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February 9, 2010

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

SUBJECT: Duke Energy Carolinas, LLC
McGuire Nuclear Station
Docket No. 50-369, 370
Lake Norman Maintenance Monitoring Program:
2008 Summary

Please find attached a copy of the annual "Lake Norman Maintenance Monitoring Program: 2008 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 January 25, 2010.

Questions regarding the attached report should be directed to Kay L. Crane at (980) 875-4306.

Regis T. Repko

Regis T. Repko

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January 25, 2010

Mr. Jay Sauber
North Carolina Department of Environment
and Natural Resources
Environmental Sciences Section
1621 Mail Service Center
Raleigh, NC 27699-1621

Subject: McGuire Nuclear Station
Lake Norman Environmental Monitoring Program: 2008 Summary Report

Certified:

Dear Mr. Sauber:

Enclosed are three copies of the annual Lake Norman Environmental Monitoring Program: 2008 Summary Report, as required by NPDES permit NC0024392.

Results of the 2008 data were comparable with that of previous years. No obvious short-term or long-term impacts of station operations were observed in water quality, phytoplankton, zooplankton, and fish communities. Additionally, 2008 station operation data demonstrates compliance with permit thermal limits and cool water management requirements.

Fishery studies continue to be coordinated with the Division of Inland Fisheries of the North Carolina Wildlife Resource Commission to address Lake Norman's fishery management issues.

If you have any questions concerning this report, please contact John Williamson by phone at (704) 875-5894 or by email at John.Williamson@duke-energy.com

Sincerely,

Regis T. Repko
Site Vice President
Duke Energy Carolinas, LLC
McGuire Nuclear Station

Duke Energy Carolinas LLC
McGuire Nuclear Station
12700 Hagers Ferry Road
Huntersville, NC 28078

January 25, 2010

Mr. Brian McRae
NC Wildlife Resources Commission
2312 Summit Drive
Hillsboro, NC 27278

Subject: McGuire Nuclear Station
Lake Norman Environmental Monitoring Program: 2008 Summary Report

Dear Mr. McRae:

Enclosed are three copies of the annual Lake Norman Environmental Monitoring Program: 2008 Summary Report, as required by NPDES permit NC0024392.

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If you have any questions concerning this report, please contact John Williamson by phone at (704) 875-5894 or by email at John.Williamson@duke-energy.com

Sincerely,

Regis T. Repko
Site Vice President
Duke Energy Carolinas, LLC
McGuire Nuclear Station

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	3 copies to NCDENR	
	1 copy NCWRC	

bcc w/attch: Record No. MN-004775

LAKE NORMAN

MAINTENANCE MONITORING PROGRAM:

2008 SUMMARY

McGuire Nuclear Station: NPDES No. NC0024392

Principal Investigators:

Michael A. Abney
John E. Derwort
William J. Foris

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December 2009

LAKE NORMAN

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December 2009

ACKNOWLEDGMENTS

The authors wish to express their gratitude to a number of individuals who made significant contributions to this report. First, we are much indebted to the EHS Scientific Services field staff in carrying out a complex, multiple-discipline sampling effort that provides the underpinning of this report. We would like to thank Glenn Long for support in water quality sample collections. Kim Baker, Bob Doby, James Hall, Bryan Kalb, Glenn Long, and Todd Lynn were vital contributors in completing fisheries collections and sample processing. James Hall, Aileen Lockhart, Shannon McCorkle, and Jan Williams contributed in macroinvertebrate sampling, sorting and taxonomic processing.

We would also like to thank multiple reviewers; including Penny Franklin, Duane Harrell, Ron Lewis, and John Velte. The insightful commentary and suggestions from these individuals and also between co-authors have benefited the report in myriad ways.

TABLE OF CONTENTS

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 2008. Overall, no obvious long-term impacts of station operations were observed in water quality or phytoplankton, zooplankton, and fish communities. The 2008 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 2008 were 99.8, 100.0 and 81.9% during July, August, and September, respectively. The average monthly discharge temperature was 97.7 °F (36.5 °C) for July, 98.3 °F (36.8 °C) for August and 94.6 °F (34.8 °C) for September 2008, below the 99.0-°F (37.2-°C) thermal limit for these months. The volume of cool water in Lake Norman in 2008 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 2008 totaled 119.1 cm or 40.9 cm more than observed in 2007 (78.2 cm), and 1.5 cm more than the long-term precipitation average for this area (117.6 cm). Air temperatures near the MNS in 2008 were cooler than in 2007 and similar to the long-term mean, based on monthly average data.

Temporal and spatial trends in water temperature and DO in 2008 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in 2008 for the months of January, March, and April ranged from 0.1 to 4.8 °C cooler than measured in 2007 with minor differences between zones, whereas February temperatures were generally similar between years. 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 2 at MNS in March 2008 also contributed to these interannual differences during the winter and early spring.

Summer water temperatures in 2008 were similar to those observed in 2007 in both zones, with minor exceptions in the mixing zone. Surface water temperatures in the mixing zone in June and August 2008 were up to 2.9 °C warmer than observed in 2007. Late summer, fall, and early winter water temperatures in 2008 were consistently cooler in both zones than those measured in 2007, and followed the trend exhibited in air temperatures. The most striking differences were observed in the mixing zone in October when 2008 temperatures were as much as 4.1 °C cooler than measured in 2007. Temperatures at the discharge location in 2008 were generally similar to 2007 and historical data. Temperatures in 2008 were slightly cooler from September – December than in 2007. The warmest discharge temperature of 2008 (38.5 °C) occurred in August and was identical to the maximum measured in 2002.

Seasonal and spatial patterns of DO in 2008 were reflective of the patterns exhibited for temperature, i.e., generally similar in both the mixing and background zones. Winter and spring DO values measured during this period were either equal to or greater, in both the background and mixing zones, than measured in 2007 and appeared to be related predominantly to the differences in water column temperatures in 2008 versus 2007. Summer DO values in 2008 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 2007 and earlier years. All dissolved oxygen values recorded in 2008 during this period were within the historical range. Considerable differences were observed between 2008 and 2007 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, November, and December. The 2008 late summer and autumn DO data indicated that fall convective reaeration proceeded faster and was more advanced than observed in the corresponding months in 2007. Consequently, 2008 DO levels at most depths were either equal to or greater than observed in 2007. The seasonal pattern of DO in 2008 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 2008 at location 4.0 were slightly higher than observed in 2007 and most likely attributable to greater DO concentrations in the intake waters during this period, and cooler discharge temperatures. The lowest DO concentration measured at the discharge location in 2008 (6.2 mg/L) occurred in August, and was 0.5 mg/L higher than measured in August, 2007; it was also 2.2 mg/L higher than the historical minimum, measured in August 2003 (4.1 mg/L).

Reservoir-wide isotherm and isopleth information for 2008, 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 2008 were similar to conditions in most previous years except that in 2008 no habitat existed in the upper, riverine segments of the reservoir.

Observed striped bass mortalities in 2008 totaled seventeen fish; however, many appeared to be fishing release mortalities.

The results of all chemical parameters measured in 2008 were similar to 2007 and within the concentration ranges previously reported for the lake during both preoperational and operational years of MNS. Specific conductance, 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 2008 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 2008, 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. No iron values in 2008 exceeded the North Carolina water quality action level for iron (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 *a* concentrations were generally within historical ranges during 2008; however, monthly means in February and May, while above long-term minima, were well below the long-term lake-wide means for these periods. Seasonally, chlorophyll *a* concentrations decreased from February through May to the annual minimum, and then increased through August to the annual lake-wide maximum in November. Maximum concentrations among sampling locations were typically observed at Location 69.0 (furthest uplake), with the exception of Location 15.9 in November when the concentration was the only one greater than 12 µg/L. The highest chlorophyll *a* value recorded in 2008, 12.51 µg/L, was well below the NC State Water Quality standard of 40 µg/L.

Phytoplankton densities and biovolumes during February and May 2008 were lower than in these months of 2007, while standing crop values in August and November 2008 were higher than during these periods of the previous year. Phytoplankton densities during 2008 never exceeded the NC guideline for algae blooms, however, one biovolume was in excess of the guideline of 5,000 mm^3/m^3.
Seston dry and ash-free weights were most often higher in 2008 than in 2007 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, while minimum values occurred most often 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 was slightly lower in 2008 than in 2007 and within historical ranges observed since 1992.

Diversity, or the number of phytoplankton taxa in 2008 was the second highest recorded since the beginning of this monitoring program. The taxonomic composition during 2008 was similar to many previous years. Cryptophytes were dominant in February at all but Location 15.9 in May, while diatoms were dominant during May at Location 15.9 and all locations in November. Green algae were dominant during August. Blue-green algae were less abundant in 2008 than in 2007, and their contribution to total densities was rarely over 1%.

The cryptophyte *Rhodomonas minuta* was the most abundant alga observed each year of the Lake Norman Maintenance Monitoring Program. The diatom *Fragillaria crotonensis* was the most abundant diatom at Location 15.9 in May, while *Tabellaria fenestrata* was dominant in November. The small desmid, *Cosmarium asphearosporum* var. *strigosum* was dominant in August 2008. These taxa have been common and abundant throughout the program.

During 2008, there was a considerable amount of spatial variability in annual epilimnetic zooplankton maxima. Epilimnetic zooplankton densities have been observed most often in the spring of previous years. During 2008, however, only Location 2.0 demonstrated its peak annual density in the spring. Location 5.0 demonstrated its peak annual density in the summer. Annual maxima at Locations 9.5 and 15.9 occurred in the fall, and the annual maximum at Location 11.0 was recorded in the winter.

Epilimnetic zooplankton densities were generally within the ranges of densities observed in previous years, except at Location 2.0 in the winter and spring, and Location 5.0 in the spring. On both occasions, these locations demonstrated long-term seasonal minimum densities.

Overall, zooplankton densities in 2008 followed long-term spatial trends. Epilimnetic densities were higher than whole-column densities. Mean zooplankton densities were usually lower among mixing zone locations than among background locations in 2008 and in most previous years of the program. Much higher seasonal and spatial variability occurred at background locations than at mixing zone locations. Zooplankton population densities generally increased from down-lake to up-lake locations.

Since the Lake Norman Maintenance Monitoring Program began in 1987, 123 zooplankton taxa have been observed in samples. Of these, 48 were identified in 2008. Additionally, one previously unreported taxon was identified during 2008.

During 2007, rotifers were dominant in all but five samples. During 2008 and similar to 2006, copepods were dominant in two-thirds of the samples while rotifers were the dominant forms in all other samples collected in 2008. Compared to 2007, microcrustaceans substantially increased in relative abundances to the highest yet recorded for 1988 – 2008 in both the epilimnetic and whole-column samples of the mixing zone. At background locations microcrustaceans increased more moderately in epilimnetic and whole-column samples and percent compositions were within historical ranges

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* and *Bosmina* was the dominant cladoceran. *Bosminopsis* dominated several cladoceran populations during the summer. The most abundant rotifers observed in 2008, as in many previous years, were *Polyarthra*, *Conochilus*, and *Keratella*. *Asplanchna*, and *Ptygura* were also important among rotifer populations.

In accordance with the Lake Norman Maintenance Monitoring Program, fish monitoring programs continued during 2008. Spring electrofishing indicated that numbers and biomass of fish in 2008 were generally similar to those noted since 1993. Additionally, electrofishing indicated that 16 to 19 fish species and two hybrid complexes comprised fish populations in the three sampling areas. Largemouth bass numbers and biomass remain low with some of the lowest recorded since sampling began in 1993. During 2008, the number of summer striped bass mortalities (17) and winter mean relative weight (82.8) were similar to those of previous years. Hydroacoustic sampling estimated the 2008 forage fish population at approximately 106.4 million. This is the highest estimate since surveys began in 1997. Purse seine sampling indicated that alewives continue to comprise a small percentage (4.4%) of pelagic forage fish. Threadfin shad lengths remained at pre-alewife introduction sizes.

Lake Norman Maintenance Monitoring results from 2008 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.

LIST OF TABLES

LIST OF TABLES, Continued

LIST OF FIGURES

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

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 conducted during 2008.

OPERATIONAL DATA FOR 2008

Station operational data for 2008 are listed in Table 1-1. Operational maintenance was performed on Unit 2 from March – April and Unit 1 from September – November, resulting in a reduction in the total thermal loading to the lake during these periods. The monthly average capacity factors for MNS were 99.8, 100.0 and 81.9% 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 97.7 °F (36.5 °C) for July, 98.3 °F (36.8 °C) for August and 94.6 °F (34.8 °C) for September 2008. 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 2008.

	MONTHLY AVERAGE CAPACITY FACTORS (%)			MONTHLY AVERAGE NPDES DISCHARGE TEMPERATURES	
Month	Unit 1	Unit 2	Station	°F	°C
January	99.9	100.0	99.9	70.4	21.2
February	100.0	100.0	100.0	69.1	20.6
March	100.0	0.4	50.0	70.6	21.4
April	100.0	40.5	70.1	73.5	23.1
May	99.9	100.0	99.9	83.2	28.4
June	86.7	100.0	93.4	92.1	33.4
July	99.6	100.0	99.8	97.7	36.5
August	99.9	100.0	100.0	98.3	36.8
September	63.6	100.0	81.9	94.6	34.8
October	0.0	100.0	50.2	83.0	28.3
November	54.9	99.9	77.5	74.1	23.4
December	100.0	100.0	100.0	71.2	21.8
Average	79.4	103.4	91.4	82.8	28.2

CHAPTER 2

WATER CHEMISTRY

INTRODUCTION

The objectives of the water quality portion of the McGuire Nuclear Station (MNS) NPDES Maintenance Monitoring Program (MMP) 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 2007 and 2008. Where appropriate, reference to pre-2007 data will be made by citing reports previously submitted to the NCDENR.

METHODS AND MATERIALS

The complete water quality monitoring program for 2008, including specific variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1. Sampling locations were selected at the initation of the MMP in 1986 to provide a thorough assessment of water quality throughout the spatial expanse of the reservoir and include sites within the projected thermal mixing zone of MNS, and in background areas. Physicochemical data collected at these locations also serve to track the temporal and spatial variability in striped bass habitat in the reservoir during the stratified period.

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.

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 pre-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 pre-rinsed with 500 mL of sample water, and then placed in pre-acidified HDPE bottles. 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 2007, except where noted, 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 Division of Water Quality 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 numerical, 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 numerical and statistical assessments. 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, 2008). 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 (maximum – minimum heat content).

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 to address safety issues associated with potential radiological releases into the atmosphere by MNS (Duke Power 2004b), as required by the Nuclear Regulatory Commission. The data also serve to document localized temporal trends in air temperatures and rainfall patterns. Lake level and hydroelectric flow data were obtained from Duke Energy-Carolinas Fossil/Hydro Generation.

RESULTS AND DISCUSSION

Precipitation and Air Temperature

Annual precipitation in the vicinity of MNS in 2008 totaled 119.1 cm (Figures 2-2a, b) or 40.9 cm more than observed in 2007 (78.2 cm), and 1.5 cm more than the long-term precipitation average for this area (117.6 cm), based on Charlotte, NC airport data. Monthly rainfall in 2008 was greatest in August with 23.14 cm and the least in October with 3.35 cm.

Air temperatures near MNS in 2008 were generally similar to the long-term mean, based on monthly average data, and cooler than measured in 2007 especially during the fall and early winter (Figure 2-2c). The temporal differences were most pronounced in August and October when 2008 temperatures averaged 3.5 and 4.1 °C cooler, respectively, than recorded in 2007.

Temperature and Dissolved Oxygen

Water temperatures measured in 2008 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3 and 2-4), as they did in 2007. 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, 2008).

Water temperatures in 2008 for January – April ranged from 0.1 to 4.8 °C cooler than measured in 2007, with minor differences observed between zones, whereas February temperatures were, for the most part, similar between years (Figures 2-3 and 2-4). These interannual differences in water temperatures generally paralleled differences in air temperatures (Figure 2-2c), but because lake sampling is routinely performed in the first week of each month, the observed data reflect the cumulative influences of meteorology and hydrology prior to that date. Reduced operations of Unit 2 in March 2008 (Table 1-1) also undoubtedly contributed to slightly cooler epilimnion temperatures in April 2008, especially in the mixing zone. Minimum water temperatures in 2008 were recorded in early February and ranged from 7.6 °C to 11.7 °C in the background zone and from 8.0 °C to 13.1 °C in the mixing zone. Minimum water temperatures measured in 2008 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, 2008).

Summer (June, July, and August) water temperatures in 2008 were similar to those observed in 2007 in both zones, with minor exceptions observed in the mixing zone in June and August when 2008 temperatures were as much as 2.9 °C warmer than measured in 2007. Late-summer, fall and early winter water temperatures (September – December) in 2008 were consistently cooler in both zones than those measured in 2007, indicating that the reservoir was cooling at a faster rate in 2008 than 2007 (Figures 2-3 and 2-4). This pattern followed the trend exhibited in air temperatures (Figures 2-2c). The most striking differences in temperature profiles were observed in the mixing zone in October when 2008 temperatures were as much as 4.1 °C cooler than measured in 2007.

Temperatures at the discharge location in 2008 were generally similar to 2007 (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, 2008). Temperatures in 2008 were similar to 2007 over the period January – August (March 2007 temperatures were taken during a station outage), and slightly cooler from September – December. The warmest discharge temperature of 2008 (38.5 °C) occurred in August and was 0.7 °C warmer than measured in 2007 (37.8 °C), but identical to the maximum measured in 2002.

Seasonal and spatial patterns of DO in 2008 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 2008 were generally equal to or greater than measured in 2007 (Figures 2-6 and 2-7). The interannual differences in DO values measured during this period appeared to be related predominantly to the cooler water column temperatures in 2008 versus 2007 and were consistent with observations made during previous years (Duke Energy 2007, 2008). Cooler temperatures would be expected to exhibit higher oxygen values because of increased oxygen solubility and an enhanced convective mixing regime associated with increased water column instability. Conversely, 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.

Summer DO values in 2008 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 2007 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, 2008). Water column summer DO values in 2008 were generally either equal to or higher than observed in 2007 which may be attributable to, at least partially, a greater degree of reaeration during the winter mixing period. All DO values recorded in 2008 during this period were within the historical range.

Considerable differences were observed between 2008 and 2007 late summer and fall DO values in both the mixing and background zones, especially in the metalimnion and hypolimnion, during the months of September, October, November, and December (Figures 2-6, 2-7). These interannual differences in DO levels during the cooling season are common in Catawba River reservoirs and are explained by the effects of variable weather patterns on water column cooling (heat loss) rates and mixing. 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 (Figure 2-2c). Conversely, 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.

The 2008 late summer and autumn DO data indicate that convective reaeration of the water column proceeded faster and was more advanced than observed in corresponding months in 2007. Consequently, 2008 DO levels at most depths were either equal to or greater than observed in 2007. 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 2008 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 2008 at location 4.0 were slightly higher than observed in 2007 and most likely attributable to greater DO concentrations in the intake waters during this period (Figure 2-7), and cooler discharge temperatures (Figure 2-5). The lowest DO concentration measured at the discharge location in 2008 (6.2 mg/L) occurred in August, and was 0.5 mg/L higher than measured in August, 2007; it was also 2.2 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 2008 (Figures 2-8 and 2-9) 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 2008 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 2007 and 2008 is presented in Table 2-3. Annual minimum heat content for the entire water column in 2008 (9.65 Kcal/cm^2; 9.75 °C) occurred in early February, whereas the maximum heat content (29.06 Kcal/cm^2; 28.55 °C) occurred in 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 5.17 Kcal/cm^2 (8.23 °C), but the maximum occurred in early September and measured 16.11 Kcal/cm^2 (24.41 °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 eplimnion equaled 0.11 °C/day and 0.08 °C/day for the hypolimnion and were either equal to or slightly less than observed in 2007 (Table 2-3). The 2008 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, 2008).

The seasonal oxygen content and percent saturation of the whole water column, and the hypolimnion, are depicted for 2008 in Figure 2-10b. Additional oxygen data can be found in Table 2-4 which presents the 2008 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 10.2 mg/L for the hypolimnion. Percent saturation values at this time approached 94% for the entire water column and 91% for the hypolimnion, indicating that reaeration of the reservoir approached 100%. 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. The minimum summer volume-weighted DO value for the entire water column measured 5.0 mg/L (67% saturation), whereas the minimum for the hypolimnion was 0.6 mg/L (12.8% saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.04 $mg/cm^2/day$ (0.05 mg/L/day) (Figure 2-10b), and is similar to that measured in 2007 (Duke Energy 2008).

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 0.04 $mg/cm^2/day$ for 2008. The oxygen-based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 2008 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 2007 through mid July 2008. Beginning in late June 2008, 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 2008 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. Historical data have illustrated that the presence of suitable habitat in the upper reaches of the reservoir is strongly influenced by both inflows 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, these cooler waters mix with ambient waters and create local refugia.

A 2008 summer refugia was observed in the metalimnion and hypolimnion near the Cowans Ford Dam, but this lasted only until 28 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 2008 were similar to 2007; both these years also exhibited habitat conditions that were more severe than 2004 when the largest striped bass die-off ever was observed in the reservoir (2,610 fish). Conditions in 2008 were most recently similar to those measured in 2007 when habitat elimination was observed for a period of about 50 – 60 days. Although habitat was absent for almost two months, observed striped bass mortalities in 2008 totaled only 17 fish, many of which appeared to be fishing release mortalities (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 (Figure 2-2c). The temporal and spatial pattern of striped bass habitat expansion and reduction observed in 2008 was 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, 2008).

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 2008, ranging from 1.1 to 3.3 NTUs (Table 2-5). Bottom turbidity values were also low over the 2008 study period, ranging from 1.0 to 4.1 NTUs. Turbidity values observed in 2008 were near the low end of 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, 2008).

Specific conductance in Lake Norman in 2008 ranged from 65.6 to 80.6 µmhos/cm and was generally similar to that observed 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, 2008). Specific conductance values in surface and bottom waters in 2008 were similar throughout the year except in August, 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 2008, 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, 2008). Values of pH in 2008 ranged from 7.1 to 8.4 in surface waters and from 6.2 to 7.2 in bottom waters. Alkalinity values in 2008 ranged from 13.0 to 17.0 mg/L, expressed as $CaCO_3$, in surface waters and from 13.0 to 18.0 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 2008 was generally similar to that reported for 2007 (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, 2008).

Nutrients

Nutrient concentrations in the discharge, mixing and mid lake background zones of Lake Norman in 2008 (Table 2-5) were low and generally similar to those measured in 2007 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, 2008). All 44 total phosphorus (TP) samples analyzed in 2008 exceeded the analytical reporting limit (ARL) of 5 μg/L, but most measurements (43 of 44) were ≤ 9 μg/L. The maximum TP value reported in 2008 was 9 μg/L and was observed separately at both the surface and bottom at Location 11.0. Conversely, almost all measurements of orthophosphorus (OP) (40 of 44) were recorded as ≤ 5 μg/L, whereas the maximum value (7 μg/L) was measured in surface waters at Location 2.0 in August. Nitrite-nitrate and ammonia nitrogen concentrations were low at all locations (Table 2-5) and similar to 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, 2008). Overall, nutrients in 2008 were 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).

<u>Metals</u>

Metal concentrations in the discharge, mixing, and mid lake background zones of Lake Norman for 2008 were similar to those 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, 2008). Iron concentrations in surface and bottom waters were generally low (≤ 0.2 mg/L) during 2008, the exceptions being values of 0.210 mg/L and 0.209 mg/L in the bottom waters at Location 11.0 in February and November, respectively. No iron values in 2008 exceeded the North Carolina water quality action level for iron (1.0 mg/L; NCDENR 2004).

Similarly, 2008 manganese concentrations in the surface and bottom waters were low (≤ 100 µg/L), 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 (200 µg/L; NCDENR 2004) at various locations throughout the lake in summer and fall, 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, 2008). The highest concentration of manganese reported in 2008 (1,440 ug/L) was measured in the bottom waters at Location 5.0; the 2007 maximum (2,542 ug/L) was also recorded at this location. 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 2008 were low, and often below the analytical reporting limit for the specific constituent (Table 2-5). These findings are consistent with those reported 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, 2008). All values for cadmium and lead were reported as either equal to or below the respective ARL for those parameters. Zinc values were consistently above the ARL and ranged from < 1.0 µg/L to 4.2 µg/L. 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 2008 (3.7 µg/L) was measured in the surface waters (0.3 m) at Location 2.0 in August. All values reported for cadmium, lead, zinc, and copper in 2008 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 2008 totaled 119.1 cm or 40.9 cm more than observed in 2007 and 1.5 cm more than the long-term average of 117.6 cm. Temporal and spatial trends in water temperature and DO in 2008 were similar to those observed historically, and all data were within the range of previously measured values. Water temperatures in winter and early spring 2008 ranged from 0.1 to 4.8 °C cooler than measured in 2007 and generally paralleled differences exhibited in monthly air temperature data, but with about a one-month lag time. Reduced operations of Unit 2 at MNS in March and April 2008 also undoubtedly contributed to these interannual differences during this period.

Summer water temperatures in 2008 were similar to those observed in 2007 in both zones, with only minor exceptions observed in the mixing zone in June and August when 2008 temperatures were as much as 2.9 °C warmer than measured in 2007. Late summer, fall, and early winter water temperatures were consistently cooler in both zones than those measured in 2007, indicating that the reservoir was cooling at a faster rate than the previous year. This pattern followed the trend exhibited in air temperatures. Temperatures at the discharge location in 2008 were generally similar to 2007 and historical data. The warmest discharge temperature of 2008 (38.5 °C) occurred in August and was 0.7 °C warmer than measured in 2007 (37.8 °C), but identical to the maximum measured in 2002.

Seasonal and spatial patterns of DO in 2008 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 2008 were generally equal to or greater, in both the background and mixing zones, than measured in 2007 and were correlated with interannual differences in water temperatures. Summer DO values in 2008 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6 to 8 mg/L in surface waters to lows of 0 to 2 mg/L in bottom waters. This pattern is similar to that measured in earlier years. Considerable differences were observed between 2008 and 2007 late summer and fall DO values in both the mixing and background zone, especially in the metalimnion and hypolimnion. Data indicated that fall convective reaeration proceeded faster and was more complete throughout the water column than observed in the corresponding months in 2007. Consequently, 2008 water column DO levels were greater than observed in 2007. 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 2008 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 2008 at location 4.0 were slightly higher than observed in 2007 and most likely attributable to greater DO concentrations in the intake waters during this period, and cooler discharge temperatures. The lowest DO concentration measured at the discharge location in 2008 (6.2 mg/L) occurred in August.

Reservoir-wide isotherm and isopleth information for 2008, 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 water with temperatures ≤ 26 °C and DO levels ≥ 2.0 mg/L, was found lake-wide from mid September 2007 through mid July 2008. Beginning in late June 2008, 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 and most recently similar to conditions measured in 2007 when habitat elimination was observed for a period of about 50 – 60 days. Observed striped bass mortalities in 2008 totaled 17 fish.

The results of all chemical parameters measured in 2008 were similar to 2007 and within the concentration ranges previously reported during both preoperational and operational years of MNS. Specific conductance values, and all cation and anion concentrations, were low. Nutrient concentrations were also low with most values reported close to or below the analytical reporting limits for those variables. Concentrations of metals in 2008 were low, and often below the analytical reporting limits. All 2008 values for cadmium, lead, zinc, copper, and iron were below the State water quality standard or action level for each of these metals. Manganese concentrations were generally low in 2008, except during the summer and fall when bottom waters were anoxic and redox induced releases of manganese occurred. The highest concentration of manganese reported in 2008 (1,440 ug/L) was measured in November in the bottom waters at Location 5.0 in the mixing zone.

Table 2-1. Water quality 2008 program for the MNS NPDES Maintenance Monitoring Program on Lake Norman.

2008 McGUIRE NPDES SAMPLING PROGRAM																
PARAMETERS	LOCATIONS	1	2	4	5	8	9.5	11	13	14	15	15.9	62	69	72	80
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4
	Method	IN-SITU ANALYSIS														
Temperature	Hydrolab															
Dissolved Oxygen	Hydrolab	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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		
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		

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

Table 2-2. Analytical methods and reporting limits employed in the MNS 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[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[b]
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[b]
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	1.0 ug/L

References: USEPA 1983, and APHA 1995

[a] Reporting limit increased to 1.0µg/L in November samples.
[b] Reporting limits decreased to 1.0 µg/L in November samples.

Table 2-3. Heat content calculations for the thermal regime in Lake Norman for 2007 and 2008.

	2007	2008
Maximum Areal Heat Content (g·cal/cm^2)	28,787	29,062
Minimum Areal Heat Content (g·cal/cm^2)	8,882	9,648
Birgean Heat Budget (g·cal/ cm^2)	19,905	19,414
Epilimnion (above 11.5 m) Heating Rate (°C /day)	0.11	0.11
Hypolimnion (below 11.5 m) Heating Rate (°C /day)	0.09	0.08

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	0.040	4.5	1.7	10.3
TVA [c]				
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

[c]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 2007 and 2008. Values less than detection were assumed to be equal to the detection limit for calculating a mean.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Turbidity (NTU)																						
Feb	2.3	2.0	2.3	1.6	2.7	1.2	3.6	1.5	2.7	1.1	2.4	1.4	2.9	1.2	2.2	1.5	3.5	1.7	5.6	1.5	5.7	1.4
May	2.0	1.3	1.3	1.7	1.3	1.3	1.5	1.2	1.5	1.3	1.0	1.3	1.1	2.1	1.0	1.4	1.6	1.4	1.2	1.6	1.6	4.1
Aug	1.3	1.9	1.0	1.1	1.4	3.3	1.0	1.0	1.5	2.1	1.4	1.7	8.4	2.9	1.3	1.5	1.6	1.4	1.4	2.0	1.6	1.7
Nov	2.6	2.1	3.4	2.0	2.7	1.9	4.3	1.6	2.7	1.1	2.8	1.1	4.3	2.6	1.7	1.7	3.0	3.7	3.1	2.9	3.4	3.9
Annual Mean	2.1	1.8	2.0	1.6	2.0	1.9	2.6	1.3	2.1	1.4	1.9	1.4	4.2	2.2	1.5	1.5	2.4	2.1	2.8	2.0	3.1	2.8
Specific Conductance (umho/cm)																						
Feb	53.8	66.0	52.6	65.6	53.8	66.1	53.1	68.1	54.7	67.3	54.3	66.3	53.2	65.6	53.8	65.8	53.8	65.1	51.5	76.4	51.4	72.7
May	55.8	72.4	55.2	71.1	55.7	72.5	55.0	70.9	56.3	73.6	56.0	72.8	54.7	71.5	55.9	72.4	55.1	72.6	56.6	77.7	55.2	76.4
Aug	61.1	76.1	73.9	75.6	60.9	75.0	71.2	75.9	61.0	75.3	61.0	75.6	68.9	79.6	61.1	75.3	65.6	74.4	64.3	80.6	68.0	75.0
Nov	64.8	76.8	104.7	78.2	64.9	76.9	67.2	77.6	65.7	77.3	65.3	77.0	65.3	76.6	64.5	76.9	64.4	77.3	69.1	78.4	69.2	76.6
Annual Mean	58.9	72.8	71.6	72.6	58.8	72.6	61.6	73.1	59.4	73.4	59.2	72.9	60.5	73.3	58.8	72.6	59.7	72.4	60.4	78.3	61.0	75.2
pH (units)																						
Feb	7.3	7.2	6.7	7.1	7.3	7.4	7.1	7.2	7.3	7.3	7.4	7.4	7.5	7.2	7.4	7.3	7.3	7.2	7.3	7.3	7.1	7.2
May	7.2	7.4	6.8	6.9	7.5	7.5	6.5	6.9	7.4	7.4	7.4	7.5	6.5	6.9	7.6	7.6	6.5	6.9	7.5	7.6	6.5	6.8
Aug	7.6	7.6	6.0	6.2	7.4	7.4	6.0	6.3	7.2	7.1	7.5	7.4	6.5	6.4	8.2	8.0	6.5	6.3	7.9	8.4	6.5	6.3
Nov	7.4	7.5	7.1	7.2	7.5	7.6	7.3	7.2	7.4	7.6	7.4	7.6	7.4	7.2	7.6	7.5	7.6	7.2	7.6	7.5	7.4	7.2
Annual Mean	7.4	7.4	6.7	6.9	7.4	7.5	6.7	6.9	7.1	7.4	7.4	7.5	7.0	6.9	7.7	7.6	7.0	6.9	7.6	7.7	6.9	6.9
Alkalinity (mg CaCO3/L)																						
Feb	13.5	16	13.5	16	14.0	16	13.5	16	13.5	16	14.0	16	13.5	16	14.0	16	14.0	16	13.0	16	13.0	16
May	13.5	13	14.0	15	13.5	13	13.5	13	13.5	13	14.0	13	13.5	14	13.5	13	13.5	15	13.5	14	13.5	15
Aug	15.0	16	15.5	16	15.0	15	16.0	15	15.0	15	15.0	16	22.5	18	15.0	15	19.0	16	15.5	16	19.0	16
Nov	16.0	16	17.0	16	16.0	16	20.0	17	16.5	16	16.0	16	16.5	16	15.5	17	11.5	16	16.0	15	16.0	15
Annual Mean	14.5	15.3	15.0	15.8	14.6	15.0	15.8	15.3	14.6	15.0	14.8	15.3	16.5	16.0	14.5	15.3	14.5	15.8	14.5	15.3	15.4	15.5
Chloride (mg/L)																						
Feb	4.6	7.3	4.7	7.4	4.6	7.3	4.6	7.7	4.5	7.3	4.7	7.2	4.5	7.1	4.7	7.4	4.7	7.3	4.5	10.0	4.6	9.1
May	5.1	8.3	4.7	8.2	4.9	8.2	4.8	8.1	5.0	8.4	4.8	8.3	4.8	8.3	5.1	8.3	5.1	8.6	5.3	9.7	5.3	9.3
Aug	5.4	9.0	4.8	8.3	5.4	8.8	4.7	8.3	5.4	9.0	5.2	9.0	5.0	8.4	5.3	8.9	4.9	8.4	5.9	10.0	4.6	8.5
Nov	6.6	9.4	6.5	9.4	6.5	9.5	6.3	9.4	6.5	9.5	6.7	9.5	6.5	9.4	6.7	9.4	6.6	9.4	7.6	9.8	7.6	9.6
Annual Mean	5.4	8.5	5.2	8.3	5.4	8.5	5.1	8.4	5.4	8.6	5.4	8.5	5.2	8.3	5.5	8.5	5.3	8.4	5.8	9.9	5.5	9.1
Sulfate (mg/L)																						
Feb	3.8	4.7	3.6	4.7	3.6	4.8	3.9	4.9	3.6	4.8	3.7	4.8	3.7	4.8	3.7	4.8	3.7	4.8	3.6	5.4	3.8	5.1
May	4.2	5.1	4.2	5.0	4.2	5.2	4.1	5.0	4.2	5.1	4.2	5.2	4.2	5.0	4.2	5.1	4.2	5.1	4.1	5.5	4.1	5.2
Aug	4.8	5.3	4.3	5.0	4.5	5.3	4.3	5.0	4.6	5.3	4.6	5.3	3.8	5.0	4.5	5.3	4.2	5.0	4.5	5.5	4.1	5.0
Nov	4.5	5.5	4.4	5.6	4.6	5.5	3.9	5.6	4.5	5.2	4.6	5.5	4.6	5.6	4.7	5.6	9.6	5.6	4.8	5.6	4.8	5.3
Annual Mean	4.3	5.2	4.1	5.1	4.2	5.2	4.1	5.1	4.2	5.1	4.3	5.2	4.1	5.1	4.3	5.2	5.4	5.1	4.3	5.5	4.2	5.2
Calcium (mg/L)																						
Feb	3.23	4.01	3.21	4.01	3.23	4.02	3.26	4.19	3.19	4.02	3.18	3.98	3.22	4.02	3.19	4.10	3.18	4.05	3.52	5.00	3.41	4.68
May	3.44	4.30	3.43	4.26	3.50	4.31	3.44	4.28	3.47	4.30	3.42	4.31	3.40	4.37	3.49	4.28	3.60	4.45	3.92	4.86	3.83	4.73
Aug	3.76	4.61	3.90	4.65	3.78	4.62	3.93	4.71	3.77	4.65	3.78	4.61	4.26	4.94	3.82	4.60	3.97	4.82	4.14	5.26	4.03	4.86
Nov	4.10	4.69	4.13	4.72	4.09	4.67	4.23	4.68	4.11	4.67	4.11	4.66	4.07	4.66	4.11	4.73	4.09	4.70	4.44	4.91	4.44	4.70
Annual Mean	3.63	4.40	3.67	4.41	3.65	4.41	3.72	4.47	3.64	4.41	3.62	4.39	3.74	4.50	3.65	4.43	3.71	4.51	4.01	5.01	3.93	4.74
Magnesium (mg/L)																						
Feb	1.66	2.10	1.65	2.09	1.65	2.08	1.64	2.14	1.64	2.08	1.65	2.07	1.65	2.09	1.65	2.10	1.66	2.07	1.63	2.41	1.61	2.30
May	1.64	2.17	1.64	2.16	1.64	2.18	1.64	2.17	1.65	2.18	1.65	2.19	1.63	2.21	1.67	2.16	1.67	2.23	1.74	2.30	1.74	2.24
Aug	1.89	2.28	1.81	2.24	1.90	2.27	1.84	2.24	1.89	2.29	1.89	2.28	1.94	2.34	1.89	2.27	1.87	2.28	2.06	2.51	1.88	2.26
Nov	2.06	2.42	2.05	2.41	2.05	2.41	2.06	2.38	2.06	2.38	2.06	2.39	2.05	2.39	2.08	2.42	2.06	2.40	2.22	2.49	2.22	2.39
Annual Mean	1.81	2.24	1.79	2.23	1.81	2.24	1.80	2.23	1.81	2.23	1.81	2.23	1.82	2.26	1.82	2.24	1.82	2.25	1.91	2.43	1.86	2.30

Table 2-5 (Continued)

