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Harris Nuclear Power Plant

1993 Environmental Monitoring Report

Environmental Services Section

HARRIS NUCLEAR POWER PLANT
1993 ANNUAL ENVIRONMENTAL MONITORING REPORT

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Environmental Services Section

CAROLINA POWER & LIGHT COMPANY

New Hill, North Carolina

October 1994

Reviewed and Approved by:

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Biological Assessment Unit

Manager
Water & Natural Resources Unit

This report was prepared under my supervision and direction, and I accept full responsibility for its content.

Manager
Environmental Services Section

This copy of the report is not a controlled document as detailed in the *Biological Monitoring Unit, Biological Assessment Unit, and Environmental Assessment Unit Procedures Manual and Quality Assurance Manual*. Any changes made to the original of this report subsequent to the date of issuance can be obtained from:

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Metric-English Conversion and Units of Measure

Length

1 micron (μm) = 4.0 x 10^{-5} inch
1 millimeter (mm) = 1000 m = 0.04 inch
1 centimeter (cm) = 10 mm = 0.4 inch
1 meter (m) = 100 cm = 3.28 feet
1 kilometer (km) = 1000 m = 0.62 mile

Area

1 square meter (m^2) = 10.76 square feet
1 hectare (ha) = 10,000 m^2 = 2.47 acres

Weight

1 microgram (μg) = 10^{-3} mg or 10^{-6} g = 3.5 x 10^{-8} ounce
1 milligram (mg) = 3.5 x 10^{-5} ounce
1 gram (g) = 1000 mg = 0.035 ounce
1 kilogram (kg) = 1000 g = 2.2 pounds
1 metric ton = 1000 kg = 1.1 tons
1 kg/hectare = 0.89 pound/acre

Volume

1 milliliter (ml) = 0.034 fluid ounce
1 liter = 1000 ml = 0.26 gallon
1 cubic meter = 35.3 cubic feet

Temperature

Degrees Celsius (°C) = 5/9 (°F-32)

Specific Conductance

Microsiemens/centimeter = μS/cm = μmhos/cm

Turbidity

NTU = Nephelometric Turbidity Unit

Water Chemistry Abbreviations

Cl^-	Chloride	TOC	Total organic carbon	Cu	Total copper
SO_4^{2-}	Sulfate	TS	Total solids	Hg	Total mercury
Ca^{2+}	Total calcium	TDS	Total dissolved solids	Ni	Total nickel
Mg^{2+}	Total magnesium	TSS	Total suspended solids	Pb	Total lead
Na^+	Total sodium	Al	Total aluminum	Se	Total selenium
TN	Total nitrogen	As	Total arsenic	Zn	Total zinc
NH_3-N	Ammonia nitrogen	Cd	Total cadmium		
TP	Total phosphorus	Cr	Total chromium		

Executive Summary

Harris Lake was constructed by Carolina Power & Light Company to supply cooling tower makeup and auxiliary reservoir makeup water to the Harris Nuclear Power Plant. Prior to commercial operation of the Harris Plant in May 1987, the reservoir was moderately productive. However, the reservoir became more biologically productive when the Harris Plant began discharging, under the auspices of the plant's National Pollutant Discharge Elimination System permit, primarily cooling tower blowdown along with low volume waste discharges into the reservoir near the main dam.

The aquatic monitoring program conducted in 1993 continued to provide an assessment of the effects of the Harris Nuclear Power Plant's operation on the various components of the aquatic environment. Water quality assessments in 1993 determined that nutrient concentrations, as measured by total phosphorus and total nitrogen, seemed to have stabilized but at a level greater than the concentrations observed when the reservoir was first created (early 1980s) and prior to power plant operations (1986-1987). Total phosphorus concentrations have not changed significantly since 1991 and have actually decreased slightly in contrast to concentrations measured during 1990.

Reservoirwide algal biomass estimates have also not changed significantly since 1989. However, algal blooms, although not uncommon in other piedmont reservoirs, now occur at least twice a year in Harris Lake. For the first time in 1993, a summer-time algal bloom was dominated by undesirable and noxious blue-green algae--indicators of elevated nutrient concentrations. However, the bloom did not result in a fish kill. Also for the first time in 1993, a filamentous blue-green algae was observed growing in several coves along the north shoreline of the Buckhorn Creek arm. This species has caused recreational problems in other southeastern reservoirs and the species has the additional characteristic of imparting an unpleasant odor and taste to fish that inhabit areas where it grows.

Concentrations of the major ions decreased slightly in 1993 as compared with the concentrations measured in 1992. Such slight decreases may be reflective of the shorter retention time of water in the reservoir and the frequent discharge of water over the spillway during the November 1992-May 1993 period. Eighty-one percent of the 300 metal and metalloid samples analyzed in 1993 were less than their respective laboratory reporting limit concentrations.

Biofouling by unintentionally introduced nonnative organisms--the Asiatic clam and the aquatic plant hydrilla--did not affect Harris Plant operations. No Asiatic clams were collected from the auxiliary intake canal, the intake structures, or the fire protection system and no zebra mussels were found in the main or the auxiliary reservoirs.

During 1993 the fishery continued to be dominated by several species of sunfish and largemouth bass. However, the electrofishing catch rates of total fish in 1993 decreased by 41%-67% compared with the catch rates during the previous five years. The recruitment and the quality of the fishery of several sport fish were also reduced in 1993. However, the largemouth bass population continued to be considered "balanced" from a fisheries management perspective.

The specific causes for the sportfish recruitment and density declines were unknown but may be an artifact of the reduced sampling frequency or the inability to effectively sample the hydrilla-infested shallow water areas which cover a substantial portion of the near shore zone of the main reservoir.

HARRIS NUCLEAR POWER PLANT
1993 ANNUAL ENVIRONMENTAL MONITORING REPORT

Reservoir Description

The main body of Harris Lake has a surface area of 1680 ha; the auxiliary reservoir has a surface area of 130 ha (Appendix 1). The main reservoir has a maximum depth of 18 m, a mean depth of 5.29 m, a volume of 8.88×10^7 m^3, a full-pool elevation of 67.1 m (220 ft) National Geodetic Vertical Datum (formerly called mean sea level by the U.S. Geological Survey), and an average residence time of 28 months. The reservoir began filling in December 1980, and full-pool elevation was reached in February 1983. The 64.5-km shoreline is mostly wooded, and the 183.89-km^2 drainage area is mostly rolling hills with land used primarily for forestry and agriculture.

Historical Overview

Harris Lake was constructed to supply cooling tower makeup and auxiliary reservoir makeup water to the 900-MW, single-unit Harris Nuclear Power Plant, which began commercial operation in May 1987. In 1986 the bottom waters of the reservoir began receiving National Pollution Discharge Elimination System (NPDES)-permitted wastewater discharges near the main dam. In 1987 macronutrients (as estimated by total phosphorus and total nitrogen concentrations) and ions (as estimated by total chloride and total sulfate concentrations) increased above the previous years' concentrations in the reservoir, particularly at the monitoring station closest to the dam. Concomitantly, an increase in algal biomass (as estimated by chlorophyll *a* concentrations) was also observed throughout much of the reservoir. In May 1989 an algal bloom was observed throughout the reservoir for the first time, and chlorophyll *a* concentrations were measured above the North Carolina water quality standard (40 µg/liter) at each of the four monitoring stations. In 1990 chlorophyll *a* concentrations approached or exceeded the water quality standard on three separate occasions and in 1991 and 1992 on two separate occasions each year.

The increased nutrient loadings from all point and nonpoint sources accelerated the primary productivity of Harris Lake from low/moderate productivity to moderate/high productivity within the period 1986-1989. The nutrient and chlorophyll *a* concentrations between

1989 and 1992 have remained stable but were at greater concentrations than they were when the reservoir was first created and prior to operation of the plant.

The shift in productivity has also resulted in a greater volume of the hypolimnion being oxygen-depleted during the summer months, diurnal fluctuations in the dissolved oxygen concentration in the shallow-water zone during the summer months, and reduced water clarity. In June 1991 a die-off of freshwater mussels occurred, primarily in the Buckhorn Creek and White Oak Creek arms. This die-off was the first reported incident of this type in Harris Lake, and low dissolved oxygen concentrations in the shallow-water zone may have caused the die-off.

Another significant change to the reservoir's benthic invertebrate community since impoundment was the colonization of the reservoir by the Asiatic clam *Corbicula fluminea* in 1984. This nonnative organism has the potential to block power plant pipes and tubes in raw-water systems. Increases in population densities of the clam were not detected until 1988 when samples collected near the two public boat ramps indicated "moderate" densities. Although densities remained at low levels during 1991 and 1992 (based on results from the reservoirwide monitoring program), the presence of shells along the shoreline in many areas has indicated that the clam has continued to spread throughout the main reservoir. The species has yet to colonize the auxiliary reservoir. No clams had been collected from either of the intake structures until 1990 when one individual was collected in the main intake canal.

There have been no incidences of biofouling by the Asiatic clam within the Harris Plant, and operations have not been affected by their presence in the main reservoir. The current standard and widely accepted chlorination practice and schedule and the use of other biocides have been effective solutions to control the species in the plant's circulating water system. Environmental conditions in the plant's fire protection system have not been conducive to the species' survival in that system.

The fishery has been dominated by the sport fishes--bluegill, pumpkinseed, largemouth bass, redear sunfish, and black crappie--and by the prey fish gizzard shad. Earlier studies of the age and growth of largemouth bass in Harris Lake documented slow growth rates during the mid-1980s. However, during 1988 and 1989 and since then, the size distributions shifted towards larger-size bass. This size shift was probably the result of the reservoir's increased primary productivity, the availability of suitable-size forage fish (due to the introduction of threadfin shad by the North Carolina Wildlife Resources Commission (NCWRC) in 1987), and an increased abundance of suitable-size gizzard shad. This shift towards intermediate- to large-size largemouth bass has presented anglers the opportunity for greater fishing success. No detrimental impacts on the fish community from power plant operations have been observed since the Harris Plant became operational.

The aquatic plant hydrilla *Hydrilla verticillata* was initially found in 1988 growing in the White Oak Creek arm. Within a two-year period, this nonnative species had displaced the native species and had become the dominant littoral zone plant species. Since 1990 creeping water primrose *Ludwigia uruguayensis* has also increased its littoral zone coverage in the main reservoir. The auxiliary reservoir, however, has remained relatively free of aquatic vegetation since its impoundment. Despite these shifts in the structure of the aquatic macrophyte community, the community has not impacted Harris Plant operations.

Objectives

The objectives of the 1993 nonradiological environmental monitoring program were 1) to continue to provide an assessment of the effects of the Harris Nuclear Power Plant's operations on the various components of the aquatic environment in Harris Lake, 2) to document any natural changes or changes induced by sources within the reservoir's watershed other than the power plant, and 3) to assess the impact of any introduced nonnative species. These objectives have also been addressed in previous reports (e.g., CP&L 1990, 1991, 1992, 1994).

Methods

The 1993 environmental program included monitoring the limnological characteristics (water quality, chemistry, and phytoplankton [algae]); the Asiatic clam and fish populations; the distribution of aquatic vegetation; and to document the possible introduction of the zebra mussel *Dreissena polymorpha* or the quagga mussel *D. bugensis* (Appendices 2 and 3). Sampling methods in 1993 were similar to those used in 1992 (CP&L 1994). Supporting data summaries, and appropriate statistical analyses were used to describe and interpret the environmental quality of the reservoir (Appendix 4). Key environmental indicators were included when a significant change or abnormal event occurred, an important trend was observed, or the potential for any of these was present. Other data were included as key indicators when there was environmental, public, or regulatory interest.

The accuracy and precision of laboratory analyses of water chemistry data were determined with analytical standards, spikes, and replicates (Appendix 5). Water surface elevations and the raw data collected as part of the limnological monitoring program may be found in Appendices 6-9. In this report where concentrations were less than the laboratory reporting limit, the concentrations were assumed to be at one-half the reporting limit for the calculation of the mean.

[Note: biases introduced by the electrofishing sampling technique against the collection of small fish (i.e., < 65 mm) (Reynolds 1983), the sampling frequency (May and November), and the inability to effectively sample hydrilla-infested areas may have affected the catch rates of many fish, especially small species and small-sized fish, in 1993. For example, the small individuals of the brown bullhead are usually found in dense vegetation whereas young-of-year gizzard shad inhabit open, deep water--two areas not efficiently sampled with the boat electrofisher. Consequently, any conclusions drawn regarding a species recruitment should be interpreted with caution. In addition, the number of fish of many species collected in 1993 was less than the number collected in previous years. Any indices based on percentages should be interpreted with caution and in context to the actual catch rates of the individual species.]

Key Indicators of Environmental Quality During 1993

Limnology

(Appendices 7-18)

Reservoir Elevations

- Daily reservoir water surface elevations ranged from 217.4 to 222.0 ft (66.2-67.7 m) in 1993. As a result of above-normal precipitation during the period October 1992-April 1993, water spillage occurred from early November 1992 through mid-May 1993 (Appendix 6). There was no spillage from the reservoir during the remainder of the year.

Temperature

- Harris Lake is a warm-water, monomictic reservoir. [A monomictic reservoir is defined as a reservoir whose water temperature is not less than 4°C and whose waters circulate freely in the winter but thermally stratify during the summer.] During 1993 surface water minimum temperatures ranged from 7.5° to 8.2°C and maximum temperatures ranged from 30.9° to 31.4°C (Appendix 7). The waters at the deeper stations (E2, H2, and P2) were generally stratified from May through September (except for Station E2 which remained stratified in October) and were freely circulating from January through April and from October through December (Appendices 7 and 10).

Dissolved Oxygen

- A clinograde oxygen curve was observed from April-May through September-November (Appendices 7 and 11). [A clinograde oxygen curve is defined as an abrupt depletion and undersaturation of oxygen with a concomitant increase in depth.] As water temperature increased and a well-defined thermocline developed during the summer, dissolved oxygen concentrations in the hypolimnion (bottom waters) typically decreased to anoxic (where dissolved oxygen concentrations were < 1 mg/liter) conditions (Appendices 7 and 11).

- Depressed percent oxygen saturation levels (< 65%) were observed in the surface waters during October at Stations E2, H2, and P2 and in December at E2. These levels generally coincided with fall turnover when oxygen-depleted bottom waters were circulated to the surface.

Solids, Turbidity, and Water Clarity

- During 1993, as in 1992, there were no overall consistent spatial trends among the surface waters for all indicators and measurements of the optical clarity of the water--solids (total, total dissolved, and total suspended), turbidity, and Secchi disk transparency depth data (Appendix 12). However, the annual mean turbidity and total suspended solids values at the upper reservoir station (Station S2) were significantly greater than the values from the middle and lower reservoir stations (Stations E2 and P2) (Appendix 12). Conversely, the mean Secchi disk transparency depth value at Station S2 was significantly less than at either of these two stations. This inverse relationship was expected due to the tributary inflow and subsequent sediment transport from White Oak Creek, especially in April (Appendix 9), and the inverse relationships between Secchi disk transparency depth and turbidity and total suspended solids.

- There were no significant spatial trends for total solids, total dissolved or total suspended solids during the period 1987-1993 (Appendix 13). As expected, the Secchi disk transparency depth and the turbidity values were spatially inversely related during this seven-year period. However, Secchi disk transparency depth and turbidity were not correlated during the period 1987-1993 (Appendix 14). There were no significant temporal differences in the solids or secchi disk transparency depth data during the period 1987-1993.

Algal Biomass

- Reservoirwide mean chlorophyll *a* concentrations (an algal pigment that is used as an approximate measure of algal biomass) during 1993 ranged from 3.4 to 66.1 μg/liter (Appendices 8, 12, and 15). Annual mean concentrations were significantly greater at Stations E2 and H2 than at Station S2 (Appendix 12). There were no significant spatial differences from 1987 to 1993 (Appendix 13) and the annual mean chlorophyll *a* concentration for Stations E2, H2, and P2 has not changed significantly since 1989 (Appendix 14).

- The mean chlorophyll *a* concentrations for June and July 1993 at Station E2 (40.8 and 66.1 μg/liter) were greater than the North Carolina water quality standard of 40 μg/liter (Appendices 8 and 15) which indicated the occurrences of algal blooms as defined by the NCDEM (1992). During each bloom there was a metalimnetic peak of 69.8 and 175.9 μg/liter, respectively. [A metalimnion is defined as the stratum of steep thermal gradient. During the summer months the metalimnion separates the warmer surface waters (epilimnion) from the colder bottom waters (the hypolimnion).] Occasional chlorophyll *a* concentrations greater than the water quality standard are not an uncommon occurrence in piedmont reservoirs and have occurred periodically in Harris Lake since 1989.

- When the mean chlorophyll *a* concentration at Station E2 was elevated in June, the total algal density (4,570 units/ml) was slightly below the moderate range (5-10,000 units/ml). *Cryptomonas erosa* was the dominant taxon, accounting for approximately 21.5% of the total algal abundance. In July 1993, the total algal density (5,490 units/ml) was in the moderate range and dominated (44.1%) by cyanobacteria (blue-green algae--*Anabaena* spp., *Oscillatoria* spp., *Microcystis* spp., *Gomphosphaeria lacustris*, and *Dactylococcopsis raphidiodes*). This was the first occurrence of an algal bloom in Harris Lake dominated by blue-green algae. The remaining 55.1% of the density was composed of green algae (26.5%), diatoms (14.5%), cryptomonads (11.5%) and euglenoids, dinoflagellates, and chrysophytes (each 1.2%).

Nutrients

- As in 1992, there were no clear spatial differences in mean total phosphorus concentrations during 1993 (Appendix 12). At Station S2, greater concentrations were detected during March and April than during the other months of the year and coincided with the above normal precipitation (and subsequent run-off) received during those months.

- Mean total phosphorus concentrations remained approximately 1.5-1.7 times greater at Station E2 than at either Station H2 or P2 during the 1987-1993 period (Appendix 13). The annual mean concentrations have not changed significantly since 1991 and have actually decreased slightly in contrast to concentrations measured during 1990 (Appendix 14).

