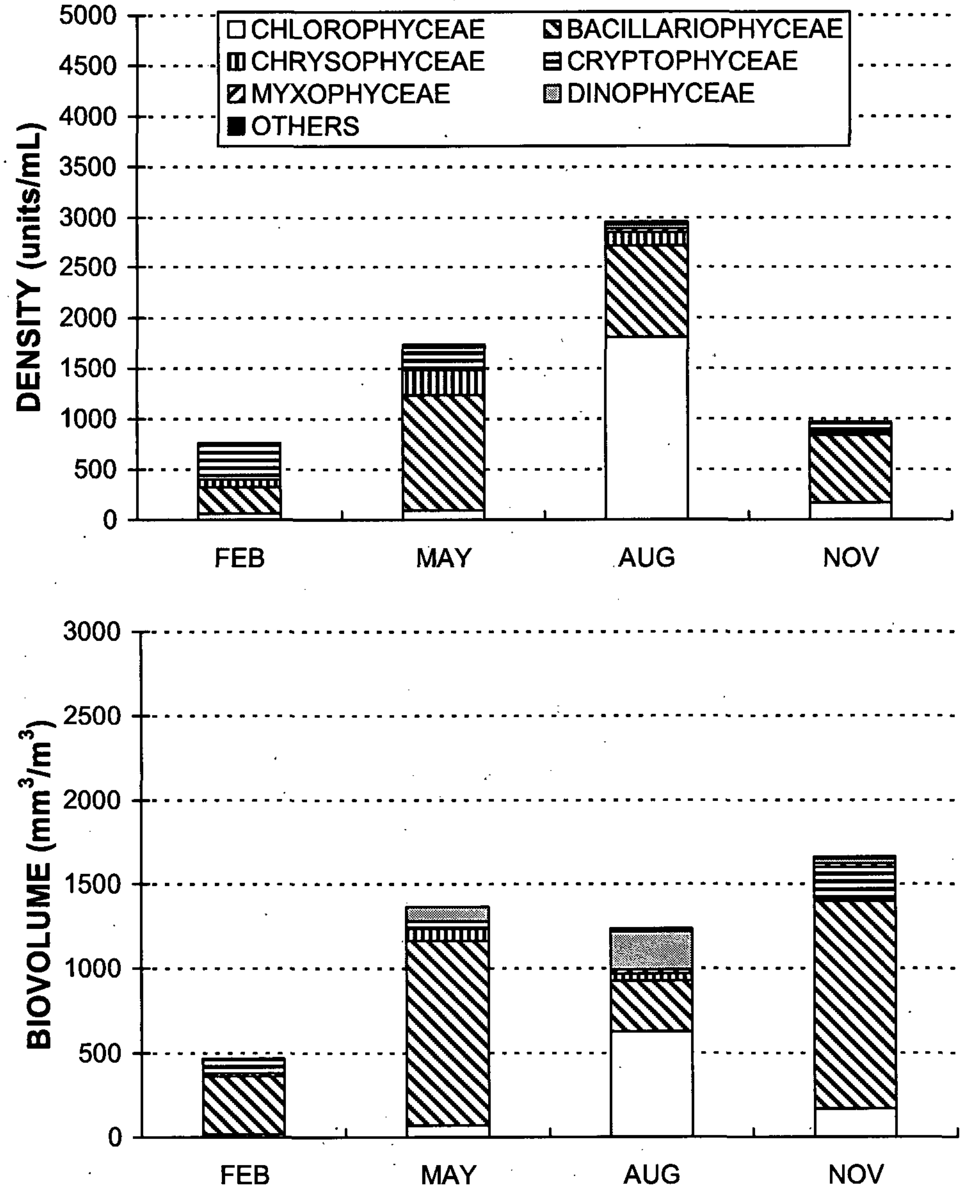


Figure 3-7. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC during 2007.

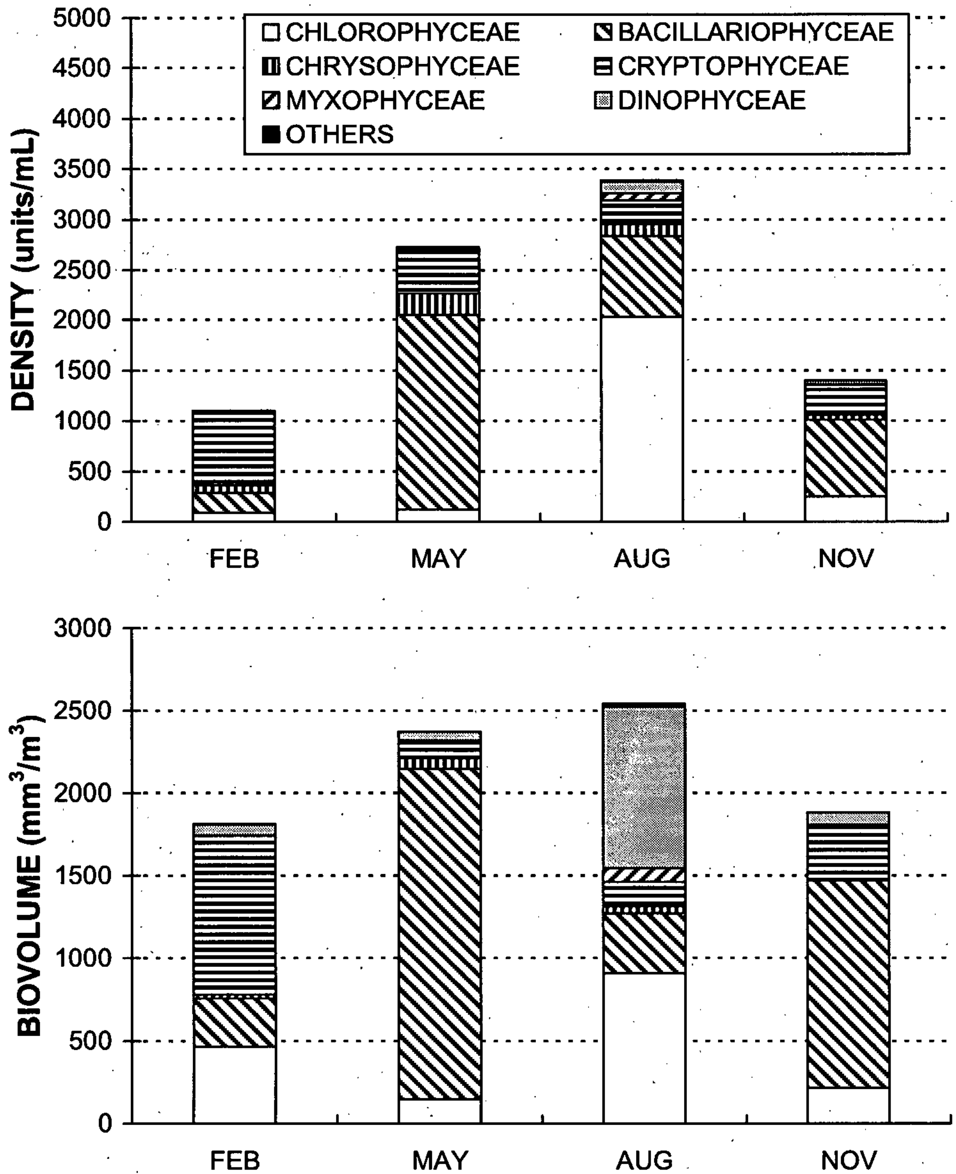


Figure 3-8. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC during 2007.

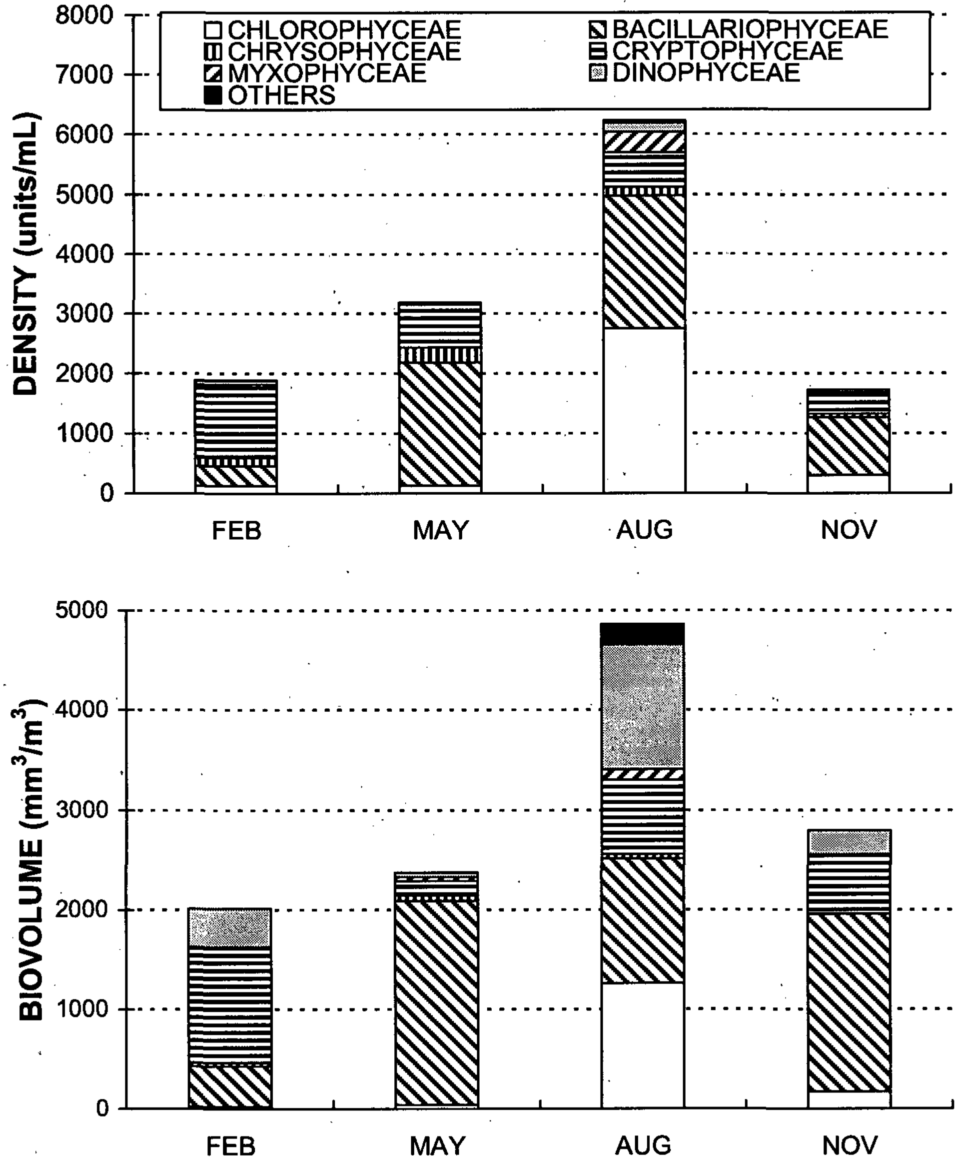


Figure 3-9. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC during 2007.

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, where possible, zooplankton data collected during 2007 with historical data collected during the period 1987 – 2006.

Previous studies of Lake Norman zooplankton populations, using monthly data, demonstrated a bimodal seasonal distribution with highest values generally occurring in the spring, and a less pronounced fall peak. Considerable spatial and year-to-year variability has been observed in zooplankton abundance in Lake Norman (Duke Power Company 1976, 1985; Hamme 1982; Menhinick and Jensen 1974). Since quarterly sampling was initiated in August 1987, distinct bimodal seasonal distribution has been less apparent, due to the 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 (Figure 2-1) during each season: winter (February), spring (May), summer (August), and fall (November) 2007. 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 2007 were compared with corresponding data from quarterly monitoring begun in August 1987.

RESULTS AND DISCUSSION

Total Abundance

Highest epilimnetic zooplankton densities at Lake Norman locations have predominantly been observed in the spring, with winter peaks observed about 25% of the time, and peaks observed only occasionally in the summer and fall (Duke Energy 2007). During 2007, annual epilimnetic maxima were recorded from Locations 2.0, 5.0, and 15.9 in the spring. while Locations 9.5 and 11.0 demonstrated peak annual densities in February (Table 4-1, Figures 4-1 and 4-2). The lowest epilimnetic densities occurred in the fall at all but Location 15.9, which had the annual minimum density in the summer. Epilimnetic zooplankton densities ranged from a low of 33,564/m^3 at Location 2.0 in the fall, to a high of 394,182/m^3 at Location 15.9 in the spring.

Maximum densities in 2007 whole-column samples were observed during different seasons at different locations. At Locations 9.5 and 11.0, maximum values occurred in the winter, annual maxima at Locations 2.0 and 15.9 were observed in the spring, and the highest density from Location 5.0 occurred in the summer (Table 4-1 and Figure 4-1). Minimum whole-column densities were observed in the summer at Locations 11.0 and 15.9 and in the fall at Locations 2.0, 5.0, and 9.5. Whole-column densities ranged from a low of 30,611/m^3 at Location 2.0 in the fall, to 218,242/m^3 at Location 15.9 in the spring.

Consistent with historical data, during 2007 total zooplankton densities were most often higher in epilimnetic samples than in whole-column samples (Duke Energy 2007). 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). Since epilimnetic zooplankton communities are far more representative of overall seasonal and temporal trends, most of the following discussion will focus primarily on zooplankton communities in this area of the water column.

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 2007 (Table 4-1, Figures 4-1 and 4-2). Location 15.9, the uppermost background location, had higher epilimnetic densities than mixing zone locations during all sampling periods (Table 4-1). This spatial trend was similar to that of the phytoplankton

(Chapter 3). In most previous years of the program, background locations had higher mean densities than mixing zone locations (Figures 4-3 through 4-6; and Duke Energy 2007).

Historically, both seasonal and spatial variability of 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 2007 (Table 4-1, Figures 4-3 through 4-6). 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). Additionally, the effects of MNS once-through cooling could cause somewhat lower production at these locations. A similar trend was observed in the phytoplankton communities (Chapter 3).

Epilimnetic zooplankton densities during 2007 were most often within historical ranges (Figures 4-3 through 4-6). The exceptions were at Location 9.5 in the summer and Location 15.9 in the winter. On both occasions, these locations demonstrated long-term seasonal maximum densities (Figures 4-3 and 4-6).

The highest winter densities recorded from Locations 2.0 and 11.0 occurred in 1996, while the winter maximum at Location 9.5 was recorded in 1995 (Figure 4-3). The winter maxima from Locations 5.0 and 15.9 occurred in 2004 and 2007, respectively. Long-term maximum densities for spring were observed at Locations 2.0 and 5.0 in 2005, while the highest spring values from Locations 11.0 and 15.9 occurred in 2002. The highest spring peak at Location 9.5 was observed in 2005 (Figure 4-4). Long-term summer maxima occurred in 1988 at Locations 2.0, 5.0, and 11.0, while summer maxima at Locations 9.5 and 15.9 occurred in 2007 and 2003, respectively (Figure 4-5). Long-term maxima for the fall occurred at all but Location 15.9 in 2006, while the long-term maximum at Location 15.9 was recorded in 1999 (Figure 4-6).

From 1990 – 2003, the densities at mixing zone locations in the spring, summer, and fall demonstrated moderate degrees of year-to-year variability, and the long-term trend at mixing zone locations in the spring had been a gradual increase through 2005. During the spring of 2006, zooplankton densities in the mixing zone declined sharply, as compared to 2005, and were well within earlier historical ranges. During 2007, mixing zone locations demonstrated increases. Year-to-year fluctuations of densities in the mixing zone during the winter 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 through 4-6).

Community Composition

One hundred and twenty-three zooplankton taxa have been identified since the Lake Norman Maintenance Monitoring Program began in August 1987 (Table 4-2). Forty-nine taxa were identified during 2007, as compared to 44 recorded for 2006 (Duke Energy 2007). Two previously unreported taxa, the copepod *Eucyclops prionophorus* and the rotifer, *Keratella americana,* were identified in 2007.

In 2006, copepods were the most abundant zooplankters in eight samples; one in the winter and seven in the summer (Duke Energy 2007). During 2007, copepods were dominant in only three samples: the epilimnion at Locations 2.0 and 5.0 in the spring, and the whole column sample from Location 2.0 in the summer (Table 4-1). Cladocerans, most often the least abundant forms in Lake Norman, were dominant in two whole column samples, one from Location 2.0 in the spring and another from Location 9.5 in the winter (Table 4-1). Rotifers were dominant in all other samples collected in 2007. During most years, microcrustaceans (copepods and cladocerans) dominated mixing zone samples, but were less important among background locations (Figures 4-7 and 4-8). Compared to 2006, microcrustaceans showed a slight increase in relative abundances in the epilimnion of the mixing zone, while they demonstrated a slight decrease among whole-column samples at these locations (Figure 4-7). At background locations microcrustacean relative abundances were similar to those of 2006 (Figure 4-8)

Copepoda

As has always been the case, copepod populations were consistently dominated by immature forms (primarily nauplii) during 2007. Adult copepods seldom comprised more than 7% of the total zooplankton density at any location. *Tropocyclops* was the most important genus in adult populations, particularly during summer and fall (Table 4-3). *Epishura* was important among winter and spring samples, while *Cyclops* and *Diaptomus* were occasionally abundant.

