LAKE NORMAN: 1998 SUMMARY

MAINTENANCE MONITORING PROGRAM

McGUIRE NUCLEAR STATION: NPDES No. NC0024392

DUKE POWER
A COMPANY OF DUKE ENERGY

DECEMBER 1999

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EXECUTIVE SUMMARY

As required per the National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 1998.

OPERATIONAL DATA

The monthly average capacity factor of MNS averaged over 90% during July, August, and September of 1998 (Table 1-1). These are the months when conservation of cool water and discharge temperatures are most critical and the thermal limit for MNS increases from a monthly average of 95°F to 99°F. The average monthly discharge temperature was 96.6°F (35.9°C) for July, 98.0°F (36.7°C) for August, and 95.9°F (35.5°C) for September 1998. Two of three low level intake water pumps of Unit 1 were operated to provide additional cooling for 7 days in August, 9 days in September, and 15 days in October of 1998. The volume of cool water in Lake Norman was tracked throughout the year to ensure that an adequate volume was available to comply with both the Nuclear Regulatory Commission Technical Specification requirements and the NPDES discharge water temperature limits.

WATER CHEMISTRY DATA

Temporal and spatial trends in water temperature and dissolved oxygen (DO) data collected in 1998 were similar to those observed historically. Reservoir-wide isotherm and isopleth information for 1998, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics characteristic of historic conditions and similar to other Southeastern reservoirs of comparable size, depth, flow conditions, and trophic status.

All chemical parameters measured in 1998 were within the concentration ranges previously reported for the lake during both MNS preoperational and operational years. As has been observed historically, manganese concentrations in the bottom waters in the summer and fall of 1998 often exceeded the NC water quality standard. This is characteristic of waterbodies that experience hypolimnetic deoxygenation during the summer.

PHYTOPLANKTON DATA

Lake Norman continues to support highly variable and diverse phytoplankton communities. In 1998 chlorophyll *a* concentrations at all locations were generally within ranges reported during previous years. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. Lake-wide chlorophyll means increased from February to August, and then declined in November. Considerable spatial and seasonal variability was observed during 1998, as has been the case in previous years.

In most cases, total phytoplankton densities and biovolumes observed in 1998 were within ranges of those observed during previous years. However, the density and biovolume at uplake Location 15.9 in May, and the density at this location in August, exceeded NC State phytoplankton bloom guidelines. This was the second time since the program began that such an excursion was documented, and the May density at Location 15.9 was the highest recorded to date. Very high standing crops of diatoms, primarily the pennates *Tabellaria fenestrata* and *Achnanthes microcephala*, were responsible for these high values. Chlorophyll concentrations remained below the standard of 40 ug/l due to the low chlorophyll to volume ratios associated with diatoms. Since high standing crops occurred at a location well uplake from MNS, and above the MSS discharge, plant operations were not responsible for these excursions. Natural conditions such as low flow, increased retention time, inputs of nutrients uplake, seasonal increases in temperature and light penetration, and longer photoperiod were most likely contributed to the higher than normal standing crops.

ZOOPLANKTON DATA

Lake Norman continues to support a highly diverse and viable zooplankton community. Maximum zooplankton standing crops in 1998 usually occurred in May. Minimum values were most often observed in August; however, lowest densities at certain locations occurred in November (Mixing Zone, epilimnion) and February (15.9 and 5.0, whole column). This represented a slight shift from 1997 when all minimum values were observed in August. In 1998, densities were higher in epilimnetic samples than in whole column samples. Mean zooplankton densities tended to be higher among Background Locations than among Mixing Zone Locations during all seasons of 1998.

Long term trends showed much higher year-to-year variability at Background Locations than at Mixing Zone Locations. Epilimnetic zooplankton densities during 1998 were generally within ranges of those observed in previous years. The relative abundance of copepods and cladocerans was higher in 1998 than in 1997, representing a continuing trend of increasing microcrustacean abundance since 1995. A similar trend was observed throughout Lake Norman between 1988 and 1991. Long term and seasonal changes observed over the course of the study, as well as seasonal and spatial variability observed during 1998, were likely due to normal environmental factors.

FISHERIES DATA

Through consultation with the NCWRC, the Lake Norman fisheries program continues to be reviewed and modified annually to address fishery issues. Fisheries data continue to be collected through cooperative monitoring programs with the NCWRC for their assessment and management of Lake Norman fish populations. Fisheries data to date indicate that the Lake Norman fishery is consistent with the trophic status and productivity of the reservoir.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 1998 was generally similar to historic conditions. Habitat reduction was most severe from early August through September when no suitable habitat was observed in the reservoir except for a small refugium in the upper, riverine portion of the reservoir (Chapter 2). General monitoring of Lake Norman and specific monitoring of the MNS mixing zone for striped bass mortalities during the summer of 1998, yielded 13 mortalities within the mixing zone and 4 mortalities in the main channel outside the mixing zone. Physicochemical habitat was observed to have expanded appreciably by early October, primarily as a result of epilimnion cooling and deepening, and in response to changing meteorological conditions. The temporal and spatial pattern of striped bass habitat expansion and reduction observed in 1998 was similar to that previously reported in Lake Norman and many other Southeastern reservoirs.

Gillnetting for striped bass during 1998 yielded a total of 233 striped bass, ranging in length from 314 mm to 746 mm. Age determinations of striped bass indicated fish ranging in age from 1 to 6 years. Age 1 fish comprised the largest age group (42%). All striped bass data were submitted to the NCWRC for detailed analyses of striped bass growth and condition that will be used for management of this put-grow-take fishery.

Black crappie comprised 98% of the total catch (724 crappie) in trap-nets over a 2 year study completed in 1998. Crappie ranged in size from 105 mm to 340 mm. Age determinations of black crappie indicated fish ranging in age from 0 to 6 years. These data were submitted to the NCWRC for detailed analyses of crappie condition and age/size composition.

Analyses of forage fish population data for 1993 through 1997 were completed, and a summary report was prepared (see Addendum to Chapter 5). Average forage fish densities in Lake Norman exceeded densities in lakes immediately above and below Lake Norman, and were comparable to densities in other Catawba River lakes. Forage population data collected during 1998 will be analyzed and submitted with the 1999 forage data, during 2000.

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CHAPTER 1
McGUIRE NUCLEAR STATION
OPERATIONAL DATA

INTRODUCTION

As required per the National Pollutant Discharge Elimination System (NPDES) permit number NC0024392 for McGuire Nuclear Station (MNS) issued by the North Carolina Department of Environment and Natural Resources (NCDENR), the following annual report has been prepared. This report summarizes environmental monitoring of Lake Norman conducted during 1998.

OPERATIONAL DATA FOR 1998

The monthly average capacity factor of MNS averaged over 90% during July, August, and September of 1998 (Table 1-1). These are the months when conservation of cool water and discharge temperatures are most critical and the thermal limit for MNS increases from a monthly average of 95.0^{O}F (35.0^{O}C) to 99.0^{O}F (37.2^{O}C). The average monthly discharge temperature was 96.6^{O}F (35.9^{O}C) for July, 98.0^{O}F (36.7^{O}C) for August, and 95.9^{O}F (35.5^{O}C) for September 1998. Two of three low level intake water pumps of Unit 1 were operated to provide additional cooling for 7 days in August, 9 days in September, and 15 days in October of 1998. The volume of cool water in Lake Norman was tracked throughout the year to ensure that an adequate volume was available to comply with both the Nuclear Regulatory Commission Technical Specification requirements and the NPDES discharge water temperature limits.

Table 1-1. **Average monthly capacity factors (%) calculated from daily unit capacity factors [Net Generation (Mwe per unit day) x 100 / 24 h per day x 1129 mw per unit] and monthly average discharge water temperatures for McGuire Nuclear Station during 1998.**

Month	CAPACITY FACTOR (%)			NPDES DISCHARGE TEMPERATURE	
	Unit 1 Average	Unit 2 Average	Station Average	Monthly Average °F	°C
January	102.8	102.9	102.8	69.3	20.7
February	94.2	97.3	95.8	67.9	19.9
March	100.5	103.3	101.9	69.4	20.8
April	105.0	105.0	105.0	75.6	24.2
May	93.8	104.5	99.2	82.4	28.0
June	0.0	103.2	51.2	87.3	30.7
July	87.4	101.8	94.6	96.6	35.9
August	95.5	101.2	98.4	98.0	36.7
September	101.9	101.3	101.6	95.9	35.5
October	103.5	103.1	103.3	89.3	31.8
November	104.6	104.5	104.6	81.2	27.3
December	105.2	105.0	105.1	76.8	24.9

CHAPTER 2
LAKE NORMAN WATER CHEMISTRY

INTRODUCTION

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

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

This year's report focuses primarily on 1997 and 1998. Where appropriate, reference to pre-1997 data will be made by citing reports previously submitted to the North Carolina Department of Environment and Natural Resources (NCDENR).

METHODS AND MATERIALS

The complete water chemistry monitoring program, including specific variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1, whereas specific chemical methodologies, along with the appropriate references are presented in Table 2-2. Data were analyzed using two approaches, both of which were consistent with earlier studies (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998). The first method involved partitioning the reservoir into mixing, background, and discharge zones, and making comparisons among zones and years. In this report, the discharge includes only Location 4; the mixing zone encompasses Locations 1 and 5; the background zone includes Locations 8, 11, and 15. The second approach emphasized a much broader lake-wide investigation and encompassed the plotting of monthly isotherms and isopleths, and summer-time striped bass habitat. Several quantitative calculations were also performed; these included the calculation of the areal hypolimnetic oxygen deficit (AHOD), maximum whole-water column and hypolimnion oxygen content, maximum whole-water column and hypolimnion heat content, mean epilimnion and hypolimnion heating rates over the stratified period, and the Birgean heat budget.

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

$$Lt = A_0^{-1} \bullet \int TO \bullet Az \bullet dz$$

where;

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

RESULTS AND DISCUSSION

Precipitation Amount

Total annual precipitation in the vicinity of MNS in 1998 (33.5 inches) was appreciably less than measured in the 1997 (48.0 inches) (Figure 2-2). The highest total monthly rainfall in 1998 occurred in January with a value of 5.3 inches.

Temperature and Dissolved Oxygen

Water temperatures measured in 1998 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3, 2-4). This similarity in temperature patterns between zones has been a dominant feature of the thermal regime in Lake Norman since MNS began operations in 1983. Water temperatures in the winter of 1998 were generally similar to those measured in 1997 except in the epilimnion in the background zone where 1998 temperatures were 2 to 4 °C cooler than in 1997 (Figures 2-3 and 2-4). Minimum metalimnion and hypolimnion winter temperatures in 1998 measured 8 to 9 °C, and were similar to those measured in 1997 but noticeably warmer than the 5 to 6 °C corresponding temperatures in 1996. Some interannual variability in water temperatures during the spring months was observed, but these conditions were well within the observed historical variability and were not considered of biological significance (Duke Power Company 1985, 1989, 1991, 1993. 1994, 1995, 1996, 1997, and 1998). No major differences between 1997 and 1998 water temperatures were observed in either the mixing or background zones for the remainder of the lake's heating period.

Temperatures in the fall of 1998 were noticeably warmer in both the mixing and background zones, especially in November and December, than those measured at similar times in 1997 (Figures 2-3 and 2-4). These inter-year differences can be explained by the effect of El Nino on local meteorological conditions and the corresponding water column response; a warmer air temperature would result in delayed cooling of the water column.

Temperature data at the discharge location in 1998 were generally similar to 1997 (Figure 2-5) and historically (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998). The warmest temperature of 1998 at the discharge location occurred in August and measured 36.7 °C, or 0.7 °C cooler than measured in August, 1997 (Duke Power Company 1998).

Seasonal and spatial patterns of dissolved oxygen (DO) concentrations in 1998 were reflective of the patterns exhibited for temperature, i. e., generally similar in both the mixing and background zones (Figures 2-6 and 2-7). Winter and spring DO values in 1998 were generally higher than measured in 1997, and appeared to be related predominantly to the cooler water column temperatures measured in 1998 versus 1997. The cooler water temperatures would be expected to exhibit a higher oxygen content because of the direct effect of temperature on oxygen solubility, and indirectly via a enhanced convective mixing regime, which would promote reaeration. Summer DO values in 1998 were highly variable throughout the water column in both the mixing and background zones ranging from highs of 6 to 8 mg/L in the surface waters to lows of 0 to 2 mg/L in the bottom waters; this pattern is similar to that measured in 1997 and earlier years (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993,1994, 1995, 1996, and 1998). All dissolved oxygen values recorded in 1998 were well within the historic range (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993,1994, 1995, 1996, 1997, and 1998).

Considerable differences were observed between 1997 and 1998 fall and early-winter DO values in both the mixing and background zones, especially in the metalimnion and hypolimnion (Figures 2-6 and 2-7). Dissolved oxygen values in 1998 were appreciably lower than measured in 1997 and these differences are believed to be related to the effect of El Nino on water column cooling and reaeration. Warmer air temperatures would delay water column cooling (Figures 2-3 and 2-4) which, in turn, would delay the onset of convective mixing of the water column and the resultant reaeration of the metalimnion and hypolimnion. Interannual differences in DO are common in Southeastern reservoirs, particularly during the stratified period, and can reflect yearly differences in hydrological, meteorological, and limnological forcing variables (Cole and Hannon 1985; Petts1984).

The seasonal pattern of DO in 1998 at the discharge location was similar to that measured historically, with the highest values observed during the winter and lowest observed in the summer and early-fall (Figure 2-5). The lowest DO concentrations measured at the discharge location in 1998 (< 5.5 mg/L) were measured in July, August and September, and occurred concurrently with hypolimnetic water usage at MNS for condenser cooling water needs.

Reservoir-wide Temperature and Dissolved Oxygen

The monthly reservoir-wide temperature and dissolved oxygen data for 1998 are presented in Figures 2-8 and 2-9. These data are similar to that observed in previous years and are characteristic of cooling impoundments and hydropower reservoirs in the Southeast (Cole and Hannon, 1985; Hannon et. al., 1979; Petts, 1984). For a detailed discussion on the seasonal and spatial dynamics of temperature and dissolved oxygen during both the cooling and heating periods in Lake Norman, the reader is referred to earlier reports (Duke Power Company 1992, 1993, 1994, 1995, and 1996).

The seasonal heat content of both the entire water column and the hypolimnion for Lake Norman in 1998 are presented in Figure 2-10a; additional information on the thermal regime in the reservoir for the years 1997 and 1998 are found in Table 2-3. Annual minimum heat content for the entire water column in 1998 (8.97 Kcal/cm^2; 8.6 °C) occurred in early February, whereas the maximum heat content (29.5 Kcal/cm^2; 28.2 °C) occurred in early September. Heat content of the hypolimnion exhibited somewhat the same temporal trend as that observed for the entire water column. Annual minimum hypolimnetic heat content occurred in January and measured 5.4 Kcal/cm^2 (8.3 °C), whereas the maximum occurred in September and measured 15.92 Kcal/cm^2 (24.7 °C). Heating of both the entire water column and the hypolimnion occurred at approximately a linear rate from minimum to maximum heat content. The mean heating rate of the entire water column equalled 0.095 Kcal/cm^2/day versus 0.043 Kcal/cm^2/day for the hypolimnion. The 1998 heat content data were slightly elevated compared to previous years and appeared to be primarily related to the effects of El Nino (Duke Power Company 1992, 1993, 1994, 1995, 1996, 1997, and 1998).

The seasonal oxygen content and percent saturation of the whole water column and the hypolimnion for 1998 are depicted in Figure 2-10b. Additional oxygen data can be found in Table 2-4, which presents the 1998 AHOD for Lake Norman and similar estimates for 18 TVA reservoirs. Reservöir oxygen content was greatest in mid-winter when DO content measured 11 mg/L for the whole water and 10.9 mg/L for the hypolimnion. Percent saturation values at this time approached 98% for the entire water column and 95% for the hypolimnion. Beginning in early-spring, oxygen content began to decline precipitously in both the whole water column and the hypolimnion, and continued to do so in a linear fashion until reaching a minimum in mid-summer. Minimum summer DO values for the entire water column measured 4.3 mg/L (56% saturation), whereas the minimum for the hypolimnion was 0.3 mg/L (3.7% saturation). The mean rate of DO decline in the hypolimnion over the stratified period, i.e., the AHOD, was 0.051 $mg/cm^2/day$ (0.076 mg/L/day) (Figure 2-10b), and is similar to that measured in 1997 (Duke Power Company 1998).

Hutchinson (1938 and 1957) proposed that the decrease of dissolved oxygen in the hypolimnion of a waterbody should be related to the productivity of the trophogenic zone. Mortimer (1941) adopted a similar perspective and proposed the following criteria for AHOD associated with various trophic states; oligotrophic - $\leq$ 0.025 mg/cm^2 /day, mesotrophic - 0.026 $mg/cm^2/day$ to 0.054 $mg/cm^2/day$, and eutrophic - $\geq$ 0.055 $mg/cm^2/day$. Employing these limits, Lake Norman should be classified as mesotrophic based on the calculated AHOD value of 0.051 $mg/cm^2/day$. The oxygen based mesotrophic classification agrees well with the mesotrophic classification based on chlorophyll *a* levels (Chapter 3). The 1998 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 late- September 1997 through June 1998. Beginning in July 1998, 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 early August through September when no suitable habitat was observed in the reservoir except for a small refugium in the upper, riverine portion of the reservoir, near the confluence of Lyles Creek with Lake Norman. Habitat measured in the upper reaches of the reservoir at this time appeared to be influenced by both inflow from Lyles Creek and discharges from Lookout Shoals Hydroelectric facility, which were somewhat cooler than ambient conditions in Lake Norman. Upon entering Lake Norman, this water apparently mixes and then proceeds as a subsurface underflow (Ford 1985) as it migrates downriver.

Physicochemical habitat was observed to have expanded appreciably by early October, primarily as a result of epilimnion cooling and deepening, and in response to changing meteorological conditions. The temporal and spatial pattern of striped bass habitat expansion and reduction observed in 1998 was similar to that previously reported in Lake Norman and many other Southeastern reservoirs (Coutant 1985, Matthews 1985, Duke Power Company 1992, 1993, 1994, 1995, 1996, 1997, and 1998). These conditions were similar to that in 1994, 1996, and 1997 when no mortalities of striped bass were reported by local fishermen or observed by Duke Power Company personnel.

Turbidity and Specific Conductance

Surface turbidity values were generally low at the MNS discharge, mixing zone, and mid-lake background locations during 1998, ranging from 1.48 to 9.2 NTUs (Table 2-5). Bottom turbidity values were also relatively low over the study period, ranging from 2.9 to 31 NTUs (Table 2-5). These values were similar to those measured in 1997 (Table 2-5), and well within the historic range (Duke Power Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996,1997, and 1998).

Specific conductance in Lake Norman in 1998 ranged from 35 to 66 umho/cm, and was similar to that observed in 1997 (Table 2-5) and historically (Duke Power Company 1989, 1992, 1993, 1994, 1995, 1996, 1997, and 1998). Specific conductance values in surface and bottom waters were generally similar throughout the year except during the period of intense thermal stratification when bottom waters averaged about 10 umhos/cm higher than surface values. These increases in conductance appeared to be related primarily to the release of soluble iron and manganese from the lake bottom under anoxic conditions (Table 2-5). This phenomenon is common in both natural lakes and reservoirs that exhibit hypolimnetic oxygen depletion (Hutchinson 1957, Wetzel 1975).

pH and Alkalinity

During 1998, pH and alkalinity values were similar among MNS discharge, mixing and background zones (Table 2-5); they were also similar to values measured in 1997 (Table 2-5) and historically (Duke Power Company 1989,1992, 1993, 1994, 1995, 1996, 1997, and 1998). Individual pH values in 1998 ranged from 5.9 to 8.0, whereas alkalinity ranged from 10.5 to 18.5 mg/L of $CaCO_3$.

Major Cations and Anions

The concentrations (mg/L) of major ionic species in the MNS discharge, mixing, and mid-lake background zones are provided in Table 2-5. The overall ionic composition of Lake Norman during 1998 was similar to that reported for 1997 (Table 2-5) and previously (Duke Power Company 1989,1992, 1993, 1994, 1995, 1996, 1997, and 1998). Lake-wide, the major cations were sodium, calcium, magnesium, and potassium, whereas the major anions were bicarbonate, sulfate, and chloride.

Nutrients

Nutrient concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman are provided in Table 2-5. Overall, nitrogen and phosphorus levels in 1998 were similar to those measured in 1997 and historically (Duke Power Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998); they were also characteristic of the lake's oligo-mesotrophic status. Ammonia nitrogen concentrations increased in bottom waters in each of the two zones and at the discharge location during the summer and fall, concurrent with the development of anoxic conditions. Total and soluble phosphorus concentrations in 1998 were similar to values recorded in 1997 and historically (Duke Power Company 1989, 1990, 1991, 1992 , 1993, 1994, 1995, 1996, 1997, and 1998). Phosphorus values for several locations in November of 1998 appeared to be in error or possibly contaminated during processing or analysing, because orthophosphate (the soluble inorganic fraction of phosphorus) was reported to be greater than total phosphorus (Table 2-5).

Metals

Metal concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 1998 were similar to that measured in 1997 (Table 2-5) and historically (Duke

Power Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998). Iron concentrations near the surface were generally low (≤ 0.1 mg/L) during 1997 and 1998, whereas iron levels near the bottom were slightly higher during the stratified period. Similarly, manganese concentrations in the surface and bottom waters were generally low (≤ 0.1 mg/L) in both 1997 and 1998, except during the summer and fall when bottom waters were anoxic (Table 2-5). This phenomenon, i.e., the release of iron and manganese from bottom sediments because of increased solubility induced by low redox conditions (low oxygen levels), is common in stratified waterbodies (Wetzel 1975). Manganese concentrations near the bottom rose above the NC water quality standard (0.5 mg/L) at various locations throughout the lake in summer and fall of both years, and is characteristic of historic conditions (Duke Power Company 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998). Heavy metal concentrations in Lake Norman never approached NC water quality standards, and no consistent appreciable differences between 1997 and 1998 were noted.

FUTURE STUDIES

No changes are planned for the Water Chemistry portion of the Lake Norman maintenance monitoring program during 1999 or 2000.

SUMMARY

Temporal and spatial trends in water temperature and DO data collected in 1998 were similar to those observed historically. Temperature and DO data collected in 1998 were within the range of previously measured values.

Reservoir-wide isotherm and isopleth information for 1998, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics characteristic of historic conditions and similar to other Southeastern reservoirs of comparable size, depth, flow conditions, and trophic status.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 1998 was generally similar to historic conditions. Habitat reduction was most severe from early August through September when no suitable habitat was observed in the reservoir except for a small refugium in the upper, riverine portion of the reservoir.

All chemical parameters measured in 1998 were within the concentration ranges previously reported for the lake during both MNS preoperational and operational years. As has been observed historically, manganese concentrations in the bottom waters in the summer and fall of 1998 often exceeded the NC water quality standard. This is characteristic of waterbodies that experience hypolimnetic deoxygenation during the summer.

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Table 2-1. Water chemistry program for the McGuire Nuclear Station NPDES long-term maintenace monitoring on Lake Norman.

1998 McGUIRE NPDES SAMPLING PROGRAM

PARAMETERS	LOCATIONS	1.0	2.0	4.0	5.0	8.0	9.5	11.0	13.0	14.0	15.0	15.9	62.0	69.0	72.0	80.0	16.0
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
	SAM CODE	IN-SITU ANALYSIS															
Temperature	Hydrolab	In-situ measurements are collected monthly at the above locations at 1m intervals from 0.3m to 1m above bottom. Measurements are taken weekly from July-August for striped bass habitat.															
Dissolved Oxygen	Hydrolab																
pH	Hydrolab																
Conductivity	Hydrolab																
		NUTRIENT ANALYSES															
Ammonia	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Nitrate+Nitrite	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Orthophosphate	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Total Phosphorus	AA-TP,DG-P	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Silica	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cl	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
TKN	AA-TKN	S/T,B												S/T,B			S/T
		ELEMENTAL ANALYSES															
Aluminum	ICP-24	Q/T,B	S/T,B	S/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Calcium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Iron	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Magnesium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Manganese	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Potassium	306-K	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sodium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Zinc	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cadminum	HGA-CD		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Copper	HGA-CU		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Lead	HGA-PB		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
		ADDITIONAL ANALYSES															
Alkalinity	T-ALKT	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Turbidity	F-TURB	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sulfate	UV_SO4		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T
Total Solids	S-TSE		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T
Total Suspended Sc	S-TSSE		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T

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

Table 2-2. Water chemistry methods and analyte detection limits for the McGuire Nuclear Station NPDES long-term maintenance program for Lake Norman.

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

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

Table 2-3. Heat content calculations for the thermal regime in Lake Norman in 1997 and 1998.

	1997	1998
Maximum areal heat content (g cal/cm^2)	28,019	28,432
Minimum areal heat content (g cal/cm^2)	8,547	8,970
Maximum hypolimnetic (below 11.5 m) areal heat content (g cal/cm^2)	15,766	15,917
Birgean heat budget (g cal/cm^2)	19,472	19,462
Epilimnion (above 11.5 m) heating rate (°C /day)	0.094	0.84
Hypolimnion (below 11.5 m) heating rate (°C /day)	0.074	0.079

Table 2-4. A comparison of areal hypolimnetic oxygen deficits (AHOD), summer chlorophyll a (chl a), secchi depth (SD), and mean depth of Lake Norman and 18 TVA reservoirs.

Reservoir	- AHOD ($mg/cm^2/day$)	Summer Chl a (ug/L)	Secchi Depth (m)	Mean Depth (m)
Lake Norman	0.051	11.7	1.9	10.3
TVA [a]				
Mainstem				
Kentucky	0.012	9.1	1.0	5.0
Pickwick	0.010	3.9	0.9	6.5
Wilson	0.028	5.9	1.4	12.3
Wheelee	0.012	4.4		5.3
Guntersville	0.007	4.8	1.1	5.3
Nickajack	0.016	2.8	1.1	6.8
Chickamauga	0.008	3.0	1.1	5.0
Watts Bar	0.012	6.2	1.0	7.3
Fort London	0.023	5.9	0.9	7.3
Tributary				
Chatuge	0.041	5.5	2.7	9.5
Cherokee	0.078	10.9	1.7	13.9
Douglas	0.046	6.3	1.6	10.7
Fontana	0.113	4.1	2.6	37.8
Hiwassee	0.061	5.0	2.4	20.2
Norris	0.058	2.1	3.9	16.3
South Holston	0.070	6.5	2.6	23.4
Tims Ford	0.059	6.1	2.4	14.9
Watauga	0.066	2.9	2.7	24.5

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

Table 2-5. Quarterly surface (0.3 m) and bottom (bottom minus 1 m) water chemistry for the MNS discharge, mixing zone, and background locations on Lake Norman during 1997 and 1998. Values less than detection were assumed to be the detection limit for calculating a mean.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97
Turbidity (ntu)																						
Feb	2.8	4.5	4.5	4.6	5.4	2.8	8.3	3.4	4.7	3.3	3	5.7	NS	4.5	9.2	2.9	4.2	5.3	NS	3.6	31	11.1
May	2.7	6.4	6.4	8.5	2.5	10.3	7.1	3.3	3.1	11.3	2.7	3.3	5.4	16.1	1.78	4.0	7.1	3.3	2.3	14.5	8.1	10.5
Aug	1.7	2.86	2.9	4.9	1.52	1.9	3.3	4.5	1.48	3.8	1.76	2.0	6.84	1.8	1.65	4.8	8.05	2.0	3.05	7.1	17.6	4.1
Nov	2.2	7.6	7.6	2.0	2.0	2.9	3.7	4.3	2.0	2.8	2.1	2.2	8.5	4.4	2.5	2.6	4.7	2.5	3.9	2.2	3.2	4.6
Annual Mean	2.35	5.34	5.34	5.0	2.84	4.5	5.60	3.9	2.83	5.3	2.40	3.3	6.91	6.7	3.79	3.6	6.01	3.3	3.07	6.9	14.98	7.6
Specific Conductance (umho/cm)																						
Feb	58	51	60	50	58	51	60	50	60	52	59	51	58	50	62	49	'58	49	58	48	53	47
May	42	54	38	55	46	54	38	55	40	55	40	55	45	55	40	54	38	55	35	51	37	54
Aug	54	49	66	58	55	49	61	58	55	50	56	49	65	57	55	48	63	57	55	48	64	59
Nov	55	53	58	53		53		53	56	54	55	53	55	53	55	53	57	53	58	54	57	54
Annual Mean	52.3	51.8	55.5	54.0	53.0	51.8	53.0	54.0	52.8	52.8	52.5	52.0	55.8	53.8	53.0	51.0	54.0	53.5	51.5	50.3	52.8	53.5
pH (units)																						
Feb	6.4	6.6	6.6	6.6	6.5	6.7	6.6	6.6	6.4	6.6	6.8	6.8	6.6	6.6	6.5	6.9	6.6	6.5	6.6	6.8	6.4	6.4
May	6.6	6.7	5.9	5.9	6.6	6.7	6.0	5.9	6.3	6.6	6.4	6.8	6.0	6.0	6.7	6.8	6.0	6.0	6.9	7.6	5.9	5.9
Aug	7.5	6.8	6.4	6.0	7.4	6.7	6.3	6.0	7.1	6.5	7.3	6.7	6.4	6.0	8.0	7.0	6.3	6.0	7.1	6.8	6.3	6.1
Nov	7.0	6.6	6.6	6.5		6.6		6.5	6.9	6.6	7.2	6.6	6.8	6.6	7.1	6.7	6.7	6.6	7.3	6.6	6.7	6.4
Annual Mean	6.88	6.68	6.38	6.25	6.83	6.68	6.30	6.25	6.68	6.58	6.93	6.73	6.45	6.30	7.08	6.85	6.40	6.28	6.98	6.95	6.33	6.20
Alkalinity (mg CaCO3/l)																						
Feb	13.5	13.0	13.0	13.0	12.5	12.5	13.0	10.0	13.5	9.5	11.5	12.5	NS	11.0	12.0	11.0	12.0	13.0	NS	11.0	10.5	12.5
May	11.0	11.5	11.0	11.5	11.0	11.5	11.5	11.5	11.0	11.5	12.0	12.0	11.5	12.0	11.5	11.5	10.5	12.5	11.0	11.5	10.5	12.0
Aug	13.0	11.5	15.5	16.0	13.0	10.5	15.5	14.0	13.0	12.0	11.0	10.5	18.5	16.5	13.0	11.0	17.0	15.5	13.5	12.0	16.5	16.5
Nov	14.0	13.0	17.5	11.5	14.0	13.5	14.0	12.0	14.0	13.5	13.5	12.5	14.5	12.0	14.0	12.0	14.0	13.0	13.5	12.0	14.0	13.0
Annual Mean	12.88	12.25	14.25	13.00	12.63	12.00	13.50	11.88	12.88	11.63	12.00	11.88	14.83	12.88	12.63	11.38	13.38	13.50	12.67	11.63	12.88	13.50
Chloride (mg/l)																						
Feb	5.5	5.5	5.9	5.5	5.5	5.7	5.9	5.5	5.6	5.5	5.4	5.6	NS	5.4	6.1	5.4	5.7	5.3	NS	5.0	5.1	4.9
May	4.3	5.2	4.4	5.2	4.3	5.4	4.4	5.4	4.4	4.9	4.2	5.4	4.5	5.2	4.4	5.0	4.2	5.2	3.8	4.9	4.1	5.3
Aug	4.1	5.4	4.5	5.7	4.3	4.7	4.3	4.9	4.1	5.1	4.2	5.9	4.2	8.8	4.5	5.2	4.2	5.2	4.1	4.6	4.2	5.0
Nov	4.3	4.8	4.8	4.8	4.4	4.7	4.5	4.8	4.4	4.8	4.3	4.8	4.4	4.9	4.6	4.8	4.3	4.8	4.7	5.1	4.7	5.1
Annual Mean	4.55	5.23	4.90	5.30	4.63	5.13	4.78	5.15	4.63	5.08	4.53	5.43	4.37	6.08	4.90	5.10	4.60	5.13	4.20	4.90	4.53	5.08
Sulfate (mg/l)																						
Feb	NS	NS	NS	NS	4.9	3.7	6.5	5.8	5.8	4.0	NS	NS	NS	NS	8.4	3.6	8.4	4.5	NS	NS	NS	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	NS	NS	NS	NS	5.2	3.6	4.6	3.9	5.4	3.4	NS	NS	NS	NS	5.0	4.1	1.6	3.5	NS	NS	NS	NS
Nov	NS	NS	NS	NS	4.0	NS	5.3	NS	3.7	NS	NS	NS	NS	NS	3.8	NS	3.8	NS	NS	NS	NS	NS
Annual Mean					4.70	3.65	5.47	4.85	4.97	3.70					5.73	3.85	4.60	4.00				
Calcium (mg/l)																						
Feb	2.58	2.66	2.62	2.66	2.58	2.64	2.64	2.64	2.64	2.64	2.67	2.63	NS	2.60	2.70	2.70	2.62	2.67	NS	2.85	2.82	2.89
May	2.76	2.81	2.82	2.86	2.70	2.80	2.83	2.88	2.76	2.81	2.60	2.78	2.79	2.86	2.73	2.82	2.85	2.90	2.73	2.81	2.90	2.97
Aug	2.88	2.60	3.14	3.17	2.87	2.68	3.13	3.14	2.86	2.68	2.77	2.69	3.22	3.18	2.90	2.62	3.27	3.17	2.98	2.65	3.22	3.17
Nov	2.86	2.77	2.83	2.76	2.91	2.74	2.92	2.74	2.91	2.75	2.89	2.74	2.90	2.64	2.89	2.73	2.85	2.79	2.68	2.53	2.70	2.51
Annual Mean	2.77	2.71	2.85	2.86	2.76	2.71	2.88	2.85	2.79	2.72	2.73	2.71	2.97	2.82	2.80	2.72	2.90	2.88	2.79	2.71	2.91	2.88
Magnesium (mg/l)																						
Feb	1.34	1.29	1.33	1.29	1.33	1.28	1.33	1.28	1.35	1.29	1.36	1.28	NS	1.26	1.32	1.28	1.34	1.26	NS	1.26	1.25	1.26
May	1.23	1.23	1.23	1.26	1.19	1.22	1.25	1.26	1.21	1.23	1.21	1.35	1.24	1.30	1.21	1.23	1.23	1.27	1.14	1.20	1.23	1.27
Aug	1.29	1.26	1.36	1.37	1.31	1.30	1.36	1.37	1.29	1.30	1.31	1.23	1.38	1.26	1.30	1.27	1.40	1.37	1.33	1.28	1.39	1.38
Nov	1.34	1.36	1.40	1.37	1.37	1.34	1.37	1.34	1.36	1.36	1.37	1.31	1.35	1.39	1.35	1.36	1.36	1.38	1.35	1.33	1.37	1.33
Annual Mean	1.30	1.29	1.33	1.32	1.30	1.28	1.33	1.31	1.30	1.29	1.31	1.29	1.32	1.30	1.30	1.28	1.33	1.32	1.27	1.27	1.31	1.31

NS = Not Sampled

Table 2-5. (Continued)

PARAMETERS	Mixing Zone 1.0 Surface 98	Mixing Zone 1.0 Surface 97	Mixing Zone 1.0 Bottom 98	Mixing Zone 1.0 Bottom 97	Mixing Zone 2.0 Surface 98	Mixing Zone 2.0 Surface 97	Mixing Zone 2.0 Bottom 98	Mixing Zone 2.0 Bottom 97	MNS Discharge 4.0 Surface 98	MNS Discharge 4.0 Surface 97
Potassium (mg/l)										
Feb	1.70	1.76	1.74	1.77	1.65	1.75	1.68	1.74	1.63	1.75
May	1.54	1.58	1.51	1.56	1.47	1.60	1.52	1.60	1.46	1.55
Aug	1.63	1.42	1.63	1.56	1.59	1.52	1.64	1.52	1.57	1.51
Nov	1.59	1.56	1.76	1.57	1.63	1.56	1.72	1.55	1.63	1.59
Annual Mean	1.62	1.58	1.66	1.62	1.59	1.61	1.64	1.60	1.57	1.60
Sodium (mg/l)										
Feb	4.95	6.24	5.14	5.70	4.80	6.03	4.83	5.80	4.68	5.59
May	3.99	4.69	3.85	4.54	3.83	4.82	3.98	4.55	4.09	4.75
Aug	5.70	3.71	5.66	3.90	5.31	4.00	6.25	3.68	5.28	3.81
Nov	4.36	4.95	5.36	4.56	4.77	4.65	4.21	4.60	4.86	4.84
Annual Mean	4.75	4.90	5.00	4.68	4.68	4.88	4.82	4.66	4.73	4.75
Aluminum (mg/l)										
Feb	0.12	0.11	0.184	0.12	0.139	0.10	0.168	0.11	0.144	0.09
May	0.25	0.09	0.25	0.09	0.141	0.10	0.221	0.09	0.188	0.12
Aug	< 0.090	0.03	0.103	0.09	< 0.09	0.06	0.116	0.08	< 0.09	0.06
Nov	< 0.09	< 0.09	0.12	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09
Annual Mean	0.14	0.08	0.165	0.10	0.115	0.09	0.149	0.09	0.128	0.09
Iron (mg/l)										
Feb	0.071	0.041	0.128	0.082	0.062	0.054	0.138	0.056	0.080	0.046
May	0.075	0.218	0.168	0.095	0.040	0.035	0.176	0.072	0.095	0.041
Aug	0.030	0.016	0.226	0.262	0.033	0.066	0.273	0.221	0.039	0.043
Nov	0.043	0.077	0.265	0.114	0.055	0.059	0.110	0.093	0.057	0.055
Annual Mean	0.055	0.088	0.197	0.138	0.048	0.054	0.174	0.111	0.068	0.046
Manganese (mg/l)										
Feb	0.01	0.01	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01
May	0.01	0.01	0.04	0.04	0.01	0.01	0.05	0.03	0.01	0.01
Aug	0.03	0.02	1.30	1.50	0.03	0.02	1.22	1.31	0.06	0.04
Nov	0.06	0.04	1.36	0.06	0.06	0.04	0.20	0.05	0.08	0.04
Annual Mean	0.03	0.02	0.68	0.41	0.03	0.02	0.37	0.35	0.04	0.02
Cadmium (ug/l)										
Feb	NS	NS	NS	NS	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.1
May	NS	NS	NS	NS	NA	NS	NS	NS	< NS	NS
Aug	NS	NS	NS	NS	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.1
Nov	NS	NS	NS	NS	< 0.5	NS	< 0.5	NS	< 0.5	NS
Annual Mean					< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.1
Copper (ug/l)										
Feb	NS	NS	NS	NS	2.4	2.4	3.9	2.0	4.5	2.2
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	NS	NS	NS	NS	1.0	1.5	1.5	0.9	1.1	0.9
Nov	NS	NS	NS	NS	1.2	NS	< 1.0	NS	1.1	NS
Annual Mean					1.5	2.0	2.1	1.5	2.2	1.6
Lead (ug/l)										
Feb	NS	NS	NS	NS	< 2	< 2	< 2	< 2	< 2	< 2
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	NS	NS	NS	NS	< 2	< 2	< 2	< 2	< 2	< 2
Nov	NS	NS	NS	NS	< 2	NS	< 2	NS	< 2	NS
Annual Mean					< 2	< 2	< 2	< 2	< 2	< 2

PARAMETERS	Mixing Zone 5.0 Surface 98	Mixing Zone 5.0 Surface 97	Mixing Zone 5.0 Bottom 98	Mixing Zone 5.0 Bottom 97	Background 8.0 Surface 98	Background 8.0 Surface 97	Background 8.0 Bottom 98	Background 8.0 Bottom 97	Background 11.0 Surface 98	Background 11.0 Surface 97	Background 11.0 Bottom 98	Background 11.0 Bottom 97
Potassium (mg/l)												
Feb	1.69	1.73	NS	1.72	1.73	1.72	1.68	1.69	NS	1.65	1.73	1.67
May	1.55	1.55	1.48	1.56	1.46	1.57	1.52	1.61	1.34	1.48	1.54	1.51
Aug	1.64	1.50	1.68	1.58	1.65	1.55	1.63	1.57	1.64	1.55	1.64	1.58
Nov	1.64	1.55	1.62	1.48	1.64	1.54	1.62	1.59	1.70	1.56	1.67	1.61
Annual Mean	1.63	1.58	1.59	1.59	1.62	1.60	1.61	1.62	1.56	1.56	1.65	1.59
Sodium (mg/l)												
Feb	4.68	6.06	NS	5.91	5.24	5.77	4.66	5.94	NS	5.22	4.37	4.88
May	4.27	4.74	4.05	4.43	3.87	4.55	3.96	4.75	3.77	4.16	4.73	4.38
Aug	5.55	3.84	6.61	3.96	5.73	4.23	5.69	3.96	5.56	4.26	5.68	3.99
Nov	4.76	4.73	4.78	4.54	5.20	4.50	5.02	4.74	5.35	4.87	1.67	5.17
Annual Mean	4.82	4.84	5.15	4.71	5.01	4.76	4.83	4.85	4.89	4.63	4.11	4.61
Aluminum (mg/l)												
Feb	0.123	0.11	NS	0.11	0.206	0.13	0.157	0.11	NS	0.18	0.356	0.19
May	0.238	0.12	0.153	0.16	0.116	0.10	0.278	0.09	0.117	0.10	0.323	0.13
Aug	0.11	0.06	0.134	0.08	0.118	0.06	< 0.09	0.09	0.106	0.05	0.2	0.09
Nov	0.09	< 0.09	0.16	< 0.09	0.09	< 0.09	< 0.09	0.18	< 0.09	< 0.09	0.09	< 0.09
Annual Mean	0.141	0.10	0.149	0.11	0.133	0.09	0.154	0.12	0.104	0.11	0.243	0.12
Iron (mg/l)												
Feb	0.054	0.048	NS	0.053	0.134	0.056	0.087	0.081	NS	0.124	0.348	0.231
May	0.074	0.036	0.115	0.075	0.050	0.028	0.143	0.095	0.081	0.040	0.164	0.106
Aug	0.031	0.036	0.964	0.293	0.032	0.031	0.821	0.394	0.051	0.026	0.750	0.257
Nov	0.049	0.075	0.226	0.060	0.066	0.053	0.126	0.325	0.071	0.112	0.083	0.075
Annual Mean	0.052	0.049	0.435	0.120	0.071	0.042	0.294	0.224	0.068	0.076	0.336	0.167
Manganese (mg/l)												
Feb	0.02	0.01	NS	0.03	0.02	0.01	0.02	0.04	NS	0.03	0.06	0.09
May	0.01	0.01	0.04	0.04	<0.0050	0.01	0.03	0.04	0.01	0.01	0.04	0.06
Aug	0.04	0.03	1.66	1.63	0.02	0.01	1.69	1.44	0.06	0.03	1.49	1.56
Nov	0.07	0.06	0.56	0.05	0.06	0.03	0.15	0.10	0.07	0.06	0.07	0.05
Annual Mean	0.03	0.03	0.75	0.44	0.04	0.01	0.47	0.40	0.04	0.03	0.41	0.44
Cadmium (ug/l)												
Feb	NS	NS	NS	NS	< 0.5	< 0.1	< 0.5	< 0.1	NS	NS	NS	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	NS	NS	NS	NS	< 0.5	< 0.1	< 0.5	< 0.1	NS	NS	NS	NS
Nov	NS	NS	NS	NS	< 0.5	NS	< 0.5	NS	NS	NS	NS	NS
Annual Mean					< 0.5	< 0.1	< 0.5	< 0.1				
Copper (ug/l)												
Feb	NS	NS	NS	NS	3.4	1.9	2.7	1.8	NS	NS	NS	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	NS	NS	NS	NS	1.3	0.9	< 1.0	1.3	NS	NS	NS	NS
Nov	NS	NS	NS	NS	1.6	NS	1.2	NS	NS	NS	NS	NS
Annual Mean					2.1	1.4	1.6	1.6				
Lead (ug/l)												
Feb	NS	NS	NS	NS	< 2	< 2	< 2	< 2	NS	NS	NS	NS
May	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aug	NS	NS	NS	NS	< 2	< 2	< 2	< 2	NS	NS	NS	NS
Nov	NS	NS	NS	NS	< 2	NS	< 2	NS	NS	NS	NS	NS
Annual Mean					< 2	< 2	< 2	< 2				

NS = Not sampled

Table 2-5. (Continued)

PARAMETERS	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
YEAR:	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97
Zinc (ug/l)																						
Feb	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	NS	< 5	< 5	< 5	< 5	< 5	NS	< 5	< 5	< 5
May	10	< 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	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	< 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	6.3	< 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	5.3	< 5.0	< 5.0
Nitrate (ug/l)																						
Feb	200	250	210	200	180	210	220	210	190	230	180	250	NS	210	290	230	200	250	NS	300	360	350
May	310	280	410	380	300	300	400	380	310	280	300	330	380	360	290	280	400	380	260	230	400	410
Aug	< 50	130	390	310	< 50	130	380	320	< 50	140	< 50	150	< 50	260	< 50	100	240	280	80	120	410	240
Nov	80	90	90	90	70	90	< 50	90	70	90	70	90	< 50	90	70	100	80	90	140	150	160	140
Annual Mean	160.0	187.5	275.0	245.0	150.0	182.5	262.5	250.0	155.0	185.0	150.0	205.0	160.0	230.0	175.0	177.5	230.0	250.0	160.0	200.0	332.5	285.0
Ammonia (ug/l)																						
Feb	< 50	50	50	< 50	< 50	< 50	< 50	60	< 50	< 50	< 50	< 50	NS	60	50	< 50	< 50	60	NS	< 50	100	60
May	< 50	< 50	< 50	< 50	< 50	60	< 50	< 50	< 50	80	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Aug	< 50	< 50	< 50	90	< 50	< 50	60	70	< 50	< 50	< 50	< 50	180	130	< 50	< 50	70	80	< 50	< 50	60	80
Nov	90	60	310	60	80	60	130	50	80	50	80	60	180	60	80	< 50	110	< 50	60	< 50	50	< 50
Annual Mean	60.0	52.5	115.0	62.5	57.5	55.0	72.5	57.5	57.5	57.5	57.5	52.5	136.7	75.0	57.5	< 50.0	70.0	60.0	53.3	< 50.0	65.0	60.0
Total Phosphorous (ug/l)																						
Feb	7	10	8	12	7	13	11	15	8	9	7	8	NS	8	23	8	11	23	NS	14	46	25
May	8	9	10	26	9	10	11	7	8	6	6	9	62	< 5	7	6	12	11	12	17	16	25
Aug	73	11	6	18	5	10	6	19	5	11	5	7	5	16	5	8	7	8	6	17	30	8
Nov	< 5	12	13	10	< 5	10	5	9	< 5	7	< 5	9	6	9	< 5	9	< 5	24	< 5	10	8	7
Annual Mean	23.3	10.5	9.3	16.5	6.5	10.8	8.3	12.5	6.5	8.3	5.8	8.3	24.3	9.5	10.0	7.8	8.8	16.5	7.7	14.5	25.0	16.3
Orthophosphate (ug/l)																						
Feb	5	< 5	< 5	< 5	< 5	5	< 5	6	< 5	5	< 5	5	NS	< 5	6	< 5	7	< 5	NS	< 5	18	8
May	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	7	< 5	< 5	< 5	< 5	< 5	< 5	5	< 5	< 5	< 5	< 5	< 5
Aug	< 5	< 5	< 5	5	< 5	< 5	< 5	7	< 5	8	< 5	8	< 5	12	< 5	8	< 5	6	< 5	< 5	< 5	10
Nov	23	< 5	24	< 5	20	< 5	6	< 5	17	< 5	< 5	2	11	< 5	< 5	< 5	< 5	< 5	8	< 5	< 5	< 5
Annual Mean	9.5	< 5.0	9.8	5.0	8.8	5.0	5.3	6	8.0	6	< 5.0	5	7.0	7	5.3	6	5.5	5	6.0	< 5	8.3	7
Silica (mg/l)																						
Feb	3.0	2.9	3.6	3.0	3.0	2.9	3.6	3.0	3.2	2.9	3.0	3.0	NS	3.0	4.5	3.1	3.4	3.4	NS	3.8	4.5	4.1
May	3.9	3.5	4.5	4.3	3.9	3.5	4.5	4.3	4.0	3.5	4.0	3.6	4.5	4.2	3.9	3.6	4.5	4.4	3.6	3.1	4.6	4.6
Aug	2.5	1.9	5.0	5.0	2.5	2.0	4.9	4.9	2.5	2.0	2.6	2.1	4.5	4.3	2.4	1.7	5.1	4.8	3.2	2.2	4.9	4.8
Nov	3.6	2.9	4.7	2.8	3.6	2.8	3.6	2.8	3.7	2.8	3.6	2.9	3.9	2.9	3.7	2.8	3.9	2.7	4.5	3.5	4.5	3.5
Annual Mean	3.3	2.8	4.5	3.8	3.3	2.8	4.2	3.8	3.4	2.8	3.3	2.9	4.3	3.6	3.6	2.8	4.2	3.8	3.8	3.2	4.6	4.3

NS = Not Sampled

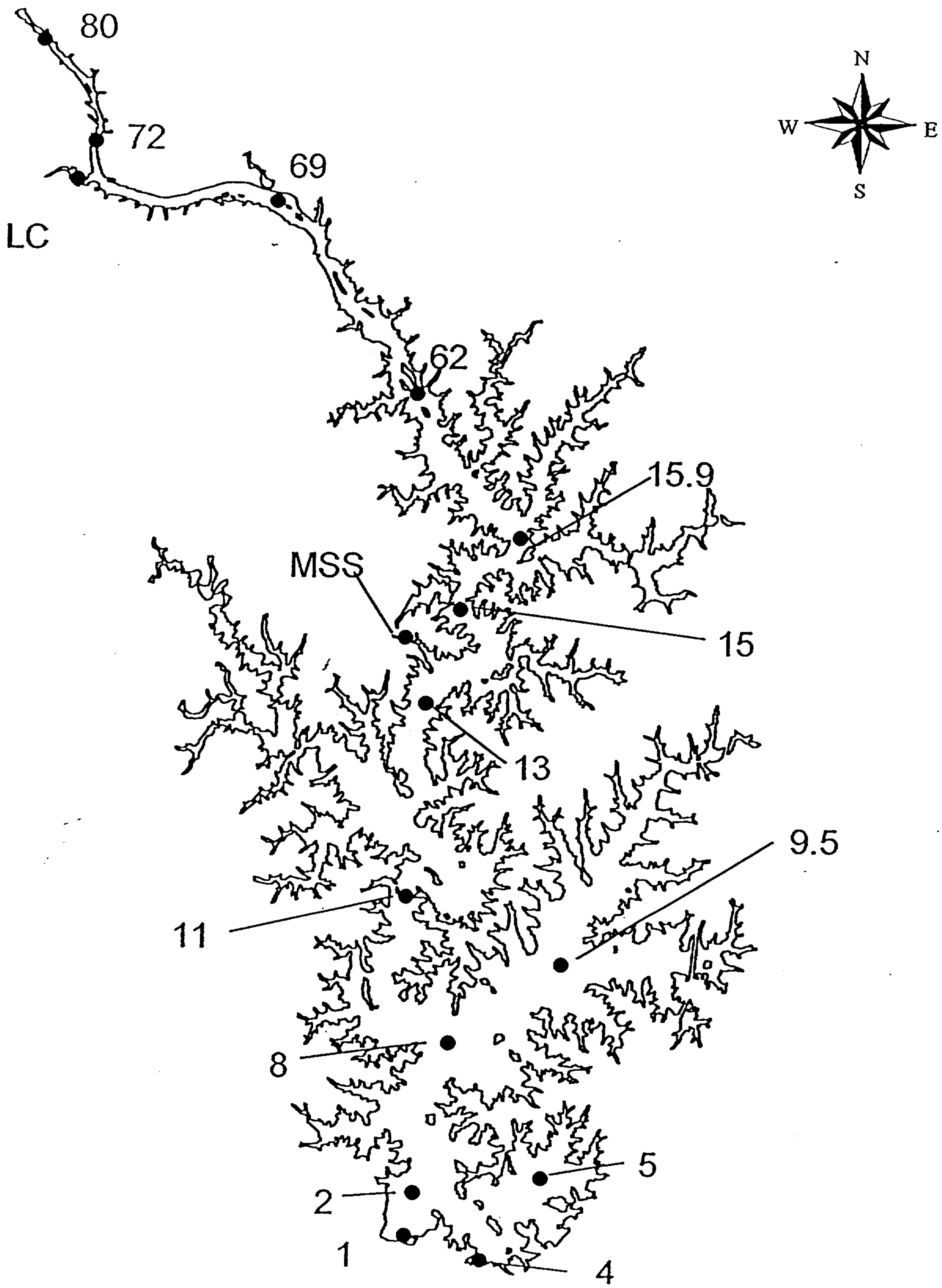

Figure 2-1. Water quality sampling locations for Lake Norman.

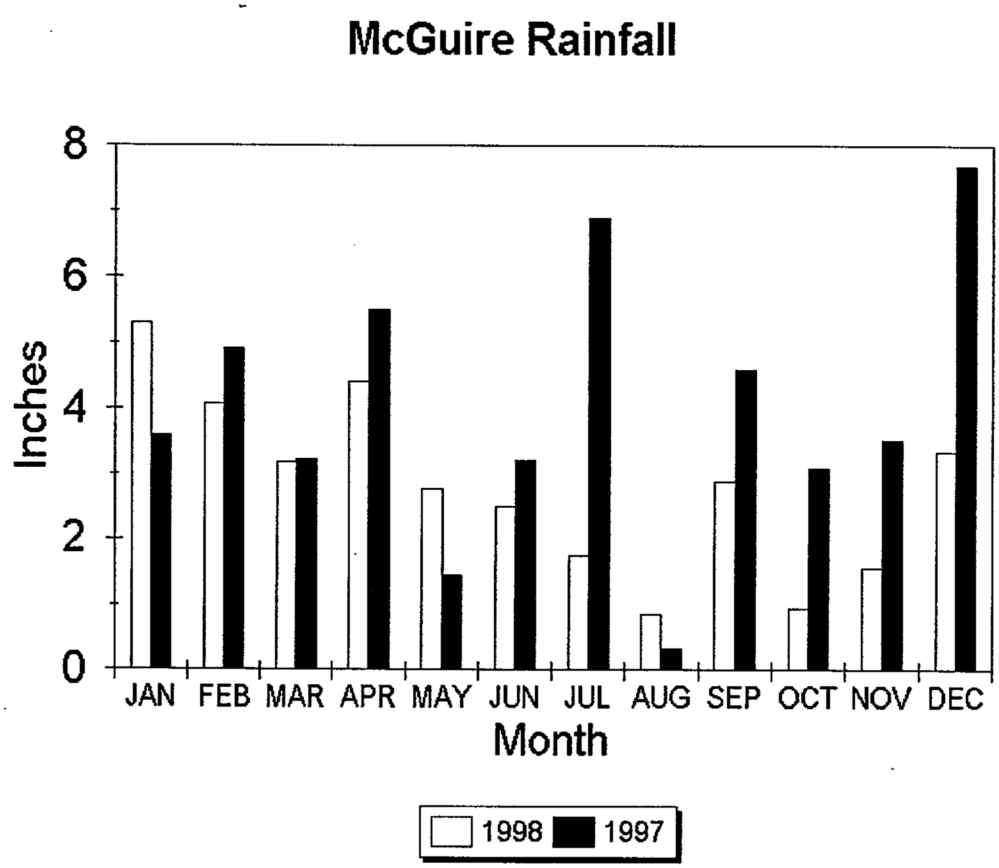

Figure 2-2. Monthly precipitation in the vicinity of McGuire Nuclear Station.

