TENNESSEE VALLEY AUTHORITY

Office of Natural Resources
Division of Air and Water Resources

AQUATIC ENVIRONMENTAL CONDITIONS IN CHICKAMAUGA RESERVOIR DURING OPERATION OF SEQUOYAH NUCLEAR PLANT, SECOND ANNUAL REPORT (1982)

TVA/ONR/WRF--83/12(a)

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Abstract

The Tennessee Valley Authority conducts water quality and biological monitoring in Chickamauga Reservoir as required by the National Pollutant Discharge Elimination System Permit for Sequoyah Nuclear Plant (SQN). Evaluations of 1982 operational monitoring data and comparisons of these data to previous operational and preoperational data are presented in this report. Plant operations were limited during the initial period of operational monitoring (1980 and 1981) because of plant testing. In 1982 SQN operations probably reflect "normal" conditions.

Comparisons of aquatic parameters upstream and downstream of SQN showed occasional differences among stations in 1982. Most of these differences were thought to be associated with factors other than SQN. However, plant operation was judged to cause or contribute to changes in phytoplankton, zooplankton, and benthic macroinvertebrate communities during certain periods, and to attraction of white bass and avoidance by sauger of the diffuser area during summer. With the possible exception of freshwater drum larval entrainment, intake losses were not believed to have adversely affected the Chickamauga Reservoir fish community. Except for the above observations, overall differences identified between preoperational and operational periods were considered unrelated to plant operation. To date, SQN apparently has not significantly impacted the aquatic environment.

1.0 INTRODUCTION

1.1 Purpose and Objective

The Tennessee Valley Authority (TVA) initiated construction of Sequoyah Nuclear Plant (SQN) in 1969. TVA began loading fuel in the first of two units on March 1, 1980 and in the second unit on July 3, 1981. Important dates in progression of plant testing are in table 1-1.

SQN uses water from Chickamauga Reservoir (Tennessee River) for various plant processes and then discharges this water back to the reservoir. To evaluate potential intake and discharge effects to the aquatic environment, the National Pollutant Discharge Elimination System (NPDES) Permit (No. TN0026450) requires nonradiological monitoring of the aquatic environment for at least two years after commercial operation of unit 2.

Table 1-2 summarizes this monitoring program which was developed by TVA and approved by the Environmental Protection Agency (EPA). Monitoring programs such as this are designed to detect and evaluate significant changes in water quality and biological communities rather than to investigate cause/effect mechanisms. Cause/effect investigations are targeted at specific, identified concerns and are beyond the scope of this initial program. However, these results can be used to postulate potential causative factors when changes are identified, although quantification (i.e., relative contribution) of each potential causative factor is not possible.

This is the second annual monitoring report following initiation of operation for this facility. The first operational monitoring report (TVA, 1982a) included data from 1980 and 1981. The first report did not identify changes in the aquatic environment associated with SQN operations;

however, plant operations during 1980 and 1981 were limited because of plant testing. Plant operation during 1982 is described in chapter 2.

Data analyses in this second operational monitoring report were similar to those in the first in that both spatial and temporal differences were examined. Spatial alterations were determined for 1982 by comparing data from stations upstream and downstream of SQN. Temporal changes were determined by comparing operational data (data collected 1980, 1981, and 1982) to preoperational data (data collected between 1970 and 1980, dates varying by data type, and reported in TVA, 1978a and b).

1.2 Plant Description

Sequoyah Nuclear Plant is about 29 km (18 mi) northeast of Chattanooga, Tennessee, on the west shore of Chickamauga Reservoir at Tennessee River Mile (TRM) 484.5 (figure 1-1). It has two pressurized water reactors with a total nameplate rating of 2,441 MWe. The plant was initially designed in the mid-1960's to use open-mode (once-through) cooling to comply with then existing thermal criteria. More stringent thermal criteria were proposed by the State of Tennessee and approved by EPA in 1972. To meet these more stringent criteria, natural draft cooling towers were constructed to enable the plant to operate in open, helper, or closed modes.

Cooling water is withdrawn from lower strata of Chickamauga Reservoir under a deep skimmer wall (figure 1-2). This skimmer wall has an opening length of 165 m, an opening height of approximately 2 m, and is situated near the river channel where water depth is approximately 13 m. Because of the deep opening at the skimmer wall, water temperature in the intake canal is often lower than reservoir surface water temperature.

An intake channel leads from the intake embayment to the intake pumping structure, which houses six, 3 m wide vertical traveling screens. Each screen bay opening is 4.67 m by 7.16 m and screen mesh openings are 0.95 cm^2. Under open-mode operation with both units operating at maximum power, total water demand is 72.45 m^3/s. Calculated temperature rise across the condensers is 16.4° C.

A separate shoreline-mounted Essential Raw Cooling Water (ERCW) pumping station is located adjacent to the upstream end of the skimmer wall (figure 1-2). Total pumping capacity of this four-screen intake is 0.5 m^3/s.

Water leaving the condensers can be routed in one of three ways: (1) to the diffuser pond and out the diffuser pipes (open mode); (2) through the cooling towers, then to the diffuser pond and out diffuser pipes (helper mode); or (3) through the cooling towers and recirculated to the intake (closed mode) with only blowdown discharged through the diffuser pipes.

Surface area of the diffuser pond is about 13 ha. As a result of head loss through the diffusers, pond elevation is 1-2 m higher than the reservoir. Two discharge pipes lead from the discharge pond to diffuser sections which are located in the main navigation channel. Each of the actual diffuser sections contains several thousand 5 cm diameter ports, through which heated water is discharged at a velocity of about 3 m/s.

An underwater dam, which crosses the river channel approximately 76 m upstream from the diffusers, decreases the thickness of any upstream warm-water wedge from the thermal discharge and "impounds" cooler water in lower strata of the reservoir near the plant making this water available to the plant intake. The dam is about 27 m wide by 274 m long with the crest at elevation 199.3 m msl.

1.3 Reservoir Description

Chickamauga Reservoir is formed by Chickamauga Dam, situated at TRM 471.0. Water elevation normally varies from 205.7 m msl in winter to 208.0 m msl in summer. At elevation 208 m msl, the reservoir is 94.8 km (58.9 mi) long on the Tennessee River and extends 51.5 km (32 mi) up the Hiwassee River. Water depths downstream of the plant range from about 24 m at Chickamauga Dam to about 15 m at the Sequoyah site. Reservoir widths vary from 213 m to 2.7 km (1.7 mi).

At the plant site, the reservoir makes a sharp bend to the right (facing downstream) as shown in figure 1-3. The main river channel in this vicinity is approximately 300 m wide and bordered on each side by shallow overbank areas.

Average streamflows in the vicinity of SQN closely approximate flow released from Chickamauga Dam. Flow release records for the period 1957 through 1976 show a mean annual discharge of 1,020 m^3/s (36,000 cfs). Monthly average discharges ranged between 800 m^3/s (28,200 cfs) in April and 1,470 m^3/s (51,800 cfs) in February.

The duration of zero flow periods from Chickamauga Dam is typically short as a result of operating patterns designed to assure minimum flows in the Tennessee River near Chattanooga. According to current operating guidelines which have been in effect since July 22, 1975, TVA attempts to maintain a minimum daily average discharge of 170 m^3/s (6,000 cfs) from Chickamauga Dam.

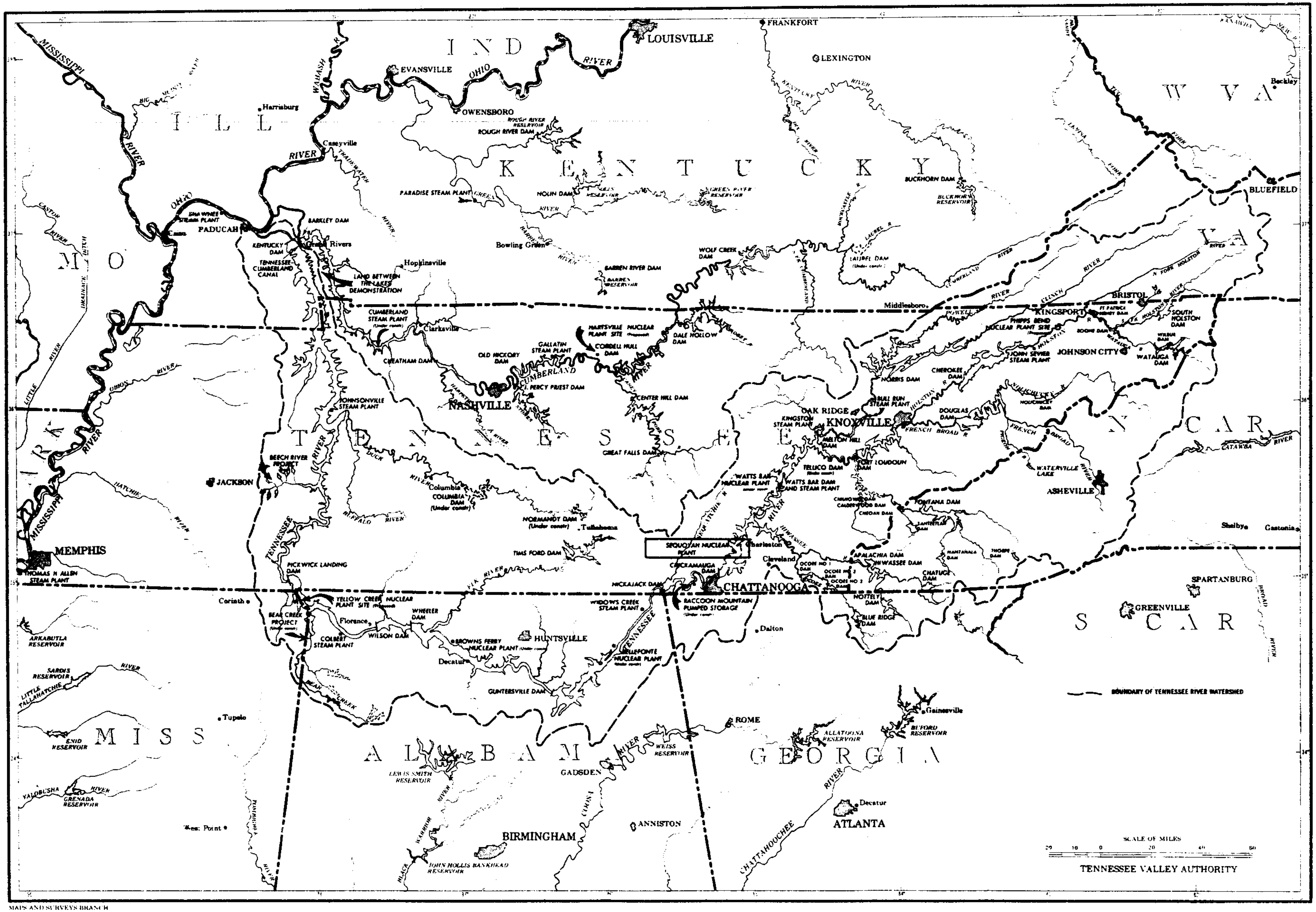

Figure 1-1. Location of Sequoyah Nuclear Plant in the Tennessee Valley.

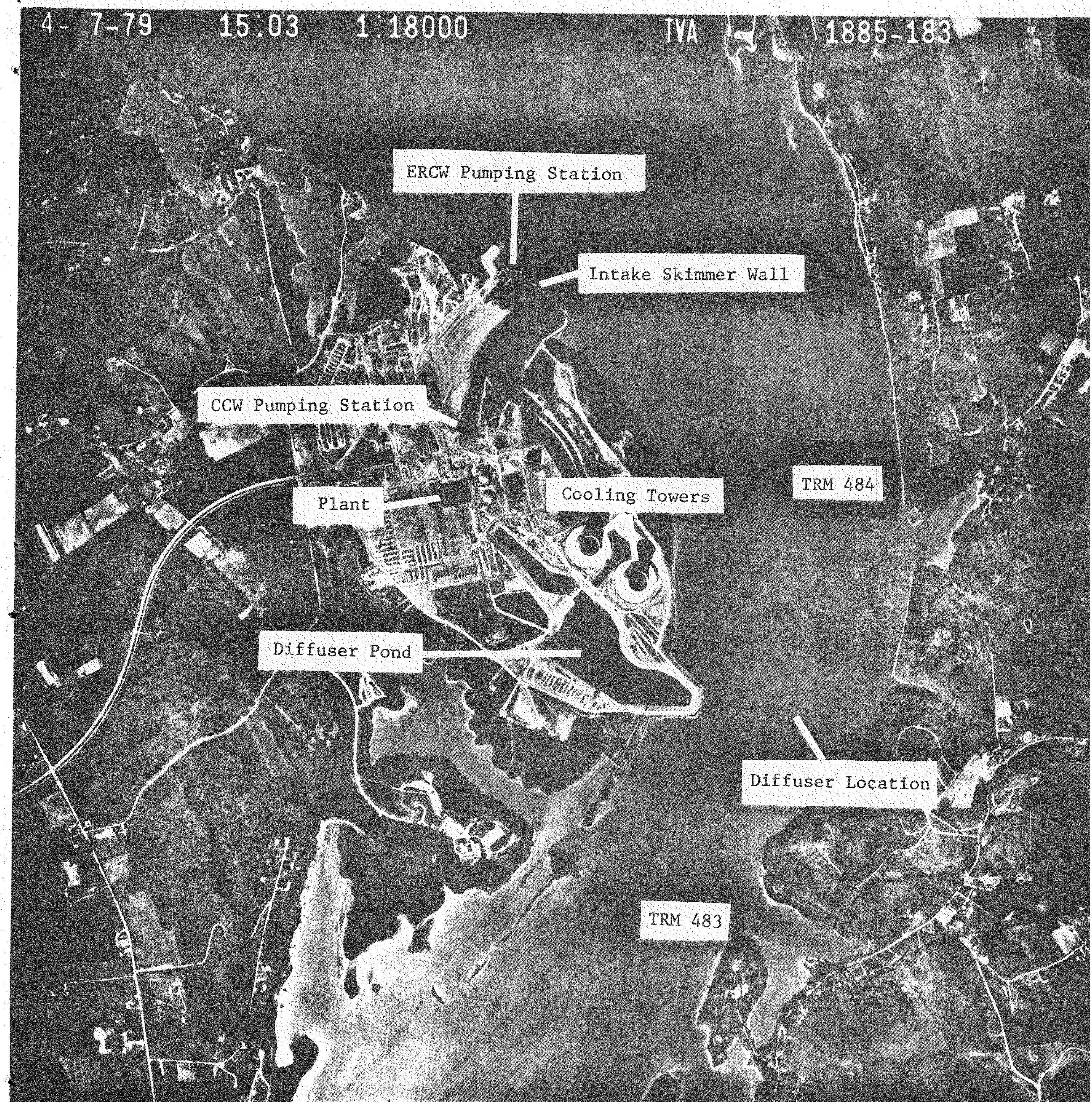

Figure 1-2. Major Features of Sequoyah Nuclear Plant.

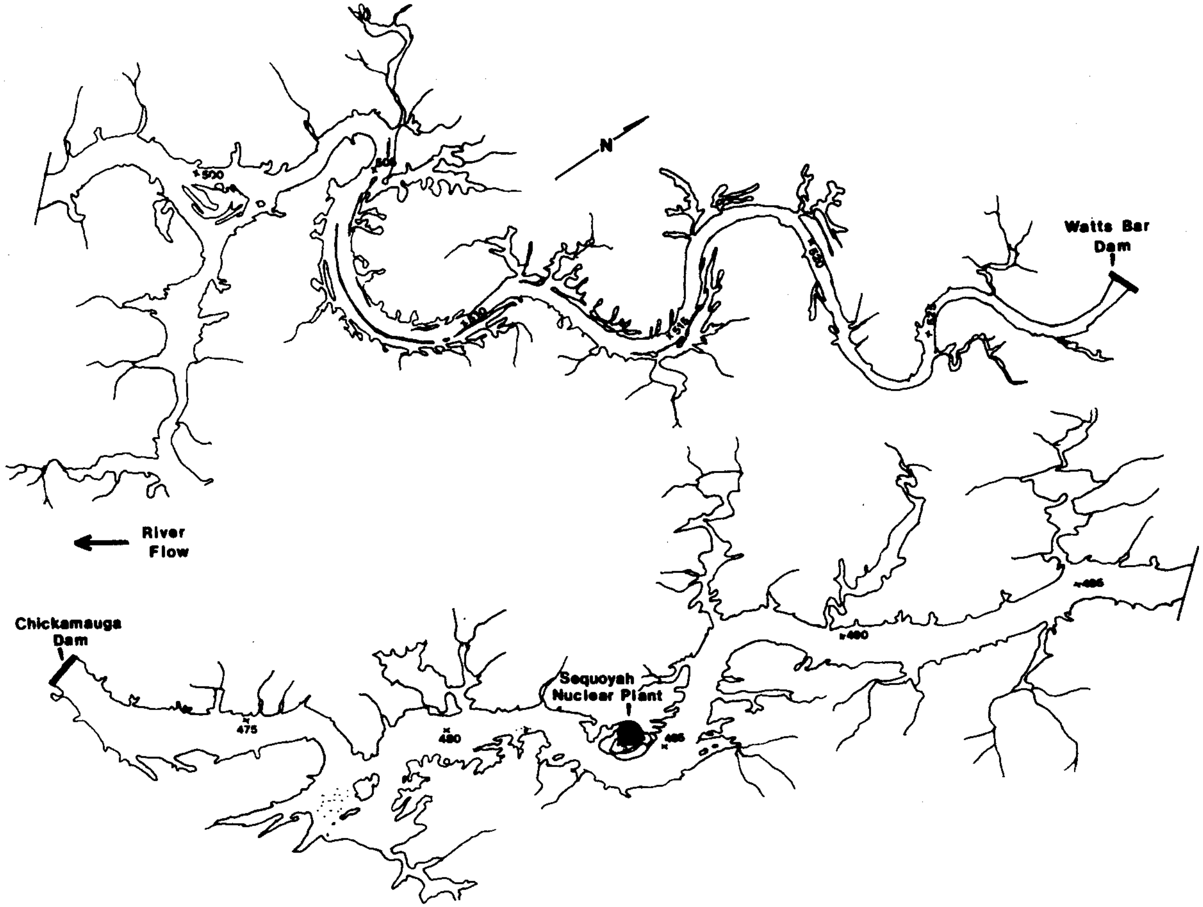

Figure 1-3. Location of Sequoyah Nuclear Plant on Chickamauga Reservoir.

2.0 PHYSICAL AND CHEMICAL CONDITIONS OF CHICKAMAUGA RESERVOIR

Evaluation of possible effects from SQN operations (intake and discharge) on the aquatic environment begins with the physical characteristics of the reservoir and the flow, temperature, and light conditions during the study period. Reservoir geometry and flow pattern determine the travel time of water passing SQN. Heating, cooling, and mixing processes govern the natural temperature patterns in the reservoir. Water temperature, nutrients, and available light largely control the growth potential of phytoplankton both upstream and downstream of the SQN site. The SQN operation pattern governs potential entrainment and discharge effects on reservoir biota relative to these natural conditions.

2.1 Physical Characteristics and Natural Conditions

Travel time of water in Chickamauga Reservoir governs the time available for biological growth and decay processes. Growth of phytoplankton and zooplankton, settling of suspended materials, decay of detritus and dissolved organics, and cumulative effects from sediment oxygen demands are all dependent on travel time within the reservoir.

Water released from Watts Bar Dam moves through the reservoir toward Chickamauga Dam in a plug flow manner. If the reservoir is stratified in the downstream end, the plug flow separates into surface and bottom layers and continues past SQN and toward Chickamauga Dam. Stratified conditions may be more suitable for phytoplankton growth because they stay mixed within the euphotic (light) zone. When the reservoir is fully mixed vertically, phytoplankton tend to mix throughout the water column and light conditions are much more limiting. On the other hand, stratification may reduce the availability of nutrients in the euphotic zone.

Water from the Hiwassee River basin enters Chickamauga Reservoir near the mid-point of the reservoir. Flow from the Hiwassee River represents about 10 percent of the total flow in Chickamauga Reservoir. Direct effects from these relatively cool inflows are moderated by the travel time through the Hiwassee River embayment that extends about 20 miles up the Hiwassee River.

Chickamauga Reservoir often is fully mixed vertically because of relatively large flows through the reservoir. However, during periods of low flow, with several consecutive days of sunshine and warming air temperatures, the reservoir can become thermally stratified and flow can separate into a surface layer and a bottom layer. During spring and summer the reservoir may stratify during the day but becomes fully mixed at night. These stratification patterns are often strongest in the downstream portion of the reservoir because velocities are reduced somewhat by larger cross section and travel time of the water is longer. Stratification is enhanced during low flow periods because reduced velocities provide less mixing energy.

2.1.1 Residence Times

Water surface elevation at Chickamauga Dam varies throughout the year in accordance with the seasonal operating guide curve shown in figure 2-1a. Surface water elevation varies from 205.7 m during winter, to 208 m during summer. Total reservoir volume fluctuates with surface water elevation from 465 x 10^6 m^3 (375 x 10^3 Ac-ft) to 735 x 10^6 m^3 (600 x 10^3 Ac-ft). Actual headwater elevations in 1982 are also shown in figure 2-1a.

Considering that water generally moves through the reservoir from Watts Bar Dam to Chickamauga Dam as a plug flow, residence time in the reservoir can be approximated as:

$$\text{Residence Time} = \frac{\text{Reservoir Volume}}{\text{Average Flow}}$$

For a river flow equal to the long term annual average of 1020 m^3/s (36,000 cfs), travel time through the reservoir is between 5 and 8 days, depending on water surface elevation. Daily average flows during 1982 are shown in figure 2-1b. Residence time determines the period available for natural processes to occur in the reservoir before water reaches the intake of SQN and after being discharged or mixed with the diffuser discharge downstream of SQN. If the reservoir is divided at SQN, residence times for these two segments can be calculated. Dividing the reservoir at TRM 485, the segment downstream of SQN has a volume of 182 x 10^6 m^3 at elevation 205.7 m and 277 x 10^6 m^3 at elevation 208 m. This represents 39 percent of the total reservoir volume or residence time at elevation 205.7 m, and 46 percent of the total reservoir volume or residence time at elevation 208. In the same way, travel time between any two points can be estimated by the volume between these two points divided by the flow. Figure 2-2 shows Chickamauga Reservoir segmented into several reaches of interest. Table 2-1 presents these volumes and travel times at two elevations (205.7 m and 208 m), for flows of 283 m^3/s and 1130 m^3/s (10,000 cfs and 40,000 cfs).

2.1.2 Flow Patterns

Water flowing past SQN comes from three sources: (1) releases from Watts Bar Reservoir, (2) releases from Ocoee No. 1 and Apalachia Reservoirs on the Hiwassee River, and (3) local inflow from streams entering Chickamauga Reservoir itself. The relative contribution from these three sources may be important for interpreting water quality or biological data for a particular day, although the flow is dominated by Watts Bar releases.

On a seasonal time scale, flows through Chickamauga Reservoir are relatively uniform due to flow regulation by upstream reservoirs. Chickamauga Dam releases include all three sources and long term average monthly flows are shown in table 2-2.

Monthly average flows in Chickamauga reservoir during 1982 are also listed in table 2-2. Flows were quite high in January and February. March flows were near the long term March average, but April and May flows were very low. Flows throughout the June-November period were quite uniform and near the long term average pattern. December flows were higher than normal. The most notable flow conditions were low spring releases from Chickamauga. This produced very long residence times and allowed significant stratification to develop in the reservoir during May and June.

While flows and corresponding travel times are helpful in interpreting plankton and water quality samples, velocities within the reservoir may be more important for evaluating potential effects from SQN on other organisms. Average velocity at a particular location in the reservoir is determined by river flow and cross sectional area. The distribution of velocities at a particular site is further dependent on the geometry of the reservoir near the sample location.

For macrobenthic sample sites at TRM 478.2, TRM 483.4, and TRM 490.5, the reservoir cross sectional areas are nearly the same, although the cross sectional geometry is different as shown in figure 2-3. These particular cross sections do not indicate the general downstream increase in area. The upstream site (TRM 490.5) has a cross section of approximately 6,000 m^2 with a depth of 12 m and an overbank area. The SQN diffuser site (TRM 483.4) is much deeper (17 m) with a similar overbank region and a total cross section of approximately 5,100 m^2. The downstream site (TRM 478.2) has very little overbank, with a depth of 17 m and a cross section of 5,100 m^2. Average velocity in these cross sections is therefore approximately the same and can be estimated as

$$\text{Velocity (cm/sec)} = 5\times10^{-4}\times\text{Flow (cfs)}$$

Velocity distributions shown in figure 2-3 were obtained during steady flow of 1,135 m^3/s (40,000 cfs), so the average velocity is about 20 cm/sec. The largest velocity gradients (shear) occur along the sides of the transition from overbank to main channel. These regions experience the greatest scouring. The velocity gradients are more gradual at the bottom of the main channel.

2.1.3 Temperatures and Mixing

A very pronounced episode of stable stratification developed during the extremely low flows of May 1982 (figure 2-4). Temperatures at the SQN intake remained fully mixed throughout April, but in early May, as surface temperatures warmed from 17° C to 21° C, bottom temperatures remained at 16° C. Bottom temperatures warmed slowly to 20° C by the end of May and to 25° C by the end of June. Surface temperatures warmed more rapidly from 20° C on May 10 to 23-25° C throughout the second half of May.

This created a stratification of about 5-7° C throughout May, decreasing to become only a diurnal stratification pattern by the middle of June. Downstream surface temperatures were 1-2° C warmer throughout the spring period. Downstream bottom temperatures were 2-4° C warmer. This warming is due to a combination of natural heating, blockage of cool water by the submerged dam, and plant discharge of heated water. The remainder of the summer was characterized by intermittent and diurnal stratification, with full mixing occuring on most nights (figure 2-5). Both units at SQN were operating throughout this period and downstream temperatures were warmer than those at SQN intake. The pattern of stratification was nearly identical at the two locations, and the downstream temperatures were 2-3° C warmer. Downstream surface temperatures approached 29° C during a couple of sunny periods of August, while bottom temperatures remained below 28° C.

Temperatures were fully mixed during the fall, as they were during the winter months of January through March. Upstream-downstream temperature differences were relatively small during these fully mixed periods because of high flows and low plant loads.

Table 2-1. Volumes and Representative Travel Times for Selected Segments of Chickamauga Reservoir Used in Interpretation of Operational Monitoring Data, Sequoyah Nuclear Plant

Segment	Volume ($10^6 m^3$) at 205.7 m	at 208 m	Representative Flow (m^3/s)	Travel Time (Days) at 205.7 m	at 208 m
1. Watts Bar to Hiwassee Confluence	101	160	283 1130	4.1 1.0	6.6 1.6
2. Hiwassee Arm	28	62	71 283	4.6 1.2	8.4 2.1
3. Hiwassee Confluence to SQN Intake	153	227	283 1130	6.3 1.6	9.3 2.3
4. SQN Discharge to Chickamauga Dam	182	277	283 1130	7.5 1.9	11.4 2.8
5. Upstream Sample (490.5) to SQN Intake	58	84	283 1130	2.4 0.6	3.4 0.8
6. SQN Discharge to 478.2 Sample	44	65	283 1130	1.8 0.4	2.7 0.7

Table 2-2. Long-Term Monthly Average Releases and Corresponding Travel Times Through Chickamauga Reservoir Compared to Flows and Travel Times During 1982

	Long Term Average			1982 Conditions		
Month	Chickamauga Dam Releases (m^3/s)	(cfs)	Travel Time Through Chickamauga Reservoir (days)	Chickamauga Dam Release (m^3/s)	(cfs)	Travel Time (days)
January	1,365	48,200	4	1,787	63,100	3.5
February	1,470	51,800	4	2,185	77,140	2.8
March	1,300	45,800	4	1,350	47,650	4.5
April	800	28,200	9	363	12,810	25
May	800	28,300	11	356	12,580	25
June	825	29,100	10	574	20,280	16
July	840	29,700	10	763	26,950	12
August	895	31,500	9	924	32,630	10
September	800	28,300	10	855	30,180	11
October	870	30,700	9	785	27,730	10
November	1,020	36,100	7	927	32,730	7
December	1,260	44,500	5	1,968	69,480	3
Annual Average	1,020	36,000	8	1,069	37,770	7

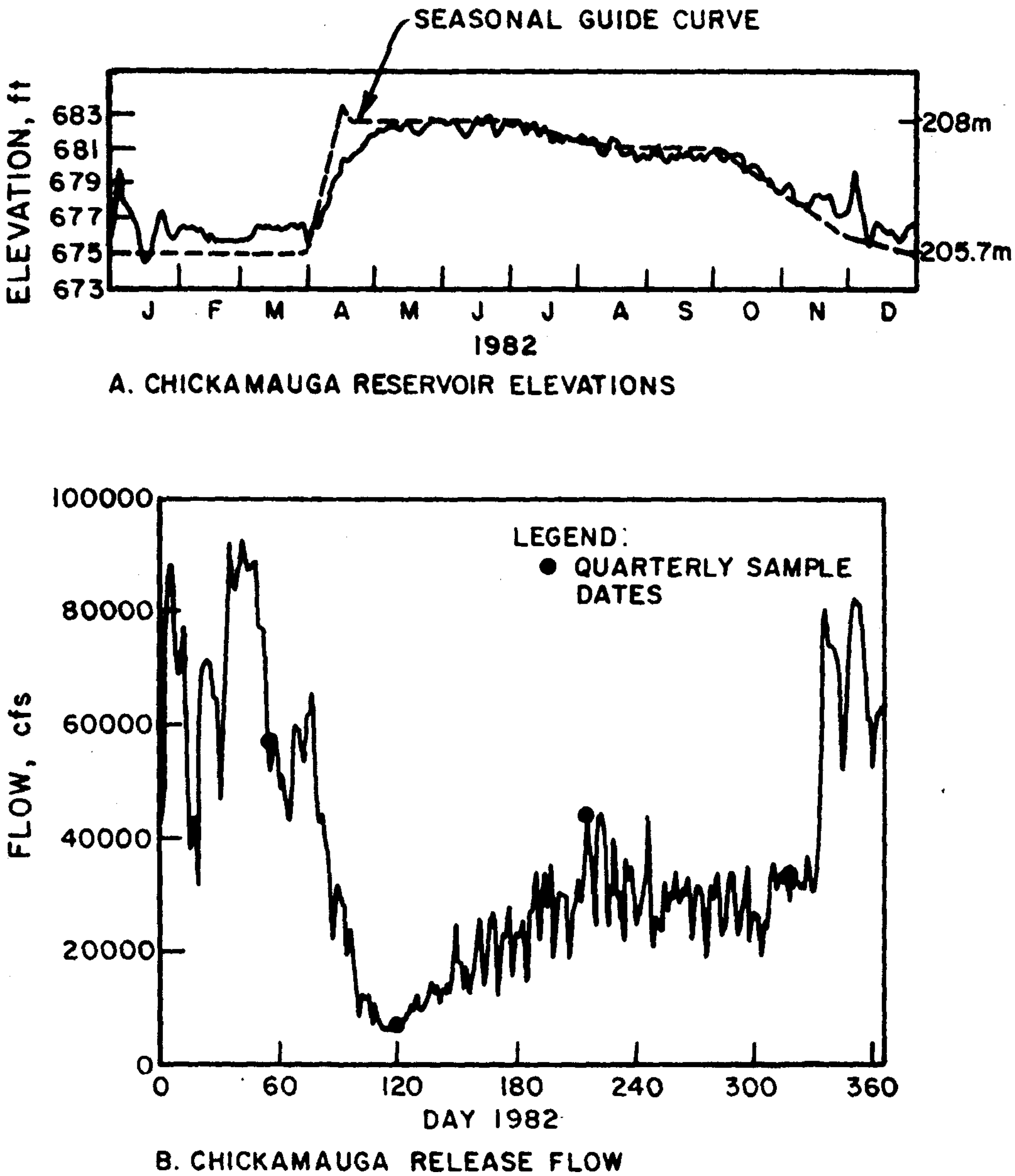

Figure 2-1. Chickamauga Reservoir Elevations and Release Flows for 1982

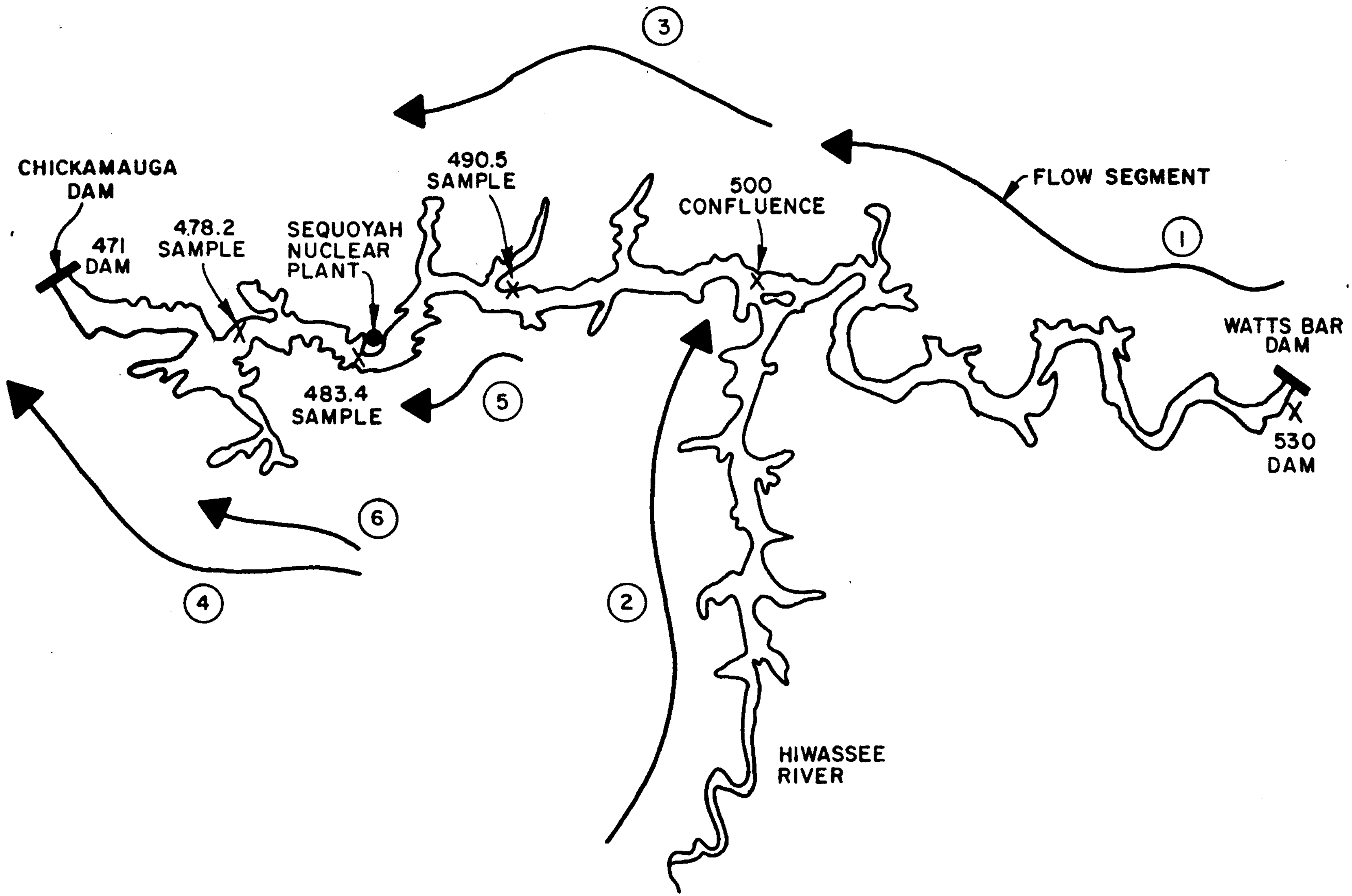

Figure 2-2. Flow Segments of Chickamauga Reservoir Used in Interpretation of Operational Monitoring Data, Sequoyah Nuclear Plant

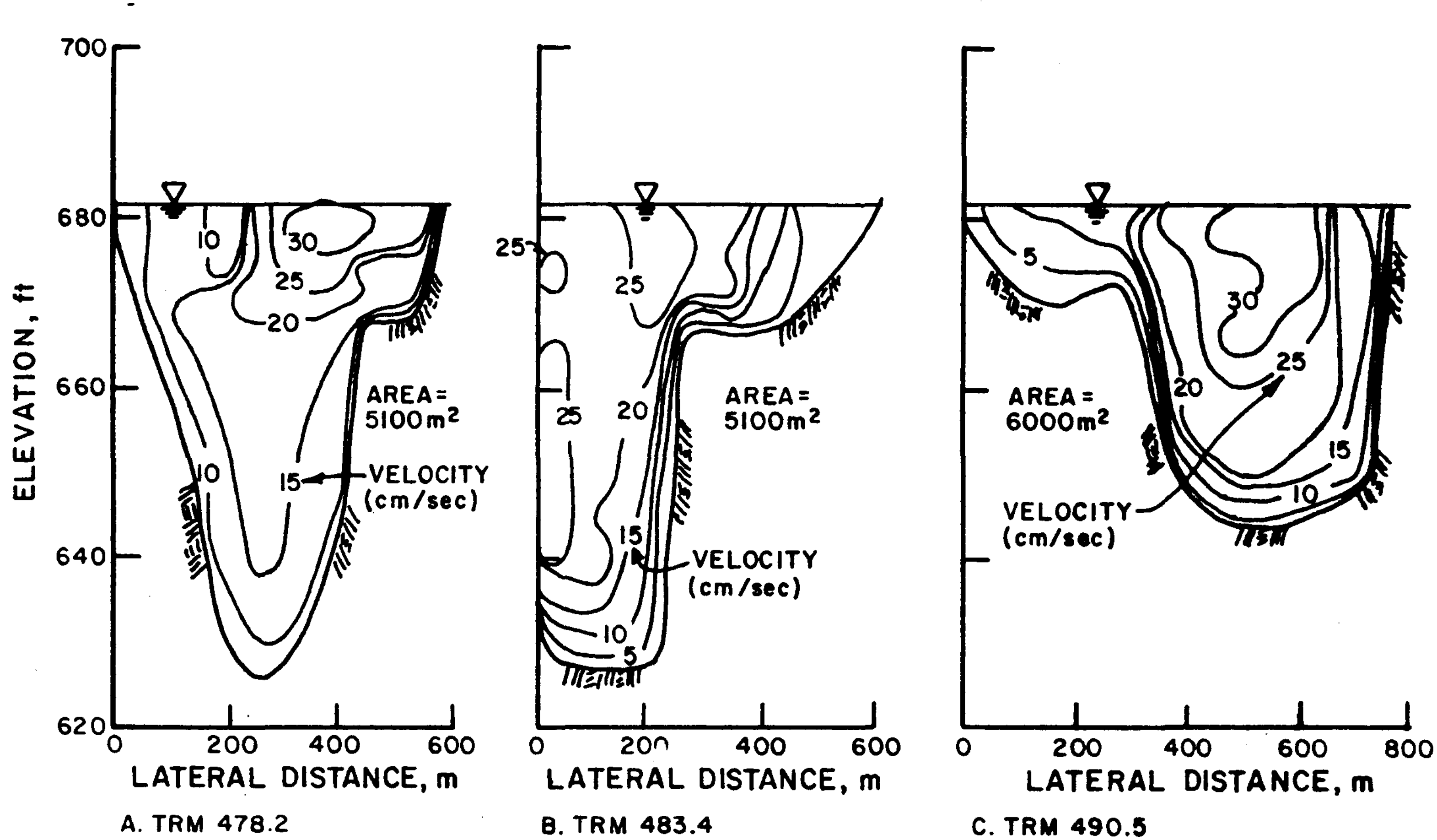

Figure 2-3. Velocity Distributions in Chickamauga Reservoir With a Flow of 40,000 cfs