Similar patterns of copepod taxonomic distributions were observed in previous years (Duke Energy 2007).

Copepods tended to be somewhat more abundant at background locations than at mixing zone locations during 2007, and their densities peaked at all locations in the spring, as was typically recorded during past years (Table 4-1; Figure 4-9).

Rotifera

Polyarthra was the most abundant rotifer at all locations during the fall of 2007, when it demonstrated dominance among all rotifer populations (Table 4-3). *Keratella* was the most abundant rotifer in most spring samples, while *Ptygura* was most often dominant among summer populations. During the winter, *Asplanchna* was the most abundant rotifer in epilimnetic samples from Locations 2.0, 5.0, and 9.5 and among whole column samples at Locations 2.0 and 9.5. *Conochilus* and *Synchaeta* were occasionally dominant in samples from winter, spring, and summer. All of these taxa have been identified as important constituents of rotifer populations, as well as zooplankton communities, in previous studies (Duke Energy 2007, Hamme 1982).

Long-term tracking of rotifer populations indicated high year-to-year seasonal variability. Peak densities have most often occurred in the winter and spring, with occasional peaks in the summer and fall (Figure 4-11). During 2007, peak rotifer densities were observed at mixing zone locations in the summer and at background locations in the spring.

FUTURE STUDIES

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

SUMMARY

Maximum zooplankton densities most often occurred in the spring of 2007, while minimum zooplankton densities were generally noted in the fall. 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 2007. Spatial trends of zooplankton populations were similar to those of the phytoplankton, with increasing densities from down-lake to up-lake. From around 1997 through 2005, a year-to-year trend of increasing zooplankton densities was observed among mixing zone locations in the spring. Densities at these locations declined sharply in 2006, followed by an increase in 2007. 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 during winter at Location 15.9 and during the summer at Location 9.5.

One hundred and twenty-three zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (49 were identified during 2007). Two previously unreported taxa were identified during 2007.

Overall, relative abundance of copepods in 2007 decreased over 2006, and they were dominant in only three samples. Cladocerans were dominant in two samples, while rotifers were dominant in all remaining samples. The relative abundance of microcrustaceans increased slightly in the epilimnion of the mixing zone since 2006, but decreased among whole-column samples since the previous year. At background locations, relative abundances of microcrustaceans in 2007 were similar to those of 2006. Historically, copepods and rotifers have most often shown annual peaks in the spring, while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms with adults rarely accounting for more than 7% 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 several cladoceran populations during the summer. The most abundant rotifers observed in 2007, as in many previous years, were *Polyarthra*, *Keratella,* and *Ptygura.* *Conochilus*, *Asplanchna,* and *Syncheata* were also important among rotifer populations.

Lake Norman continues to support a highly diverse and viable zooplankton community. Other than somewhat lower productivity from MNS induced mixing at Locations 2.0 and 5.0, no impacts of plant operations were observed.

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 the epilimnion and whole column net tow samples collected from Lake Norman in February, May, August, and November 2007.

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
2/27/2007	Epilimnion	Copepoda	20.4	26.0	33.9	45.9	41.8
			(30.5)	(37.0)	(20.9)	(22.9)	(19.7)
		Cladocera	8.6	12.7	60.5	26.6	12.6
			(12.9)	(18.0)	(37.2)	(13.2)	(5.9)
		Rotifera	37.8	31.7	68.0	128.3	157.9
			(56.6)	(45.0)	(41.9)	(63.9)	(74.4)
		Total	66.8	70.4	162.4	200.8	212.3
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	30 m	19 m	20 m	25 m	21 m
		Copepoda	11.9	16.7	24.7	27.7	24.2
			(29.2)	(30.5)	(21.8)	(22.1)	(23.0)
		Cladocera	6.8	9.4	47.5	21.2	12.3
			(16.8)	(17.2)	(42.0)	(16.9)	(11.7)
		Rotifera	21.9	28.6	41.0	76.5	68.8
			(54.0)	(52.3)	(36.2)	(61.0)	(65.3)
		Total	40.6	54.7	113.2	125.4	105.3

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
5/24/2007	Epilimnion	Copepoda	31.2	62.1	30.1	51.0	47.4
			(36.5)	(41.0)	(34.3)	(28.5)	(12.0)
		Cladocera	24.8	27.4	20.0	37.4	47.4
			(29.0)	(18.1)	(22.9)	(20.9)	(12.0)
		Rotifera	29.5	61.8	37.5	90.6	299.3
			(34.5)	(40.9)	(42.8)	(50.6)	(76.0)
		Total	85.5	151.3	87.6	179.0	394.1
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	30 m	19 m	20 m	25 m	21 m
		Copepoda	16.0	34.5	24.2	28.6	32.6
			(39.1)	(40.2)	(34.9)	(26.2)	(14.9)
		Cladocera	16.8	15.9	16.7	26.1	30.3
			(41.1)	(18.5)	(24.1)	(23.8)	(13.9)
		Rotifera	8.1	35.5	28.4	54.6	155.4
			(19.8)	(41.3)	(41.0)	(50.0)	(71.2)
		Total	40.9	85.9	69.3	109.3	218.3

Table 4-1. (Continued).

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
8/13/2007	Epilimnion	Copepoda	18.8	22.5	29.3	23.4	37.5
			(37.5)	(20.4)	(19.7)	(16.8)	(33.1)
		Cladocera	7.1	5.2	10.1	15.8	10.8
			(14.2)	(4.7)	(6.8)	(11.4)	(9.5)
		Rotifera	24.2	82.3	109.3	100.0	65.0
			(48.3)	(74.9)	(73.5)	(71.8)	(57.4)
		Total	50.1	110.0	148.7	139.2	113.3
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	30 m	19 m	20 m	25 m	21 m
		Copepoda	15.6	22.6	27.0	18.4	20.9
			(48.6)	(22.5)	(26.2)	(25.8)	(36.3)
		Cladocera	5.0	3.4	9.1	6.9	6.0
			(15.6)	(3.3)	(8.8)	(9.7)	(10.4)
		Rotifera	11.5	74.7	67.0	46.0	30.5
			(35.8)	(74.2)	(65.0)	(64.5)	(53.0)
		Total	32.1	100.7	103.1	71.3	57.6*

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
11/20/2007	Epilimnion	Copepoda	7.6	12.4	19.6	32.2	14.6
			(22.6)	(28.3)	(32.6)	(23.8)	(11.4)
		Cladocera	4.0	11.1	7.3	8.1	12.8
			(12.1)	(25.1)	(12.2)	(6.0)	(10.0)
		Rotifera	21.9	20.4	33.3	94.8	100.7
			(65.3)	(46.6)	(55.2)	(70.2)	(78.6)
		Total	33.5	43.9	60.2	135.1	128.1
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	29 m	19 m	20 m	24 m	20 m
		Copepoda	12.2	13.5	19.0	32.5	16.4
			(40.0)	(36.2)	(33.3)	(34.2)	(17.4)
		Cladocera	4.5	8.6	3.6	8.1	7.7
			(14.6)	(23.1)	(6.3)	(8.6)	(8.2)
		Rotifera	13.9	15.2	34.5	54.5	70.3
			(45.4)	(40.7)	(60.4)	(57.3)	(74.4)
		Total	30.6	37.3	57.1	95.1	94.4

* = *Chaoborus* (Insecta) observed in a whole water sample from Location 15.9 in August (197/m^3, 0.34%).

Table 4-2. Zooplankton taxa identified from samples collected quarterly on Lake Norman from 1987 – 2007.

TAXON	87-92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
COPEPODA																
Cyclops thomasi Forbes	X		X	X		X	X	X	X	X	X	X	X	X	X	X
C. vernalis Fischer					X											
C. spp. O. F. Muller	X	X	X	X	X	X	X			X	X	X				
Diaptomus birgei Marsh	X	X							X							
D. mississippiensis Marsh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. pallidus Herick	X	X		X	X	X		X				X		X		
D. reighardi Marsh								X								
D. spp. Marsh	X	X	X	X	X	X	X	X	X		X	X				
Epishura fluviatilis Herrick				X	X	X	X	X	X	X	X	X	X	X	X	X
Ergasilus spp. Smith					X										X	
Eucyclops agilis (Koch)							X									
E. prionophorus Kiefer																X
Mesocyclops edax (S. A. Forbes)	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. spp. Sars	X	X	X	X	X	X				X	X	X				
Paracyclops limbricatus v. *poppei*														X		
Tropocyclops prasinus (Fischer)	X			X	X	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
CLADOCERA																
Alona spp.Baird					X	X										X
Alonella spp. (Birge)			X					X								
Bosmina longirostris (O. F. M.)	X	X				X	X	X	X	X	X	X	X	X	X	X
B. spp. Baird	X	X	X	X	X	X	X		X	X	X					
Bosminopsis dietersi Richard	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ceriodaphnia lacustris Birge	X					X	X	X	X	X		X	X	X	X	X
C. spp. Dana	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	X		
Daphnia ambigua Scourfield	X				X	X	X	X		X				X	X	X
D. catawba Coker					X	X				X						
D. galeata Sars					X											
D. laevis Birge					X							X				
D. longiremis Sars					X	X			X	X		X	X			
D. lumholzi Sars	X	X	X	X	X		X	X	X					X		
D. mendotae (Sars) Birge						X	X	X	X			X				X
D. parvula Fordyce	X			X	X	X	X	X	X	X	X	X	X	X	X	X
D. pulex (de Geer)					X	X										X
D. pulicaria Sars					X	X										
D. retrocurva Forbes					X	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	X
Diaphanosoma brachyurum (Lievin)						X	X	X	X	X	X	X	X	X	X	X
D. spp. Fischer	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	X	X	X
H. gibberum Zaddach	X					X	X									

Table 4-2. (Continued).

TAXON	87-92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
H. spp. Stingelin	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	X	X
Leydigia acanthoceroides (Fis.)													X			
L. spp. Freyberg		X	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															
Simocephalus expinosus (Koch)	X															
Simocephalus spp. Schodler								X								
ROTIFERA																
Anuraeopsis fissa (Gosse)													X			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 calyciflorus Halb.														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				X	X	X
C. spp. Lauterborne	X	X	X	X	X											
Collotheca balatonica Harring					X	X	X	X	X		X	X	X	X	X	X
C. mutabilis (Hudson)					X	X	X	X	X			X	X	X	X	X
C. spp. Harring	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	X	X	X
C. spp. Hlava	X	X	X	X	X	X				X		X				
Conochilus unicornis (Rouss.)	X					X	X	X	X	X	X	X	X	X	X	X
C. spp. Hlava	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		X	X
G. spp. Imhof	X	X	X	X	X	X	X			X						
Hexarthra mira Hudson						X	X	X	X		X				X	X
H. spp. Schmada	X	X	X	X	X	X				X						
Kellicottia bostoniensis (Rou.)	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
K. longispina Kellicott						X	X	X	X	X	X	X	X	X	X	X
K. spp. Rousselet	X	X	X	X	X	X				X	X	X	X	X		
Keratella Americana Carlin																X

Table 4-2. (Continued).

TAXON	87-92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
K. cochlearis Bory de St. Vinc.								X	X				X			X
K. taurocephala Myers						X		X					X	X		X
K. spp. Bory de St. Vincent	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Lecane spp. Nitzsch	X		X	X		X	X		X		X	X		X	X	
Macrochaetus subquadratus P.						X	X									
M. spp. Perty	X	X			X			X	X		X			X		
Monommata spp.															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	X	X	X
P. truncatum (Levander)	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Herrick	X	X	X	X	X		X			X						
Polyarthra euryptera (Weir.)	X						X						X		X	X
P. major Burckhart						X		X	X		X	X	X	X	X	X
P. vulgaris Carlin	X					X		X	X	X	X	X	X	X	X	X
P. spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pompholyx spp. Gosse					X											
Ptygura libra Meyers						X	X		X		X	X	X	X	X	X
P. spp. Ehrenberg	X	X	X	X	X	X					X	X				
Synchaeta spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichocerca capucina (Weir.)	X		X	X	X	X	X				X					
T. cylindrica (Imhof)	X			X	X	X	X	X	X		X	X	X	X	X	X
T. longiseta Schrank						X									X	X
T. multicrinis (Kellicott)							X	X	X		X	X	X	X	X	X
T. porcellus (Gosse)				X	X	X		X	X		X		X			
T. pusilla Jennings						X										
T. similis Lamark				X											X	
T. spp. Lamark	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trichotria spp. Bory de St. 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							
INSECTA																
Chaoborus spp. Lichtenstein	X	X					X	X		X	X		X	X	X	X
OSTRACODA (unidentified)							X					X	X			

Table 4-3. Dominant copepod (adults), cladoceran, and rotifer taxa and their percent composition (in parentheses) of the copepod, cladoceran and rotifer densities by location and sample period in Lake Norman in 2007.

Locations	FEBRUARY	MAY	AUGUST	NOVEMBER
2.0	*Tropocyclops* (5.6)	*Epishura* (0.7)	*Tropocyclops* (6.2)*	*Tropocyclops* (7.2)
5.0	*Epishura* (2.9)	*Epishura* (3.3)	*Tropocyclops* (6.0)*	*Tropocyclops* (4.9)
9.5	*Cyclops* (3.8)	*Epishura* (7.4)	*Tropocyclops* (2.3)*	*Tropocyclops* (18.2)*
11.0	*Tropocyclops* (0.8)	*Epishura* (2.7)	*Tropocyclops* (9.4)*	*Tropocyclops* (5.6)
15.9	*Cyclops* (1.2)	No adults	*Tropocyclops* (4.6)*	*Tropocyclops* (30.8)
2.0	*Epishura* (4.9)	*Epishura* (8.2)	*Tropocyclops* (5.1)	*Diaptomus* (10.0)
5.0	*Tropocyclops* (10.8)	*Epishura* (5.2)	*Tropocyclops* (6.9)	*Tropocyclops* (7.1)
9.5	*Epishura* (4.9)	*Tropocyclops* (8.4)	*Tropocyclops* (2.2)*	*Tropocyclops* (25.4)
11.0	*Tropocyclops* (1.4)	*Epishura* (6.0)	*Tropocyclops* (9.0)	*Diaptomus* (12.8)
15.9	*Cyclops* (4.0)	*Diaptomus* (1.8)	*Tropocyclops* (7.6)	*Tropocyclops* (17.1)
2.0	*Bosmina* (88.8)	*Diaphanosoma* (38.4)	*Bosminopsis* (65.3)	*Bosmina* (100.0)
5.0	*Bosmina* (88.2)	*Bosmina* (61.3)	*Bosminopsis* (64.6)	*Bosmina* (98.7)
9.5	*Bosmina* (95.1)	*Diaphanosoma* (39.9)	*Bosminopsis* (76.8)	*Bosmina* (94.0)
11.0	*Bosmina* (98.7)	*Diaphanosoma* (40.2)	*Bosminopsis* (74.0)	*Bosmina* (91.6)
15.9	*Bosmina* (86.5)	*Bosmina* (92.0)	*Bosmina* (60.9)	*Bosmina* (97.4)
2.0	*Bosmina* (91.5)	*Bosmina* (57.2)	*Bosmina* (42.8)	*Bosmina* (93.1)
5.0	*Bosmina* (90.6)	*Bosmina* (55.9)	*Bosminopsis* (73.3)	*Bosmina* (89.3)
9.5	*Bosmina* (94.3)	*Diaphanosoma* (51.8)	*Bosminopsis* (64.7)	*Bosmina* (91.6)
11.0	*Bosmina* (92.1)	*Diaphanosoma* (49.3)	*Bosminopsis* (65.6)	*Bosmina* (58.5)
15.9	*Bosmina* (88.4)	*Bosmina* (92.2)	*Bosmina* (63.4)	*Bosmina* (96.9)

* = Only adults present in samples.

Table 4-3. (Continued).