Specific Conductance, Ions, and Hardness

- Specific conductance (an estimate of the concentration of the dissolved ions) ranged from 34 to 132 µS/cm throughout the water column during 1993 and increased with depth during the summer months as the reservoir became thermally stratified (Appendix 7). When the bottom waters became increasingly devoid of oxygen during stratification, conditions were favorable for chemical reduction to occur and subsequent dissolution of ions.

- During 1993 specific conductance was significantly greater at the main reservoir stations than at the headwaters Station S2 (Appendix 12). During the period 1987-1993 there were no significant spatial differences. Values decreased approximately one-third between 1992 and 1993 (Appendix 14).

- In 1993 hardness and all concentrations of ions were significantly greater near the dam (Station E2) than at the headwater station (Station S2); concentrations at Stations H2 and P2 were intermediate (Appendix 12). A similar ionic spatial pattern between Stations E2 and P2 was also observed during the period 1987-1993 (Appendix 13). Except for calcium, all ions experienced a very slight decrease in concentrations between 1993 and 1992 (Appendix 14). These decreases may be reflective of the shorter retention time of the water in the reservoir and the frequent discharge over the spillway during the November 1992-May 1993 period (Appendix 6).

Trace Metals and Metalloids

- Excluding mercury and copper, all metal and metalloid concentrations measured in 1993, as in 1992, were less than the respective North Carolina water quality standard or action level (Appendices 9 and 16). Approximately 81% of the analyses were less than the laboratory detection levels.

- All mercury concentrations, except for one sample collected from the bottom waters at Station E2 during March (0.11 µg/liter) were below the laboratory detection level of 0.05 µg/liter (Appendices 9 and 16). The North Carolina water quality standard for mercury is 0.012 µg/liter.

- All copper concentrations during 1993 were less than the North Carolina action level (7 µg/liter), except during May when the concentration in bottom waters at Station E2 was 7.3 µg/liter (Appendices 9 and 16). In 1992 the only sample that was greater than the action level was collected from the bottom waters at Station E2.

- The 1993 annual mean copper concentration was similar to the mean concentrations for 1991 and 1992 and was less than the annual mean concentrations observed for the years 1987-1990 (Appendix 14). There were no significant spatial differences during the period 1987-1993 (Appendix 13).

- There were no significant spatial differences in the annual mean aluminum concentrations during 1993 (Appendix 16). At Station S2 the maximum concentration (1,500 µg/l) occurred during March as it had in 1992 (Appendix 9). There were no significant spatial differences in the concentrations in the surface waters for the period 1987-1993 and there has been no clear change in the annual mean concentration since 1988 (Appendices 13 and 14).

Chemical Constituents from the Bottom Waters at Station E2

- The bottom waters at Station E2 were anoxic (dissolved oxygen < 1 mg/liter) from June through October (Appendices 7 and 11). Under the reducing and anoxic conditions found at the sediment-water interface at this time, concentrations of most chemical constituents (i.e., total alkalinity, hardness, the solids, turbidity, total phosphorus, total nitrogen, ammonia, total organic carbon, total calcium, and total magnesium) increased to a maximum concentration by September (Appendix 9). Sulfate concentrations decreased during the stratification period because the sulfate was reduced to hydrogen sulfide.

- The bottom waters had significantly greater concentrations/values of solids, turbidity, total nitrogen, ammonia, aluminum, and specific conductance than in the surface waters (Appendices 12 and 16).

- There were no significant differences among years (1987-1993) for solids (total, dissolved, and suspended solids), turbidity, nutrients (total nitrogen, nitrate + nitrite-N, ammonia-N, and total phosphorus), total organic carbon, total alkalinity, specific conductance, and metals in the bottom water at Station E2 (Appendix 17). The extreme variability in the concentrations between periods of stratification and periods of uniform mixing throughout the water column was the probable cause for being unable to detect any significant temporal differences in the chemical constituents in the bottom waters.

- There were no evident trends for concentrations of calcium, magnesium, sodium, chloride, or hardness for the period 1987-1993 in the bottom waters at Station E2. Sulfate concentrations have not changed during the past three years and have remained approximately twice the concentrations measured in 1987-1988 (Appendix 17).

Biofouling Monitoring

(Appendix 18)

Asiatic Clam Surveys

- No Asiatic clams *Corbicula fluminea* were collected in the auxiliary or main reservoir's intake canals during April 1993; however, during October one specimen was collected near the intake structure on the main reservoir at Station MI (Appendix 1). The estimated density at this location was 14 clams/m^2. No Asiatic clams were collected in the auxiliary reservoir intake canal, in the intake structures, or in the fire protection system during 1992.

- Asiatic clam shells were qualitatively observed at many locations along the shoreline which indicated that the species has continued to spread throughout the reservoir.

Zebra Mussel and Quagga Mussel Surveys

- Zebra mussels *Dreissena polymorpha* and quagga mussels *D. bugensis*, potentially serious biofouling organisms to power plant operations, were not found in Harris Lake or the auxiliary reservoir.

- Although these species have yet to be reported from North Carolina, they have the potential to colonize the state during the next few years. However, zebra mussels and quagga mussels are not expected to thrive in Harris Lake due to the suboptimal concentrations of alkalinity, calcium, total hardness, and pH (Appendix 18). These variables have been shown to be good indicators for the potential of a body of water to support these two species (Claudi and Mackie 1993).

Fisheries

(Appendices 19-33)

Community Structure (Electrofishing)

- The species composition during 1993 (i.e., 16 species representing 7 families (Appendix 19)) was similar to that observed in previous years. The fish community and sport fishery

- The length-frequency histograms indicated reduced recruitment (i.e., a weak year class) in 1993 in contrast to the levels of recruitment in earlier years (Appendix 30). However, due to the small sample size (n=59), any further interpretation of the species' poor reproductive success in 1993 would be speculative.

- The quality of the largemouth bass fishery was evaluated with the length-frequency index based on world record lengths as previously applied to the bluegill and redear sunfish fishery. The overall quality of the fishery declined in 1993 as measured by this index. The catch rates of stock-length, quality-length, and preferred-length fish all decreased to less than 3 fish/hr (Appendix 24).

- The quality of the largemouth bass fishery was further assessed with two interrelated indicies--Proportional Stock Density (PSD) and Relative Stock Density (RSD). The PSD is a measure of the proportion of quality-size fish (fish ≥ 300 mm) in the population (all fish collected ≥ 200 mm), and the RSD is the proportion of fish of any designated size group in a population (Anderson and Gutreuter 1983). For example, an RSD-380 (i.e., preferred-length) is the proportion of the population that was ≥ 380 mm.

- The PSD of largemouth bass in 1993 continued to be in the optimal range (Appendix 31), indicating that the population contained quality-length fish and was balanced for a moderate density objective (Gabelhouse 1984). [A moderate density objective is defined by Gabelhouse (1984) as where largemouth bass is one of several species of equal importance in a balanced community.] This was opposite the situation which occurred during the period 1983-1987, when the PSD was below the optimal level indicating that the population contained few quality-size fish.

- Since 1989, the RSD-380 of largemouth bass has been in the optimal range for a moderate density objective (Appendix 31). This proportion of the total population was the greatest since impoundment but the index may be biased by the small sample size in 1993.

- During March 1993, 114 anglers participated in a largemouth bass tournament held at Harris Lake. The tournament rules allowed each team to "weigh-in" ten fish. Two of the fish were allowed to be between 12 and 14 inches (305-356 mm) and the eight other fish were required to be ≥ 14 inches. One hundred sixty-eight fish were "weighed-in" during the tournament. This resulted in a tournament weigh-in catch rate of 0.12 fish/angler-hour (Appendix 34). [Note: "tournament weigh-in catch rate" is not synonymous with the term "catch rate" used elsewhere in this report. This term is used by CP&L fishery biologists to conveniently measure the relative success of largemouth bass tournaments.] This value was the second lowest during the past 5 tournaments.

- The length-frequency distribution of "weighed-in" fish during the tournament indicated that a similar number of fish ≥ 356 mm were caught in 1993 as occurred in 1991 and 1992 (Appendix 33). The 1993 length-frequency distribution was similar to that from the 1992 tournament.

Aquatic Vegetation

- During 1993 hydrilla *Hydrilla verticillata* continued to be the dominant species of aquatic vegetation in Harris Lake. This nonnative, submersed plant grew in homogeneous stands throughout the littoral zone (< 3 m deep) except for the Buckhorn Creek arm. The areal coverage and distribution in 1993 (i.e., approximately 433 ha) have remained essentially the same since 1991 (CP&L 1992) and have increased approximately 8 ha since then. Several nonrooted fragments of hydrilla were also observed floating in the auxiliary reservoir during the survey. These occurred near the dam and in the headwaters near U.S. Highway 1. Although hydrilla has colonized 75% of the available habitat in the main reservoir, it has had no impact to the operation of the Harris Plant.

- Lyngbya *Lyngbya wolleii*, a filamentous cyanobacteria (blue-green algae) was observed growing in several coves along the north shoreline of the Buckhorn Creek arm of Harris Lake. This species had not been previously observed in the lake. Similar to hydrilla, it has caused recreational problems in other southeastern reservoirs and has the additional characteristic of imparting an unpleasant odor and taste to fish that inhabit areas where it grows.

- The dominant species of emergent vegetation in the main and auxiliary reservoirs were cat-tail *Typha latifolia*, rush *Juncus effusus*, bulrush *Scirpus cyperinus*, and the emergent form of creeping water primrose *Ludwigia uruguayensis* (which did not occur in the auxiliary reservoir). Creeping water primrose grew along the shoreline of all major arms of the main reservoir, primarily in the coves.

- Floating-leaf vegetation was dominated by creeping water primrose and lotus *Nelumbo lutea*. Lotus was restricted to several stands in the headwater area of the White Oak Creek arm. Water shield *Brasenia schreberi* and water-lily *Nymphaea odorata* also grew in small to moderate areas throughout the main reservoir's littoral zone.

- The auxiliary reservoir also supported small quantities of bushy-pondweed *Najas minor*, spike-rush *Eleocharis* spp., and pondweed *Potamogeton diversifolius*, mostly in the shallow areas near shore. One small patch of water shield occurred near the auxiliary reservoir dam.

Conclusions

The objectives of the 1993 nonradiological environmental monitoring program were 1) to continue to provide an assessment of the effects of the Harris Nuclear Power Plant's operations on the various components of the aquatic environment in Harris Lake, 2) to document any natural changes or changes induced by sources within the reservoir's watershed other than the power plant, and 3) to assess the impact of any introduced nonnative species.

The environmental monitoring programs that were conducted prior to commercial operation of the Harris Plant determined that Harris Lake was a typical southeastern, moderately productive reservoir. After the Harris Plant began discharging cooling tower blowdown and other NPDES-permitted wastewater discharges into the reservoir, the reservoir became more biologically productive. Environmental characteristics of a typical southeastern, biologically productive reservoir include the presence of oxygen-deficient subsurface waters, elevated nutrient and algal concentrations, reduced water clarity, an abundance of rooted shallow-water aquatic plants, and a productive sport fishery--all characteristics of Harris Lake.

Water quality assessments determined that reservoirwide total phosphorus concentrations did not increase during 1993. In fact, concentrations have decreased slightly during the last three years in contrast to concentrations measured during 1989-1990. For the period 1991-1993, concentrations seemed to have stabilized but remain at a level greater than the concentrations observed prior to the operation of the Harris Plant. The concentrations of the major ions (i.e., calcium, magnesium, sodium, chloride, and sulfate) did not continue to increase in 1993 as they had in 1992. Eighty-one percent of the 300 metal and metalloid concentrations analyzed in 1992 was less than the laboratory reporting limit.

Algal blooms, although not uncommon in other piedmont reservoirs, now occur at least twice per year in Harris Lake. For the first time, a summertime algal bloom was dominated by undesirable species of blue-green algae in 1993. However, the bloom did not result in a fish kill. Also for the first time, a filamentous blue-green algae *Lyngbya* with the capability of causing future recreational problems was observed in 1993 growing in several coves in the Buckhorn Creek arm.

Biofouling by the Asiatic clam and the aquatic plant hydrilla did not impact Harris Plant operations. No clams were collected in the auxiliary intake canal, in the intake structures, or in the fire protection system. The zebra mussel and the quagga mussel, other potentially biofouling organisms, were not found in the main or the auxiliary reservoirs.

During 1993 the fishery continued to be dominated by bluegill, redear and pumpkinseed sunfish, and largemouth bass. However, the catch rates of total fish in 1993 had decreased by 41%-67% of the catch rates during the previous five years. Recruitment of several species of sport fish, including largemouth bass, bluegill, and pumpkinseed, was also reduced. The quality of the redear sunfish and the largemouth bass fishery also decreased in 1993. However, the largemouth bass population continued to be considered "balanced" from a fisheries management perspective.

The specific causes for the sportfish recruitment declines were unknown. The appearance of a decline may be an artifact of the reduced sampling frequency (May and November, only). The sportfish population density declines may be related to the inability to effectively sample the hydrilla-infested shallow water areas which cover a substantial portion of the near-shore zone of the main reservoir. Small sample sizes, as was the case in 1993, strongly biased the percentage-based recruitment and size-structured fishery indicies that were applied to the data.

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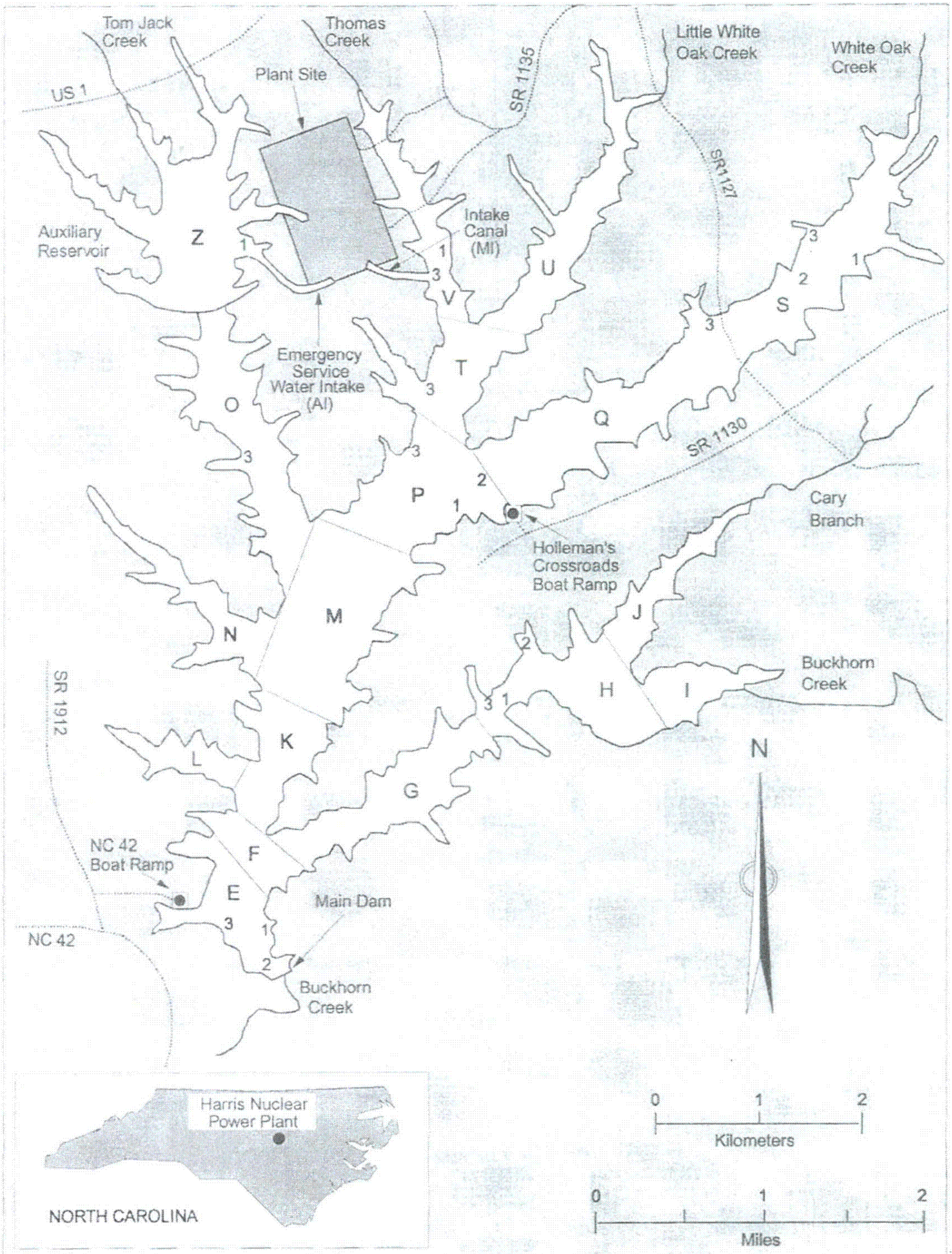


Appendix 1. Sampling areas and stations at Harris Lake during 1993.

Appendix 2. Environmental monitoring program at Harris Lake for 1993.

