LAKE NORMAN: 1990 SUMMARY

MAINTENANCE MONITORING PROGRAM

McGUIRE NUCLEAR STATION: NPDES No. NC0024392

DUKE POWER COMPANY

Production Environmental Services, TTC/ASC

13339 Hagers Ferry Road

Huntersville, North Carolina 28078

JUNE, 1991

LAKE NORMAN: 1990 SUMMARY

I. EXECUTIVE SUMMARY

This report summarizes the 1990 results of the Lake Norman aquatic environment maintenance monitoring program, as required by NPDES Permit No. 0024392, for McGuire Nuclear Station. The overall capacity factor for McGuire during 1990 was 56.6%, in contrast to 77.1% in 1989. The average monthly discharge temperatures were 96.9, 96.5, and 92.5 F for July, August, and September, respectively; these were below the NPDES-permitted monthly average of 99 F for those months.

The thermal and oxygen dynamics of Lake Norman in 1990 were similar to other southeastern reservoirs of comparable size and trophic status. Aerial infrared imagery of the lake, with McGuire's discharge at 99 F, indicated a 5 F-above background plume of 730 acres around MNS, and a 90 F surface plume of 386 acres around MNS, both substantially smaller than earlier modeling studies had predicted under worst-case meteorology. Water temperatures in 1990 were up to 3.5 C cooler than winter 1989, and up to 4.1 C warmer than other seasons in 1989, with temporal and spatial trends as in prior operating years; these seasonal differences between years were attributed to meteorological differences and to increased 1990 pumping operations (+23%) at Marshall Steam Station relative to 1989. Spring and summer dissolved oxygen ranged up to 2.2 mg/L lower than observed historically, reflecting the concurrent thermal differences; other DO values and temporal/spatial trends were similar to previous years.

All water chemistry parameters (turbidity, specific conductance, pH, alkalinity, major cations and anions, nutrients, and metals) were within the historical ranges previously reported for Lake Norman during both MNS-operating and pre-operational years.

Phytoplankton and zooplankton standing crops showed a trend of increasing values from downlake to uplake locations, as in previous years. Seasonal community composition remained relatively stable between years, and the annual ranges in standing crop values were similar to 1988 and 1989. Phytoplankton and zooplankton communities were dominated by diatoms, green algae, chrysophytes, cryptophytes, rotifers, and copepods.

McGuire's thermal discharge clearly affected localized fish distribution, but evidently caused no direct mortalities or adverse impacts to the lake's fish composition or standing crop. Rotenone sampling in McGuire's discharge area indicated a similar fish stock in May 1990 as in previous years, followed by a decline to a record low of 14 kg/ha in August 1990. Hydroacoustic density estimates confirmed that limnetic fish species avoided the discharge area when temperatures exceeded 30 C. Vertical distribution of fish also reflected a response to temperature profiles, with fish moving deeper as surface temperatures increased, and later redistributing as waters cooled. Although temperature and dissolved oxygen conditions in the summer of 1990 were deemed unsuitable for adult striped bass, no mortalities were observed or reported.

II. McGUIRE NUCLEAR STATION OPERATIONAL DATA

OPERATIONAL CHARACTERISTICS--1990

The 1990 annual mean capacity factor (CF) was 56.6% for McGuire Nuclear Station (MNS), 47.6% for Unit 1, and 65.6% for Unit 2 (Table 1). Both units were operational during July and August and only Unit 1 during September, when discharge temperatures are most critical. During these three months the thermal limit for MNS increases from a monthly average of 95 ^{o}F to 99 ^{o}F. The average monthly discharge temperature was 96.9 ^{o}F for July, 96.5 ^{o}F for August, and 92.5 ^{o}F for September 1990. Use of low level intake water was not necessary for compliance with the new thermal limit for MNS. This helped to conserve habitat for cool water fish in Lake Norman. Other than a test of low level intake pump operability in September, use of low level intake water to improve the efficiency of MNS was postponed until October 1990 (Figure 1). The volume of cool water in Lake Norman is tracked throughout the year to ensure that an adequate volume of cool water is available to comply with both the NRC Technical Specification requirements and the NPDES monthly discharge water temperature limit.

Table 1. Average monthly capacity factors (%) calculated from daily unit capacity factors [Net Generation (mw per unit day) x 100 / 24 h per day x 1129 mw per unit] for McGuire Nuclear Station during 1990.

Month	Unit 1 Average	Unit 2 Average	Station Average
January	23.1	102.0	62.5
February	0.0	98.9	49.5
March	0.0	99.7	49.8
April	0.0	102.2	51.1
May	16.4	99.1	57.8
June	84.6	97.7	91.2
July	96.1	98.6	97.4
August	79.4	89.3	84.4
September	85.7	0.0	42.9
October	39.9	0.0	20.0
November	45.4	0.0	22.7
December	100.2	0.0	50.1
Annual Average	47.6	65.6	56.6

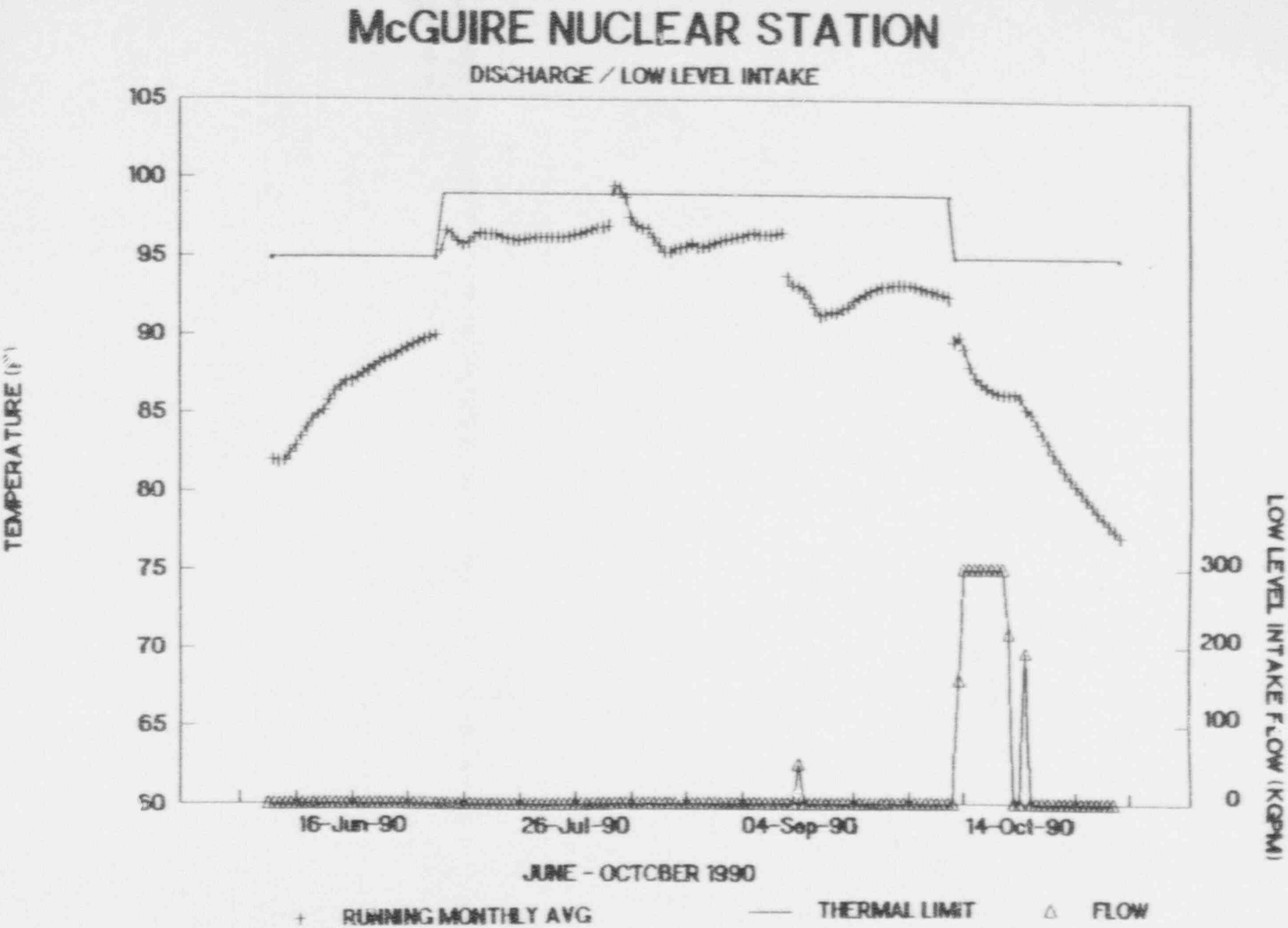


Figure 1. The running monthly average (plus) cond·ser cooling water discharge temperature, discharge thermal limit (———), and the low-level intake flow (triangle) for McGuire Nuclear Station.

III. TEMPERATURE AND DISSOLVED OXYGEN

INTRODUCTION

The objectives of the temperature and dissolved oxygen (DO) portion of the McGuire Nuclear Station (MNS) NPDES Maintenance Monitoring Program are to:

1) maintain continuity in Lake Norman's temperature and DO 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 1989 and 1990, with the specific objective of assessing the impact of raising the summer (July-September) discharge temperature at MNS from 95° F (1989) to 99° F (1990) on the lake-wide thermal and DO structure of Lake Norman. Specific areas of investigation covered in this chapter include thermal plume validation and assessment, striped bass habitat, and reservoir-wide temperature and DO information. Where appropriate, reference to pre-1989 data will be made by citing reports previously submitted to the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR).

METHODS AND MATERIALS

Water temperature and DO were measured monthly at 12 locations (Locations 1, 5, 8, 9.5, 11, 13, 15, 15.9, 62, 69, 72, and 80; Figure 1) throughout Lake Norman in 1990 using a Hydrolab Datasonde (Hydrolab Corporation, 1986). Additional measurements were taken at these locations at weekly to biweekly intervals during the summer to more accurately define the distribution and rate of decline of striped bass habitat. Measurements of temperature and DO were taken at 1-m intervals throughout the water column at each location extending from the surface (0.3 m) to 1 m above the lake bottom. Calibration of the instrument followed procedures recommended by the manufacturer (Hydrolab Corporation, 1986) and was performed before and after each data collection period.

The relationship between heating and cooling of lakes can be examined by comparing lake temperatures with the equilibrium temperature. The equilibrium temperature is defined as that temperature, under extant meteorological conditions, at which the net rate of heat exchange with the atmosphere would be zero (Edinger et al., 1974). Expressed in another way, the equilibrium temperature represents the theoretical temperature that the water body would attain, under a specific combination of meteorological conditions (air temperature, wind speed, dew point), given sufficient time. In this study, Ryan unheated equilibrium temperatures were calculated for 1988, 1989, and 1990, according to Ryan and Harleman (1973), and used to assess the influence of meteorology on reservoir heat flux.

Data were analyzed using two approaches, both of which were consistent with earlier studies (DPC 1985, 1987, 1988a, 1989, 1990). 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 heat content, mean epilimnion and hypolimnion heating rates over the stratified period, and the Birgean heat budget.

RESULTS AND DISCUSSION

McGuire/Marshall Plume Size Validation

Duke Power Company requested from Aero Dynamics, Corporation (1990) an aerial infrared survey of the thermal plumes at MNS and MSS during the summer of 1990. This information was used to validate plume size predictions at a thermal discharge of 99° F at MNS using the Massachusetts Institute of Technology thermal model (DPC 1988b). Results of the survey are illustrated in Figure 2. The 5° F (2.8° C) above background isotherm measured 730 ac at MNS and 145 ac at MSS, both of which were substantially less than the 2006 ac at MNS and 552 ac at MSS predicted under worst-case meteorology at a discharge temperature of 99° F (DPC 1988b). The observed acreage was also appreciably less than that predicted under worst-case meteorology for the 95° F discharge criteria, i.e., 1492 ac at MNS and 714 ac at MSS (DPC 1985). Similarly, the observed acreage of the 90°F (32.2°C) isotherm was 386 ac at MNS and 69 ac at MSS. These values were significantly less than the 1452 ac at MNS and 303 ac at MSS predicted under worst-case meteorology at a discharge temperature of 99° F. The acreages were also less than predicted under worst-case meteorological conditions at a 95° F discharge temperature, i.e., 982 ac at MNS and 432 ac at MSS.

Temperature and Dissolved Oxygen

Water temperatures measured in 1990 illustrated similar temporal and spatial trends in the mixing and background zones (Figures 3 and 4). Winter water temperatures ranged from 0.1° to 3.5° C cooler throughout the water column in both zones than in 1989 (Figures 3 and 4), and were well within the historic range (DPC 1985, 1987, 1988a, 1989, 1990). Spring and summer water temperatures, on the other hand, were generally warmer throughout the water column in both zones in 1990 as compared to 1989 and historically, whereas fall temperatures were within the historic range. Spring water temperatures ranged from 0.1° to 3.3° C warmer than 1989 and historically, whereas summer water temperatures ranged from 0.1° to 4.1°C warmer than historic conditions with the major increases restricted

primarily to the metalimnion and hypolimnion. Fall temperatures ranged from 0.1° to 3.1° C warmer than in 1989, but were within the historic range. These seasonal differences in water temperature among years appears to be due primarily to a combination of meteorology and increased operations at MSS. Meteorological conditions during the winter of 1989-1990 were harsher than 1988-1989, and as a result, more water column cooling occurred in the winter of 1990 than in 1989 (Table 1). Conversely, 1990 spring meteorology was warmer than 1989, resulting in a greater storage of heat at the mid and bottom depths prior to and at the early stages of lake stratification in 1990 than in 1989. The effect of this increased heat storage was then carried over into the summer period. In other words, temperatures were warmer in the mid-to-lower portions of the water column during the summer stratified period in 1990 than in 1989 because of, in part, the increased storage of 'natural' heat prior to the lake becoming strongly stratified. This explanation is supported by 1) these between-year differences were generally consistent in both the background and mixing zones, and 2) the average lake-wide metalimnion / hypolimnion heating rate in 1990 (0.077° C/day) was slightly less than in 1989 (0.085° C/day).

A second factor contributing to the observed increase in summer-time temperatures in the metalimnion and hypolimnion in 1990 over 1989 was operations at MSS. Condenser cooling water flow at MSS in 1990, over the period 1 May through 30 September, averaged 812,000 gallons/minute contrasted with 661,500 gallons/minute in 1989, or about a 23% increase. The importance of condenser cooling water flow at MSS in influencing interannual variability in the temperatures of Lake Norman was illustrated in studies by Foris (1985) and DPC (1986). Fall water temperatures ranged from 0.1° to 2.5° C warmer than measured in 1989, but generally were within the historic range (Figure 3 and 4). Mild meteorological conditions also appear to explain the differences between 1989 and 1990 September through December water temperature data (Figures 3 and 4; Table 1).

Discharge temperatures illustrated the same temporal trend between 1989 and 1990 as did water column temperatures, i.e., winter temperatures were

slightly cooler (by 4° C), whereas spring and early-summer temperatures were slightly warmer (by 2° to 6° C) in 1990 than in 1989 (Figure 5). Meteorology again appears to be the primary factor influencing these differences, because the 99° F variance did not take effect until July. The warmest discharge temperature of 1990 occurred in July and measured 34.6° C (94.3° F), which was 1.9° C warmer than in 1989 and historically (DPC 1985, 1990).

Seasonal and spatial patterns of DO in 1990 were generally similar in both the mixing and background zones (Figures 6 and 7). Winter DO values ranged from 0.1 to 1.0 mg/l higher throughout the water column in both zones in 1990 than in 1989, but were well within the historic range (DPC 1985, 1987, 1988a, 1989, 1990). These between-year differences appear to be due primarily to meteorology, with the cooler 1990 winter equilibrium temperatures promoting a greater degree of mixing and reaeration than occurred in 1989. Conversely, spring and summer DO values were generally less than observed historically, particularly in the metalimnion and hypolimnion where DO concentrations ranged from 0.1 to 2.2 mg/l lower than observed previously. August metalimnetic DO values were greater in 1990 than 1989 in both zones, and were similar to maximum values observed for these depths historically. The differences among 1990 and historic spring and summer DO values are believed to be predominantly related to the warmer than historic water temperatures measured in the spring and summer of 1990 which, as discussed earlier, appears to be due to a combination of meteorology and operations at MSS. Warmer water column temperatures would decrease oxygen solubility and increase biological respiration rates, thereby reducing the available supply of DO. An additional contributing component is the quantity of advected oxygen brought into Lake Norman via upstream inputs from Lookout Shoals (Figure 1). The average summer flow-through at Lookout Shoals Hydroelectric Station in 1989 was 70.8 m^3/s contrasted with only 45.5 m^3/s in 1990, indicating that less oxygen was advected into Lake Norman in 1990 than in 1989. Fall and early-winter DO concentrations were generally lower than observed in 1989, but were within the historic range. Meteorology, and its subsequent impact on the timing and degree of lake turnover, is believed to be the primary factor contributing to the differences between 1990 and 1989.

The seasonal pattern of DO in 1990 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 eary-fall (Figure 5). Winter DO values measured in 1990 were greater than in 1989 (Figure 5) but similar to historic values, whereas spring, summer, and fall values were slightly less (by <1.0 mg/l), equal to, or slightly more (by < 1.0 mg/l) than 1989, and historic data (DPC 1985, 1986, 1987, 1988a, 1989, 1990). The lowest DO concentration measured at the discharge location in 1990 (3.9 mg/l) occurred in October and coincided with low-level pumping at MNS.

The monthly reservoir-wide temperature and dissolved oxygen data for 1990 are presented in Figures 8 and 9. For the most part, the temporal and spatial distributional patterns of both temperature and dissolved oxygen are similar to other cooling impoundments and hydropower reservoirs in the Southeast. During the winter cooling and mixing period, vertical rather than horizontal homogeneity in temperature predominated, with the shallower uplake 'riverine' zone exhibiting slightly cooler temperatures than the deeper downlake 'lacustrine' zone (Figure 8). These longitudinal differences in temperatures were clearly illustrated in January and February. The principal factors influencing this gradient in Lake Norman are thermal discharges from MSS and MNS, morphometric (depth) differences within the reservoir, and surface water inputs from the upper reaches of the reservoir.

The heating period in Lake Norman generally begins in March, as more heat is gained at the water's surface than is lost at night. During the initial stages of the heating period, buoyancy forces "smooth out" the horizontal differences in temperature, thereby reducing temperature differences between up-reservoir and down-reservoir locations. Due to the vertical instability of the water column during this period, temperature increases are observed at all depths. These points are illustrated by contrasting the January and February temperature data with the March and April data (Figure 8). As solar radiation and air temperatures increase, heating occurs at a greater rate in the upper waters than in the mid or bottom waters.

Eventually, differential heating at the surface leads to the formation of the classical epilimnion, metalimnion, and hypolimnion zones. These zones (strata) are clearly depicted in the July, 1990 data (Figure 8).
In contrast to most natural lakes, but not unlike many reservoirs in the Southeast, a distinct thermocline within the metalimnion was not observed in Lake Norman in 1990. Rather, the metalimnion was more or less continuous with respect to vertical density differences within the lower water column, and even showed signs of merging with the hypolimnion, as illustrated in the August data (Figure 8).

Cooling of the water column began in early September as illustrated by decreases in surface temperatures compared to August data. Concurrent with decreases in surface temperatures were an increase in the depth of the epilimnion (caused by convective mixing) and a disruption of the horizontal homogeneity in epilimnion temperatures (caused by reservoir-wide differential heating and cooling, and advective inputs from upstream). Continuation of these differential vertical and horizontal processes led to even more pronounced thermal differences within the reservoir. For example, by October the uplake riverine zone had already 'turned over', while the downlake lacustrine zone was still strongly stratified. Not until early November was Lake Norman completely mixed vertically throughout the reservoir.

Distributional patterns of dissolved oxygen in 1990 were similar to but not identical to temperature (Figure 9). Generally, dissolved oxygen concentrations were greatest during the winter cooling and mixing period when biological respiration was at a minimum and atmospheric reaeration was at a maximum. The highest reservoir-wide mean concentration of dissolved oxygen (11.5 mg/l) occurred in March when the reservoir exhibited a mean temperature of 10.7°C (Figure 8). Unlike the thermal regime, no major longitudinal differences existed in dissolved oxygen within the reservoir during the winter. Not until the lake became stratified, thereby isolating the metalimnion and hypolimnion from atmospheric reaeration, were uplake-to-downlake gradients in dissolved oxygen observed. Longitudinal gradients in metalimnetic and hypolimnetic dissolved oxygen in 1990 were first observed in May. Differential

dissolved oxygen depletion and eventual anoxia were first observed in the transitional zone (Locations 15 through 62) where hypolimnetic volume is small, water column and sediment organic matter high, and advective mixing minimal. By August, the complete hypolimnion throughout the reservoir below elevation 217 m was anoxic. This represents approximately 18% of the entire volume of the lake at full pond.

Reaeration of the water column started in September concomitantly with the cooling and mixing of the reservoir. Decreasing air temperatures cooled the surface waters resulting in a convective deepening, aided by wind-induced mixing, of the epilimnion. As the oxygenated epilimnion eroded progressively deeper into the water column, the width of the anoxic zone decreased. Longitudinal differences in reaeration were also observed and apparently were related to differential mixing caused by MNS and MSS, upstream advective inputs, and horizontal gradients in photosynthesis (Chapter IV). Reaeration of the reservoir was essentially complete by early November, except for the bottom waters in the downlake "lacustrine" zone.

Table 2 presents some common quantitative limnological calculations for the thermal environment in Lake Norman. Few comparable calculations exist in the literature for reservoirs, but these data are generally within the "ballpark" of those presented by Hutchinson (1957) for natural lakes at similar latitudes throughout the world.

Table 3 presents the 1990 AHOD for Lake Norman compared to similar estimates for 18 TVA reservoirs. The data illustrate that Lake Norman exhibits an AHOD that is similar to other Southeastern reservoirs of comparable depth, chlorophyll $\bar{a}$ status, and secchi depth.

Striped Bass Habitat

Suitable pelagic habitat for adult striped bass, defined as that layer of water with temperatures ≤ 26° C and DO levels ≥ 2.0 mg/l, existed in all months in Lake Norman in 1990 except in late-July and most of August (Figure 10). The pattern and degree of habitat reduction in 1990 was similar to historic conditions; it is also typical of striped bass habitat distribution and reduction patterns in many other Southeastern reservoirs (Coutant 1985). Despite habitat elimination in most of the reservoir for a period ranging from about two to four weeks in 1990, no mortalities of striped bass were reported by local fishermen or observed during weekly habitat searches conducted by DPC personnel in July, August, and September.

FUTURE STUDIES

No changes are planned for the Temperature and Dissolved Oxygen portion of the Lake Norman maintenance monitoring program during 1991.

SUMMARY

The reservoir-wide physicochemical structure of Lake Norman in 1990 was studied using several techniques. Aerial infrared imagery illustrated that, at a summer discharge temperature of 99° F at MNS, the size of both the 5° F above background and the 90° F isotherm plumes were substantially less than predicted by mathematical modeling using worst-case meteorological inputs. The observed acreages were also appreciably less than predicted under worst-case meteorological conditions at a discharge temperature of 95° F.

Temporal and spatial trends in water temperature and DO data collected monthly in 1990 were similar to those observed historically. Winter and fall temperature and DO data were generally within the range of previously measured values, whereas spring and summer temperatures ranged from 0.1° to 4.1° C warmer than historic values. These differences among years appeared to be related primarily to a combination of meteorology and

steam-electric operations. Similarly, spring and summer DO values ranged from 0.1 to 2.2 mg/l lower than observed historically. Dissolved oxygen differences among years were attributed to 1) a decrease in oxygen solubility and an increase in biological respiration rates due to warmer water temperatures, and 2) a reduction in the quantity of oxygen brought into Lake Norman via upstream inputs from Lookout Shoals.

Reservoir-wide isotherm and isopleth information for 1990, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics similar to other Southeastern reservoirs of comparable size and trophic status.

Suitable pelagic habitat for adult striped bass existed in all months in Lake Norman in 1990 except in late-July and most of August. The pattern and degree of habitat reduction in 1990 was similar to historic conditions; it was also typical of striped bass habitat distribution and reduction patterns observed in other Southeastern reservoirs. Despite habitat elimination in the reservoir for a period ranging from two to four weeks in 1990, no mortalities of striped bass were observed or reported.

LITERATURE CITED

Aero Dynamics, Corporation. 1990. An aerial infrared survey of Lake Norman. Charlotte, NC. 5p.

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

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

Duke Power Company. 1986. Lake Norman hypolimnetic water utilization study. DPC. Charlotte, NC

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

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

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

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

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

Edinger, J. E., D. K. Brady, and J. C. Geyer. 1974. Natural water temperature responses, p. 17-26. In-Heat Exchange and Transport in the Environment. RP 49 Report No. 14. EPRI, John Hopkins Univ, Baltimore, MD. 125p.

Foris, W.J. 1985. Factors influencing temperature and disolved oxygen in Lake Norman and other Southeastern reserviors: thermal pollution and multiple-use management implications. DPC, Charlotte, NC

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

Higgins, J. M., W. L. Poppe, and M. L. Iwanski. 1981. Eutrophication analysis of TVA reservoirs. In: Surface Water Impoundments. H. G. Stefan, Ed. Am. Soc. Civ. Eng., NY, pp.404-412.

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

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

Ryan, P. J. and D. F. R. Harleman. 1973. Analytical and experimental study of transient cooling pond behavior. Report No. 161. Ralph M. Parsons Lab for Water Resources and Hydrodynamics, Massachusetts Institute of Technology, Cambridge, MA.

Table 1. Monthly average equilibrium temperatures (°C) for the Lake Norman watershed in 1988, 1989, and 1990.

	1988	1989	1990
January	1.0	6.6	7.5
February	6.7	7.5	10.7
March	13.0	12.9	14.2
April	17.2	18.3	18.5
May	24.1	22.0	22.6
June	27.5	27.9	27.5
July	29.3	28.6	28.3
August	29.2	27.5	28.5
September	23.3	23.4	24.7
October	13.8	17.9	18.7
November	10.7	10.7	12.5
December	4.8	0.5	7.7

Table 2. Heat content calculations for the thermal regime in Lake Norman in 1990

Maximum areal heat content	28,306 $g \cdot cal \cdot cm^{-2}$
Maximum hypolimnetic (below 11.5 m) areal heat content	15,672 $g \cdot cal \cdot cm^{-2}$
Birgean heat budget	19,594 $g \cdot cal \cdot cm^{-2}$
Epilimnion (above 11.5 m) heating rate	0.095° $C \cdot day^{-1}$
Hypolimnion (below 11.5 m) heating rate	0.077° $C \cdot day^{-1}$

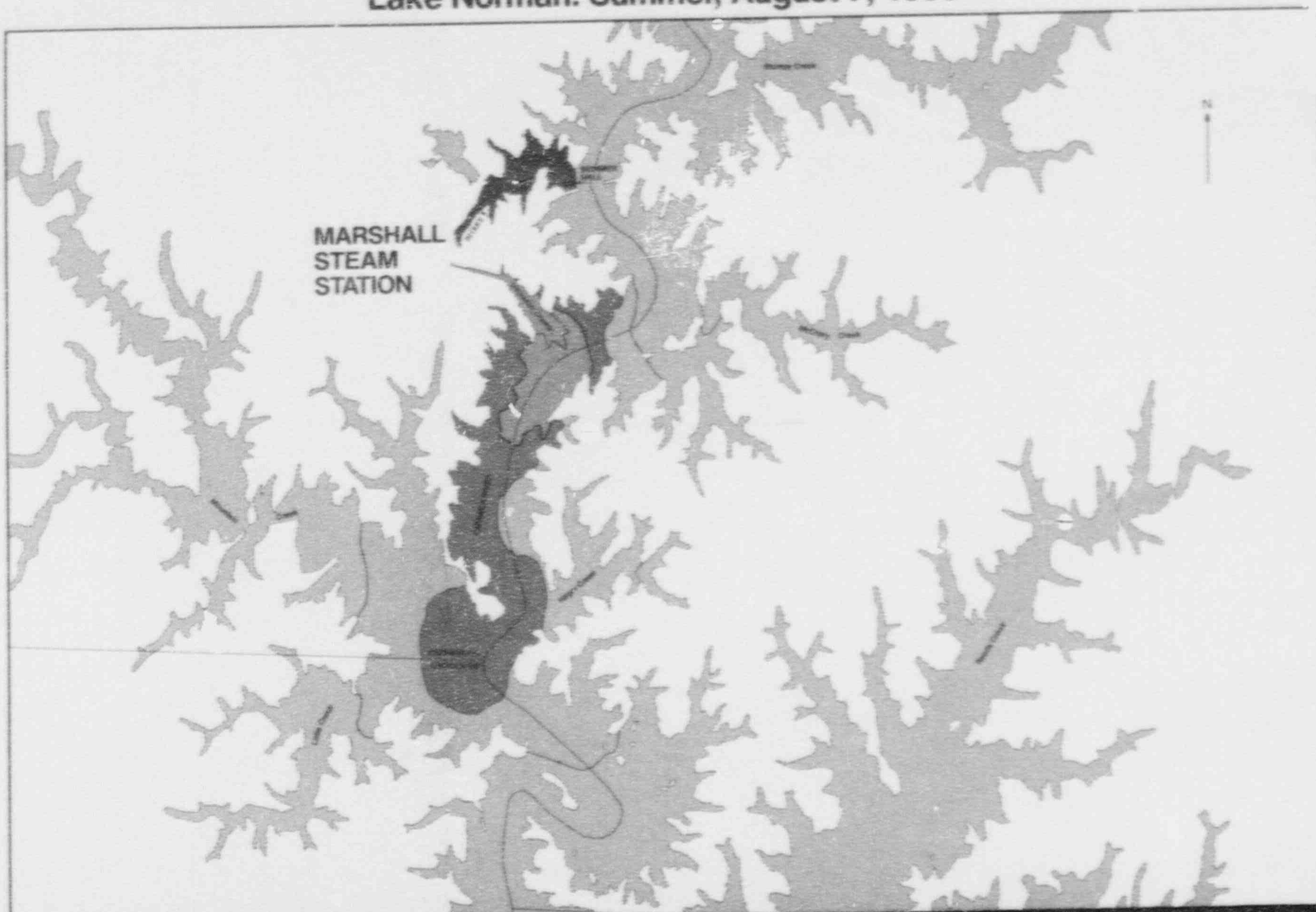
Table 3. A comparison of areal hypolimnetic oxygen deficits (AHOD), summer chlorophyll a (chl a), secchi depth (SD), and mean depths of Lake Norman and 18 TVA reservoirs.