Locations	FEBRUARY	MAY	AUGUST	NOVEMBER
2.0	*Asplanchna* (29.4)	*Keratella* (34.3)	*Ptygura* (38.3)	*Polyarthra* (88.5)
5.0	*Asplanchna* (37.0)	*Keratella* (35.6)	*Ptygura* (83.7)	*Polyarthra* (91.1)
9.5	*Asplanchna* (80.3)	*Keratella* (60.0)	*Ptygura* (76.8)	*Polyarthra* (68.8)
11.0	*Synchaeta* (47.5)	*Keratella* (39.1)	*Ptygura* (60.9)	*Polyarthra* (78.7)
15.9	*Keratella* (37.0)	*Keratella* (51.5)	*Conochilus* (84.5)	*Polyarthra* (76.0)
2.0	*Asplanchna* (37.7)	*Conochilus* (27.9)	*Ptygura* (52.4)	*Polyarthra* (78.8)
5.0	*Keratella* (45.7)	*Conochilus* (41.1)	*Ptygura* (87.6)	*Polyarthra* (93.2)
9.5	*Asplanchna* (62.7)	*Keratella* (60.9)	*Ptygura* (79.0)	*Polyarthra* (61.0)
11.0	*Synchaeta* (49.2)	*Keratella* (38.7)	*Ptygura* (69.6)	*Polyarthra* (74.1)
15.9	*Keratella* (41.9)	*Keratella* (55.8)	*Cocochilus* (79.2)	*Polyarthra* (75.3)

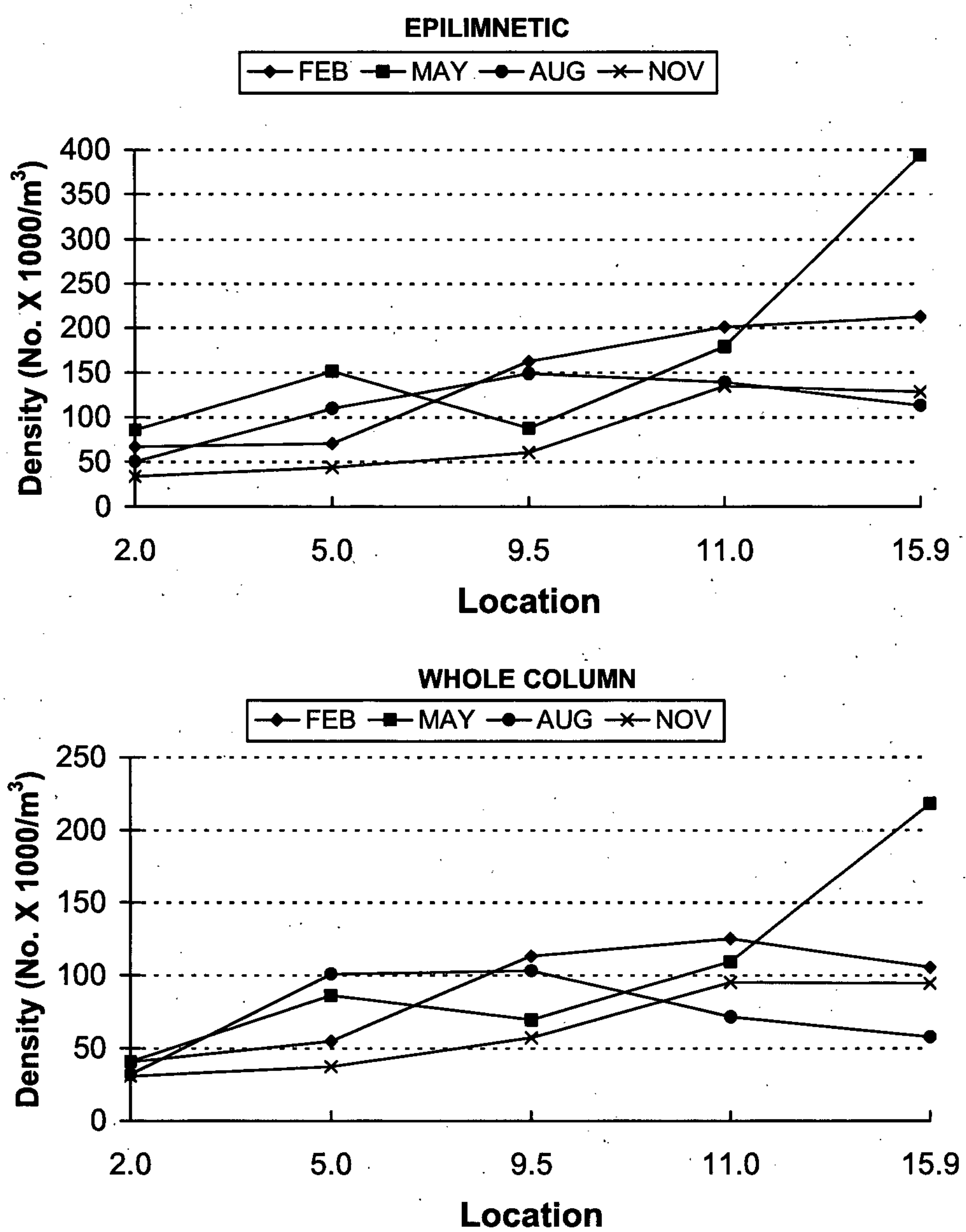


Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman in 2007.

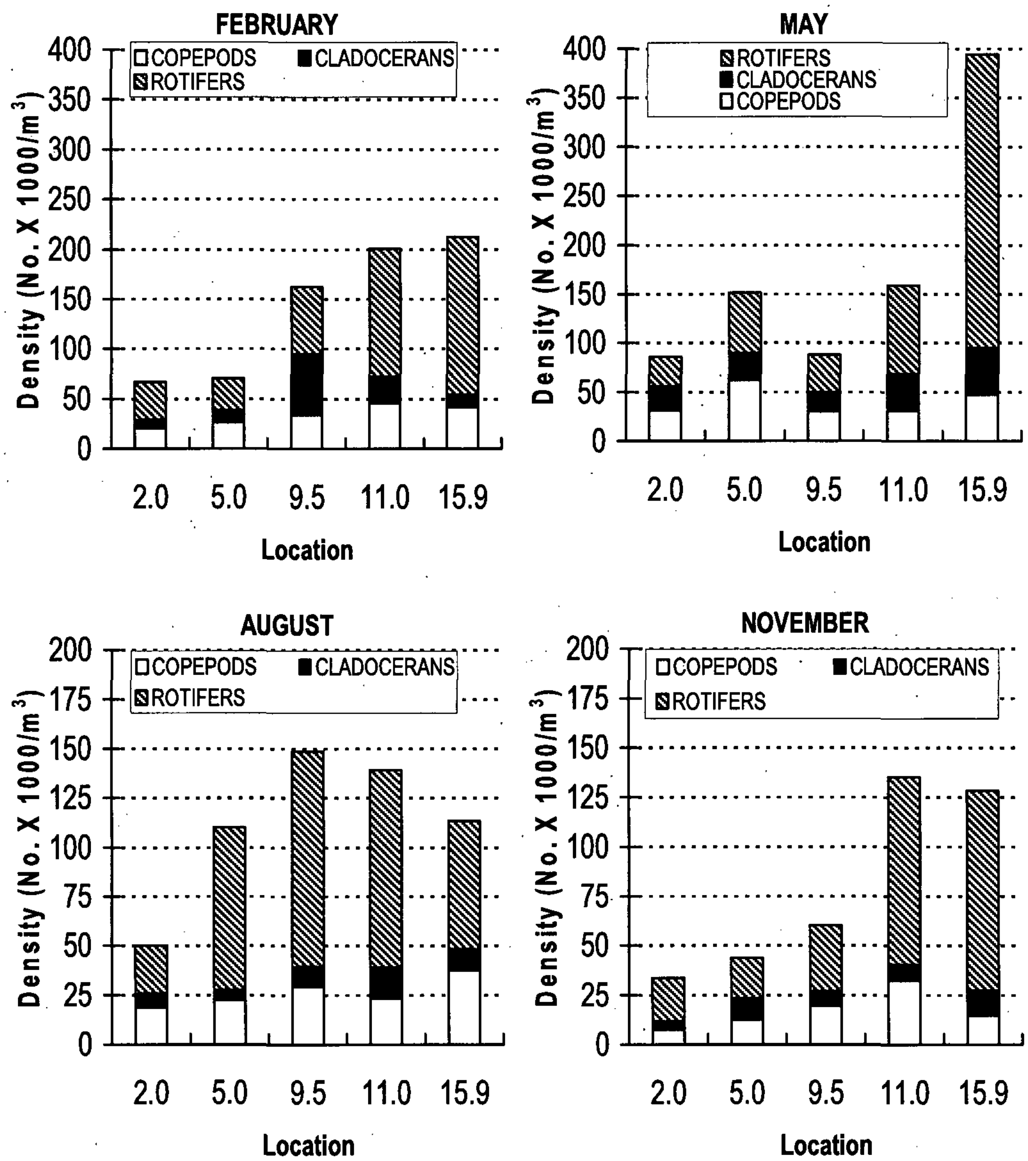
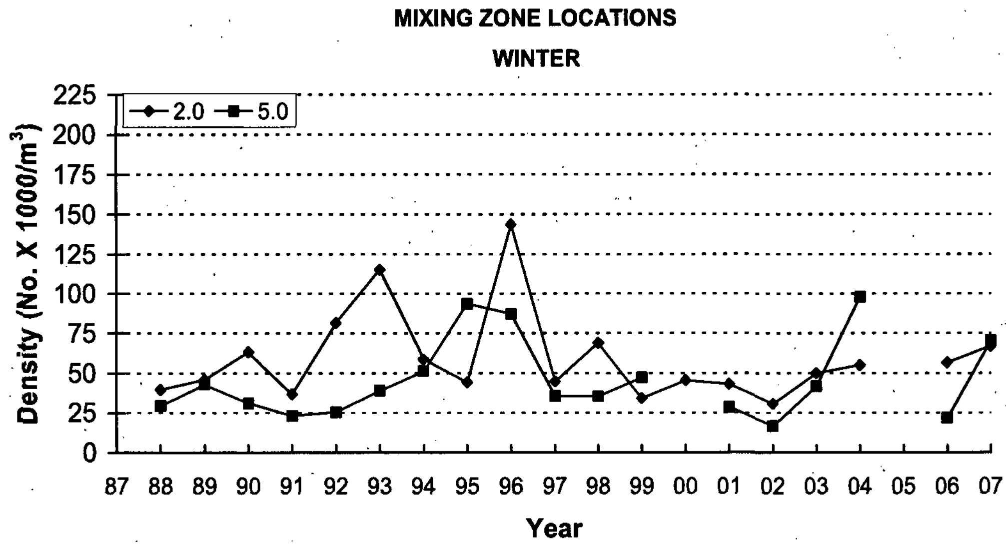


Figure 4-2. Zooplankton community composition by sample period and location for epilimnetic samples collected in Lake Norman in 2007.



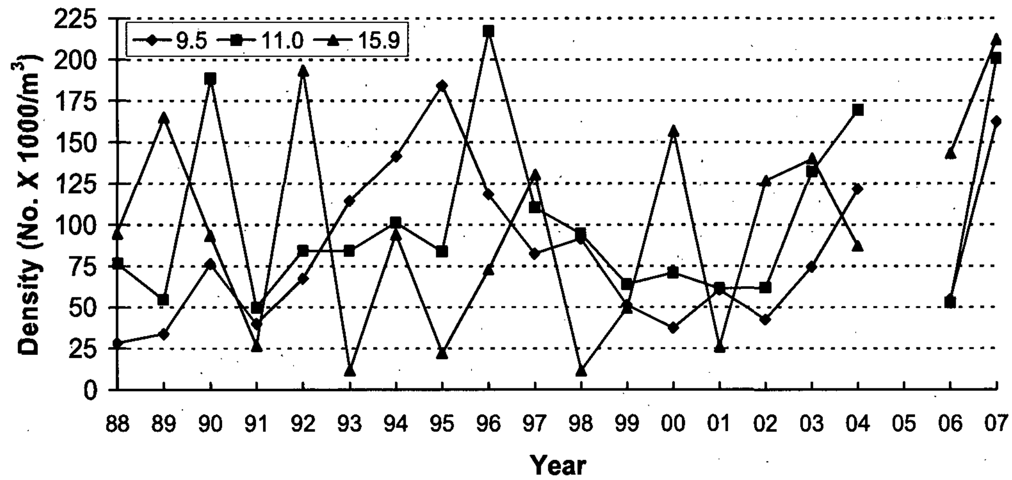
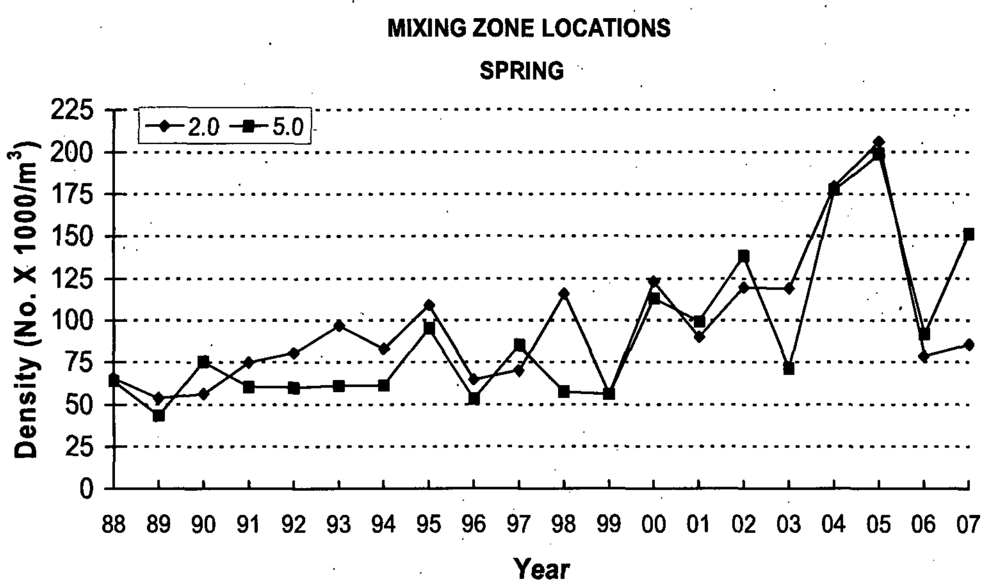


Figure 4-3. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman, NC, in the winter periods of 1988 – 2007.



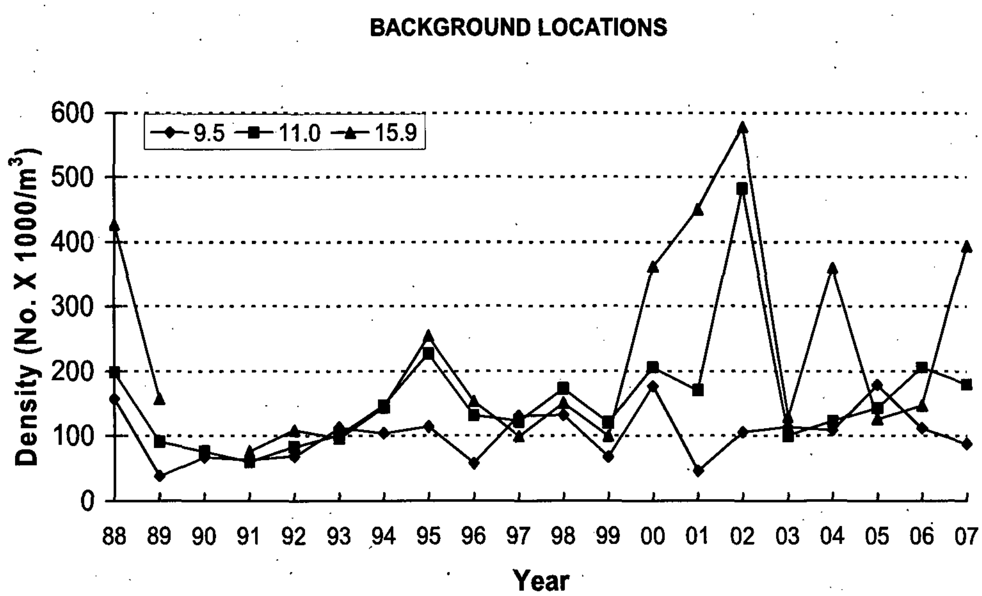


Figure 4-4. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman in the spring periods of 1988 – 2007.