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Potassium (mg/L)																						
Feb	1.89	1.97	1.91	1.96	1.91	1.96	2.10	1.96	1.88	1.96	1.89	1.94	1.89	1.97	1.93	1.95	1.89	1.95	1.84	1.98	1.84	1.95
May	1.78	1.93	1.84	1.90	1.83	1.93	1.80	1.92	1.81	1.91	1.81	1.93	1.76	1.92	1.75	1.90	1.72	1.91	1.65	1.88	1.66	1.87
Aug	1.87	1.94	1.88	1.94	1.90	1.98	1.88	1.96	1.88	1.92	1.87	1.92	1.94	1.99	1.92	1.94	1.89	1.91	1.86	1.88	1.90	1.85
Nov	1.93	2.02	1.90	2.01	1.94	2.02	1.93	1.99	1.92	2.05	1.91	2.03	1.88	2.00	1.92	2.01	1.90	2.05	1.89	2.02	1.91	2.01
Annual Mean	1.87	1.97	1.88	1.95	1.90	1.97	1.93	1.96	1.87	1.96	1.87	1.96	1.87	1.97	1.88	1.95	1.85	1.96	1.81	1.94	1.83	1.92
Sodium (mg/L)																						
Feb	5.00	5.08	5.03	5.06	5.03	5.06	4.90	5.15	4.94	5.02	4.96	5.01	4.93	5.07	4.03	5.10	5.04	5.07	4.21	5.60	4.41	5.46
May	4.49	5.45	4.47	5.40	4.51	5.45	4.52	5.39	4.49	5.47	4.51	5.46	4.48	5.51	4.41	5.41	4.33	5.63	4.21	5.91	4.19	5.91
Aug	4.71	5.66	4.52	5.43	4.71	5.60	4.48	5.40	4.68	5.63	4.67	5.56	4.56	5.49	4.75	5.59	4.48	5.44	4.73	5.61	4.51	5.45
Nov	4.75	5.71	4.73	5.70	4.75	5.67	4.73	5.64	4.78	5.67	4.76	5.66	4.71	5.63	4.82	5.60	4.76	5.67	5.08	5.61	5.04	5.54
Annual Mean	4.74	5.48	4.69	5.40	4.75	5.45	4.66	5.40	4.72	5.45	4.73	5.42	4.67	5.43	4.50	5.43	4.65	5.45	4.56	5.68	4.54	5.59
Aluminum (mg/L)																						
Feb	0.066	0.054	0.070	0.056	0.075	0.056	0.118	0.050	0.082	0.050	0.073	0.05	0.088	0.050	0.077	0.052	0.083	0.065	0.145	0.050	0.157	0.050
May	0.050	0.050	0.050	0.050	0.050	0.053	0.050	0.050	0.050	0.050	0.051	0.050	0.050	0.053	0.050	0.059	0.050	0.050	0.057	0.050	0.054	0.050
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	0.060	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Nov	0.068	0.062	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	0.054
Annual Mean	0.059	0.054	0.062	0.052	0.059	0.052	0.067	0.050	0.062	0.050	0.061	0.050	0.061	0.053	0.059	0.053	0.061	0.054	0.079	0.050	0.083	0.051
Iron (mg/L)																						
Feb	0.110	0.091	0.110	0.144	0.120	0.093	0.240	0.136	0.130	0.107	0.110	0.139	0.170	0.105	0.090	0.101	0.160	0.167	0.300	0.107	0.320	0.151
May	0.060	0.069	0.070	0.095	0.060	0.074	0.080	0.103	0.090	0.071	0.090	0.072	0.070	0.130	0.040	0.066	0.070	0.126	0.050	0.072	0.080	0.210
Aug	0.050	0.045	0.060	0.040	0.050	0.030	0.060	0.043	0.040	0.031	0.040	0.033	1.260	0.122	0.050	0.022	0.090	0.053	0.040	0.038	0.250	0.063
Nov	0.160	0.092	0.370	0.131	0.170	0.091	0.820	0.163	0.190	0.094	0.170	0.087	0.250	0.194	0.160	0.117	0.360	0.184	0.180	0.125	0.250	0.209
Annual Mean	0.095	0.074	0.153	0.103	0.100	0.072	0.300	0.111	0.113	0.076	0.103	0.083	0.438	0.138	0.085	0.077	0.170	0.133	0.143	0.086	0.225	0.158
Manganese (ug/L)																						
Feb	12	11	12	34	14	11	82	18	15	13	14	25	25	12	11	10	13	15	26	19	28	27
May	5	5	9	12	6	5	7	16	6	6	7	6	8	29	5	4	6	20	11	4	12	48
Aug	17	16	493	205	28	16	979	305	36	21	30	18	2542	1440	16	12	1698	564	47	35	1550	523
Nov	138	37	552	56	142	37	1324	106	253	37	163	38	245	105	58	28	87	66	74	46	92	75
Annual Mean	43	17	267	77	48	17	598	111	78	19	54	22	705	397	23	13	451	166	40	26	421	168
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	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	0.5
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	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
Annual Mean	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Copper (ug/L)																						
Feb	2.0	2.0	2.0	2.0	2.0	2.0	2.6	2.0	2.0	2.0	2.0	2.0	2.1	2.0	2.0	2.0	2.0	2.0	3.0	2.8	2.6	2.3
May	2.2	2.0	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	2.0	3.1	2.2	3.0	2.2
Aug	2.0	2.0	2.0	2.0	2.0	3.7	2.0	2.0	2.0	2.3	2.0	2.3	2.0	2.0	2.1	2.0	2.0	2.0	2.2	2.9	2.0	2.1
Nov	2.0	1.5	2.0	1.4	2.0	1.5	2.0	1.4	2.0	1.6	2.0	1.5	2.0	1.5	2.0	2.1	2.0	2.0	2.2	3.3	2.3	2.1
Annual Mean	2.1	1.9	2.1	1.9	2.1	2.3	2.2	1.9	2.2	2.0	2.1	1.9	2.1	1.9	2.2	2.0	2.1	2.0	2.6	2.8	2.5	2.2
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	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0
Annual Mean	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8

Table 2-5 (Continued)

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Zinc (ug/L)																						
Feb	1.4	1.5	1.6	1.7	1.0	2.5	24.9	1.9	1.3	1.8	1.4	1.7	5.4	2.2	2.8	1.9	2.5	2.8	2.4	4.0	3.6	1.9
May	6.3	2.2	10.2	4.2	10.9	1.7	5.2	2.3	6.9	2.0	4.7	2.2	6.5	2.8	4.6	3.2	4.4	2.0	6.5	2.0	5.0	2.2
Aug	2.1	1.3	2.6	1.2	1.4	2.1	1.9	1.4	1.0	1.5	1.3	1.1	2.2	1.0	2.8	1.0	2.1	1.2	1.6	1.3	1.8	1.1
Nov	1.7	1.0	1.6	1.0	1.3	1.0	1.4	1.1	1.7	1.0	1.0	1.0	2.4	1.0	2.4	1.4	1.8	1.3	1.8	1.5	1.8	1.4
Annual Mean	2.9	1.5	4.0	2.0	3.7	1.8	8.4	1.7	2.7	1.6	2.1	1.5	4.1	1.7	3.2	1.9	2.7	1.8	3.1	2.2	3.1	1.6
Nitrite-Nitrate (ug/L)																						
Feb	160	150	170	130	180	140	190	160	200	150	160	150	170	140	160	140	160	140	290	210	350	290
May	190	280	190	510	190	450	200	300	190	340	190	450	190	240	200	250	210	300	230	510	240	640
Aug	70	150	440	390	180	150	450	370	150	150	170	160	450	300	190	140	330	360	210	110	350	370
Nov	130	110	570	110	120	120	80	96	100	110	130	110	120	110	130	120	230	100	260	150	290	110
Annual Mean	138	173	343	285	168	215	230	232	160	188	163	218	233	198	170	163	233	225	248	245	308	353
Ammonia (ug/L)																						
Feb	42	120	40	83	37	130	54	130	69	140	72	59	57	150	38	81	50	94	46	71	58	92
May	20	270	24	210	23	200	20	250	29	190	20	200	25	280	29	270	20	280	21	220	20	240
Aug	20	20	39	20	25	20	68	20	31	20	29	20	180	55	28	24	98	20	43	20	110	25
Nov	92	50	120	57	93	59	220	78	100	120	94	61	110	55	79	45	78	79	60	48	85	76
Annual Mean	44	115	56	93	45	102	91	120	57	118	54	85	93	135	44	105	62	118	43	90	68	108
Total Phosphorous (ug/L)																						
Feb	9	6	8	6	10	6	114	6	9	6	8	6	11	6	9	6	9	6	17	6	14	7
May	7	8	6	7	7	7	7	7	7	7	7	8	7	7	6	7	9	7	7	8	7	9
Aug	7	7	10	6	8	7	7	6	7	7	7	7	7	7	8	6	7	7	8	8	8	8
Nov	7	8	7	8	7	7	8	8	8	8	7	7	8	8	7	5	9	8	9	9	9	8
Annual Mean	7.5	7.0	7.8	6.9	8.0	6.6	34.0	6.7	7.8	6.8	7.3	6.9	8.3	7.2	7.5	5.9	8.5	7.1	10.3	7.6	9.5	8.2
Orthophosphate (ug/L)																						
Feb	5	5	5	5	5	5	13	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6
May	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Aug	5	5	5	5	5	7	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5
Nov	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Annual Mean	5.0	5.0	5.0	5.0	5.0	5.5	7	5	5	5	5	5	5	5	5	5	5	5	5.0	5.0	5	5
Silicon (mg/L)																						
Feb	4.2	4.9	3.9	5.0	4.0	4.9	4.0	5.2	4.0	5.0	4.0	5.0	4.1	5.0	4.0	5.0	3.7	5.0	4.8	5.3	4.7	5.3
May	4.2	5.1	4.7	5.0	4.2	4.9	4.6	5.2	4.3	4.9	4.0	4.9	4.0	5.2	3.9	4.8	3.7	5.2	3.6	4.8	3.6	5.4
Aug	3.8	4.5	5.0	5.3	3.7	4.4	5.2	5.4	3.7	4.4	3.7	4.4	5.4	5.5	3.6	4.4	5.1	5.5	3.9	4.4	5.1	5.4
Nov	4.6	5.0	4.9	4.9	4.7	4.9	5.0	4.9	4.7	4.9	4.7	5.0	4.7	5.0	4.6	4.8	4.6	5.0	5.1	4.7	5.1	4.9
Annual Mean	4.2	4.9	4.6	5.1	4.2	4.8	4.7	5.2	4.2	4.8	4.1	4.8	4.6	5.2	4.0	4.8	4.3	5.2	4.4	4.8	4.6	5.3

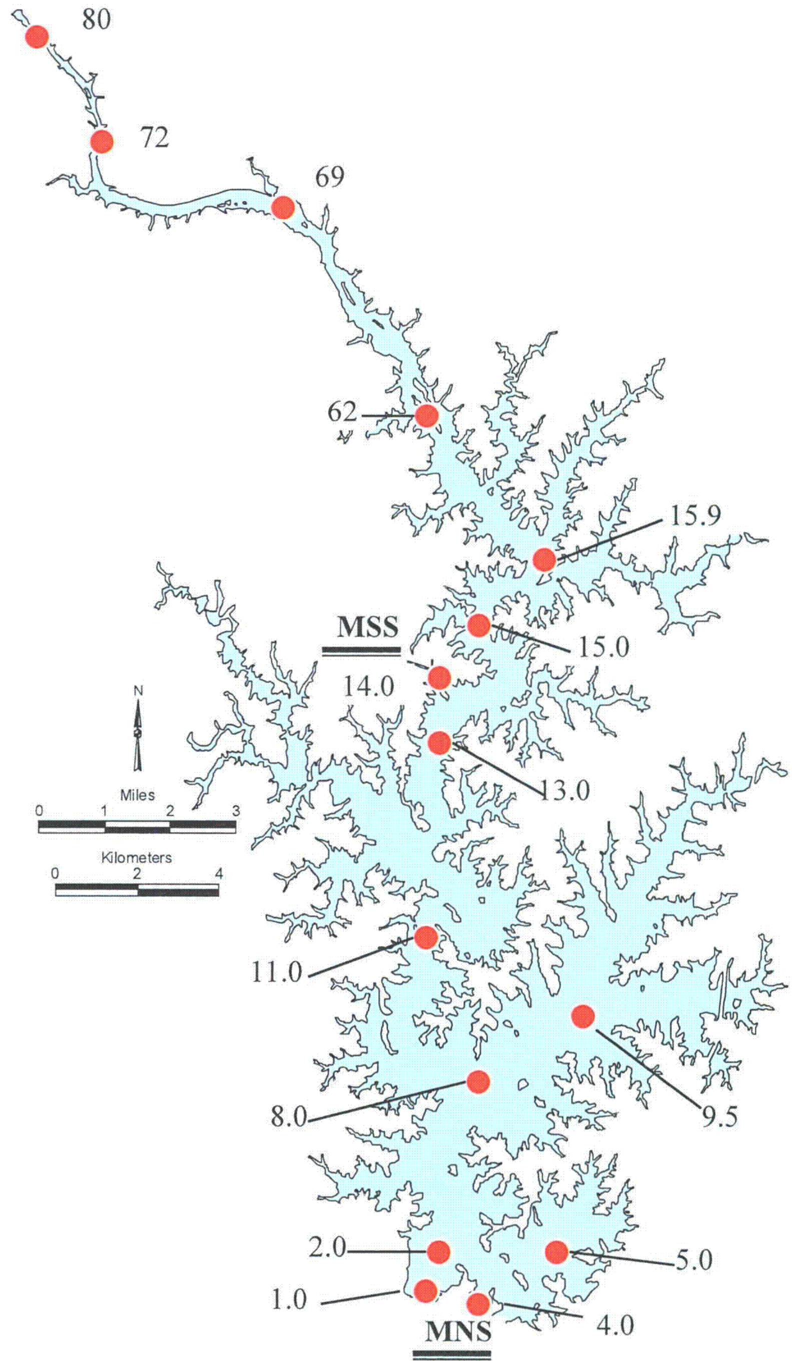


Figure 2-1. Water quality sampling locations (numbered) for Lake Norman. Approximate locations of Marshall Steam Station (MSS) and MNS are also shown.

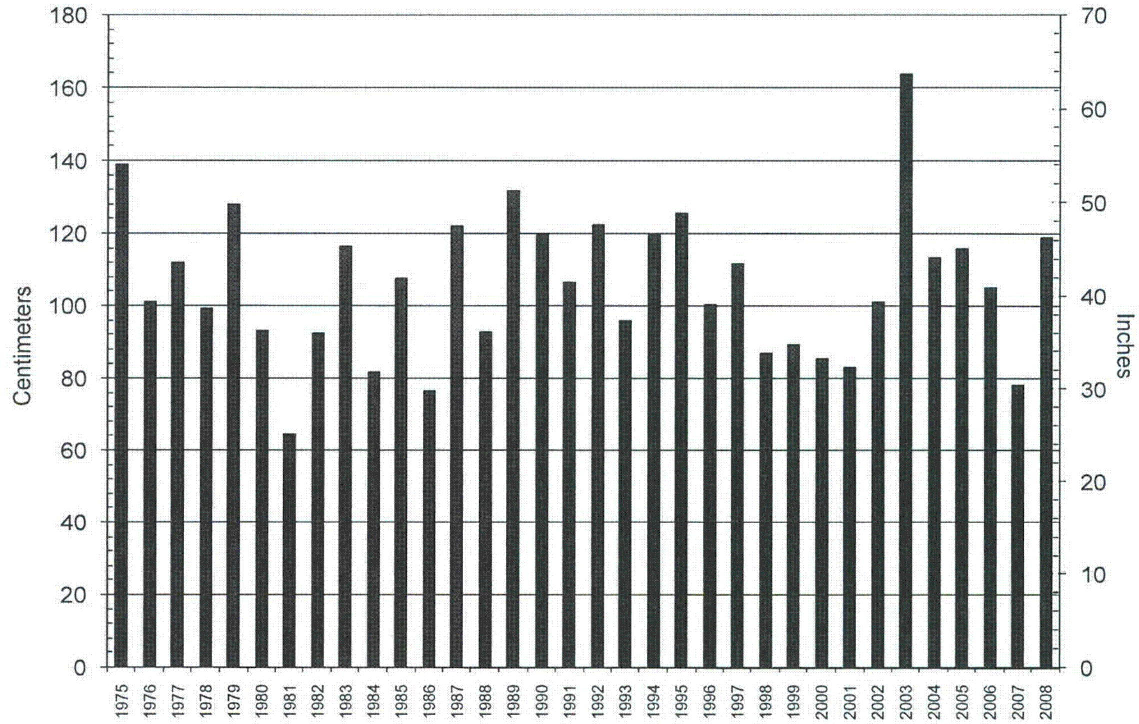


Figure 2-2a. Annual precipitation totals in the vicinity of MNS.

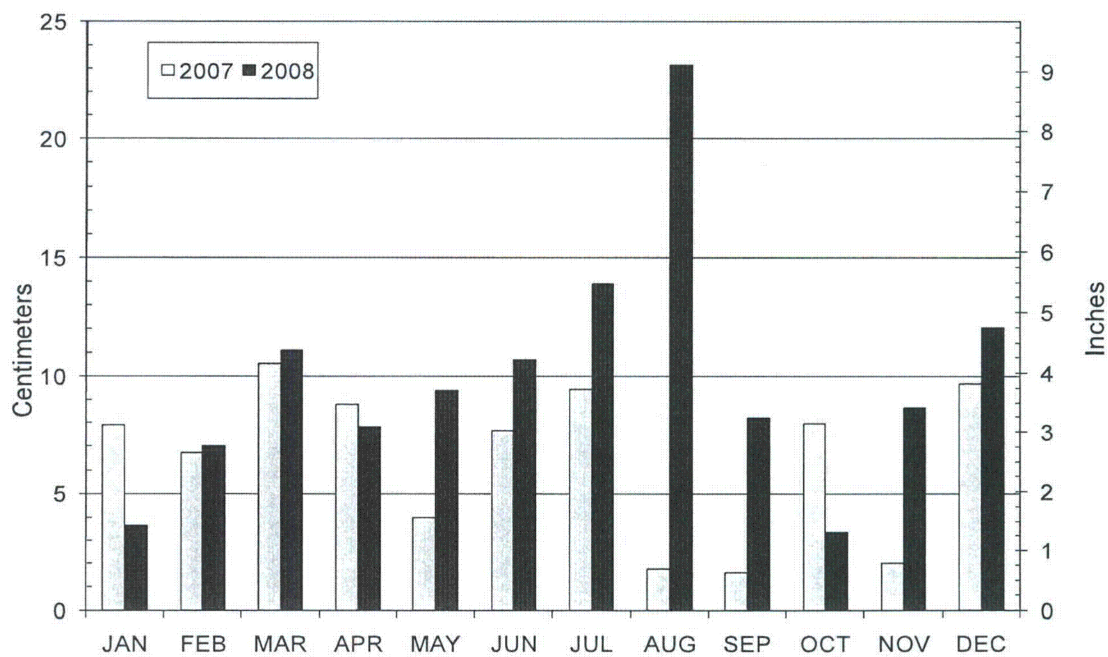


Figure 2-2b. Monthly precipitation totals in the vicinity of MNS in 2007 and 2008.

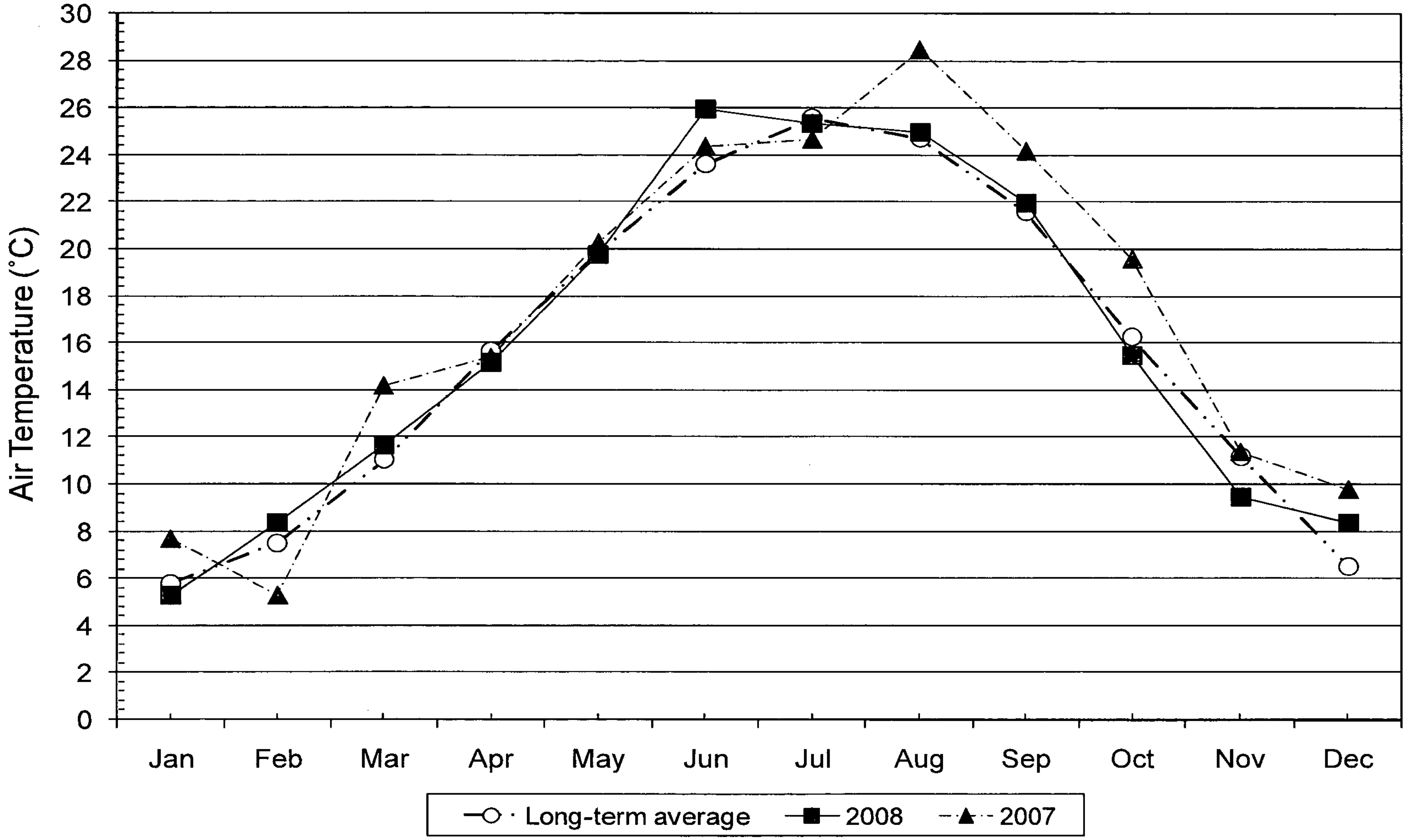


Figure 2-2c. Mean monthly air temperatures recorded at MNS beginning in 1989. Data were complied from average daily temperatures which, in turn, were created from hourly measurements.

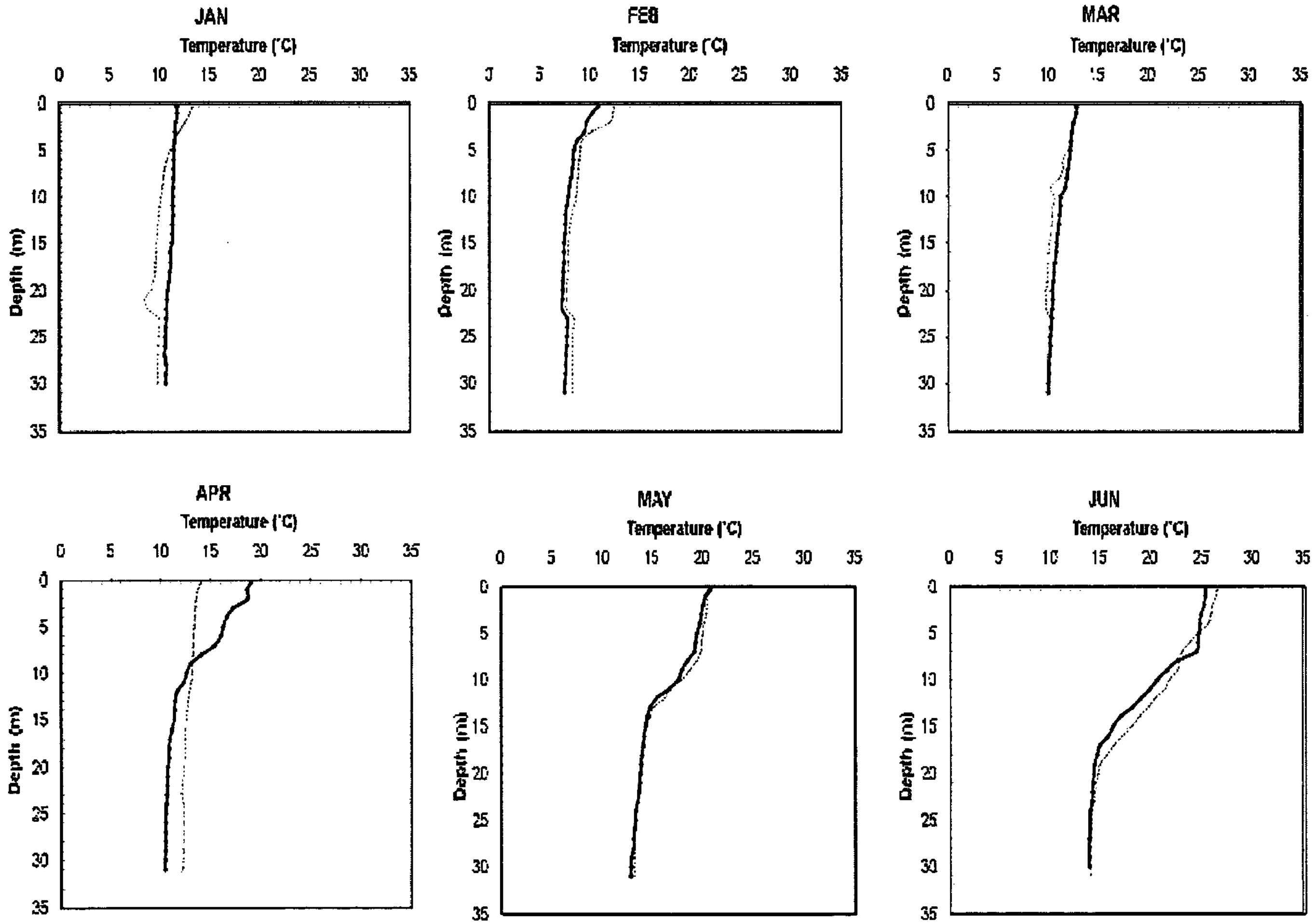


Figure 2-3. Monthly mean temperature profiles for the MNS background zone in 2007 (♦♦) and 2008 (xx).

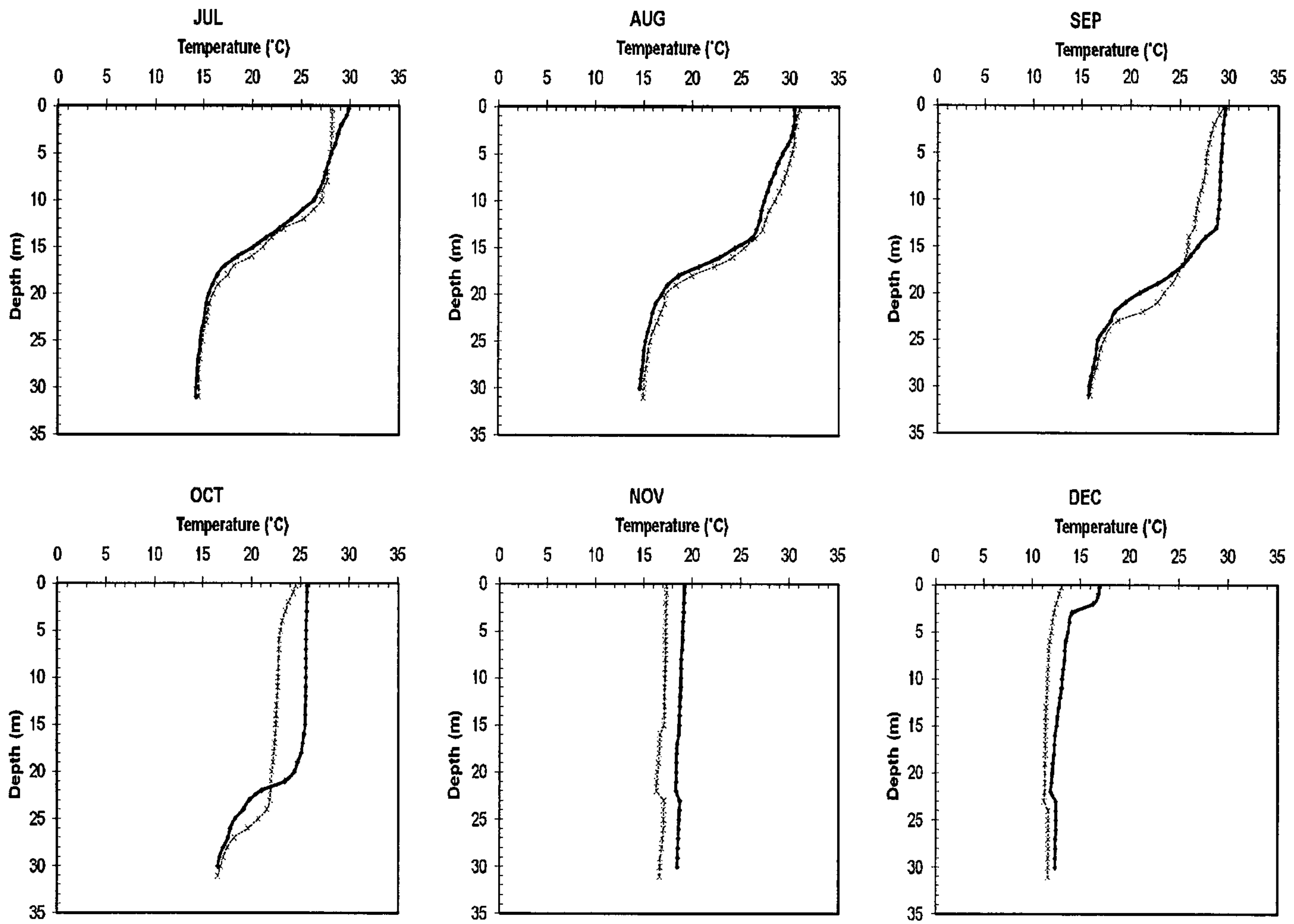


Figure 2-3. (Continued).

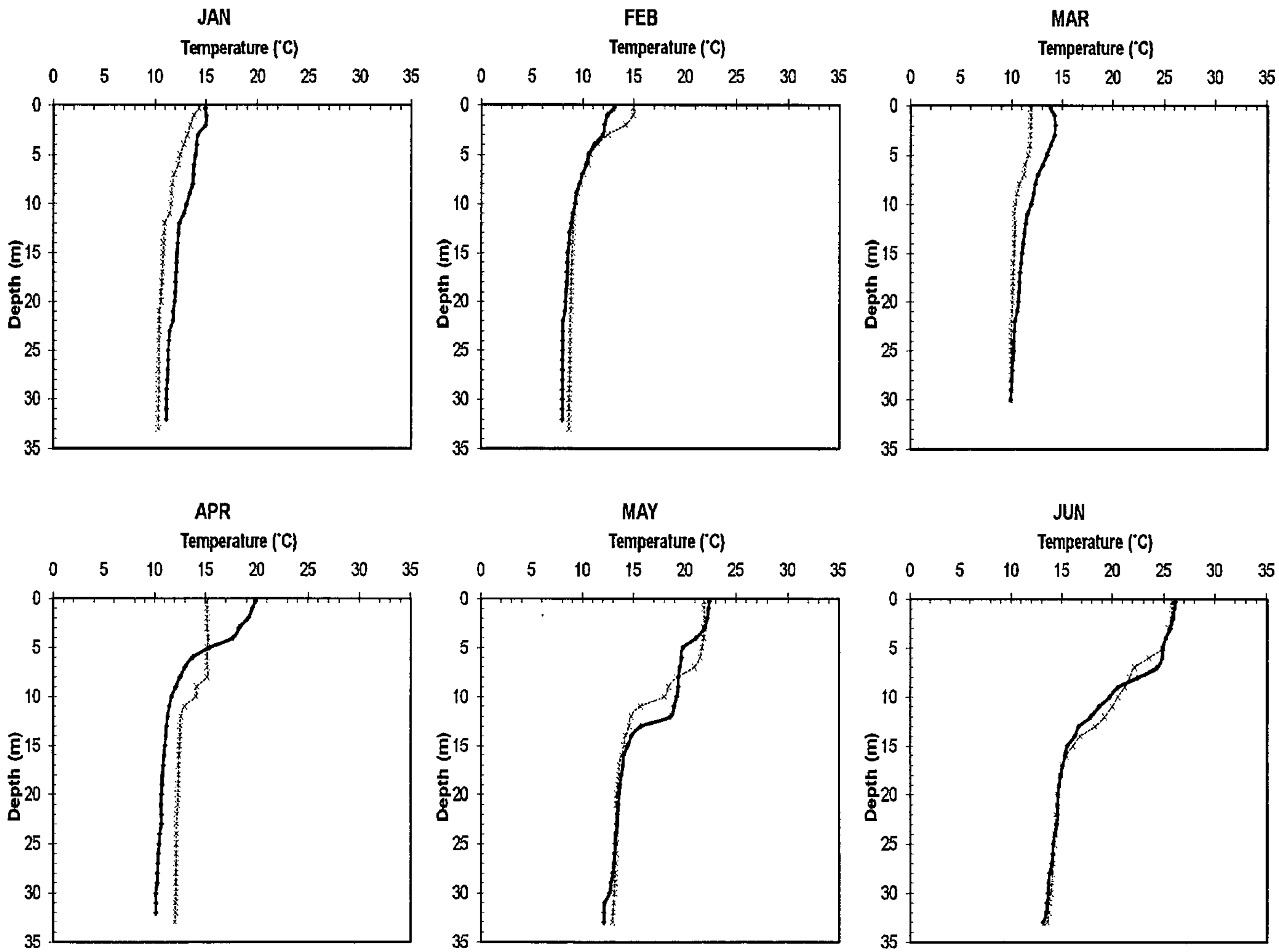


Figure 2-4. Monthly mean temperature profiles for the MNS mixing zone in 2007 (♦♦) and 2008 (xx).

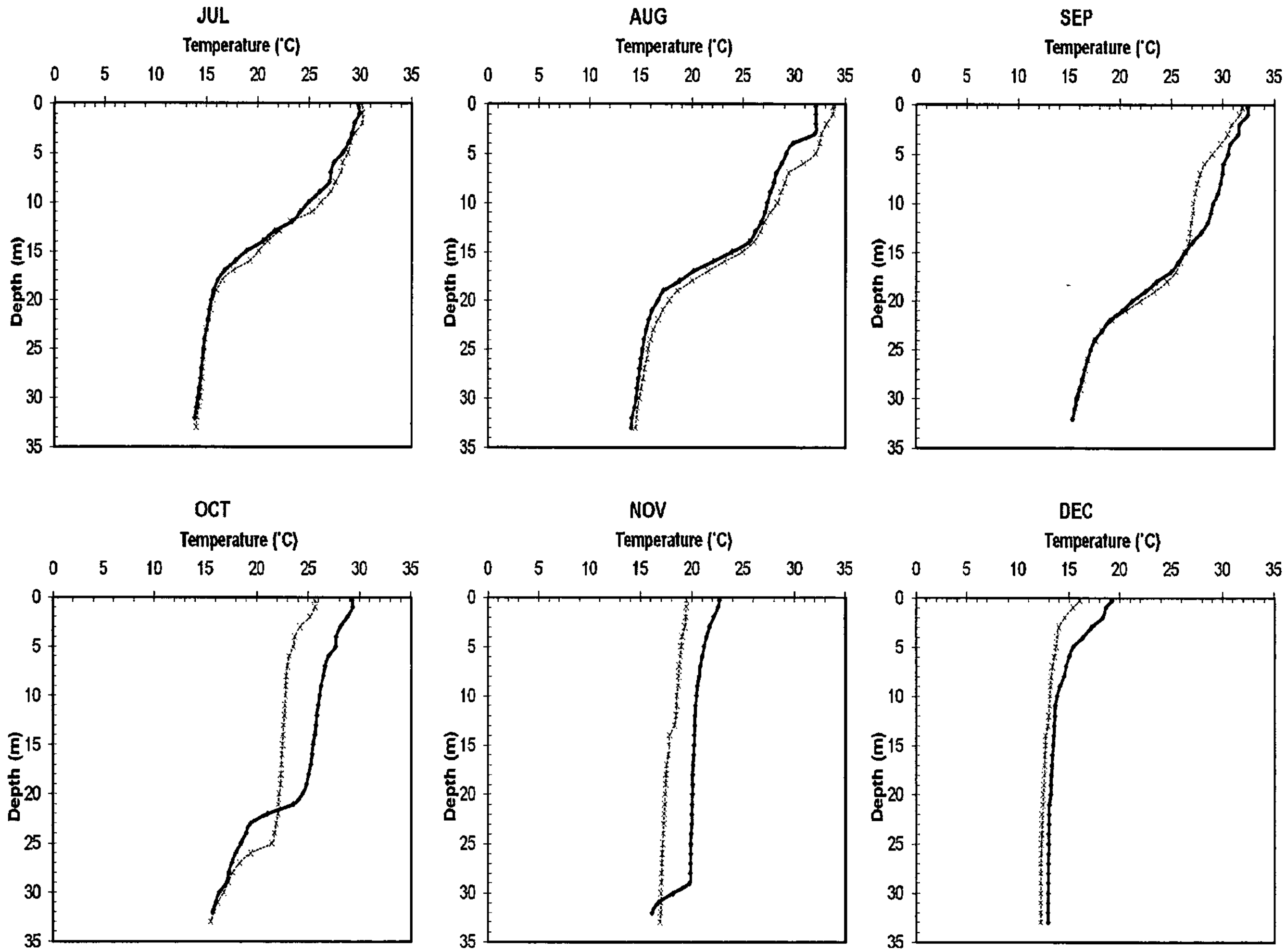


Figure 2-4. (Continued).