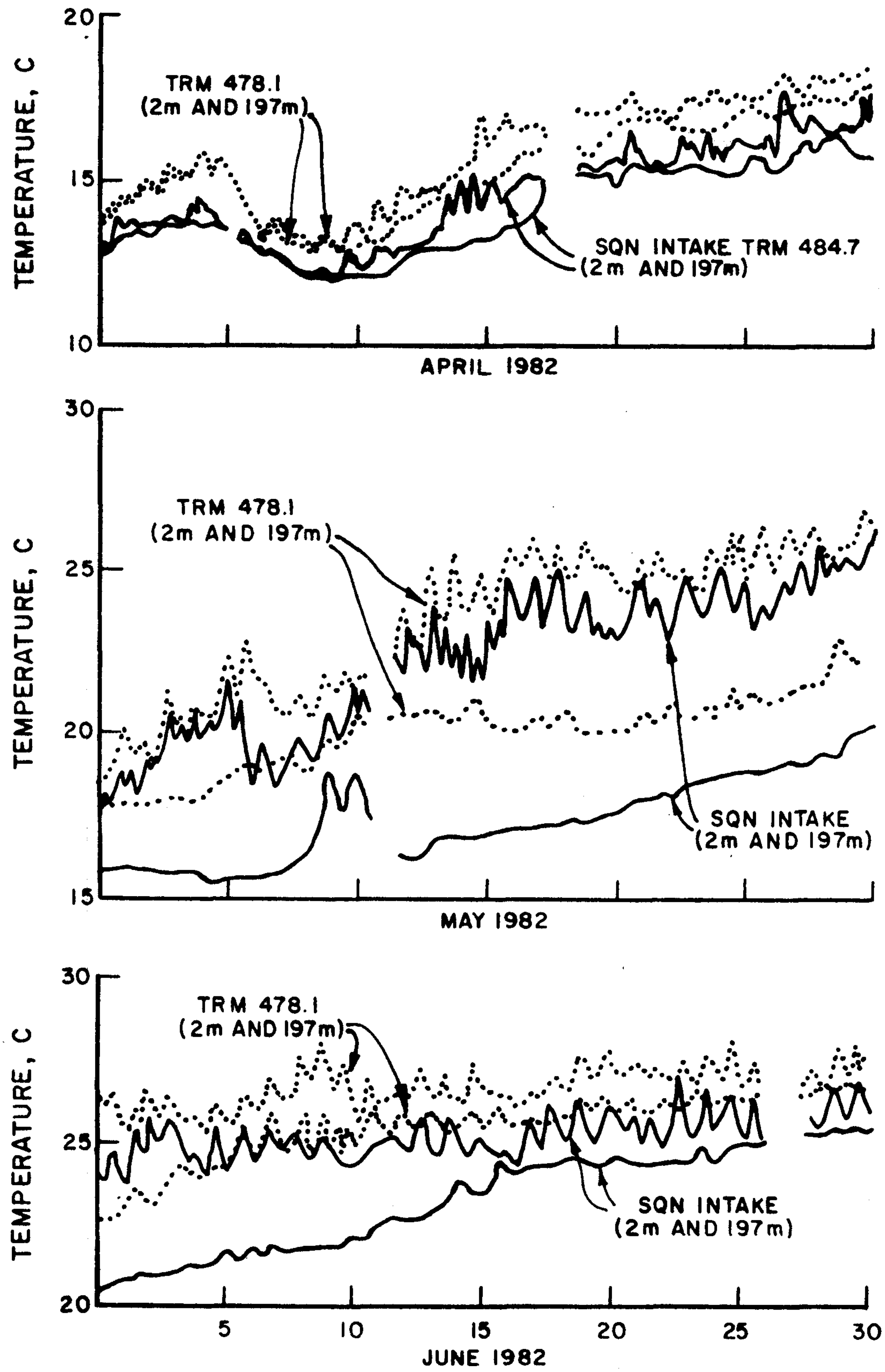

Figure 2-4. Temperature Patterns in Chickamauga Reservoir During the Spring of 1982 at Near Surface (2 m Depth) and Near Bottom (197 m msl)

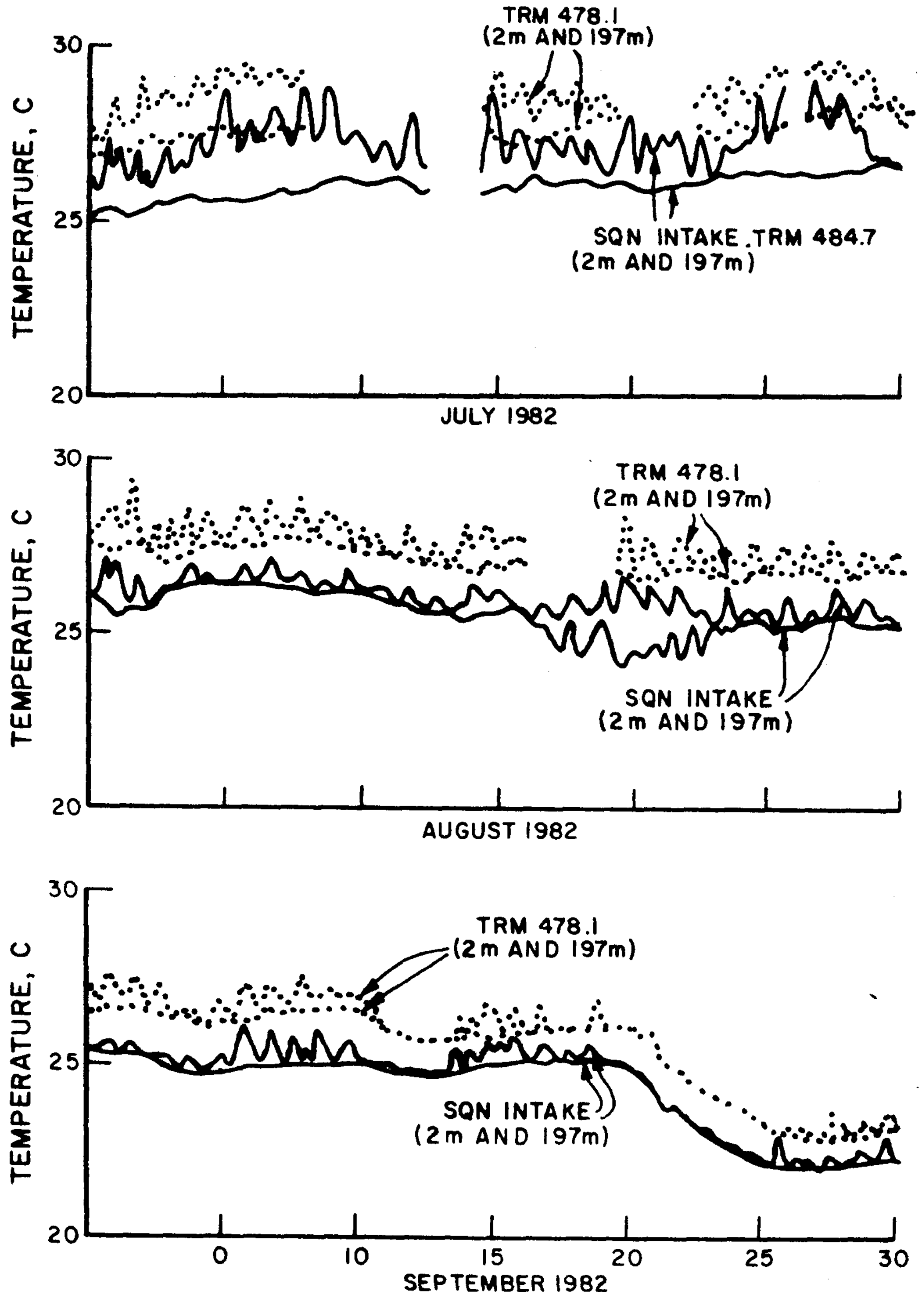

Figure 2-5. Temperature Patterns in Chickamauga Reservoir During the Summer of 1982 at Near Surface (2 m Depth) and Near Bottom (197 m msl)

2.2 Conditions During Operation of SQN

Potential effects of SQN depend on actual plant operation in relation to natural conditions in the reservoir. These are briefly discussed below.

2.2.1 SQN Operation During 1982

Both units 1 and 2 operated for much of 1982. A summary of monthly output (MWh) and percentage of unit capacity for each month are shown in table 2-3. Combined output of units 1 and 2 was fairly low in January and February, increased to about 50 percent capacity in March, and remained about 70 percent capacity during the spring and summer months of April through August.

Unit 1 was shut down for refueling and modifications during September and remained offline through December. Unit 2 was also offline for maintenance during the second half of November and all of December. SQN was operated at near capacity during the warmest months of the year, and possible plant induced changes in Chickamauga Reservoir should be most evident during spring and summer quarters.

2.2.2 Physical Conditions Prior to 1982 Quarterly Plankton Samples

Physical conditions in Chickamauga Reservoir prior to quarterly plankton samples are important for proper interpretation of sample data because these are transient organisms. This section summarizes water temperatures, flows (travel times), solar heating (light), and plant operations (pumping and load) prior to these sample periods.

February 1982 Conditions

Conditions prior to the February 24, 1982 sample date are shown in figure 2-6. Travel times between several points of interest are shown. Daily average releases from Chickamauga Dam were extremely high and resulting travel times through Chickamauga Reservoir were very short. The travel time from Watts Bar to the upstream sample location was about two days, and travel time from SQN to the downstream sample site was only about five hours.

SQN was operating with partial load on only one unit. Meteorology was sunny, and river temperatures were warming, although the water column remained fully mixed because of the high flows. Water was turbid and the photic zone (1 percent surface light level) was only 2 m deep.

May 1982 Conditions

Physical conditions in Chickamauga Reservoir prior to May 3, 1982, are shown in figure 2-7. Flows during April and May of 1982 were extremely low, and the resulting travel time of water moving through Chickamauga Reservoir was very long. Travel time between Watts Bar and SQN was 22 days, so phytoplankton and zooplankton populations had ample time to develop. Travel time between SQN and the downstream sample site was four days, so that any effects from SQN discharge were initiated several days prior to the time of sampling.

SQN was operating with both one and two units during the period prior to the May 3, 1982, sample date. Reservoir temperatures showed a definite diurnal stratification pattern during the end of April, and warming sunny conditions a few days prior to the May 3 sample date had produced a stable stratification, with surface layers isolated from bottom layers. Stratification at SQN on May 3 was about 3° C. Turbidity was relatively low, with a photic depth of 5 m, and sunny conditions prevailed so that physical factors were quite suitable for phytoplankton growth to occur.

August 1982 Conditions

Conditions prior to August 3, 1982, are shown in figure 2-8. River flows were moderate during the several days prior to the August 3, 1982, sampling date, averaging 30,000 to 40,000 cfs. Increased flows due to heavy rainfall several days prior to sampling may have had an effect on plankton. Travel times between points of interest were much shorter than during April and May. Travel time between Watts Bar and SQN was about three days, and travel time between SQN and the downstream sample site was only 12 hours. SQN was operating at steady full load throughout the period prior to the August 3 sample. A slight cooling episode three to five days prior to the sample date produced full mixing of the reservoir water column, which had been slightly stratified for about five days. A diurnal stratification pattern existed for the three days prior to sampling. Meteorology was sunny and warm and the photic zone extended to a depth of 4 m.

November 1982 Conditions

Conditions prior to the November 16 sample date are shown in figure 2-9. Flows in Chickamauga Reservoir remained about 30,000 cfs prior to the November 16 sample date. Residence times were similar to those throughout the summer and fall with about 4 days travel time from Watts Bar to SQN and about 16 hours travel time from SQN to the downstream sample location.

SQN unit 1 was down for refueling/modifications and unit 2 was shut down three days prior to November 16 sampling for maintenance, so that no plant-induced thermal effects would be evident in downstream zooplankton and phytoplankton samples. Some pumping was occurring prior to the sample date, but the entire reservoir water column was fully mixed because of cooling meteorology during this period. River temperatures were about 13° C and the photic zone extended to 5 m depth.

Table 2-3. Monthly Unit Loads for Sequoyah Nuclear Plant During 1982

	Unit 1 Load (MWh)	Capacity Factor	Unit 2 Load (MWh)	Capacity Factor	Total Capacity Factor
Jan.	286,000	(33%)	65,000	(7%)	(20%)
Feb.	7,400	(1%)	170,000	(21%)	(11%)
Mar.	555,000	(64%)	302,000	(34%)	(48%)
Apr.	681,000	(81%)	538,000	(63%)	(72%)
May	858,000	(99%)	316,000	(36%)	(67%)
Jun.	755,000	(90%)	646,000	(76%)	(83%)
Jul.	851,000	(98%)	837,000	(97%)	(97%)
Aug.	847,000	(98%)	812,000	(94%)	(96%)
Sept.	274,000	(33%)	689,000	(82%)	(51%)
Oct.	Refueling/modification outage		771,000	(89%)	(45%)
Nov.	Refueling/modification outage		326,000	(39%)	(20%)
Dec.	Refueling/modification outage		Maintenance outage		(0%)

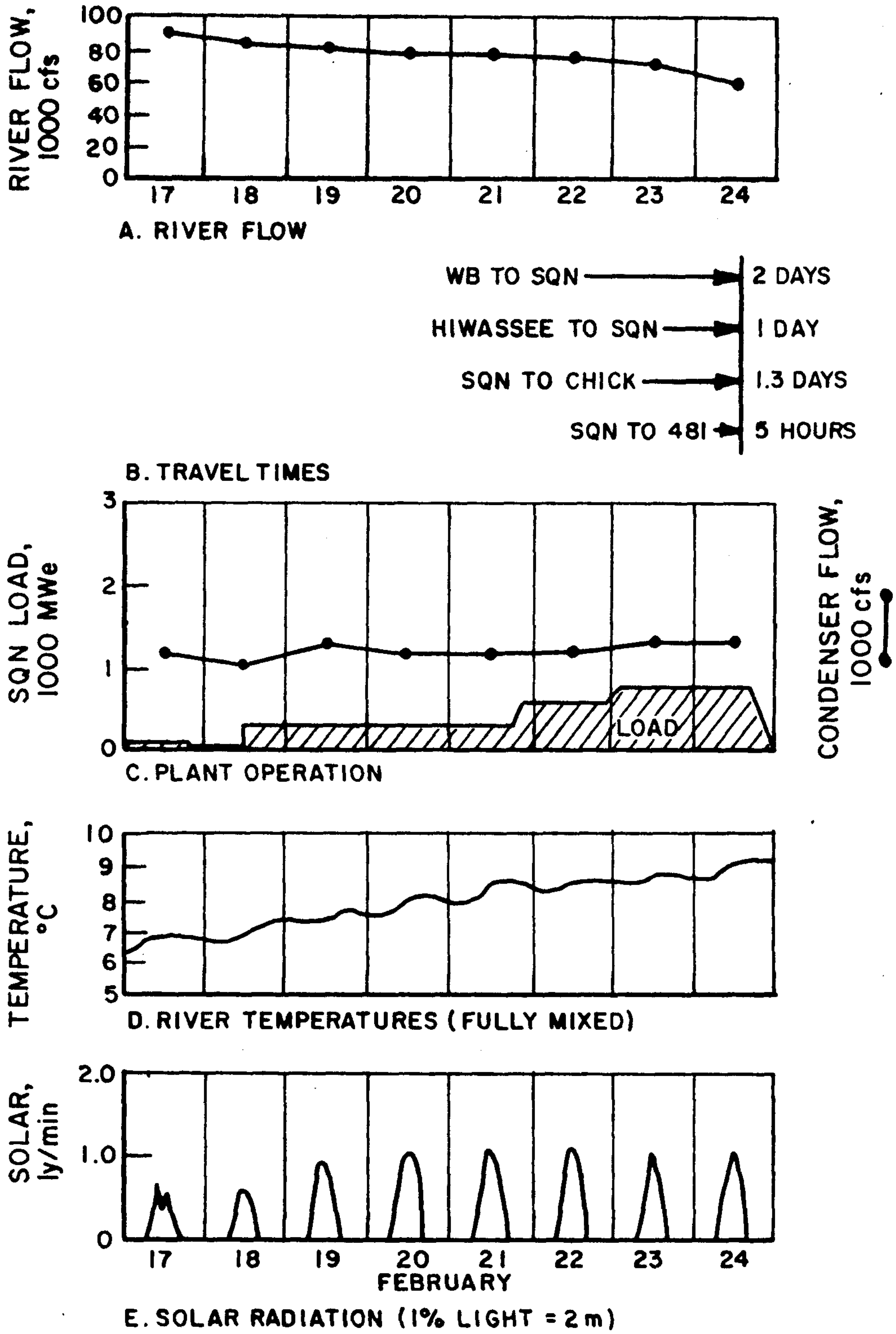

Figure 2-6. Conditions Prior to Plankton Sampling on February 24, 1982, for Operational Monitoring of Sequoyah Nuclear Plant

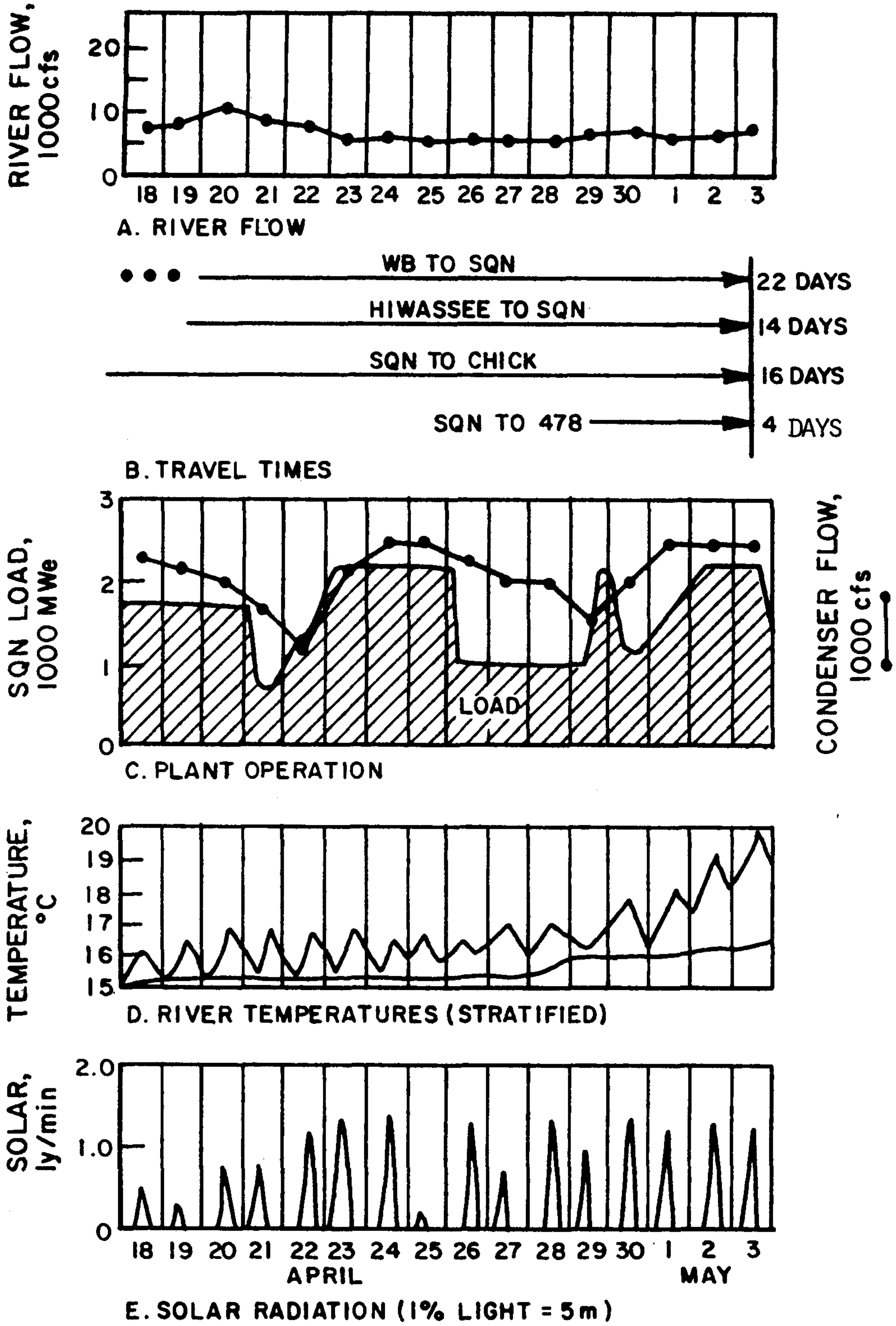

Figure 2-7. Conditions Prior to Plankton Sampling on May 3, 1982, for Operational Monitoring of Sequoyah Nuclear Plant

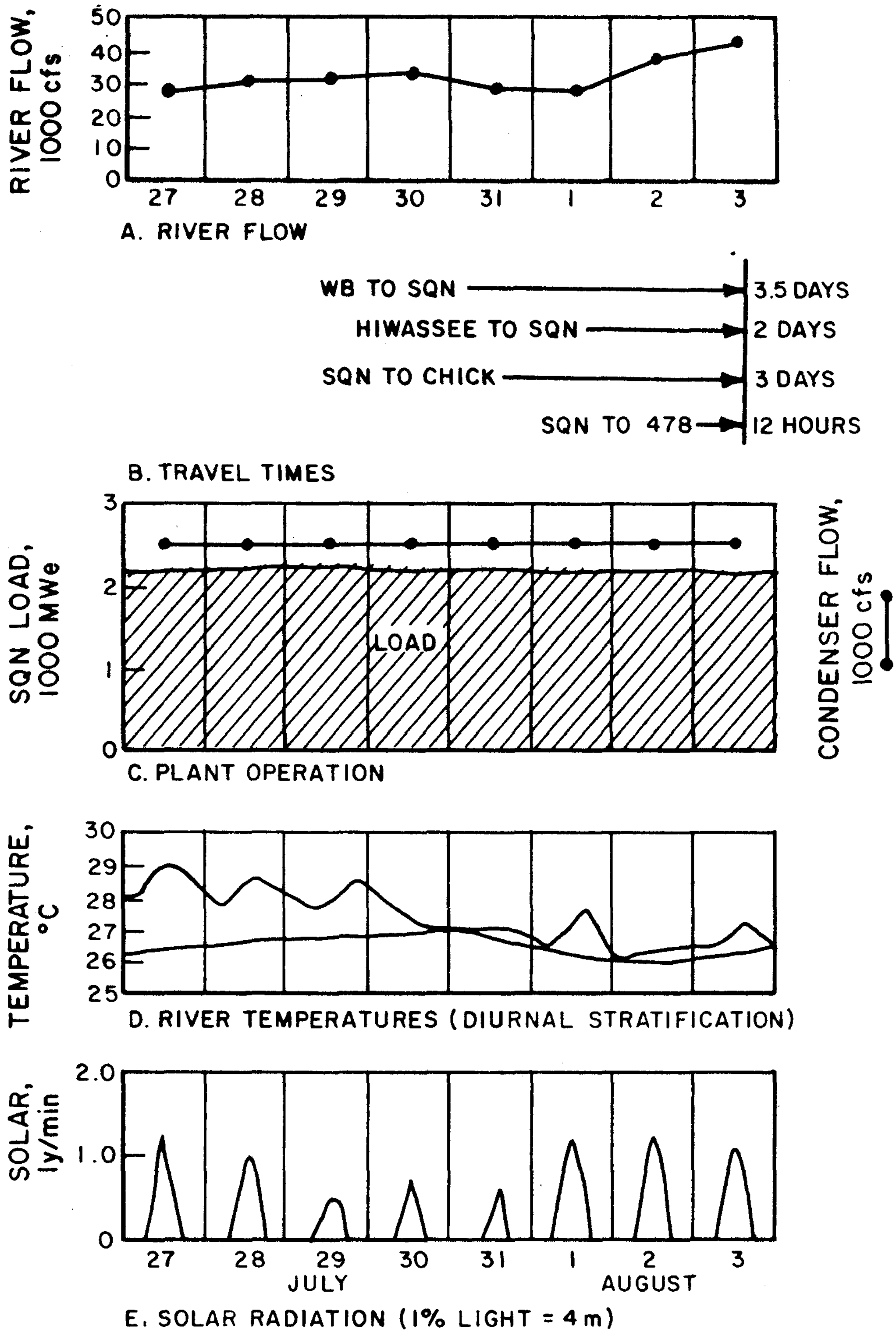

Figure 2-8. Conditions Prior to Plankton Sampling on August 3, 1982, for Operational Monitoring of Sequoyah Nuclear Plant

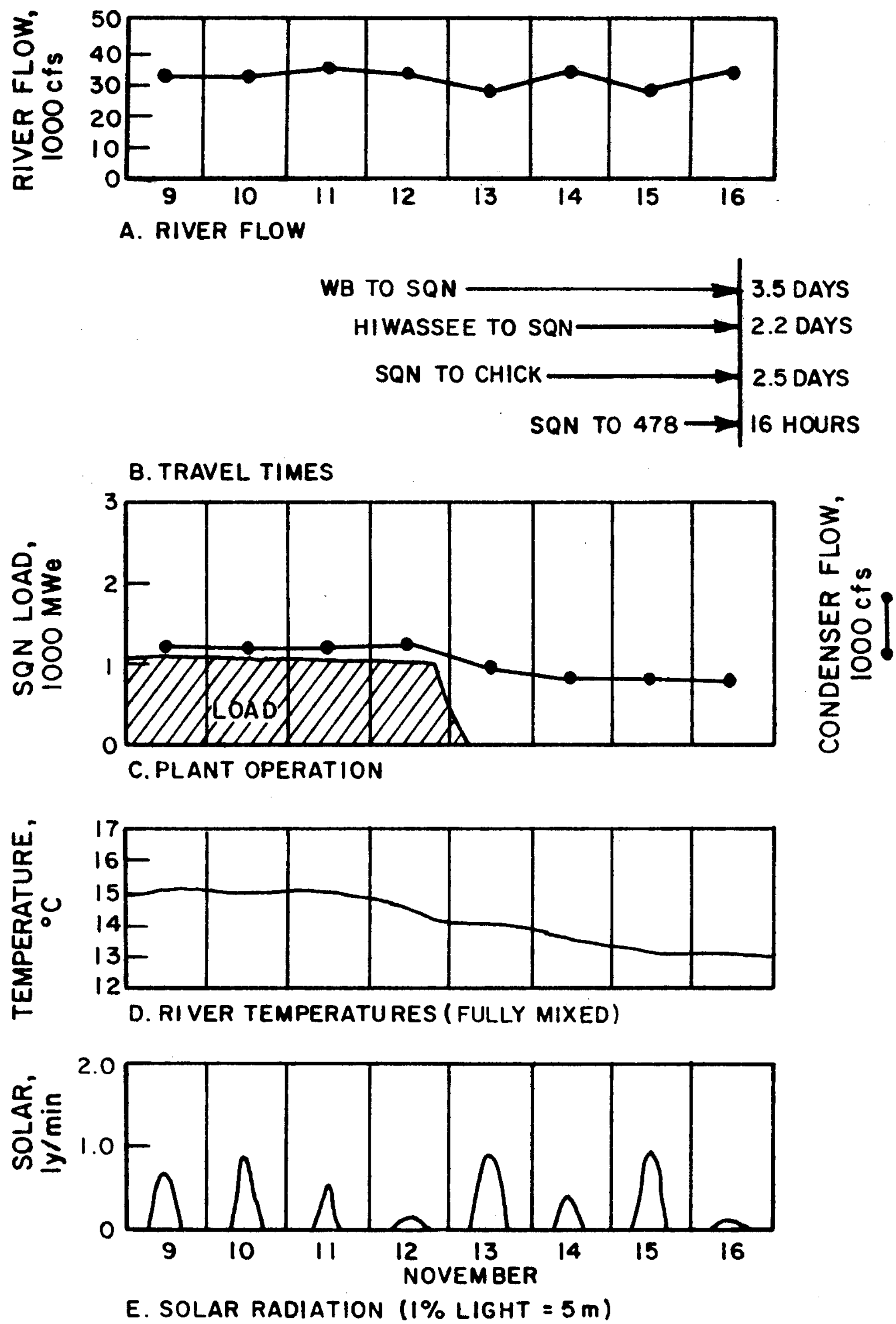

Figure 2-9. Conditions Prior to Plankton Sampling on November 16, 1982, for Operational Monitoring of Sequoyah Nuclear Plant

2.3 Effluent Characteristics

The NPDES permit for SQN contains effluent limitations for protecting the water quality of Chickamauga Reservoir. This NPDES permit also requires additional monitoring of the Condenser Cooling Water (CCW) intake and diffuser for selected chemical constituents. The following section summarizes results of the intake and effluent monitoring program.

2.3.1 Materials and Methods

Sample Collection--Grab samples of the CCW intake and diffuser pond effluent are collected once per month. The CCW intake sample is collected by lowering a liter glass bottle into the intake channel at the upstream side of the intake screens. The diffuser sample is collected by lowering a liter glass bottle into the diffuser pond at the head of the diffuser pipe. At both of these sample locations it is assumed the water columns are well mixed because of the water velocity observed during sampling, allowing collection of representative samples.

Laboratory--Analytical and sample preservation methods used by the SQN Chemical Laboratory for analysis of the intake and diffuser water quality samples are shown in table 2-4. The referenced laboratory methods are the SQN Chemical Laboratory preferred methods, which are approved by EPA. The SQN Chemical Laboratory may occasionally use other approved EPA laboratory methods.

Twelve water quality measurements were made: chloride, sodium, sulfate, total suspended solids, settleable solids, total dissolved solids, total solids, ammonia nitrogen, total copper, total iron, total manganese, and total zinc.

Data Analyses--All intake and effluent quality data were reported on a Discharge Monitoring Report (DMR) Form (EPA No. 3320.1) and submitted quarterly to the Regional Administrator of the Environmental Protection Agency and the Director, Division of Water Management, Tennessee Department of Public Health (DWM). These data are also available from TVA's Water Quality Branch, 248 401 Building, Chattanooga, Tennessee 37401. Intake and diffuser water quality were compared using the paired t test to determine whether the two data sets were statistically different. All data reductions and statistics were accomplished using the Statistical Analysis System (SAS) package available through SAS Institute. All procedures used are documented in the SAS User's Guide; therefore, a detailed discussion of these procedures is not included in this report.

2.3.2 Results and Discussion

CCW intake and diffuser water quality data collected monthly from July 1979 through December 1982 are summarized in table 2-5 and detailed in appendix A.

The paired t test failed to show a statistical difference at the 90 percent confidence level between intake and diffuser water quality for all constituents except sulfates and copper (table 2-6). Failure to show a difference at the 90 percent confidence level is indicated by a value in the PR>|t| column greater than 0.1. The reason for the difference in sulfate concentration is unknown. Because the concentrations of sulfate are low, the diffuser averages 14 mg/ℓ and the intake averages 12 mg/ℓ, the increase of 2 mg/ℓ would not be expected to cause any adverse environmental problems in Chickamauga Reservoir or impair any future uses. Although the mean and range of copper concentrations in the intake and diffuser (means of 74 and

70 μg/ℓ, respectively, and maximum values of 200 μg/ℓ for both) appear similar, the paired t test indicated a statistical difference at the 90 percent confidence level. However, the majority of the samples had copper concentrations less than the minimum detectable limit, restricting interpretation of the data.

Shown in table 2-5 are selected water quality criteria established by EPA and the Tennessee Division of Water Quality Control (TDWQC). These criteria represent water quality levels that should provide for the protection and propagation of fish and other aquatic life and allow use as a domestic water supply but should not be construed as effluent limitations. Also shown in table 2-5 are guidelines recommended by EPA in their secondary drinking water regulations for finished drinking water. Secondary standards are aesthetic standards (i.e., high levels of these parameters can result in undesirable taste, color, or odor). Mean concentrations of total iron and manganese in both the intake and diffuser were slightly above the secondary standards for these metals of 300 and 50 μg/ℓ, respectively. Mean concentrations of total iron and manganese were 330 and 150 μg/ℓ in the CCW intake, respectively, and 300 and 60 μg/ℓ in the diffuser, respectively. Concentrations of all other water quality parameters (i.e., chloride, sulfate, total dissolved solids, ammonia nitrogen, copper, and zinc) were below the respective criteria shown in table 2.5.

Although data did not show Tennessee's criterion for ammonia nitrogen to be exceeded (see table 2-7) the concentration in the diffuser probably exceeds the criterion occasionally during summer simply because the water discharged is warmer than that of the intake. The ammonia nitrogen criterion is a function of temperature and pH. As pH and/or temperature increases, the criterion concentration decreases. The diffuser has, on occasion, had a pH as high as 8.6 and a temperature as high as 37° C. For this condition, the ammonia criterion is less than 0.2 mg/ℓ which is less than the average 0.3 mg/ℓ ammonia nitrogen observed in samples from the diffuser. The frequency at which the ammonia nitrogen criterion may be exceeded is unknown. However, once the discharge has been cooled and neutralized by mixing in the reservoir, ammonia nitrogen concentrations in Chickamauga Reservoir should be below the criterion.

2.3.3 Summary and Conclusions

Diffuser water quality is comparable to that of the intake suggesting operation of SQN has had little, if any, effect on the chemical composition of the water withdrawn from and discharged back to Chickamauga Reservoir. An increase in the average sulfate concentration of 2.0 mg/ℓ was the only statistically significant increase in a chemical constituent that might be attributable to operation of SQN. Because sulfate concentrations in the intake are well below any water quality criteria, the slight increase should not cause adverse environmental problems in Chickamauga Reservoir or impair any future water uses. A statistically significant difference in copper concentrations was indicated. However, since copper concentrations in both intake and diffuser were at or near the minimum detectable limit, this difference is suspect.

Table 2-4. Analytical Methods for Chemical Parameters, Intake and Effluent Additional Monitoring Sequoyah Nuclear Plant

Parameter	Method and Reference*	Preservation Techniques	Detection Limits
Chloride, mg/ℓ	Specific Ion Electrode, Ion Chromatography TVA Nuc Pr DPM N79E2-7B,30	Cool to 4°C	0.20 mg/ℓ
Copper, total, μg/ℓ	Atomic Absorption TVA Nuc Pr DPM N79E2-16	0.5 ml HNO_3/100 ml sample	50 μg/ℓ
Iron, total, μg/ℓ	Atomic Absorption TVA Nuc Pr DPM N79E2-16	0.5 ml HNO_3/100 ml sample	100 μg/ℓ
Manganese, total, μg/ℓ	Atomic Absorption TVA Nuc Pr DPM N79E2-16	0.5 ml HNO_3/100 ml sample	100 mg/ℓ
Nitrogen, ammonia, mg/ℓ	Specific Ion Electrode TVA Nuc Pr DPM N79E2-2B	N/A	0.2 mg/ℓ
Dissolved solids, mg/ℓ	Gravimetric TVA Nuc Pr DPM N79E2-25B	N/A	1 mg/ℓ
Suspended solids, mg/ℓ	Gravimetric TVA Nuc Pr DPM N79E2-25A	N/A	1 mg/ℓ
Total solids, mg/ℓ	Gravimetric TVA Nuc Pr DPM N79E2-25B	N/A	1 mg/ℓ
Settleable solids, mg/ℓ	Imhoff Cone TVA Nuc Pr DPM N79E2-25C	N/A	1 ml/ℓ
Sodium, mg/ℓ	Atomic Absorption TVA Nuc Pr DPM N79E2-16	0.5 ml HNO_3/100 ml sample	0.10 mg/ℓ
Sulfate, mg/ℓ	Turbidimetric, Ion Chromatography TVA Nuc Pr DPM N79E2-36D	Cool to 4°C	1 mg/L, 0.2 mg/ℓ
Zinc, μg/ℓ	Atomic Absorption TVA Nuc Pr DPM N79E2-16	0.5 ml HNO_3/100 ml sample	100 μg/ℓ

* Reference abbreviation refers to the following: TVA Nuc Pr DPM--Division of Nuclear Power, Division Procedures Manual, 1979, Tennessee Valley Authority.

Table 2-5. Summary of Monthly Intake and Diffuser Water Quality Data for Sequoyah Nuclear Plant, July 1979 through December 1982

Water Quality Characteristic	Condenser Cooling Water Intake				Diffuser				Criteria Concentration
	Number of Samples	Mean	Maximum	Minimum	Number of Samples	Mean	Maximum	Minimum	
Chloride, mg/ℓ	38	7.1	60	<0.2	41	5.3	60	<0.2	250[*,‡]
Sodium, mg/ℓ	38	4.3	18	0.3	41	4.6	18	0.3	
Sulfate, mg/ℓ	38	12	30	<1	41	14	32	<1	250[*,‡]
Total suspended solids, mg/ℓ	38	17	416	<1	41	6	22	<1	
Settleable solids, mg/ℓ	38	<1	1	<1	41	<1	1	<1	
Total dissolved solids, mg/ℓ	38	79	260	<1	41	77	250	<1	500[*,†]
Total solids, mg/ℓ	38	99	458	<1	41	83	260	<1	
Ammonia, mg/ℓ	37	0.3	1.6	<0.2	41	0.4	1.2	<0.2	See table 2-7
Copper, μg/ℓ	38	74	200	<50	41	70	200	<50	1000[*,†,‡]
Iron, μg/ℓ	37	350	2800	<100	41	310	3100	<100	300[*,†], 1000[‡]
Manganese, μg/ℓ	38	210	2800	<100	41	117	630	<100	50[*,†]
Zinc, μg/ℓ	36	110	420	<100	40	110	420	<100	5000[*,†,‡]

*National Secondary Drinking Water Standards (EPA, 1977).

†Water Quality Criteria for Domestic Water Supplies Adopted by the Tennessee Water Quality Control Board, October 22, 1982.

‡Quality Criteria for Water (EPA, 1976).

Table 2-6. Paired t Statistic for Comparison of Intake and Diffuser Water Quality Characteristics

Water Quality Characteristic	Number of Samples	t Value	PR> t *	Rejection of Null Hypothesis at the 90% Confidence Level
Chloride	36	1.60	0.12	No
Sodium	36	-0.38	0.71	No
Sulfate	36	-2.11	0.04	Yes
Suspended solids	36	0.95	0.35	No
Settleable solids	36	0	0	No
Dissolved solids	36	-0.48	0.63	No
Total solids†	36	1.04	0.30	No
Ammonia	35	-0.08	0.93	No
Copper	36	1.87	0.07	Yes
Iron	35	0.54	0.59	No
Manganese	36	1.23	0.23	No
Zinc	34	0.91	0.37	No

*PR> t is the probability of rejecting the null hypothesis (intake concentration minus diffuser concentration equals zero) when it is true.

†Values in parentheses are the statistics when the paired t test was run omitting those dates where either the intake or diffuser total solids data were questionable.

Table 2-7. Comparison of Ammonia Concentration in the Diffuser During 1982 with Tennessee Division of Water Quality Control's Water Quality Criteria

Date (1982)	pH (S.U.)	Temperature (°C)	Ammonia Concentration in Diffuser (mg/ℓ)	Water Quality Criteria* (mg/ℓ)
Feb. 01	7.4	11.1	0.51	9.9
Mar. 01	8.1	8.3	0.36	2.5
Mar. 31	8.2	21.7	0.30	0.75
Apr. 30	7.5	29.4	0.27	2.0
May 31	7.2	27.8	0.75	4.6
Jun. 30	7.4	37.8	0.30	1.6
Jul. 30	7.5	37.8	0.22	0.7
Sep. 04	7.8	37.8	0.33	0.5
Sep. 29	7.9	35	<0.2	0.6
Oct. 31	7.8	30	0.33	1.0
Nov. 30	7.7	13.9	0.54	4.0
Dec. 31	7.5	13.9	<0.2	4.0

*Criteria are based on the concentration of total ammonia (NH_3+NH_4^+) which contains 0.05 mg/L un-ionized ammonia (NH_3). This concentration is a function of pH and temperature.

2.4. Water Quality

The Tennessee River in the vicinity of SQN is presently classified by the State of Tennessee as an "effluent limited" stream, where stream standards are met and with no significant sources of pollution (Tennessee, 1978). An effluent limited stream is one where stream standards are met after application of secondary treatment for municipalities and best practicable treatment for industries. The Tennessee River from mile 460.6 (Chattanooga Creek) to mile 499.4 (Hiwassee River) has been classified as suitable for all water uses--domestic, industrial, fishing and aquatic life, recreation, irrigation, livestock watering and wildlife, and navigation (Tennessee, 1978).

The following section summarizes results of the quarterly in-stream water quality monitoring program.