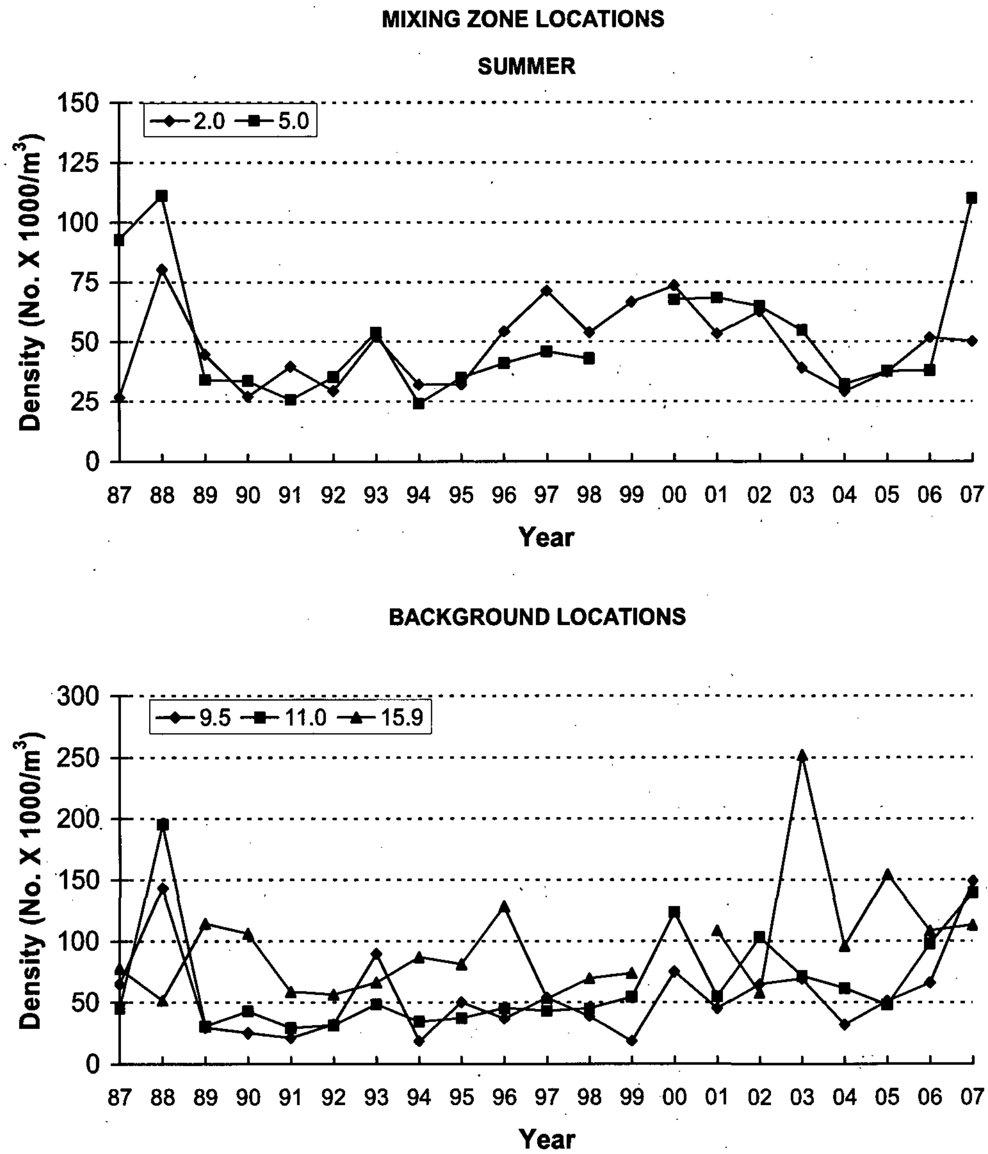


Figure 4-5. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman in the summer periods of 1987 – 2007.

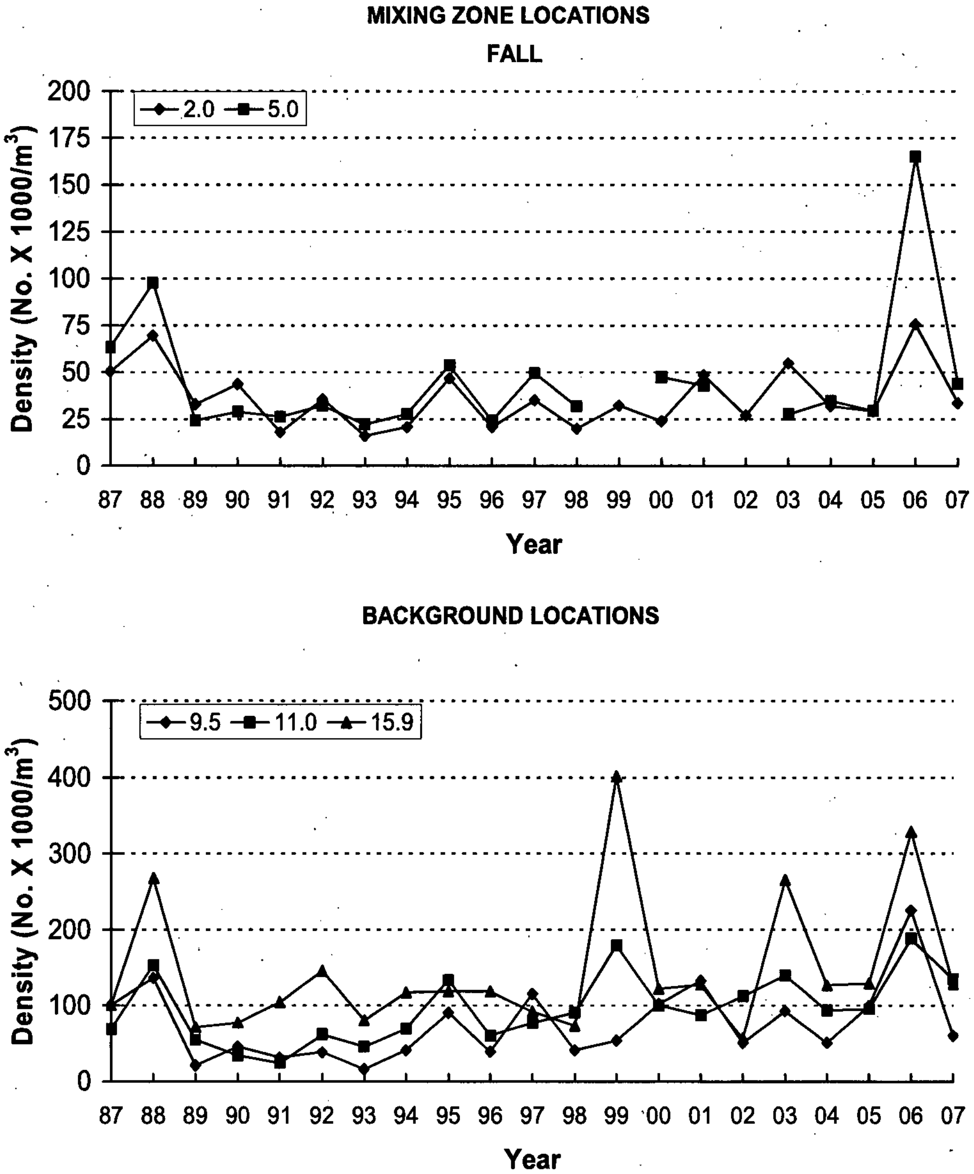


Figure 4-6. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman in the fall periods of 1987 – 2007.

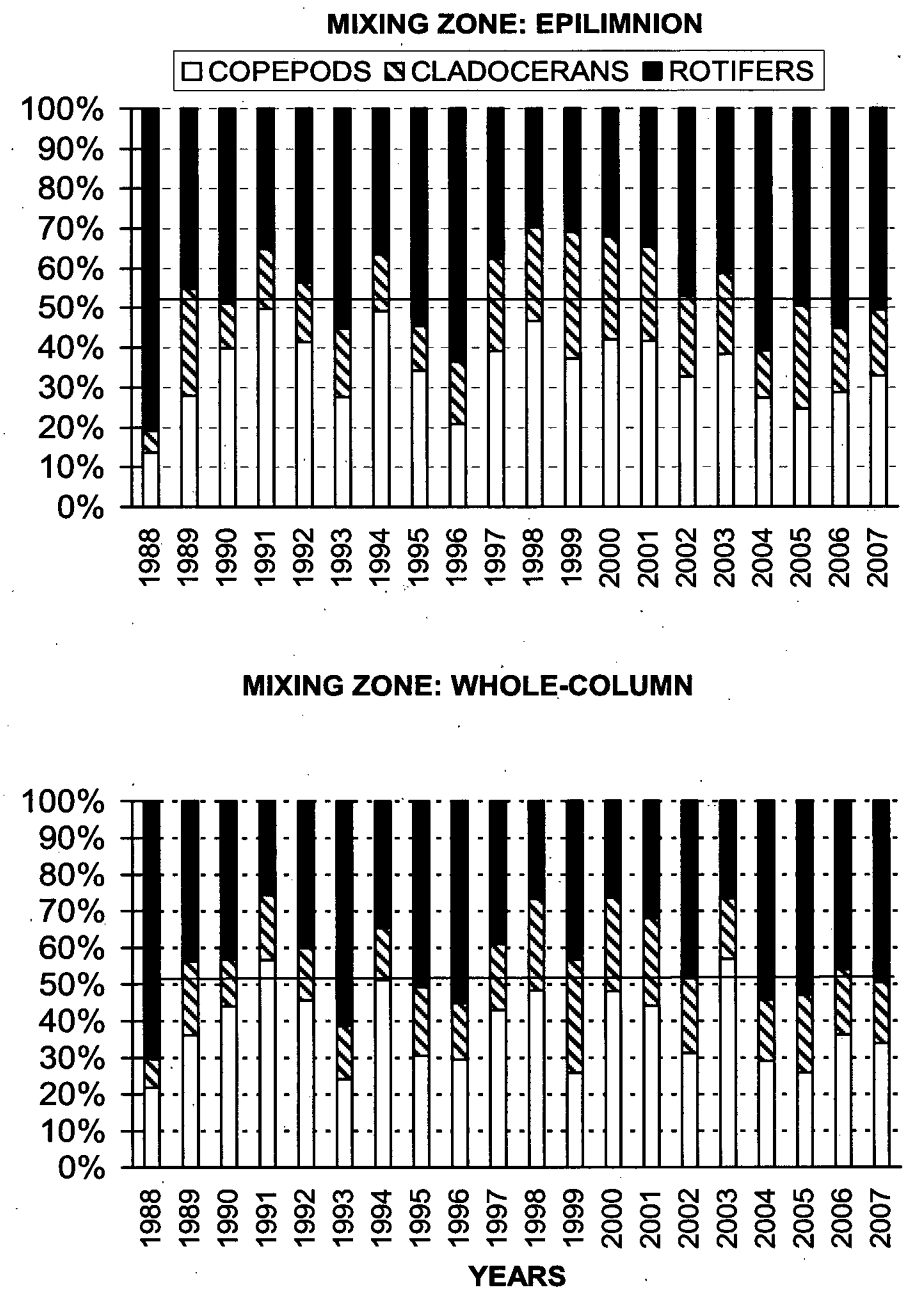
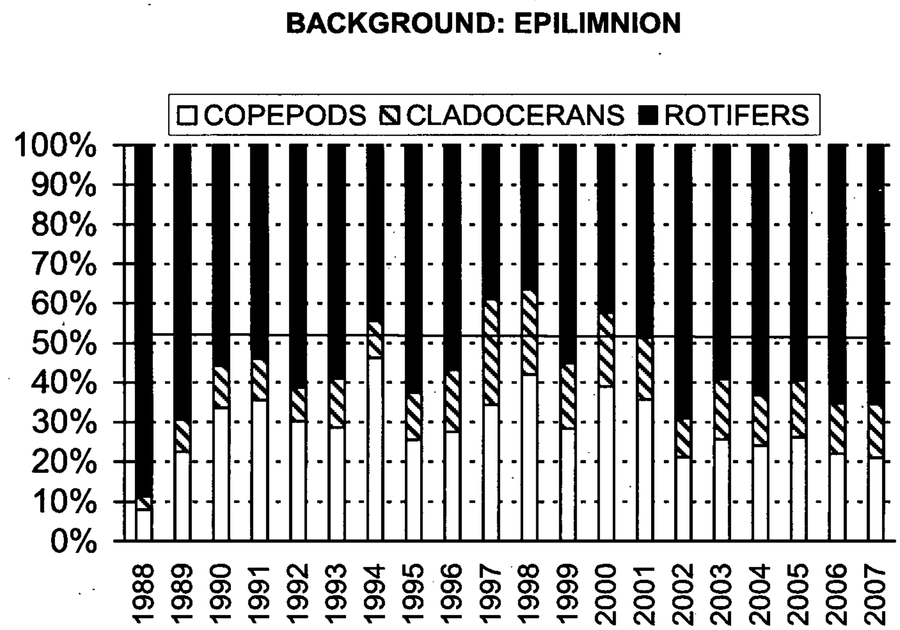


Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from mixing zone locations (Locations 2.0 and 5.0 combined) during 1988 – 2007 (Note: Does not include Location 5.0 in the fall of 2002 or winter samples from 2005).



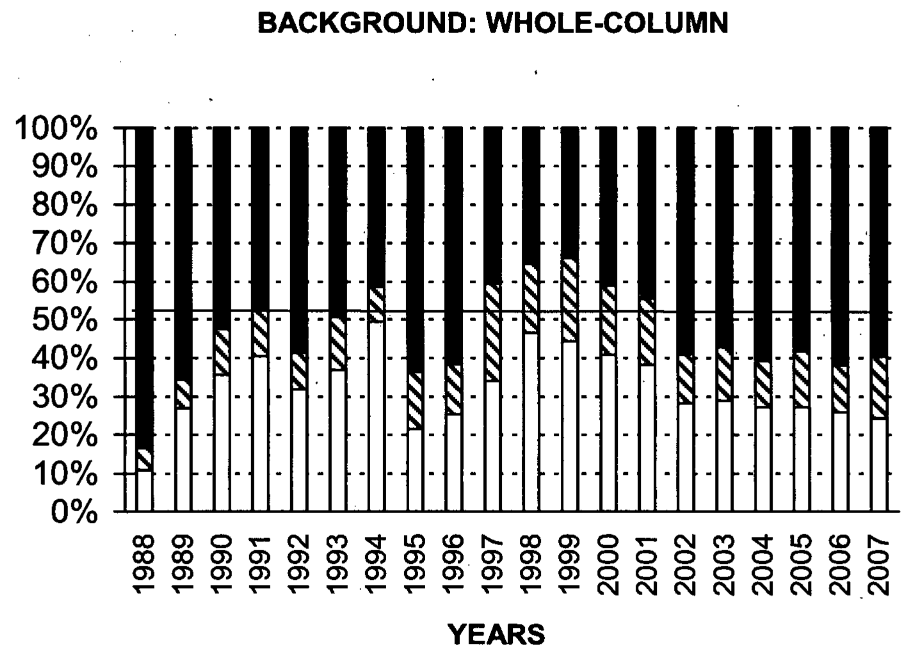


Figure 4-8. Annual percent composition of major zooplankton taxonomic groups from background locations (Locations 9.5, 11.0, and 15.9 combined) during 1988 – 2007 (Note: Does not include winter samples from 2005).