Program	Frequency	Location
Limnology		
Water quality (temperature, dissolved oxygen, pH, specific conductance, and Secchi disk transparency)	Once per calendar month	E2, H2, P2, and S2 (surface to bottom at 1-m intervals)
Water chemistry		
Monitoring	Alternate months (Jan, Mar, May, Jul, Sep, Nov)	E2 (surface and bottom); H2, P2, and S2 (surface)
Nutrients (turbidity, solids, total phosphorus, ammonia-nitrogen, nitrate + nitrite-nitrogen, and total nitrogen)	Once per calendar month	E2 (surface and bottom); H2, P2, and S2 (surface)
Plankton (phytoplankton and chlorophyll *a*)	Once per calendar month	E2, H2, P2, and S2 (surface, Secchi disk transparency depth, and twice the Secchi disk transparency depth)
Biofouling monitoring		
Asiatic clam surveys	Twice per calendar year (Apr, Oct)	Emergency service water and cooling tower makeup system intake structures and Stations V3, Z1, MI, and AI
Zebra mussel and quagga mussel surveys	Once per calendar month	Intake structure, water quality station buoys, or Holleman's Crossroads boat ramp
Fisheries		
Fish community structure (electrofishing)	Twice per calendar year (May, Nov)	E1, E3, H1, H3, P1, P3, S1, S3, V1, V3
Largemouth bass tournaments	Mar	Holleman's Crossroads boat ramp
Aquatic vegetation		
Survey	Oct	I, E, P, Q, S, V, Z

Appendix 3 (continued)

Program	Method
Biofouling monitoring	
Asiatic clam surveys	At Stations V3, Z1, MI, and AI, three replicate samples were collected with a petite Ponar at the 2-m depth. In the emergency service water and cooling tower makeup intake structures, seven samples were collected with a petite Ponar. Samples were preserved with 5% formalin and returned to the laboratory where they were elutriated through 1000-, 500-, and 300-μ mesh sieves. Asiatic clams were counted, measured, and preserved.
Zebra mussel and quagga mussel surveys	An artificial substrate sampler, constructed of a PVC frame and fitted with removable PVC plates, was placed near the cooling tower makeup intake structure. This sampler, the dock at the Holleman's boat ramp, or the water quality station marker buoys were visually inspected for the presence of mussels during routine water quality or Asiatic clam survey monitoring.
Fisheries	
Community structure (electrofishing)	Fifteen-minute samples were collected at each station using a Smith-Root equipped Wisconsin-design electrofishing boat with pulsed DC current. Fish were weighed, measured, and released.
Largemouth bass tournament	After tournament officials had recorded their necessary measurements, fish were weighed, measured, tagged, and released.
Aquatic vegetation	Portions of the shoreline and/or littoral zone of the lake and auxiliary reservoir were systematically surveyed by boat for the presence of aquatic vegetation. The location and extent of observed species were recorded on maps and in field notes. Estimation of areal coverage of hydrilla was made by measuring the maximum depth of its growth at 49 transects throughout the lake and applying these data to topographic maps.

Appendix 4. Statistical analyses performed on data collected in the 1993 and 1983-1993 environmental monitoring programs at Harris Lake.

Variable	Statistical test/model+	Main effect(s)	Interaction term
For 1993 data only			
Secchi disk transparency depth, specific conductance, selected chemical variables, and chlorophyll *a*¶	One-way ANOVA, block on month	Station	
	Paired t-test at Station E2	Surface *vs.* bottom	
Catch rate of select individual fish species§	One-way ANOVA, block on month	Area	
For 1983-1993 data			
Secchi disk transparency depth, specific conductance, selected chemical variables, and chlorophyll *a*¶	Multi-factor ANOVA, block on month	Station, year	Station-by-year
Catch rate of select individual fish species§	Multi-factor ANOVA, block on month	Area, year	Area-by-year

+A Type I error rate of 5% ($\alpha = 0.05$) was used to judge the significance of all tests. Fisher's protected least significant difference test was applied to determine where differences in means occurred if the overall F test from the analysis of variance (ANOVA) indicated that the main effect was significant.

¶Chlorophyll *a* ANOVA models were structured using the mean station-by-month concentration based on three paired replicate samples.

§Fisheries data were transformed using the $\log_e$ (number of fish/hour + 1) transformation.

Appendix 5. **Mean percent recovery and sample size of water chemistry standards for the CP&L Chemistry Laboratory during 1993.**

Variable	Standard+	Known value	Units	n	Mean	Standard deviation	Recovery (%)	RSD¶ (%)
Chloride	LQC	1.0	mg/L	15	0.9952	0.0512	99.52	5.14
	HQC	2.0	mg/L	15	1.9432	0.0549	97.16	2.83
	Spike	2.0	mg/L	7	1.8604	0.1643	93.02	8.83
Total Phosphorus	LQC	0.005	mg/L	14	0.0054	0.0013	108.00	24.07
	HQC	0.05	mg/L	14	0.0499	0.0038	99.80	7.62
	Spike	0.005	mg/L	4	0.0056	0.0011	112.00	19.64
	Spike	0.0125	mg/L	4	0.0129	0.0011	103.20	8.53
	Spike	0.025	mg/L	4	0.0264	0.0049	105.60	18.56
	Spike	0.05	mg/L	8	0.0555	0.0021	111.00	3.78
Total Nitrogen	LQC	0.2	mg/L	8	0.1999	0.0314	99.95	15.71
	HQC	0.5	mg/L	8	0.4950	0.0449	99.00	9.07
	Spike	0.3	mg/L	4	0.2988	0.0271	99.60	9.07
Sulfate	LQC	2.0	mg/L	13	1.9962	0.0502	99.81	2.51
	HQC	5.0	mg/L	13	4.8005	0.0701	96.01	1.46
	Spike	5.0	mg/L	7	4.6581	0.1671	93.16	3.59
TOC (1)§	QC	6.8	mg/L	3	6.5917	0.1405	96.94	2.13
(2)§	QC	6.79	mg/L	5	6.7080	0.1710	98.79	2.55
(3)§	QC	6.29	mg/L	3	6.1267	0.1832	97.40	2.99
(4)§	QC	9.96	mg/L	1	9.5500	---	95.88	---
Aluminum	LQC	50.0	µg/L	3	47.7333	2.8711	95.47	6.01
	MQC	100.0	µg/L	4	97.7500	5.1881	97.75	5.31
	HQC	500.0	µg/L	4	479.000	25.3903	95.80	5.30
	LQC	22.9	µg/L	2	26.6000	0.1414	116.16	0.53
	Spike	50.0	µg/L	5	50.9000	8.2079	101.80	16.13
	Spike	500.0	µg/L	4	494.750	26.7379	98.95	5.40
Arsenic	LQC	5.0	µg/L	16	5.2125	0.1025	104.25	1.97
	Spike	2.5	µg/L	11	2.5368	0.1173	101.47	4.62
Cadmium	LQC	0.2	µg/L	16	0.1963	0.0141	98.15	7.18
	HQC	0.5	µg/L	16	0.5125	0.0317	102.50	6.19
	Spike	0.2	µg/L	9	0.2178	0.0244	108.90	11.20
	Spike	0.5	µg/L	7	0.5186	0.0348	103.72	6.71
Calcium	LQC	1.0	mg/L	11	0.9975	0.0510	99.75	5.11
	MQC	5.0	mg/L	10	4.9958	0.2691	99.92	5.39
	HQC	10.0	mg/L	8	10.0963	0.4854	100.96	4.81
	Spike	5.0	mg/L	10	4.7545	0.3009	95.09	6.33
Chromium	LQC	5.0	µg/L	10	5.5970	0.2750	111.94	4.91
	HQC	10.0	µg/L	10	10.0610	0.2453	100.61	2.44
	Spike	5.0	µg/L	10	4.9050	0.2580	98.10	5.26
	Spike	10.0	µg/L	9	9.5911	0.3503	95.91	3.65
Copper	LQC	4.46	µg/L	1	5.6900	---	127.58	---
	LQC	5.0	µg/L	4	5.3525	0.0866	107.05	1.62

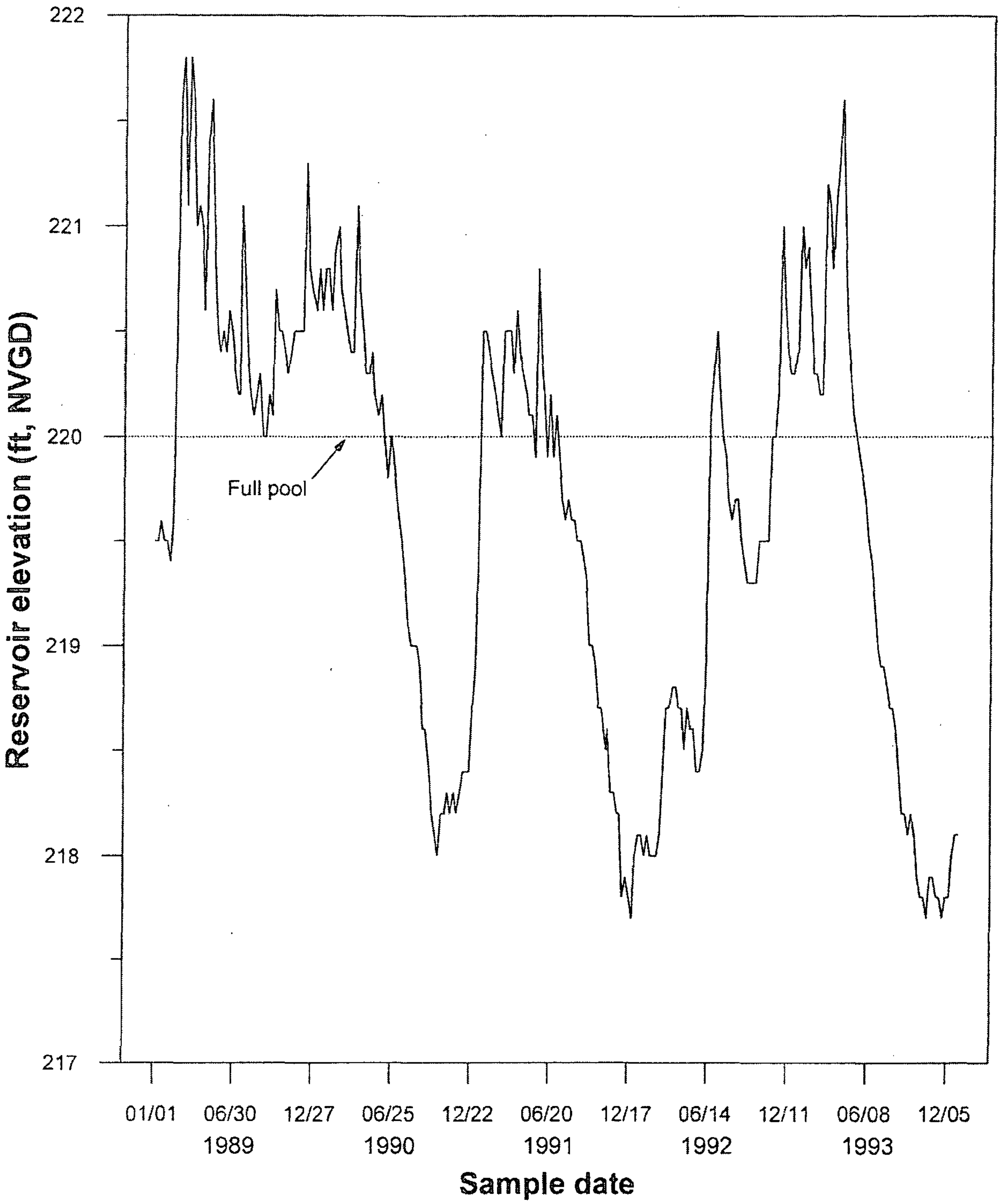
Appendix 5 (continued)

Variable	Standard+	Known value	Units	n	Mean	Standard deviation	Recovery (%)	RSD¶ (%)
Copper	HQC	10.0	µg/L	2	9.9550	0.0354	99.55	0.36
	Spike	5.0	µg/L	2	5.1700	0.5374	103.40	10.39
	Spike	10.0	µg/L	2	10.5950	0.1626	105.95	1.53
Lead	LQC	2.0	µg/L	16	2.0500	0.1725	102.50	8.41
	HQC	5.0	µg/L	16	4.9950	0.2485	99.90	4.97
	Spike	2.0	µg/L	9	1.9956	0.2401	99.78	12.03
	Spike	5.0	µg/L	10	4.7990	0.6052	95.98	12.61
Magnesium	LQC	1.0	mg/L	11	1.0376	0.0368	103.76	3.55
	MQC	5.0	mg/L	10	5.2219	0.1989	104.44	3.81
	HQC	10.0	mg/L	8	10.3700	0.3420	103.70	3.30
	Spike	5.0	mg/L	10	5.0670	0.1817	101.34	3.59
Mercury	LQC	0.10	µg/L	10	0.1052	0.0163	105.20	15.49
	HQC	0.30	µg/L	10	0.2904	0.0482	96.80	16.60
	Spike	0.30	µg/L	4	0.2193	0.0453	73.10	20.66
	Spike	0.60	µg/L	5	0.5922	0.0360	98.70	6.08
Nickel	LQC	10.0	µg/L	11	10.7064	0.5923	107.06	5.53
	HQC	20.0	µg/L	12	20.1458	0.9976	100.73	4.95
	Spike	10.0	µg/L	10	9.9790	0.9356	99.79	9.38
	Spike	20.0	µg/L	8	20.0250	1.6042	100.13	8.01
Selenium	LQC	5.0	µg/L	23	4.8739	0.1738	97.48	3.57
	Spike	2.5	µg/L	11	2.6214	0.1613	104.86	6.15
Sodium	LQC	1.0	mg/L	10	1.0006	0.0154	100.06	1.54
	HQC	2.0	mg/L	10	1.9895	0.0528	99.48	2.65
	Spike	2.0	mg/L	7	1.8586	0.1069	92.93	5.75
Zinc	LQC	0.05	mg/L	7	0.0487	0.0029	97.40	5.95
	MQC	0.10	mg/L	6	0.1020	0.0041	102.00	4.02
	HQC	0.50	mg/L	6	0.5048	0.0140	100.96	2.77
	Spike	0.05	mg/L	8	0.0475	0.0030	95.00	6.32
	Spike	0.10	mg/L	1	0.0990	---	99.00	---

+LQC = low-range quality control standard, MQC = midrange quality control standard, HQC= high-range quality control standard, QC = quality control standard, and Spike = sample matrix spike.

¶RSD = Relative standard deviation = standard deviation ÷ mean x 100.

§There were four different concentrations used for the known values of total organic carbon in the laboratory analyses.



Appendix 6. **Seven-day mean water surface elevations at Harris Lake, 1989-1993. NGVD = National Geodetic Vertical Datum (formerly called mean sea level by the U.S. Geological Survey).**

Appendix 7. Water temperature, dissolved oxygen, specific conductance, and pH data collected from Harris Lake during 1993.

January 6, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance (µS/cm)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	10.2	10.7	9.5	10.5	10.2	10.2	9.8	9.4	72	61	66	53	7.5	6.7	6.7	7.7
1.0	10.1	10.6	9.5	10.2	10.2	10.1	9.7	9.0	72	61	68	53	7.5	6.7	6.7	7.7
2.0	10.0	10.4	9.5	9.0	10.0	10.0	9.8	8.3	71	61	67	53	7.5	6.7	6.7	7.7
3.0	9.8	10.0	9.5	8.8	9.8	9.7	9.8	8.1	71	61	66	53	7.4	6.7	6.7	7.7
4.0	9.6	9.5	9.5		9.6	9.1	9.7		71	60	66		7.3	6.7	6.6	
5.0	9.5	8.9	9.0		9.6	8.6	9.4		71	58	66		7.2	6.7	6.4	
6.0	9.3	8.8	8.7		9.5	8.4	9.1		69	58	65		7.2	6.7	6.7	
7.0	9.0	8.6	8.7		9.1	7.9	9.0		69	57	65		7.2	6.7	6.7	
8.0	8.9		8.6		8.8		8.5		68		64		7.1		6.8	
9.0	8.8				8.8				68				7.1			
10.0	8.7				8.7				68				7.1			
11.0	8.6				8.6				68				7.1			
12.0	8.6				8.6				68				7.1			
13.0	8.6				8.2				68				7.1			

February 1, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance (µS/cm)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	7.9	8.2	7.7	7.5	11.1	10.8	11.4	10.2	58	50	56	44	6.5	6.4	6.7	6.1
1.0	7.9	7.5	7.7	7.5	10.8	10.4	11.0	10.1	59	47	54	46	6.5	6.4	6.7	6.0
2.0	7.9	7.4	7.7	7.5	10.8	10.4	11.0	10.0	58	46	53	45	6.4	6.3	6.6	5.9
3.0	7.9	7.4	7.7	7.4	10.7	10.2	11.0	9.9	58	45	52	45	6.4	6.3	6.6	5.9
4.0	7.9	7.4	7.7		10.6	10.2	11.0		56	45	52		6.4	6.3	6.6	
5.0	7.9	7.4	7.7		10.5	10.1	10.8		57	45	52		6.4	6.3	6.6	
6.0	7.8	7.4	7.7		10.4	10.0	10.8		57	44	52		6.4	6.2	6.6	
7.0	7.8	7.4	7.7		10.4	9.9	10.7		56	44	52		6.4	6.2	6.5	
8.0	7.8		7.7		10.4		10.6		56		51		6.4		6.5	
9.0	7.8				10.4				56				6.4			
10.0	7.8				10.4				55				6.4			
11.0	7.7				10.3				55				6.4			
12.0	7.7				10.2				55				6.4			
13.0	7.6				10.1				55				6.3			

Appendix 7 (continued)

March 9, 1993

Depth (m)	Temperature (°C) E2	H2	P2	S2	Dissolved oxygen (mg/liter) E2	H2	P2	S2	Specific conductance (μS/cm) E2	H2	P2	S2	pH E2	H2	P2	S2
0.2	8.7	9.8	9.4	10.5	11.6	11.2	12.0	9.0	83	63	73	41	7.2	6.9	7.0	6.6
1.0	8.7	9.4	9.4	10.5	11.6	10.8	12.0	8.9	82	62	73	41	7.1	6.9	7.0	6.5
2.0	8.6	9.4	9.3	10.5	11.6	10.7	12.0	9.0	81	63	73	41	7.1	6.9	7.0	6.5
3.0	8.6	9.3	9.3	10.4	11.7	10.6	12.0	9.1	80	62	73	40	7.1	6.8	7.0	6.4
4.0	8.6	9.3	9.2	10.4	11.7	10.5	12.1	9.1	80	62	72	40	7.1	6.8	7.0	6.4
5.0	8.5	9.2	9.2		11.7	10.5	12.1		81	62	72		7.1	6.8	7.0	
6.0	8.5	9.2	9.2		11.7	10.4	12.1		81	61	72		7.1	6.8	7.0	
7.0	8.5	9.1	9.1		11.7	10.3	12.1		80	62	71		7.1	6.8	7.0	
8.0	8.4		9.1		11.6		12.1		79		71		7.1		7.0	
9.0	8.4				11.6				79				7.1			
10.0	8.4				11.6				79				7.1			
11.0	8.3				11.6				79				7.1			
12.0	8.2				11.5				80				7.1			
13.0	8.0				10.8				80				7.0			