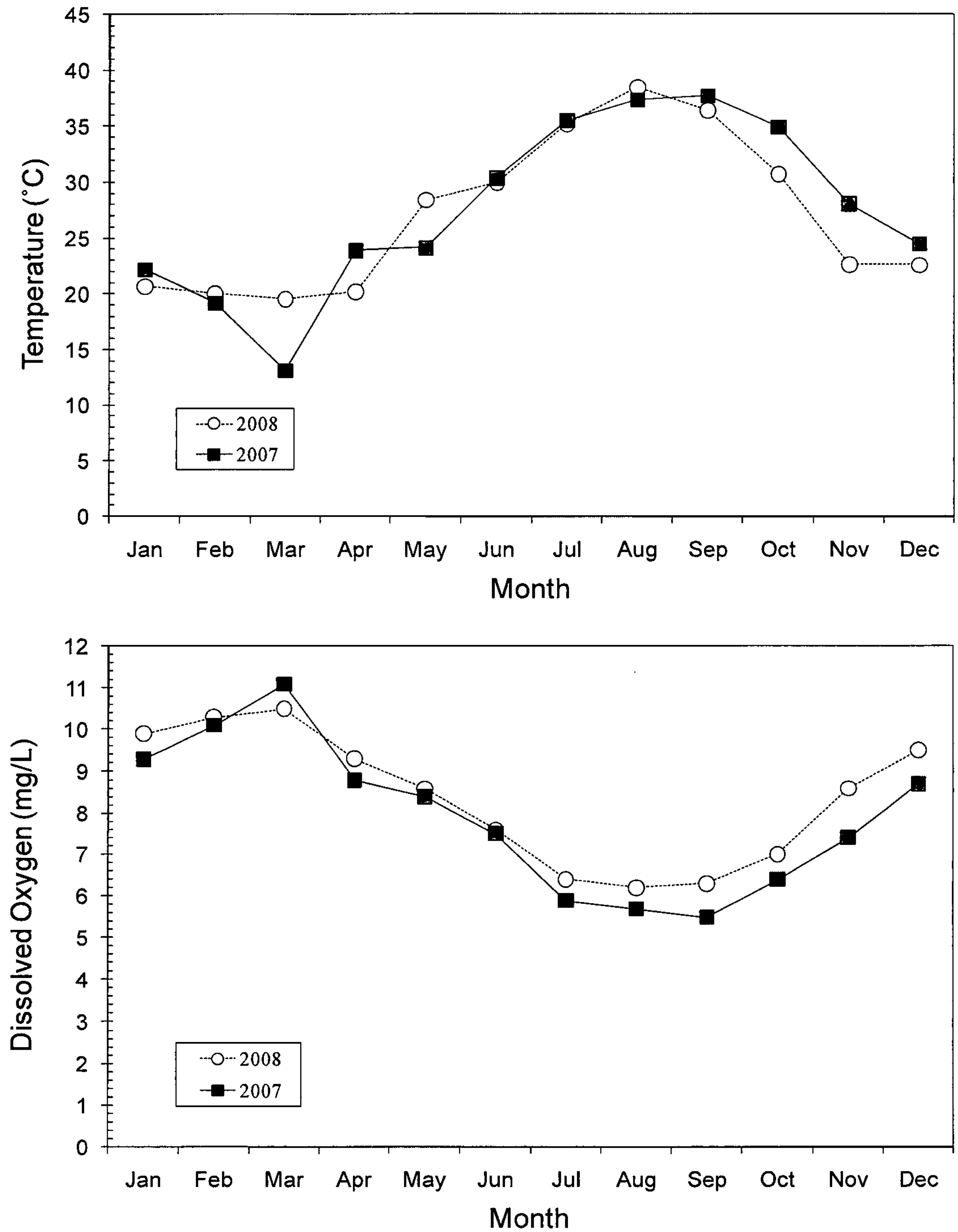


Figure 2-5. Monthly surface (0.3m) temperature and dissolved oxygen data at the discharge location (Location 4.0) in 2007 (■) and 2008 (O).

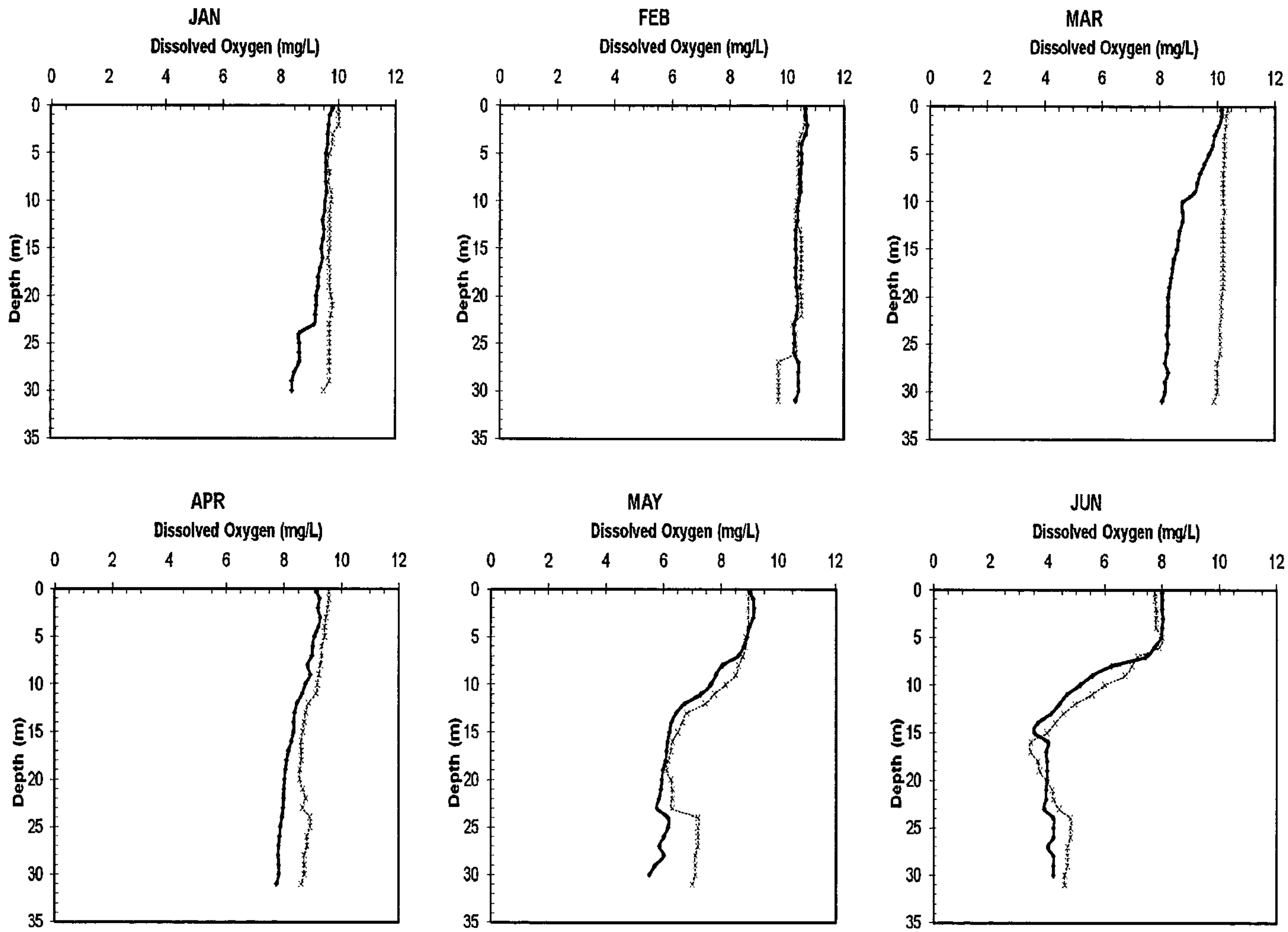


Figure 2-6. Monthly mean dissolved oxygen profiles for the MNS background zone in 2007 (××) and 2008 (♦♦).

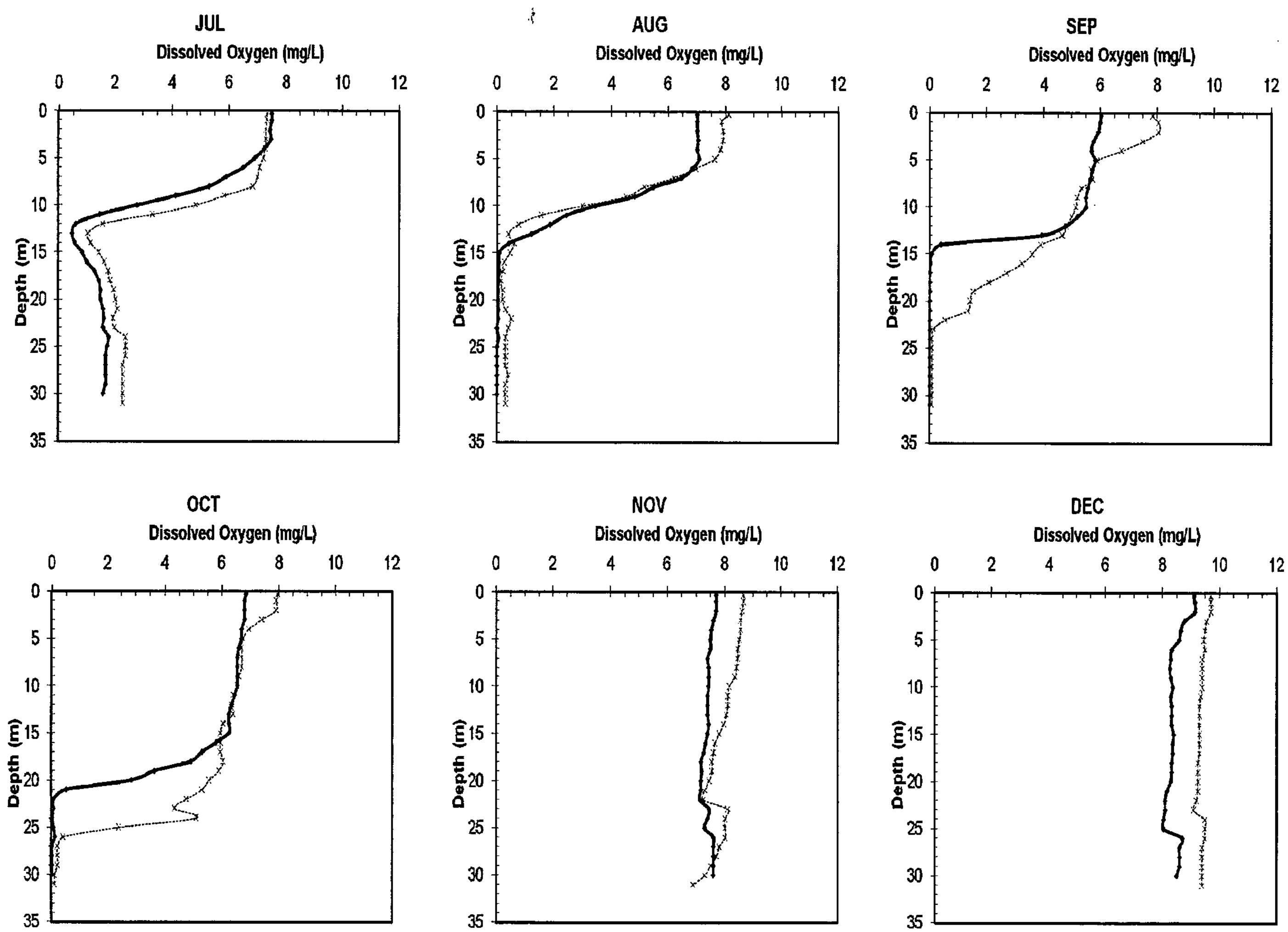


Figure 2-6. (Continued).

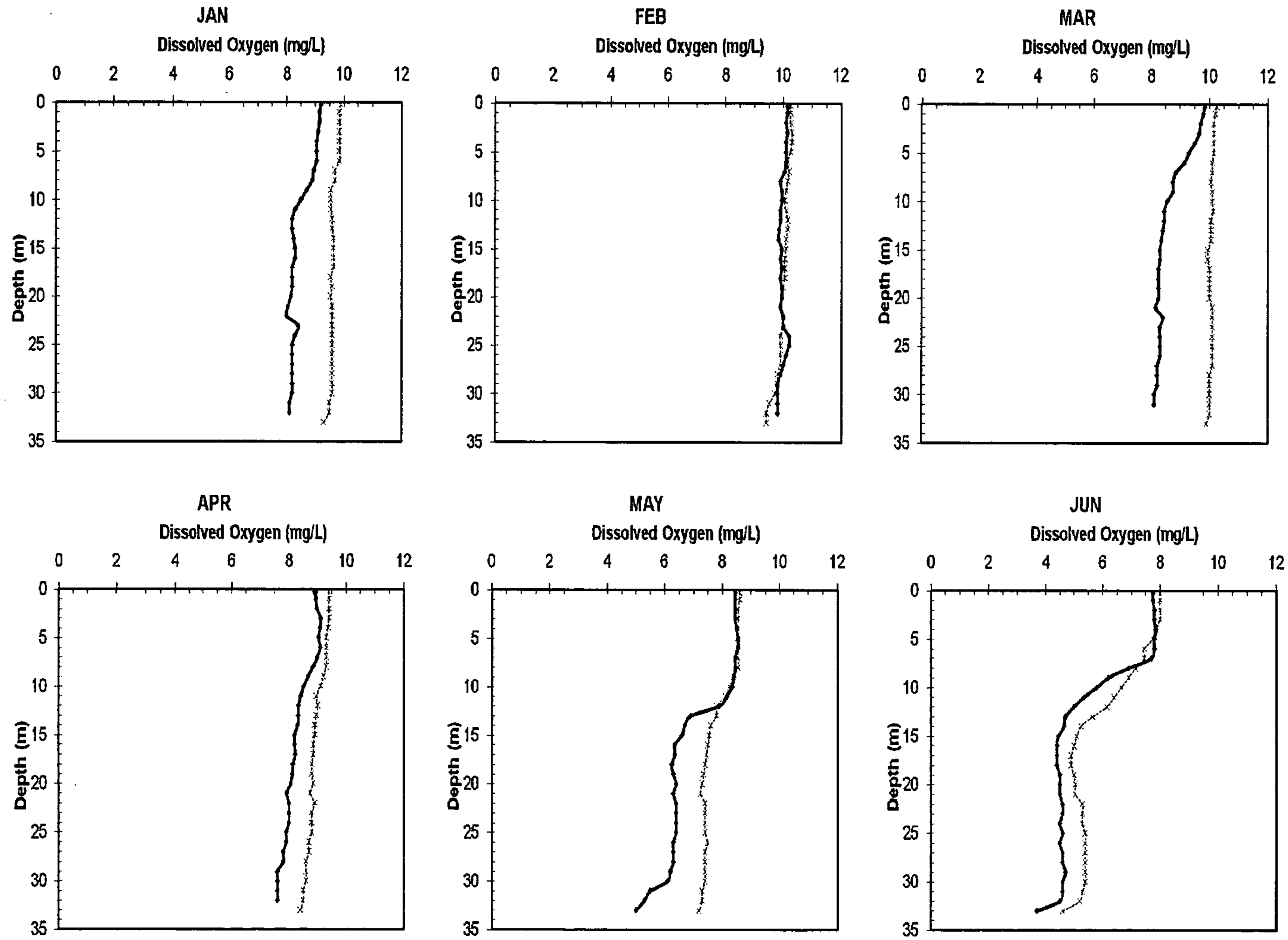


Figure 2-7. Monthly mean dissolved oxygen profiles for the MNS mixing zone in 2007 (××) and 2008 (♦ ♦).

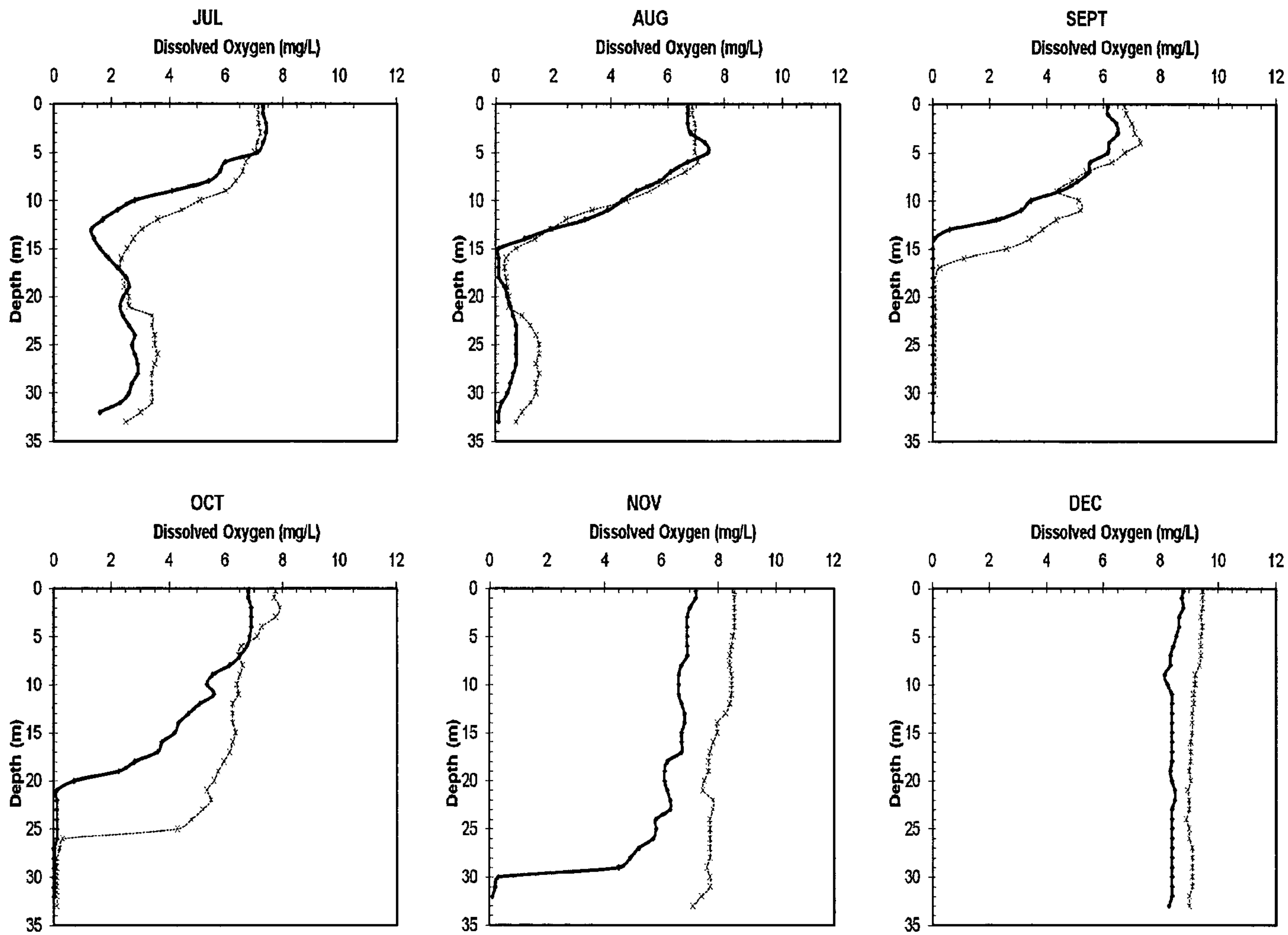


Figure 2-7. (Continued).

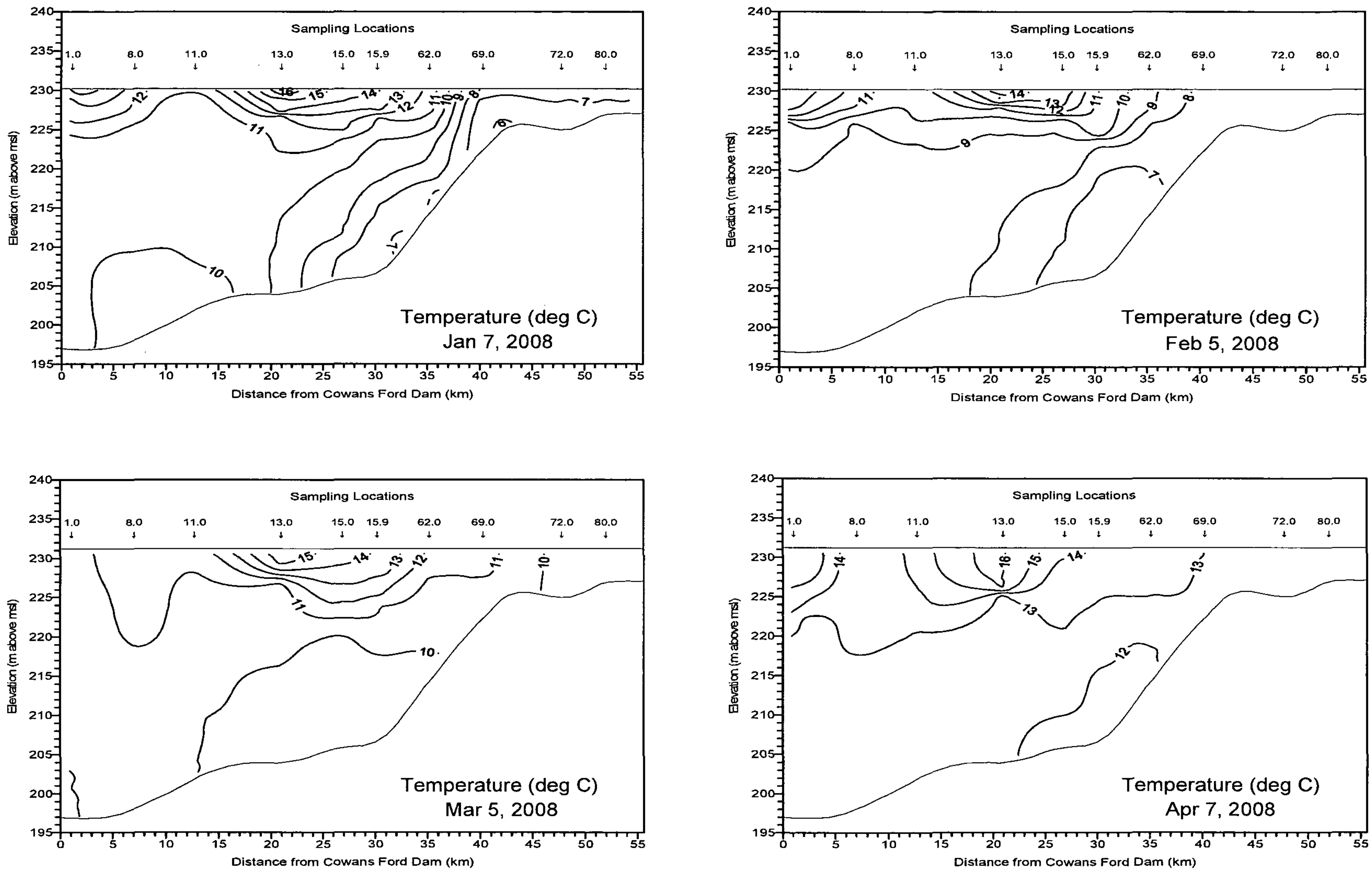


Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 2008.

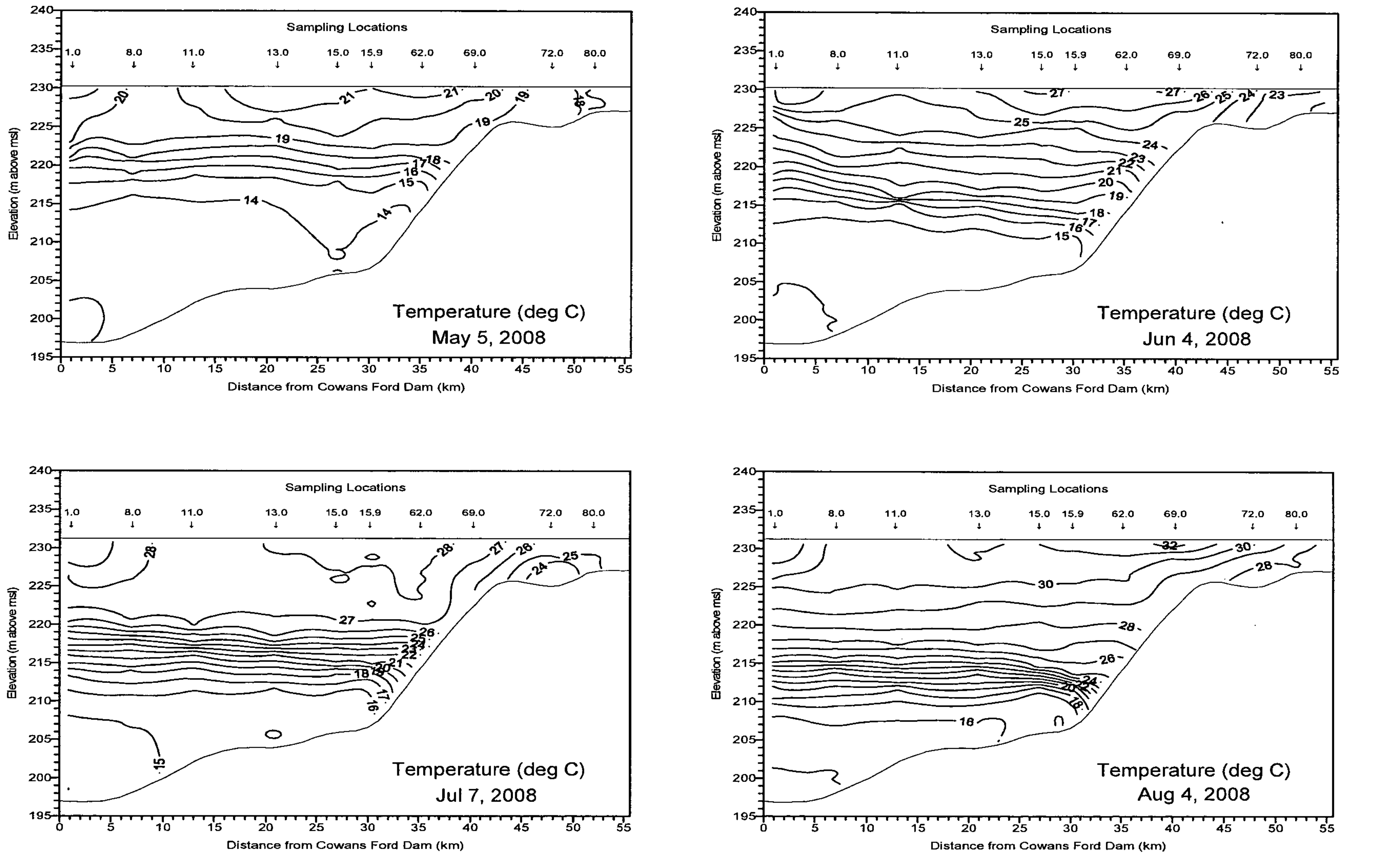


Figure 2-8. (Continued).

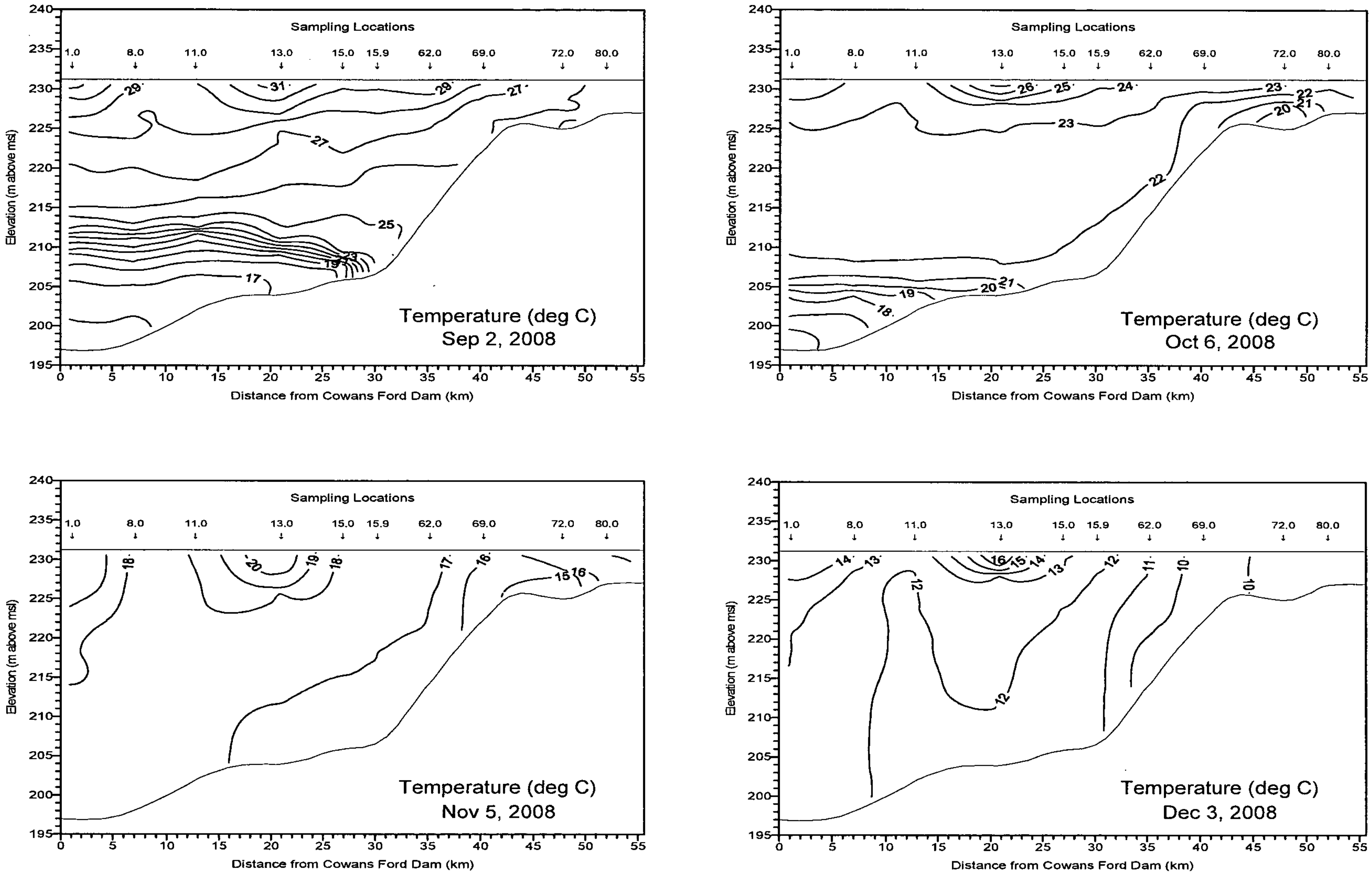


Figure 2-8. (Continued).

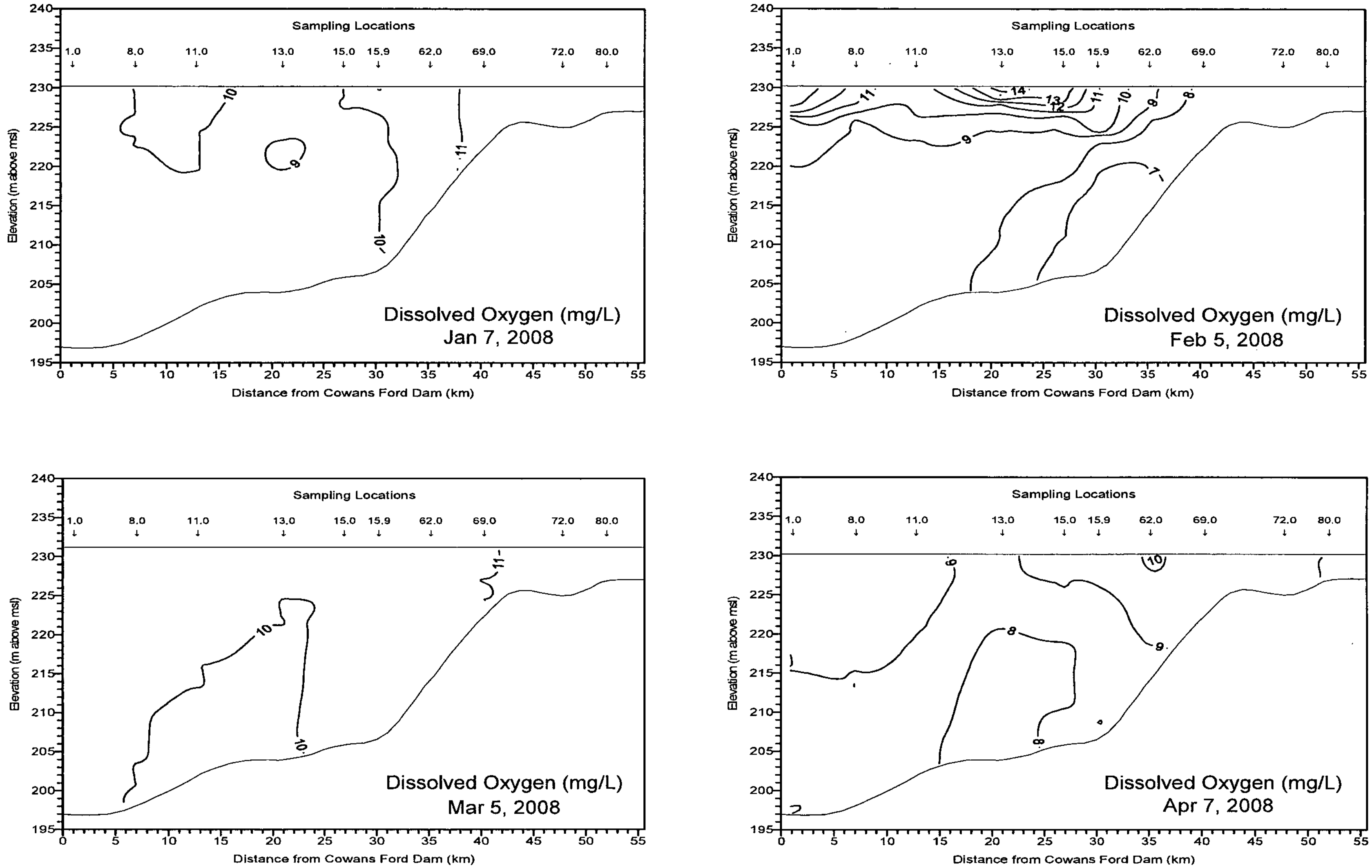


Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 2008.

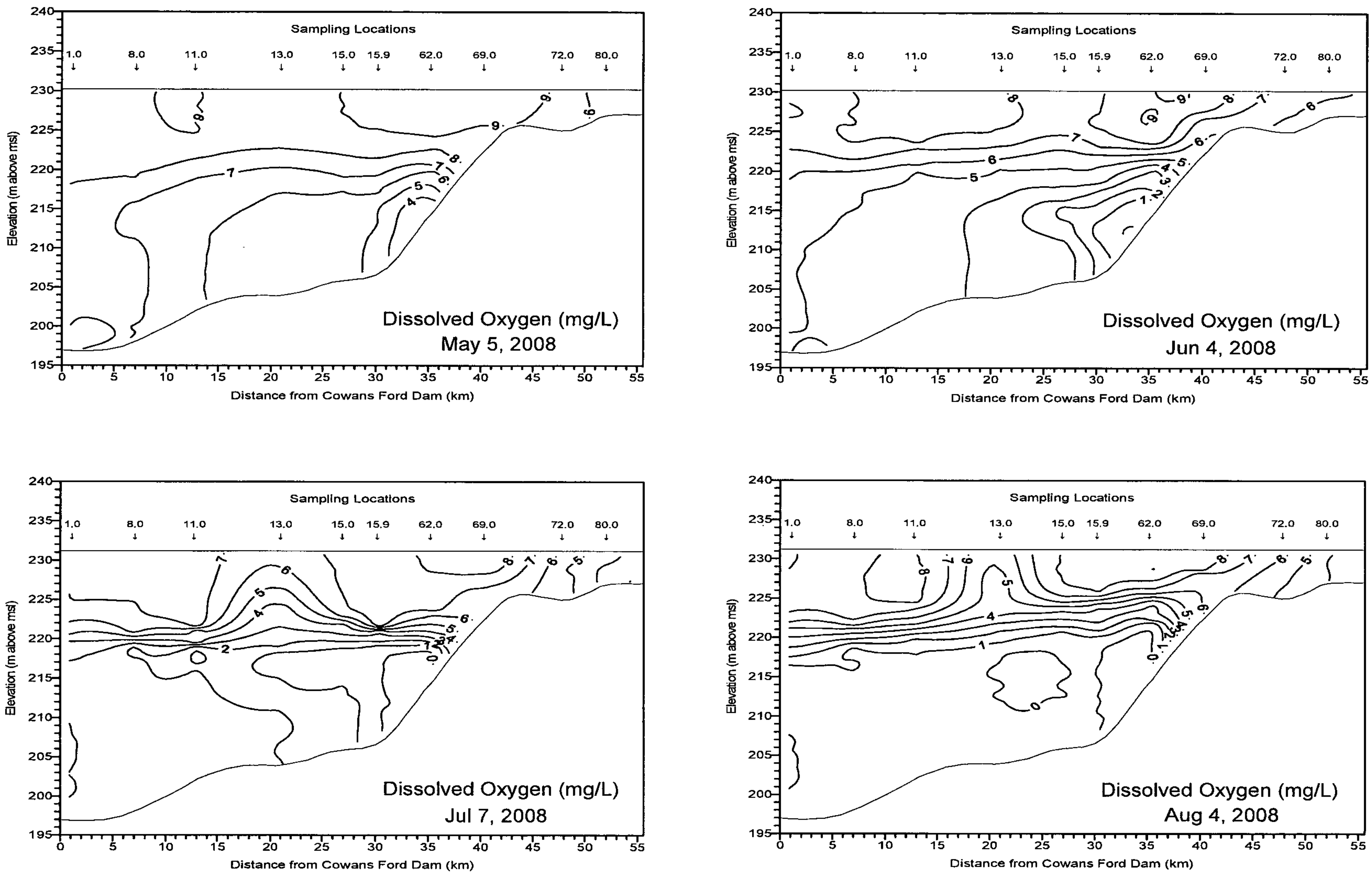


Figure 2-9. (Continued).

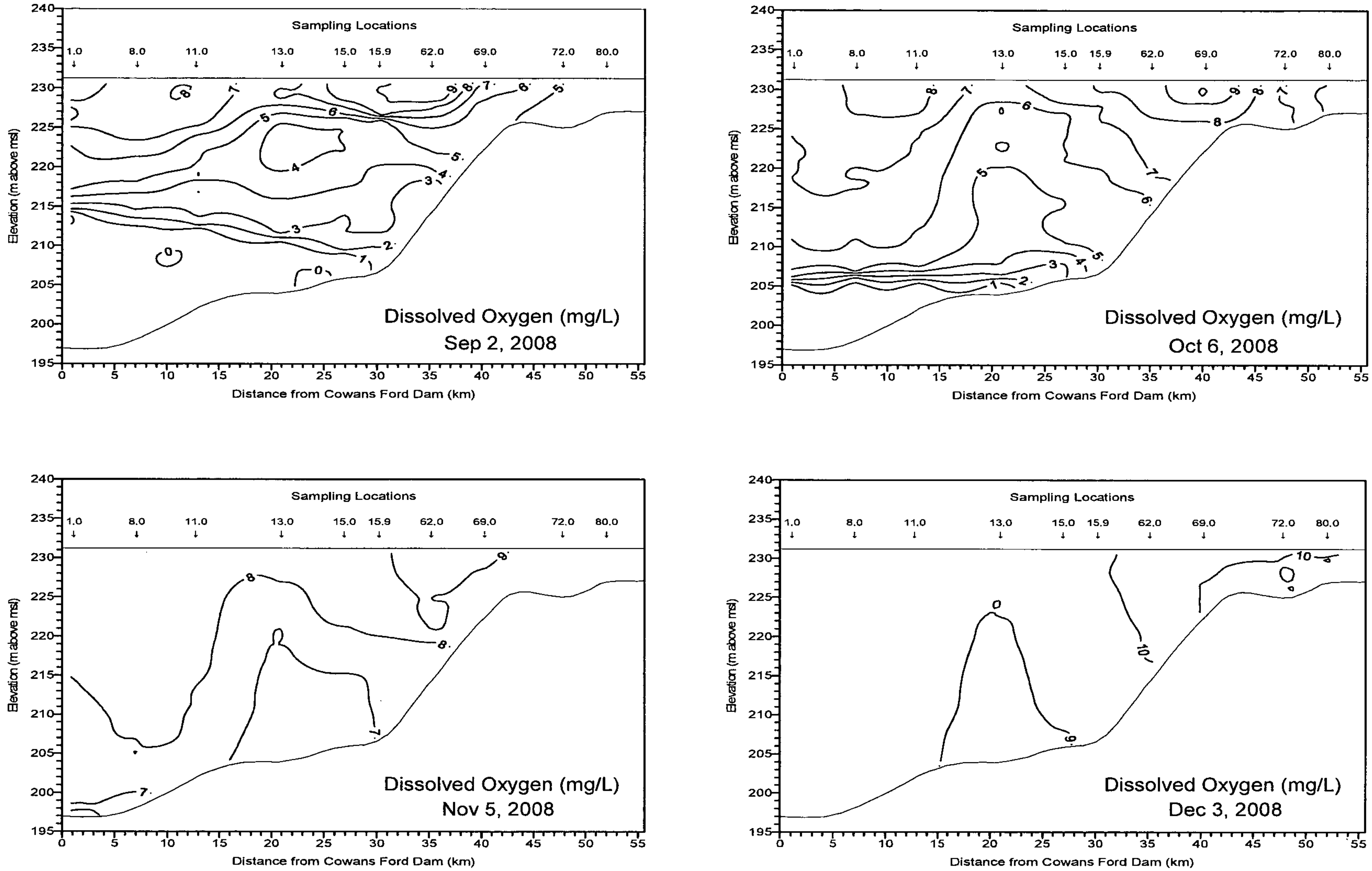


Figure 2-9. (Continued).