2.4.1 Materials and Methods

Field--The SQN quarterly operational water quality sampling stations are at TRMs 490.5 at 85 percent from the left bank looking downstream, 484.1 at 66 percent, 483.4 at 17 percent, and 478.2 at 74 percent (figure 2-10). In February 1982, water quality and aquatic biological sampling was mistakenly performed at TRM 480.8 at 74 percent instead of 478.2 at 74 percent. Horizontal locations at each river mile were selected to coincide with the original river channel prior to impoundment. Water quality data reported herein were collected quarterly during four sampling surveys (i.e., February 24, 1982; May 3, 1982; August 3, 1982; and November 16, 1982). Table 2-8 summarizes the SQN quarterly water quality monitoring program in Chickamauga Reservoir since May 1971.

At three of the four operational water quality monitoring stations (TRMs 490.5, 483.4, and 478.2), water quality data were obtained to support assessment of biological data. Biological support water quality samples were collected at depths of 0.3, 1, 3, and 5 m. These samples were poured from the same Var Dorn water bottle as the first replicate phytoplankton samples.

In situ full stratum measurements of dissolved oxygen (DO), pH, temperature and conductivity were made during sample collections at all four sample stations. Water samples were collected for subsequent alkalinity titrations at the same depths at which these in situ measurements were made. Chemical water quality samples were also collected at all four sample stations at depths of 1 and 12 m. In situ full stratum measurements of DO, pH, conductivity, and temperature were also made during the benthic sample collection trips on February 12, May 5, August 5, and November 1.

Laboratory--Analytical and sample preservation methods used for chemical water quality characterizations are shown in table 2-9. The referenced laboratory methods are the TVA preferred methods, which are approved by EPA. The TVA Laboratory Branch may occasionally use other approved EPA laboratory methods.

Eighteen water quality measurements were made. In addition to DO, pH, temperature conductivity, and alkalinity which were measured in the field, biological support water quality samples were analyzed for nitrogen (organic, ammonia, nitrate plus nitrite), dissolved phosphorus, and total organic carbon (TOC). Chemical water quality samples were analyzed for chloride, sodium, sulfate, total dissolved solids, copper, iron, manganese, and zinc.

Data Analyses--All water quality data were entered into the EPA water quality data STOrage and RETrieval (STORET) system and are also available from TVA's Water Quality Branch. All data reduction and statistical evaluation procedures utilized in evaluating the data involve standard statistical routines available through the STORET system.

2.4.2 Results and Discussion

Operational water quality data collected quarterly from February 1982 to November 1982 are summarized in tables 2-10 and 2-11 and are compared with data collected at the same sample locations during quarterly preoperational monitoring. The raw data are tabulated in appendix B. The data for the profiles conducted during the benthic surveys are tabulated in appendix C.

Water quality of Chickamauga Reservoir in the vicinity of SQN (TRM 484) is considered good. The major factor influencing water quality in the main body of the Tennessee River is the high rate of flow through Chickamauga Reservoir.

The long-term average annual discharge at Chickamauga Dam is 1,020 m^3/s (36,000 cfs) according to the USGS (1982). This high flow rate inhibits stratification and establishment of a strong thermocline so that for most of the year chemical constituents are reasonably well mixed through the water column in the main channel. Embayment and overbank areas tend to be hydrologically removed from the main river, enhancing stratification and hindering mixing. Embayment and overbank areas favor development of phytoplankton and aquatic macrophyte communities that also influence water quality (pH, DO, alkalinity, and nutrients) and sometimes result in chemical concentrations different from those observed in the main river.

Dissolved Oxygen--Figure 2-10 shows quarterly DO data that have been averaged throughout the vertical water column at each of the four sample locations. Seasonal trends for DO were as expected: higher in the winter and lower in the summer, reflecting the lower solubility of oxygen and increased oxygen consumption and higher metabolic rates of biota in warmer water.

DO observations during this reporting period generally fell within the range of values observed during preoperational monitoring (tables 2-9 and 2-10; and chapter II.A of TVA, 1978a). However, the quarterly survey on August 3, 1982 revealed slightly lower concentrations of DO both upstream and downstream of SQN than heretofore observed. DO concentrations, which were averaged from the surface to the bottom, were 4.5 mg/ℓ at both TRMs 490.5 and 483.4 with a minimum concentration of 4.1 mg/ℓ.

The State of Tennessee recommends a minimum DO concentration of 5.0 mg/ℓ measured at the five-foot depth (Tennessee, 1982). Minimum DO concentrations measured at the five-foot depth during the August 3, 1982 quarterly survey were 4.5 mg/ℓ at both TRMs 490.5 and 483.4.

DO concentrations greater than 100 percent saturation were observed during the May 3, 1982 survey at TRMs 490.5, 484.1, and 478.2 and are further discussed in the next section.

pH and Alkalinity--State of Tennessee water quality criteria specify that pH shall be within a range of 6.0 to 9.0 for waters used for domestic raw water supply, industrial water supply, recreation, irrigation, and livestock watering and wildlife (Tennessee, 1982). The criterion used for fish and aquatic life is a pH range of 6.5 to 8.5 (Tennessee, 1982). All operational pH measurements (1981 and 1982) were within the range of 6.0 to 9.0. Observations during this reporting period (1982) fell within the range of 6.7 to 8.2, well within the range of values observed during preoperational monitoring.

During the May 3, 1982 survey pH values greater than 8.0 were recorded at TRM 490.5. Simultaneously recorded were oxygen saturation values in excess of 100 percent. These pH and DO values were possibly related to photosynthetic activity during the sample period (see section 3.1)

Total alkalinity of samples collected during the 1982 quarterly operational monitoring program ranged from 49 to 69 mg/ℓ as $CaCO_3$ and averaged about 59 mg/ℓ, indicating a moderately high buffering capacity.

Nutrients--Concentrations of organic nitrogen, ammonia nitrogen, and nitrite plus nitrate nitrogen averaged 0.16, 0.08, and 0.36 mg/ℓ, respectively, in samples collected for quarterly operational monitoring. Concentrations of dissolved phosphorus averaged 0.02 mg/ℓ with about 20 percent of the samples having concentrations below the laboratory detection limit of 0.01 mg/ℓ. With the exception of a single sample collected at TRM 478.2 on May 3, 1982 at 1 m (concentrations of organic nitrogen, ammonia nitrogen, and dissolved phosphorus were 0.84, 0.76, and 0.22 mg/ℓ, respectively), all operational nitrogen and phosphorus data fell within the range of concentrations observed during preoperational monitoring (see tables 2-10 and 2-11).

Concentrations of TOC were higher in operational than in preoperational monitoring samples, averaging about 4 mg/ℓ compared to about 2.3 mg/ℓ during preoperational sampling. Mean TOC concentrations were observed to be higher both upstream and downstream from the diffuser discharge; however, all but two observations (16.0 mg/ℓ at TRM 483.4 on February 24, 1982 and 19.0 mg/ℓ at TRM 480.8 on February 24, 1982) fell within the range of values observed during preoperational monitoring.

Other Parameters--Results of minerals, metals, and other water quality parameters measured during the operational monitoring program upstream and downstream from SQN are summarized in tables 2-10 and 2-11. TRM 484.1 is 0.4 miles upstream from the discharge diffuser and TRM 483.4 is 0.3 miles downstream. The data, therefore, represent characteristics both of water withdrawn at the plant intake and water after discharge of plant effluents and are comparable to data given in table 2-5, except for ammonia nitrogen. The ammonia nitrogen data in table 2-5 are higher than expected for water taken from Chickamauga Reservoir. Also shown in tables 2-10 and 2-11 are the guidelines recommended by EPA in their primary and secondary drinking water standards (for finished drinking water) and their "Quality Criteria for Water" (EPA, 1975; 1976; and 1977). Operational nitrate-nitrogen concentrations were far below the primary criterion of 10.0 mg/ℓ to prevent the effects of methemoglobinemia in infants.

During the 1982 quarterly operational monitoring, mean concentrations of total manganese were slightly above the secondary standard of 50 μg/ℓ at all four operational sampling locations; and for about half the samples collected, total iron concentrations were above the secondary standard of 300 μg/ℓ. These higher concentrations of iron and manganese in raw water are largely associated with oxidized forms (i.e., particulates), are easily removed by conventional water treatment, and were observed during preoperational monitoring. Mean concentrations of total iron and manganese were 395 and 57 μg/ℓ, respectively, during 1982. Concentrations of all other water quality parameters (i.e., chloride, sulfate, dissolved solids, copper, and zinc) were well below their respective secondary standards.

Higher concentrations of conservative chemical constituents (i.e., sodium, chloride, sulfate, and dissolved solids) were observed in 1982 than during preoperational monitoring at stations upstream and downstream from SQN.

2.4.3 Summary and Conclusions

The water quality of Chickamauga Reservoir in the vicinity of SQN is considered good. The relatively high flow of the Tennessee River through the reservoir was the major factor influencing water quality and, except for brief periods of weak thermal stratification, this resulted in well mixed conditions. During this reporting period, DO measurements at upstream and downstream stations were below the recommended Tennessee criteria in August 1982.

Higher concentrations of conservative chemical constituents were observed during operational monitoring when compared with preoperational monitoring. These higher concentrations were observed both upstream and downstream from SQN.

In conclusion, the quarterly instream monitoring data in support of biological monitoring do not suggest any alteration of water quality in Chickamauga Reservoir due to the operation of SQN.

Table 2-8. Summary of the Sequoyah Nuclear Plant Nonradiological Water Quality Monitoring Program--Quarterly[*] Sampling in Chickamauga Reservoir, 1971-1982

Tennessee River Mile	Horizontal Location[†]	Sample Collection Depths (meters)	Physical-Chemical Measurements	Period of Record[‡]	List of Current Analyses (refer to table)
496.5	30	-	Hydrolab[§]	May 71 to Nov 75	-
	57	1, 3, 5	Hydrolab, nutrients,[¶] metals[#]	May 71 to Nov 78	-
490.5	21	-	Hydrolab	May 71 to Nov 75	-
	59	-	Hydrolab	May 71 to Nov 75	-
	85	0.3, 1, 3, 5, 12	Hydrolab, nutrients, metals, minerals[**]	May 71 to Nov 78 and Nov 80 to Nov 82	2-8
484.1	40	-	Hydrolab	May 71 to Nov 78	-
	66	1, 12	Hydrolab, complete[††]	May 71 to Nov 78 and Nov 80 to Nov 82	2-8
483.5	23	-	Hydrolab	May 71 to Nov 78	-
483.4	11	-	Hydrolab	May 71 to Nov 78	-
	17	0.3, 1, 3, 5, 12	Hydrolab, complete	May 71 to Nov 78 and Nov 80 to Nov 82	2-9
	51	-	Hydrolab	May 71 to Nov 75	-
480.8	10	-	Hydrolab	May 71 to Nov 75	-
	74	1, 3, 5	Hydrolab, nutrients, metals	May 71 to Nov 78 (and Feb 82)	-
	92	-	Hydrolab	May 71 to Nov 75	-
478.2	74[‡‡]	0.3, 1, 3, 5, 12	Hydrolab, nutrients, metals, minerals	May 71 to Nov 78 and Nov 80 to Nov 82[§§]	2-9
477.9	15	-	Hydrolab	May 71 to Nov 78	-
	30	-	Hydrolab	May 71 to Nov 75	-
472.8	9	-	Hydrolab	May 71 to Nov 78	-
	65	-	Hydrolab	May 71 to Nov 75	-
	89	1, 3, 5	Hydrolab, nutrients, metals	May 71 to Nov 78	-

*February, May, August, November.
†Percent distance from left bank looking downstream.
‡Quarterly preoperational sampling was discontinued in November 1978; quarterly operational sampling was begun in November 1980.
§Profiles of dissolved oxygen, pH, and conductivity measurements made in situ at various depths, depending on station location.
¶Nutrients (alkalinity, organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, phosphorus, total organic carbon).
#Metals (chromium, copper, iron, manganese, nickel, zinc).
**Minerals (sodium, chloride, sulfate, total dissolved solids).
††Samples collected and analyzed for a comprehensive suite of parameters.
‡‡Preoperational sampling was at 83%.
§§February 82 quarterly operational sampling was at TRM 480.8.

Table 2-9. Analytical Methods for Chemical Parameters, Operational Water Quality Monitoring Sequoyah Nuclear Plant

Parameter	STORET Code Number*	Method and Reference†	Preservation Techniques	Detection Limits
Alkalinity, total mg/ℓ as $CaCO_3$	00410	Potentiometric Titration TVA NR OPS-FO-NRE-42.1	None (field titration)	1 mg/ℓ
Alkalinity, phenolphthalein, mg/ℓ as $CaCO_3$	00415	Potentiometric Titration TVA NR OPS-FO-NRE-42.1	None (field titration)	1 mg/ℓ
Carbon, total organic, mg/ℓ	00680	Oxidation-Infrared TVA NRS-LB-AP-30.502.1	1+4 H_2SO_4, 4°C 1 ml/8 oz.	0.2 mg/ℓ
Chloride, mg/ℓ	00940	Auto Ferricyanide TVA NRS-LB-AP-30.320.1	4°C	1 mg/ℓ
Conductance, specific µmhos/cm at 25°C	00095	Wheatstone Bridge or Equivalent TVA NR OPS-FO-NRE-42.3	None (in situ)	10 µmhos/cm
Copper, µg/ℓ	01042	Atomic Absorption, Direct Method TVA NRS-LB-AP-30.223.1	1+1 HNO_3 2 ml/8 oz.	10 µg/ℓ
Iron, total, µg/ℓ	01045	Atomic Absorption, Direct Method TVA NRS-LB-AP-30.241.1	1+1 HNO_3 2 ml/8 oz.	50 µg/ℓ
Manganese, total, µg/ℓ	01055	Atomic Absorption TVA NRS-LB-AP-30.248.1	1+1 HNO_3 2 ml/8 oz.	10 µg/ℓ
Nitrogen, ammonia, mg/ℓ	00610	Auto Colorimetric Phenate TVA NRS-LB-AP-30.356.1	1+4 H_2SO_4, 4°C 1 ml/8 oz.	0.01 mg/ℓ

Table 2-9 (Continued)

Parameter	STORET Code Number*	Method and Reference†	Preservation Techniques	Detection Limits
Nitrogen, nitrate plus nitrite, mg/ℓ	00630	Auto Cadmium Reduction TVA NRS-LB-AP-30.356.4	1+4 H_2SO_4, 4°C 1 ml/8 oz.	0.01 mg/ℓ
Nitrogen, organic, mg/ℓ	00605	Calculated from kjeldahl nitrogen minus ammonia nitrogen TVA NRS-LB-AP-30.360.2	1+4 H_2SO_4, 4°C 1 ml/8 oz.	0.01 mg/ℓ
Oxygen, dissolved, mg/ℓ	00300	Electrode and/or Titrimetric TVA NR OPS-FO-NRE-42.4	In situ Determine immediately	0.01 mg/ℓ
pH, units	00400	Electrometric TVA NR OPS-FO-NRE-42.8	In situ or Determine immediately	Not applicable
Phosphorus, dissolved, mg/ℓ	00666	Colorimetric TVA NRS-LB-AP-30.360.2	1+4 H_2SO_4, 4°C 1 ml/8 oz.	0.01 mg/ℓ
Residue, total filtrable (dissolved solids), mg/ℓ	70300	Gravimetric TVA NRS-LB-AP-30.1.4.1	4°C	10 mg/ℓ
Sodium, mg/ℓ	00929	Atomic Absorption, Direct Method TVA NRS-LB-AP-30.279.1	4°C	0.1 mg/ℓ
Sulfate, mg/ℓ	00945	Turbidimetric TVA NRS-LB-AP-30.381.1	4°C	1 mg/ℓ

Table 2-9 (Continued)

Parameter	STORET Code Number*	Method and Reference†	Preservation Techniques	Detection Limits
Temperature, °C	00010	Thermistor, Thermometer	*In situ*	0.1°C
Zinc, μg/ℓ	01092	Atomic Absorption, Direct Method TVA NRS-LB-AP-30.297.1	1+1 HNO_3 1 ml/8 oz.	10 μg/ℓ

*STORET is the acronym for EPA's data storage and retrieval system in which all TVA water quality data is entered.

†Reference abbreviations refer to the following: TVA NRS = Laboratory Branch Quality Manual, 1980, Tennessee Valley Authority; TVA NR OPS = Field Operations NRE Procedures Manual, Volume 1, 1983, Tennessee Valley Authority; EPA = Methods for Chemical Analysis of Water and Wastes, 1980, United States Environmental Protection Agency.

Table 2-10. Summary of Quarterly Water Quality Data - Chickamauga Reservoir (Sampling Stations Located Upstream from Sequoyah Nuclear Plant)

	Tennessee River Mile 490.5 (85%)								Tennessee River Mile 484.1 (66%)								
	Preoperational (1971-78)				Operational (1980-82)				Preoperational (1971-78)				Operational (1980-82)				
Parameter	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Criteria Concentration
Temperature, °C	156	16.5	26.5	2.1	68	15.6	26.0	4.8	197	16.2	26.5	2.5	61	16.6	28.5	4.8	
Conductivity, mmhos/cm @ 25°C	93	170	220	140	60	188	220	150	135	180	250	130	61	189	220	150	
Dissolved oxygen, mg/ℓ	156	8.5	13.4	4.5	68	8.5	13.8	3.8	197	8.5	13.4	4.7	61	8.6	13.4	3.6	
pH, standard units	97	7.1	8.0	5.0	68	7.6	8.8	7.0	135	7.2	7.8	6.1	61	7.5	8.3	7.0	6.5-8.5*
Total alkalinity as $CaCO_3$, mg/ℓ	41	52	60	33	52	58	67	41	41	51	61	38	34	57	68	47	
Organic nitrogen, mg/ℓ	36	0.11	0.33	0.01	33	0.16	0.38	0.05	45	0.12	0.39	<0.01	8	0.17	0.28	0.09	
NH_3+NH_4-nitrogen, mg/ℓ	36	0.08	0.45	0.01	38	0.06	0.14	<0.01	45	0.06	0.19	0.01	18	0.09	0.62	<0.01	
NO_2+NO_3-nitrogen, mg/ℓ	36	0.36	0.59	0.23	37	0.34	0.96	0.22	45	0.38	1.80	0.17	10	0.25	0.31	0.18	10.0†
Phosphorus, total, mg/ℓ	36	0.03	0.04	0.02	-	-	-	-	45	0.03	0.06	<0.01	-	-	-	-	
Phosphorus, dissolved, mg/ℓ	-	-	-	-	34	0.02	0.04	<0.01	45	0.02	0.17	<0.01	2	<0.01	<0.01	<0.01	
Total organic carbon, mg/ℓ	36	2.2	6.2	1.2	37	3.9	10.0	1.9	39	2.6	14.0	1.0	14	3.7	8.9	2.3	
Sodium, mg/ℓ	-	-	-	-	13	8.0	10.8	4.5	45	5.3	9.1	3.0	18	8.0	10.5	4.8	
Chloride, mg/ℓ	-	-	-	-	10	9.5	12.0	6.0	45	6.6	12.0	4.0	18	9.8	12.0	6.0	250*
Sulfate, mg/ℓ	-	-	-	-	11	17	20	15	45	13	18	4	18	17	19	14	250*
Dissolved solids, mg/ℓ	-	-	-	-	11	101	120	62	37	87	120	60	18	102	130	70	500*
Copper, mg/ℓ	11	<14	30	<10	13	16	60	<1	52	33	290	<10	18	17	60	<1	1000*

Table 2-10 (Continued)

Parameter	Tennessee River Mile 490.5 (85%)								Tennessee River Mile 484.1 (66%)								Criteria Concentration
	Preoperational (1971-78)				Operational (1980-82)				Preoperational (1971-78)				Operational (1980-82)				
	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	
Iron, mg/ℓ	11	485	660	340	13	225	610	80	52	510	2100	80	18	316	940	70	300*, 1000‡
Manganese, mg/ℓ	7	71	100	50	13	63	146	20	49	70	180	30	18	63	140	<10	50*, 100‡
Zinc, mg/ℓ	11	44	130	20	13	<15	80	<5	52	40	150	<10	18	<18	95	<5	5000*

*National Secondary Drinking Water Standards (EPA, 1977).

†National Primary Drinking Water Standards (EPA, 1975).

‡Quality Criteria for Water (EPA, 1976).

Table 2-11. Summary of Quarterly Water Quality Data - Chickamauga Reservoir (Sampling Stations Located Downstream from Sequoyah Nuclear Plant) Tennessee River Mile 483.4 (17%)

Parameter	Tennessee River Mile 483.4 (17%)								Tennessee River Mile 478.2 (74%)*								Criteria Concentration
	Preoperational (1971-78)				Operational (1980-82)				Preoperational (1971-78)				Operational (1980-82)				
	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	
Temperature, °C	215	16.3	26.4	2.4	72	16.1	27.5	4.7	211	16.2	27.8	2.4	64	17.0	28.5	4.7	
Conductivity, mmhos/cm @ 25°C	133	167	220	140	72	182	220	150	130	167	220	140	64	186	220	160	
Dissolved oxygen, mg/ℓ	214	8.6	13.4	5.1	72	8.3	13.4	4.3	210	8.7	13.4	5.0	61	8.2	13.2	4.6	
pH, standard units	133	7.2	8.8	5.0	72	7.5	9.0	6.7	135	7.3	8.8	6.3	64	7.5	8.4	6.9	6.5-8.5†
Total alkalinity as $CaCO_3$, mg/ℓ	49	49	58	36	28	56	66	47	42	50	61	38	51	57	68	33	
Organic nitrogen, mg/ℓ	49	0.11	0.52	<0.01	33	0.15	0.42	0.05	36	0.11	0.17	0.05	29	0.17	0.84	0.06	
NH_3+NH_4-nitrogen, mg/ℓ	49	0.10	1.30	0.01	40	0.06	0.30	<0.01	36	0.06	0.34	0.01	36	0.07	0.76	<0.01	
NO_2+NO_3-nitrogen, mg/ℓ	49	0.36	1.50	0.21	37	0.32	0.91	0.16	36	0.33	0.55	0.15	33	0.29	0.85	0.15	10.0‡
Phosphorus, total, mg/ℓ	49	0.03	0.11	0.01	-	-	-	-	36	0.03	0.04	0.01	-	-	-	-	
Phosphorus, dissolved, mg/ℓ	25	0.02	0.06	<0.01	34	0.02	0.04	<0.01	-	-	-	-	30	0.03	0.22	<0.01	
Total organic carbon, mg/ℓ	49	2.3	7.2	1.1	38	4.1	16.0	1.3	36	2.1	2.9	1.2	34	4.4	9.8	2.2	
Sodium, mg/ℓ	25	5.8	9.1	3.7	18	8.0	10.6	4.4	-	-	-	-	16	8.2	10.6	5.3	
Chloride, mg/ℓ	25	7.0	12.0	4.0	16	9.4	12.0	6.0	-	-	-	-	14	9.9	12.0	7.0	250†
Sulfate, mg/ℓ	25	14	18	9	17	17	20	8	-	-	-	-	16	17	20	14	250†
Dissolved solids, mg/ℓ	25	88	110	60	17	102	120	80	-	-	-	-	16	101	120	70	500†
Copper, mg/ℓ	25	24	50	<10	18	19	70	<1	11	<13	30	<10	16	22	70	<1	1000†

Table 2-11 (Continued)

Parameter	Tennessee River Mile 483.4 (17%)								Tennessee River Mile 478.2 (74%)*								Criteria Concentration
	Preoperational (1971-78)				Operational (1980-82)				Preoperational (1971-78)				Operational (1980-82)				
	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	Number of Samples	Mean	Max	Min	
Iron, mg/ℓ	25	490	2200	150	18	276	830	<50	11	437	690	260	16	244	610	<50	300[†], 1000[K]
Manganese, mg/ℓ	25	70	170	30	18	60	90	40	7	70	90	50	16	52	110	20	50[†], 100[K]
Zinc, mg/ℓ	25	27	160	<10	18	25	150	<5	11	37	80	10	16	11	30	<5	5000[†]

*Preoperational data collected at 83% horizontal location (see table 2-6).

†National Secondary Drinking Water Standards (EPA, 1977).

‡National Primary Drinking Water Standards (EPA, 1975).

§Quality Criteria for Water (EPA, 1976).

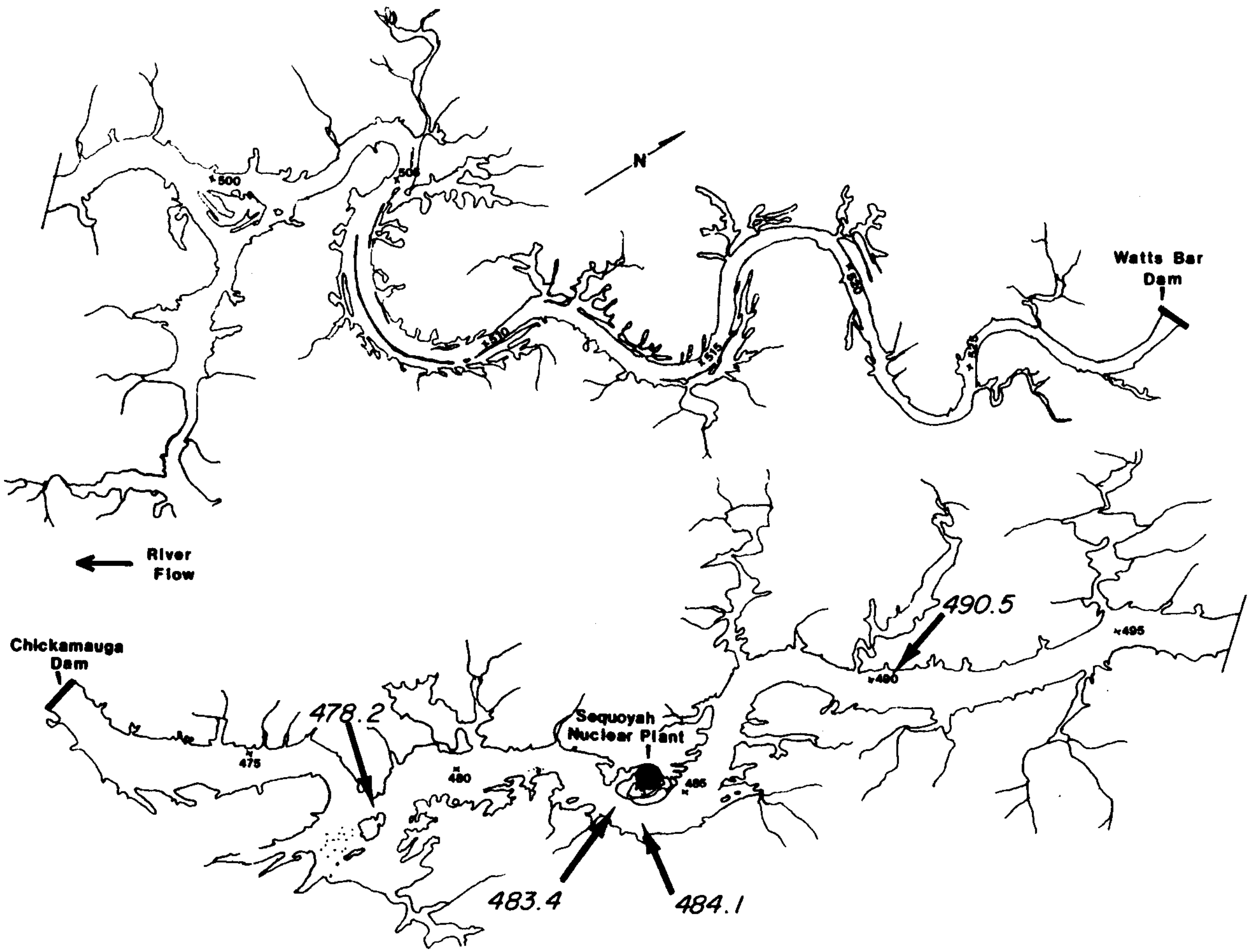

Figure 2-10. Nonradiological Water Quality Sampling Locations During Operational Monitoring (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir.

Legend

W = Winter (February)
S = Spring (May)
S = Summer (August)
F = Fall (November)

Note:
(In February 1982 data were collected at TRM 480.8 instead of TRM 478.2)

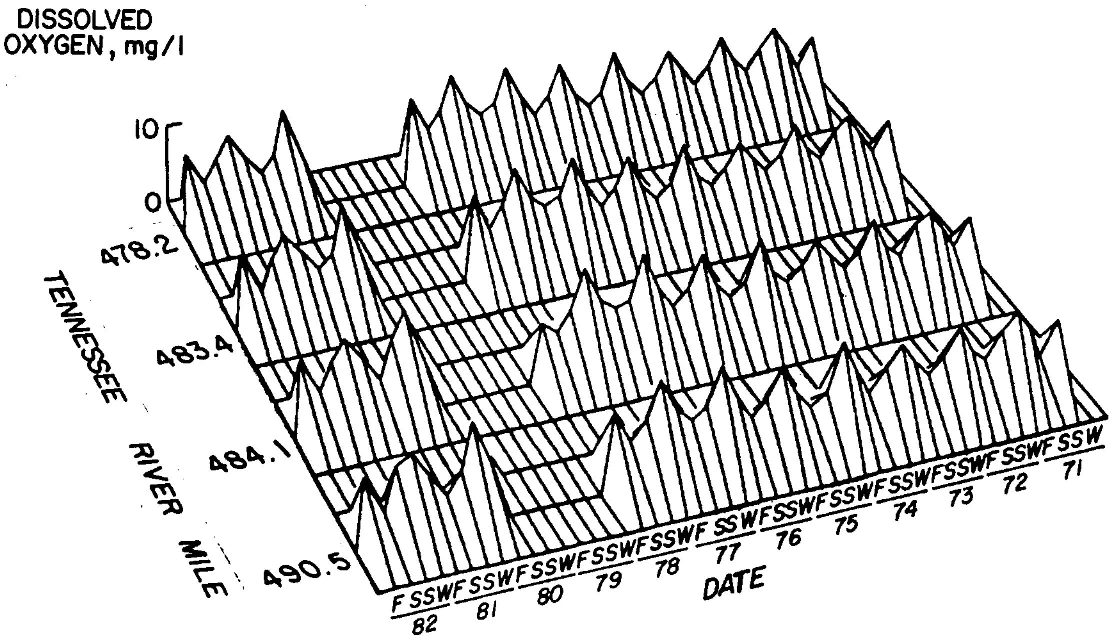

Figure 2-11. Seasonal Dissolved Oxygen Variations at the Water Quality Sampling Locations, Chickamauga Reservoir, 1971 - 1982.

3.0 PLANKTON

SQN has potential to influence aquatic biological communities through: (1) entrainment of water into the condenser cooling water system (CCWS), subsequent discharge of this water through the diffusers, and entrainment of ambient water into this discharged water; and (2) discharge of heat and possibly other waste by-products. The former of these potential perturbations has little potential to affect the phytoplankton community during periods when heat is not added to the discharged condenser cooling water unless river flows are very low and the plant pulls water from a large part of the water column. That is, when the plant is not dissipating heat to the circulating water and river flows are sufficient that circulating water is pulled only from lower strata, discharge of this ambient water through the diffusers to deep strata does not influence upper strata where most phytoplankton activity occurs. However, both potential perturbations could affect zooplankton because they occur throughout the water column.

Because planktonic organisms are members of a transient community, daily changes in physical and chemical factors which influence the aquatic environment control population and community dynamics. Therefore, the following sections in this chapter use daily physical and chemical conditions during each sample period (as described in chapter 2) to evaluate possible plant induced community or population changes.

3.1 Phytoplankton

3.1.1 Materials and Methods

Field--Phytoplankton community measurements included in this monitoring program are: organism enumeration, phytopigment concentrations, and primary production estimates. An 8-ℓ Van Dorn water sampler was used to collect sufficient water for all 3 sample types--100 ml for each enumeration sample; 500 ml for each phytopigment sample; and 125 ml for each primary productivity sample. Two replicate samples for each measurement were collected from 0.3, 1.0, 3.0, and 5.0 m at midchannel for each of three stations (station 1 upstream of SQN at TRM 490.5; station 2 immediately downstream of the diffusers at TRM 483.4; and station 3 downstream of SQN at TRM 478.2; figure 3-1). During the winter survey, samples were collected from TRM 480.8 rather than TRM 478.2. Table 1-2 shows collection dates reported here.

Enumeration samples were preserved with M_3 (Meyer 1971) immediately after collection. Phytopigment samples were placed in bottles in a light-excluding box, 500 ml filtered through glass fiber filters on shore, and filters placed in 5.0 ml of 90 percent acetone then stored frozen until analyzed in the laboratory.

Primary productivity samples were spiked with one milliliter (approximately 2 μc) of labeled sodium bicarbonate, suspended at collection depth at station where collected, allowed to incubate for three hours, and 100 ml filtered through a 0.45 μm membrane filter. Filters were folded and placed in scintillation vials for return to the laboratory. A dark bottle was suspended at 0.3 and 5.0 m depths to compensate for nonphotosynthetic assimilation of carbon-14.

Laboratory--Each enumeration sample was agitated, a 15-ml aliquot removed and placed in a counting chamber, and allowed to settle for a minimum of 12 hours. Algal cells were enumerated at the generic level. References and publications used in identification included: Cocke (1967), Desikachary (1959), Drouet (1973), and Drouet and Daily (1973), Forest (1954), Hustedt (1930), Patrick and Reimer (1966), Prescott (1962; 1964), Smith (1933), Tiffany and Britton (1971), and Whitford and Schumacher (1969).

Phytopigment samples were allowed to reach room temperature, ground with a glass rod, and subjected to ultrasonic vibrations to rupture algal cell walls. Samples were then clarified by centrifugation for 20 minutes at 2700 r/m and analyzed spectrophotometrically. Optical densities at 750, 664, 647, and 630 nm were read. Each sample was then acidified with two drops of 0.1 N HCl, allowed to steep for one minute, then reread at 750 and 665 nm. Chlorophyll a, b, c, and phaeophytin a concentrations were calculated using the UNESCO (1966), or Jeffrey-Humphrey (1975) equations for chlorophylls and the Lorenzen (1967) equations for phaeophytin a.

Activity of primary productivity samples was determined using liquid scintillation techniques. Using the conversion table of Saunders, et al. (1962), total inorganic carbon available at each station was determined by utilizing pH readings, temperatures, and alkalinity values. Mean carbon-14 activity incorporated into algal cells in the light bottles minus that absorbed by materials in dark bottles results in an estimate of net photosynthetic activity. Total carbon assimilated by algal cells is expressed as milligrams carbon per cubic meter per hour (mg $C/m^3/hr$). These values, averaged for depth intervals, multiplied by the respective depth interval, summed, and proportioned to daily solar radiation energy were used to represent total daily productivity that occurred in a column of water with a surface area of one square meter and a depth of 5 m (mg $C/m^2/day$).

Data Analyses--Sampling and processing precision of total community and group densities (cells/ℓ), chlorophyll *a* concentrations (mg/m^3), and carbon assimilation rates (mg $C/m^3/hr$) was estimated by calculating the coefficient of variation for each set of duplicate samples. Coefficients less than 20 percent were considered indicative of good sample replicability. Coefficients of variation greater than 40 percent indicated larger than desirable variability between replicate samples.

Data were transformed ($\log_{10}$) and tested using a two-way analysis of variance (ANOVA) with stations and depths as the main effects. Significant station differences resulting from the two-way ANOVA were examined in one of two ways depending on results of the interaction term. If stations were significant but interaction not significant, station means, calculated over all depths, were further compared using the Student, Newman, Keuls (SNK) multiple range test (Sokal and Rohlf, 1969) as applied by Zar (1974) to two-way ANOVA. If stations and interaction were both significant, station differences were examined for each depth using a one-way ANOVA and SNK. For purposes of this report, significant depth differences were not examined because the main point of concern was upstream/downstream differences.

A slightly different approach was used when carbon assimilation rates were low (< 2 mg $C/m^3/hr$) because such a low rate was considered questionable as an absolute measure or at best indicative of maintenance photosynthesis and inappropriate for statistical testing. If all data within a set were below 2 mg $C/m^3/hr$, no statistical tests were performed. However, if several data points in the set were above this level, low values were included in the two-way ANOVA but excluded from subsequent statistical testing.

Phytoplankton community structure was analyzed using a diversity index ($\bar{d}$) applying the following formula (Patten, 1962):

$$\bar{d} = -\Sigma_1^s (n_i/n) \log_2 (n_i/n), \text{ where}$$

s = number of genera in unit area

n_i = number of individuals belonging to the i^{th} genus

n = total number of organisms

$\bar{d}$ = diversity per individual

Diversity index as applied to these data was used only as a reference to evaluate changes among stations.

Similarity of algal communities between reservoir sections was determined using a two-step approach. Sorenson's Quotient of Similarity, SQN (McCain, 1975) was first calculated to determine similarities based solely on presence/absence of genera (qualitative characteristics of community composition). Next a percentage similarity (PS) index (Pielou, 1975) was calculated to determine similarities based on both qualitative and quantitative characteristics of community structure. In both cases, values of 70 percent or greater were assumed to show similarity.

SQS was calculated as follows:

$$SQS = 2s/(x + y) \cdot 100$$

where, x = number of taxa at station x

y = number of taxa at station y

s = number of taxa in common between stations x and y

Percentage similarity index was calculated as follows:

$$PS = 200\Sigma_{i=1}^{s} \min (P_{iX}, P_{iY})$$

where, P_{iX} and P_{iY} are the quantities of species i at stations X and Y as proportions of the quantities of all s species at the two stations combined.

Both coefficients were calculated because they are additive and should be used in combination to provide the greatest information. If comparisons between two locations provided low SQS and PS values, the communities were considered different. If SQS was high but PS low, communities were composed of similar genera but differed either in absolute cell density or in relative abundance of genera present. When SQS was low and PS high (a rare occurrence), communities were still considered similar because the low SQS probably was related to random occurrence of rare genera which affects SQS much more than PS. If both coefficients were high, communities were similar in generic composition, relative abundance of genera present, and absolute cell number.

3.1.2 Results and Discussion

Spatial Comparisons of Operational Monitoring Data--As discussed in section 2.2, at least one unit was generating power on winter, spring, and summer phytoplankton sample dates in 1982 (potential effects from both operation of CCWS and thermal input); neither unit was generating on the November sample date (potential effects from operation of CCWS only). The following section presents results for each of these sample dates.

February 1982--River flows were quite high (approximately 1,700 m^3/s 60,000 cfs) during this sample period. These high flows coupled with low light penetration due to high turbidity would have limited algal growth. High flows also would have rapidly mixed discharged water from SQN; hence, potential for plant related effects was low during this period.

Chrysophyta was the dominant algal group at all stations (86, 85, and 58 percent at stations 1, 2, and 3, respectively; table 3-1), but Cyanophyta increased in proportion from being absent at station 1 to 35 percent of the total at station 3. Melosira, a chrysophyte, was the dominant genus in all samples except the surface at station 3 where the cyanophyte Oscillatoria was dominant (appendices D and E). Relatively high densities of another cyanophyte, Cylindrospermum, were also found in surface samples at station 3 as well as at the 1.0 m depth at that station. Both Oscillatoria and Cylindrospermum were absent from 3.0 and 5.0 m sample depths at station 3 as well as all depths at the other two stations. Collection of relatively high densities of these two blue-greens at only surface and 1.0m depths of station 3 was probably a chance occurrence.

Number of taxa increased from 12 at station 1 to 18 at station 3 and $\bar{d}$ values were similar (range 2.15 to 2.22) at all stations (table 3-2). Sorensen's quotient of similarity indicates similar genera existed for station 1-2 and station 2-3 comparisons but not the station 1-3 comparison, thus indicating a change in community composition from up- to downstream (table 3-3). Percentage similarity coefficients indicate community structure at stations 1 and 2 were similar but the community at station 3 was different from that at stations 1 and 2 as reflected by coefficients for stations 1-3 and 2-3 comparisons below the 70 percent "cut-off" value (table 3-3). These apparent differences at station 3 were probably related to the relatively high densities of Oscillatoria and Cylindrospermum previously discussed.