April 8, 1993

Depth (m)	Temperature (°C) E2	H2	P2	S2	Dissolved oxygen (mg/liter) E2	H2	P2	S2	Specific conductance (μS/cm) E2	H2	P2	S2	pH E2	H2	P2	S2
0.2	12.8	12.4	11.4	10.1	9.6	9.0	9.6	9.4	67	63	64	35	6.8	6.8	7.0	6.5
1.0	12.8	12.0	11.5	10.2	9.7	8.8	9.6	9.4	67	66	66	35	6.8	6.8	7.0	6.5
2.0	12.7	12.0	11.5	10.2	9.7	8.6	9.5	9.3	68	64	66	35	6.7	6.8	7.0	6.5
3.0	12.7	11.4	11.5	10.2	9.6	8.1	9.5	9.4	68	65	64	35	6.7	6.8	7.0	6.5
4.0	12.5	11.1	11.4	9.5	9.4	8.0	9.4	9.1	68	62	66	34	6.7	6.7	7.0	6.4
5.0	12.3	10.8	11.4	9.4	9.2	7.6	9.3	9.0	68	60	66	34	6.7	6.7	6.9	6.3
6.0	12.0	10.4	11.4	9.4	8.9	7.7	9.2	9.0	68	53	66	34	6.7	6.6	6.9	6.3
7.0	11.9	10.3	11.4		8.9	7.7	9.1		69	50	67		6.7	6.5	6.9	
8.0	11.8		11.0		8.8		8.9		69		68		6.7		6.9	
9.0	11.7		11.0		8.7		8.6		69		68		6.7		6.9	
10.0	11.7				8.7				69				6.7			
11.0	11.6				8.7				69				6.6			
12.0	11.5				8.5				69				6.6			
13.0	11.3				8.3				69				6.6			
14.0	10.2				6.8				73				6.6			

Appendix 7 (continued)

May 11, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance (µS/cm)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	24.7	26.3	25.9	25.8	8.0	6.6	7.6	7.4	68	66	67	61	6.9	7.0	6.6	7.0
1.0	22.2	26.1	25.5	25.2	7.8	7.1	8.1	6.0	71	66	68	60	6.8	6.9	6.6	7.0
2.0	20.7	22.1	24.5	22.6	6.5	6.8	8.1	5.2	69	64	68	61	6.9	7.0	6.6	6.9
3.0	17.9	18.9	21.7	18.0	4.2	6.8	7.3	1.0	70	66	67	73	6.9	7.0	6.6	6.6
4.0	16.5	17.4	17.3	18.0	3.1	3.9	3.6	0.4	76	67	69	73	6.7	7.0	6.6	6.5
5.0	16.1	16.4	16.4		3.3	2.0	3.2		78	69	68		6.5	6.8	6.4	
6.0	15.6	15.9	15.9		3.4	1.6	3.5		76	70	68		6.4	6.6	6.2	
7.0	15.5	15.9	15.5		3.5	1.6	2.7		77	71	70		6.2	6.4	6.2	
8.0	15.3		15.1		3.5		1.8		78		76		6.1		6.1	
9.0	15.2				3.6				78				6.1			
10.0	14.8				3.7				78				6.1			
11.0	14.5				3.6				77				6.1			
12.0	12.8				2.1				77				6.1			
13.0	12.1				1.1				81				6.1			

June 3, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance (µS/cm)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	25.1	25.6	24.2	24.4	9.0	8.6	8.9	8.4	71	71	70	66	8.8	8.7	8.4	7.8
1.0	24.6	25.3	24.2	24.4	9.3	8.6	8.7	8.2	72	71	71	66	8.7	8.8	8.3	7.8
2.0	24.3	24.5	24.1	24.4	8.2	7.8	8.5	7.6	71	70	71	67	8.4	8.4	7.9	7.8
3.0	23.2	22.9	23.9	23.7	5.6	4.5	8.1	0.9	71	71	70	74	8.0	7.9	7.2	7.3
4.0	20.6	22.1	23.1	20.5	1.2	4.8	6.0	0.1	76	72	71	79	7.2	7.5	6.5	7.0
5.0	18.3	19.7	21.1	19.9	0.6	0.2	1.7	0.1	80	77	72	85	7.1	7.1	6.5	6.9
6.0	17.6	19.2	18.1		0.5	0.1	0.1		83	79	77		7.0	6.7	6.5	
7.0	17.3		17.3		0.3		0.1		83		80		6.8		6.6	
8.0	16.8		16.1		0.3		0.1		84		84		6.7		6.6	
9.0	15.9				0.2				83				6.7			
10.0	15.5				0.1				81				6.7			
11.0	15.1				0.1				82				6.4			
12.0	14.3				0.1				82				6.4			
13.0	12.7				0.1				94				6.3			

Appendix 7 (continued)

July 6, 1993

Depth (m)	Temperature (°C) E2	H2	P2	S2	Dissolved oxygen (mg/liter) E2	H2	P2	S2	Specific conductance (μS/cm) E2	H2	P2	S2	pH E2	H2	P2	S2
0.2	31.4	31.1	30.9	31.1	8.5	8.5	8.2	8.5	72	74	75	73	8.2	8.6	8.7	8.7
1.0	29.7	30.9	30.6	30.7	7.8	7.7	8.1	8.1	75	74	75	74	8.0	8.6	8.7	8.7
2.0	28.0	30.3	30.3	29.9	1.9	7.0	7.5	6.1	75	75	75	72	7.5	8.3	8.7	8.3
3.0	26.7	27.6	28.7	27.4	0.3	0.3	4.8	0.6	77	74	74	77	7.0	7.2	8.1	7.5
4.0	25.1	22.7	22.8	26.9	0.2	0.2	0.3	0.1	86	70	92	84	6.8	7.0	7.1	7.1
5.0	22.6	20.1	20.1		0.2	0.2	0.2		99	94	94		6.7	6.7	6.9	
6.0	20.7	19.4	19.4		0.2	0.1	0.1		102	96	93		6.6	6.7	6.6	
7.0	18.4	18.6	18.6		0.2	0.1	0.1		102	97	94		6.5	6.6	6.4	
8.0	17.6	18.0	18.2		0.2	0.1	0.1		98	101	96		6.4	6.6	6.3	
9.0	16.9				0.2				94				6.4			
10.0	16.5				0.1				95				6.5			
11.0	15.8				0.1				95				6.6			
12.0	14.5				0.1				102				6.8			
13.0	13.6				0.1				115				7.0			
14.0	13.2				0.1				123				7.1			
15.0	12.8				0.1				129				7.2			

August 2, 1993

Depth (m)	Temperature (°C) E2	H2	P2	S2	Dissolved oxygen (mg/liter) E2	H2	P2	S2	Specific conductance (μS/cm) E2	H2	P2	S2	pH E2	H2	P2	S2
0.2	29.6	30.2	29.8	29.5	7.3	6.3	6.8	6.9	36	37	38	35	7.2	7.0	7.1	6.9
1.0	29.3	30.2	29.8	29.5	6.6	6.1	6.7	6.5	38	37	38	35	7.1	7.0	7.1	6.9
2.0	28.9	29.6	29.7	29.3	5.4	4.2	6.5	6.3	38	37	38	35	7.2	7.0	7.1	6.9
3.0	27.8	29.3	29.5	28.6	0.8	2.0	6.1	4.5	40	37	37	40	6.7	6.9	7.1	6.8
4.0	25.5	27.8	28.8	28.1	0.2	0.4	1.1	0.4	60	49	37	51	6.4	6.6	7.0	6.6
5.0	22.7	22.5	23.4		0.1	0.2	0.1		77	69	75		6.4	6.4	6.4	
6.0	21.7	20.8	21.4		0.1	0.1	0.1		80	71	70		6.4	6.3	6.4	
7.0	20.3	19.7	20.1		0.1	0.0	0.1		81	81	71		6.4	6.4	6.3	
8.0	19.0		19.2		0.0		0.1		73		78		6.3		6.3	
9.0	18.1				0.0				62				6.3			
10.0	17.3				0.0				56				6.3			
11.0	16.1				0.0				57				6.5			
12.0	15.2				0.0				61				6.8			
13.0	14.2				0.0				79				6.9			
14.0	13.8				0.0				95				6.9			

Appendix 7 (continued)

September 1, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance ($\mu S/cm$)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	30.3	29.7	28.9	28.6	8.1	7.3	7.4	6.6	44	44	40	40	8.1	7.4	6.8	6.9
1.0	29.5	29.4	28.9	28.6	7.7	7.1	7.0	6.1	44	45	40	39	8.1	7.5	6.9	6.9
2.0	29.4	29.1	28.8	28.4	7.3	6.7	6.8	5.7	44	45	41	38	8.0	7.5	6.9	6.9
3.0	29.3	28.6	28.7	28.4	7.3	2.9	6.2	0.2	43	44	41	38	7.8	7.3	6.9	6.8
4.0	26.9	28.3	28.5		0.1	2.1	5.7		49	44	40		7.2	7.1	6.9	
5.0	23.4	27.8	27.1		0.0	2.0	0.2		75	45	41		6.5	6.5	6.5	
6.0	22.7	24.5	23.6		0.0	0.0	0.1		90	83	86		6.5	6.5	6.3	
7.0	21.9	21.9	21.4		0.0	0.0	0.1		95	112	101		6.4	6.4	6.2	
8.0	21.3		20.6		0.0		0.0		94		128		6.4		6.2	
9.0	19.5				0.0				95				6.4			
10.0	18.0				0.0				82				6.3			
11.0	16.8				0.0				74				6.2			
12.0	15.4				0.0				81				6.2			
13.0	14.5				0.0				119				6.8			
14.0	14.0				0.0				138				6.9			

October 7, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance ($\mu S/cm$)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	22.0	21.6	21.4	20.1	5.7	5.0	5.6	8.3	89	89	87	80	6.7	6.9	6.5	6.9
1.0	22.0	21.6	21.5	20.1	5.2	4.6	5.5	8.1	91	89	89	80	6.7	6.9	6.5	6.9
2.0	22.0	21.6	21.4	20.0	5.1	4.5	5.4	7.8	92	89	87	80	6.7	6.9	6.6	7.0
3.0	22.0	21.6	21.4	19.9	5.1	4.7	5.2	7.3	92	89	87	80	6.7	6.9	6.6	7.0
4.0	22.0	21.5	21.4		5.0	4.7	5.2		92	88	86		6.7	6.9	6.7	
5.0	22.0	21.5	21.4		5.0	4.8	5.2		91	88	85		6.7	6.9	6.7	
6.0	22.0	21.5	21.3		5.1	0.5	5.1		91	87	85		6.7	6.9	6.7	
7.0	21.9		21.2		4.8		5.2		91		85		6.7		6.7	
8.0	21.9		21.2		4.8		3.9		90		85		6.7		6.7	
9.0	21.7				2.3				91				6.7			
10.0	21.3				0.5				95				6.6			
11.0	20.0				0.3				112				6.5			
12.0	16.7				0.2				132				6.4			

Appendix 7 (continued)

November 10, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance (µS/cm)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	14.6	14.4	14.3	12.2	7.7	8.8	10.4	10.7	57	54	58	53	6.7	6.9	7.0	6.9
1.0	14.6	14.3	14.3	12.2	7.6	8.4	10.3	10.5	59	57	59	53	6.7	6.8	7.0	6.9
2.0	14.6	14.1	14.1	12.2	7.5	8.1	9.9	10.3	60	55	58	53	6.7	6.8	7.0	6.9
3.0	14.6	14.0	14.0	12.2	7.5	8.0	9.7	10.0	61	56	57	53	6.7	6.8	7.0	6.9
4.0	14.6	14.0	14.0		7.5	7.9	9.5		60	54	57		6.7	6.8	7.0	
5.0	14.6	13.9	14.0		7.4	7.6	9.4		60	55	57		6.7	6.8	7.0	
6.0	14.5	13.9	14.0		7.2	7.3	9.1		60	55	57		6.7	6.7	6.9	
7.0	14.5	13.2	13.9		7.1	7.2	9.0		60	54	56		6.7	6.7	7.0	
8.0	14.4	12.7	13.8		7.1	7.0	7.8		59	51	56		6.7	6.7	6.9	
9.0	14.4				7.1				59				6.6			
10.0	14.3				6.9				59				6.7			
11.0	14.3				6.9				59				6.7			
12.0	14.3				4.4				59				6.6			

December 6, 1993

Depth (m)	Temperature (°C)				Dissolved oxygen (mg/liter)				Specific conductance (µS/cm)				pH			
	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2	E2	H2	P2	S2
0.2	13.2	12.7	12.4	11.6	6.7	7.7	7.7	8.3	94	90	91	85	6.7	6.7	7.0	6.9
1.0	13.1	12.7	12.4	11.6	6.4	7.5	7.7	8.2	95	91	89	85	6.6	6.7	7.0	6.9
2.0	12.9	12.5	12.5	11.5	6.2	7.5	7.7	8.1	95	90	89	85	6.6	6.7	7.0	6.9
3.0	12.4	12.3	12.3	11.4	6.2	7.4	7.5	8.0	94	90	89	86	6.6	6.6	7.0	6.9
4.0	12.3	12.3	12.3	11.2	5.8	7.2	7.5	7.8	94	90	89	85	6.6	6.6	7.0	6.9
5.0	12.3	12.3	12.2		6.1	7.0	7.2		94	90	89		6.6	6.6	7.0	
6.0	12.3	12.2	12.2		5.9	6.1	7.3		94	90	89		6.6	6.6	7.0	
7.0	12.3		12.2		6.2		7.3		94		89		6.6		7.0	
8.0	12.3		12.2		6.2		6.8		94		89		6.6		7.0	
9.0	12.3				6.2				94				6.6			
10.0	12.3				6.2				94				6.6			
11.0	12.3				6.2				94				6.6			
12.0	12.3				6.1				94				6.6			

Appendix 9 (continued)

Station E2, bottom

Month	Total Alkalinity ($CaCO_3$)	Hardness (calculated)	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	TN	NH_3-N	Nitrate + nitrite-N	TP	TOC
Jan	12	16	9.5	16	3.3	1.8	11	0.74	0.06	0.18	0.061	7.0
Feb								0.76	0.03	0.17	0.060	
Mar	10	16	9.2	16	3.3	1.8	11	0.72	0.05	0.03	0.053	6.9
Apr								0.63	0.09	0.04	0.040	
May	12	16	7.6	13	3.6	1.7	8.6	0.95	0.31	0.06	0.082	7.8
Jun								1.2	0.65	0.04	0.099	
Jul	40	23	8.7	5.9	5.3	2.3	9.0	1.6	1.5	< 0.02	0.22	10
Aug								0.34	0.84	< 0.02	0.25	
Sep	54	24	7.7	2.6	5.5	2.5	9.9	1.8	2.6	< 0.02	1.3	10
Oct								1.3	0.60	< 0.02	0.084	
Nov	17	20	9.3	12	4.4	2.2	11	0.75	0.14	0.14	0.044	6.2
Dec								0.70	0.15	0.02	0.038	

Month	Turbidity	TS	TDS	TSS	Al	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Jan	3.4	78	73	5	41	< 1	< 0.1	< 2	2.4	< 0.05	< 5	< 1	< 1	< 20
Feb	2.8	82	66	4										
Mar	2.7	67	58	5	120	< 1	< 0.1	< 2	4.3	0.11	< 5	< 1	1	< 20
Apr	6.1	79	68	5										
May	9.1	69	64	5	110	< 1	< 0.1	< 2	7.3	< 0.05	< 5	< 1	< 1	20
Jun	10	74	51	4										
Jul	13	96	67	14	98	2	< 0.1	< 2	4.3	< 0.05	< 5	< 1	< 1	< 20
Aug	15	74	70	4										
Sep	17	112	100	11	54	2	< 0.1	< 2	2.0	< 0.05	< 5	< 1	< 1	20
Oct	4.2	90	75	8										
Nov	2.2	74	66	2	< 20	< 1	< 0.1	< 2	< 1.0	< 0.05	< 5	< 1	< 1	< 20
Dec	3.9	83	77	5										

Appendix 9 (continued)

Station H2, surface

Month	Total Alkalinity ($CaCO_3$)	Hardness (calculated)	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	TN	NH_3-N	Nitrate + nitrite-N	TP	TOC
Jan	9.4	15	7.8	12	3.2	1.6	8.7	0.69	0.05	0.18	0.031	6.6
Feb								0.71	0.04	0.20	0.055	
Mar	8.2	14	6.6	11	3.0	1.5	7.7	0.64	< 0.02	0.09	0.037	6.1
Apr								0.57	0.03	0.04	0.033	
May	9.7	14	6.4	10	3.2	1.5	7.4	0.59	0.02	< 0.02	0.029	7.2
Jun								0.77	< 0.02	< 0.02	0.035	
Jul	12	16	8.1	11	3.6	1.8	8.4	0.59	< 0.02	< 0.02	0.020	7.9
Aug								0.58	< 0.02	< 0.02	0.031	
Sep	14	17	7.7	10	3.6	1.9	9.8	0.31	< 0.02	< 0.02	0.024	6.6
Oct								0.53	0.07	< 0.02	0.028	
Nov	16	20	9.1	12	4.4	2.2	10	0.67	0.06	0.10	0.032	6.2
Dec								0.46	< 0.02	< 0.02	0.027	

Month	Turbidity	TS	TDS	TSS	Al	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Jan	7.7	74	68	7	120	< 1	< 0.1	< 2	< 1.0	< 0.05	< 5	< 1	< 1	< 20
Feb	7.1	72	56	7										
Mar	8.1	63	44	9	380	< 1	< 0.1	< 2	1.7	< 0.05	< 5	< 1	< 1	< 20
Apr	7.2	58	47	5										
May	2.4	47	37	4	72	< 1	< 0.1	< 2	3.0	< 0.05	< 5	< 1	< 1	< 20
Jun	2.8	59	36	3										
Jul	3.2	60	34	4	45	< 1	< 0.1	< 2	1.2	< 0.05	< 5	< 1	< 1	< 20
Aug	2.0	48	43	4										
Sep	1.4	62	59	2	20	< 1	< 0.1	< 2	1.0	< 0.05	< 5	< 1	< 1	< 20
Oct	2.1	74	63	3										
Nov	3.4	69	63	5	20	< 1	< 0.1	< 2	< 1.0	< 0.05	< 5	< 1	< 1	< 20
Dec	2.7	80	76	3										