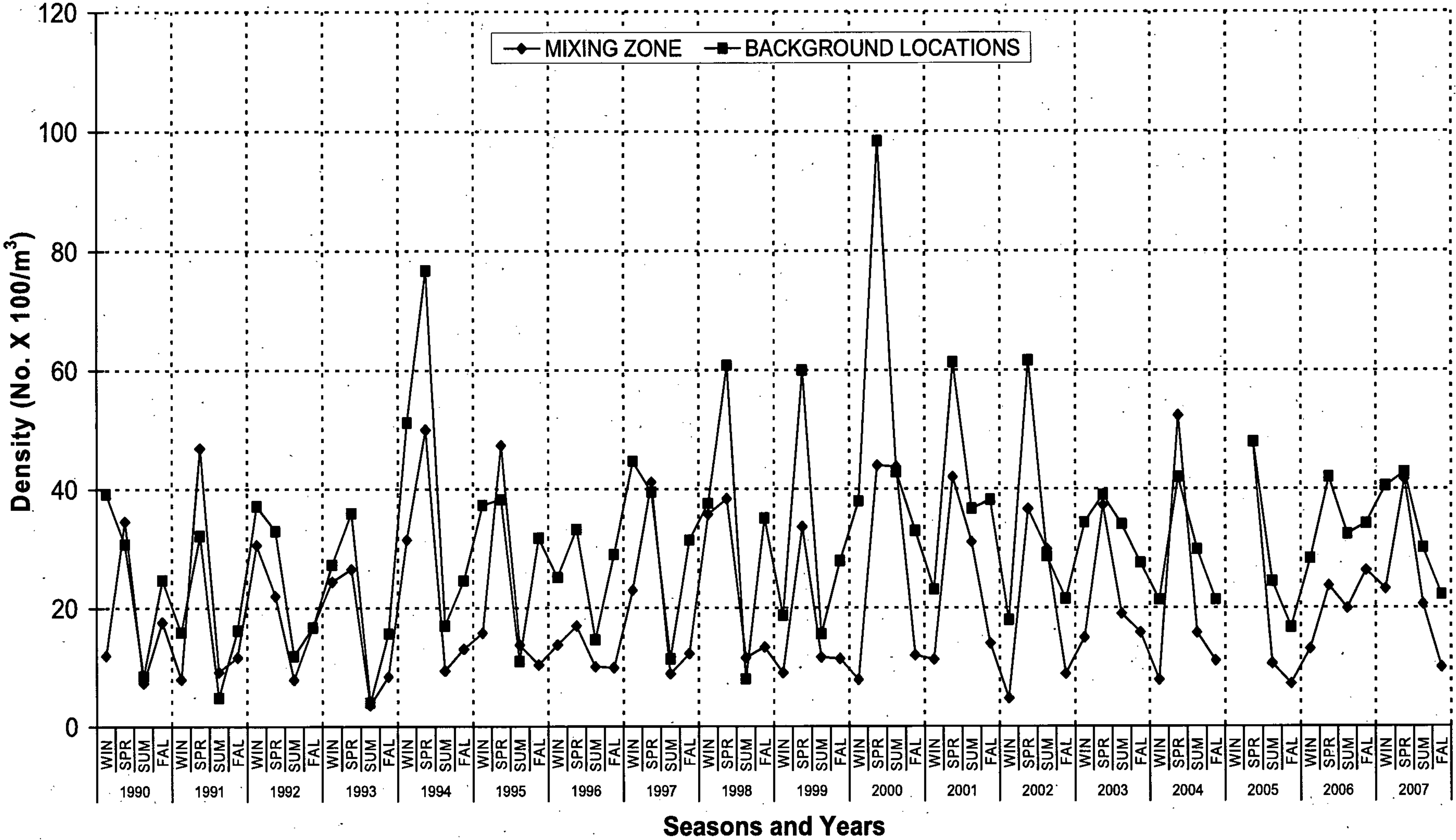


Figure 4-9. Copepod densities during each season of each year among epilimnetic samples collected in Lake Norman from 1990 – 2007 (mixing zone = mean of Locations 2.0 and 5.0; background = mean of Locations 9.5, 11.0, and 15.9).

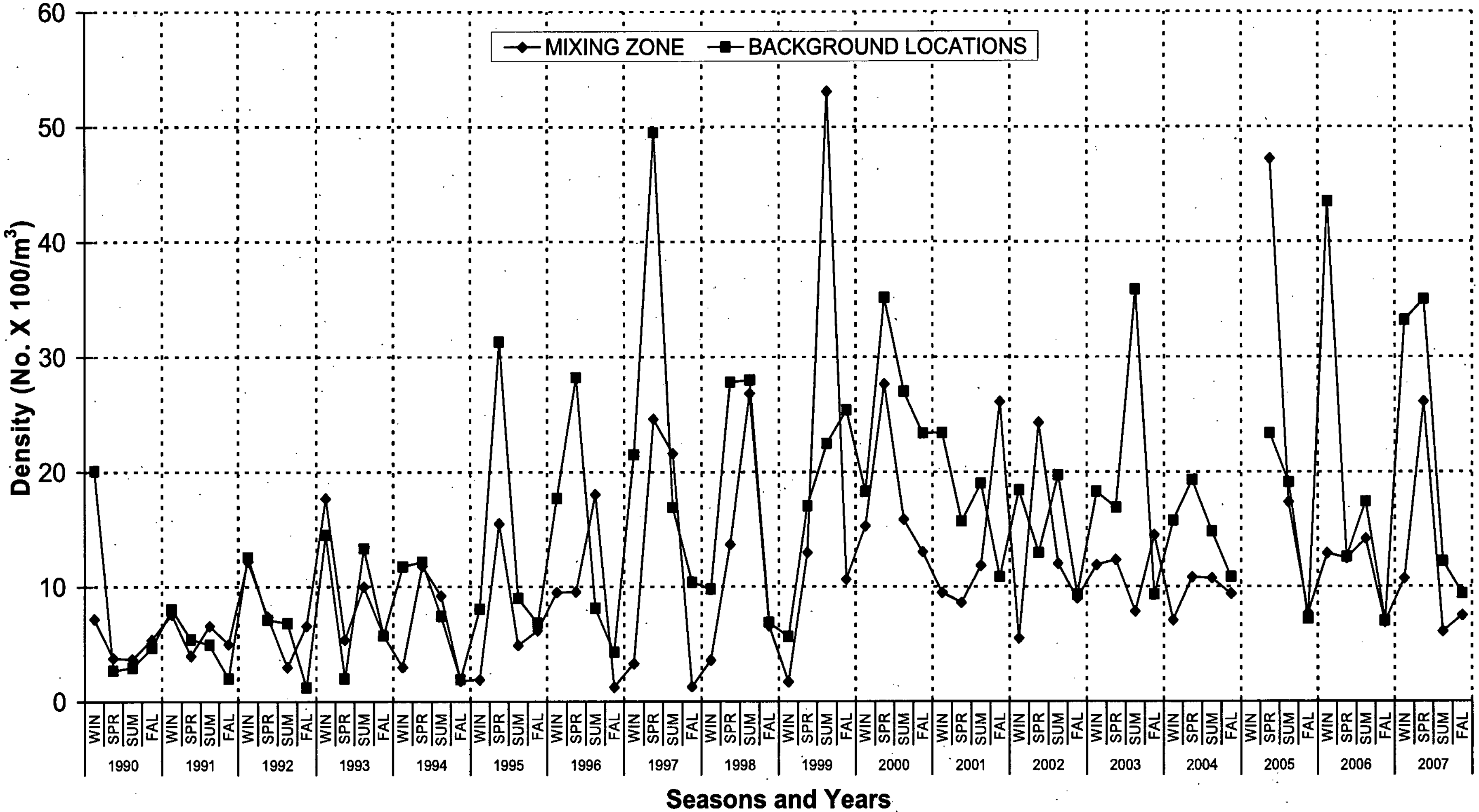


Figure 4-10. Cladoceran densities during each season of each year among epilimnetic samples collected in Lake Norman from 1990 – 2007 (mixing zone = mean of Locations 2.0 and 5.0; background = mean of Locations 9.5, 11.0, and 15.9).

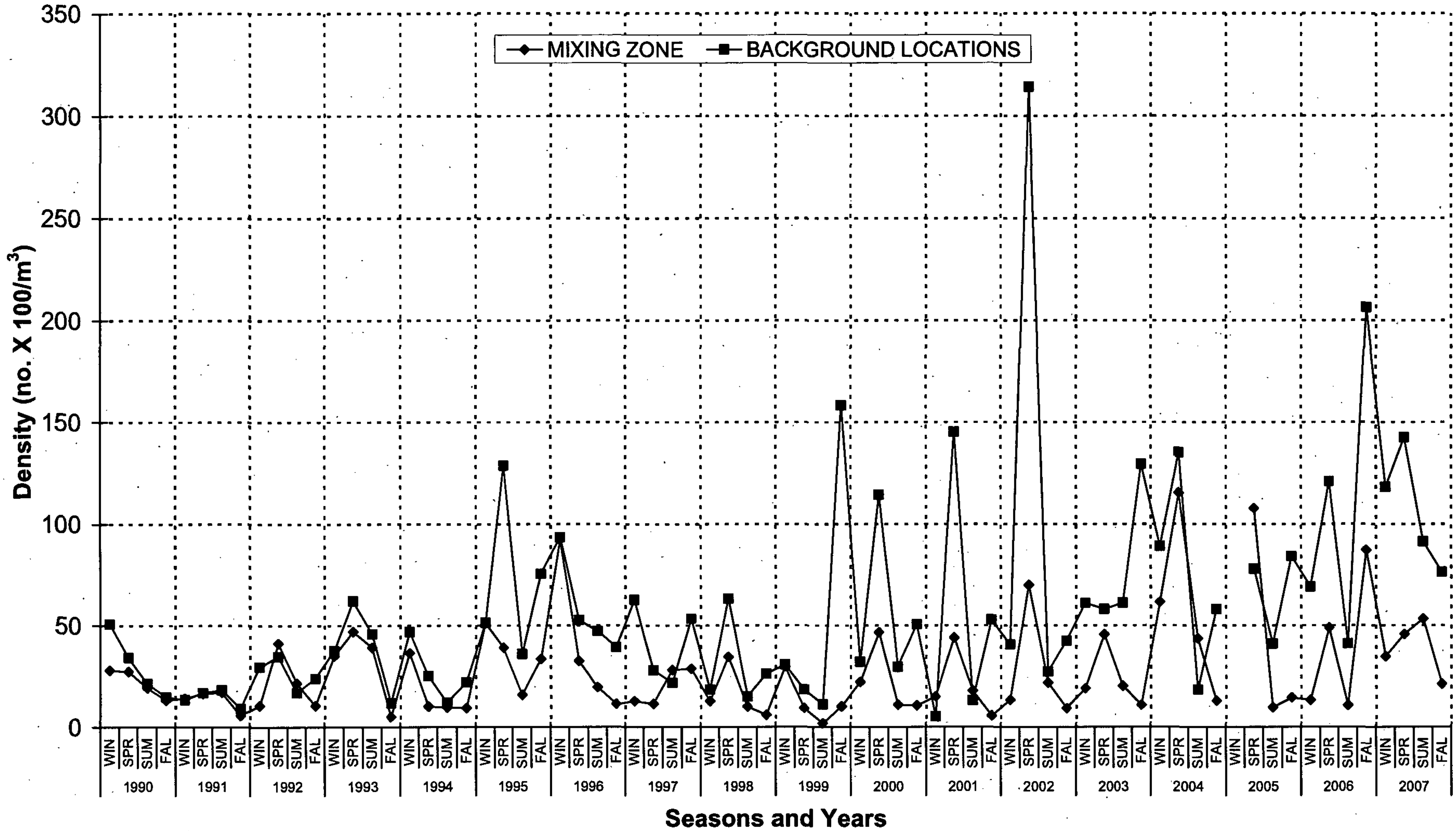


Figure 4-11. Rotifer densities during each season of each year among epilimnetic samples collected in Lake Norman from 1990 – 2007 (mixing zone = mean of Locations 2.0 and 5.0; background = mean of Locations 9.5, 11.0, and 15.9).

CHAPTER 5

FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS) and associated requirements from the North Carolina Wildlife Resources Commission (NCWRC), monitoring of specific fish population parameters in Lake Norman continued during 2007. The components of this program were:

1. spring electrofishing survey of littoral fish populations with emphasis on age, growth, size distribution, and condition of spotted bass and largemouth bass;
2. fall electrofishing survey to assess largemouth and spotted bass young-of-year abundance;
3. summer striped bass mortality surveys;
4. winter striped bass gill net survey with the NCWRC with emphasis on age, growth, and condition;
5. fall hydroacoustic and purse seine surveys of pelagic fish abundance and species composition;
6. fall crappie trap-net survey with the NCWRC with emphasis on age and growth.

METHODS AND MATERIALS

Spring Electrofishing Surveys

A spring electrofishing survey was conducted in March and April at three locations: (1) near Marshall Steam Station (MSS) in Zone 4, (2) a reference (REF) area located between McGuire Nuclear Station (MNS) and MSS in Zone 3, and (3) near MNS in Zone 1 (Figure 5-1). The locations sampled in 2007 were identical to historical locations sampled since 1993 and consisted of ten 300-m shoreline transects at each location. Transects included habitats representative of those found in Lake Norman. Shallow flats where the boat could not access within 3-4 m of the shoreline were excluded. All sampling was conducted during daylight, when water temperatures were expected to be between 15 and 20 °C. All stunned fish were collected and identified to species (scientific names of fish collected are listed in Table 5-1). Fish were enumerated and weighed in aggregate by taxon, except for largemouth and spotted bass, where total lengths (mm) and weights (g) were obtained for each individual collected. Sagittal otoliths were removed from all bass > 125 mm long (bass < 125 mm were assumed to be age 1 because young-of-year bass are historically not collected in spring samples) and sectioned for age determination (Devries and Frie 1996). Growth was calculated with the mean length for all fish of the same age. Condition based on relative weight was calculated for largemouth bass >150 mm long and spotted bass >100 mm long, using the formula Wr = (W/Ws) x 100, where W = weight of the individual fish (g) and Ws = length-specific mean weight (g) for a fish as predicted by a length-weight equation for that species (Anderson and Neumann 1996).

Fall Electrofishing Surveys for Young-of-Year Bass

A fall electrofishing survey was conducted in November at the same three locations as the spring survey and consisted of five 300-m shoreline transects at each location. Again, shallow flats where the boat could not access within 3-4 m of the shoreline were excluded. All stunned bass were collected, identified to species, and individually measured and weighed. A year class "cut off" of 150 mm was determined for all black bass by examining length-frequency data.

Summer Striped Bass Mortality Surveys

Mortality surveys were conducted weekly during July and August to specifically search for dead or dying striped bass in Zones 1-4. All observed dead striped bass were collected during these surveys and their location was noted. Individual total lengths were measured prior to disposal.

Striped Bass Netting Survey

Striped bass were collected for age, growth, and condition (Wr) determinations in early December by Duke Energy (DE) personnel. Four monofilament nets (76.2 m long x 6.1 m deep), two each containing two 38.1-m panels of 38- and 51-mm square mesh and two each containing 38.1-m panels of 63- and 76-mm square mesh, were set overnight in areas where striped bass were previously located. Individual total lengths and weights were obtained for all striped bass collected. Sagittal otoliths were removed to determine age, growth, and condition (Wr), as described previously for largemouth bass. Additionally, all catfish collected were identified and enumerated by species.

Fall Hydroacoustics and Purse Seine Surveys

The abundance and distribution of pelagic prey fish in Lake Norman were determined using mobile hydroacoustic (Brandt 1996) and purse seine (Hayes et al. 1996) techniques. The lake was divided into six zones (Figure 5-1) due to its large size and spatial heterogeneity. A mobile hydroacoustic survey of the entire lake was conducted in mid-September with multiplexing, side- and down-looking transducers to detect surface-oriented fish and deeper fish (from 2.0-m depth to the bottom), respectively. Both transducers were capable of determining target strength directly by measuring fish position relative to the acoustic axis.

Purse seine samples were also collected in mid-September from the downlake (Zone 1), midlake (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 estimate taxa composition and size distribution.

Crappie Trap-Net Survey

Duke Energy personnel provided logistical support to the NCWRC during Lake Norman crappie population sampling in early November as described by Nelson and Dorsey (2005). Crappie were collected with trap nets, identified to species, measured for individual total length and weight, and sagittal otoliths were removed for age and growth determinations.

RESULTS AND DISCUSSION

Spring Electrofishing Surveys

Electrofishing was conducted at water temperatures ranging from 14.6 to 20.0 °C. One thousand three hundred forty fish (19 species and two hybrid complexes) weighing 125.3 kg were collected in the MSS area, 1,673 fish (20 species and two hybrid complexes) weighing 77.8 kg in the REF area, and 1,563 fish (12 species and one hybrid complex) weighing 50.6

kg in the MNS area (Table 5-2). Overall, bluegill dominated samples numerically, while common carp, largemouth bass, and spotted bass dominated samples gravimetrically.

Total numbers of fish collected in spring 2007 were highest in the REF area, intermediate in the MNS area, and lowest in the MSS area (Figure 5-2). There is no apparent trend in the number of fish collected within or among areas since 1993.

Total biomass of fish was highest in the MSS area, intermediate in the REF area, and lowest in the MNS area, following the trend of previous years. This spring trend in Lake Norman fish biomass supports the spatial heterogeneity theory noted by Siler et al. (1986). The authors reported that fish biomass was higher uplake than downlake, due to higher levels of nutrients and resulting higher productivity uplake versus downlake. The spatial heterogeneity theory is further supported by higher concentrations of chlorophyll a, greater phytoplankton standing crops, and elevated epilimnetic zooplankton densities in uplake compared to downlake regions of Lake Norman (Chapters 3 and 4).

Spotted bass, thought to have originated from angler introductions, were first collected in Lake Norman in the MNS area during a 2000 fish health assessment survey. They have increased in numbers and biomass since 2001 spring electrofishing samples (Figure 5-3) and, in 2007, were most abundant in the MSS area, intermediate in the REF area, and least abundant in the MNS area. Biomass was highest in the MNS area, intermediate in the REF area, and lowest in the MSS area.