Total cell densities were low, as expected under high flow and low light penetration conditions. Densities only ranged from 0.1 to 0.2 $x10^6$ cells/ℓ (table 3-4 and appendix F), and no significant differences were detected when tested with the two-way ANOVA (table 3-5). Cell densities for each group were proportionately low (table 3-4) and no significant differences were detected for Chlorophyta and Chrysophyta (table 3-5). The two-way ANOVA indicated a significant difference for cyanophyte densities among stations; however, the SNK failed to detect a difference in these densities (table 3-6). Opposing results between ANOVA and SNK can occur, especially in cases such as this when the calculated F-ratio (4.01) is near the tabular F-value (3.89).

Chlorophyll a concentrations were low (maximum of 3.68 mg/m^3 table 3-7 and appendix G) and the two-way ANOVA failed to detect significant differences (table 3-8). Phaeophytin index values were also low (table 3-7) indicating the community was relatively inactive at all locations.

Carbon assimilation rates were low at all stations with hourly rates ranging from 0.12 to 2.34 mg $C/m^3/hr$ and daily rates ranging from 29 to 43 mg $C/m^2/day$ (table 3-9 and appendix H). The two-way ANOVA test on hourly rates indicated a significant difference for both station and depth effects (table 3-10). The SNK indicated station 2 was significantly higher than stations 1 and 3, which were not significantly different from one another (table 3-10). This slight elevation in carbon assimilation may have been associated with thermal enrichment because samples at station 2 were exposed at slightly warmer water temperatures than at other stations (appendix B). Conversely, differences could have been due to natural variability among stations because assimilation rates were very low at all stations and near maintenance levels. Even if this slight increase was associated with the thermal effluent, assimilation rates were far below problematic levels.

Phytoplankton measurements (cell densities, chlorophyll a concentrations, and carbon assimilation rates) indicate the community was essentially stable and unproductive at all sample locations. There may have been a slight stimulation of carbon assimilation rates immediately downstream of the diffuser. However, high flows and low light penetration should have had much more influence on phytoplankton during this period than did operation of SQN.

May 1982--Section 2.2 describes river flows as quite low (approximately 204 m^3/s; 7,200 cfs) during this sample period. Long retention times created by these low river flows, coupled with low turbidity and sunny conditions should have provided good growing conditions for phytoplankton. However, low flows and high solar radiation caused reservoir stratification which could have adversely affected phytoplankton growth by hindering recycling of nutrients. This probably was not the case because sufficient nutrients were available at all stations at which algal growth should not have been limited. In fact, nutrients were quite high at station 3, indicating little algal uptake (appendix B).

Chlorophyta was the most numerous algal group at all stations composing 51, 35, and 37 percent of the total density at stations 1, 2, and 3, respectively (table 3-1). Eudorina, a colonial chlorophyte, was the dominant genus in most samples (appendix D). Eudorina, as well as almost all other genera, decreased from station 1 to stations 2 and 3.

Total number of genera also decreased from station 1 (36) to stations 2 and 3 (27 and 24, respectively; table 3-2). Diversity index values were high and similar among stations (range 3.26 to 3.54; table 3-2). Sorensen's Quotient of Similarity indicates community composition was similar at all stations since all SQS coefficients were greater than 70 percent (table 3-3). However, PS coefficients indicate community structure (quantitative aspects) at station 1 differed from those at stations 2 and 3, whereas stations 2 and 3 were similar to each other. The difference between station 1 and stations 2 and 3 was caused by reductions in densities of most genera. This difference, coupled with the similarity of community structure at stations 2 and 3, indicates most of the community change occurred between stations 1 and 2 with little change between stations 2 and 3.

Because most genera decreased from up- to downstream, total cell density exhibited a marked decrease ranging from 4.0 to 0.3 x 10^6 cell/ℓ (highest and lowest means for all depths) at stations 1 and 3, respectively (table 3-4). The two-way ANOVA indicates significant F-ratios for station, depth, and interaction (table 3-5). Because interaction was significant, station differences were tested for each depth. The SNK provided similar results for each depth--all stations were significantly different from one another with the largest mean at station 1 and the smallest at station 3 (table 3-6).

Chlorophyte densities decreased from station 1 (highest mean 2.2 x 10^6 cells/ℓ) to stations 2 and 3 (lowest mean 0.1 x 10^6 cells/ℓ at station 3; table 3-4). Chrysophyte and cyanophyte densities exhibited similar decreases (table 3-4). The two-way ANOVA and SNK on the above group densities generally provided the same results as for total density (table 3-5 and 3-6)--station 1 was significantly higher than stations 2 and 3 which were significantly different from one another for some test groups (mainly Chlorophyta) but not for others (mainly Chrysophyta and Cyanophyta).

Chlorophyll a concentrations generally followed the same pattern as cell densities but the magnitude of decrease from up- to downstream was much smaller for chloropyll than for cell densities. Chlorophyll a concentrations were highest at station 1 (mean for each depth ranged 6.96 to 10.76 mg/m^3) and lowest at station 2 (range 5.23 to 5.76 mg/m^3; table 3-7). Both station and interaction were significant when tested with two-way ANOVA (table 3-8); therefore, station differences were determined for each depth. The SNK procedure ranked station 1 mean highest for each depth but did not identify any significant difference among means at 0.3m depth; all stations were different at 1.0 m depth; and station 1 was significantly higher than stations 2 and 3 (which were not statistically different) at both 3.0 and 5.0 m depths (table 3-8).

Carbon assimilation rates were highest and similar at stations 1 and 3 and lowest at station 2 (table 3-9). The highest hourly assimilation rate (16.75 mg $C/m^3/hr$) occurred at station 3, 1.0 m, while the lowest (0.10 mg $C/m^3/hr$) occurred at station 2, 5.0 m. The two-way ANOVA indicated significant differences for both station and depth effects and a significant interaction term. Significant depth differences are expected with carbon assimilation rates because extinction of solar radiation at greater depths retards carbon uptake. The significant interaction term indicates the effect of depth (light penetration) varied among stations. This is apparent at station 1 where much higher hourly assimilation rates were found at the 3.0 and 5.0 m sample depths than at stations 2 and 3.

Secchi disc readings indicated light penetration was greater at station 1, allowing assimilation to occur at greater depths. To exclude this depth effect, station differences were tested with a one-way ANOVA and SNK for each depth--station 2 was significantly lower than station 1 and 3 (not different from one another) at the 0.3 and 1.0 m depths, while all stations were significantly different from each other with assimilation rates highest at station 1 and lowest at station 2 at both 3.0 and 5.0 m depths (table 3-10).

The three indicators (i.e., enumeration, chlorophyll a, and carbon assimilation rates) used to evaluate the phytoplankton generally provided inconsistent trends for the May sample period. Inconsistencies among these parameters frequently occur and have been documented in numerous studies. These parameters do not necessarily parallel one another because chlorophyll a concentrations and carbon assimilation rates vary with physiological state and cell size. Various combinations of physiological state and cell size coupled with external physical forces can and frequently do result in inconsistent results among these three parameters.

During most periods of the year the expected trend for Chickamauga Reservoir phytoplankton is for cell density and chlorophyll a to increase from up- to downstream as a result of increased retention time, decreased turbidity, and decreased turbulence in lower reservoir reaches. Carbon assimilation rate is not expected to always follow this pattern because, as a rate measure, it measures the potential of a community by incubating a sample at a selected depth for a specified period (three hours), hence, some of the above effects would be offset.

Cell densities and chlorophyll a concentrations did not increase from up- to downstream as expected. In fact, cell densities decreased drastically from up- to downstream, while chlorophyll a and carbon assimilation rates were generally similar at stations 1 and 3 with lower values at station 2. It is difficult to determine the exact cause(s) of these results but at least three explanations are possible:

(1)--The long retention time during this sample period altered normal plankton community patterns in Chickamauga Reservoir such that population peaks which usually occur in downstream reservoir reaches due to increased retention time actually occurred in upstream reaches. Phytoplankton increases would have provided a greater food source for herbivorous zooplankters (see section 3.2). Increased pressure from predators and the fact that the community was in a transitional period from spring chrysophyte/chlorophyte dominance to summer cyanophyte dominance could have been very influential in causing the unusual phytoplankton patterns observed during May.

(2)--Another possible explanation, also associated with physical conditions resulting from low river flows, is that differences among stations were not actually "decreases" at all but, rather, representative of different watermasses. Section 2.2 discusses travel times through Chickamauga Reservoir. These travel times were more than sufficient for community dynamics to change from one station to another, and it should not be too suprising for the community to exhibit different characteristics, or be essentially different communities, at each station.

(3)--These differences could have been associated with operation of SQN. If they were plant induced, plant entrainment would be a more likely mechanism than thermal effects or toxicity. Reductions due to thermal effect can be ruled out because during the sample period when surface water temperatures were approximately 20^{o} C, stimulation of carbon assimilation at station 2 and maybe station 3 and increases in cell density and chlorophyll _a_ at station 3 (not station 2 due to its proximity to the diffuser) would be the expected effect from thermal input. Toxicity can be ruled out because reduced densities were apparent at the station (station 2) immediately downstream of the diffusers. Sufficient travel time does not exist from diffusers to this sample location for organisms to die and settle from the water column. Hence, if these reductions were due to plant operation, they would have to be caused by organism destruction during plant entrainment. Although data are not available to determine if the plant actually entrained water from upper strata where most active phytoplankton cells would be, this possibility exists because SQN was using approximately 30 percent of the river flow.

Available data do not allow determining which of the above hypotheses was responsible for differences in the phytoplankton observed during May. In reality, some combination of factors was probably responsible for observed characteristics of the phytoplankton community. It is obvious that the very low flows would have had a definite influence on the phytoplankton community; that grazing by the relatively large zooplankton community would have affected the phytoplankton; and that entrainment and discharge of cooling water by SQN had some influence on plankton dynamics especially at these low flows. Unfortunately, the magnitude of SQN influence cannot be defined with existing data.

August 1982--River flows were near the seasonal average a few days prior to sample collection (section 2.1 and 2.2.). However, as a result of very heavy rainfall in east Tennessee, flows increased and were about 30 percent higher than the long-term average for August on the sample date. These higher flows could have flushed plankton out of the system or at least would have moved the area of greatest productivity to lower reservoir reaches where retention time was greatest. Evidence of this flushing is indicated by reservoir destratification (figure 2-8) and low dissolved oxygen concentrations at station 1 (range 5.2 to 4.2 mg/ℓ from top to bottom, appendix B). Even though heavy rainfall had occurred, turbidity was low so light availability should not have been limiting to phytoplankton. SQN was operating at maximum capacity but high river flows would have provided low CCW entrainment percentages and rapid mixing of discharge water.

Cyanophyta was the numerically dominant phytoplankton group at all stations (65, 64, and 58 percent at stations 1, 2, and 3, respectively; table 3-1). Chlorophyta was subdominant at all stations ranging from 23 to 24 percent. The cyanophyte Oscillatoria generally dominated at stations 1 and 2 with Anacystis subdominant, while the reverse was generally true at station 3 (appendix E). Such blue-green dominance is expected in summer months. These as well as most other genera increased from up- to downstream (appendix E).

Number of taxa was the highest of any sample period in 1982 and increased from station 1 (50) to station 2 (55) to station 3 (60) (table 3-2). Diversity index values showed a similar trend (3.44, 3.49, and 4.04, at stations 1, 2, and 3, respectively). Genera present at sample locations were very similar as SQS coefficients ranged from 87 to 92 percent (table 3-3). The PS values for station 1-2 and station 2-3 comparisions were above 70 percent, indicating similarity of community structure for these locations, but the station 1-3 comparison was too low to be considered similar. These PS coefficients indicate a transitional change from up- to downstream.

Total cell densities increased from 2.1 x 10^6 cells/ℓ at 3.0 m depth at station 1 to 7.2 x 10^6 cells/ℓ at 0.3 m at station 3 (table 3-4). The two-way ANOVA indicated significant station, depth, and interaction F-ratios (table 3-5). Because the interaction term was significant, station differences were analyzed for each depth with a one-way ANOVA and SNK (table 3-6). Station differences were apparent for 0.3, 3.0, and 5.0 m sample depths but differences were not detected among station means at the 1.0 m depth. Station 3 densities were significantly higher than stations 1 and 2 for the 0.3 and 5.0 m sample depths, while for the 3.0 m depth stations 2 and 3 were not significantly different from one another, although both were significantly larger than station 1 densities.

Chlorophyte, chrysophyte, and cyanophyte densities generally followed the trend of increases from up- to downstream exhibited by total densities (table 3-4). Additionally, statistical analysis of these data provided essentially the same results as total density (tables 3-5 and 3-6).

Chlorophyll a and carbon assimilation rates generally followed the same trend as density data and provided about the same statistical test results--station 3 significantly higher than other stations (table 3-7, 3-8, 3-9, and 3-10). Phaeophytin index values increased from up- to downstream indicating the community was in a better physiological state in downstream areas and better able to synthesize chlorophyll and assimilate carbon.

Phytoplankton data for August followed the expected trend for Chickamauga Reservoir considering physical conditions which existed during this sample period. Measurements showed increased values from up- to downstream, paralleling increased retention time in Chickamauga Reservoir.

It appears that, even though SQN operated under full load during this period, river flows were adequate to fully mix plant effluents, and no effects from operation were observed.

November 1982--Because neither SQN unit was generating electricity on or three days prior to sample collection, thermal effects were not possible (section 2.2). River flows were normal for fall and had been relatively stable for most of the summer and fall.

Chrysophyta dominated at all stations (range only 64 to 71 percent; table 3-1) and Melosira was the dominant genus in all samples (appendix D). Number of taxa and $\bar{d}$ values were less than in August but were similar from one station to another (taxa ranged 18 to 21 and $\bar{d}$ ranged from 2.58 to 2.93; table 3-2). Both SQS and PS indicated community composition/structure were generally similar among stations (table 3-3).

Total cell densities were low (maximum of 0.2 x 10^6 cells/ℓ; table 3-4) and did not indicate any upstream/downstream trends. Statistical analyses indicated station 2 (the lowest mean) to be significantly different from station 3 (the highest mean) (tables 3-5 and 3-6). Densities of each major group were low and no significant differences were detected among stations (table 3-5).

Chloropyll a concentrations were low (maximum of 2.55 mg/m^3; table 3-7) at all stations. Statistical analysis indicated station 3 was significantly lower than stations 1 and 2, which were not significantly different (table 3-7).

Carbon assimilation rates were also low (maximum hourly rate of 3.80 mg C/m^3/hr and daily rate of 84 mg C/m^2/day; table 3-9). The two-way ANOVA indicated both station and depth effects were significant and the interaction term was significant (table 3-10). When the one-way ANOVA and

SNK was used to detect station differences for each depth, only the 3.0 m depth was significant. The SNK indicated station 1 was significantly lower than stations 2 and 3, which were not significantly different (table 3-10).

Data for November indicate the phytoplankton community had completed its transition to winter levels. These data indicate only minor differences between up- and downstream stations. Hence, SQN could have had little influence on this community during this sample period.

Temporal Comparisons of Preoperational and Operational Monitoring Data--Data collected during preoperational monitoring (1973-1977) indicated Chrysophyta always dominated the Chickamauga Reservoir phytoplankton community in winter and usually dominated during the transition periods of spring and fall (TVA, 1978a). Dominance during the summer sample period changed from either Chrysophyta or Chlorophyta in 1973 and 1974 to Cyanophyta in 1975, 1976, and 1977. Dominance during operational monitoring (1981 and 1982) showed a continuance of trends for winter (Chrysophyta) and summer (Cyanophyta) of both 1981 and 1982; however, Chlorophyta dominated during spring of 1981 and 1982 and fall of 1981 with Chrysophyta dominant only during fall of 1982 rather than the typical Chrysophyta dominance during both of these periods found in preoperational monitoring. Dominance of Chlorophyta may indicate a change in the Chickamauga Reservoir phytoplankton community (both up- and downstream of SQN), but such a conclusion is premature because this group was occasionally dominant in both spring and fall sample periods of preoperational monitoring.

Several genera were collected both up- and downstream of SQN during essentially all (17 of 19) preoperational sample periods. These included the chlorophyte genera Chlamydomonas and Scenedesmus; the chrysophyte genera Melosira, Navicula, and Synedra; and the cyanophyte genus Dactylococcopsis (TVA, 1978a). These genera were collected during both operational monitoring years at about the same frequency as during preoperational monitoring. In addition to the above genera, several others were collected during eight of nine operational sample periods at both up- and downstream locations. These include the chlorophyte genera Ankistrodesmus and Chlorella; the chrysophyte genus Stephanodiscus; the cryptophyte genus Cryptomonas; and the euglenophyte genus Euglena (appendix D and E of this report and appendix C of TVA 1982a). It is interesting to note that the chlorophyte genus Pyramimonas, an abundant and common genus in 1981 was not collected in 1982. This is a transient organism (occurs primarily during seasonal transitional periods), and its presence one year yet absence the next indicate a weakness of quarterly monitoring programs such as this.

Preoperational and operational cell densities at the 1.0 m sample depth (the only depth consistently sampled during these two monitoring periods) for stations 1 and 3 are compared in figure 3-2 for comparative purposes. Total cell densities during preoperational monitoring were usually largest in summer (maximum of 11.58×10^6 cells/ℓ in summer 1977 at station 3) and lowest in winter, spring or (usually) fall (minimum of 0.07×10^6 cells/ℓ in winter 1974 at station 1). Cell densities during operational monitoring were largest in summer and winter (maximum of 11.10 and 7.19×10^6 cells/ℓ in summers 1981 and 1982, respectively, both at station 3) and smallest in fall (minimum of 0.12×10^6 cells/ℓ in fall 1980 at stations 1 and 3 and 0.11×10^6 cells/ℓ in fall 1982 at station 1). High cell densities during most seasons of 1981 reflect continuance of a trend toward increased densities over time during preoperational monitoring (TVA 1982). However, densities during all seasons of 1982 were lower than in 1981 and for most seasons were similar to the lower densities which occurred in early years of preoperational monitoring. Contradictory results from the two operational years make it difficult to determine if Chickamauga Reservoir is continuing toward increased phytoplankton production or if it has peaked. Data from subsequent years will be necessary to define this trend. Whatever the case, these changes are apparent in areas both up- and downstream of SQN.

The general trend of increased densities from up- to downstream identified during preoperational monitoring was not consistently seen in operational monitoring. During both years, there was a decrease from up- to downstream in May and an increase in August.

Chlorophyll a concentrations during preoperational monitoring were usually lowest in fall and highest in summer with no particular upstream-downstream trends (figure 3-3). During operational monitoring, considerable variation existed between years. Concentrations were higher in 1981 than in either 1982 or any preoperational year. Concentrations in 1982 were only slightly higher than in most preoperational years. Larger concentrations in 1981 were associated with greater algal production which could have been caused by the longer reservoir retention times during most sample periods or by a tendency toward a more productive reservoir. Reservoir flows during 1982 were near normal, except during May, and could account for the similarity of 1982 to preoperational periods. These fluctuations do not appear to be related to initiation of operation of SQN because increases were also apparent upstream of the plant.

Daily carbon assimilation rates for stations 1 and 3 during preoperational and operational monitoring periods are presented in figure 3-4. Comparison of absolute carbon assimilation rates between preoperational and operational periods must be made conservatively because of a change in laboratory procedure to a liquid scintillation counter for operational samples rather than the thin-window, low-background gas flow proportional counter for preoperational samples. Preoperational carbon assimilation rates were typically highest in spring and summer and usually higher at station 3 than at station 1. Winter and spring rates showed no definite trend of increases or decreases during the preoperational period, but summer and fall tended toward higher assimilation rates from beginning to end of the preoperational period. Carbon assimilation rates during operational monitoring were highest in spring and summer and lowest in fall. Operational data are inadequate to demonstrate long-term trends in spatial or seasonal assimilation rates.

It should be noted that carbon assimilation data for 1980 and 1981 reported in TVA (1982a) were incorrect because an incorrect constant was used in the computer program. Because the error was constant, it would affect absolute values and not relative values. Hence, spatial tests on 1981 data in TVA (1982a) were correct. However, absolute comparisons among years in figure 3.4 of that report should not be made for this reason and because of the change in laboratory methodology discussed above. This error was corrected prior to analysis of 1982 data and all values in this report are correct.

Preoperational and 1981 operational monitoring data indicate a tendency toward increases in the Chickamauga Reservoir phytoplankton community. However, 1982 operational data do not reflect continuation of this trend established in the mid to late 1970's and continued in 1981. The 1982 data are more like data collected in early 1970's except for Cyanophyta dominance which also has been apparent during summer since the mid-1970's.

Data to be collected in 1983 and 1984 will be evaluated to determine if this apparent return to a phytoplankton community were characteristic of less productive conditions is long-term.

An interesting trend noted in the spring sample period of both operational years is a general decrease in cell densities, chlorophyll a concentrations, and carbon assimilation rates from up- to downstream. Considerable discussion of these data was presented in TVA (1982a) and in this report. Data for 1981 and 1982 are not totally alike, but they follow the same trend. Decreases in 1981 were thought to be related to characteristics of different watermasses, rather than operation of SQN. This conclusion was reached because plant effects should have been manifested in stimulation rather than depression of most parameters during this time of year and because decreases were apparent at station 2, which is too close to the diffusers for plant induced effects to have time to be manifested. Decreases in 1982 were not as easily reconciled. Reservoir flows were lower and SQN water demand was higher in 1982 than 1981 resulting in the plant using about 30 percent of the river flow in 1982 compared to 10 percent in 1981. Longer reservoir retention time and conflicting trends in phytoplankton parameters in 1982 make interpretation of those data difficult. As a result, three explanations of possible causes were postulated but no singular causative factor could be identified. Data from subsequent years will, if this trend continues, could provide insight into influencing mechanisms.

An important point to note is that, during winter 1981, phytoplankton measurements were quite high, apparently a result of very low river flows. However, in 1982 river flows were very high during the winter sample period and phytoplankton parameters were low.

3.1.3 Summary and Conclusions

SQN operation during periods of sample collection in 1982 varied from one to two units of electrical generation in winter, spring, and summer with plant entrainment alone a potential perturbation in fall. When river flows during sample periods were compared to long-term flows, winter and summer were seasonally high, spring low, and fall normal. Flows greatly influence plankton, and therefore, results of this monitoring program.

Data for winter and fall 1982 sample periods indicated almost no differences between up- and downstream stations, indicating SQN had very little influence on the phytoplankton during these periods in 1982. Very high river flows during winter and normal flows with no plant generation during fall probably accounted for similarity among stations.

Data for spring 1982 indicated significant differences among stations. Longer reservoir retention time and conflicting trends in phytoplankton parameters made interpretation of station differences difficult. As a result, various hypotheses were stated but no conclusions were reached. However, effects from operation of SQN could not be ruled out because it was entraining about 30 percent of the river flow during this sample period.

The phytoplankton community exhibited increases from up- to downstream during the summer 1982 sample period. These types of increases were expected based on the relatively high river flows which existed. Although stimulation from plant operation cannot be ruled out, it appears that plant operation had little effect on the phytoplankton during this period.

When operational data were compared to preoperational data, cell density, chlorophyll a concentration, and carbon assimilation rate increases which were apparent in preoperational monitoring and the first year of operational monitoring were not apparent during this second year of operational sampling although Cyanophyta continued to dominate the summer phytoplankton community. Rather, data for 1982 were more similar to mesotrophic conditions in the early 1970's. Data to be collected in 1983 and 1984 will be evaluated to determine if this apparent return to a phytoplankton community more characteristic of mesotrophic conditions is long-term. SQN has apparently had little influence on Chickamauga Reservoir trophic status because similar trends were apparent both upstream and downstream of the plant.

Data for this second operational period indicate that SQN had little influnce on the phytoplankton community during winter, summer, and fall. However, the significance of effects resulting from operation of SQN during the spring sample period could not be determined.

Table 3-1. Percentage Composition of Phytoplankton Groups During Operational Monitoring Periods (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

Phytoplankton Group	Date	Tennessee River Mile		
		478.2*	483.4	490.5
Chlorophyta	Feb 1982	7	4	14
Chrysophyta		58	85	86
Cryptophyta		0	0	0
Cyanophyta		35	10	0
Euglenophyta		0	0	0
Pyrrophyta		0	0	0
Chlorophyta	May 1982	37	35	51
Chrysophyta		24	25	18
Cryptophyta		19	19	6
Cyanophyta		19	17	25
Euglenophyta		1	1	0
Pyrrophyta		0	0	0
Chlorophyta	Aug 1982	23	23	24
Chrysophyta		18	12	10
Cryptophyta		0	0	0
Cyanophyta		58	64	65
Euglenophyta		0	0	0
Pyrrophyta		0	0	0
Chlorophyta	Nov 1982	30	28	21
Chrysophyta		64	64	71
Cryptophyta		2	2	2
Cyanophyta		0	2	2
Euglenophyta		3	3	4
Pyrrophyta		0	0	0

*February 1982 samples were collected at river mile 480.8.

Table 3-2. Diversity Index Values ($\bar{d}$) for Phytoplankton Communities During Nuclear Plant, Chickamauga Reservoir

Date	Tennessee River Mile					
	478.2		483.4		490.5	
	No. Taxa	$\bar{d}$	No. Taxa	$\bar{d}$	No. Taxa	$\bar{d}$
Feb 1982*	18	2.49	15	2.15	12	2.22
May 1982	24	3.54	27	3.26	36	3.30
Aug 1982	60	4.04	55	3.49	50	3.44
Nov 1982	21	2.93	20	2.86	18	2.58

*February 1982 samples were collected at river mile 480.8.

Table 3-3. Similarity of Phytoplankton Community Composition/Structure During Operational Monitoring in 1982 Based on Sorensen's Quotient of Similarity and Percentage Similarity, Sequoyah Nuclear Plant, Chickamauga Reservoir

Date	Station Comparision*	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
Feb 1982	TRM 490.5-483.4	74	80
	TRM 490.5-480.8	60	63
	TRM 483.8-480.8	73	68
May 1982	TRM 490.5-483.4	73	31
	TRM 490.5-478.2	73	24
	TRM 483.4-478.2	90	75
Aug 1982	TRM 490.5-483.4	91	87
	TRM 490.5-478.2	87	65
	TRM 483.4-478.2	92	72
Nov 1982	TRM 490.5-483.4	74	78
	TRM 490.5-478.2	77	82
	TRM 483.4-478.2	68	76

*Tennessee River Mile (TRM) 490.5 = station 1.
Tennessee River Mile 483.4 = station 2.
Tennessee River Mile 480.8 (February only) and 478.2 = station 3.

Table 3-4. Mean Phytoplankton Densities (Cells x $10^6/\ell$) at Each Sample Station During Operational Monitoring (1982) Sequoyah Nuclear Plant, Chickamauga Reservoir

		Chlorophyta			Chrysophyta			Cyanophyta			Total Phytoplankton		
Date	Depth(m)	478.2*	483.4	490.5	478.2	483.4	490.5	478.2	483.4	490.5	478.2	483.4	490.5
Feb 1982	0.3	0.01	0.002	0.02	0.08	0.10	0.14	0.14	0.003	0	0.23	0.11	0.16
	1.0	0.02	0.002	0.02	0.04	0.11	0.13	0.08	0.003	0	0.22	0.12	0.15
	3.0	0.008	0.008	0.01	0.10	0.11	0.13	0	0.04	0	0.10	0.16	0.14
	5.0	0.003	0.01	0.03	0.08	0.10	0.07	0.002	0.003	0	0.10	0.11	0.10
May 1982	0.3	0.22	0.41	2.15	0.11	0.14	0.53	0.11	0.10	0.85	0.53	0.79	3.64
	1.0	0.19	0.30	1.90	0.12	0.19	0.74	0.16	0.18	1.08	0.60	0.88	3.96
	3.0	0.20	0.19	1.88	0.21	0.14	0.85	0.12	0.10	1.00	0.66	0.55	4.02
	5.0	0.14	0.24	1.39	0.05	0.29	0.45	0.004	0.12	0.74	0.27	0.77	2.82
Aug 1982	0.3	1.46	0.65	0.53	1.00	0.35	0.25	4.68	2.17	1.43	7.19	3.20	2.23
	1.0	0.83	0.69	0.77	1.00	0.30	0.30	2.24	1.56	2.18	4.08	2.55	3.28
	3.0	1.13	0.79	0.57	0.93	0.45	0.27	2.24	2.35	1.25	4.39	3.60	2.11
	5.0	1.10	0.57	0.54	0.79	0.29	0.23	2.42	1.29	1.61	4.34	2.17	2.40
Nov 1982	0.3	0.05	0.04	0.04	0.11	0.09	0.10	0	0.008	0	0.17	0.14	0.14
	1.0	0.03	0.03	0.03	0.08	0.07	0.07	0	0.002	0.003	0.12	0.11	0.11
	3.0	0.05	0.02	0.03	0.09	0.07	0.10	0	0	0.005	0.14	0.09	0.14
	5.0	0.04	0.02	0.02	0.08	0.05	0.09	0	0	0	0.13	0.08	0.11

*Tennessee River Mile.

Table 3-5. Results of Two-Way Analysis of Variance on Total Phytoplankton and Group Cell Densities, Operational Monitoring During 1982 at Sequoyah Nuclear Plant, Chickamauga Reservoir

	Chlorophyta		Chrysophyta		Cyanophyta		Total Phytoplankton	
	F-Ratio	P>F	F-Ratio	P>F	F-Ratio	P>F	F-Ratio	P>F
Feb 1982								
River Mile	3.50	0.0636	2.40	0.1331	4.01*	0.0465	0.24	0.7885
Depth	0.42	0.7444	3.23	0.0611	0.25	0.8568	1.52	0.2599
River Mile & Depth	1.28	0.3363	1.19	0.3735	1.17	0.3833	0.92	0.5159
May 1982								
River Mile	695.91*	0.0001	85.09*	0.0001	8.86*	0.0043	863.19*	0.0001
Depth	15.57*	0.0002	2.87	0.0805	3.12	0.0660	19.76*	0.0001
River Mile & Depth	3.92*	0.0211	5.97*	0.0043	2.62	0.0738	13.14*	0.0001
Aug 1982								
River Mile	35.57*	0.0001	55.17*	0.0001	21.21*	0.0001	65.03*	0.0001
Depth	1.07	0.3965	0.97	0.4406	4.67*	0.0220	4.88*	0.0192
River Mile & Depth	3.75*	0.0244	0.55	0.7586	6.35*	0.0033	7.73*	0.0014
Nov 1982								
River Mile	1.56	0.2501	3.82	0.0520	2.27	0.1457	5.20*	0.0236
Depth	1.26	0.3339	2.23	0.1372	1.18	0.3599	4.40*	0.0262
River Mile & Depth	0.54	0.7695	0.38	0.8792	1.95	0.1533	0.96	0.4885

*Significant at a = 0.05.

Table 3-6. Disposition of Phytoplankton Density (Cells/P) Data Sets with Significant F-Ratios Identified in Table 3-5, Operational Monitoring During 1982 at Sequoyah Nuclear Plant, Chickamauga Reservoir

Date	Test Group	Sample Depth (m)	F-Ratio Two-Way ANOVA	F-Ratio One-Way ANOVA	SNK* Low Mean		High Mean
Feb 1982	Cyanophyta†		4.01		1	3	2
May 1982	Chlorophyta‡	0.3		339.33§	3	2	1
		1.0		272.17§	3	2	1
		3.0		230.04§	2	3	1
		5.0		84.74§	3	2	1
May 1982	Chrysophyta‡	0.3		31.27§	3	2	1
		1.0		28.94§	3	2	1
		3.0		17.28§	2	3	1
		5.0		31.41§	3	2	1
May 1982	Cyanophyta†		8.86		3	2	1
May 1982	Total Phytoplankton‡	0.3		1072.45§	3	2	1
		1.0		396.26§	3	2	1
		3.0		192.50§	2	3	1
		5.0		126.08§	3	2	1

Table 3-6. (Continued)

Date	Test Group	Sample Depth (m)	F-Ratio Two-Way ANOVA	F-Ratio One-Way ANOVA	SNK Low Mean		SNK High Mean
Aug 1982	Chlorophyta[‡]	0.3		978.31[§]	1	2	3
		1.0		0.41	2	1	3
		3.0		21.44[§]	1	2	3
		5.0		6.81	1	2	3
Aug 1982	Chrysophyta[†]		55.17		1	2	3
Aug 1982	Cyanophyta[‡]	0.3		54.28[§]	1	2	3
		1.0		3.46	2	1	3
		3.0		19.25[§]	1	3	2
		5.0		2.59	2	1	3
Aug 1982	Total Phytoplankton[‡]	0.3		189.20[§]	1	2	3
		1.0		5.74	2	1	3
		3.0		31.49[§]	1	2	3
		5.0		8.98	2	1	3

Table 3-6. (Continued)

Date	Test Group	Sample Depth (m)	F-Ratio Two-Way ANOVA	F-Ratio One-Way ANOVA	SNK Low Mean	High Mean
Nov 1982	Total Phytoplankton†		5.20		2	1 3

*Student, Newman, Keuls Multiple Range Test; means ranked lowest to highest using station numbers; means underscored by same line are not significantly different at $\alpha = 0.05$, means not so underscored are significantly different.

Tennessee River Mile 490.5 = station 1.
Tennessee River Mile 483.4 = station 2.
Tennessee River Mile 480.8 (February only) and 478.2 = station 3.

†Depths combined in two-way ANOVA since interaction was not significant.

‡Depths tested separately with one-way ANOVA since interaction was significant in two-way ANOVA.

§Significant at $\alpha = 0.05$.

Table 3-7. Mean Phytoplankton Chlorophyll a Concentrations (mg/m^3) and Phaeophytin Index Values at Each Station During Operational Monitoring (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

Date	Depth (m)	TRM 490.5* Chloro†	TRM 490.5* Phaeo‡	TRM 483.4 Chloro	TRM 483.4 Phaeo	TRM 478.2 Chloro	TRM 478.2 Phaeo
Feb 1982	0.3	3.61	1.46	3.68	1.36	2.99	1.37
	1.0	3.16	1.40	1.51	§	2.84	1.29
	3.0	3.29	1.35	3.19	1.35	3.25	1.30
	5.0	3.29	1.46	3.41	1.40	3.38	1.57
May 1982	0.3	6.96	1.48	5.76	1.35	6.82	1.48
	1.0	7.79	1.55	5.62	1.48	6.92	1.47
	3.0	10.76	1.48	5.76	1.46	6.46	1.48
	5.0	9.73	1.44	5.23	1.32	6.13	1.40
Aug 1982	0.3	3.93	1.35	4.60	1.32	8.79	1.53
	1.0	3.91	1.30	5.05	1.43	8.84	1.47
	3.0	3.68	1.19	4.95	1.49	8.42	1.50
	5.0	3.57	1.20	5.51	1.39	7.31	1.47
Nov 1982	0.3	1.89	1.50	2.41	1.65	2.55	1.45
	1.0	2.04	1.56	2.36	1.55	2.28	1.33
	3.0	2.21	1.56	2.09	1.48	2.42	1.53
	5.0	1.97	1.59	2.10	1.50	2.31	1.41

*Tennessee River Mile.

†Chlorophyll a concentrations.

‡Phaeophytin index values.

§Value in error or unavailable.

Table 3-8. Results of Statistical Analyses (One- and Two-Way Analyses of Variance and Student, Newman, Keuls Multiple Range Test) on Phytoplankton Chlorophyll *a* Data, Operational Monitoring During 1982 at Sequoyah Nuclear Plant, Chickamauga Reservoir

	Results of Two-Way ANOVA					
	Station		Depth		Interaction	
Date	F-Ratio	P>F	F-Ratio	P>F	F-Ratio	P>F
Feb 1982	0.72	0.5052	1.63	0.2346	0.99	0.4752
May 1982	60.91*	0.0001	2.70	0.0923	5.80*	0.0048
Aug 1982	126.01*	0.0001	0.52	0.6792	1.24	0.3529
Nov 1982	14.91*	0.0006	1.37	0.2995	2.70	0.0677

Results of One-Way ANOVA and SNK on Data Sets with Significant F-Ratios

Date	Sample Depth (m)	F-Ratio One-Way ANOVA	SNK† Low $\bar{X}$		High $\bar{X}$
May 1982	0.3	5.72	2	1	1
	1.0	60.50*	2	3	1
	3.0	14.81*	2	3	1
	5.0	33.65*	2	3	1
Aug 1982‡	-	-	1	2	3
Nov 1982‡	-	-	3	2	1

*Significant at $\alpha = 0.05$.

†Student, Newman, Kuels Multiple Range Test; means ranked lowest to highest using station numbers; means underscored by same line are not significantly different at $\alpha = 0.05$; means not so underscored are significantly different.

‡Depths combined in two-way since interaction was not significant.

Table 3-9. Hourly and Daily Carbon Assimilation Rates at Each Sample Location During Operational Monitoring (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

		TRM 478.2*		TRM 483.4		TRM 490.5	
DATE	DEPTH	MG C/M³/HR	MG C/M²/DAY	MG C/M³/HR	MG C/M²/DAY	MG C/M³/HR	MG C/M²/DAY
Feb 1982	0.3	1.51		2.34		1.84	
	1.0	1.64		2.18		1.73	
	3.0	0.43		0.49		0.16	
	5.0	0.12		0.34		0.03	
	SURFACE TO 5.0 M		29		43		31
May 1982	0.3	13.99		7.40		12.59	
	1.0	16.75		9.03		13.71	
	3.0	8.09		2.69		14.52	
	5.0	0.96		0.10		2.34	
	SURFACE TO 5.0 M		429		193		410
Aug 1982	0.3	52.16		18.67		13.01	
	1.0	46.38		13.92		11.89	
	3.0	11.13		3.63		3.48	
	5.0	1.98		0.67		0.74	
	SURFACE TO 5.0 M		571		232		189
Nov 1982	0.3	2.67		2.31		1.98	
	1.0	2.58		3.80		2.02	
	3.0	1.40		0.97		0.48	
	5.0	0.36		0.13		0.21	
	SURFACE TO 5.0 M		84		65		59

*Tennessee River Mile 480.8 was sampled in February.

Table 3-10. Results of Statistical Analyses (One- and Two-Way Analyses of Variance and Student, Newman, Keuls Multiple Range Test) on Phytoplankton Carbon Assimilation Rates, Operational Monitoring During 1982 Near Sequoyah Nuclear Plant, Chickamauga Reservoir

	Results of Two-Way ANOVA					
	Station		Depth		Interaction	
Date	F-Ratio	P>F	F-Ratio	P>F	F-Ratio	P>F
Feb 1982	17.91*	0.0002	253.99*	0.0001	2.20	0.1160
May 1982	191.12*	0.0001	583.91*	0.0001	17.33*	0.0001
Aug 1982	331.51*	0.0001	1022.55*	0.0001	9.54*	0.0005
Nov 1982	9.68*	0.0031	114.33*	0.0001	3.26*	0.0387

Results of One-Way ANOVA and SNK on Data Sets with Significant F-Ratios

Date	Sample Depth (m)	F-Ratio One-Way ANOVA	SNK† Low $\bar{X}$		High $\bar{X}$
Feb			1	3	2
May	0.3	43.19*	2	1	3
	1.0	21.64*	2	1	3
	3.0	130.91*	2	3	1
	5.0	‡			
Aug	0.3	299.09*	1	2	3
	1.0	94.71*	1	2	3
	3.0	48.24*	1	2	3
	5.0	‡			
Nov	0.3	1.61	1	2	3
	1.0	6.12	1	3	2
	3.0	‡			
	5.0	‡			

*Significantly different at a = 0.05.

†Newman, Kuels Multiple Range Test; means ranked lowest to highest using station numbers; means underscored by same line are not significantly different at a = 0.05; means not so underscored are significantly different.

‡Not tested statistically because all rates were below 2 mg C/m^3/hr.