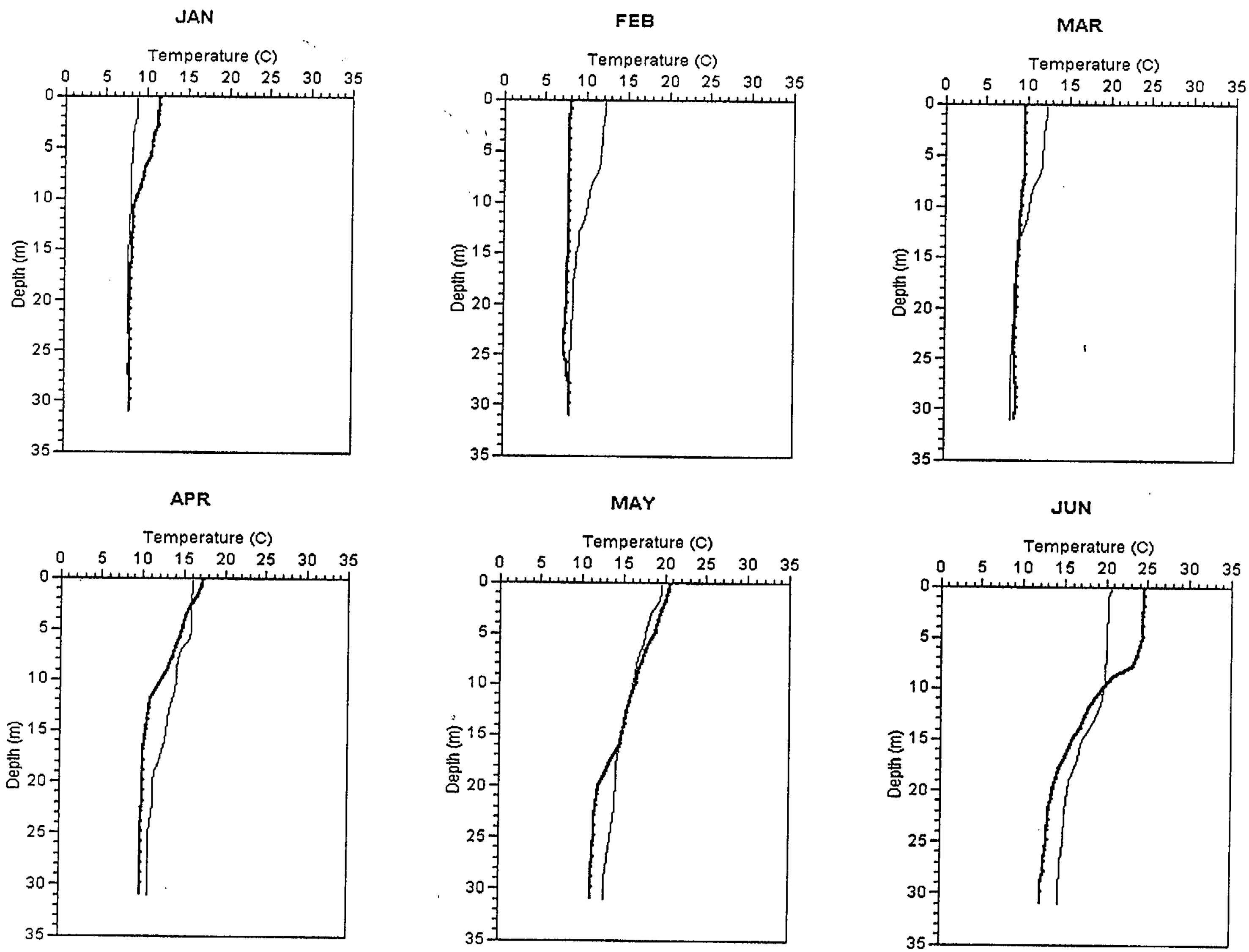

Figure 2-3. Monthly mean temperature profiles for McGuire Nuclear Station background zone in 1997 (–) and 1998 (▬).

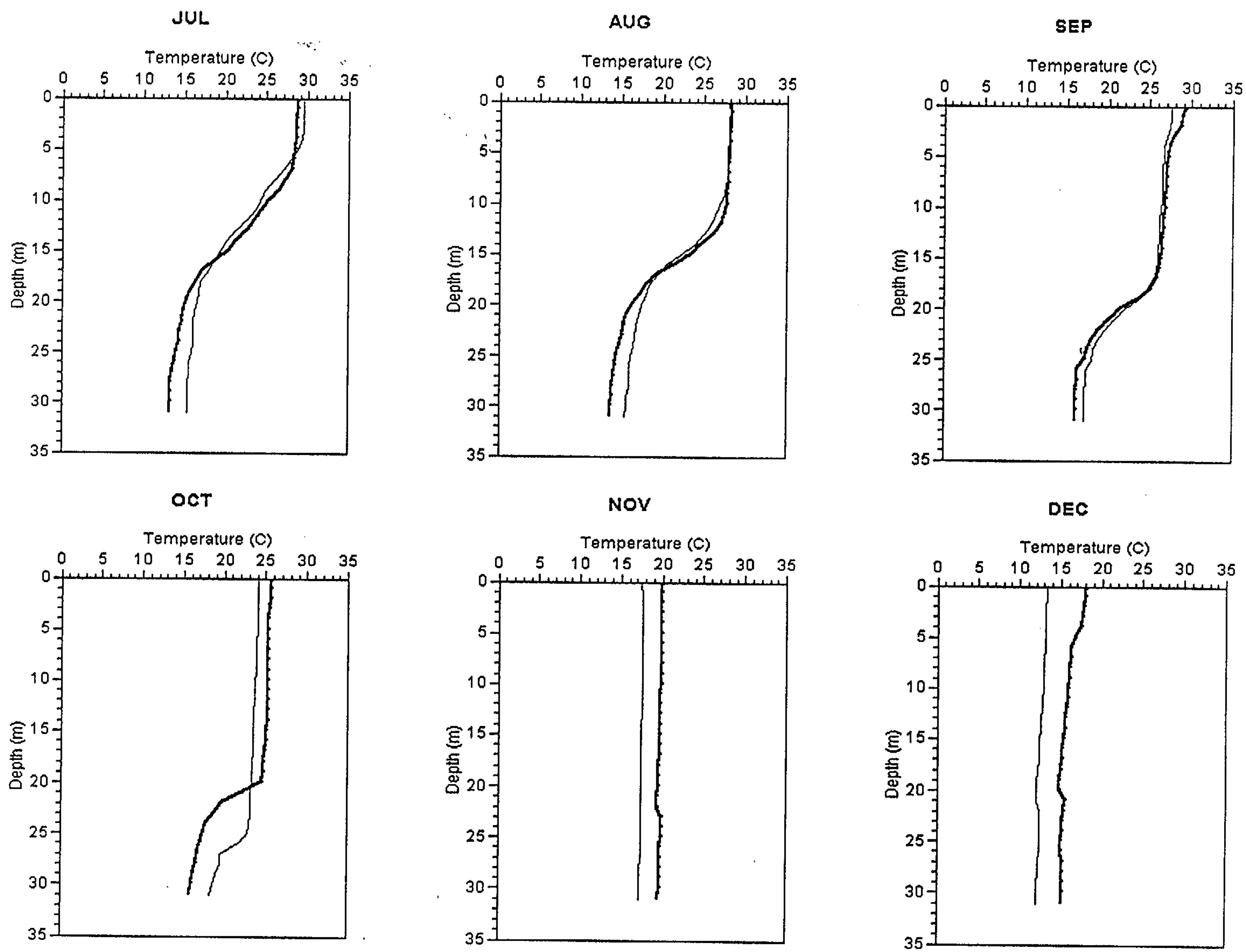

Figure 2-3. Monthly mean temperature profiles for McGuire Nuclear Station background zone in 1997 (–) and 1998 (▬).

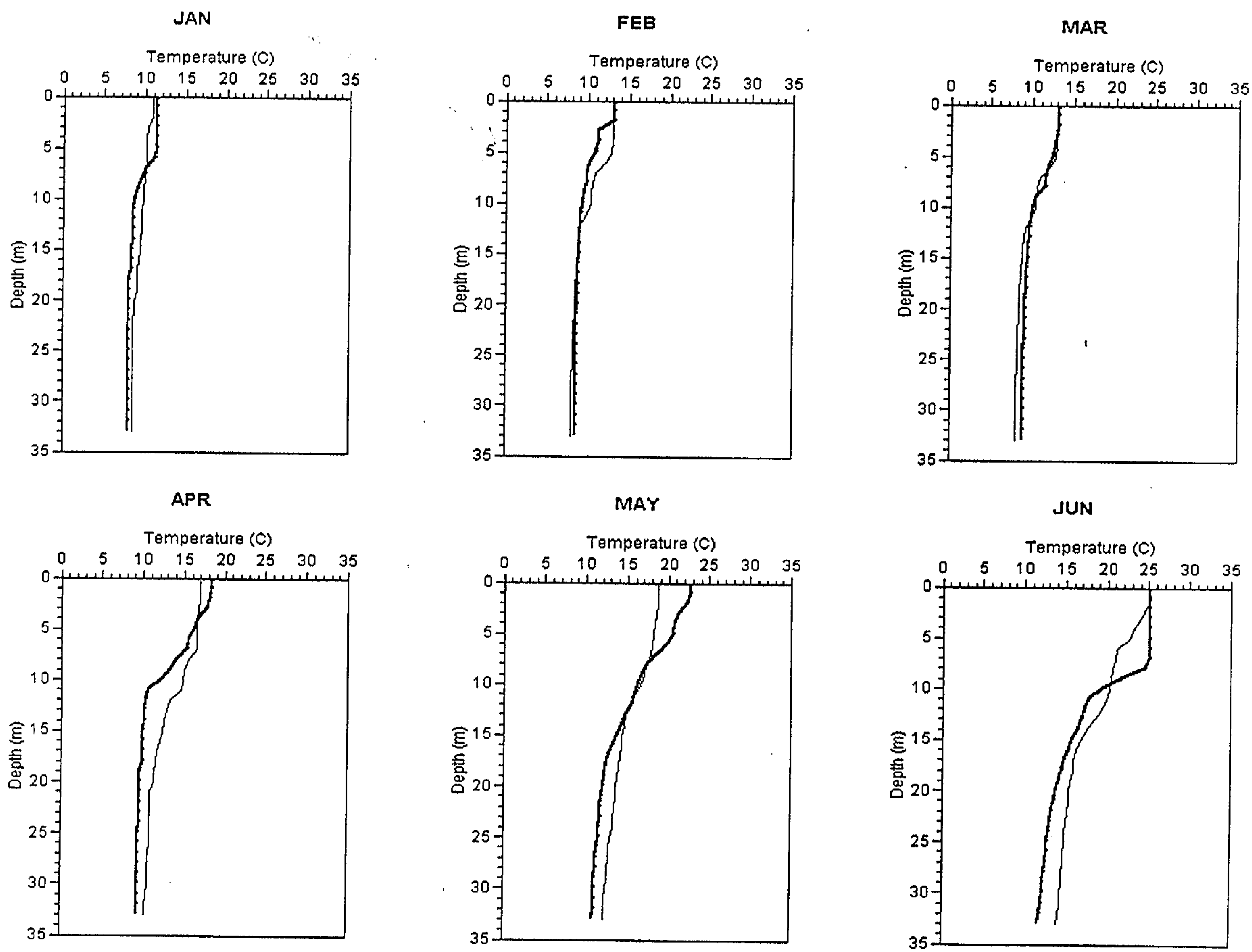

Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 1997 (–) and 1998 (▬).

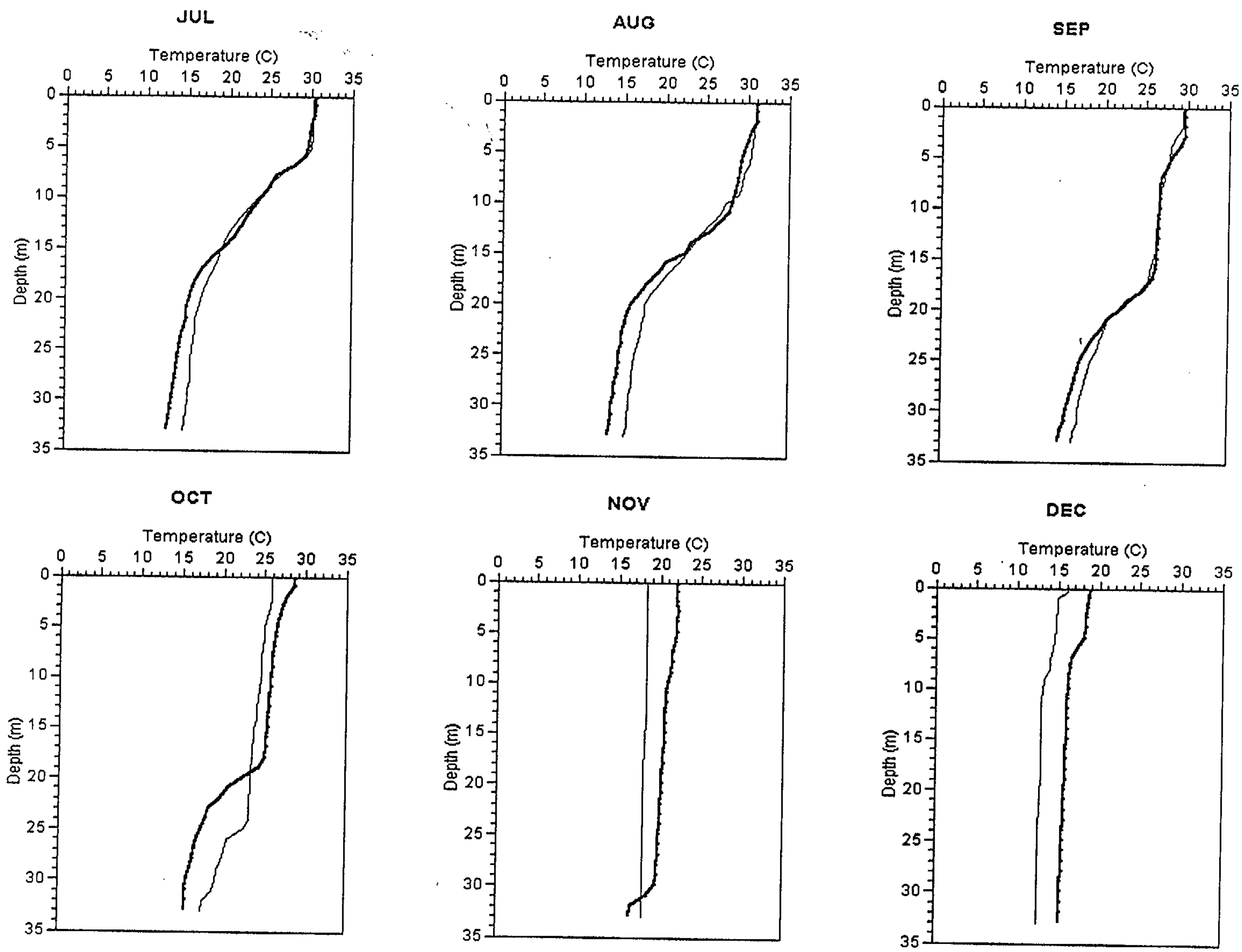

Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 1997 (–) and 1998 (▬).

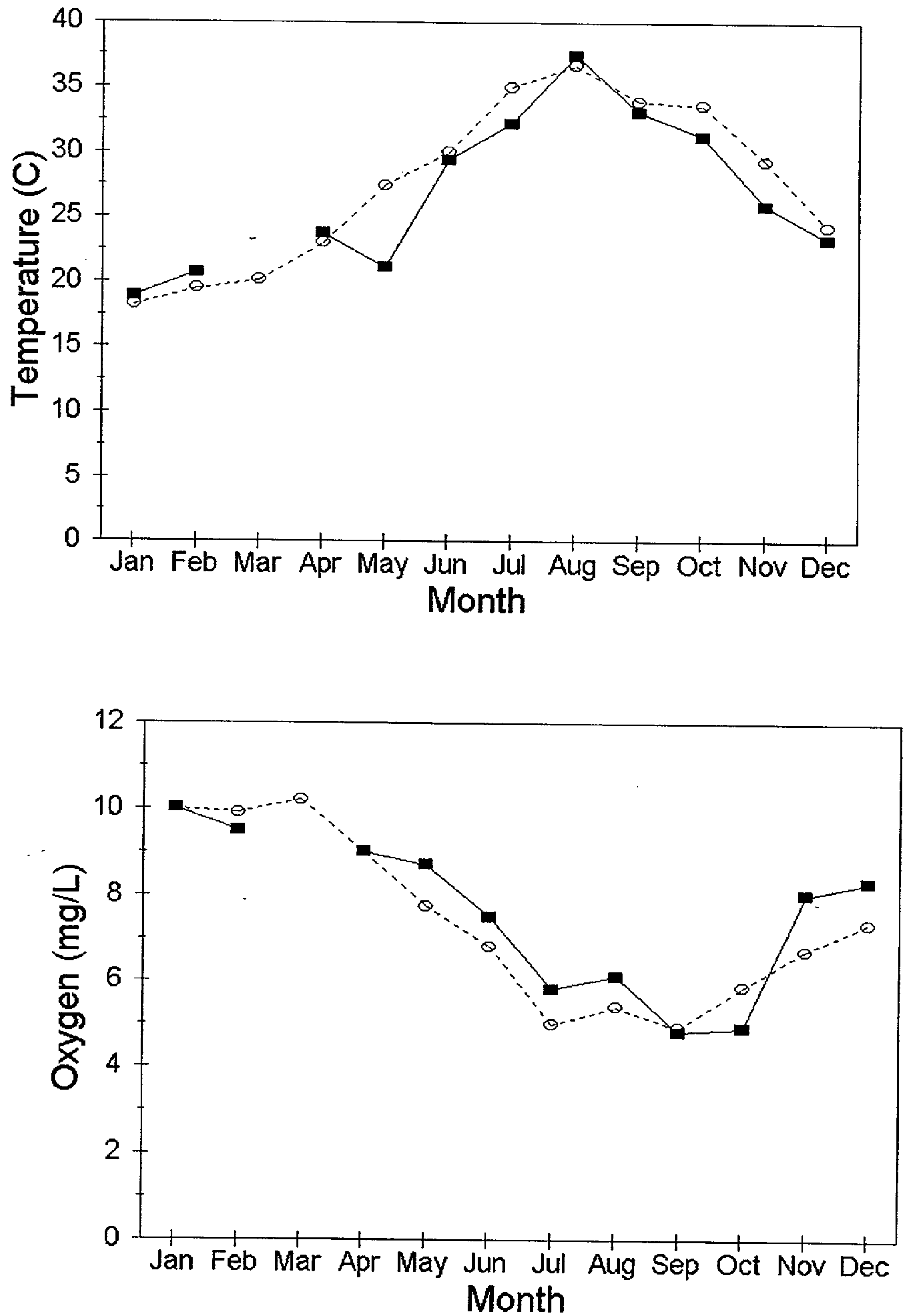

Figure 2-5. Monthly temperature and dissolved oxygen data at the discharge location (loc 4.0 @ 0.3m) in 1998 (○) and 1997 (■).

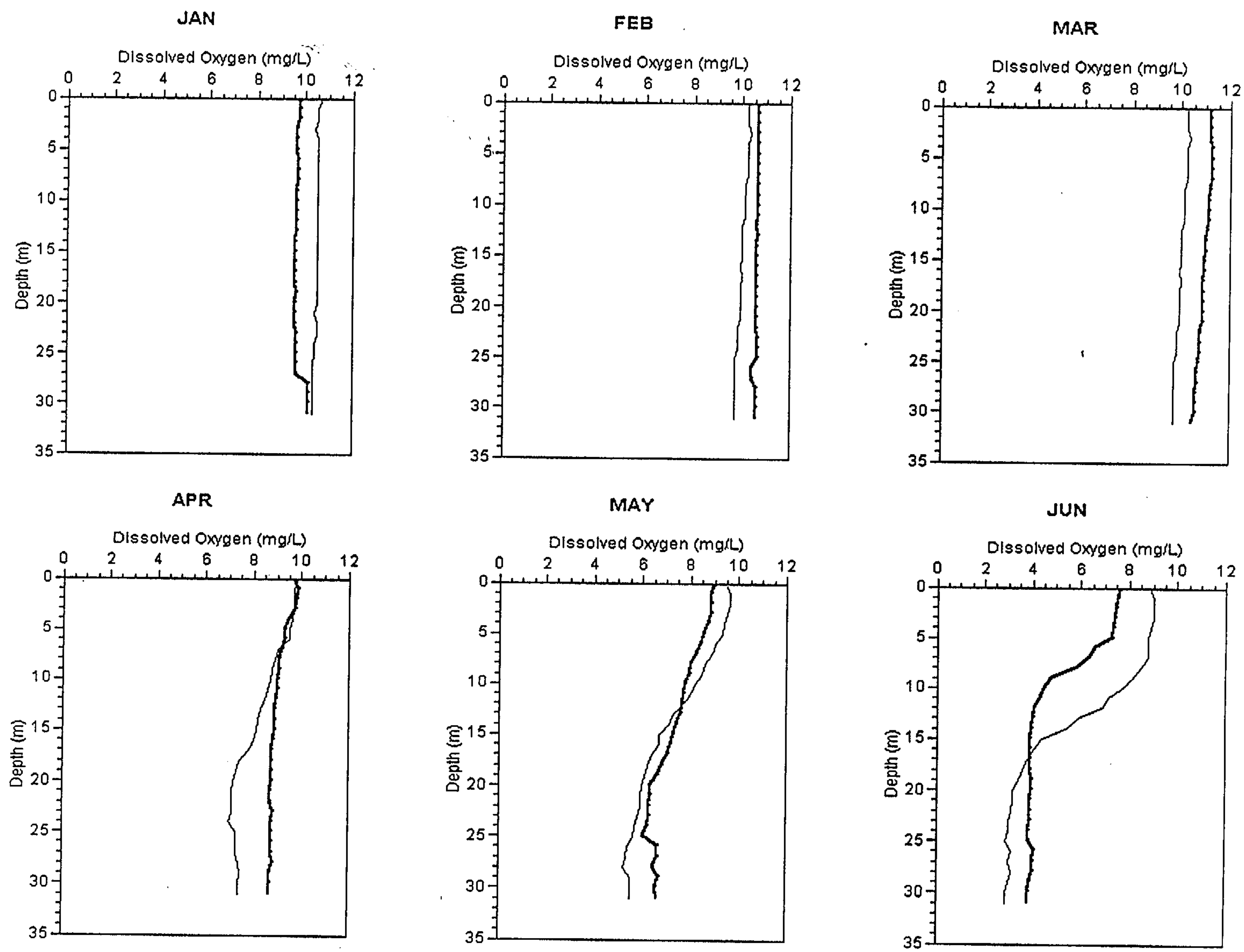

Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 1997 (–) and 1998 (▬).

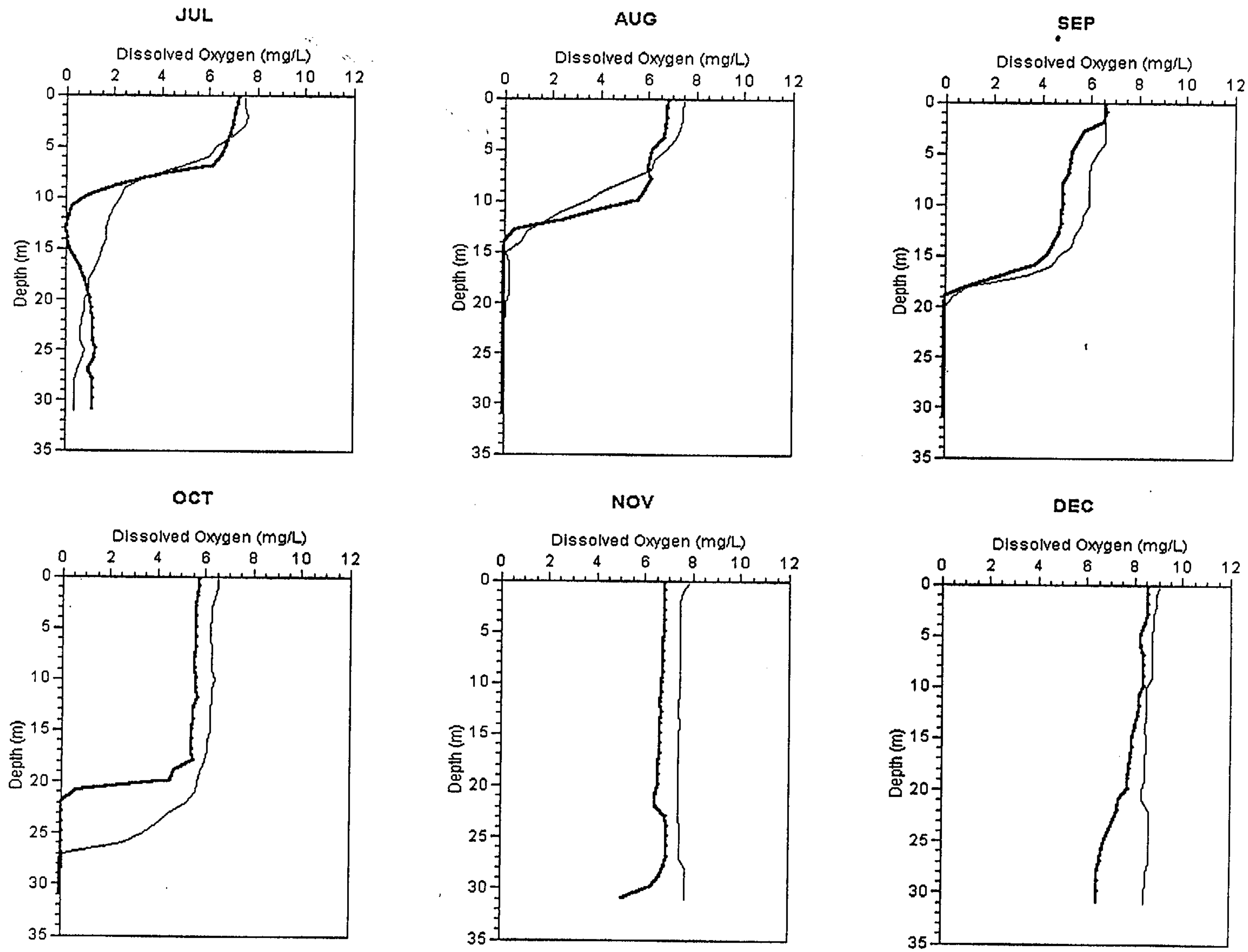

Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 1997 (–) and 1998 (▬).

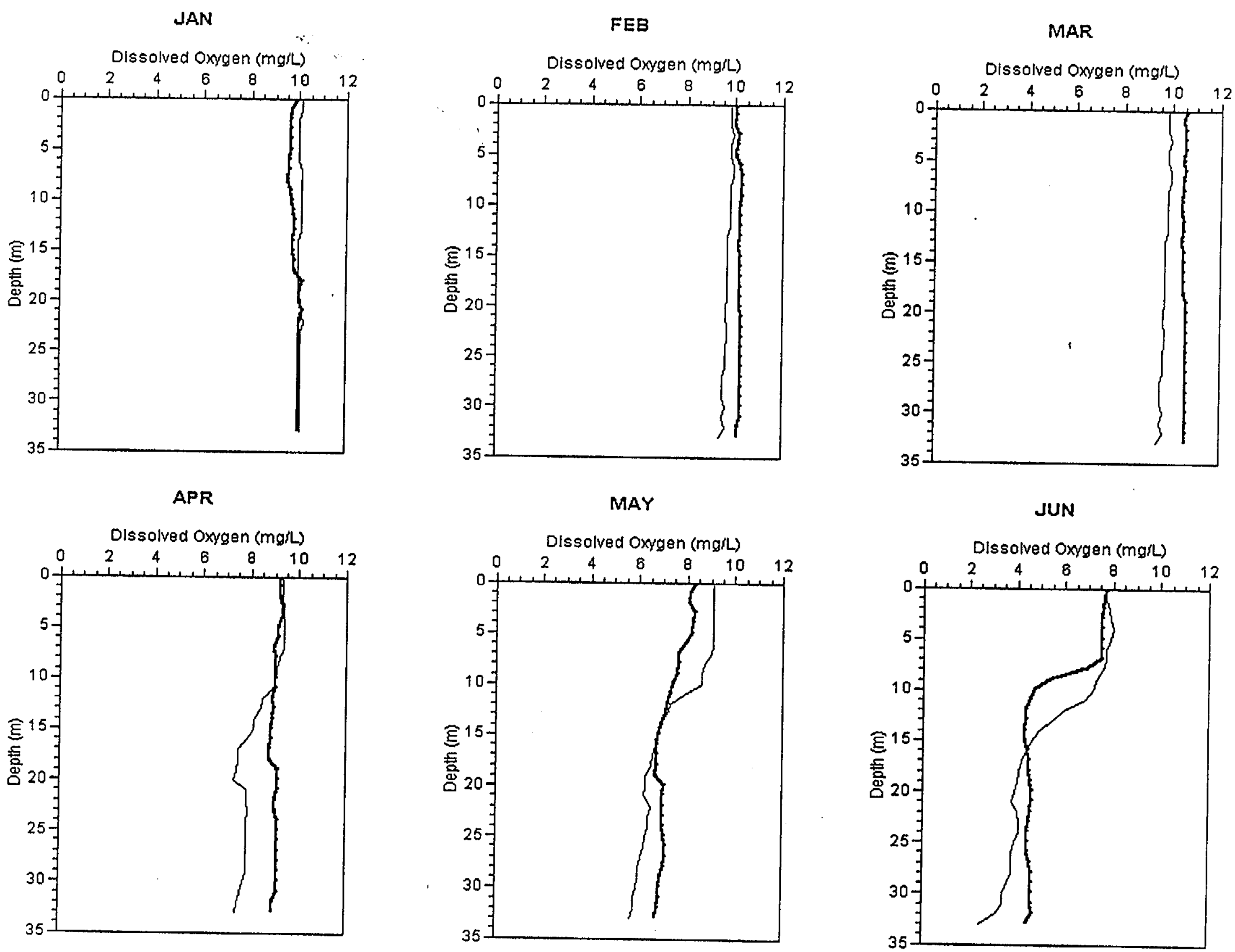

Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 1997 (–) and 1998 (▬).

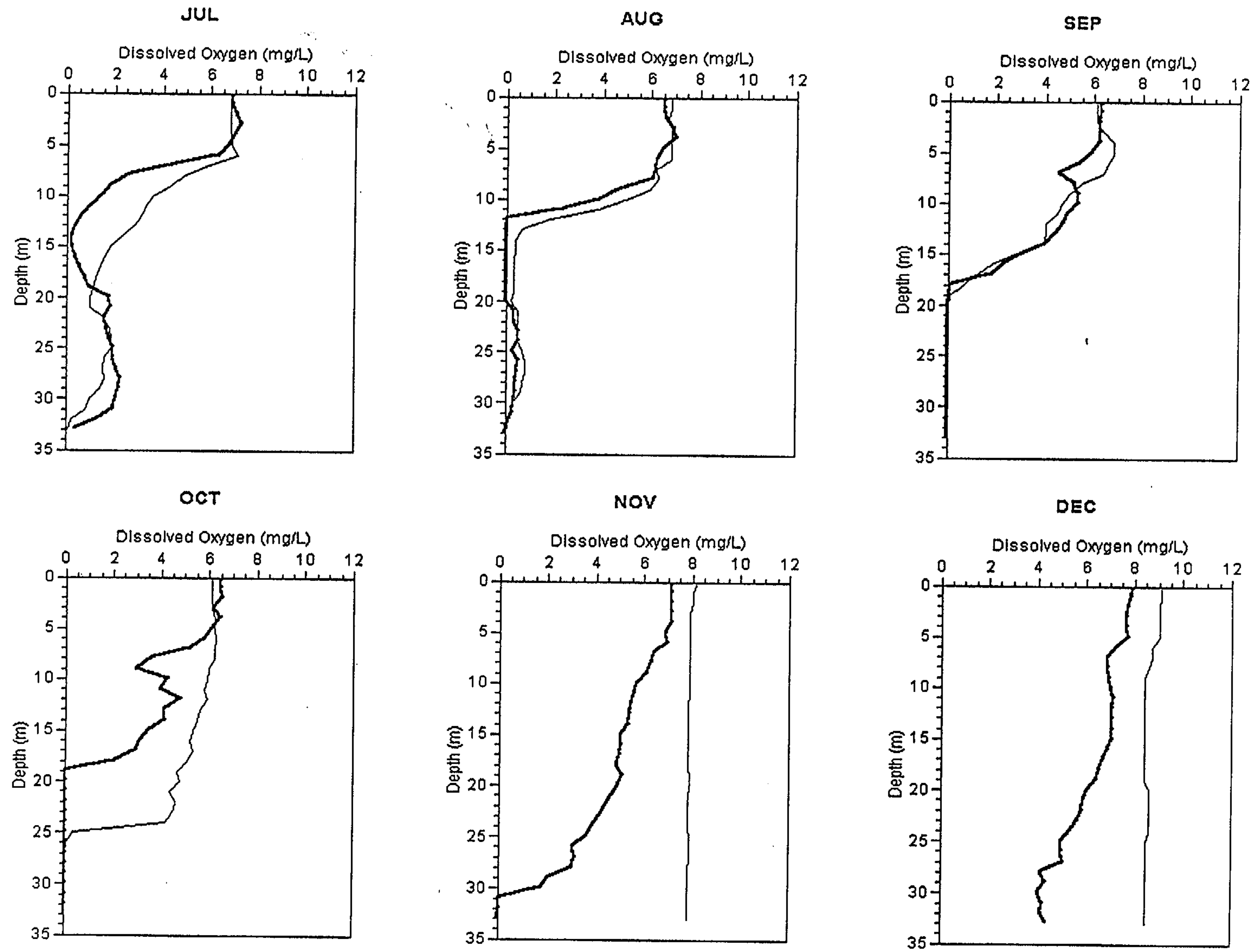

Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 1997 (–) and 1998 (▬).

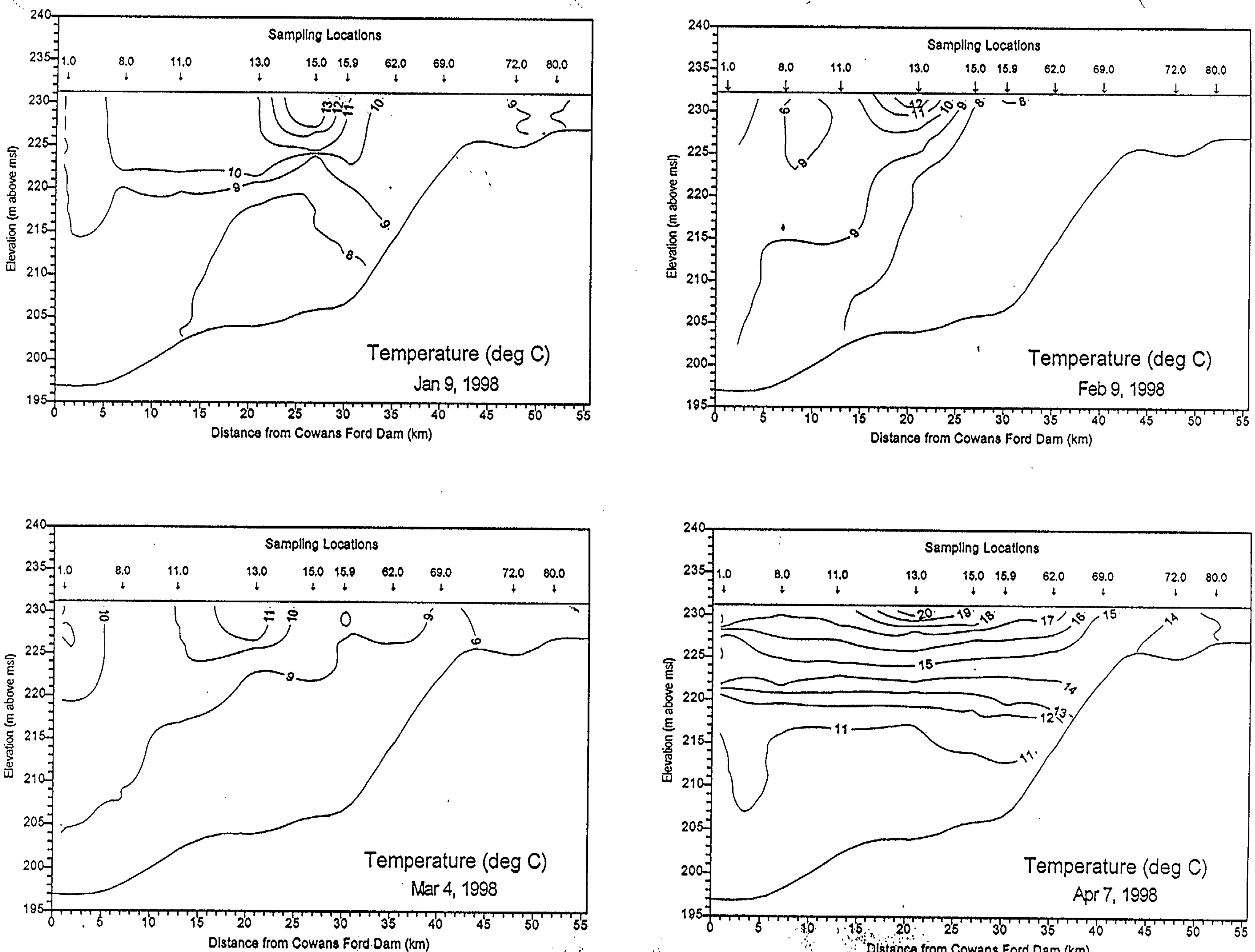

Figure 2-8. Monthly reservoir-wide temperature isotherms for Lake Norman in 1998.

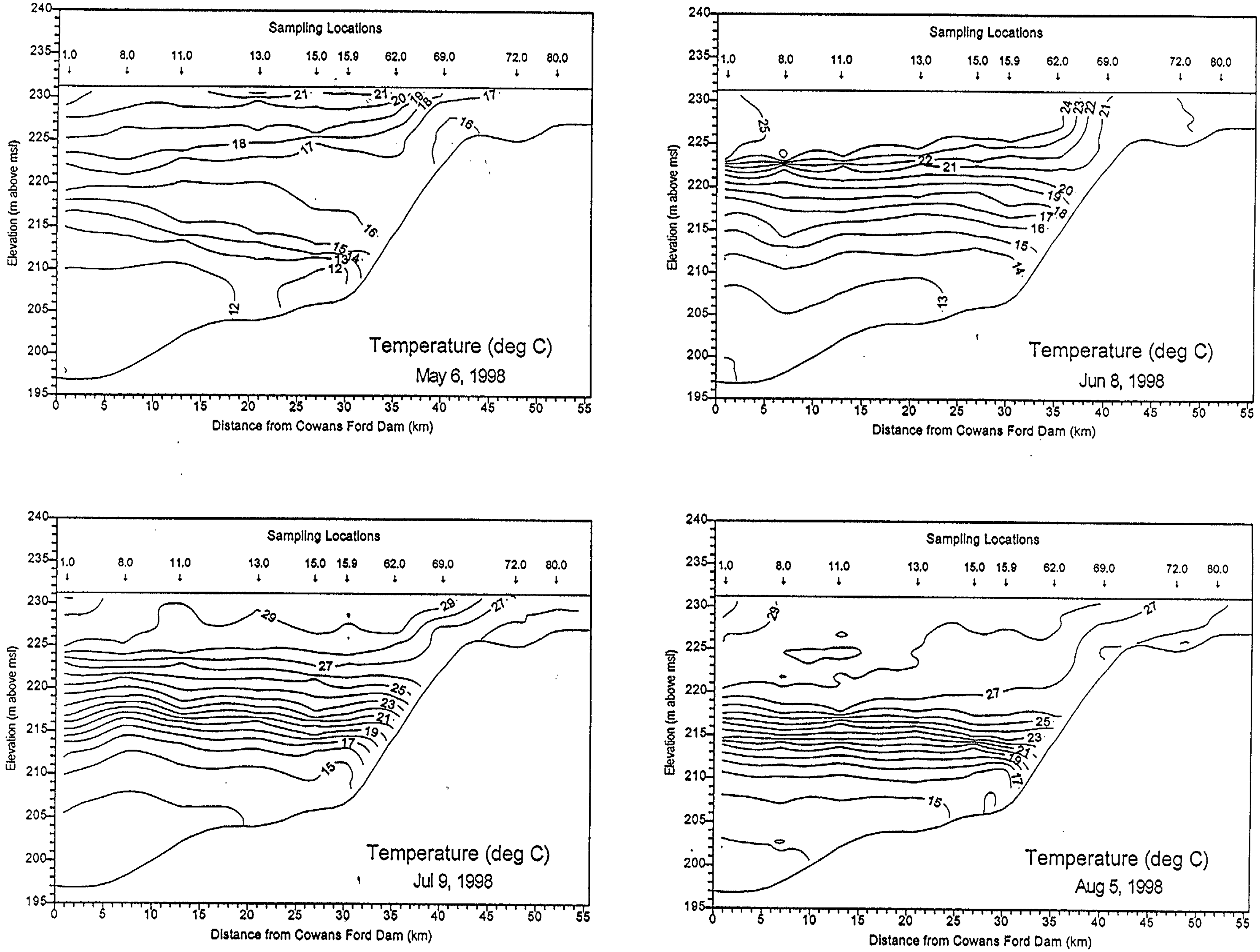

Figure 2-8. Continued.

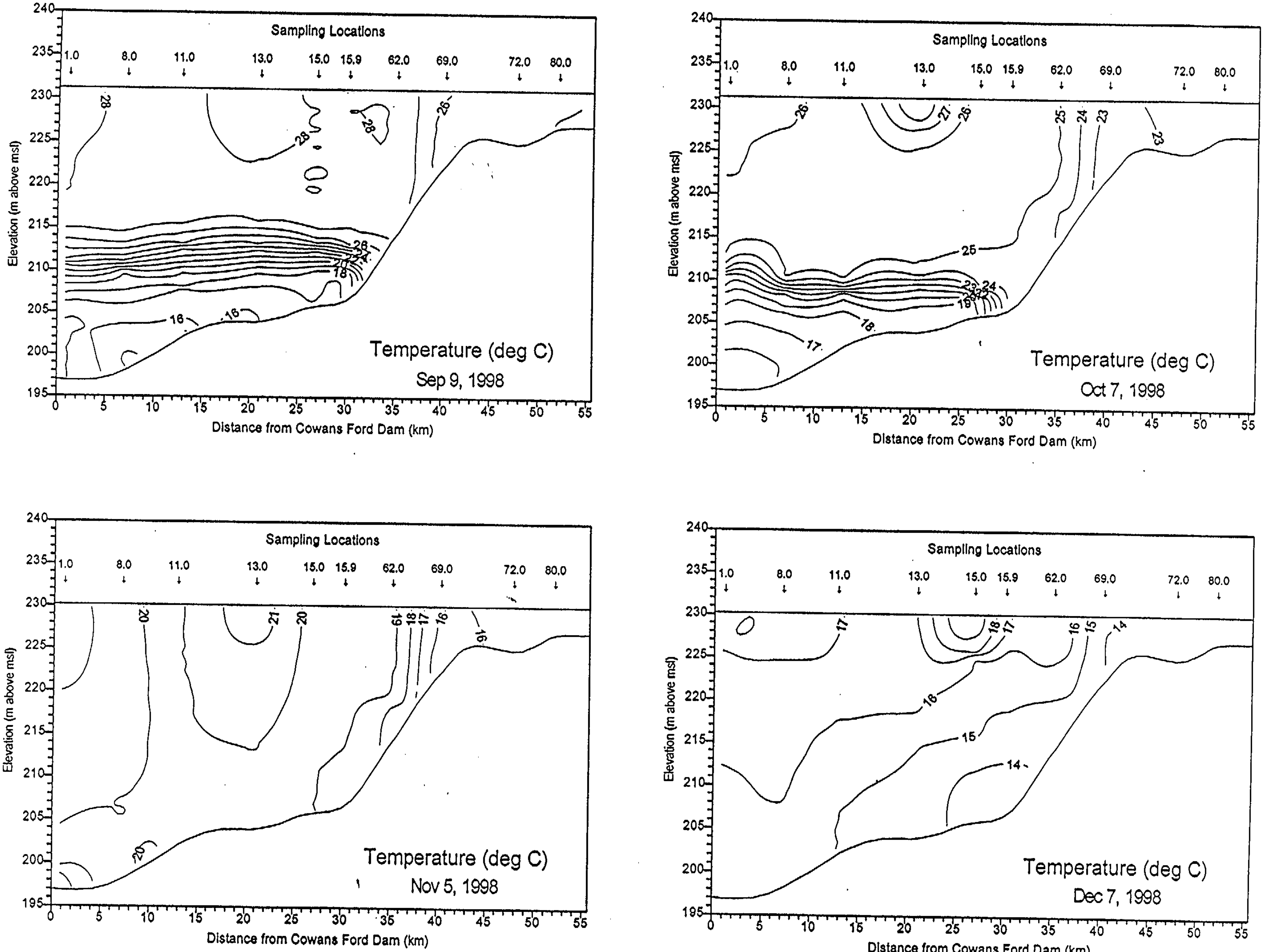

Figure 2-8. Continued.

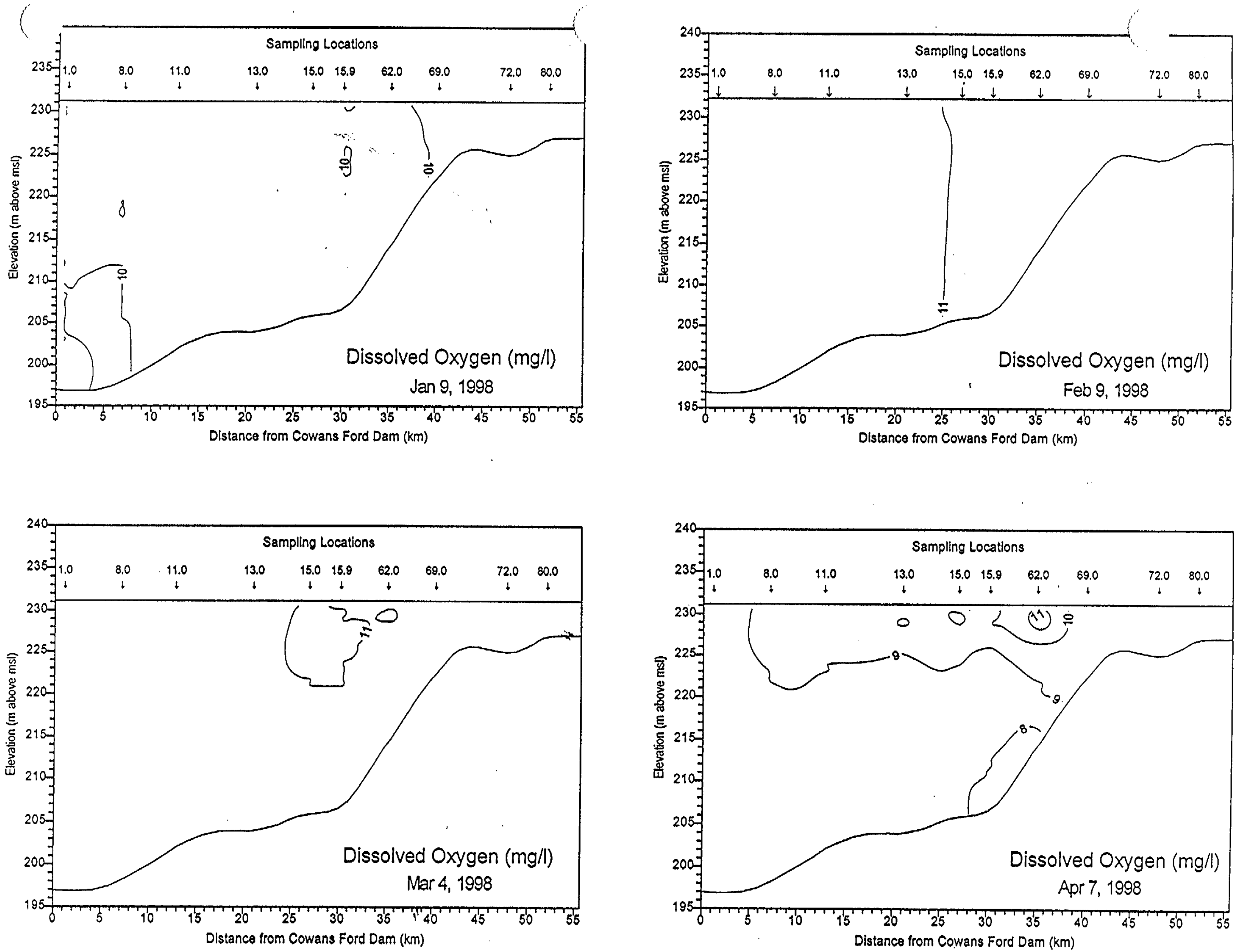

Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 1998.

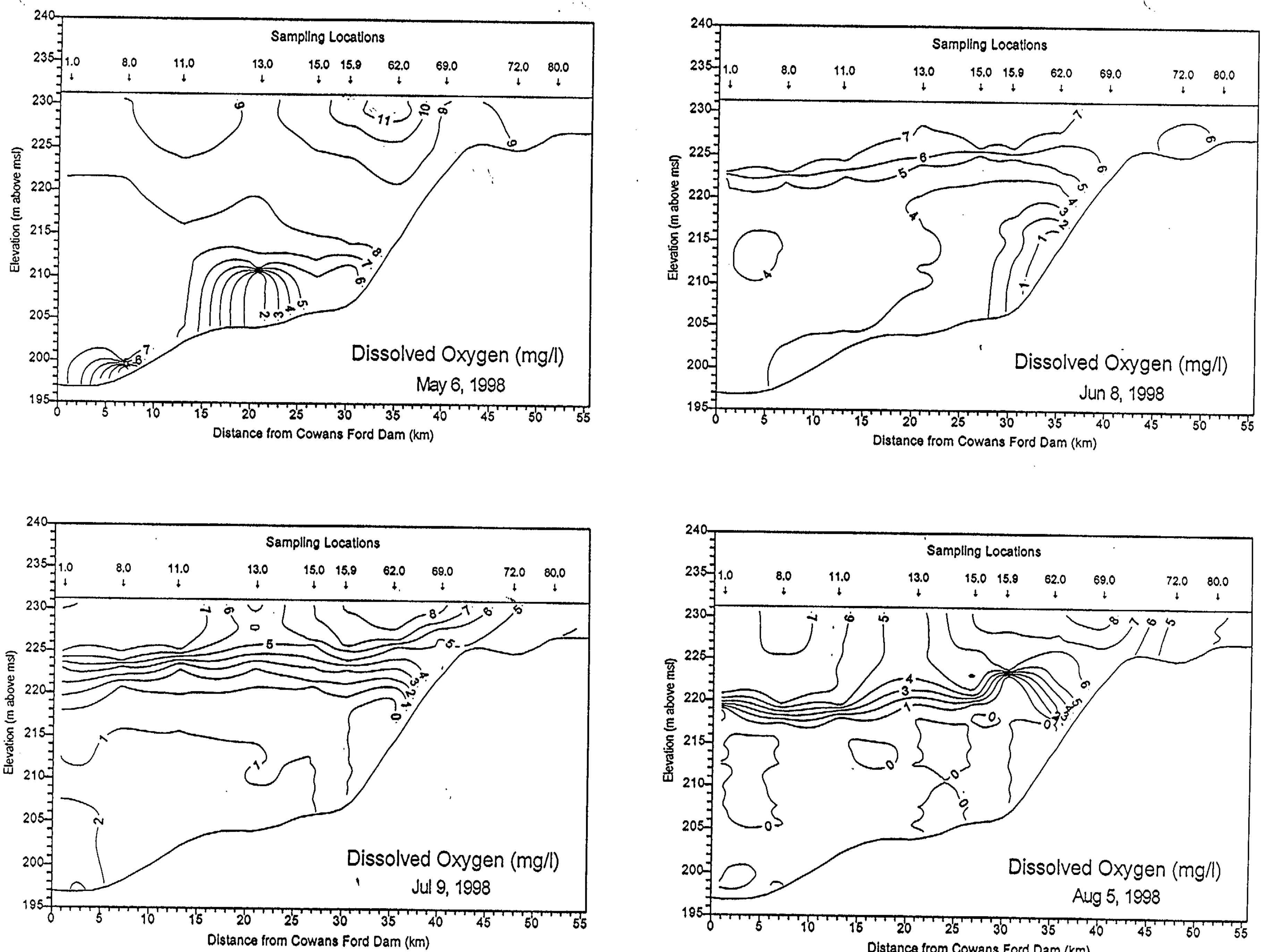

Figure 2-9. Continued.

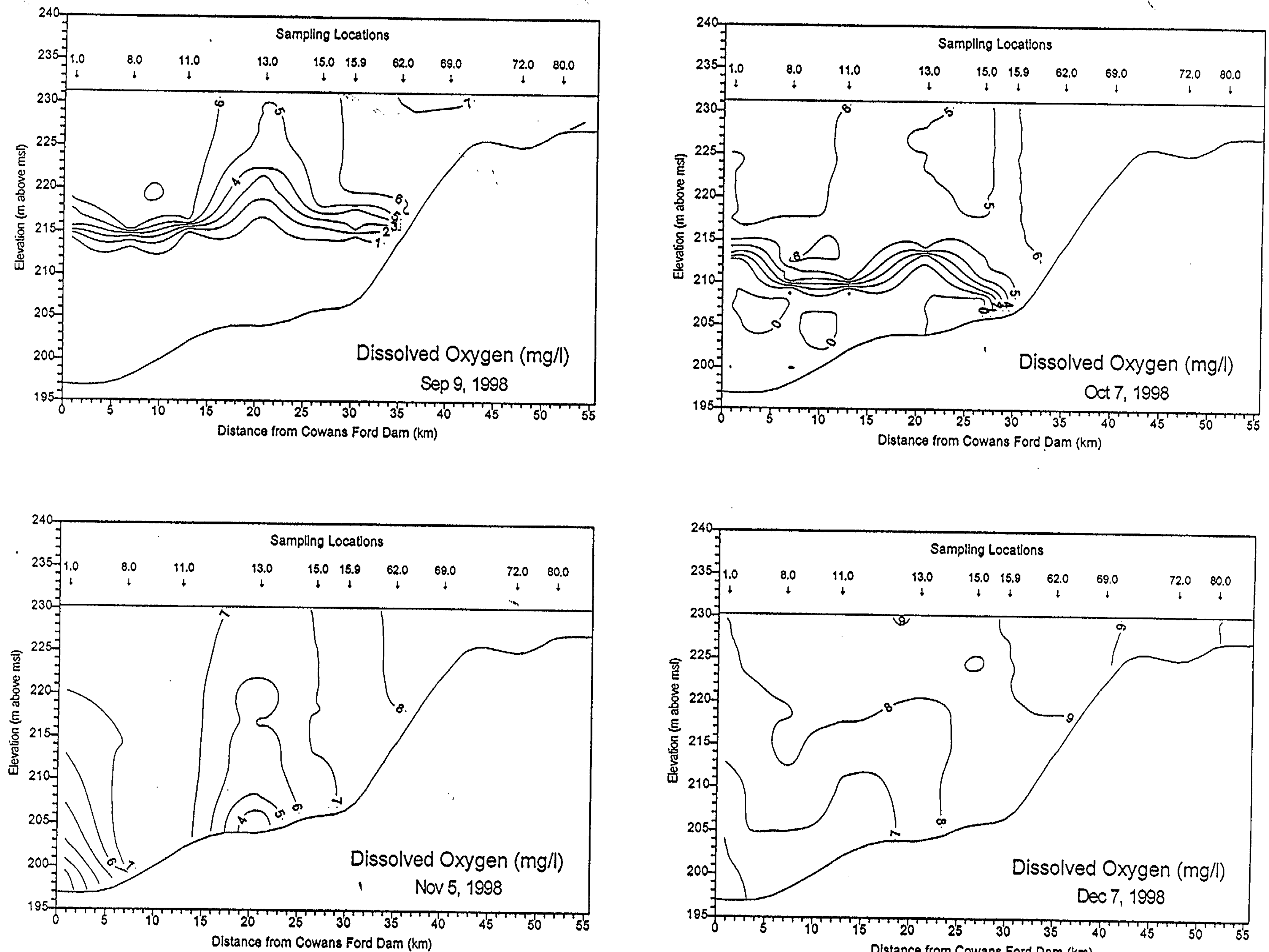

Figure 2-9. Continued.