In 2007, small spotted bass (< 150 mm) dominated the black bass catch in all areas sampled (Figure 5-4), and their growth was generally similar among all areas sampled (Table 5-3). Spotted bass Wr ranged from 66.4 for fish 100-149 mm long in the MNS area to 85.5 for fish 350-399 mm long in the MSS area (Figure 5-5). Overall, spotted bass Wr values were highest in the MSS area (75.3), intermediate in the REF area (75.1), and lowest in the MNS area (71.6); a decrease relative to 2006 values (MSS=77.2, REF=80.7, MNS=77.4) and within the range of observed historical values (71.4-82.3) (Duke Power unpublished data, 2004, 2005; Duke Energy 2006, 2007).

Relative to 2006, 2007 largemouth bass numbers increased slightly in the REF and MNS areas and decreased slightly in the MSS area (Figure 5-6). Largemouth bass biomass increased in the MSS and REF areas and decreased in the MNS area. Numbers and biomass values at all locations were generally similar to 2006, the lowest recorded since sampling began in 1993. As in most years, 2007 largemouth bass numbers and biomass were highest in the MSS area, intermediate in the REF area, and lowest in the MNS area.

Since 2000, largemouth bass >300 mm dominated the catch in all three sampling areas (Duke Power 2001, 2002, 2003, 2004, 2005; Duke Energy 2006), with largemouth bass < 150 mm low in abundance. An exception was in 2006, where a high abundance of largemouth bass < 150 mm occurred in the MSS area (Duke Energy 2007). In 2007, largemouth bass >300 were relatively abundant, but not dominant (Figure 5-4).

There was no trend in largemouth bass growth among areas in 2007 (Table 5-3); however, largemouth bass mean lengths for ages 2, 3, and 4 were generally higher beginning in 2003, relative to historical data (1974 – 78, 1993, and 1994)(Table 5-4). While displacement of largemouth bass since the introduction of spotted bass in the lower lake is apparent, the direct effect on largemouth bass recruitment is indeterminate, possibly due to confounding effects of other introductions including alewife and white perch (Kohler and Ney 1980, Madenjian et al. 2000).

Largemouth bass Wr ranged from 79.1 for fish 200-249 mm long to 89.9 for fish 300-349 mm long, both in the REF area (Figure 5-5). Overall, largemouth bass Wr values were highest in the MNS area (84.8), intermediate in the MSS area (84.6), and lowest in the REF area (82.5); a decrease relative to 2006 values (MNS=86.3, MSS=87.2, REF=88.0) and within the range of observed historical values (76.0-89.9). (Duke Power unpublished data, 2004, 2005; Duke Energy 2006, 2007).

Fall Electrofishing Young-of-Year Bass Surveys

Fall 2007 electrofishing resulted in the collection of 109 spotted and five largemouth bass young-of-year (< 150 mm), compared to 95 spotted and four largemouth bass in 2006 and 94 spotted and 20 largemouth bass in 2005 (Figure 5-7). Additionally, no hybrid bass young-of-year were collected in 2007. As in 2005 and 2006, young-of-year black bass numbers were highest in the MSS area.

Summer Striped Bass Mortality Surveys

In 2007, a total of 13 dead striped bass were collected during the July-August surveys (Table 5-5). Since the survey began in 1983, summer mortalities in excess of 25 dead striped bass occurred in three years: 163 in 1983, 43 in 1986, and 2,610 in 2004.

Striped Bass Netting Survey

Dominated by age 1 and age 2 fish, 181 striped bass were collected in early December 2007 (Figure 5-8). Striped bass growth was fastest through age 3 and slowed with increasing age. Additionally, mean Wr was highest for age 1 fish and declined with age. Mean Wr was 79.5 for all striped bass in 2007, within the range of observed historical values (78.5-84.1). Growth and condition in 2007 were similar to historical values since consistent gillnetting began in 2003 (Duke Power 2004, 2005; Duke Energy 2006, 2007).

The December striped bass gillnetting also yielded 76 catfish. Blue catfish (63) dominated the catch, followed by flathead catfish (11), and channel catfish (2).

Fall Hydroacoustics and Purse Seine

Average forage fish densities in the six zones of Lake Norman ranged from 1,338 (Zone 1) to 13,421 (Zones 5 and 6) fish/ha in September 2007 (Table 5-6). Zone 6 fish densities were assumed to be the same as Zone 5, as the shallow nature of the riverine Zone 6 limits habitat available for acoustic sampling. The lake-wide population estimate in September 2007, approximately 72 million fish, was within the range of annual estimates since 1997 and well above the lowest estimate of 47.1 million recorded in 2004 (Figure 5-9). As in most years since 1997, Zone 5 had the highest forage fish density estimates. No temporal trends are evident in lakewide pelagic fish population estimates in Lake Norman from 1997 through 2007.

Purse seine sampling in 2007 indicated that the forage fish population estimated by hydroacoustics was comprised of 98.3% threadfin shad and 1.7% alewives (Table 5-7). As in 2006, no gizzard shad were collected in the 2007 purse seine samples, and the modal length of threadfin shad was between 41 and 45 mm (Figure 5-10). Alewives were first detected in low numbers in 1999 and increased to approximately 25% of the pelagic forage fish community by 2002. The percent composition of alewives declined from 2002 to 2005, increasing to approximately 5.1% in 2006, and down to 1.7% of the forage fish catch in 2007. The overall increase and subsequent decrease in the percent composition of alewife was concurrent with an increase in the threadfin shad modal length class and subsequent decrease to values measured prior to the alewife introduction.

Crappie Trap-Net Study

In 2007, NCWRC personnel set 90 overnight trap-nets in Lake Norman. They collected 350 black crappie and 24 white crappie. Various life history data were collected for use in fish management decisions.

FUTURE STUDIES

In addition to the 2007 Lake Norman Monitoring Program surveys, DE will conduct biennial fall trap-net surveys with the NCWRC for crappies, with emphasis on age and growth. Additionally, DE will conduct purse seine sampling in late June/early July 2008 to assist NCWRC in evaluating the changing forage fish community. These changes were approved by NCWRC in a letter dated March 7, 2008.

SUMMARY

In accordance with the Lake Norman Maintenance Monitoring Program for the MNS NPDES permit, specific fish monitoring programs continued during 2007. Spring electrofishing indicated that 12 to 20 species of fish and two hybrid complexes comprised fish populations in the three sampling areas, and numbers and biomass of fish in 2007 were generally similar to those noted annually since 1993. Largemouth bass numbers and biomass continue to decline in recent years and the 2007 numbers and biomass were some of the lowest recorded since sampling began in 1993. During 2007, the number of summer striped bass mortalities (13) and winter mean relative weight (79.5) were similar to those of previous years. Hydroacoustic sampling estimated a forage fish population of approximately 72 million in 2007, comparable to previous years. After an increase in 2006, purse seine sampling indicated a decrease in the percentage of alewives in 2007 to the lowest percent composition since their 1999 introduction. During 2007, threadfin shad lengths remained at pre-alewife introduction sizes.

Table 5-1. Common and scientific names of fish collected in Lake Norman, 2007.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorosoma petenense*
Greenfin shiner	*Cyprinella chloristia*
Whitefin shiner	*Cyprinella nivea*
Common carp	*Cyprinus carpio*
Bluehead chub	*Nocomis leptocephalus*
Golden shiner	*Notemigonus crysoleucas*
Spottail shiner	*Notropis hudsonius*
Quillback	*Carpiodes cyprinus*
Shorthead redhorse	*Moxostoma macrolepidotum*
Blue catfish	*Ictalurus furcatus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
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 each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 2007.

	MSS		REF		MNS	
Taxa	No.	kg	No.	kg	No.	kg
Gizzard shad	9	3.93	10	4.89	1	0.49
Threadfin shad					292	1.75
Greenfin shiner	1	< 0.01	1	< 0.01	7	0.02
Whitefin shiner	43	0.27	20	0.08		
Common carp	20	52.60	5	11.80	5	11.27
Bluehead chub	1	< 0.01				
Golden shiner	2	0.01	1	< 0.01		
Spottail shiner	14	0.17	42	0.30	2	0.01
Quillback			1	0.30		
Blue catfish			1	2.25		
Channel catfish	8	2.80	4	1.34	2	0.72
Flathead catfish	1	0.38	5	2.30		
White perch	1	0.02				
Redbreast sunfish	139	2.89	392	5.72	240	4.03
Green sunfish	51	0.81	2	0.02		
Warmouth	23	0.19	52	0.30	26	0.17
Bluegill	713	8.08	895	7.88	830	7.72
Redear sunfish	113	10.93	98	8.12	51	4.18
Hybrid sunfish	63	1.71	40	0.73	30	0.73
Spotted bass	72	7.39	62	11.94	60	13.68
Largemouth bass	55	29.58	31	17.09	17	5.86
Hybrid black bass	5	1.92	3	0.50		
Black crappie	5	1.64	5	2.21		
Tessellated darter	1	< 0.01	2	< 0.01		
Yellow perch			1	< 0.01		
Total	1340	125.34	1673	77.81	1563	50.62

Table 5-3. Mean total lengths (mm) at age for spotted bass (SPB) and largemouth bass (LMB) collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 2007.

		Age										
Taxa	Location	1	2	3	4	5	6	7	8	9	10	11
SPB	MSS	192	287	344	401							
	REF	175	307	378	421	410						
	MNS	193	314	389	390							
LMB	MSS	215	261	363	394	418	412	463	411	465		436
	REF	186	285	371	367	369	429	456				
	MNS		355	402	433	382	382					

Table 5-4. Comparison of mean total length (mm) at age for largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 2007, to historical largemouth bass mean lengths.

	Age			
Location and year	1	2	3	4
MSS 1974-78[a]	170	266	310	377
MSS 1993[b]	170	277	314	338
MSS 1994[b]	164	273	308	332
MSS 2003[c]	216	317	349	378
MSS 2004[d]	176	309	355	367
MSS 2005[e]	190	314	358	396
MSS 2006[f]	184	347	346	408
MSS 2007	215	261	363	394
REF 1993[b]	157	242	279	330
REF 1994[b]	155	279	326	344
REF 2003[c]	139	296	358	390
REF 2004[d]	143	288	364	415
REF 2005[e]	139	307	357	386
REF 2006[f]	180	300	363	378
REF 2007	186	285	371	367
MNS 1971-78[a]	134	257	325	376
MNS 1993[b]	176	256	316	334
MNS 1994[b]	169	256	298	347
MNS 2003[c]	197	315	248	389
MNS 2004[d]	170	276	335	370
MNS 2005[e]	136	342	359	429
MNS 2006[f]	169	308	361	402
MNS 2007	-	355	402	433

[a] Siler 1981; [b] Duke Power unpublished data; [c] Duke Power 2004a; [d] Duke Power 2005; [e] Duke Energy 2006; [f] Duke Energy 2007

Table 5-5. Striped bass mortalities observed in Lake Norman during weekly surveys during July and August 2007.

Date	Number	Zone	Total length (mm)
Jul 2	5	1	562,602
		4	464, 582, 590
Jul 9	2	2	550
		4	520
Jul 23	1	2	583
Aug 6	3	1	572, 580
		4	586
Aug 30	2	1	608
		3	465

Table 5-6. Lake Norman forage fish densities (number/hectare) and population estimates from hydroacoustic surveys in September 2007.

Zone	No./ha	Population Estimate
1	1,338	3,052,557
2	3,176	9,789,539
3	5,461	18,871,072
4	4,531	5,577,740
5	13,421	28,264,588
6	13,421[a]	6,415,229
Lakewide total		71,970,725
95% CI		65,300,347 – 78,641,103

[a] Zone 6 fish density was assumed to be the same as Zone 5

Table 5-7. Total numbers and percent composition of forage fish, and modal length class of threadfin shad collected in purse seine samples from Lake Norman during late summer/fall, 1993 – 2007.

		Species Composition			Threadfin shad modal
Year	No.	Threadfin	Gizzard	Alewife	length class (mm)
1993	13,063	100.00%	0.00%	0.00%	31-35
1994	1,619	99.94%	0.06%	0.00%	36-40
1995	4,389	99.95%	0.05%	0.00%	31-35
1996	4,465	100.00%	0.00%	0.00%	41-45
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
2005	23,147	98.10%	0.00%	1.90%	41-45
2006	14,823	94.87%	0.00%	5.13%	41-45
2007	27,169	98.34%	0.00%	1.66%	41-45

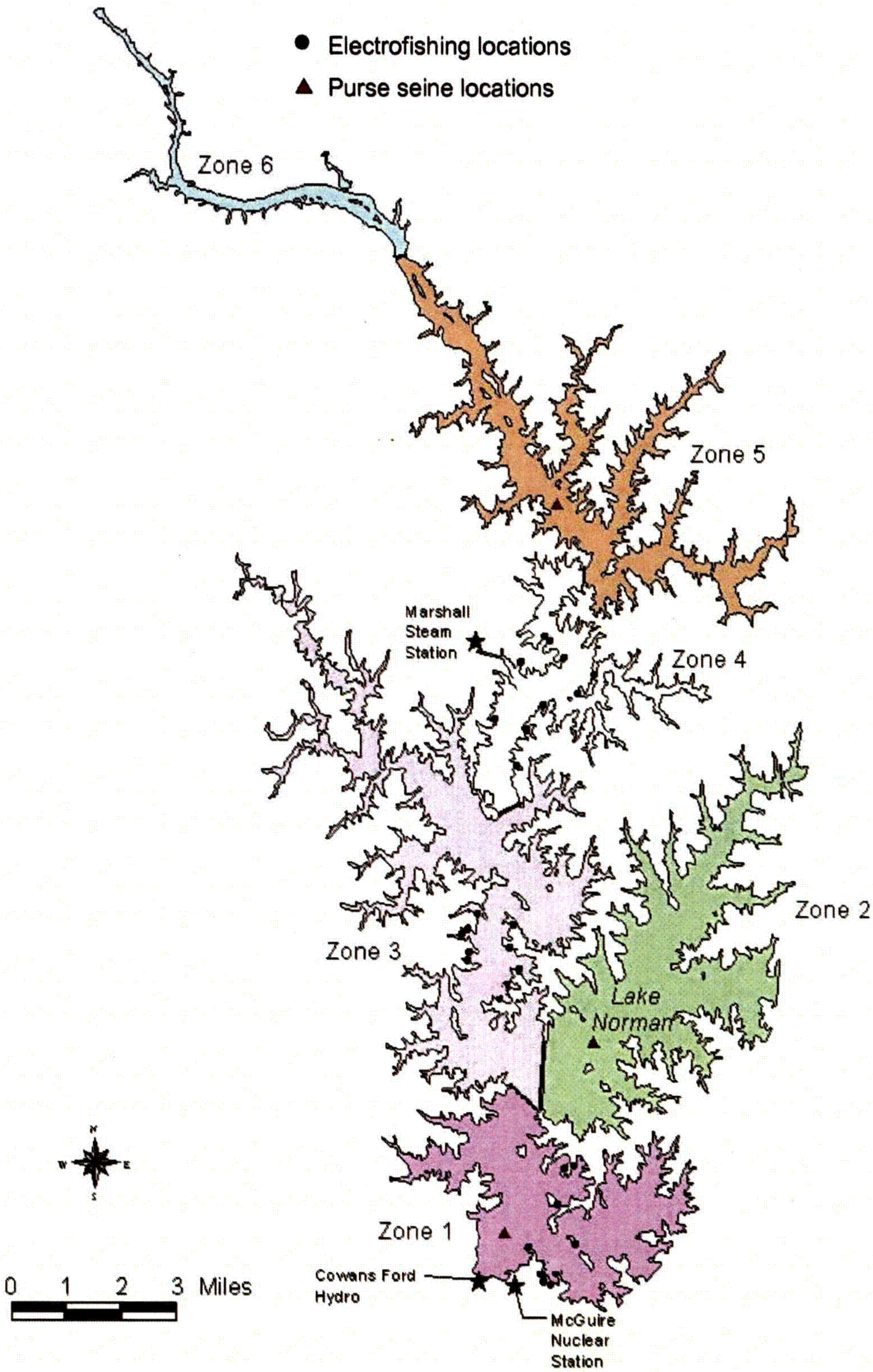
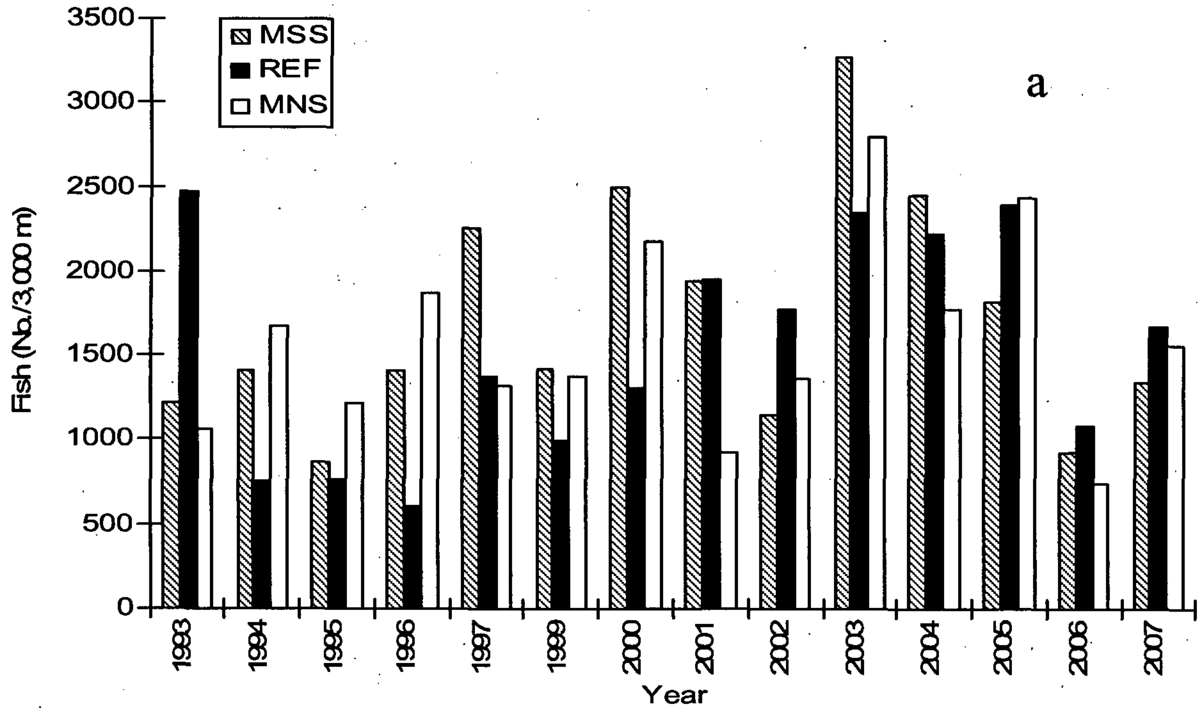


Figure 5-1. Sampling locations and zones associated with fishery assessments in Lake Norman.