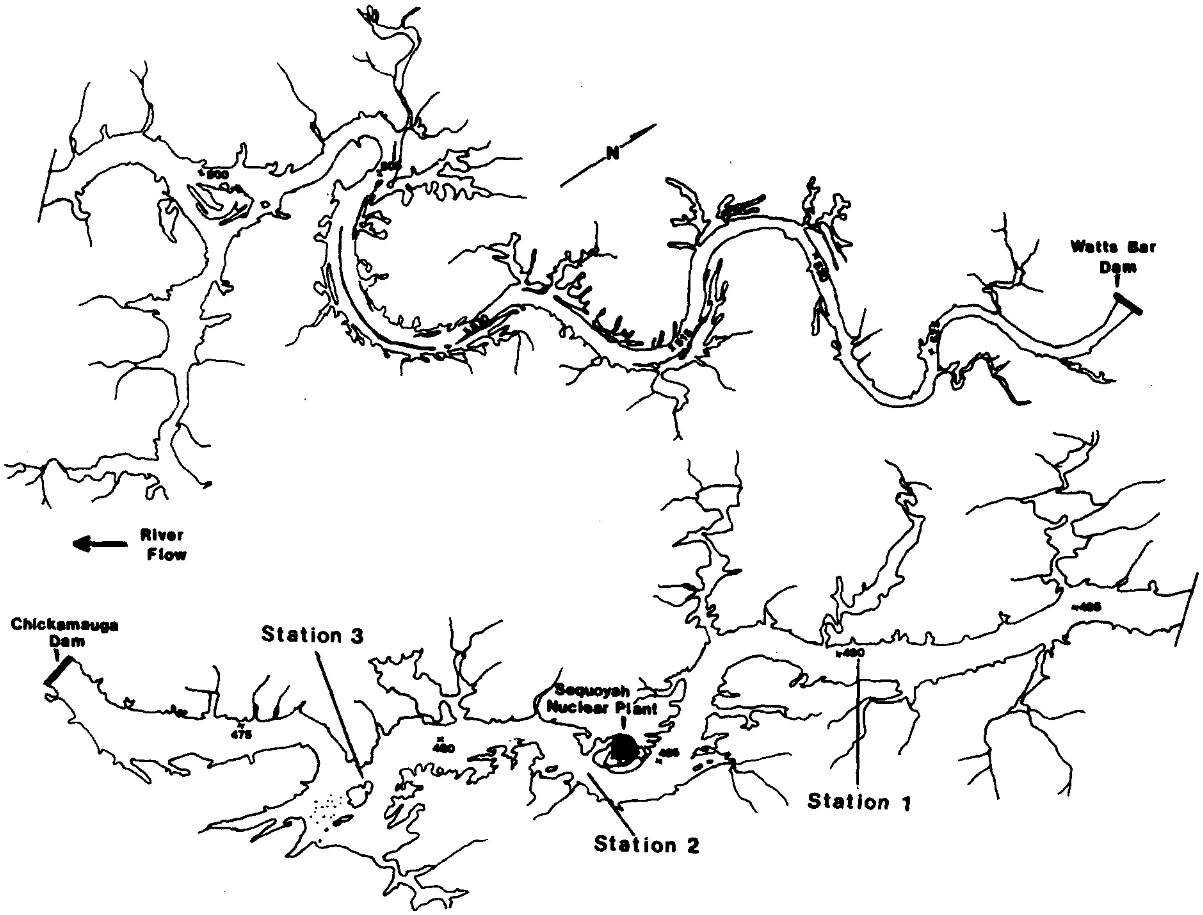

Figure 3-1. Location of Phytoplankton and Zooplankton Sample Stations for Operational Monitoring (1980 and 1981), Sequoyah Nuclear Plant, Chickamauga Reservoir.

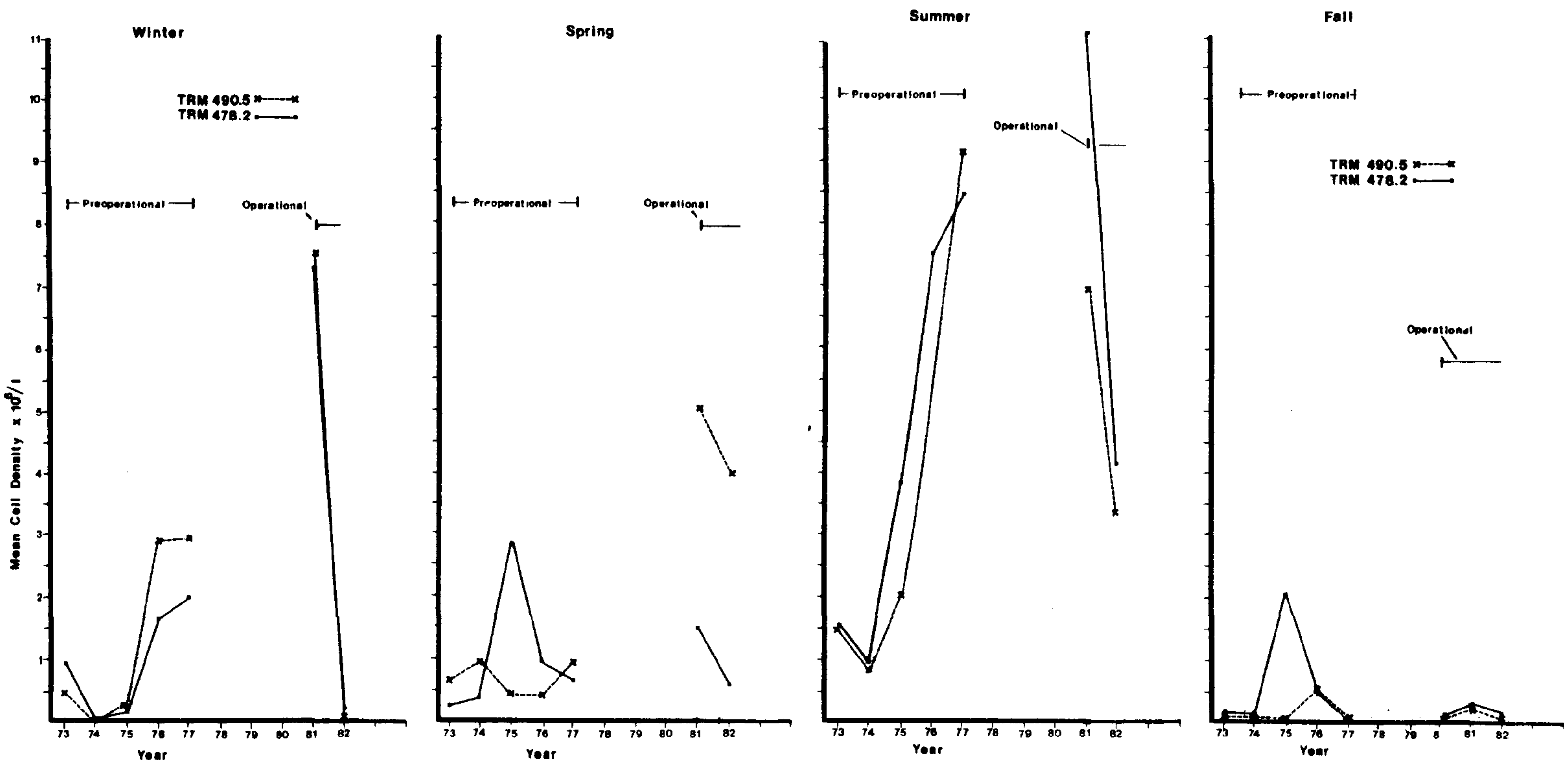

Figure 3-2. Comparisons of Phytoplankton Densities at One-Meter Sample Depth of Selected Stations During Preoperational and Operational Monitoring, Sequoyah Nuclear Plant, Chickamauga Reservoir.

CHLOROPHYLL A DATA
PREOPERATIONAL AND OPERATIONAL PERIODS

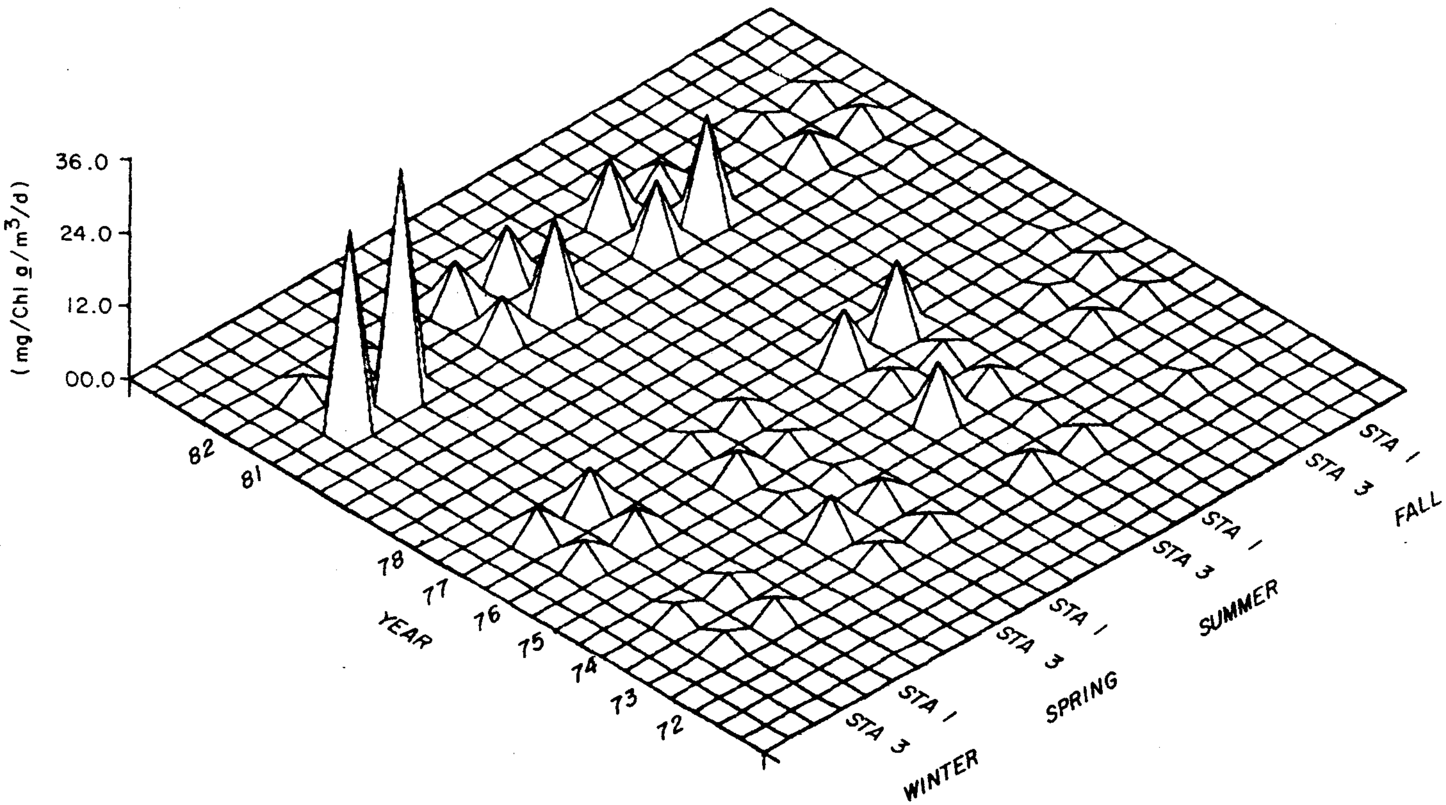

Figure 3-3. Comparisons of Phytoplankton Chlorophyll a Concentrations at the One-Meter Sample Depth of Selected Stations During Preoperational and Operational Monitoring Periods, Sequoyah Nuclear Plant, Chickamauga Reservoir.

PRIMARY PRODUCTIVITY DATA
PREOPERATIONAL AND OPERATIONAL PERIODS

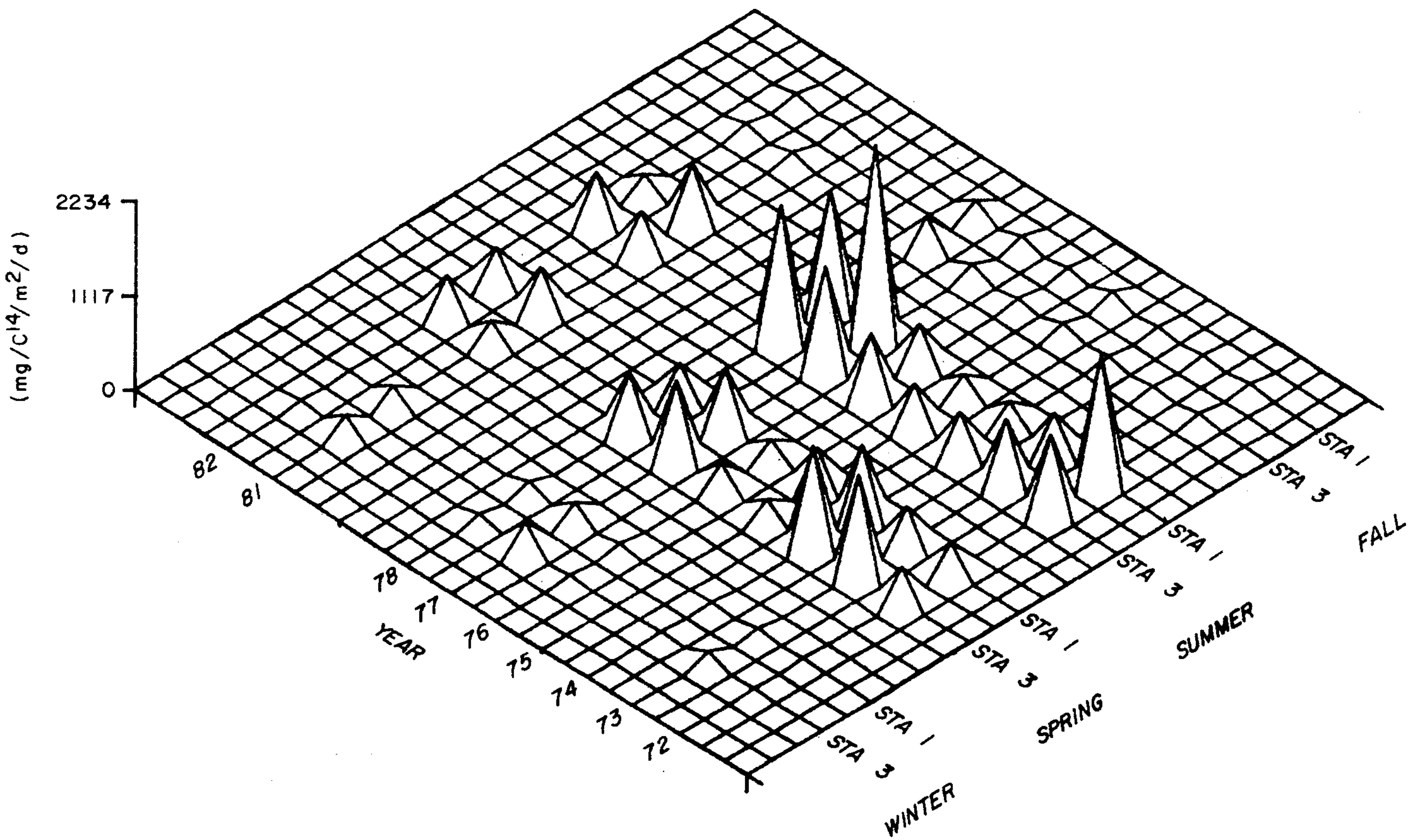

Figure 3-4. Comparisons of Phytoplankton Carbon Assimilation Rates at Selected Stations During Preoperational and Operational Monitoring Periods, Sequoyah Nuclear Plant, Chickamauga Reservoir.

3.2 Zooplankton

3.2.1 Materials and Methods

Field--Two replicate zooplankton samples were collected quarterly (see table 1-2) from mid-channel at each of three stations (station 1 at TRM 490.5, upstream of SQN; station 2 at TRM 483.4, immediately downstream of the diffuser pipes; and station 3 at TRM 478.2 downstream of SQN; figure 3-1). During the winter survey, samples were collected from TRM 480.8 rather than TRM 478.2. A half-meter plankton net (80 µm mesh) with a flowmeter suspended in the throat as described by Dycus and Wade (1977) was used to collect these bottom to surface samples. Samples were preserved with Formalin immediately after collection.

Laboratory--Samples were diluted or concentrated, depending on the abundance of detritus and organisms. Four 1-ml subsamples were taken from the magnetically stirred sample using a 1-ml Hensen-Stempel pipette and each subsample placed in a Sedgewick Rafter cell. Organisms were enumerated at the lowest practicable taxonomic level, usually species, on a compound microscope at 35 X or 50 X. After subsample enumeration, the remainder of the sample was scanned under a dissecting microscope at 14 X for any additional taxa not encountered in subsampling. Resultant counts were extrapolated to total numbers in the sample and then these numbers were converted to numbers per cubic meter. References and publications used in identifications include: Ahlstrom (1940, 1943), Brooks (1957), Deevey and Deevey (1971), Goulden (1968), Harring and Myers (1926), Ruttner-Kolisko (1974), Voigt (1956), and Ward and Whipple (1959).

Data Analyses--Sampling and processing precision of total community and group densities was estimated by calculating the coefficient of variation for each set of duplicate samples. Coefficients less than 20 percent were considered indicative of good sample replicability. Coefficients of variation greater than 40 percent indicated larger than desirable variability among replicate samples.

Total and group numbers were tested statistically using a one-way analysis of variance (ANOVA). The Student, Newman, Keuls multiple range test (SNK) was applied to data sets which were significantly different as shown by the ANOVA. All tests were evaluated at the 0.05 level of probability.

Rotifera and adult members of the Copepoda and Cladocera were used to determine the number of taxa in each sample. Zooplankton community structure was analyzed using $\bar{d}$, SQS, and PS in the same manner as for the phytoplankton (see section 3.1.1), except zooplankton analyses were based on species rather than genera.

3.2.2 Results and Discussion

Spatial Comparisons of Operational Monitoring Data--Section 2.2 shows that at least one unit was generating power on the winter, spring, and summer zooplankton sample dates in 1982; neither unit was generating on the November sample date. The following section presents results for each of these sample dates.

February 1982--Very high river flows existed during and before this sample period. These high flows provided ample dilution for SQN effluent such that community alterations as a result of this effluent would be highly unlikely.

The zooplankton community was numerically dominated by Copepoda (50-56 percent of total density) at all sample stations (table 3-11).

Larval copepods (nauplii) were the most numerous "taxon" at stations 2 and 3 and subdominant at station 1 where Bosmina longirostris was dominant (appendices I and J).

Diversity index values were relatively high and increased from up- to downstream (2.20, 2.67, and 3.08 at stations 1, 2, and 3, respectively; table 3-12). Likewise, number of taxa (25, 32, and 32) followed the same trend.

Taxa present at station 1 were sufficiently different from taxa at stations 2 and 3 that SQS values for station 1-2 and 1-3 comparisons were below 70 percent and considered different, while genera present at stations 2 and 3 were sufficiently similar to one another that the SQS value was above the 70 percent "cut-off" value (table 3-13). These upstream/downstream differences could be indicative of plant effects but not in a situation such as this where lower SQS values were related to collecting a greater number of rare species (i.e., those represented by only a few specimens) at downstream stations.

Percentage similarity values indicate all stations were similar (table 3-13). This test adds a dimension not provided by SQS because it includes quantitative characteristics of species at two stations being compared and is not affected as much as SQS by presence/absence of rare species.

Total organism mean densities were similar at stations 1 and 3 (11,000 and 12,800 per m^3, respectively; table 3-14 and figure 3-5) and slightly higher at station 2 (18,700 per m^3). No statistical significance was detected among these means (table 3-15). Densities for the numerically dominant group, Copepoda, showed the same pattern as total densities (6,200 and 6,400 per m^3 at stations 1 and 3, respectively; with 9,700 at station 2) and no significant difference among means. Cladocera densities ranged from 2,400 to 4,200 per m^3 and no significant difference was detected. Rotifera densities increased from station 1 (1,700 per m^3) to stations 2 and 3 (4,800 and 4,000 per m^3, respectively) but were not significantly different.

Data for February indicate little difference existed in the zooplankton community between up- and downstream stations. Perturbations resulting from plant operations were probably negligible compared to high river flows which existed during this sample period.

May 1982--Section 2.2 describes flow conditions in Chickamauga Reservoir during this sample period as atypically low. Hence, river flows probably had an important influence on plankton dynamics.

Rotifera was the numerically dominant zooplankton group at all locations but decreased in proportion from 81 percent at station 1 to 58 and 68 percent at stations 2 and 3, respectively (table 3-11). Most of this reduction was due to a large reduction in one rotifer genus (Asplanchna), which exhibited large decreases in density from station 1 to stations 2 and 3 (180,000, 26,300, and 35,000 per m^3 at stations 1, 2, and 3, respectively; appendix J). Most other taxa were relatively similar among stations except the rotifers, Synchaeta spp. and Brachianus calyciflorus, which exhibited reductions similar to Asplanchna, and the cladoceran Bosmina longirostris which exhibited a reduction from stations 1 and 2 (densities similar) to station 3 (appendix J).

Although there was a reduction in densities of these taxa, total number of taxa at each station was similar (range 24-28) and $\bar{d}$ values were similar (range 2.25 to 2.38, table 3-12). Taxa present (i.e., community composition) at each station were also similar as all SQS values were 80 percent or greater (table 3-13). However, when quantitative aspects of the community (i.e., community structure) were considered by PS, station 1 was different from stations 2 and 3, but stations 2 and 3 were similar to one another, apparently a result of the changes discussed before.

Total organism density was reduced from station 1 (399,800 per m^3) to stations 2 and 3 (212,000 and 164,500 per m^3, respectively; table 3-14 and figure 3-5), with most of the reduction resulting from Rotifera (mainly Asplanchna). When total zooplankton densities and rotifer densities were tested statistically, both had significant differences among means with station 1 significantly larger than stations 2 and 3, which were not significantly different from one another (table 3-15). Cladoceran densities ranged from 27,900 per m^3 at station 3 to 51,400 per m^3 at station 2 but no significant difference was detected among means for the three stations. Copepod densities ranged from 24,000 per m^3 at station 3 to 36,700 per m^3 at station 2. The SNK indicated mean copepod density at station 2 was significantly higher than densities at stations 1 and 3, which were not different from one another.

The zooplankton community exhibited several notable differences from up- to downstream stations during the May sample period. Most of these differences were related to reductions in densities of a few taxa, especially Asplanchna spp. Reductions were also apparent for the phytoplankton community (see section 3.1). Such reductions from up- to downstream are opposite the expected trend for mainstem reservoirs. A discussion of possible causative mechanisms for trends observed in May was presented in section 3.1. Although that discussion concerned phytoplankton, similar rationale is appropriate for zooplankton. The first explanation discussed is that the long retention time during the May sample period greatly altered normal plankton community patterns in Chickamauga

Reservoir such that population peaks which usually occur in downstream reservoir reaches due to increased retention time actually occurred in upstream reaches. As a result, phytoplankton increased in density in upstream reaches thereby providing a greater food source for herbivorous zooplankters and in turn for carnivorous zooplankters such as Asplanchna. As phytoplankton and zooplankton densities increased, environmental conditions may have become limiting resulting in subsequent decreases.

Another possible explanation associated with physical conditions resulting from low river flows is that lower densities at TRM's 483.4 and 478.2 than those observed at TRM 490.5 were representative of different watermasses or patchiness (see Hutchinson, 1967 for a thorough discussion on plankton patchiness) and were not actually "decreases." Section 2.2 discusses travel times through Chickamauga Reservoir. These travel times were more than sufficient for community dynamics to change from one station to another and it is not suprising for the community to exhibit different characteristics at different stations.

A third explanation is that differences among stations could have been associated with operation of SQN. If they were plant induced, they would more likely be caused by plant entrainment rather than thermal effects or toxicity. During the May sample period when water temperatures were similar among stations and reached a maximum of 20.4° C at surface of station 3, stimulation (i.e., increased densities due to a shortened generation time resulting from a slight increase in temperature) rather than reduction in zooplankton density would be the expected effect from thermal input. Toxicity can be ruled out because these reductions were apparent at the station immediately downstream of the diffusers. Sufficient travel time does not exist from diffusers to this sample location for organisms to die and settle from the water column. Hence, if these reductions were due to plant operation, they would have to be caused by organism destruction during plant entrainment. This possibility cannot be ruled out because the plant was using approximately 30 percent of the river flow and entrained water from much of the water column. Asplanchna would be particularly susceptible to destruction during plant entrainment because these organisms have a weak and flexible body covering which would provide little protection during entrainment.

Identifying the exact factor(s) responsible for decreases observed in May is not possible with existing data. Speculations such as those above can be made, but whether reductions were due to plant operation or natural conditions cannot be determined.

August 1982--River flows immediately before and on the sample date were slightly higher than usual as a result of heavy rainfall in the upper portion of the Tennessee Valley, and Chickamauga Reservoir had destratified a few days prior to sample collection. Slightly higher river flows would decrease retention time and reduce accumulation of plankton in upstream reaches, while destratification and turbulence would make nutrients in deeper reservoir strata available for use by algae in the photic zone.

The zooplankton community was dominated by Cladocera at station 1 and by Rotifera at stations 2 and 3 (table 3-11). Bosmina longirostris was the dominant taxon at stations 1 and 3 and subdominant at station 2 as a result of a rather substantial decrease in density of this species at station 2 (appendix J). Conochilus unicornis (a colonial rotifer) was the dominant taxon at station 2. Densities of almost every rotifer taxon increased from station 1 to station 2 with a large increase at station 3. Nauplii (larval copepods) also increased from up- to downstream.

Number of taxa was slightly higher at downstream stations (46 at station 2 and 45 at station 3; table 3-12) than at the upstream station (38). Diversity index values showed the same trend (2.22, 2.81, and 2.58 at stations 1, 2, and 3, respectively). Community composition was also similar among stations as all SQS values were well above 70 percent (table 3-13). However, community structure (quantitative aspects of each species) differed between stations because all PS values were less than 70 percent. Low PS values between stations are not surprising given the increases in densities of several species from up- to downstream.

Total organism density was similar at stations 1 and 2 (37,100 and 39,200 per m^3, respectively) and higher at station 3 (124,300 per m^3; table 3-14 and figure 3-5). Station 2 total density appeared similar to station 1 density as a result of a decrease in cladoceran densities (19,000, 8,500, and 48,500 per m^3 at stations 1, 2, and 3; respectively) and increase in rotifer densities (12,700, 22,300, 58,700 per m^3 at stations 1, 2, and 3, respectively). Copepod densities increased from station 1 to station 3 (5,400, 8,400, and 17,000 per m^3 station 1, 2, and 3, respectively). Increases in all groups accounted for the large total density at station 3. When densities were tested statistically, total number, Copepoda, and Rotifera provided the same results--station 3 was significantly higher than stations 1 and 2, which were not significantly different (table 3-15). Mean cladoceran density at each location was significantly different from all other locations.

Increased densities of most zooplankton taxa from up- to downstream are expected under flow conditions such as those which existed during the August sample period because retention time is usually not sufficient for increased zooplankton densities to be manifested until the reservoir cross-sectional area increases in downstream reservoir reaches. This would allow increases from reproduction to accumulate. However, increases such as these could be indicative of thermal stimulation, except that the approximate eight-hour travel time from the plant to the downstream station would be insufficient for densities to increase as a result of reproduction. Thus, increases noted were most likely related to recruitment from large embayments and to increased retention time in lower reservoir reaches rather than to thermal stimulation.

November 1982--Because neither of the units was generating electricity on or three days prior to sample collection, thermal effects were not possible (section 2.2). River flows were normal for fall and had been relatively stable for most of the summer and fall.

Cladocera numerically dominated the zooplankton community at all stations (54, 61, and 63 percent at stations 1, 2, and 3, respectively; table 3-11). *Bosmina longirostris* was the dominant taxon at all stations and composed almost the entire cladoceran density (appendix J). Nauplii were subdominant at all stations.

Number of taxa was the same at stations 1 and 2 (34) but lower (24) at station 3 (table 3-12). Appendix J shows that taxa absent from station 3 were represented at stations 1 and 2 by very low densities (<10 per m^3). Therefore, absence of the rare taxa from station 3 is not considered problematic. Diversity index values decreased from up- to downstream (2.18, 1.79, and 1.63 at stations 1, 2, and 3, respectively). This difference is not considered representative of community change worthy of concern; rather it was probably associated with fluctuations in population levels of the dominant taxon (*Bosmina longirostris*) whose densities were 53, 61, and 63 percent of total organism densities at stations 1, 2, and 3, respectively. (Increases in one taxon lowers $\bar{d}$ values.)

Community composition was similar at station 1 and 2 (SQS 71 percent) and stations 2 and 3 (SQS 76 percent) but not stations 1 and 3 (SQS 60 percent; table 3-13). However, PS coefficients indicated all stations had similar community structure. Differences between SQS and PS results are not surprising because low SQS values can result from present/absence of taxa represented by only a few specimens.

Total organism density was lower during this sample period than during any other sampling period in 1982. Densities ranged from 4,000 per m^3 at station 1 to 6,800 per m^3 at station 2 (table 3-14). These means were not significantly different when tested statistically (table 3-15). Likewise, statistically significant differences were not detected for cladoceran, copepod, or rotifer means.

Data for November indicate only minor differences existed in the zooplankton community between up- and downstream sample locations. Hence, SQN apparently had little influence on this community during this sample period.

Temporal Comparisons of Preoperational and Operational Monitoring Data--Data collected during preoperational monitoring show either Rotifera (usually) or Copepoda (occasionally) was the dominant group during winter and summer and either Rotifera or Cladocera during spring and fall (TVA, 1978a). These trends continued into operational monitoring with either Rotifera or Copepoda dominant in winter, Rotifera in spring and summer, and Cladocera in fall. In addition to group composition being similar during the two monitoring periods, all taxa occurring consistently in Chickamauga Reservoir during preoperational monitoring were collected during operational monitoring.

A trend identified in the preoperational monitoring report was that more taxa were usually collected downstream of SQN (TVA, 1978a). This trend was not apparent in either year of operational monitoring--station 1 had the highest number of taxa during about half of the operational monitoring sample periods. Although this represents an apparent change from preoperational conditions, the number of taxa during operational monitoring varied little among stations with no apparent upstream/downstream trends.

Enumeration data for preoperational monitoring indicate maximum densities of organisms in Chickamauga Reservoir usually occurred during spring. Preoperational data also showed that organisms were more numerous downstream of SQN during spring, summer, and fall but higher upstream during winter. Data collected during operational monitoring show similar trends except, in 1982 when the greatest density occurred upstream in spring and downstream in winter.

A comparison of mean zooplankton densities at up- and downstream stations for each season over preoperational years (1973-1978) showed fluctuations with a general increase over time apparent for all seasons, but especially in spring and summer (figure 3-6). Operational data varied between the two years with densities typically higher in 1981 than in 1982. When operational data were compared to preoperational data for the upstream station (TRM 490.5) and the farthest downstream station (TRM 478.2), the general trend toward increased densities established in preoperational monitoring was apparent only for spring samples. Data for both operational years indicate the trend of increasing densities observed in preoperational monitoring during winter, summer, and fall has not continued.

Another point about the spring sample period is that zooplankton densities have usually been either similar between up- and downstream stations or higher at the downstream station (figure 3-6). However, as discussed previously, densities during spring 1982 exhibited drastic reductions from up- to downstream. Similar reductions, although not as great, were also apparent during one spring preoperational sample period (1974). Three explanations for decreases in 1982 were provided: (1) populations peaked in upper or middle reservoir segments rather than in lower segments as a result of low river flows; (2) differences among stations reflected characteristics of different watermasses; and (3) reductions were associated with operation of SQN. Of these, only the second can explain reductions for spring 1974 because flows during that sample period were relatively high (850 m^3/s, 30,000 cfs) and SQN was not in operation. Spatial differences owing to different watermasses or patchiness make interpretation of plankton data, especially quarterly data, difficult. For this reason, only potential causative mechanisms for such differences can be postulated. As stated previously, the relative contribution of SQN effects on these reductions cannot be determined; although is seems a safe assumption that plant operation was involved to some extent because SQN entrained about 30 percent of the river flow.

Identifying the effect(s) of SQN on fluctuations in zooplankton densities over years is difficult because other physical factors, especially river flow, have such an important influence on plankton dynamics. However, these data do not show any preoperational/operational trends. Rather, most operational densities fall within the range of preoperational densities.

3.2.3 Summary and Conclusions

SQN operation during periods of sample collection in 1982 varied from one to two units in winter, spring, and summer with plant entrainment alone a potential perturbation in fall. When river flows during sample periods were compared to long-term flows, winter and summer were seasonally high, spring low, and fall normal. Flows greatly influence plankton, and therefore, results of this monitoring program.

Data for winter and fall 1982 sample periods indicated almost no differences between up- and downstream stations; therefore, SQN had very little influence on the zooplankton during these periods in 1982. Very high river flows during winter and normal flows with no plant generation during fall accounted for the similarity among stations.

Data for spring 1982 indicated significant differences among stations. Reductions in densities of a few taxa, but especially in soft-bodied rotifers, resulted in large decreases from up- to downstream. Longer reservoir retention time made interpretation of station differences difficult. As a result, various hypotheses were stated but no conclusions were reached. However, plant effect was possible because SQN entrained about 30 percent of the river flow during this sample period.

The zooplankton community exhibited increases from up- to downstream during summer 1982 sample period. These increases were expected based on river flows which existed. It would appear that plant operation had little effect on zooplankton during this period.

When operational data were compared to preoperational data, trends which were apparent in preoperational monitoring (i.e., increases in zooplankton densities over time) were not apparent during three of the four sample periods in both years of operational sampling. Only during May of each operational year did trends observed during preoperational monitoring continue.

Data for this second operational period suggest that SQN had little influence of the zooplankton community during winter, summer, and fall under physical conditions which have existed during monitoring periods. However, effects resulting from operation of SQN during the spring sample period may have occurred during unusually low river flows.

Table 3-11. Percentage Composition of Zooplankton Groups During Operational Monitoring Periods (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

Zooplankton Group	Date	Tennessee River Mile		
		478.2*	483.4	490.5
Cladocera	Feb 1982	18	23	29
Copepoda		50	52	56
Rotifera		31	25	15
Cladocera	May 1982	17	24	12
Copepoda		15	17	7
Rotifera		68	58	81
Cladocera	Aug 1982	39	22	51
Copepoda		14	21	14
Rotifera		47	57	34
Cladocera	Nov 1982	63	61	54
Copepoda		16	17	11
Rotifera		21	22	35

* February 1982 samples were collected at river mile 480.8.

Table 3-12. Zooplankton Diversity Index Values ($\bar{d}$) during Operational Monitoring Periods (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

	Tennessee River Mile					
	478.2		483.4		490.5	
Date	No. Taxa	$\bar{d}$	No. Taxa	$\bar{d}$	No. Taxa	$\bar{d}$
Feb 1982*	32	3.08	32	2.67	25	2.20
May 1982	27	2.38	24	2.27	28	2.25
Aug 1982	45	2.58	46	2.81	38	2.22
Nov 1982	24	1.63	34	1.79	34	2.18

* February 1982 samples were collected at River Mile 480.8.

Table 3-13. Similarity of Zooplankton Community Composition/Structure During Operational Monitoring in 1982 Based on Sorensen's Quotient of Similarity and Percentage Similarity, Sequoyah Nuclear Plant, Chickamauga Reservoir

Date	Station Comparision*	Sorensen's Quotient of Similarity (%)	Percentage Similarity (%)
Feb 1982	TRM 490.5-483.4	63	73
	TRM 490.5-480.8	67	72
	TRM 483.8-480.8	72	74
May 1982	TRM 490.5-483.4	81	58
	TRM 490.5-478.2	80	53
	TRM 483.4-478.2	82	78
Aug 1982	TRM 490.5-483.4	81	67
	TRM 490.5-478.2	77	45
	TRM 483.4-478.2	86	44
Nov 1982	TRM 490.5-483.4	71	70
	TRM 490.5-478.2	66	72
	TRM 483.4-478.2	76	90

*Tennessee River Mile (TRM) 490.5 = station 1.
Tennessee River Mile 483.4 = station 2.
Tennessee River Mile 480.8 (February only) and 478.2 = station 3.

Table 3-14. Summary of Zooplankton Data Collected during Operational Monitoring Periods (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

Date	Tennessee River Mile	Rep No.	Group	No./m^3	Mean	STD*	CV†
Feb 1982	480.8	1	Total	8194	12821	6542.9	51.03
		2		17447			
		1	Cladocera	2220	2363	201.5	8.53
		2		2505			
		1	Copepoda	2551	6432	5487.9	85.33
		2		10312			
		1	Rotifera	3423	4027	853.5	21.20
		2		4630			
Feb 1982	483.4	1	Total	14652	18702	5727.6	30.63
		2		22752			
		1	Cladocera	3368	4234	1224.0	28.91
		2		5099			
		1	Copepoda	7633	9716	2945.1	30.31
		2		11798			
		1	Rotifera	3651	4753	1558.5	32.79
		2		5855			
Feb 1982	490.5	1	Total	9424	11032	2273.3	20.61
		2		12639			
		1	Cladocera	2859	3163	429.2	13.57
		2		3466			
		1	Copepoda	5271	6219	1340.7	21.56
		2		7167			
		1	Rotifera	1294	1650	503.5	30.51
		2		2006			
May 1982	478.2	1	Total	136188	164493	40029.3	24.33
		2		192798			
		1	Cladocera	27258	27890	893.1	3.20

Table 3-14. (Continued).

Date	Tennessee River Mile	Rep No.	Group	No./m^3	Mean	STD*	CV†
		2		28521			
		1	Copepoda	22847	24042	1690.0	7.03
		2		25237			
		1	Rotifera	86083	112562	37446.3	33.27
		2		139040			
May 1982	483.4	1	Total	202659	212047	13275.9	6.26
		2		221434			
		1	Cladocera	59039	51440	10747.3	20.89
		2		43840			
		1	Copepoda	39220	36712	3546.8	9.66
		2		34204			
		1	Rotifera	104400	123895	27570.1	22.25
		2		143390			
May 1982	490.5	1	Total	339016	399807	85971.5	21.50
		2		460598			
		1	Cladocera	41934	48240	8918.0	18.49
		2		54546			
		1	Copepoda	29052	28452	848.5	2.98
		2		27852			
		1	Rotifera	268030	323115	77902.0	24.11
		2		378200			
Aug 1982	478.2	1	Total	112916	124315	16120.6	12.97
		2		135714			
		1	Cladocera	44595	48542	5581.9	11.50
		2		52489			
		1	Copepoda	16553	17030	674.6	3.96
		2		17507			
		1	Rotifera	51768	58743	9864.1	16.79
		2		65718			

Table 3-14. (Continued).

Date	Tennessee River Mile	Rep No.	Group	No./m^3	Mean	STD*	CV†
Aug 1982	483.4	1	Total	33695	39169	7741.4	19.76
		2		44643			
		1	Cladocera	7647	8532	1250.9	14.66
		2		9416			
		1	Copepoda	7794	8356	794.1	9.50
		2		8917			
		1	Rotifera	18254	22282	5696.5	25.57
		2		26310			
Aug 1982	490.5	1	Total	31260	37066	8210.2	22.15
		2		42871			
		1	Cladocera	15894	19005	4398.9	23.15
		2		22115			
		1	Copepoda	4261	5352	1542.9	28.83
		2		6443			
		1	Rotifera	11105	12709	2268.4	17.85
		2		14313			
Nov 1982	478.2	1‡	Total	5819			
		1	Cladocera	3677			
		1	Rotifera	1200			
Nov 1982	483.4	1	Total	8501	6826	2368.8	34.70
		2		5151			
		1	Cladocera	5135	4189	1338.6	31.96
		2		3242			
		1	Copepoda	1512	1152	509.8	44.27
		2		791			
		1	Rotifera	1854	1486	520.4	35.02
		2		1118			

Table 3-14. (Continued).

Date	Tennessee River Mile	Rep No.	Group	No./m^3	Mean	STD*	CV†
Nov 1982	490.5	1	Total	2995	3967	1373.9	34.64
		2		4938			
		1	Cladocera	1591	2138	773.6	36.18
		2		2685			
		1	Copepoda	372	444	101.1	22.80
		2		515			
		1	Rotifera	1032	1385	499.2	36.04
		2		1738			

*Standard Deviation.

†Coefficient of Variation.

‡Replicate sample not available.