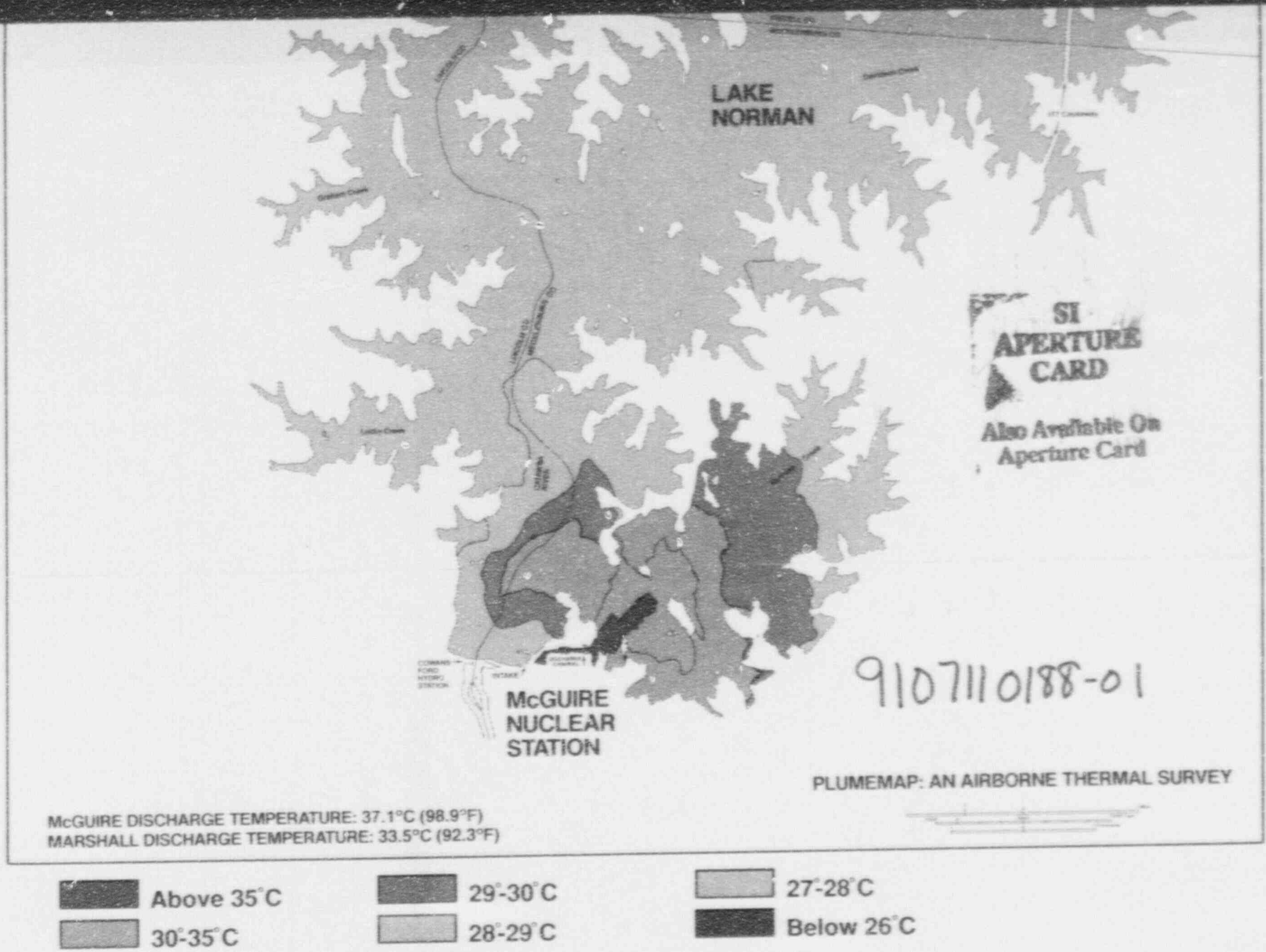
Reservoir	AHOD ($mg \cdot cm^{-2} \cdot day^{-1}$)	Summer Chl a ($\mu g \cdot L^{-1}$)	Secchi Depth (m)	Mean Depth (m)
Lake Norman	0.056	5.0	3.0	10.25
TVA[a]				
Mainstem				
Kentucky	0.012	9.1	1.0	5.0
Pickwick	0.010	3.9	0.9	6.5
Wilson	0.028	5.9	1.4	12.3
Wheelee	0.012	4.4	--	5.3
Guntersville	0.007	4.8	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 taken from Higgins et al. (1980), and Higgins and Kim (1981)

Figure 1. Sampling locations on Lake Norman, North Carolina during maintenance monitoring program for McGuire Nuclear Station.

Lake Norman: Summer, August 7, 1990





9107110188-01

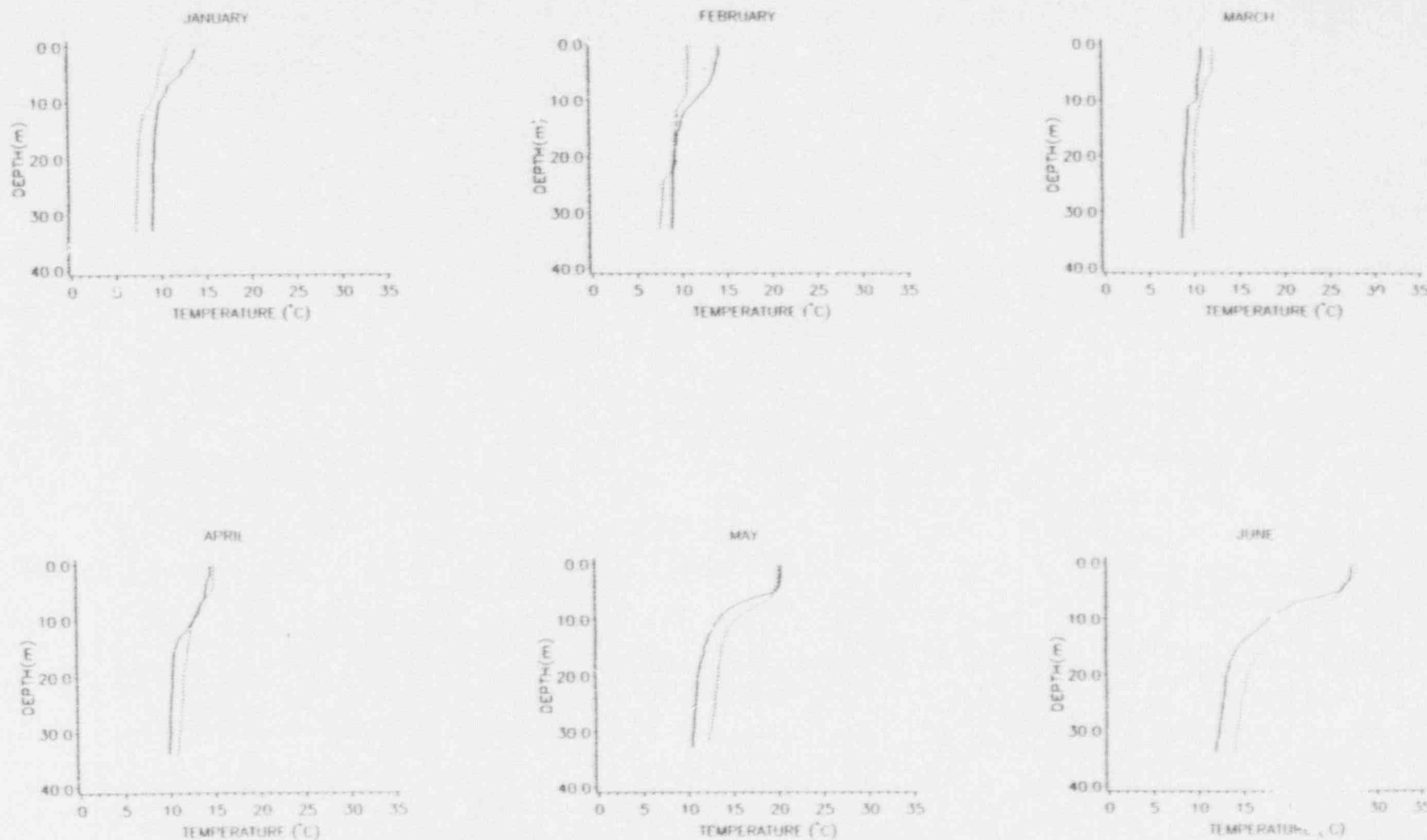


Figure 3. Monthly mean temperature profiles for the McGuire mixing zone in 1989 (—) and 1990 (---).

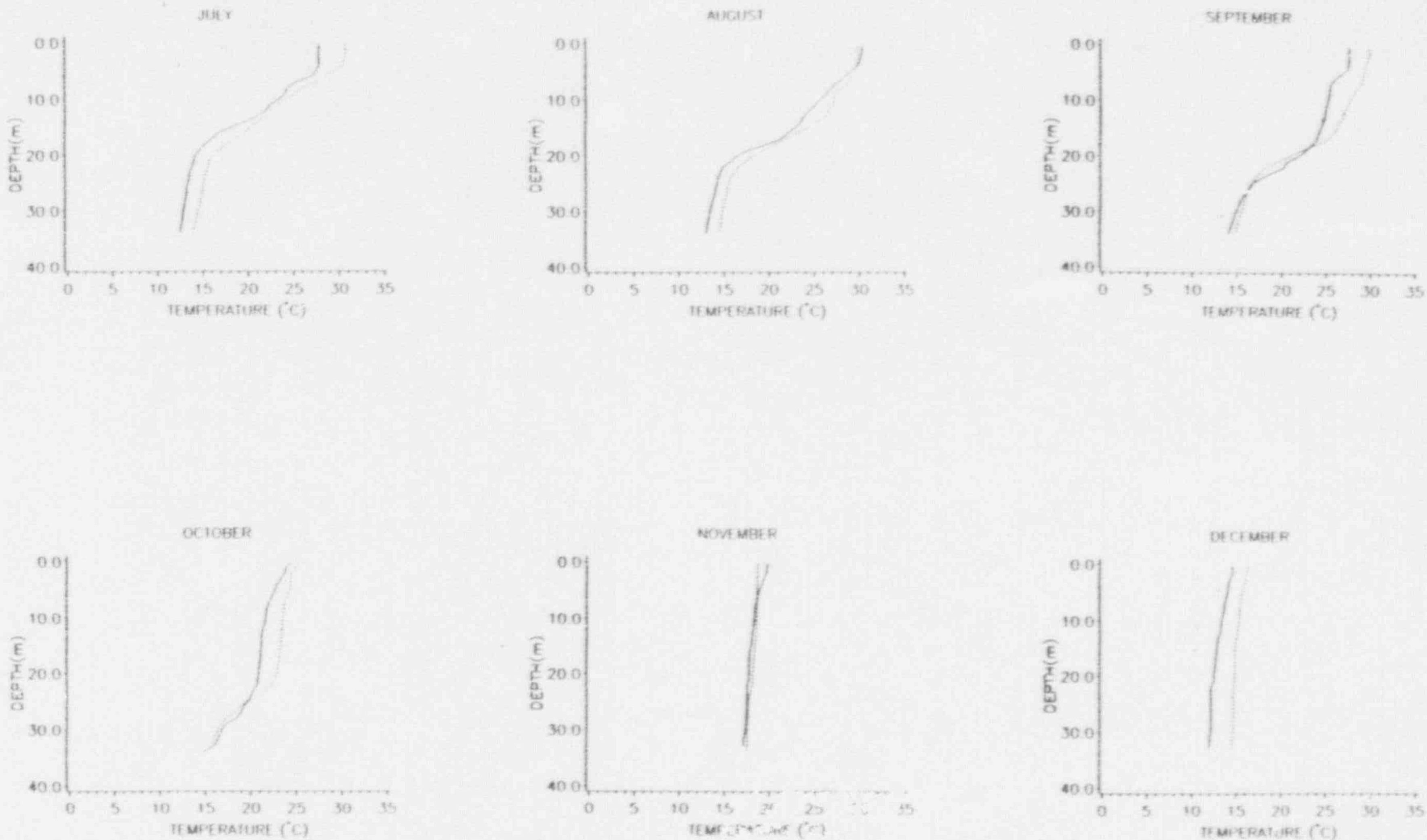


Figure 3. (con't)

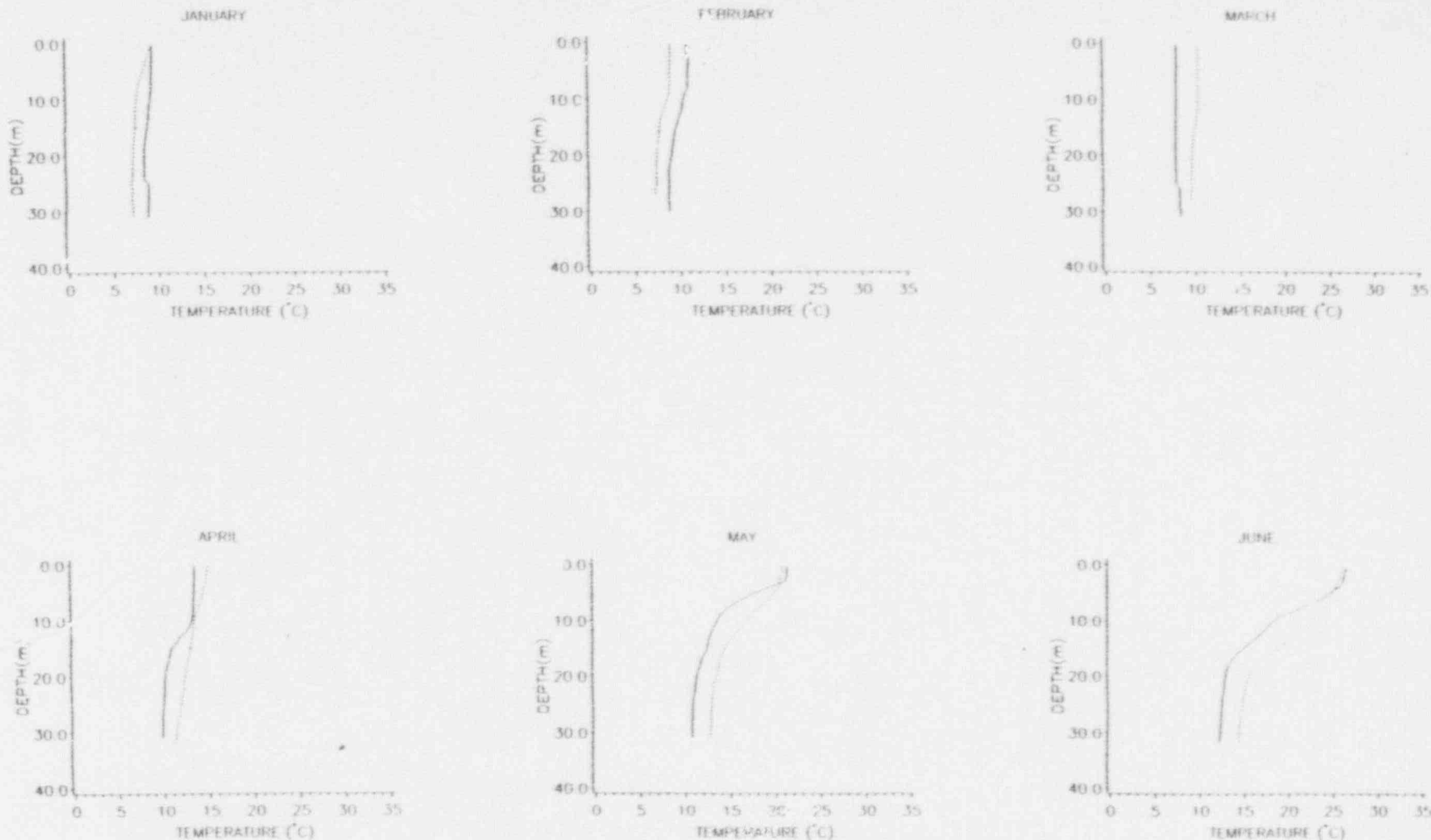


Figure 4. Monthly mean temperature profiles for the background zone in 1989 (—) and 1990 (--).

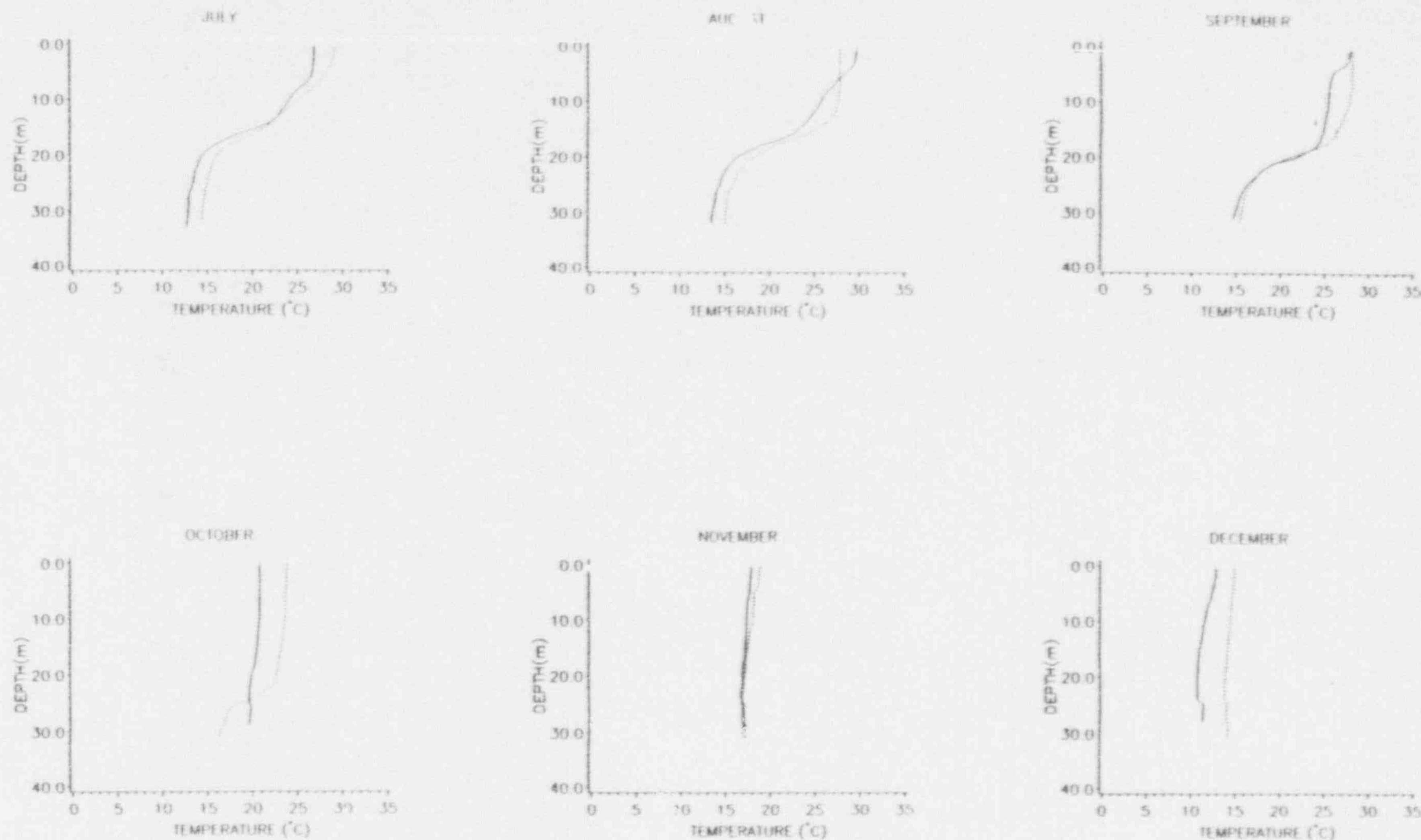


Figure 4. (con't)

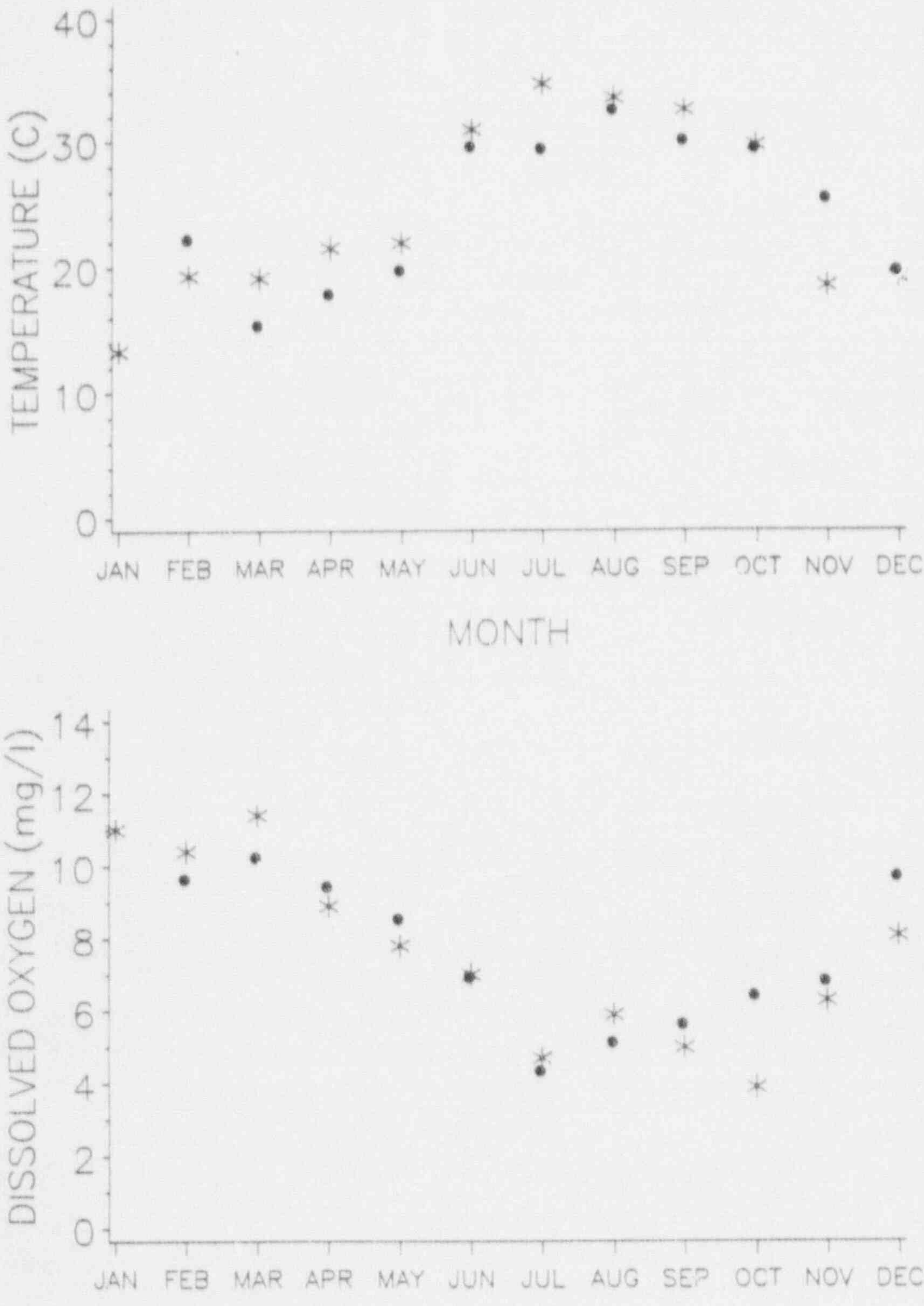


Figure 5. Monthly temperature and dissolved oxygen data for the discharge location in 1989 (•) and 1990 (✱).

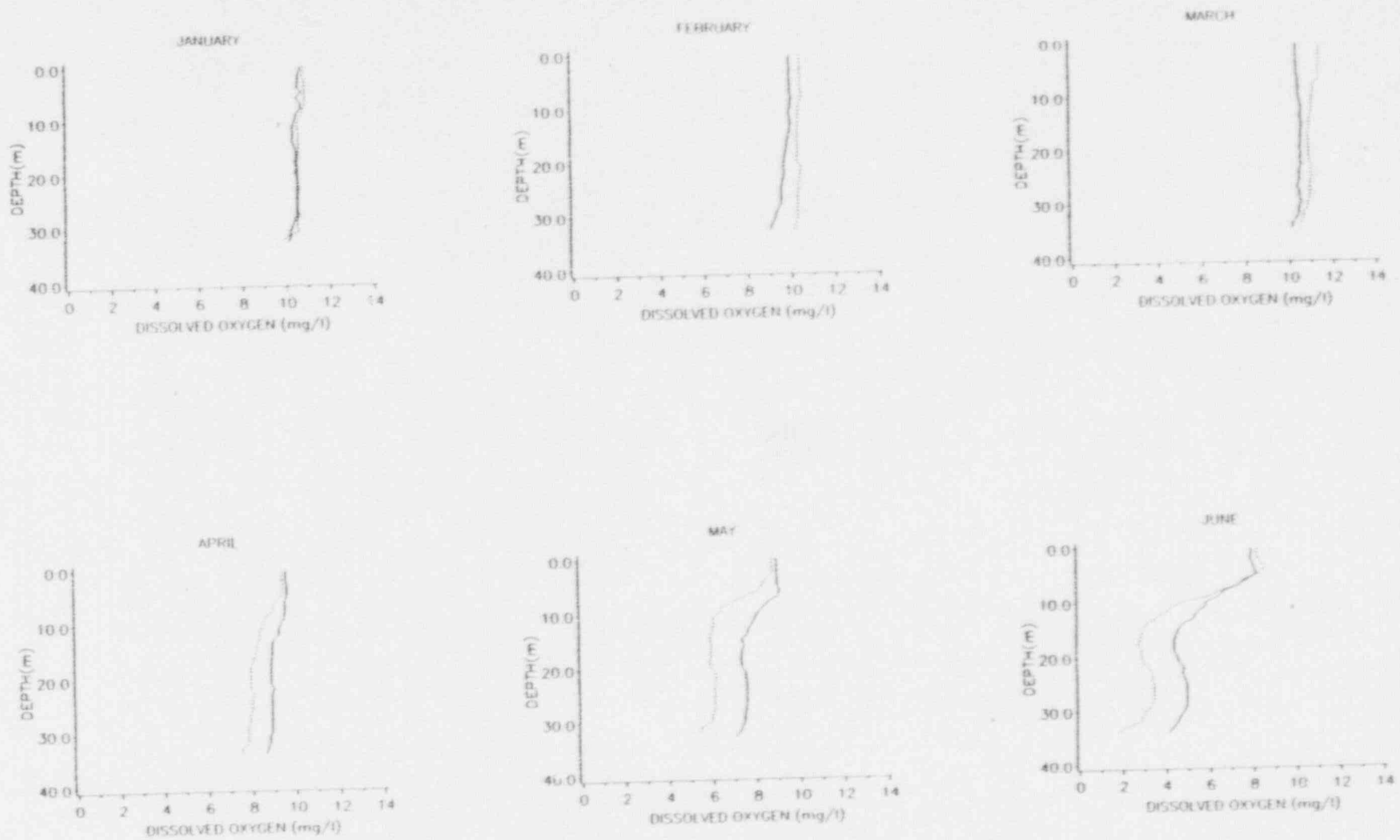


Figure 6. Monthly mean dissolved oxygen profiles for the McGuire mixing zone in 1989 (—) and 1990 (---).

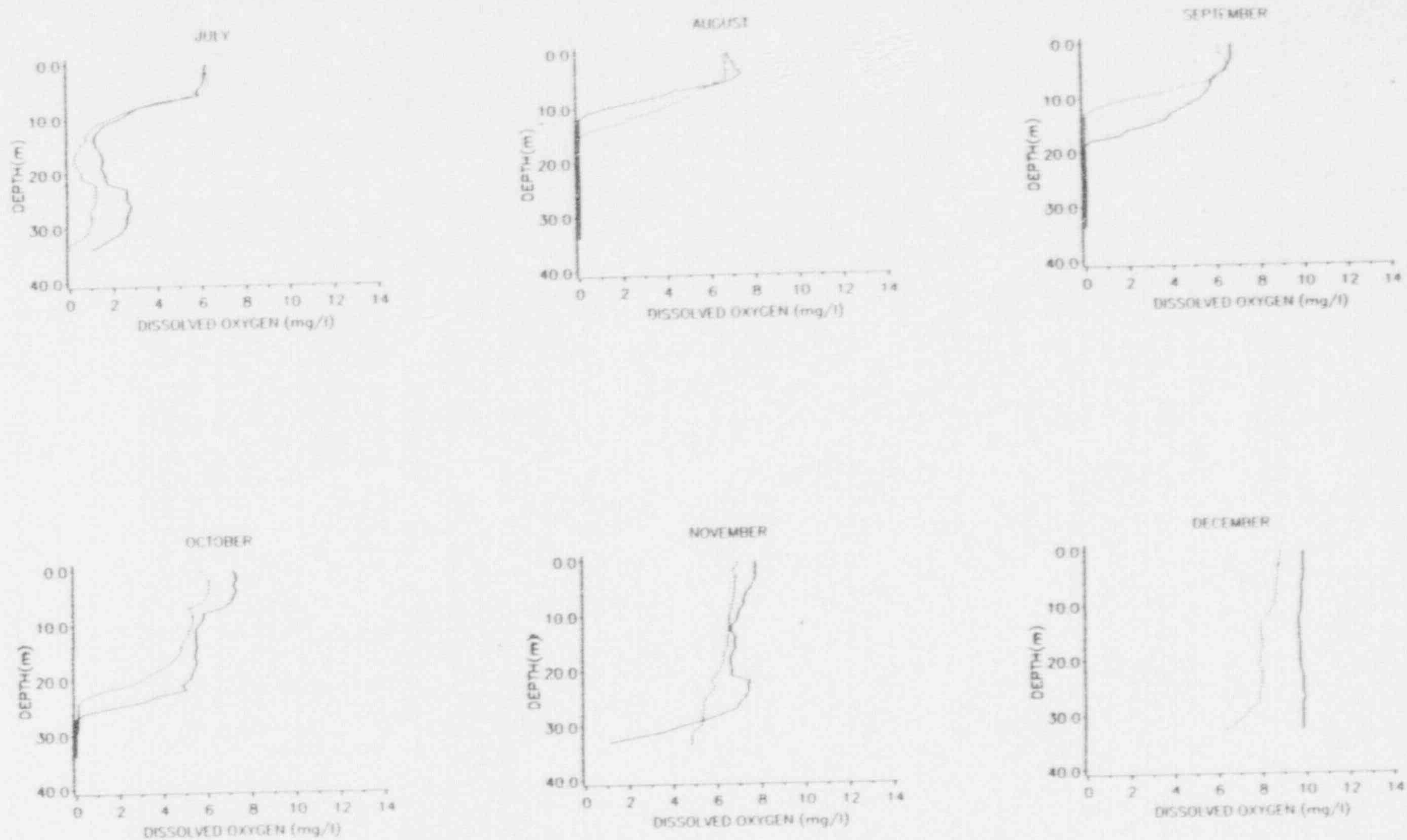


Figure 6. (con't)

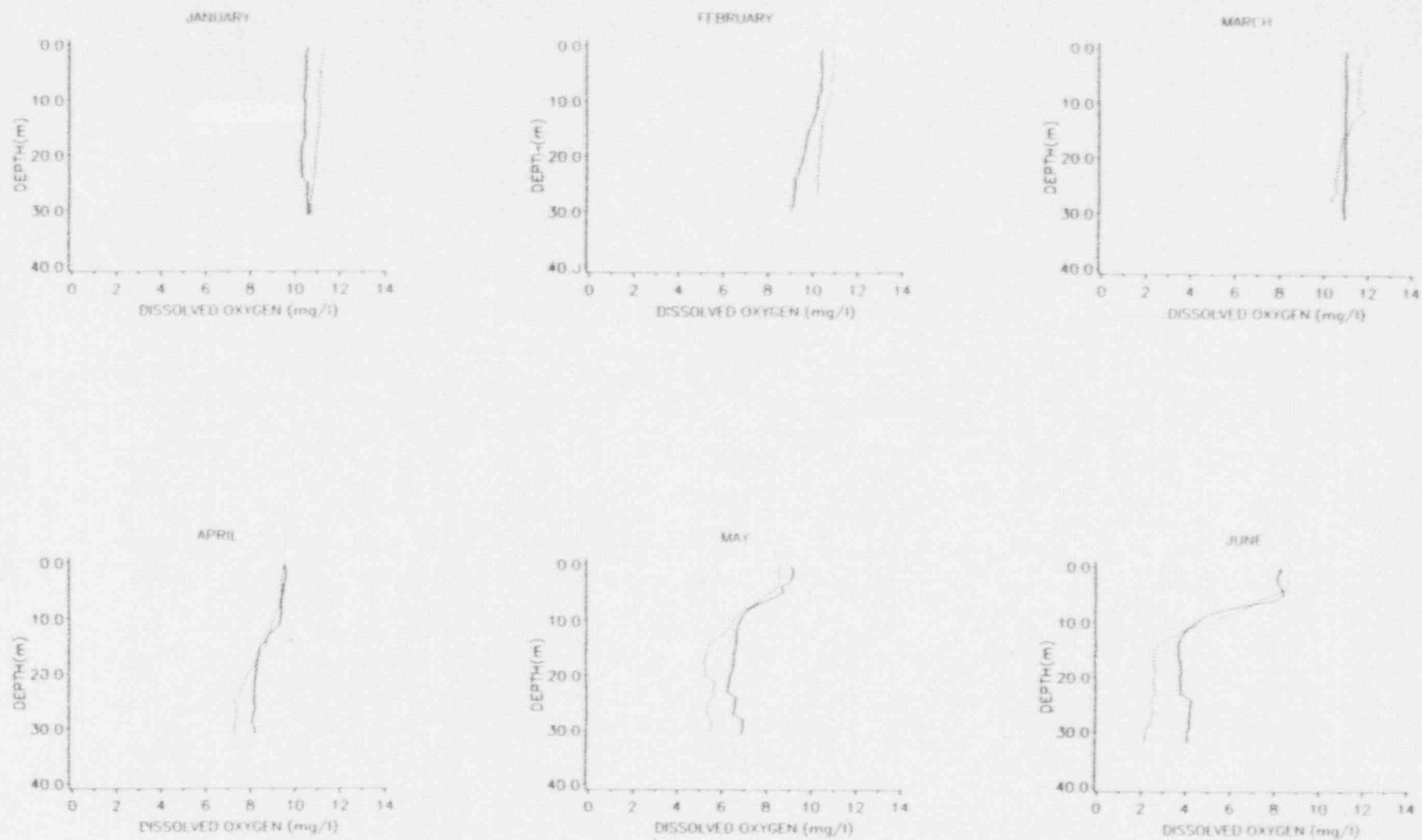


Figure 7. Monthly mean dissolved oxygen profiles for the background zone in 1989 (—) and 1990 (- - -).