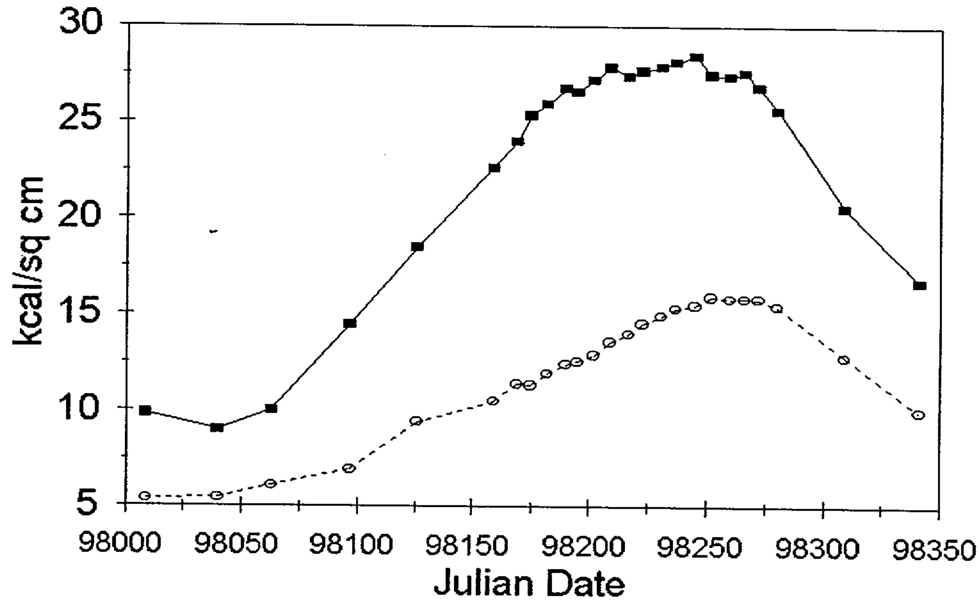

Figure 2-10a. Heat content of the entire water column (■) and the hypolimnion (O) in Lake Norman in 1998.

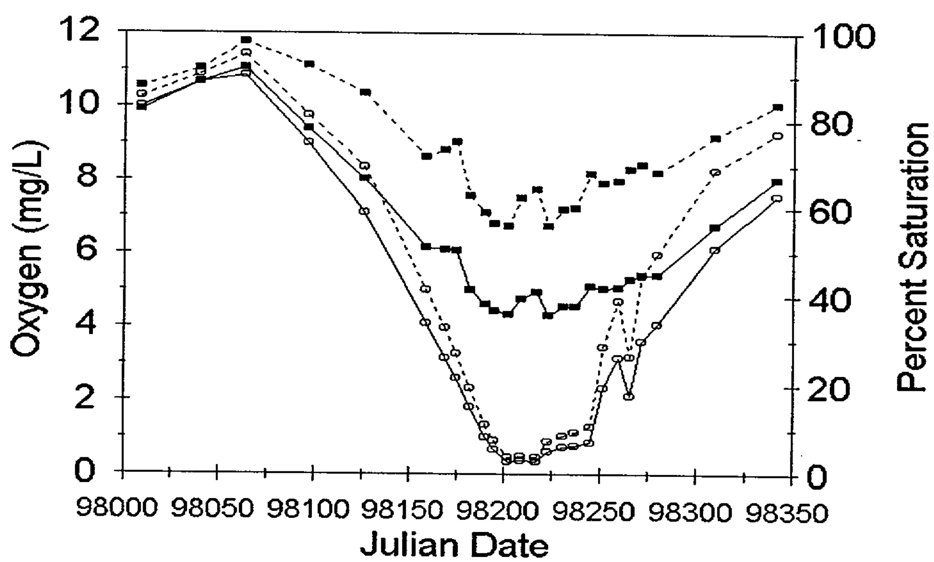

Figure 2-10b. Dissolved oxygen content (–) and percent saturation (---) of the entire water column (■) and the hypolimnion (O) of Lake Norman in 1998.

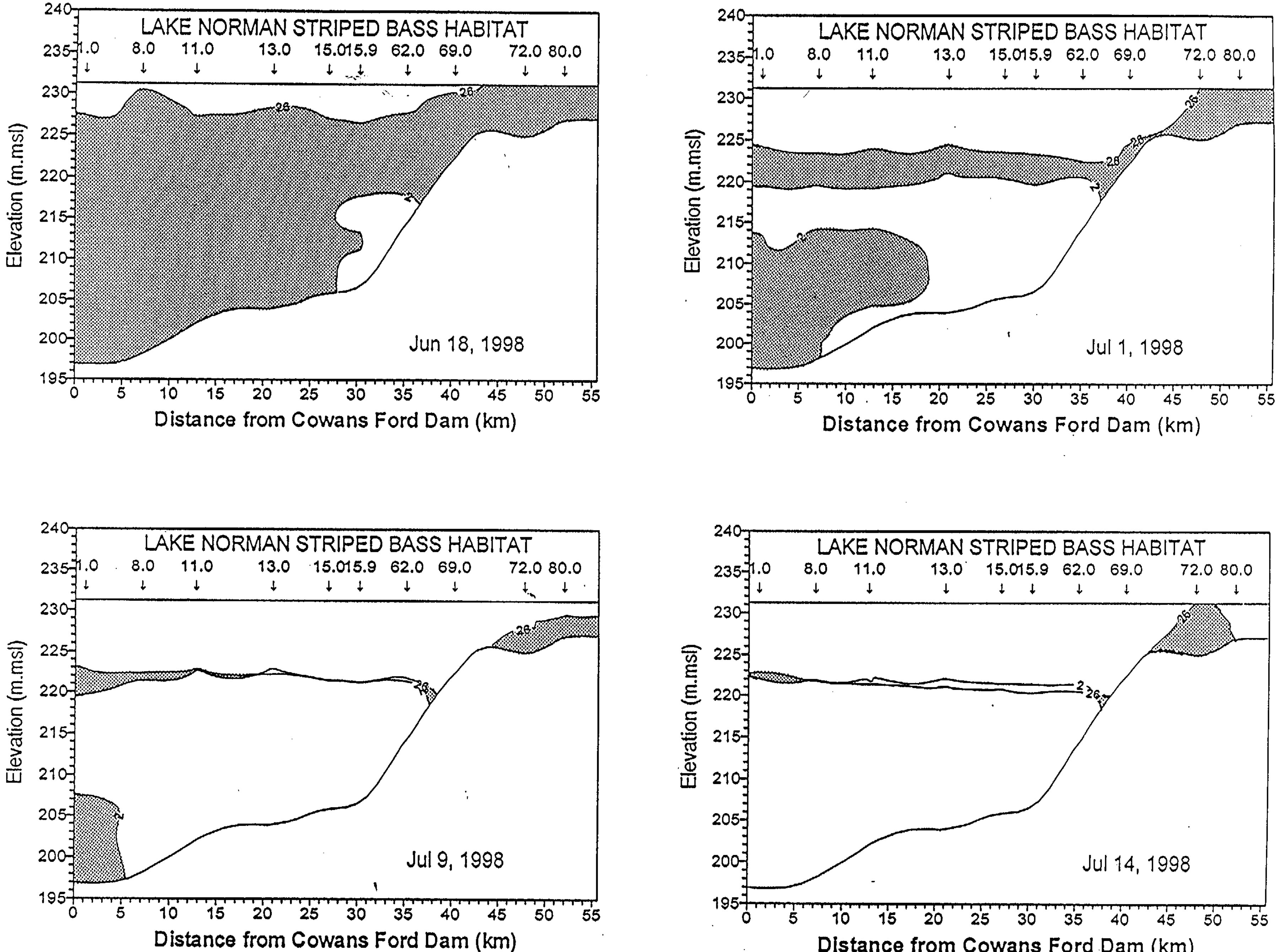

Figure 2-11. Striped bass habitat (temperatures ≤ 26 C and dissolved oxygen ≥ 2.0 mg/L in Lake Norman in June, July, August, September and October 1998.

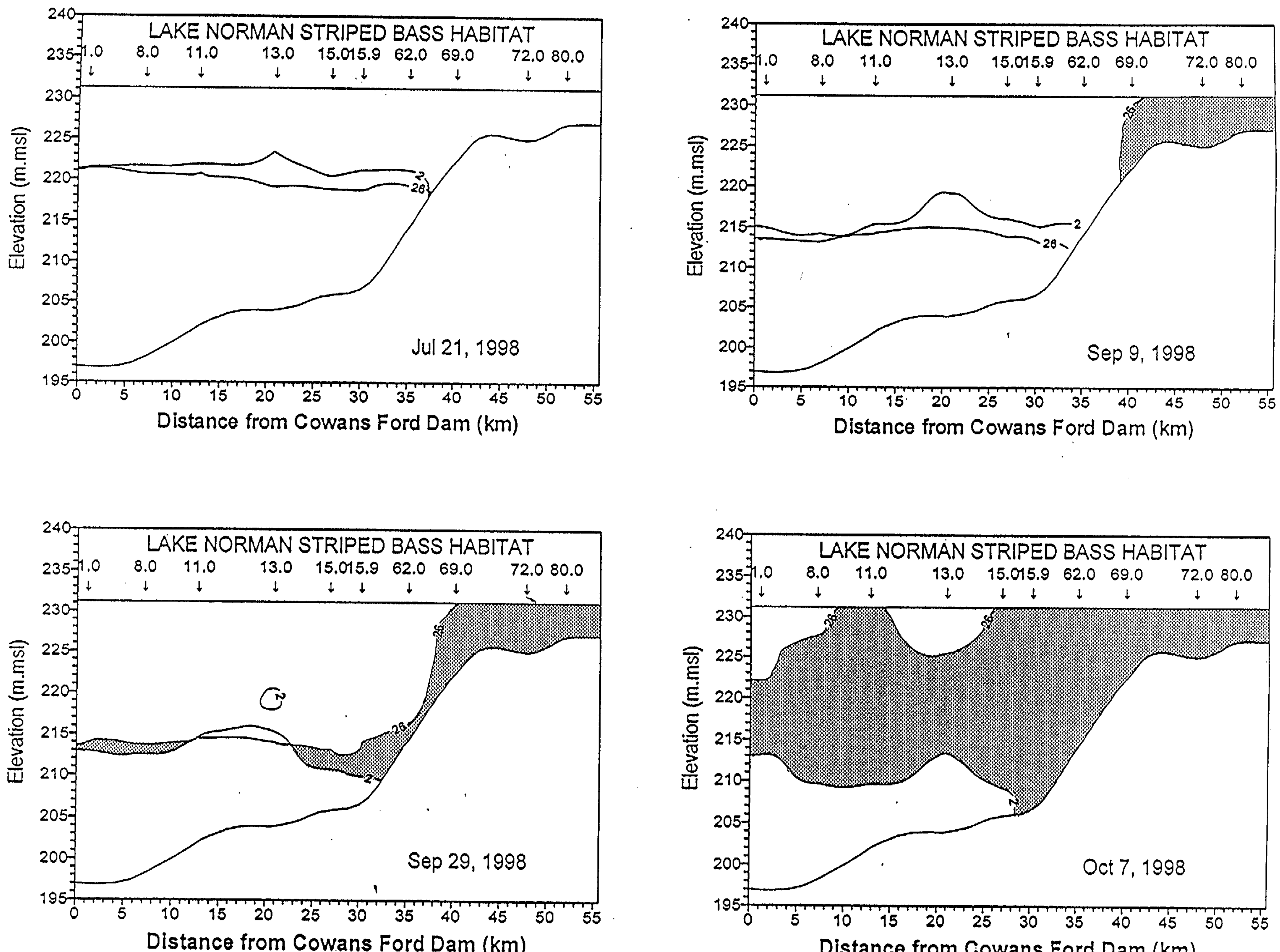

Figure 2-11. Continued.

CHAPTER 3
PHYTOPLANKTON

INTRODUCTION

Phytoplankton population parameters were monitored in 1998 in accordance with the NPDES permit for McGuire Nuclear Station (MNS). The objectives of the phytoplankton section for the Lake Norman Maintenance Monitoring Program are to:

1. Describe quarterly patterns of phytoplankton standing crop and species composition throughout Lake Norman; and
2. Compare phytoplankton data collected during this study (February, May, August, November 1998) with historical data collected in other years during these months.

In previous studies on Lake Norman considerable spatial and temporal variability in phytoplankton standing crops and taxonomic composition have been reported (Duke Power Company 1976, 1985; Menhinick and Jensen 1974; Rodriguez 1982). Rodriguez (1982) classified the lake as oligo-mesotrophic based on phytoplankton abundance, distribution, and taxonomic composition. Past Maintenance Monitoring Program studies have tended to confirm this classification.

METHODS AND MATERIALS

Quarterly sampling was conducted at Locations 2.0, 5.0, 8.0, 9.5, 11.0, 13.0, 15.9, and 69.0 in Lake Norman (see map of locations in Chapter 2, Figure 2-1). Duplicate grabs from 0.3, 4.0, and 8.0 m (i.e., the estimated euphotic zone) were taken at all locations and then composited. Sampling was conducted on 26 February, 15 May, 6 August, and 5 November 1998. Phytoplankton density, biovolume and taxonomic composition were determined for samples collected at Locations 2.0, 5.0, 9.5, 11.0, and 15.9; chlorophyll *a* concentrations and seston dry and ash-free dry weights were determined for samples from all locations. Chlorophyll *a* and total phytoplankton densities and biovolumes were used in determining phytoplankton standing crop. Field sampling methods, and laboratory methods used for chlorophyll *a*, seston dry weights and population identification and enumeration were identical to those used by Rodriguez (1982). Data collected in 1998 were compared with corresponding data from quarterly monitoring beginning in August 1987.

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

RESULTS AND DISCUSSION

Standing Crop

Chlorophyll *a*

Chlorophyll *a* concentrations (mean of two replicates) ranged from a low of 2.1 ug/l at Location 69.0 in February, to a high of 17.36 ug/l at Location 15.9 in May (Table 3-1, Figure 3-1). All values were below the North Carolina water quality standard of 40 ug/l (NCDEHNR 1991). Lakewide mean chlorophyll concentrations in 1998 were within ranges of those observed during previous years since 1987 (Figure 3-2). The annual trend of increasing values from February to August, with minimum values in November, was also observed in 1993. Lake Norman continues to be primarily in the mesotrophic range.

During 1998, chlorophyll *a* concentrations showed considerable spatial variability. Maximum concentrations were observed at Location 15.9 during all but February, when the maximum concentration occurred at Location 8.0. Minimum concentrations occurred at different locations during each sampling period. The trend of increasing chlorophyll concentrations from downlake to uplake, which had been observed in 1994 (Duke Power Company 1995), was not very apparent during 1998. Increasing values from downlake to uplake were observed to some extent in May when chlorophyll concentrations increased from the Mixing Zone locations (2.0 and 5.0) to 15.9, then declined at Location 69.0 (Table 3-1, Figure 3-1). In fact, a consistent pattern of increasing values from downlake to uplake has not been observed since 1994. Location 15.9 (uplake, above Plant Marshall) had significantly higher chlorophyll values than Mixing Zone locations in all but February, and Location 69.0 (the uppermost, riverine location) had significantly higher values than Mixing Zone locations in May (Table 3-2). Locations 2.0 and 5.0 had significantly higher concentrations than 15.9 and 69.0 in February when chlorophyll values were higher downalke than uplake. Flow in the riverine zone of a reservoir is subject to wide fluctuations depending, ultimately, on meteorological conditions (Thornton 1990), although influences may be moderated due to upstream dams. During periods of high flow, algal production and standing crop would be depressed, due in great part, to washout. Conversely, production and standing crop would increase during periods of low flow and high retention time. These conditions result in the high variability in chlorophyll concentrations observed between Locations 15.9 and 69.0 throughout the year, as opposed to Locations 2.0 and 5.0 which were very similar during each sampling period.

Average quarterly chlorophyll concentrations during the period of record (August 1987 – November 1998) have varied considerably. During February 1998, Locations 2.0 through 9.5 had concentrations in the intermediate range, with long term peaks occurring in 1996 (Figure 3-3). Chlorophyll concentrations at Locations 11.0 through 69.0 during February were in the low to mid range, with long term peaks occurring in 1991, except for Location 69.0 where the peak occurred in 1997. During May 1998 Locations 2.0 through 69.0 had concentrations in the intermediate to high range. 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 1997; and at Location 69.0 in 1996.

Chlorophyll concentrations at the Mixing Zone locations in August 1998 were the highest recorded to date. August chlorophyll concentrations at 8.0 and 9.5 were in the high range, with long term peaks occurring in 1993; at Locations 11.0 and 13.0 chlorophyll values were in the upper and intermediate ranges with long term peaks observed in 1991 and 1993, respectively. The August chlorophyll concentration at Location 15.9 was the highest yet observed during this month. At location 69.0 the chlorophyll concentration was in the mid range for August, with the long term maximum occurring in 1993.

In November, chlorophyll concentrations were in the low range at Locations 2.0 through 13.0 had declined dramatically from November 1997. At all of these locations, November chlorophyll values had been generally increasing from 1992 to 1997. November chlorophyll concentrations at Locations 15.9 and 69.0 were also in the low range, and long term November peaks at these locations occurred in 1996 and 1991, respectively. There was no notable decline from 1997 as there was at the downlake locations.

Total Abundance

Density and biovolume are measurements of phytoplankton abundance. The lowest density during 1998 occurred at Location 15.9 in February (1,163 units/ml), and the lowest biovolume (501 mm^3/m^3) occurred at Location 5.0 during this same month (Table 3-3, Figure 3-1). The maximum density and biovolume occurred at Location 15.9 in May (25,142 units/ml, 9,677 mm^3/m^3). The May and August 1998 densities, as well as the May biovolume, at Location 15.9 exceeded the NC State guidelines for phytoplankton blooms of 10,000 units/ml density, and 5,000 mm^3/m^3 biovolume (NCDEHNR 1991). In May of 1997, standing crop parameters at this location were also in excess of bloom guidelines. The density at Location 15.9 in May was the highest recorded from Lake Norman since the Maintenance Monitoring Program began.

Location 15.9 is well uplake and out of the influence of the MNS mixing zone and the discharge of the Marshall Steam Station (MSS) and it is unlikely that operations of these plants were responsible for the high phytoplankton standing crops. Comparatively high standing crops have historically occurred at Location 15.9.

Although densities and biovolumes exceeded state guidelines for algal blooms, chlorophyll concentrations were still below the state water quality standard of 40 ug/l. Diatoms, primarily the pennate *Achnanthes microcephala*, were the principal components of the phytoplankton standing crop at Location 15.9 in May. Diatoms were also the primary contributors to the density at this location in August. Diatoms typically have much lower chlorophyll to volume ratios than other forms (Patrick and Reimer 1966, Strathman 1967). This would explain why the chlorophyll concentrations remained below the state standard.

Total densities at locations in the Mixing Zone (2.0 and 5.0) were within the same statistical ranges during all sampling periods of 1998 (Table 3-4). In May, August, and November, Location 15.9 had significantly higher densities than Mixing Zone locations; while in February there were no statistically significant differences among locations.

In May and November, phytoplankton densities showed a general spatial trend of lower values at downlake locations versus uplake locations. During February and August, no consistent distribution patterns were observed.

Seston

Seston dry weights represent a combination of algal matter, and other organic and inorganic material. Location 69.0, the uppermost riverine location, had the highest seston dry weights during all sample periods (Table 3-5). A general trend of increasing seston dry weights from downlake to uplake was evident in 1998, as was the case in previous years (Figure 3-1). Statistically, Location 69.0 had significantly higher values than most locations in February, May, and August. During November, no statistical differences were observed, even though the maximum value was over three times higher than the minimum. Lack of statistical significance was due to interaction resulting from extreme variability among certain replicates. From 1995 through 1997 seston dry weights had been on the increase (Duke Power Company 1998). Values in 1998 represented a reversal of this trend.

Seston ash free dry weights represent organic material and may reflect trends of algal standing crops. For the most part, this was not the case during 1998; most notably at Location 69.0, which had the highest ash free dry weights in all but November, and comparatively low chlorophyll concentrations during February, August, and November. In terms of statistical significance, Location 69.0 had significantly higher values than most other locations in February and May (Table 3-5). In May, three distinct statistical groups were indentified: Locations 2.0 through 9.5 in the low range; Locations 11.0 and 13.0 in the intermediate range; and, Locations 15.9 and 69.0 in the high range. The proportions of ash free dry weights to dry weights during 1998 were also similar to those of 1997, indicating no change in organic/inorganic inputs between years. Between 1994 and 1997 a trend of declining organic/inorganic ratios was observed (Duke Power Company 1995, 1996, 1997, and 1998).

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 downlake. Depths ranged from 0.54 m at Location 13.0 in February, to 3.35 m at Location 9.5 in May (Table 3-1).

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 especially true in 1998. Ten classes comprising 86 genera and 168 species, varieties, and forms of phytoplankton were identified in samples collected during the year, as compared to 71 genera and 122 lower taxa identified in 1997 (Table 3-6). The 1998 total was the highest number of individual taxa recorded since monitoring began in 1987. Twenty-one taxa previously unrecorded during the program were observed in 1998.

Species Compositon and Seasonal Succession

The phytoplankton community in Lake Norman varies both seasonally and spatially within the reservoir. In addition, considerable variation may also be observed between years for the same months sampled. As mentioned earlier, bloom guidelines (i.e., based on densities in excess of 10,000 units/ml and biovolumes in excess of 5,000 mm^3/m^3) were first exceeded during May 1997. In May and August 1998 these guidelines were again exceeded at Location 15.9. Diatoms accounted for approximately 76% of the density and 83% of the biovolume in the May sample, and 40% of the density in the August sample.

Cryptophytes (Cryptophyceae) dominated densities at all locations in February, as has been the case in previous years (Figures 3-4 through 3-7). The most abundant crypophyte was the small flagellate, *Rhodomonas minuta*. This species has been one of the most common and abundant forms observed in February samples since monitoring began in 1987. Cryptophytes are characterized as light limited, often found deeper in the water column, or near surface under low light conditions which are common during winter (Lee 1989).

Diatoms (Bacillariophyceae) dominated algal densities and biovolumes during May and at most locations in November. During 1997, diatoms were dominant at all locations during May and November (Duke Power Company 1998). The dominant diatom during 1998, at all but Location 15.9, was *Tabellaria fenestrata*. *T. fenestrata* has always been a common constituent of phytoplankton assemblages in Lake Norman, and was also the most abundant form observed during 1996 and 1997. This taxon has been described as being found in meso-eutrophic water, acidophilous, and often tycho-meroplanktonic (Patrick and Reimer 1966; Lowe 1974). At Location 15.9, *Achnanthes microcephala* was the principle contributor to the diatom population in May. Although *A. microcephala* is a common constituent of diatom populations in Lake Norman, it is seldom observed in great abundance. It has been described by Lowe (1974) as widely distributed and a good indicator of permanent oxygen concentrations in low to circumneutral pH water.

In 1998, and most previous years, green algae (Chlorophyceae) dominated most August samples. The most abundant green alga identified was the small desmid, *Cosmarium asphearosporum* v. *strigosum*. This is a common constituent of summer phytoplankton assemblages in Lake Norman. Diatoms, primarily *Synedra rumpens*, were dominant at Location 15.9 in August.

During November 1998, densities at Locaitons 2.0 and 5.0 were dominated by cryptophytes (*Rhodomonas minuta*) and green algae (unidentified coccoids), respectively. Diatoms (*Melosira ambigua*, and *T. fenestrata*) were dominat at Locations 9.5 to 15.9 in November.

Blue green-algae (Myxophyceae), which are often implicated in nuisance blooms, were never abundant in 1998 samples. Densities and biovolumes of blue greens seldom exceeded 10% of totals as was the case in 1997. The relative abundances of blue-green algae during August and November 1998 were higher than those of 1997. The highest percent compositions of Myxophyceae during all sampling periods in 1998 occurred at Location 15.9. This pattern was also observed in previous years.

Phytoplankton index

Phytoplankton indexes have been used with varying degrees of success ever since the concept was formalized by Kolkwitz and Marsson in 1902 (Hutchinson 1967). In 1949 Nygaard (1949) proposed a series of indexes based on the number of species in certain taxonomic categories (Divisions, Classes, and Orders). The Myxophycean index was selected to help determine long term changes in the trophic status of Lake Norman. This index is a ratio of the number of blue green algal taxa to desmid taxa, and was designed to reflect the "potential" trophic status as opposed to chlorophyll, which gives an "instantaneous" view of phytoplankton concentrations. The index was calculated on an annual basis for the entire lake, for each sampling period of 1998, and for each location during 1998 (Figure 3-8).

For the most part, the long term annual Myxophycean index values confirmed that Lake Norman has been in the oligo-mesotrophic (low to intermediate) range since 1988 (Figure 3-8). Values were in the high, or eutrophic, range in 1989, 1990, and 1992; in the intermediate, or mesotrophic, range in 1991, 1993, 1994, and 1996; and in the low, or oligotrophic, range in 1988, 1995, and 1997. The index for 1998 was higher than that of 1997 (the lowest on record), but was still lower than in most previous years.

The highest index value among sample periods of 1998 was observed in May, and the lowest index value occurred in August. The index values for locations during 1998 showed a clear pattern of increased trophic state from downlake to uplake locations (figure 3-8). This tends to confirm the premise of higher potential productivity at uplake compared to downlake locations.

FUTURE STUDIES

No changes are planned for the phytoplankton portion of the Lake Norman Maintenance Monitoring program during 1998.

SUMMARY

In 1998 chlorophyll *a* concentrations were generally within ranges reported during previous years. Lake Norman continues to be classified as oligo-mesotrophic based on long term, annual mean chlorophyll concentrations. Lakewide chlorophyll means increased from February to August, then declined in November. Chlorophyll concentrations from Locations 2.0, 5.0 and 15.9 in August were the highest yet recorded for this month. November chlorophyll concentreations at Locations 2.0 through 13.0 had declined substantially compared to November 1997. This ended a long term trend of increasing November chlorophyll values at these locations. The 1998 maximum chlorophyll value of 17.36 ug/l was well below the NC State Water Quality standard of 40 ug/l. Considerable spatial and seasonal variability was observed during 1998, as has been the case in previous years.

In most cases, total phytoplankton densities and biovolumes observed in 1998 were within ranges of those observed during previous years. However, the density and biovolume at Location 15.9 in May, and the density at this location in August, exceeded NC State phytoplankton bloom guidelines. This was the second time since the Program began that such an excursion was documented, and the May density at Location 15.9 was the highest recorded to date. Very high standing crops of diatoms, prmarily the pennates *Tabellaria fenestrata* and *Achnanthes microcephala*, were responsible for these high values. Chlorophyll concentrations remained below the standard of 40 ug/l due to the low chlorophyll to volume ratios assosiated with diatoms. Since high standing crops occurred at a location well uplake from MNS, and above the MSS discharge, plant operations were not responsible for these excursions. Natural conditions such as low flow, increased retention time, inputs of nutrients uplake, seasonal increases in temperature and light penetration, and longer photoperiod were most the likely causes contributing to the higher than normal standing crops. Minimum standing crops were typically observed in February, and values in the mixing zone were generally lower than those uplake.

Seston dry weights were lower in 1998 than in 1997, and downlake to uplake differences were still quite apparent. Maximum dry and ash free dry weights were most often observed at the riverine location (69.0); while minima were most often noted at Locations 2.0 and 9.5. The proportions of ash free dry weights to dry weights in 1998 were similar to those of 1997, indicating no appreciable change in organic/inorganic inputs into Lake Norman. This is a reversal of the trend of increasing inorganic inputs first observed in 1995.

Diversity, or numbers of taxa, of phytoplankton had increased since 1997, and more individual taxa were identified in 1998 than in any previous year of the Program. Overall phytoplankton community composition was similar to 1997. Diatoms were were the principal contributors to standing crops in May and November. Cryptophytes were dominant in Febraury; while green algae dominated most August samples, as has been the case in previous years. Although blue-green algae were more abundant during 1998 than 1997, their contribution to total standing crops seldom exceeded 10%.

The most abundant alga, on an annual basis, was the cryptophyte *Rhodomonas minuta*. The most common and abundant green alga and diatom were *Cosmarium asphearosporum* v. *strigosum*, and *Tabellaria fenetrata*, respectively. All of these taxa have been common and abundant throughout the 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.

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Table 3-1. Mean chlorophyll *a* concentrations (ug/l) in composite samples (0.3, 4 and 8m depths) and secchi depths (m) observed in Lake Norman, NC, in 1998.

Chlorophyll *a*

Location	FEB	MAY	AUG	NOV
2.0	4.85	5.50	11.21	2.58
5.0	5.54	3.65	9.88	2.71
8.0	7.09	5.74	10.68	3.74
9.5	3.37	3.87	10.15	3.92
11.0	5.45	9.25	9.08	6.02
13.0	3.06	10.02	3.97	3.42
15.9	3.52	17.36	14.42	6.93
69.0	2.10	11.21	9.08	2.87

Secchi depths

Location	FEB	MAY	AUG	NOV
2.0	1.40	2.40	2.45	2.17
5.0	1.40	2.20	2.11	NS
8.0	1.10	2.33	1.88	2.44
9.5	2.10	3.35	2.10	1.93
11.0	0.66	1.98	2.25	1.52
13.0	0.54	1.30	1.58	1.16
15.9	0.64	1.30	1.81	1.35
69.0	0.64	0.80	1.46	1.20

* = Not sampled due to high wind conditions

Table 3-2. Duncan's multiple Range Test on chlorophyll *a* concentrations in Lake Norman, NC, during 1998.

February	Location	**69.0**	**13.0**	**9.5**	**15.9**	**2.0**	**11.0**	**5.0**	**8.0**
Mean		2.10	3.06	3.37	3.52	4.85	5.45	5.54	7.09
May	Location	**5.0**	**9.5**	**2.0**	**8.0**	**11.0**	**13.0**	**69.0**	**15.9**
	Mean	3.65	3.87	5.50	5.74	9.25	10.02	11.21	17.36
August	Location	**13.0**	**69.0**	**11.0**	**5.0**	**9.5**	**8.0**	**2.0**	**15.9**
	Mean	3.97	9.08	9.08	9.88	10.15	10.68	11.21	14.42
November	Location	**2.0**	**5.0**	**69.0**	**13.0**	**8.0**	**9.5**	**11.0**	**15.9**
	Mean	2.58	2.71	2.87	3.42	3.74	3.92	6.02	6.93

Table 3-3. Total mean phytoplankton densities and biovolumes from samples collected in Lake Norman, NC, during 1998.

Density (units/ml)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	1427	1465	1427	1439	1163	1384
MAY	2640	1886	1659	5029	25142	7271
AUG	5707	4513	7191	4442	12173	6805
NOV	1326	1496	1823	2074	2351	1814

Biovolume (mm^3/m^3)

	Locations					
Month	2.0	5.0	9.5	11.0	15.9	Mean
FEB	600	501	509	690	600	580
MAY	2258	1764	1260	4980	9677	3988
AUG	4709	4282	4582	2383	4974	4186
NOV	656	894	1092	1600	2309	1310

Table 3-4. Duncan's multiple Range Test on phytoplankton densities in Lake Norman, NC, during 1998.

February						
	Location	**15.9**	**9.5**	**2.0**	**11.0**	**5.0**
	Mean	1163	1427	1427	1439	1465

May						
	Location	**9.5**	**5.0**	**2.0**	**11.0**	**15.9**
	Mean	1659	1886	2640	5029	25142

August						
	Location	**11.0**	**5.0**	**2.0**	**9.5**	**15.9**
	Mean	4442	4513	5707	7191	12173

November						
	Location	**2.0**	**5.0**	**9.5**	**11.0**	**15.9**
	Mean	1326	1496	1823	2074	2351

Table 3-5. Duncan's multiple Range Test on dry and ash free dry weights (mg/l) in Lake Norman, NC during 1998.

DRY WEIGHT

February	Location	**9.5**	**2.0**	**5.0**	**8.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	1.95	2.69	2.70	2.82	3.74	4.76	6.00	7.88
May	Location	**9.5**	**2.0**	**8.0**	**5.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	1.87	2.65	2.71	2.75	3.91	5.09	6.66	10.82
August	Location	**11.0**	**8.0**	**13.0**	**2.0**	**5.0**	**9.5**	**15.9**	**69.0**
	Mean	2.72	2.83	2.87	2.90	3.18	3.36	3.62	9.77
November	Location	**2.0**	**9.5**	**8.0**	**15.9**	**5.0**	**11.0**	**13.0**	**69.0**
	Mean	1.29	1.44	1.96	2.01	2.10	2.73	3.40	3.89

ASH FREE DRY WEIGHT

February	Location	**9.5**	**5.0**	**8.0**	**11.0**	**2.0**	**13.0**	**15.9**	**69.0**
	Mean	0.38	0.47	0.61	0.62	0.69	0.82	1.01	1.45
May	Location	**9.5**	**8.0**	**2.0**	**5.0**	**11.0**	**13.0**	**15.9**	**69.0**
	Mean	1.41	1.57	1.58	1.63	2.25	2.44	3.03	3.22
August	Location	**13.0**	**9.5**	**11.0**	**5.0**	**8.0**	**2.0**	**15.9**	**69.0**
	Mean	1.54	1.78	1.78	1.86	1.95	2.01	2.40	2.48
November	Location	**2.0**	**11.0**	**9.5**	**15.9**	**8.0**	**69.0**	**13.0**	**5.0**
	Mean	0.39	0.68	0.79	0.92	1.23	1.48	1.51	1.53

Table 3-6. Phytoplankton taxa identified in quarterly samples collected in Lake Norman from August 1987 to November 1998.

TAXON	87	88	89	90	91	92	93	94	95	96	97	98
CLASS: CHLOROPHYCEAE												
Acanthospaera zachariasi Lemm.				X	X		X					
Actidesmium hookeri Reinsch							X					
Actinastrum hantzchii Lagerheim	X	X		X	X	X	X	X				
Ankistrodesmus braunii (Naeg) Brunn									X	X	X	X
A. falcatus (Corda) Ralfs	X	X	X	X	X	X	X	X	X	X	X	X
A. fusiformis Corda sensu Korsch.			X	X	X	X	X	X				
A. spiralis (Turner) Lemm.	X	X	X	X	X		X				X	
A. spp. Corda					X		X					
Arthrodesmus convergens Ehrenberg									X			
A. incus (Breb.) Hassall		X			X				X			X
A. subulatus Kutzing										X	X	X
A. spp. Ehrenberg							X	X				
Asterococcus limneticus G. M. Smith				X	X	X	X	X				
Botryococcus braunii Kutzing					X	X						
Carteria frtzschii Takeda	X	X										
C. spp. Diesing		X		X		X	X				X	
Characium spp. Braun			X									
Chlamydomonas spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X
Chlorella vulgaris Beyerink											X	
Chlorogonium euchlorum Ehrenberg	X			X						X	X	
C. spirale Scherffel & Pascher								X	X			
Closteriopsis longissima West & West	X	X	X	X	X	X	X	X	X	X	X	X
Closterium gracile Brebisson										X		
C. incurvum Brebisson	X	X						X	X	X	X	X
C. spp. Nitzsch			X	X	X		X					
Coccomonas orbicularis Stein												X
Coelastrum cambricum Archer	X	X	X	X	X	X	X	X	X	X	X	X
C. microporum Nageli									X	X		X
C. sphaericum Nageli				X	X			X		X		
C. proboscideum Bohlin					X							
C. spp. Nageli				X	X							
Cosmarium anulosum v. *concinnum* (Rab) W&W	X											
C. asphaerosporum v. *strigosum* Nord.	X	X	X	X	X	X	X	X	X	X	X	X
C. contractum Kirchner	X				X			X	X	X	X	X
C. pokornyanum (Grun.) W. & G.S. West												X
C. polygonum (Nag.) Archer	X								X	X	X	X
C. phaseolus f. *minor* Boldt.											X	X
C. regnellii Wille	X						X			X	X	X

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
C. regnesi Schmidle					X	X	X					
C. tenue Archer	X	X							X	X	X	X
C. tinctum Ralfs	X	X					X	X	X	X	X	X
C. tinctum v. *tumidum* Borge.											X	
C. spp. Corda	X	X	X	X	X	X	X	X				
Crucigenia crucifera (Wolle) Collins	X	X		X	X				X	X	X	X
C. fenestrata Schmidle					X							
C. irregularis Wille		X				X	X	X		X		X
C. rectangularis (A. Braun) Gay												X
C. tetrapedia (Kirch.) West & West	X	X	X	X	X	X	X	X	X	X	X	X
Dictyospaerium ehrenbergianum Nageli	X	X										
D. pulchellum Wood	X	X	X	X	X	X	X	X	X	X	X	X
Dimorphococcus spp. Braun				X								
Elakatothrix gelatinosa Wille	X	X	X	X	X	X	X	X	X	X	X	X
Euastrum denticulatum (Kirch.) Gay									X	X	X	X
E. spp. Ehrenberg		X		X		X	X					
Eudorina elegans Ehrenberg		X								X		
Franceia droescheri (Lemm.) G. M. Smith	X	X							X	X	X	X
F. ovalis (France) Lemm.		X	X	X	X	X	X	X				
Gloeocystis botryoides (Kutz.) Nageli	X											
G. gigas Kutzing	X	X	X							X	X	X
G. major Gerneck *ex.* Lemmermann												X
G. planktonica (West & West) Lemm.			X	X	X	X	X	X	X	X	X	X
G. vesiculosa Naegeli												X
G. spp. Nageli	X	X	X	X	X	X	X	X				
Golenkinia paucispina West & West	X	X										
G. radiata Chodat	X	X	X	X	X	X	X	X	X	X	X	X
Gonium pectorale Mueller												X
G. sociale (Duj.) Warming		X							X			X
Kirchneriella contorta (Schmidle) Bohlin		X	X	X	X	X	X	X				X
K. lunaris (Kirch.) Mobius		X	X		X							
K. lunaris v. *dianae* Bohlin			X								X	
K. obesa W. West		X	X	X	X	X	X	X				
K. subsulitaria G. S. West	X	X							X	X	X	X
K. spp. Schmidle	X	X							X	X	X	
Lagerheimia ciliata (Lag.) Chodat	X											
L. citriformis (Snow) G. M. Smith											X	
L. longiseta (Lemmermann) Printz	X											
L. quadriseta (Lemm.) G. M. Smith			X	X	X	X						
L. subsala Lemmerman	X	X		X	X	X	X	X		X	X	X
Mesostigma viridE Lauterborne	X	X							X	X	X	X
Micractinium pusillum Fresen.	X	X	X	X	X	X	X	X	X	X	X	X
Monoraphidium contortum Thuret		X	X		X	X	X	X				
M. pusillum Printz		X	X		X	X	X	X				

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
Mougeitia elegantula Whittrock	X	X							X	X	X	X
M. spp. Agardh		X				X	X	X				
Nephrocytium agardhianum Nageli		X			X							
N. limneticum (G.M. Smith) G.M. Smith	X	X										
Oocystis borgii Snow												X
O. ellyptica W. West		X										X
O. lacustris Chodat		X										
O. parva West & West	X	X	X	X					X	X	X	X
O. pusilla Hansgirg			X	X			X	X	X	X	X	X
O. pyriformis Prescott												X
O. spp. Nageli				X								
Pandorina charkowiensis Kprshikov	X											
P. morum Bory			X	X		X	X					
Pediastrum biradiatum Meyen	X											
P. duplex Meyen	X	X		X	X		X		X	X	X	
P. duplex v. *gracillimum* West and West											X	X
P. tetras v. *tetroadon* (Corda) Rabenhorst	X	X	X	X	X	X	X	X	X	X	X	X
P. spp. Meyen				X	X							
Planktosphaeria gelatinosa G. M. Smith	X	X							X			
Quadrigula closterioides (Bohlin) Printz					X					X	X	
Q. lacustris (Chodat) G. M. Smith		X										
Scenedesmus abundans (Kirchner) Chodat	X	X	X	X								
S. abundans v. *asymetrica* (Schr.) G. Sm.	X	X	X	X	X	X	X	X		X	X	
S. abundans v. *brevicauda* G. M. Smith	X								X			
S. acuminatus (Lagerheim) Chodat	X					X	X	X	X	X		X
S. armatus v. *bicaudatus* (Gug.-Prin.)Chod	X	X		X	X	X	X	X	X	X	X	X
S. bijuga (Turp.) Lagerheim	X	X	X	X			X	X	X	X	X	X
S. bijuga v. *alterans* (Reinsch) Hansg.	X											
S. brasiliensis Bohlin									X	X	X	X
S. denticulatus Lagerheim	X	X	X	X	X	X	X	X	X	X		X
S. dimorphus (Turp.) Kutzing	X			X		X	X	X			X	X
S. incrassulatus G. M. Smith	X											
S. quadricauda (Turp.) Brebisson	X	X	X	X	X	X	X	X	X	X	X	X
S. smithii Teiling										X		
S. spp. Meyen			X	X	X	X	X	X				
Schizochlamys compacta Prescott										X		X
Schoederia setigera (Schroed.) Lemm.		X			X							
Selenastrum gracile Reinsch					X					X		
S. minutum (Nageli) Collins	X	X	X	X	X	X	X	X	X	X	X	X
S. westii G. M. Smith	X	X				X			X	X		X
Sorastrum americanum (Bohlin) Schmidle											X	
Sphaerocystis schoeteri Chodat	X	X		X					X			X
Sphaerozosma granulatum Roy & Bliss	X	X										
Stauastrum americanum (W&W) G. Sm.	X	X							X	X	X	X

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
S. apiculatum Brebisson	X										X	X
S. brachiatum Ralfs											X	X
S. brevispinum Brebisson	X											X
S. chaetocerus (Schoed.) G. M. Smith						X	X	X				
S. curvatum W. West	X			X	X	X	X	X	X	X	X	X
S. cuspidatum Brebisson	X										X	X
S. dejectum Brebisson	X	X	X	X	X	X		X				
S. dickeii v. *maximum* West & West		X										
S. gladiosum Turner							X					
S. leptocladum v. *sinuatum* Wolle	X				X							
S. manfeldtii v. *fluminense* Schumacher		X		X	X			X	X		X	X
S. megacanthum Lundell	X	X					X	X				
S. orbiculare Ralfs								X				
S. paradoxum Meyen			X	X	X	X	X	X				X
S. paradoxum v. *cingulum* West & West	X											
S. paradoxum v. *parvum* W. West	X											X
S. subcruciatum Cook & Wille	X								X		X	X
S. tetracerum Ralfs	X	X	X	X	X	X	X	X	X	X	X	X
S. turgescens de Not.	X	X										
S. spp. Meyen			X	X	X	X		X				
Tetraedron bifurcatum v. *minor* Prescott										X		
T. caudatum (Corda) Hansgirg	X	X	X	X		X		X		X	X	X
T. limneticum Borge						X						
T. lobulatum v. *crassum* Prescott							X					
T. minmum (Braun) Hansgirg	X	X	X	X				X	X	X		X
T. muticum (Braun) Hansgirg		X			X	X	X	X	X	X		X
T. obesum (W & W) Wille *ex* Brunnthaler										X		
T. planktonicum G. M. Smith												X
T. pentaedricum West & West			X					X				
T. regulare Kutzing					X	X	X	X				
T. regulare v. *bifurcatum* Wille												X
T. regulare v. *incus* Teiling		X	X				X					
T. trigonum (Nageli) Hansgirg	X	X		X	X		X			X	X	X
T. trigonum v. *gracile* (Reinsch) DeToni						X				X		
T. spp. Kutzing		X		X			X					
Tetrospora spp. Link							X	X				
Tetrastrum heteracanthum (Nordst.) Chod.				X								
Treubaria setigerum (Archer) G. M. Smith	X	X	X	X	X	X	X	X	X	X	X	X
Westella botryoides (West & West) Wilde.												X
W. linearis G. M. Smith		X										X
Xanthidium spp. Ehrenberg								X				
CLASS: BACILLARIOPHYCEAE												
Achnanthes microcephala Kutzing	X		X	X					X	X	X	X

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
A. spp. Bory	X	X	X	X	X	X	X	X		X		
Anomoeoneis vitrea (Grunow) Ross		X		X				X	X	X		X
A. spp. Pfitzer								X				
Asterionella formosa Hassall		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
Cocconeis placentula Ehrenberg	X	X										X
C. spp. Ehrenberg								X				
Cyclotella comta (Ehrenberg) Kutzing			X					X	X	X	X	X
C. glomerata Bachmann									X	X	X	X
C. meneghiniana Kutzing		X	X					X	X	X	X	X
C. pseudostelligera Hustedt	X											
C. stelligera Cleve & Grunow	X	X		X	X	X	X	X	X	X	X	X
C. spp. Kutzing		X	X	X								
Cymbella minuta (Bliesch & Rabn.) Reim.				X		X	X		X	X		X
C. tumida (Breb.) van Huerck								X				
C. turgida (Gregory) Cleve		X										
C. spp. Agardh		X			X							
Denticula thermalis Kuetzing												X
Diploneis spp. Ehrenberg				X								
Eunotia zasuminensis (Cab.) Koerner			X	X	X	X	X	X	X	X	X	X
Fragilaria crotonensis Kitton	X	X		X	X	X	X	X	X	X	X	X
Frustulia rhomboides (Ehr.) de Toni	X	X										
Gomphonema spp. Agardh					X			X				
Melosira ambigua (Grun.) O. Muller	X	X	X	X	X	X	X	X	X	X	X	X
M. distans (Ehr.) Kutzing		X	X	X	X	X	X	X	X	X	X	X
M. granulata (Ehr.) Ralfs		X		X	X		X					
M. granulata v. *angustissima* O. Muller	X	X	X	X	X	X	X	X	X	X	X	X
M. italica (Ehr.) Kutzing	X	X										
M. varians Agardh						X	X					X
M. spp. Agardh	X	X	X	X	X	X	X	X		X		
Navicula cryptocephala Kutzing				X						X	X	
N. exigua (Gregory) O. Muller									X			
N. exigua v. *capitata* Patrick										X		
N. subtilissima Cleve									X			
N. spp. Bory			X	X	X	X	X	X				
Nitzschia acicularis W. Smith		X		X	X	X	X			X	X	X
N. agnita Hustedt		X	X	X	X	X	X	X	X	X	X	X
N. holsatica Hustedt	X	X	X	X	X				X		X	X
N. palea (Kutzing) W. Smith	X	X						X	X	X	X	X
N. sublinearis Hustedt	X									X		X
N. spp. Hassall	X	X	X	X	X	X	X	X				
Pinnularia spp. Ehrenberg							X					

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
Rhizosolenia spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X
Skeletonema potemos (Weber) Hilse	X	X					X		X	X		X
Stephanodiscus spp. Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X
Surirella linearis v. *constricta* (Ehr.) Grun.												X
Synedra actinastroides Lemmerman								X				
S. acus Kutzing	X	X					X	X			X	X
S. delicatissima Lewis						X	X	X				
S. filiformis v. *exilis* Cleve-Euler												X
S. planktonica Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X
S. rumpens Kutzing	X	X							X	X	X	X
S. rumpens v. *fragilarioides* Grunow		X										
S. rumpens v. *scotica* Grunow		X										
S. ulna (Nitzsch) Ehrenberg	X	X			X				X	X	X	X
S. spp. Ehrenberg	X	X	X	X	X	X	X	X				
Tabellaria fenestrata (Lyngb) Kutzing	X	X	X	X	X	X	X	X	X	X	X	X
T. flocculosa (Roth.) Kutzing	X	X		X				X				
CLASS: CHRYSOPHYCEAE												
Aulomonas purdyii Lackey		X						X	X	X	X	X
Bicoeca petiolatum (Stien) Pringsheim											X	X
Calcicomonas pascheri (Van Goor) Lund									X			
Chromulina spp. Chien.	X	X										X
Chrysosphaerella solitaria Lauterb.					X	X	X	X	X	X	X	X
Codomonas annulata Lackey										X	X	X
Dinobryon bavaricum Imhof	X	X	X	X	X	X	X	X	X	X	X	X
D. cylindricum Imhof				X	X	X	X	X		X		X
D. divergens Imhof			X	X		X	X	X	X	X		
D. sertularia Ehrenberg		X							X			
D. spp. Ehrenberg		X	X	X	X				X	X	X	X
Domatomococcus cylindricum Lackey												X
Erkinia subaequicilliata Skuja	X	X	X	X				X	X	X	X	X
Kephyrion littorale Lund												X
K. rubi-claustri Conrad	X	X										
K. skujae Ettl		X										
K. spp. Pascher			X	X	X	X	X	X	X	X	X	X
Mallomonas acaroides Perty								X				
M. akrokomos (Naumann) Krieger				X								X
M. alpina Pascher												X
M. caudata Conrad			X	X	X	X	X	X	X			
M. globosa Schiller				X								X
M. pseudocoronata Prescott		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
M. spp. Perty	X	X	X	X	X	X	X	X				
Ochromonas granularis Doflein												X

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
Ochromonas spp. Wyss	X	X	X					X	X	X	X	X
Pseudokephyrion schilleri Conrad												X
P. tintinabulum Conrad												X
Rhizochrisis spp. Pascher		X			X							
Salpingoeca frequentissima (Zachary) Lemm.												X
Stelexomonas dichotoma Lackey		X	X	X	X	X	X	X	X	X	X	X
Stokesiella epipyxis Pascher											X	X
Synura spinosa Korschikov	X	X		X					X	X	X	X
S. uvella Ehrenberg		X	X	X	X		X	X				
S. spp. Ehrenberg			X	X	X	X	X	X				
Uroglenopsis americana (Caulk.) Lemm.		X							X	X	X	
CLASS: HAPTOPHYCEAE												
Chrysochromulina parva Lackey	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: XANTHOPHYCEAE												
Characiopsis dubia Pascher									X	X		X
Dichotomococcus curvata Korschikov	X											
Ophiocytium caoitatum v. *longisp.* (M) Lem							X	X				
CLASS: CRYPTOPHYCEAE												
Cryptomonas erosa Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X
C. erosa v. *reflexa* Marsson				X								X
C. marsonii Skuja			X	X	X	X	X	X				
C. ovata Ehrenberg	X	X	X	X	X	X	X	X	X	X	X	X
C. phaseolus Skuja			X	X	X	X	X	X				
C. reflexa Skuja	X	X	X	X	X	X	X	X	X	X	X	X
C. spp. Ehrenberg			X	X	X	X	X	X				
Rhodomonas minuta Skuja	X	X	X	X	X	X	X	X	X	X	X	X
CLASS: MYXOPHYCEAE												
Agmenellum quadriduplicatum Brebisson						X	X	X	X		X	X
Anabaena catenula (Kutzing) Born.		X									X	X
A. scheremetievi Elenkin											X	X
A. wisconsinense Prescott	X	X							X	X	X	X
A. spp. Bory		X	X	X	X	X	X	X		X		
Anacystis incerta (Lemm.) Druet & Daily			X	X	X	X	X	X				X
A. spp. Meneghini	X											
Chroococcus dispersus (Keissl.) Lemm.												X
C. limneticus Lemmermann	X	X		X							X	X
C. minor Kutzing	X											
C. turgidus (Kutz.) Lemmermann					X		X					
C. spp. Nageli	X		X	X	X	X	X	X	X	X	X	X
Coelosphaerium kuetzingiana Nageli				X								

Table 3-6 (continued)

	87	88	89	90	91	92	93	94	95	96	97	98
Dactylococcopsis irregularis Hansgirg				X	X			X				
D. smithii Chodat and Chodat											X	X
Gomphospaeria lacustris Chodat		X	X	X	X	X	X	X				
Lyngbya contorta Lemmermann					X	X						
L. limnetica Lemmermann			X	X	X	X	X	X				
L. subtilis W. West			X	X	X	X		X				
L. spp. Agardh	X	X	X	X	X	X	X	X	X	X	X	X
Merismopedia tenuissima Lemmermann												X
Microcystis aeruginosa Kutz. *emend* Elen.	X		X	X	X	X	X	X	X	X		X
Oscillatoria geminata Meneghini	X	X		X					X	X	X	X
O. limnetica Lemmermann		X							X	X	X	X
O. splendida Greville									X	X		X
O. spp. Vaucher	X	X	X					X				
Phormidium angustissimum West & West			X	X	X			X				
P. spp. Kutzing		X	X	X			X	X				
Raphidiopsis curvata Fritsch & Rich	X	X				X		X	X	X	X	X
Rhabdoderma sigmoidea Schm. & Lautrb.			X									
Synecococcus lineare (Sch. & Laut.) Kom.				X	X	X	X	X	X	X		X
CLASS: EUGLENOPHYCEAE												
Euglena acus Ehrenberg				X								
E. minuta Prescott			X									
E. polymorpha Dangeard										X		
E. spp. Ehrenberg		X	X	X	X		X	X	X	X		X
Lepocinclus spp. Perty		X										X
Phacus orbicularis Hubner						X						
P. tortus (Lemm.) Skvortzow			X	X		X						
P. spp. Dujardin			X									
Trachelomonas acanthostoma (Stok.) Defl.		X										
T. hispida (Perty) Stein							X		X			
T. pulcherrima Playfair		X										
T. volvocina Ehrenberg	X	X							X			
T. spp. Ehrenberg				X	X			X				
CLASS: DINOPHYCEAE												
Ceratium hirundinella (OFM) Schrank	X	X	X	X		X		X	X		X	X
Glenodinium borgei (Lemm.) Schiller	X	X								X		
G. gymnodinium Penard			X	X	X	X	X				X	
G. palustre (Lemm.) Schiller	X											
G. quadridens (Stein) Schiller				X				X				
G. spp. (Ehrenberg) Stein					X			X				
Gymnodinium aeruginosum Stein												X
Gymnodinium spp. (Stein) Kofoid & Swezy				X	X	X	X	X	X		X	X
Peridinium aciculiferum Lemmermann		X										

Table 3-6 (continued)

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

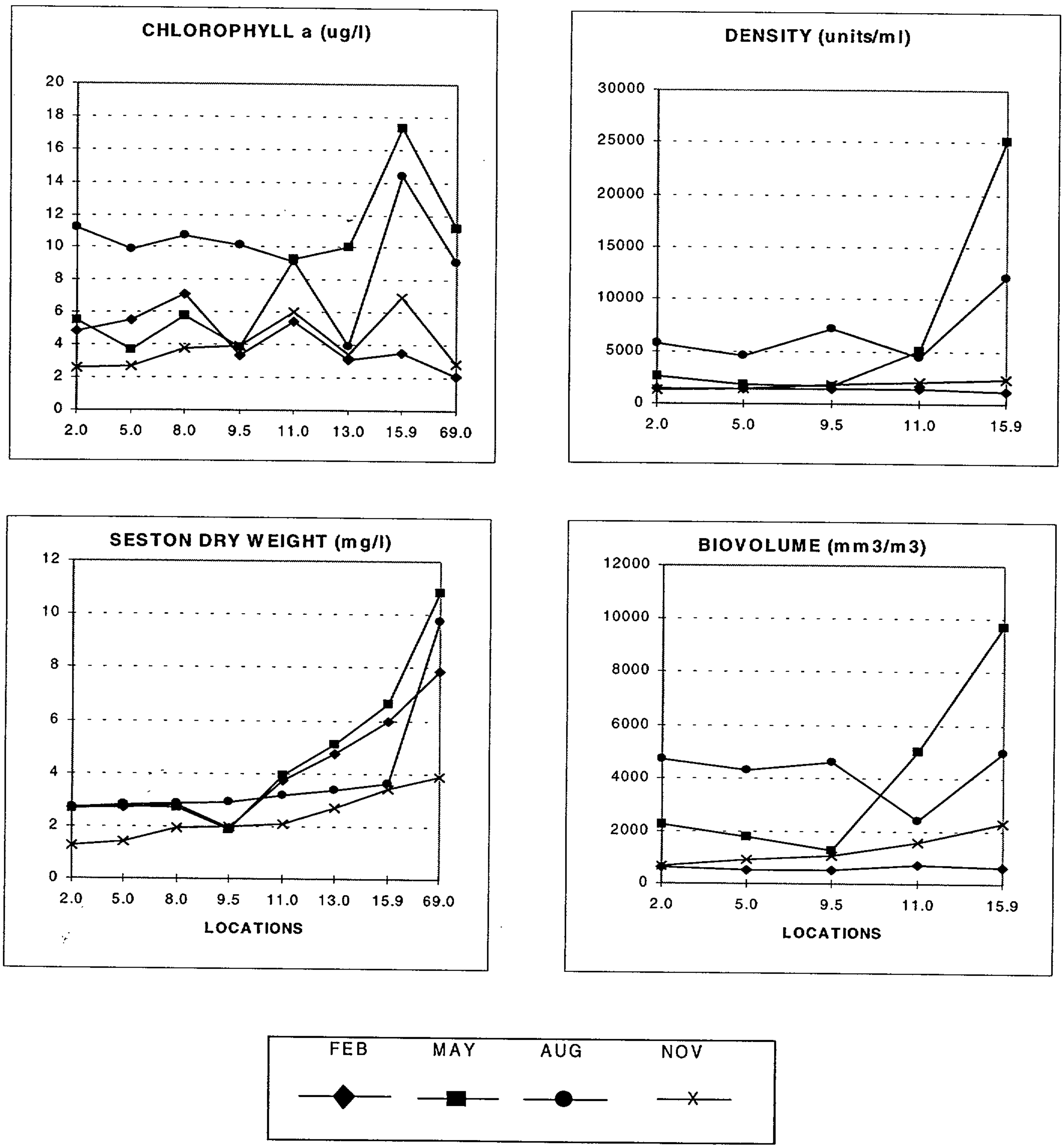

Figure 3-1. Phytoplankton chlorophyll *a*, densities, and biovolumes; and seston weights at locations in Lake Norman, NC, in February, May, August, and November 1998.