Table 3-15. Results of One-Way-Analysis of Variance and Student, Newman, Keuls Multiple Range Test on Zooplankton Data for Operational Monitoring in 1982, Sequoyah Nucler Plant, Chickamauga Reservoir

Date	Test Group	F Ratio	P>F	SNK*		
				Low $\bar{x}$		High $\bar{x}$
Feb 1982	Total zooplankton	1.06	0.4477	490.5	480.8	483.4
	Cladocera	4.26	0.1327	480.8	490.5	483.4
	Copepoda	0.54	0.6320	480.8	490.5	483.4
	Rotifera	7.71	0.0657	490.5	480.8	483.4
May 1982	Total zooplankton	11.28	0.0402†	478.2	483.4	490.5
	Cladocera	8.22	0.0606	478.2	490.5	483.4
	Copepoda	17.82	0.0216†	478.2	490.5	483.4
	Rotifera	9.21	0.0524	478.2	483.4	490.5
Aug 1982	Total zooplankton	26.65	0.0123†	490.5	483.4	478.2
	Cladocera	50.93	0.0048†	483.4	490.5	478.2
	Copepoda	21.99	0.0161†	490.5	483.4	478.2
	Rotifera	28.32	0.0113†	490.5	483.4	478.2
Nov 1982‡	Total zooplankton	1.24	0.4462	490.5		483.4
	Cladocera	2.09	0.3237	490.5		483.4
	Copepoda	3.48	0.2232	490.5		483.4
	Rotifera	0.08	0.9221	490.5		483.4

*Student, Newman, Keuls Multiple Range Test; means ranked lowest to highest using Tennessee River Mile (TRM) to identify stations; means underscored by same line are not significantly different at $\alpha = 0.05$, means not so underscored are significantly different.

†Significant at $\alpha = 0.05$.

‡Data for TRM 478.2 not included in statistical tests of significance for November.

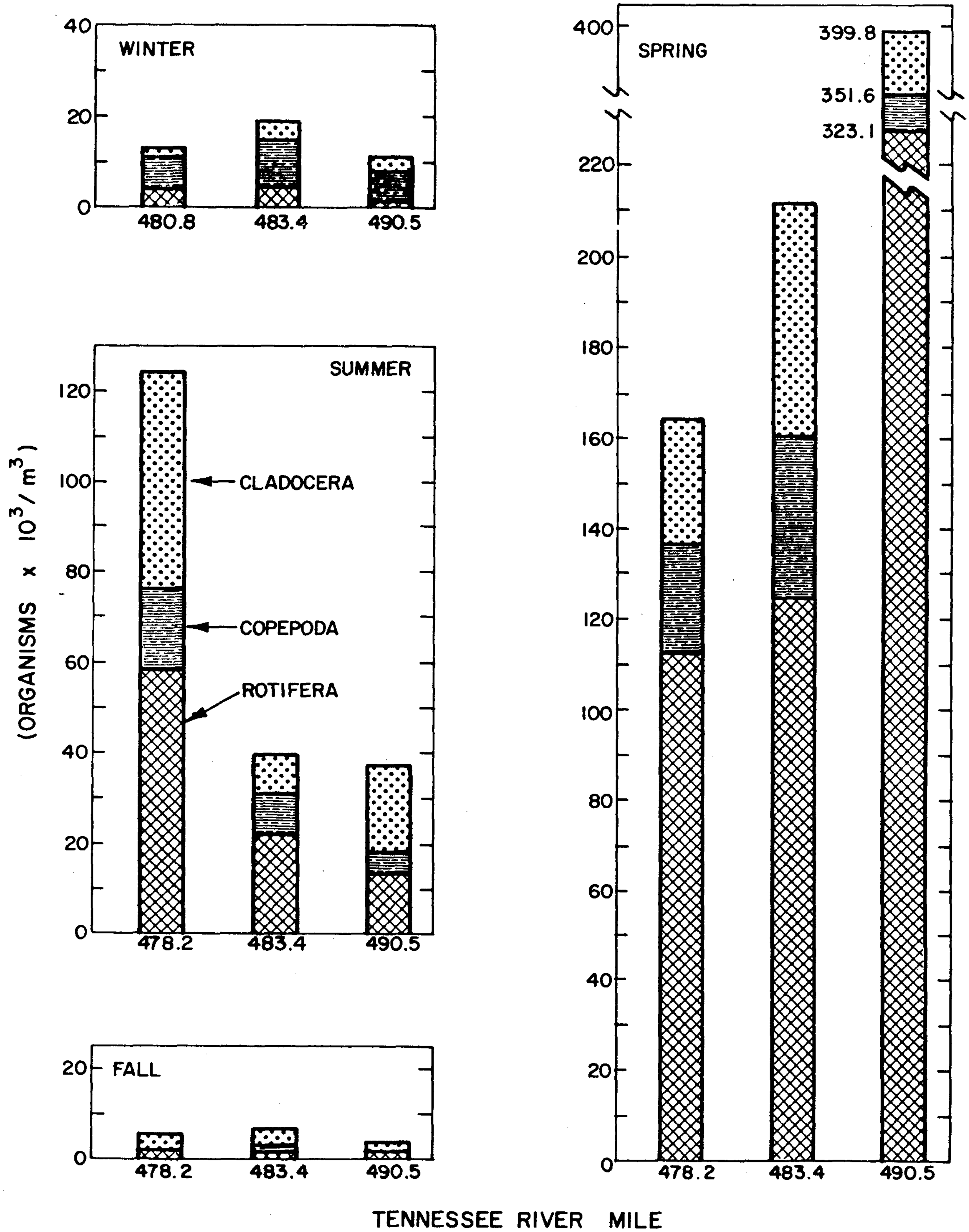

Figure 3-5. Mean Concentrations of Zooplankton During Each Quarter of Operational Monitoring 1982, Sequoyah Nuclear Plant, Chickamauga Reservoir.

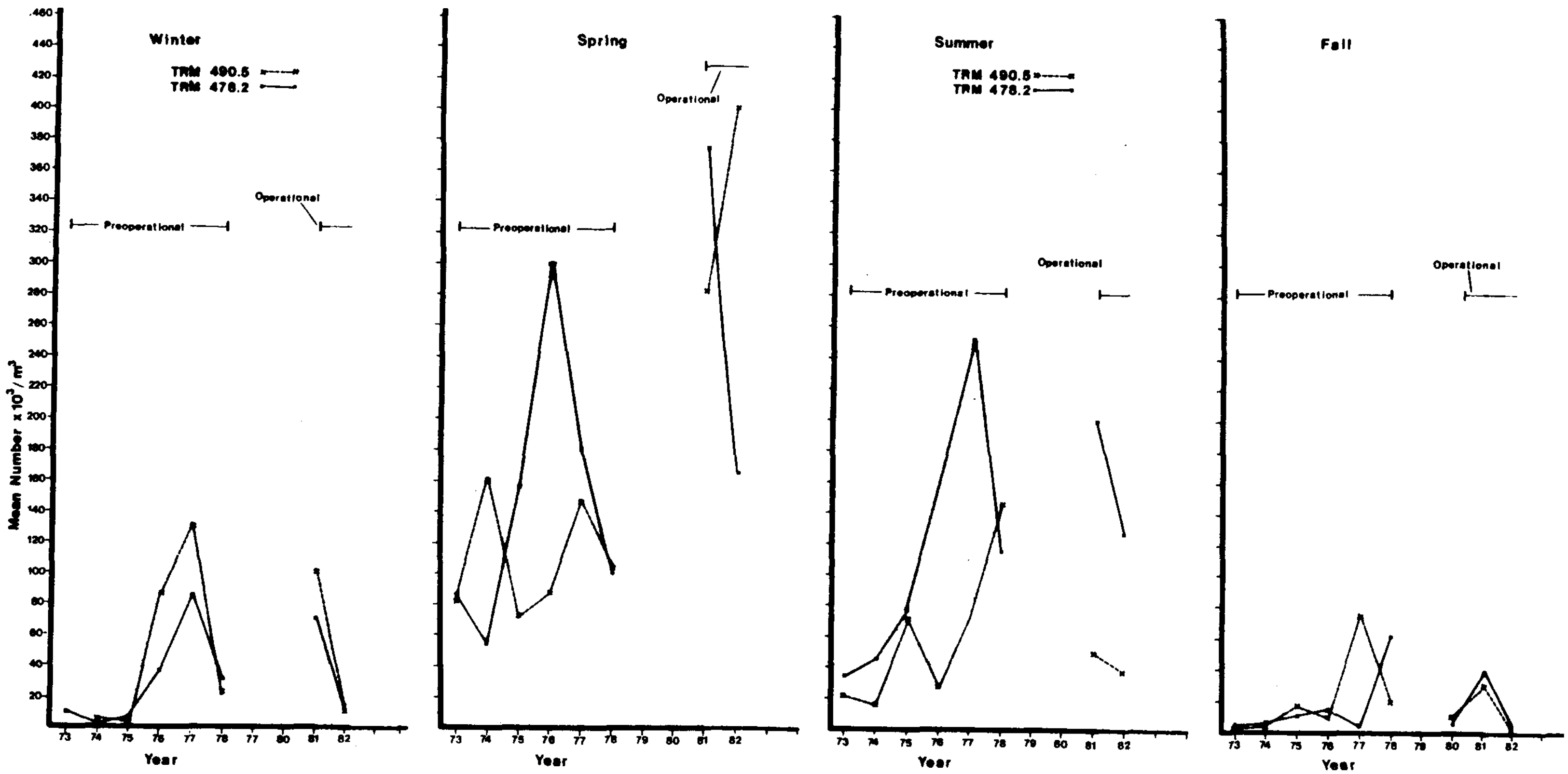

Figure 3-6. Comparisons of Zooplankton Densities at Selected Stations During Preoperational and Operational Monitoring, Sequoyah Nuclear Plant, Chickamauga Reservoir.

4.0 BENTHIC MACROINVERTEBRATES

Several characteristics of the benthic macroinvertebrate community make this group of organisms a valuable tool for evaluating power plant effects. First, many species are sensitive to pollution and respond quickly to it. Second, many have a relatively long and usually complex life cycle of a year or more, and their presence or absence helps describe environmental conditions over a period of time. Third, because many have an attached, or sessile, mode of life and are not subject to rapid migrations, they reflect exposure history and serve as natural monitors of environmental conditions.

In addition to responding to unnatural environmental factors (e.g., a power plant effluent), macroinvertebrate species composition and population levels also respond readily to naturally occurring factors such as availability of food, nature of benthic sediments, current flow, and reproductive success (Cummings, 1975). Reproductive success of many members of the benthic community (insects including *Hexagenia* and chironomid taxa) depends, in part, on factors outside the aquatic environment, as these organisms spend the adult phase of their life cycle in a terrestrial environment, returning to the water only after mating to deposit their eggs before death. Other organisms such as Oligochaeta (aquatic worms), Gastropoda (snails), and Pelecypoda (bivalve mollusks) never leave the aquatic environment.

Even though the aquatic environment is relatively stable, changes in any one or a combination of the above factors can result in large changes in population levels. Therefore, abundance data over a period of time would be cyclic rather than linear under natural conditions (Clark et al., 1967). Environmental intrusion from SQN would appear as interruptions in the "normal" pattern and is best interpreted relative to a control station.

4.1 Community Studies

4.1.1 Materials and Methods

Field--Benthic fauna samples were collected quarterly from February 1982 through November 1982 in the vicinity of SQN at TRM's 490.5 (station 1, upstream control), 483.4 (station 2, downstream), and 478.2 (station 3, downstream). February samples were collected at TRM 480.8 instead of TRM 478.2. Samples were taken in midchannel at TRM's 478.2 and 490.5 and along the right descending channel margin at TRM 483.4 (midchannel is bedrock and unsuitable for sampling). Ten Ponar grab samples were collected at each station. Samples were washed over a standard No. 30-mesh (589 μm opening) brass screen to remove clay, silt, and fine sand particles. Residue was placed in plastic bags, tagged, preserved with 70 percent alcohol and returned to the laboratory for processing. A single sediment sample was collected with each set of macroinvertebrate samples to characterize substrate composition.

Laboratory--Macroinvertebrate samples were rewashed with water over a standard No. 30-mesh screen, placed in white enamel trays, separated from remaining detrital material, transferred into vials using forceps, and preserved with a solution of 70 percent ethyl alcohol and 5 percent glycerine. Macroinvertebrates were classified to the lowest taxonomic classification practicable and enumerated. References used in identification include: Berner (1950), Brinkhurst and Jamieson (1971), Burks (1953), Cook (1956), Curry (1961), Davies (1971), Johannsen (1934-1937), Mason (1968), Needham and Westfall (1955), Needham et al. (1935), Pennak (1953), Robak (1963), Ross (1944), Usinger (1971), Walker (1953, 1958), and Ward and Whipple (1959). Sediment samples were processed through a series of sieves to determine percent composition of silt and sand particles.

Data Analyses--Enumeration data were converted to number of organisms per square meter. Spatial and temporal comparisons were made for total macroinvertebrates and dominant taxa (*Hexagenia* and *Corbicula manilensis*) and/or taxonomic units (Oligochaeta and Chironomidae).

Spatial comparisons utilized Sorensen's Quotient of Similarity (SQS) as described by McCain (1975) and Percentage Similarity (PS) as described by Pielou (1975) to evaluate differences between stations based on community structure. Diversity indices ($\bar{d}$) (Patten, 1962) and equitability values (e) (Weber, 1973) were calculated to determine community diversity at each station. A one-way analysis of variance (ANOVA) and Student-Newman-Kuels multiple range text (Sokal and Rohlf, 1969) were used to aid in evaluating station differences seasonally using transformed ($\log_{10}$) total macroinvertebrate densities (number/m^2).

Temporal comparisons over the entire period of monitoring (1971-1979, preoperational; 1981-1982, operational) were made for each season. Densities (number/m^2) of *Hexagenia*, *Corbicula manilensis*, Oligochaeta, Chironomidae, and total macroinvertebrates, using transformed ($\log_{10}$) data, were evaluated over time in a one-way ANOVA and Duncan's New Multiple Range Test modified for unbalanced sample design (Steel and Torrie, 1960). An unbalanced design was required because sample replication from spring 1971 through winter 1976 was less than 10 (usually 3). Graphical comparisons of upstream (control) and downstream (experimental) stations were made over time for total and dominant group densities. Data also were analyzed to detect any changes in taxa occurring downstream of SQN.

4.1.2 Results and Discussion

Spatial Comparisons--These data are discussed separately by season for the 1982 monitoring period. To avoid repeated reference of tables and appendices which summarize and present data for all seasons, the following list is provided.

Macrobenthic data by station and season	Table 4-1, Appendix K
Community similarity Sorensen's Quotient (SQS) and Percent Similarity (PS)	Table 4-2
Community Diversity Diversity ($\bar{d}$) and Equitability (e)	Table 4-3
Station comparisons of organism abundance - ANOVA and SNK	Table 4-4
Sediment composition	Table 4-5

February 1982--SQS, a qualitative estimate of community similarity which does not consider distribution of organisms among taxa, shows stations 1 (control) and 2 (immediately downstream of SQN) were most similar (81.8 percent similar), each having 11 taxa with 9 taxa in common. Community composition was similar between stations 1 and 3 (78.3 percent) and 2 and 3 (78.3 percent), based upon a numerical value of less than 70 being dissimilar.

While the taxonomic assemblage of macroinvertebrates was similar at all stations, PS, which considers organism abundance as well as presence and absence of taxa, shows only stations 1 and 3 (67.5 percent) approached the 70 percent criterion for similarity. Station 2, located immediately downstream of SQN, was very dissimilar to both stations 1 (51.8 percent) and 3 (46.2 percent). This dissimilarity was attributed primarily to Corbicula manilensis which was very abundant at station 2 (416 per m^2) relative to stations 1 (175 per m^2) and 3 (94 per m^2). Sediment composition at station 2 was different from the control station, with more sand and less silt and clay. Habitat differences (i.e., substrate and location) likely account for the dissimilarity of station 2 (located at the channel-overbank margin rather than in mid-channel). Sample depth at station 2 was only 4.0 m, compared to 9.5 m and 13.5 m at stations 1 and 3, respectively.

The population of Hexagenia at station 2 (2 per m^2) was small relative to stations 1 (22 per m^2) and 3 (67 per m^2). Again, habitat differences likely explain this dissimilarity, since a greater sand fraction at station 2 (39.5 percent) compared to station 1 (18.8 percent) and the shallow location (overbank-channel margin) of station 2 with greater potential for substrate scouring (see section 2.1) select against Hexagenia. Historically (1971-1981) Hexagenia has infrequently occurred at station 2, being present in only 58 of 218 samples. Swanson (1967) showed Hexagenia nymphs are unable to burrow into hard substrates produced by constant eroding effects of river currents or where current velocities were sufficient to produce shifting sand. He also found naiadal abundance decreased with increase in percentage of sand. Preferred habitat for Hexagenia is soft flocculent silt and detritus (Hudson and Swanson, 1972) that occurs in areas with low flow velocities.

In February, the farthest downstream station (TRM 480.8) contained the greatest abundance of Hexagenia, and the greatest amount of sand (54.4 percent). TRM 480.8 was sampled only during this sample period and only a single sediment sample was collected. As such, insufficient data are available to further evaluate occurrence of Hexagenia and sand at TRM 480.8.

The relationship between substrate type (percentage silt) and Hexagenia abundance based on 1982 data is shown in figure 4-1. Hexagenia densities in February at TRM 480.8 were obviously controlled by factors apart from substrate composition (percentage of silt).

Diversity index ($\bar{d}$) values relate organism distribution among species represented in a sample. Equitability (e) compares this distribution with one frequently observed in nature--one with several relatively abundant species and increasing numbers of species represented by only a few individuals (MacArthur, 1957). While $\bar{d}$ lacks sensitivity to distinguish slight to moderate levels of community degradation, equitability (e) is sensitive to even slight levels of degradation which generally reduce values below 0.5 (Weber, 1973). Lowest diversity (1.94) and equitability (0.45) occurred at station 2. Equitability at station 2 was considerably lower than at stations 1 (0.82) and 3 (0.75), indicating community stress. As discussed above, causative factors such as substrate scouring and/or texture are suspected rather than operation of SQN. SQN-induced impacts were not expected because combined unit operation during February was only 11 percent capacity. Temperature (5.3^{o} C) and dissolved oxygen (14.3 mg/ℓ) at station 2 were similar to other stations on the day of sampling (see appendix C).

Although total macroinvertebrate mean density at station 2 (754 organisms per m^2) was almost double that at stations 1 (417 per m^2) and 3 (413 per m^2), the ANOVA and SNK did not detect statistical differences among stations. Statistical significance was probably precluded by large variability at station 2 (range = 126-1800 total organisms per m^2), primarily caused by Corbicula manilensis (range = 54-1278 per m^2) (see appendix K).

Oligochaete densities at station 2 were greater than at stations 1 and 3 while chironomid and *Hexagenia* densities at station 2 were less than at stations 1 and 3. Total and group densities appeared similar between stations 1 and 3 (figure 4-2), while *Corbicula manilensis* was most abundant at station 2. As explained above, all differences at station 2 probably resulted from habitat difference rather than operation of SQN.

May 1982--Station similarity based upon taxonomic occurrence (SQS) was less pronounced than in February. Only stations 1 and 3 were similar (75.0 percent), even though station 1 had 9 taxa and station 3 (TRM 478.2) had 15. Stations 2 (14 taxa) and 3 (15 taxa), which had a combined total of 20 taxa, were dissimilar because of the relatively small (9) number of taxa in common.

PS shows all stations were dissimilar with station 2 very different from stations 1 (33.5 percent) and 3 (37.3 percent). As in February greater abundance of *Corbicula manilensis* (286 per m^2) at station 2 accounted for much of the dissimilarity. *Hexagenia* densities (2 per m^2) were also small at station 2 compared to stations 1 (94 per m^2) and 3 (56 per m^2).

Station 2 had the lowest diversity (2.09) and equitability (0.36), indicating community stress. Sample location in May was in the channel (17 m deep) as opposed to the channel overbank margin sampled in February (4.0 m) and contained an even greater amount of sand (95.7 percent). While location and substrate likely account for much of the difference at station 2 (see discussion for February), effects from SQN, which operated at 72 and 67 percent capacity during April and May, cannot be ruled out. Bottom temperature at station 2 on the day of sampling was 3.7° C higher than at the control station. However, maximum temperature measured downstream of SQN on that day (May 5) reached 21.2° C (station 3, surface), and was not high enough to cause degradation of the macroinvertebrate community (TVA, 1982b). Even though the equitability value at station 2 indicates poor distribution of organisms among taxa, it should be noted that total number of taxa (15) collected at this station was greater than number of taxa (9) collected at the control station. Diversity and equitability at stations 1 and 3 did not indicate any stressed communities (i.e., diversity >2.50, equitability >0.50).

Macroinvertebrate densities were significantly greater downstream of SQN at stations 2 (519 per m^2) and 3 (621 per m^2) than at the upstream control (247 per m^2) ($P>F = 0.0001$). This difference was caused primarily by abundance of Corbicula and Oligochaeta at station 2 and Oligochaeta at station 3 (figure 4-2). Sampling error during May at station 2 (CV = 21.5 percent) was much improved over corresponding February data (CV = 68.3 percent).

August 1982--Number of macroinvertebrate taxa downstream of SQN was lower during August than in preceeding months, especially immediately downstream of the CCW diffuser (station 2) where only 5 taxa occurred (compared to 11 and 14 taxa in February and May, respectively). SQS values were low (less than 70 percent) for all station comparisons with the greatest dissimilarity (40.0 percent) occurring between stations 1 (control) and 2. Taxa which were noticeably missing (i.e., abundant in February and May, but absent in August) at station 2 included Branchiura sowerbyi and Coelotanypus.

Stations were very different based on PS coefficients especially stations 1 and 2 (7.4 percent similarity). A comparison of macroinvertebrate densities for each taxon at these two stations (table 4-1) shows station 2 had greater densities of *Chironomus* and *Corbicula manilensis* and relatively fewer *Ablabesmyia*, *Hexagenia*, and Tubificidae (Oligochaeta). *Branchiura sowerbyi*, the other oligochete taxon, was conspicuously absent at station 2 during August. Low similarity between stations 2 and 3 is attributed primarily to large numbers of *Chironomus* at station 2 and large numbers of *Ablabesmyia*, *Coelotanypus*, *Corbicula manilensis*, *Hexagenia*, and Tubificidae at station 3.

Diversity ($\bar{d}$) was low at station 2 (1.32) because of the relatively greater abundance of *Chironomus* and the small number of taxa encountered. Equitability was uniformly high at all stations, ranging from 0.60 at stations 1 and 2 to 0.78 at station 3. Equitability at station 2 should be interpreted cautiously in light of other community parameters (SQS, PS, and $\bar{d}$), all of which indicate an abnormally reduced macroinvertebrate community.

Total macroinvertebrate abundance at station 2 (106 per m^2) was significantly ($P>F = 0.0018$) less than at other stations, with station 3 having the greatest number of organisms (229 per m^2). Densities of station 1 (188 per m^2) and station 3 were not significantly different. Macroinvertebrate abundance is normally lowest during summer because emerging adult insects leave the aquatic environment; however, reductions at station 2 were abnormally low, especially among taxa which do not leave the aquatic environment (i.e., *Corbicula manilensis*, *Branchiura sowerbyi*, and Tubificidae). The only taxon showing an increase at station 2 was Chironomidae (figure 4-2) which was represented only by the genus *Chironomus*. Data from other TVA studies (e.g., Wade, et al., 1983) and attempts by TVA biologists to collect *Chironomus* for thermal research have shown this genus to be absent or rare during summer in TVA mainstream reservoirs. Therefore, increase of Chironomus at station 2 in August is anomalous and it appears that the life cycle was altered in view of the typical decline which occurred at stations 1 and 3.

Comparisons of diversity, community similarity, and abundance indicate that a disproportionate change in the macroinvertebrate community occurred at station 2. Substrate texture at this station was more comparable to other stations (i.e., contained more silt and less sand) and should have increased similarity of macroinvertebrate communities than during February and May surveys. Such was not the case. Other factors such as insect emergence or sample location and substrate scouring such as observed in February and May, are not sufficient to explain reductions in abundance and taxa which occurred during August. Bottom temperatures recorded the day of macroinvertebrate sampling (appendix C) downstream of SQN were only slightly (less than 1.0° C) higher than at the control station. While those temperatures are not sufficient to cause the observed reductions, neither do they represent total exposure for the macroinvertebrate community because they are only instantaneous temperatures. Operational data (table 2-3) show SQN operated at 83, 97, and 96 percent total capacity during June, July and August and may have had a greater effect than that measured on the day of sampling (August 5), especially in light of the cooling episode which occurred 3-5 days before sampling (see section 2.2.2 discussion of August conditions).

November 1982--Macroinvertebrate communities at stations 1 and 3 were very similar (SQS = 87.5 percent), sharing 7 of the 9 taxa collected at both stations. Station 2 was different (SQS = 33.3 percent) from other stations, sharing only 3 of 15 taxa with stations 1 and 3. Organisms which were abundant at both stations 1 and 3, but entirely missing at station 2 included Ablabesmyia, Chaoborus, Coelotanypus, Hexagenia, and Tubificidae. Occurrence of these organisms in view of those found only at station 2 (Chironomus, Cryptochironomus, Procladius, Cyrnellus fraternus, Hyalella azteca, and Oecetis) indicate major habitat differences. As in February, station location (mid-channel versus overbank-channel margin) and substrate (relative amounts of sand and silt) appear to have influenced macroinvertebrate distribution more than SQN, which operated at 57, 45, and 20 percent capacity during September, October, and November.

Community differences between stations 1 and 3 (PS = 60.2 percent) primarily resulted from greater densities of Chaoborus, Coelotanypus, and Hexagenia at station 3 than at station 1. Similarities between stations 2 and 1 (PS = 14.0 percent) and 2 and 3 (PS = 7.8 percent) were again (as in August) very low.

Diversity ($\bar{d}$) and equitability at stations 1 and 3 were similar both to each other and to corresponding values for other seasons. Both parameters were uncharacteristically high at station 2 ($\bar{d}$ = 2.82, e = 1.00) compared to values from this station in other seasons. Even though number of taxa (10) at station 2 during November was much improved over the summer low of 5 taxa, high diversity values should not be interpreted to indicate a productive or recovered macroinvertebrate community, especially since total organism abundance was only 50 per m^2. Weber (1973) cautions against interpreting indicators of diversity when specimen abundance is less than 100.

Total macroinvertebrate abundance was significantly (P>F = 0.0001) different at all stations, ranging from 503 organisms per m^2 at station 3 to 50 per m^2 at station 2. The disproportionately low number of specimens collected at station 2 (figure 4-2) may indicate a community with little resilience and thereby reflect continuation of the decline which became especially noticeable during August.

Yearly trends during 1982 showed that macroinvertebrate densities at stations 1 and 3 declined in August to 188 and 229 organisms per m^2, respectively. The summer decrease followed by relatively larger densities in the fall (figure 4-3) reflect naturally occurring loss of organisms due to emergence of adult insects from the aquatic environment and subsequent recruitment from successful reproduction. Although station 2 exhibited the largest density of macroinvertebrates measured during the study (754 per m^2 in February), number of specimens collected declined sharply in August and, unlike other stations, continued to decline in to the fall (50 per m^2).

A total of 27 taxa was collected during 1982. Only 2 taxa (*Bezzia* and *Orthotrichia*) occurred exclusively upstream of SQN, while 10 taxa occurred exclusively downstream (table 4-6). A similar trend attributed to greater downstream sampling effort and substrate variety was noted during 1981.

Temporal Comparisons--Temporal data for the entire period of monitoring are presented seasonally in appendices L, M, N, O, and P as individual sample values for *Hexagenia*, Chironomidae, Oligochaeta, *Corbicula manilensis* and total macroinvertebrates, respectively, and in appendix Q as mean values for each sampling station and date. Data for *Corbicula manilensis* and total macroinvertebrates are not reported for 1981 because *C. manilensis* was discarded in the field without being enumerated, which also affected community totals. Mean values for each station were plotted for all years and are shown in figures 4-4, 4-5, 4-6, and 4-7 for winter, spring, summer, and fall quarters, respectively. Trends for each dominant taxon or taxonomic group of macroinvertebrates for the entire monitoring period (illustrated in figures 4-4 through 4-7) are statistically evaluated in table 4-7. A discussion of these data follows for each quarter, allowing a more complete evaluation of 1982 spatial observations in light of historical trends.

Winter--Macroinvertebrate densities were highly variable over the monitoring period (1972-1982) as winter mean densities were significantly different ($P>F = 0.0001$) among years for every comparison except Corbicula manilensis at TRM 490.5. These differences approximated normal cyclic abundance patterns expected in an aquatic ecosystem (see introduction). Low density of Hexagenia reported at TRM 483.4 in 1982 was not uncommon and was similar ($\alpha = 0.05$) to densities measured at that station in 1972, 1973, and 1981. In 1982 Oligochaeta (TRM 478.2) and C. manilensis (TRMs 490.5 and 483.4) were more abundant than in any other year, although these densities were not significantly different from other preoperational and/or operational years. Although chironomids during 1982 were reported to be less abundant at station 2 (TRM 483.4) than at other stations, they were significantly more abundant at station 2 than other (preoperational) years (i.e., 1978, 1977, 1973, and 1976).

Spring--Spring macroinvertebrate densities were comparable to those of winter in that variability among years was highly significant and followed a cyclic pattern. In 1982, Oligochaeta (stations 2 and 3), C. manilensis (station 2), and total macroinvertebrates (station 2) were more abundant than in any other year, but not significantly different from several preoperational years. In 1982, Hexagenia at station 2 was significantly less abundant than in 1972 and 1976, but similar to all other years. In summary, while some macroinvertebrate densities measured during SQN operation in spring 1982 were the highest measured during the monitoring period, or, in the case of Hexagenia (station 2), in the low range of abundance, these values were not significantly different from other spring densities measured during preoperational monitoring. Thus during this season, it cannot be shown that operation of SQN had any adverse impacts upon macroinvertebrate abundance.

Summer--Macroinvertebrate variability among years during the summer season was highly significant ($\alpha = 0.01$) except for C. manilensis and total macroinvertebrates at station 2, where no significant differences were documented. Summer Hexagenia abundance at station 2 was very low (range = 0-50/m^2) during the entire period of monitoring (1971-1982); no Hexagenia were encountered at this station in 1982, 1978, 1975, 1974, 1973, and 1972. Although station 2 had the lowest summer macroinvertebrate abundance in 1982 compared to other stations, this station was not significantly different from other years.

Fall--Except for total macroinvertebrates at station 3, variability among years was highly significant with maximum abundance generally occurring in 1973 and 1974, followed by a cyclic decline. Smallest total number of organisms measured during the entire monitoring period occurred in 1982 at station 2; however, this density (50 per m^2) was not significantly different from preoperational densities reported at this station (i.e., in 1978 and 1976). Total macroinvertebrate abundance at station 2 has always (1971-1982) been less than reported for other stations, therefore, substrate and habitat differences rather than operation of SQN appear to be major contributing factors. A general decline in abundance at this station has been paralled by a similar decline in abundance at the other two stations since 1975.

Taxonomic comparisons of preoperational and operational macroinvertebrate communities are shown in tables 4-8 and 4-9 for reservoir areas upstream (TRM 490.5) and downstream (TRM's 483.4 and 478.2, combined) of SQN, respectively. Total number of taxa, both upstream and downstream of SQN, has decreased during operational monitoring. This decline was noted in the first SQN operational report and is still believed to have resulted from a smaller sampling effort in the two years of operational monitoring compared to eight years of preoperational sampling. None of the taxa identified as absent in the first operational report (i.e., Crangonyx, Argia, Stenacron, Neureclipsis, Nyctiophylax, Hydrobia, Paragordius, and Cura) were collected during the 1982 study. Three taxa were collected for the first time during 1982, these being the snail Physa, the caddisfly Orthotrichia, and a leech in the family Erpobdellidae. As in preoperational monitoring and the first year of operational monitoring, number of taxa collected downstream of SQN in 1982 (24 taxa) was greater than upstream (16 taxa). This is still believed to have resulted from additional sampling effort (2 stations vs. 1 station) and greater habitat diversity downstream of SQN. Comparisons on a station-to-station basis were more similar; 18 taxa were collected from each of stations 3 and 2 and 16 taxa were collected from station 1. Taxa collected downstream of SQN during both preoperational and the first year of operational monitoring, but not found in 1982, include two chironomid taxa (Epiococladius and Polypedelium), the biting midge Culicoides, Nemata, the megalopteran Sialis, and the snail Amnicola. Of these, only Amnicola has occurred in relatively high numbers (range = 5-78 organisms per m^2) prior to 1982. This snail has previously been collected only at station 2 immediately downstream of SQN, occurring in quarters 2 and 3 of 1978 and quarters 1 and 2 of 1981. Its absence during 1982 could represent a SQN-induced impact; however, at this point sampling phenomena seem more plausible because of *Amnicola*'s low (4 out of a possible 35 quarters) frequency of occurrence.

4.1.3 Summary and Conclusions

In 1982, seasonal comparisons based upon macroinvertebrate diversity, community similarity, and abundance indicate that station 2 (TRM 483.4), located immediately downstream of SQN, was very different from other stations. Community similarity between station 2 and other stations began to change in May. This change was followed by a very reduced fauna (composed of only 5 taxa) at station 2 in August and significantly fewer organisms than other stations. An even smaller number of specimens was collected at this station in November (although number of taxa increased). These changes indicate that an abnormal macroinvertebrate community for Chickamauga Reservoir existed at station 2. Based upon 1982 data, close proximity of this station to SQN and the simultaneous occurrence of macroinvertebrate community reductions with increased plant load (spring and summer) make SQN a likely contributing factor.

Compared to other years (1971-1981), however, densities of macroinvertebrates at station 2 were neither significantly greater nor less than those observed during preoperational monitoring, indicating that factors other than operation of SQN may be responsible for observed differences. This station is atypical in its location at the channel-overbank margin (rather than mid-channel), making it subject to greater scouring from reservoir currents. Bottom substate at this station is also atypically composed of greater quantities of sand than at other stations. Sampling at station 2 has yielded inconsistent macroinvertebrate data because of the rapidly changing habitats in the transition from overbank to channel, as is evidenced by variability within sediment data collected simultaneously with macroinvertebrate sampling, and the variety of depths sampled at this station in 1982, ranging from 4 to 17 meters. Because factors such as station location, depth, and substrate have a high potential for affecting results, this study is inconclusive regarding impacts of SQN. It is therefore recommended that investigations to establish an additional sampling station be continued to locate a habitat similar to the control station within the nearfield area.

Table 4-1. Mean Benthic Densities (No./m^2) at Each Sample Station During Operational Monitoring (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

Taxa	Feb. 1982			May 1982			Aug. 1982			Nov. 1982		
	Tennessee River Mile											
	480.8	483.4	490.5	478.2	483.4	490.5	478.2	483.4	490.5	478.2	483.4	490.5
Ablabesmyia sp.	13	0	9	5	0	2	16	0	22	32	0	13
Bezzia sp.	0	0	0	0	0	0	0	0	5	0	0	0
Branchiura sowerbyi	25	95	27	16	70	5	0	0	9	0	0	11
Campeloma sp.	0	0	0	5	0	0	0	0	0	0	0	0
Chaoborus sp.	11	4	27	18	2	0	5	2	0	77	0	9
Chironomidae	0	0	0	0	0	0	0	0	0	0	2	0
Chironomus sp.	2	9	25	31	22	14	0	72	2	0	9	0
Coelotanypus sp.	74	20	59	88	0	58	23	0	9	137	4	70
Corbicula manilensis	94	416	175	76	286	61	99	23	2	86	16	106
Crangonyx sp.	0	0	0	0	2	0	0	0	0	0	0	0
Cryptochironomus sp.	2	7	0	0	2	0	0	0	0	0	2	0
Cyrnellus fraternus	0	0	0	0	0	0	2	2	0	0	4	0
Dicrotendipes sp.	2	0	0	0	2	0	0	0	0	0	0	0
Dugesia tigrina	0	0	0	0	9	0	0	0	0	0	0	0
Epoicocladius sp.	0	0	0	0	0	0	2	0	2	0	0	0
Erpobdellidae	0	0	0	2	0	0	0	0	0	0	0	0
Hexagenia	67	2	22	94	2	56	22	0	36	149	0	32
Hirudinea	0	4	0	0	0	0	0	0	0	2	0	0
Hyalella azteca	0	2	5	0	2	0	0	0	0	0	2	0
Oecetis sp.	0	0	0	5	4	2	0	0	0	0	2	0
Orthotrichia sp.	0	0	0	0	0	0	0	0	2	0	0	0
Pectinatella magnifica	0	0	0	2	0	0	0	0	0	0	0	0
Physa sp.	0	0	2	0	0	0	4	0	0	0	0	0
Procladius sp.	18	40	23	2	4	9	0	0	0	0	2	0
Sphaerium sp.	5	0	0	9	31	0	0	0	0	2	7	2
Tubificidae	104	155	41	266	81	40	56	7	99	18	0	18
Xenochironomus sp.	0	0	0	2	0	0	0	0	0	0	0	0
Total	417	754	413	621	519	247	229	106	188	503	50	261

Table 4-2. Similarity of Benthic Community Structure During Operational Monitoring Period (1982), Based on Sorensen's Quotient of Similarity and Percent Similarity, Sequoyah Nuclear Plant, Chickamauga Reservoir

Date	Station	NT*	Station Comparison	CS†	NC‡	SQS(%)§	PS¶
Feb 1982	TRM 490.5(1)	11	1-2	13	9	81.82	51.77
	483.4(2)	11	1-3	14	9	78.26	67.55
	480.8(3)	12	2-3	14	9	78.26	46.22
May 1982	TRM 490.5(1)	9	1-2	16	7	60.87	33.49
	483.4(2)	14	1-3	15	9	75.00	55.19
	478.2(3)	15	2-3	20	9	62.07	37.34
Aug 1982	TRM 490.5(1)	10	1-2	12	4	40.00	7.36
	483.4(2)	5	1-3	13	6	63.16	51.08
	478.2(3)	9	2-3	10	3	57.14	20.43
Nov 1982	TRM 490.5(1)	8	1-2	15	3	33.33	13.95
	483.4(2)	10	1-3	9	7	87.50	60.24
	478.2(3)	8	2-3	15	3	33.33	7.82

* Number of taxa present at each station.

† Number of taxa present at combined stations.

‡ Number of taxa in common between two stations being compared.

§ Sorensen's Quotient of Similarity, expressed as a percentage.

¶ Percent similarity.

Table 4-3. Macroinvertebrate Diversity Index ($\bar{d}$) and Equitability (e) Values During Operational Monitoring Periods (1982), Sequoyah Nuclear Plant, Chickamauga Reservoir

	Tennessee River Mile								
	478.2*			483.4			490.5		
Date	No. Taxa	$\bar{d}$	e	No. Taxa	$\bar{d}$	e	No. Taxa	$\bar{d}$	e
Feb 1982	12	2.77	0.75	11	1.94	0.45	11	2.71	0.82
May 1982	15	2.57	0.53	14	2.09	0.36	9	2.54	0.89
Aug 1982	9	2.28	0.78	5	1.32	0.60	10	2.13	0.60
Nov 1982	8	2.37	0.88	10	2.82	1.00	8	2.30	0.88

*February 1982 samples were collected at River Mile 480.8.

Table 4-4. Results of One-Way Analysis of Variance and Student-Newman-Keuls Multiple Range Test on Total Macroinvertebrate Data (Log_{10} Transformed) Collected Near Sequoyah Nuclear Plant, Chickamauga Reservoir, February Through November 1982.

Date	F Ratio	P>F	Grouping*	Mean†	N	Station‡
Feb	1.57	0.2266	A	2.7630	10	2
			A			
			A	2.5978	10	1
			A			
			A	2.5924	10	3
May	18.30	0.0001	A	2.7542	10	3
			A			
			A	2.7038	10	2
			B	2.3718	10	1
Aug	8.06	0.0018	A	2.3148	10	3
			A			
			A	2.2527	10	1
			B	1.9728	10	2
Nov	126.31	0.0001	A	2.6896	10	3
			B	2.3994	10	1
			C	1.6489	10	2

*Means with the same letter are not significantly different ($\alpha = 0.05$).

†Means are $\log_{10}$ transformed.

‡Stations are 1 = TRM 490.6, 2 = TRM 483.4, and 3 = TRM 478.2 except in February when 3 = TRM 480.8.