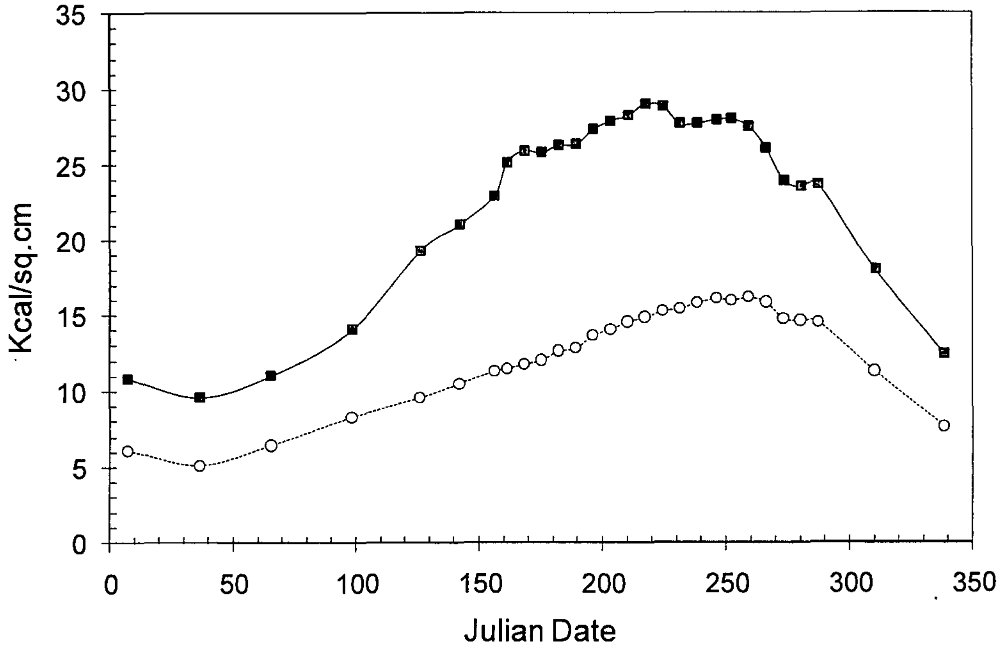


Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (○) in Lake Norman in 2008.

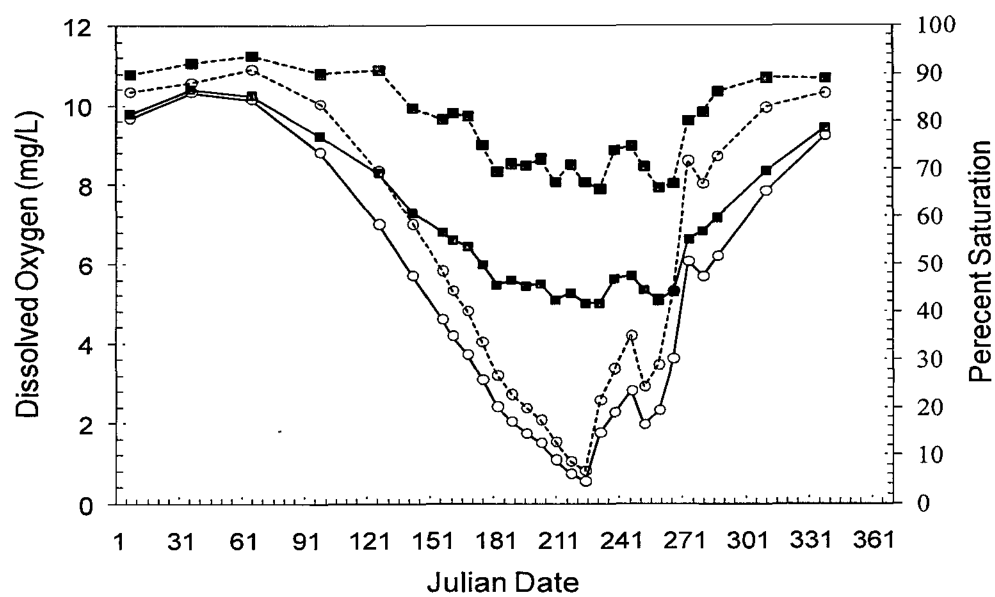


Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (○) of Lake Norman in 2008.

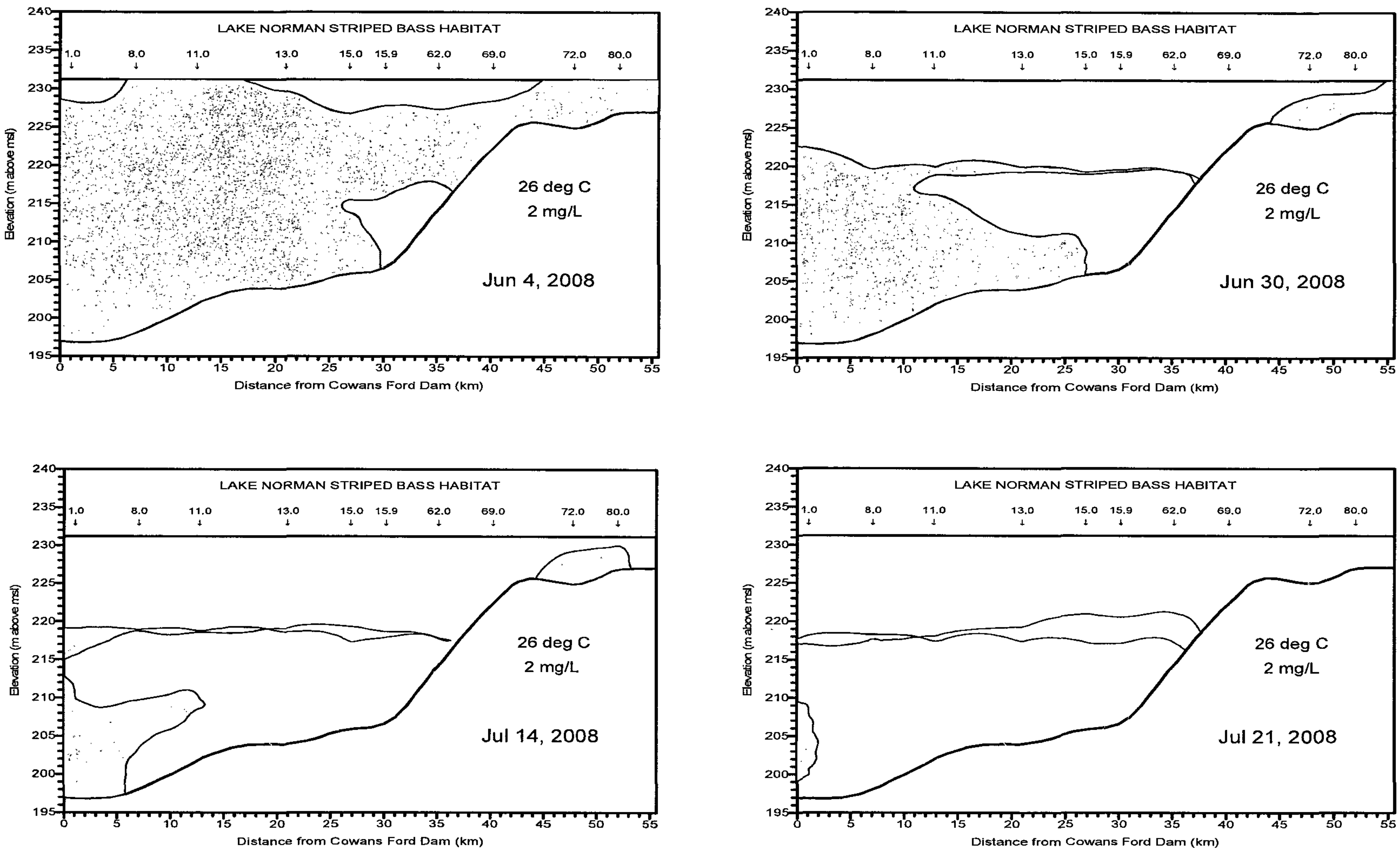


Figure 2-11. Striped bass habitat (shaded areas; temperatures ≤ 26 °C and dissolved oxygen ≥ 2 mg/L) in Lake Norman in June, July, August, and September 2008.

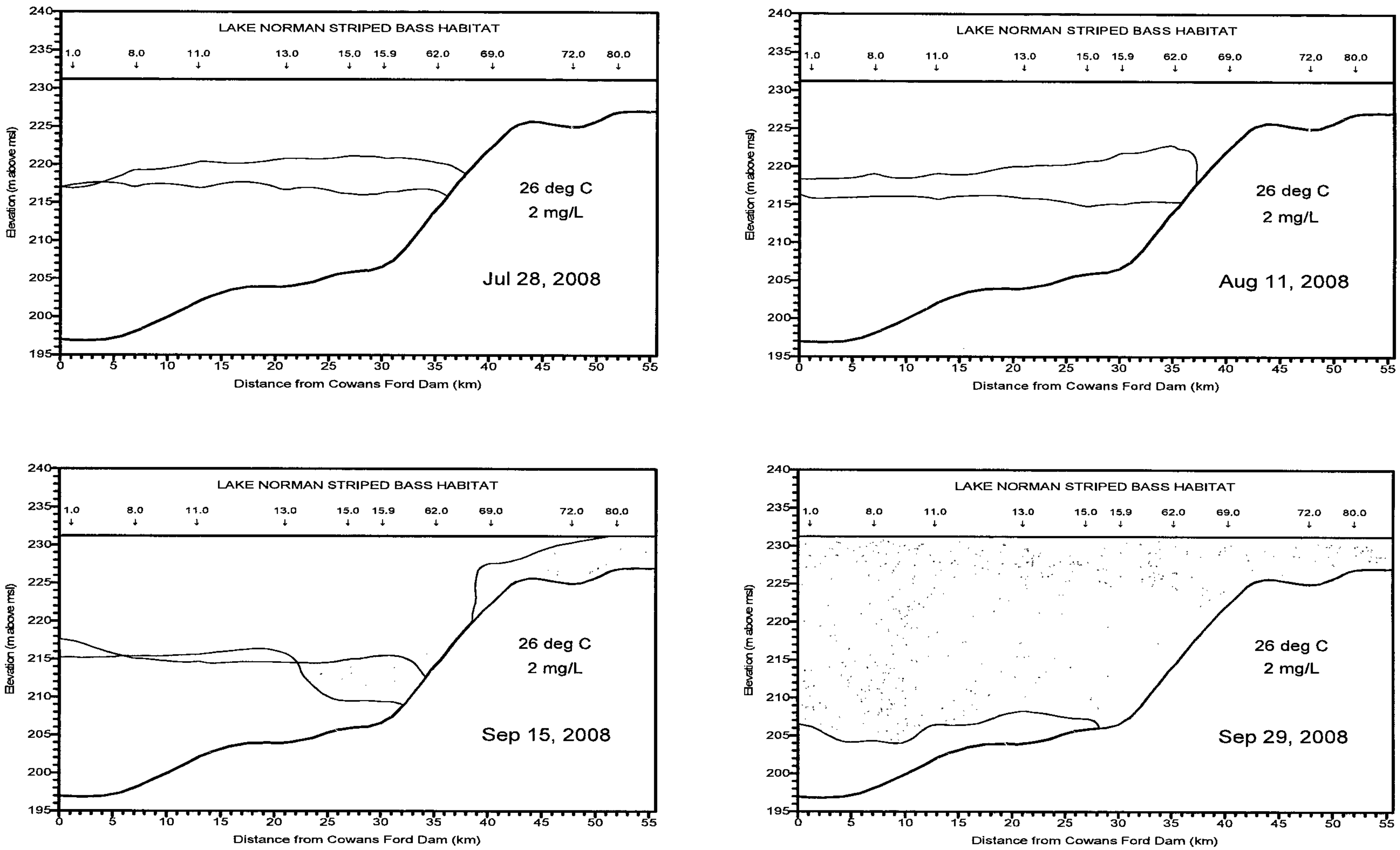


Figure 2-11. (Continued).

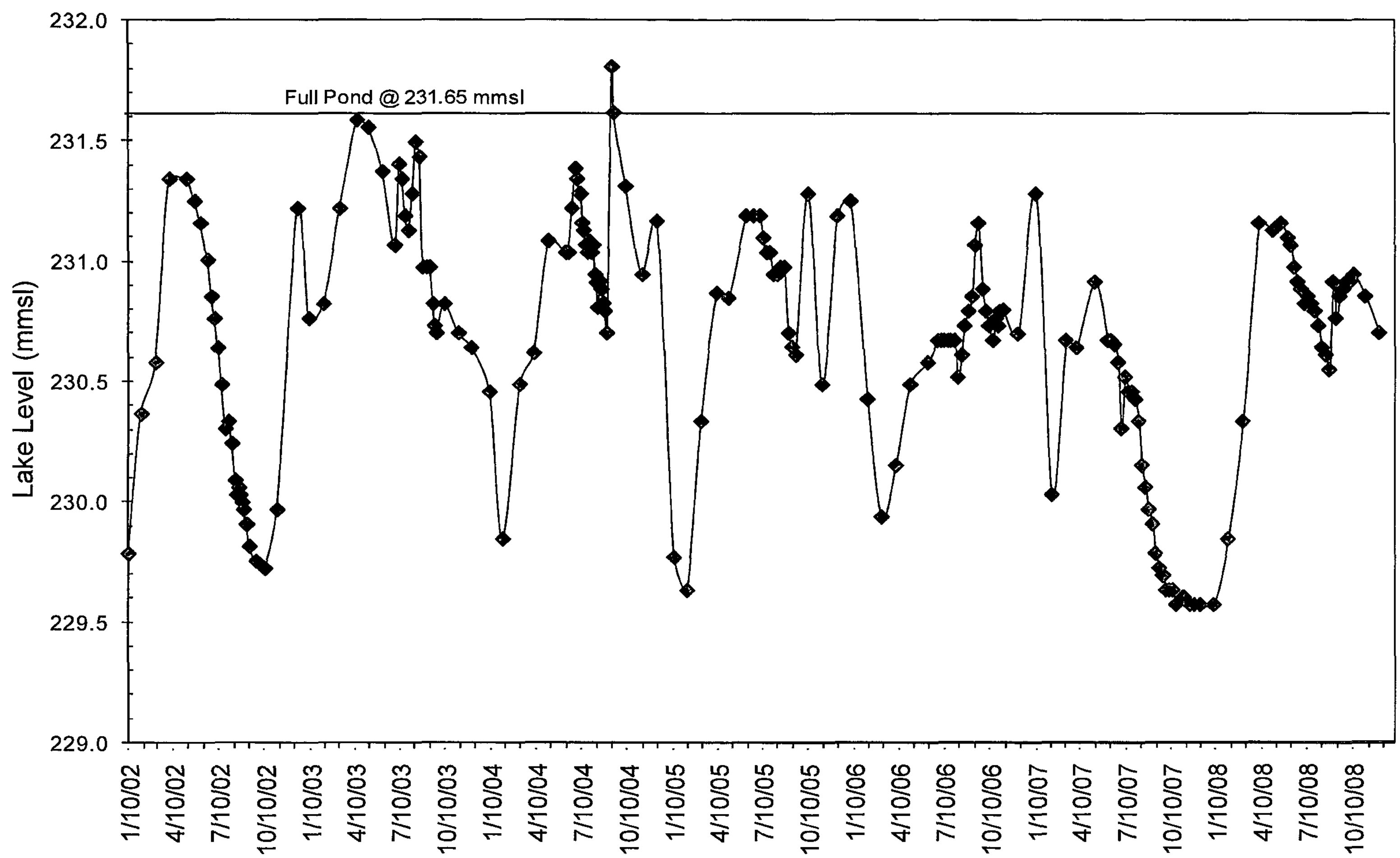


Figure 2-12. Lake Norman lake levels, expressed in meters above mean sea level (mmsl) for 2002, 2003, 2004, 2005, 2006, 2007, and 2008. Lake level data correspond to the water quality sampling dates over this time period.

CHAPTER 3

PHYTOPLANKTON

INTRODUCTION

Phytoplankton standing crop parameters were monitored in 2008 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 the 2008 study with data collected in prior study years (1987 – 2007).

In studies conducted on Lake Norman prior to the Lake Norman Maintenance Monitoring program, considerable spatial and temporal variability in phytoplankton standing crops and taxonomic composition were 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 2008).

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 shallower depth. Sampling was conducted in February, May, August, and November 2008. Secchi depths were recorded from all sampling locations. As in previous years and based on the original study design (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 crops. 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 2008 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 1.31 µg/L at Location 2.0 in May, to a high of 12.51 µg/L at Location 15.9 in November (Table 3-1 and Figure 3-1). All values were below the North Carolina water quality standard for outfalls of 40 µg/L (NCDENR 1991). Lake-wide mean chlorophyll concentrations were within ranges of those reported in previous years, but means in February and May were well below the long-term lake-wide means for these periods (Figure 3-2). The lake-wide average in August was slightly below the long-term mean, while the November 2008 average was above the long-term November mean. Seasonally, chlorophyll *a* concentrations decreased from February through May to the annual minimum, and then increased through August to the annual lake-wide maximum in November. Based on quarterly mean chlorophyll concentrations, the trophic level of Lake Norman was in the oligotrophic (low) range during February and May and in the mesotrophic (intermediate) range in August and November 2008. Nearly 47% 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 15.9 in November was the only one greater than 12 µg/L (eutrophic, or high range). Historically, quarterly mean concentrations of <4 µg/L have been recorded on 15 previous occasions, while lake-wide mean concentrations of >12 µg/L were only recorded during May of 1997 and 2000 (Duke Power 1998, 2001; Duke Energy 2008).

During 2008, 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 but November when the maximum was recorded from Location

15.9 (Table 3-1 and Figure 3-1). Minimum concentrations occurred at Location 2.0 during all but February when the lake-wide minimum was observed at Location 5.0. 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 and 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 are depressed due in great part to washout. Conversely, production and standing crop increases during periods of low flow resulting in high retention time. However, over long periods of low flow, production and standing crop gradually decline once more. These conditions result in the comparatively high variability in chlorophyll *a* 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 *a* concentrations during the period of record (August 1987 – November 2008) have varied considerably, resulting in moderate to wide historical ranges. During February 2008, chlorophyll *a* values at all but Location 69.0 were in the low range for this time of year and the value from Location 5.0 was the lowest yet recorded from any February period. The concentration at Location 69.0 in February 2008 was higher than average (Figure 3-3). Long-term February peaks at Locations 2.0, 5.0, 8.0, and 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 but Location 69.0 had lower chlorophyll concentrations in February 2008 than in February 2007 (Duke Energy 2008).

During May, mean chlorophyll *a* concentrations at all locations were in the low historical range (Figure 3-4). 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 2008 mean chlorophyll concentrations at all locations were lower than those of 2007 (Duke Energy 2008).

The lake-wide mean chlorophyll *a* concentration in August 2008 was slightly below the long-term mean for August. Concentrations from all but Location 13.0 were near the mid historical range. The concentration from Location 13.0 was the highest August concentration yet recorded from this location (Figure 3-5). Long-term August peaks at Locations 2.0, 5.0, and 15.9 were observed in 1998, while August peaks at Locations 8.0 and 9.5 occurred in 1993. The long-term August peak at Location 11.0 was observed in 1991, while Location 69.0 experienced its long-term August peak in 2001. Mean chlorophyll *a* concentrations for August 2008 were higher than those of August 2007 at all but Location 9.5 (Duke Energy 2008).

The lake-wide mean chlorophyll *a* concentration in November 2008 was the highest among all four sampling periods and was above the long-term November average (Figure 3-2). Chlorophyll *a* concentrations at all but Locations 9.5 and 69.0 were in the high historical range, while concentrations at Locations 9.5 and 69.0 were in the mid range (Figure 3-6). 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 *a* concentration at Location 69.0 occurred in 1991. November 2008 chlorophyll *a* concentrations at all but Location 69.0 were higher than during November 2007 (Duke Energy 2008).

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 2008 this was not entirely the case. Mean seasonal densities increased from the annual minimum in February to the annual peak in August, and then declined through November. Mean seasonal biovolumes increased from the annual minimum in February to the peak in November. The lowest density (451 units/mL) was recorded from Location 5.0 in May, while the minimum biovolume (125 mm^3/m^3) occurred at Location 2.0 in May (Table 3-2 and Figure 3-1). The maximum density (6,220 units/mL) occurred at Location 15.9 in August, while the peak biovolume (5,598 mm^3/m^3) was observed at this same location in November. Standing crop values during February and May of 2008 were lower than those of February and May 2007, while most standing crop values in August and November of 2008 were higher than those recorded from these periods of 2007 (Duke Energy 2008). Phytoplankton densities during 2008 never exceeded the NC state guideline for algae blooms of 10,000 units/mL density; however, the biovolume at Location 15.9 in November did exceed the bloom guideline of 5,000 mm^3/m^3 (NCDENR 1991). Densities or biovolumes in excess of NC state guidelines were also recorded in 1987, 1989, 1997, 1998, 2000, 2003, and

2006 (Duke Power Company 1988, 1990; Duke Power 1998, 1999, 2001, 2004, and Duke Energy 2007).

During all sampling periods phytoplankton densities and biovolumes demonstrated a spatial trend similar to that of chlorophyll *a*; 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 2008 were most often higher than those of 2007. A general pattern of increasing values from down-lake to up-lake was observed during 2008, as was observed with chlorophylls and algal standing crops (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 (Figure 2-2a) resulting in low sedimentation from runoff. 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 2008, especially with respect to increasing values from down-lake to up-lake areas, as was the case with chlorophyll *a* concentrations and standing crop values (Tables 3-1 through 3-3). Ash-free dry weights were also typically higher in 2008 than in 2007 (Duke Energy 2008).

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 1.0 m at Location 13.0 in August, to 3.0 m at Locations 2.0 and 5.0 in May (Table 3-1). The lake-wide mean Secchi depth during 2008 was slightly lower than in 2007 and was within historical ranges for the years since measurements were first reported in 1992. The deepest lake-wide mean Secchi depth was recorded in 1999 (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 2008. Ten classes comprising 94 genera and 247 species, varieties, and forms of phytoplankton were identified in samples collected during 2008, as compared to 98 genera and 257 species, varieties, and forms of phytoplankton identified during 2007 (Table 3-4). The 2008 total represented the second highest number of taxa recorded in any year since monitoring began in 1987 (Duke Energy 2008). Eighteen taxa previously unrecorded during the Lake Norman Maintenance Monitoring program were identified during 2008.

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 2008, cryptophytes (Cryptophyceae) dominated densities at all locations (Table 3-5; Figures 3-7 through 3-11). During most previous years, cryptophytes and occasionally diatoms dominated February phytoplankton samples in Lake Norman. The most abundant cryptophyte during February 2008 was the small flagellate *Rhodomonas minuta*. *R. minuta* has been one of the most common and abundant forms observed in Lake Norman samples since monitoring began in 1987. Cryptophytes are characterized as light limited, often found deeper in the water column or near surface under low light conditions, which are common during winter (Lee 1989).

In May, cryptophytes were dominant at all but Location 15.9 and, as in February, the most abundant cryptophyte was *R. minuta*. Diatoms were dominant at Location 15.9 and the most abundant species was the pennate, *Fragillaria crotonensis*. Diatoms have typically been the predominant forms in May samples of previous years, however, cryptophytes often dominated May samples from 1988 – 1995 (Duke Power Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996; Duke Power 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, and Duke Energy 2006, 2007, 2008).

During August 2008, green algae (Chlorophyceae) dominated densities at all locations (Table 3-5, Figures 3-7 through 3-11). The most abundant green alga was the small desmid, *Cosmarium asphearosporum* var. *strigosum* (Table 3-7). 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, and Duke Power 1997, 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 it 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, 2004, 2005, and Duke Energy 2006, 2007, 2008).

During November 2008, densities at all locations were dominated by diatoms. The most abundant species at all locations was the pennate diatom, *Tabellaria fenestrata* (Table 3-5; Figures 3-7 through 3-11). This diatom has been one of 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 2008 samples. Their overall contribution to phytoplankton densities was lower than in 2007 and densities seldom exceeded 1% of totals (Duke Energy 2008). 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 *a* concentrations during 2008 were most often within historical ranges, however, one record low chlorophyll *a* concentration was recorded in February and one record high value occurred in August. Lake-wide mean chlorophyll *a* decreased from February through May then increased through August to the annual maximum in November. Some spatial variability was observed in 2008, however, maximum chlorophyll *a* concentrations were most often observed up-lake at Location 69.0, while minimum chlorophyll *a* concentrations were typically recorded from down-lake at Location 2.0. The highest chlorophyll *a* value recorded in 2008, 12.51 µg/L, was well below the NC State Water Quality standard of 40 µg/L.

Phytoplankton densities and biovolumes during February and May 2008 were lower than in these months of 2007, while standing crop values in August and November 2008 were higher than during these periods of the previous year. Phytoplankton densities during 2008 never exceeded the NC guideline for algae blooms, however, one biovolume was in excess of the guideline of 5,000 mm^3/m^3. Standing crop values in excess of bloom guidelines have been recorded during seven previous years of the program. As in past years, standing crop spatial distribution typically mirrored that of chlorophyll *a*, with high values usually observed at up-lake locations, while comparatively low values were noted down-lake.

Seston dry and ash-free weights were most often higher in 2008 than in 2007 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 most often 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 2008 was slightly lower than in 2007 and was within historical ranges of lake-wide mean Secchi depths recorded since 1992.

Diversity or the number of taxa of phytoplankton in 2008 was the second highest yet recorded. The taxonomic compositions of phytoplankton communities during 2008 were similar to those of many previous years. Cryptophytes were dominant in February and at all but Location 15.9 in May, while diatoms were dominant during May at Location 15.9 and at all locations in November. Green algae dominated phytoplankton assemblages during August. Blue-green algae were less abundant during 2008 than during 2007 and their contribution to total densities seldom exceeded 1%.

The most abundant alga, on an annual basis, was the cryptophytes, *R. minuta*. The most abundant diatom at Location 15.9 in May was *F. crotonensis*, while the most abundant diatom during November was *T. fenestrata*. The small desmid, *C. asphearosporum* var. *strigosum*, was dominant in August 2008. 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 2008.

Chlorophyll *a* Location	Feb	May	Aug	Nov
2.0	1.66	1.31	4.90	4.77
5.0	1.55	1.48	4.94	5.06
8.0	1.70	1.74	5.17	5.73
9.5	2.02	1.75	5.06	5.77
11.0	2.87	1.80	8.44	10.43
13.0	2.91	1.99	7.28	11.13
15.9	3.32	2.35	8.56	12.51
69.0	6.58	3.58	9.23	4.87

Secchi depths Location	Feb	May	Aug	Nov
2.0	2.20	3.00	2.30	2.20
5.0	2.20	3.00	NS	2.00
8.0	2.55	2.90	2.20	2.00
9.5	2.20	2.90	NS	2.15
11.0	2.20	2.65	1.90	1.60
13.0	1.80	2.30	1.00	1.50
15.9	2.00	2.00	2.40	2.10
69.0	2.00	1.10	1.10	1.20
Annual mean from all Locations: 2008				2.09
Annual mean from all Locations: 2007				2.11

NS = Not sampled.

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 2008.

Density	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
Feb	523	451	545	877	1,164	712
May	515	599	731	964	2,442	1,050
Aug	3,962	3,994	4,111	6,100	6,220	4,877
Nov	1,955	2,288	2,332	3,149	5,252	2,995

Biovolume	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
Feb	203	241	300	550	926	444
May	125	210	220	329	1,336	555
Aug	1,511	1,918	1,723	2,794	4,092	2,408
Nov	2,441	2,481	2,702	3,625	5,598	3,369

Table 3-3. Total mean seston dry and ash free dry weights (mg/L) from samples collected in Lake Norman, NC during 2008.

Dry weights	Locations							
Month	2.0	5.0	8.0	9.5	11.0	13.0	15.9	69.0	Mean
Feb	1.71	1.76	1.37	1.19	1.34	1.26	1.17	1.59	1.42
May	0.79	0.71	0.56	0.79	0.72	0.82	1.29	5.99	1.46
Aug	1.78	1.88	2.14	2.11	2.63	2.21	3.04	14.91	3.83
Nov	1.62	1.65	1.82	2.01	3.10	2.62	2.77	7.30	2.86
Ash-free dry weights									
Month									
Feb	0.70	0.85	0.64	0.43	0.54	0.49	0.56	0.90	0.64
May	0.46	0.44	0.36	0.44	0.47	0.62	0.72	1.57	0.64
Aug	1.13	1.05	1.32	1.37	1.58	0.97	2.39	2.89	1.59
Nov	0.80	0.63	0.65	0.69	1.08	0.93	1.16	1.57	0.94

Table 3-4. Phytoplankton taxa identified in quarterly samples collected in Lake Norman each year from 1993 to 2008.

Taxon	Years															
	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Class: Chlorophyceae																
Acanthosphaera zachariasi Lemm.	X															
Actidesmium hookeri Reinsch	X															
Actinastrum hantzchii Lagerheim	X	X								X						
Ankistrodesmus braunii (Naegeli) Brunn			X	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														
A. nannoselene Skuja								X								
A. spiralis (Turner) Lemm.	X				X											
A. spp. Corda	X															
Arthrodesmus convergens Ehrenberg			X							X	X		X	X	X	X
A. incus (Breb.) Hassall			X			X			X	X	X	X	X	X	X	X
A. incus v *ralfsii* W. West																X
A. octocornis Ehrenberg										X	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	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	
A. superbus (Cienk.) Scherffel												X			X	
Botryococcus braunii Kutzing[d]																
Carteria fritzschii Takeda								X			X	X	X	X	X	X
C. globosa Korsch										X		X		X		X
C. spp. Diesing	X				X						X					
Characium ambiguum Hermann													X			
C. limneticum Lemmerman											X					
C. spp. Braun [d]																
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	X
C. spirale Scherffel & Pascher		X	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	X
C. parvulum Nageli													X			
C. tumidum Johnson								X								
C. spp. Nitzsch	X															
Coccomonas orbicularis Stein						X				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	X
C. proboscideum Bohlin																X
C. reticulatum (Dang.) Sinn.							X							X	X	
C. sphaericum Nageli		X		X			X	X	X	X	X	X	X	X	X	X
C. spp. Nageli [d]																

Table 3-4. (Continued).

Taxon	Years															
	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Cosmarium angulosum v. *concin.* (Rab) W&W								X		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
C. contractum Kirchner		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. moniliforme (Turp.) Ralfs								X			X		X	X	X	X
C. notabile Brebisson										X						
C. phaseolus f. *minor* Boldt.				X	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	X
C. raciborskii Lagerheim										X			X	X	X	
C. regnellii Wille	X			X	X	X	X	X	X	X	X	X	X	X	X	X
C. regnesi Schmidle	X									X						
C. regnesi v. *montana* Schmidle																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	X
C. tinctum Ralfs	X	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	X
C. trilobatum v. *depressum* Printz										X						
C. tumidum Borge										X						
C. spp. Corda	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	X
C. fenestrata Schmidle										X	X	X	X	X	X	X
C. irregularis Wille	X	X		X		X		X		X	X	X	X	X		X
C. quadrata Morren															X	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	X
D. pulchellum Wood	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dimorphococcus spp. Braun[d]																
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	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	X
E. elegans Kutzing											X					
E. turneri West																X
E. spp. Ehrenberg	X														X	
Eudorina elegans Ehrenberg				X						X	X		X	X		X
Franceia droescheri (Lemm.) G. M. Sm.			X	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	X
G. gigas Kutzing				X	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

Table 3-4. (Continued).

Taxon	Years 93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
G. vesciculosa Naegeli						X				X	X	X	X	X	X	X
G. spp. Nageli	X	X														
Golenkinia paucispina West & West										X	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	X
G. sociale (Duj.) Warming			X			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	X
K. lunaris (Kirch.) Mobius											X	X				X
K. lunaris v. *dianae* Bohlin					X			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	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		X
L. longiseta (Lemmermann) Printz										X	X	X	X		X	X
L. quadriseta (Lemm.) G. M. Smith[d]																
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	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														
M. pusillum Printz	X	X														
Mougeitia elegantula Whittrock			X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. spp. Agardh	X	X													X	
Nephrocytium agardhianum Nageli										X	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	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	X
O. pusilla Hansgirg	X	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		X
O. spp. Nageli[d]																
Pandorina charkowiensis Kprshikov													X	X		
P. morum Bory	X										X		X	X	X	
Pediastrum biradiatum Meyen													X	X	X	X
P. duplex Meyen	X		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. duplex v. *reticulatum* Lagerheim																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 [d]																
Phacotus angustus																X

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	Years															
Planktosphaeria gelatinosa G. M. Smith			X							X		X	X		X	X
Quadrigula closterioides (Bohlin) Printz				X	X				X	X	X	X	X	X	X	X
Q. lacustris (Chodat) G. M. Smith										X	X	X	X	X	X	X
Scenedesmus abundans (Kirchner) Chodat											X		X	X		X
S. abundans v. *asymetrica* (Schr.) G. Sm.	X	X		X	X			X		X	X	X		X	X	
S. abundans v. *brevicauda* G. M. Smith			X								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
S. arcuatus Lemmermann																X
S. arcuatus v. *platydisca* G. M. Smith																X
S. armatus (Chod.) G. M. Smith																X
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	X
S. bijuga v. *alterans* (Reinsch) Hansg.												X		X		X
S. brasiliensis Bohlin			X	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	X
S. dimorphus (Turp.) Kutzing	X	X			X	X	X	X		X	X	X	X	X	X	X
S. incrassulatus G. M. Smith [d]																X
S. opoliensis P. Richter													X			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	
S. smithii Teiling				X						X	X		X	X		
S. serratus (Corda) Bohlin												X				
S. spp. Meyen	X	X														
Schizochlamys compacta Prescott				X		X		X		X		X	X		X	X
S. gelatinosa A. Braun								X		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. [d]																
Stauastrum americanum (W&W) G. Sm.			X	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	X
S. aspinosum v. *annulatum* W.& G.S.Wst.															X	
S. brachiatum Ralfs					X	X	X			X	X	X	X	X	X	X
S. brevispinum Brebisson						X										
S. chaetocerus (Schoed.) G. M. Smith	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	X
S. dejectum Brebisson		X						X				X			X	
S. dickeii v. *maximum* West & West [d]														X		
S. dickeii v. *rhomboidium* W.& G.S. West										X						

Table 3-4. (Continued).