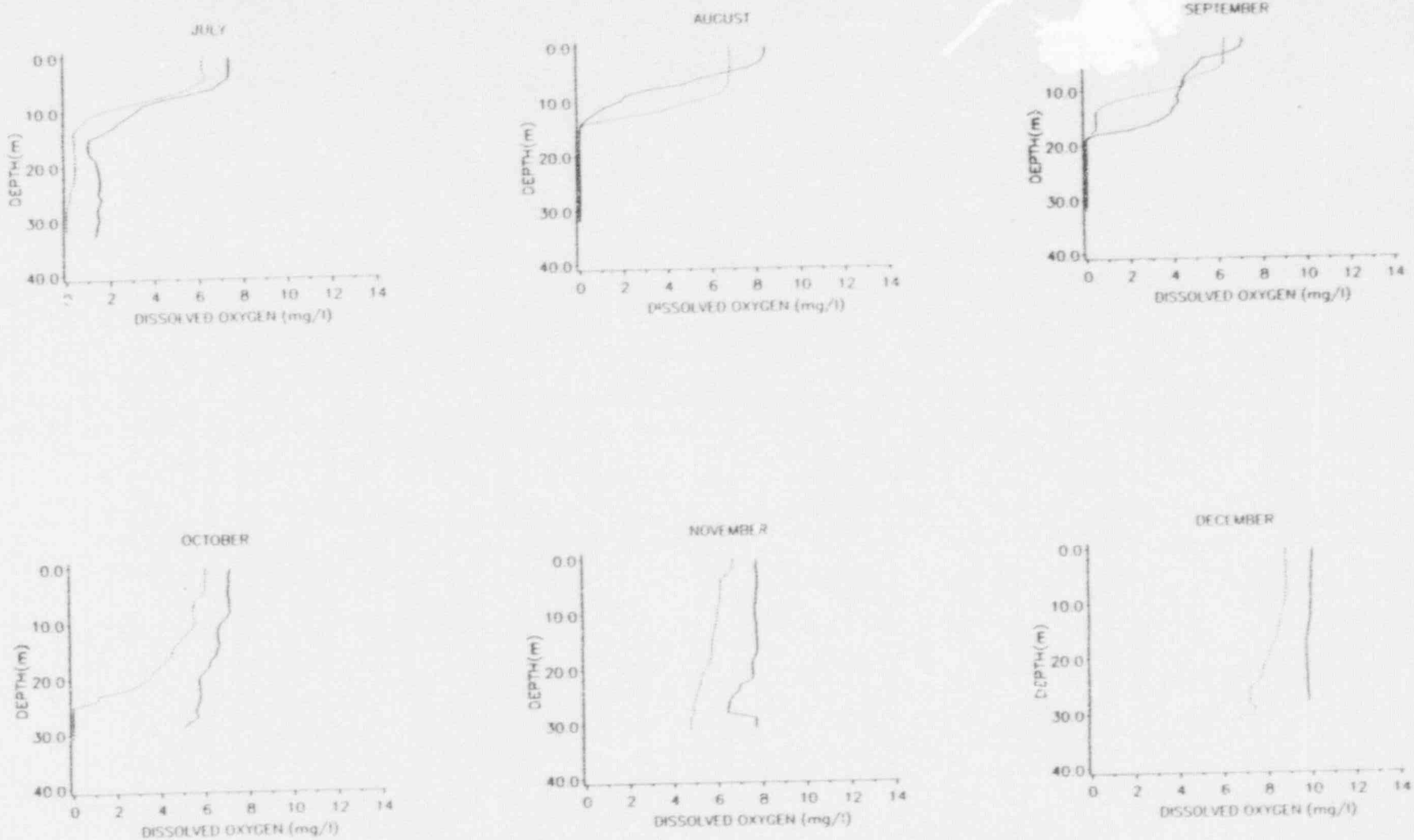


Figure 7. (con't)

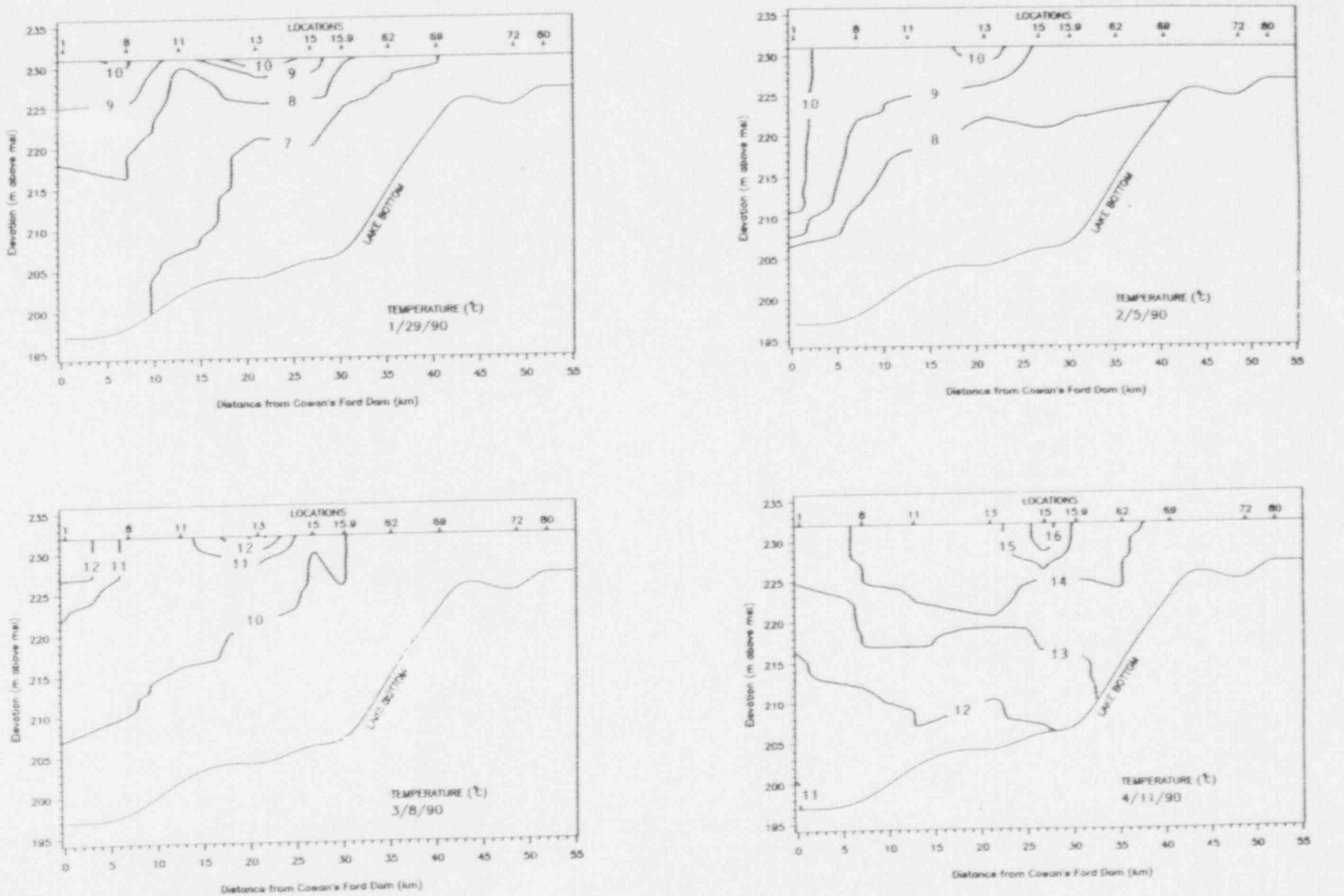


Figure 8. Monthly reservoir-wide isotherms for Lake Norman in 1990.

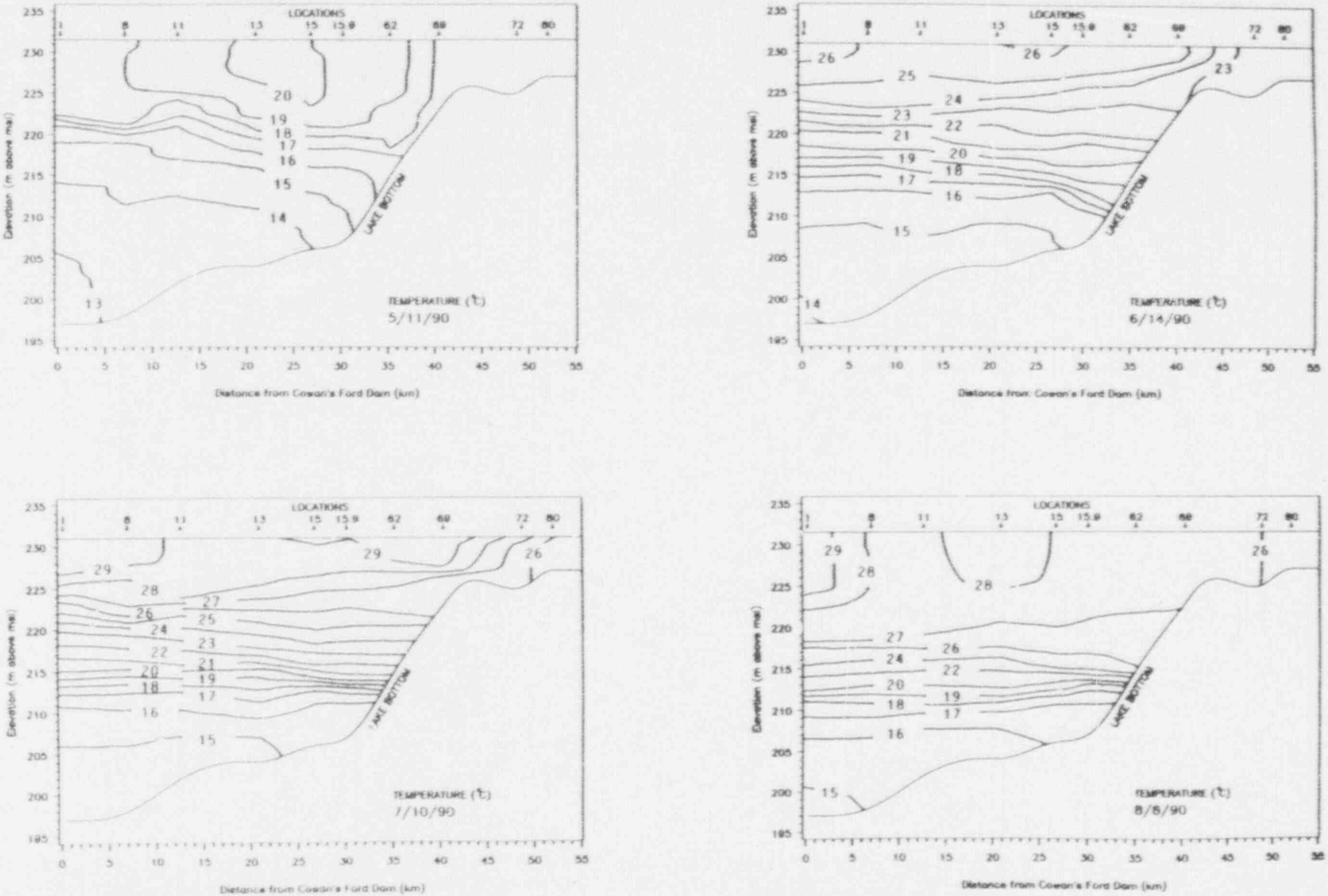


Figure 8. (con't)

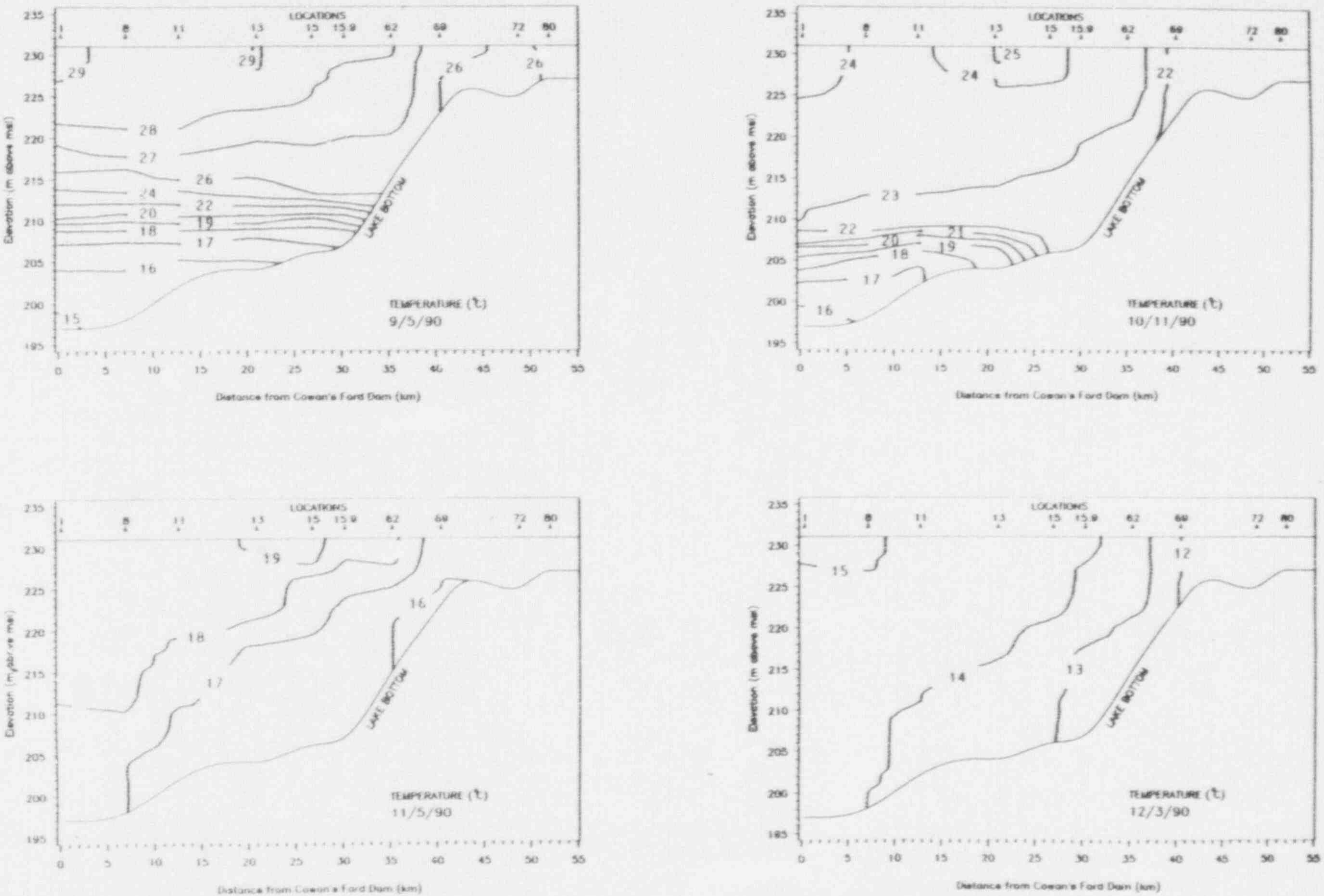


Figure 8. (con't)

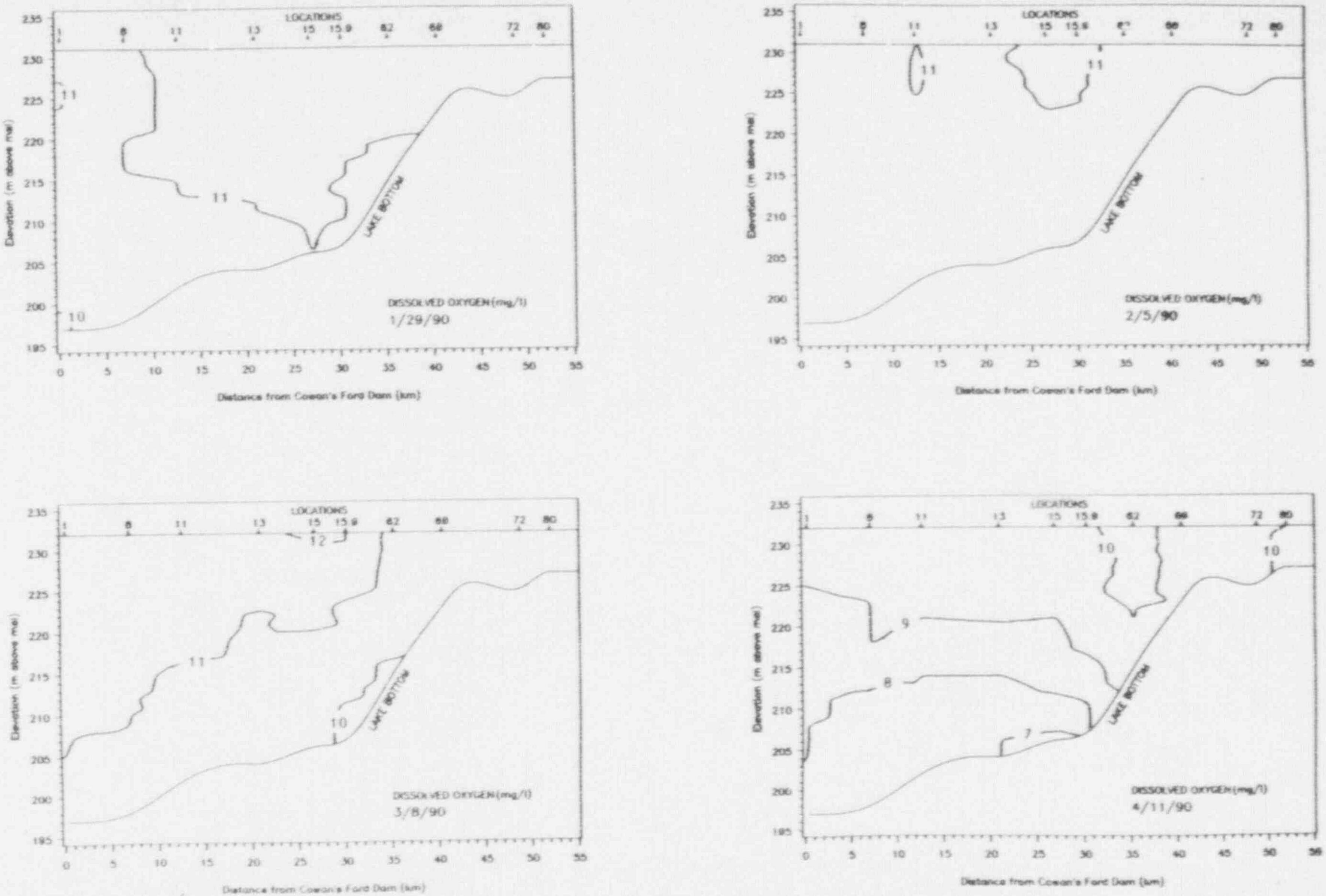


Figure 9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 1990.

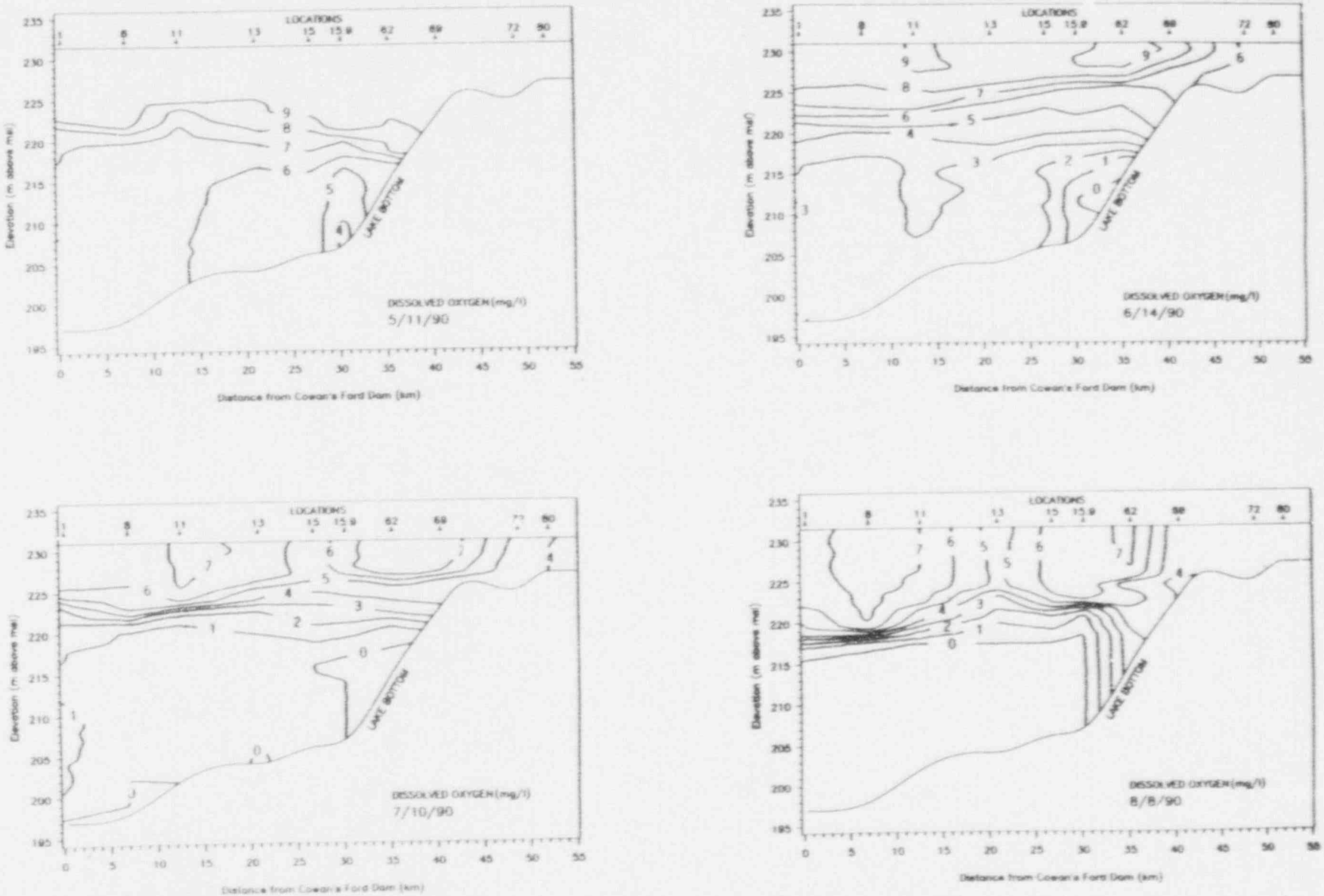


Figure 9. (con't)

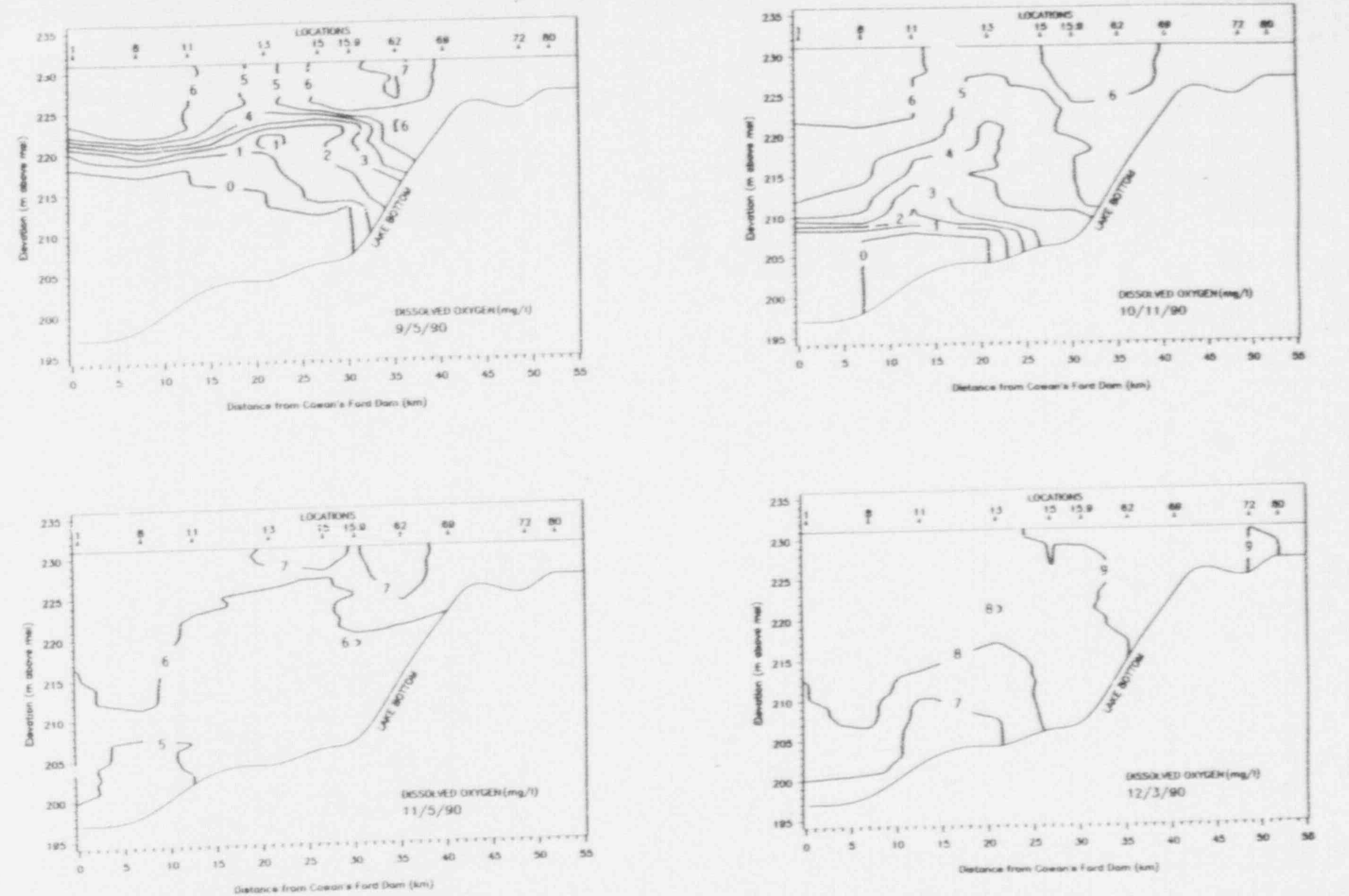


Figure 9. (con't)

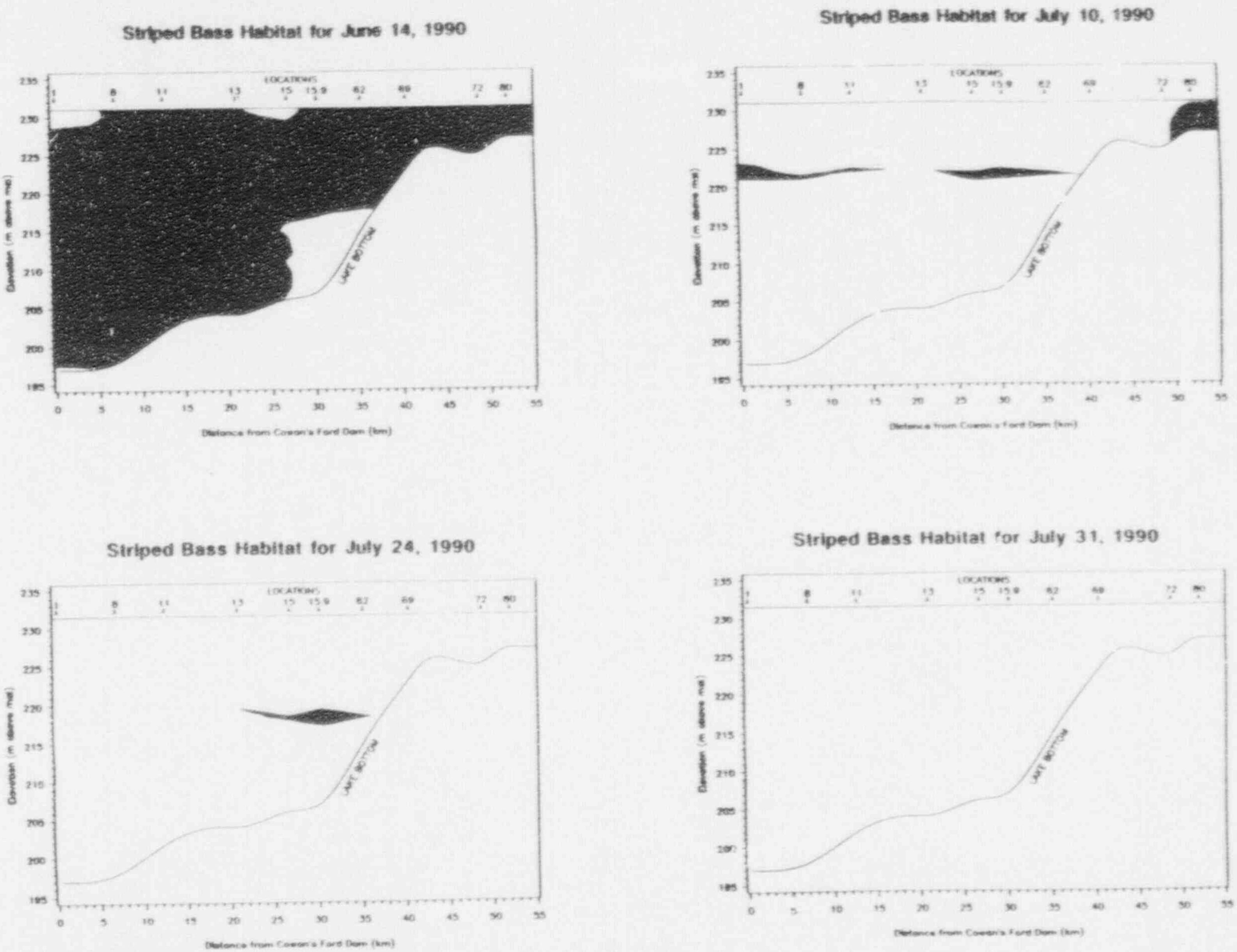


Figure 10. Striped bass habitat (temperature ≤ 26 C and dissolved oxygen ≥ 2.0 mg/l) in Lake Norman in June, July, August and September 1990.