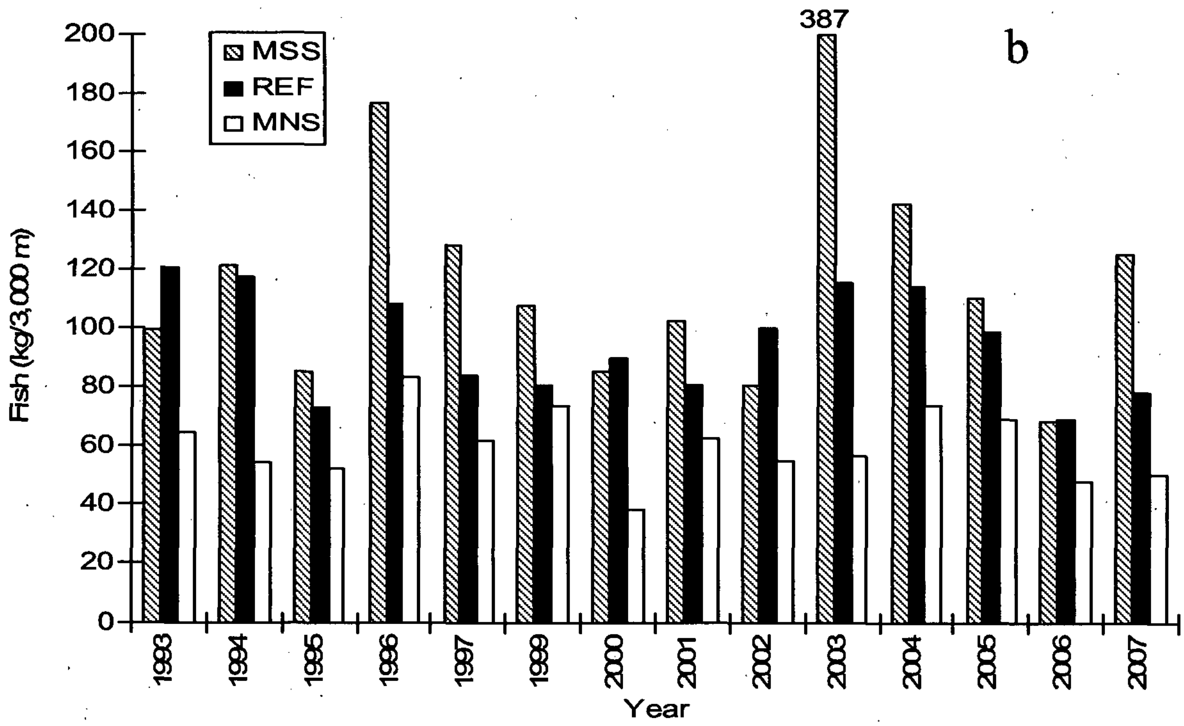
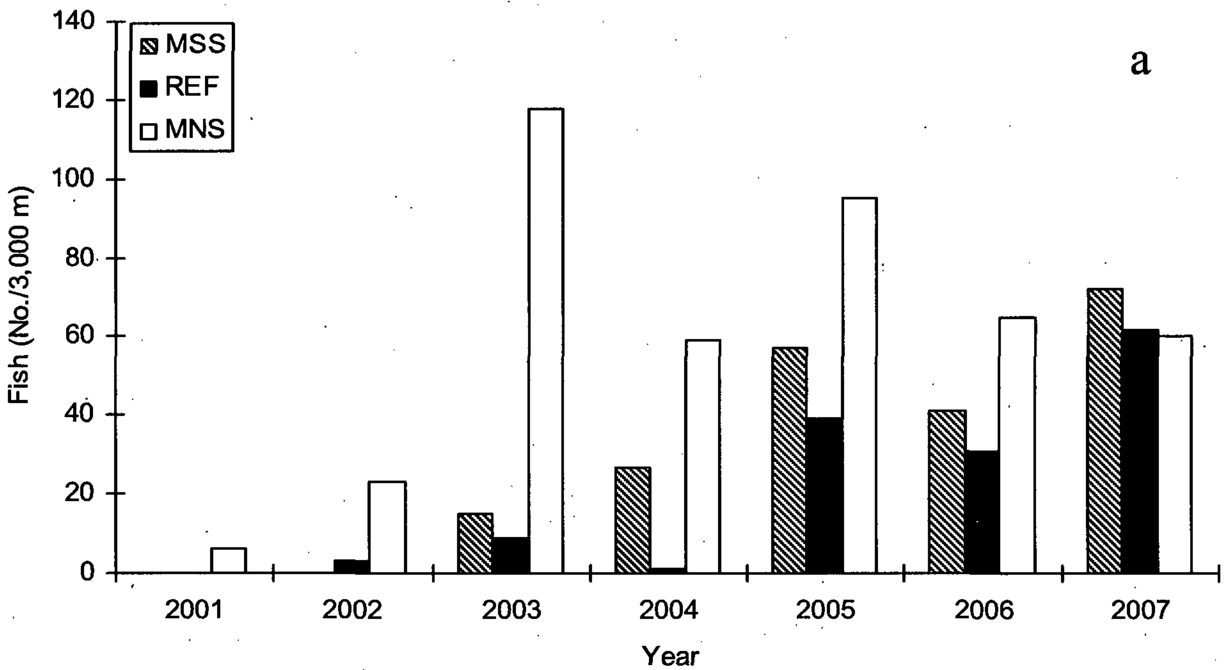


Figure 5-2. Total a) number and b) biomass of fish collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, 1993 – 1997 and 1999 – 2007.



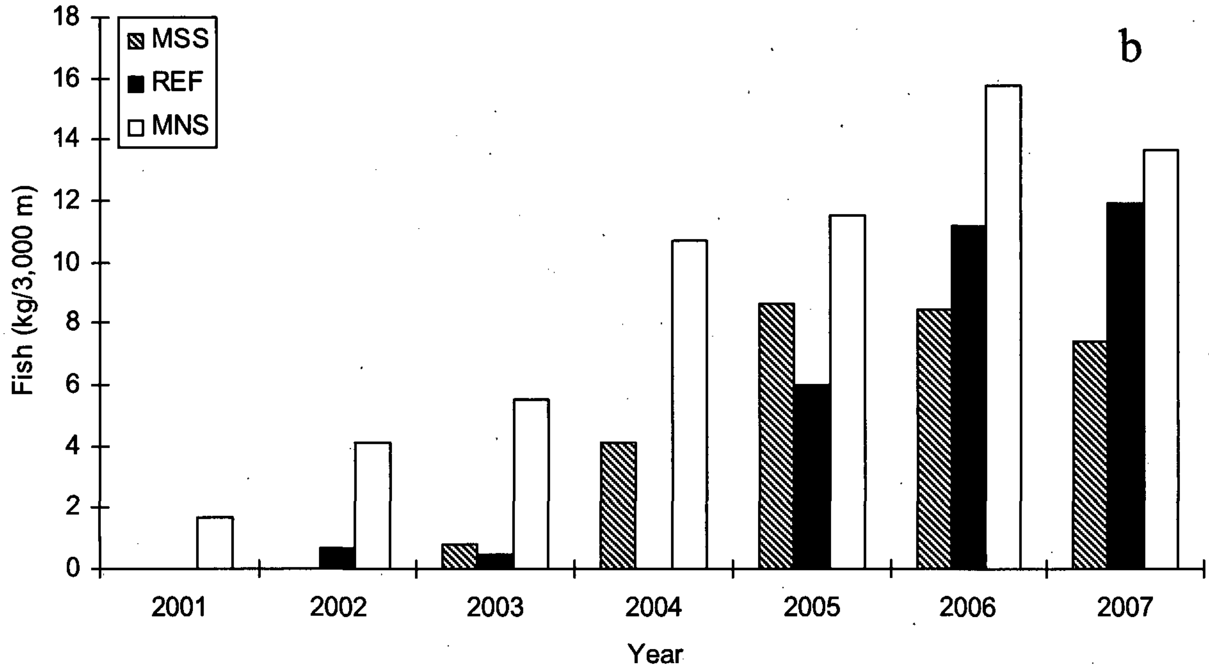


Figure 5-3. Total a) number and b) biomass of spotted bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF,MNS) in Lake Norman, 2001 – 2007.

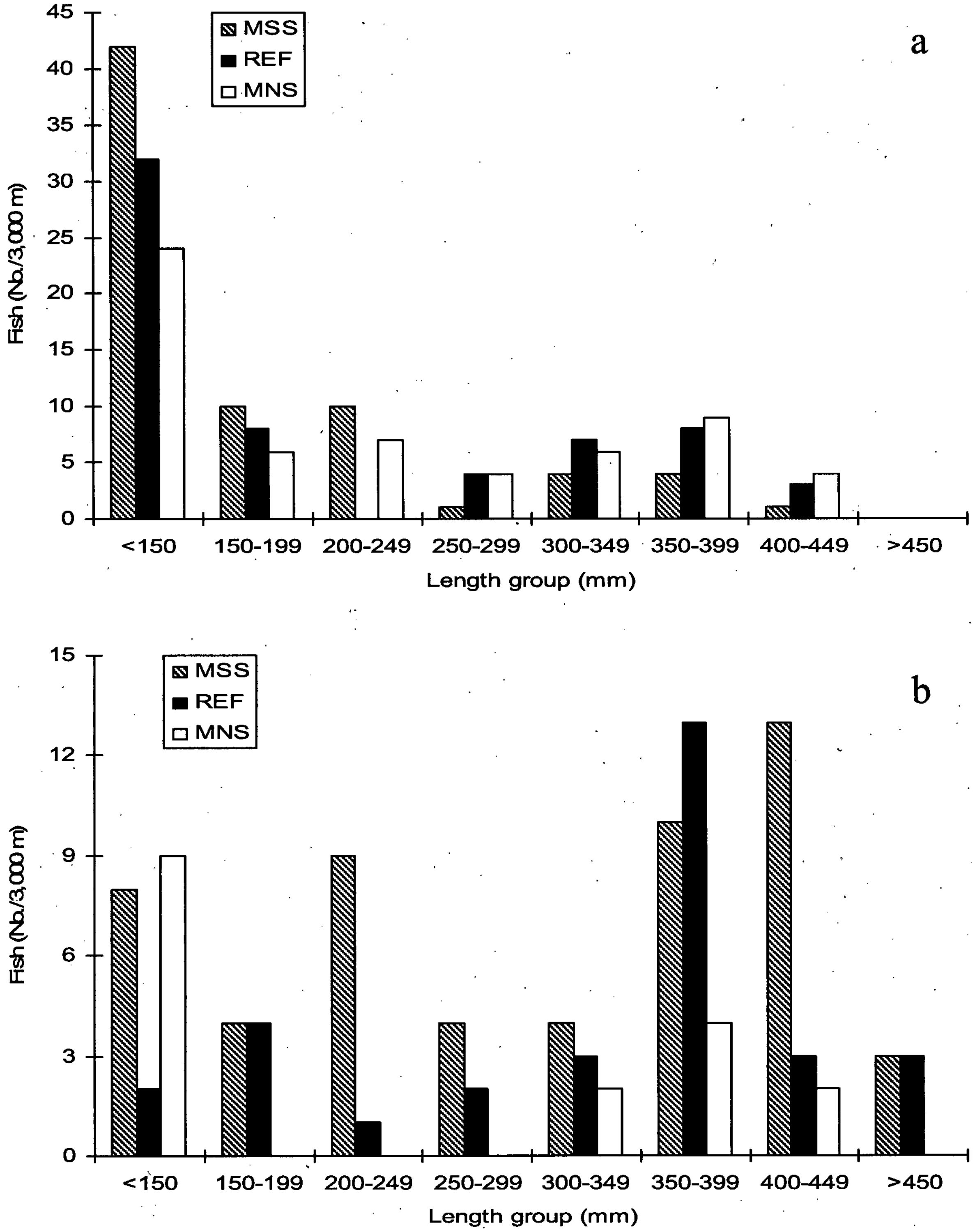


Figure 5-4. Size distributions of a) spotted bass and b) largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, 2007.

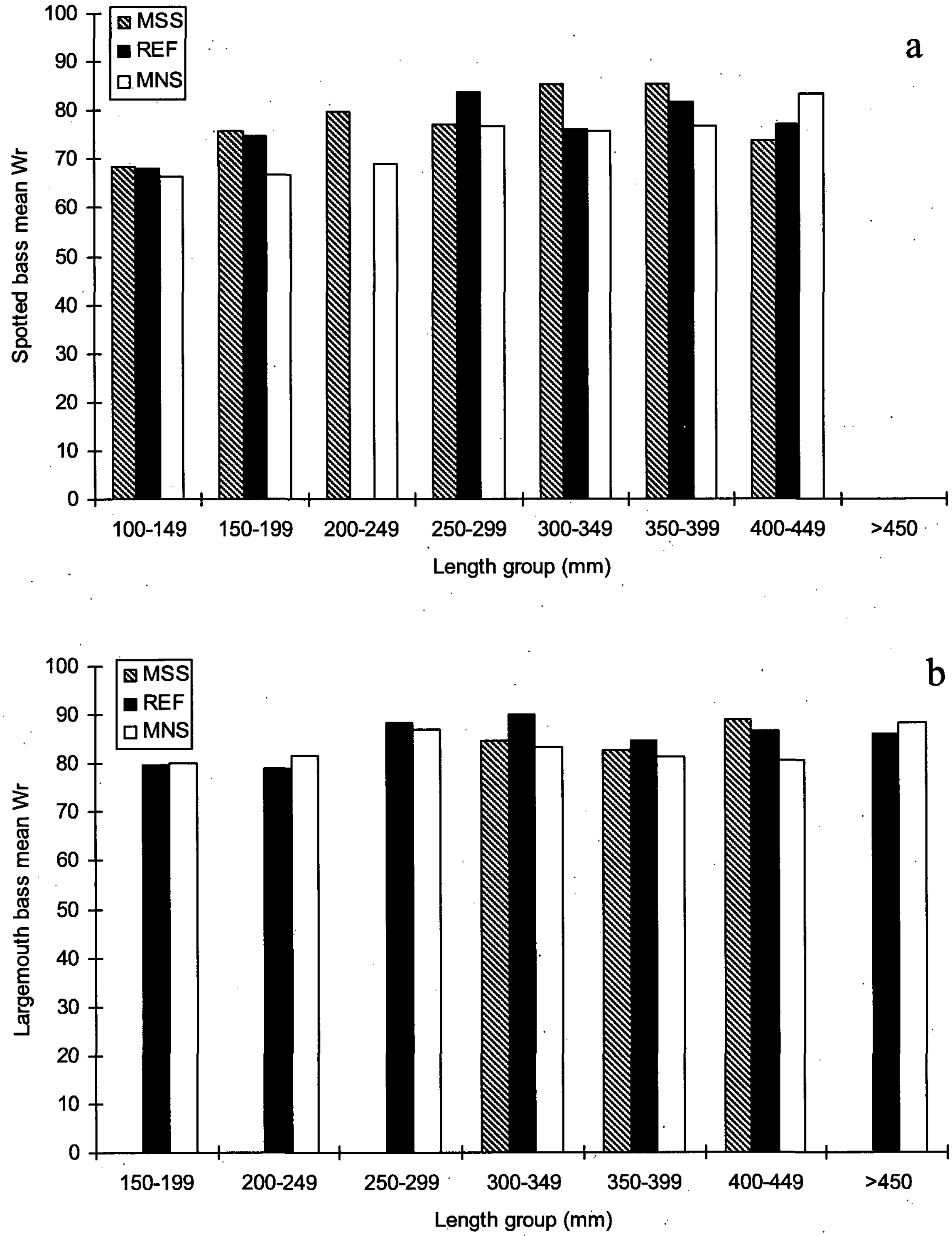


Figure 5-5. Mean relative weights (Wr) for a) spotted bass and b) largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, 2007.