Years

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
S. gladiosum Turner	X															
S. leptocladum Nordstedt													X			
S. leptocladum v. *sinuatum* Wolle [d]																
S. manfeldtii v. *fluminense* Schumacher		X	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	X
S. paradoxum v. *parvum* W. West						X				X	X	X	X	X	X	X
S. pentacerum (Wolle) G. M. Smith										X			X	X		X
S. subcruciatum Cook & Wille			X		X	X	X	X		X	X	X	X	X	X	X
S. tetracerum Ralfs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. turgescens de Not.													X		X	
S. vestitum Ralfs										X	X				X	X
S. spp. Meyen		X														
Stichococcus scopulinus Hazen										X						
S. spp. Nageli															X	
Stigeoclonium spp. Kutzing									X						X	
Tetraedron arthrodesmiforme (W.) Wol.										X	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	
T. lobulatum (Naegeli) Hansgirg								X								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	X
T. muticum (Braun) Hansgirg	X	X	X	X		X										X
T. obesum (W & W) Wille *ex* Brunnthaler				X												X
T. pentaedricum West & West		X											X	X	X	
T. planktonicum G. M. Smith						X		X		X	X	X	X	X	X	X
T. regulare Kutzing	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	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			X
T. staurogeniforme (Schroeder) Lemm.											X					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	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
X. spp. Ehrenberg		X								X						

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	Years															
Class: Bacillariophyceae																
Achnanthes lanceolata Brebisson										X			X			
A. microcephala Kutzing			X	X	X	X	X	X	X	X	X	X	X	X	X	X
A. spp. Bory	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	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	X
Cocconeis placentula Ehrenberg						X	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	X
C. glomerata Bachmann			X	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	X
C. pseudostelligera Hustedt [d]																
C. stelligera Cleve & Grunow	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Kutzing[d]																
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 [d]																
C. spp. Agardh [d]																
Denticula elegans Kutzing										X		X			X	X
D. elegans v. *crassa* (Naegeli) Hustedt																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				X
D. spp. Ehrenberg[d]																
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[d]																
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

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	Years															
M. italica (Ehrenberg) Kutzing [d]																
M. italica v. *tennuissima* (Grun.) O.Mull[d]														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						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	X
N. subtilissima Cleve			X					X			X		X	X	X	
N. spp. Bory	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		
N. holsatica Hustedt			X		X	X	X	X	X	X	X	X	X	X	X	X
N. kutzingiana Hilse												X	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	X
N. sublinearis Hustedt				X		X			X	X				X		
N. thermalis Kutzing																X
N. spp. Hassall	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	X
Stephanodiscus astraea (Her.) Grunow													X		X	
S. spp. Ehrenberg	X	X	X	X	X	X					X	X	X	X	X	
Surirella angustata Kutz.											X					
S. linearis v. *constricta* (Her.) Gr0.						X									X	
S. tenuis Mayer													X			
Synedra actinastroides Lemmerman		X														
S. acus Kutzing	X	X			X	X		X		X	X	X	X	X	X	X
S. amphicephala Kutzing														X	X	
S. delicatissima Lewis	X	X														
S. filiformis v. *exilis* Cleve-Euler						X		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	X
S. rumpens v. *fragilarioides* Grunow [d]																
S. rumpens v. *scotica* Grunow [d]																
S. ulna (Nitzsch) Ehrenberg			X	X	X	X	X	X		X	X	X	X	X	X	X
S. spp. Ehrenberg	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	X

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
							Years									
Class: Chrysophyceae																
Aulomonas purdyii Lackey	X	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		X
C. spp. Chien.						X				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	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		X
D. sociale Ehrenberg																X
D. spp. Ehrenberg			X	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	X
Kephyrion campanuliforme Conrad											X					
K. littorale Lund						X				X	X	X	X	X	X	X
K. petasatum Conrad											X					
K. rubi-claustri Conrad										X	X	X	X	X	X	X
K. skujae Ettl [d]																
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	X
M. allantoides Perty														X		X
M. allorgii (Defl.) Conrad											X					
M. alpina Pascher						X		X								
M. caudata Conrad	X	X	X				X	X	X	X	X		X	X	X	
M. globosa Schiller						X		X	X	X	X	X	X	X	X	X
M. producta Iwanoff								X		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	
Ochromonas granularis Doflein						X	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	X
Pseudokephyrion concinum (Schill.) Sch.													X			X
P. schilleri Conrad						X	X		X	X	X		X			X
P. tintinabulum Conrad						X										
P. spp. Pascher											X		X	X		X
Rhizochrisis polymorpha Naumann							X	X	X	X	X	X	X	X	X	X
R. spp. Pascher [d]																

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	Years															
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		X
Synura sphagnicola Korschikov												X				
S. spinosa Korschikov			X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. uvella Ehrenberg	X	X							X					X		X
S. spp. Ehrenberg	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	X
C. cylindrica (Lambert) Lemm.															X	X
C. dubia Pascher			X	X		X	X	X	X	X	X	X	X	X	X	X
Dichotomococcus curvata Korschikov [d]																
Ophiocytium capitatum v. *longisp.* (M) L.	X	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
C. erosa v. *reflexa* Marsson						X	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		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														
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	
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	X
A. spp. Bory	X	X		X			X		X	X		X		X	X	X
Anacystis incerta (Lemm.) Druet & Daily	X	X				X		X	X							
A. spp. Meneghini [d]																
Aphanocaspsa rivularis (Carm.) Raben.																X
Chroococcus dispersus (Keissl.) Lemm.						X		X							X	X
C. giganteous W. West														X		
C. limneticus Lemmermann					X	X	X	X	X	X	X		X	X	X	X
C. minor Kutzing										X	X		X	X	X	X

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	Years															
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[d]																
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			
Lyngbya contorta Lemmermann																
L. limnetica Lemmermann	X	X														
L. ochracea (Kutzing) Thuret								X		X		X	X			X
L. subtilis W. West		X														
L. tenue Agardh												X				X
L. spp. Agardh	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Merismopedia tenuissima Lemmermann						X										
Microcystis aeruginosa 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	X
O. limnetica Lemmermann			X	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	X
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.[d]																
Spirulina subsala Oersted										X						X
Synecococcus lineare (Sch. & Lt.) Kom.	X	X	X	X		X	X	X	X		X	X				
Class: Euglenophyceae																
Euglena acus Ehrenberg							X					X	X			
E. deses Ehrenberg													X	X		
E. fusca (Klebs). Lemmermann																X
E. minuta Prescott								X		X		X	X		X	X
E. polymorpha Dangeard				X					X	X		X	X			X
E. proxima Dangeard											X	X	X	X		
E. texta (Duj.) Hubn.																X
E. spp. Ehrenberg	X	X	X	X		X	X		X			X	X	X	X	X
Lepocinclus acicularis France														X		
L. acuta Prescott												X				
L. fusiformis Lemmermann																X

Table 3-4. (Continued).

Taxon	Years 93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
L. glabra Drezepolski											X					
L. ovum. (Ehr.) Lemm.								X				X			X	X
L. sphagnophila Lemmermann																X
L. spp. Perty						X										
Phacus cuvicauda Swirenko								X								
P. longicauda (Her.) Dujardin								X							X	
P. orbicularis Hubner													X			
P. tortus (Lemm.) Skvortzow[d]																
P. triquter Playfair												X				
P. spp. Dujardin [d]																
Trachelomonas abrupta (Swir.) Deflandre														X		
T. abrupta v. *minor* Deflan.													X	X		
T. acanthostoma (Stk.) Defl.									X			X	X	X	X	X
T. ensifera Daday											X				X	
T. euchlora (Ehrenberg) Lemmermann																X
T. hispida (Perty) Stein	X		X				X		X	X	X	X	X		X	X
T. lemmermanii v. *acuminata* Deflandre													X		X	
T. pulcherrima Playfair [d]																X
T. pulcherrima v. *minor* Playfair												X				
T. varians (Lemm.) Deflandre															X	
T. volvocina Ehrenberg			X				X		X		X	X	X		X	X
T. spp. Ehrenberg		X														
Class: Dinophyceae																
Ceratium hirundinella (OFM) Schrank		X	X		X	X	X	X								
C. hirundinella v. *brachyceras* (Day.) Est.													X			X
Glenodinium borgei (Lemm.) Schiller				X												X
G. gymnodinium Penard	X				X							X		X	X	X
G. palustre (Lemm.) Schiller [d]															X	
G. penardiforme (Linde.) Schiller							X	X				X		X	X	X
G. quadridens (Stein) Schiller		X												X	X	
G. spp. (Ehrenberg) Stein		X														
Gymnodinium aeruginosum Stein						X	X	X			X	X	X		X	
G. neglectum (Schilling) Lindemann																X
G. spp. (Stein) Kofoid & Swezy	X	X	X		X	X		X	X	X	X	X	X	X	X	
Peridinium aciculiferum Lemmermann [d]																X
P. cinctum (Muller) Ehrenberg										X				X		
P. godlewskii Wolzynska																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	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. quadridens Stein																X
P. umbonatum Stein	X	X														
P. willei Huitfeld-Kass												X	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														

Table 3-4. (Continued).

Taxon	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
	Years															
Class: Chloromonadophyceae																
Gonyostomum depresseum Lauterborne			X			X	X			X	X	X	X	X	X	X
G. semen (Ehrenberg) Diesing																X
G. spp. Diesing		X														

[d] 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 2008.

Location	February	May
2.0	Cryptophyceae (42.9)	Cryptophyceae (49.8)
	Rhodomonas minuta (32.6)	*Rhodomonas minuta* (48.2)
5.0	Cryptophyceae (33.3)	Cryptophyceae (29.1)
	R. minuta (59.8)	*R. minuta* (28.1)
9.5	Cryptophyceae (36.4)	Cryptophyceae (33.2)
	R. minuta (30.9)	*R. minuta* (32.3)
11.0	Cryptophyceae (66.2)	Cryptophyceae (48.9)
	R. minuta (55.0)	*R. minuta* (47.8)
15.9	Cryptophyceae (61.8)	Bacillariophyceae (48.9)
	R. minuta (48.2)	*F. crotonensis* (41.0)
	August	November
2.0	Chlorophyceae (45.7)	Bacillariophyceae (58.8)
	Cosmarium asphearosporum variety *strigosum* (32.5)	*Tabellaria fenestrata* (27.9)
5.0	Chlorophyceae (49.1)	Bacillariophyceae (52.4)
	C. asphear. var. *strig.* (31.5)	*T. fenestrata* (29.4)
9.5	Chlorophyceae (48.5)	Bacillariophyceae (55.7)
	C. asphear. var. *strig.* (31.8)	*T. fenestrata* (34.7)
11.0	Chlorophyceae (46.1)	Bacillariophyceae (60.3)
	C. asphear. var. *strig.* (34.9)	*T. fenestrata* (46.6)
15.9	Chlorophyceae (43.1)	Bacillariophyceae (42.1)
	C. asphear. var. *strig.* (25.1)	*T. fenestrata* (27.5)

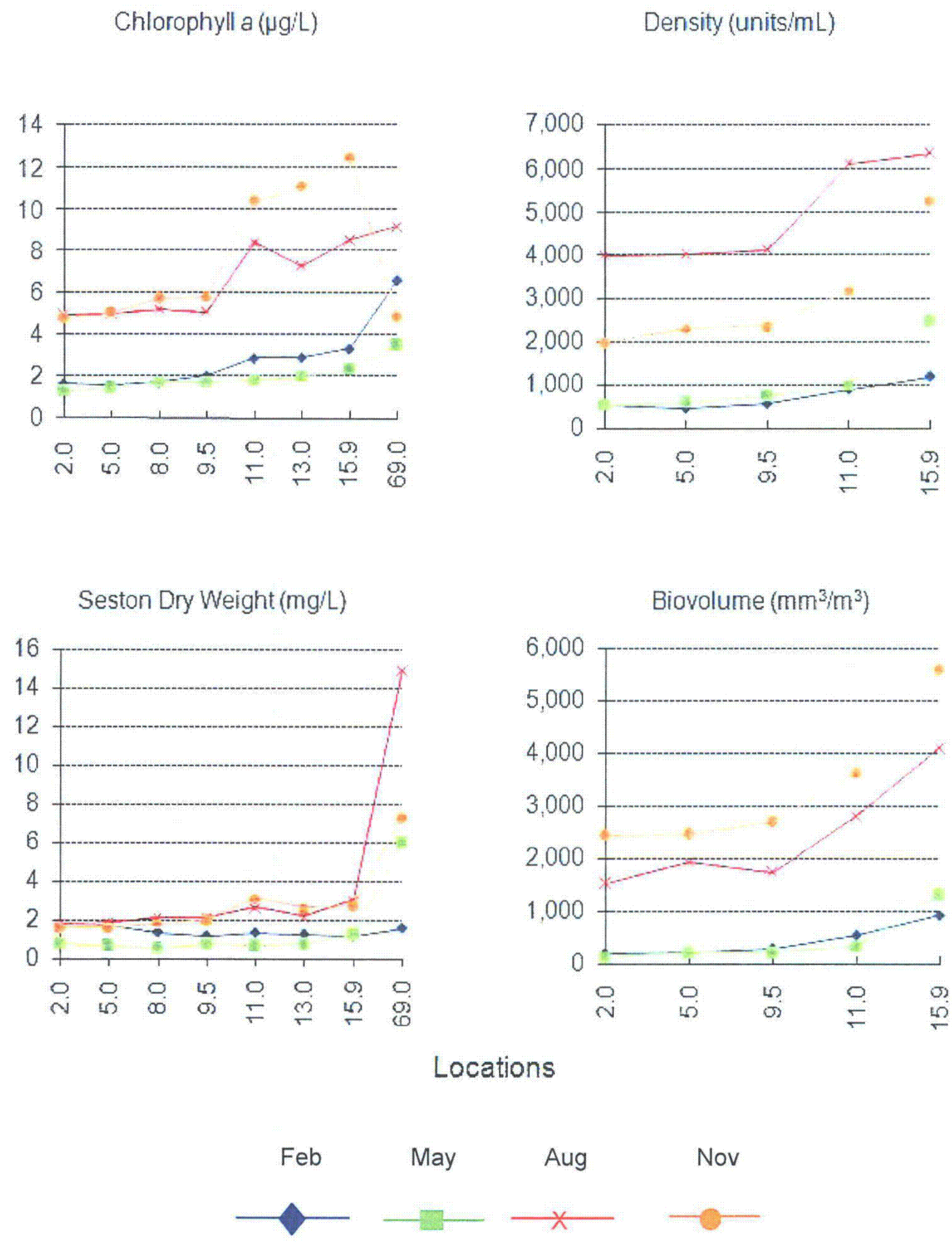


Figure 3-1. Phytoplankton chlorophyll *a*, densities, biovolumes, and seston weights at locations in Lake Norman, NC in February, May, August, and November 2008.

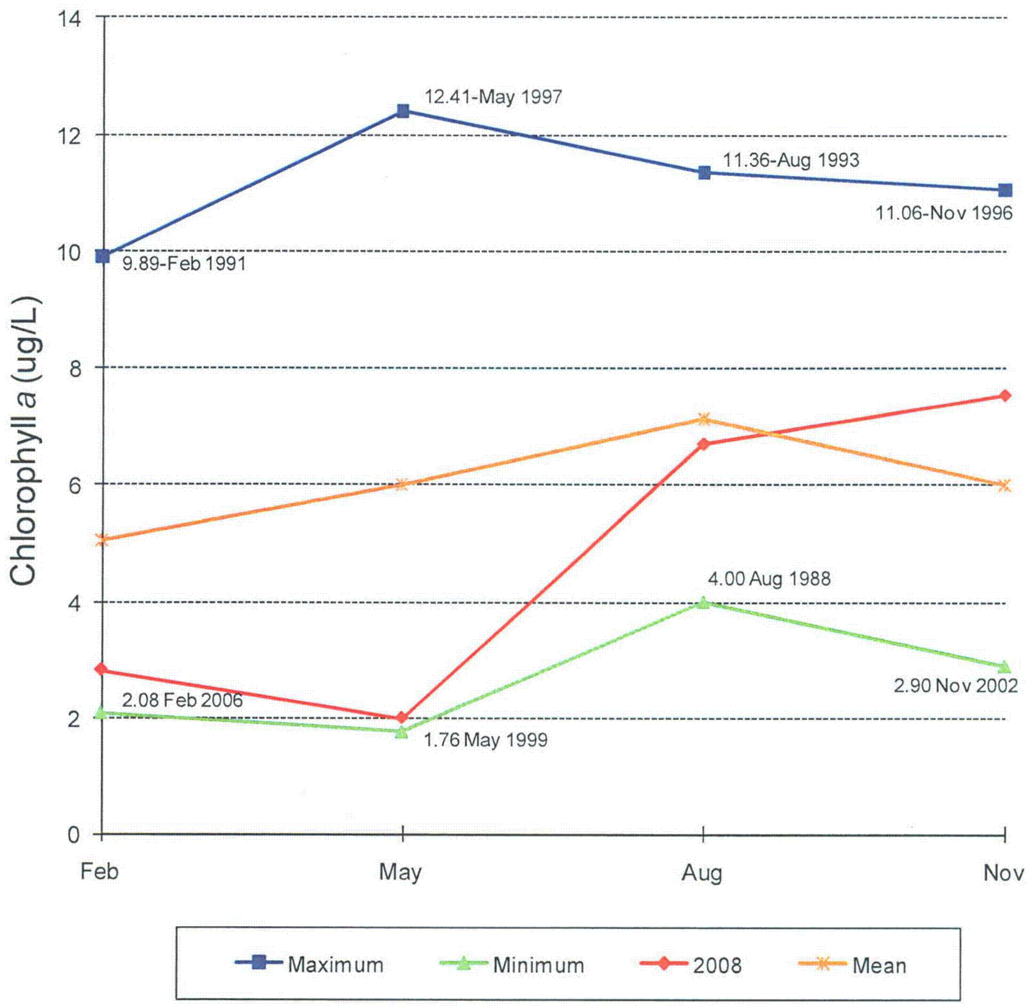


Figure 3-2. Lake Norman phytoplankton chlorophyll *a* seasonal maximum and minimum lake wide means since August 1987 compared with the long term seasonal lake wide means and lake wide means for 2008.

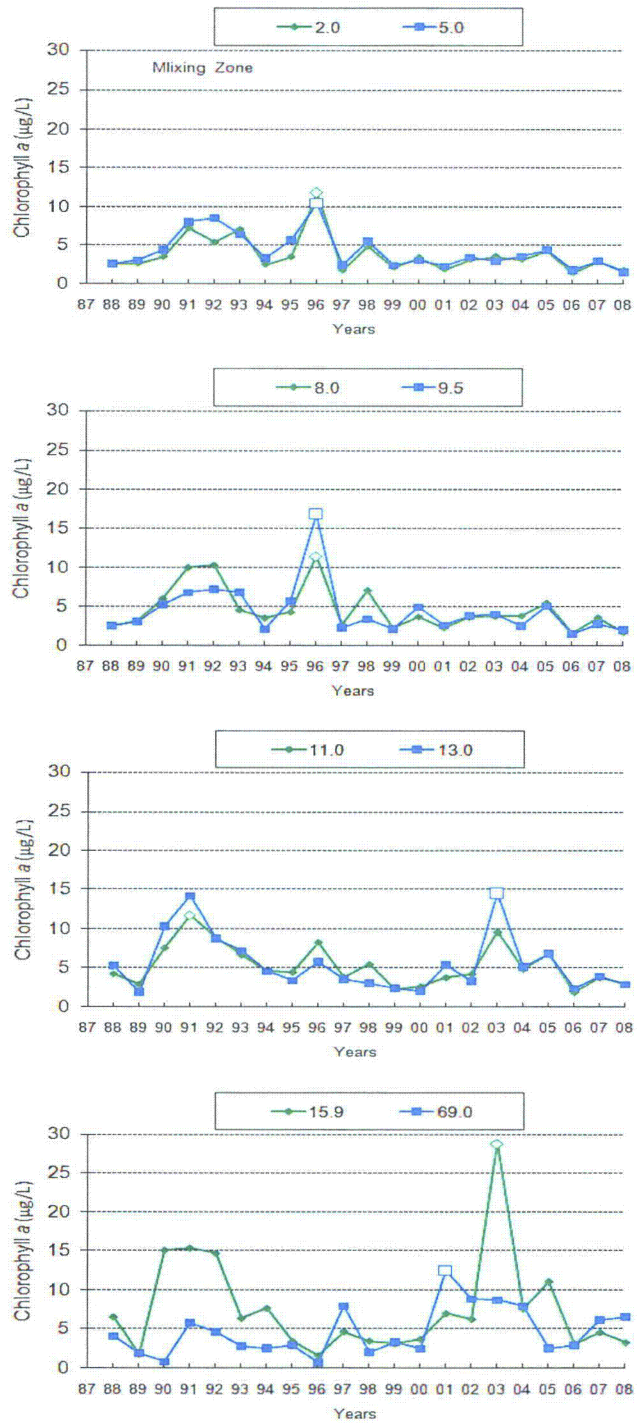


Figure 3-3. Phytoplankton mean chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from February 1988 – 2008 (clear data points represent long-term maxima.

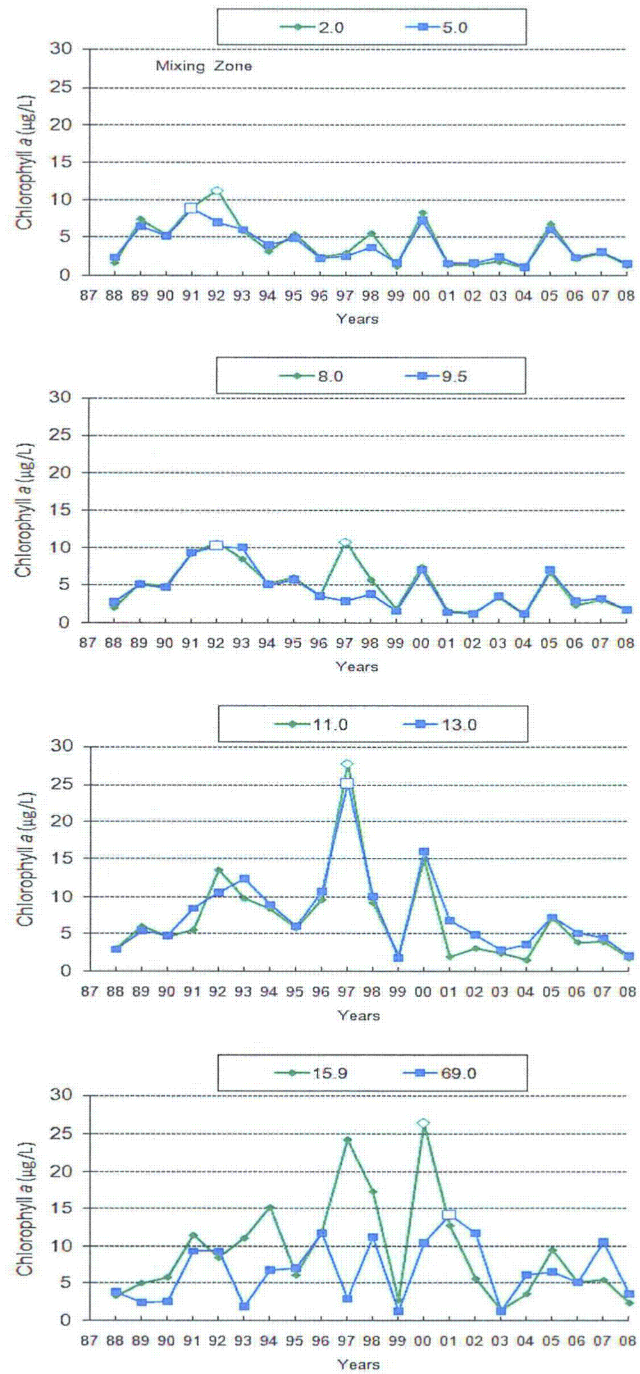


Figure 3-4. Phytoplankton mean chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from May 1988 – 2008 (clear data points represent long-term maxima).

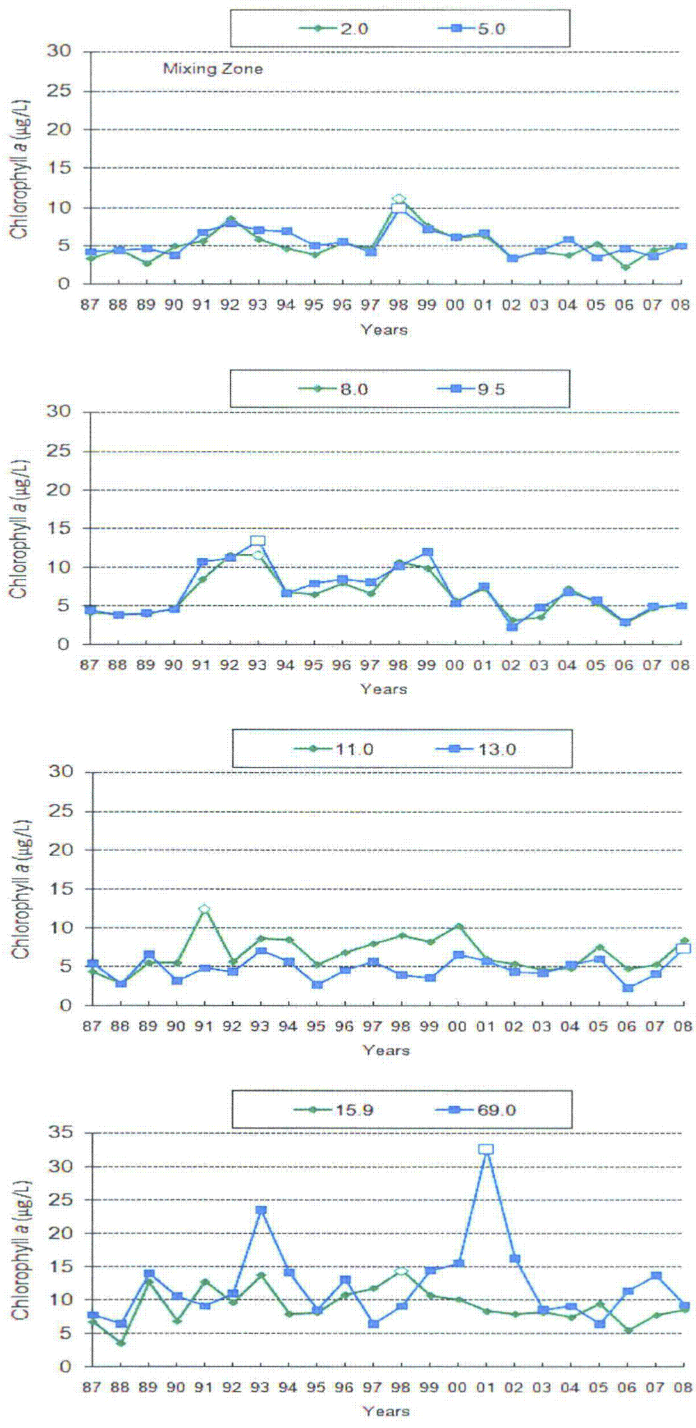


Figure 3-5. Phytoplankton mean chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, during August 1987 – 2008 (Note: axis for 15.9 and 69.0, and that clear data points represent long-term maxima).

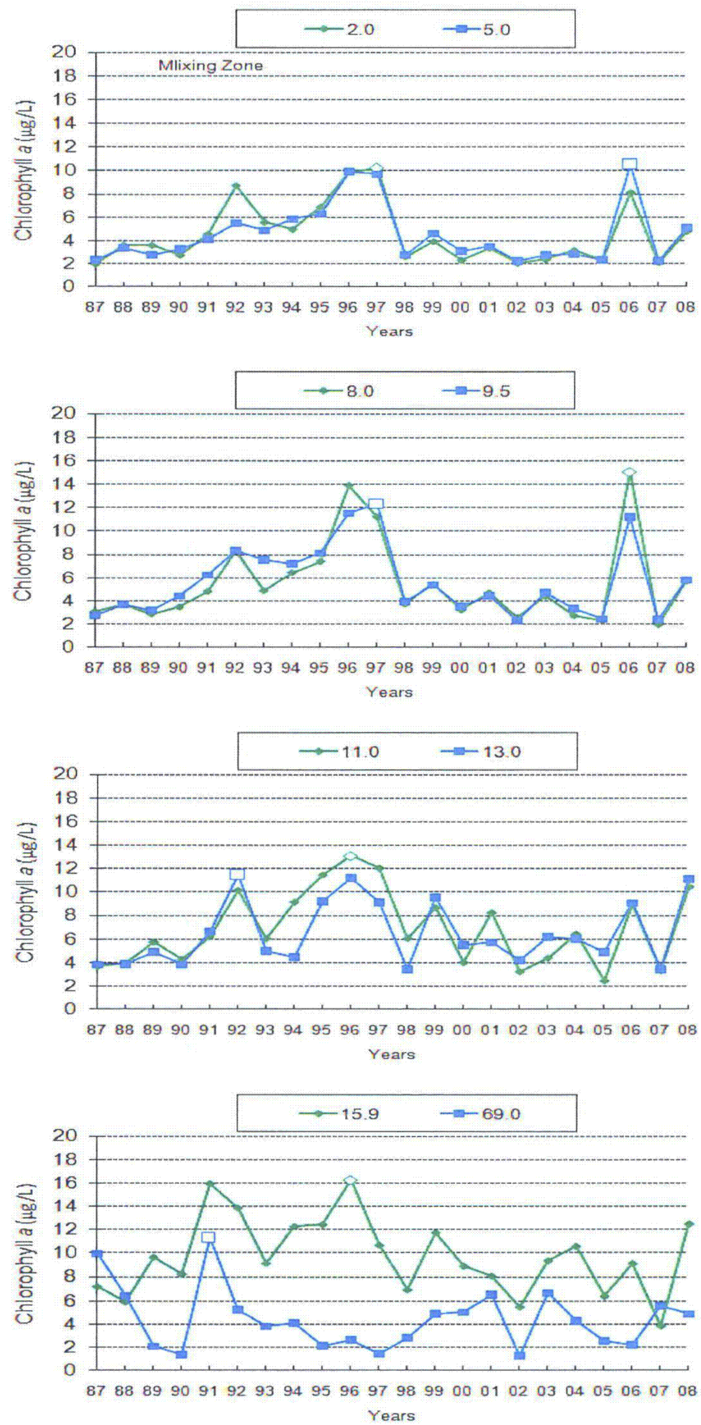


Figure 3-6. Phytoplankton mean chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, during November 1987 – 2008 (Note: change in axis, and that clear data points represent long-term maxima).

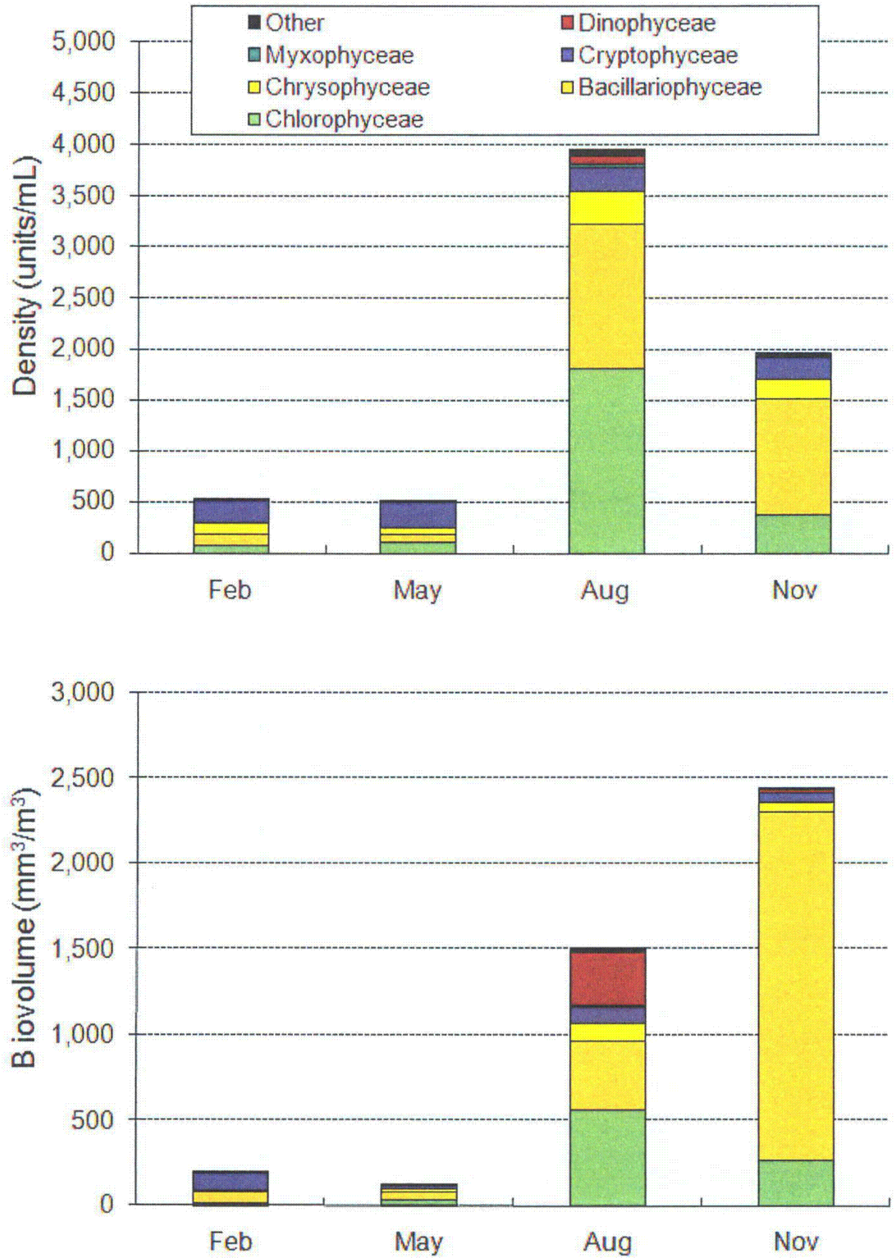


Figure 3-7. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 2.0 in Lake Norman, NC during 2008.

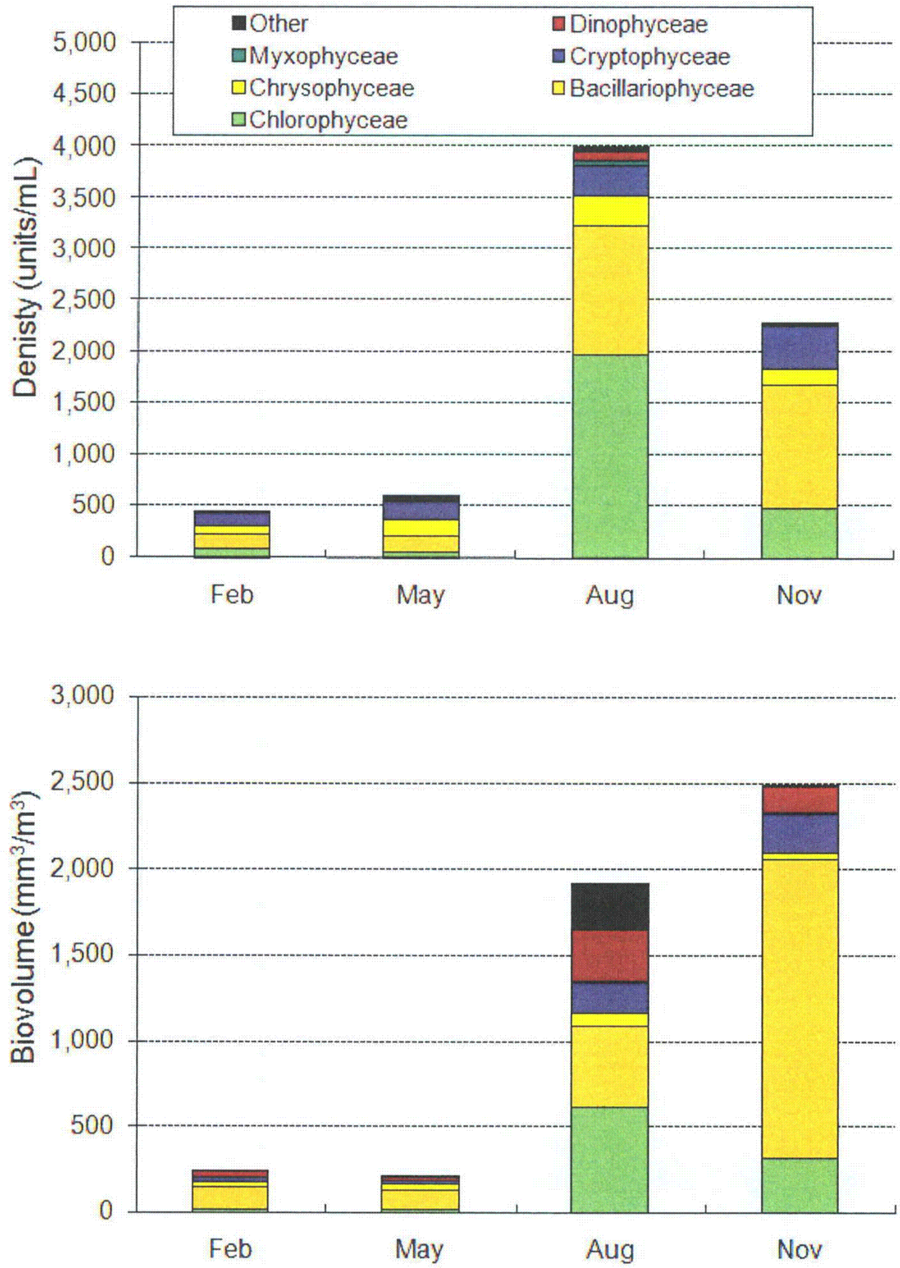


Figure 3-8. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 5.0 in Lake Norman, NC during 2008.

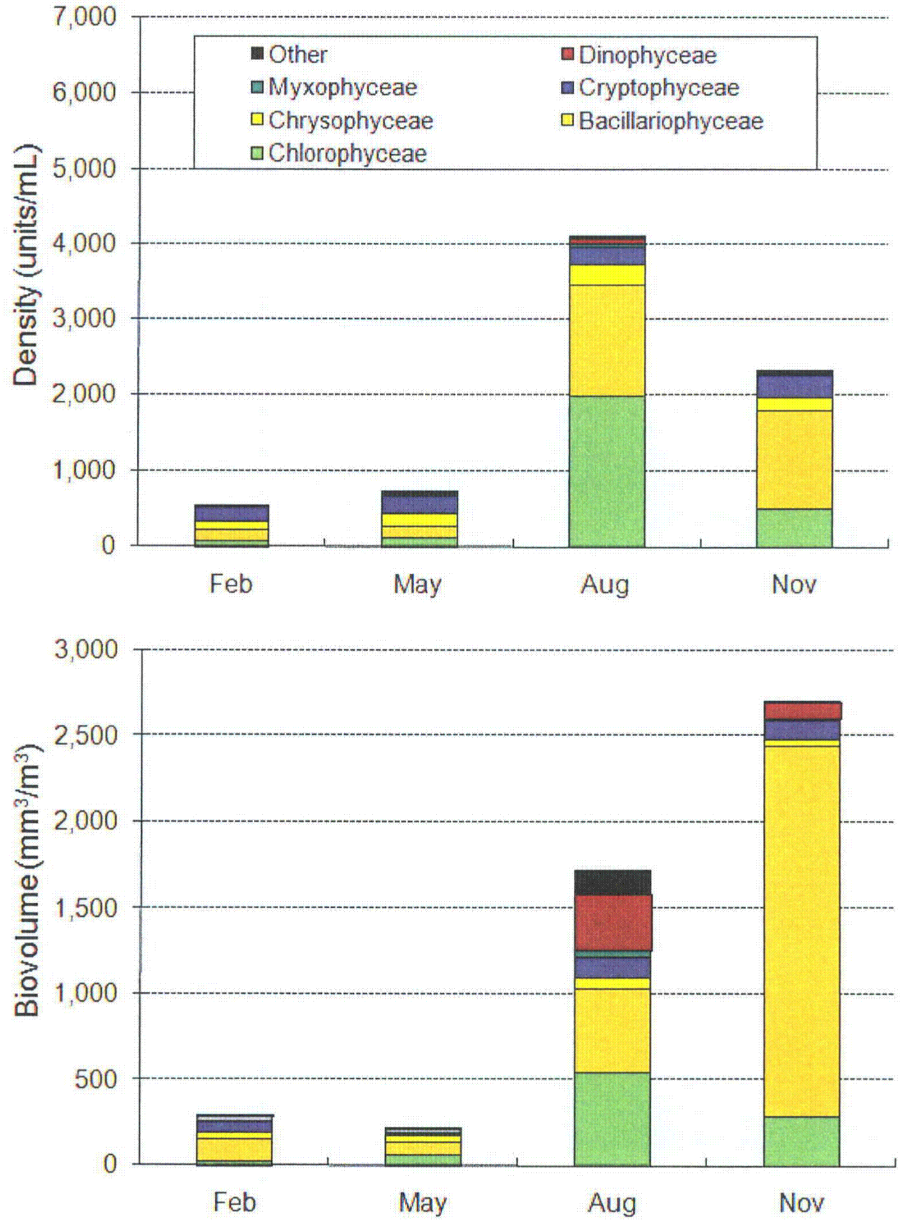


Figure 3-9. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC during 2008.