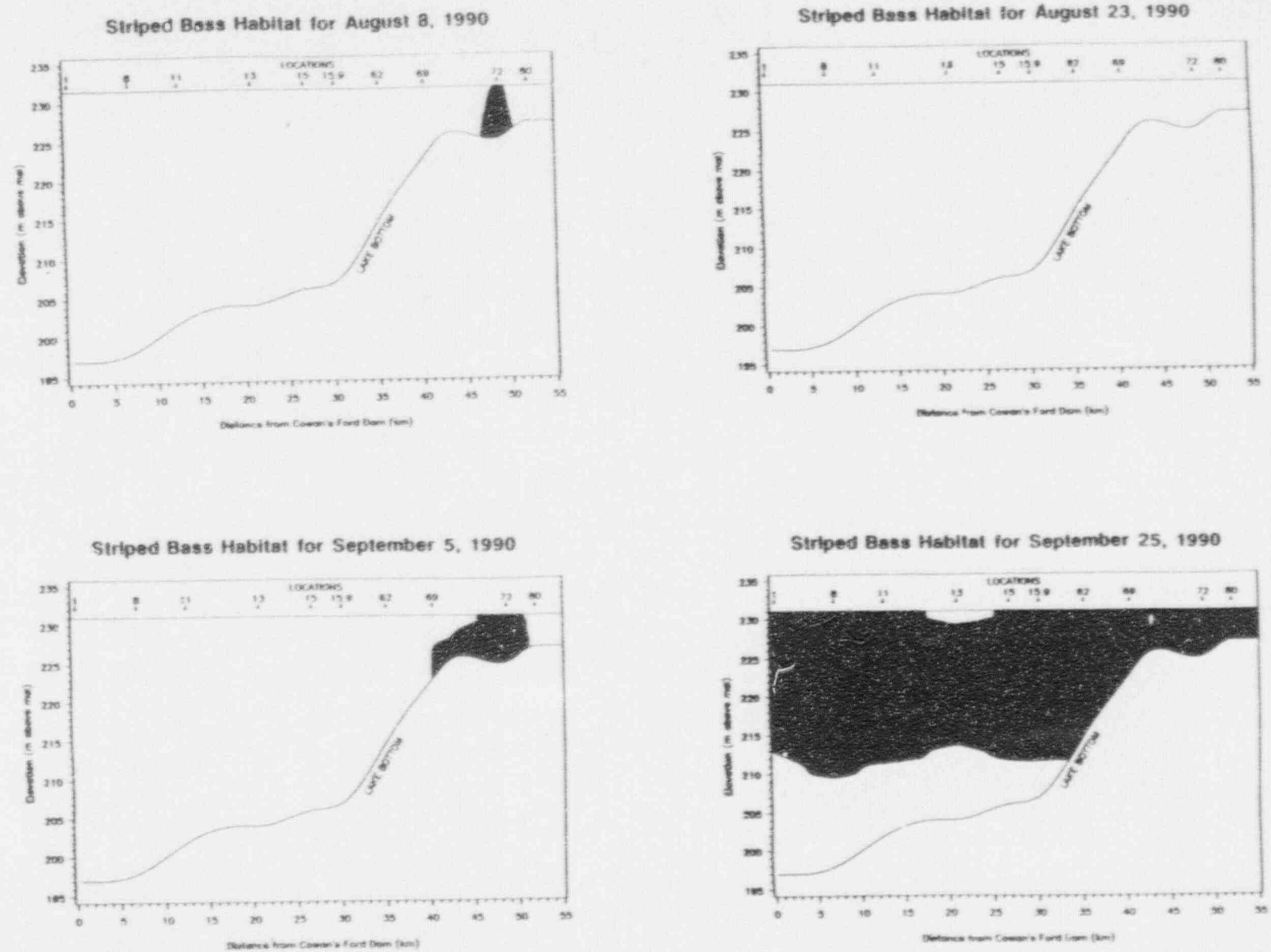


Figure 10. (con't)

IV. WATER CHEMISTRY

INTRODUCTION

The objectives of the Water Chemistry portion of the McGuire Nuclear Station NPDES Long-term Maintenance Program are to:

1) maintain continuity within Lake Norman's historic water chemistry data base at "critical" locations;
2) detect any significant impacts from Duke's operations;
3) document any long-term natural changes in the chemistry of the lake, which might affect plant operations;
4) compare, where appropriate, these data to other impoundments in the Southeast.

This year's report focuses on water chemistry in the McGuire Nuclear Station (MNS) discharge (Location 4.0), mixing zone (Locations 1.0, 2.0, and 5.0), and mid-lake background zone (Locations 8.0 and 11.0) during 1989-90 (Figure 1, Chapter III). This report particularly addresses any changes in the water chemistry that can be related to an increase in the MNS thermal discharge limit from 95 ^{O}F (summer 1989) to 99 ^{O}F (summer 1990). Any reference to earlier historical data will cite Duke Power reports previously submitted to the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR).

METHODS AND MATERIALS

All monitoring locations are depicted in Figure 1 (Chapter III). Physical and chemical water quality parameters, sample locations, and collection frequencies are denoted in Table 1. Water chemistry collection methods have been previously described (Duke Power Co. 1989). Chemical analytical methods are listed in Table 2. During 1990, potassium was analyzed by atomic adsorption graphite furnace direct injection, and the detection limit was lowered to 0.1 mg/l.

RESULTS AND DISCUSSION

Precipitation Amount

During 1990, about 47 inches of precipitation fell in the vicinity of MNS, compared to 52 inches during 1989 (Figure 1). The wettest month of 1990 was October, in which 27% (12.5 in.) of the annual precipitation fell. Annual precipitation during both years was relatively high for the fifteen-year period.

Turbidity and Specific Conductance

Annual mean turbidity values near the surface were low (2-4 NTU) at the MNS discharge, mixing zone, and mid-lake background locations during 1989 and 1990 (Table 3). Annual mean turbidity near-bottom ranged from 7 to 24 NTU over the two-year period, well within the range of values previously reported (Duke Power Co. 1989). The higher annual mean bottom turbidities in 1990 compared to 1989 are probably related to rainfall. It is presumed that suspended sediments in runoff following precipitation events in May and October had settled to the near-bottom strata of the lake when samples were collected in May and November.

Annual mean specific conductance (surface and bottom) in the MNS discharge, mixing, and mid-lake background zones decreased about 18% (10-16 umho/cm) from 1989 to 1990, which was attributed to a decrease in the dissolved ions, sodium and chloride (Table 3). The 1990 annual means ranged from 56 to 61 umho/cm. Specific conductance values were similar (within 4 umho/cm) among the discharge, mixing zone, and mid-lake background zones in 1990.

pH and Alkalinity

During 1990, annual mean pH and alkalinity values were similar among MNS discharge, mixing, and mid-lake background zones (Table 3). Annual mean pH and alkalinity for each location were consistently lower (0.2-0.5 pH units and 2-3 mg $CaCO_3$/l) in 1990 than in 1989.

Quarterly pH and alkalinity values at all locations for both years were within their historical ranges (Duke Power Co. 1989).

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 3. The overall ionic composition of Lake Norman during 1990 was similar to that reported for 1988 and 1989 (Duke Power Co. 1989, 1990). The major cations (descending order as equivalents/l) were sodium, calcium, magnesium, and potassium; major anions (descending order as equivalents/l) were bicarbonate (the primary component of alkalinity), sulfate and chloride. Annual means of sodium and chloride concentrations during 1990 were similar among the lake zones (Table 3), and were 2-3 mg/l lower than the 1989 annual means. The decrease in sodium and chloride concentrations appeared unrelated to MNS operations and/or rainfall.

Nutrients

Nutrient levels in the discharge, mixing, and mid-lake background zones of Lake Norman are provided in Table 3 (p. 4 of 4). Nitrogen and phosphorus levels during 1989-90 were within the ranges historically reported (Duke Power Co. 1989), and are characteristic of the lake's oligo-mesotrophic status (Rodriguez 1982). The slightly higher annual mean concentrations of nitrite+nitrate from all three lake-zones for 1990 compared to 1989 were attributed to the relatively higher inputs during the winter and spring of 1990. Ammonia nitrogen concentrations increased in bottom waters of the MNS discharge, mixing, and mid-lake background zones during the summer and fall of 1989-90. Phosphorus concentrations were generally similar or slightly less in 1990 than in 1989, which is partly explained by the lowered analytical detection limits in 1990.

Metals

Metal concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman during 1989-90 (Table 3) were within their historical ranges (Duke Power Co. 1989).

Iron concentrations near the surface were generally low (≤ 0.1 - 0.2 mg/l) during 1989-90. Iron levels near the bottom where higher during the summers of 1989 and 1990, when bottom waters were anoxic. The release of iron from bottom sediments during summer anoxia was sufficient to exceed the NC water quality standard (1 mg/l) at mixing and background zone locations during the summer of both years. Similarly, manganese concentrations in near-surface and near-bottom waters were generally low (≤ 0.12 mg/l) during 1989-90, except during the summer/fall of both years when bottom waters approached or became anoxic (Table 3). Manganese concentrations near the bottom rose above the NC water quality standard (0.5 mg/l) at mixing zone and background zone locations during the summer and fall of both years. Heavy metal concentrations in Lake Norman never approached NC water quality standards, and there were no consistent appreciable differences between the two years.

FUTURE STUDIES

The following changes to the Water Chemistry component of the McGuire NPDES Lake Norman Long-term Maintenance Program were approved by the NCDEHNR beginning March, 1991:

1. Elimination of water quality sampling at Location 1.2. Currently only surface data are collected at this location. Data collected at Locations 1.0 and 2.0 are indicative of conditions at the MNS intake.

2. Discontinue the analysis of soluble elements at Location 2.0. The historical data base on Lake Norman is adequate to address differences in soluble (0.45 um filtered) and unfiltered elements in Lake Norman.

3. Elimination of fluoride analyses. Fluoride is not an important ionic component of Lake Norman. Also, fluoride concentration is well under NC water quality standards and is too low to impact ion mass balance concentrations

in the lake.

4. Reduce sampling at Location 16.0 from quarterly to semi-annually, which is consistent with the sampling frequency for all other Mountain Island reservoir locations.

SUMMARY

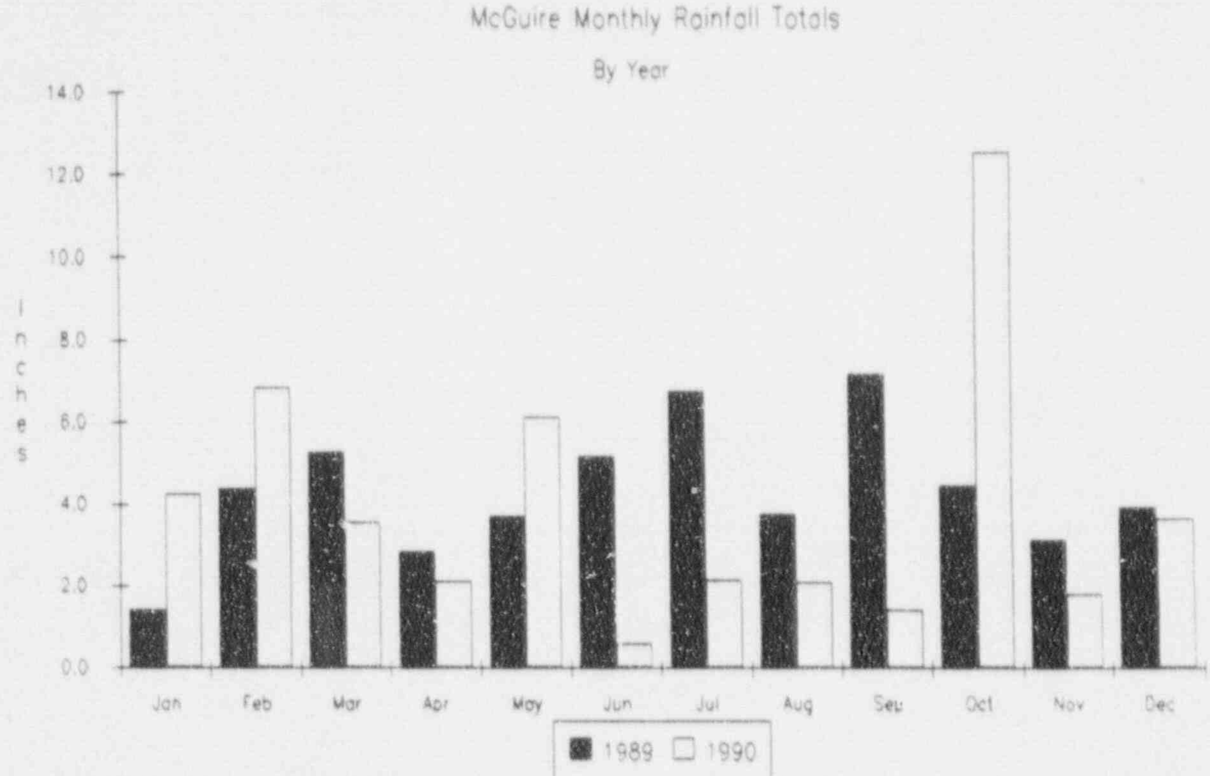
All water chemistry parameters were within the historical ranges previously reported for the lake during both MNS preoperational and operational years. The operation of MNS under a 99 $^{\circ}$F summer thermal discharge limit during 1990 had no apparent impact on the water chemistry.

LITERATURE CITED

Duke Power Company. 1989. Lake Norman maintenance program: 1988 summary. Water chemistry chapter. pp. 6-65.

Duke Power Company. 1990. Lake Norman 1989 summary--maintenance monitoring program McGuire Nuclear Station: NPDES No. NC0024392. pp. 5-56.

Figure 1. Annual and monthly precipitation in the vicinity of McGuire Nuclear Station.



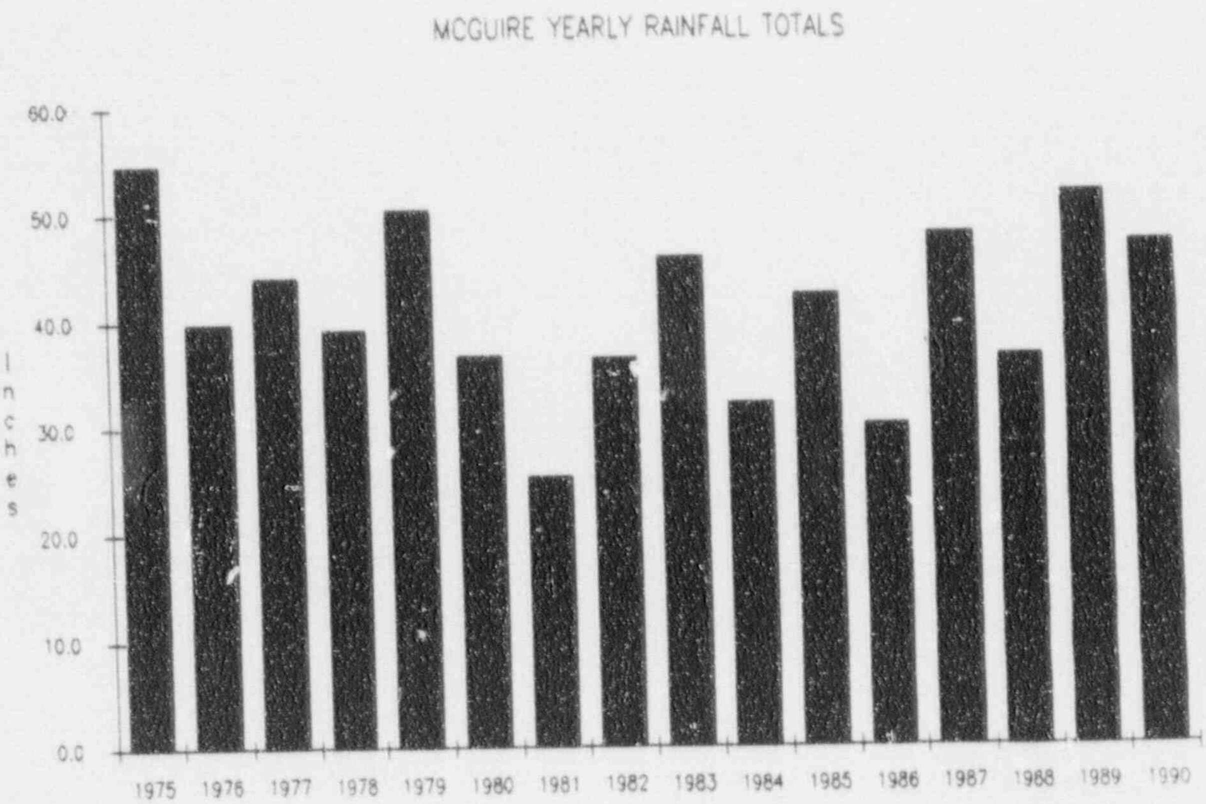


Table 1. Water chemistry program component of the McGuire Nuclear Station NPDES long-term maintenance monitoring program for Lake Norman.

PARAMETERS																	
LOCATIONS	16.0	1.0	1.2	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
DEPTH(M)	0.3	34	18	33	5	21	31	22	28	24	10	23	22	1^c	7	5	4
IN-SITU ANALYSES																	
TEMPERATURE	Q/P_1	M/P_1	Q/P_1	Q/P_1	Q/P_1	M/P_1	M/P_1	M/P_1	M/P_1	M/P_1	Q/P_1	M/P_1	M/P_1	M/P_1	M/P_1	M/P_1	M/P_1
DISSOLVED OXYGEN	Q/P_1	M/P_1	Q/P_1	Q/P_1	Q/P_1	M/P_1	M/P_1	M/P_1	M/P_1	M/P_1	Q/P_1	M/P_1	M/P_1	M/P_1	M/P_1	M/P_1	M/P_1
pH	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5		Q/P_5		Q/P_5		
SPECIFIC CONDUCTANCE	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5	Q/P_5		Q/P_5		Q/P_5		
NUTRIENT ANALYSES																	
AMMONIA	Q/T	Q/T,B	Q/T	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		
NITRATE+NITRATE	Q/T	Q/T,B	Q/T	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		
ORTHOPHOSPHATE	Q/T	Q/T,B	Q/T	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		
TOTAL PHOSPHORUS	Q/T	Q/T,B	Q/T	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		
SILICA	Q/T	Q/T,B	Q/T	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		
CHLORIDE	Q/T	Q/T,B	Q/T	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		
ELEMENTAL ANALYSES																	
CALCIUM	Q/T	Q/T,B	Q/T	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		
MAGNESIUM	Q/T	Q/T,B	Q/T	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		
SODIUM	Q/T	Q/T,B	Q/T	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		
IRON	Q/T	Q/T,B	Q/T	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		
MANGANESE	Q/T	Q/T,B	Q/T	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		
POTASSIUM	Q/T	Q/T,B	Q/T	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		
ALUMINUM	S/T		S/T	S/T,B	S/T		S/T,B				S/T						
ZINC	S/T		S/T	S/T,B	S/T		S/T,B				S/T						
CADMIUM	S/T		S/T	S/T,B	S/T		S/T,B				S/T						
SOPPER	S/T		S/T	S/T,B	S/T		S/T,B				S/T						
LEAD	S/T		S/T	S/T,B	S/T		S/T,B				S/T						
ADDITIONAL ANALYSES																	
ALKALINITY	Q/T	Q/T,B	Q/T	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		
TURBIDITY	Q/T	Q/T,B	Q/T	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		
SULFATE	S/T		S/T	Q/T,B	Q/T		Q/T,B				Q/T						
FLUORIDE	S/T		S/T	Q/T,B	Q/T		Q/T,B				Q/T						

CODES

FREQUENCY
Q = Quarterly (Feb, Apr, Aug, Nov)
S = Semiannually (Feb, Aug)

DEPTH INTERVALS
T = Top 0.3 m
B = Bottom minus 1 m

P_5 = vertical profile (5 m interval from top to bottom)
P_1 = vertical profile (1 m interval from top to bottom)

* = Soluble elements annually (February) at Location 2.0

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

Variables	Method	Preservation	Detection Limit
Alkalinity, total	Electrometric titration to a pH of 5.1[2]	4°C	1mg-$CaCO_3 \cdot l^{-1}$*
Aluminum	Atomic emission/ICP-direct injection[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 injection[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	1 $\mu mho \cdot cm^{-1}$*
Copper	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	0.5 $\mu g \cdot l^{-1}$
Fluoride	Potentiometric[3]	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[3]	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 3. Quarterly near-surface (0.3m) and near bottom (bottom minus 1m) water chemistry for the MNS discharge, mixing zone, and background locations on Lake Norman during 1989 and 1990. The symbol, "<", denotes a value less than the analytical detection limit. 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:	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90	'89	'90
Turbidity (ntu)																						
Feb	2	4	11	6	2	3	5	6	2	4	2	4	2	6	2	4	7	4	2	5	11	9
May	2	3	3	14	2	3	3	12	2	3	2	3	4	12	2	3	3	13	2	3	4	19
Aug	NA	1	NA	7	NA	1	NA	12	NA	1	NA	1	NA	11	NA	1	NA	15	NA	2	NA	11
Nov	3	3	10	18	2	4	9	20	4	5	3	3	11	7	4	5	9	22	3	6	24	22
Annual Mean	2	3	8	11	2	3	6	12	3	3	2	3	6	9	3	3	6	13	2	4	13	15
Specific conductance (umho/cm)																						
Jan/Feb	69	59	69	57	NA	59	NA	57	NA	60	68	59	65	58	68	59	68	56	76	56	73	55
May	77	51	79	53	77	51	79	53	78	52	77	52	78	52	79	51	81	51	80	48	82	50
Aug	63	58	78	68	64	59	80	70	64	59	64	59	80	75	64	58	78	68	63	59	79	70
Nov	63	59	64	56	63	59	60	55	62	58	62	58	58	59	62	59	64	54	59	61	51	53
Annual Mean	68	57	73	58	68	57	73	59	68	57	68	57	71	61	68	57	73	57	70	56	71	57
pH (units)																						
Feb	7.0	6.8	6.8	6.7	7.0	6.8	6.8	6.6	6.9	6.7	7.1	6.8	6.9	6.8	7.1	6.8	6.8	6.7	7.2	6.8	6.8	6.6
May	7.5	6.9	7.0	6.4	7.6	7.1	7.0	6.4	7.2	6.6	7.4	6.9	7.0	6.4	7.6	6.9	6.9	6.3	7.5	6.9	6.8	6.2
Aug	6.6	6.5	6.4	6.3	6.5	6.5	6.5	6.4	6.4	6.3	6.5	6.5	6.3	6.2	7.2	6.6	6.4	6.4	7.8	6.7	6.5	6.4
Nov	6.7	6.7	6.2	6.2	6.8	6.8	6.5	6.4	6.6	6.7	6.8	6.9	6.3	6.5	6.8	6.7	6.7	6.1	6.8	6.8	6.2	6.2
Annual Mean	7.0	6.7	6.6	6.4	7.0	6.8	6.7	6.5	6.8	6.6	7.0	6.8	6.6	6.4	7.2	6.8	6.7	6.4	7.3	6.8	6.6	6.4
Alkalinity (mg $CaCO_3$/l)																						
Feb	14	11	14	11	14	11	14	11	14	11	14	11	14	11	14	11	14	11	14	11	15	11
May	14	11	14	11	14	11	14	11	14	11	14	11	14	11	14	11	14	10	14	10	14	10
Aug	14	12	16	15	14	12	19	16	14	12	14	12	20	18	14	12	20	18	15	12	17	17
Nov	13	13	13	11	13	13	12	11	13	13	13	13	12	13	13	12	13	10	12	12	11	10
Annual Mean	14	12	14	12	14	12	15	12	14	12	14	12	15	13	14	12	15	12	14	11	14	12
Chloride (mg/l)																						
Feb	7.4	4.8	7.4	4.7	7.4	4.8	7.5	4.6	8.8	4.9	7.5	4.8	7.4	4.7	7.1	4.1	7.9	4.5	7.5	4.3	9.4	4.4
May	7.8	4.1	7.9	4.3	7.7	4.2	8.1	4.4	8.0	4.3	7.7	4.3	7.8	4.4	7.7	4.2	8.0	4.1	8.0	3.9	8.5	4.0
Aug	7.4	4.1	7.8	3.9	7.2	4.1	7.9	4.4	7.0	4.4	7.2	4.8	7.5	4.5	7.1	4.6	7.6	4.7	7.9	4.6	7.8	4.0
Nov	6.2	4.3	4.9	3.9	6.1	3.8	5.8	4.2	6.3	4.8	6.2	4.8	5.8	4.3	6.1	5.2	6.6	4.1	5.7	3.7	4.0	4.3
Annual Mean	7.2	4.3	7.0	4.2	7.1	4.2	7.3	4.4	7.5	4.6	7.2	4.7	7.1	4.5	7.0	4.7	7.5	4.4	7.3	4.1	7.4	4.2
Sulfate (mg/l)																						
Feb	NS	NS	NS	NS	5.8	6.5	7.3	6.5	5.8	6.5	NS	NS	NS	NS	5.9	6.4	5.8	6.4	NS	NS	NS	NS
Aug	NS	NS	NS	NS	7.1	5.0	6.7	7.6	6.8	4.8	NS	NS	NS	NS	7.0	5.0	7.5	9.0	NS	NS	NS	NS
Annual Mean					6.5	5.7	7.0	7.0	6.3	5.6					6.5	5.7	6.7	7.7				

NA = Not analyzed NS = Not sampled

Table 3. (Continued)

PARAMETERS	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0	
LOCATION: / DEPTH:	Surface		Bottom		Surface		Bottom		Surface	
YEAR:	´89	´90	´89	´90	´89	´90	´89	´90	´89	´90
Calcium (mg/l)										
Feb	3.0	2.6	2.9	2.5	3.0	2.6	3.0	2.7	3.0	2.6
May	2.9	2.6	3.0	2.6	2.9	2.8	3.1	3.0	3.0	2.5
Aug	3.0	2.6	4.0	3.0	3.4	2.6	3.8	3.0	2.9	2.6
Nov	2.7	2.7	2.7	2.5	2.7	2.6	2.8	2.5	2.7	2.6
Annual Mean	2.9	2.6	3.2	2.6	3.0	2.6	3.2	2.8	2.9	2.6
Magnesium (mg/l)										
Feb	1.4	1.2	1.4	1.1	1.4	1.2	1.4	1.2	1.4	1.2
May	.3	1.1	1.3	1.1	1.3	1.2	1.4	1.3	1.3	1.1
Aug	1.4	1.2	1.7	1.3	1.5	1.2	1.6	1.2	1.4	1.2
Nov	1.3	1.3	1.3	1.1	1.3	1.2	1.3	1.1	1.3	1.2
Annual Mean	1.4	1.2	1.4	1.1	1.4	1.2	1.4	1.2	1.4	1.2
Potassium (mg/l)										
Feb	1.7	1.6	1.7	1.5	1.8	5.1	2.0	1.7	2.0	1.7
May	NA	1.6	NA	1.5	NA	1.6	NA	1.7	N'	1.4
Aug	1.8	1.7	2.0	1.6	1.9	1.7	1.9	1.8	1.[illegible]	1.8
Nov	1.8	1.7	1.9	2.2	1.8	1.7	1.9	2.2	1.8	1.7
Annual Mean	1.8	1.6	.9	2.0	1.8	2.5	1.9	1.8	1.8	1.6
Sodium (mg/l)										
Feb	7.0	5.0	7.3	4.7	7.1	4.7	8.6	4.8	7.3	5.1
May	8.1	4.3	8.3	4.2	8.0	4.5	8.5	4.8	8.2	4.0
Aug	7.7	4.0	9.2	4.0	8.4	4.1	8.7	3.9	7.5	4.1
Nov	6.1	5.2	4.8	4.5	6.2	5.0	5.8	4.4	5.8	5.0
Annual Mean	7.2	4.6	7.4	4.3	7.4	4.6	7.9	4.5	7.2	4.5

PARAMETERS	Mixing Zone 5.0				Background 8.0				Background 11.0			
LOCATION: / DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Bottom	
YEAR:	´89	´90	´89	´90	´89	´90	´89	´90	´89	´90	´89	´90
Calcium (mg/l)												
Feb	3.0	2.5	3.0	2.7	3.0	2.6	2.9	2.7	3.0	2.7	2.9	2.7
May	2.9	2.7	3.0	2.6	3.0	2.7	3.1	2.9	3.0	2.6	3.1	3.0
Aug	3.5	2.6	4.1	3.1	3.3	2.6	3.3	3.2	2.8	2.5	3.4	3.1
Nov	2.5	2.7	2.5	2.7	2.7	2.6	2.8	2.5	2.6	2.5	2.4	2.4
Annual Mean	3.0	2.6	3.2	2.8	3.0	2.6	3.0	2.8	2.9	2.6	3.0	2.8
Magnesium (mg/l)												
Feb	1.4	1.2	1.4	1.2	1.4	1.2	1.4	1.2	1.4	1.2	1.3	1.1
May	1.3	1.2	1.4	1.1	1.3	1.2	1.3	1.2	1.3	1.1	1.3	1.3
Aug	1.6	1.2	1.7	1.3	1.5	1.2	1.4	1.3	1.3	1.2	1.4	1.3
Nov	1.2	1.2	1.2	1.3	1.3	1.2	1.3	1.1	1.2	1.2	1.1	1.1
Annual Mean	1.4	1.2	1.4	1.2	1.4	1.2	1.4	1.2	1.3	1.2	1.3	1.2
Potassium (mg/l)												
Feb	2.1	1.7	2.0	1.7	1.9	1.7	1.9	1.6	1.8	1.6	2.0	1.4
May	NA	1.5	NA	1.5	NA	1.5	NA	1.5	NA	1.3	NA	1.5
Aug	1.9	1.7	2.0	1.8	1.9	1.8	1.8	1.8	1.7	1.7	1.7	1.7
Nov	1.7	1.7	1.7	1.7	1.8	1.9	1.8	2.2	1.8	2.0	1.7	2.2
Annual Mean	1.9	1.6	1.9	1.7	1.9	1.7	1.8	1.8	1.8	1.6	1.8	1.7
Sodium (mg/l)												
Feb	7.2	5.1	7.2	5.0	7.1	5.1	7.5	4.8	7.5	4.8	9.6	4.4
May	8.1	4.3	8.1	4.3	8.2	4.3	8.2	4.3	8.0	3.8	8.2	4.1
Aug	8.6	4.2	8.8	4.0	8.4	4.2	7.7	4.0	7.1	4.2	7.9	3.9
Nov	5.7	5.0	5.1	4.9	6.2	5.6	6.2	4.3	5.6	5.8	4.1	4.6
Annual Mean	7.4	4.6	7.3	4.5	7.5	4.8	7.4	4.3	7.1	4.6	7.5	4.2

NA = Not analyzed
NS = Not sampled

Table 3. (Continued)