Appendix 9 (continued)

Station P2, surface

Month	Total Alkalinity ($CaCO_3$)	Hardness (calculated)	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	TN	NH_3-N	Nitrate + nitrite-N	TP	TOC
Jan	11	15	9.1	14	3.2	1.8	11	0.69	< 0.02	0.13	0.040	6.9
Feb								0.65	< 0.02	0.10	0.031	
Mar	8.9	14	8.2	13	3.0	1.6	9.6	0.61	< 0.02	< 0.02	0.033	7.0
Apr								0.66	0.06	0.02	0.038	
May	8.0	14	6.8	12	3.1	1.5	7.7	0.61	0.02	< 0.02	0.030	9.0
Jun								0.79	< 0.02	< 0.02	0.037	
Jul	11	16	8.2	11	3.6	1.8	8.3	0.66	< 0.02	< 0.02	0.020	8.2
Aug								0.48	< 0.02	< 0.02	0.025	
Sep	13	17	7.9	11	3.7	1.9	9.8	0.51	< 0.02	< 0.02	0.021	6.6
Oct								0.50	0.04	< 0.02	0.023	
Nov	15	19	9.0	12	4.3	2.1	10	0.68	0.06	0.10	0.025	6.1
Dec								0.36	0.03	< 0.02	0.021	

Month	*Turbidity*	*TS*	*TDS*	*TSS*	*Al*	*As*	*Cd*	*Cr*	*Cu*	*Hg*	*Ni*	*Pb*	*Se*	*Zn*
Jan	2.9	69	68	5	29	< 1	< 0.1	< 2	< 1.0	< 0.05	< 5	< 1	< 1	< 20
Feb	3.6	72	61	6										
Mar	3.8	61	55	5	130	< 1	< 0.1	< 2	2.0	< 0.05	< 5	< 1	< 1	< 20
Apr	7.5	57	46	5										
May	2.4	50	40	2	98	< 1	< 0.1	< 2	4.6	< 0.05	< 5	< 1	< 1	< 20
Jun	3.2	56	40	3										
Jul	3.1	59	34	8	39	< 1	0.2	< 2	3.7	< 0.05	< 5	< 1	< 1	< 20
Aug	1.3	43	41	2										
Sep	1.2	61	58	2	< 20	< 1	< 0.1	< 2	2.0	< 0.05	< 5	< 1	< 1	< 20
Oct	1.4	72	69	2										
Nov	2.6	68	62	4	< 20	< 1	< 0.1	< 2	< 1.0	< 0.05	< 5	< 1	< 1	< 20
Dec	3.2	77	71	5										

Appendix 9 (continued)

Station S2, surface

Month	Total Alkalinity ($CaCO_3$)	Hardness (calculated)	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	TN	NH_3-N	Nitrate + nitrite-N	TP	TOC
Jan	8.5	15	7.1	9.4	3.2	1.6	6.6	0.57	0.07	0.10	0.036	7.6
Feb								0.62	0.05	0.09	0.044	
Mar	3.8	11	3.8	7.4	2.4	1.2	3.9	0.72	0.05	0.08	0.072	9.8
Apr								0.59	< 0.02	0.04	0.072	
May	8.1	14	5.9	9.9	3.0	1.5	6.6	0.59	0.02	< 0.02	0.033	9.2
Jun								0.84	0.02	< 0.02	0.045	
Jul	12	16	8.0	10	3.5	1.8	8.3	0.65	< 0.02	< 0.02	0.025	8.3
Aug								0.53	< 0.02	< 0.02	0.027	
Sep	13	17	7.8	11	3.6	1.9	9.7	0.39	< 0.02	< 0.02	0.018	6.7
Oct								0.42	< 0.02	< 0.02	0.016	
Nov	15	20	8.8	11	4.3	2.2	9.9	0.31	0.02	0.06	0.015	6.1
Dec								0.20	< 0.02	< 0.02	0.015	

Month	Turbidity	TS	TDS	TSS	Al	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Jan	16	78	70	9	310	< 1	< 0.1	< 2	1.1	< 0.05	< 5	< 1	< 1	< 20
Feb	18	77	64	6										
Mar	32	85	62	27	1500	1	< 0.1	< 2	1.6	< 0.05	< 5	< 1	< 1	< 20
Apr	40	89	60	28										
May	3.2	48	32	6	78	< 1	< 0.1	< 2	2.1	< 0.05	< 5	< 1	< 1	< 20
Jun	4.5	68	56	6										
Jul	3.9	62	38	4	42	< 1	< 0.1	< 2	1.2	< 0.05	< 5	< 1	< 1	< 20
Aug	2.4	48	43	4										
Sep	2.2	63	55	3	40	< 1	< 0.1	< 2	1.0	< 0.05	< 5	< 1	< 1	< 20
Oct	1.3	63	61	1										
Nov	3.5	62	58	3	30	< 1	< 0.1	< 2	< 1.0	< 0.05	< 5	< 1	< 1	< 20
Dec	3.1	74	72	2										

Appendix 12. **Means, ranges, and spatial trends of selected limnological variables from the surface and bottom waters of Harris Lake during 1993.**[+]

Variable	Station				
	E2 (surface)	E2 (bottom)	H2	P2	S2
Solids (mg/liter)					
Total	69[a] (50-89)	82[§] (67-112)	64[bc] (47-80)	62[c] (43-77)	68[ab] (48-89)
Total dissolved	57 (26-76)	70[§] (51-100)	52 (34-76)	54 (34-71)	56 (32-72)
Total suspended	3[b] (2-5)	6[§] (2-14)	5[ab] (2-9)	4[b] (2-8)	8[a] (1-28)
Turbidity (NTU)	2.8[b] (1.2-6.0)	7.5[§] (2.2-17)	4.2[b] (1.4-8.1)	3.0[b] (1.2-7.5)	11[a] (1.3-40)
Secchi disk transparency (m)	1.4[a] (0.9-2.2)	NA	1.2[ab] (0.6-1.9)	1.4[a] (0.8-2.1)	1.1[b] (0.2-2.0)
Chlorophyll *a* (μg/liter)	22.4[a] (8.3-66.1)	NA	19.1[a] (12.0-32.2)	16.4[ab] (7.7-23.8)	10.4[b] (3.4-35.0)
Nutrients (mg/liter)					
Total nitrogen (TN)	0.62[a] (0.42-0.82)	0.96[§] (0.34-1.8)	0.59[ab] (0.31-0.77)	0.60[ab] (0.36-0.79)	0.54[b] (0.20-0.84)
Ammonia-N	0.05 (< 0.02-0.15)	0.59[§] (0.03-2.6)	0.03 (< 0.02-0.07)	0.02 (< 0.02-0.06)	0.02 (< 0.02-0.07)
Nitrate + Nitrite-N	0.05[ab] (< 0.02-0.18)	0.06 (< 0.02-0.18)	0.06[a] (< 0.02-0.20)	0.04[b] (< 0.02-0.13)	0.04[b] (< 0.02-0.10)
Total phosphorus (TP)	0.038[a] (0.018-0.059)	0.19 (0.038-1.3)	0.032[ab] (0.020-0.055)	0.029[b] (0.020-0.040)	0.035[ab] (0.015-0.072)
TN:TP	16	5	18	21	15
Total organic carbon (mg/liter)	7.0[b] (6.0-7.8)	8.0 (6.2-10)	6.8[b] (6.1-7.9)	7.3[ab] (6.1-9.0)	8.0[a] (6.1-9.8)
Ions (mg/liter)					
Cations					
Calcium	3.6[a] (3.2-4.3)	4.2 (3.3-5.5)	3.5[ab] (3.0-4.4)	3.5[ab] (3.0-4.3)	3.3[b] (2.4-4.3)
Magnesium	1.9[a] (1.6-2.1)	2.1 (1.7-2.5)	1.8[ab] (1.5-2.2)	1.8[ab] (1.5-2.1)	1.7[b] (1.2-2.2)
Sodium	9.9[a] (7.9-11)	10 (8.6-11)	8.7[ab] (7.4-10)	9.4[a] (7.7-11)	7.5[b] (3.9-9.9)

Appendix 12 (continued)

Variable	Station E2 (surface)	E2 (bottom)	H2	P2	S2
Anions					
Chloride	8.5[a] (6.9-9.5)	8.7 (7.6-9.5)	7.6[ab] (6.4-9.1)	8.2[a] (6.8-9.1)	6.9[b] (3.8-8.8)
Sulfate	13[a] (11-16)	11 (2.6-16)	11[bc] (10-12)	12[ab] (11-14)	9.8[c] (7.4-11)
Total alkalinity¶	12[a] (8.6-17)	24 (10-54)	12[ab] (8.2-16)	11[ab] (8.0-15)	10[b] (3.8-15)
Hardness (calculated)¶	17[a] (15-19)	19 (16-24)	16[ab] (14-20)	16[ab] (14-19)	15[b] (11-20)
Specific conductance (μS/cm)	68[a] (36-94)	92§ (55-138)	64[a] (37-90)	65[a] (38-91)	56[b] (35-85)

†Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Means followed by the same superscript were not significantly different ($P > 0.05$). Sample size equaled 12 for all variables except for total alkalinity, hardness, and all ions which equalled 6. The variable TN:TP was not subjected to statistical analyses.

¶Total alkalinity units are mg/liter as $CaCO_3$ and hardness is calculated as mg equivalents $CaCO_3$/liter.

§A significant difference in the mean concentrations was measured between the surface and bottom waters at Station E2.

NA = Not applicable.

Appendix 13. Spatial trends of selected limnological variables from the surface waters of Harris Lake at Stations E2, H2, and P2, 1987-1993.[+]

Variable[¶]	Station E2	Station H2	Station P2
Solids (mg/liter)			
Total (108)	61	59	68
Total dissolved (54)	53	46	54
Total suspended (90)	4.0	5.8	4.0
Turbidity (NTU)	2.6^{b}	3.5^{a}	2.9^{ab}
Secchi disk transparency (m)	1.5^{a}	1.3^{b}	1.4^{ab}
Chlorophyll *a* (µg/liter)	21.5	24.3	20.1
Nutrients (mg/liter)			
Total nitrogen	0.54	0.50	0.50
Ammonia-N (90)	0.07^{a}	0.04^{b}	0.04^{b}
Nitrate + nitrite-N (90)	0.08	0.07	0.06
Total phosphorus	0.047^{a}	0.032^{b}	0.028^{b}
TN:TP[£]	11	16	18
Total organic carbon (mg/liter)	6.8	6.7	6.9
Ions (mg/liter)			
Cations			
Calcium	3.3	3.2	3.3
Magnesium	1.8^{a}	1.7^{b}	1.7^{ab}
Sodium	8.4^{a}	7.7^{b}	8.0^{b}
Anions			
Chloride	6.8^{a}	6.4^{b}	6.6^{ab}
Sulfate	11^{a}	9.7^{b}	10^{ab}
Total alkalinity[§]	12.4^{a}	11.6^{b}	11.6^{b}
Hardness[§]	16	15	15
Specific conductance (µS/cm)	77	73	75
Metals (µg/liter)			
Aluminum	56	76	52
Copper	3.4	2.7	2.8

[+]Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Means followed by the same superscript were not significantly different ($P > 0.05$). Data were rounded to conform to significant digit requirements. The mean separation technique may yield separations which are obscured by data rounding.

[¶]Sample size (n) equalled 126 unless otherwise noted in parentheses.

[§]Total alkalinity units are mg/liter as $CaCO_3$ and hardness units are calculated as mg equivalents $CaCO_3$/liter.

[£]Variable was not subjected to statistical analyses.

Appendix 14. Temporal trends of selected limnological variables from the surface waters of Harris Lake at Stations E2, H2, and P2, 1987-1993.+

Variable¶	Year						
	1987	1988	1989	1990	1991	1992	1993
Solids (mg/liter)							
Total (108)	57	NS	67	56	56	73	64
Total dissolved (54)	47	NS	NS	NS	NS	53	52
Total suspended (90)	NS	NS	3.0	7.3	3.3	5.1	4.2
Turbidity (NTU)	3.7^{ab}	2.8^{bcd}	4.0^{a}	2.5^{bcd}	2.5^{d}	2.1^{d}	3.1^{abc}
Secchi disk transparency (m)	1.4	1.3	1.4	1.6	1.5	1.4	1.4
Chlorophyll *a* (µg/liter)	15.8^{b}	20.2^{b}	33.6^{a}	24.7^{ab}	18.3^{b}	20.1^{b}	21.0^{b}
Nutrients (mg/liter)							
Total nitrogen	0.44^{b}	0.47^{b}	0.49^{b}	0.58^{a}	0.58^{a}	0.43^{b}	0.62^{a}
Ammonia-N (90)	0.05	0.05	NS	NS	0.06	0.06	0.03
Nitrate + nitrite-N (90)	0.06^{b}	0.07^{b}	NS	NS	0.11^{a}	0.06^{b}	0.06^{b}
Total phosphorus	0.024^{d}	0.029^{cd}	0.045^{ab}	0.049^{a}	0.037^{bc}	0.036^{bc}	0.031^{cd}
TN:TP£	18	16	11	12	16	12	20
Total organic carbon (mg/liter)	6.1^{d}	6.7^{bc}	7.4^{a}	7.1^{ab}	6.3^{cd}	7.0^{ab}	7.0^{ab}
Ions (mg/liter)							
Cations							
Calcium	3.5^{b}	3.8^{a}	3.3^{b}	2.6^{c}	2.7^{c}	3.4^{b}	3.5^{b}
Magnesium	1.5^{e}	1.7^{d}	1.7^{d}	1.7^{cd}	1.8^{b}	1.9^{a}	1.8^{bc}
Sodium	5.1^{e}	7.8^{d}	7.3^{d}	7.6^{d}	8.5^{c}	11^{a}	9.3^{b}
Anions							
Chloride	4.3^{f}	5.7^{e}	5.5^{e}	6.3^{d}	7.4^{c}	9.1^{a}	8.1^{b}
Sulfate	6.8^{e}	8.7^{cd}	7.8^{d}	9.5^{c}	12^{b}	14^{a}	12^{b}
Total alkalinity§	13^{b}	15^{a}	12^{bc}	9.9^{d}	10^{d}	11^{c}	12^{c}
Hardness§	15^{cd}	17^{a}	15^{bc}	14^{e}	14^{de}	16^{a}	16^{ab}
Specific conductance (µS/cm)	68^{de}	83^{b}	73^{cd}	75^{c}	69^{de}	95^{a}	63^{e}
Metals (µg/liter)							
Aluminum	21^{c}	55^{abc}	84^{a}	45^{bc}	71^{ab}	80^{a}	71^{ab}
Copper	3.5^{a}	3.7^{a}	3.1^{ab}	3.8^{a}	2.2^{bc}	2.4^{bc}	2.1^{c}

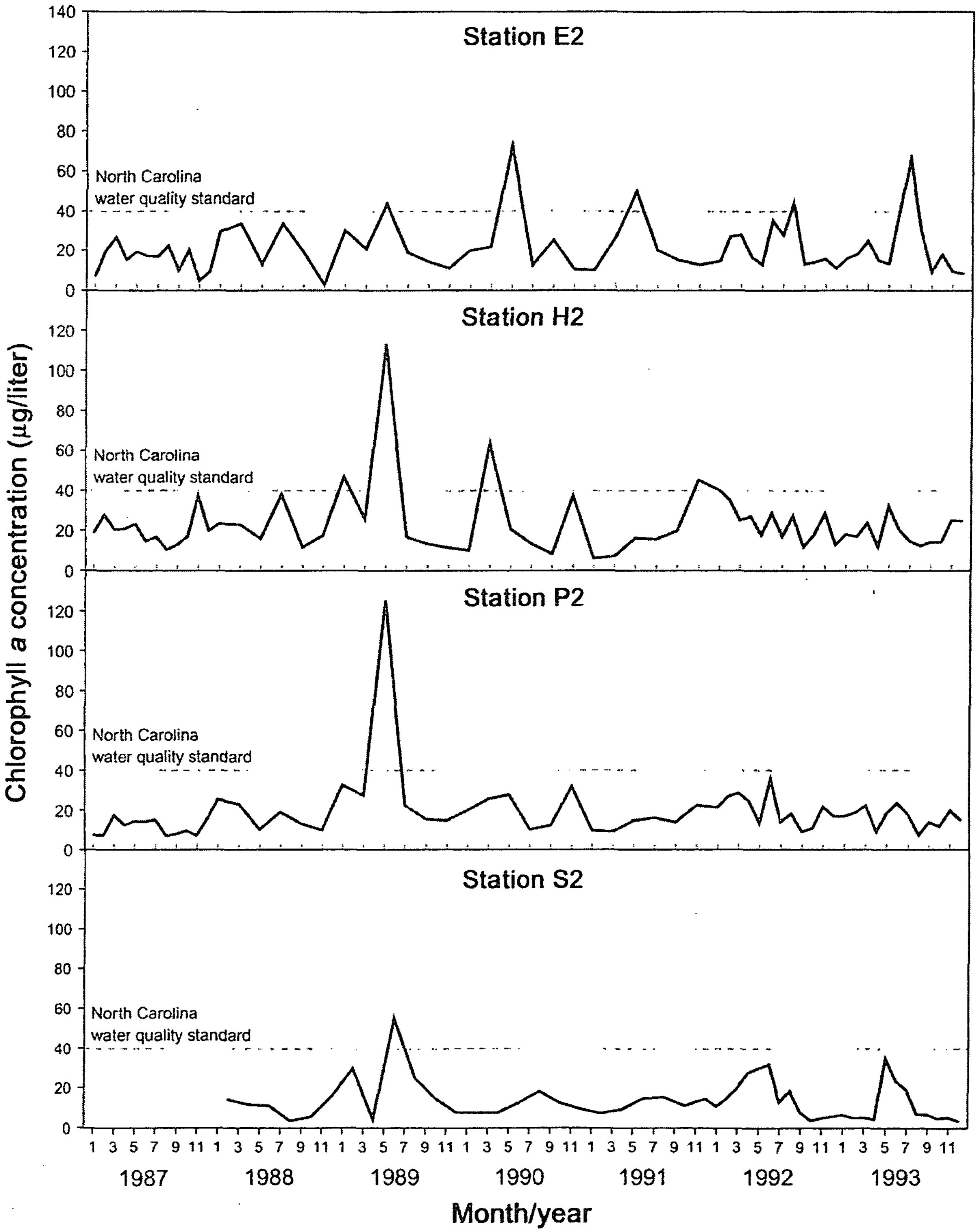
+Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Means followed by the same superscript were not significantly different ($P > 0.05$). Data were rounded to conform to significant digit requirements. The mean separation technique may yield separations which are obscured by data rounding.