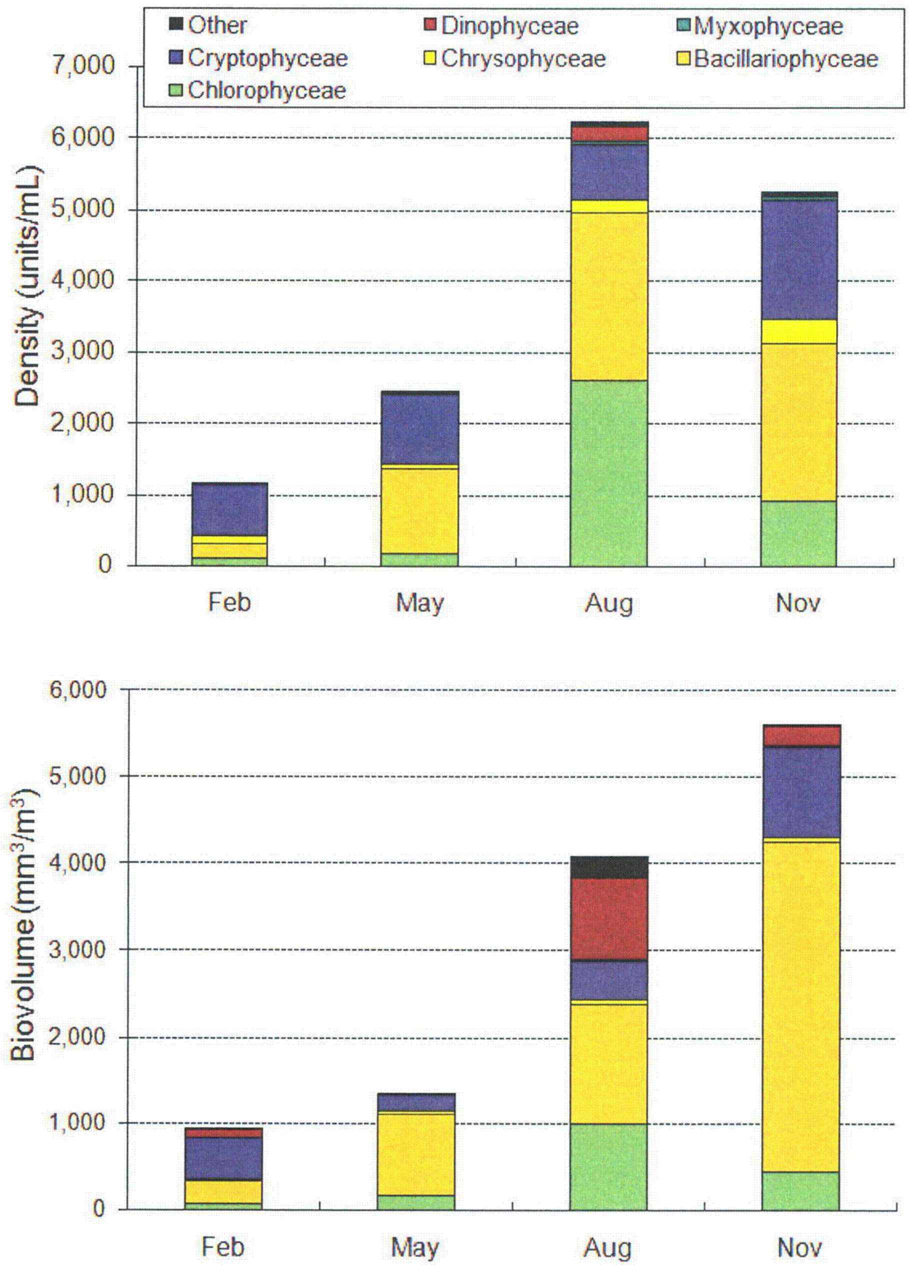


Figure 3-10. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC during 2008.

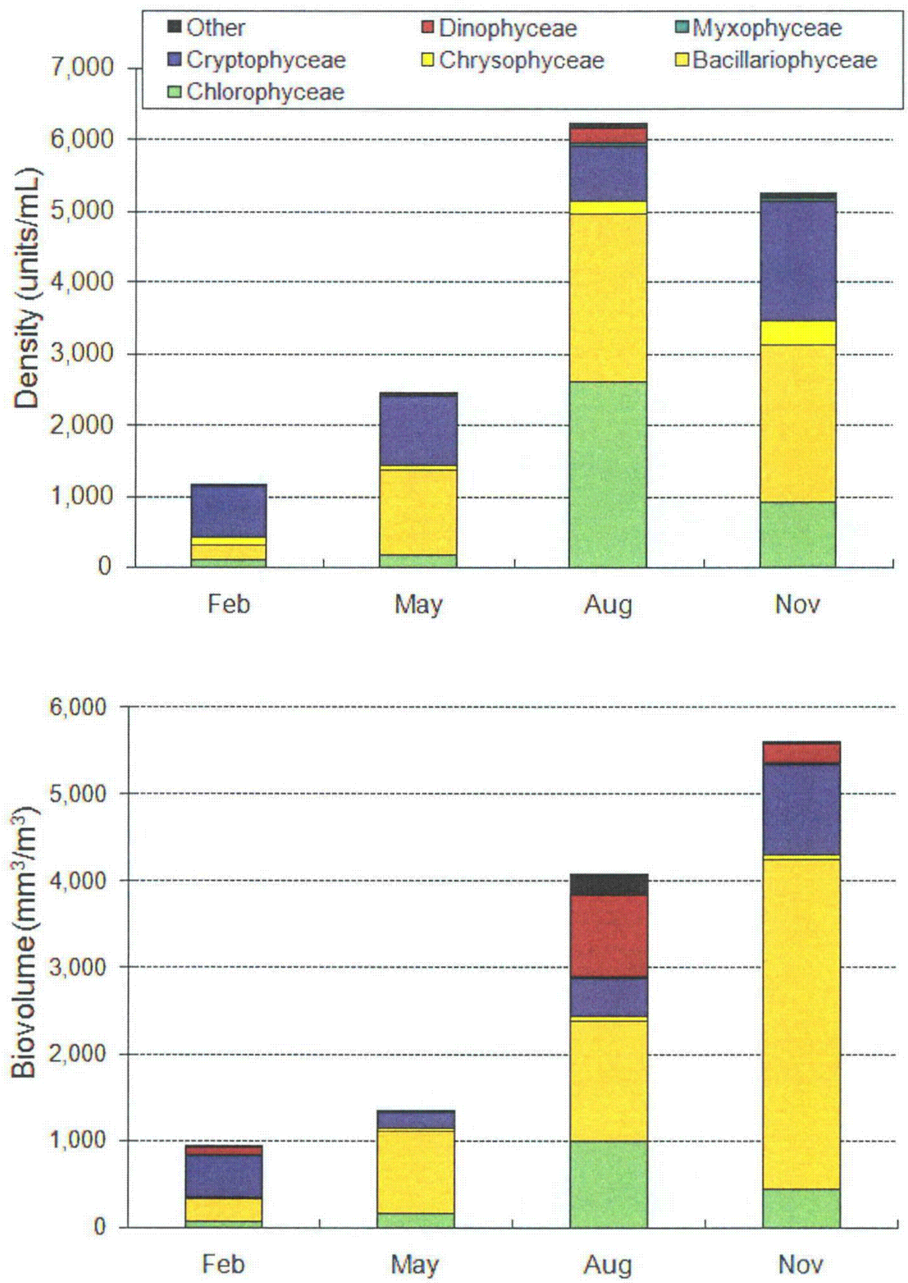


Figure 3-11. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC during 2008.

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 2008 with historical data collected during the period 1987 – 2007.

Studies conducted prior to the Lake Norman Maintenance Monitoring program, using monthly zooplankton data from Lake Norman, showed that zooplankton populations 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) 2008. 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). It was not possible to get good whole-column samples from Location 15.9 in November 2008 due to excessive clogging of the net by lower strata phytoplankton. Zooplankton standing crop data from 2008 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. Peaks were observed only occasionally in the summer and fall (Duke Energy 2008). During 2008, there was a considerable amount of variability in annual maxima among Lake Norman locations. The annual epilimnetic maximum was recorded from Location 2.0 in the spring, while Location 5.0 demonstrated its peak annual density in the summer (Table 4-1; Figures 4-1 and 4-2). Annual maxima at Locations 9.5 and 15.9 occurred in the fall, while the annual maximum at Location 11.0 was recorded in the winter. The lowest epilimnetic densities occurred at Locations 2.0 and 5.0 in the fall and winter, respectively, while Locations 9.5, 11.0, and 15.9 showed annual minima in the summer. Epilimnetic zooplankton densities ranged from a low of 19,472/m^3 at Location 5.0 in February, to a high of 295,669/m^3 at Location 15.9 in November.

Maximum densities in 2008 whole-column samples were observed at Locations 2.0, 5.0, and 9.5 in the summer, while the seasonal whole-column maximum from Location 11.0 occurred in the fall. Of the three seasons when samples were collected from Location 15.9, the maximum whole-column density was observed in the spring, however, considering that the epilimnetic maximum at this location occurred in fall, and that excessive clogging from lower strata phytoplankton prevented whole-column samples from being collected, we could assume that the whole-column maximum from Location 15.9 may have occurred at this time as well (Table 4-1 and Figure 4-1). Minimum whole-column densities were observed in the winter at Locations 2.0 and 9.5, in the spring at Location 11.0, in the summer at Location 15.9, and in the fall at Location 5.0. Whole-column densities ranged from a low of 11,790/m^3 at Location 2.0 in February, to 132,934/m^3 at Location 15.9 in May.

Consistent with historical data, during 2008 total zooplankton densities were most often higher in epilimnetic samples than in whole-column samples (Duke Energy 2008). 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 2008 (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 but winter 2008 when the spatial maximum occurred at Location 11.0 (Table 4-1). This spatial trend was similar to that of the phytoplankton (see 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 2008).

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 2008 (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 is 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 (see Chapter 3).

Epilimnetic zooplankton densities during 2008 were most often within historical ranges (Figures 4-3 through 4-6). The exceptions were at Location 2.0 in the winter and spring, and Location 5.0 in the spring. On both occasions, these locations demonstrated long-term seasonal minimum 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 fall maximum at Location 15.9 was recorded in 1999 (Figure 4-6).

Year-to-year fluctuations of densities in the mixing zone during the winter have occasionally been quite striking, particularly between 1991 and 1997. From 1998 – 2003, year-to-year fluctuations in the mixing zone were less apparent. Since 2004, higher annual fluctuations were apparent. 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, long-term 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 the spring of 2007, mixing zone locations demonstrated increases followed by sharp declines at both locations in 2008. From 1989 – 2008, year-to-year fluctuations in the mixing zone during the summer were comparatively low, with the exception of a sharp increase in density at Location 5.0 in 2007. During fall periods of 1989 – 2008, mixing zone densities showed minimal fluctuations in the low range with the exception of 2006 when values at both locations increased sharply. The background locations continue to exhibit considerable year-to-year variability in all seasons and all but Location 15.9 in the fall demonstrated lower densities in 2008 than in 2007 (Figures 4-3 through 4-6).

Community Composition

One hundred twenty-three zooplankton taxa have been identified since the Lake Norman Maintenance Monitoring Program began in August 1987 (Table 4-2). Forty-eight taxa were identified during 2008, as compared to 49 recorded for 2007 (Duke Energy 2008). One previously unreported taxon, the rotifer, *Lecane luna* was identified in 2008.

During 2007, rotifers were dominant in all but five samples (Duke Energy 2008). During 2008, dominance shifted toward the copepods, as was the case in 2006, and these zooplankters were dominant in two-thirds of the samples (Table 4-1 and Duke Energy 2007). Copepods were dominant in both epilimnetic and whole-column samples at Locations 2.0

and 9.5 in the winter of 2008, and were dominant in the epilimnetic sample from Location 5.0. During the spring and summer of 2008, copepods dominated zooplankton assemblages at all but Location 15.9. In the fall of 2008, copepods dominated epilimnetic samples at Locations 2.0 and 5.0, and the whole-column sample at Location 9.5. Rotifers were the dominant forms in all other samples collected in 2008. Cladocerans, typically the least abundant forms, were never dominant during 2008 (Table 4-1). 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 2007, microcrustaceans showed substantial increases in relative abundances in both the epilimnetic and whole-column samples of the mixing zone. In fact, the percent composition of microcrustations at these locations were the highest yet recorded for 1988 – 2008 (Figures 4-7). This substantial increase in the relative abundances of microcrustaceans in the mixing zone cannot be readily explained. At background locations microcrustacean relative abundances showed more moderate increases in epilimnetic and whole-column samples since 2007 and percent compositions were within historical ranges (Figure 4-8).

Copepoda

As has always been the case, copepod populations were consistently dominated by immature forms (primarily nauplii) during 2008. Adult copepods seldom comprised more than 7% of the total zooplankton density at any location. *Tropocyclops* was the most important genus in most adult populations during all seasons but the spring when *Epishura* was the dominant adult form at most locations (Table 4-3). *Cyclops* and *Mesocyclops* were occasionally abundant. Similar patterns of copepod taxonomic distributions were observed in previous years (Duke Energy 2008).

Cladocera

Bosmina was the most abundant cladoceran observed in 2008 samples, as has been the case in most previous studies (Duke Energy 2008 and Hamme 1982). *Bosmina* often comprised greater than 5% of the total zooplankton densities in both epilimnetic and whole-column samples, and was the dominant zooplankton taxon in six winter and two fall samples (Table 4-3). *Bosminopsis* was also important among cladocerans in the summer when it dominated cladoceran populations in all but three samples. *Diaphanosoma* was the dominant cladoceran in six samples during the spring. Similar patterns of cladoceran dominance have been observed in past years (Duke Energy 2008).

Long-term seasonal trends of cladoceran densities were variable. During 2008, maximum densities in the mixing zone occurred in the winter, while peaks at background locations were observed in the spring (Figure 4-10). From 1990 to 1993, peak densities occurred in the winter, while in 1994, 1995, 1997, 2000, 2004, 2005, and 2007 maxima were recorded in the spring (Figure 4-10). During 1996 and 2002, peak cladoceran densities occurred in the spring in the mixing zone, and in the summer among background locations, while in 1999 they peaked in the mixing zone during the summer and among background locations in the fall. Maximum cladoceran densities in 1998 occurred in the summer. In 2001, maximum cladoceran densities in the mixing zone occurred in the fall, while background locations showed peaks in the winter. During 2003, maximum densities in the mixing zone occurred in the fall, while peaks among background locations were observed in the summer. Spatially, cladocerans were well distributed among most locations (Table 4-1, Figure 4-2).

Rotifera

Polyarthra was the most abundant rotifer in 35% of epilimnetic samples and 15.8% of whole-column samples spread through all seasons of 2008 (Table 4-3). *Conochilus* was the most abundant rotifer in 20% of epilimnetic samples and 36.8% of whole-column samples spread evenly through the spring, summer, and fall. *Keratella* was the most abundant rotifer in 20% of epilimnetic samples and 26.3% of whole-column samples collected during all but the summer. *Asplanchna* dominated rotifer densities in two epilimnetic and three whole-column samples during the winter, while *Ptygura* was most often dominant among summer populations. All of these taxa have been identified as important constituents of rotifer populations, as well as zooplankton communities, in previous studies (Duke Energy 2008 and 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 2008, peak rotifer densities were observed at both mixing zone and background locations in the fall.

FUTURE STUDIES

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

SUMMARY

During 2008, seasonal maximum densities among zooplankton assemblages varied considerably and no consistent seasonal trends were observed. Minima most often occurred in the summer. 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 2008. 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. In most cases, densities in 2008 were lower than 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 low densities at Location 2.0 in the winter and spring and Location 5.0 in May.

One hundred and twenty-three zooplankton taxa have been recorded from Lake Norman since the Program began in 1987 (48 were identified during 2008). One previously unreported taxa was identified during 2008.

Overall, relative abundance of copepods in 2008 increased over 2007, and they were dominant in two-thirds of the samples. Rotifers were dominant in all remaining samples. The relative abundance of microcrustaceans increased substantially in the mixing zone during 2007 and their percent compositions at these locations were the highest yet recorded. At background locations, microcrustaceans showed less dramatic increases since 2007 and percent compositions were within historical ranges of past years. 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, while *Diaphanosoma* was an important constituent of spring populations. The most abundant rotifers observed in 2008, as in many previous years, were *Conochilus, Polyarthra,* and *Keratella. Asplanchna,* and *Ptygura* 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. The much lower than normal rotifer relative abundances at mixing zone locations in 2008 could not be explained.

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 winter (February), spring (May), summer (August), and fall (November) 2008.

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
2/25/2008	Epilimnion	Copepoda	14.91	10.90	22.78	40.89	23.22
			(63.0)	(56.0)	(51.3)	(31.0)	(21.8)
		Cladocera	6.13	7.54	15.90	26.85	8.38
			(25.9)	(38.7)	(35.8)	(20.4)	(7.8)
		Rotifera	2.63	1.03	5.71	64.03	75.13
			(11.1)	(5.3)	(12.9)	(48.6)	(70.4)
		Total	23.67	19.47	44.39	131.77	106.73
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	29 m	20 m	20 m	17 m	21 m
		Copepoda	6.54	9.87	20.67	30.61	18.50
			(55.4)	(38.8)	(52.5)	(36.0)	(21.9)
		Cladocera	3.88	4.54	13.28	17.37	19.10
			(32.9)	(17.9)	(33.8)	(20.4)	(22.6)
		Rotifera	1.31	11.02	5.40	37.09	47.03
			(11.1)	(43.3)	(13.7)	(43.6)	(55.6)
		Total	11.79[e]	25.43	39.35	85.07	84.63

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
5/9/2008	Epilimnion	Copepoda	28.75	20.61	40.15	45.99	61.77
			(77.7)	(73.7)	(74.2)	(73.1)	(36.5)
		Cladocera	4.69	3.25	9.72	10.97	43.95
			(12.7)	(11.6)	(18.0)	(17.4)	(25.9)
		Rotifera	3.56	4.12	4.24	5.99	63.74
			(9.6)	(14.7)	(7.8)	(9.5)	(37.6)
		Total	36.98	27.98	54.11	62.95	169.46
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	30 m	20 m	21 m	25 m	21 m
		Copepoda	17.47	18.18	31.83	38.94	46.10
			(77.7)	(68.8)	(72.6)	(75.6)	(34.7)
		Cladocera	3.49	5.48	10.08	9.36	28.63
			(15.5)	(20.8)	(23.0)	(18.2)	(21.5)
		Rotifera	1.54	2.75	1.94	3.22	58.20
			(6.8)	(10.4)	(4.4)	(6.2)	(43.8)
		Total	22.50	26.41	43.85	51.52	132.93

[e] Ostracoda (57/m^3, 0.51%)

Table 4-1. (Continued).

			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
8/4/2008	Epilimnion	Copepoda	28.55	38.84	15.94	30.60	11.02
			(77.8)	(77.4)	(41.3)	(67.9)	(13.8)
		Cladocera	6.08	5.96	12.03	10.22	16.16
			(16.5)	(13.2)	(31.1)	(22.7)	(20.3)
		Rotifera	2.08	4.24	10.56	4.27	52.55
			(5.7)	(9.4)	(27.3)	(9.5)	(65.9)
		Total	36.71	45.04	38.63[f]	45.09	79.73
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	30 m	19 m	20 m	23 m	21 m
		Copepoda	30.00	34.11	22.69	44.62	11.34
			(86.9)	(79.5)	(58.2)	(83.8)	(25.0)
		Cladocera	4.23	6.20	10.78	4.19	11.59
			(12.3)	(14.4)	(27.7)	(7.9)	(25.6)
		Rotifera	0.22	2.50	5.39	4.32	22.31
			(0.6)	(5.8)	(13.8)	(8.1)	(49.2)
		Total	34.52[g]	42.91[h]	103.1[i]	53.23[j]	45.32[k]
			Locations				
Sample Date	**Sample Type**	**Taxa**	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
11/12/2008	Epilimnion	Copepoda	8.29	11.22	25.12	36.36	53.76
			(40.3)	(42.9)	(43.5)	(34.8)	(18.2)
		Cladocera	8.07	5.15	7.06	8.99	7.18
			(39.2)	(19.7)	(12.2)	(8.8)	(2.4)
		Rotifera	4.23	9.78	25.60	57.32	234.73
			(20.5)	(37.4)	(44.3)	(56.4)	(79.4)
		Total	20.59	26.15	57.78	101.67	295.67
	Whole Column		**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
		Depth	31 m	20 m	21 m	26 m	Not
		Copepoda	7.56	11.81	24.81	48.37	Coll.
			(46.9)	(52.7)	(47.1)	(37.7)	
		Cladocera	5.94	5.45	6.49	10.21	
			(36.9)	(24.3)	(12.3)	(8.0)	
		Rotifera	2.61	5.16	21.35	69.66	
			(16.2)	(23.0)	(40.6)	(54.3)	
		Total	16.11	22.42	52.65	128.24	

[f] Ostracoda (103/m^3, 0.26%)
[g] Ostracoda (73/m^3, 0.20%)
[h] Ostracoda (98/m^3, 0.23%)
[i] Ostracoda (103/m^3, 0.26%)
[j] Ostracoda (95/m^3, 0.19%)
[k] *Chaoborus* (82/m^3, 0.18%)

Table 4-2. Zooplankton taxa identified from samples collected quarterly on Lake Norman from 1987 – 2008.

Taxon	87-93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Copepoda																
Cyclops thomasi Forbes	X	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					
Diaptomus birgei Marsh	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			
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	X
Ergasilus spp.				X										X		
Eucyclops agilis (Koch)						X										
E. prionophorus															X	
Mesocyclops edax (S. A. Forbes)	X	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	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						
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	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	X
D. catawba Coker				X	X				X							X
D. galeata Sars				X												
D. laevis Birge				X							X					
D. longiremis Sars				X	X			X	X		X	X				
D. lumholzi Sars	X	X	X	X		X	X	X					X			
D. mendotae (Sars) Birge					X	X	X	X			X				X	
D. parvula Fordyce	X		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			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	X
D. spp. Fischer	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	X
H. gibberum Zaddach	X				X	X										

Table 4-2. (Continued).

Taxon	87-93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
H. spp. Stingelin	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	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	
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													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										
Chromogaster ovalis (Berg.)					X	X	X		X				X	X	X	X
C. spp. Lauterborne	X	X	X	X												
Collotheca balatonica Harring				X	X	X	X	X		X	X	X	X	X	X	X
C. mutabilis (Hudson)				X	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	X
C. spp. Hlava	X	X	X	X	X				X		X					
Conochilus unicornis (Rouss.)	X				X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Hlava	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							
Hexarthra mira Hudson					X	X	X	X		X				X	X	X
H. spp. Schmada	X	X	X	X	X				X							
Kellicottia bostoniensis (Rou.)	X	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	X
K. spp. Rousselet	X	X	X	X	X				X	X	X	X	X			
Keratella americana Carlin															X	
K. cochlearis Raderorgan							X	X				X			X	X

Table 4-2. (Continued).

Taxon	87-93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
K. taurocephala Myers					X		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 luna O. F. Muller																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			
Monommata spp. Bartsch														X		
Monostyla stenroosi (Meiss.)	X															
M. spp. Ehrenberg	X	X	X	X		X					X					
Notholca spp. Gosse		X		X		X										
Platyias patulus Harring										X						
Ploesoma hudsonii Brauer	X	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	X
P. spp. Herrick	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	X
P. vulgaris Carlin	X				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	X
P. spp. Ehrenberg	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	X
T. longiseta Schrank					X									X	X	
T. multicrinis (Kellicott)						X	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								
Insecta																
Chaoborus spp. Lichtenstein	X					X	X		X	X		X	X	X	X	X
Ostracoda (unidentified)						X					X	X				X
													44	44	48	48

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 2008.

Locations	Winter	Spring	Summer	Fall
		Copepoda:	**Epilimnion**	
2.0	*Tropocyclops* (13.7)	*Epishura* (3.0)	*Tropocyclops* (1.1)	*Tropocyclops* (7.5)
5.0	*Tropocyclops* 15.1)	*Cyclops* (3.2)	*Tropocyclops* (1.8)	*Tropocyclops* (0.9)
9.5	*Tropocyclops* (6.6)	*Epishura* (4.0)	*Tropocyclops* (1.3)	*Tropocyclops* (3.1)
11.0	*Cyclops* (2.9)	*Epishura* (5.4)	*Tropocyclops* (4.1)[1]	*Tropocyclops* (2.8)
15.9	*Tropocyclops* (1.0)	*Epishura* (2.5)	*Tropocyclops* (3.2)[1]	*Tropocyclops* (5.3)[1]
		Copepoda:	**Whole Column**	
2.0	*Tropocyclops* (9.0)	*Epishura* (6.0)	*Mesocyclops* (3.2)	*Epishura* (4.8)
5.0	*Tropocyclops* (25.3)	*Epishura* (6.5)	*Tropocyclops* (4.2)	*Tropocyclops* (2.3)
9.5	*Tropocyclops* (5.1)	*Tropocyclops* (4.2)	*Tropocyclops* (3.2)	*Tropocyclops* (6.6)
11.0	*Tropocyclops* (2.4)	*Epishura* (6.7)	*Mesocyclops* (8.6)	*Tropocyclops* (4.2)
15.9	*Cyclops* (8.8)	*Mesocyclops* (2.4)	*Mesocyclops* (7.4)	No sample
		Cladocera:	**Epilimnion**	
2.0	*Bosmina* (95.1)	*Bosmina* (73.8)	*Bosminopsis* (91.2)	*Bosmina* (98.6)
5.0	*Bosmina* (87.2)	*Bosmina* (39.8)	*Bosminopsis* (67.9)	*Bosmina* (100.0)
9.5	*Bosmina* (92.9)	*Daphnia* (48.7)	*Bosminopsis* (71.8)	*Bosmina* (96.4)
11.0	*Bosmina* (84.1)	*Diaphanosoma* (38.8)	*Bosminopsis* (79.0)	*Bosmina* (82.4)
15.9	*Bosmina* (83.2)	*Diaphanosoma* (56.1)	*Bosminopsis* (83.2)	*Bosmina* (85.6)
		Cladocera:	**Whole Column**	
2.0	*Bosmina* (96.0)	*Diaphanosoma* (42.0)	*Bosmina* (55.1)	*Bosmina* (95.9)
5.0	*Bosmina* (87.4)	*Bosmina* (50.0)	*Bosmina* (47.1)	*Bosmina* (98.8)
9.5	*Bosmina* (91.5)	*Diaphanosoma* (48.0)	*Bosminopsis* (51.9)	*Bosmina* (87.6)
11.0	*Bosmina* (82.9)	*Diaphanosoma* (42.7)	*Bosmina* (44.8)	*Bosmina* (56.3)
15.9	*Bosmina* (92.5)	*Diaphanosoma* (67.2)	*Bosminopsis* (73.8)	No sample

[1] Only adults present in samples.

Table 4-3. (Continued).

Locations	Winter	Spring	Summer	Fall
		Rotifera:	**Epilimnion**	
2.0	*Keratella* (63.3)	*Polyarthra* (72.4)	*Ptygura* (79.5)	*Conochilus* (36.8)
5.0	*Keratella* (88.7)	*Polyarthra* (66.9)	*Ptygura* (52.3)	*Conochilus* (55.0)
9.5	*Asplanchna* (77.4)	*Conochilus* (64.0)	*Ptygura* (53.3)	*Keratella* (43.7)
11.0	*Asplanchna* (90.8)	*Polyarthra* (45.4)	*Polyarthra* (61.7)	*Polyarthra* (51.2)
15.9	*Polyarthra* (72.4)	*Keratella* (95.1)	*Conochilus* (40.5)	*Polyarthra* (72.1)
		Rotifera:	**Whole Column**	
2.0	*Keratella* (70.9)	*Polyarthra* (90.9)	*Polyarthra* (66.2)	*Conochilus* (37.1)
5.0	*Keratella* (55.1)	*Conochilus* (21.6)	*Conochilus* (39.5)	*Conochilus* (40.9)
9.5	*Asplanchna* (78.2)	*Conochilus* (51.6)	*Ptygura* (52.0)	*Keratella* (53.8)
11.0	*Asplanchna* (82.0)	*Keratella* (57.1)	*Conochilus* (65.6)	*Polyarthra* (46.0)
15.9	*Asplanchna* (72.1)	*Keratella* (92.9)	*Cocochilus* (35.9)	No sample

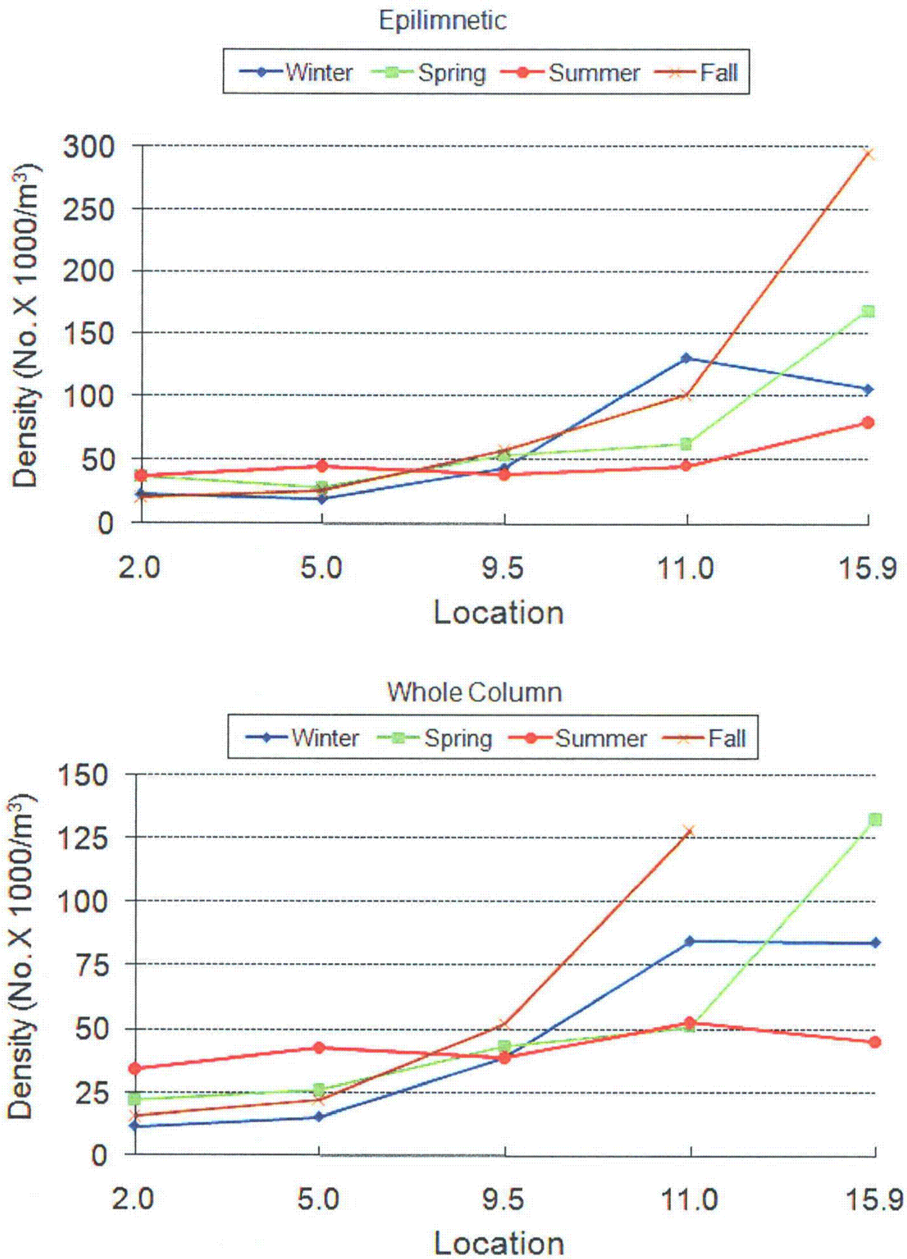


Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman in 2008.

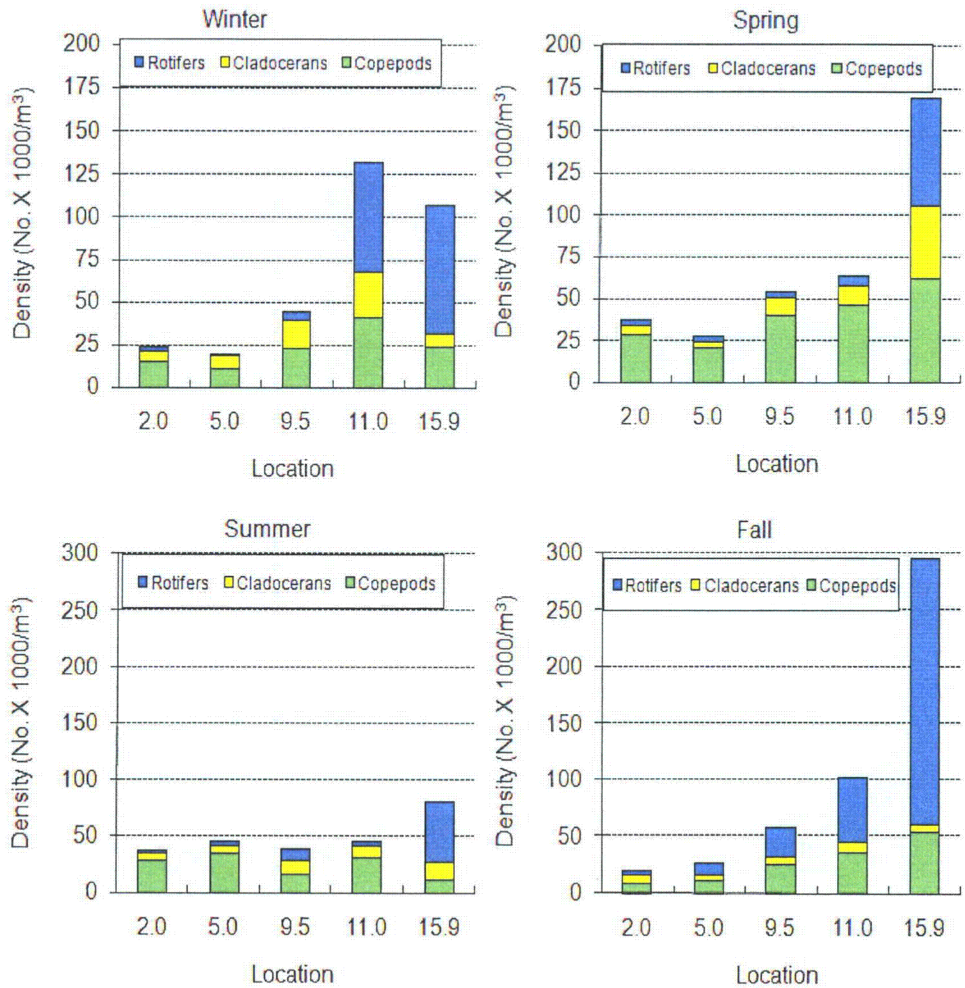
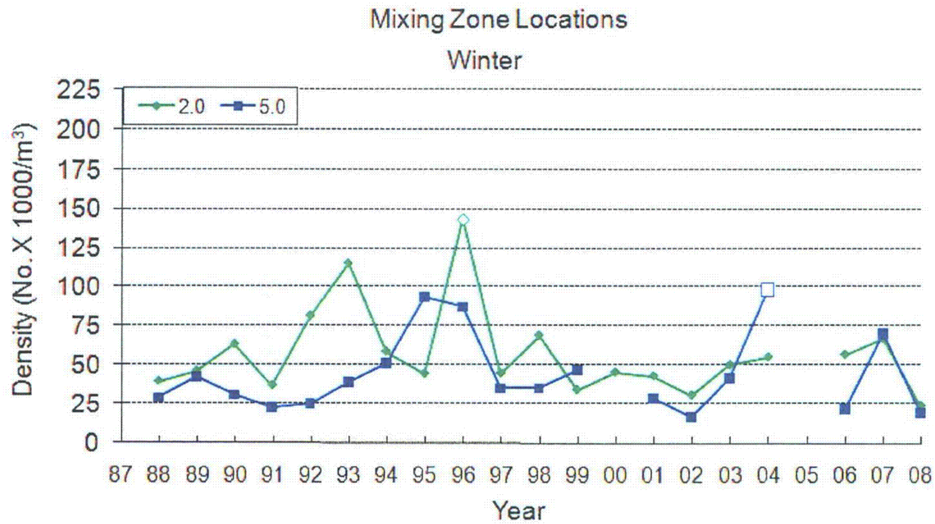


Figure 4-2. Zooplankton community composition by sample period and location for epilimnetic samples collected in Lake Norman in 2008.



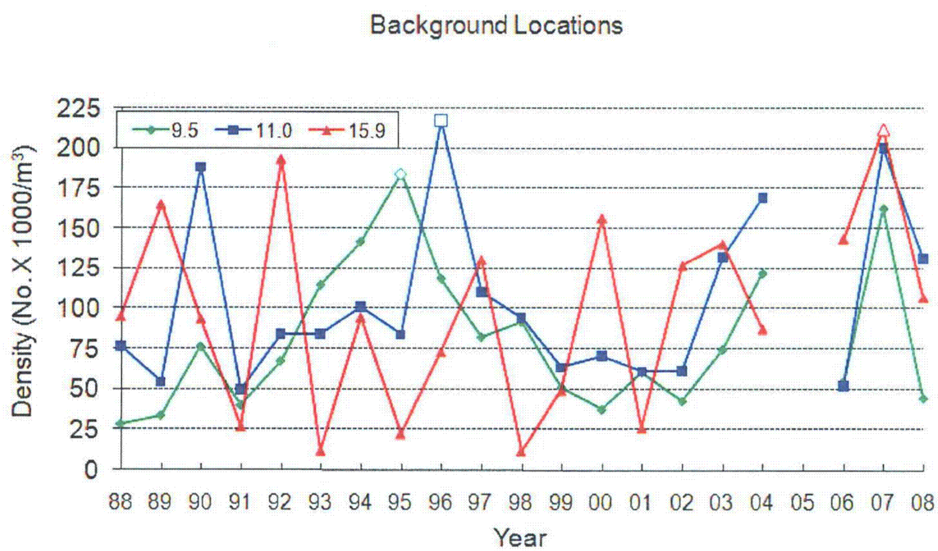
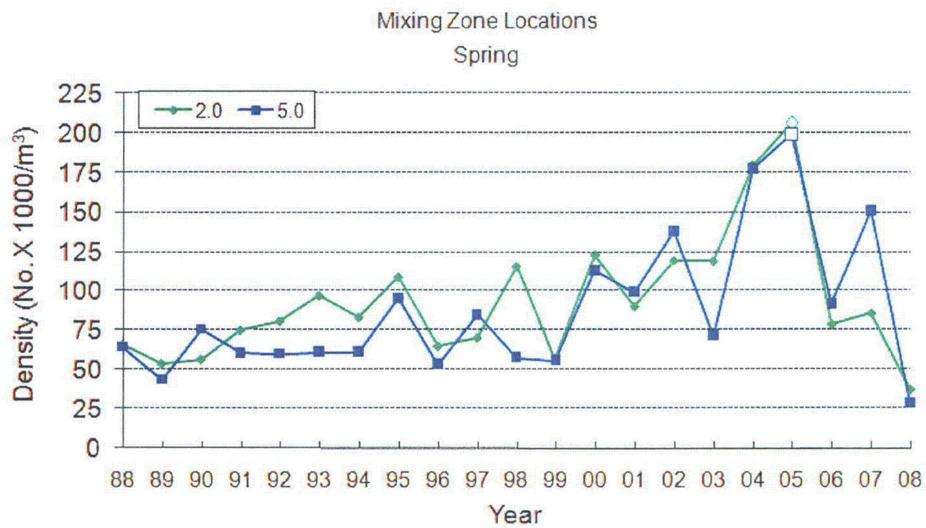


Figure 4-3. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman, NC, in the winter periods of 1988 – 2008(clear data points represent long-term maxima).