PARAMETERS	LOCATION: DEPTH: YEAR:	Mixing Zone 1.0 Surface '89	'90	Bottom '89	'90	Mixing Zone 2.0 Surface '89	'90	Bottom '89	'90	MNS Discharge 4.0 Surface '89	'90	Mixing Zone 5.0 Surface '89	'90	Bottom '89	'90	Background 8.0 Surface '89	'90	Bottom '89	'90	Background 11.0 Surface '89	'90	Bottom '89	'90
Aluminum (mg/l)																							
Feb		NS	NS	NS	NS	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	NS	NS	NS	NS	0.3	<0.3	<0.3	<0.3	NS	NS	NS	NS
Aug		NS	NS	NS	NS	<0.3	0.4	<0.3	0.4	<0.3	0.3	NS	NS	NS	NS	<0.3	0.3	<0.3	0.4	NS	NS	NS	NS
Annual Mean						<0.3	0.3	<0.3	0.3	<0.3	0.3					0.3	0.3	<0.3	0.3				
Iron (mg/l)																							
Feb		<0.1	<0.1	0.2	0.1	<0.1	0.1	0.2	0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	0.1	0.1	<0.1	0.1	0.3	0.1
May		0.1	<0.1	0.1	0.1	0.1	<0.1	0.1	0.2	0.1	<0.1	0.1	<0.1	0.1	0.1	0.1	<0.1	0.1	0.3	0.1	<0.1	0.1	0.4
Aug		<0.1	<0.1	0.1	0.6	<0.1	0.1	0.4	1.0	<0.1	0.1	<0.1	0.1	1.3	1.4	<0.1	0.1	0.7	1.5	<0.1	0.1	0.4	1.1
Nov		0.1	0.8	0.3	0.4	0.1	0.1	0.2	0.6	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.6	0.1	0.2	0.5	0.5
Annual Mean		0.1	0.3	0.2	0.3	0.1	0.1	0.2	0.5	0.1	0.1	0.1	0.1	0.4	0.4	0.1	0.1	0.3	0.6	0.1	0.1	0.3	0.5
Manganese (mg/l)																							
Feb		0.02	0.01	0.07	0.02	0.01	0.01	0.04	0.03	0.01	0.02	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.03	0.01	0.02	0.07	0.04
May		0.09	0.02	0.12	0.04	0.12	<0.01	0.13	0.03	0.12	<0.01	0.12	<0.01	0.15	0.05	0.12	<0.01	0.13	0.05	0.11	0.01	0.11	0.09
Aug		0.04	0.03	0.78	1.29	0.05	0.03	1.61	1.47	0.06	0.08	0.06	0.04	1.80	1.63	0.03	0.03	1.48	1.71	0.04	0.04	1.17	1.67
Nov		0.03	0.05	0.86	0.17	0.04	0.06	0.12	0.17	0.08	0.09	0.05	0.06	0.23	0.12	0.04	0.04	0.08	0.26	0.03	0.03	0.29	0.10
Annual Mean		0.05	0.03	0.46	0.38	0.06	0.03	0.48	0.42	0.07	0.05	0.06	0.03	0.55	0.46	0.05	0.04	0.43	0.49	0.05	0.03	0.41	0.48
Cadmium (µg/l)																							
Feb		NS	NS	NS	NS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	NS	NS	NS	NS	<0.1	<0.1	<0.1	<0.1	NS	NS	NS	NS
Aug		NS	NS	NS	NS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	NS	NS	NS	NS	<0.1	<0.1	<0.1	<0.1	NS	NS	NS	NS
Annual Mean						<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					<0.1	<0.1	<0.1	<0.1				
Copper (µg/l)																							
Feb		NS	NS	NS	NS	1.1	1.9	1.3	1.6	1.3	2.0	NS	NS	NS	NS	1.1	1.7	1.3	1.3	NS	NS	NS	NS
Aug		NS	NS	NS	NS	0.8	1.4	0.8	1.1	1.6	1.3	NS	NS	NS	NS	0.9	1.2	0.8	1.0	NS	NS	NS	NS
Annual Mean						1.0	1.6	1.1	1.3	1.5	1.6					1.0	1.4	1.1	1.1				
Lead (µg/l)																							
Feb		NS	NS	NS	NS	<2.0	NA	<2.0	NA	<2.0	NA	NS	NS	NS	NS	<2.0	NA	<2.0	NA	NS	NS	NS	NS
Aug		NS	NS	NS	NS	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NS	NS	NS	NS	<2.0	<2.0	<2.0	<2.0	NS	NS	NS	NS
Annual Mean						<2.0	<2.0	<2.0	<2.0	<2.0	<2.0					<2.0	<2.0	<2.0	<2.0				
Zinc (µg/l)																							
Feb		NS	NS	NS	NS	<4	6	<4	7	4	7	NS	NS	NS	NS	<4	6	7	<4	NS	NS	NS	NS
Aug		NS	NS	NS	NS	5	8	5	10	6	7	NS	NS	NS	NS	4	7	4	8	NS	NS	NS	NS
Annual Mean						4	7	4	8	5	7					4	6	6	5				

NA = Not analyzed
NS = Not sampled

Table 3. (Continued)

PARAMETERS	Mixing Zone 1.0 Surface '89	Mixing Zone 1.0 Surface '90	Mixing Zone 1.0 Bottom '89	Mixing Zone 1.0 Bottom '90	Mixing Zone 2.0 Surface '89	Mixing Zone 2.0 Surface '90	Mixing Zone 2.0 Bottom '89	Mixing Zone 2.0 Bottom '90	MHS Discharge 4.0 Surface '89	MHS Discharge 4.0 Surface '90	Mixing Zone 5.0 Surface '89	Mixing Zone 5.0 Surface '90	Mixing Zone 5.0 Bottom '89	Mixing Zone 5.0 Bottom '90	Background 8.0 Surface '89	Background 8.0 Surface '90	Background 8.0 Bottom '89	Background 8.0 Bottom '90	Background 11.0 Surface '89	Background 11.0 Surface '90	Background 11.0 Bottom '89	Background 11.0 Bottom '90
Nitrite + Nitrate N (µg/l)																						
Feb	195	385	167	316	142	268	229	309	163	384	137	263	146	287	125	262	169	314	151	302	243	343
May	147	284	205	397	152	301	245	376	176	311	162	292	195	378	164	292	238	374	193	266	262	382
Aug	151	104	300	244	130	105	262	172	151	117	140	107	<50	<50	95	98	<50	67	258	108	250	106
Nov	187	126	212	217	214	110	197	256	222	136	216	129	291	79	209	203	172	295	228	156	234	286
Annual Mean	170	212	221	293	124	196	233	278	178	222	163	198	170	198	146	214	157	262	208	268	247	279
Ammonia (µg/l)																						
Feb	<50	<50	<50	52	<50	<50	<50	52	<50	<50	<50	<50	<50	<50	<50	<50	<50	53	<50	<50	54	69
May	<50	<50	64	<50	<50	<50	78	<50	<50	<50	<50	<50	53	<50	<50	<50	64	<50	<50	<50	63	<50
Aug	<50	<50	<50	94	<50	<50	83	165	<50	<50	<50	<50	178	213	<50	<50	<50	194	62	<50	61	165
Nov	52	76	195	130	<50	74	79	113	70	78	<50	68	125	109	67	113	100	114	50	<50	120	128
Annual Mean	51	56	90	81	<50	56	74	95	55	57	<50	54	101	103	54	66	66	103	53	<50	75	98
Total Phosphorus (µg/l)																						
Feb	<15	7	15	10	<15	6	<15	10	<15	8	<15	5	<15	6	<15	6	<15	.	<15	10	15	10
May	<15	9	15	15	<15	10	<15	15	<15	11	21	10	<15	13	<15	11	<15	17	<15	14	42	24
Aug	32	9	<5	12	<5	9	32	11	15	10	11	9	5	10	5	8	6	19	10	10	<5	11
Nov	7	14	19	26	8	8	11	18	9	7	8	6	15	7	10	10	8	21	11	12	17	30
Annual Mean	17	10	14	15	11	8	18	13	14	9	14	7	12	9	8	9	11	16	13	11	20	19
Orthophosphate (µg/l)																						
Feb	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5
May	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	<5	<10	6	<10	<5	<10	8
Aug	<5	<5	<5	<5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5	7	5	<5	7	<5	124	<5	7
Nov	9	5	19	6	<5	5	7	5	14	5	9	5	18	5	5	<5	6	5	7	<5	<5	6
Annual Mean	9	5	11	5	<10	5	8	5	10	5	9	5	11	5	8	5	8	6	8	35	<10	6
Silica (mg/l)																						
Feb	4	3	4	3	4	3	4	3	4	3	4	3	4	2	3	2	4	1	4	2	4	1
May	3	4	4	4	3	4	4	4	3	4	3	4	4	4	3	4	4	4	3	4	4	5
Aug	4	4	4	5	4	4	4	5	4	4	4	4	4	5	3	4	3	5	4	4	4	5
Nov	4	2	4	1	4	1	4	1	4	2	4	2	4	1	4	2	4	1	4	1	4	1
Annual Mean	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4	6	4	3	4	3	4	6

NA = Not analyzed
NS = Not sampled

Note: In some instances where phosphorus species detection limits were approached, orthophosphate values exceed total phosphorus values. Differences <5 mg/l are within the measurement error. A review of the quality assurance and control data for November 1990 (orthophosphate) at Location 11.0 revealed the value is analytically correct; the sample is pressured to be contaminated.

V. PHYTOPLANKTON

INTRODUCTION

Phytoplankton population parameters were monitored in 1990 in accordance with the NPDES permit for McGuire Nuclear Station. 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 1990) with historical data collected during these months.

Previous studies on Lake Norman have reported considerable spatial and temporal variability in phytoplankton standing crops and taxonomic composition (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.

METHODS AND MATERIALS

Quarterly phytoplankton sampling was conducted at Locations 2.0, 5.0, 8.0, 9.5, 11.0, 13.0, 15.9, and 69.0 (Chapter III, Figure 1). Duplicate composite grabs from 0.3, 4.0, and 8.0 m (i.e., the euphotic zone) were taken at all locations. Sampling was conducted on 28 February, 24 May, 30 August, and 2 November 1990. Standing crop (density and 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. Field pling methods, and laboratory methods used for chlorophyll a, seston weights, standing crop, and taxonomic composition determinations were identical to those used by Rodriguez (1982). Data collected in 1990 were compared with corresponding data from quarterly monitoring beginning in August 1987.

RESULTS AND DISCUSSION

Standing Crop

Standing crop values for phytoplankton were generally highest at mid and uplake Locations 11.0, 13.0, 15.9 and 69.0 (Figure 1). All chlorophyll a values above 10 mg/m³ were found uplake, including the highest value observed during 1990, 15.1 mg/m³ at Location 15.9 in February. By contrast, no chlorophyll a concentrations greater than 6.0 mg/m³ were found at Locations 2.0, 5.0, 8.0, or 9.5 (Table 1). Chlorophyll a concentrations varied the most at Location 69.0 where the lowest values of any location were found in February, May, and November, but which exhibited the highest value in August (10.6 mg/m³). This August peak in chlorophyll a at Location 69.0 was also observed in 1988 and 1989 (Figure 2). The yearly highs for both total densities and biovolumes were also observed uplake: at Location 11.0 in February for biovolumes (2,244 mm³/m³) and at Location 15.9 in August for densities (3,973 units/ml). Total phytoplankton densities at Location 15.9 were consistently higher than at any other location during every month sampled since August 1987, except February 1990, and also peaked in August (Figure 3). This trend of increased standing crop values from downlake to uplake has been observed in past years (DPC 1988, 1989 and 1990) and may be due to higher inputs of nutrients associated with increased suspended solids uplake as evidenced by seston ash-free dry weights (Figure 1).

Table 1. **Mean Chlorophyll a concentrations (mg/m3) in Lake Norman for 1990.**

Location	Feb	May	Aug	Nov
2.0	3.47	5.25	4.95	2.70
5.0	4.36	5.14	3.71	3.23
8.0	5.97	4.94	4.76	3.47
9.5	5.25	4.69	5.04	4.40
11.0	7.54	4.69	5.54	4.24
13.0	10.36	5.13	3.15	3.83
15.9	15.09	5.83	6.80	8.25
69.0	0.85	2.58	10.56	1.38

Phytoplankton standing crop values at all locations in 1990 were generally within the ranges of those observed during the same months of 1988 and 1989 (Figures 2 and 3) except for the high chlorophyll a value observed at Location 15.9 in February. Early spring peaks in phytoplankton are typically seen uplake in Lake Norman (Rodriguez 1982) so we may have sampled this year at the

maximum. Chlorophyll a, total densities, and biovolumes in the mixing zone (Locations 2.0 and 5.0) were very similar to those observed in 1989. With the exception of total densities and biovolumes at Location 15.9, standing crop values (especially chlorophyll a) in February of 1990 were generally higher than in 1989.

Community Composition

Ten classes comprising 77 genera and 146 taxa of phytoplankton were identified from samples collected in Lake Norman in 1990. The distribution of species within classes was as follows: Chlorophyceae (Green algae), 63; Bacillariophyceae (Diatoms), 28; Chrysophyceae, 15; Haptophyceae and Xanthophyceae, 1 each; Cryptophyceae, 7; Myxophyceae (Blue-green algae), 16; Euglenophyceae, 4; Dinophyceae, 9; Chloromonadophyceae, 1; and 1 Unidentified taxon (Table 2). Twenty-two taxa were identified in 1990 which were not recorded in the Maintenance Monitoring Program since August 1987. However, none of these taxa was found in any abundance and all but six of these taxa have been listed in previous studies in Lake Norman (Rodriguez 1982).

Phytoplankton class composition in 1990 was similar to that found in 1989 (DPC 1990). Diatoms and cryptophytes were dominants in terms of densities at all locations during February, with green algae also being important downlake at Locations 2.0, 5.0, and 9.5 (Figure 4). Diatoms dominated the total biovolume in February, comprising more than 45% of the total biovolume at all locations and almost 80% of the biovolume at Location 11.0. Class composition in May was similar to that observed in February, with diatoms and cryptophytes generally codominant for density, and green algae and chrysophytes becoming more important at all locations. Diatoms again dominated the biovolumes in May, comprising more than 40% of the total at each of the locations. Dinophyceae were important in terms of biovolume at Locations 9.5 and 11.0 during May. In August, green algae dominated phytoplankton assemblages at all locations except Location 15.9, where blue-green algae were dominant with 36.6% of the total density. This was the only occurrence of blue-green algal dominance observed in 1990. High populations of blue-green algae were also observed at Location 15.9 during August in 1988 and 1989 (DPC 1989, 1990). Blue-greens comprised less than 5% of the total density at all other locations

during August of 1990. Diatoms and cryptophytes were also important numerically in August. Dinophyceae dominated the biovolume in August, comprising more than 35% of the total biovolumes at all locations and 60.3% of the biovolume at Location 9.5. In November, diatoms, green algae, and cryptophytes were codominant numerically. Diatoms dominated the biovolumes, comprising more than 40% of the total biovolume at all locations.

Major species of phytoplankton (>5% of the total density or biovolume) observed during 1990 are presented in Tables 3 and 4. Species composition among phytoplankton samples collected during 1990 was generally similar to that observed for samples collected during 1989 (DPC 1990). Melosira ambigua, a centrate diatom, dominated the phytoplankton biovolume at all locations during February, comprising from 17.8% of the total at Location 5.0 to 65.4% of the total at Location 11.0. Melosira ambigua (formerly called Melosira italica) is a perenial spring dominant in Lake Norman (Rodriguez 1982). Another centric diatom, Attheya zachariasi dominated the biovolume of phytoplankton assemblages downlake during May, comprising more than 20% of the total biovolume at Locations 2.0, 5.0, and 9.5. This species appeared to take the place of Cyclotella comta, which dominated the biovolume at these same locations during May of 1989. Cyclotella comta was not seen at all in 1990 and had not been observed in previous Lake Norman studies prior to 1989. The presence of this species in 1989 was an unusual event for which there is no ready explaination. Attheya zachariasi was also a major (>5% biovolume) species during May 1989 at most locations so its dominance in May 1990 is not unusual. Synedra spp., a pennate diatom, dominated the biovolume at Location 15.9 in May, comprising 32.2% of the total. Dinoflagellate species, primarily Peridinium spp., dominated the biovolumes at all locations during August of 1990. This was similar to 1989 except that few dinoflagellates were found at Location 15.9 in August of 1989. In November, Melosira ambigua was again an important part of the biovolume at all locations, while Attheya zachariasi was only important downlake.

Rhodomonas minuta, a small cryptophyte, was overall the most numerically abundant taxon in 1990, comprising from 12% to 30% of the total phytoplankton density at all locations in February, May, and November. Rhodomonas minuta has consistently been a numerical dominant in phytoplankton assemblages in

Lake Norman (Rodriguez 1982). In August, coccoid greens comprised more than 10% of the total densities at all locations and were the numerical dominant except at Location 15.9 where Raphidiopsis curvata, a blue-green alga, comprised 17.3%. R. curvata was also abundant at Location 15.9 in August of 1989. Other taxa comprising greater than 10% of the total densities during 1990, all commonly observed in previous studies, were Ankistrodesmus falcatus v. mirabilis, Micractinium pusillum, Unidentified chrysophytes and Cryptomonas erosa.

SUMMARY

Phytoplankton sampling was conducted at Locations 2.0, 5.0, 8.0, 9.5, 11.0, 13.0, 15.9, and 69.0 on Lake Norman in February, May, August, and November 1990. Chlorophyll a analyses and seston weights were performed at all locations, while phytoplankton standing crops and taxonomic composition were determined at Locations 2.0, 5.0, 9.5, 11.0, and 15.9.

Phytoplankton standing crops (chlorophyll a, total densities, and biovolumes) generally showed a trend of increasing values from downlake to uplake locations. Except for chlorophyll a concentrations at Location 15.9 in February, phytoplankton standing crop values during 1990 were generally within the ranges of those observed during 1987, 1988, and 1989.

Phytoplankton taxonomic composition during 1990 was similar to that observed during the same months of 1989, with diatoms, green algae, chrysophytes, and cryptophytes the most abundant classes of algae observed. Diatoms generally dominated the phytoplankton biovolumes in all months but August when dinoflagellates were dominant. Blue-green algae were not an important part of the phytoplankton community except at Location 15.9 in August as was also observed in 1989. Major taxa observed in 1990 were also similar to those observed in 1989. Melosira ambigua dominated the algal biovolume in February and November of 1990 and Rhodomonas minuta was the numerical dominant during all months but August when coccoid greens were generally most abundant. Cyclotella comta which had dominated the biovolumes at most locations during May 1989 was replaced in May 1990 by another centric diatom Attheya zachariasi.

LITERATURE CITED

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

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

Duke Power Company. 19C8. Lake Norman maintenance monitoring program: 1987 summary.

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

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

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

Rodriguez, M. S. 1982. Phytoplankton, p. 154-260 In J. E. Hogan and W. D. Adair (eds.). Lake Norman summary, Technical Report DUKEPWR/82-02 Duke Power Company, Charlotte, NC. 460 p.

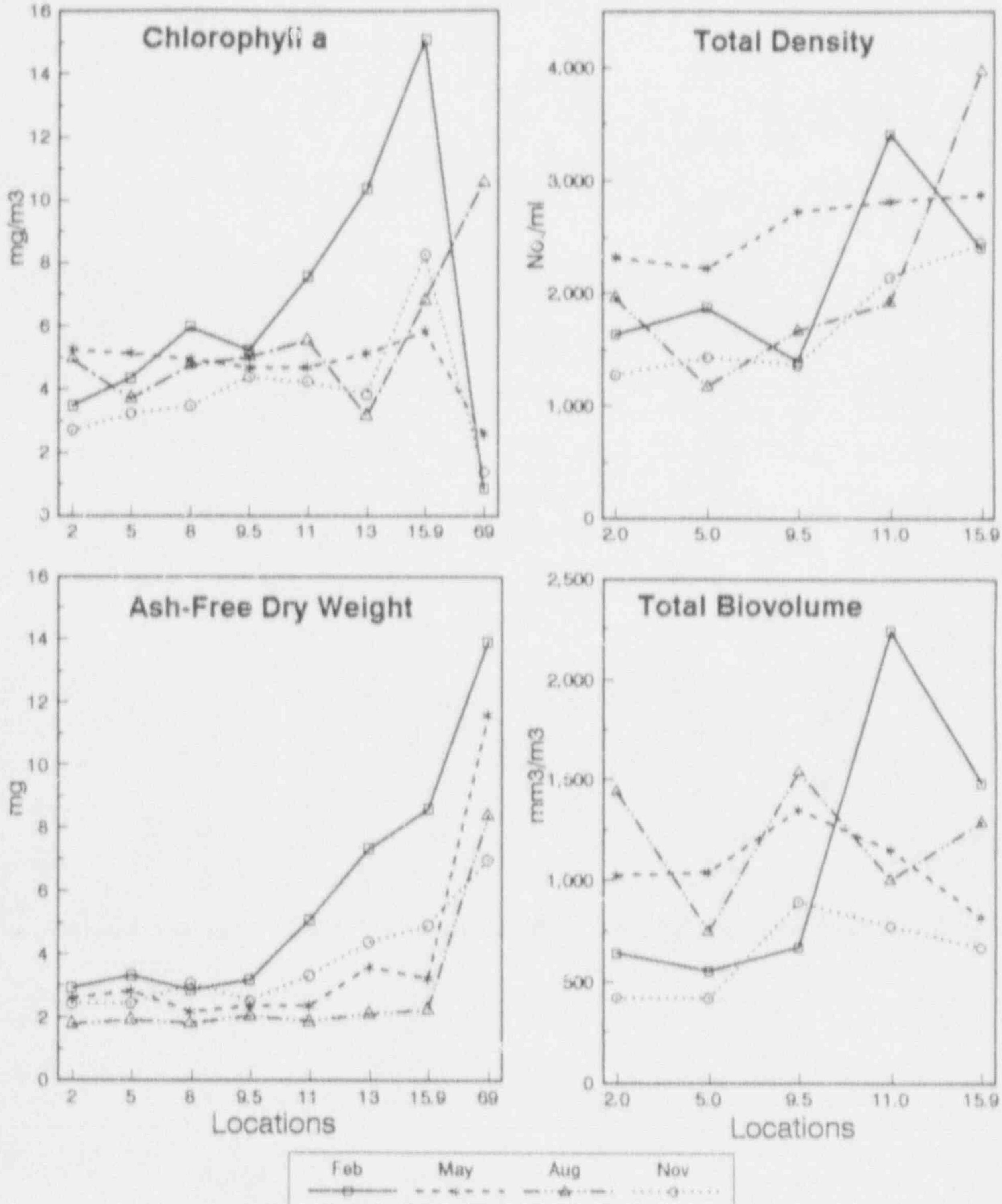


Figure 1. Chlorophyll a, ash-free dry weights, total densities and total biovolumes for locations in Lake Norman, NC during February, May, August and November 1990.

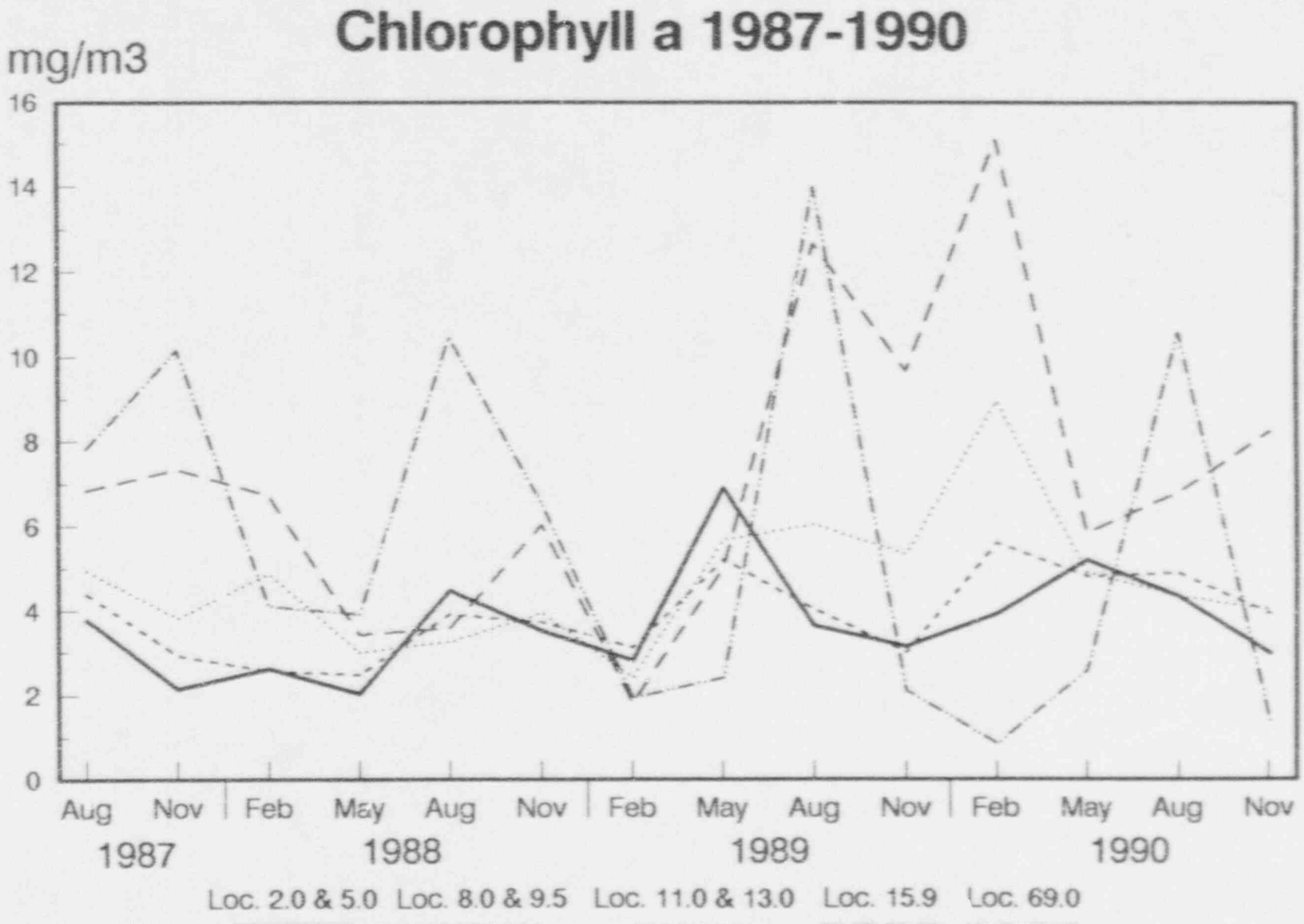


Figure 2. Chlorophyll a concentrations (mg/m³) from locations in Lake Norman, NC during quarterly monitoring from August 1987 through November 1990.

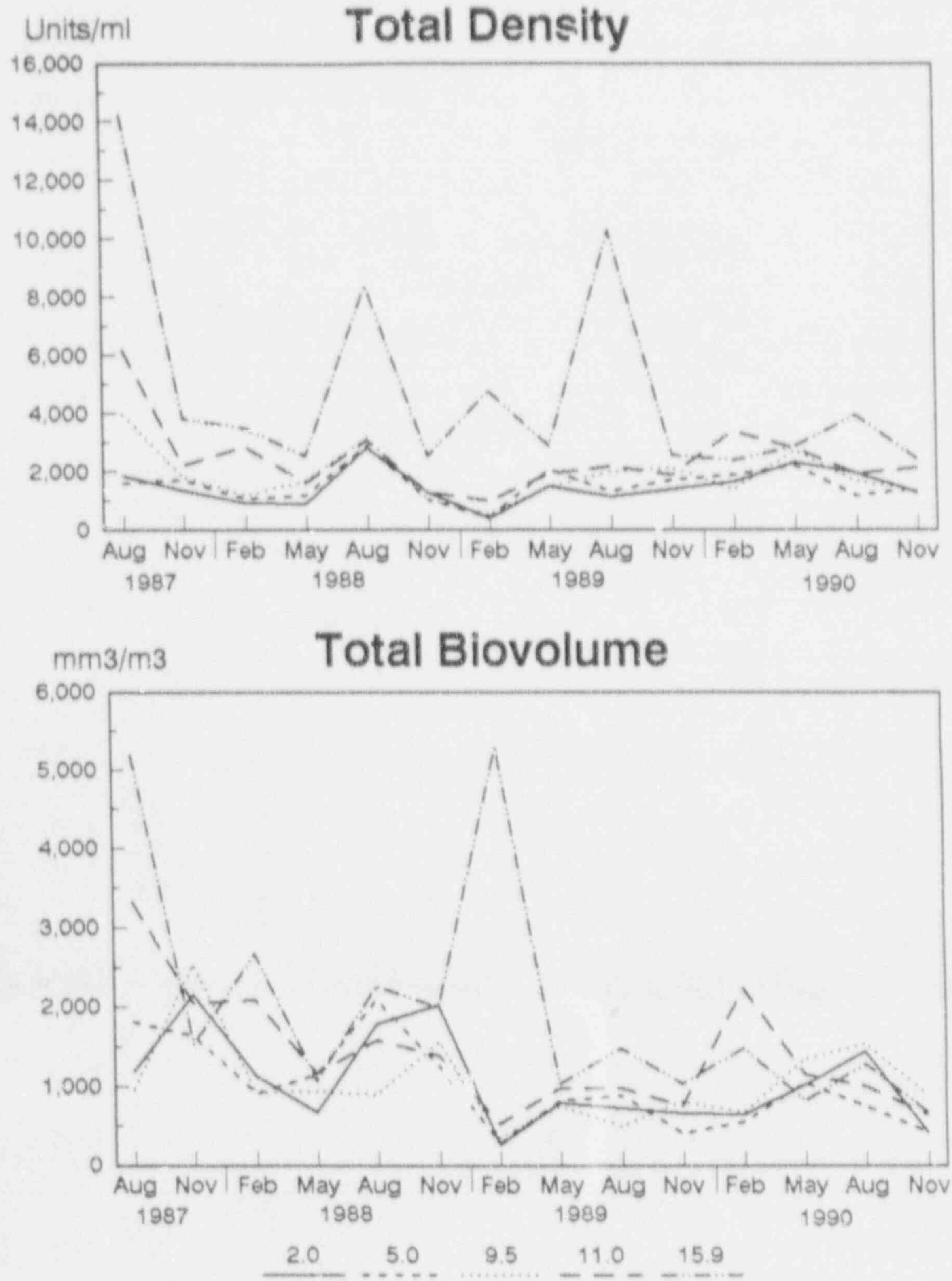


Figure 3. Total densities (units/ml) and total biovolume (mm^3/m^3) of phytoplankton in samples collected from locations in Lake Norman, NC during quarterly sampling 1987 through 1990.

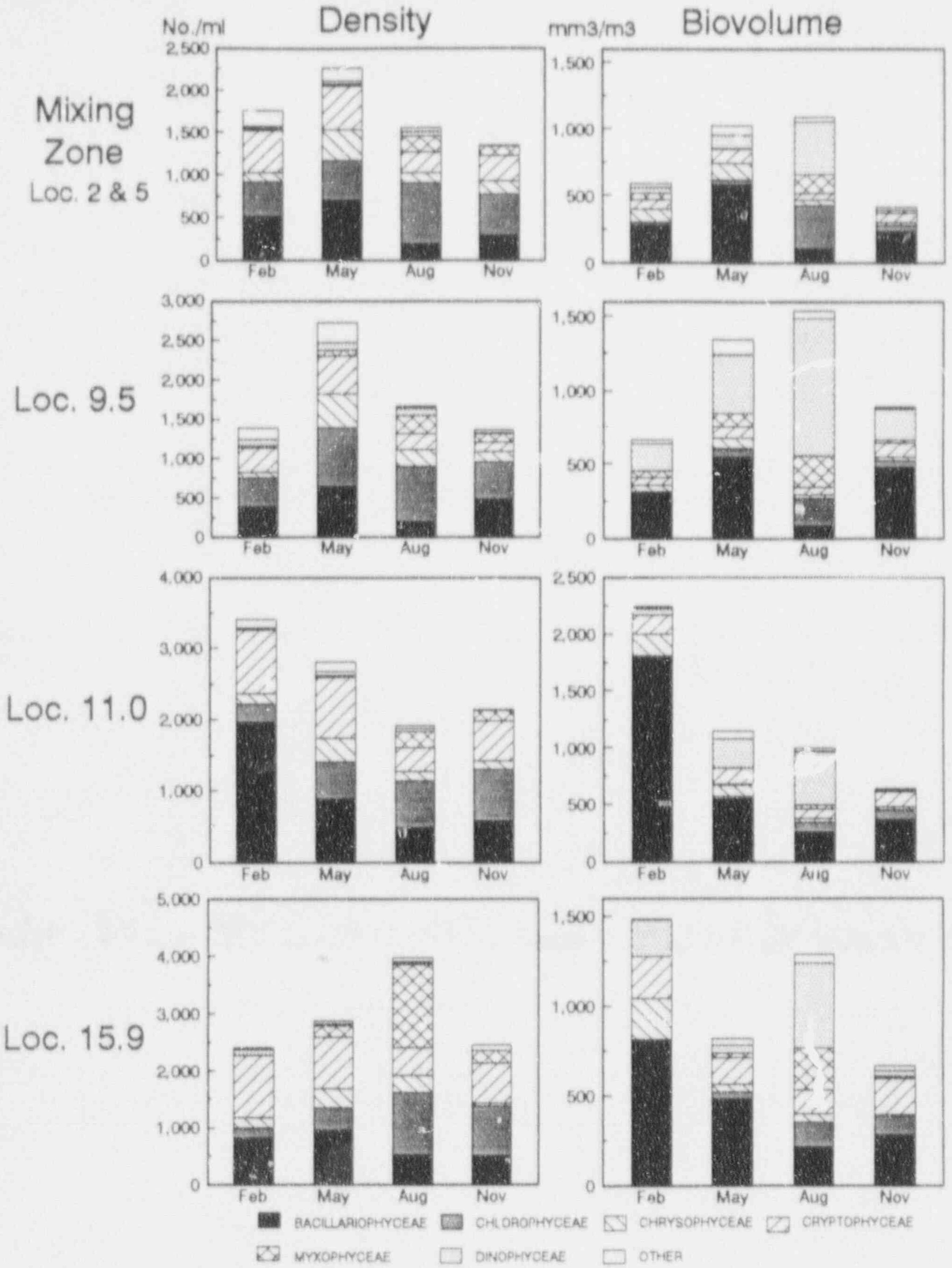


Figure 4. Class composition of phytoplankton in samples collected from locations in Lake Norman, NC during 1990.