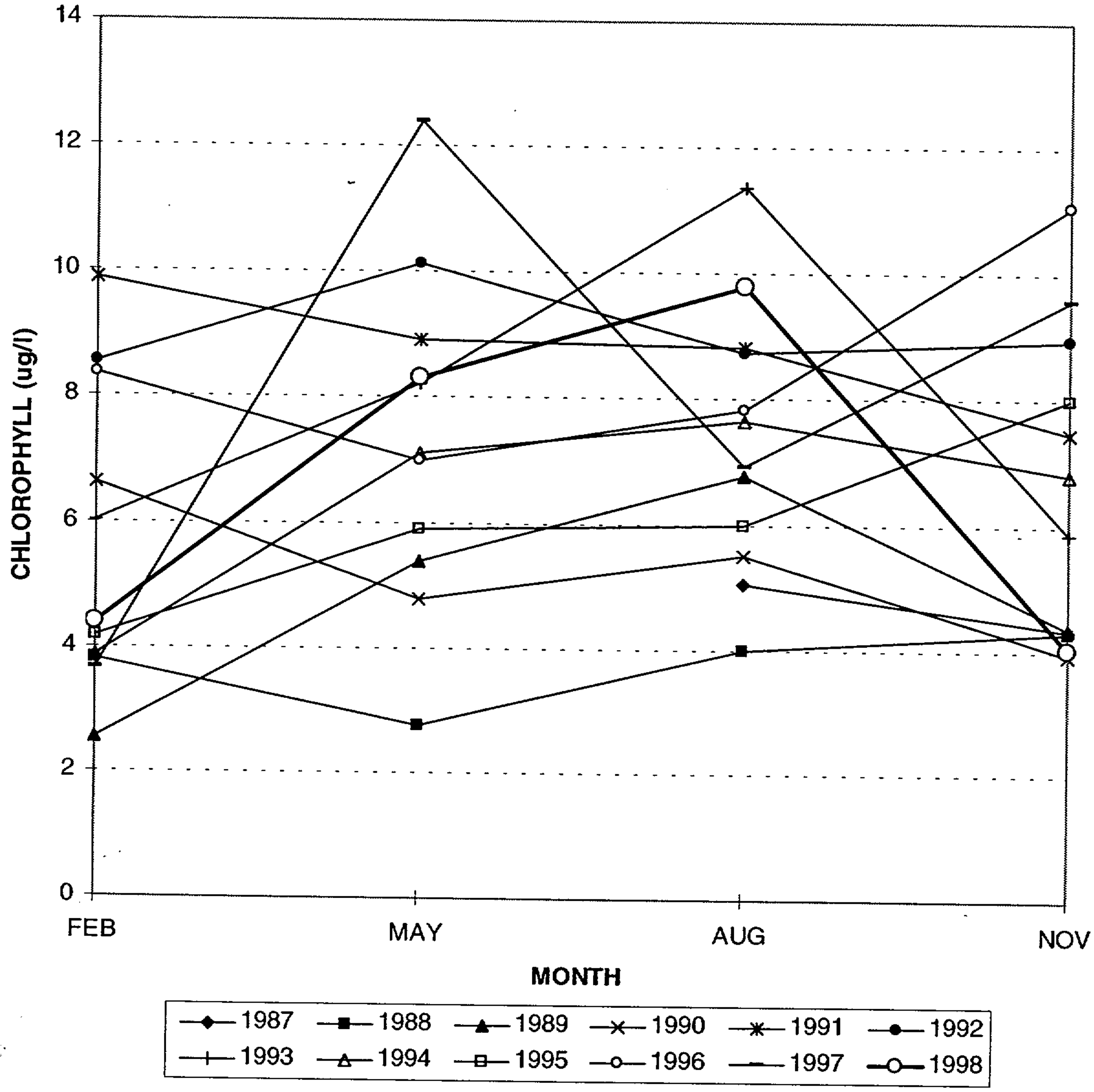

Figure 3-2. Phytoplankton chlorophyll *a* annual lake means from all locations in Lake Norman, NC, for each quarter since August 1987.

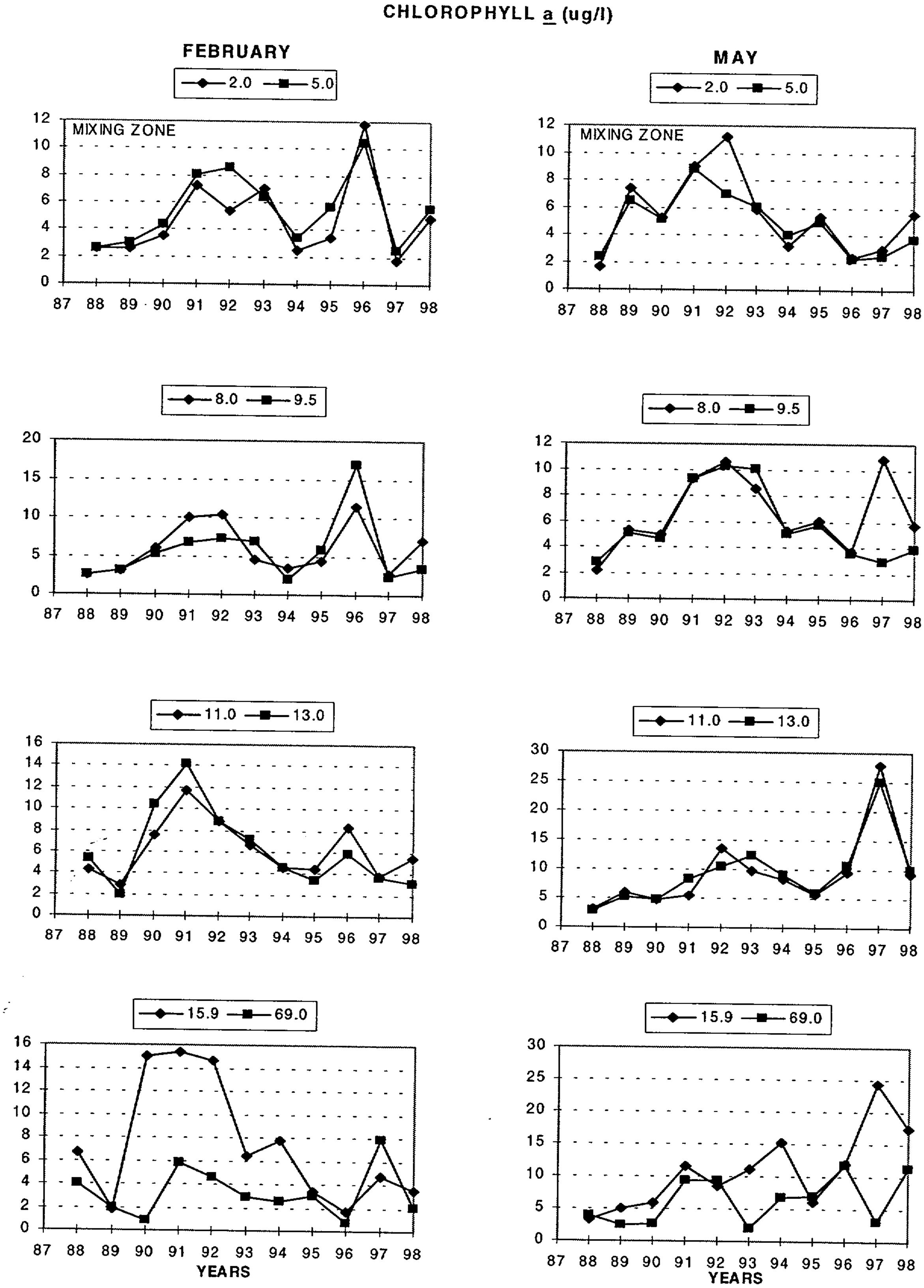

Figure 3-3. Phytoplankton chlorophyll *a* concentrations by location for samples collected in Lake Norman, NC, from August 1987 through November 1998.

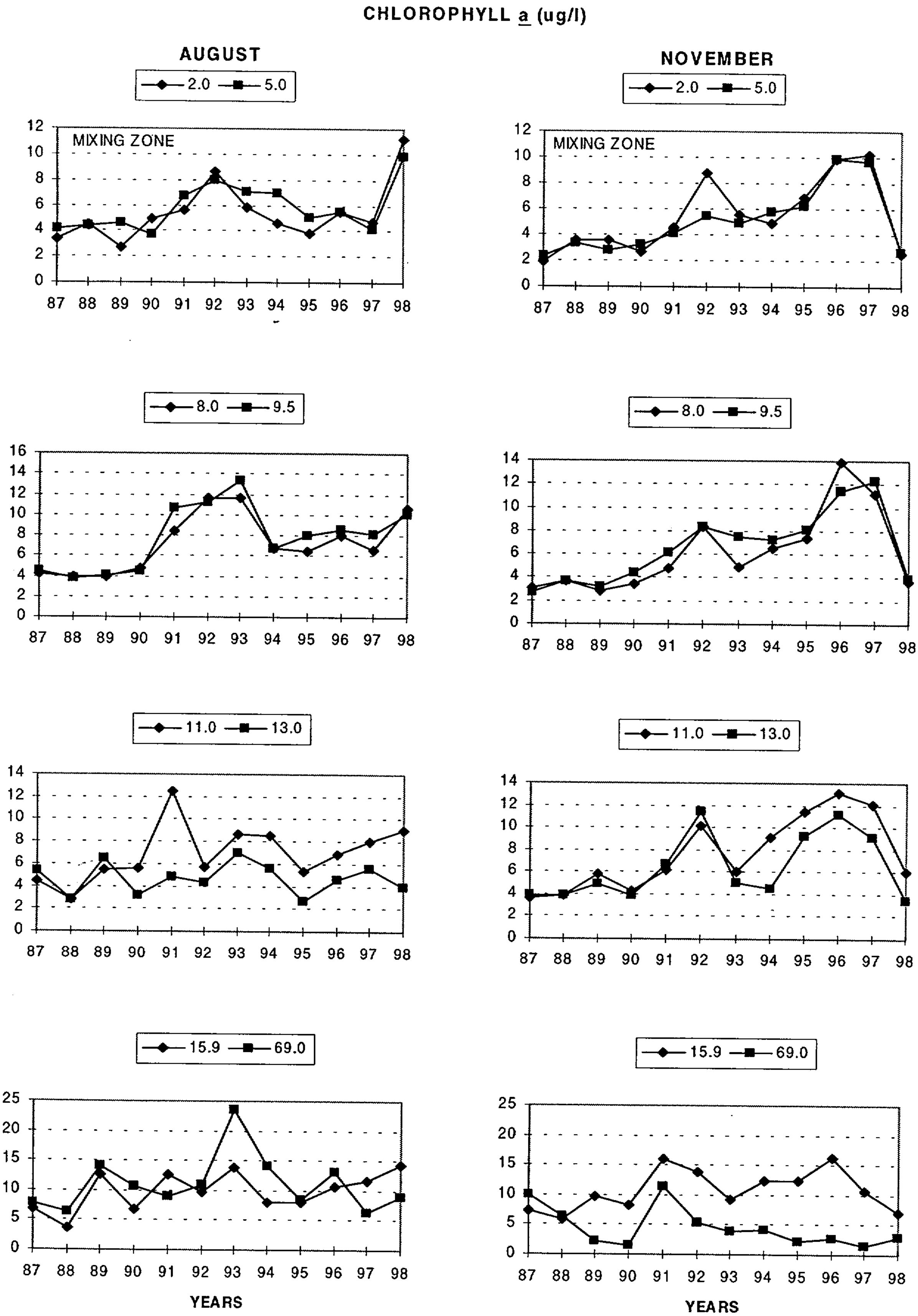

Figure 3-3 (continued).

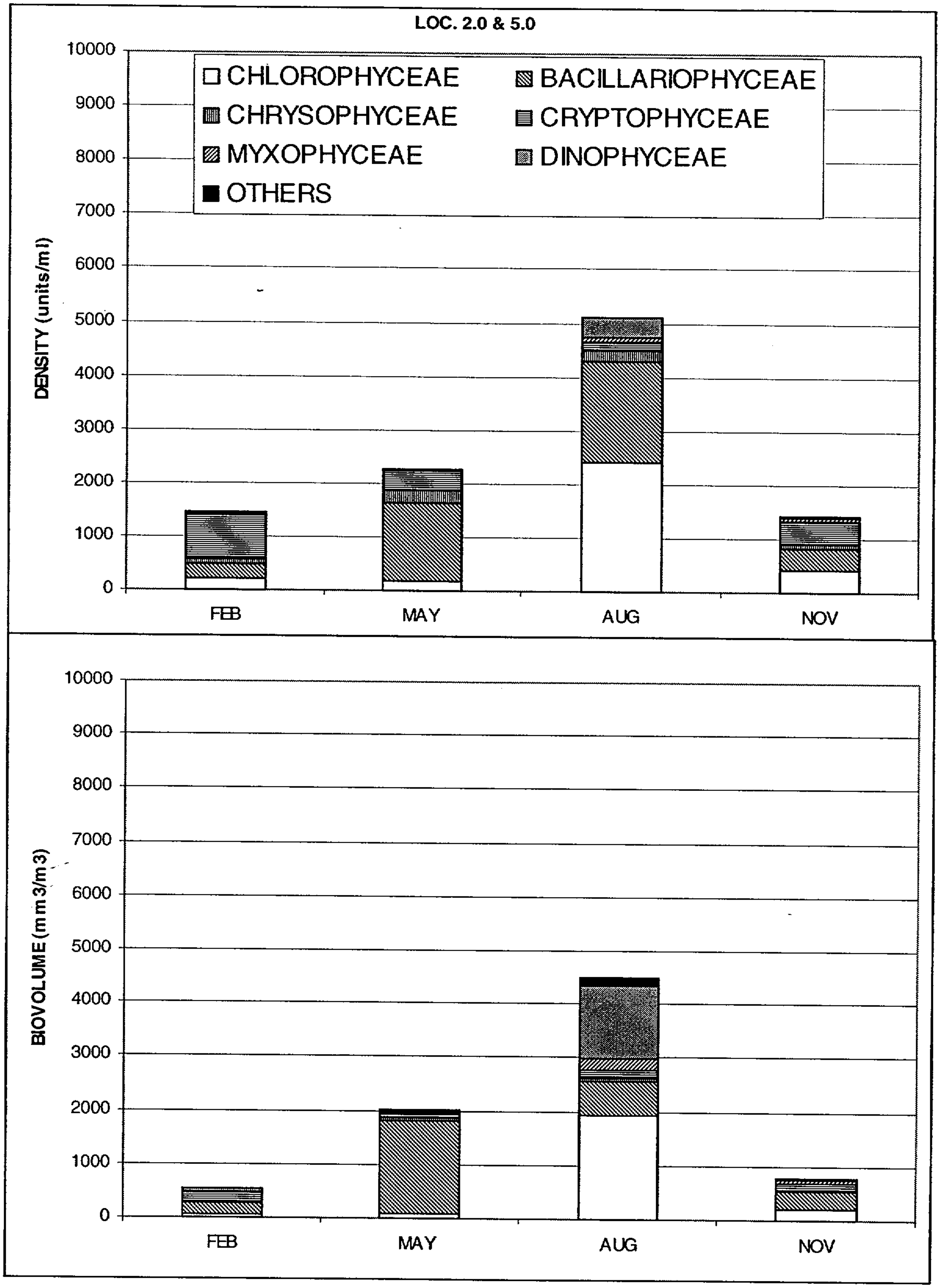

Figure 3-4. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Locations 2.0 and 5.0 in Lake Norman, NC, during 1998.

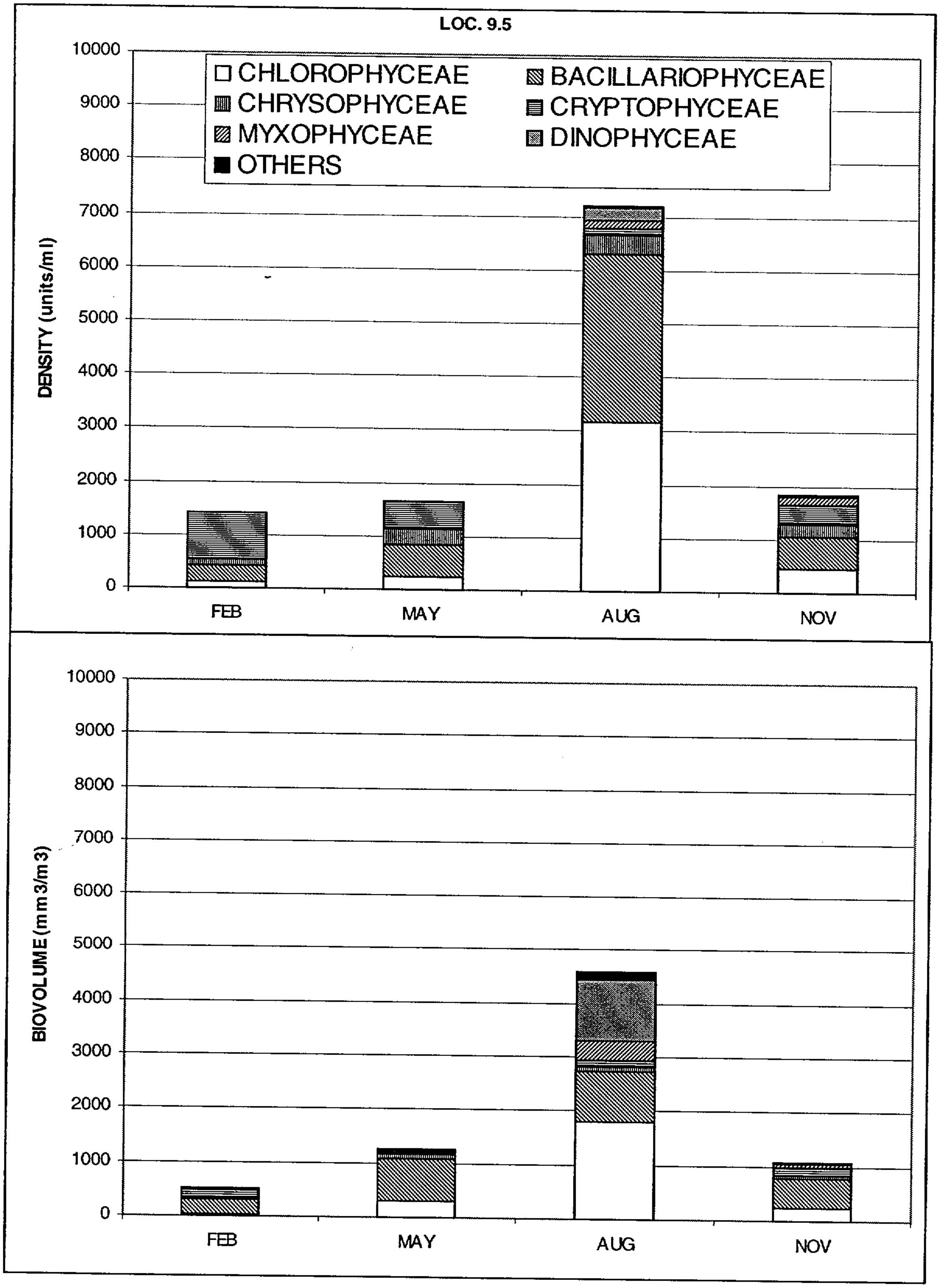

Figure 3-5. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 9.5 in Lake Norman, NC, during 1998.

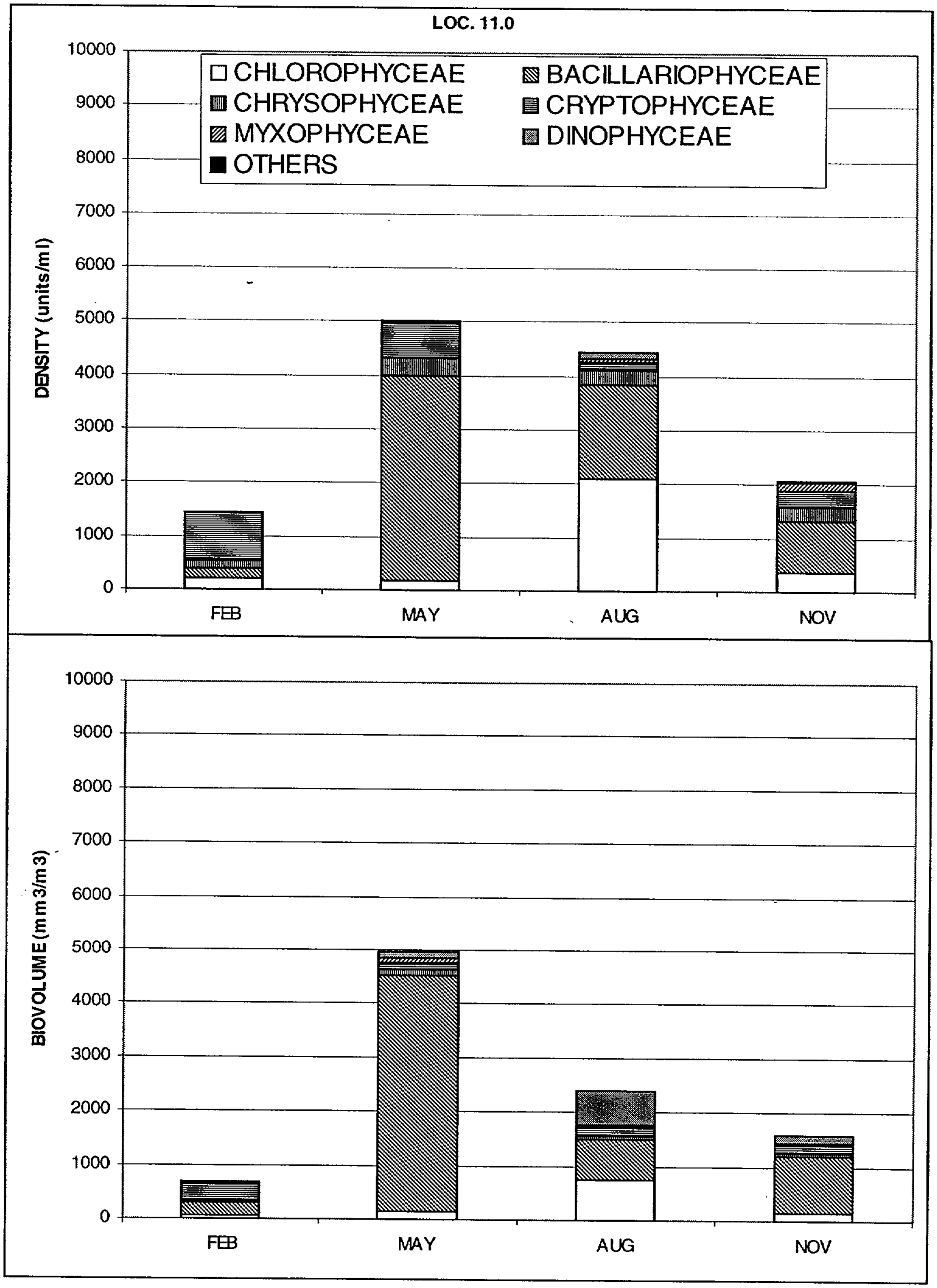

Figure 3-6. Class composition (mean density and biovolume) of phytoplankton from euphotic zone samples collected at Location 11.0 in Lake Norman, NC, during 1998.

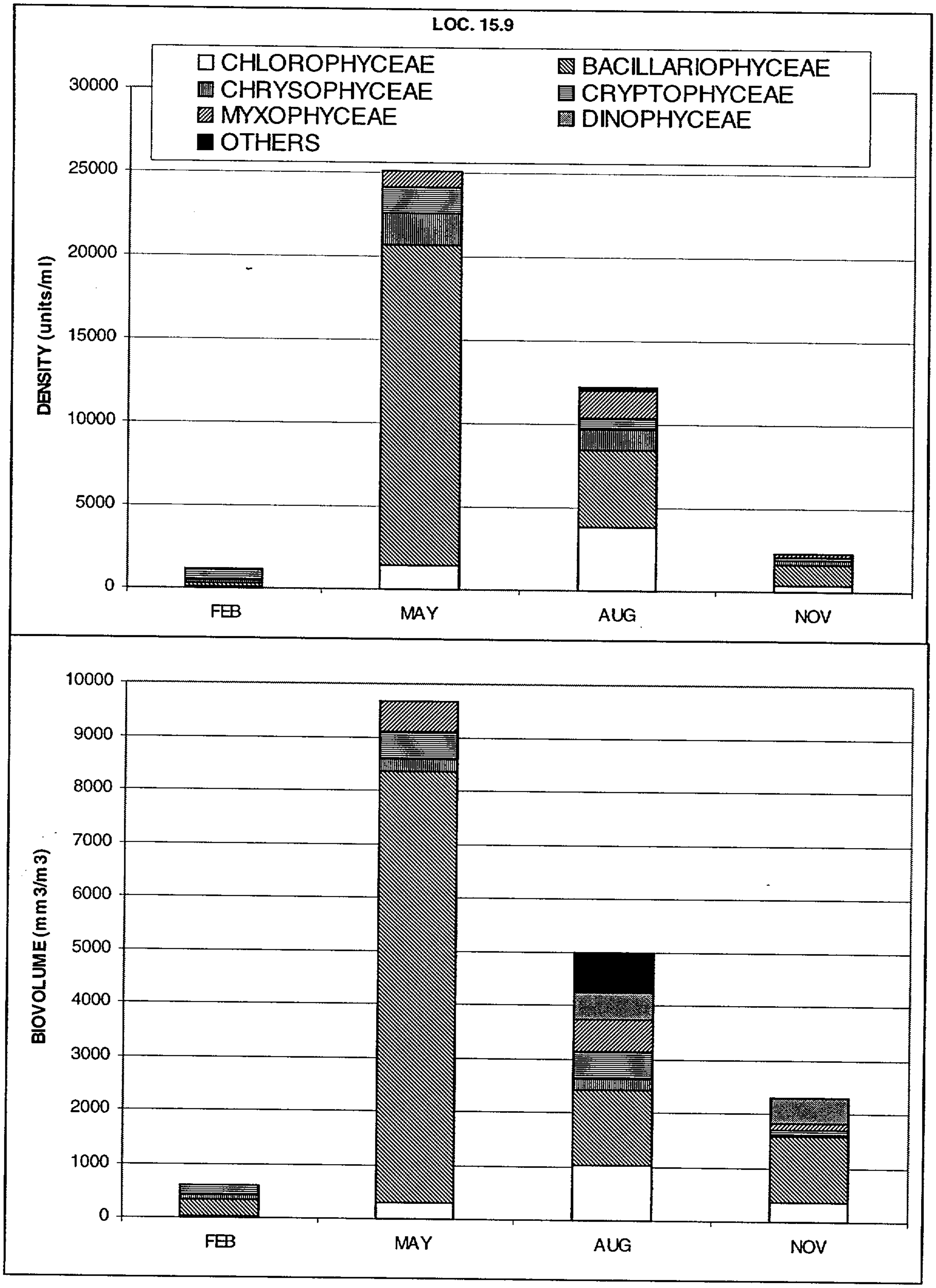

Figure 3-7. Class composition (density and biovolume) of phytoplankton from euphotic zone samples collected at Location 15.9 in Lake Norman, NC, during 1998.

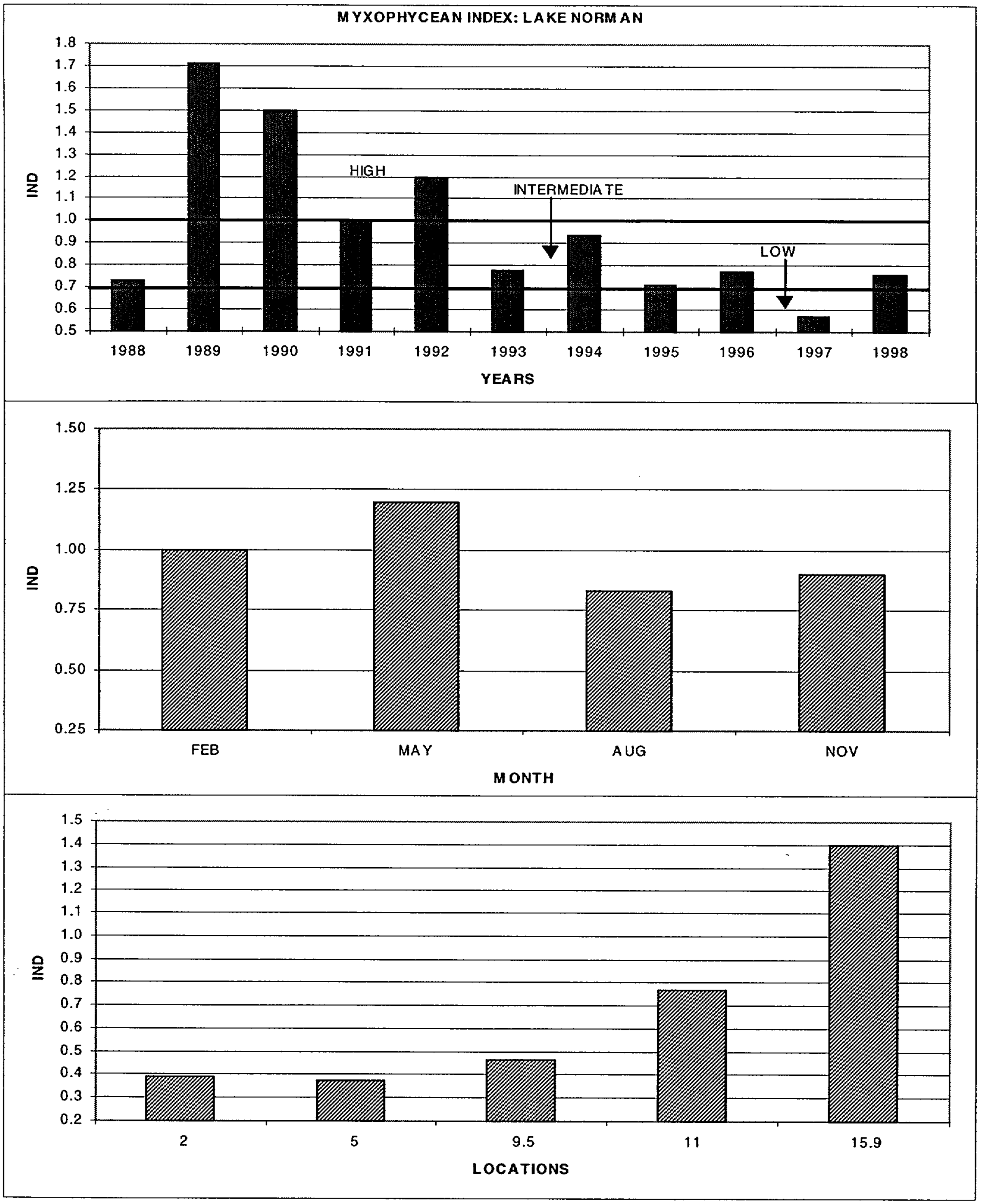

Figure 3-8. Myxophycean index values by year (top), each season in 1998 (mid), and each location in Lake Norman, NC, during 1998.

CHAPTER 4

ZOOPLANKTON

INTRODUCTION

The objectives of the Lake Norman Maintenance Monitoring Program for zooplankton are to:

1. Describe and characterize quarterly patterns of zooplankton standing crops at selected locations on lake Norman; and
2. compare and evaluate zooplankton data collected during this study (February, May, August, and November 1998) with historical data collected during the period 1987-1997.

Previous studies of Lake Norman zooplankton populations have demonstrated a bimodal seasonal distribution with highest values generally occurring in the spring, and a less pronounced fall peak. Considerable spatial and year-to-year variability has been observed in zooplankton abundance in Lake Norman (Duke power Company 1976, 1985; Hamme 1982; Menhinick and Jensen 1974).

METHODS AND MATERIALS

Duplicate 10 m to surface and bottom to surface net tows were taken at Locations 2.0, 5.0, 9.5, 11.0, and 15.9 in Lake Norman (Chapter 2, Figure 2-1) on 26 February, 15 May, 6 August, and 5 November, 1998 (Note: bottom to surface net tows were not taken at Location 5.0 in November due to high wind conditions). For discussion purposes the 10 m to surface tow samples are called epilimnetic samples and the bottom to surface net tow samples are called whole column samples. Locations 2.0 and 5.0 are defined as the Mixing Zone and Locations 9.5, 11.0 and 15.9 are defined as Background Locations. Field and laboratory methods for zooplankton standing crop analysis were the same as those reported in Hamme (1982). Zooplankton standing crop data from 1998 were compared with corresponding data from quarterly monitoring begun in August 1987.

A one way ANOVA was performed on epilimnetic total zooplankton densities by quarter. This was followed by a Duncan's Multiple Range Test to determine which location means were significantly different.

RESULTS AND DISCUSSION

Total Abundance

During 1998, total zooplankton densities in epilimnetic samples were highest in May at all locations (Table 4-1, Figure 4-1). The lowest epilimnetic densities in the Mixing Zone occurred in November; while annual minimum densities at Locations 9.5 and 11.0 were observed in August. The lowest mean epilimnetic density at Location 15.9 occurred in February. Epilimnetic densities ranged from a low of 11,500/m^3 at Location 15.9 in February, to a high of 172,600/m^3 at Location 11.0 in May. In the whole column samples, maximum densities at Locations 2.0, 9.5, and 15.9 were observed in May, and maximum densities at Locations 5.0 and 11.0 occurred in August and November, respectively. Minimum densities were observed in February at Locations 5.0 and 15.9, and in August at all other locations. Whole column densities ranged from 12,400/m^3 at Location 15.9 in February to 93,800/m^3 at Location 11.0 in November. Zooplankton data from 1998 were generally within historical ranges (Duke Power Company 1998, Hamme (1982). High values in May 1998 could have been, in part, a response to elevated phytoplankton concentrations observed during that month (Chapter 3). Zooplankton responses to phytoplankton standing crops were documented in previous years.

Total zooplankton densities were most often higher in epilimnetic samples than in whole column samples during 1998, as has been the case in previous years (Duke Power Company 1998). 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).

Considerable spatial variability in epilimnetic zooplankton densities was observed during each sampling period. However, the results of the Duncan's multiple range test revealed few statistically significant differences (Table 4-2). In February, the mean density at Location 11.0 was significantly higher than at Locations 2.0, 5.0, and 15.9. During May, Location 5.0 ranked significantly lower than all but Location 2.0. During August, the density at Location 15.9 was significantly higher than at Locations 5.0, 9.5, and 11.0, but was in the same range as Location 2.0. Locations 11.0 and 15.9 had significantly higher densities than other locations in November. Mean zooplankton densities in the Mixing Zone were consistently lower than mean densities from Background Locations, as has been the case in most previous years of the Program (Duke Power Company 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998).

Historically, both seasonal and spatial variability among epilimnetic zooplankton densities has been much higher among Background Locations than among Mixing Zone locations. The uppermost location, 15.9, showed the greatest range of densities during 1998 (Table 4-1, Figure 4-2). Apparently epilimnetic zooplankton communities are more greatly influenced by environmental conditions at the uplake locations than at downlake locations. Location 15.9 represents the transition zone between river and reservoir where populations would be expected to fluctuate due to the dynamic nature of this region of Lake Norman. At the locations nearest the dam (Locations 2.0 and 5.0), seasonal variations are dampened and the overall production would be lower due to the relative stability of this area (Thornton, et al. 1990). A similar trend was observed among phytoplankton communities (Chapter 3).

Epilimnetic zooplankton densities during 1998 were generally within the seasonal ranges of those observed during previous years of the Program. The highest long term February densities occurred in 1996 at Locations 2.0 and 11.0, in 1995 at Locations 5.0 and 9.5, and in 1992 at Location 15.9 (Figure 4-2). Long term maximum densities for May occurred at Location 2.0 in 1998, at Locations 5.0, and 11.0 in 1995, and at Locations 9.5 and 15.9 in 1988. Long term August maxima occurred in 1988 at all but Location 15.9, which had its highest August value in 1996. For November, maximum densities occurred at all locations in 1988. Since 1990, the densities at Mixing Zone Locations in May, August, and November have not fluctuated much between years; while fluctuations in densities during February appear to be increasing. The Background locations continue to demonstrate high year-to-year variability.

Community Composition

One hundred zooplankton taxa have been identified since the Lake Norman Maintenance Monitoring Program began in August 1987 (Table 4-3). Eight taxa previously unreported during this Program were identified in 1998; however, six of these had been reported from Lake Norman in earlier studies (Hamme 1982, Duke Power Company 1985). The two previously unreported taxa were the rotifer, *Asplanchna brightweli*, and an unidentified ostracod.

Copepods were the most abundant group during most of 1998 (Table 4-1, Figures 4-3 and 4-4). These microcrustaceans were dominant at all locations in February, at all but Location 15.9 in May, and at all but Location 2.0 (whole column) in November. Copepods were also dominant at Location 5.0 in August. Cladocerans were dominant in eplimnetic and whole column samples at Locations 2.0, 9.5, and 11.0 in August, and in the whole column sample at Location 2.0 in November. Rotifers dominated zooplankton at Location 15.9 in May and August. Both numbers and percent composition of rotifers had declined since 1997, and the overall lakewide percent composition was the lowest yet observed. This represents the continuation of a trend of increasing relative abundances of microcrustaceans and declining rotifer abundances first observed in 1995 (Figure 4-5). A similar trend was observed between 1988 and 1991. During that period, the annual lake-wide percent composition of microcrustaceans increased from 13% to approximately 52% in epilimnetic samples, and showed an overall increase of from 20% to 60% in whole column samples. Between 1995 and 1998 lake-wide percent composition of microcrustaceans increased from approximately 40% to 63% in epilimnetic samples, and increased from approximately 40% to 67% in whole column samples. This trend was also observed among Mixing Zone and Background locations (Figures 4-6 and 4-7). The nature of both trends would indicate some lake-wide natural cause at work, and not the impacts of station operations which would be reflected in localized areas. In addition, the annual zooplankton density (based on quarterly data from the same months sampled during this Program) in the Mixing Zone was dominated by microcrustaceans in 1979, several years prior to MNS station operations (Duke Power Company 1985).

Copepoda

Copepod populations were consistently dominated by immature forms (primarily nauplii) during 1998, as has always been the case. Adult copepods seldom constituted more than 5% of the total zooplankton density at any location during 1998. *Tropocyclops*, and *Epischura* were often important constituents of adult populations; while *Mesocyclops*, *Cyclops* and *Diaptomus* were occasionally important (Table 4-4).

Copepods showed no consistent spatial trends during 1998 (Table 4-1, Figure 4-3). Copepod densities peaked in May at both Mixing Zone and Background Locations (Table 4-1, Figure 4-4). Historically, maximum copepod densities were most often observed in May.

Cladocera

Bosmina was the most abundant cladoceran observed in 1998 samples, as had been the case in most previous studies (Duke Power Company 1998, Hamme 1982). *Bosmina* often comprised greater than 5% of the total zooplankton densities in both epilimnetic and whole column samples. *Bosminopsis* and *Diaphanosoma* were also important among cladocerans (Table 4-4). During August, *Bosminopsis* dominated cladoceran populations at all locations, and was the dominant zooplankter in the epilimnion at Locations 9.5 and 11.0, and in whole column samples from all but Location 15.9. *Diaphanosoma* dominated cladoceran populations in most May samples.

Long-term seasonal trends of cladoceran densities were variable: From 1990 to 1993, peak densities occurred in February; while in 1994 and 1995, maxima were recorded in May (Duke Power Company 1996). During 1996, peak cladoceran densities occurred in May in the Mixing Zone, and in August among Background Locations (Duke Power Company 1997). During 1997, cladoceran densities again peaked in May (Duke Power Company 1998). Maximum cladoceran densities in 1998 occurred in August (Figure 4-4). Spatially, cladocerans were more abundant at Locations 9.5 and 11.0 than at other locations (Table 4-1, Figure 4-3).

Rotifera

Polyarthra was the most abundant rotifer in 1998 samples, as was the case in 1997 (Duke Power Company 1998). This taxon dominated rotifer populations at Locations 2.0 (epilimnion) and 5.0 (whole column) in February, and was the dominant rotifer at all locations in May (Table 4-4). *Polyarthra* dominated rotifer populations in the Mixing Zone and Location 9.5 in August; and was the dominant rotifer at all but Location 15.9 in November. *Conochilus* was the most abundant rotifer at Locations 5.0 (epilimnion), 9.5 (all), and 15.9 (whole column) in February; and was also the dominant rotifer at Location 15.9 (all) in August. *Synchaeta* dominated rotifer populations at Location 11.0 (all) and 15.9 (epilimnion) in February. *Ploesoma* and *Keratella* were the dominant rotifers among samples from Locations 11.0 (February) and 15.9 (November), respectively. All of these taxa have been identified as important constituents of rotifer populations, as well as zooplankton communities, in previous studies (Duke power Company 1998; Hamme 1982).

Long term tracking of rotifer populations indicated some notable seasonal patterns. Peak mean densities typically occurred in May. Mean densities were higher at Background Locations than in the Mixing Zone except for May and August 1996, and August 1997 (Figure 4-4). The highest Mixing Zone mean rotifer density since 1990 occurred in February 1996; while the highest mean rotifer density from Background Locations was observed in May 1995. Since then, the densities have decreased substantially. Rotifer densities were generally higher among Background Locations than locations in the Mixing Zone, as was the case in 1997 (Duke power company 1998). This pattern was also documented by Hamme (1982) in earlier studies on Lake Norman.

FUTURE STUDIES

No changes are planned for the zooplankton portion of the Lake Norman Maintenance Monitoring Program in 2000.

SUMMARY

Maximum zooplankton standing crops in 1998 usually occurred in May. Minimum values were most often observed in August; however, lowest densities at certain locations occurred in November (Mixing Zone, epilimnion) and February (15.9 and 5.0, whole column). This represented a slight shift from 1997 when all minimum values were observed in August. In 1998, densities were higher in epilimnetic samples than in whole column samples. Mean zooplankton densities tended to be higher among Background Locations than among Mixing Zone locations during all seasons of 1998.

Long term trends showed much higher year-to-year variability at Background Locations than at Mixing Zone Locations. Epilimnetic zooplankton densities during 1998 were generally within ranges of those observed in previous years.

One-hundred zooplankton taxa have been recorded from Lake Norman since the Program began in 1987. Eight taxa previously unreported during the Program were identified during 1998.

Copepods dominated zooplankton standing crops through most of 1998. Overall relative abundance of copepods in 1998 was the highest observed in recent years. The relative abundance of copepods and cladocerans was higher in 1998 than in 1997, representing a continuing trend of increasing microcrustacean abundance since 1995. A similar trend was observed throughout Lake Norman between 1988 and 1991. Microcrustaceans also dominated the annual mean zooplankton density in the Mixing Zone during at least one pre-operational year. Cladocerans dominated most zooplankton densities in August; while rotifers were dominant only at Location 15.9 in May and August. Historically, copepods and rotifers have shown annual peaks in May; while cladocerans continued to demonstrate year-to-year variability.

Copepods were dominated by immature forms with adults seldom accounting for more than 5% of zooplankton densities. The most important adult copepods were *Tropocyclops* and *Epischura*. *Bosmina* was the predominant cladoceran, as has been the case in most previous years of the Program. *Bosminopsis* dominated cladoceran populations in August; while *Diaphanosoma* dominated cladoceran populations at most locations in May. The most abundant rotifer observed in 1998 was *Polyarthra*, as in previous years.

Lake Norman continues to support a highly diverse and viable zooplankton community. Long term and seasonal changes observed over the course of the study, as well as seasonal and spatial variability observed during 1998, were likely due to normal environmental factors.

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Table 4-1. Total zooplankton densities (no. X 1000/m3), densities of major zooplankton taxonomic groups, and percent composition (in parentheses) of major taxa in 10m to surface (10-S) and bottom to surface (B-S) net tow samples collected from Lake Norman in February, May, August, and November 1998.

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
2/26/98	10-S	COPEPODA	48.1	23.5	56.7	48.0	8.1
			(69.9)	(66.7)	(61.9)	(50.7)	(70.5)
		CLADOCERA	5.4	1.8	13.4	14.9	1.2
			(7.8)	(5.0)	(14.6)	(15.7)	(10.1)
		ROTIFERA	15.4	10.0	21.4	31.8	2.2
			(22.3)	(28.3)	(23.4)	(33.6)	(19.4)
		TOTAL	**68.9**	**35.3**	**91.6**	**94.7**	**11.5**
	B-S						
	depth (m)						
	of tow	COPEPODA	32.4	21.1	34.2	32.6	9.4
	for each		(64.3)	(61.7)	(57.8)	(51.8)	(76.2)
	Location	CLADOCERA	4.4	2.9	11.3	7.4	0.9
	2.0=30		(8.8)	(8.4)	(19.1)	(11.9)	(7.6)
	5.0=17	ROTIFERA	13.6	10.2	13.6	22.8	2.0
	9.5=21		(26.8)	(29.9)	(23.0)	(36.3)	(15.8)
	11.0=25						
	15.9=20	**TOTAL**	**50.4**	**34.2**	**59.2**	**62.8**	**12.4***
5/15/98	10-S	COPEPODA	50.8	26.0	72.3	63.6	46.5
			(43.8)	(45.4)	(54.8)	(36.9)	(30.9)
		CLADOCERA	19.3	8.1	22.2	49.4	11.8
			(16.6)	(14.1)	(16.8)	(28.6)	(7.8)
		ROTIFERA	45.8	23.3	37.4	59.6	92.4
			(39.9)	(40.6)	(28.4)	(34.5)	(61.3)
		TOTAL	**115.8**	**57.4**	**131.9**	**172.6**	**150.7**
	B-S						
	depth (m)						
	of tow	COPEPODA	26.0	19.4	52.9	32.3	30.7
	for each		(49.1)	(50.9)	(61.6)	(40.3)	(36.5)
	Location	CLADOCERA	8.7	5.6	12.3	22.1	4.8
	2.0=30		(16.4)	(14.9)	(14.3)	(27.6)	(5.7)
	5.0=17	ROTIFERA	18.2	13.0	20.7	25.7	48.8
	9.5=21		(34.5)	(34.2)	(24.1)	(32.1)	(57.9)
	11.0=25						
	15.9=20	**TOTAL**	**52.9**	**38.0**	**86.0**	**80.1**	**84.3**

Table 1 (continued).

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
8/6/98	10-S	COPEPODA	5.7	17.5	3.0	4.6	16.5
			(10.7)	(40.7)	(7.7)	(10.4)	(23.5)
		CLADOCERA	38.7	14.8	30.6	35.1	18.3
			(72.0)	(34.4)	(79.1)	(78.2)	(26.2)
		ROTIFERA	9.3	10.7	5.1	5.1	35.0
			(17.3)	(24.9)	(13.2)	(11.4)	(50.0)
		TOTAL	**53.8**	**43.0**	**38.7**	**44.9**	**70.0****
	B-S						
	depth (m)						
	of tow	COPEPODA	3.9	15.7	6.4	7.6	20.7
	for each		(17.5)	(40.3)	(18.6)	(26.1)	(34.5)
	Location	CLADOCERA	15.9	10.3	22.1	18.4	9.7
	2.0=29		(71.3)	(26.4)	(64.6)	(62.9)	(16.2)
	5.0=17	ROTIFERA	2.5	13.0	5.7	3.2	29.6
	9.5=21		(11.2)	(33.3)	(16.8)	(11.0)	(49.3)
	11.0=25						
	15.9=19	**TOTAL**	**22.3**	**39.0**	**34.2**	**29.3**	**59.9**
11/5/98	10-S	COPEPODA	11.4	15.4	22.0	46.6	36.7
			(56.8)	(48.5)	(54.1)	(51.2)	(50.0)
		CLADOCERA	4.9	8.2	4.0	9.4	7.2
			(24.9)	(25.7)	(9.9)	(10.5)	(9.8)
		ROTIFERA	3.7	8.2	14.7	34.9	29.4
			(18.3)	(25.7)	(36.0)	(38.3)	(40.2)
		TOTAL	**20.0**	**31.8**	**40.8**	**90.9**	**73.3**
	B-S						
	depth (m)						
	of tow	COPEPODA	17.2		24.4	45.4	28.0
	for each		(38.7)		(61.6)	(48.5)	(47.6)
	Location	CLADOCERA	22.8		2.8	10.5	5.3
	2.0=30		(51.3)		(7.1)	(11.2)	(9.1)
	5.0=	ROTIFERA	4.4		12.4	37.8	25.4
	9.5=19		(10.0)		(31.4)	(40.3)	(43.3)
	11.0=25						
	15.9=20	**TOTAL**	**44.4**	**NS**	**39.7**	**93.8**	**58.8**

* = *Chaoborus* spp., < 0.1/m^3, 0.4%
** = Ostracoda, 0.2/m^3, 0.2%
NS= Sample not collected due to high winds

Table 4-2. Dunkan's Multiple Range Test on epilimnetic zooplankton densities (no. X $1000/m^3$) in Lake Norman, NC during 1998.

February	Location	**15.9**	**5.0**	**2.0**	**9.5**	**11.0**
	Mean	11.5	35.3	68.9	91.6	94.7

May	Location	**5.0**	**2.0**	**9.5**	**15.9**	**11.0**
	Mean	57.4	115.8	131.9	150.7	172.6

August	Location	**9.5**	**5.0**	**11.0**	**2.0**	**15.9**
	Mean	38.7	43.0	44.9	53.8	70.0

November	Location	**2.0**	**5.0***	**9.5**	**15.9**	**11.0**
	Mean	20.0	31.8	40.8	73.3	90.9

* Location 5.0 had only one replicate

Table 4-3. Zooplankton taxa identified from samples collected quarterly on Lake Norman from August 1987 through November 1998 (* indicates new taxa observed in 1998).

COPEPODA

Cyclops thomasi Forbes
C. vernalis Fischer
C. spp.
Diaptomus birgei Marsh
D. mississippiensis Marsh
D. pallidus Herick
D. spp. Marsh
Epishura fluviatisis Herrick
Ergasilus spp.
* *Eucyclops agilis* (Koch)
Mesocyclops edax (S. A. Forbes)
M. spp. Sars
Tropocyclops prasinus (Fischer)
T. spp.
Calanoid copepodites
Cyclopoid copepodites
Harpacticoidea
Nauplii

CLADOCERA

Alona spp.Baird
Bosmina longirostris (O. F. Muller)
B. spp. Baird
Bosminopsis dietersi Richard
Ceriodaphnia lacustris Birge
C. spp. Dana
Chydorus spp. Leach
Daphnia ambigua Scourfield
D. catawba Coker
D. galeata Sars
D. laevis Birge
D. longiremisi Sars
D. lumholzi Sars
D. mendotae (Sars) Birge
D. parvula Fordyce
D. pulex (de Geer)
D. pulicaria Sars
D. retrocurva Forbes
D. schodleri Sars
D. spp. Mullen
Diaphanosoma brachyuram s. str. (Lievin)
D. spp. Fischer
Holopedium amazonicum Stingelin
H. gibberum Zaddach
H. spp. Stingelin
Ilyocryptus sordidus (Lieven)
I. spp. Sars
Leptodora kindtii (Focke)
Leydigia spp. Freyberg
Sida crystallina O. F. Muller

ROTIFERA

Anuropsis spp. Lauterborne
**Asplanchna brightwelli* Gosse
**A. priodonta* Gosse
A. spp. Gosse
Brachionus caydata Barrois and Daday
B. havavaensis Rousselet
B. patulus O. F. Muller
B. spp. Pallas
**Chromogaster ovalis* (Bergendel)
C. spp. Lauterborne
Collotheca balatonica Harring
C. mutabilis (Hudson)
C. spp. Harring
Colurella spp. Bory de St. Vincent
Conochiloides dossuarius Hudson
C. spp. Hlava
Conochilus unicornis (Rousselet)
C. spp. Hlava
**Filinia* spp. Bory de St. Vincent
**Gastropus stylifer* Imhof
G. spp. Imhof
Hexarthra mira Hudson
H. spp. Schmada
Kellicotia bostoniensis (Rousselet)
K. longispina Kellicott
K. spp. Rousselet
Keratella taurocephala Myers

Table 4-3 (continued)

ROTIFERA (cont.)

K. spp. Bory de St. Vincent
Lecane spp. Nitzsch
Macrochaetus subquadratus Perty
M. spp. Perty
Monostyla stenroosi (Meissener)
M. spp. Ehrenberg
Nothloca spp. Gosse
Ploeosoma hudsonii Brauer
P. truncatum (Levander)
P. spp. Herrick
Polyarthra euryptera (Weirzeijski)
P. major Burckhart
P. vulgaris Carlin
P. spp. Ehrenberg
Pompholyx spp. Gosse
Ptygure libra Meyers
P. spp. Ehrenberg
Synchaeta spp. Ehrenberg
Trichocerca capucina (Weireijski)
T. cylindrica (Imhof)
T. longiseta Schrank
**T. multicrinis* (Kellicott)
T. porcellus (Gosse)
T. pusilla Jennings
T. similis Lamark
T. spp. Lamark
Trichotria spp. Bory de St. Vincent
Unidentified Bdelloidea

INSECTA

Chaoborus spp. Lichtenstein

***OSTRACODA** (unidentified)

Table 4-4. Dominant taxa among copepods (adults), cladocerans, and rotifers, and their percent composition (in parentheses) of copepod, cladoceran and rotifer densities in Lake Norman samples during 1998.