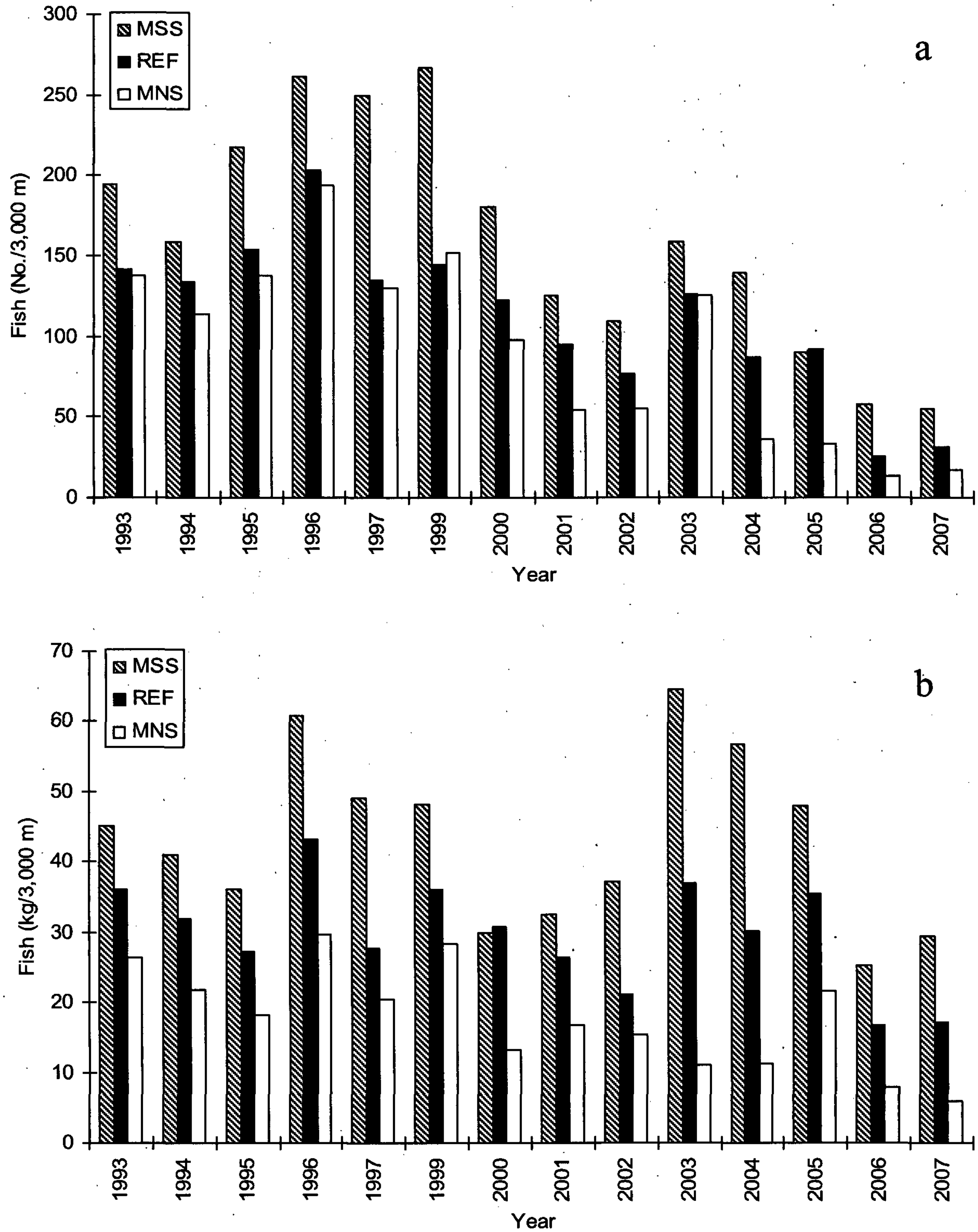


Figure 5-6. Total a) number and b) biomass of largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, 1993 – 1997 and 1999 – 2007.

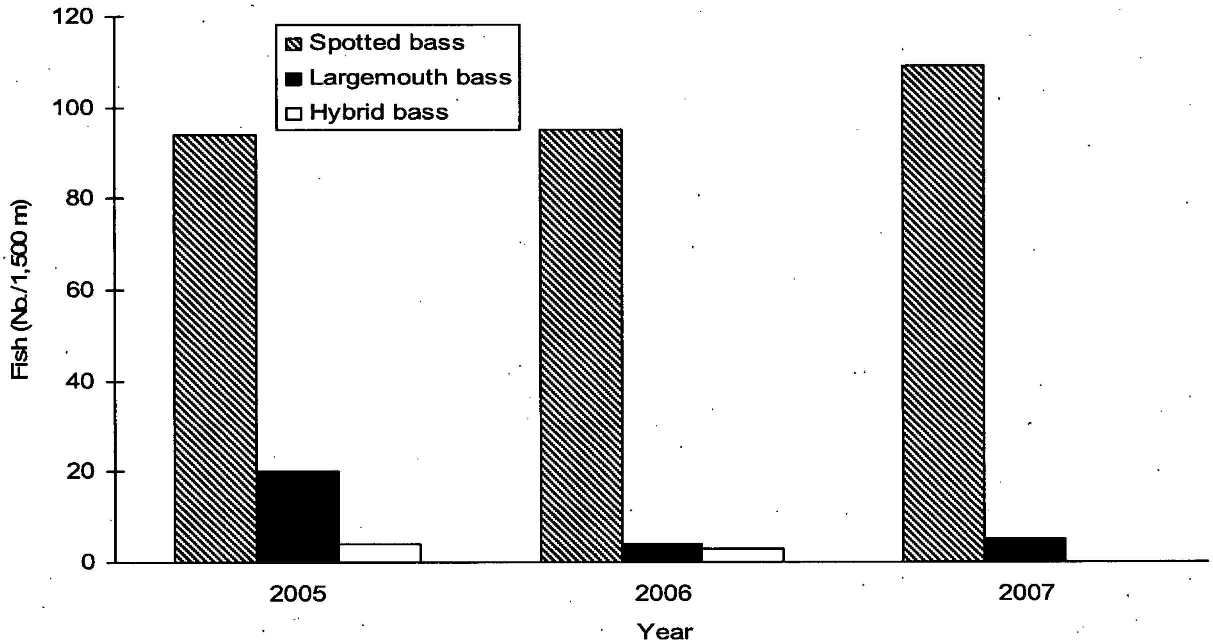


Figure 5-7. Total number of young-of-year black bass collected from electrofishing five 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, 2005 – 2007.

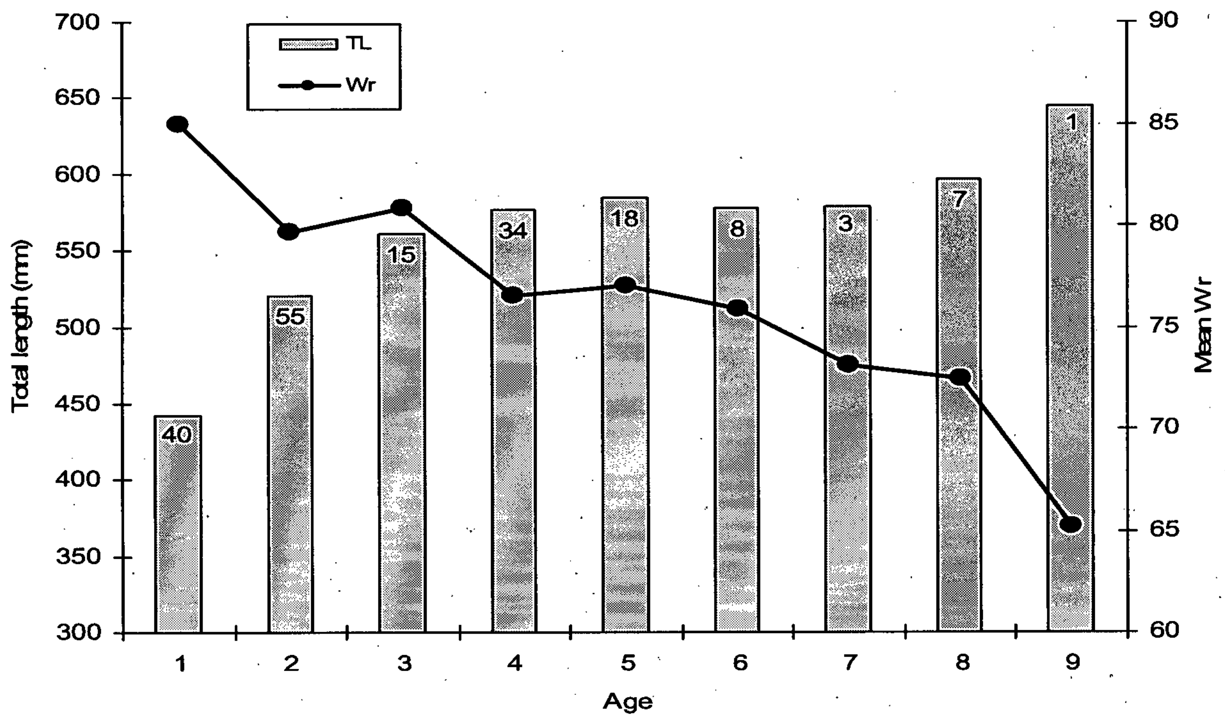


Figure 5-8. Mean total length and mean relative weight (Wr) for striped bass collected from Lake Norman, December 2007. Numbers of fish associated with mean length are inside bars.

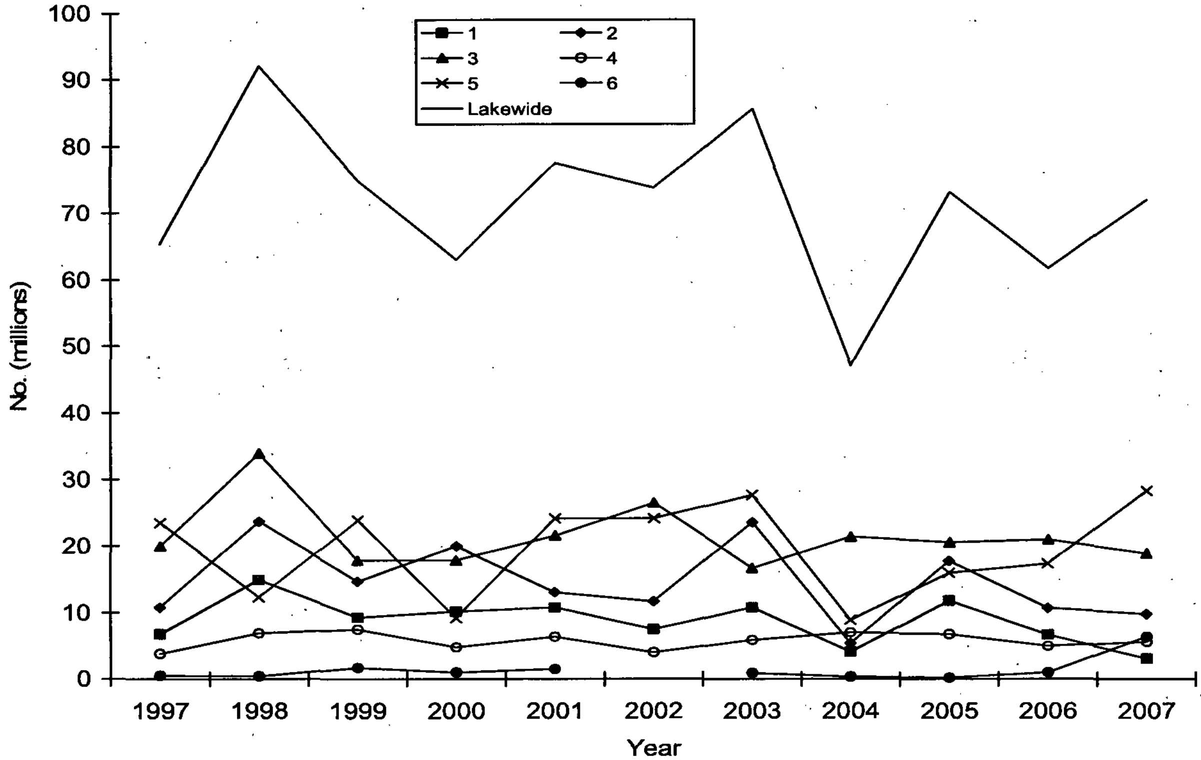


Figure 5-9. Zonal and lake-wide population estimates of pelagic forage fish in Lake Norman, 1997 – 2007.

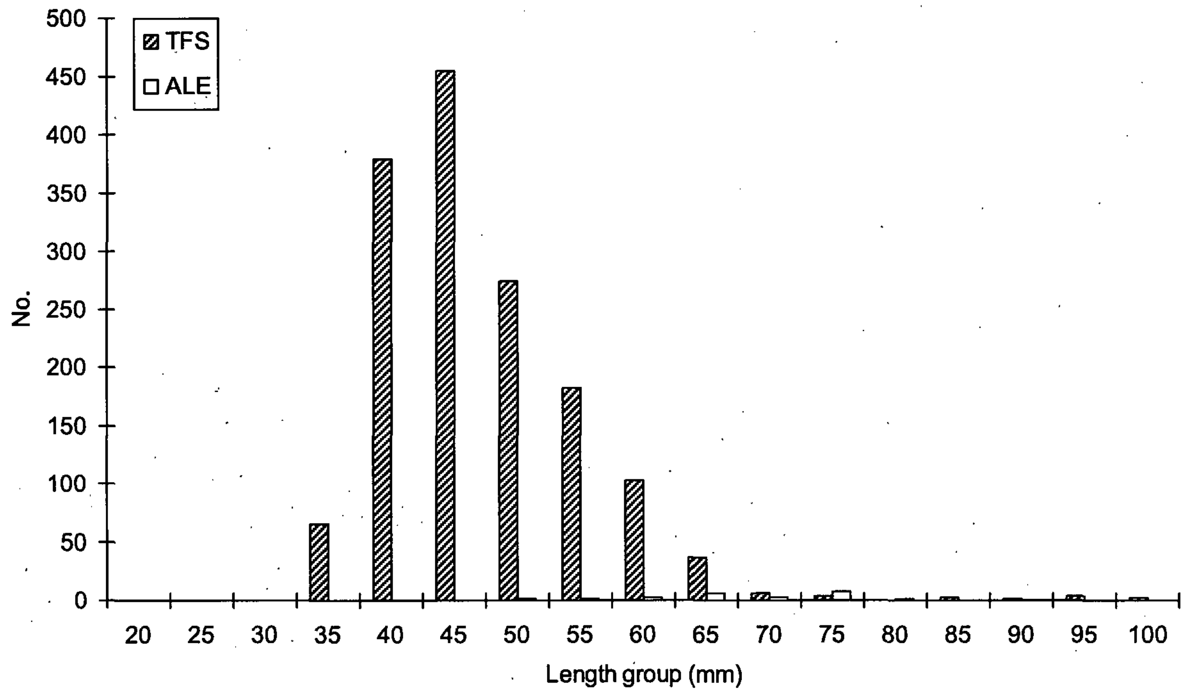


Figure 5-10. Number and size distributions of threadfin shad (TFS) and alewives (ALE) collected in purse seine surveys of Lake Norman, 2007.

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