¶Sample size (n) equalled 126 unless otherwise noted in parentheses.

§Total alkalinity units are mg/liter as $CaCO_3$ and hardness units are calculated as mg equivalents $CaCO_3$/liter.

£Variable was not subjected to statistical analyses.

NS = Not sampled.



Appendix 15. Chlorophyll *a* concentrations by station in Harris Lake, 1987-1993.

Appendix 16. Means, ranges, and spatial trends of trace metals and metalloids in the surface and bottom waters of Harris Lake during 1993[+].

Variable	Station: E2 (surface)	E2 (bottom)	H2	P2	S2	N.C. water quality standard	CP&L reporting limit[§]
Aluminum	51 (< 20-100)	72[¶] (< 20-120)	110 (< 20-380)	53 (< 20-130)	333 (30-1500)	None	20
Arsenic	< 1	1 (< 1-2)	< 1	< 1	0.7 (< 1-1)	50	1
Cadmium	< 0.1	< 0.1	< 0.1	0.2 (< 0.1-1.0)	< 0.1	2	0.1
Chromium	< 2	< 2	< 2	< 2	< 2	50	2
Copper	2.7[a] (< 1.0-5.8)	3.5 (< 1.0-7.3)	1.3[b] (<1.0-3.0)	2.2[ab] (1.0-4.6)	1.3[b] (< 1.0-2.1)	7[£]	1
Lead	< 1	< 1	< 1	< 1	< 1	25	1
Mercury	< 0.05	0.04 (< 0.05-0.11)	< 0.05	< 0.05	< 0.05	0.012	0.05
Nickel	< 5	< 5	< 5	< 5	< 5	88	5
Selenium	< 1	0.6 (< 1-1)	< 1	< 1	< 1	5	1
Zinc	< 20	13 (< 20-20)	< 20	< 20	< 20	50	20

[+]Statistical analyses were applied only to the aluminum and copper surface water data. Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Means followed by the same superscript were not significantly different ($P > 0.05$).

[¶]A significant spatial difference in the mean concentrations was measured between the surface and bottom waters at Station E2.

[§]A statistically determined lower reporting limit (LRL) beyond which a chemical concentration cannot be reliably reported. LRL = 3 sx + | x |, where x = the concentration of the blank, | x | = the absolute concentration of the blank, and s = sample standard deviation.

[£]This value is an action level (NCDEM 1993).

Appendix 17. Temporal trends of selected limnological variables from the bottom waters of Harris Lake at Station E2, 1987-1993.[+]

Variable	1987	1988	1989	1990	1991	1992	1993
Solids (mg/liter)							
Total (36)	75	NS	77	66	68	94	83
Total dissolved (18)	67	NS	NS	NS	NS	82	71
Total suspended (30)	NS	NS	3.8	11.3	6.8	7.2	7.0
Turbidity (NTU)	14	10	5.2	4.2	7.1	8.2	7.9
Nutrients (mg/liter)							
Total nitrogen	1.3	2.7	1.0	1.0	1.1	2.0	1.1
Nitrate + nitrite-N (30)	0.80	0.07	NS	NS	0.14	0.09	0.07
Ammonia-N (30)	0.59	2.0	NS	NS	0.58	1.2	0.78
Total phosphorus	0.28	0.31	0.21	0.15	0.20	0.21	0.29
TN:TP[§]	5	9	5	7	6	10	4
Total organic carbon (mg/liter)	6.6	6.8	7.9	7.4	6.9	8.2	8.0
Ions (mg/liter)							
Cations							
Calcium	4.5[b]	5.5[a]	4.2[b]	3.2[c]	3.2[c]	4.1[b]	4.2[b]
Magnesium	1.7[d]	2.1[ab]	1.9[bcd]	1.8[cd]	2.0[bc]	2.3[a]	2.1[ab]
Sodium	4.6[c]	7.8[d]	8.2[d]	7.5[d]	9.1[c]	12[a]	10[b]
Anions							
Chloride	4.2[f]	5.6[e]	5.8[e]	6.2[d]	7.8[c]	9.7[a]	8.7[b]
Sulfate	5.1[c]	5.3[c]	8.2[b]	8.3[b]	11[a]	12[a]	11[a]
Total alkalinity[¶]	26	42	22	19	19	30	24
Hardness[¶]	18[bcd]	22[a]	18[bc]	15[d]	16[cd]	20[ab]	19[bc]
Specific conductance (μS/cm)	148	139	125	102	94	111	93
Metals (μg/liter)							
Aluminum	37	55	113	69	76	82	72
Copper	4.4	3.7	4.5	4.0	2.3	3.7	3.5

[+]Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Annual means followed by the same superscript were not significantly different ($P > 0.05$). Sample size (n) equalled 42 unless otherwise noted in parentheses.

[¶]Total alkalinity units are mg/liter as $CaCO_3$ and hardness is calculated as mg equivalents $CaCO_3$/liter.

[§]Variable was not subjected to statistical analyses.

NS = Not sampled.

Appendix 18. Approximate growth performance of zebra mussels in relation to alkalinity, calcium, total hardness, specific conductance, and pH and range of these values reported in 1993 from Harris Lake. The appendix was adopted from Claudi and Mackie (1993).

Criterion	No survival		Poor growth		Moderate growth		Good growth		Best growth	Harris Lake (surface)
	From	To	From	To	From	To	From	To		
Alkalinity (mg $CaCO_3$/l)	0	17	18	35	36	87	88	122	> 122	12
Calcium (mg/l)	5	6	10	11	25	26	35	> 35	≥ 35	3.5
Total hardness (mg $CaCO_3$/l)	0	22	23	41	43	90	91	125	> 125	16
Specific conductance (μS/cm)	0	21	22	36	37	82	83	110	> 110	63
pH	0	6.8	6.9	7.4	7.5	7.8	7.9	8.0	> 8.0	7.0
Temperature (°C)$^+$	< -2	> 40	0-8	28-30	9-12	25-27	13-17	21-24	18-20	20

$^+$According to Claudi and Mackie (1993): "Temperature should be interpreted with caution here because it affects mussels at both high and low values. For example, there is no survival at temperatures below - 2 or above 40°C but there is survival between these temperatures; there is poor growth both between 0-8°C and 28-30°C but moderate to best growth between these extremes; etc. The values should be used only for "guestimates"; they are **NOT** hard and fast predictors."

Appendix 19. Fish taxa collected by electrofishing sampling from Harris Lake, 1985-1992 and 1993.

Scientific name	Common name	Year 1985-1992	Year 1993
Amiidae	**bowfins**		
Amia calva	bowfin	X	X
Anguillidae	**freshwater eels**		
Anguilla rostrata	American eel	X	
Clupeidae	**herrings**		
Dorosoma cepedianum	gizzard shad	X	X
D. pretenense	threadfin shad	X	X
Esocidae	**pikes**		
Esox americanus americanus	redfin pickerel	X	
E. niger	chain pickerel	X	X
Cyprinidae	**carps and minnows**		
Clinostomus funduloides	rosyside dace	X	
Notemigonus crysoleucas	golden shiner	X	X
Notropis petersoni	coastal shiner	X	
N. spp.	unidentified shiner	X	X
Catostomidae	**suckers**		
Erimyzon oblongus	creek chubsucker	X	
Ictaluridae	**bullhead catfishes**		
Ameiurus natalis	yellow bullhead	X	
A. nebulosus	brown bullhead	X	X
A. platycephalus	flat bullhead	X	X
A. spp.	unidentified bullhead	X	
Ictalurus punctatus	channel catfish	X	X
Noturus spp.	unidentified madtom	X	
Pylodictis olivaris	flathead catfish	X	
Poeciliidae	**livebearers**		
Gambusia holbrooki	eastern mosquitofish	X	
Centrarchidae	**sunfishes**		
Centrarchus macropterus	flier	X	
Enneacanthus gloriosus	bluespotted sunfish	X	
Lepomis auritus	redbreast sunfish	X	X
L. cyanellus	green sunfish	X	
L. gibbosus	pumpkinseed	X	X
L. gulosus	warmouth	X	X
L. macrochirus	bluegill	X	X
L. microlophus	redear sunfish	X	X
L. sp.	hybrid sunfish	X	X
Micropterus salmoides	largemouth bass	X	X
Pomoxis annularis	white crappie	X	X
P. nigromaculatus	black crappie	X	X
Percidae	**perches**		
Etheostoma fusiforme	swamp darter	X	
E. spp.	unidentified darter	X	
Total		**28**	**16**

+Taxonomic nomenclature follows Robins et al. (1991).

Appendix 20. Annual mean catch rate (number of fish/hour) of fish collected during electrofishing sampling at Harris Lake, May and November 1993.

Taxon	Area+ E	H	P	S	V	Area mean
Bowfin	0	0	0	1	1	< 1
Gizzard shad	12	15	26	15	16	17
Threadfin shad	0	0	0	2	0	< 1
Golden shiner	2	1	10	0	5	4
Unidentified shiner	0	2	0	1	0	< 1
Brown bullhead	0	4	3	2	2	2
Flat bullhead	0	0	1	0	0	< 1
Channel catfish	0	0	3	0	2	1
Chain pickerel	0	1	2	3	0	1
Hybrid sunfish	1	1	0	0	0	< 1
Redbreast sunfish	8	9	2	7	1	5
Pumpkinseed	14	17	9	2	5	10
Warmouth	0	0	3	4	0	1
Bluegill	80	116	47	40	72	71
Redear sunfish	25	35	17	8	21	21
Largemouth bass	6	17	7	9	14	10
White crappie	0	0	0	0	2	< 1
Black crappie	1	1	2	4	8	3
Total¶	**150**	**219**	**130**	**96**	**149**	**149**

+There were no statistically significant spatial differences in the annual mean catch rates for these taxa that were analyzed: gizzard shad, brown bullhead, bluegill, pumpkinseed, redear sunfish, and largemouth bass ($P > 0.05$).

¶Totals may vary from column sums due to rounding.

Appendix 21. Annual mean catch rate (number of fish/hour) of the numerically dominant fish species collected during electrofishing sampling at Harris Lake, 1983-1993.+

Taxon	Year										
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Gizzard shad	15	14	8	6	11	14	35	10	25	24	17
Threadfin shad	¶	¶	¶	¶	---§	---	24	---	---	6	---
Golden shiner	---	7	---	---	---	10	16	8	---	7	---
Brown bullhead	17	9	24	19	32	29	12	10	10	8	---
Flat bullhead	---	---	---	---	---	---	---	---	13	---	---
Redbreast sunfish	---	---	---	---	---	---	6	---	6	6	5
Pumpkinseed	16	15	13	7	10	14	68	33	19	23	10
Warmouth	11	13	14	17	16	9	13	9	---	---	---
Bluegill	40	32	48	43	18	91	131	134	96	80	71
Redear sunfish	5	8	5	6	10	10	15	28	29	29	21
Largemouth bass	63	65	40	58	36	46	63	20	27	39	10
Black crappie	---	---	---	---	---	12	18	19	8	---	---
Total£	**188**	**180**	**171**	**167**	**145**	**244**	**414**	**280**	**230**	**229**	**149**

+Areas E, H, P, S, and V and months May and November combined. A numerically dominant fish was defined subjectively as having an annual mean catch rate $\geq$ 5 fish/hour.

¶Threadfin shad was introduced into Harris Lake in 1987.

§Annual mean catch rate was < 5 fish/hour.

£Total catch rate of all species combined (i.e., numerically dominant and subordinate species).

Appendix 22. **Temporal trends of the annual mean catch rate (number of fish/hour) of selected sportfish species and total fish collected during electrofishing sampling at Harris Lake, 1983-1993.[+]**

	Year										
Taxon[¶]	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
Bluegill	23^{cd}	23^{cd}	35^{abc}	25^{bcd}	11^{d}	35^{abc}	50^{ab}	38^{abc}	36^{abc}	58^{a}	33^{abc}
Redear sunfish	2^{ef}	5^{cd}	3^{de}	1^{f}	7^{c}	6^{cd}	9^{c}	19^{ab}	24^{a}	22^{a}	10^{bc}
Pumpkinseed	10^{bcd}	9^{cd}	9^{bcd}	3^{e}	6^{de}	9^{cd}	44^{a}	20^{b}	7^{cde}	13^{bc}	3^{e}
Largemouth bass	53^{ab}	61^{a}	26^{def}	43^{abc}	29^{cde}	36^{bcd}	56^{ab}	17^{f}	18^{ef}	30^{cd}	8^{g}
Total fish	163^{b}	174^{b}	159^{b}	148^{b}	135^{bc}	184^{b}	309^{a}	181^{b}	169^{b}	194^{b}	100^{c}

[+]Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Geometric means followed by the same superscript were not significantly different ($P > 0.05$).

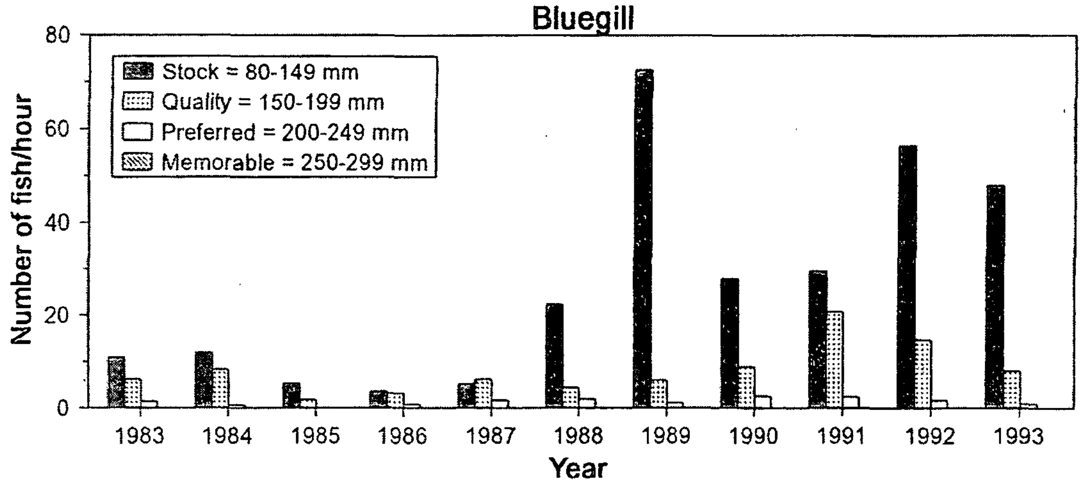
[¶]Sample size (n) equalled 220.

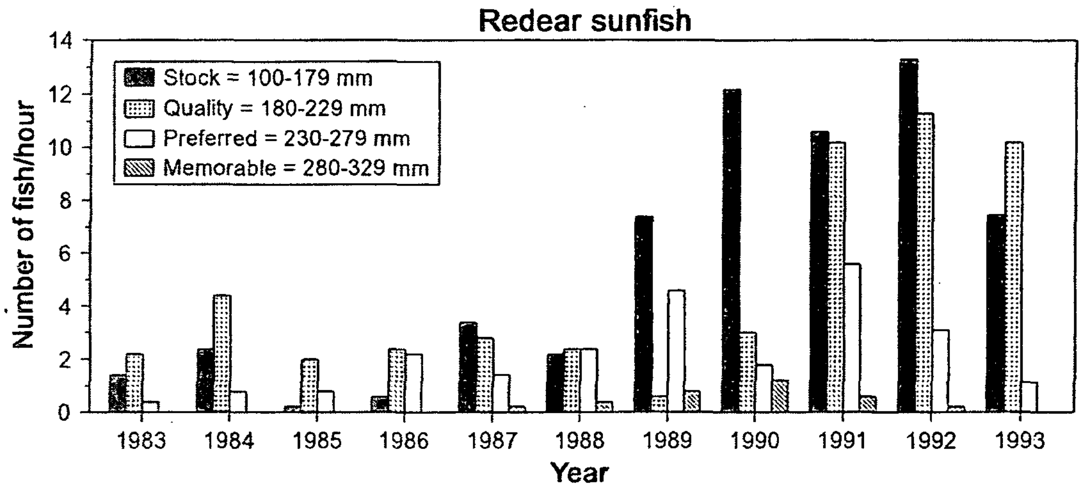
Appendix 23. Spatial trends of the annual mean catch rate (number of fish/hour) of selected sportfish species and total fish collected during electrofishing sampling at Harris Lake, 1983-1993.+

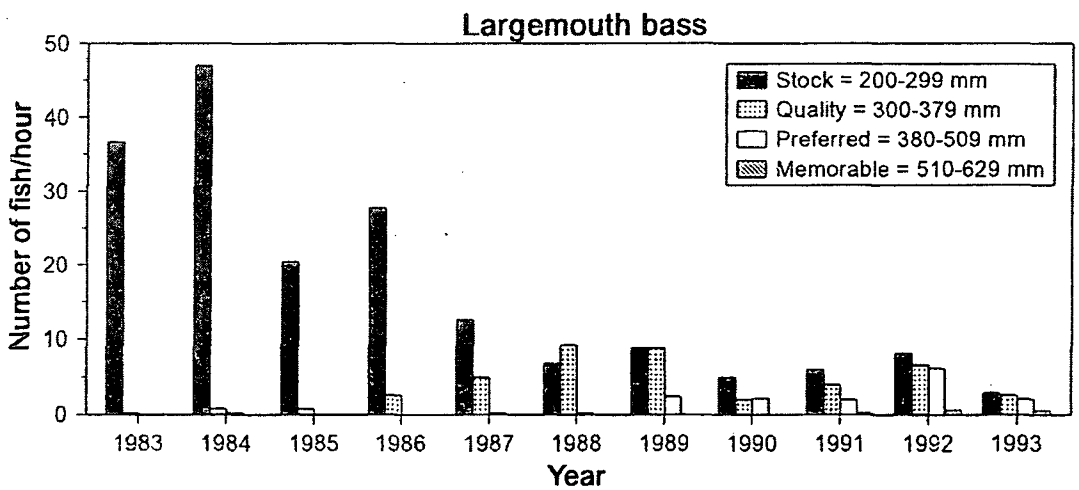
	Area				
Taxon¶	E	H	P	S	V
Bluegill	18^{c}	31^{b}	32^{b}	25^{bc}	58^{a}
Redear sunfish	6^{ab}	10^{a}	8^{a}	4^{b}	9^{a}
Pumpkinseed	7	9	10	9	12
Largemouth bass	29^{b}	32^{ab}	34^{ab}	18^{c}	40^{a}
Total fish	150^{bc}	159^{bc}	173^{b}	129^{c}	230^{a}

+Fisher's protected least significant difference test was applied only if the overall F test for the treatment was significant. Geometric means followed by the same superscript were not significantly different ($P > 0.05$).