	FEBRUARY	MAY	AUGUST	NOVEMBER
		COPEPODA	**EPILIMNION**	
2.0	*Epischura* (3.1)	*Epischura* (1.9)	No adults present	*Epischura* (2.8)
5.0	*Cycl/Tropo* (0.4)*	*Mesocyclops* (1.2)	*Tropocyclops* (0.9)*	*Tropocyclops* (3.0)*
9.5	*Tropocyclops* (2.4)	*Epischura* (2.2)	*Tropocyclops* (3.0)*	*Tropocyclops* (6.7)
11.0	*Cyclops* (3.3)	*Epischura* (6.4)	*Tropocyclops* (7.2)	*Tropocyclops* (5.4)
15.9	*Cyclops* (1.3)*	*Epischura* (16.0)	*Tropocyclops* (3.0)	*Tropocyclops* (17.4)
		COPEPODA	**WHOLE COLUMN**	
2.0	*Epischura* (1.8)	*Mesocyclops* (1.5)	*Mesocyclops* (3.6)	*Diaptomus* (6.2)
5.0	*Tropocyclops* (2.7)	*Epischura* (7.1)	*Tropocyclops* (10.6)	NOT SAMPLED
9.5	Epis/*Meso* (1.8)	*Epischura* (3.5)	*Tropocyclops* (9.5)	*Tropocyclops* (4.0)
11.0	*Cyclops* (4.0)	*Epischura* (6.8)	*Tropocyclops* (13.5)	*Diaptomus* (3.9)
15.9	*Tropocyclops* (0.5)*	*Epischura* (9.6)	*Tropocyclops* (5.6)	*Tropocyclops* (4.0)
		CLADOCERA	**EPILIMNION**	
2.0	*Bosmina* (84.9)	*Diaphanosoma* (67.2)	*Bosminopsis* (97.4)	*Bosmina* (85.8)
5.0	*Bosmina* (76.8)	*Diaphanosoma* (42.1)	*Bosminopsis* (96.6)	*Bosmina* (77.1)
9.5	*Bosmina* (75.5)	*Diaphanosoma* (43.1)	*Bosminopsis* (93.0)	*Bosmina* (84.6)
11.0	*Bosmina* (63.3)	*Diaphanosoma* (85.0)	*Bosminopsis* (79.7)	*Bosmina* (87.4)
15.9	*Bosmina* (82.0)	*Diaphanosoma* (45.6)	*Bosminopsis* (70.5)	*Bosmina* (90.5)
		CLADOCERA	**WHOLE COLUMN**	
2.0	*Bosmina* (88.6)	*Diaphanosoma* (77.6)	*Bosminopsis* (94.3)	*Diaphanosoma* (67.3)
5.0	*Bosmina* (63.0)	*Diaphanosoma* (52.2)	*Bosminopsis* (90.9)	NOT SAMPLED
9.5	*Bosmina* (74.6)	*Diaphanosoma* (42.5)	*Bosminopsis* (93.5)	*Bosmina* (86.1)
11.0	*Bosmina* (78.3)	*Diaphanosoma* (83.3)	*Bosminopsis* (78.2)	*Bosmina* (66.6)
15.9	*Bosmina* (58.2)	*Diaphanosoma* (57.8)	*Bosminopsis* (67.5)	*Bosmina* (83.1)

Table 4-4 (continued)

	FEBRUARY	MAY	AUGUST	NOVEMBER
		ROTIFERA	**EPILIMNION**	
2.0	*Polyarthra* (34.8)	*Polyarthra* (69.8)	*Polyarthra* (56.4)	*Polyarthra* (78.0)
5.0	*Conochilus* (28.6)	*Polyarthra* (45.7)	*Polyarthra* (46.4)	*Polyarthra* (74.3)
9.5	*Conochilus* (62.8)	*Polyarthra* (64.5)	*Polyarthra* (39.0)	*Polyarthra* (54.6)
11.0	*Synchaeta* (53.9)	*Polyarthra* (60.9)	*Ploeosoma* (35.6)	*Polyarthra* (45.7)
15.9	*Synchaeta* (48.0)	*Polyarthra* (54.7)	*Conochilus* (40.7)	*Keratella* (39.2)
		ROTIFERA	**WHOLE COLUMN**	
2.0	*Polyarthra* (28.0)	*Polyarthra* (56.7)	*Polyarthra* (42.7)	*Polyarthra* (74.7)
5.0	*Polyarthra* (36.9)	*Polyarthra* (36.0)	*Polyarthra* (60.5)	NOT SAMPLED
9.5	*Conochilus* (67.4)	*Polyarthra* (69.9)	*Polyarthra* (69.1)	*Polyarthra* (46.5)
11.0	*Synchaeta* (55.8)	*Polyarthra* (53.8)	*Ploeosoma* (34.0)	*Polyarthra* (46.3)
15.9	*Conochilus* (30.3)	*Polyarthra* (53.2)	*Conochilus* (37.4)	*Keratella* (35.8)

* = Only adults present in samples.

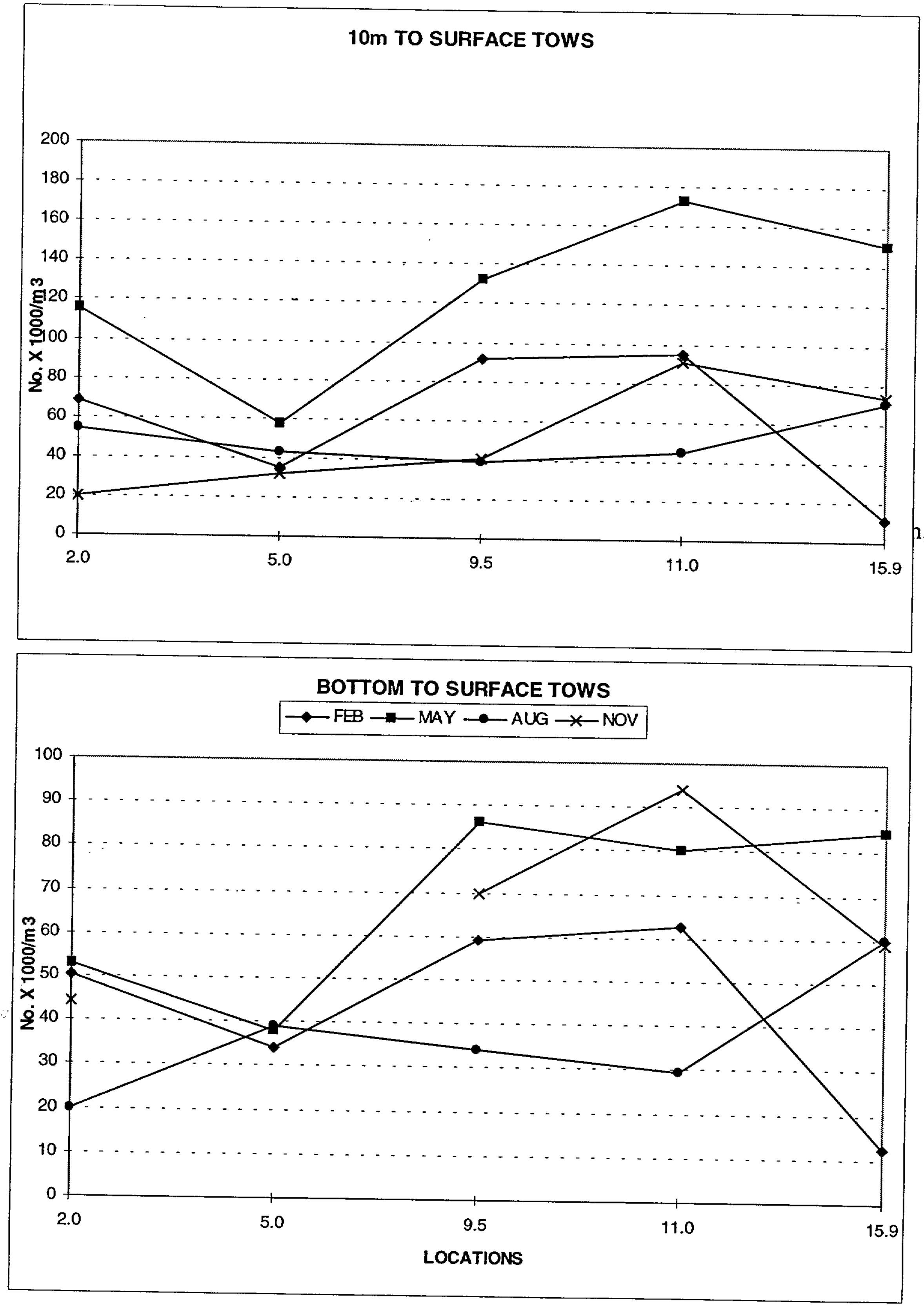
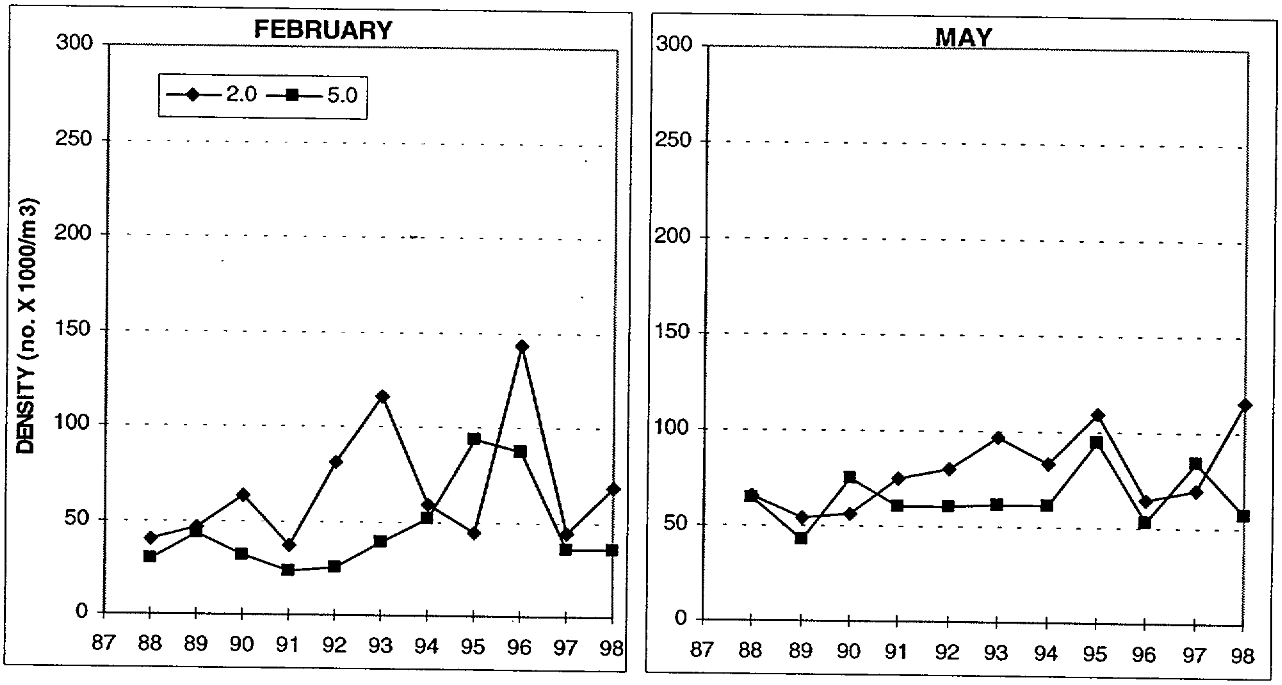


Figure 4-1. Total zooplankton density by location for samples collected in Lake Norman, NC, in 1998.

MIXING ZONE



BACKGOUND LOCATIONS

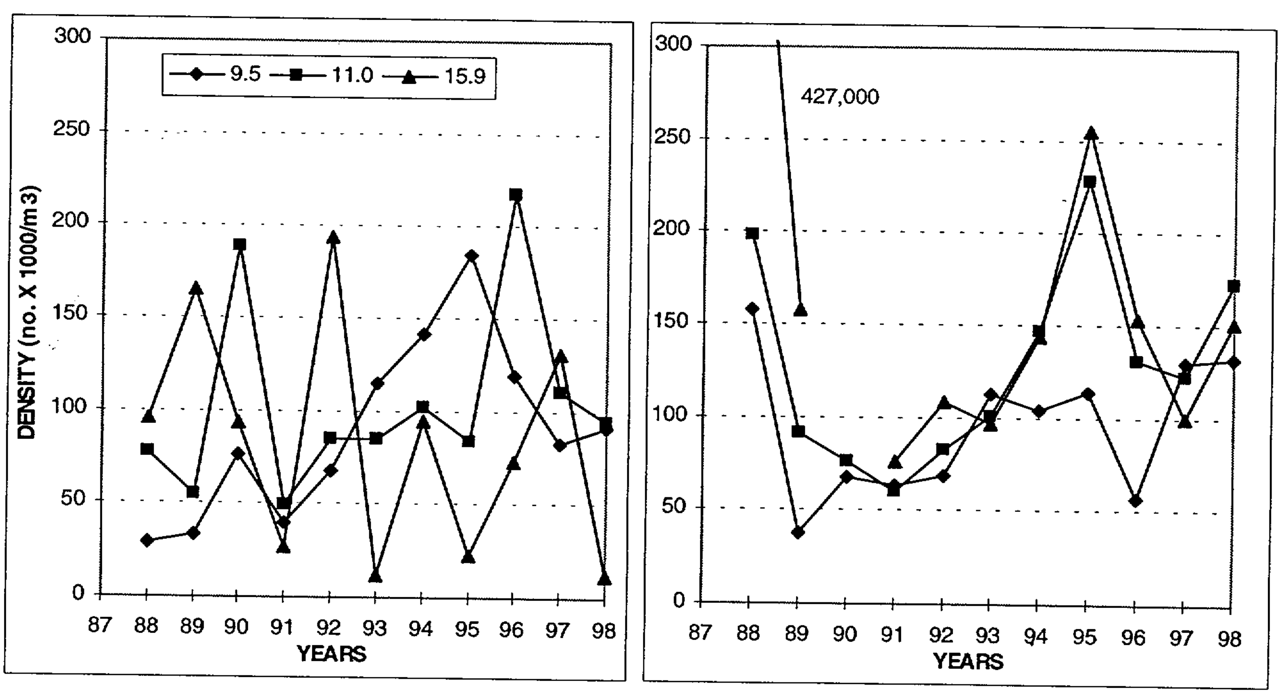


Figure 4-2. Total zooplankton densities by location for epilimnetic samples collected in Lake Norman, NC, in 1998.

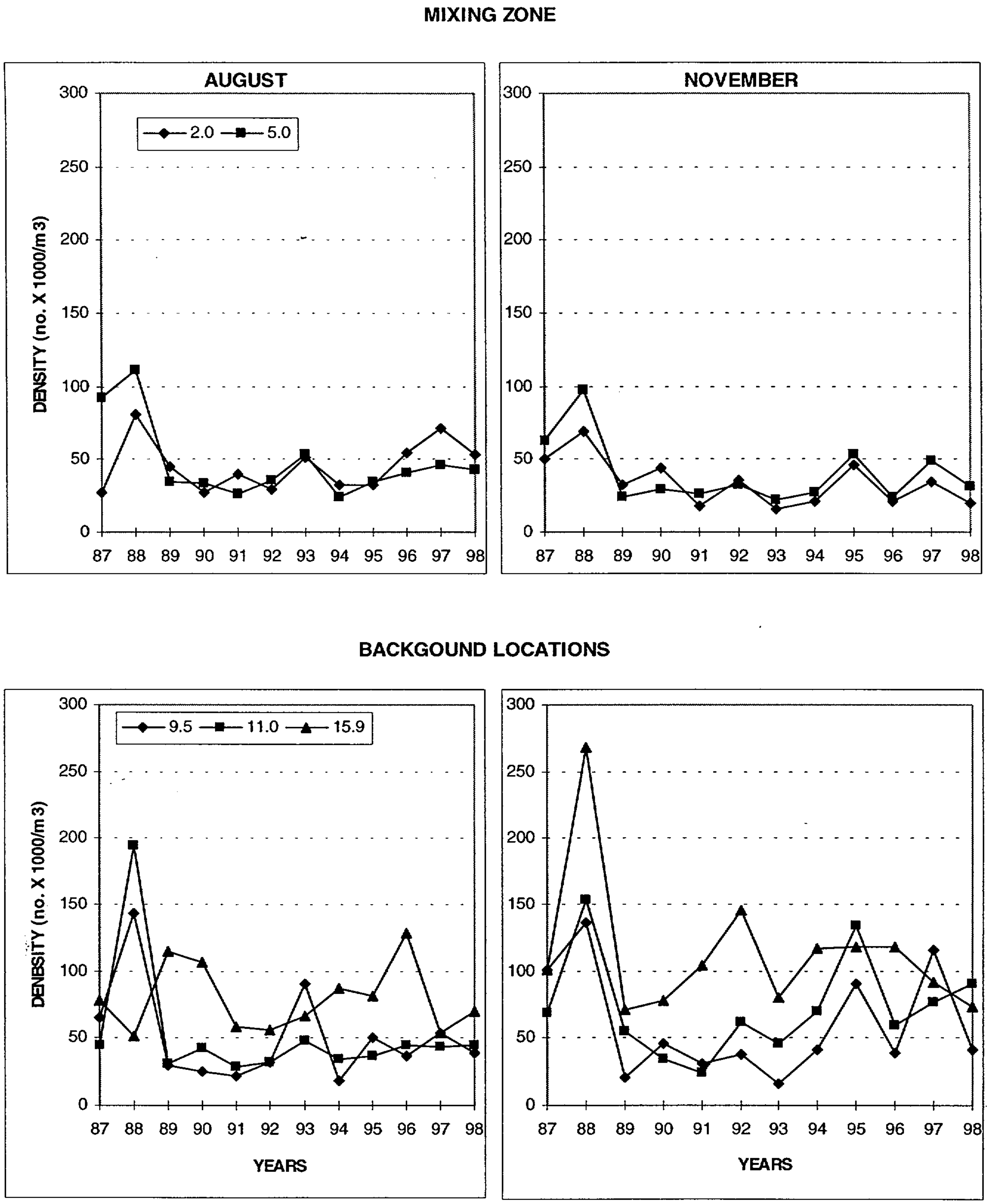


Figure 4-2 (continued).

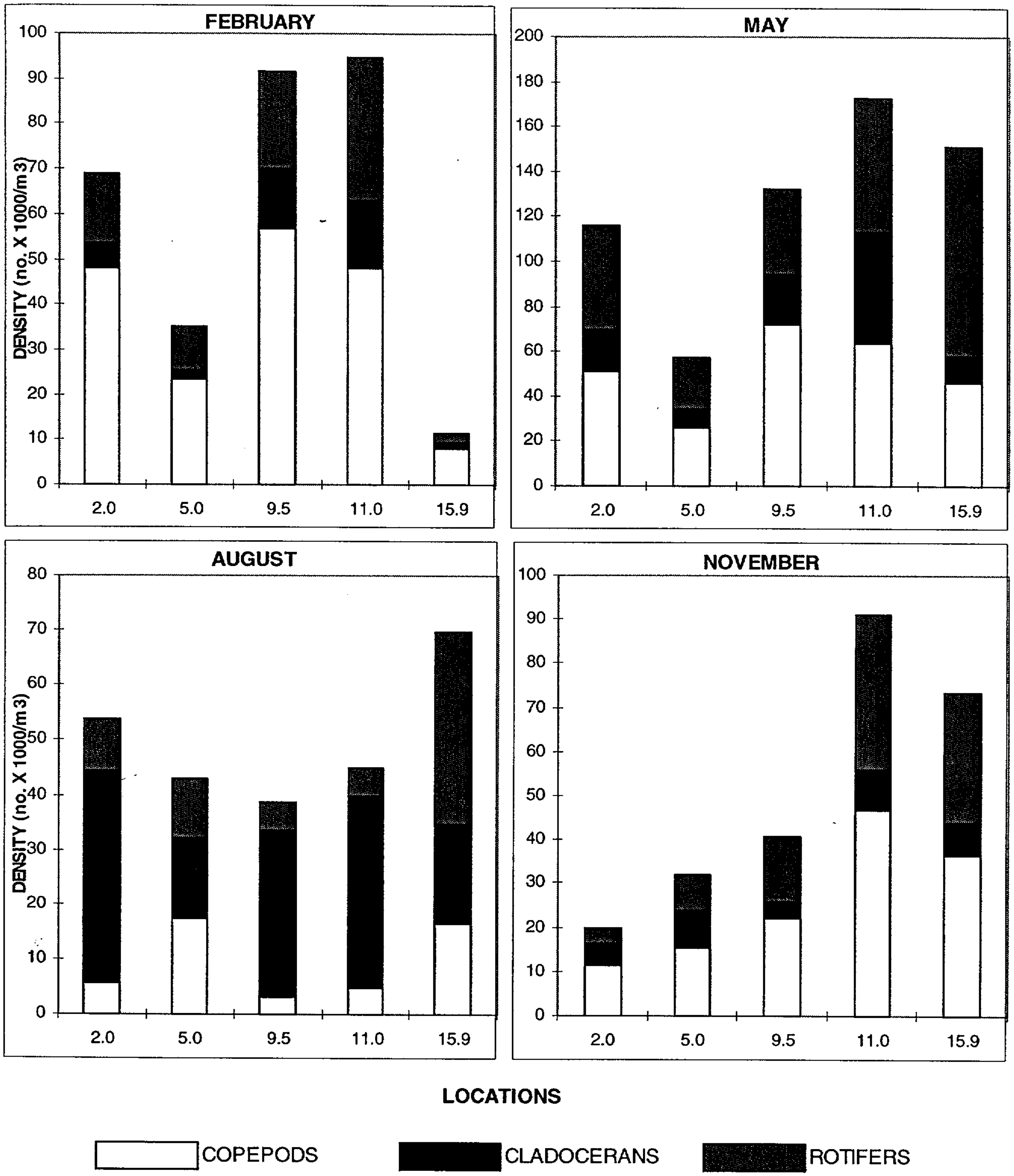


Figure 4-3. Zooplankton community composition by month for epilimnetic samples collected in lake Norman, NC, in 1998.

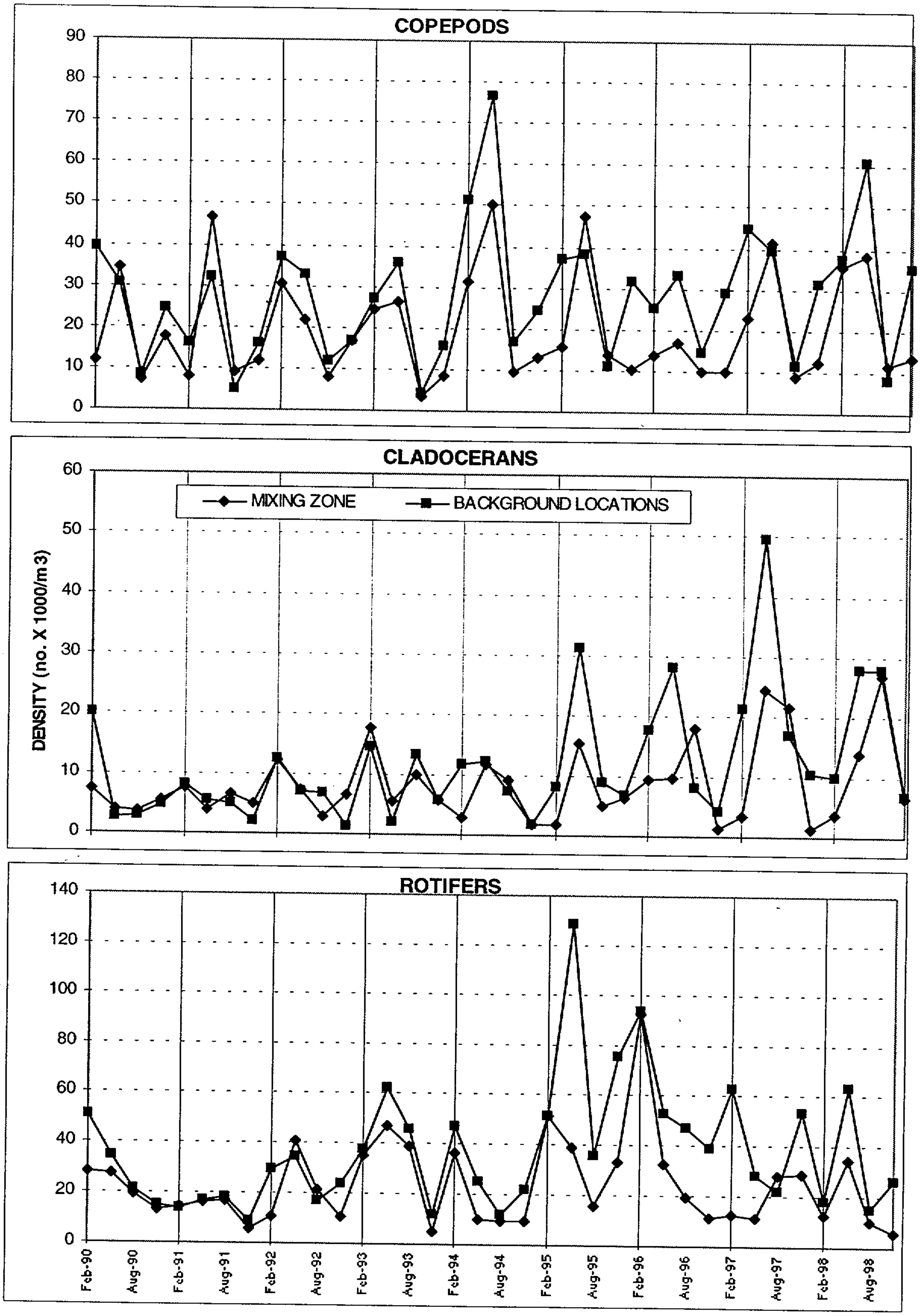
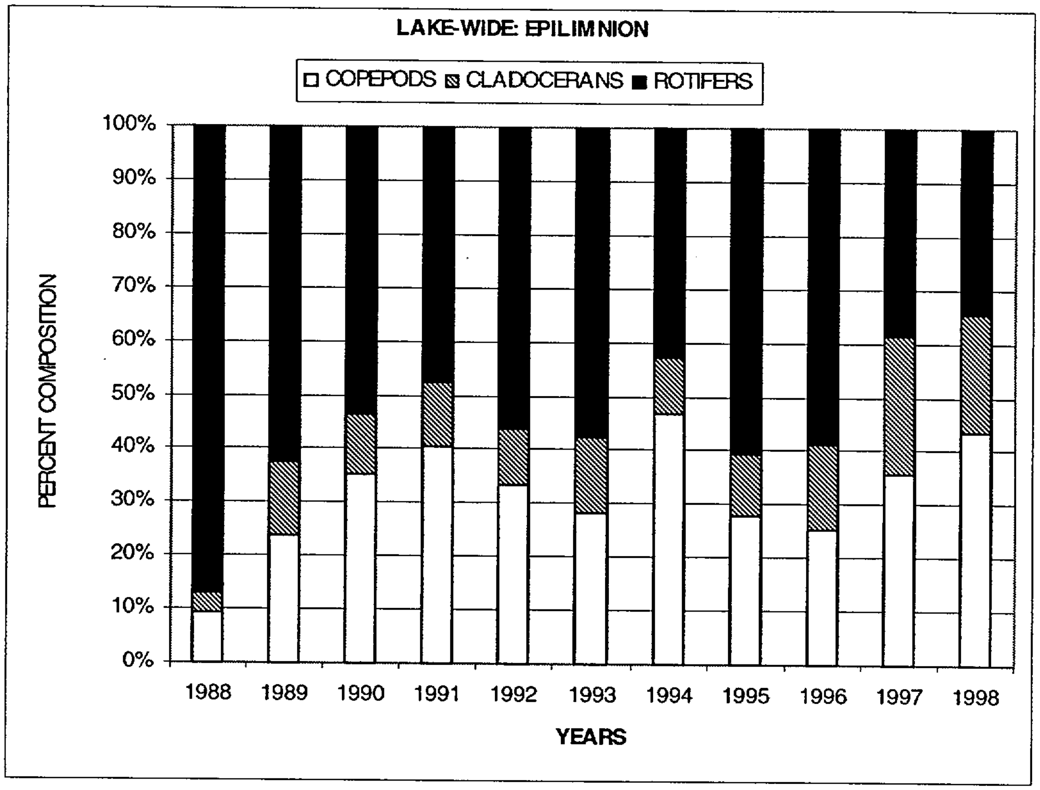


Figure 4-4. Zooplankton composition by month for epimlimnetic samples collected in Lake Norman, NC, in 1998.



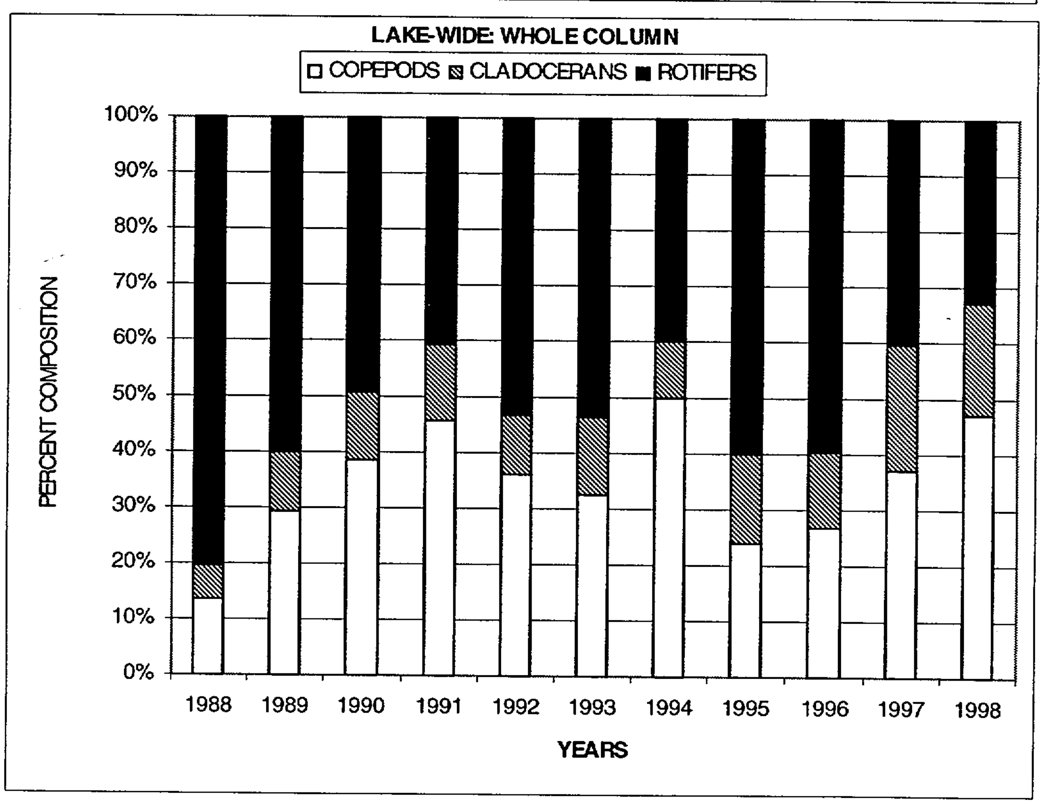


Figure 4-5. Annual lake-wide percent composition of major zooplankton taxonomic groups from 1988 through 1998.

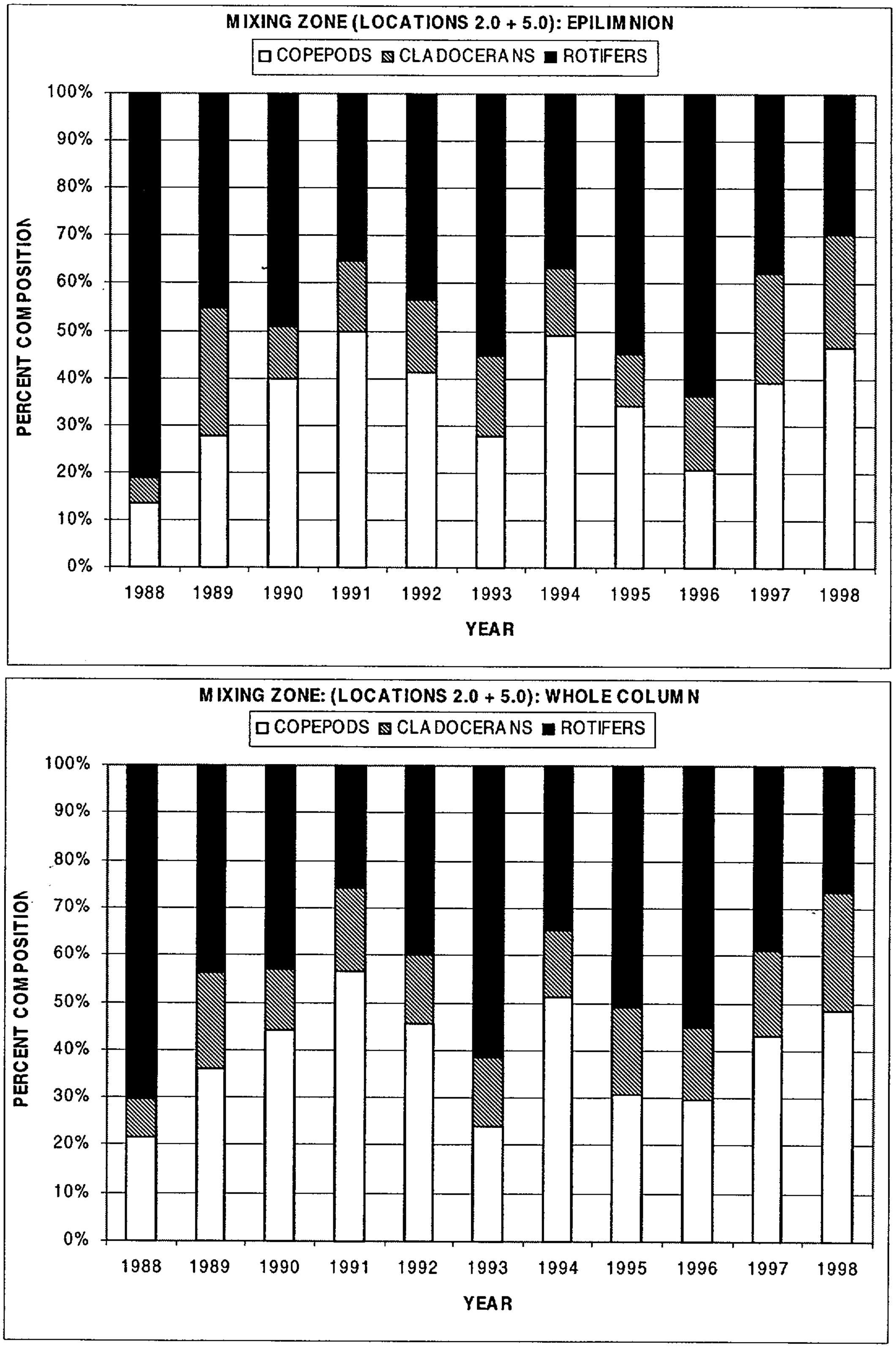
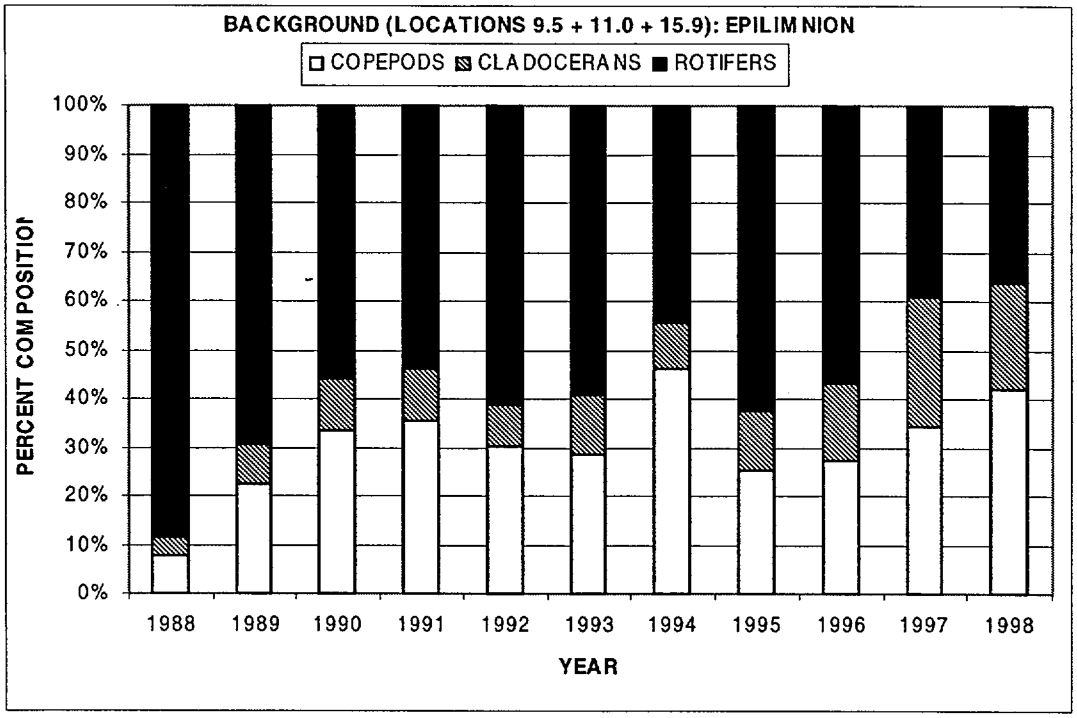


Figure 4-6. Annual percent composition of major zooplankton taxonomic groups from Mixing Zone Locations: 1988 through 1998.



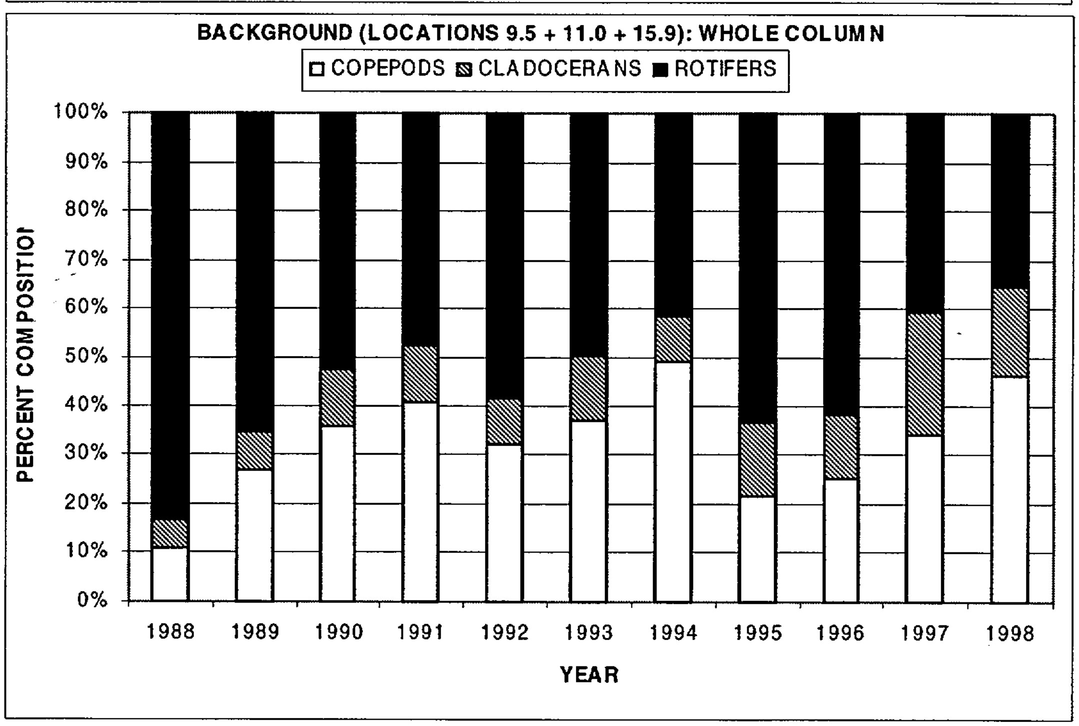


Figure 4-7. Annual percent composition of major zooplankton taxonomic groups from Background Locations: 1988 through 1998.

CHAPTER 5

FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters was continued during 1998. The components of the 1998 fish monitoring program for Lake Norman were to:

*Continue striped bass mortality monitoring throughout the summer.

*Continue a cooperative striped bass study with NCWRC to evaluate striped bass growth and condition as a function of stocking rates, forage availability, and summer striped bass habitat in Lake Norman.

*Continue the fall hydroacoustic/purse seine forage population assessment.

*Revise annual, spring shoreline electrofishing program to be conducted every 3 years, with next sample due in 2000.

*Complete the final year of a 2-year crappie assessment utilizing fall trap-net sampling of lower, mid, and uplake areas of Lake Norman.

*Summarize Lake Norman hydroacoustics/purse seine data for period 1993 through 1997.

METHODS AND MATERIALS

The mixing zone was monitored for striped bass mortalities during all summer sampling trips on the lake. From July 1 through September 15, weekly surveys were conducted specifically to locate dead or dying striped bass.

Summer pre-stress (July 13-15) and winter post-stress (December 1-3) gill-net samples for striped bass were collected for condition factor determination as part of a cooperative study with NCWRC. Three 250-ft suspended gill nets were fished for two days during July and two days during December. Nets were fished in the lower (Davidson Creek), mid (Mountain Creek to Marshall Steam Station), and uplake (Stumpy Creek to Hicks Creek) areas of Lake

Norman. The number of days that gill nets were fished was dependent upon catching a sufficient number and size range of fish for analysis. A total target catch of approximately 75 fish was established, with individual targets of 20 to 30 fish each in age groups two and three and some representative collections of older fish. Collected striped bass were weighed (g) and measured for total length (mm). Otoliths for aging were extracted from striped bass collected during the December post-stress gill-netting sample.

Mobile hydroacoustic surveys of the entire lake were conducted on November 11-12, to estimate forage fish populations. Hydroacoustic surveys employed multiplexing, side-scan and down-looking transducers to detect surface-oriented fish and deeper fish (2.0 m to bottom), respectively. Purse seine samples were collected on November 2 from the lower (main channel near Marker 1), mid (mouth of Davidson Creek), and uplake (just downlake of Duke Power State Park) areas of the reservoir. A subsample of forage fish collected from each area was used to determine taxa composition and size distribution.

Trap-netting of crappie for determination of crappie size, condition, and age composition was conducted during November 9-13, November 16-18, and December 8-10. Twelve to fifteen trap nets were fished for two to three nights each in the lower (Ramsey Creek, Lucky Creek, and Davidson Creek), mid (Mountain Creek to McCrary Creek), and uplake (Stumpy Creek to Duke Power State Park) areas of Lake Norman. The number of nets set and nights fished in a particular area was determined by the total number of fish needed from each area. Duke Power Company crews conducted the sampling in the lower and mid-lake areas, while NCWRC crews conducted the sampling in the uplake area. Collected crappie were identified by species, weighed (g), and measured for total length (mm). Otoliths for aging were removed from at least five fish per 10-mm size group per species for each of the three areas sampled. Additionally, 52 black crappie collected during fall gillnetting for the Reservoir Fish Assemblage Index (RFAI) were used to supplement crappie collected during the trap-net study. These fish were processed in the same manner as those collected in the trap-net study.

RESULTS AND DISCUSSION

General monitoring of Lake Norman and specific monitoring of the MNS mixing zone for striped bass mortalities during the summer of 1998, yielded 13 mortalities within the mixing zone and four mortalities in the main channel outside the mixing zone. The 17 observed mortalities ranged in size from 380 mm to 810 mm. Over half of the mortalities (10 fish) were observed in the lower lake area on July 28. The specific observations by date were:

DATE	LOCATION	LENGTH (mm)	NUMBER
July 3	Vicinity of Highway 150 Bridge	580	1
July 7	Vicinity of Channel Marker 17	450	1
July 21	Shoreline of Environmental Center	545	1
July 28	Vicinity of Channel Marker 14	380	1
July 28	Cowan's Ford Dam	545	2
July 28	Cowan's Ford Dam	575	
July 28	MNS Intake	440	6
July 28	MNS Intake	450	
July 28	MNS Intake	530	
July 28	MNS Intake	560	
July 28	MNS Intake	710	
July 28	MNS Intake	810	
July 28	MNS Discharge	630	1
August 3	Vicinity of Channel Marker 14	520	1
August 3	MNS Intake	490	2
August 3	MNS Intake	590	
September 15	MNS Intake	500	1

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 1998 was generally similar to historic conditions (Chapter 2). Habitat reduction was most severe from early August through September when no suitable habitat was observed in the reservoir except for a small refugium in the upper, riverine portion of the reservoir. Physicochemical habitat was observed to have expanded appreciably by early October, primarily as a result of epilimnion cooling and deepening, and in response to changing meteorological conditions. The temporal and spatial pattern of striped bass habitat expansion and reduction observed in 1998 was similar to that previously reported in Lake Norman and many other Southeastern reservoirs. These conditions were similar to that in 1994, 1996, and 1997 when no mortalities of striped bass were reported by local fishermen or observed by Duke Power Company personnel.

Gillnetting for striped bass condition during 1998 yielded variable catches for summer and winter sampling. Pre-stress, summer gillnetting yielded 100 striped bass ranging in length from 314 mm to 746 mm. Post-stress, winter sampling yielded 133 striped bass ranging in length from 373 mm to 722 mm. Individual fish lengths and weights for all striped bass collected in the study were reported to the NCWRC. Additionally, otoliths removed from 81 post-stress, winter fish were used for age determinations. Post-stress striped bass ranged in age from 1 to 6 years. Of the age groups represented, age 1 fish comprised the largest group (42%), followed by age 2 (33%), age 4 (11%), age 3 (9%), and age 5 (4%). Age 6 striped bass was represented by only one fish.

Fall trap-netting for Lake Norman crappie resulted in the collection of 672 crappie. An additional 52 crappie were collected during the fall RFAI sample, for a total catch of 724 fish. Black crappie comprised 98% of the total catch and ranged in size from 105 mm to 340 mm. White crappie ranged in size from 173 mm to 264 mm. Otoliths from 401 crappie (392 black crappie and 9 white crappie) were used to determine age composition. The mean lengths at age were as follows:

AGE	BLACK CRAPPIE MEAN LENGTH (mm)	WHITE CRAPPIE MEAN LENGTH (mm)
Age 0	149 (N = 7)	-
Age 1	176 (N = 96)	196 (N = 5)
Age 2	232 (N = 198)	254 (N = 4)

Age 3	257 (N = 55)	-
Age 4	301 (N = 28)	-
Age 5	311 (N = 7)	-
Age 6	317 (N = 1)	-

Analyses of hydroacoustics data collected during 1993 through 1997 to estimate Lake Norman forage populations has been completed. A separate summary report has been prepared and is included (see Addendum to this chapter). Analysis of the 1998 hydroacoustics data is underway and will be reported next year, with the 1999 data. Purse seine sampling was conducted in conjunction with hydroacoustics, to determine species composition and size distribution. With the exception of three gizzard shad (total lengths ranged from 87 mm to 91 mm), the catch was comprised of threadfin shad, with a modal size class of 45-49 mm.

FUTURE FISH STUDIES

- Continue striped bass mortality monitoring throughout the summer.
- Continue a cooperative striped bass study with NCWRC to evaluate striped bass growth and condition as a function of stocking rates, forage availability, and summer striped bass habitat in Lake Norman.
- Continue the annual, fall hydroacoustic/purse seine forage population assessment.
- Revise spring electrofishing program from a three year frequency to a two year frequency, beginning spring 1999.
- Complete analyses of the 1998 and 1999 forage population data and summarize these data in the 1999 annual report.

The future studies/activities outlined above are subject to revision, based on an annual review of the data submitted to date and a re-evaluation of the McGuire Maintenance Monitoring program by the NCWRC.

SUMMARY

In accordance with the Lake Norman environmental maintenance monitoring program for the NPDES permit for McGuire Nuclear Station (MNS), specific fish monitoring programs were coordinated with the NCWRC and continued during 1998. General monitoring of Lake Norman and specific monitoring of the MNS mixing zone for striped bass mortalities during the summer of 1998, yielded 13 mortalities within the mixing zone and 4 mortalities in the main channel outside the mixing zone.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 1998 was generally similar to historic conditions (Chapter 2). Habitat reduction was most severe from early August through September when no suitable habitat was observed in the reservoir except for a small refugium in the upper, riverine portion of the reservoir. Physicochemical habitat was observed to have expanded appreciably by early October, primarily as a result of epilimnion cooling and deepening, and in response to changing meteorological conditions. These conditions were similar to that in 1994, 1996, and 1997 when no mortalities of striped bass were reported by local fishermen or observed by Duke Power Company personnel.

Gillnetting for striped bass during 1998 yielded a total of 233 striped bass, ranging in length from 314 mm to 746 mm. Age determinations of post-stress striped bass indicated fish ranging in age from 1 to 6 years. Age 1 fish comprised the largest age group (42%). All striped bass data were submitted to the NCWRC for detailed analyses of striped bass growth and condition.

The 2-year Lake Norman crappie study was completed in 1998. Trap-net and RFAI sampling combined, yielded 724 crappie, ranging in size from 105 mm to 340 mm. Black crappie comprised 98% of the total catch. Age determinations of black crappie indicated fish ranging in age from 0 to 6 years. All crappie data were submitted to the NCWRC for detailed analyses of crappie condition and age/size composition.

Fall hydroacoustic/purse seine sampling for estimation of Lake Norman forage populations continued in 1998. Analyses of forage fish population data for 1993 through 1997 were completed, and a summary report was prepared (see Addendum). Average forage fish densities in Lake Norman exceeded densities in lakes immediately above and below Lake Norman, and were comparable to densities in other Catawba River lakes. Forage population data collected during 1998 will be analyzed and submitted with the 1999 forage data, during 2000.

Through consultation with the NCWRC, the Lake Norman fisheries program continues to be reviewed and modified annually to address fishery issues. Fisheries data continue to be collected through cooperative monitoring programs with the NCWRC, to allow the Commission's assessment and management of Lake Norman fish populations. Fisheries data to date indicate that the Lake Norman fishery is consistent with the trophic status and productivity of the reservoir.

ADEDENDUM to the LAKE NORMAN: 1998 SUMMARY

MAINTENANCE MONITORING PROGRAM

McGUIRE NUCLEAR STATION: NPDES No. NC0024392

Catawba River Forage Fish Densities, Population Estimates, and Species Composition: 1993 - 1997

DUKE POWER

A COMPANY OF DUKE ENERGY

INTRODUCTION

Gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*Dorosoma petenense*) are widely distributed clupeids that have tremendous value as forage fish in southern reservoirs (Noble 1981). Investigations of clupeid population size may provide information associated with seasonal changes in clupeid abundance, entrainment and impingement at water withdrawal facilities, effectiveness as forage for predatory fish, and plankton dynamics. This information is of tremendous value to Duke Power Company, North Carolina Wildlife Resources Commission, and South Carolina Department of Natural Resources; thus this study was initiated. This study employed hydroacoustic techniques and purse seining to estimate the density, population size, and taxa composition of forage fish in nine Catawba River reservoirs from 1993 to 1997.

METHODS

Study Locations - Nine Catawba River reservoirs (James, Rhodhiss, Hickory, Lookout, Norman, Mountain Island, Wylie, Fishing Creek, and Wateree) in North and South Carolina were sampled annually from 1993 through 1997 during late summer to early fall. The entire river system will be sampled again in 2000 and every three years thereafter (Lake Norman was sampled in 1998 and Lakes Norman, Mt. Island, and Wylie were sampled in 1999). Sampling typically consisted of a mid-channel transect running from the forebay of the dam to the influent; significant side channels (creeks) were also sampled. All lakes were treated as a single zone for the generation of an average forage fish density with the exception of Lakes Norman and Wylie. The large size, spatial heterogeneity, multiple power generation facilities, and significant inflow (Wylie) necessitated the division of Lakes Norman and Wylie into six and four zones, respectively (Figure 1, Siler et al. 1986, McInerny and Degan 1991). Lake surface areas (hectares) were calculated by Geographic Information System analysis of United States Geological Survey 1:100,000 digital line graphs.

Hydroacoustic Data Collection and Analysis - The collection and processing of hydroacoustic data for this study coincided with an era of great technological advance in portable computers and hydroacoustic equipment. Accordingly, a specific data collection system was rarely used for more than two years, so collection methods and analyses will be discussed by year(s). All mobile hydroacoustic surveys were conducted at night. All transducer systems were calibrated using US Navy standards at the BioSonics

Laboratory, Seattle, Washington, and standardized with a tungsten carbide reference sphere as a standard target prior to sampling.

Hydroacoustic sampling in 1993 and 1994 was conducted with 200-kHz 6x15° nominal dual-beam, bow-mounted analog transducer with two echo signal processors to simultaneously capture dual-beam target strength and echo integration information. Echo integration processing parameters were set to collect data from 2 m below the surface to 1 m above the bottom. The mean back-scattering cross section was calculated by dual-beam analysis. The mean back-scattered cross section for each reservoir was used to scale the total back-scattered voltage (echo integration) for each 1-meter depth strata and ¼-km interval to arrive at fish densities (number/hectare).

Hydroacoustic sampling in 1995 employed the same equipment as in 1993-1994 in combination with a 200-kHz digital transducer system and a 6° single-beam transducer aboard a second boat. On larger reservoirs one-half of the data was collected with each system; on smaller reservoirs a single system was used. The digital transducer collected data from 2 m below the water surface to the bottom. The mean back-scattering cross section was calculated with an expectation, maximization, and smoothing algorithm (EMS) developed by John Hedgepeth, Biosonics, Inc. Echo integration methodology was similar to that used previously.

Hydroacoustic surveys in 1996 and 1997 employed a multiplexing 200-kHz digital transducer system. This multiplexing system consisted of side-scan 6° single-beam (ensonifying the top 2 m of the water column) and down-looking 6x15° dual-beam (ensonifying from 2 m to bottom) transducers to detect surface-oriented and deeper fish, respectively. Dual-beam analysis was used to determine acoustic size of single fish targets (EMS techniques were used on the side-scan data) and echo integration was used to measure relative fish density. Surface fish densities (from 0 to 2 m deep) were added to deeper fish densities (2 m to bottom) to arrive at total fish densities for each ¼-km interval.

Hydroacoustic data collected in 1993 through 1995 did not account for forage fish near the surface and were not comparable to multiplexed data collected in 1996 and 1997. Analysis of 1997 Catawba River hydroacoustic data demonstrated a one-to-one relationship between fish density in the 2 to 3 m depth strata and the top two meters of the water column. This relationship was applied to the 1993 through 1995 data to correct fish densities to include estimated fish near the surface. All data reported herein account for forage fish near the surface, whether measured or estimated.

Purse Seine Sampling - Forage fish species composition and length frequencies were sampled with a 4.8-mm (3/16 in) mesh purse seine measuring 118 x 9 m (400 x 30 ft). Purse seine samples were generally collected from two locations (three in Lake Norman) during late summer to early fall in reservoirs with maximum depths exceeding 9 m. Fishing Creek reservoir was too shallow to sample without damage to the net.

Non-forage fish (e.g., catfish, crappie, white bass, bluegill, etc.) were sorted, measured (TL, mm), and released; the remaining volume or weight of forage fish was measured. A subsample of forage fish (usually at least 200 individuals) was measured and preserved for laboratory analyses. Forage fish were processed by determining taxa composition and size distribution (TL, mm). The number of forage fish in the entire purse seine haul was estimated by expanding the number of fish in the subsample, based on the ratio of the subsample to the entire forage fish haul.

RESULTS AND DISCUSSION

Catawba River - Estimated forage fish densities in nine Catawba River reservoirs from 1993 to 1997 ranged from 870 to 322,324 (Table 1, Figure 2). For comparative purposes, a single density (based on the sum of population estimates for individual zones divided by the total lake surface area) was calculated for Lakes Norman and Wylie (Lakes Norman and Wylie will subsequently be discussed in more detail due to their spatial heterogeneity and division into sampling zones). Forage fish densities exhibit high variability from year to year on all reservoirs except James. The estimated number of forage fish in nine Catawba River reservoirs from 1993 to 1997 ranged from 994,407 to 1,540,837,649 (Table 1, Figure 3).

Purse seine sampling for forage fish species composition yielded variable percentages of gizzard and threadfin shad in Catawba River reservoirs from 1993 to 1997 (Table 2). For example, Lake James gizzard shad comprised 0.12 and 100.00 % of the forage fish in 1993 and 1994, respectively. The percentage of gizzard shad remained extremely high in Lake James through 1996 and then dipped to approximately 81% in 1997. Similar results were also observed in Lakes Rhodhiss, Hickory, and Lookout Shoals although the decline in percentages of gizzard shad in Lakes Hickory and Lookout Shoals in 1997 was very extreme. Even Lake Wateree, the most southerly of the Catawba River reservoirs, demonstrated this same gizzard shad trend, although to a lesser degree. Variable species composition was most likely due to winter climatic conditions influencing water temperatures on reservoirs that receive no heated effluents. Threadfin shad succumb to cold stress at water temperatures of 9 °C and below (Strawn 1965, Griffith 1978). Lakes Norman, Mt. Island, and Wylie receive heated effluents that provide winter refugia for the overwinter survival of threadfin shad populations. The percentage of threadfin shad in these three reservoirs has typically remained quite high from 1993 to 1997.

Forage fish length frequency distributions (in 5-mm size classes) for each reservoir from 1993 to 1997 are presented in Appendix 1.

Lake Norman - Purse seine sampling identified threadfin shad as the dominant forage fish from 1993 to 1997 on Lake Norman (Table 2). Threadfin shad comprised from 99.94 to 100.00 % of the forage fish in the purse seine hauls.

Threadfin shad densities (number / hectare) in the six zones of Lake Norman were variable and ranged from 1,102 to 99,845 during 1993 to 1997 (Table 3). Within a given year threadfin shad densities were generally higher uplake than downlake, though several large creeks and the limited amount of 'sampleable' habitat in Zone 6 (the most uplake zone) sometimes complicated this trend. Higher densities of forage fish in uplake regions have been demonstrated previously on Lake Norman (Siler et al. 1986) and in Missouri reservoirs (Michaletz and Gale 1999). Average forage fish densities for nine Catawba River reservoirs indicate that Lake Norman densities typically exceed those for Lookout Shoals and Mt. Island reservoirs (the immediate upstream and downstream reservoirs, respectively) and are comparable with those measured elsewhere on the Catawba River. Lake Norman threadfin shad population estimates ranged from approximately 65 million to 670 million fish from 1993 to 1997 (Table 3).