Table 2. Phytoplankton taxa identified from Lake Norman samples collected in August and November 1987 and February, May, August, and November 1988, 1989 and 1990 (*=taxon not recorded before 1990).

CHLOROPHYCEAE

Acanthosphaera zachariasi Lemmerman
Actinastrum hantzschii Lagerheim
Ankistrodesmus falcatus (Corda) Ralfs
A. falcatus v. *mirabilis* (Corda) Ralfs
A. falcatus v. *tumidus* (West & West) G. S. West
A. fusiformis Corda sensu Korshikov
A. spiralis (Turner) Lemmerman
Arthrodesmus incus (Breb.) Hassall
Asterococcus limneticus G. M. Smith
Carteria frizschii Takeda
C. spp. Diesing
Characium spp.
Chlamydomonas spp. Ehrenberg
Chlorogonium spp. Ehrenberg
Closteriopsis longissima Lemmermann
C. longissima v. *tropica* West & West
Closterium incurvum Brebisson
Closterium spp. Nitzsch
Coelastrum cambricum Archer
C. sphaericum Naegeli
Coelastrum spp. Naegeli
Cosmarium angulosum v. *concinnum* (Rab.)West & West
C. asphaerosporum v. *strigosum* Norstedt
C. contractum Kirchner
C. polygonum (Naegeli) Archer
C. tenue Archer
C. tinctum Lundell
C. spp. Corda
Crucigenia crucifera (Wolle) Collins
C. irregulare Wille
C. tetrapedia (Kirchner) West & West
Dictyosphearium ehrenbergianum Neageli
D. pulchella Wood
Elakatothrix gelatinosa Wille
Euastrum spp. Ehrenberg
Eudorina elegans Ehrenberg
Franceia droescheri (Lemmerman) G. M. Smith
F. ovalis (France) Lemmerman
Gloeocystis planktonica (West & West) Lemmerman
G. gigas (Kuetzing) Lagerheim
G. spp. Neageli
Golenkinia paucispina West & West
G. radiata (Chodat) Wille
Gonium sociale (Dujar.) Warm.
Kirchneriella contorta (Schmidle) Buhlin
K. lunaris (Kirchner) Moab.
K. obesa (W. West) Schmidle
K. subsolitaria G. S. West
K. spp. Schmidle
Lagerheimia ciliata (Lagerheim) Chodat
L. longiseta (Lemmerman) Printz
L. quadriseta (Lemm.) G. M. Smith
L. subsala Lemmerman
Mesostigma viride Lauterborn
Micractinium pusillum Fresenius
Monoraphidium contortum Thuret
M. pusillum Printz
Mougeotia elongatum (Agardh) Wittrock
Mougeotia spp. (agardh) Wittrock
Nephrocytium agardhianum Neageli
N. limneticum (G. M. Smith) G. M. Smith
Oocystis ellyptica W. West
O. lacustris Chodat
O. parva West & West
Oocystis spp. Naegeli
Pandorina charkowiensis Korshikov
Pediastrum biradiatum Meyen
P. duplex Meyen
P. obtusum Lucks
P. tetras (Ehrenberg) Ralfs
P. tetras v. *tetraodon* (Corda) Ralfs
Pediastrum spp. Meyen
Planktosphaeria gelatinosa G. M. Smith
Quadrigula lacustris (Chodat) G. M. Smith
Scenedesmus abundans (Kirchner) Chodat
S. abundans v. *asymetrica* (Shroeder) G. M. Smith
S. abundans v. *brevicauda* G. M. Smith
S. acuminatus (Lagerheim) Chodat
S. armatus v. *bicaudatus* (Guglielı-Printz) Chodat
S. bijuga (Turpin) Lagerheim
S. bijuga v. *alterans* (Reinsch) Hansgirg
S. denticulatus Lagerheim
S. dimorphus (Turpin) Kuetzing
S. incrassulatus
S. quadricauda (Turpin) Brebisson
Selenastrum minutum (Neageli) Collins
S. westii G. M. Smith
Sphearocystis schroeteri Chodat
Sphearozosma granulata Roy & Bliss
Staurastrum americanum (West & West) G. M. Smith
S. apiculatum Brebisson
S. brevispinum Brebisson
S. curvatum v. *elongatum* G. M. Smith
S. cuspidatum Brebisson
S. dejectum Brebisson
S. dickeii v. *rhomboideum* West and West
S. manfeldtii v. *fluminense* Schumacher
S. megacanthum Lundell
S. paradoxum v. *cingulum* West & West
S. paradoxum v. *parvum* W. West
S. subcruciatum Cooke & Wille
S. tetracerum Ralfs
S. turgescens Denot
Tetraedron arthrodesmiforme v. *contorta* Wolosz.
T. caudatum (Corda) Hansgirg
T. caudatum v. *longispinum* Lemmerman
T. minimum (A. Braun) Hansgirg
T. muticum (A. Braun) Hansgirg
T. regulare v. *incus* Teiling

(Continued)

Table 2. (Continued)

Tetraedron spp. Kuetzing
Tetrastrum heterocanthum (Nordst.) Chodat
Truebaria setigera (Archer) G. M. Smith
Westella linearis G. M. Smith
BACILLARIOPHYCEAE
Achnanthes microcephala (Kuetzing) Grunow
A. spp. Bory
Anomoeoneis vitrea (Grunow) Ross
* *A.* spp. Pfitz.
Asterionella formosa Hassall
Attheya zachariasi J. Brun
Cocconeis placentula Ehrenberg
Cyclotella comta
C. meneghiniana Kuetzing
C. pseudostelligera Hustedt
C. stelligera (Cleve) Van Huerck
Cymbella minuta Hilse ex. Rabenhorst
C. turgida Gregory
Cymbella spp. Agardh
* *Diploneis* spp. Ehrenberg
Fragilaria crotonensis Kitton
Frustulia rhomboides (Ehrenberg) DeToni
Melosira ambigua (Grunow) O. Muller
M. distans (Ehrenberg) Kuetzing
M. granulata (Ehrenberg) Ralfs
M. granulata v. *angustissima* Mueller
M. italica (Ehrenberg) Kuetzing
M. spp. Agardh
Nitzschia acicularis (Kuetzing) W. Smith
N. agnita Hustedt
N. holsatica Hustedt
N. palea (Kuetzing) W. Smith
N. sublinearis Hustedt
N. spp. Hassall
Rhizosolenia spp. Ehrenberg
Skeletonema potamos (Weber) Hasle
Stephanodiscus spp. Ehrenberg
Synedra acus Kuetzing
S. planktonica Ehrenberg
S. rumpens Kuetzing
S. rumpens v. *fragilarioides* Grunow
S. rumpens v. *scotica* Grunow
S. ulna (Nitzsch) Ehrenberg
S. spp. Ehrenberg
Tabellaria fenestrata (Lyngby) Kuetzing
T. flocculosa (Roth) Kuetzing
CHRYSOPHYCEAE
Chromulina spp. Cienkowski
Chrysosphaerella solitaria Preisig and Takahashi
Dinobryon bavaricum Imhof
D. cylindricum Imhof
D. sertularia Ehrenberg
D. spp. Ehrenberg
Erkenia subaequiciliata Skuja
Kephyrion rubi-klaustri Conrad
Mallomonas pseudocoronata Prescott
M. tonsurata Teiling
M. spp. Perty
Ochromonas spp. Wyssotzki
Rhizochrysis spp. Pascher
Stelexomonas dichotoma Lackey
Synura spinosa Korshikov
S. uvella Ehrenberg
S. spp Ehrenberg
Uroglenopsis americana (Calk) Lemmerman
HAPTOPHYCEAE
Chrysochromulina parva Lackey
XANTHOPHYCEAE
Dichotomococcus spp. Korshikpv
CRYPTOPHYCEAE
Cryptomonas erosa Ehrenberg
C. ovata Ehrenberg
C. reflexa Skuja
Rhodomonas minuta Skuja
MYXOPHYCEAE
Agmenellum quadriduplicatum Brebisson
Anabaena wisconsinense Prescott
A. spp. Bory
Chroococcus limneticus Lemmerman
C. minor Kuetzing
C. spp. Neageli
Coelosphaerium kuetzingianum Naegeli
Gomphosphearia lacustris Chodat
* *Lyngbya limnetica* Lemmermann
Lyngbya spp. Agardh
Microcystis aeruginosa Kuetzing
Oscillatoria geminata Meneghini
O. limnetica Lemmerman
O. spp. Vaucher
Phormidium spp. Kuetzing
Raphidiopsis curvata Fritsch & Rich
* *Synechococcus lineare* (Sch. et Lauterb.) Komarek
EUGLENOPHYCEAE
* *Euglena acus* Ehrenberg
E. spp. Ehrenberg
Lepocinclus spp. Perty
Trachelomonas acanthostoma (Stokes) Deflandre
T. pulcherrima Playfair
T. volvocina Ehrenberg
T. spp. Ehrenberg
DINOPHYCEAE
Ceratium hirundinella (Mueller) Schrank
Glenodinium borgei (Lemmerman) Schiller
G. palustre Schilling
G. quadridens (Stein) Schiller
Gymnodinium spp. Stein
Peridinium aciculiferum Lemmerman
P. inconspicuum Lemmerman
P. pusillum (Pennard) Lemmerman
P. wisconsinense Eddy
* Unidentified dinoflagellates
CHLOROMONADOPHYCEAE
Gonyostomum depressum (Lauterborne) Lemmerman
G. latum Iwanoff
G. spp. Deising
Unidentified flagellates

Table 3. Total densities (units/ml) and percent composition of major taxa (>5%) of phytoplankton collected at locations in Lake Norman, NC during February, May, August and November of 1990.

	Locations									
	2.0		5.0		9.5		11.0		15.9	
Taxon	units/ml	%	units/ml	%	units/ml	%	units/ml	%	units/ml	%
FEBRUARY										
Ank. falcatus v. mir.					77	5.5				
Ank. spiralis	94	5.7	142	7.6	77	5.5				
Coccoid greens	151	9.2	150	8.0	167	12.0				
Melosira ambigua	90	5.5			122	8.8	969	28.4	452	18.8
Mel. distans v. alp.	134	8.2								
Melosira spp.	187	11.4	171	9.1	78	5.6	545	16.0	159	6.6
Rhizosolenia eriensis					90	6.4				
Stephanodiscus spp.							208	6.1		
Synura uvella									130	5.4
Chrysochrom. parva	94	5.7	183	9.8	126	9.1				
Cryptomonas erosa	98	6.0							281	11.7
Rhodomonas minuta	358	21.9	456	24.3	273	19.6	700	20.5	765	31.8
MAY										
Ank. falcatus v. mir.			228	10.2	220	8.1	183	6.5		
Micractinium pusillum	126	5.4	167	7.5	330	12.1	171	6.1		
Attheya zachariasi	138	6.0	151	6.8	155	5.7				
Fragilaria crotonensis									167	5.8
Melosira ambigua			122	5.5						
Melosira distans	220	9.5	122	5.5	138	5.1	183	6.5		
Synedra spp.	139	6.0					228	8.1	501	17.4
Unid. chrysophytes			122	5.5	269	9.9	220	7.8	281	9.8
Chrysochrom. parva	142	6.1	146	6.6	253	9.3				
Cryptomonas erosa										
Rhodomonas minuta	395	17.0	350	15.7	399	14.6	729	25.9	765	26.6
AUGUST										
Cosmarium asphaerosporum v. stri	118	6.0	81	6.9						
Coccoid greens	269	13.7	179	15.3	281	16.8	212	11.0	427	10.7
Rhizosolenia eriensis							110	5.7		
Synedra spp.	118	6.0	90	7.6	98	5.9	126	6.6	212	5.3
Unid. chrysophytes					195	11.7			260	6.5
Cryptomonas erosa	102	5.2			90	5.4	110	5.7	202	5.1
Crypt. phaseolus	98	5.0								
Rhodomonas minuta	154	7.9			90	5.4	175	9.1		
Anabaena spp.					90	5.4			64	1.6
Anacystis incerta					85	5.1	118	6.1	201	5.1
Raphidiopsis curvata									686	17.3
NOVEMBER										
Ank. falcatus v. mir.	110	8.6	171	11.9			126	5.8		
Coccoid greens									126	5.1
Scen. quadricauda	81	6.4					155	7.2	126	5.1
Coccoid greens	73	5.7	98	6.8	126	7.7			175	7.1
Melosira ambigua					211	12.8	123	5.7	73	3.0
Erkenia spp.			134	9.4						
Cryptomonas erosa	73	5.7	102	7.1	90	5.4	159	7.3	224	9.1
Rhodomonas minuta	175	13.7	183	12.8	269	16.3	362	16.8	419	17.1
Gomph. lacustris	65	5.1								

Table 4. Biovolumes (mm^3/m^3) and percent composition of major taxa (>5%) of phytoplankton collected at locations in Lake Norman, NC during February, May, August and November 1990.

	Locations									
	2.0		5.0		9.5		11.0		15.9	
Taxon	mm/m3	%	mm/m3	%	mm/m3	%	mm/m3	%	mm/m3	%
FEBRUARY										
Melosira ambigua	136	21.2	99	17.8	185	27.4	1468	65.4	685	46.1
Mel. distans v. alp.	44	6.8								
Melosira spp.	76	11.9	69	12.5			222	9.9		
Rhizosolenia eriensis					35	5.2				
Synedra spp.			36	6.6						
Mallomonas caudata	87	13.5							69	4.7
Synura uvella	43	6.7	43	7.8			87	3.9	138	9.3
Chrysochrom. parva			[illegible]	7.6						
Cryptomonas erosa	39	6.1							112	7.5
Rhodomonas minuta	38	6.0	49	8.9					82	5.5
Anabaena spp.	36	5.6			45	6.7				
Peridinium inconspicuum	41	6.4	69	12.5	99	14.7				
Peridinium pusillum					87	12.9			156	10.5
MAY										
Attheya zachariasi	264	26.8	280	30.3	295	21.8	179	15.5		
Fragilaria crotonensis									125	15.2
Melosira ambigua			92	9.7	98	7.3	129	11.2		
Melosira distans	56	6.0								
Synedra spp.	73	7.4	52	5.4	69	5.1	120	10.5	265	32.2
Mall. pseudocoronata	72	7.4	57	6.0						
Cryptomonas erosa									44	5.3
Rhodomonas minuta							78	6.8	82	10.0
Anabaena spp.					90	6.7				
Glenodinium gymnodinium	49	5.0			145	10.7	146	12.7		
Per. pusillum					69	5.1				
AUGUST										
Staur. paradoxum	120	8.3	100	13.3						
Staur. manfeldtii v. fluminense	120	8.4	67	8.9						
Attheya zachariasi							70	7.0		
Synedra spp.			47	6.3	52	3.3	67	6.6	112	8.7
Tabellaria fenestrata							53	5.3		
Cryptomonas erosa									80	6.2
Anabaena spp.	207	14.4	54	7.2	198	12.9			142	11.0
Glenodinium quadridens	145	10.0								
Per. wisconsinense	133	9.2					134	13.3		
Peridinium spp.	210	14.6	210	28.1	790	51.3	317	31.5	453	35.1
NOVEMBER										
Attheya zachariasi	70	16.4	70	16.6	54	6.1				
Melosira ambigua	55	13.1	68	16.2	320	35.6	186	24.0	111	16.6
Rhizosolenia eriensis			27	6.4						
Synedra spp.	22	5.1					49	6.4		
Tabellaria fenestrata	40	9.4	44	10.5						
Cryptomonas erosa	29	6.9	40	9.6			63	8.1	89	13.3
Crypt. reflexa									34	5.1
Rhodomonas minuta							39	5.0	45	6.7
Anabaena spp.	27	6.3								
Ceratium hirundinella					196	21.9	65	8.4		
Peridinium spp.							53	6.8		
Phacus tortus	24	5.5								

VI. ZOOPLANKTON

INTRODUCTION

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

1. Describe quarterly patterns of zooplankton standing crops at selected locations on Lake Norman, and
2. Compare zooplankton data collected during this study (February, May, August, and November 1990) with historical data collected during these months.

Previous studies on Lake Norman zooplankton populations have demonstrated a bimodal seasonal distribution with peaks occurring in spring and fall. Considerable spatial and year to year variability has also been observed (Duke Power Company 1976, 1985; Hamme 1982; Menhinick and Jensen 1974).

METHODS AND MATERIALS

Quarterly zooplankton samples were collected at Locations 2.0, 5.0, 9.5, 11.0, and 15.9 (Chapter III, Figure 1). Duplicate 10 m to surface and bottom to surface net tows were taken at these locations on 28 February, 24 May, 31 August, and 2 November 1990. Field and laboratory methods for zooplankton standing crop analysis were reported in Hamme (1982). Zooplankton standing crop data from 1990 were compared primarily with corresponding data from quarterly monitoring in 1989.

RESULTS AND DISCUSSION

Standing Crop

Zooplankton densities in 1990 were generally higher in 10 m to surface samples than among bottom to surface samples except in February when little difference was observed (Table 1; Figure 1). This vertical population stratification was also observed in previous years (DPC 1988, 1989 and 1990) and is probably

related to the ability of zooplankton to maintain their position in the water column in response to the light gradient (Hamme 1982). Zooplankton standing crops in 1990 were generally highest in February and lowest in August. The large population observed uplake in Februay was in contrast to 1989 where highest densities were found in May (Figure 2). However, since the February samples in 1990 were collected at the end of the month, this could be considered an early spring sample which is generally the time of maximum zooplankton standing crops (Hamme 1982). As in 1989, zooplankton standing crops in the surface tows were, in general, greater uplake than downlake (Figure 1).

Zooplankton densities during February, May, August, and November of 1990 were generally within the range of those observed during these months of 1989 and previous years (DPC 1988, 1989, and 1990). Zooplankton densities in the mixing zone (Locations 2.0 and 5.0) in 1990 especially were quite similar to those observed in 1989 (Figure 2). Densities further uplake appeared to be higher in February and May compared with 1989 (Figure 2), especially at Location 11.0 (10 m to surface) in February, which were over three times higher than those observed in 1989 (188,400 no./m^3 and 54.6 no./m^3, respectively). This high density, however, is similar to zooplankton standing crops observed at Location 15.9 in February of 1989. In fact, overall the range of zooplankton densities observed at all locations in 1990 (high of 188,400 no./m^3 at Location 11.0 in February and low of 15,600 no./m^3 at Location 2.0 in August) is very similar to that observed in 1989 (high of 189,600 no./m^3 at Location 15.9 in February and low of 17,500 no./m^3 at Location 11.0 in August).

Community Composition

Fifty-three zooplankton taxa have been identified in samples collected since the Lake Norman Maintenance Monitoring Program was initiated in August 1987 (Table 2). No new zooplankton taxa were identified in samples collected in 1990.

Rotifers generally dominated zooplankton assemblages at all locations during 1990, followed closely in importance by copepods, with cladocerans a distant

third (Table 1; Figure 3). Rotifers dominated zooplankton populations of most samples collected in February and August, whereas copepods dominated most samples collected in May and November. Cladocerans never comprised more than 25% of the total zooplankton density at any location in any month, and were never dominant in 1990. The highest percent composition of rotifers was recorded at Location 15.9 in August, where rotifers accounted for more than 80% of the total densities in both 10 m to surface tows and bottom to surface tows (Figure 2). Hamme (1982) also found that highest rotifer densities generally occurred at uplake locations.

During February 1990, Keratella and Polyarthra were codominant in rotifer populations at all locations with Collotheca also occassionally becoming important. Asplanchna was the dominant rotifer taxon at all locations except 11.0 in May where Synchaeta was more abundant. Keratella and Collotheca were again important rotifers at all locations in May as in February. Conochilus was the dominant rotifer at most locations in August in 1990 as in 1989. It was especially abundant at Location 15.9 where it comprised about 70% of the total zooplankton densities in both 10 m to surface and bottom to surface tows. Asplanchna, Polyarthra, Keratella, and Hexarthra were also important rotifer taxa in August. In November 1990, Keratella and Polyarthra again were codominant rotifers at most locations with Conochilus important at some downlake locations. These taxa were also the most abundant rotifers observed during 1989 and in previous years (DPC 1988, 1989 and 1990)(Hamme 1982).

As in 1989, copepod populations were dominated by immature forms (primarily nauplii and cyclopoid copepodids with some calanoid copepodids) during all sampling periods of 1990. With the exception of Tropocyclops spp. in the bottom to surface tow at Location 5.0 in August, no adult copepod comprised more than 5% of the total zooplankton densities at any time. No distinct spatial trend in copepod abundance was detected for samples collected in 1990. Copepods appeared to be slightly more abundant overall in 1990 compared with 1989 (Figure 2)(DPC 1990).

Bosmina was the most abundant cladoceran observed in samples collected in 1990, just as it had also been in 1989 (DPC 1990) and in previous years (Hamme 1982). Bosmina was especially abundant in February, when it comprised more

than 5% of the total density at all locations, including the high for the year of 21.3% (40,128 no./m³) at Location 11.0. Bosminopsis was an important constituent of cladoceran populations at Location 2.0 in August. Daphnia spp. comprised over 5% of the total density at Location 15.9 in November in both 10 m to surface and bottom to surface samples. Cladoceran densities appeared to be slightly lower in 1990 than 1989 especially in August (Figure 2). No distinct spatial trend in cladoceran abundance was observed in 1990.

SUMMARY

Zooplankton densities, in general, were slightly higher in 10 m to surface samples than in bottom to surface samples in 1990 as in 1989. Total zooplankton standing crops were generally highest in February and, except for Location 15.9, lowest in August. Since the February sampling was done at the end of the month, this could be considered early spring in Lake Norman. Therefore, this seasonal trend was not unlike past studies where zooplankton peaks were often observed in the spring. The overall range of zooplankton densities observed during 1990 was similar to the range observed in 1989.

Rotifers dominated zooplankton standing crops throughout 1990, as they did in 1989, followed closely in importance by copepods. Rotifers were generally dominant at most locations in February and August, and copepods were dominant at most locations in November. Cladocerans were never dominant in 1990. Major rotifer taxa observed in 1990 were Keratella, Polyarthra, and Conochilus. Copepod populations were dominated by immature forms (nauplii and cyclopoid copepodids). As in 1989, Bosmina was the most abundant cladoceran taxa observed at all locations, with Bosminopsis abundant at Location 2.0 in August and Daphnia spp. at Location 15.9 in November. All of the major genera identified during 1990 were also listed as among the most abundant taxa in 1989 and during previous years. Copepod percent composition by month in 1990 was slighty higher than in 1989, while rotifers and cladocerans were lower.

LITERATURE CITED

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

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

Duke Power Company. 1988. Lake Norman Maintenance monitoring program: 1987 Summary.

Duke Power Company. 1989. Lake Norman Maintenance monitoring program: 1988 Summary.

Duke Power Company. 1990. Lake Norman Maintenance monitoring program: 1989 Summary.

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

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

Table 1. Total zooplankton densities (no./m³), densities of major zooplankton taxonomic groups, and percent composition (in parenthesis) of major taxa in 10 m to surface (10-S) and bottom to surface (B-S) net tow samples collected from Lake Norman in 1990.

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
02/28/90	10-S	COPEPODA	18.1 (28.7)	5.8 (18.5)	39.6 (51.8)	47.0 (25.0)	31.2 (16.0)
		CLADOCERA	11.3 (17.8)	3.1 (9.8)	8.5 (11.2)	45.5 (24.1)	6.3 (6.7)
		ROTIFERA	33.8 (53.4)	22.3 (71.7)	28.4 (37.1)	95.9 (50.9)	56.2 (60.1)
		TOTAL	63.2	31.1	76.4	188.4	93.5
	B-S (depth[m] of tow for each location: 2.0=32 5.0=20 9.5=18 11.0=27 15.9=21)	COPEPODA	16.2 (23.6)	5.9 (19.0)	35.4 (27.8)	29.4 (17.2)	16.5 (37.6)
		CLADOCERA	10.4 (15.1)	6.3 (20.2)	9.3 (14.2)	30.8 (18.1)	4.3 (9.7)
		ROTIFERA	42.0 (61.2)	18.9 (60.9)	20.5 (31.4)	110.3 (64.7)	23.2 (52.7)
		TOTAL	68.6	31.0	65.1	170.5	43.9
05/24/90	10-S	COPEPODA	35.4 (62.9)	33.8 (44.8)	25.5 (37.8)	36.5 (48.2)	NS
		CLADOCERA	3.9 (6.9)	3.8 (5.0)	1.8 (2.7)	3.9 (5.1)	NS
		ROTIFERA	17.0 (30.2)	37.8 (50.1)	40.1 (59.5)	35.4 (46.7)	NS
		TOTAL	56.3	75.4	67.4	75.7	NS
	B-S (depth[m] of tow for each location: 2.0=31 5.0=20 9.5=21 11.0=26 15.9=21)	COPEPODA	22.0 (70.0)	31.3 (59.3)	24.5 (51.9)	26.6 (57.4)	NS
		CLADOCERA	3.2 (10.1)	3.0 (5.7)	1.9 (4.1)	3.9 (8.4)	NS
		ROTIFERA	6.3 (19.9)	18.5 (35.0)	20.7 (44.0)	15.8 (34.2)	NS
		TOTAL	31.4	52.8	47.2	46.3	NS

(Continued)

Table 1 (continued)

Date	Sample Type	Taxon	2.0	5.0	9.5	11.0	15.9
			Locations				
08/31/90	10-S	COPEPODA	6.9	8.0	7.6	8.3	9.7
			(25.3)	(17.4)	(23.4)	(19.4)	(9.1)
		CLADOCERA	4.5	2.9	2.1	4.9	1.9
			(16.5)	(8.7)	(8.3)	(11.4)	(1.8)
		ROTIFERA	15.8	22.8	15.4	29.6	94.6
			(58.2)	(67.6)	(61.4)	(69.3)	(89.0)
		TOTAL	27.1	33.7	25.1	42.8	106.3
	B-S	COPEPODA	7.2	11.7	6.9	7.9	10.8
	(depth[m]		(46.3)	(41.3)	(35.6)	(39.5)	(13.2)
	of tow						
	for each	CLADOCERA	1.5	4.0	1.9	2.5	4.4
	location:		(9.4)	(14.3)	(10.0)	(12.8)	(5.4)
	2.0=31						
	5.0=20	ROTIFERA	6.9	12.6	10.6	9.5	66.3
	9.5=21		(44.3)	(44.4)	(54.4)	(47.7)	(81.4)
	11.0=26						
	15.9=21)	TOTAL	15.6	28.4	19.4	19.9	81.5
11/02/90	10-S	COPEPODA	19.5	15.7	23.8	17.3	33.0
			(44.8)	(54.3)	(52.0)	(51.1)	(42.7)
		CLADOCERA	7.7	3.1	5.2	2.2	6.7
			(17.7)	(10.7)	(11.3)	(6.4)	(8.7)
		ROTIFERA	16.3	10.1	16.8	14.4	37.6
			(37.5)	(35.0)	(36.7)	(42.4)	(48.6)
		TOTAL	43.6	28.9	45.8	33.9	77.3
	B-S	COPEPODA	14.4	15.2	20.4	13.7	24.4
	(depth[m]		(55.9)	(54.8)	(49.9)	(46.8)	(58.3)
	of tow						
	for each	CLADOCERA	5.0	2.7	5.9	1.4	4.4
	location:		(19.6)	(9.6)	(14.4)	(4.7)	(10.5)
	2.0=28						
	5.0=19	ROTIFERA	6.3	9.9	14.6	14.2	13.0
	9.5=18		(24.5)	(35.6)	(35.7)	(48.5)	(31.2)
	11.0=24	TOTAL	25.7	27.8	40.8	29.2	41.8
	15.9=21)						

Table 2. Zooplankton taxa identified from samples collected in Lake Norman on August and November 1987 and February, May, August, and November 1988, 1989, and 1990.

COPEPODA

- Cyclops thomasi (S. A. Forbes)
- C. spp. (O. F. Muller)
- Diaptomus bergei Marsh
- D. mississippiensis Marsh
- D. pallidus Herick
- D. spp. Marsh
- Mesocyclops edax (S. A. Forbes)
- M. spp. Sars
- Tropocyclops prasinus (Fischer)
- T. spp. Kiefer
- Calanoid copepodites
- Cyclopoid copepodites
- Nauplii

CLADOCERA

- Bosmina longirostris (O. F. Muller)
- B. spp. Baird
- Bosminopsis deitersi Richard
- Ceriodaphnia spp. Dana
- Daphnia ambigua Scourfield
- D. parvula Fordyce
- D. spp. Muller
- Diaphanosoma spp. Fischer
- Holopedium amazonicum Stingelin
- H. spp. Zaddach
- Leptodora kindtii (Focke)
- Ilyocryptus sordidus (Lieven)
- Sida crystallina O. F. Muller

ROTIFERA

- Anuraeopsis spp. Lauterborn
- Asplanchna spp. Gosse
- Brachionus caudata Barrois and Daday
- B. havanaensis Rousselet
- B. patulus O. F. Muller
- Chromogaster spp. Lauterborn
- Collotheca spp. Harring
- Conochiloides spp. Hlava
- Conochilus unicornis (Rousselet)
- C spp. Hlava
- Gastropus spp. Imhof
- Hexarthra spp. Schmarda
- Kellicotia bostonensis (Rousselet)
- K. spp. Ahlstrom
- Keratella spp. Bory de St. Vincent
- Lecane spp. Nitzsch
- Macrocheatus spp. Perty
- Monostyla stenroosi (Meissener)
- M. spp. Ehrenberg
- Ploeosoma truncatum (Levander)
- P. spp. Herrick
- Polyarthra euryptera (Weirzeijski)
- P. vulgaris Carlin
- P. spp. Ehrenberg
- Ptygura spp. Ehrenberg
- Synchaeta spp. Ehrenberg
- Trichocera capucina (Weireijski)
- T. cylindrica (Imhof)
- T. spp. Lamarck
- Unidentified Bdelloidea

INSECTA

- Chaoborus spp. Lichtenstein

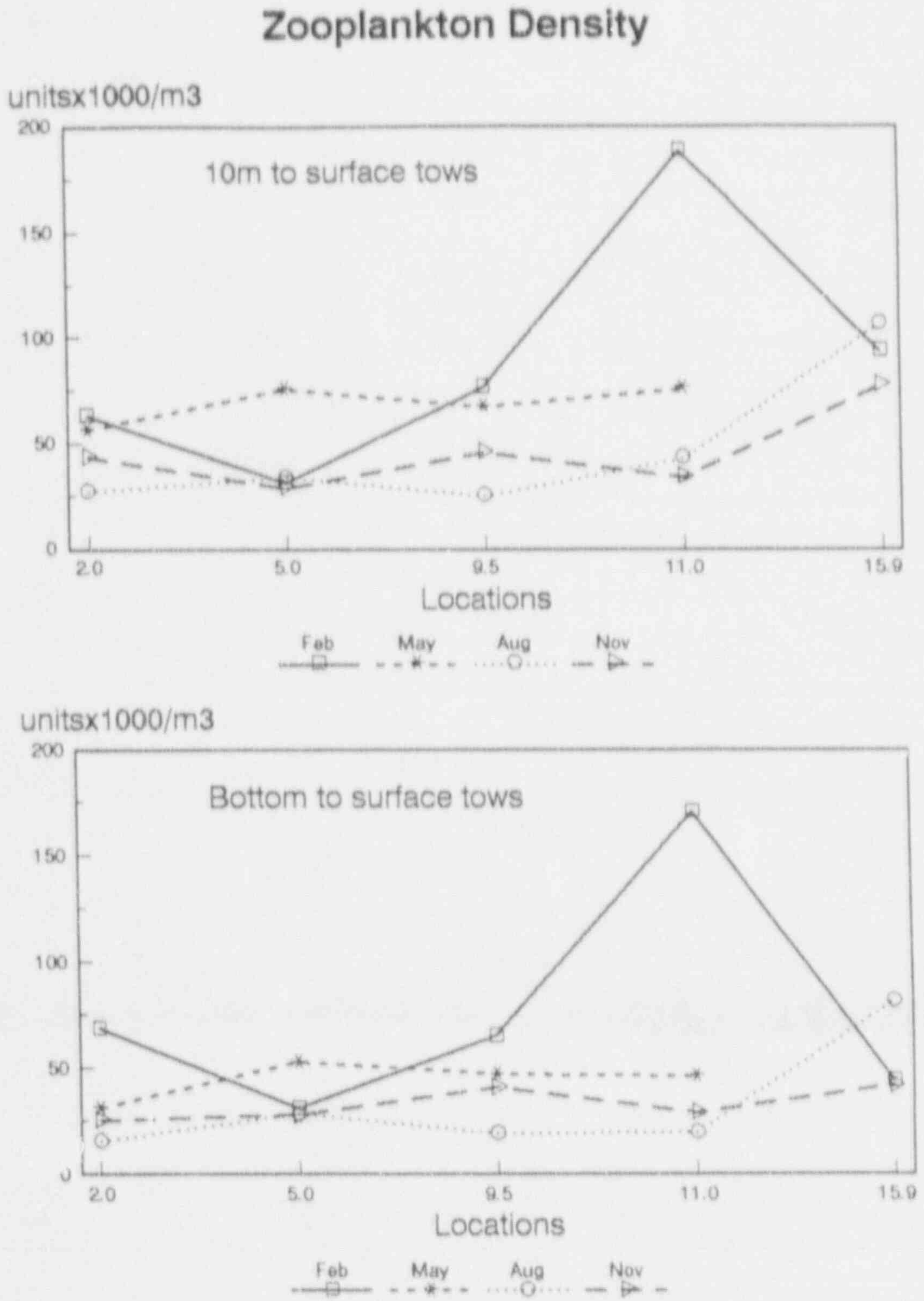


Figure 1. Zooplankton density (units x 1000/m³) by location for samples collected in Lake Norman, NC in 1990.