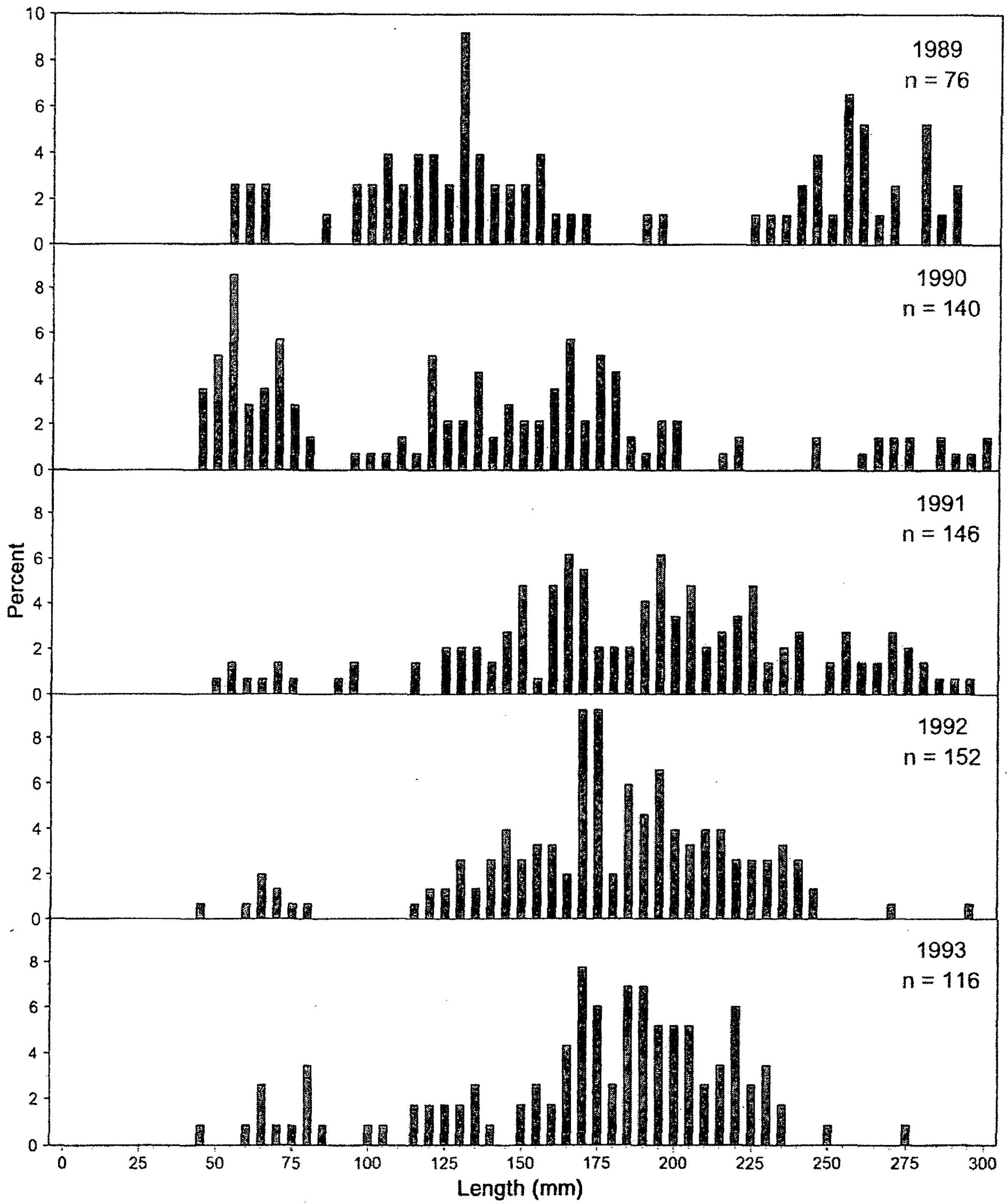
¶Sample size (n) equalled 220.



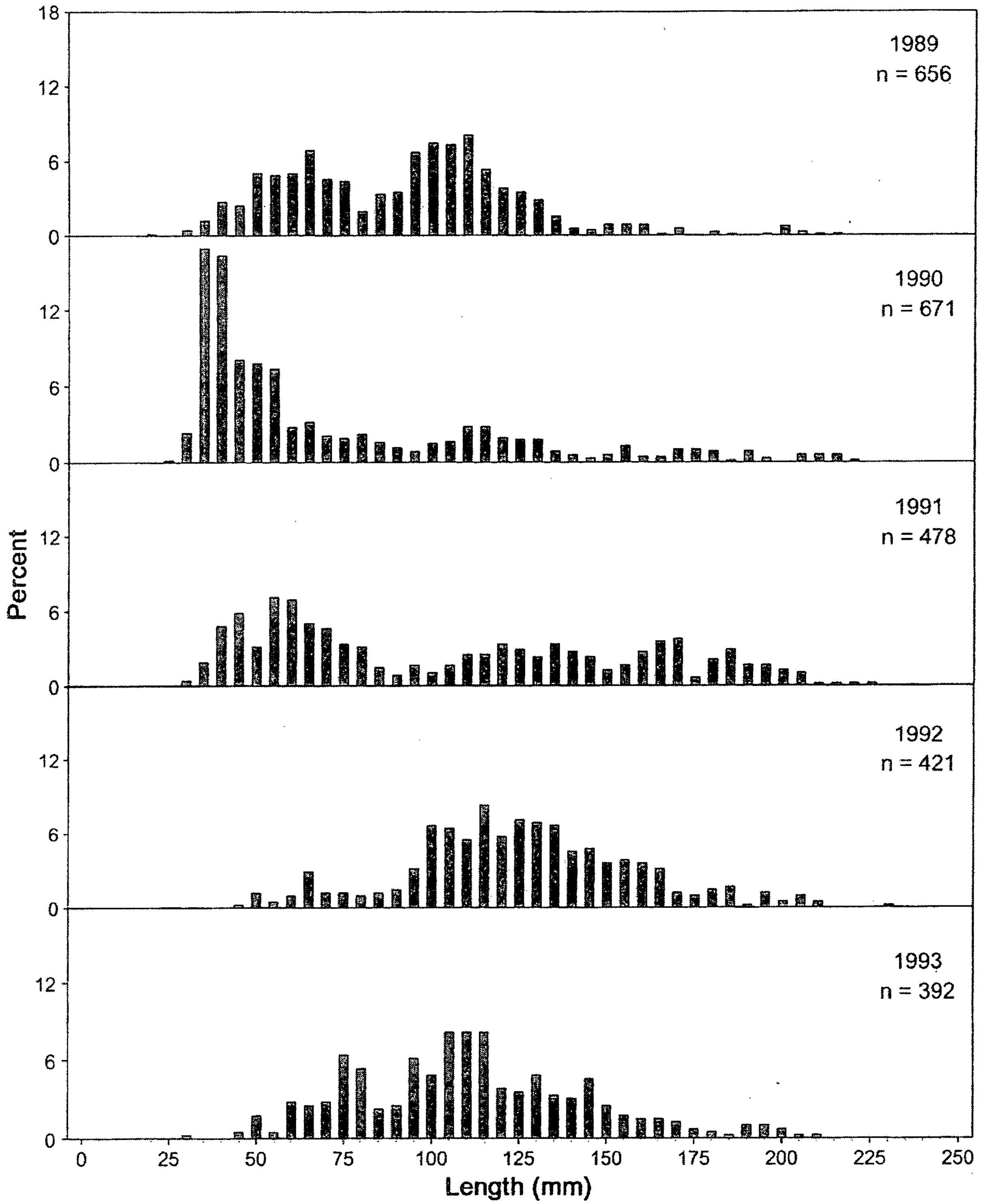




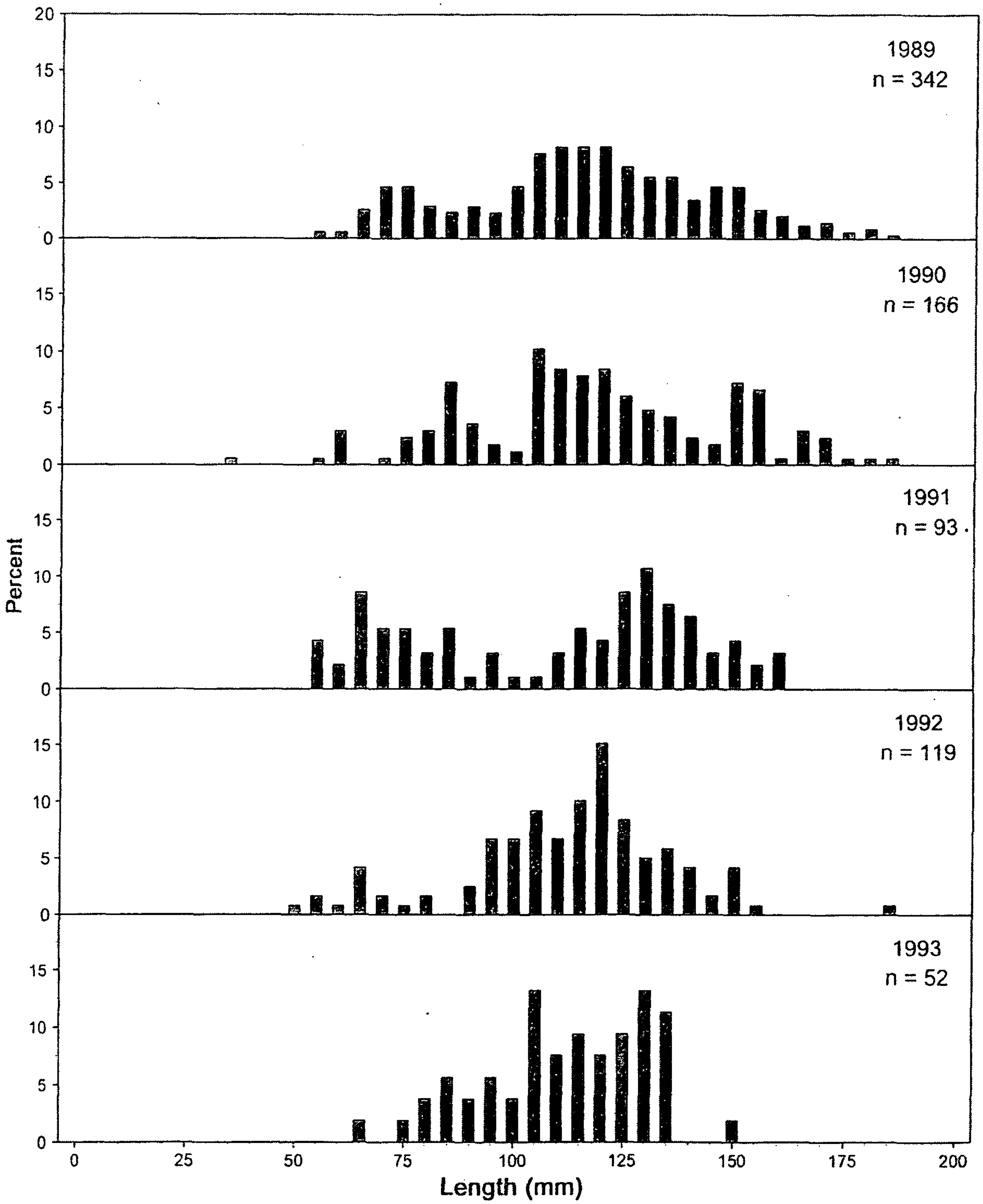
Appendix 24. **Catch rates of bluegill, redear sunfish, and largemouth bass by length group at Harris Lake, 1983-1993. Length groups were adopted from Gabelhouse (1984).**



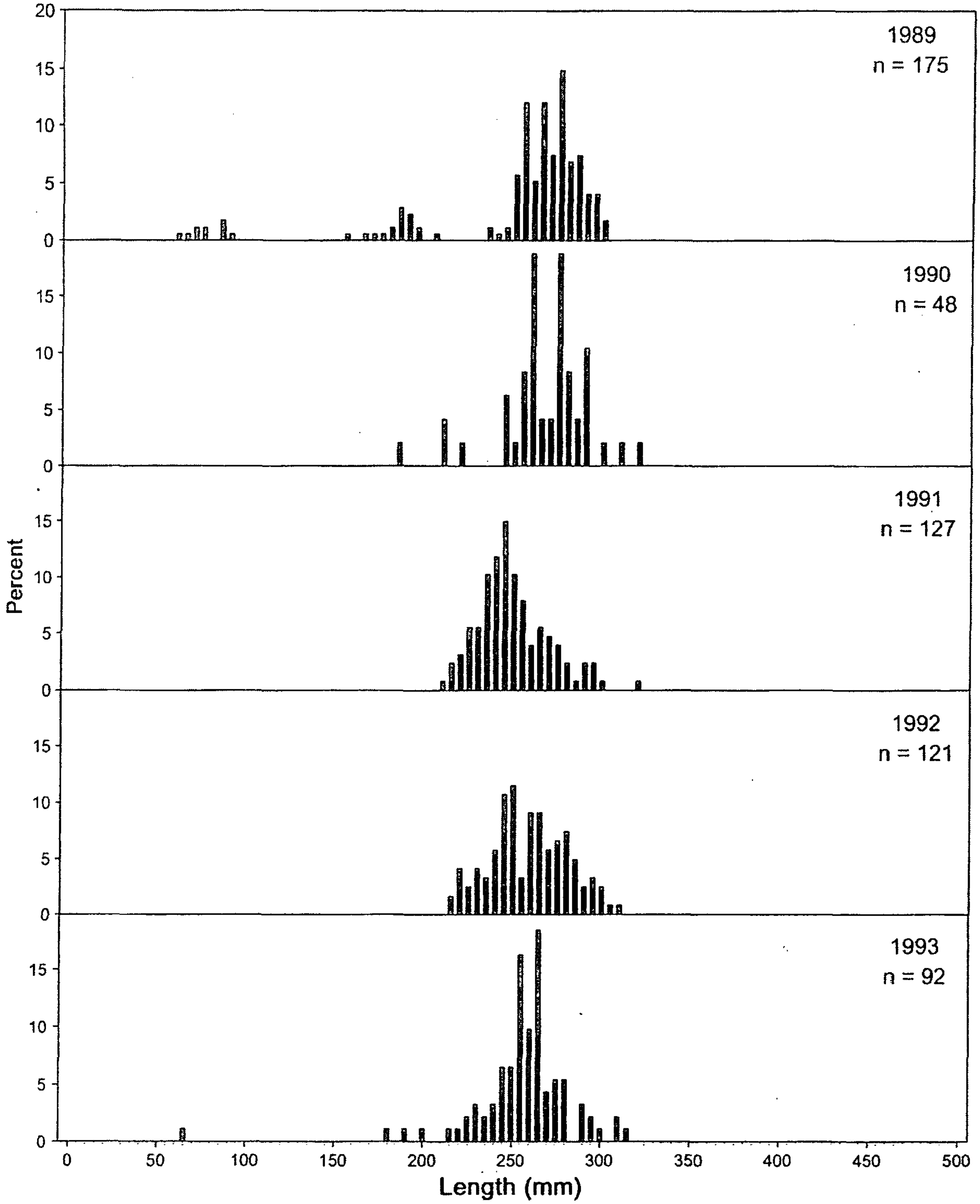
Appendix 25. **Length-frequency distributions of redear sunfish collected during electrofishing sampling at Harris Lake, 1989-1993.**



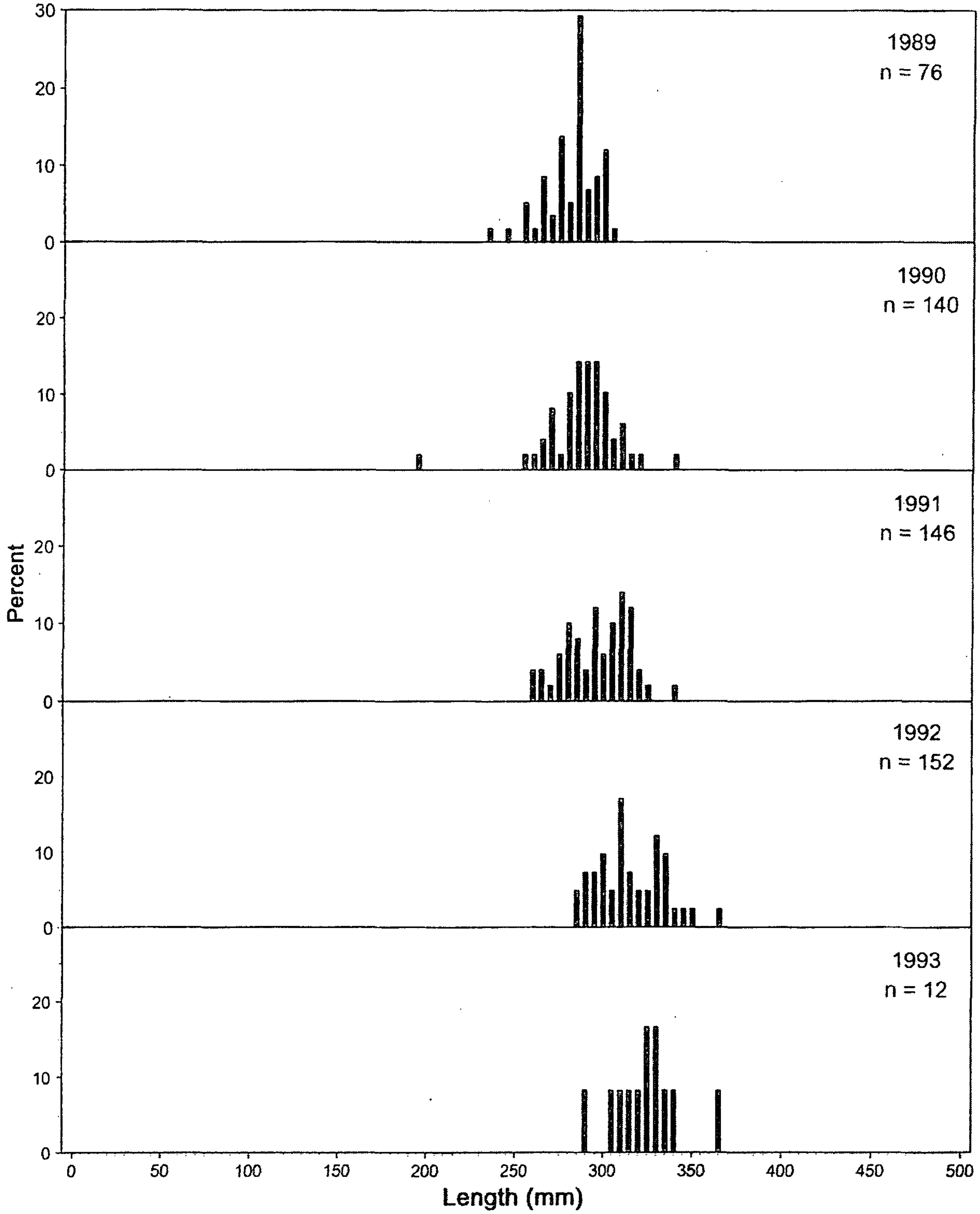
Appendix 26. Length-frequency distributions of bluegill collected during electrofishing sampling at Harris Lake, 1989-1993.