<u>Lake Wylie</u> - Purse seine sampling identified threadfin shad as the dominant forage fish from 1993 to 1997 on Lake Wylie (Table 2). Threadfin shad comprised from 99.77 to 100.00 % of the forage fish in the purse seine hauls.

Threadfin shad densities (number / hectare) in the four zones of Lake Wylie were variable and ranged from 1,692 to 156,657 during 1993 to 1997 (Table 4). Lake Wylie threadfin shad did not exhibit a greater density uplake compared to downlake; in fact the reverse was true. With the exception of 1993, threadfin shad densities were greater downlake than uplake. Lake Wylie forage fish densities exceeded those of Mt. Island and Fishing Creek (the immediate upstream and downstream reservoirs, respectively) on all occasions except for Fishing Creek in 1994 and 1997. Lake Wylie threadfin shad population estimates ranged from approximately 15 million to 403 million fish from 1993 to 1997 (Table 4).

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Table 1. Forage fish densities, population estimates, and 95% confidence limits in Catawba River reservoirs as estimated by hydroacoustic sampling from 1993 - 1997 (Lakes Norman and Wylie are listed separately).

		James	Rhodhiss	Hickory	Lookout	Mt. Island	Fishing Creek	Wateree
1993*	Density	12,120	48,195	147,271	15,492	75,862	9,999	44,490
	95% Lower Limit	9,876	40,779	117,407	13,327	66,000	8,618	36,608
	95% Upper Limit	14,458	57,047	184,280	17,583	86,863	11,280	52,534
1994*	Density	1,454	15,227	20,715	2,055	3,867	12,932	29,632
	95% Lower Limit	914	12,782	17,651	1,746	2,908	9,013	23,758
	95% Upper Limit	1,999	17,890	23,750	2,364	4,917	17,307	35,428
1995*	Density	7,708	87,465	24,641	38,909	4,312	37,764	322,324
	95% Lower Limit	6,469	58,892	21,580	30,875	2,587	30,211	260,377
	95% Upper Limit	9,020	121,187	28,185	47,421	6,477	44,741	389,926
1996**	Density	7,683	18,351	19,358	4,448	6,798	1,510	85,007
	95% Lower Limit	5,806	16,021	17,268	3,817	5,821	1,272	63,693
	95% Upper Limit	9,848	20,823	21,577	5,056	7,935	1,769	106,675
1997**	Density	870	6,510	30,438	8,655	998	3,163	7,402
	95% Lower Limit	610	5,701	22,920	7,526	791	2,778	5,618
	95% Upper Limit	1,170	7,281	38,466	9,805	1,212	3,574	9,643
1993*	Population Estimate	30,043,000	42,363,000	239,139,000	7,665,000	75,589,000	10,037,000	212,680,000
	95% Lower Limit	24,481,000	35,845,000	190,645,000	6,594,000	65,762,000	8,651,000	175,001,000
	95% Upper Limit	35,838,000	50,144,000	299,234,000	8,700,000	86,550,000	11,323,000	251,134,000
1994*	Population Estimate	3,604,000	13,385,000	33,637,000	1,017,000	3,853,000	12,981,000	141,653,000
	95% Lower Limit	2,266,000	11,235,000	28,662,000	864,000	2,898,000	9,047,000	113,573,000
	95% Upper Limit	4,955,000	15,725,000	38,565,000	1,170,000	4,899,000	17,373,000	169,360,000
1995*	Population Estimate	19,107,000	76,882,000	40,012,000	19,252,000	4,296,000	37,908,000	1,540,838,000
	95% Lower Limit	16,035,000	51,766,000	35,042,000	15,277,000	2,578,000	30,326,000	1,244,706,000
	95% Upper Limit	22,359,000	106,523,000	45,767,000	23,464,000	6,454,000	44,911,000	1,864,002,000
1996**	Population Estimate	19,045,000	16,131,000	31,434,000	2,201,000	6,774,000	1,516,000	406,367,000
	95% Lower Limit	14,392,000	14,082,000	28,040,000	1,889,000	5,800,000	1,277,000	304,478,000
	95% Upper Limit	24,411,000	18,303,000	35,037,000	2,502,000	7,906,000	1,776,000	509,949,000
1997**	Population Estimate	2,157,000	5,722,000	49,425,000	4,282,000	994,000	3,175,000	35,385,000
	95% Lower Limit	1,512,000	5,011,000	37,217,000	3,724,000	788,000	2,789,000	26,856,000
	95% Upper Limit	2,900,000	6,400,000	62,461,000	4,852,000	1,208,000	3,588,000	46,097,000

* 1993 thru 1995 data corrected for inclusion of surface oriented fish.

** 1996 and 1997 data collected with side-looking acoustics to ensonify surface oriented fish.

Table 2. Number and species composition (%) of forage fish collected by purse seining during late summer - early fall, 1993 to 1997.

	1993	1994	1995	1996	1997
James					
# collected	8,578	120	1,320	86	702
Gizzard shad	0.12%	100.00%	99.70%	100.00%	81.05%
Threadfin shad	99.88%	0.00%	0.30%	0.00%	18.95%
Rhodhiss					
# collected	18,552	1,959	965	460	1,041
Gizzard shad	0.92%	100.00%	64.66%	100.00%	72.24%
Threadfin shad	99.08%	0.00%	35.34%	0.00%	27.76%
Hickory					
# collected	93,065	435	2,959	1,985	5,903
Gizzard shad	0.07%	100.00%	91.92%	99.70%	1.56%
Threadfin shad	99.93%	0.00%	8.08%	0.30%	98.44%
Lookout Shoals					
# collected	23,569	1,587	739	699	6,810
Gizzard shad	0.01%	100.00%	100.00%	91.13%	0.01%
Threadfin shad	99.99%	0.00%	0.00%	8.87%	99.99%
Norman					
# collected	13,063	1,619	4,389	4,465	6,711
Gizzard shad	0.00%	0.06%	0.05%	0.00%	0.01%
Threadfin shad	100.00%	99.94%	99.95%	100.00%	99.99%
Mt. Island					
# collected	2,642	583	1,007	1,174	182
Gizzard shad	2.27%	0.51%	18.07%	0.43%	0.00%
Threadfin shad	97.73%	99.49%	81.93%	99.57%	100.00%
Wylie					
# collected	125,894	19,026	6,612	4,321	9,842
Gizzard shad	0.01%	0.01%	0.00%	0.23%	0.01%
Threadfin shad	99.99%	99.99%	100.00%	99.77%	99.99%
Wateree					
# collected	26,867	350	83,622	52,768	47,767
Gizzard shad	0.83%	20.00%	1.63%	10.06%	1.69%
Threadfin shad	99.17%	80.00%	98.37%	89.94%	98.31%

Table 3. Lake Norman forage fish densities and population estimates by zones, and lakewide population estimates and 95% confidence limits as estimated by hydroacoustic sampling from 1993 to 1997.

Density (no./hectare)

Zone	1993*	1994*	1995*	1996**	1997**
1	34,309	14,340	33,013	25,585	2,971
2	45,239	14,186	15,070	14,420	3,520
3	51,257	20,409	57,200	46,434	5,793
4	44,082	21,638	75,374	29,263	3,105
5	73,687	25,816	99,845	38,463	11,139
6	73,687	25,816	99,845	3,638	1,102

Population Estimate

Zone	1993*	1994*	1995*	1996**	1997**
1	78,259,000	32,710,000	75,303,000	58,359,000	6,777,000
2	139,431,000	43,723,000	46,447,000	44,444,000	10,849,000
3	177,120,000	70,524,000	197,656,000	160,454,000	20,018,000
4	54,265,000	26,636,000	92,785,000	36,023,000	3,822,000
5	155,185,000	54,368,000	210,274,000	81,003,000	23,459,000
6	35,222,000	12,340,000	47,726,000	1,739,000	527,000
Total	639,482,000	240,301,000	670,191,000	382,022,000	65,451,000
95% Lower Limit	580,205,000	219,290,000	599,113,000	357,065,000	58,251,000
95% Upper Limit	698,759,000	261,312,000	741,268,000	406,978,000	72,652,000

* 1993 thru 1995 data corrected for inclusion of surface oriented fish.

** 1996 and 1997 data collected with side-looking acoustics to ensonify surface oriented fish.

Table 4. Lake Wylie forage fish densities and population estimates by zones, and lakewide population estimates and 95% confidence limits as estimated by hydroacoustics from 1993 to 1997.

Density (no./hectare)

Zone	1993*	1994*	1995*	1996**	1997**
1	32,714	3,489	156,657	21,288	4,811
2	78,443	13,653	37,902	15,537	5,069
3	76,764	6,634	16,055	5,462	1,692
4	115,432	4,199	41,926	9,783	2,218

Population Estimate

Zone	1993*	1994*	1995*	1996**	1997**
1	20,878,000	2,227,000	99,978,000	13,586,000	3,070,000
2	86,005,000	14,969,000	41,556,000	17,035,000	5,558,000
3	121,318,000	10,484,000	25,373,000	8,632,000	2,674,000
4	174,556,000	6,350,000	63,400,000	14,794,000	3,354,000
Total	402,757,000	34,030,000	230,308,000	54,047,000	14,656,000
95% Lower Limit	374,310,000	29,838,000	196,396,000	48,413,000	13,181,000
95% Upper Limit	431,204,000	38,222,000	264,221,000	59,681,000	16,131,000

* 1993 thru 1995 data corrected for inclusion of surface oriented fish.

** 1996 and 1997 data collected with side-looking acoustics to ensonify surface oriented fish.

Figure 1. Sampling zones in Lakes Norman and Wylie with latitude and longitude boundaries (decimal degrees).

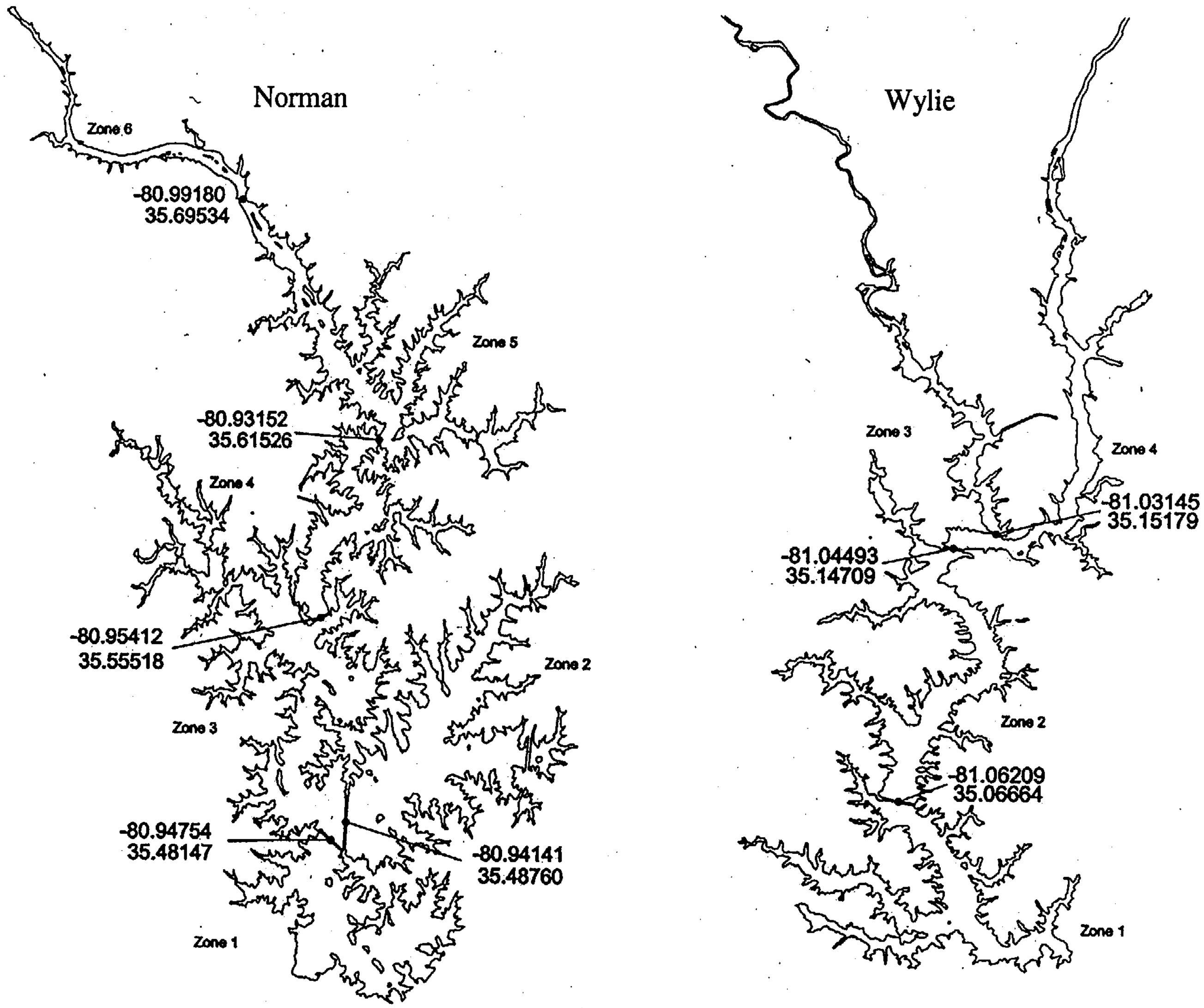


Figure 2. Forage fish densities in Catawba River reservoirs from 1993 to 1997. Data collected from 1993 through 1995 were corrected for inclusion of surface oriented fish.

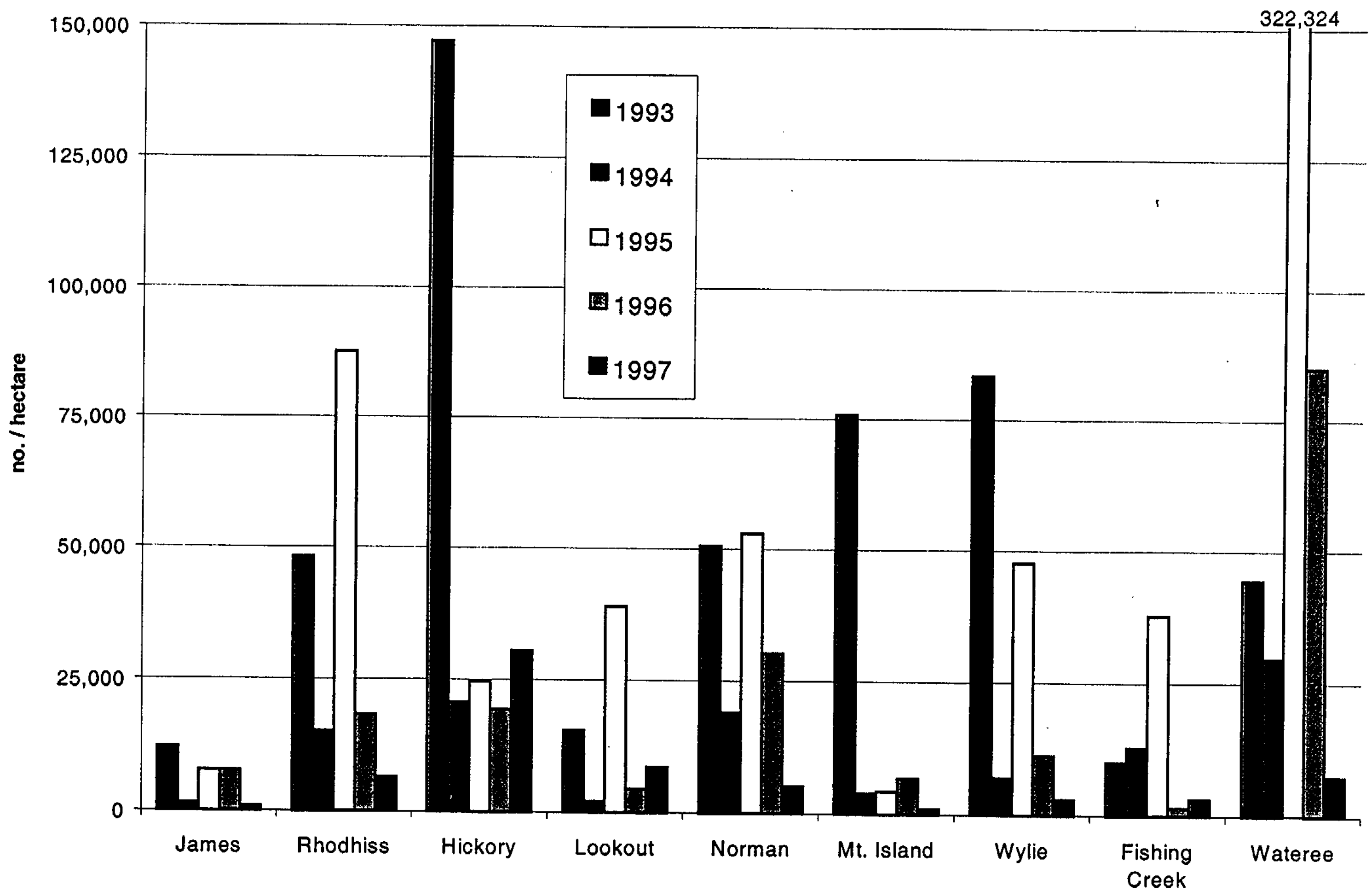
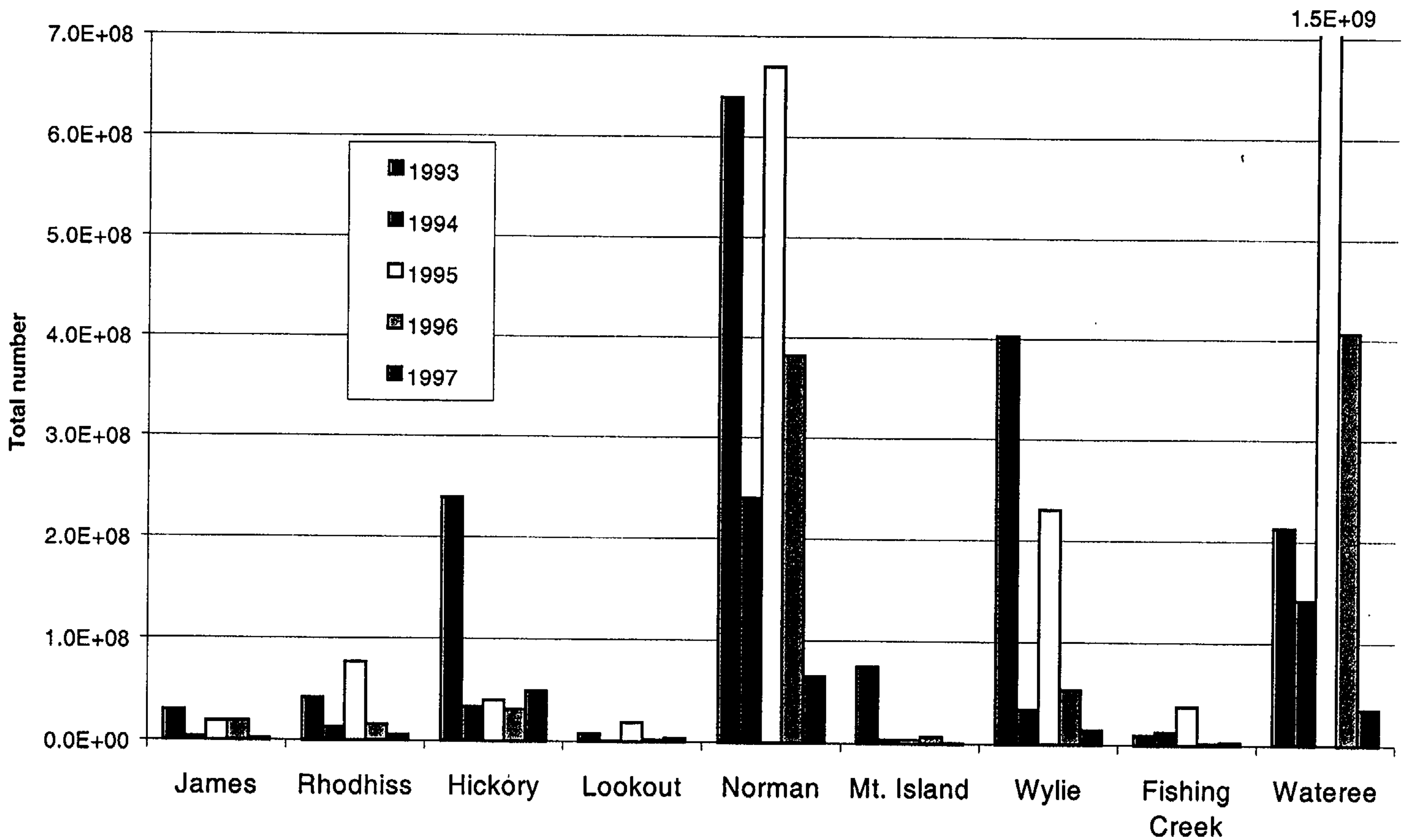
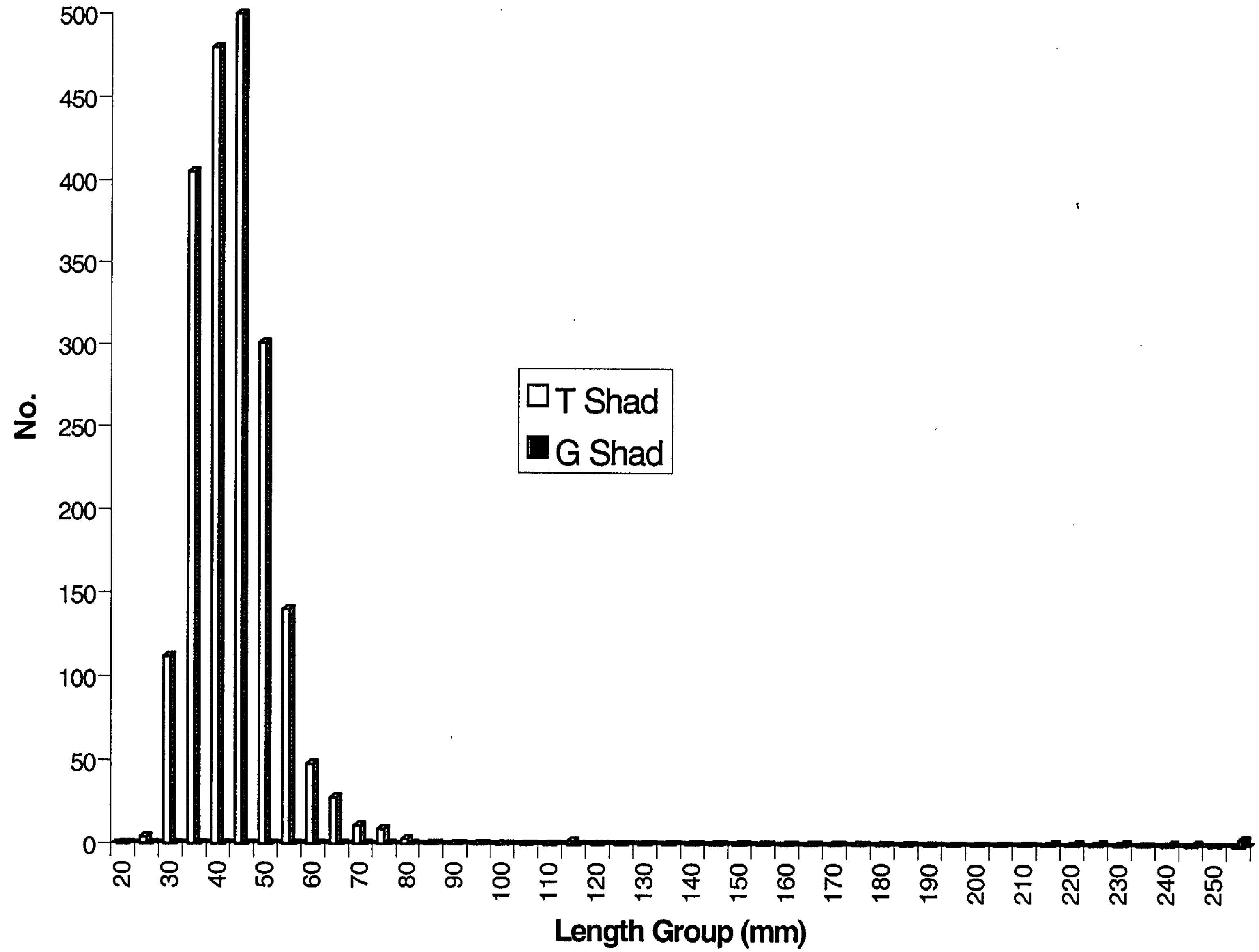


Figure 3. Forage fish population in Catawba River reservoirs from 1993 to 1997. Data collected from 1993 through 1995 were corrected for inclusion of surface oriented fish.

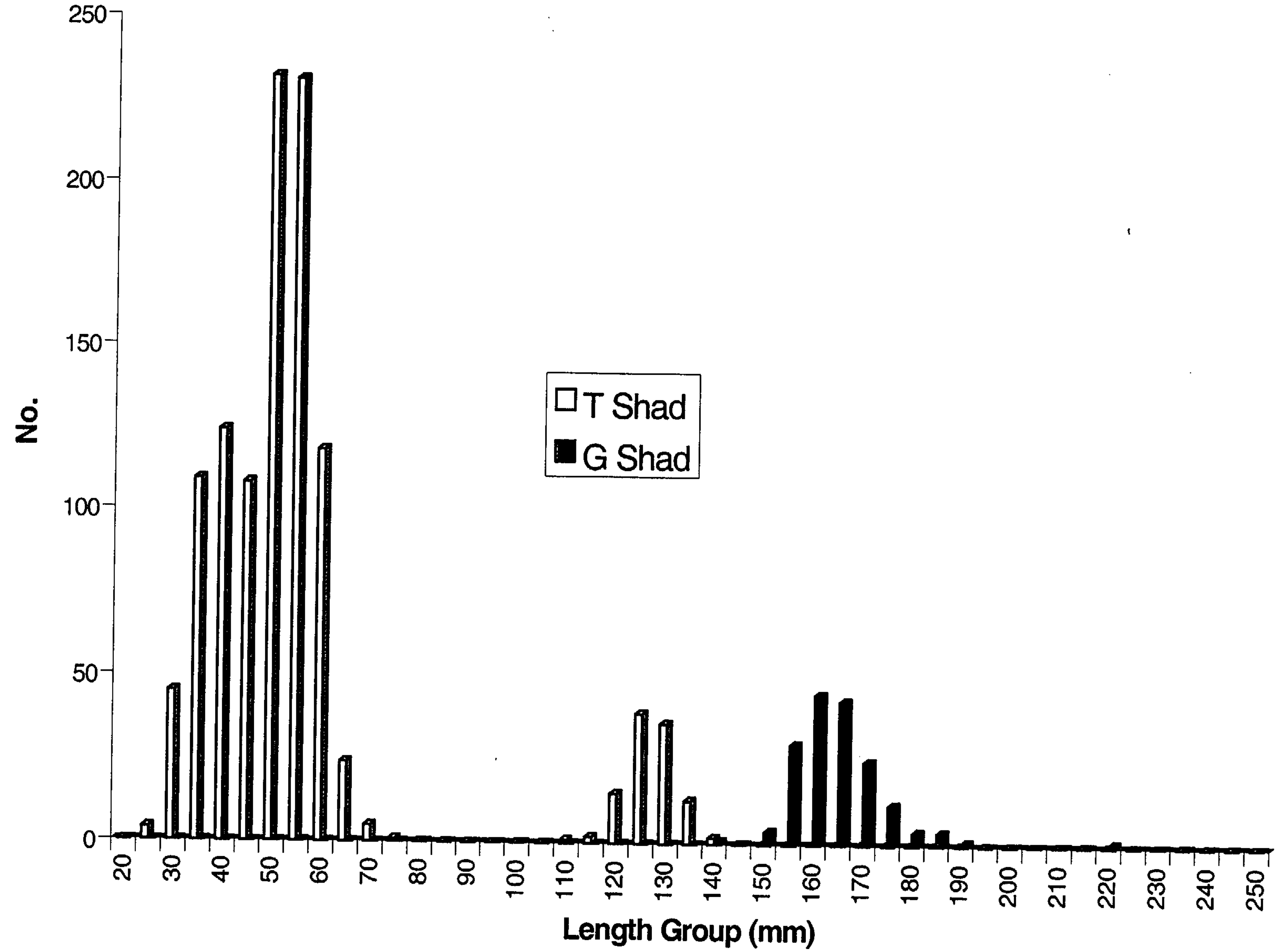


Appendix 1. Length frequency distribution of purse seine-collected forage fish from eight Catawba River reservoirs, 1993 to 1997.

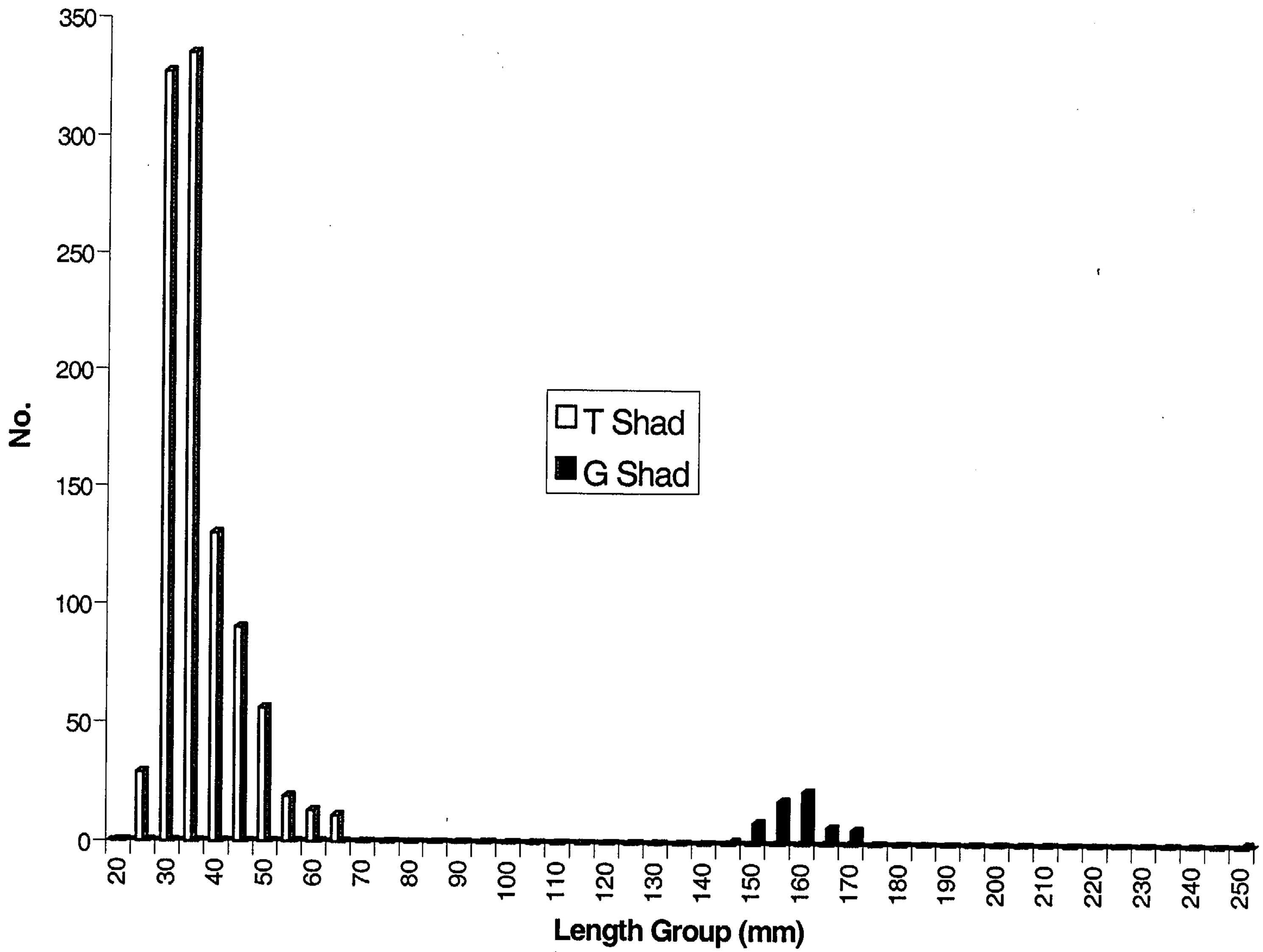
Lake James Forage Fish - 1993



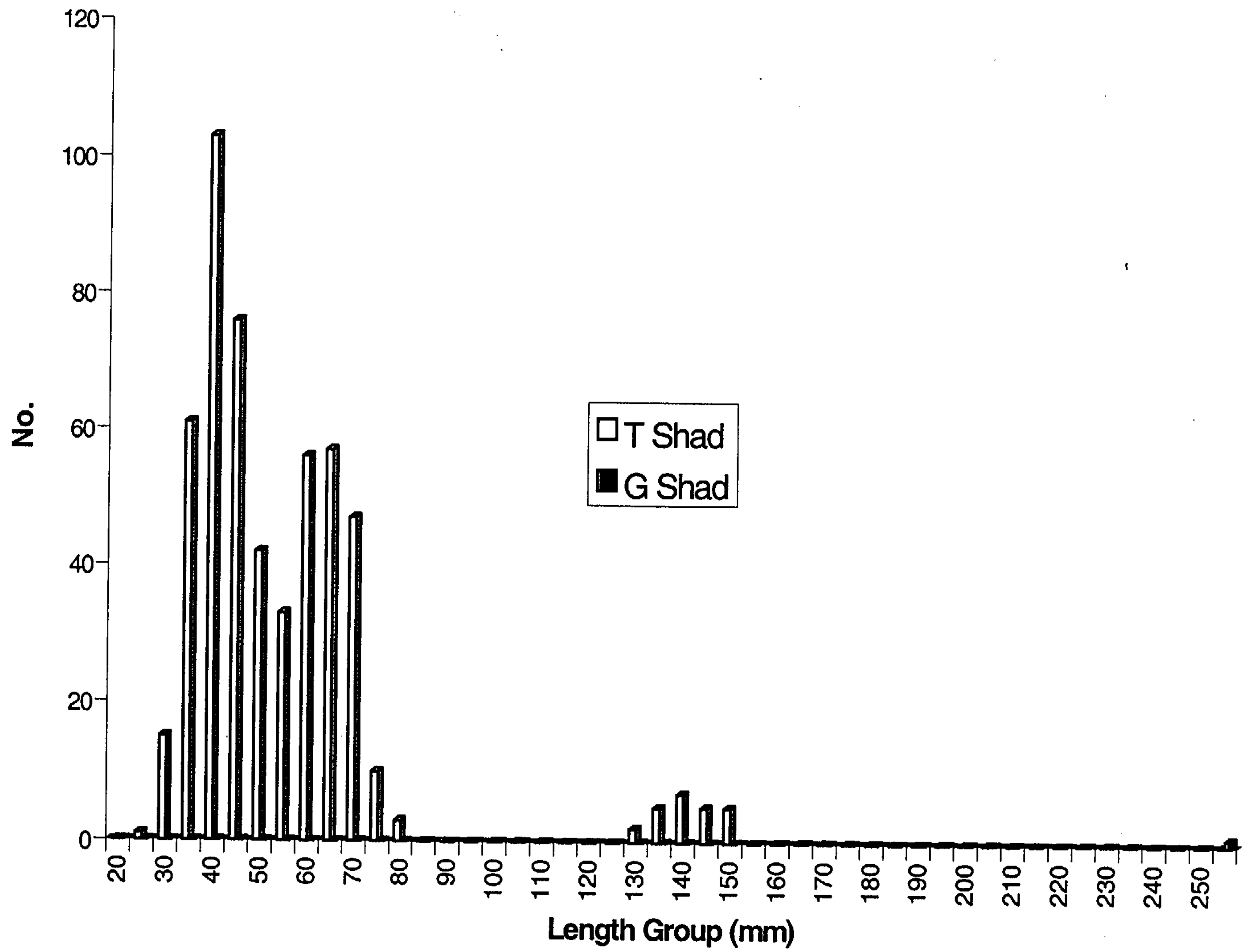
Lake Rhodhiss Forage Fish - 1993

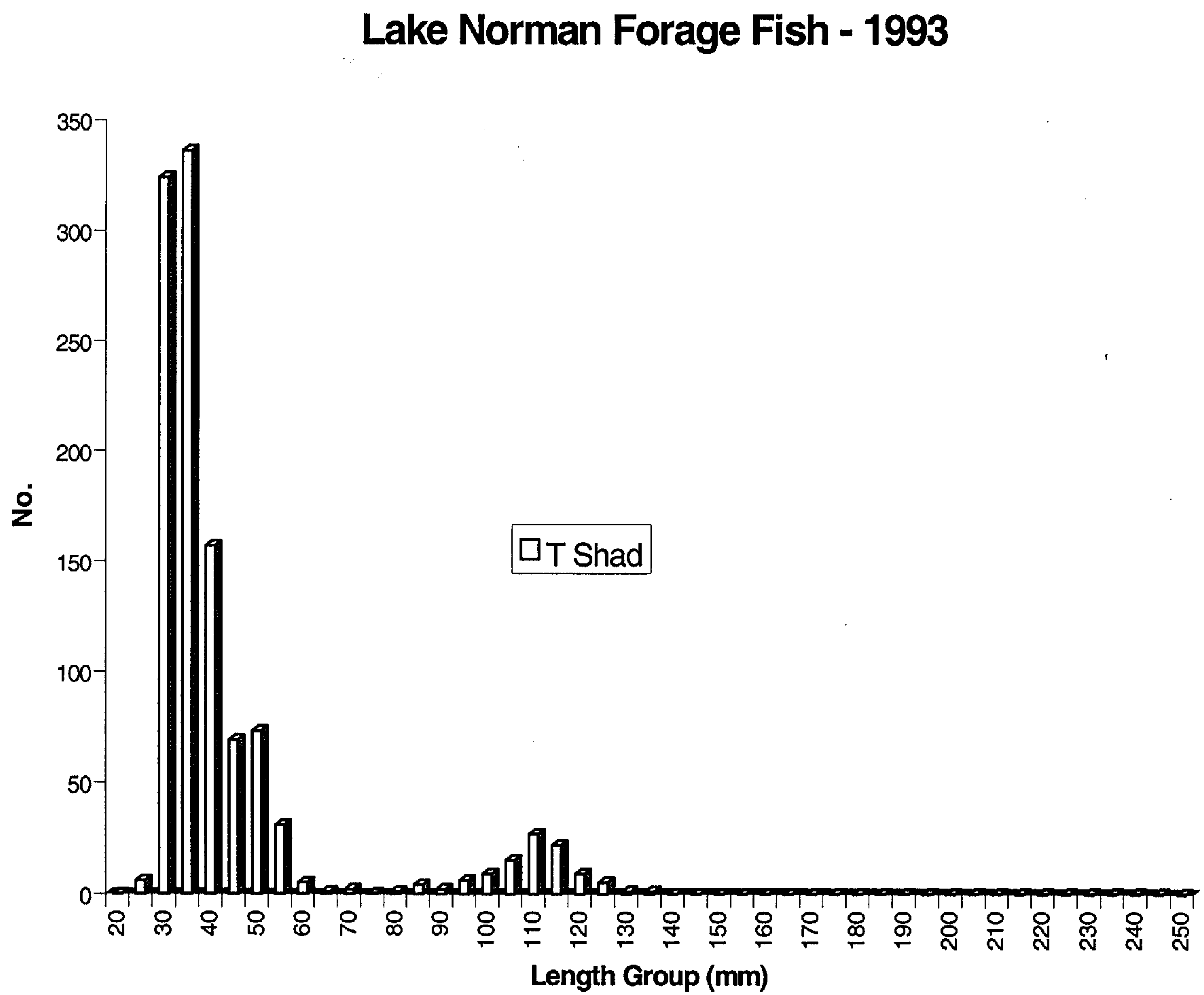


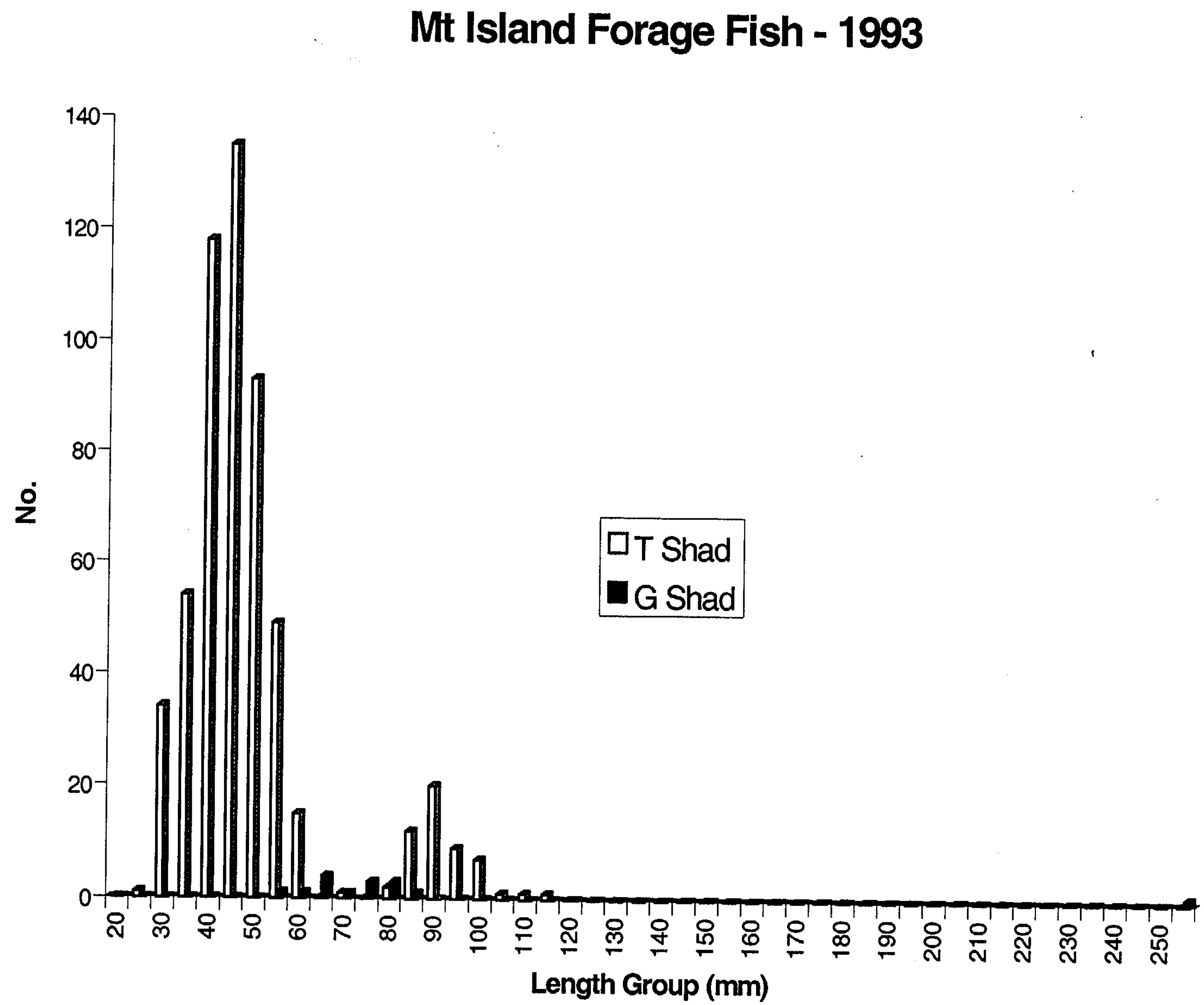
Lake Hickory Forage Fish - 1993



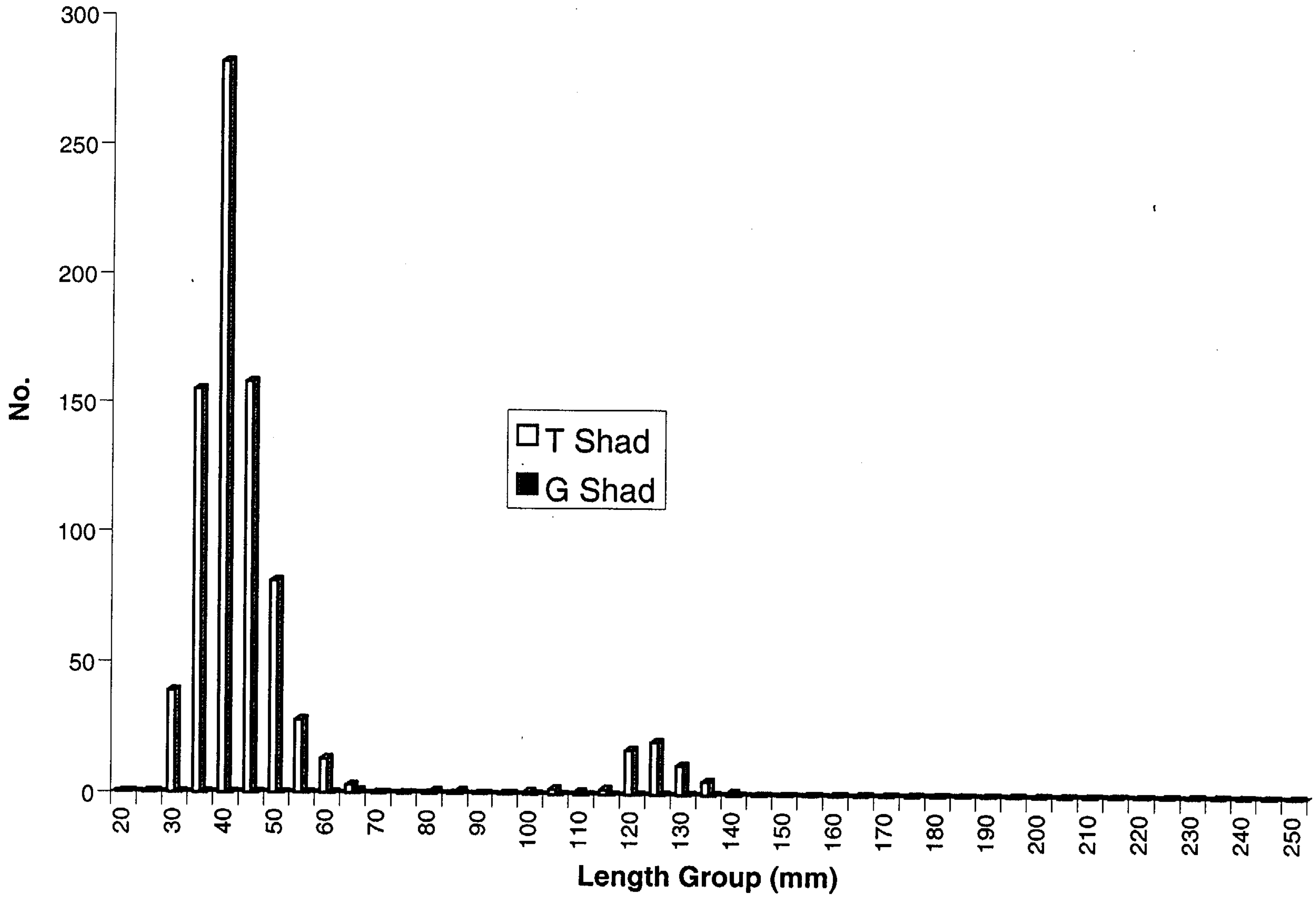
Lookout Shoals Forage Fish - 1993

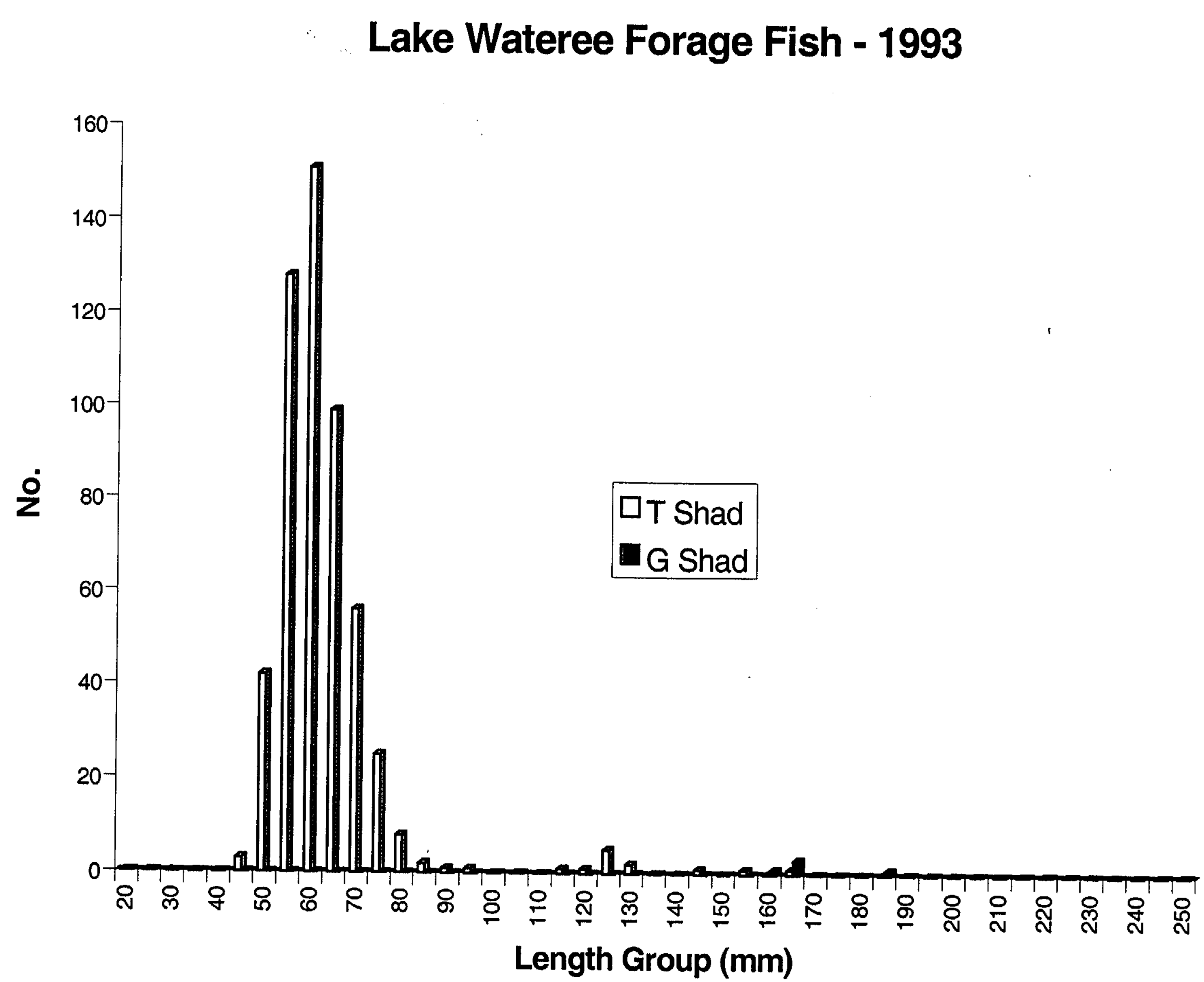



Lake Norman Forage Fish - 1993
No.
350
300
250
200
150
100
50
0
T Shad
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Length Group (mm)

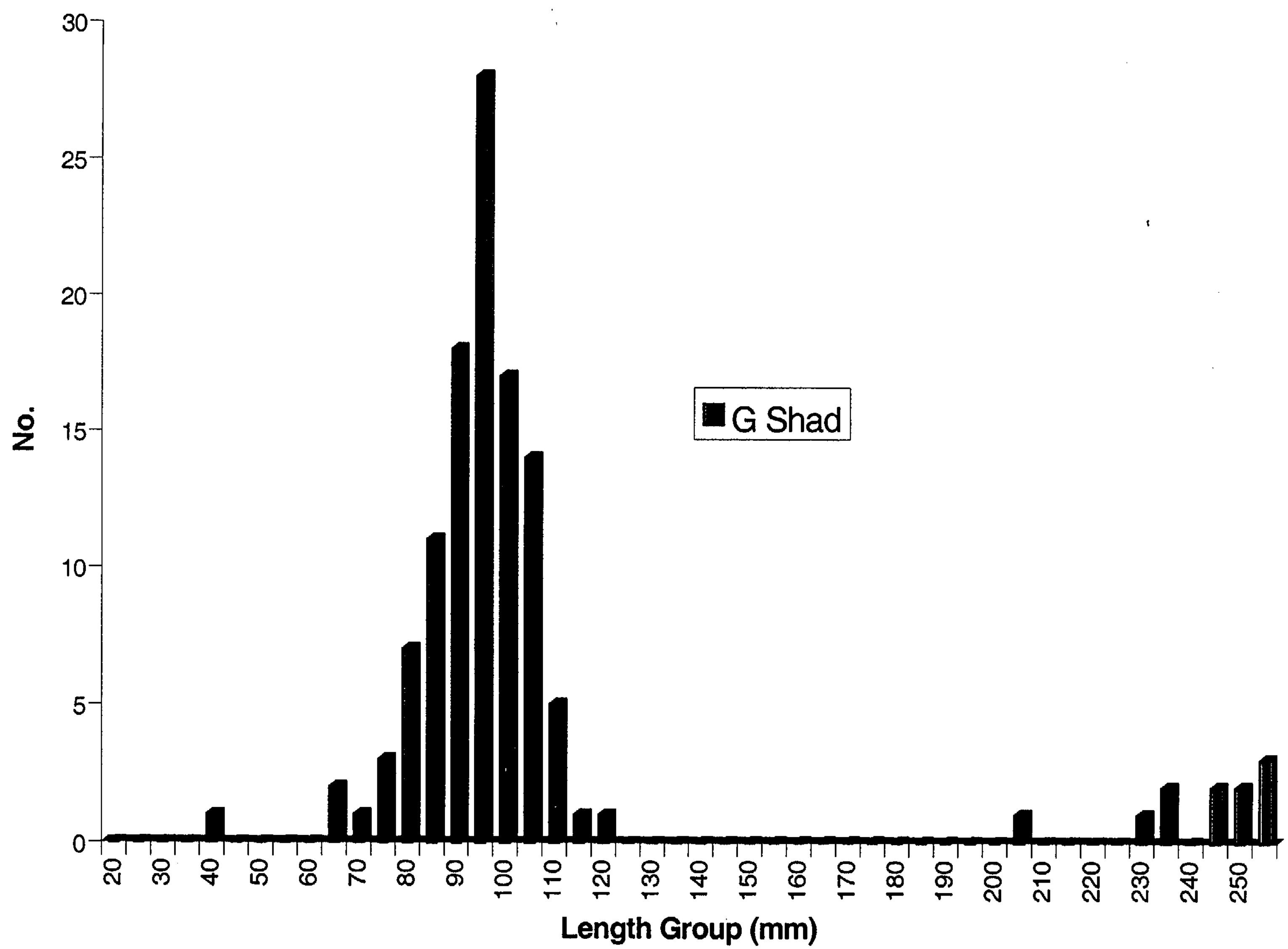

Mt Island Forage Fish - 1993
No.
0
20
40
60
80
100
120
140
T Shad
G Shad
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Length Group (mm)