Table 4-5. Particle Size Analysis of Substrates in the Vicinity of Sequoyah Nuclear Plant for February, May, August, and November 1982

Survey Date	Substrate Characteristics*	TRM 478.2†	TRM 483.4	TRM 490.5
(1982)				
Feb	Depth (m)	13.5	4.0	9.5
	Percent Moisture	37.22	50.72	50.79
	Percent Volatile Solids	5.07	6.58	6.69
	Percent Solids (finer than 2.00 mm)	94.76	99.77	99.90
	Percent Solids (finer than 0.50 mm)	63.85	98.01	99.90
	Percent Solids (finer than 0.125 mm)	47.60	65.34	94.57
	Percent Solids (finer than 0.063 mm)	45.56	60.51	81.20
May	Depth (m)	17.0	17.0	11.0
	Percent Moisture	54.27	18.57	51.67
	Percent Volatile Solids	7.79	1.27	6.28
	Percent Solids (finer than 2.00 mm)	100.00	96.28	100.00
	Percent Solids (finer than 0.50 mm)	99.46	34.99	99.17
	Percent Solids (finer than 0.125 mm)	96.75	5.81	96.17
	Percent Solids (finer than 0.063 mm)	95.12	4.34	83.15
Aug	Depth (m)	15.0	8.0	9.0
	Percent Moisture	49.33	31.28	47.84
	Percent Volatile Solids	7.21	5.15	6.26
	Percent Solids (finer than 2.00 mm)	100.00	100.00	100.00
	Percent Solids (finer than 0.50 mm)	99.90	99.14	100.00
	Percent Solids (finer than 0.125 mm)	92.81	82.14	96.92
	Percent Solids (finer than 0.063 mm)	86.53	74.75	85.65
Nov	Depth (m)	14.0	5.0	10.0
	Percent Moisture	49.97	30.10	45.17
	Percent Volatile Solids	5.36	3.78	6.09
	Percent Solids (finer than 2.00 mm)	100.00	100.00	100.00
	Percent Solids (finer than 0.50 mm)	93.74	99.22	99.91
	Percent Solids (finer than 0.125 mm)	67.42	64.69	94.79
	Percent Solids (finer than 0.063 mm)	66.00	53.50	81.66

*Particle sizes >0.063 mm = sand.
Particle sizes <0.063 mm = S:H.

†Substrate was sampled at TRM 480.8 in February 1982 rather than TRM 478.2.

Table 4-6. Macroinvertebrate Taxa Collected Exclusively Upstream or Downstream of Sequoyah Nuclear Power Plant, During Operational Monitoring, February 1982 Through November 1982

Taxon	Downstream	Upstream*
Bezzia sp.		X
Campeloma sp.	X	
Crangonyx sp.	X	
Cryptochironomus sp.	X	
Cyrnellus fraternus	X	
Dicrotendipes sp.	X	
Dugesia tigrina	X	
Erpobdellidae	X	
Hirudinea	X	
Orthotrichia sp.		X
Pectinatella magnifica	X	
Xenochironomus sp.	X	

* Upstream: River Mile 490.5.
Downstream: River Miles 478.2 and 483.4.
River Mile 480.8 was sampled in February instead of 478.2.

Table 4-7. Macroinvertebrate One-Way Analysis of Variance and Duncan's New Multiple Range Test, Sequoyah Nuclear Plant, Chickamauga Reservoir, 1971 Through 1982

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest								Highest
Winter	490.5	*Hexagenia* (1972-1982)	7.44	0.0001	0.564	1981	1982	1972	1973	1977	1976	1974	1975	1978
	483.4	*Hexagenia* (1972-1982)	3.00	0.0085	0.343	1978	1972	1982	1981	1976	1975	1974	1977	1973
	478.2	*Hexagenia* (1972-1982)	15.86	0.0001	0.734	1976	1973	1978	1972	1974	1975	1982	1981	1977
	490.5	Chironomidae (1972-1982)	8.85	0.0001	0.606	1977	1976	1973	1974	1972	1982	1975	1978	1981
	483.4	Chironomidae (1972-1982)	10.09	0.0001	0.637	1978	1977	1973	1976	1972	1975	1974	1982	1981
	478.2	Chironomidae (1972-1982)	12.68	0.0001	0.688	1978	1982	1977	1976	1972	1981	1973	1975	1974
	490.5	Oligochaeta† (1973-1982)	11.08	0.0001	0.638		1977	1976	1978	1973	1974	1982	1981	1975
	483.4	Oligochaeta† (1973-1982)	16.84	0.0001	0.728		1974	1977	1973	1976	1978	1981	1982	1975

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest							Highest
	478.2	Oligochaeta† (1973-1982)	4.96	0.0003	0.441	1975	1976	1973	1977	1978	1974	1981	1982
	490.5	*Corbicula manilensis*‡ (1972-1982)	1.67	0.1475	0.240	1972	1978	1973	1975	1976	1974	1977	1982
	483.4	*Corbicula manilensis*‡ (1972-1982)	6.25	0.0001	0.542	1973	1978	1972	1977	1976	1974	1975	1982
	478.2	*Corbicula manilensis*‡ (1972-1982)	5.49	0.0002	0.509	1976	1972	1973	1975	1974	1978	1982	1977
	490.5	Total Macroinvertebrates‡ (1972-1982)	6.65	0.0001	0.557	1972	1976	1977	1973	1982	1974	1978	1975
	483.4	Total Macroinvertebrates‡ (1972-1982)	3.85	0.0030	0.422	1978	1973	1972	1976	1977	1974	1982	1975
	478.2	Total Macroinvertebrates‡ (1972-1982)	4.12	0.0019	0.438	1978	1972	1982	1977	1976	1974	1975	1973

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest								Highest
Spring	490.5	*Hexagenia* (1972-1982)	7.27	0.0001	0.523	1975	1976	1982	1974	1981	1972	1977	1978	1973
	483.4	*Hexagenia* (1972-1982)	7.08	0.0001	0.517	1977	1975	1974	1973	1982	1978	1981	1976	1972
	478.2	*Hexagenia* (1972-1982)	3.73	0.0016	0.360	1978	1972	1974	1982	1976	1973	1977	1981	1975
	490.5	Chironomidae (1972-1982)	2.96	0.0147	0.289	1975	1972	1976	1974	1973	1982	1981	1977	1978
	483.4	Chironomidae (1972-1982)	8.50	0.0001	0.562	1978	1975	1973	1974	1977	1976	1982	1972	1981
	478.2	Chironomidae	9.20	0.0001	0.581	1974	1978	1973	1976	1975	1982	1972	1977	1981
	490.5	Oligochaeta (1972-1982)	5.35	0.0001	0.447	1973	1972	1974	1982	1976	1977	1978	1981	1975
	483.4	Oligochaeta (1972-1982)	15.42	0.0001	0.699	1974	1973	1978	1976	1977	1981	1975	1972	1982

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest								Highest
	478.2	Oligochaeta (1972-1982)	6.89	0.0001	0.510	1973	1972	1974	1976	1975	1978	1977	1981	1982
	490.5	*Corbicula manilensis*‡ (1972-1982)	33.66	0.0001	0.843		1977	1972	1975	1982	1973	1976	1974	1978
	483.4	*Corbicula manilensis*‡ (1972-1982)	7.93	0.0001	0.558		1973	1974	1972	1977	1978	1976	1975	1982
	478.2	*Corbicula manilensis*‡ (1972-1982)	13.68	0.0001	0.685		1972	1978	1977	1975	1973	1982	1976	1974
	490.5	Total Macroinvertebrates‡ (1972-1982)	8.56	0.0001	0.577		1975	1982	1974	1976	1972	1977	1973	1978
	483.4	Total Macroinvertebrates‡ (1972-1982)	18.16	0.0001	0.743		1973	1974	1978	1977	1976	1972	1975	1982
	478.2	Total Macroinvertebrates‡ (1972-1982)	8.56	0.0001	0.577		1978	1973	1972	1975	1974	1982	1976	1977

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest									Highest
Summer	490.5	Hexagenia (1971-1982)	7.76	0.0001	0.559	1981	1976	1982	1971	1975	1974	1973	1977	1972	1978
	483.4	Hexagenia (1971-1982)	5.88	0.0001	0.490	1982	1981	1978	1975	1974	1973	1972	1977	1976	1971
	478.2	Hexagenia§ (1971-1982)	8.79	0.0001	0.605		1973	1974	1982	1976	1971	1972	1977	1975	1978
	490.5	Chironomidae (1971-1982)	3.64	0.0013	0.373	1975	1974	1982	1976	1981	1971	1972	1973	1978	1977
	483.4	Chironomidae (1971-1982)	3.44	0.0020	0.360	1981	1976	1978	1977	1973	1982	1974	1971	1975	1972
	478.2	Chironomidae§ (1971-1982)	4.27	0.0007	0.426		1973	1975	1982	1974	1972	1971	1976	1977	1978
	490.5	Oligochaeta (1971-1982)	3.26	0.0031	0.348	1971	1974	1975	1972	1977	1976	1973	1978	1982	1981
	483.4	Oligochaeta (1971-1982)	4.02	0.0006	0.397	1982	1972	1973	1976	1978	1971	1981	1977	1975	1974

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest								Highest
	478.2	Oligochaeta[§] (1971-1982)	3.82	0.0016	0.399	1971	1972	1973	1974	1982	1977	1978	1976	1975
	490.5	*Corbicula manilensis*[‡] (1971-1982)	7.41	0.0001	0.563	1982	1978	1974	1975	1977	1976	1973	1971	1972
	483.4	*Corbicula manilensis*[‡] (1971-1982)	1.85	0.0920	0.243	1982	1972	1978	1973	1977	1976	1974	1975	1971
	478.2	*Corbicula manilensis*[§] (1971-1982)	13.30	0.0001	0.698	1975	1974	1973	1977	1972	1978	1982	1971	1976
	490.5	Total Macroinvertebrates[‡] (1971-1982)	14.60	0.0001	0.717	1975	1976	1974	1971	1982	1973	1978	1972	1977
	483.4	Total Macroinvertebrates[‡]	2.03	0.0630	0.261	1973	1976	1982	1972	1978	1974	1977	1971	1975
	478.2	Total Macroinvertebrates[§] (1971-1982)	3.45	0.0035	0.375	1972	1982	1971	1973	1975	1977	1974	1978	1976

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest										Highest
Fall	490.5	*Hexagenia* (1971-1982)	13.20	0.0001	0.674	1981	1982	1980	1971	1975	1978	1977	1974	1972	1973	1976
	483.4	*Hexagenia* (1971-1982)	23.40	0.0001	0.785	1982	1978	1977	1981	1976	1974	1975	1980	1971	1972	1973
	478.2	*Hexagenia* (1971-1982)	8.85	0.0001	0.580	1975	1973	1974	1981	1972	1978	1971	1980	1982	1976	1977
	490.5	Chironomidae (1971-1982)	3.97	0.0003	0.383	1980	1975	1981	1974	1976	1978	1982	1971	1972	1977	1973
	483.4	Chironomidae (1971-1982)	11.22	0.0001	0.637	1975	1974	1978	1977	1976	1982	1981	1973	1971	1980	1972
	478.2	Chironomidae (1971-1982)	3.56	0.0009	0.357	1978	1977	1981	1976	1975	1980	1982	1972	1971	1974	1973
	490.5	Oligochaeta (1971-1982)	4.24	0.0002	0.398	1971	1973	1976	1980	1974	1981	1982	1972	1978	1977	1975
	483.4	Oligochaeta (1971-1982)	4.94	0.0001	0.435	1982	1973	1971	1976	1975	1972	1978	1980	1981	1974	1977

Table 4-7 (Continued)

Season	TRM	Data	F Value	P>F	R-Square	Rank (α = 0.05)* Lowest										Highest
	478.2	Oligochaeta (1971-1982)	3.16	0.0024	0.330	1973	1972	1982	1980	1974	1976	1975	1981	1977	1971	1978
	490.5	*Corbicula manilensis*‡ (1971-1982)	5.63	0.0001	0.480		1978	1971	1973	1976	1972	1975	1980	1982	1977	1974
	483.4	*Corbicula manilensis*‡ (1971-1982)	6.18	0.0001	0.503		1978	1982	1976	1973	1972	1980	1977	1971	1974	1975
	478.2	*Corbicula manilensis*‡ (1971-1982)	53.53	0.0001	0.898		1978	1975	1973	1977	1972	1974	1982	1980	1971	1976
	490.5	Total Macroinvertebrates‡ (1971-1982)	18.68	0.0001	0.754		1980	1971	1982	1978	1974	1976	1972	1977	1975	1973
	483.4	Total Macroinvertebrates‡ (1971-1982)	6.60	0.0001	0.519		1978	1982	1976	1977	1974	1980	1975	1971	1972	1973
	478.2	Total Macroinvertebrates‡ (1971-1982)	1.92	0.0681	0.239		1978	1982	1980	1977	1972	1975	1971	1976	1973	1974

* Years underscored by the same line are not significantly different.
† 1972 data (winter) are not included. Taxa of oligochaeta were not identified; therefore, conversion from cm lengths to organisms was not possible.
‡ 1981 data (all seasons) are not included. *Corbicula* were discarded in the field and are not enumerated.
§ 1981 data (summer) are not included. Samples were not collected from the specified habitat.

Table 4-8. Benthic Macroinvertebrate Taxa Collected Upstream of Sequoyah Nuclear Plant During Preoperational and Operational Monitoring, 1971 Through 1982

Taxa	Preoperational (1971-1978)	Operational (1980-1981)	Operational (1982)
Amphipoda (scuds)			
Crangonyx			
Gammarus			
Hyalella azteca	X		X
Ceratopogonidae (biting midges)		X	
Bezzia	X		X
Culicoides			
Chironomidae (midges)	X		
Ablabesmyia	X	X	X
Chironomous	X	X	X
Coelotanypus	X	X	X
Crictopus			
Cryptochironomus	X	X	
Dicrotendipes	X		
Epoicocladius	X	X	X
Glyptotendipes			
Parachironomus			
Paratendipes		X	
Polypedilum	X		
Procladius	X	X	X
Xenochironomus	X		
Culicidae			
Chaoborus	X	X	X
Ephemeroptera (mayflies)			
Caenis		X	
Ephemerella		X	
Hexagenia	X	X	X
Stenacron	X		
Odonata (dragonflies, damselflies)			
Coenagrionidae			
Argia	X		
Enallagma		X	
Hirudinea (leeches)	X		
Erpobdellidae			
Glossiphoniidae			
Nemata (nematodes)	X	X	
Megaloptera			
Sialis	X		
Pelecypoda (bivalve mollusks)			
Anodonta	X		
Corbicula manilensis	X	X	X
Sphaerium	X		X
Oligochaeta (aquatic worms)			
Tubificidae	X	X	X
Branchiura sowerbyi	X	X	X

Table 4-8. (Continued)

Taxa	Preoperational (1971-1978)	Operational (1980-1981)	Operational (1982)
Trichoptera (Caddisflies)	X		
Cheumatopsyche	X		
Crynellus fraternus			
Neureclipsis			
Nyctiophylax			
Oecetis			X
Orthotrichia			X
Bryozoa	X		
Lophopodella		X	
Pectinatella magnifica	X	X	
Gastropoda (snails)			
Amnicola			
Hydrobia			
Campeloma			
Physa			X
Nematomorpha			
Paragordius			
Turbellaria (flat worms)			
Planariidae			
Cura foremanii	X		
Dugesia			
Total	29	19	16

Table 4-9. Benthic Macroinvertebrate Taxa Collected Downstream of Sequoyah Nuclear Plant During Preoperational and Operational Monitoring, 1971 Through 1982

Taxa	Preoperational (1971-1978)	Operational (1980-1981)	(1982)
Amphipoda (scuds)			
Crangonyx	X		X
Gammarus	X		
Hyalella azteca	X	X	X
Ceratopogonidae (biting midges)		X	
Bezzia	X		
Culicoides	X	X	
Chironomidae (midges)	X	X	X
Ablabesmyia	X	X	X
Chironomous	X	X	X
Coelotanypus	X	X	X
Crictopus	X		
Cryptochironomus	X	X	X
Dicrotendipes	X	X	X
Epoicocladius	X	X	
Glyptotendipes	X		
Parachironomus	X	X	
Paratendipes		X	
Polypedilum	X	X	
Procladius	X	X	X
Xenochironomus	X	X	X
Culicidae			
Chaoborus	X	X	X
Ephemeroptera (mayflies)			
Caenis		X	
Ephemerella	X		
Hexagenia	X	X	X
Stenacron			
Odonata (dragonflies, damselflies)			
Coenagrionidae			
Argia			
Enallagma		X	
Hirudinea (leeches)	X	X	X
Erpobdellidae			X
Glossiphoniidae		X	
Nemata (nematodes)	X	X	
Megaloptera			
Sialis	X	X	
Pelecypoda (bivalve mollusks)	X		
Anodonta	X		
Corbicula manilensis	X	X	X
Sphaerium	X		X
Oligochaeta (aquatic worms)			
Tubificidae	X	X	X
Branchiura sowerbyi	X	X	X

Table 4-9. (Continued)

Taxa	Preoperational (1971-1978)	Operational (1980-1981)	(1982)
Trichoptera (Caddisflies)	X		
Cheumatopsyche			
Crynellus fraternus	X		X
Neureclipsis	X		
Nyctiophylax	X		
Oecetis	X	X	X
Orthotrichia			
Bryozoa	X		
Lophopodella			
Pectinatella magnifica	X	X	X
Gastropoda (snails)			
Amnicola	X	X	
Hydrobia	X		
Campeloma		X	X
Physa			X
Nematomorpha			
Paragordius	X		
Turbellaria (flat worms)			
Planariidae			
Cura foremanii	X		
Dugesia	X	X	X
Total	42	31	24

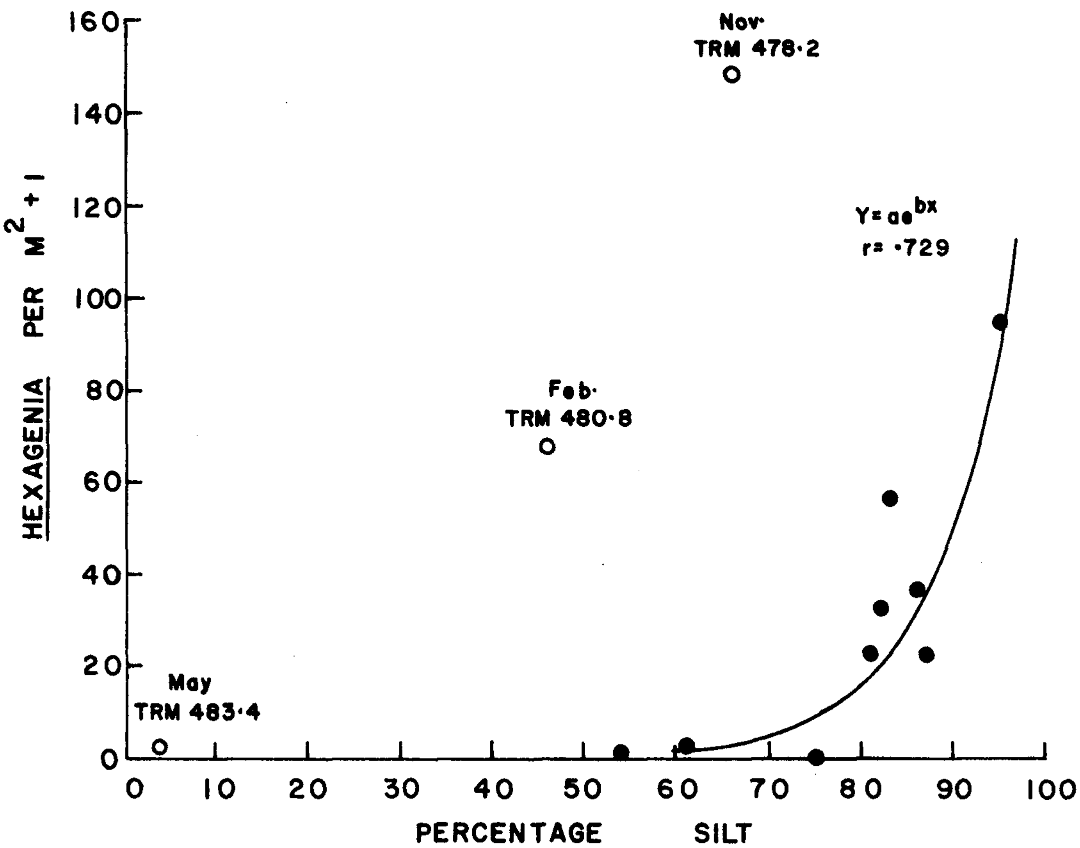

Figure 4-1. Relationship Between Silt and *Hexagenia* Abundance Near Sequoyah Nuclear Plant, Chickamauga Reservoir, 1982.

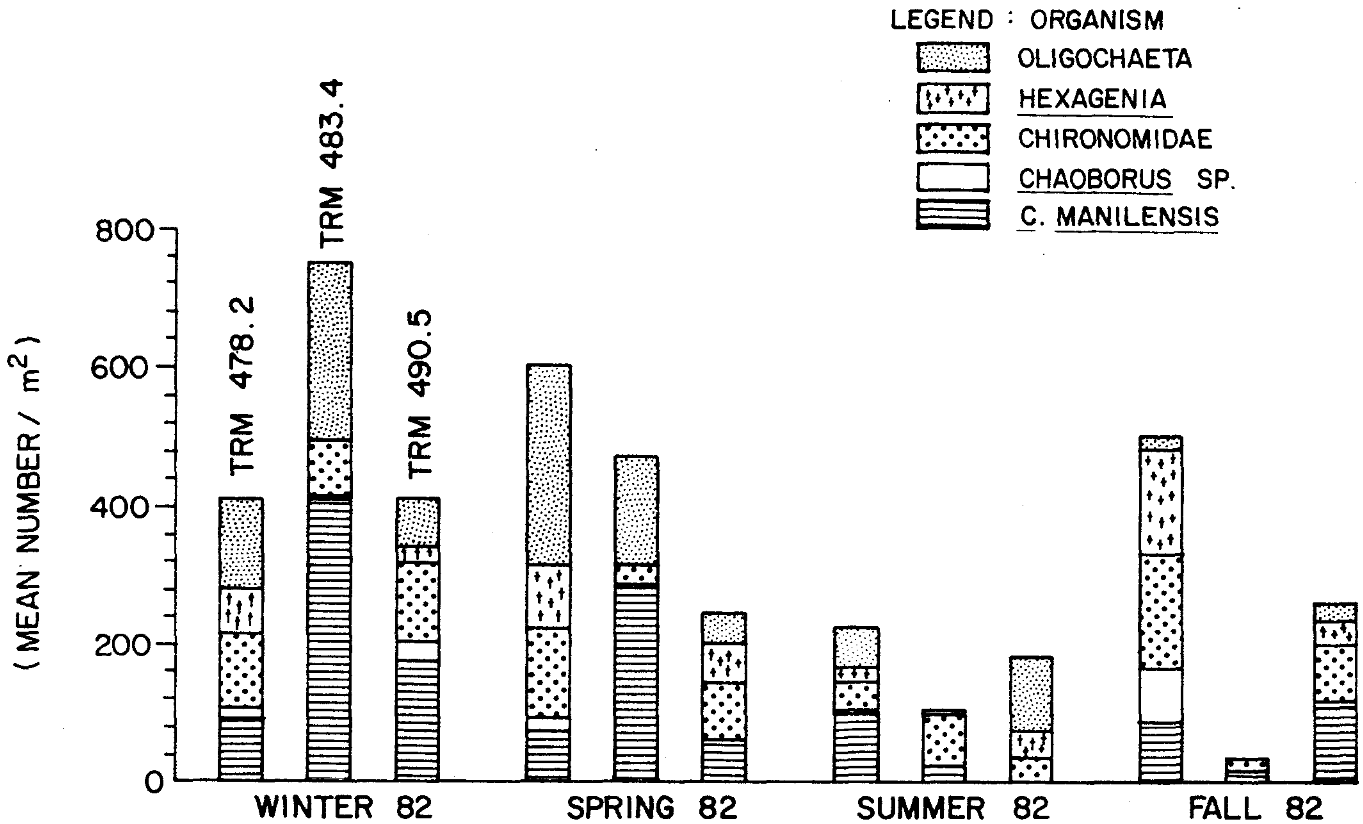

Figure 4-2. Abundance of Dominant Macroinvertebrate Taxa in the Vicinity of Sequoyah Nuclear Plant, Chickamauga Reservoir, Tennessee, February, May, August, and November 1982.

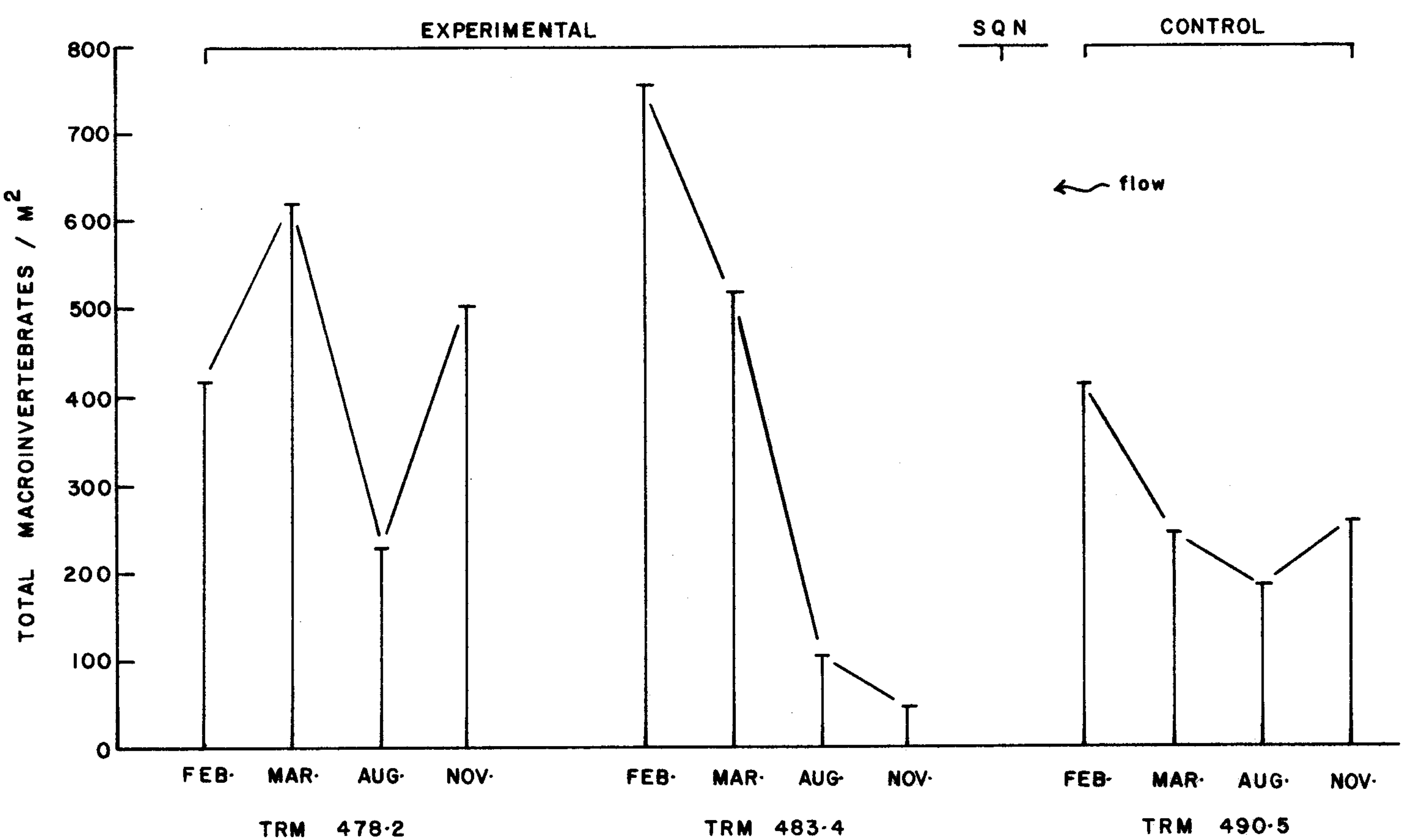

Figure 4-3. Total Macroinvertebrates Collected February, March, August, and November in the Vicinity of Sequoyah Nuclear Plant, Chickamauga Reservoir, 1982.

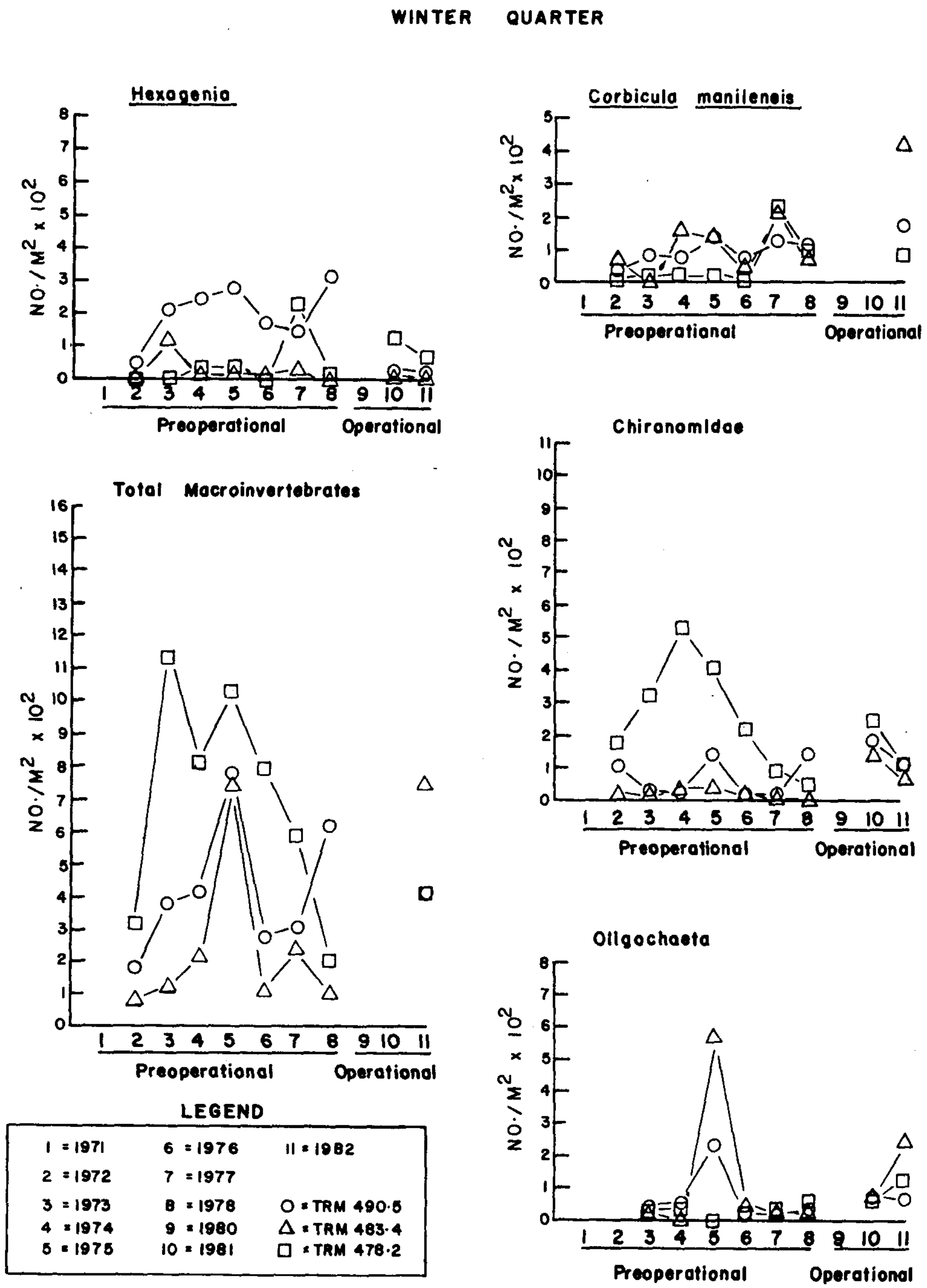

Figure 4-4. Winter Macroinvertebrate Densities During Preoperational and Operational Monitoring at Sequoyah Nuclear Plant, Chickamauga Reservoir, 1972 Through 1982.

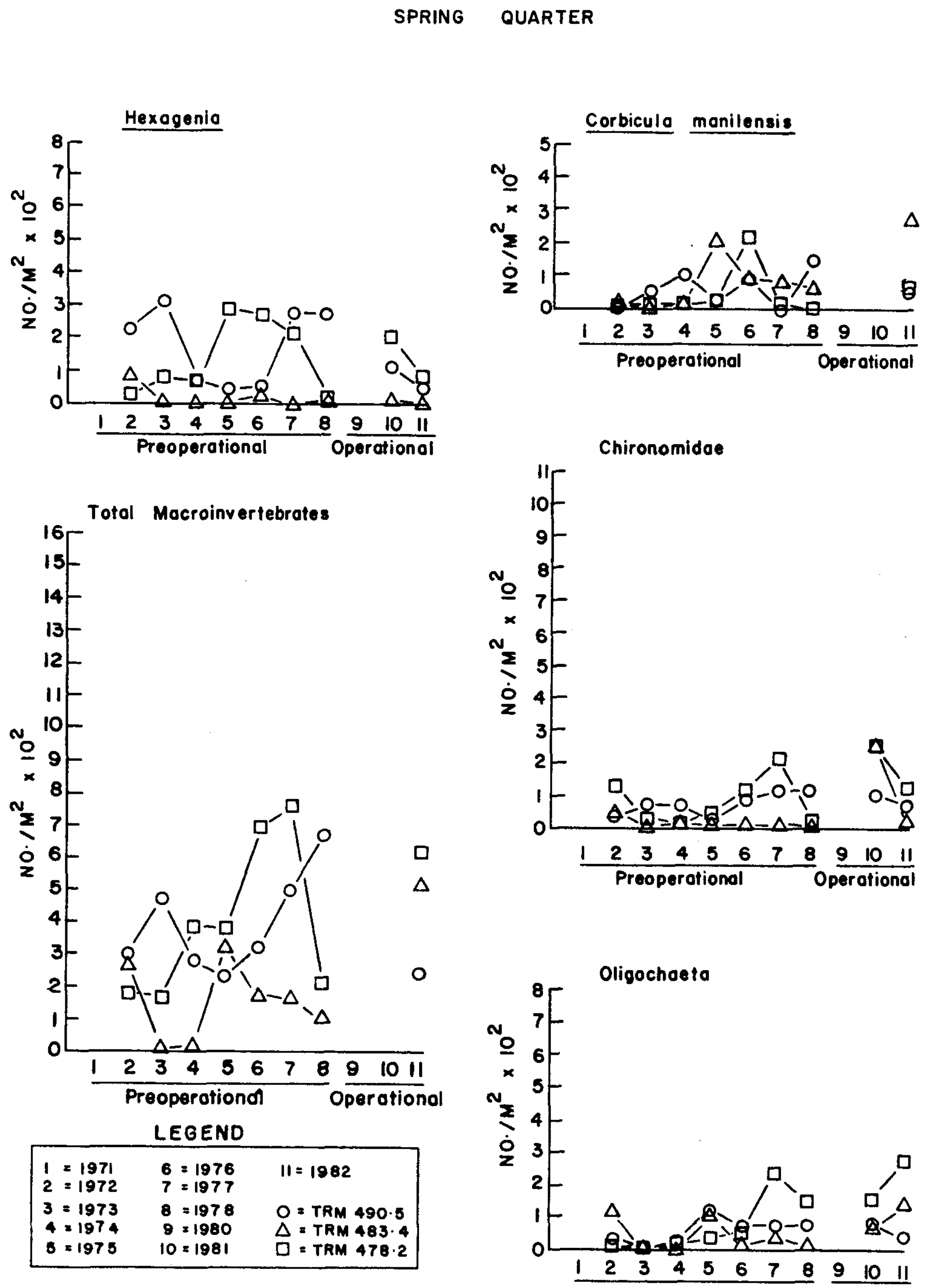

Figure 4-5. Spring Macroinvertebrate Densities During Preoperational and Operational Monitoring at Sequoyah Nuclear Plant, Chickamauga Reservoir, 1972 Through 1982.

SUMMER QUARTER

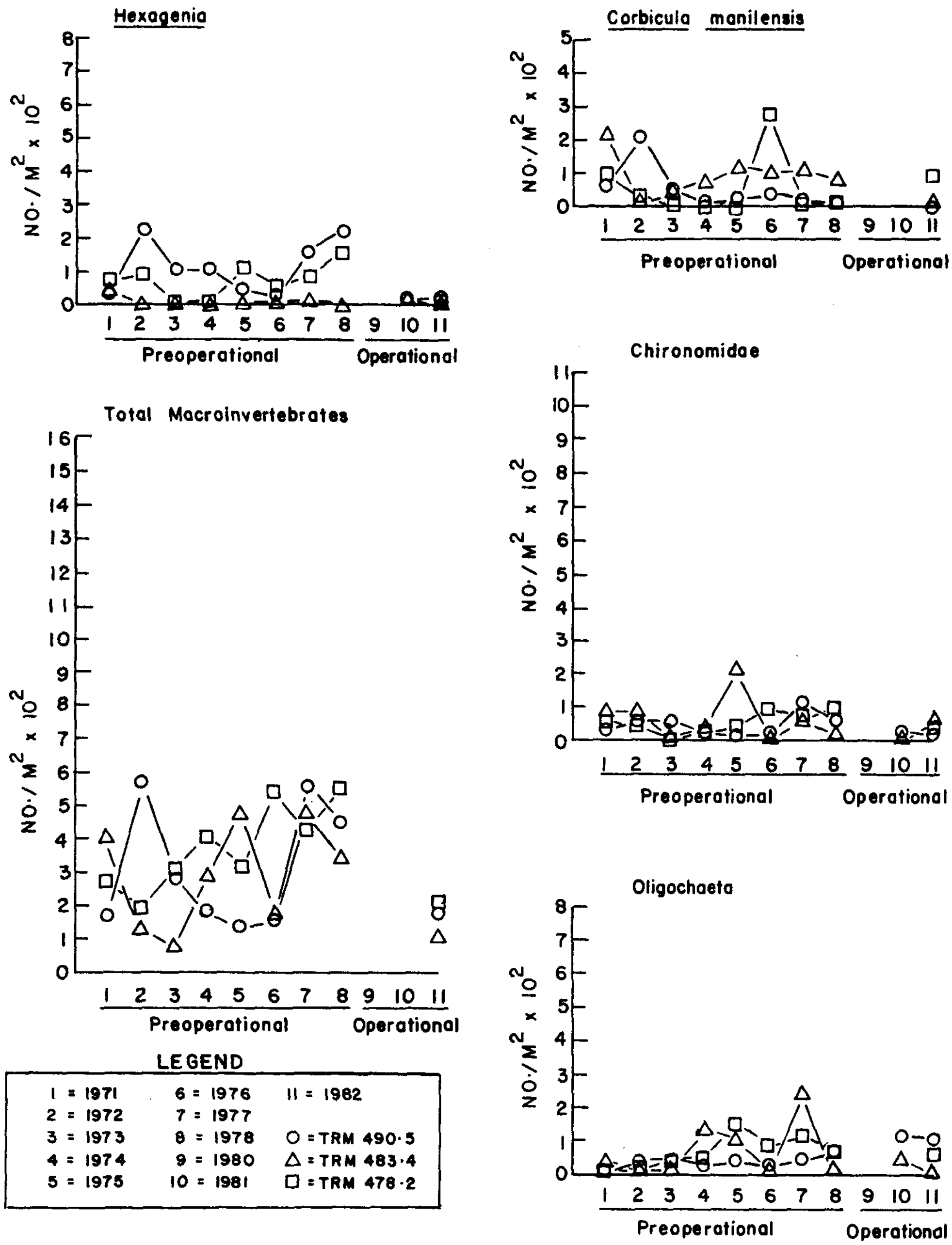

Figure 4-6. Summer Macroinvertebrate Densities During Preoperational and Operational Monitoring at Sequoyah Nuclear Plant, Chickamauga Reservoir, 1981 Through 1982.