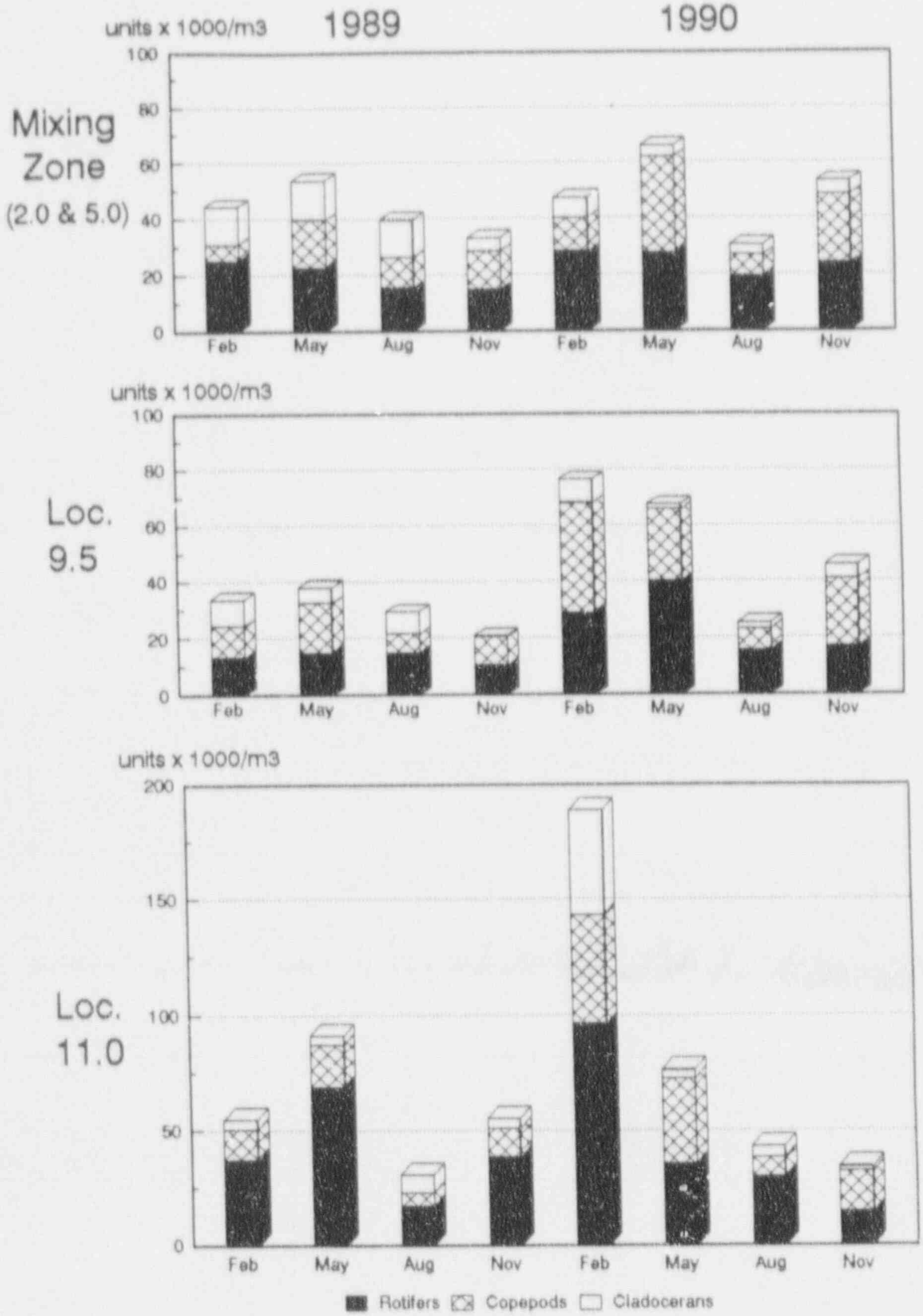


Figure 2. Comparison of zooplankton density and composition in 10 m to surface net tows collected in Lake Norman, NC in 1989 and 1990.

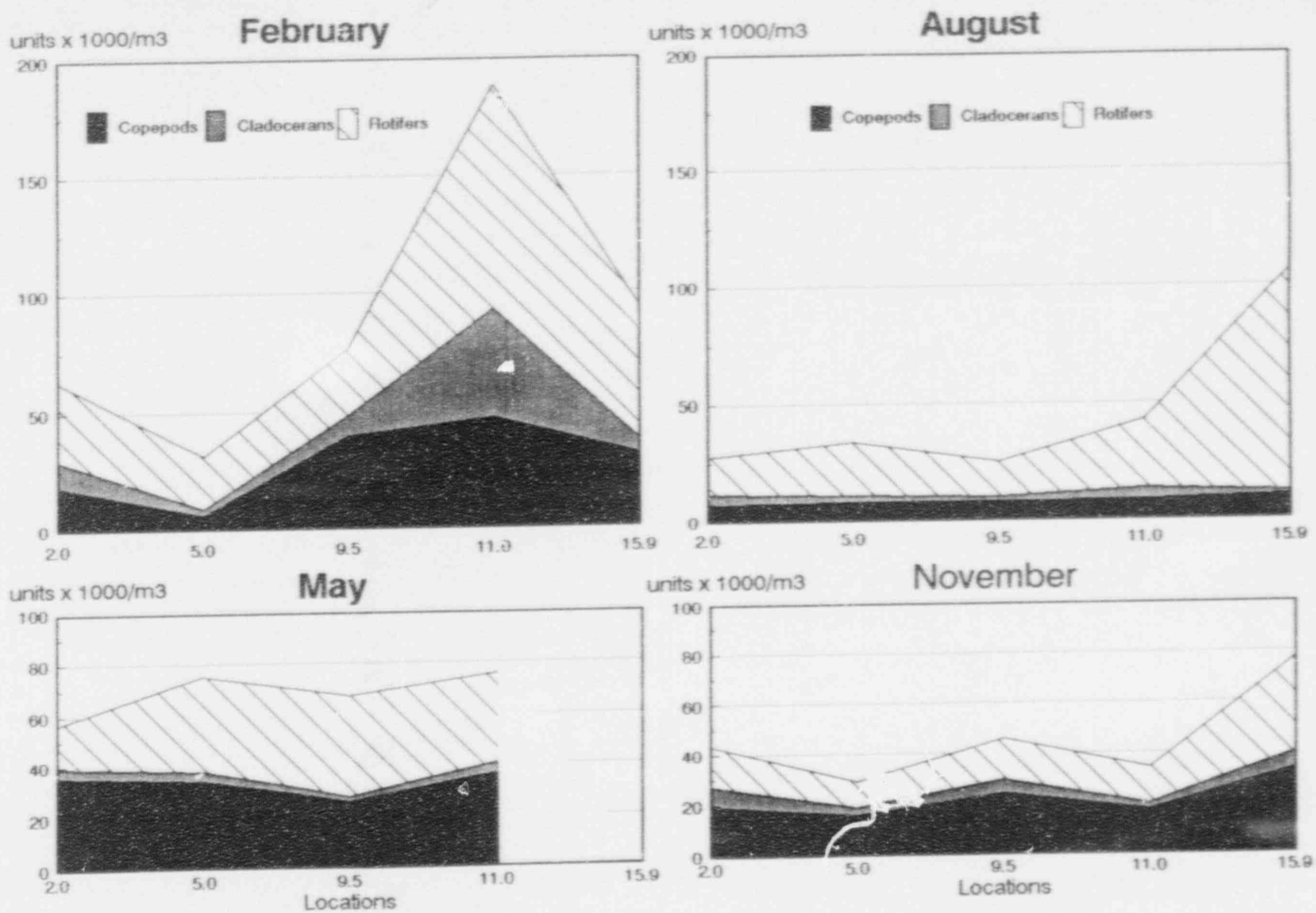


Figure 3. Zooplankton composition by month for 10 m to surface net tows collected in Lake Norman, NC during 1990.

VII. FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters was continued during 1990. The objectives of the fish monitoring program for Lake Norman during 1990 were to:

1. determine taxonomic composition, standing stock, and density of fish at the McGuire Nuclear Station discharge from cove rotenone samples;

2. determine density and distribution of fish with hydroacoustics in the MNS mixing zone when surface water temperatures reached 32, 35, 37, and then returned to 32° C;

3. note any occurrence of fish mortalities near the MNS mixing zone during the summer period; and

4. conduct angler diary surveys of selected striped bass anglers to gather information about striped bass distribution through the summer period.

The primary focus of this report will be to compare data collected in 1990 with data collected during MNS operation with a 35° C discharge limit (1984 through 1989).

MATERIALS AND METHODS

Taxonomic composition, standing stock ($kg \cdot ha^{-1}$), and density ($number \cdot ha^{-1}$) of fish were determined with cove rotenone samples during May and August 1990 at MNS discharge Location 4.0, using methods described in 1989 (Duke Power Company 1990) and (Siler et al. 1982) (Chapter 3, Figure 1).

A 600 ft x 40 ft deep x 1/4 inch mesh purse seine was set in the main channel and near the MNS discharge after sunset in June, August, and

October 1990 to collect limnetic fish. The fish captured with the purse seine were identified to species, counted, and a subsample of 500 were measured (mm, TL).

Density of fish in the limnetic areas of the MNS mixing zone was determined with 120-KHz hydroacoustic gear on 18 June, 16 July, 8 August, and 1 October 1990 after sunset. We sampled in the MNS mixing zone using methods similar to 1988 and 1989 (Duke Power Company 1990). Hydroacoustic samples were collected along transects in the mixing zone for MNS (Figure 1).

The main channel of Lake Norman was searched for dead and moribund fish in conjunction with physicochemical samples during June, July, August, and September. Additional searches for stressed and dead fish were also conducted twice per week in the MNS mixing zone in late June, July, and early August 1990.

The striped bass angler diary program, initiated in 1989 to provide seasonal distribution of striped bass in Lake Norman, catch rates and harvest, and size distribution of angler caught striped bass was continued in 1990.

RESULTS AND DISCUSSION

The fish community, as determined by cove rotenone sampling, at Location 4.0, was similar to 1984 through 1989 cove rotenone species compostions (Duke Power Co., 1990). In 1990, 23 fish species were collected at Location 4.0 (Table 1). Standing stock in May 1990 was similar to August collections from previous years, however, August standing stock declined dramatically to 14.34 kg/ha (Figure 2). This is the lowest we have ever recorded for a Lake Norman cove.

Hydroacoustic density estimates reflected the movement of limnetic fish species away from the MNS discharge when water temperatures exceeded 31° C. Densities were lower near the MNS discharge (transect 4) than at any other area sampled in 1990 (Table 2). Density estimates were highest in the back of Ramsey Creek, and in the main channel on 18 June (Figure 3). By 16 July densities were greatest in the main channel

(Figure 4). Densities at the main channel locations remained highest on 8 August (Figure 5), but by 1 October fish moved closer to the MNS discharge (Figure 6).

Depth distribution of fish was also related to water temperature. During the 18 June sample, the highest fish densities were near the surface where water temperatures were 29° C at transect 9 and 31° C (coolest available water) at transect 4 (MNS discharge)(Figure 7). By the 16 July sample, the highest densities were at 8 meters (26° C) at transect 9 and 10 meters (31° C) at transect 4 (Figure 8). The fish moved deeper as the water temperature increased in August (Figure 9). Limnetic fish returned to the surface by the 1 October sample where water temperatures were 26° C and 29° C at transects 9 and 4, respectively (Figure 10).

Purse seine samples conducted at the time of hydroacoustic data collection in June, August, and October revealed that over 99.6% of the fish in the limnetic region of Lake Norman were threadfin shad (Table 3). The length frequency distribution of purse seined threadfin shad were similar to lengths calculated from hydroacoustic target strengths with Love's dorsal aspect equation (Love, 1971; Figure 11). The mean length of threadfin shad captured in June and October purse seining was greater than hydroacoustics, however, in August they matched well. Hydroacoustics was set to effectively sample all fish greater than 35 mm, but subsampled to 17 mm. The 1/4-inch mesh purse seine effectively samples threadfin shad greater than 50 mm, but we captured threadfin shad 27 mm long. This bias in size selectivity for larger shad by the purse seine was for all samples, but was more evident in June and October.

Eight striped bass were reported caught in the voluntary striped bass angler diary program during the summer (June-August) period, declining from 21 in 1989 (Table 4). No fish were caught in the MNS mixing zone in either year during summer. The striped bass caught in summer 1990 were in the Mountain Creek (Zone 3) and riverine (Zone 6) areas. However, the small number of anglers reporting information does not provide good distribution information about striped bass during the

summer period.

FUTURE STUDIES

*Fish distribution and density in the MNS mixing zone in 1991 using hydroacoustics and purse seine when water temperatures approximate 32, 35, 37, and 32° C to continue to evaluate the change in the discharge temperature limit from 35 to 37.2° C.

*Plan a lakewide creel survey for December 1991 through November 1992 in cooperation with NCWRC to collect striped bass distribution information required for the NPDES permit.

*Continue striped bass mortality monitoring throughout the summer.

SUMMARY

The MNS warmwater discharge does affect the behavior of fish in lower Lake Norman. Rotenone standing stock declined from pre-1984 levels of approximately 140 kg/ha to 74 kg/ha after 1984, and 14 kg/ha in August 1991. This change in the standing stock near the MNS discharge indicates that the fish are avoiding the warmer water in the summer. May 1990 rotenone standing stock was similar to previous MNS operational years, however, littoral fish populations probably selected cooler water away from the MNS discharge in August, thereby, reducing the standing stock in the cove further in August. The hydroacoustic data better shows the movement of fish away from the heated water, when temperatures exceed 31° C. Fish moved to areas in lower Lake Norman where temperatures were below 31° C by moving away from the discharge area, and moving deeper when summer heating of the surface water pushed surface water temperatures above the 26 - 28° C preferred by threadfin shad and other warmwater fish species (Welch and Wojtalik, 1968).

The voluntary angler creel is not providing sufficient information to determine distribution of striped bass in Lake Norman as required by the NPDES permit. A creel survey will need to be implemented in 1991 - 1992 to provide information about the distribution of striped bass throughout the year. This creel survey will be a cooperative study with NCWRC,

will provide information about all species of game fish, will allow comparison of harvest and fishing pressure during MNS operation to pre-MNS operation in 1982, and will provide distribution of striped bass using a larger angler population than is presently available with the voluntary creel.

LITERATURE CITED

Duke Power Company. 1990. Lake Norman: 1989 maintainance monitoring program, McGuire Nuclear Station.

Love, R. H. 1971. Dorsal-aspect target strength on an individual fish. Journal of the Acoustical Sciety of America 49:816-823.

Siler, J.R.; Lewis, R.E.; Baker, B.K.; Vaughan, G.E.; Hansen, R.A. 1982. Chapter 10. Fish. In Hogan, J.E. and W.D. Adair (eds.). Lake Norman Summary. Duke Power Technical Report No. DUKE PWR/82-02. Duke Power Company, Charlotte, NC. 460 p. plus appendices.

Welch, E.B. and T.A. Wojtalik. 1986. Some effects of increased water temperature on aquatic life. TVA, Division of Health and Safety, Water Quality Branch, Chattanooga, TN. 48pp.

Table 1. Standing stock (kg/ha) and density (no/ha) for cove 4.0 in May and August 1990.

	May		August	
Taxa	kg/ha	no/ha	kg/ha	no/ha
Dorosoma cepedianum	4.88	20	0.92	3
Dorosoma petenense	4.19	562	0.42	430
Cyprinus carpio	14.21	10	0.84	1
Notemigonus crysoleucas	0.02	1	0.00	0
Notropis chloristius	0.01	2	0.00	0
Notropis hudsonius	0.00	1	0.00	0
Notropis niveus	0.37	113	0.27	221
Pimephales promelas	0.00	1	0.00	0
Carpiodes cyprinus	18.46	25	0.00	0
Ictalurus catus	2.05	10	0.01	4
Ictalurus punctatus	0.00	0	0.17	6
Plyodictis olivaris	8.73	1	0.12	1
Gambusia affinis	0.00	2	0.00	0
Morone chrysops	0.09	1	0.00	0
Lepomis auritus	3.12	306	2.54	260
Lepomis gibbosus	0.01	1	0.00	0
Lepomis gulosus	0.43	51	0.23	43
Lepomis macrochirus	4.09	610	7.80	1043
Lepomis microlophus	1.48	51	0.14	2
Lepomis hybrid	0.52	35	0.65	16
Micropterus salmoides	5.90	1902	0.23	23
Pomoxis nigromaculatus	2.16	13	0.00	0
Etheostoma olmstedi	0.00	1	0.00	0
Perca flavescens	0.94	101	0.00	0
TOTAL	71.66	3820	14.34	2053

Table 2. Hydroacoustic density estimates (no/ha) by transect.

TRANSECT	18-Jun-90	16-Jul-90	8-Aug-90	1-Oct-90
1	7,217	5,668	3,824	1,843
2	9,634	7,906	5,909	5,836
3	2,990	6,204	6,296	4,531
4	1,081	2,737	3,069	1,466
5	1,603	9,729	8,027	8,615
6	1,562	8,921	7,385	3,962
7	6,446	25,000	11,102	1,813
8	3,702	20,546	9,148	3,664
9	6,163	33,837	10,246	5,369
10	4,949	not sampled	8,952	2,321

Table 3. Fish caught with 600 ft X 40 ft X 1/4 inch mesh purse seine in Lake Norman near McGuire Nuclear Station in 1990.

	DATE				
SPECIES	6/13/90	6/14/90	6/18/90	8/23/90	10/1/90
Dorosoma cepedianum	3	1	2	0	0
Dorosoma petenense	13,489	4,013	17,233	3,210	5,264
Ictalurus furcatus	0	0	2	0	0
Ictalurus punctatus	1	3	1	0	0
Morone chrysops	3	0	3	0	0
Morone saxatilis	0	3	0	0	0
Pomoxis nigromaculatus	2	1	4	5	19

Table 4. Number of striped bass caught by anglers participating in the voluntary creel.

	ZONE							
	1	2	3	4	5	6	8	9
Apr-89	1	3	7	13	25	1	0	0
May-89	0	0	3	2	5	0	1	0
Jun-89	0	0	8	0	4	1	0	1
Jul-89	0	2	1	0	0	1	0	0
Aug-89	0	0	0	0	0	3	0	0
Sep-89	0	0	0	0	0	3	0	0
Oct-89	0	0	0	0	0	0	0	0
Nov-89	0	0	0	0	27	0	0	2
Dec-89	7	0	21	29	31	0	0	0
Jan-90	3	5	0	18	0	0	0	1
Feb-90	0	0	0	10	10	0	0	0
Mar-90	0	0	3	8	8	0	0	0
Apr-90	0	1	3	12	6	0	0	0
May-90	0	0	0	0	1	0	0	0
Jun-90	0	0	0	0	0	0	0	0
Jul-90	0	0	3	0	0	4	0	0
Aug-90	0	0	0	0	0	1	0	0
Sep-90	0	0	0	0	0	0	0	0
Oct-90	0	0	9	0	3	0	0	0
Nov-90	0	0	8	0	34	0	0	0
Dec-90	0	0	0	0	19	0	0	0

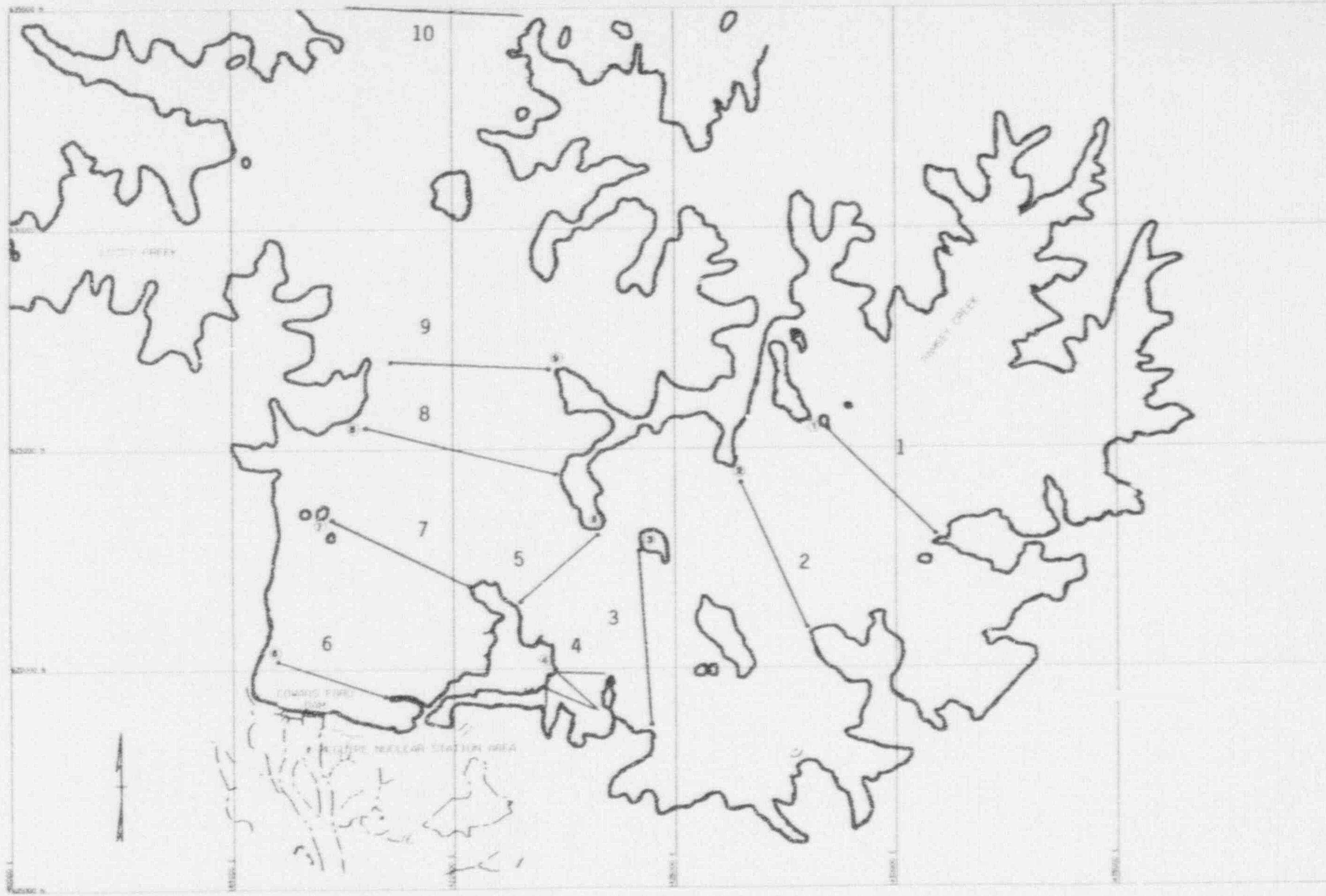


Figure 1. Location of hydroacoustic sampling transects on lower Lake Norman.

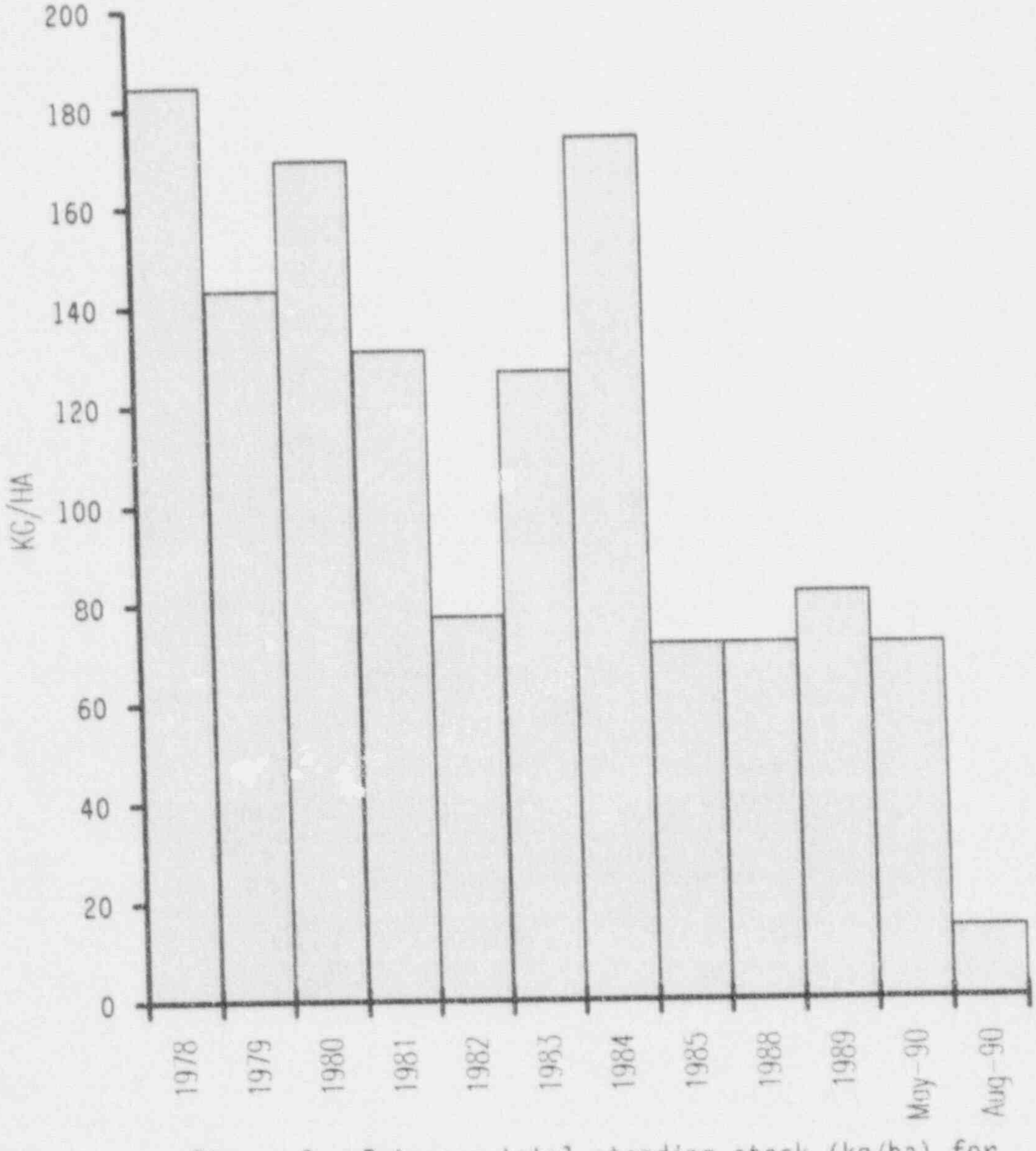


Figure 2. Rotenone total standing stock (kg/ha) for cove 4 near the MNS discharge.

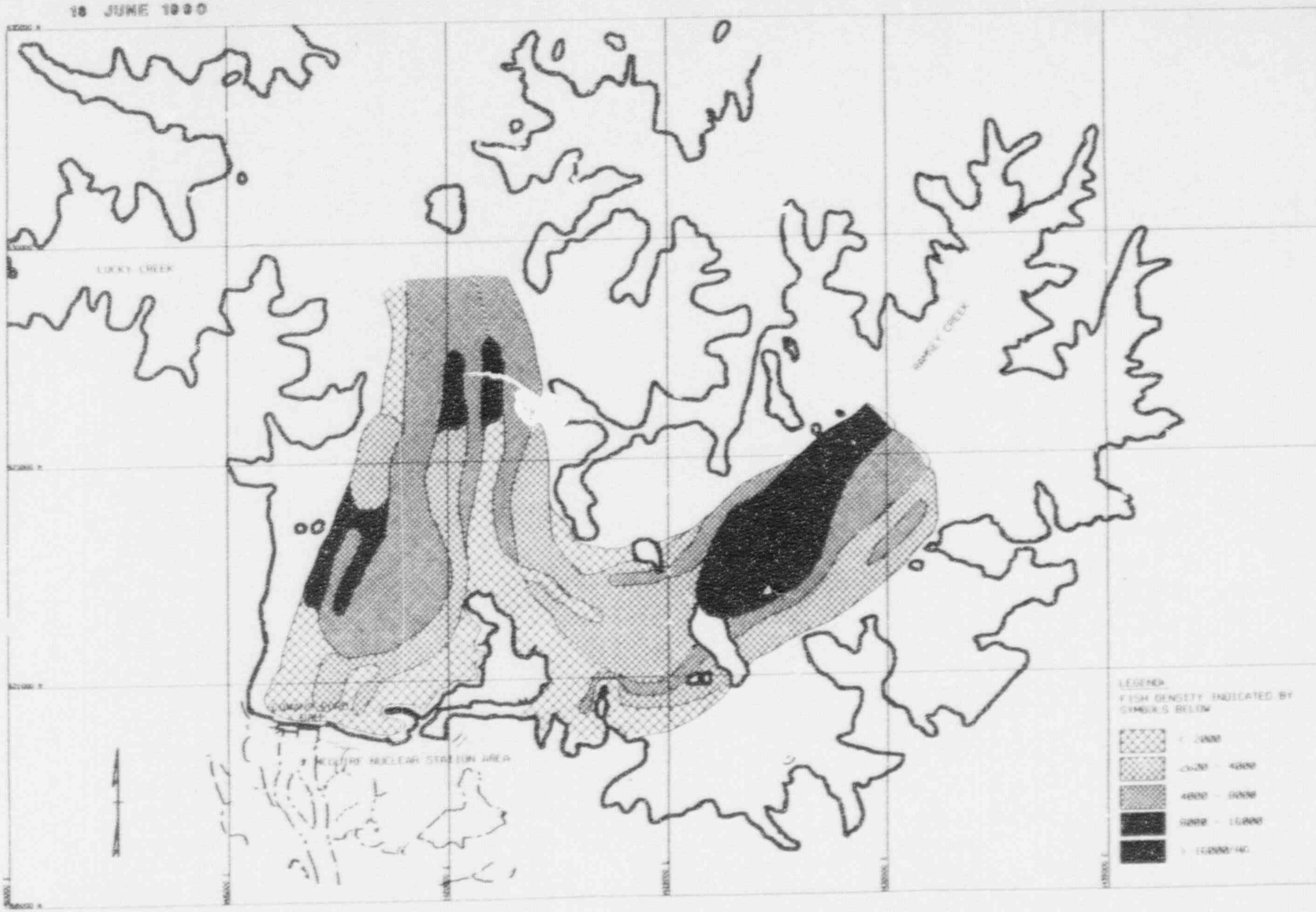


Figure 3. Hydroacoustic estimates of fish density and distribution on 18 June 1990.