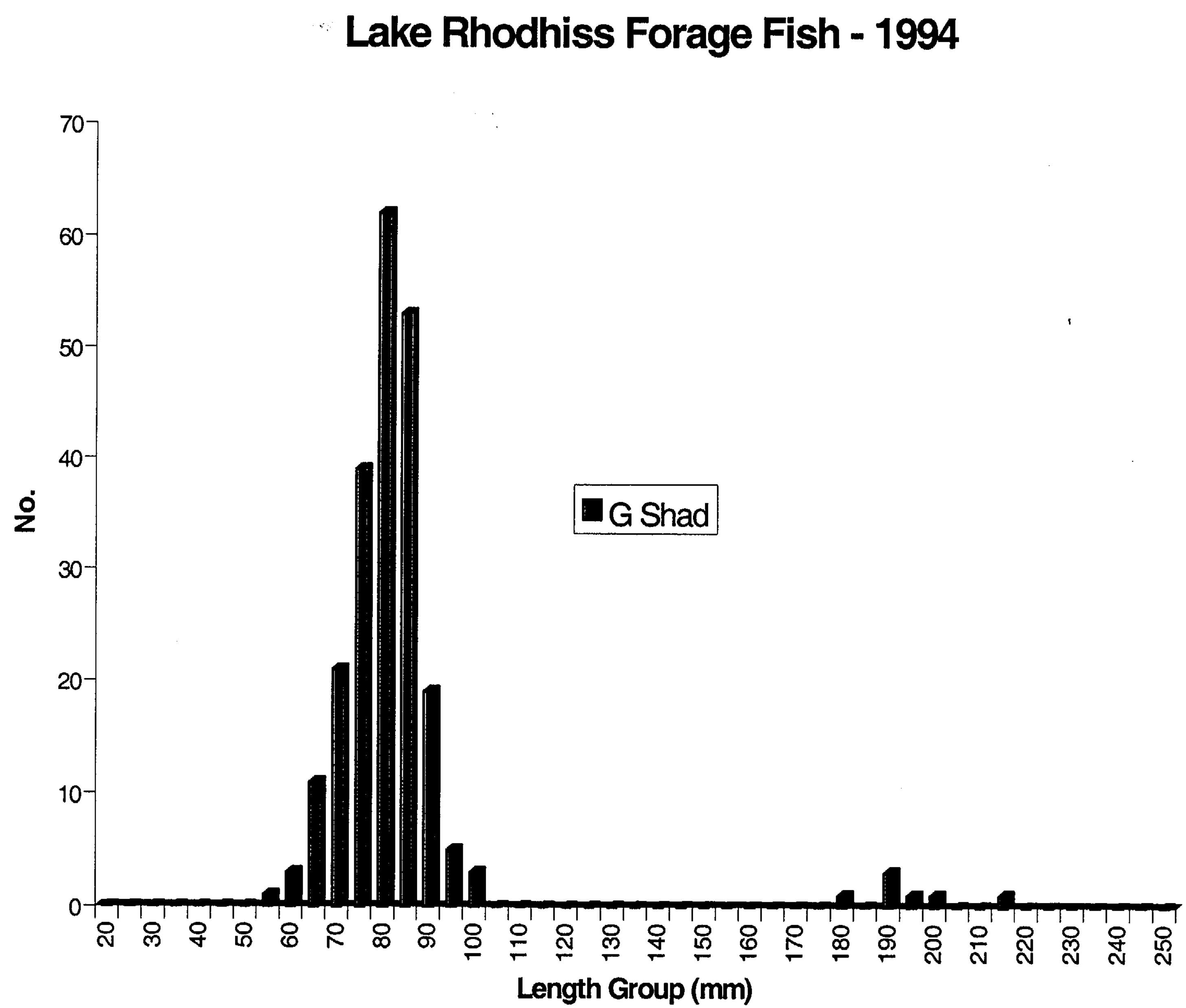
Lake Wylie Forage Fish - 1993



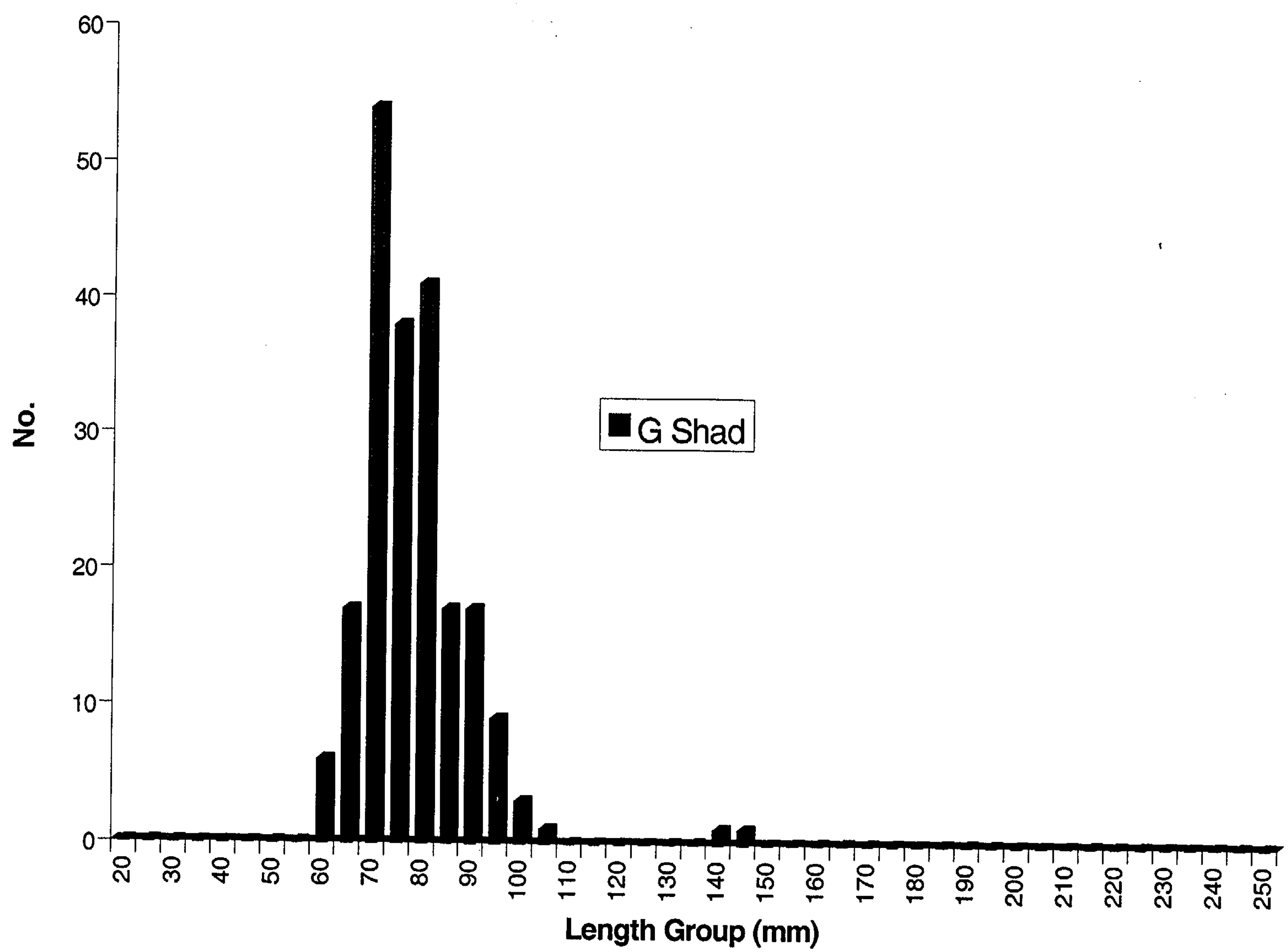

Lake Wateree Forage Fish - 1993
No.
0
20
40
60
80
100
120
140
160
T Shad
G Shad
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Length Group (mm)

Lake James Forage Fish - 1994

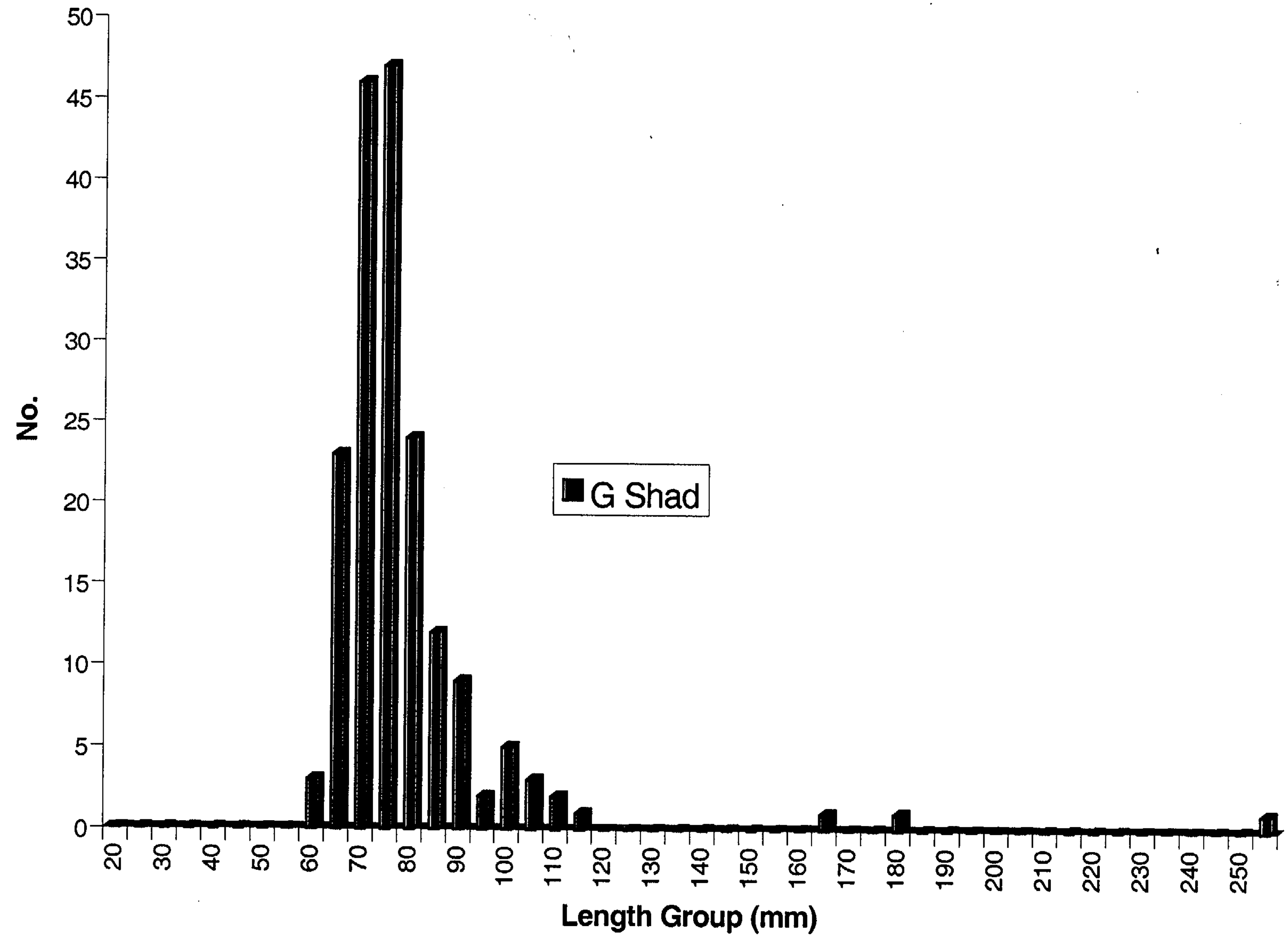



Lake Rhodhiss Forage Fish - 1994
No.
70
60
50
40
30
20
10
0
G Shad
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Length Group (mm)

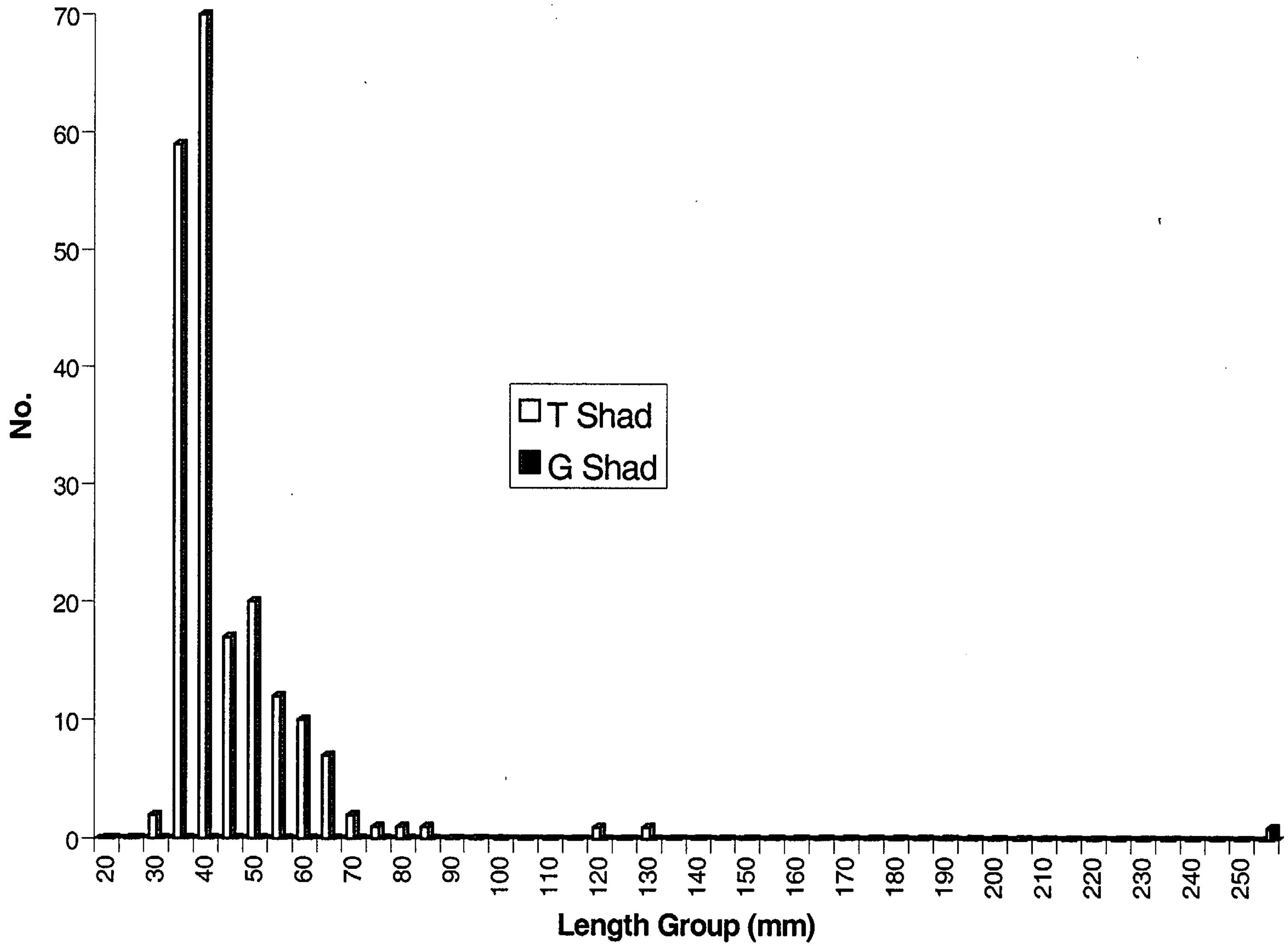
Lake Hickory Forage Fish - 1994



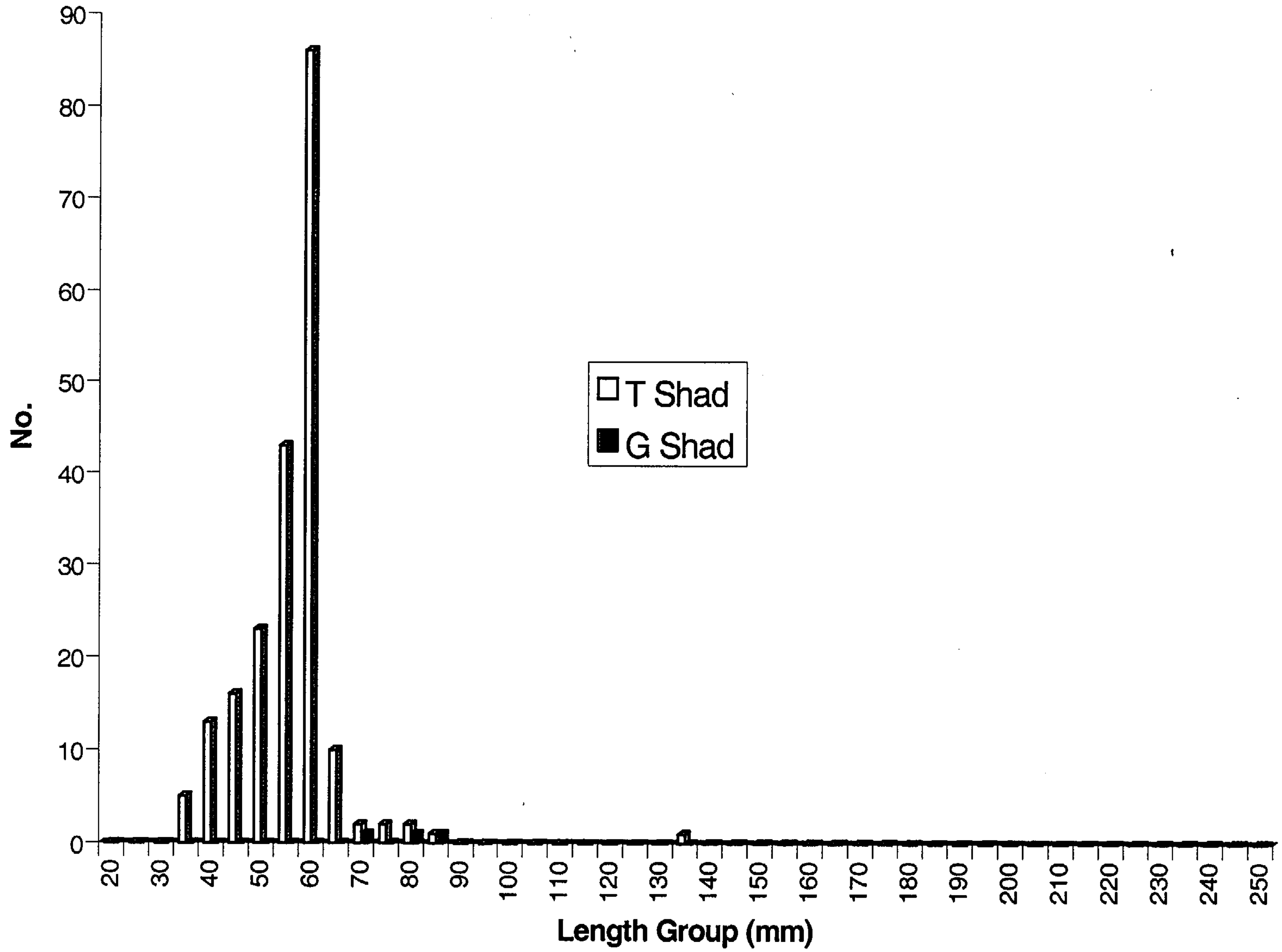
Lookout Shoals Forage Fish - 1994



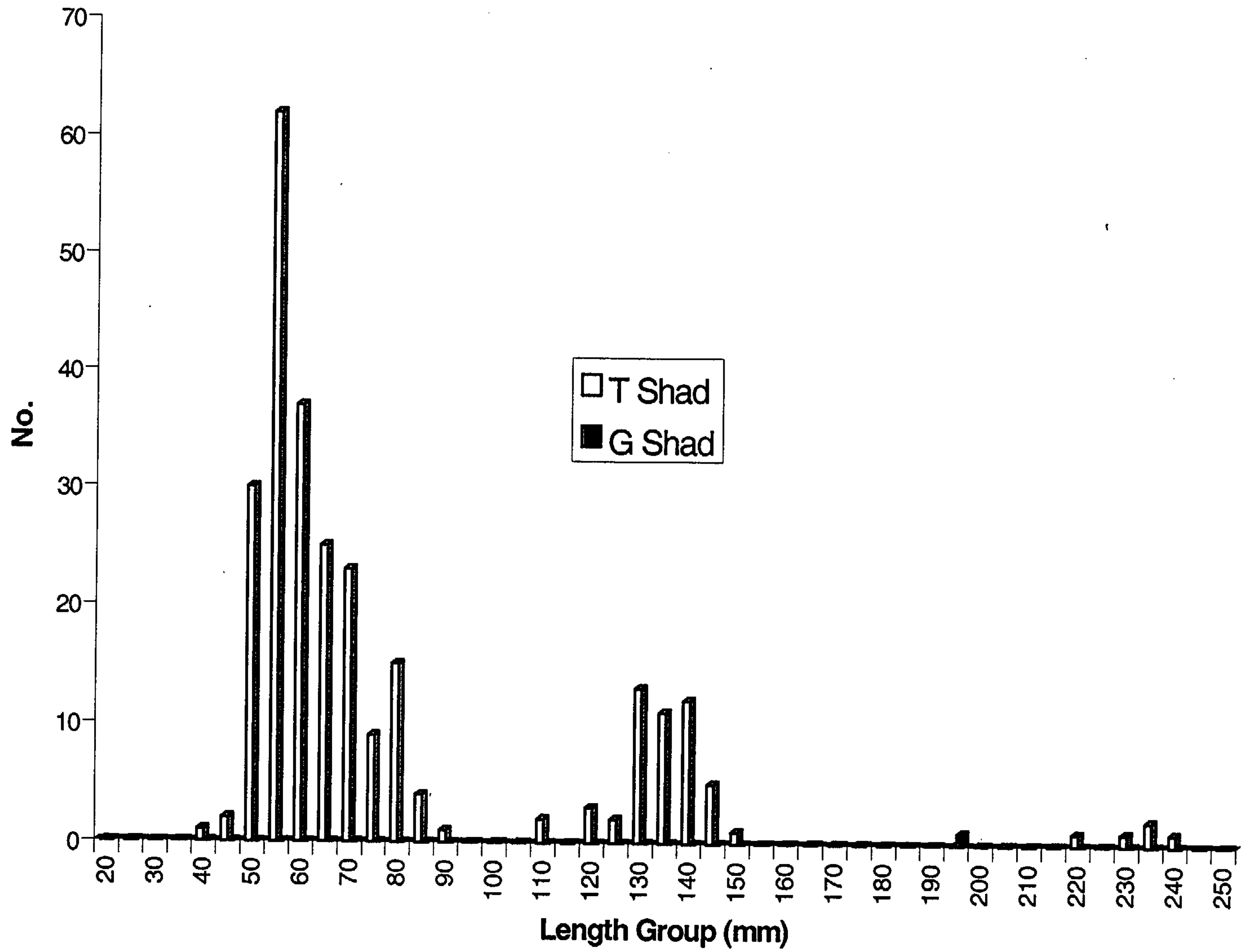
Lake Norman Forage Fish - 1994



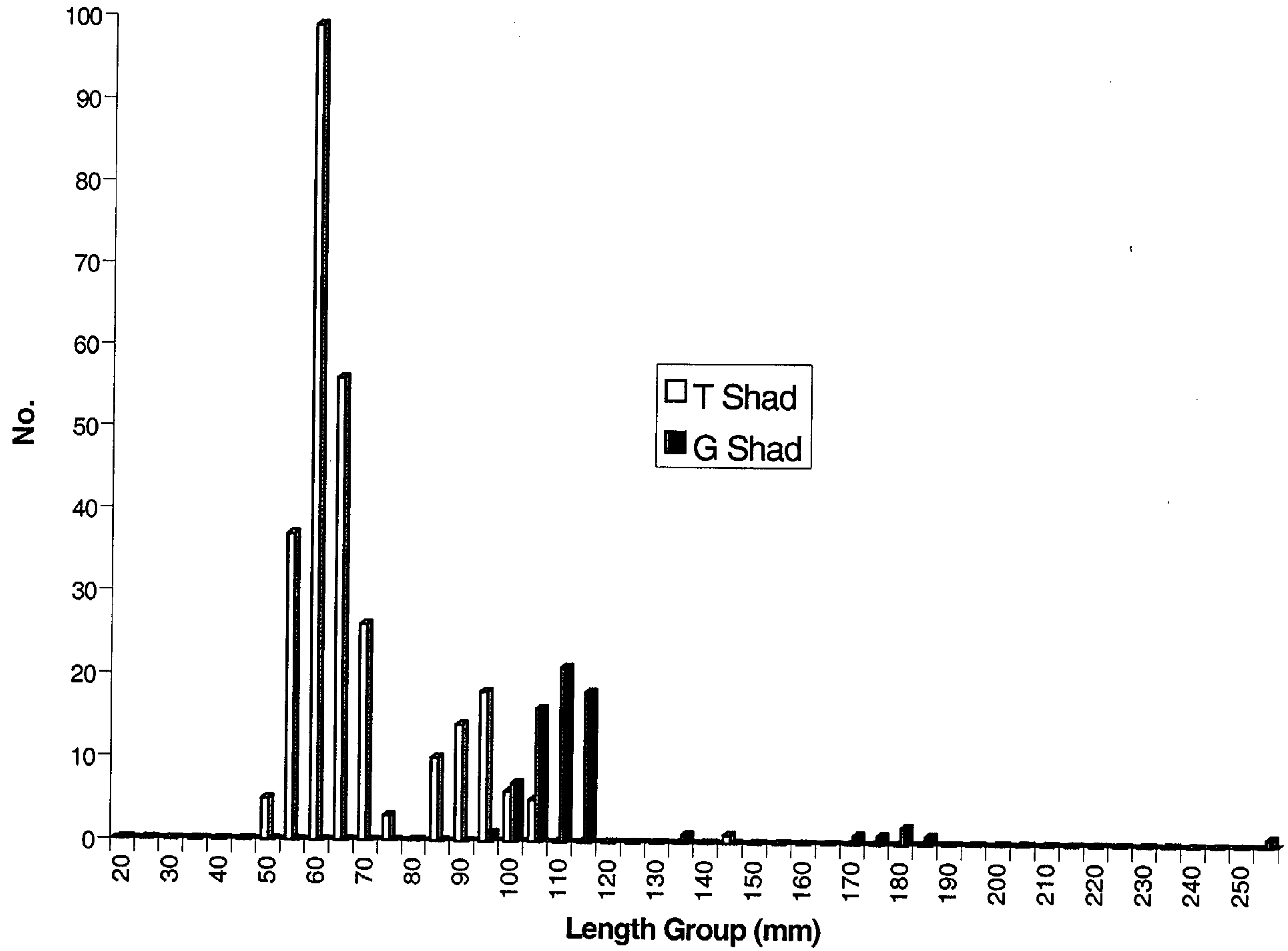
Mt. Island Forage Fish - 1994



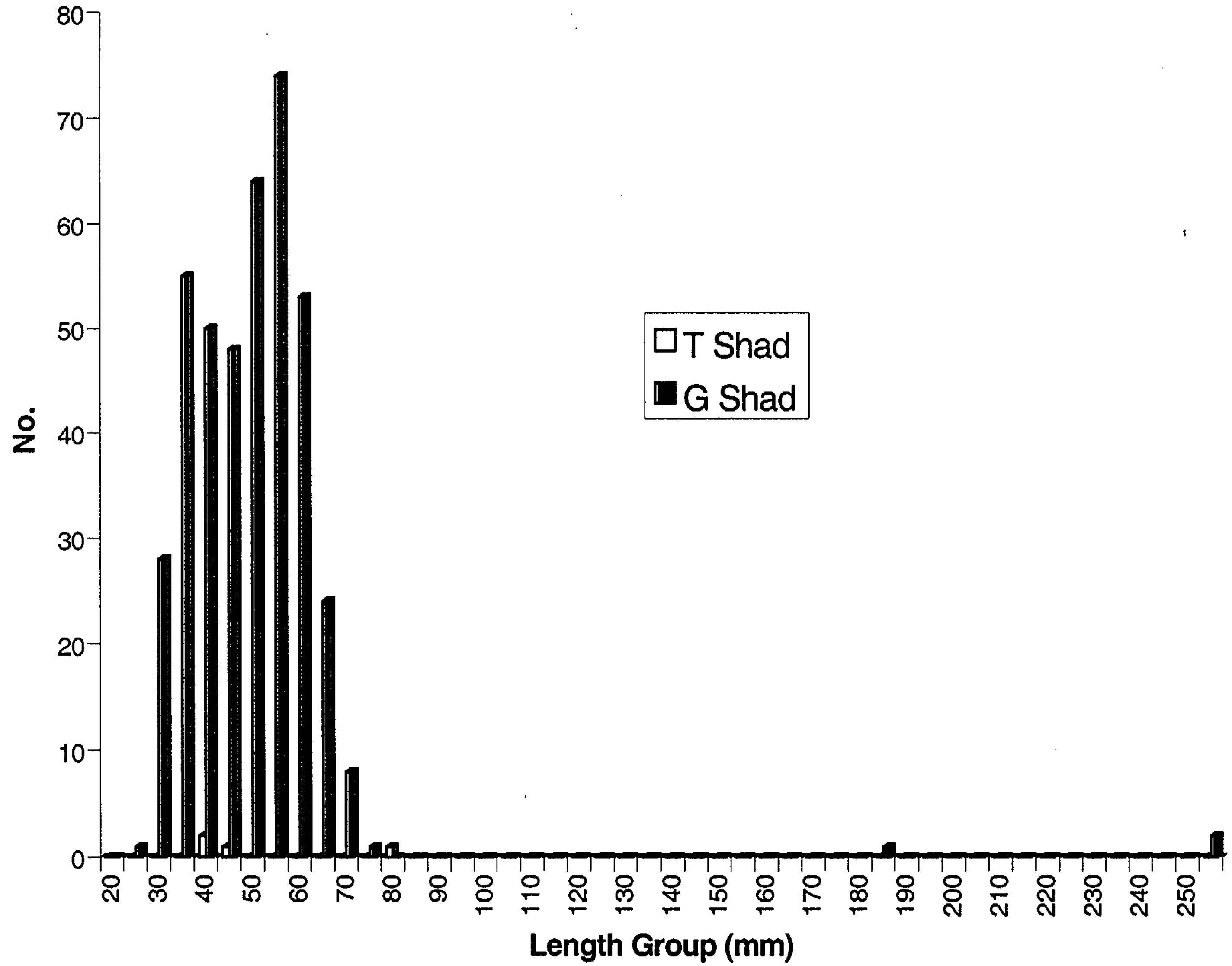
Lake Wylie Forage Fish - 1994



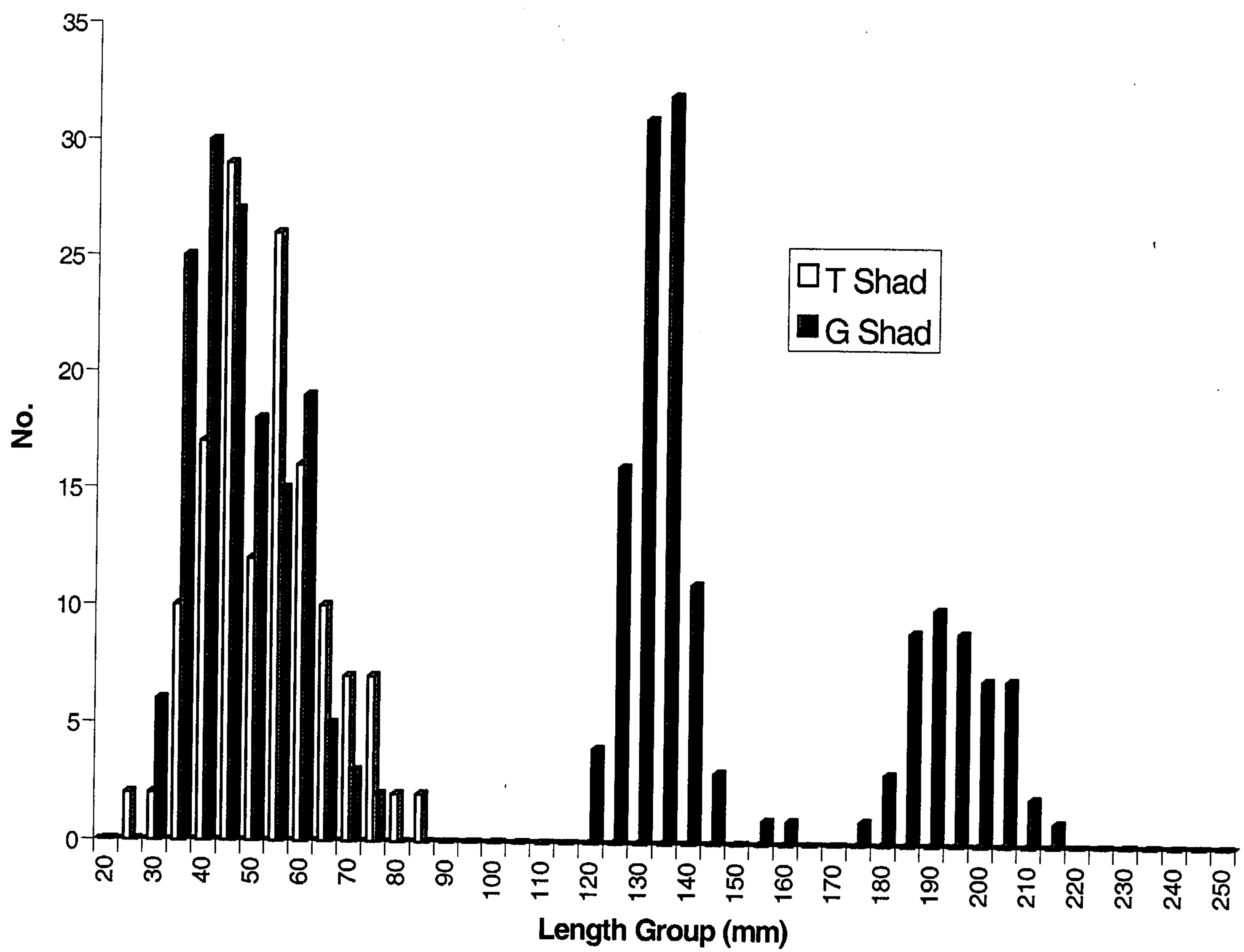
Lake Wateree Forage Fish - 1994



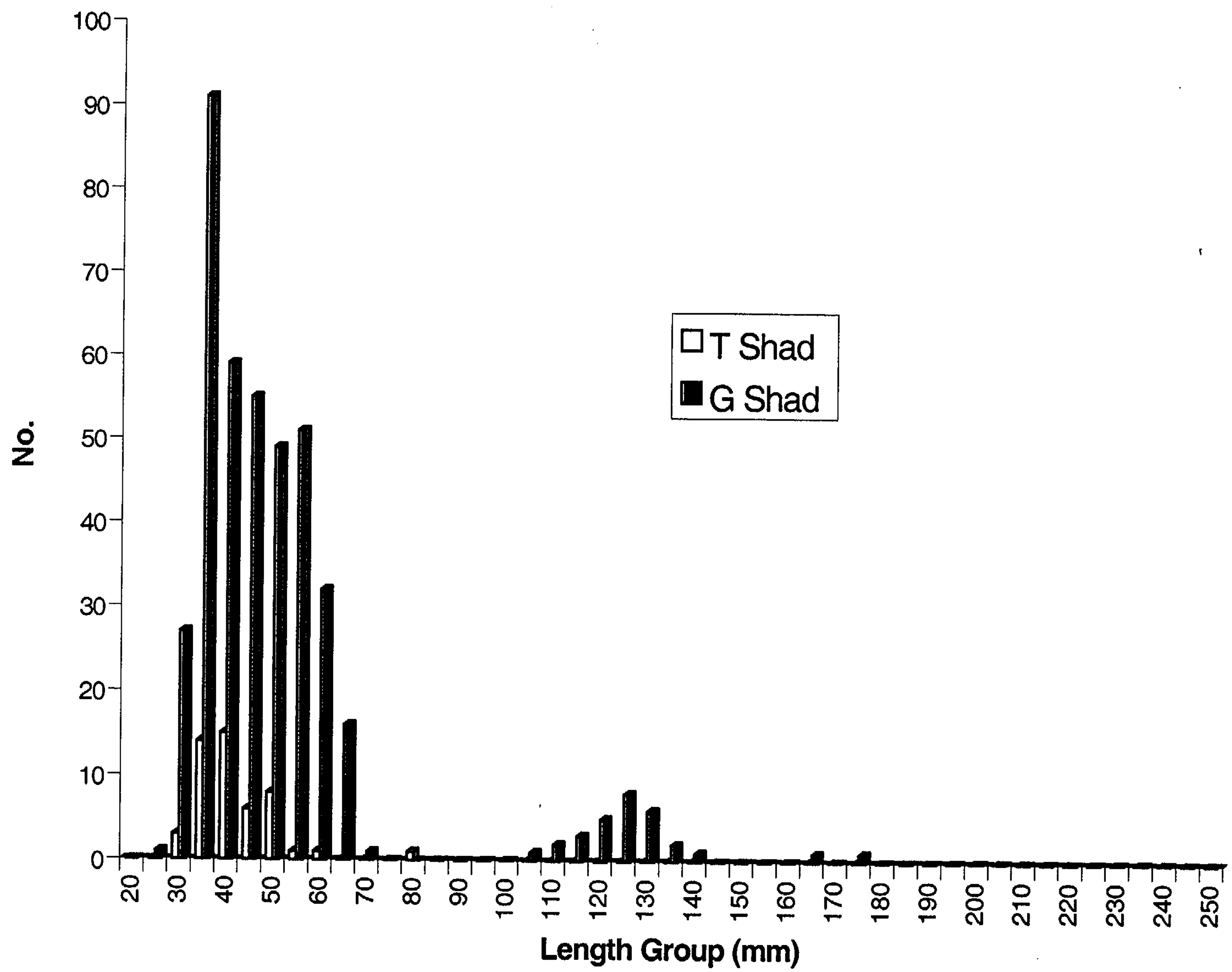
Lake James Forage Fish - 1995

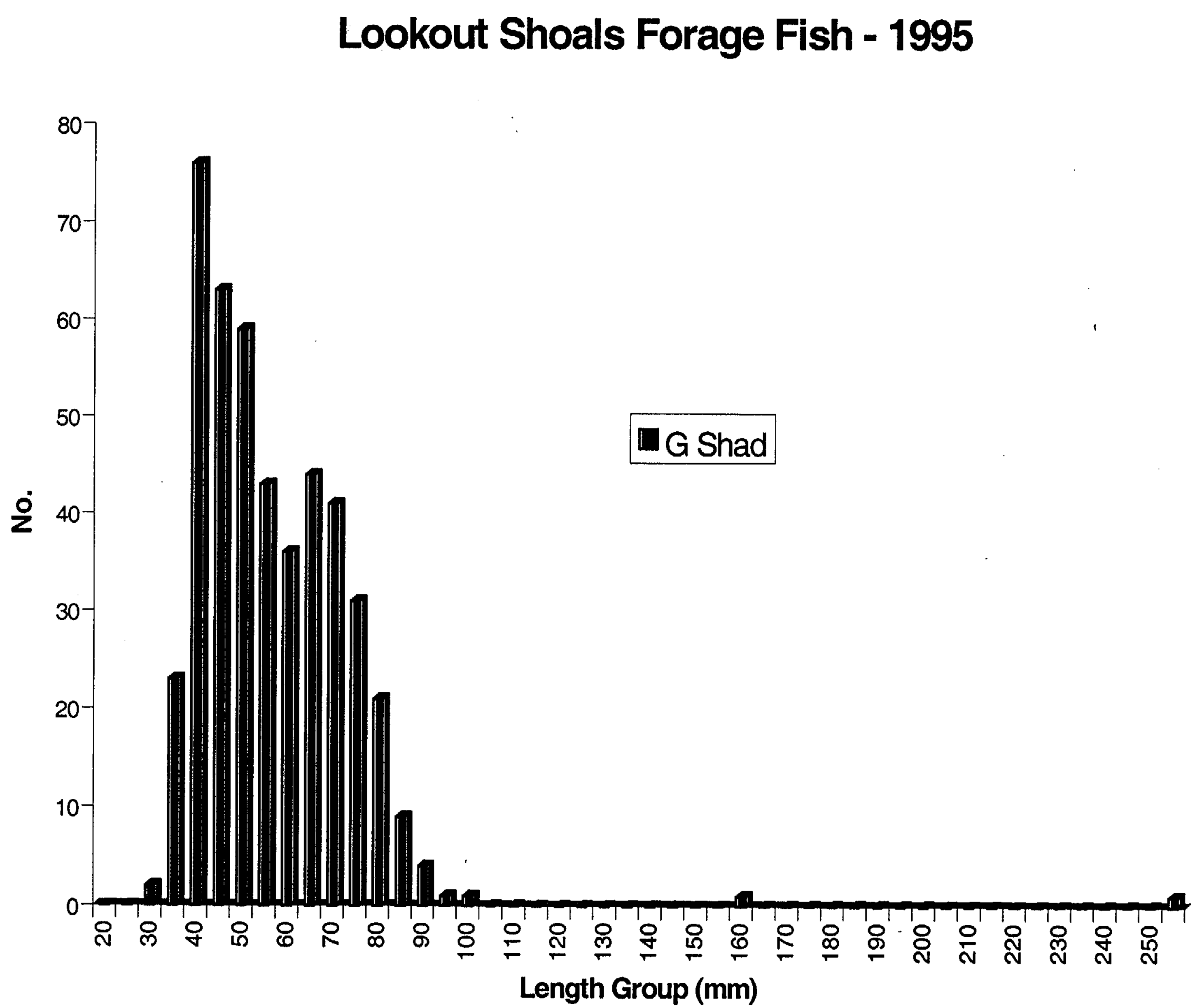


Lake Rhodhiss Forage Fish - 1995

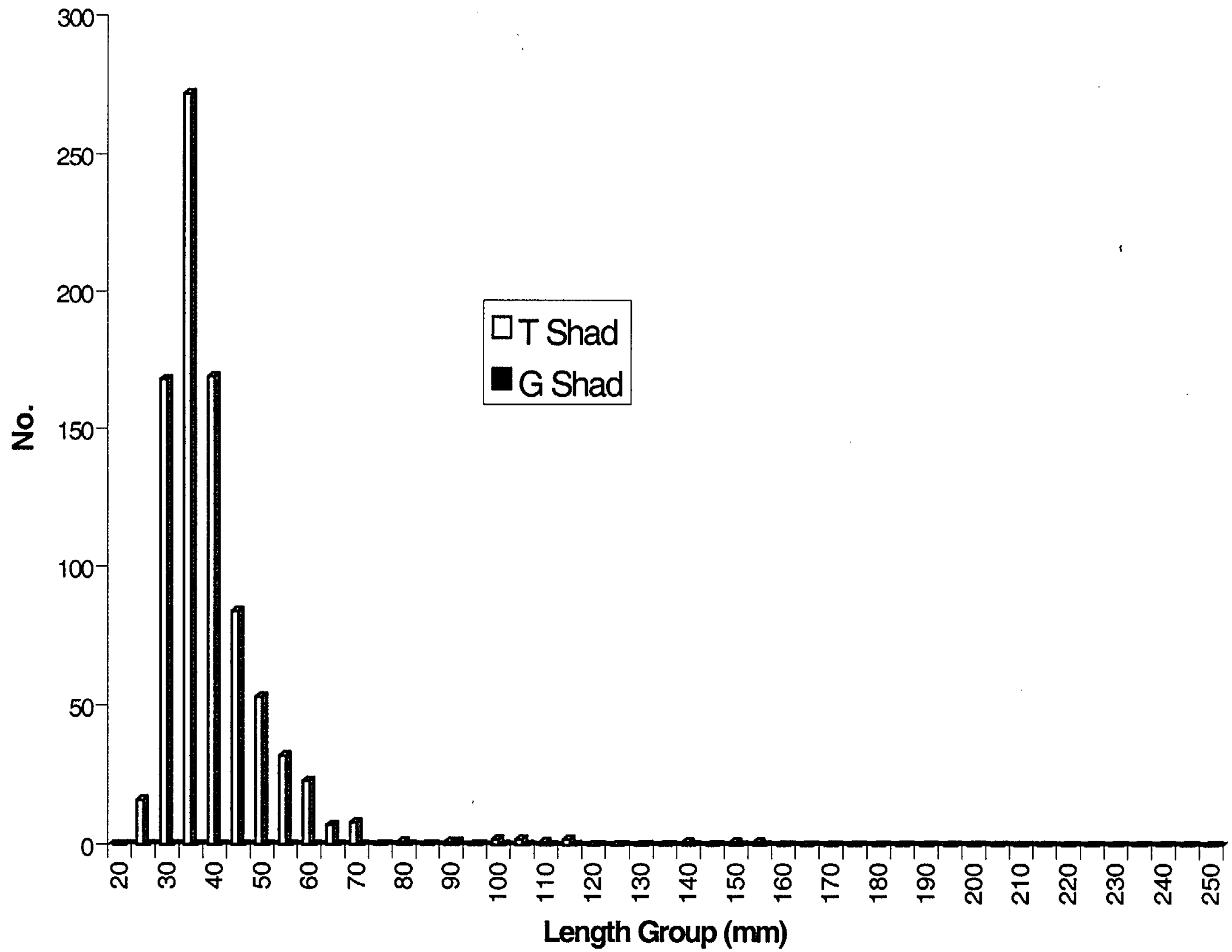


Lake Hickory Forage Fish - 1995

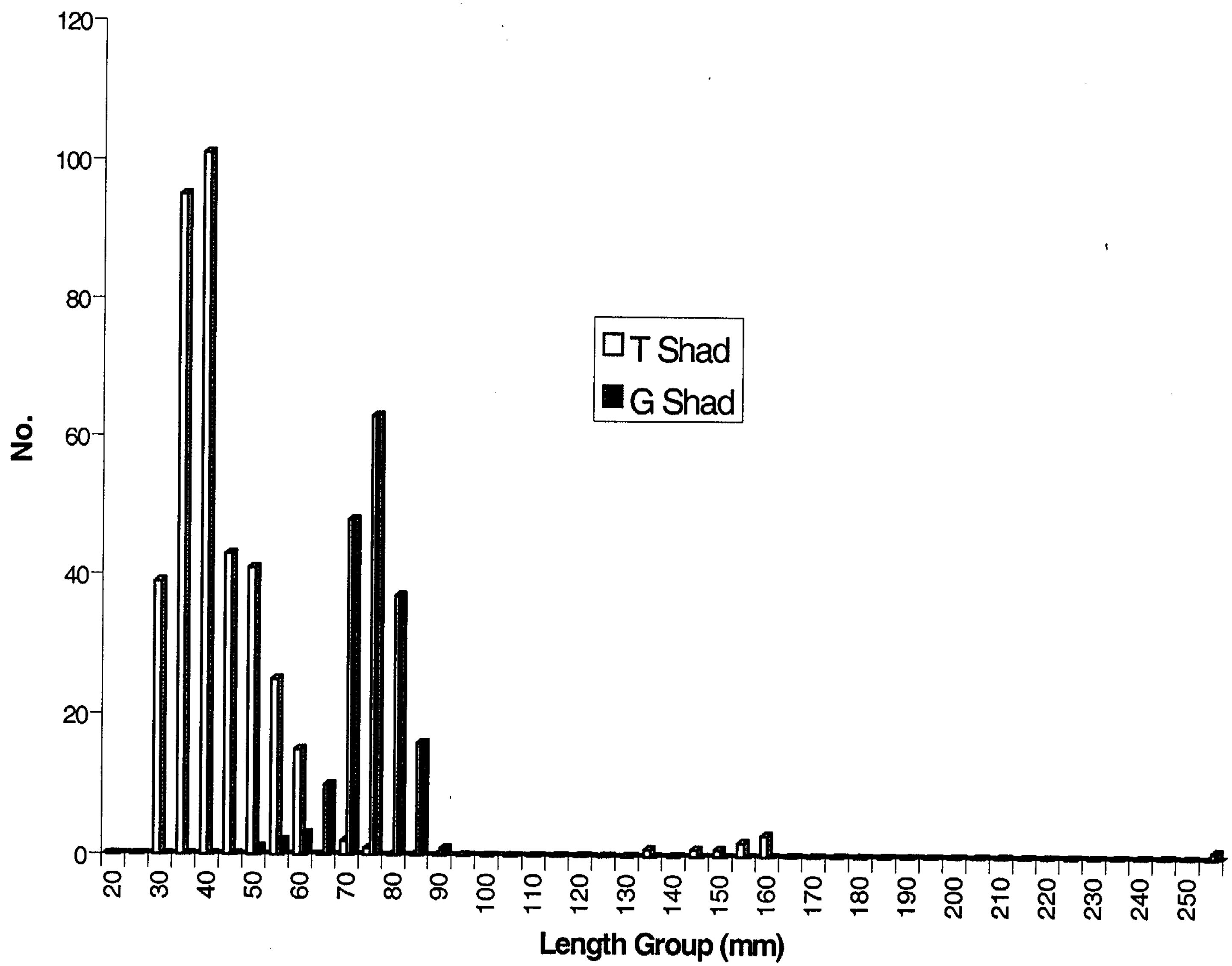



Lookout Shoals Forage Fish - 1995
No.
80
70
60
50
40
30
20
10
0
G Shad
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Length Group (mm)