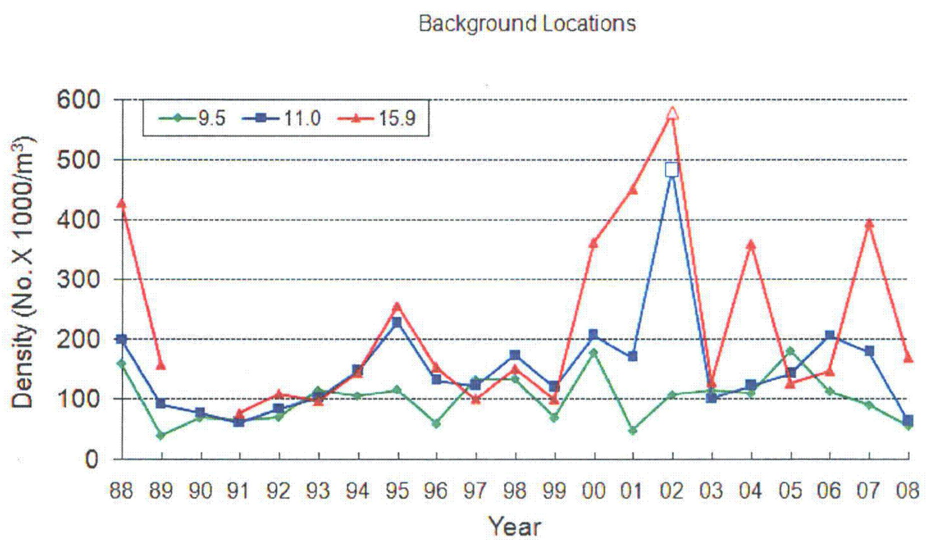
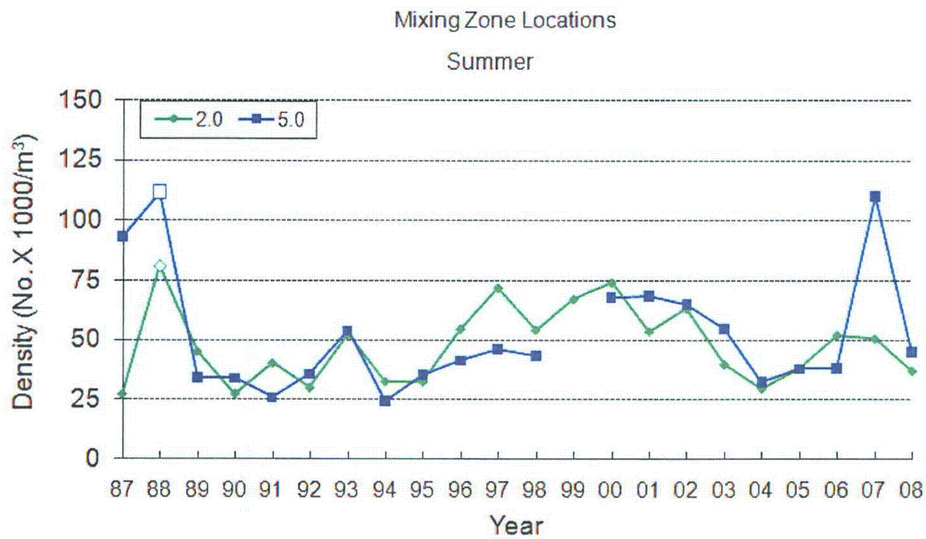


Figure 4-4. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman in the spring periods of 1988 – 2008 (clear data points represent long-term maxima).



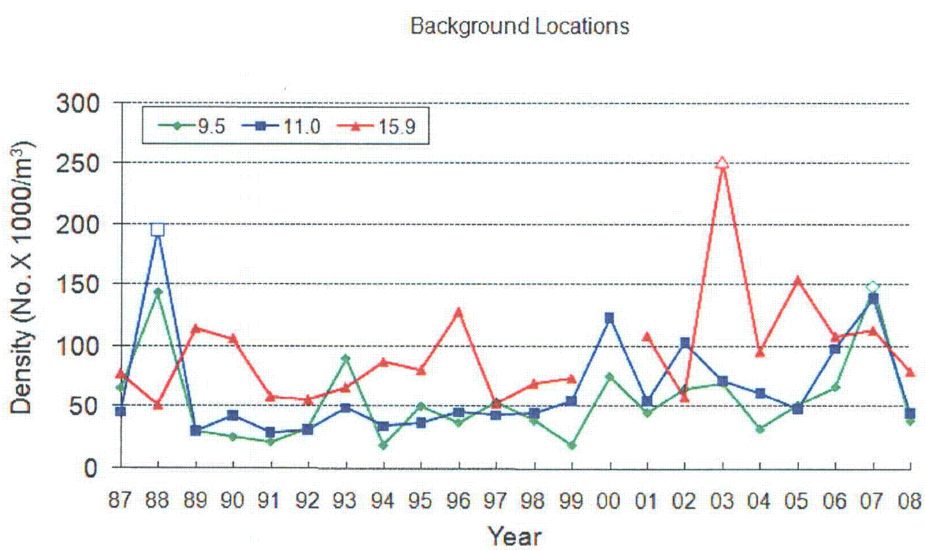


Figure 4-5. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman in the summer periods of 1987 – 2008 (clear data points represent long-term maxima).

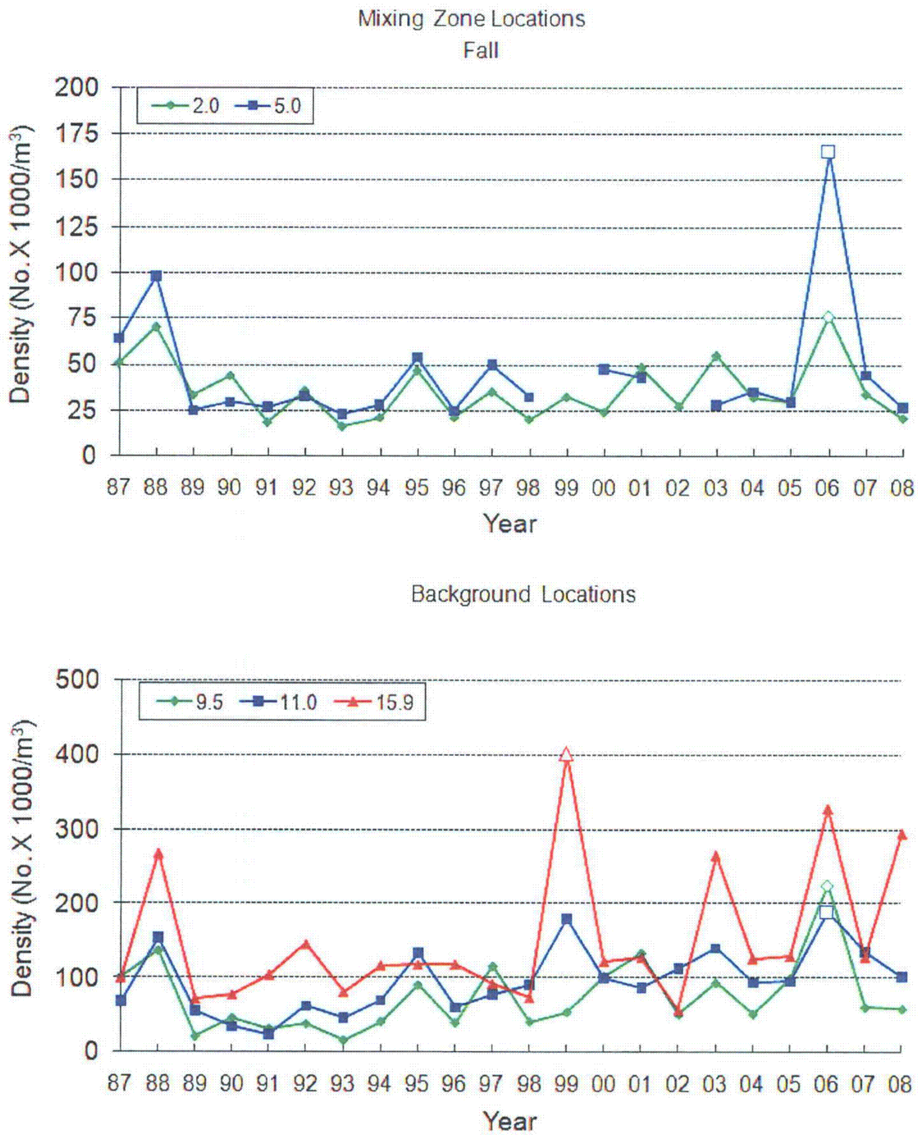


Figure 4-6. Total zooplankton densities by location and year for epilimnetic samples collected in Lake Norman in the fall periods of 1987 – 2008 (clear data points represent seasonal maxima).

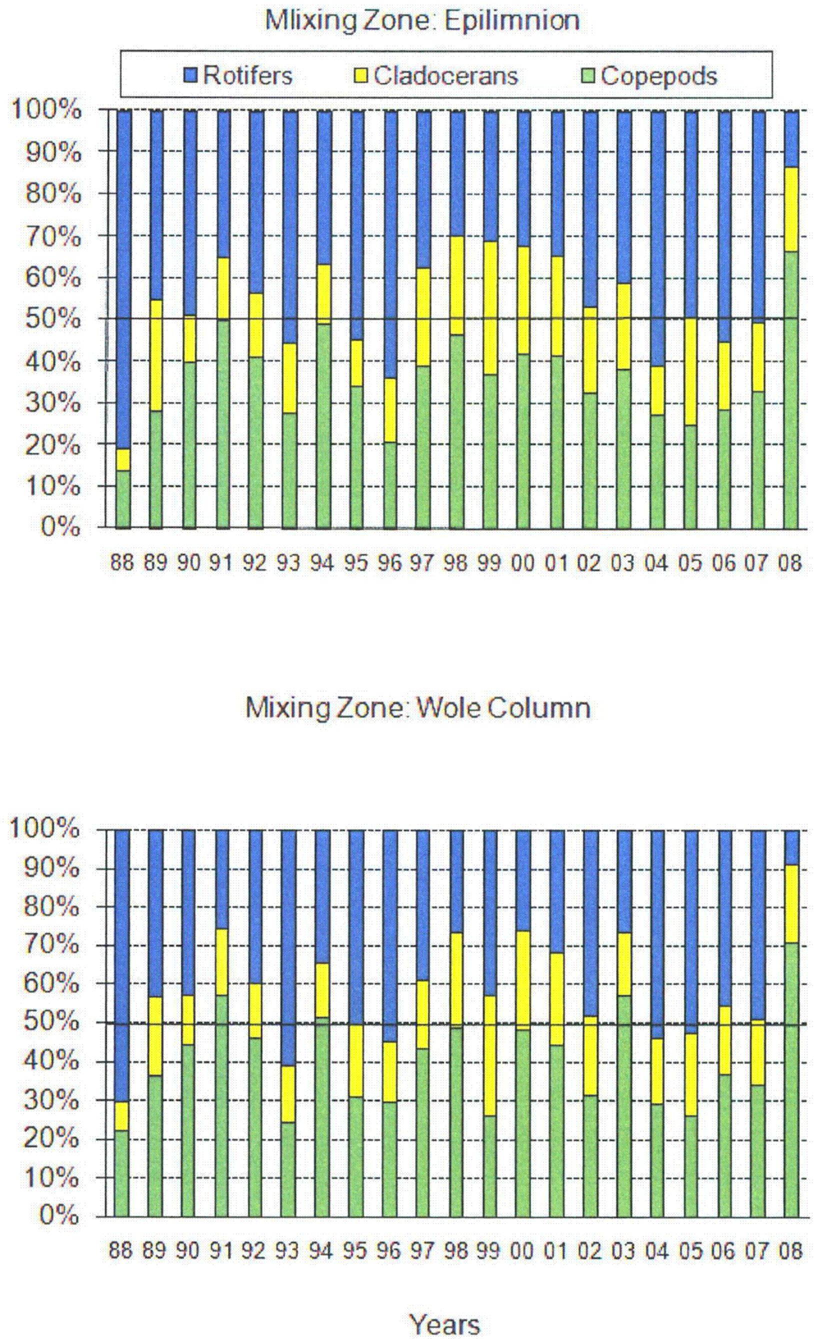


Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from mixing zone locations (Locations 2.0 and 5.0 combined) during 1988 – 2008 (Note: Does not include Location 5.0 in the fall of 2002 or winter samples from 2005).

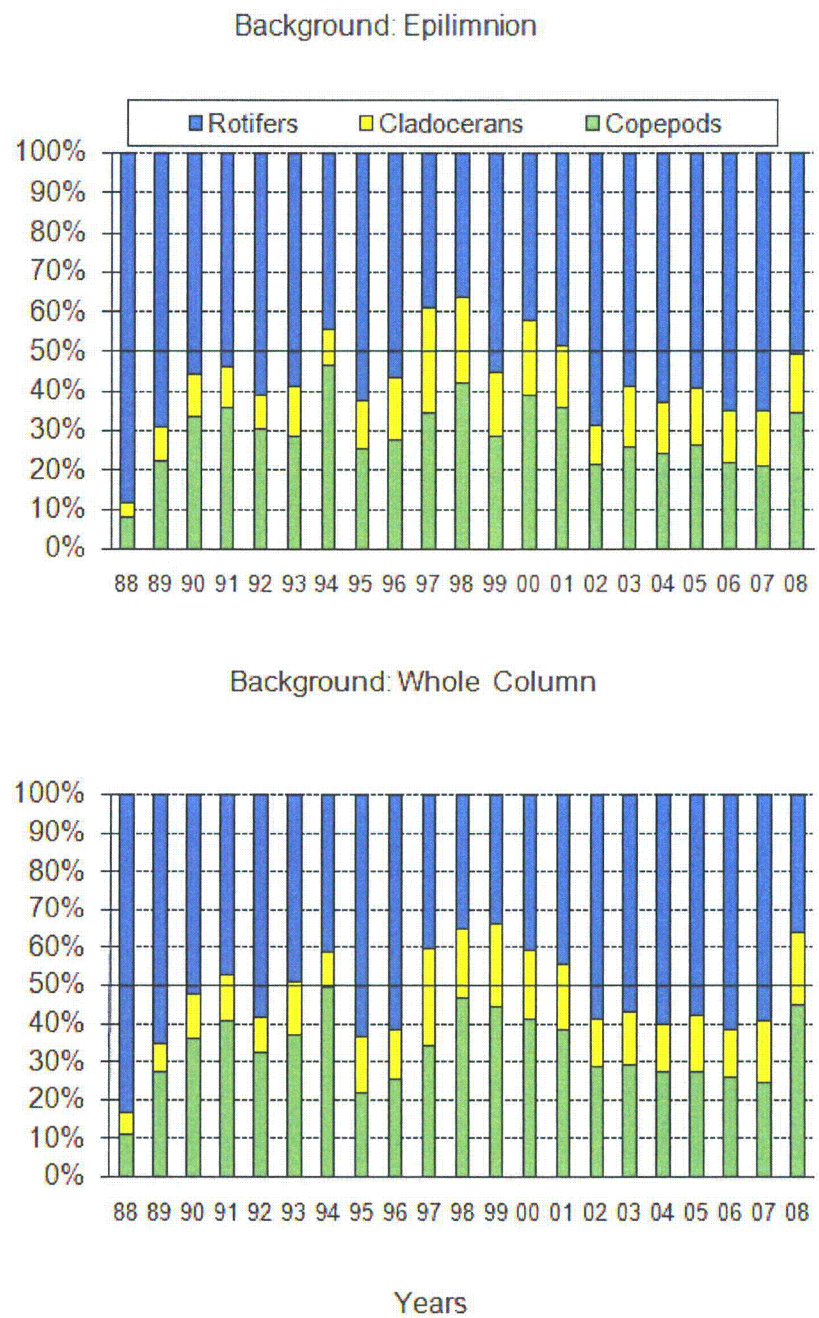


Figure 4-8. Annual percent composition of major zooplankton taxonomic groups from background locations (Locations 9.5, 11.0, and 15.9 combined) during 1988 – 2008 (Note: Does not include winter samples from 2005).

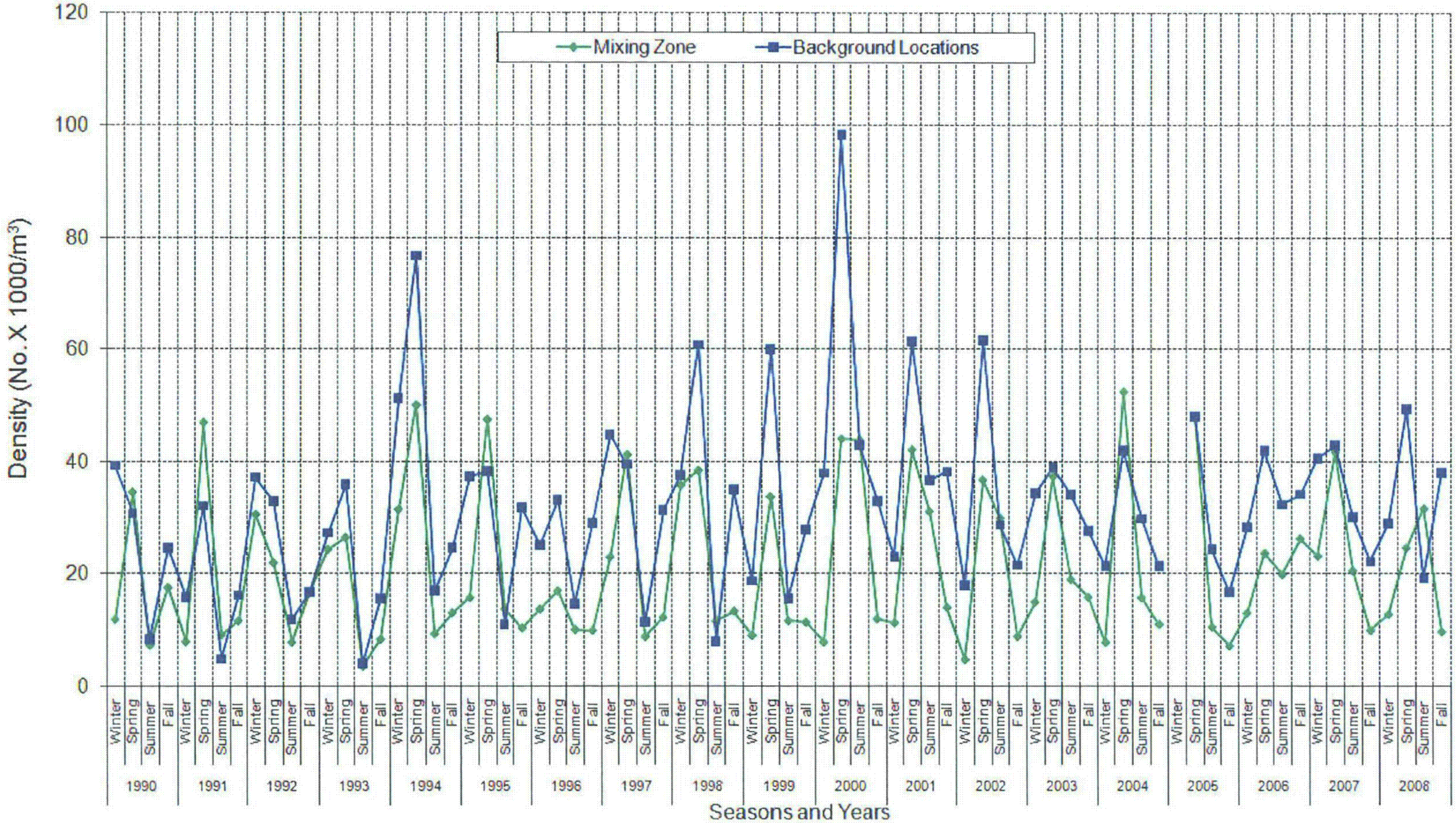


Figure 4-9. Copepod densities during each season of each year among epilimnetic samples collected in Lake Norman from 1990 – 2008 (mixing zone = mean of Locations 2.0 and 5.0; background = mean of Locations 9.5, 11.0, and 15.9).

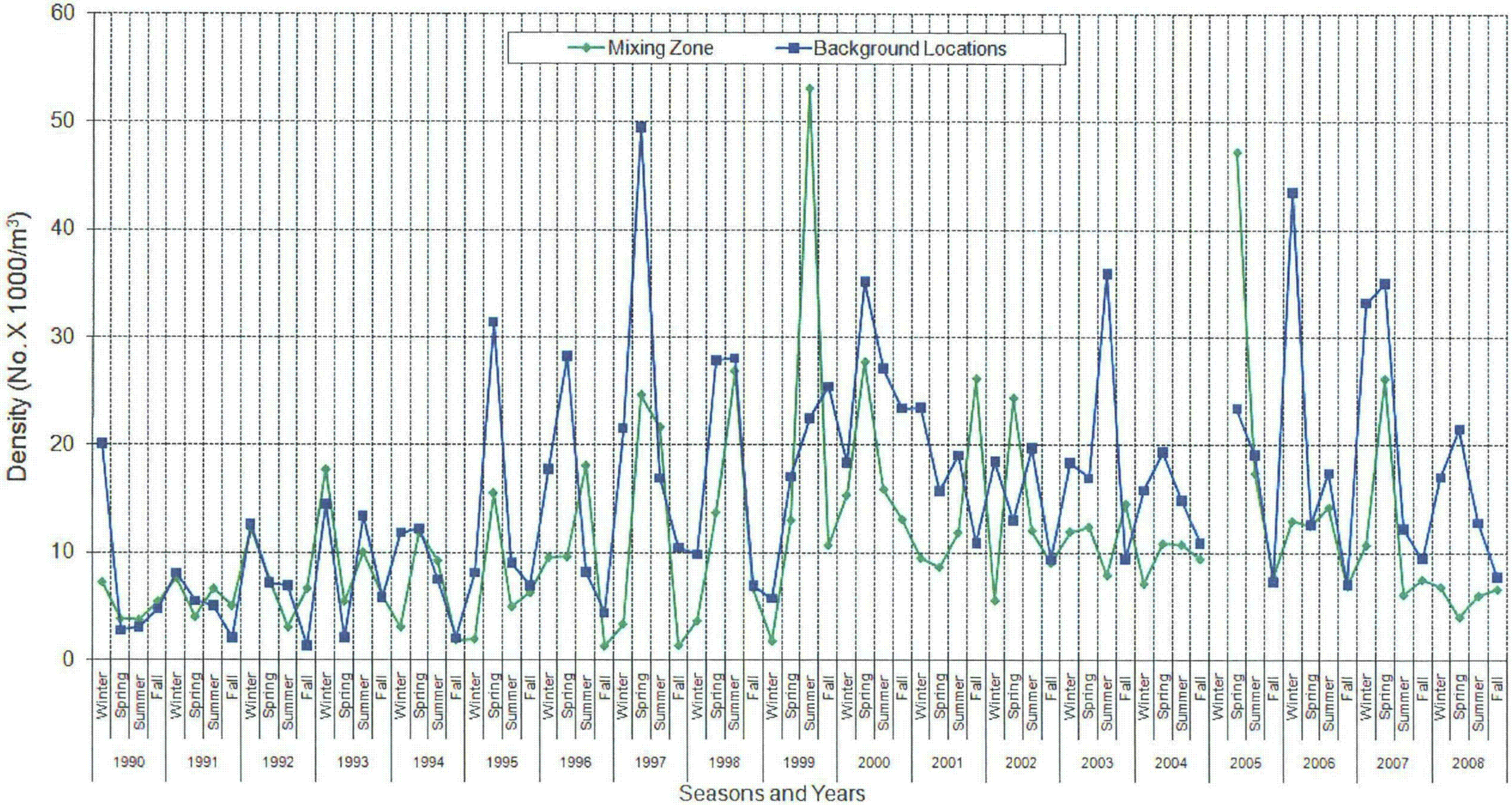


Figure 4-10. Cladoceran densities during each season of each year among epilimnetic samples collected in Lake Norman from 1990 – 2008 (mixing zone = mean of Locations 2.0 and 5.0; background = mean of Locations 9.5, 11.0, and 15.9).

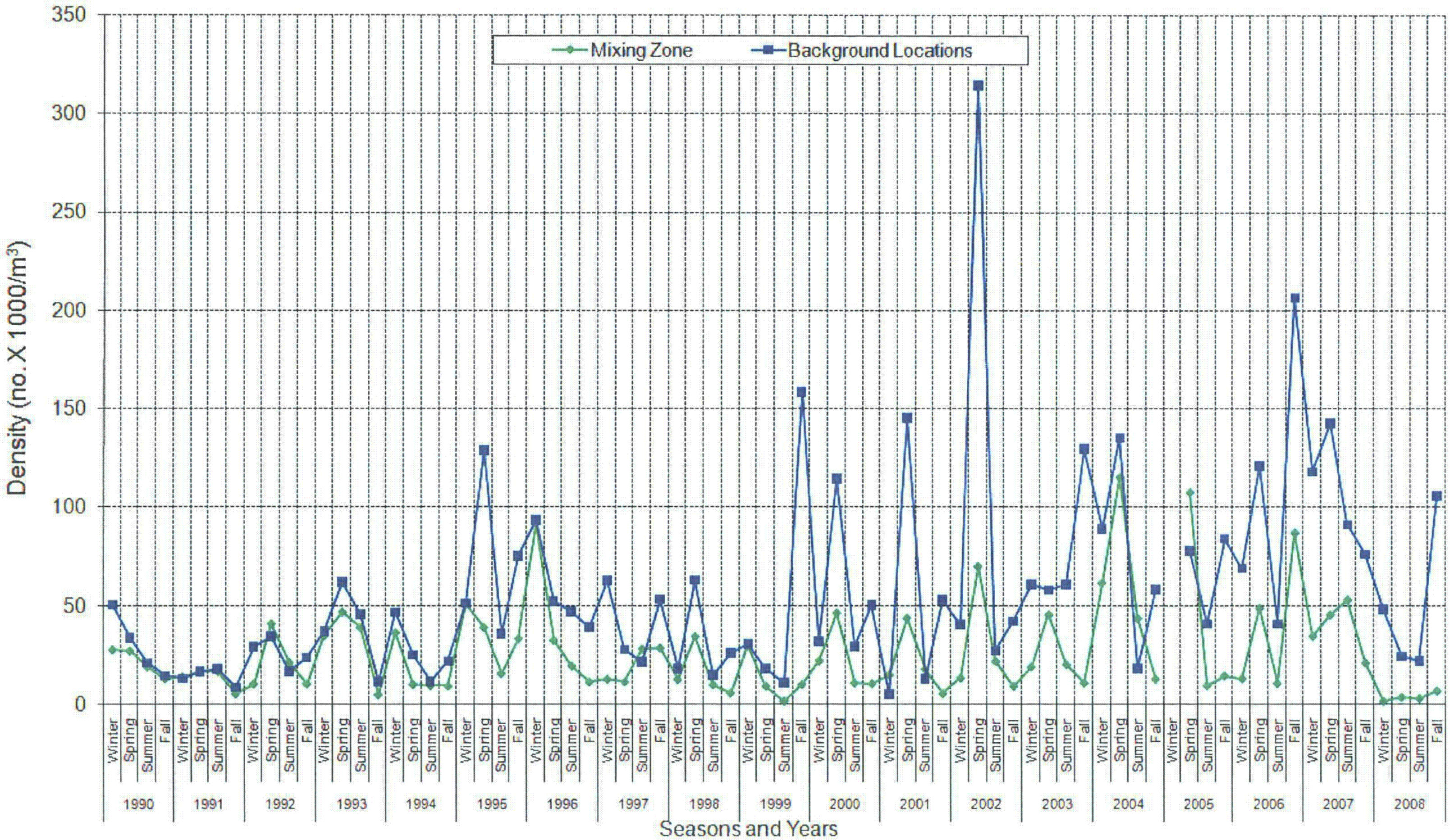


Figure 4-11. Rotifer densities during each season of each year among epilimnetic samples collected in Lake Norman from 1990 – 2008 (mixing zone = mean of Locations 2.0 and 5.0; background = mean of Locations 9.5, 11.0, and 15.9).

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), Duke Energy (DE) personnel monitored specific fish population parameters in Lake Norman during 2008. 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 *Micropterus punctulatus* and largemouth bass *M. salmoides*;
2. fall electrofishing survey to assess spotted bass and largemouth bass young-of-year abundance;
3. summer striped bass *Morone saxatilis* 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; and
6. fall white crappie *Pomoxis annularis* and black crappie *P. nigromaculatus* trap-net survey with the NCWRC with emphasis on age and growth.

METHODS AND MATERIALS

Spring Electrofishing Survey

An electrofishing survey was conducted in Lake Norman in March and April at three areas (Figure 5-1): in the Marshall Steam Station (MSS, Zone 4) mixing zone, a reference (REF, Zone 3) area located between the MNS and MSS mixing zones, and in the MNS mixing zone (Zone 1). Ten 300-m shoreline transects were surveyed in each area and were identical to historical locations surveyed since 1993. 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. Surface water temperature (°C) was measured with a calibrated thermistor at each location. Stunned fish were collected by two netters and identified to species. Fish were enumerated and weighed in aggregate by taxon, except for spotted bass and largemouth bass, where total length (TL, mm) and weight (g) were obtained for each individual collected. Catch per unit effort (number of individuals/3,000 m) and the number of species were calculated for each sampling area. Sagittal otoliths were removed from all bass $\geq$ 125 mm long (bass < 125 mm were assumed to be age 1 because young-of-year bass are historically not collected in spring surveys) and sectioned for age determination (Devries and Frie 1996).

Condition (W_r) based on relative weight was calculated for spotted bass $\geq$100 mm long and largemouth bass $\geq$150 mm long, using the formula $W_r = (W/W_s) \times 100$, where W = weight of the individual fish (g) and W_s = length-specific mean weight (g) for a fish as predicted by a weight-length equation for that species (Anderson and Neumann 1996). Growth rates (age 2-6 years) were compared between species and among areas with analysis of variance (α = 0.05) and Tukey's pairwise comparison (Analytical Software 2008).

Fall ElectrofishingYoung-of-Year Bass Survey

An electrofishing survey was conducted in November at the same three areas as the spring survey and consisted of five 300-m shoreline transects at each area. Again, shallow flats where the boat could not access within 3-4 m of the shoreline were excluded. Stunned bass were collected by two netters, identified to species, and individually measured and weighed. A year class "cut off" of 150 mm was determined for all black bass by examining historical 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 noted. Individual TL was measured prior to disposal.

Striped Bass Netting Survey

Striped bass were collected for age, growth, and W_r determinations in December by 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 W_r, as described previously for largemouth bass. Additionally, all catfish collected were identified and enumerated by species.

Fall Hydroacoustics and Purse Seine Surveys

Abundance and distribution of pelagic forage 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. An annual mobile hydroacoustic survey of the 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.

Annual purse seine samples were also collected in mid-September from the downlake (Zone 1), midlake (Zone 2), and uplake (Zone 5) areas of Lake Norman. The purse seine measured 122.0 x 9.1 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

The Lake Norman black and white crappie population was surveyed by DE and NCWRC personnel in late October as described by Nelson and Dorsey (2005). Fifteen locations in each of Zones 1, 2, and 3 were sampled with trap nets over two consecutive nights for a total of 90 net nights. Trap nets measured 1.83 x 0.91 x 0.91 m with a 15.24 x 0.91 m lead and 1.91 cm mesh. All crappie were weighed, and sagittal otoliths removed for age and growth determinations.

RESULTS AND DISCUSSION

Spring Electrofishing Survey

Spring 2008 electrofishing resulted in the collection of 5,663 individuals (22 species and two centrarchid hybrid complexes) weighing 293.82 kg at average water temperatures ranging from 16.8 to 17.9 °C (Table 5-1). The survey consisted of 1,859 individuals (16 species and two centrarchid hybrid complexes) weighing 115.20 kg in the MSS area, 2,245 fish (17 species and two centrarchid hybrid complexes) weighing 93.59 kg in the REF area, and 1,559 individuals (19 species and two hybrid centrarchid complexes) weighing 85.02 kg in the MNS area (Figure 5-2). Overall, bluegill *Lepomis macrochirus* dominated samples numerically, while bluegill, common carp *Cyprinus carpio*, largemouth bass, and spotted bass dominated samples gravimetrically.

The total number of individuals collected in spring 2008 was highest in the REF area, intermediate in the MSS area, and lowest in the MNS area. Although the total number of individuals was also highest in the REF area in 2006 and 2007, there is no apparent temporal trend in the number of individuals collected within or among areas since 1993.

Total biomass of fish in 2008 was highest in the MSS area, intermediate in the REF area, and lowest in the MNS area, following the spatial 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 (see Chapters 2 – 4). There is no apparent temporal trend in the biomass of fish collected within areas since 1993.

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 number of individuals and biomass since the 2001 spring electrofishing survey (Figure 5-3) and, in 2008, were most abundant in the MSS area, intermediate in the MNS area, and least abundant in the REF area. Similarly, biomass was highest in the MSS area, intermediate in the MNS area, and lowest in the REF area. In 2008, small spotted bass (< 150 mm) dominated the black bass catch in all areas (Figure 5-4a).

Spotted bass mean W_r ranged from 62.3 for fish 150-199 mm in the MNS area to 79.1 for fish 250-299 mm in the REF area (Figure 5-5a). Overall, spotted bass mean W_r values were highest in the REF area (76.2), intermediate in the MSS area (75.2), and lowest in the MNS area (72.4); similar to 2007 values (REF-75.1, MSS-75.3, MNS-71.6) and within the range of observed historical values (71.4-82.3) (Duke Power unpublished data, 2004, 2005; Duke Energy 2006, 2007, 2008).

Relative to 2007, the number of individual largemouth bass in 2008 increased slightly in the MSS and REF areas, but decreased in the MNS area (Figure 5-6a). Largemouth bass biomass increased in all areas (Figure 5-6b). Number of individuals and biomass at all areas were generally similar to 2006 and 2007, the lowest recorded since sampling began in 1993. As in most years, 2008 largemouth bass number of individuals and biomass were highest in the MSS area, intermediate in the REF area, and lowest in the MNS area.

From 2000 – 2006, largemouth bass $\geq$ 300 mm dominated the catch in all three areas (Duke Power 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006), with largemouth bass < 150 mm low in abundance. An exception was in 2006, when a high abundance of largemouth bass < 150 mm occurred in the MSS area (Duke Energy 2007). In 2007 and 2008, largemouth bass $\geq$ 300 mm were relatively abundant, but not dominant (Figure 5-4b).

Largemouth bass mean W_r ranged from 73.0 for fish > 450 mm in the REF area to 83.3 for fish 350-399 mm in the MNS area (Figure 5-5b). Overall, largemouth bass mean W_r values were highest in the MNS area (81.2), intermediate in the MSS area (81.1), and lowest in the REF area (77.2); a decrease relative to 2007 values (MNS-84.8, MSS-84.6, REF-82.5), but within the range of observed historical values (76.0-89.9; Duke Power unpublished data, 2004, 2005; Duke Energy 2006, 2007, 2008).

In 2008 (and 2007), there was no significant difference between the growth rates of spotted and largemouth bass (age 2-6 years; Table 5-2). Bass in the REF area showed a decreased growth rate relative to the MSS and MNS areas in 2008, a difference also present when comparing largemouth bass growth rates over all years of data (1993 – 1994, 2003 – 2008). Additionally, largemouth bass had significantly lower growth rates from 1993 – 1994 than from 2003 – 2008 (Table 5-3). Although correlations exist between spotted bass introduction and largemouth bass population parameters, a causal effect is indeterminate due to possible confounding effects of other introduced species, including alewife *Alosa pseudoharengus* and white perch *Morone americana* (Kohler and Ney 1980, Madenjian et al. 2000).

Fall Electrofishing Young-of-Year Bass Survey

Fall 2008 electrofishing resulted in the collection of 253 spotted, eight largemouth, and two hybrid black bass young-of-year (< 150 mm), continuing an increasing trend in spotted bass young-of-year numbers since 2005 (Figure 5-7). As in 2005 – 2007, young-of-year black bass numbers were highest in the MSS area.

Summer Striped Bass Mortality Surveys

In 2008, a total of 17 dead striped bass were collected during the July-August surveys, mostly in Zone 1 (Table 5-4). 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 1-3 fish, 123 striped bass were collected in early to mid-December 2008 (Figure 5-8). Striped bass growth was fastest through age 3 and slowed with increasing age. Additionally, mean W_r was highest for age 1 fish (87.6) and declined with age. Mean W_r was 82.8 for all striped bass in 2008, within the range of observed historical values (78.5-84.1). Growth and condition in 2008 were similar to historical values since consistent gillnetting began in 2003 (Duke Power 2004a, 2005; Duke Energy 2006, 2007, 2008).

The December striped bass gillnetting also yielded 107 catfish. Blue catfish *Ictalurus furcatus* (85) dominated the catch, followed by channel catfish *I. punctatus* (12) and flathead catfish *Pylodictis olivaris* (10).

Fall Hydroacoustics and Purse Seine Surveys

Mean forage fish densities in the six zones of Lake Norman ranged from 1,443 (Zone 1) to 22,157 (Zones 5 and 6) fish/ha in September 2008 (Table 5-5). 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 lakewide population estimate in September 2008, approximately 106.4 million fish, was the highest population estimate since surveys began in 1997 (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 forage fish population estimates in Lake Norman from 1997 – 2008.

Purse seine surveys from 1993 – 2008 indicate that threadfin shad *Dorosoma petenense* continue to dominate the Lake Norman forage fish community comprising 95.6% of the catch in 2008 (Table 5-6). Alewife, first detected in Lake Norman in 1999 (Duke Power 2000), have comprised as much as 25.0% (2002) of mid-September pelagic forage fish surveys, but have remained relatively low since 2005 (range = 1.7 – 5.1%). The modal threadfin shad TL class increased after alewife introduction, but has declined and been consistent in recent years (41-45 mm in 2008; Figure 5-10).

Crappie Trap-Net Survey

In 2008, DE and NCWRC personnel set 90 overnight trap-nets in Lake Norman collecting 147 black crappie and one white crappie. Various life history data were collected for use in fish management decisions by the NCWRC.

SUMMARY

In accordance with the Lake Norman Maintenance Monitoring Program for the MNS NPDES permit, specific fish monitoring programs continued during 2008. Spring electrofishing indicated that 16 to 19 species of fish and two hybrid complexes comprised fish populations in the three survey areas, and number of individuals and biomass of fish in 2008 were generally similar to those noted annually since 1993. Largemouth bass number of individuals and biomass remain low with some of the lowest recorded data since sampling began in 1993. During 2008, the number of summer striped bass mortalities (17) and winter W_r (82.8) were similar to those of previous years. Hydroacoustic sampling estimated a forage fish population of approximately 106.4 million in 2008, the highest estimate since surveys began in 1997. Alewife continued to comprise a small percentage (4.4%) of pelagic forage fish in fall purse seine surveys. During 2008, the modal threadfin shad TL class remained at pre-alewife introduction sizes.