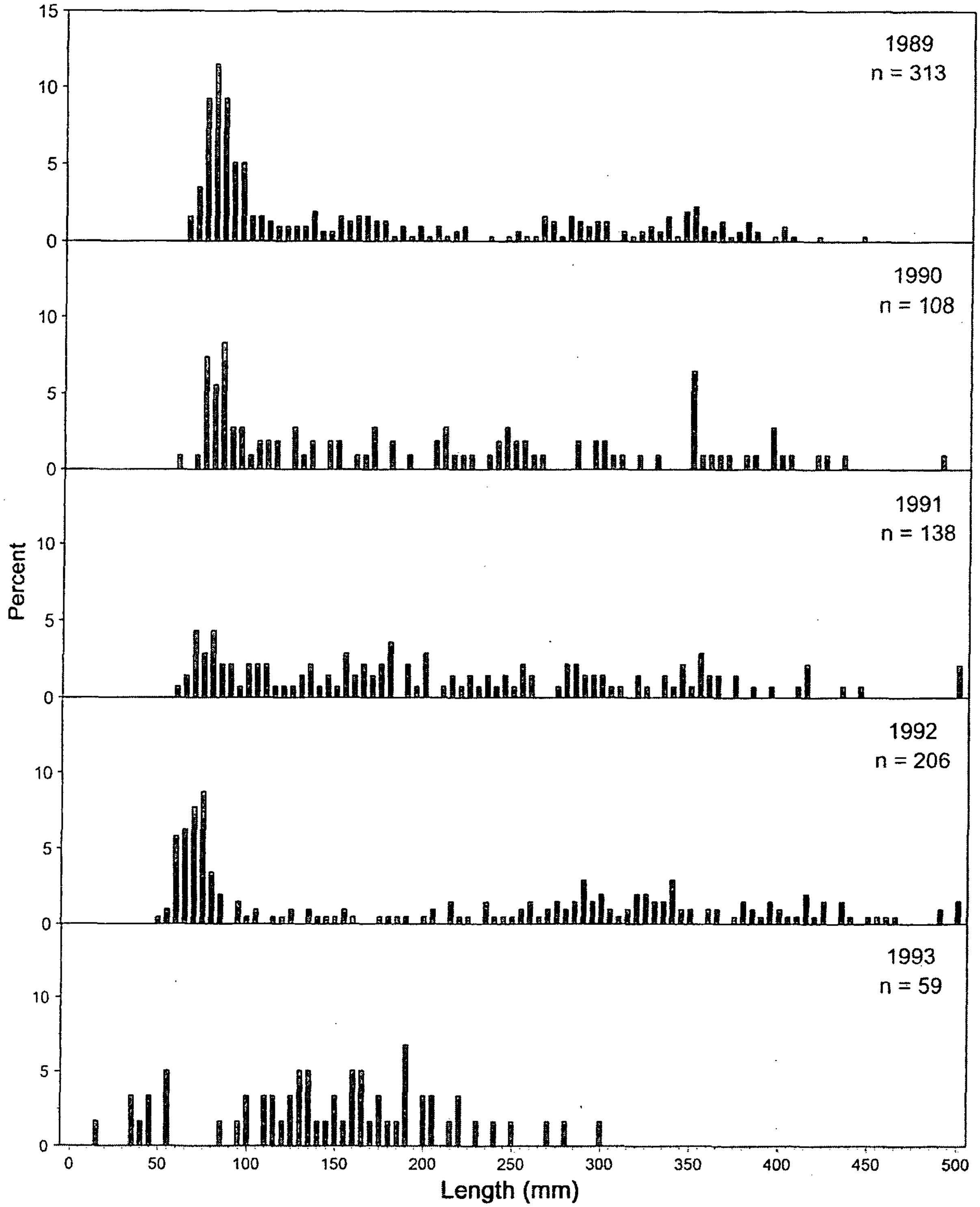
Appendix 27. **Length-frequency distributions of pumpkinseed collected during electrofishing sampling at Harris Lake, 1989-1993.**



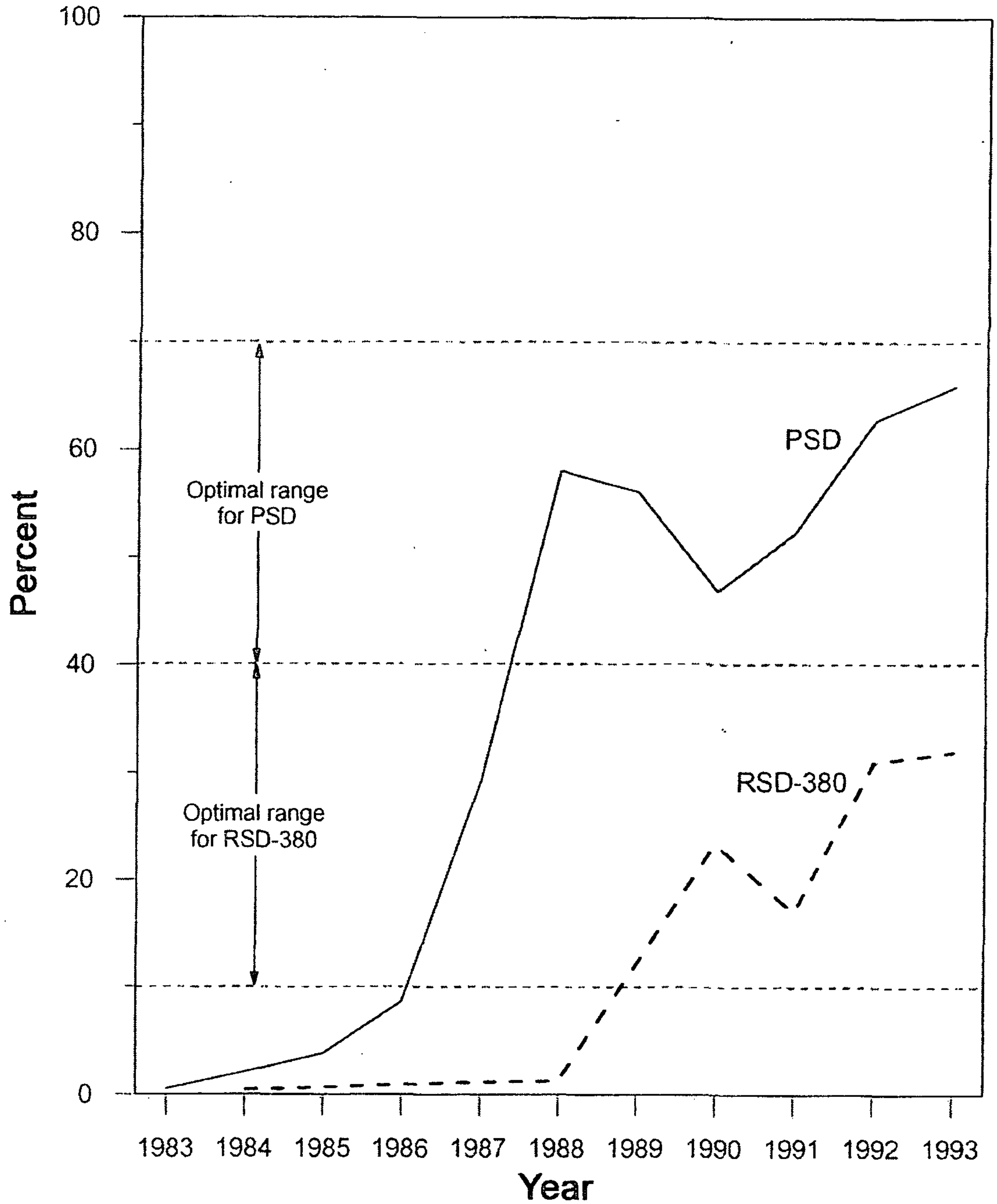
Appendix 28. **Length-frequency distributions of gizzard shad collected during electrofishing sampling at Harris Lake, 1989-1993.**



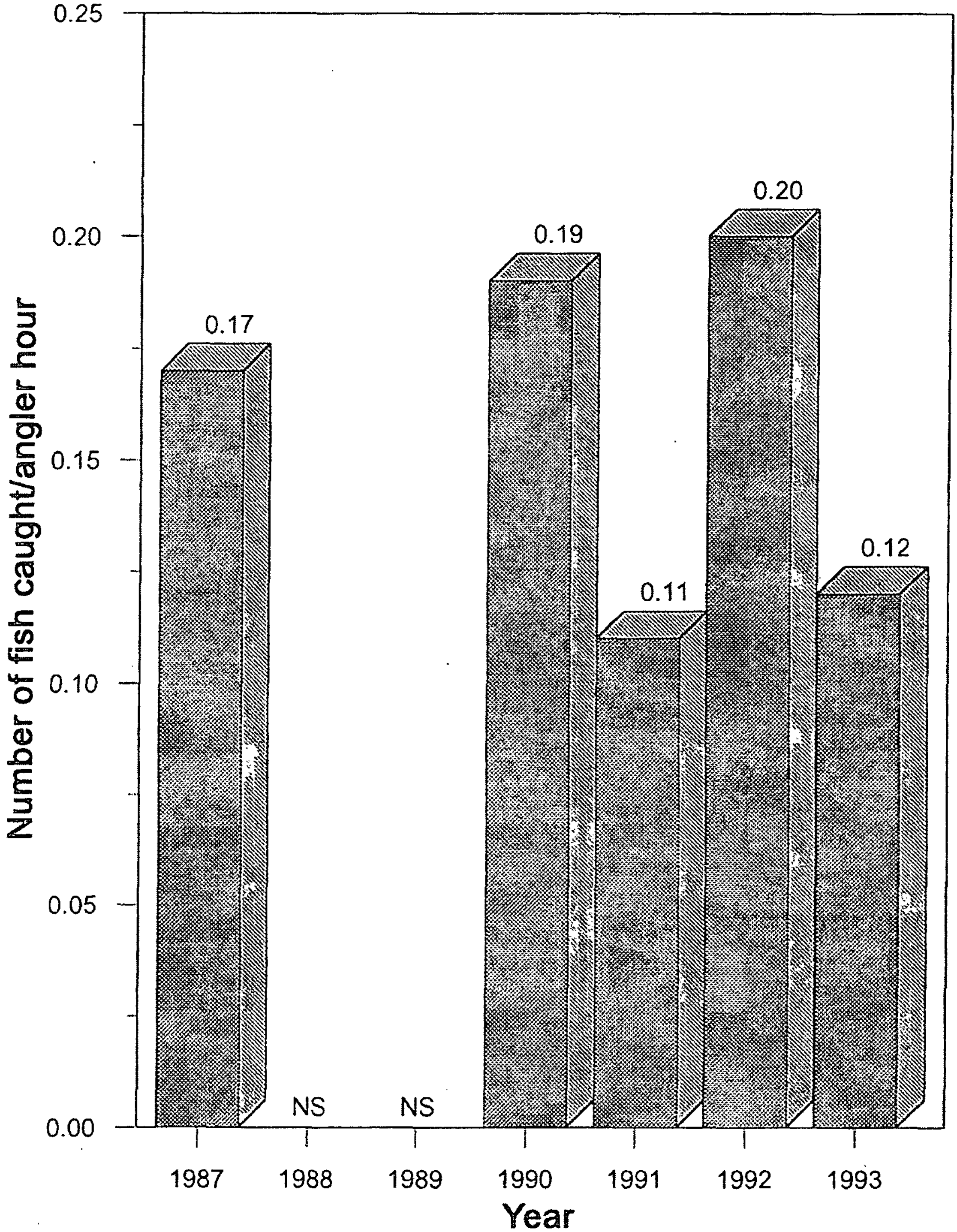
Appendix 29. Length-frequency distributions of brown bullhead collected during electrofishing sampling at Harris Lake, 1989-1993.



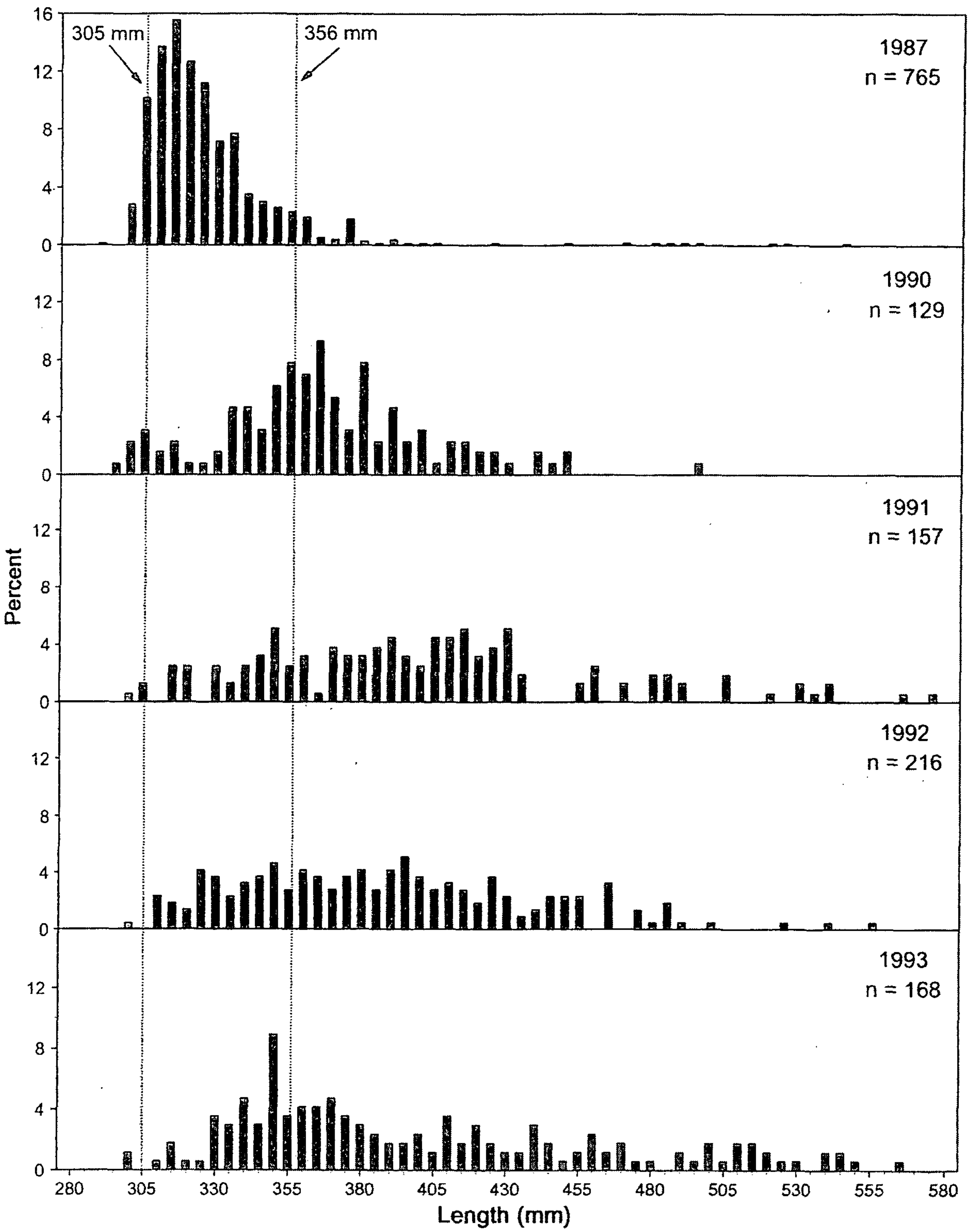
Appendix 30. Length-frequency distributions of largemouth bass collected during electrofishing sampling at Harris Lake, 1989-1993.



Appendix 31. **Proportional Stock Density (PSD) and Relative Stock Density-380 mm (RSD-380) for largemouth bass collected during electrofishing sampling at Harris Lake, 1983-1993. The optimal ranges were adopted from Gabelhouse (1984).**



Appendix 32. **Catch rate of largemouth bass caught during selected Harris Lake fishing tournaments, 1987-1993. NS = Not sampled.**



Appendix 33. **Length-frequency distributions of largemouth bass caught during selected fishing tournaments at Harris Lake, 1987-1993.**