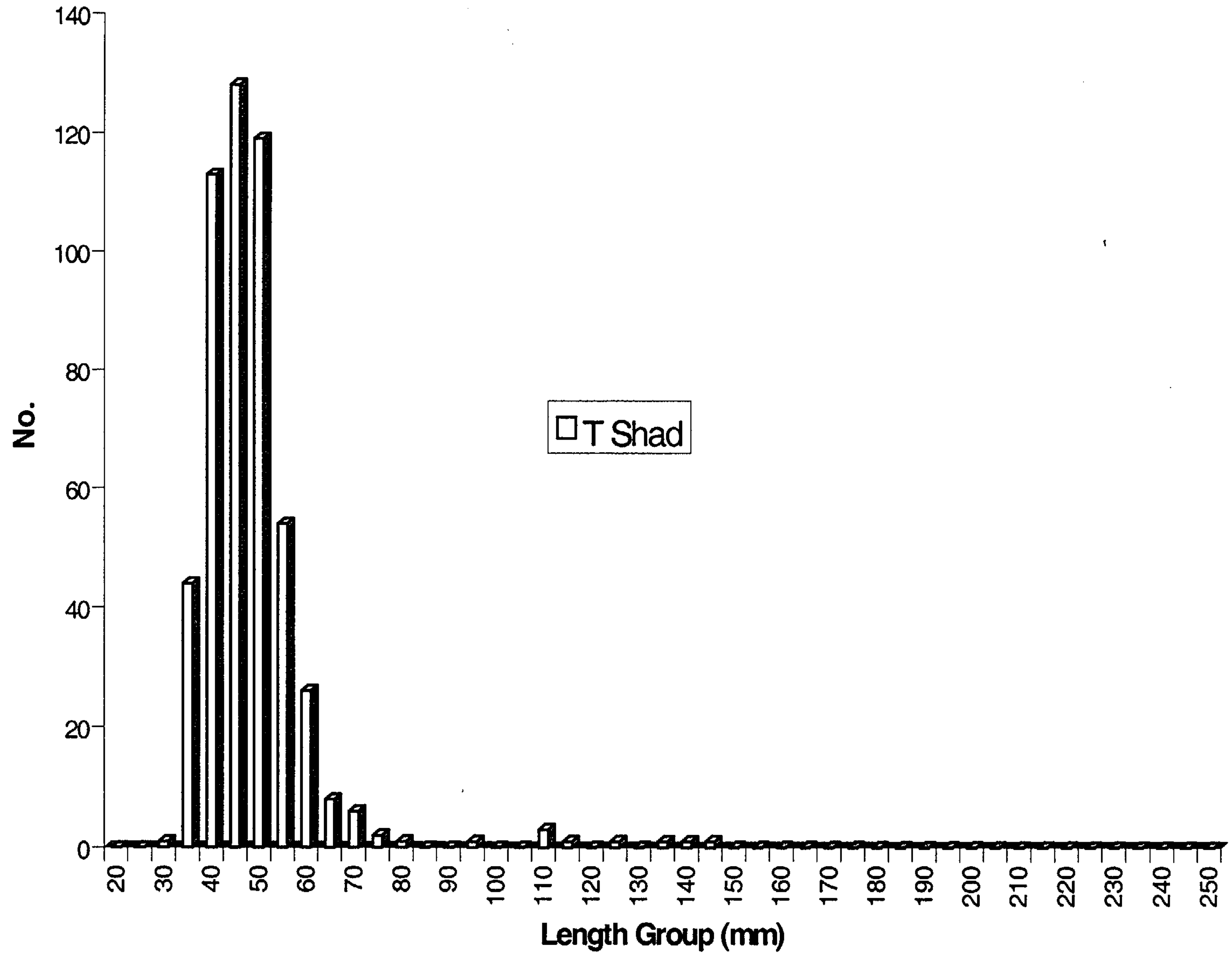
Lake Norman Forage Fish - 1995



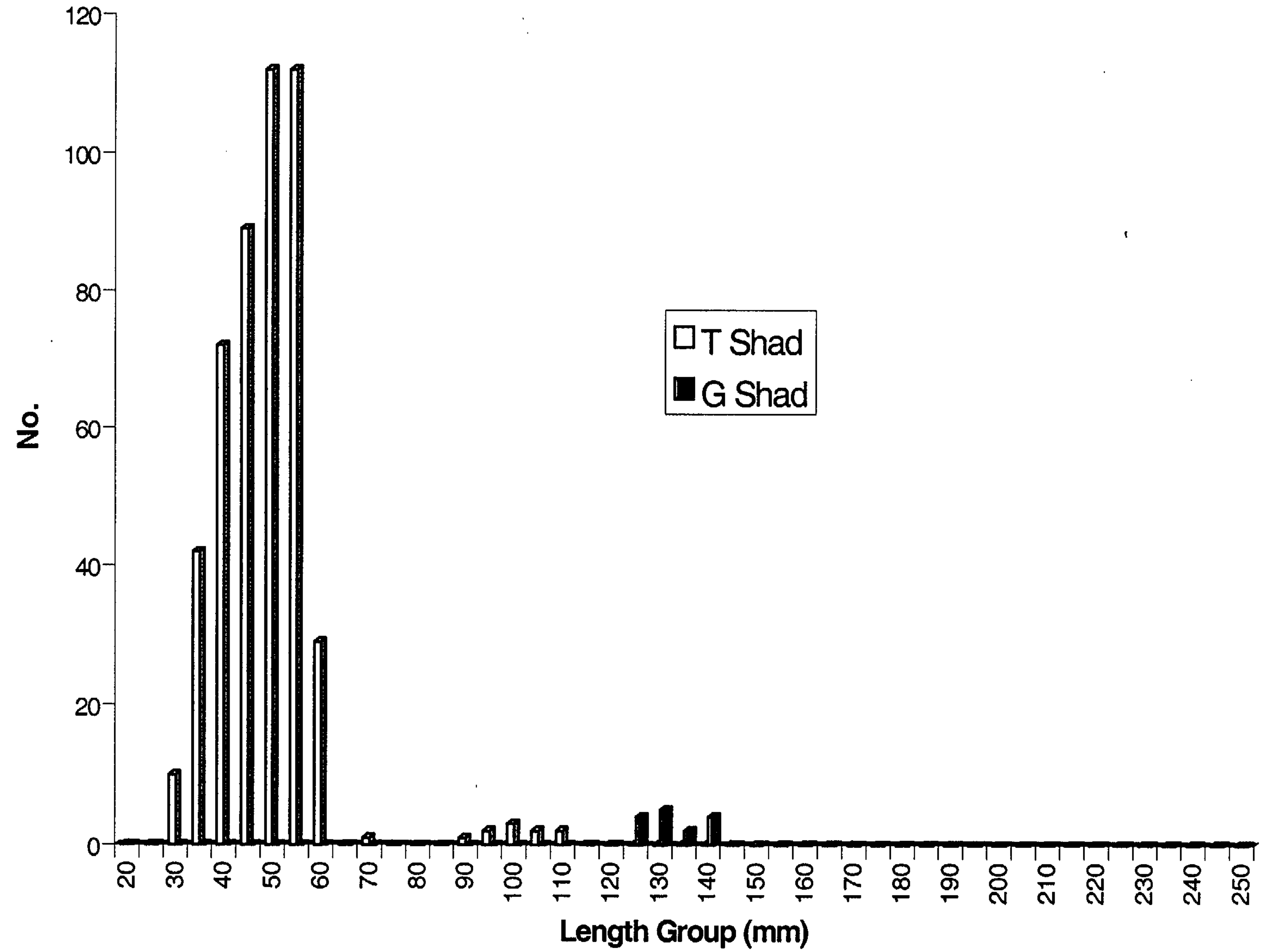
Mt. Island Forage Fish - 1995



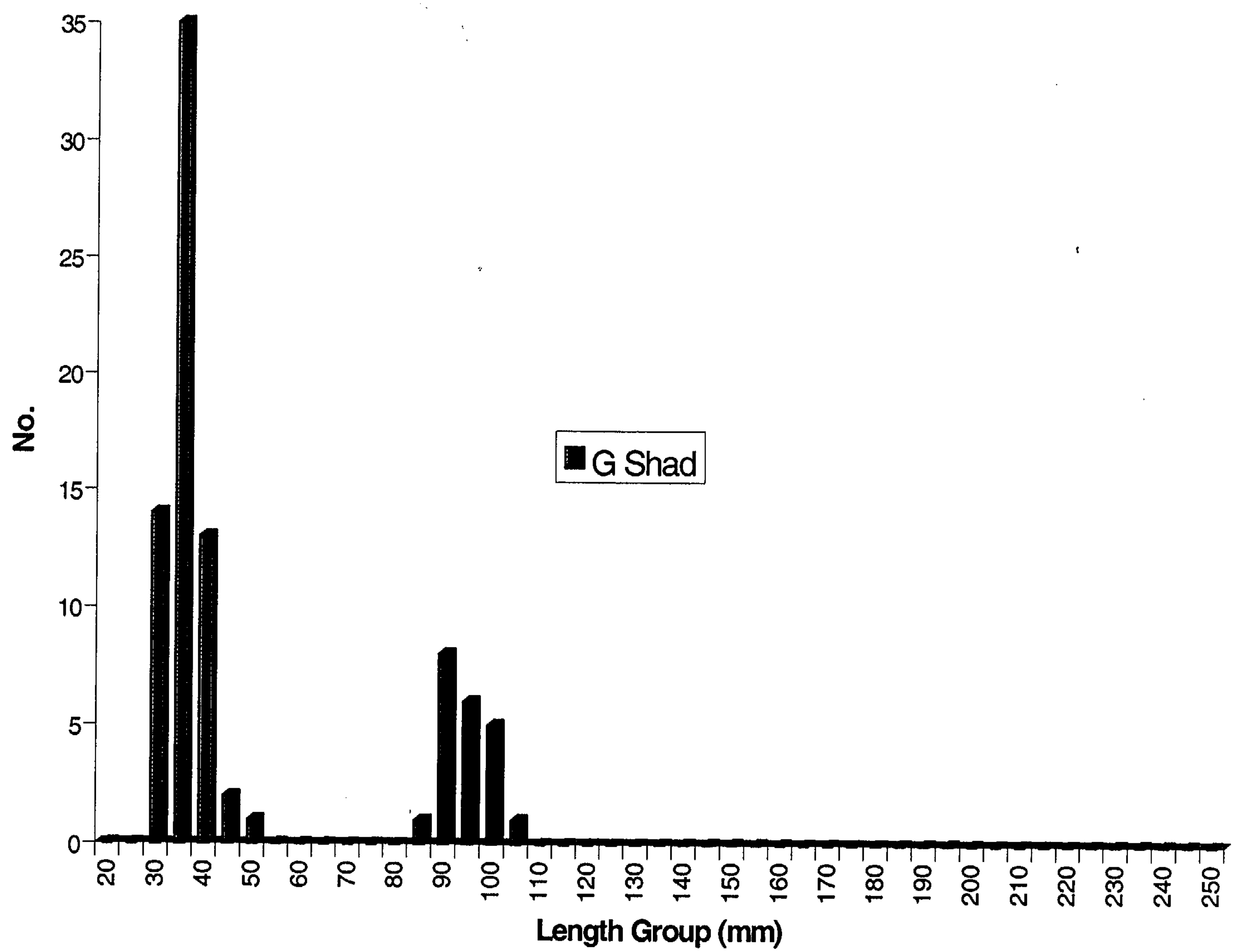
Lake Wylie Forage Fish - 1995



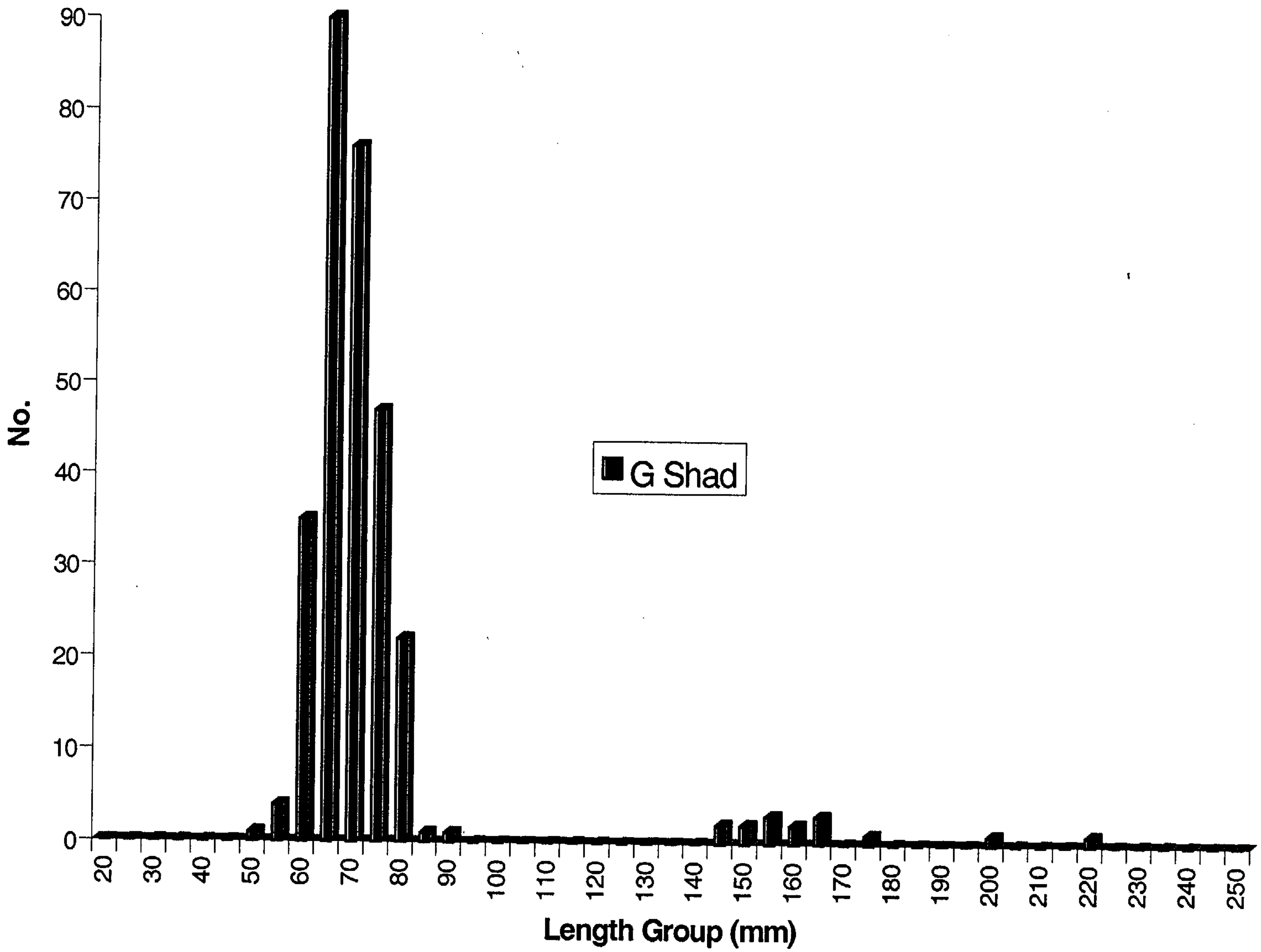
Lake Wateree Forage Fish - 1995



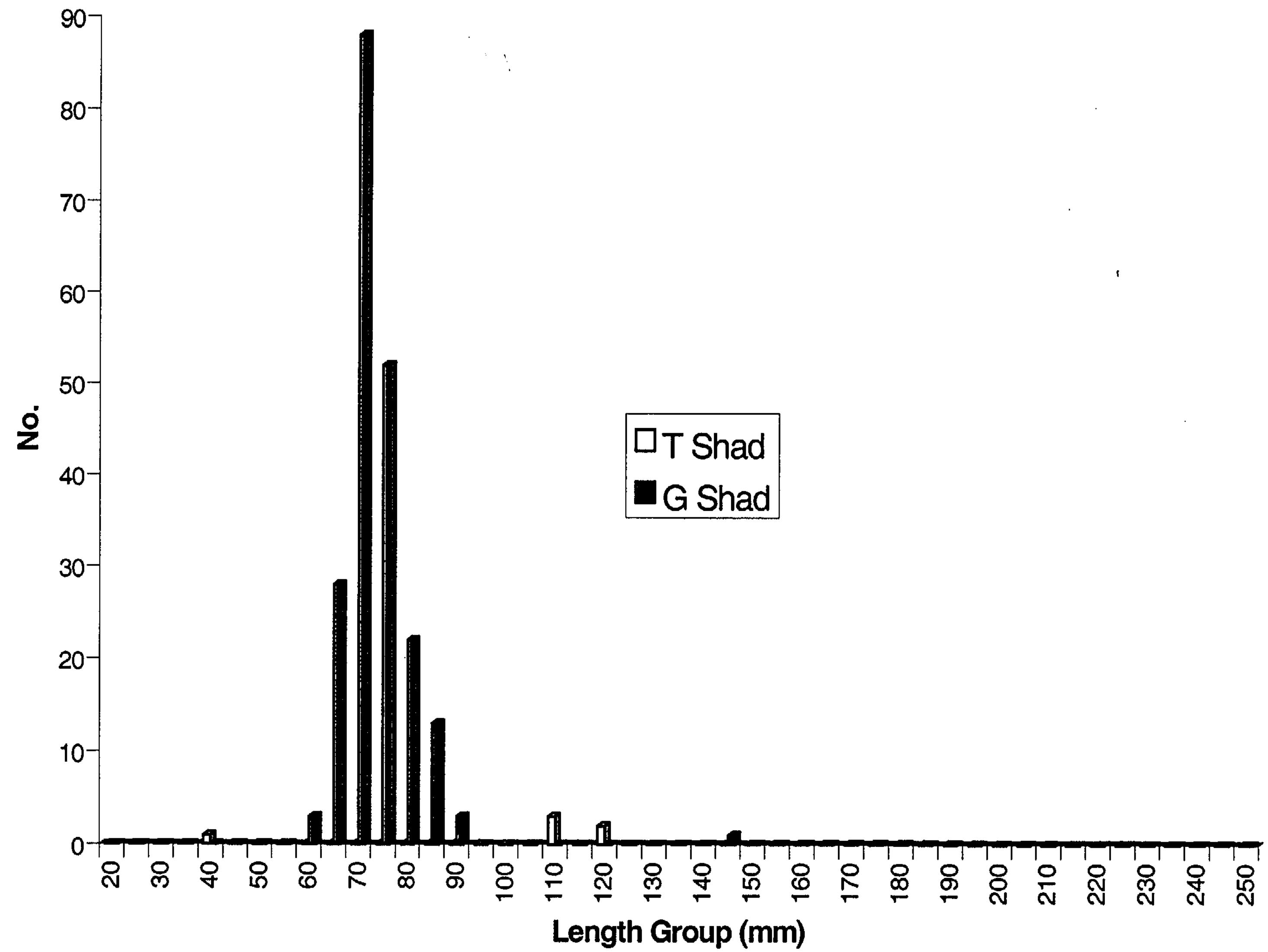
Lake James Forage Fish - 1996



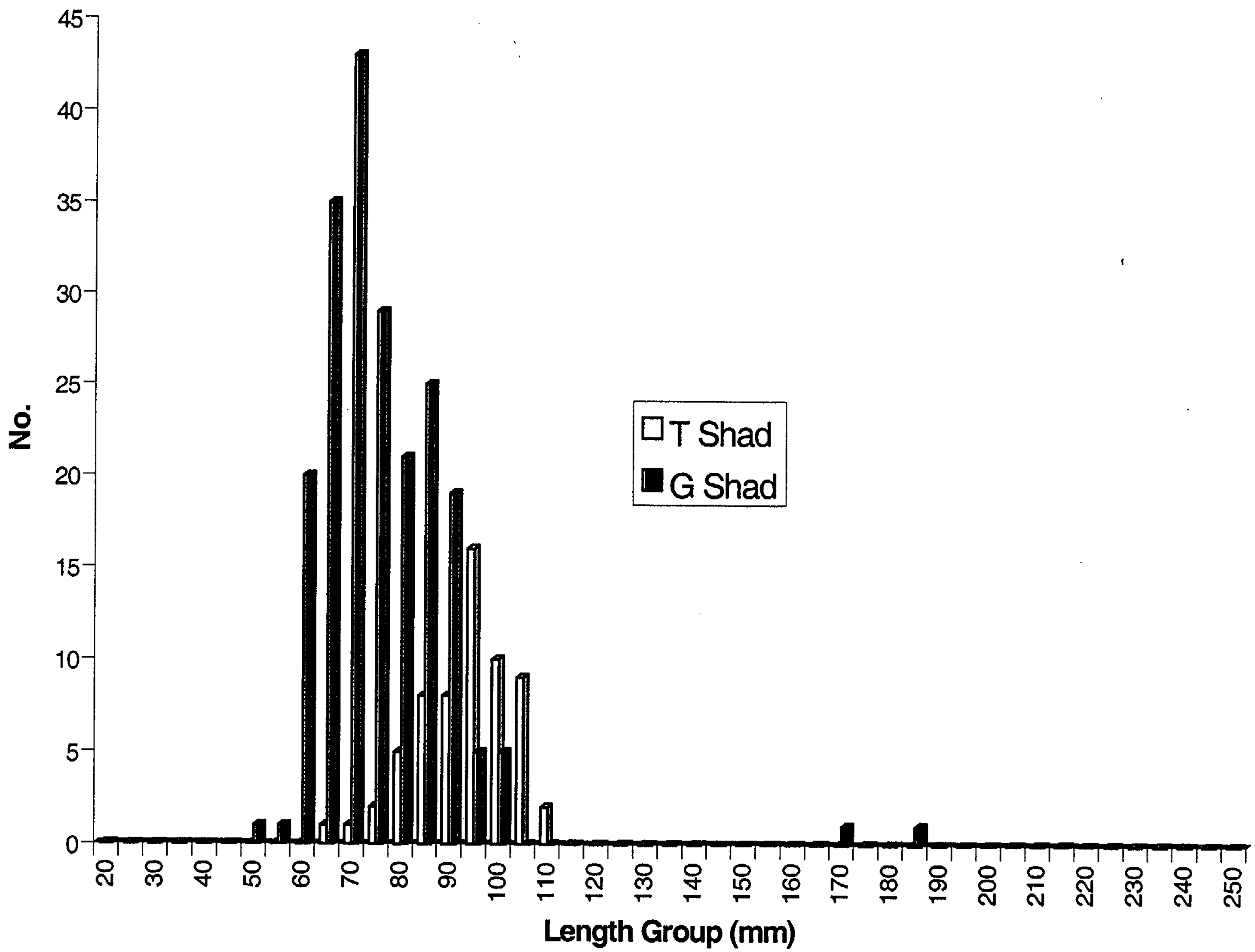
Lake Rhodhiss Forage Fish - 1996



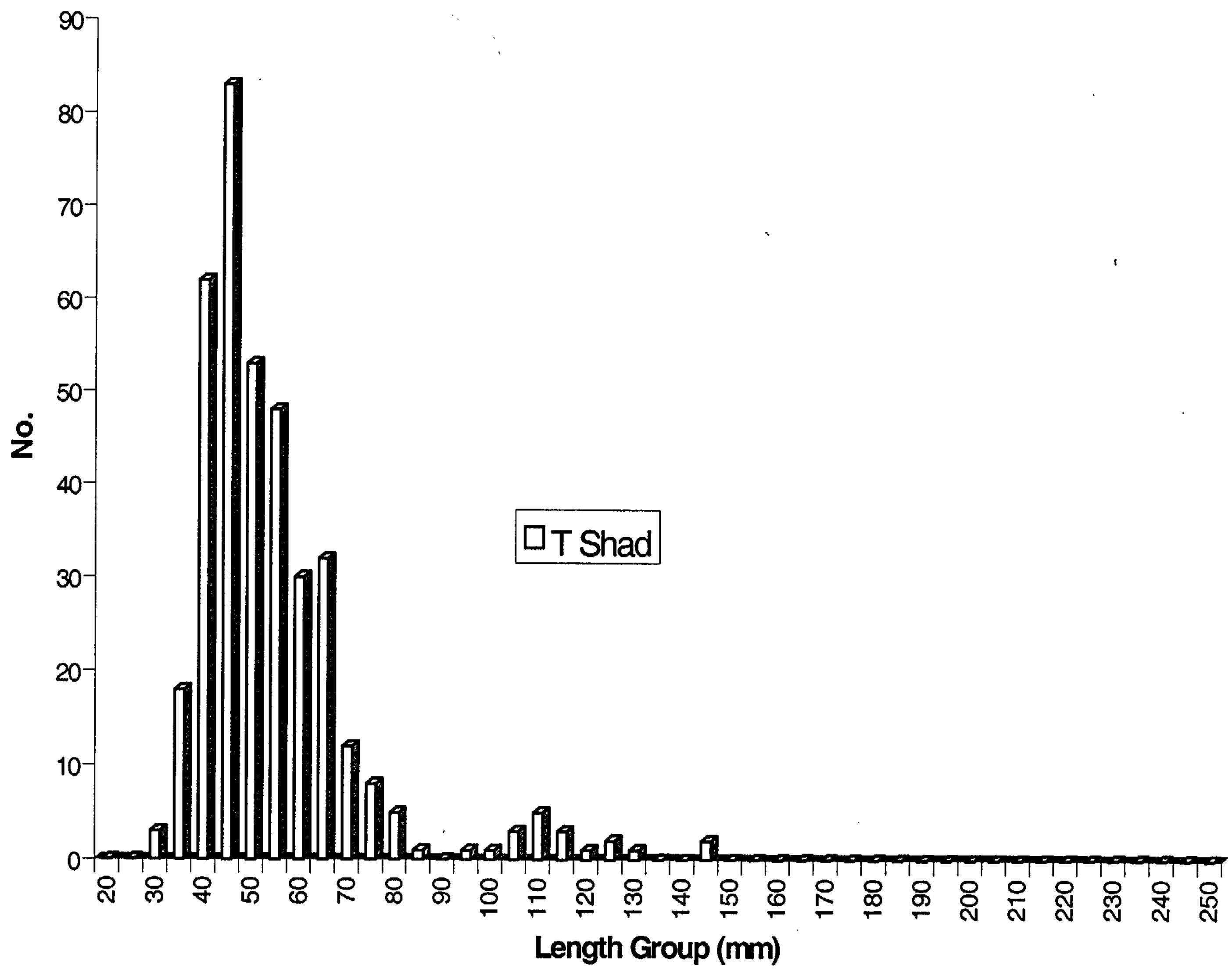
Lake Hickory Forage Fish - 1996



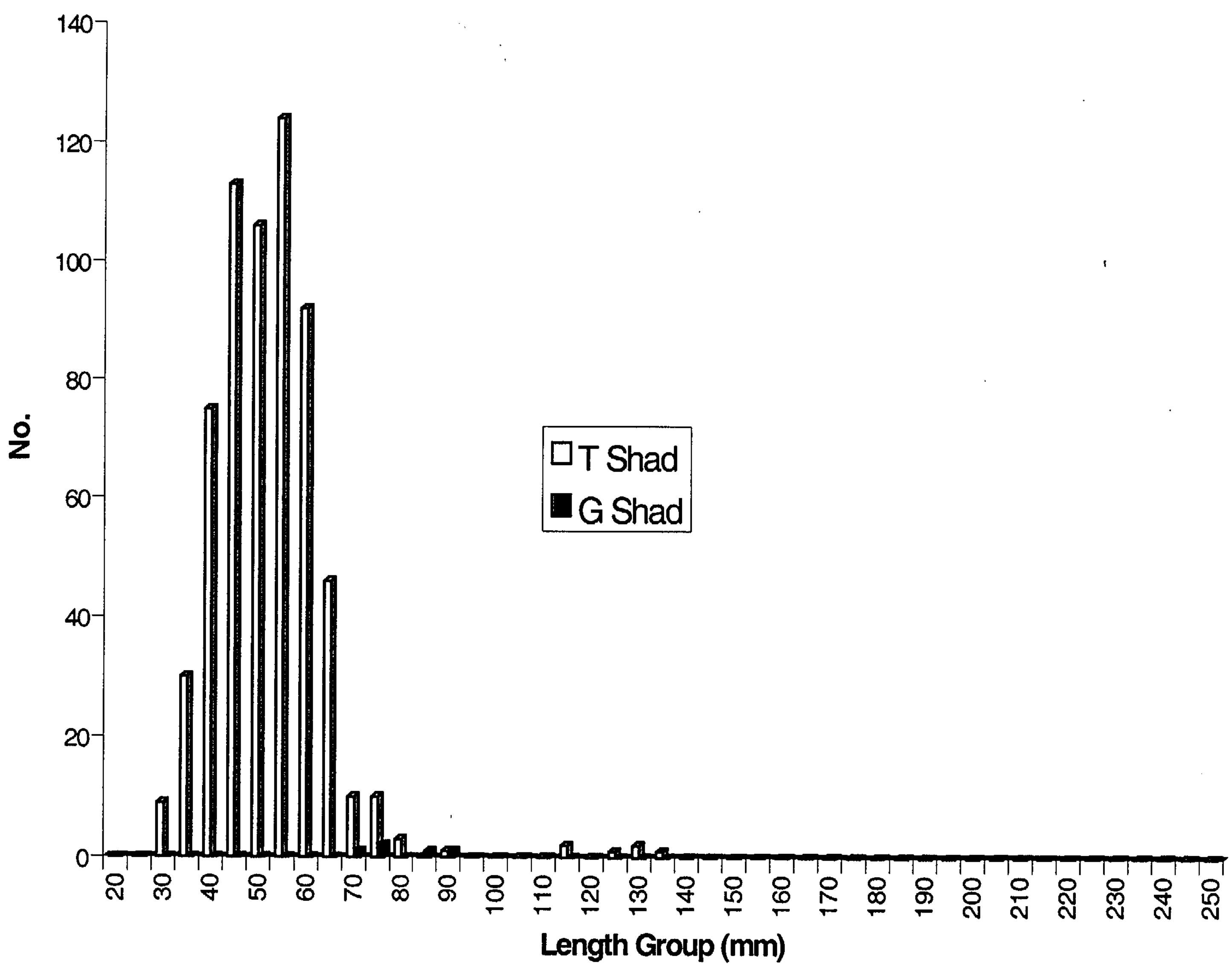
Lookout Shoals Forage Fish - 1996

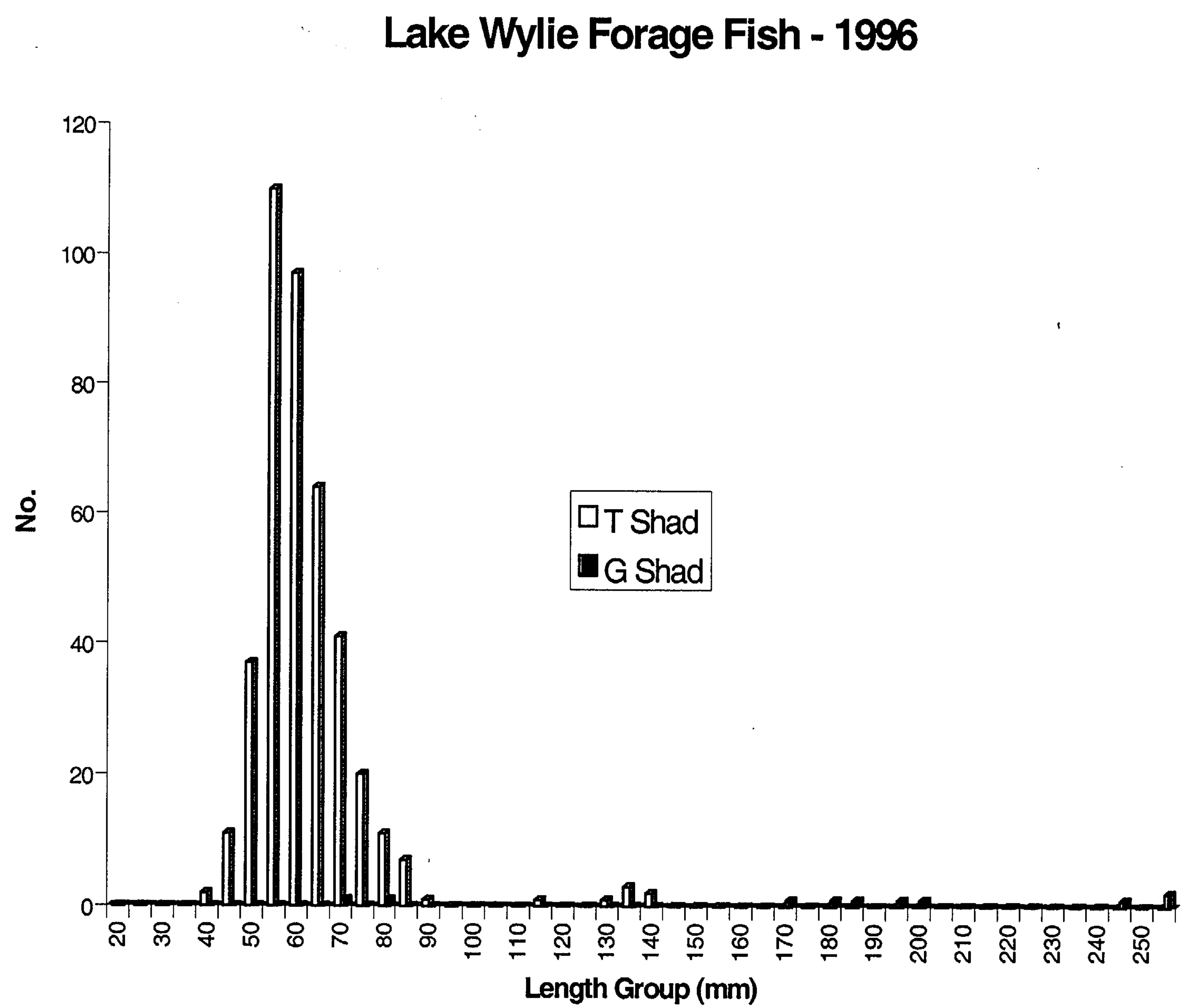


Lake Norman Forage Fish - 1996



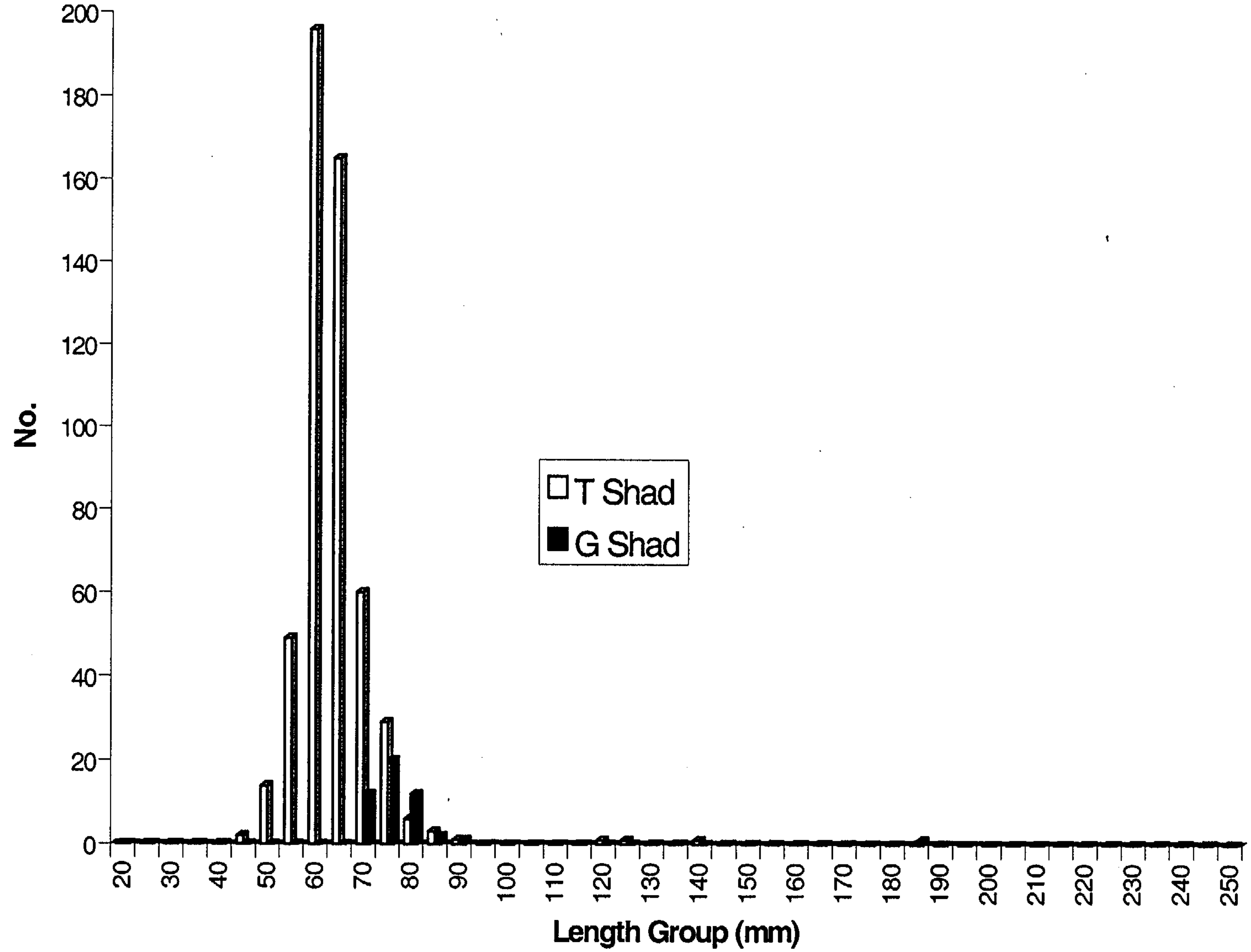
Mt. Island Forage Fish - 1996



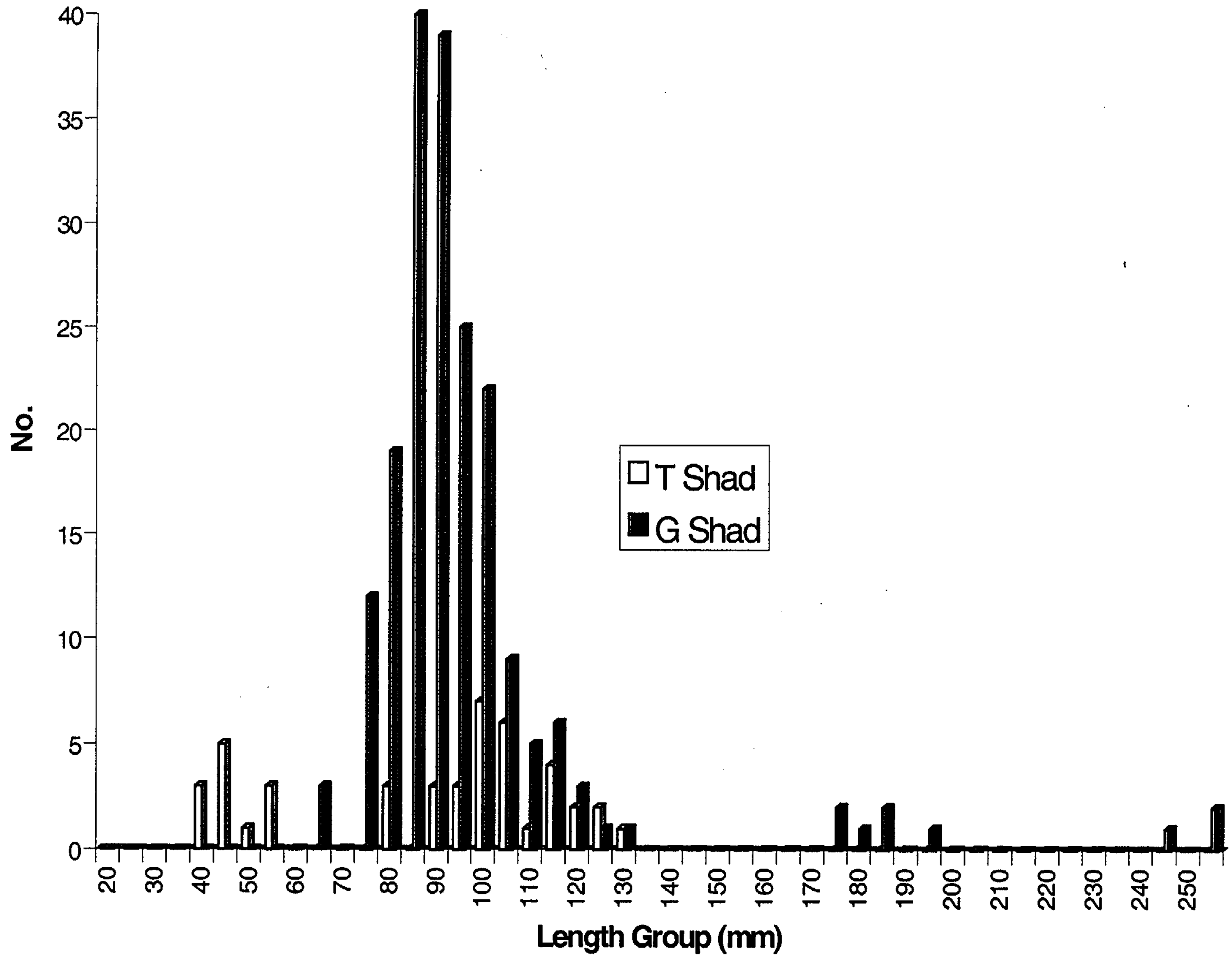


Lake Wylie Forage Fish - 1996
No.
120
100
80
60
40
20
0
T Shad
G Shad
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Length Group (mm)

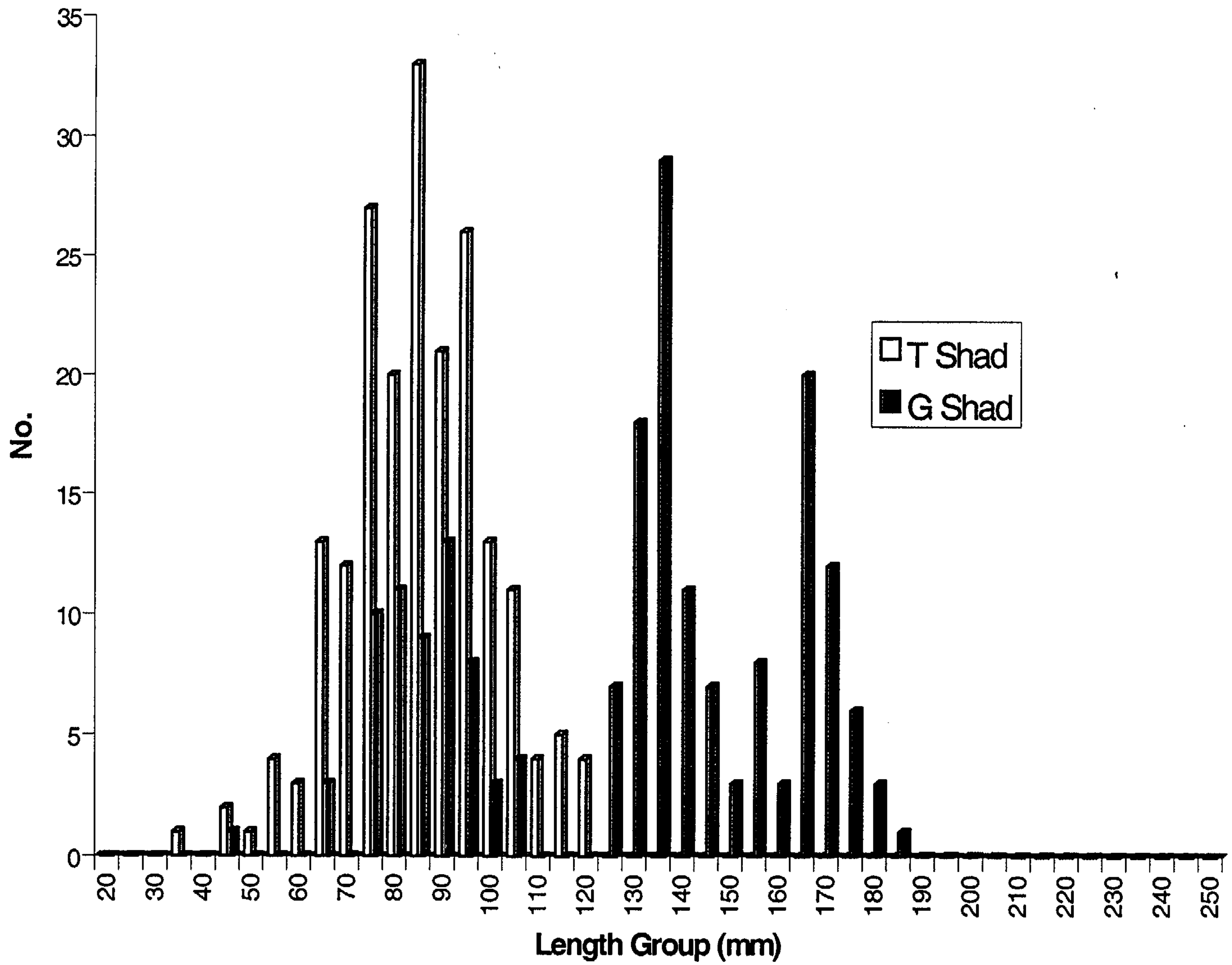
Lake Wateree Forage Fish - 1996



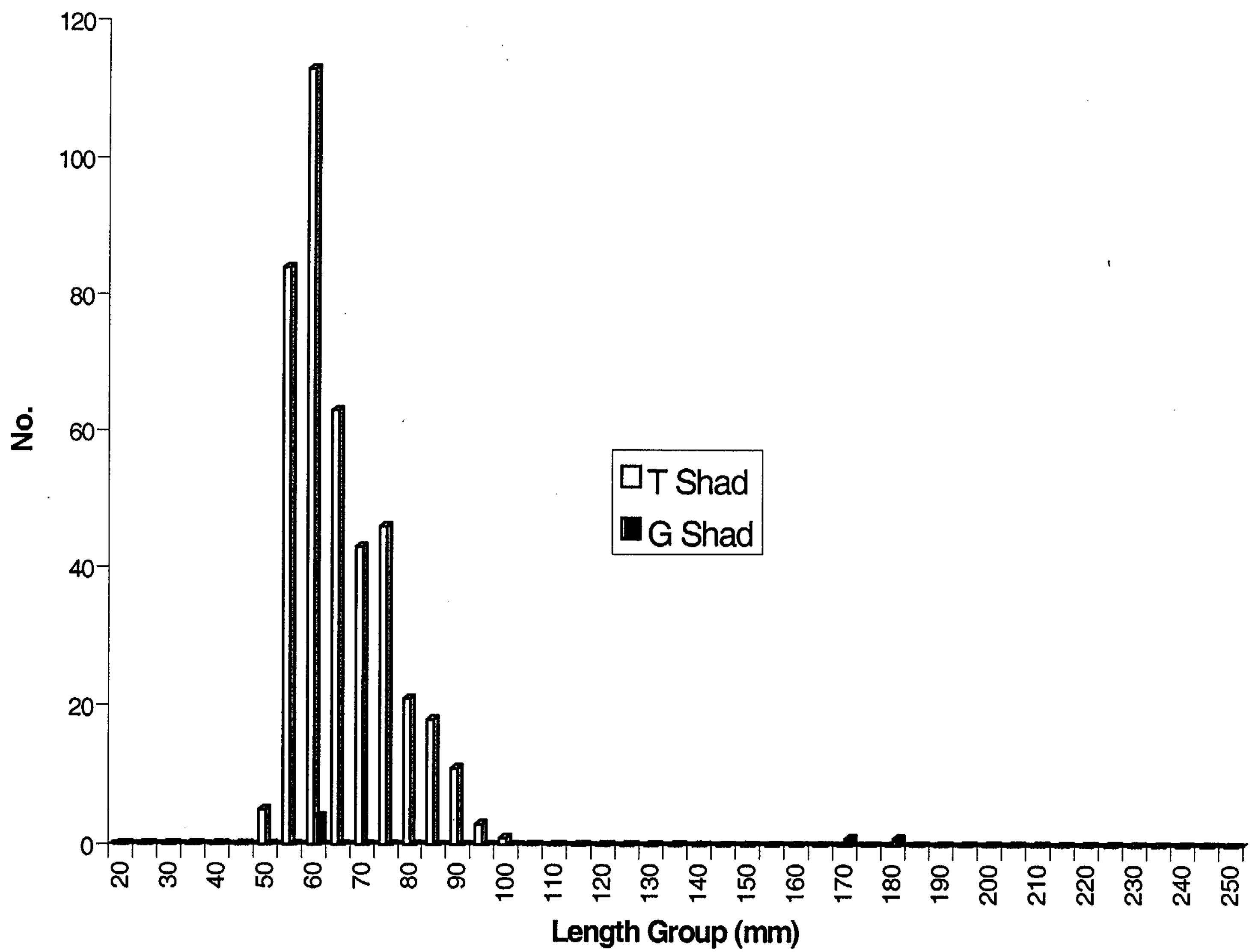
Lake James Forage Fish - 1997



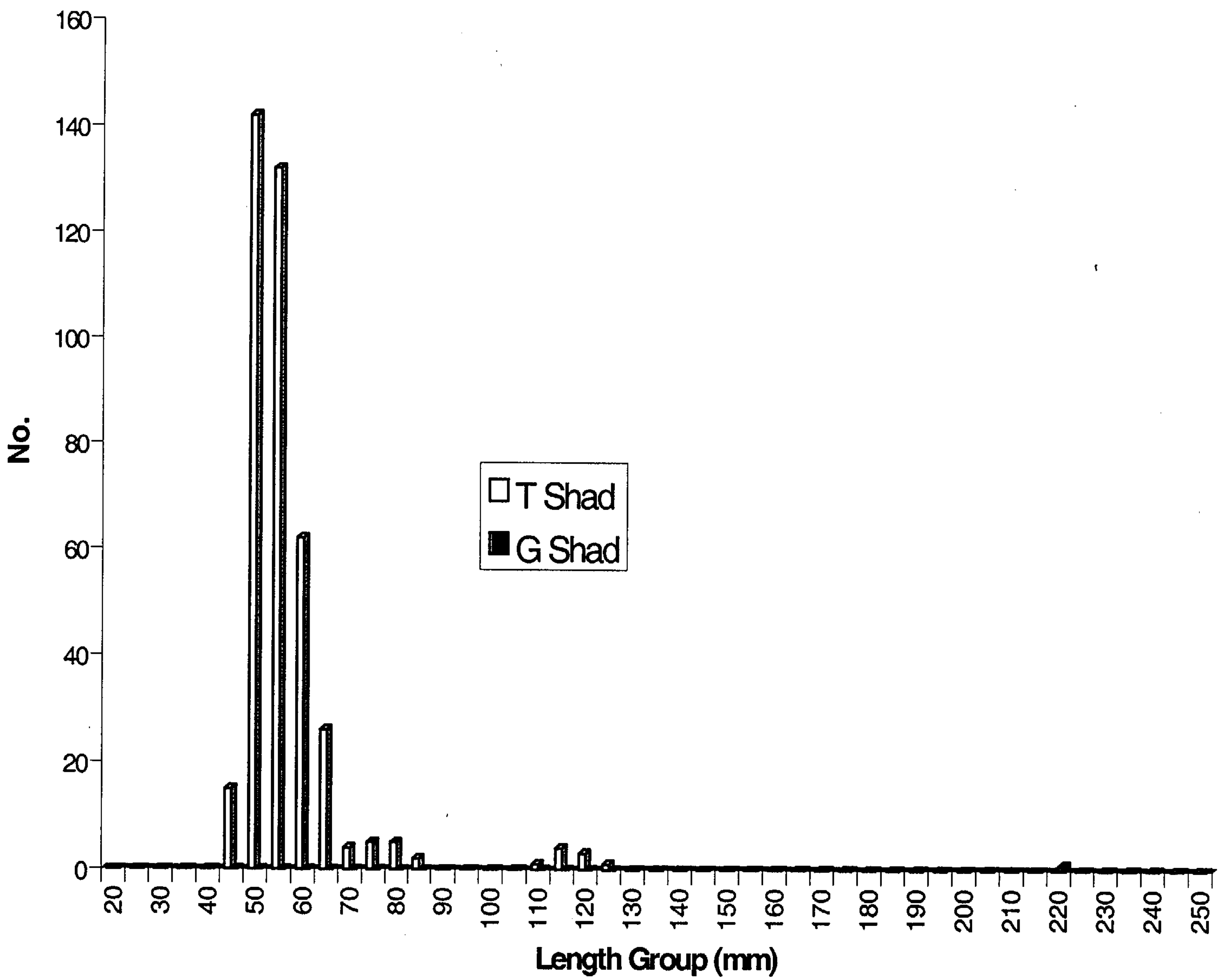
Lake Rhodhiss Forage Fish - 1997



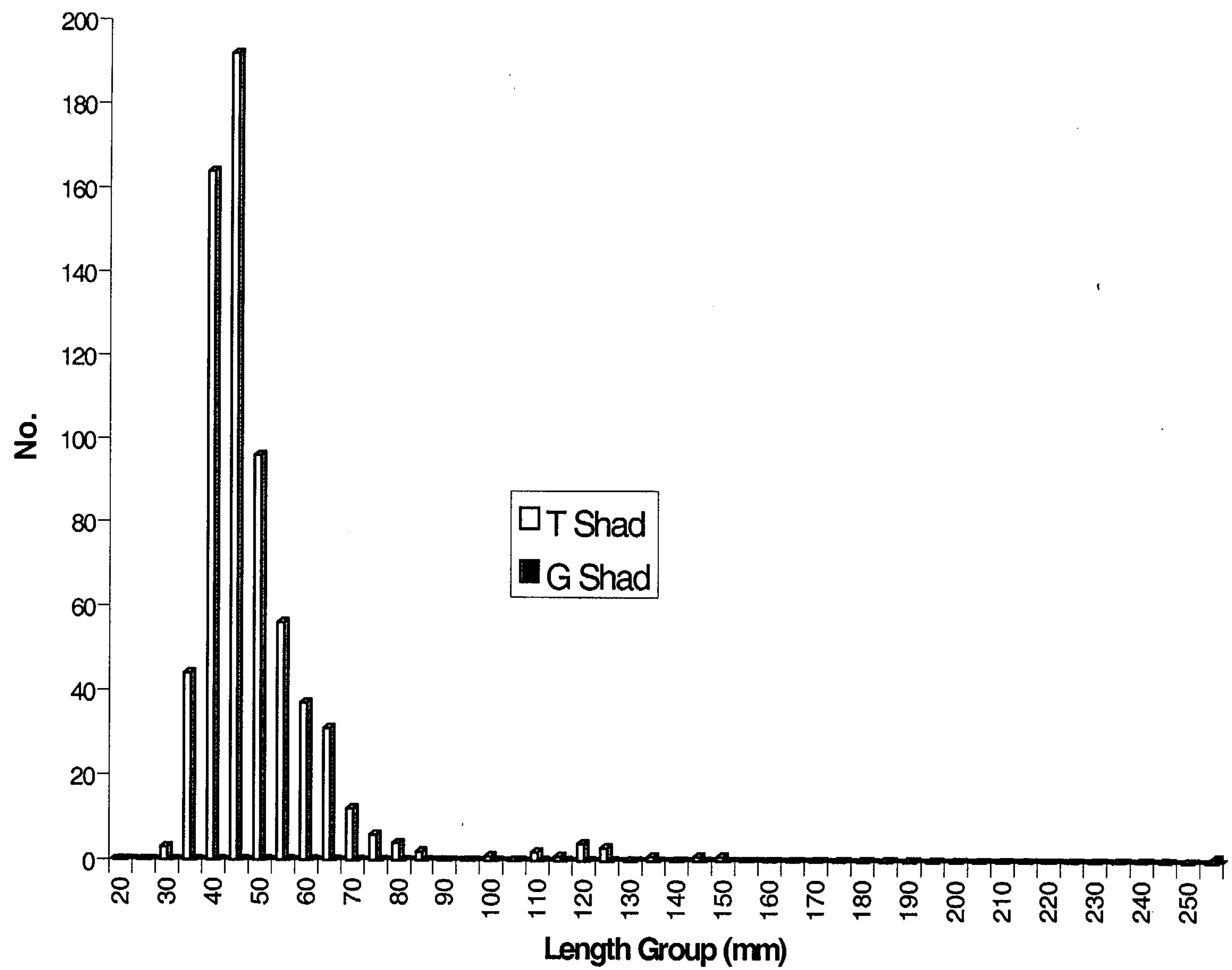
Lake Hickory Forage Fish - 1997



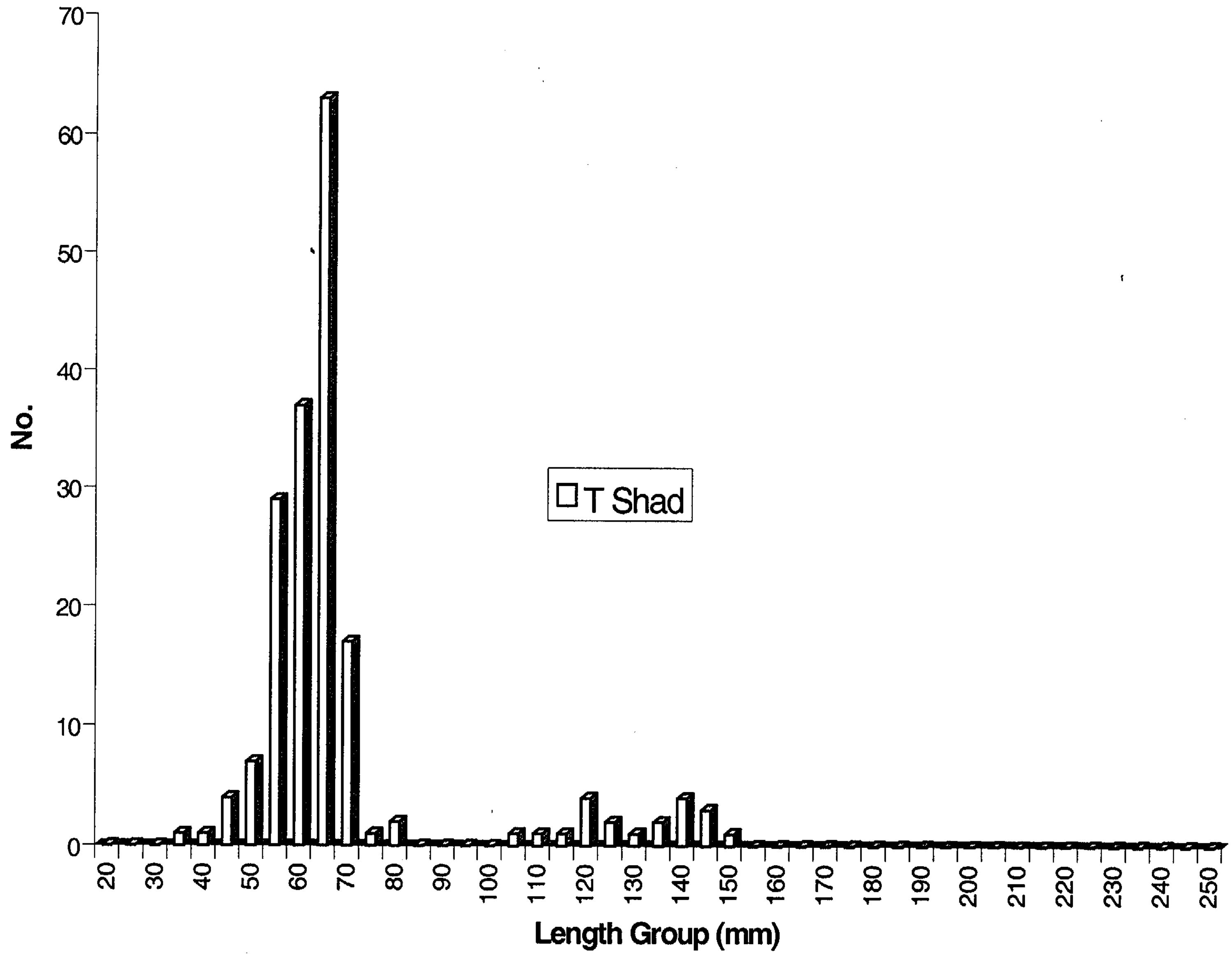
Lookout Shoals Forage Fish - 1997



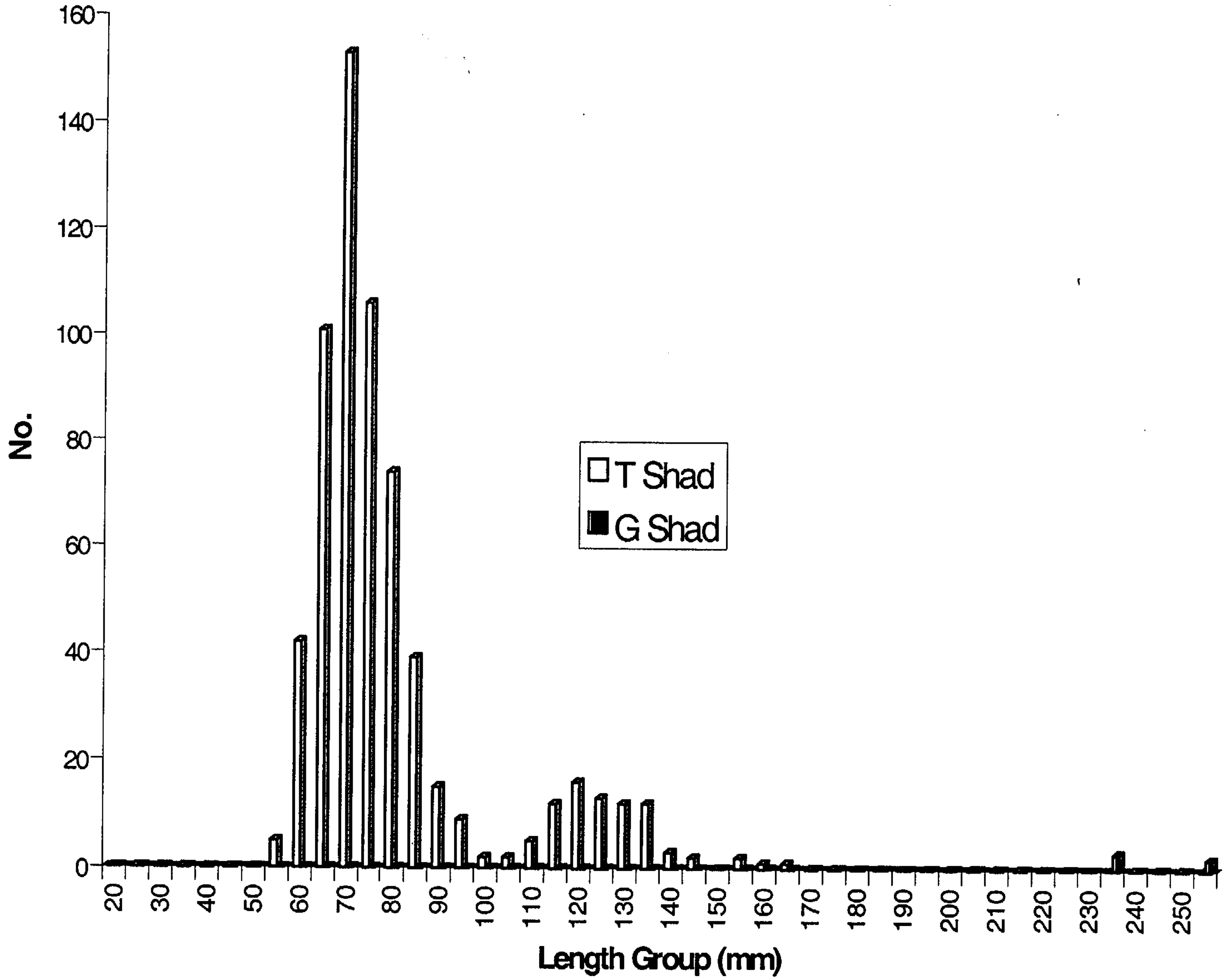
Lake Norman Forage Fish - 1997



Mt. Island Forage Fish - 1997



Lake Wylie Forage Fish - 1997



Lake Wateree Forage Fish - 1997