Past studies have indicated that a balanced indigenous fish community exists in Lake Norman (Duke Power 2000, 2001, 2002, 2003, 2004a, 2005; Duke Energy 2006, 2007, 2008). The present study adds another year of comparable data, reinforcing that conclusion. Based on the diversity and numbers of individuals in the Lake Norman littoral fish community during spring and the regular availability of forage fish to limnetic predators, it is concluded that the operation of MNS has not impaired the Lake Norman fish community.

Table 5-1. Number of individuals and biomass of fish collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman March/April 2008.

		MSS		REF		MNS		Total	
Scientific Name	Common Name	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Lepisosteidae									
Lepisosteus osseus	Longnose gar			1	1.73			1	1.73
Clupeidae									
Dorosoma cepedianum	Gizzard shad	6	2.67	15	6.35	15	6.38	36	15.40
Cyprinidae									
Cyprinella chloristia	Greenfin shiner	31	0.07	32	0.07	93	0.21	156	0.34
Cyprinella nivea	Whitefin shiner	15	0.06	57	0.20	32	0.11	104	0.37
Cyprinus carpio	Common carp	8	19.88	5	10.40	6	15.45	19	45.73
Notemigonus crysoleucas	Golden shiner	4	0.01					4	0.01
Notropis hudsonius	Spottail shiner	32	0.25	31	0.19	28	0.19	91	0.63
Catostomidae									
Carpiodes cyprinus	Quillback					2	1.72	2	1.72
Ictaluridae									
Ictalurus furcatus	Blue catfish					1	1.35	1	1.35
Ictalurus punctatus	Channel catfish	1	0.89	4	1.99	1	0.32	6	3.20
Pylodictis olivaris	Flathead catfish	1	1.01	2	0.28	1	0.09	4	1.38
Salmonidae									
Oncorhynchus mykiss	Rainbow trout					2	0.09	2	0.09
Poeciliidae									
Gambusia holbrooki	Eastern mosquitofish					1	0.00	1	0.00
Moronidae									
Morone saxatilis	Striped bass			1	2.14	3	3.81	4	5.94
Centrarchidae									
Lepomis auritus	Redbreast sunfish	106	2.24	303	5.06	178	2.96	587	10.26
Lepomis cyanellus	Green sunfish	62	0.69	9	0.25			71	0.93
Lepomis gulosus	Warmouth	19	0.08	39	0.28	50	0.13	108	0.49
Lepomis hybrid	Hybrid sunfish	56	1.72	70	1.45	35	0.54	161	3.71
Lepomis macrochirus	Bluegill	1,260	12.94	1,495	15.53	913	8.83	3,668	37.29
Lepomis microlophus	Redear sunfish	78	6.76	72	7.35	98	5.35	248	19.45
Micropterus punctulatus	Spotted bass	107	28.86	65	16.73	81	22.98	253	68.57
Micropterus salmoides	Largemouth bass	65	31.69	34	18.84	14	11.35	113	61.88
Micropterus hybrid	Hybrid black bass	7	5.14	6	2.85	4	2.44	17	10.43
Pomoxis nigromaculatus	Black crappie	1	0.25	4	1.92	1	0.75	6	2.92
Total No. Individuals		1,859	115.20	2,245	93.59	1,559	85.02	5,663	293.82
Total No. Species		16		17		19		22	
Mean Water Temperature (° C)		17.6		16.8		17.9			

Table 5-2. Mean TL (mm) at age (years) for spotted bass and largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman March/April 2008.

		Age (years)												
Taxa	Area	1	2	3	4	5	6	7	8	9	10	11	12	13
Spotted bass	MSS	139	288	356	394	396	458				466			479
	REF	117	288	368	399	439	416							
	MNS	141	290	384	404	403	416	545						
	Mean TL (mm)	**134**	**289**	**365**	**398**	**410**	**426**	**545**			**466**			**479**
Largemouth bass	MSS	213	307	365	390	395	405	364		408				
	REF	167	236	346	384	397	419	415		446				
	MNS	81		399	384	428	449							
	Mean TL (mm)	**195**	**283**	**362**	**386**	**408**	**416**	**381**		**427**				

Table 5-3. Comparison of mean TL (mm) at age (years) for largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman March/April 2008 to historical largemouth bass mean lengths.

	Age (years)			
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[g]	215	261	363	394
MSS 2008	213	307	365	390
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[g]	186	285	371	367
REF 2008	167	236	346	384
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[g]	-	355	402	433
MNS 2008	81	-	399	384

[a] Siler 1981; [b] Duke Power unpublished data; [c] Duke Power 2004; [d] Duke Power 2005; [e] Duke Energy 2006; [f] Duke Energy 2007; [g] Duke Energy 2008

Table 5-4. Striped bass mortalities observed in Lake Norman from weekly surveys during July/August 2008.

Date	No.	Zone	TL (mm)
Jul 7	2	3	530, 537
Jul 14	1	1	560
Jul 21	1	1	375
Jul 29	1	1	510
Aug 4	4	1	547, 568, 576, 607
	3	3	554, 569, 596
Aug 11	2	1	589, 593
Aug 13	1	1	540
Aug 15	1	1	609
Aug 18	1	2	465

Table 5-5. Lake Norman forage fish densities (No./ha) and population estimates from September 2008 hydroacoustic survey.

Zone	No./ha	Population estimate
1	1,443	3,291,483
2	2,439	7,517,242
3	8,489	29,333,909
4	7,346	9,042,926
5	22,157	46,662,642
6	22,157[a]	10,591,046
Lakewide total		106,439,248
95% CI		88,924,441 – 123,954,055

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

Table 5-6. Number of individuals (No.), percent composition of forage fish, and modal threadfin shad TL class collected from purse seine surveys in Lake Norman during late summer/fall, 1993 – 2008.

		Species composition			Modal threadfin shad
Year	No.	Threadfin shad	Gizzard shad	Alewife	TL class (mm)
1993	13,063	100.00%			31-35
1994	1,619	99.94%	0.06%		36-40
1995	4,389	99.95%	0.05%		31-35
1996	4,465	100.00%			41-45
1997	6,711	99.99%	0.01%		41-45
1998	5,723	99.95%	0.05%		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%		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%		1.90%	36-45
2006	14,823	94.87%		5.13%	41-45
2007	27,169	98.34%		1.66%	41-45
2008	47,586	95.58%		4.42%	41-45

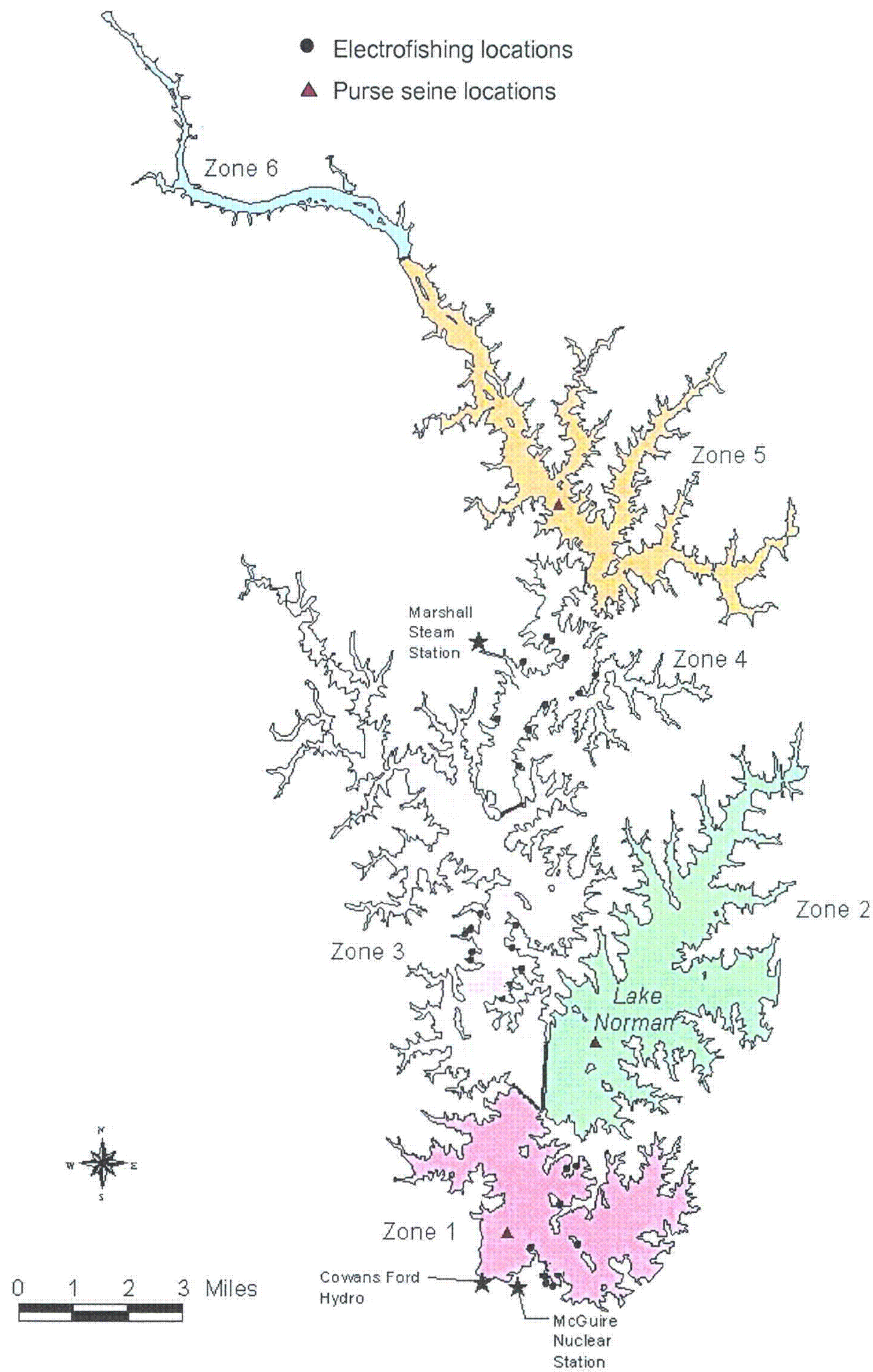


Figure 5-1. Sampling locations and zones associated with fishery assessments in Lake Norman.

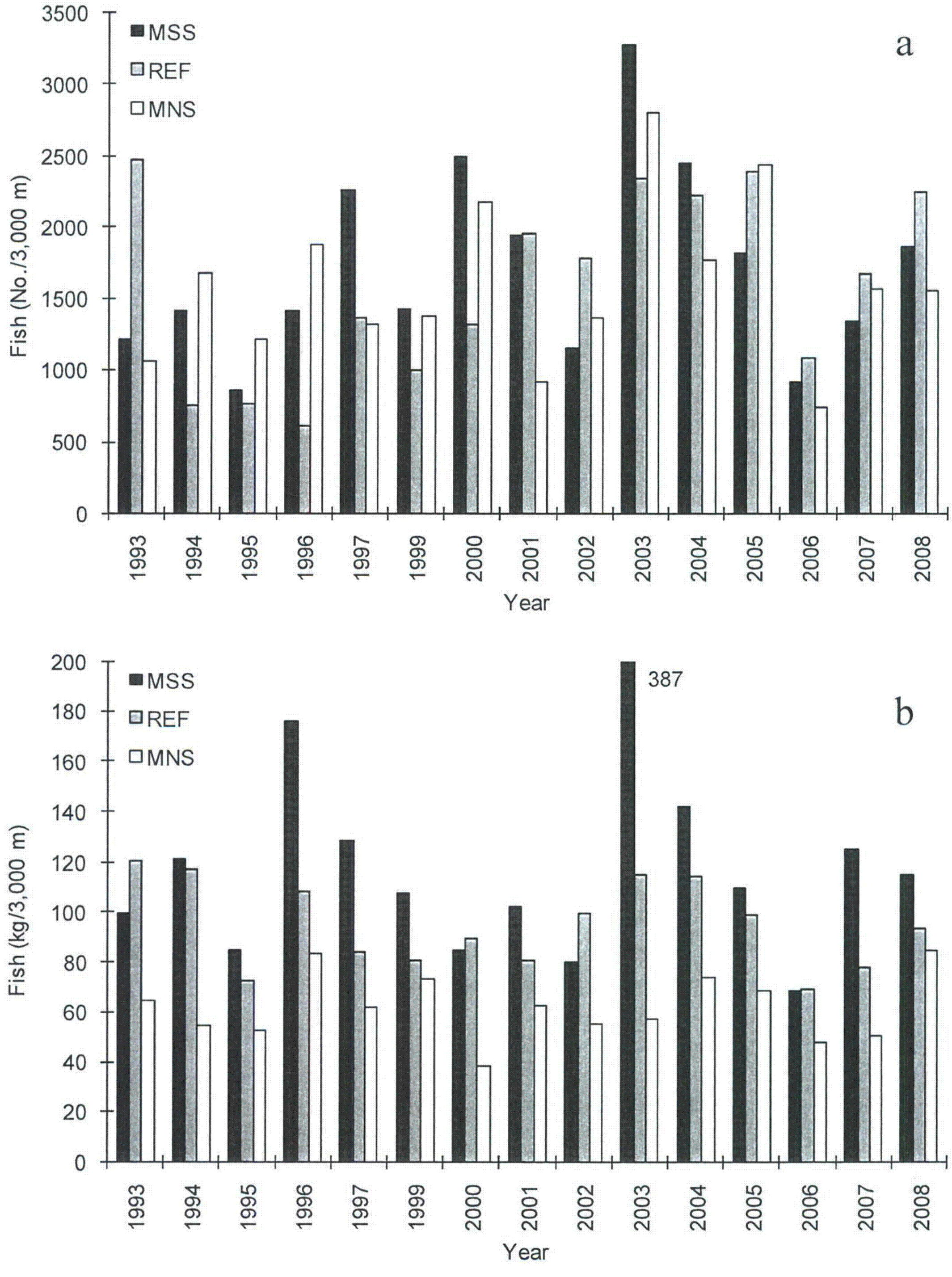


Figure 5-2. Number of individuals (a) and biomass (b) of fish collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/ April 1993 – 1997 and 1999 – 2008.

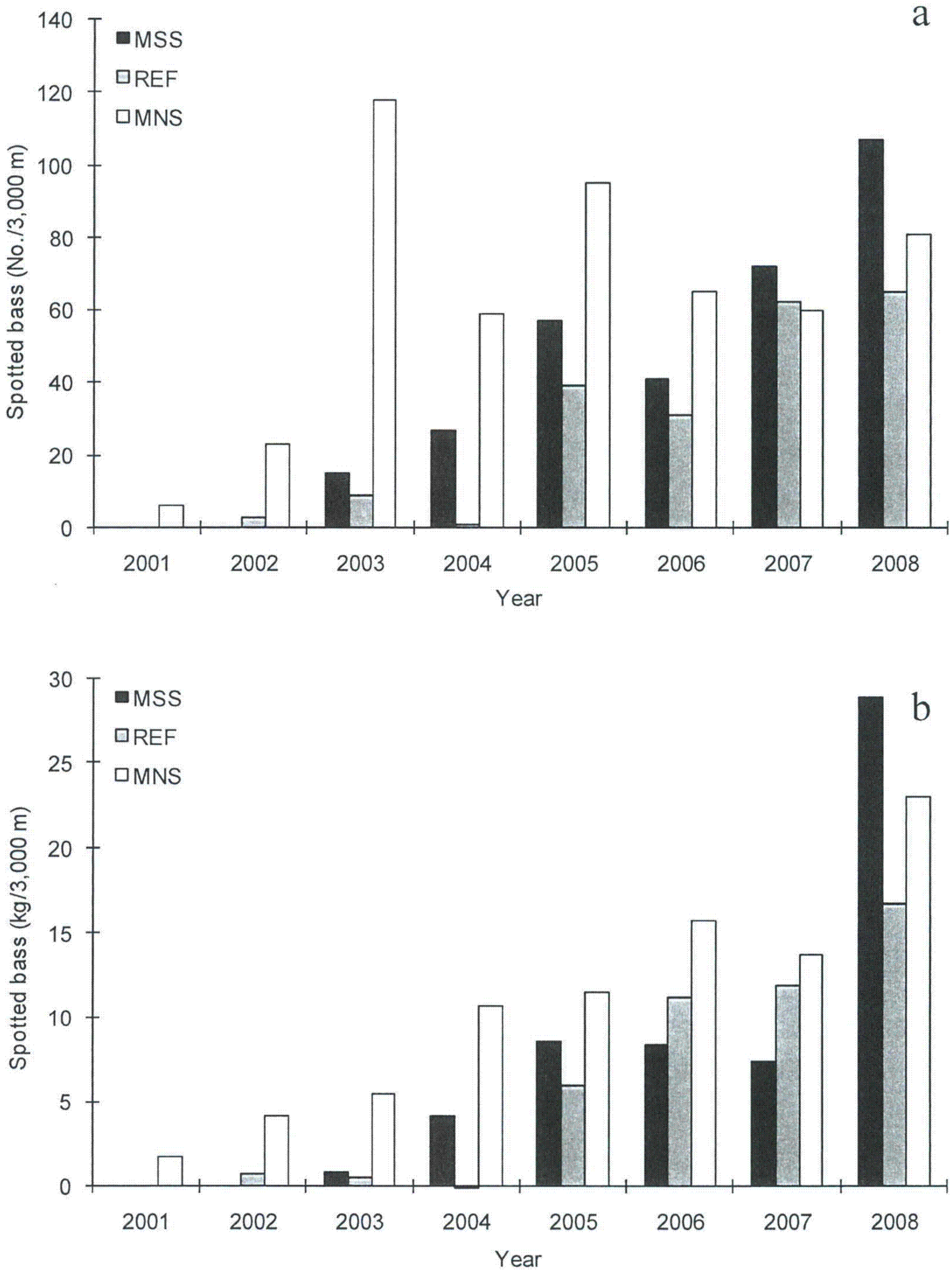


Figure 5-3. Number of individuals (a) and biomass (b) of spotted bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 2001 – 2008.

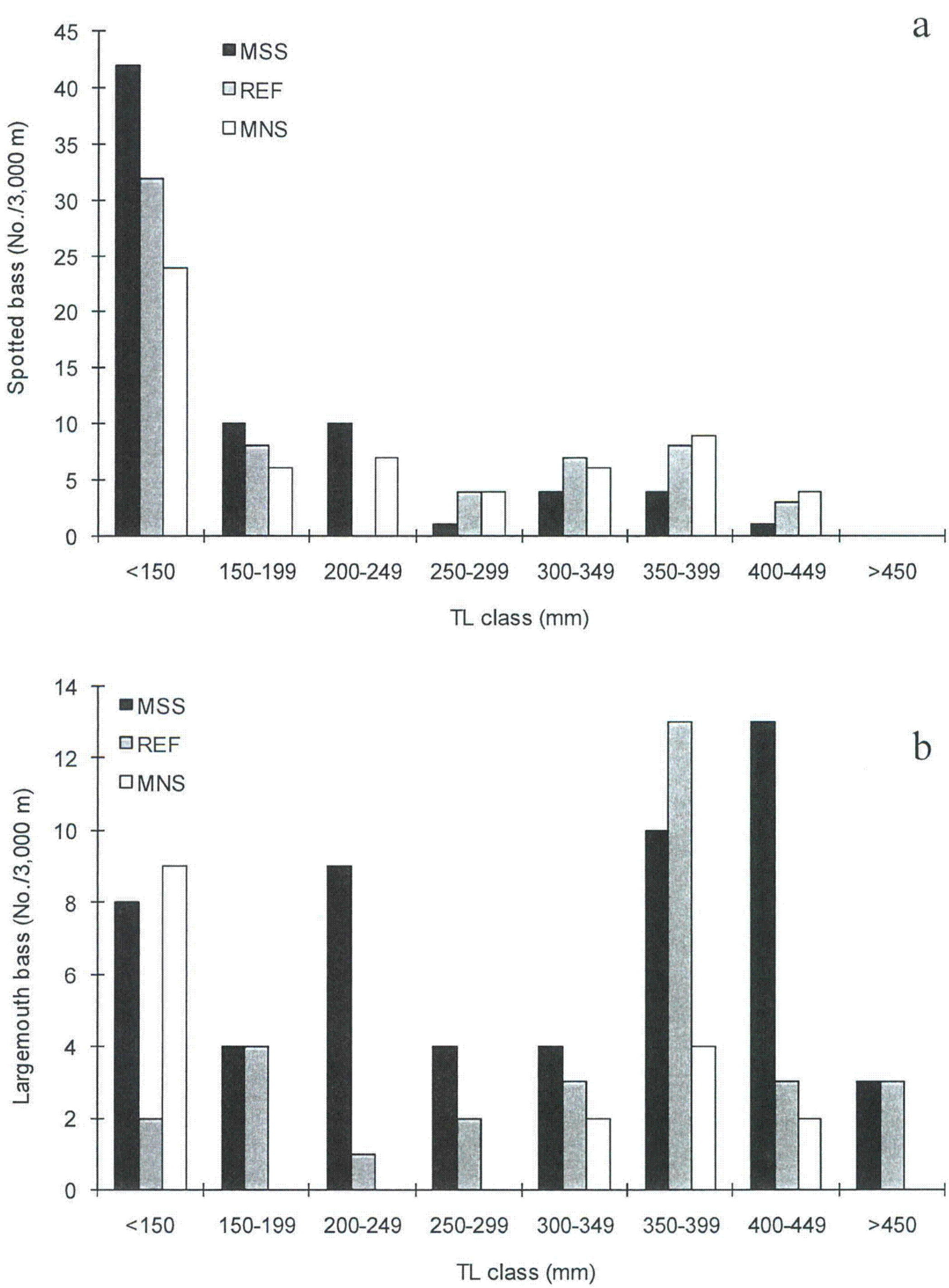


Figure 5-4. Size distributions of spotted bass (a) and largemouth bass (b) collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 2008.

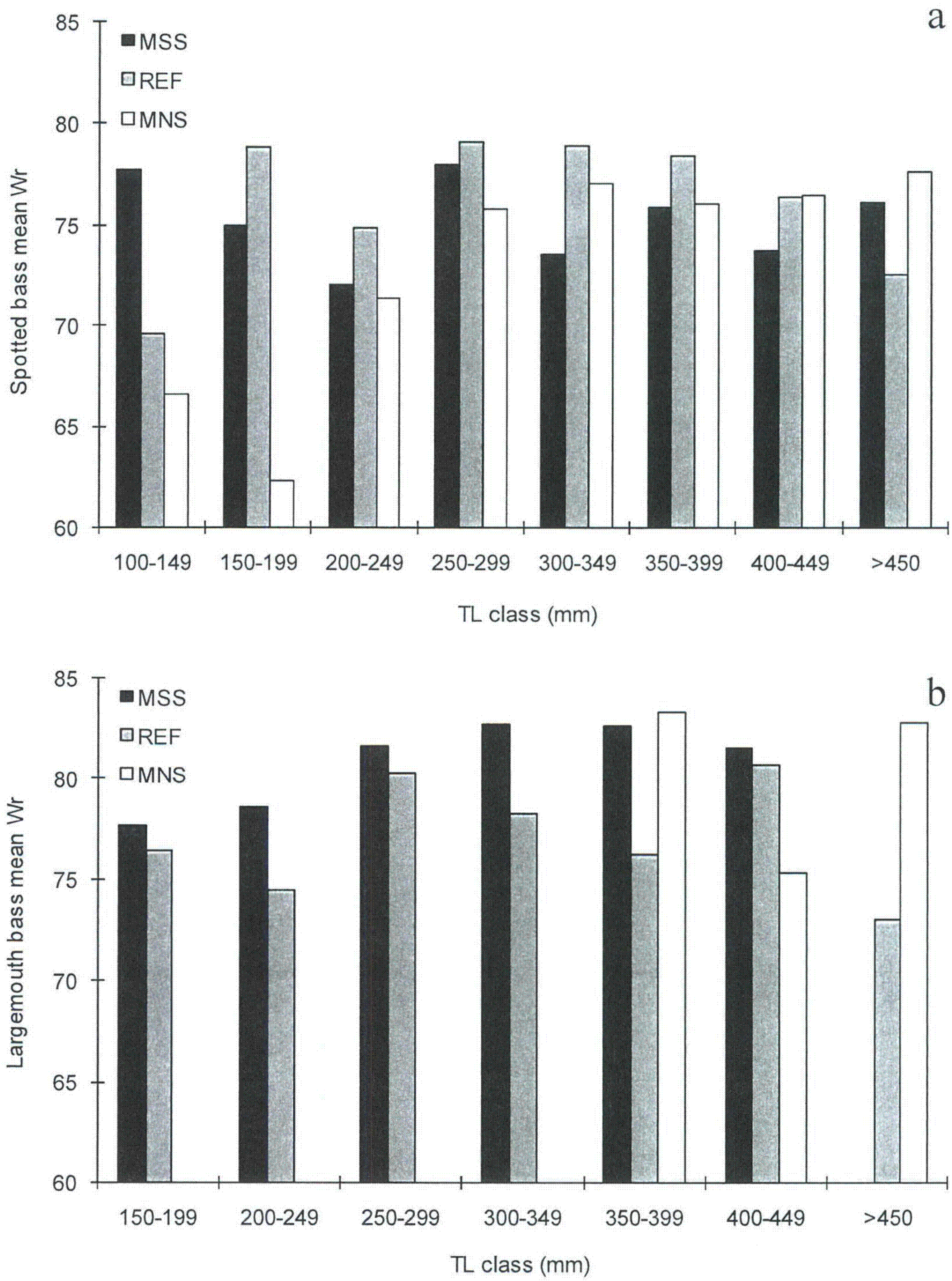


Figure 5-5. Mean relative weights (Wr) for spotted bass (a) and largemouth bass (b) collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 2008.

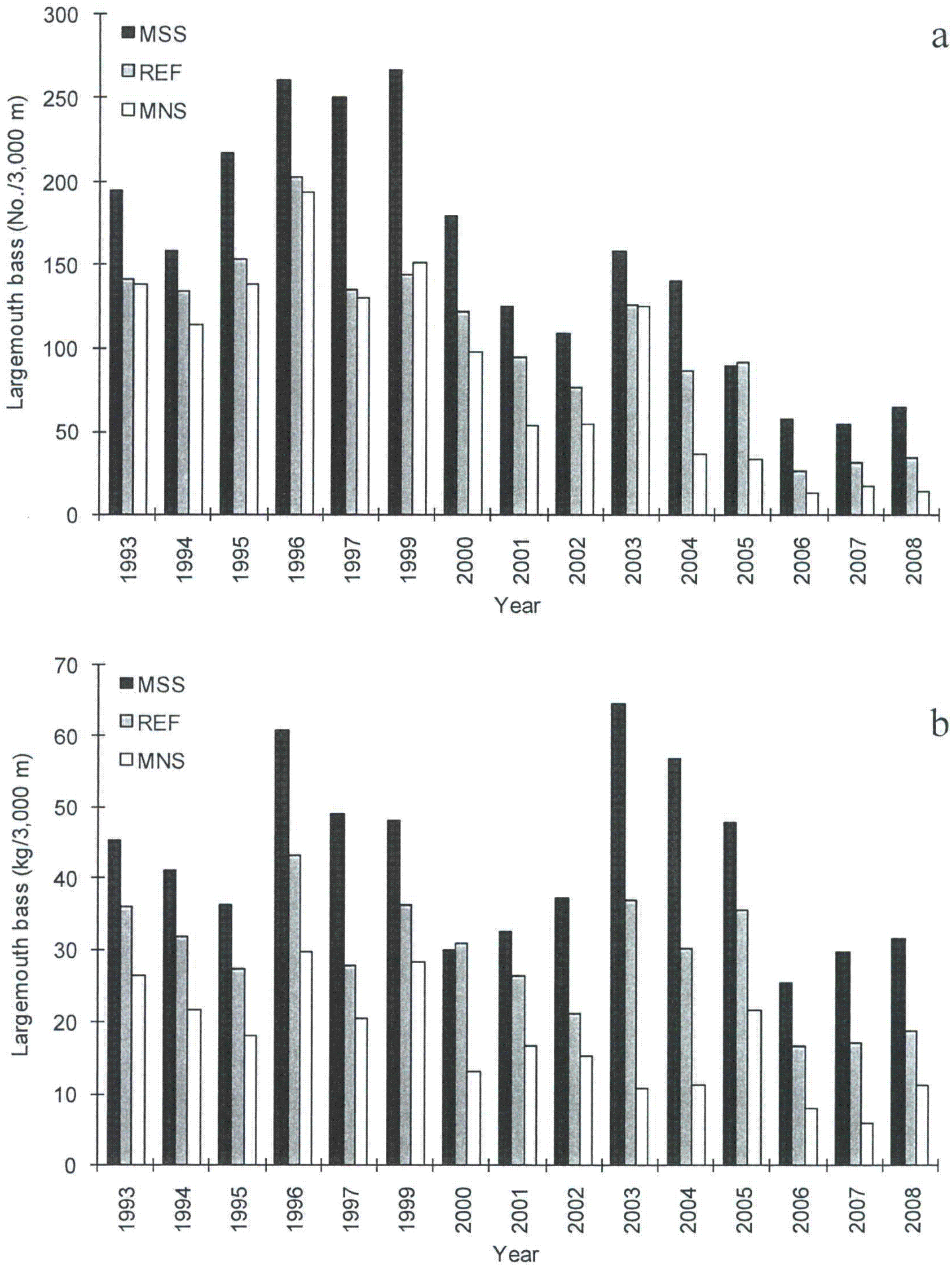


Figure 5-6. Number of individuals (a) and biomass (b) of largemouth bass collected from electrofishing ten 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, March/April 1993 – 1997 and 1999 – 2008.

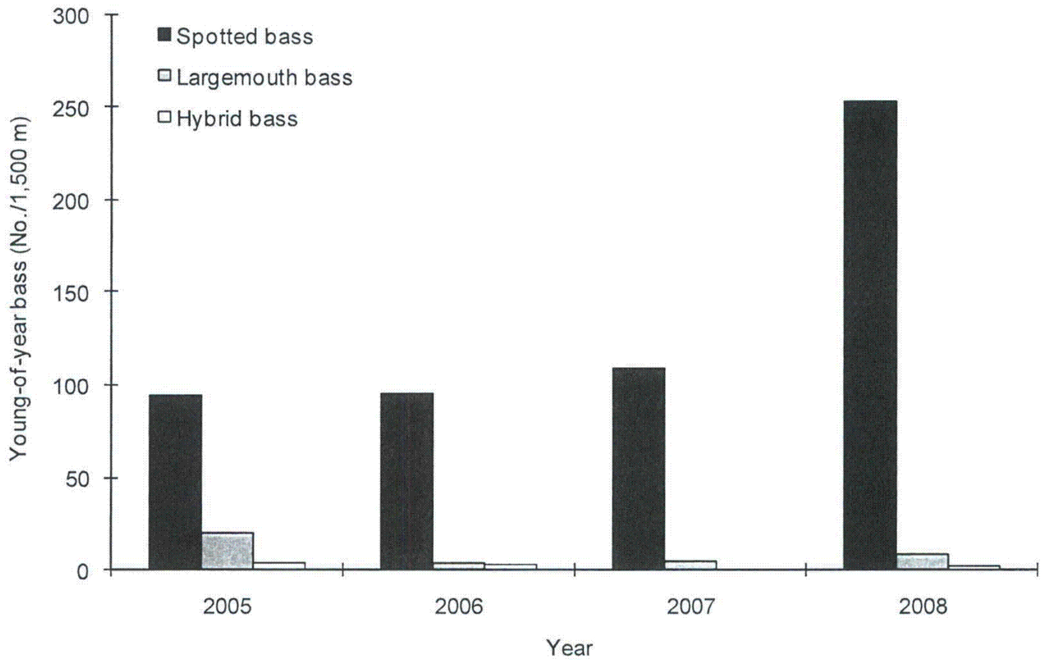


Figure 5-7. Number of young-of-year black bass (< 150 mm) collected from electrofishing five 300-m transects each, at three areas (MSS, REF, MNS) in Lake Norman, November 2005 – 2008.

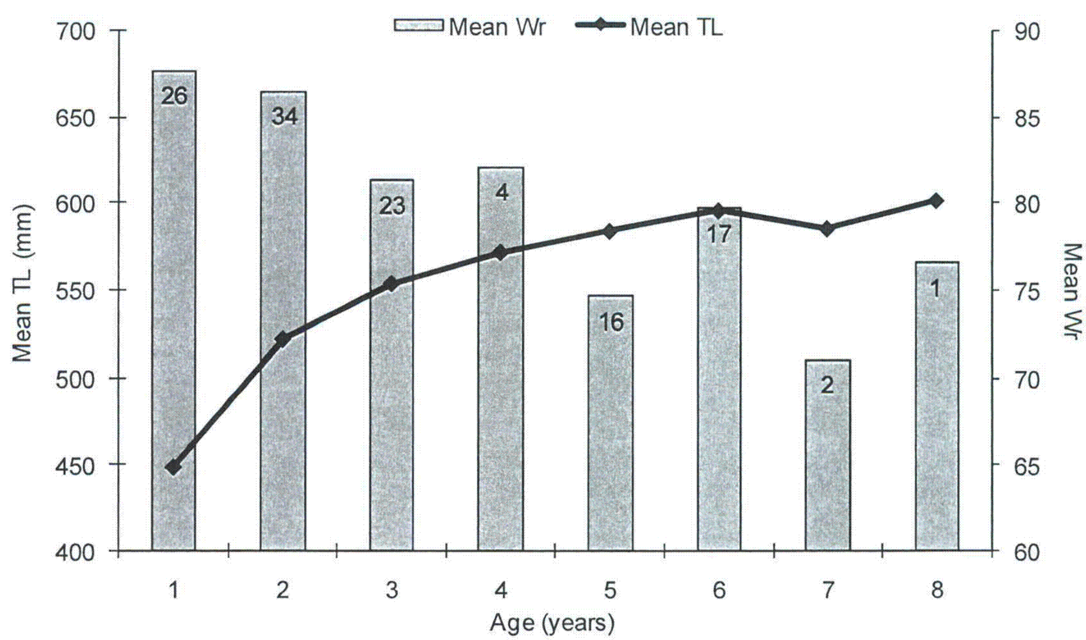


Figure 5-8. Mean TL and relative weight (Wr) by age of striped bass collected in Lake Norman, December 2008. Numbers of fish by age are inside bars.

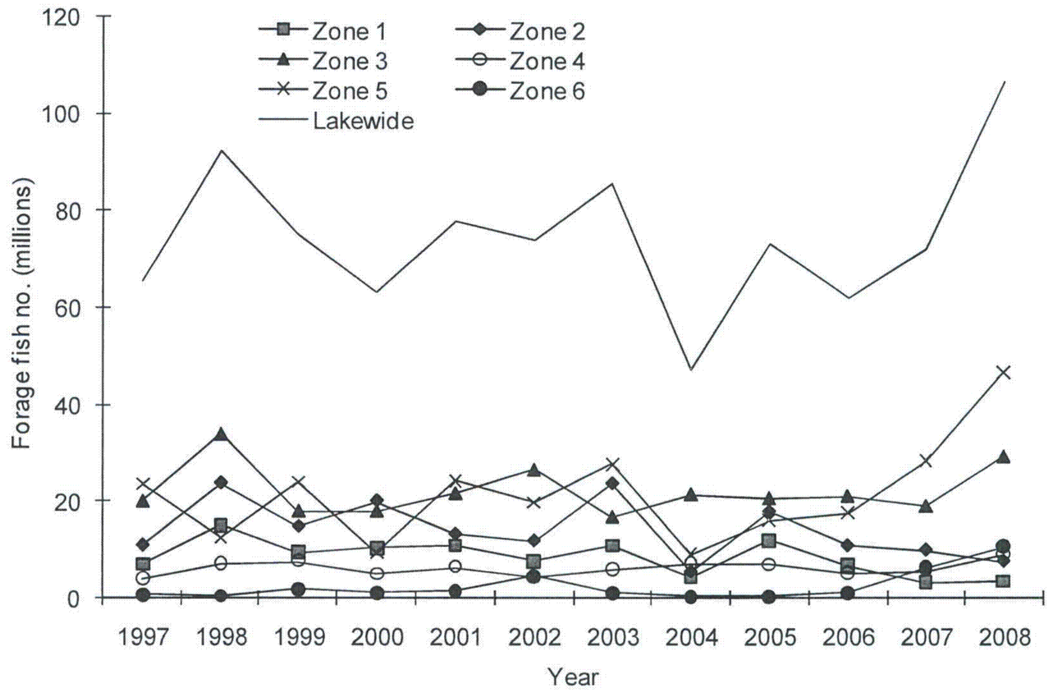


Figure 5-9. Zonal and lake-wide population estimates of pelagic forage fish in Lake Norman, September 1997 – 2008.

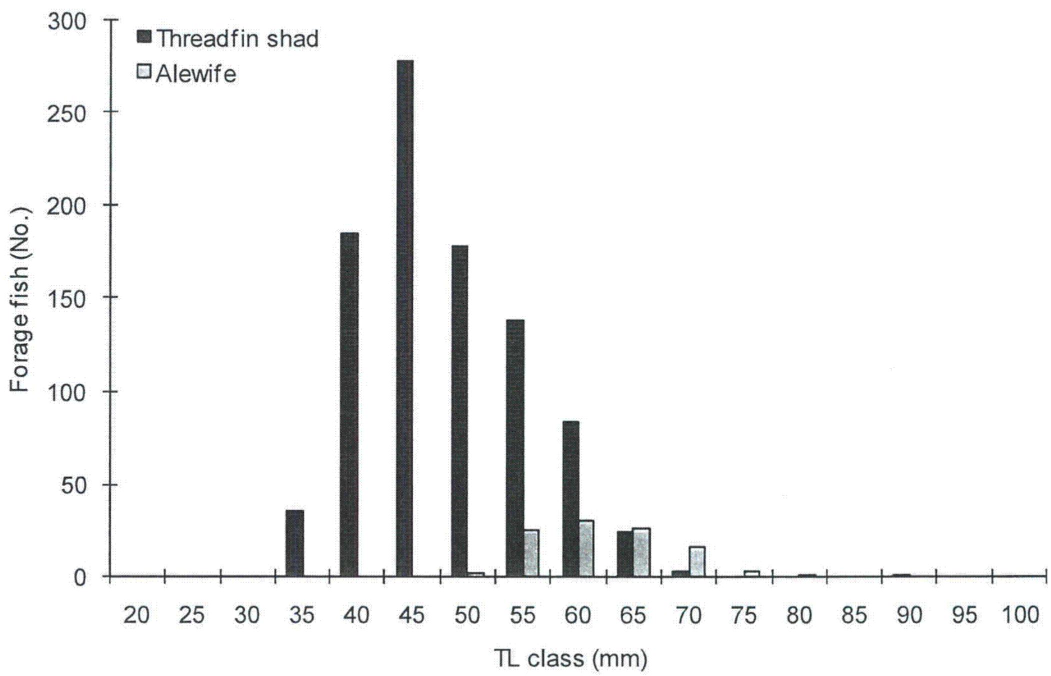


Figure 5-10. Number of individuals and size distribution of threadfin shad and alewife collected from purse seine surveys in Lake Norman, September 2008.

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