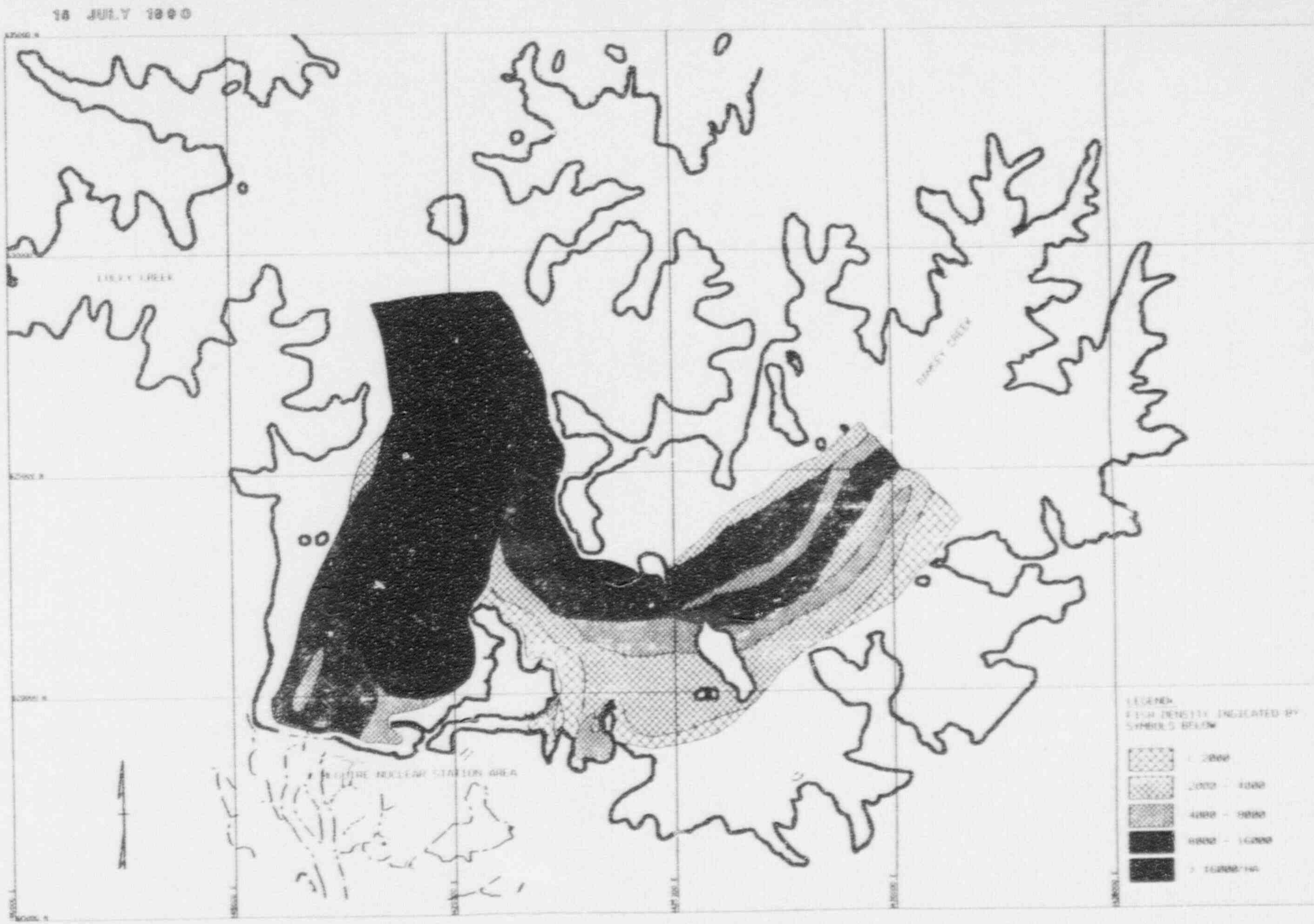


Figure 4. Hydroacoustic estimates of fish density and distribution on 16 July 1990.

8 AUGUST 1990

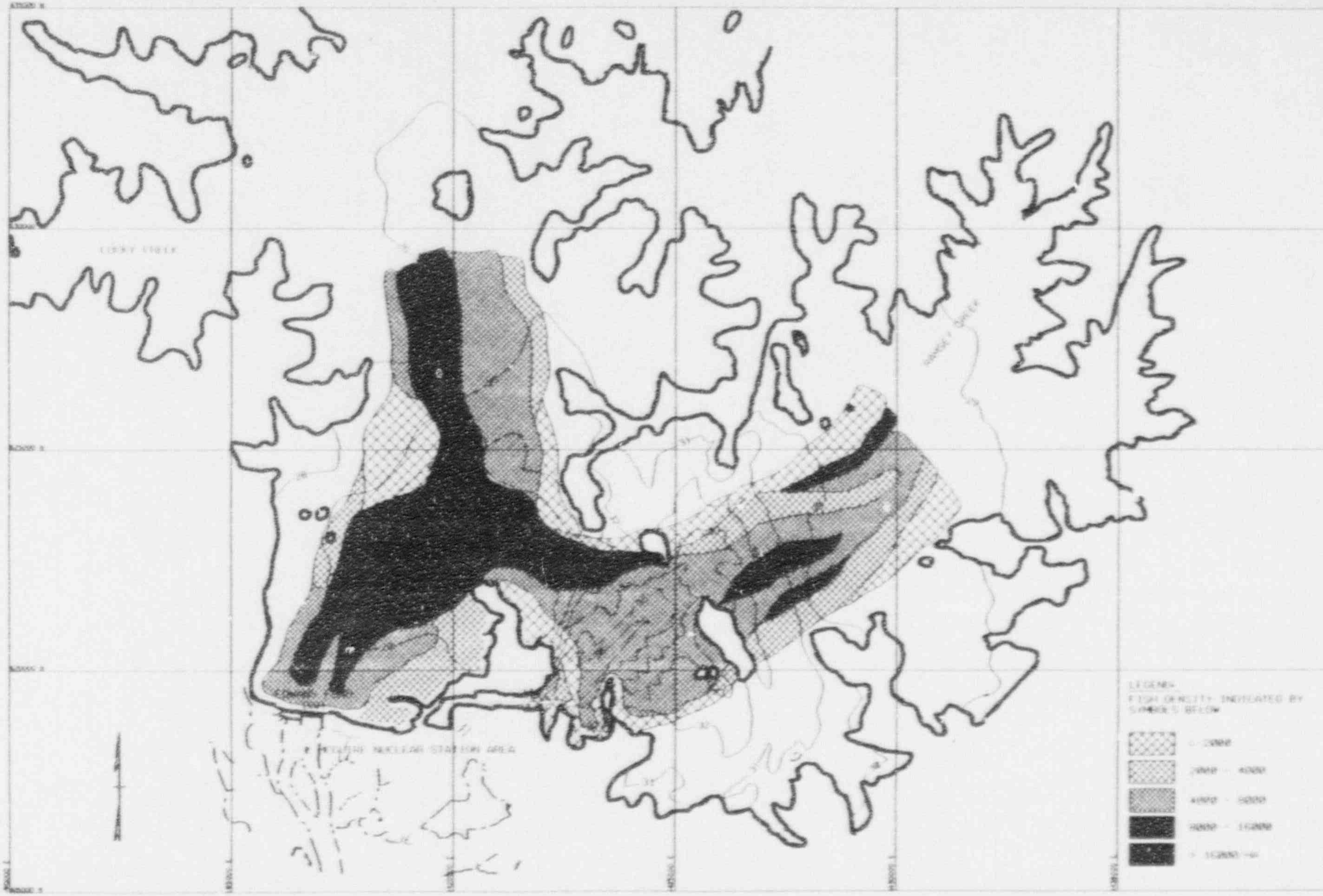


Figure 5. Hydroacoustic estimates of fish density and distribution on 8 August 1990.

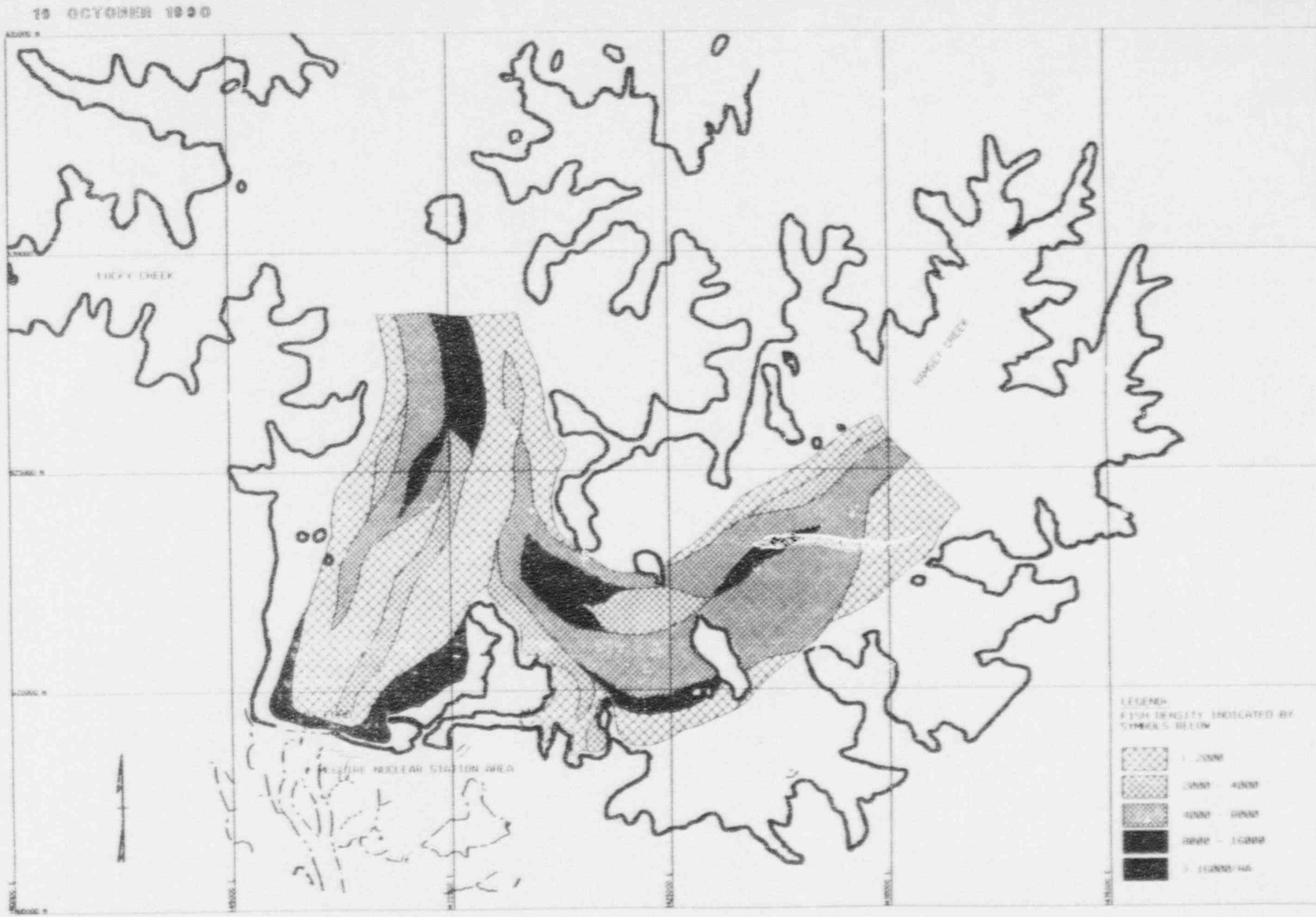


Figure 6. Hydroacoustic estimates of fish density and distribution on 16 October 1990.

Figure 7. Depth distribution of fish near the MNS discharge (transect 4) and in an area with ambient surface water temperatures (transect 9) on 18 June 1990.

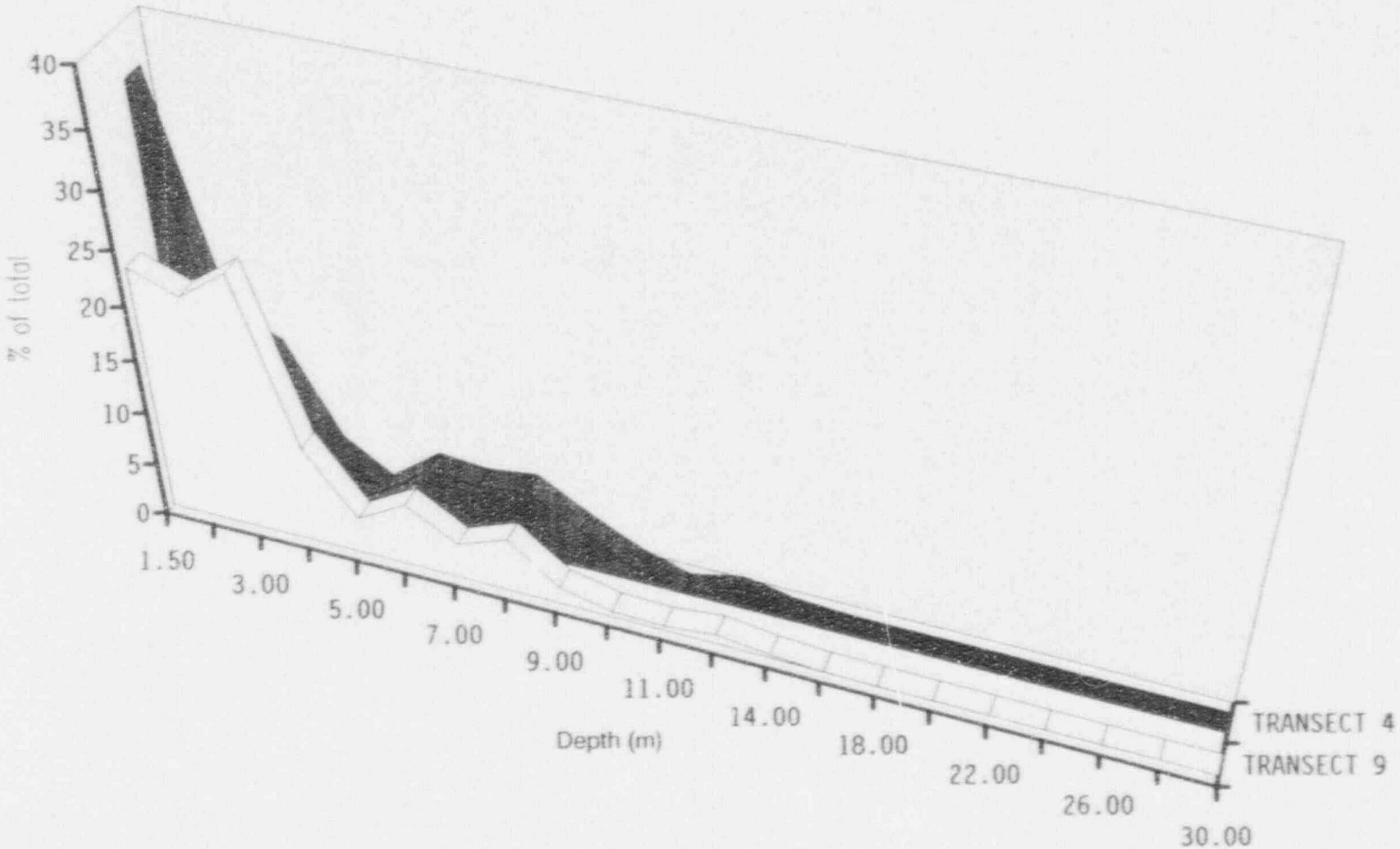
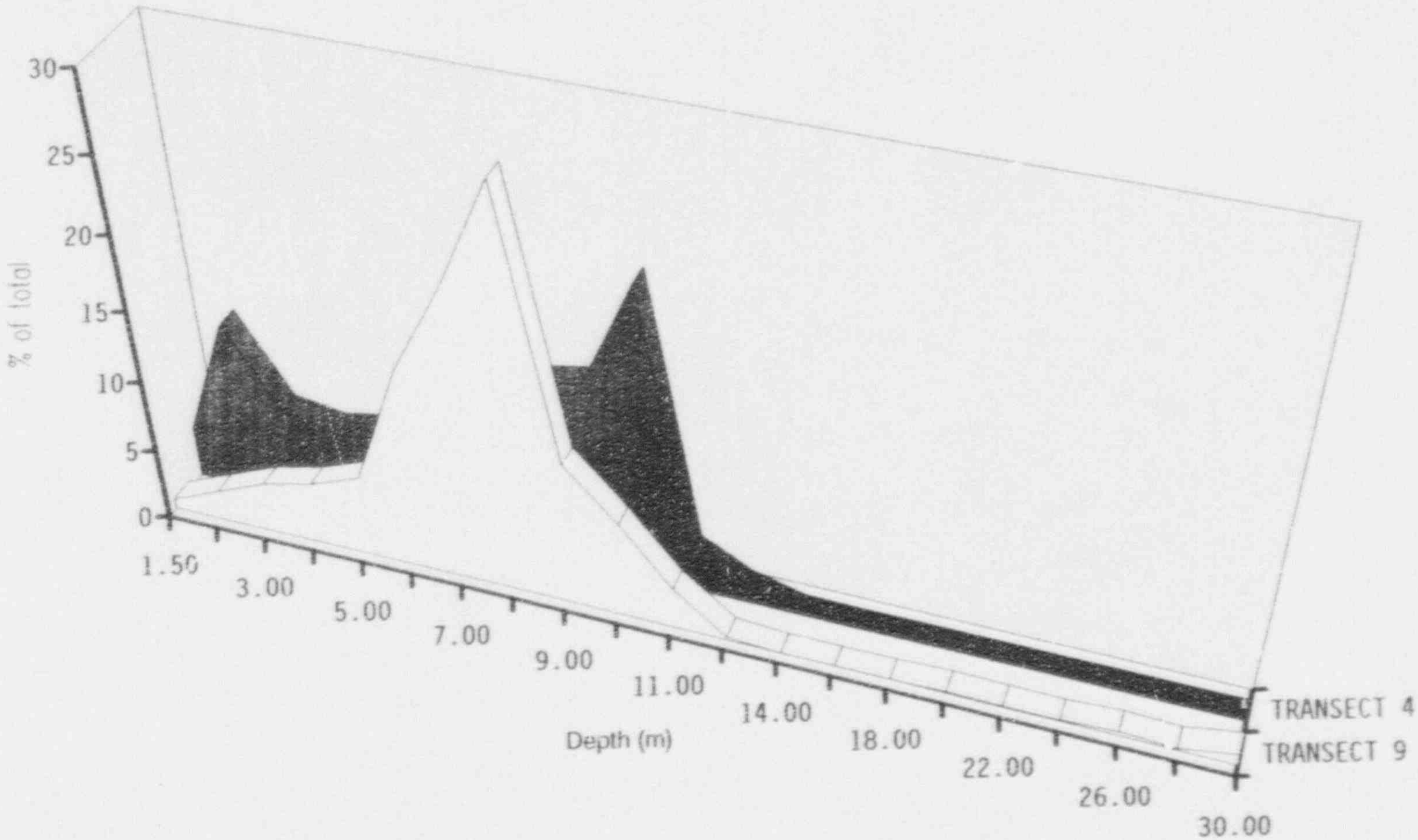


Figure 8. Depth distribution of fish near the MNS discharge (transect 4) and in an area with ambient surface water temperatures (transect 9) on 16 July 1990.



16

Figure 9. Depth distribution of fish near the MNS discharge (transect 4) and in an area with ambient surface water temperatures (transect 9) on 8 August 1990.

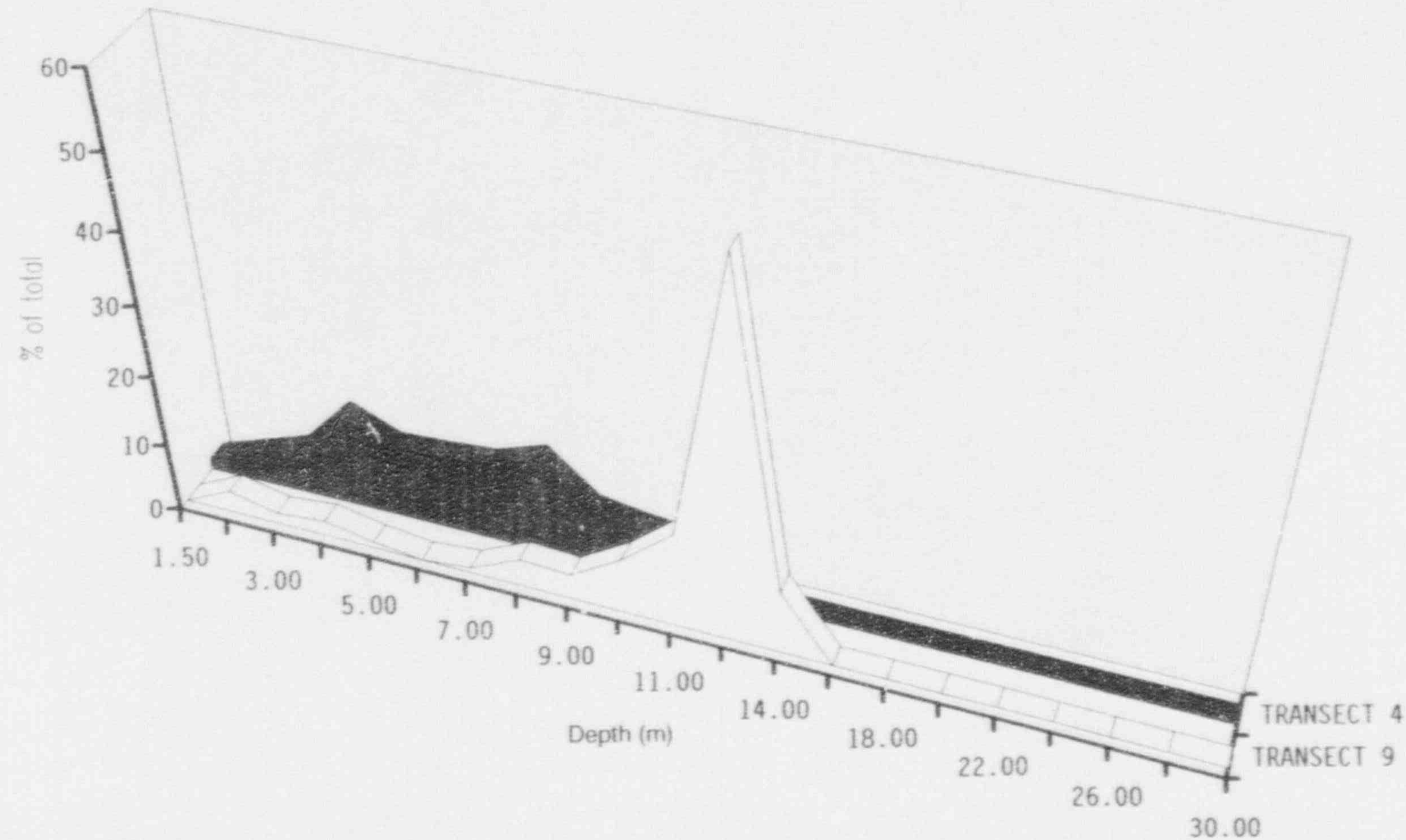
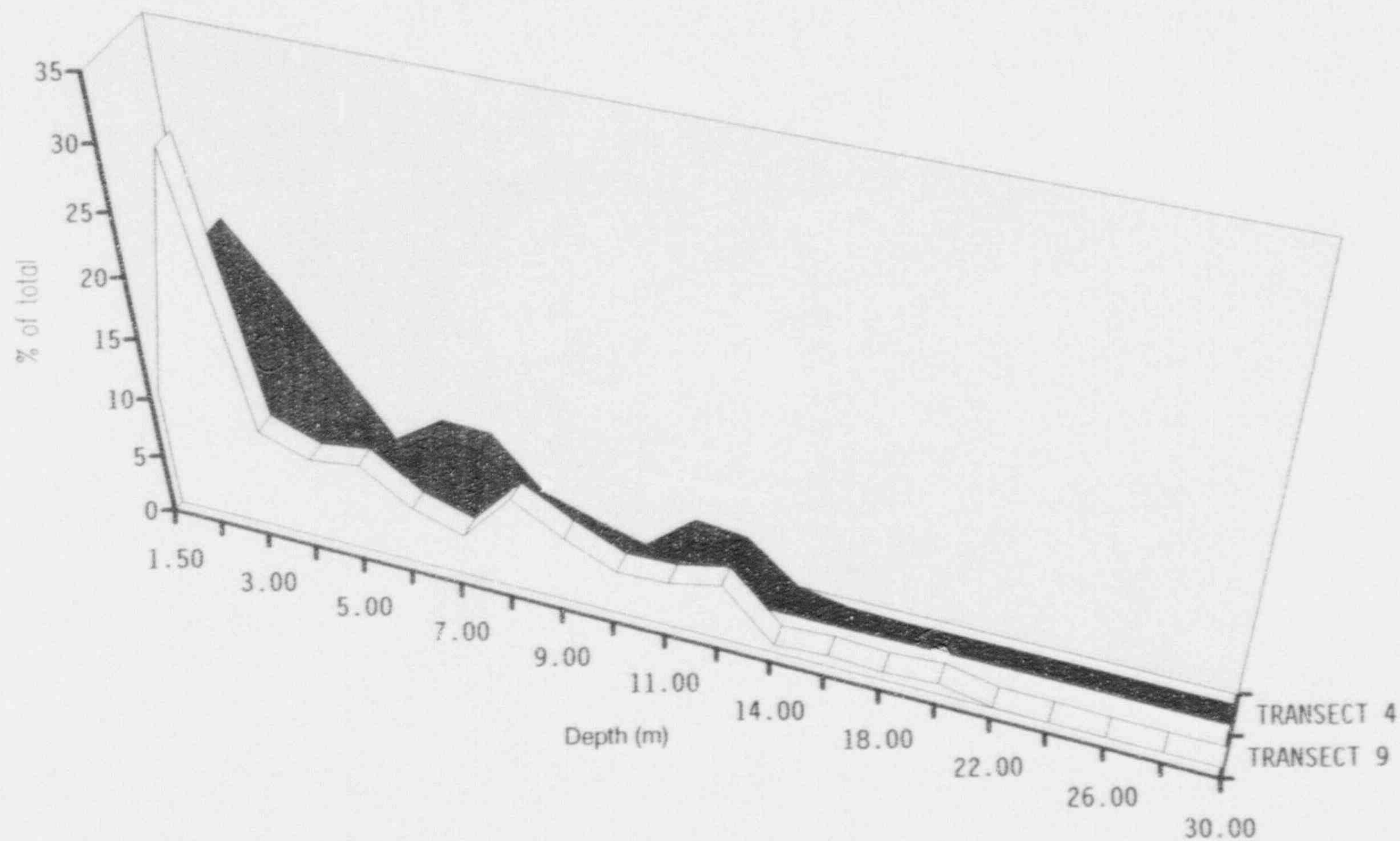


Figure 10. Depth distribution of fish near the MNS discharge (transect 4) and in an area with ambient surface water temperatures (transect 9) on 1 October 1990.



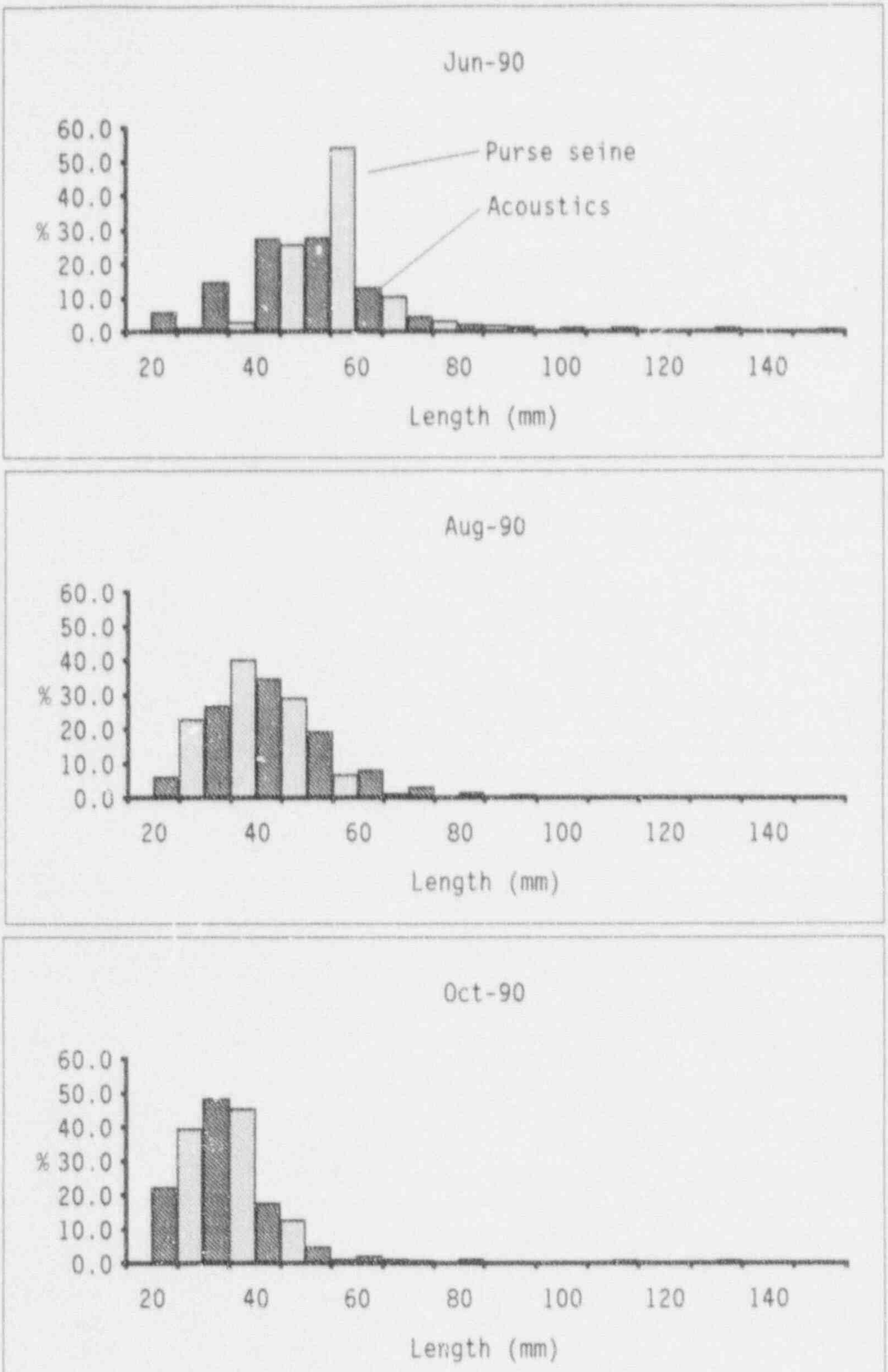


Figure 11. Length frequency distribution for purse seine and hydroacoustics near the MNS discharge.