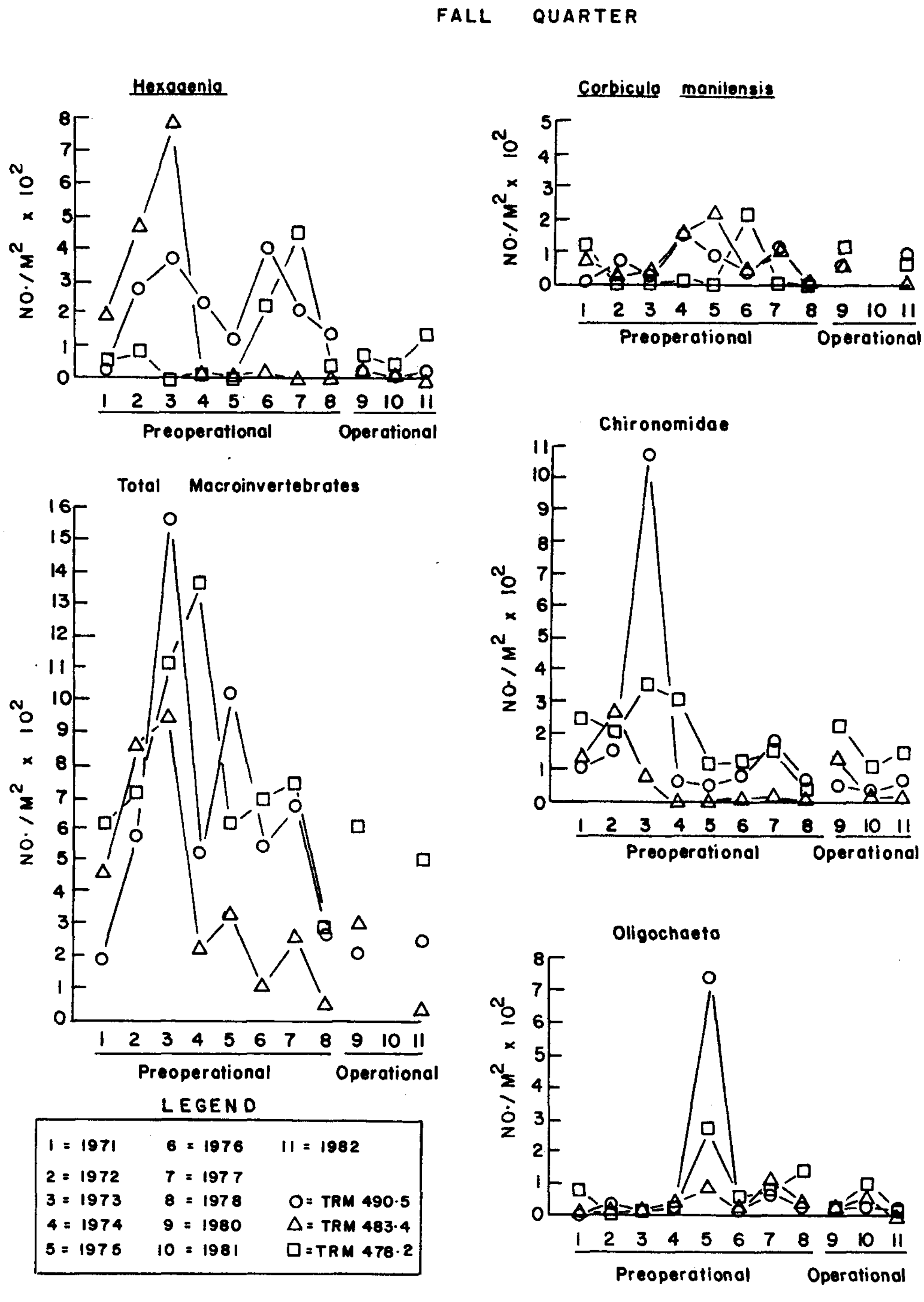

Figure 4-7. Fall Macroinvertebrate Densities During Preoperational and Operational Monitoring at Sequoyah Nuclear Plant, Chickamauga Reservoir, 1971 Through 1982.

4.2 Bioaccumualtion

Copper and nickel are the primary constituents of SQN condenser cooling water tubes. Iron, zinc, aluminum, and cadmium are other metallic components of interest in the SQN system. Investigations were performed to determine if these metals are being accumulated in the food chain of Chickamauga Reservoir near (downstream of) SQN. Freshwater, bivalve mollusks were chosen as test organisms because of their method of feeding. Filtering action of the gills, with assistance of secreted mucus and numerous cilia, retain particles from water which is directed at rates of up to 24 ml per minute of 35 ℓ of water per day (Allen, 1914), through the mussel's incurrent siphon. Only limited bioaccumulation probably occurs from dissolved metals within the volumes of water filtered; the primary source of metals within mollusk tissues most likely occurs through ingestion of plankton and other particulate matter. Therefore, metals have been preconcentrated (complexing, inclusion, precipitation) into the seston prior to ingestion (Lord et al., 1975).

4.2.1 Materials and Methods

Field--Test animals used were two species of freshwater mussels, *Cyclonaias tuberculata* and *Amblema plicata*, and the asiatic clam, *Corbicula manilensis*. Mollusks were collected from source populations so that all animals used throughout the study are from a common gene pool. Mussels were collected October 1981 from Wilson Dam tailwater (TRM 258.3), and clams were collected on the same day from Spring Creek embayment on Wheeler Reservoir near TRM 283.8.

After collection, mollusks were held for 36 hours in charcoal-filtered tap water to purge gut contents. They were then packed between layers of wet burlap, placed in styrofoam or plastic ice chests, and transported to SQN incubation sites. Samples of each species were retained to determine background metals concentrations.

Test animals were placed in nylon mesh bags and suspended from racks made of polyvinyl-chloride pipe anchored with concrete. Nonmetalic Holding devices were placed upstream (TRM 485.0) and downstream (TRM 482.9) of SQN.

Sufficient test animals were suspended from racks in order to collect quarterly sample sets from each location. A sample set consisted of three samples of each species. Each sample of mussel tissue consisted of three individuals (whole body), and a sample of C. manilensis consisted of a sufficient number of individuals to provide enough tissue for analyses (5-10 individuals, depending on size). Following collection, stainless steel knives were used to remove mollusk tissues from the shells. Tissues were rinsed with deionized, distilled water, placed in plastic bags, and frozen until analyses could be performed. Because mollusk tissues were removed in the field, gut contents were not purged before analyses.

Laboratory--Metals analyses were performed on soft tissues of the test animals. Tissues were analyzed for copper, nickel, iron, aluminum, zinc, and cadmium. Standard atomic absorption spectroscopy techniques were used for all but cadmium, which was measured by graphite furnace atomic absorption methods.

Data Analyses--Metals analyses were graphically illustrated for March, May, August, and November 1982. Representations of background (purged) bioaccumulation data for C. tuberculata, A. plicata, and

C. manilensis were also included for comparisons. Where possible (i.e., when observations were paired), a Students-t test was used to compare control and experimental populations.

4.2.2 Results and Discussion

This section summarizes data presented during the first year's (1981) bioaccumulation study and then describes bioaccumulation during 1982. Results are discussed for each metal, including pertinent observations for each mollusk species during the four quarters of monitoring.

Results from the first SQN bioaccumulation study conducted May, August, and December 1981 were difficult to interpret because of poor sample replication (due to vandalism and mortality) and failure to retrieve control specimens. Metals concentrations downstream of SQN were higher than background concentrations from purged stock specimens, indicating increases in copper (C. manilensis), zinc (C. tuberculata), aluminum (C. tuberculata, C. manilensis), and cadmium (C. tuberculata, A. plicata, C. manilensis) during at least one of the three sampling periods. The only consistent trend (nonstatistical) for metals accumulation occurred in C. manilensis for copper as downstream concentrations increased from 7.8, to 9.9, to 14.0 μg/g during May, August, and December, respectively. Even though metals concentrations appeared to increase downstream of SQN (especially copper), the above mentioned problems prevented an evaluation of SQN influence.

During the present study, vandalism and sample replication were not a problem, although in March, a sampling error invalidated results from the experimental station. Data for 1982 are in appendix R and summarized in table 4-10. Results (illustrated in figures 4-8 and 4-9) show concentrations of iron, and especially aluminum, were greatly increased above background concentrations at both experimental and control stations. Because specimens incubated in Chickamauga Reservoir were not purged before analyses, such increases above background levels likely represent gut contents and not metals concentrated into body tissues because iron and aluminum do not readily bioaccumulate in bivalve mollusks (Jones, et al., 1979). These authors conclude that mollusks would not be a good short-term monitor for iron. Statistically, significant differences between experimental and control stations for iron and aluminum occurred only in May (table 4-11). Significantly more iron was measured at the control station in C. manilensis (∝ 0.01) and more aluminum occurred at the control station in both A. plicata and C. manilensis (∝ 0.01). Concentrations of iron in 1982 were slightly greater than those measured downstream of SQN in 1981 while aluminum concentrations during 1981 and 1982 studies were similar, both years having the highest concentration in C. manilensis during fall.

Copper concentrations were significantly (∝ 0.05) greater downstream of SQN in five of nine analyses; however, except for November (C. manilensis), downstream concentrations remained near background levels (figure 4-8). Results for C. manilensis were different from those measured in 1981 in that copper concentrations during 1982 did not increase substantially throughout the study period. However, results from both studies were similar during the fall quarter in that copper concentrations were greatly increased (significantly over the control station in 1982). While it is apparent that copper concentrations have increased significantly in whole body mussel and clam samples downstream of SQN, it is not possible to determine if these increases are due to bioaccumulation within mollusk tissues or reflect preconcentration in seston contained in their gut.

Copper concentrations were slightly higher during the 1981 study than in 1982 and greatly increased over background levels in C. manilensis.

Zinc concentrations in A. plicata downstream of SQN were higher than the control station during May, August, and November (figure 4-8), with the highest mean concentration (72.3 µg/g) measured in August. However, variability among experimental samples precluded these increases from inferring statistical significance. The only statistically significant difference (α 0.05) occurred in C. manilensis during May when zinc was slightly higher at the control station than downstream of SQN. Zinc concentrations downstream of SQN for the entire year were similar during both 1981 and 1982 studies.

Nickel remained at concentrations less than minimum detectable limits throughout the study except at the control station during March in A. plicata. Similar low concentrations of nickel were encountered in 1981. Manly (1977) compared concentration sites for various metals in the freshwater mussel Anadonta and showed the greatest concentrations of nickel occurred in the kidneys whereas other metals (i.e., zinc, cadmium, and copper) concentrated mainly in the digestive gland, ctenidia, mantle, and gonads. Relative small size of the kidneys compared to total body may have accounted for poor detection of nickel during operational investigations at SQN.

Cadmium was significantly (α 0.05) higher in A. plicata downstream of SQN during May and November than control values, although concentrations were only slightly above background levels in May and less than background (figure 4.9) levels during November. A notable increase in cadmium occurred during August in all species at both control and experimental stations, with concentrations well above background levels. Concentrations in all mollusk species declined to below background levels in November. Frazier (1976) reported losses in body residues of zinc (33 percent), copper (50 percent), and cadmium (33 percent) from mid-August through mid-September, coinciding with the period of decline of cadmium in the present study. At SQN, a similar decline also occurred for zinc (*A. plicata* and *C. tuberculata*) and copper (*A. plicata* and *C. tuberculata*). If these metals were present in gut contents rather than body tissues, trends toward increased metals in seston (i.e., plankton and particulates) during summer with declines during fall are implied, although similar trends were not observed in 1981. Cadmium concentrations were similar during both 1981 and 1982 studies.

4.2.3 Summary and Conclusions

Concentrations of copper and cadmium downstream of SQN were higher than background levels during both 1981 and 1982 and were significantly higher (seasonally) than concentrations in organisms of the control station during 1982. Concentrations of zinc were also elevated downstream of SQN in *A. plicata*, although high variability among downstream replicate samples prevented determination of statistical significance. Other metals such as iron and aluminum were also greater than background concentrations at both control and experimental stations and are thought to represent gut contents rather than true bioaccumulation. A failure to purge gut contents of test organisms before analyses made it impossible to determine if metals from SQN are being incorporated into mollusks tissues in Chickamauga Reservoir. However, it does appear that copper, cadmium, and zinc are being increased seasonally in the trophic system downstream of SQN.

Table 4-10. Mean Metals Data from Mollusks (Whole Body, Soft Tissues) Utilized in Determining Bioaccumulation in the Vicinity of Sequoyah Nuclear Plant, Chickamauga Reservoir, 1982

Date Collected	Species	Number of Samples	Location*	Mean Metal Concentration (µg/g) Iron	Copper	Zinc	Nickel	Aluminum	Cadmium
10/23/81	Cyclonaias tuberculata	3	Background	173.3	3.7	48.0	<1.0	2.4	0.30
	Amblema plicata	3	Background	283.3	2.2	48.3	<1.0	3.1	0.23
	Corbicula manilensis	1	Background	44.0	8.6	17.0	<1.0	9.4	0.15
3/1/82	Cyclonaias tuberculata	3	Upstream	180.0	2.6	42.3	<1.0	45.3	0.26
		0	Downstream	-	-	-	-	-	-
	Amblema plicata	3	Upstream	340.0	2.8	47.3	1.9	61.3	0.19
		0	Downstream	-	-	-	-	-	-
	Corbicula manilensis	3	Upstream	180.0	8.9	20.7	<1.0	153.3	0.13
		0	Downstream	-	-	-	-	-	-
5/25/82	Cyclonaias tuberculata	3	Upstream	230.0	2.3	41.3	<1.0	68.3	0.28
		3	Downstream	263.3	3.3	44.7	<1.0	71.0	0.29
	Amblema plicata	3	Upstream	206.7	0.9	45.0	<1.0	65.3	0.21
		3	Downstream	313.3	1.3	61.7	<1.0	20.7	0.25
	Corbicula manilensis	3	Upstream	130.0	8.1	21.3	<1.0	123.3	0.17
		3	Downstream	77.7	9.2	17.7	<1.0	58.0	0.13
8/25/82	Cyclonaias tuberculata	3	Upstream	363.3	2.9	56.3	<1.0	183.3	0.46
		3	Downstream	280.0	3.1	48.3	<1.0	90.3	0.42
	Amblema plicata	3	Upstream	343.3	1.3	52.3	<1.0	89.7	0.24
		3	Downstream	410.0	1.8	72.3	<1.0	137.3	0.32
	Corbicula manilensis	3	Upstream	70.33	8.5	15.7	<1.0	66.0	0.21
		3	Downstream	123.3	9.1	18.0	<1.0	121.3	0.24
11/4/82	Cyclonaias tuberculata	3	Upstream	213.3	2.2	49.7	<1.0	51.7	0.25
		3	Downstream	236.7	2.3	41.3	<1.0	81.3	0.19
	Amblema plicata	2	Upstream	305.0	0.9	52.5	<1.0	59.5	0.17
		3	Downstream	383.3	0.6	55.3	<1.0	57.3	0.19
	Corbicula manilensis	3	Upstream	186.7	6.8	18.3	<1.0	160.0	0.12
		3	Downstream	210.0	12.3	18.3	<1.0	176.7	0.15

*Upstream = TRM 485.0
Downstream = TRM 482.9

Table 4-11 Statistical Comparison of Metal Concentrations (μg/g) in Mollusks Incubated Upstream (TRM 485.0) and Downstream (TRM 482.9) of Sequoyah Nuclear Plant, Chickamauga Reservoir, 1982

Metal	Month	Test Organism	$\bar{X}_1$ (Control)	$\bar{X}_2$ (Experimental)	df	t
Iron	Mar	C. tuberculata	180.0	-*		
		A. plicata	340.0	-		
		C. manilensis	180.0	-		
	May	C. tuberculata	230.0	263.3	4	0.648
		A. plicata	206.7	313.3	4	1.216
		C. manilensis	130.0	77.7	4	5.085†
	Aug	C. tuberculata	363.3	280.0	4	0.929
		A. plicata	343.3	410.0	4	1.040
		C. manilensis	70.3	123.3	4	1.733
	Nov	C. tuberculata	213.2	236.7	4	0.613
		A. plicata	305.0	383.3	3	1.178
		C. manilensis	186.7	210.0	4	0.802
Copper	Mar	C. tuberculata	2.6	-		
		A. plicata	2.8	-		
		C. manilensis	8.9	-		
	May	C. tuberculata	2.3	3.3	4	2.970‡
		A. plicata	0.9	1.3	4	3.098‡
		C. manilensis	8.1	9.2	4	1.674
	Aug	C. tuberculata	2.9	3.1	4	2.000
		A. plicata	1.3	1.8	4	2.810‡
		C. manilensis	8.5	9.1	4	0.798
	Nov	C. tuberculata	2.2	2.3	4	0.285
		A. plicata	0.9	0.6	3	4.025‡
		C. manilensis	6.8	12.3	4	3.445‡

Table 4-11. (Continued)

Metal	Date	Test Organism	$\bar{X}_1$ (Control)	$\bar{X}_2$ (Experimental)	df	t
Zinc	Mar	_C. tuberculata_	42.3	-		
		A. plicata	47.3	-		
		C. manilensis	20.7	-		
	May	_C. tuberculata_	41.3	44.7	4	0.426
		A. plicata	45.0	61.7	4	1.282
		C. manilensis	21.3	17.7	4	3.816‡
	Aug	_C. tuberculata_	56.3	48.3	4	1.368
		A. plicata	52.3	72.3	4	2.011
		C. manilensis	15.7	18.0	4	1.365
	Nov	_C. tuberculata_	49.7	41.3	4	0.804
		A. plicata	52.5	55.3	3	0.429
		C. manilensis	18.3	18.3	4	0.000
Nickel			(All but 1 value less than minimum detectable concentration)			
Aluminum	Mar	_C. tuberculata_	45.3	-		
		A. plicata	61.3	-		
		C. manilensis	153.3	-		
	May	_C. tuberculata_	68.3	71.0	4	0.191
		A. plicata	65.3	20.7	4	7.410†
		C. manilensis	123.3	58.0	4	5.215†
	Aug	_C. tuberculata_	183.3	90.3	4	2.603
		A. plicata	89.7	137.3	4	0.945
		C. manilensis	66.0	121.3	4	0.961
	Nov	_C. tuberculata_	51.7	81.3	4	2.144
		A. plicata	59.5	57.3	3	0.005
		C. manilensis	160.0	176.7	4	0.641

Table 4-11. (Continued)

Metal	Month	Test Organism	$\bar{X}_1$ (Control)	$\bar{X}_2$ (Experimental)	df	t
Cadmium	Mar	*C. tuberculata*	0.26	-		
		A. plicata	0.19	-		
		C. manilensis	0.13	-		
	May	*C. tuberculata*	0.28	0.29	4	0.269
		A. plicata	0.21	0.25	4	3.098‡
		C. manilensis	0.17	0.13	4	1.819
	Aug	*C. tuberculata*	0.46	0.42	4	0.357
		A. plicata	0.24	0.32	4	2.744
		C. manilensis	0.21	0.24	4	0.949
	Nov	*C. tuberculata*	0.25	0.19	4	0.699
		A. plicata	0.17	0.19	3	3.692‡
		C. manilensis	0.12	0.15	4	1.095

* Data missing from experimental station; no statistical comparison possible.

† Significant at the 0.01 level of testing
$t_{(.01)}$ @ 4 df = 4.604
@ 3 df = 5.841

‡ Significant at the 0.05 level of testing
$t_{(.05)}$ @ 4 df = 2.776
@ 3 df = 3.182

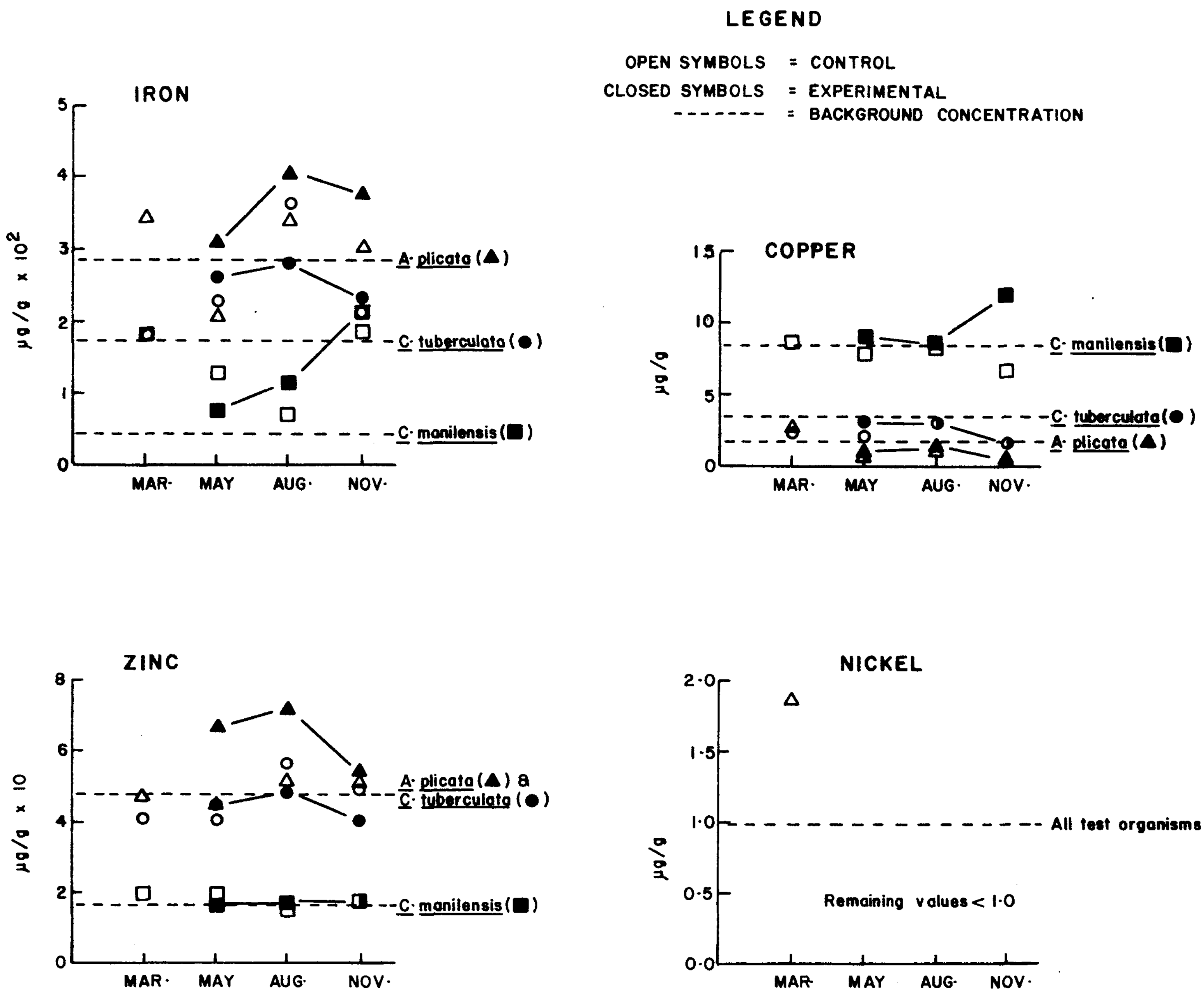

Figure 4-8. Concentrations of Iron, Copper, Zinc, and Nickel Found in Mollusks Whole-body Tissues Upstream (TRM 485.0) and Downstream (TRM 482.9) of Sequoyah Nuclear Plant, Chickamauga Reservoir, 1982.

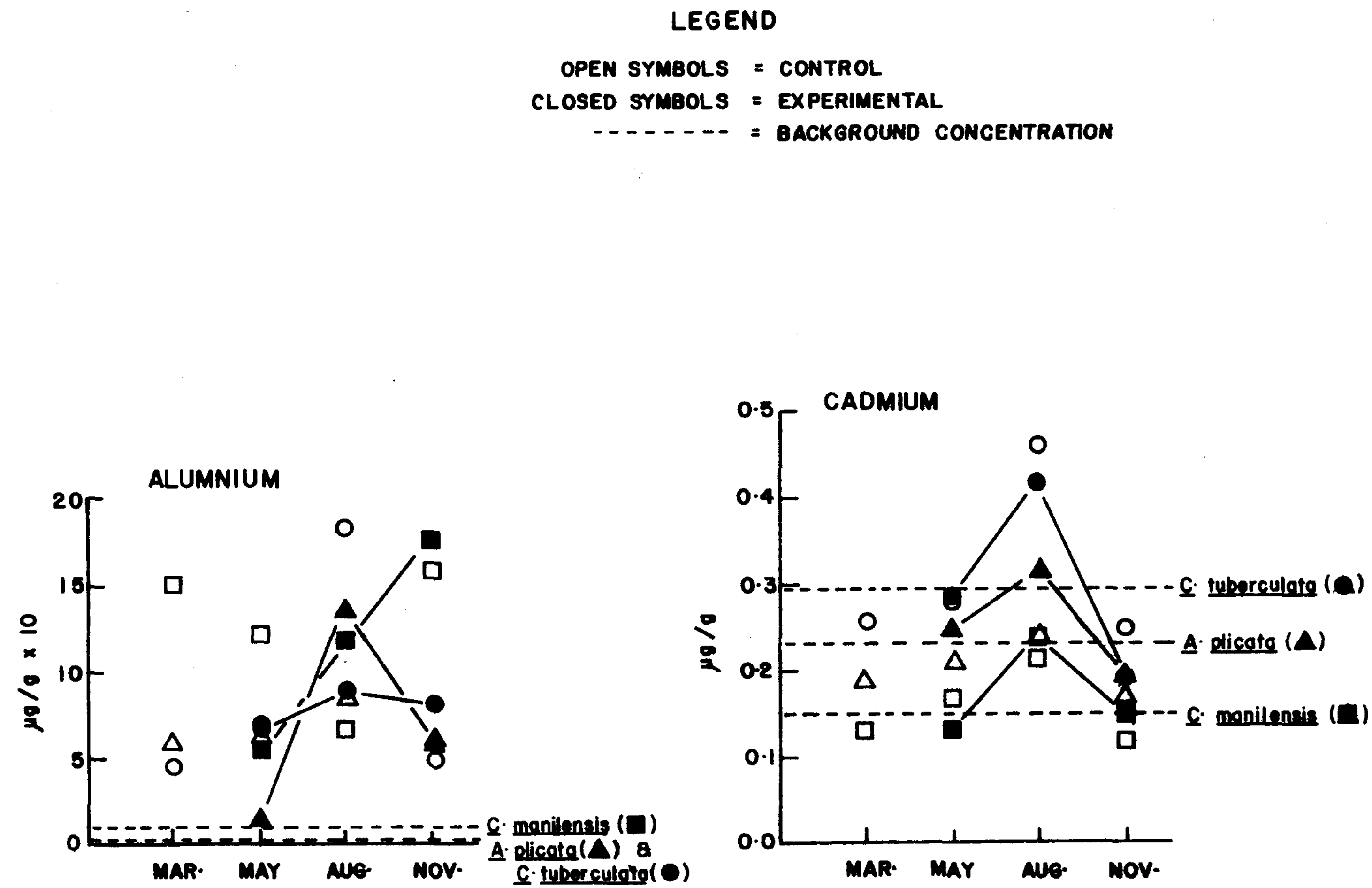

Figure 4-9. Concentrations of Aluminum and Cadmium Found in Mollusks Whole-body Tissues Upstream (TRM 485.0) and Downstream (TRM 482.9) of Sequoyah Nuclear Plant, Chickamauga Reservoir, 1982.

5.0 FISH

Potential impacts to the fish community of Chickamauga Reservoir from operation of SQN could be classified into three basic categories: (1) losses of planktonic fish eggs and larvae entrained with CCW; (2) losses of juvenile and adult fish impinged on plant intake screens; and (3) effects of thermal or chemical discharges on relative abundance and distribution of game, prey, and commercial species in the reservoir. To identify effects of entrainment losses of fish eggs and larvae, annual densities immediately adjacent to the intake skimmer wall, as well as densities passing the plant, are estimated. Entrainment estimates are then calculated as a percentage of eggs and larvae passing the plant that are removed by the intake. While total numbers removed from the reservoir can be estimated, total numbers produced in the reservoir cannot be estimated from these data. Therefore, entrainment loss estimates presented in this report are not expressed as a proportion of total production of eggs and larvae in Chickamauga Reservoir. Rather, these estimates represent the proportion of eggs and larvae moving past SQN that are removed. Because many more larvae are present each year in Chickamauga Reservoir than actually pass SQN, entrainment percentages in this report are much higher than if reported based on total reservoir production.

Juvenile and adult fish losses from impingement on intake screens provide estimates of annual losses. Unlike entrainment losses, impingement losses are not expressed relative to numbers of fish adjacent to the plant. Rather, these are related to annual standing stock estimates from cove rotenone samples. In this manner, impingement mortality is viewed as the amount of reservoir fish production (estimated from coves) removed by SQN each year.

Reservoir populations of juvenile and adult fish are evaluated by gill net and cove rotenone sampling. Gill nets are passive sampling devices that effectively sample only those fish that swim into them and become entangled. As such, gill nets do not sample all fish present at the location where nets are set and are selective as to size and species of fish that are captured. Some species (e.g., sunfish) may be abundant in an area but few are caught in gill nets, although other species (e.g., sauger) are quite susceptible to capture in gill nets. Therefore, gill net data are not used to estimate actual number of fish present in an area, but rather, are used as indicators of relative abundance, movement, and spatial distribution. The basic assumption is that the greater the number of fish in or moving through an area, the larger the catch will be.

Cove rotenone sampling is a quantitative, active sampling method wherein fish in a cove are isolated from the rest of the reservoir by placement of a block net. Toxicant (rotenone) is then applied and all fish collected, yielding quantitative stock estimates of fish populations in coves. These estimates are not equivalent to standing stocks in the entire reservoir, nor are they true population estimates. However, cove rotenone samples represent the best available quantitative estimates of relative abundance from year to year. As such, these data provide indications of reproductive success, year-class strengths, and size of fish stocks. Cove rotenone data are useful in determining long-term trends of these parameters for several important species in a reservoir.

Angling success is determined through creel surveys. These surveys are designed to be random samples yielding information on fishing pressure and fish harvest. By dividing a reservoir into several compartments and sampling each compartment, comparisons can be made among areas.

Information gained from creel estimates include number of fishing trips to a reservoir, numbers and biomass of each species of fish harvested, harvest rates, and seasonality of fishing pressure and harvest.

5.1 FISH EGGS AND LARVAE

Preoperational monitoring to determine seasonal abundance of fish eggs and larvae near SQN was conducted from 1973 through 1977. Sample gear and procedures employed during that period were previously described by TVA (1978b). Gear and methods utilized in 1979 and during operational (1980 through 1982) monitoring are described below.

5.1.1 Materials and Methods

Field--Day and night larval fish samples were collected biweekly from March through August at three transects: (1) plant-TRM 484.8 adjacent to the plant intake; (2) diffuser-TRM 482.7 immediately downstream of the diffuser; and (3) Dallas Bay-TRM 479.4 three miles downstream from the diffuser (figure 5-1). Six samples were collected biweekly at the plant transect (TRM 484.8) including one full-stratum (i.e., bottom to surface) sample along each shoreline and two stratified (i.e., bottom to mid-depth and mid-depth to surface) samples at each of two main channel locations. Five samples were taken at each of the two downstream transects: one full-stratum tow near the overbank (left overbank-Dallas Bay, right overbank-diffuser transect), and two stratified tows each at two locations in the main channel. For each sample, a half-meter plankton net (500 μm mesh) equipped with a TSK flowmeter was towed upstream for ten minutes at a speed of one meter per second.

In 1980, a sample station was added directly in front of the intake skimmer wall opening to estimate plant entrainment of fish eggs and larvae. Six, four-minute tows were made with the half-meter net during both day and night. The net was towed through the 9.0-13.0 m stratum (at full pool) corresponding with the skimmer wall opening to most accurately sample water entering the plant.

Laboratory--Methods of preserving and processing (sorting and identifying) samples remained basically the same as described for pre-operational monitoring (TVA, 1978b). All larval fish specimens were identified to the lowest level possible (e.g., family, genus, species), which for most species was a function of specimen size and developmental stage.

Data Analyses--Densities of fish eggs and larvae are expressed as numbers per 1,000 m^3 for comparisons between transects and among years. Relative abundance of eggs and larvae by taxon was calculated for each year.

Estimated entrainment of fish eggs and larvae at SQN in 1980 through 1982 was calculated by the following method: densities of eggs and larvae transported past the plant were estimated for each sample period by averaging densities (all stations) of eggs and larvae from the plant transect (TRM 484.8) and multiplying by the corresponding 24-hour flow past the plant. Reservoir flows were estimated from releases at upstream (Watts Bar) and downstream (Chickamauga) dams and tributary inflow. Intake-skimmer wall samples were averaged to provide an overall intake density for each sample period. Percentage of transported ichthyofauna entrained by the plant was estimated by family and for total eggs and larvae by sample period from the formula:

$$E = \frac{100\ D_i\ Q_i}{D_r\ Q_r}$$

where D_i = mean density (N/1000 m^3) of eggs or larvae in intake samples;

D_r = mean density (N/1000 m^3) of eggs or larvae in reservoir (plant transect);

Q_i = plant intake water demand (m^3/day);

Q_r = reservoir flow (m^3/day).

Intake water demand was established from known rating (708 m^3/min each) of plant circulating water pumps. Number of pumps operated during each sample period was recorded. Table 5-1 lists 24-hour reservoir (Qr) and intake (Qi) flows ($m^3 \times 10^6$) and proportion hydraulic plant entrainment (Qi/Qr) for each sample period in 1980 through 1982.

5.1.2 Results and Discussion

Table 5-2 lists dates, number of samples, and mean temperature (all depths and transects) for each sample period, 1980 through 1982. Table 5-3 lists scientific and common names for each taxon discussed in this chapter.

Reservoir Populations - Eggs--A total of 16,521 fish eggs was collected from 491 tow-net samples made near SQN in 1982 compared to a three year (1979-1981) total of 17,145 (TVA, 1982a). Only 69 (0.42 percent) of these were unidentifiable fish eggs, the rest were eggs of freshwater drum; therefore all fish eggs will be referred to as freshwater drum eggs throughout this report. Freshwater drum eggs occurred in samples from April 28, 1982 through the last sample period on August 17, 1982. Greatest densities (day and night samples combined) were recorded at the diffuser transect where the peak density of 5,807/1,000 m^3 occurred on June 23, 1982.

The highest density from the other three transects was 278/1,000 m^3 at the skimmer wall on July 6, 1982. Seasonal density (average of all samples) of freshwater drum eggs was highest at the diffuser transect (967/1,000 m^3) and much lower (62, 53, and 13/1,000 m^3) at the Dallas Bay, skimmer wall, and plant transects, respectively. Average seasonal density for all transects was 286/1,000 m^3 compared to 176/1,000 m^3 in 1981.

Few freshwater drum eggs were collected in samples near shore; in channel samples, largest densities were observed in samples from the deep stratum. Figure 5-2 shows freshwater drum egg densities by sample period for each stratum sampled (three reservoir transects combined); channel and near-shore samples. Densities of freshwater drum eggs from intake skimmer wall samples are shown in figure 5-3.

Reservoir Populations - Fish Larvae--Total numbers of fish eggs (16,521) and larvae (87,453) collected in 1982, percentage composition, and period of occurrence by taxon are in table 5-4. Three species (paddlefish, mooneye, and redear sunfish) collected at least once between 1979 and 1981 (TVA, 1982a) were absent in 1982 samples. One specimen of the bluntnose minnow (*Pimephales notatus*), a species not collected in SQN larval fish samples during 1979 through 1981, was identified in 1982 collections. Clupeids (shad) comprised 74.9 percent of larvae collected in 1982, compared to 69 percent in 1981 (TVA, 1982a). Larval sunfish were next in abundance (13.0 percent) in 1982 followed by white and yellow bass (*Morone*), crappie, and freshwater drum larvae at 4.2, 3.1, and 2.9 percent, respectively. Percentage composition of freshwater drum larvae was lower in 1982 than in 1981 when they comprised 9.0 percent of the larval catch.

Seasonal density of total larvae in 1982 was highest (2,973/1,000 m^3) at the plant transect and lowest (405/1,000 m^3) at the skimmer wall (table 5-5). This could be influenced by samples being collected from both overbanks at the plant transect and only one at the other two. Shad larvae are more abundant in overbank samples. Seasonal density of freshwater drum larvae, however, was greater at the skimmer wall (109/1,000 m^3) than at all other transects combined (range 31.5-37.5/1,000 m^3). Skimmer wall samples also contained highest densities of drum larvae in 1980 and 1981 (TVA, 1982a).

Peak density for total larvae occurred on May 12, 1982 at the Dallas Bay (8,710/1,000 m^3) and plant (16,002/1,000 m^3) transects and on May 26, 1982 at the diffuser (4,145/1,000 m^3) transect (table 5-6). As observed in 1980 and 1981, peak larval density at the skimmer wall (1,347/ 1,000^3) in 1982 again occurred later (June 9) than at the other transects. Table 5-6 contains peak larval densities, sample dates, and mean water temperatures recorded for each transect during 1980 through 1982. Seasonal peak densities of fish larvae near SQN typically reflect periods of greatest larval shad abundance. This was true for three of four transects sampled in 1982; however, at the diffuser transect, the peak density of 4,145 larvae per 1,000 m^3 on May 26 consisted of 72 percent sunfish (e.g., bluegill, redear, longear) larvae.

Estimated Hydraulic Entrainment--Average hydraulic entrainment (proportion of reservoir flow entrained by SQN) for 12 sample periods in 1982 was 12.6 percent, a slight decrease from 13.4 percent in 1981. Hydraulic entrainment ranged from 2.4 percent on March 18 to 32.9 percent on April 28 (table 5-1).

Estimated Entrainment of Fish Eggs--An estimated 1.27 x 10^8 freshwater drum eggs were transported past SQN in 1982 with 5.28 x 10^7 or 41.3 percent entrained. Estimated entrainment of freshwater drum eggs in

1981 was 21.8 percent although hydraulic entrainment was similar both years. Since sampling first began at the skimmer wall in 1980, densities of freshwater drum eggs have exceeded those recorded at the adjacent plant transect (TVA, 1982a). This trend continued in 1982 and accounts for the entrainment of fish eggs exceeding percentage hydraulic entrainment. Analysis of samples by stratum (depth) indicates greater densities of freshwater drum eggs in deep stratum samples (figure 5-2). Because all skimmer wall samples are collected from the 9 to 13 meter stratum, and plant transect samples include shoreline and upper stratum (0-6.5 meter) channel tows where densities are lower, egg densities used to estimate numbers entrained are relatively higher than those used to estimate numbers transported.

Highest seasonal densities of freshwater drum eggs were at the diffuser transect (table 5-5) as observed in 1980 and 1981 samples. This suggests that the area near or just downstream from the diffusers is a preferred spawning site for drum. Freshwater drum spawning near or downstream of diffuser pipes has also been observed at TVA's Browns Ferry Plant (TVA, 1979). Entrainment of 41 percent of the freshwater drum eggs transported past SQN based on a seasonal density of 13/1,000 m^3 at the plant transect is insignificant when compared to the seasonal density of 967/1,000 m^3 freshwater drum eggs downstream at the diffuser transect.

Estimated Entrainment of Fish Larvae--Total seasonal transport of fish larvae past SQN in 1982 estimated from 12 biweekly sample densities at the plant transect was 1.4×10^{10}, of which 3.3×10^{8} or 2.24 percent were estimated entrained by the plant. These estimates are nearly identical to 1981 (11 sample periods), when 1.4×10^{10} larvae were transported and 2.3 percent entrained. Table 5-7 lists estimated entrainment (percentage of transported) for fish eggs and larvae by family and sample period in 1982. Freshwater drum larvae had the highest percentage entrainment (25.6 percent). This was nearly five times greater than the estimate of 5.5 percent in 1981. Unidentifiable fish larvae and catfish were next highest with 7.7 percent entrainment. Only two other taxa, minnows (4.2 percent), and white and yellow bass (2.7 percent), showed entrainment estimates greater than that for total larvae (2.2 percent).

5.1.3 Summary and Conclusions

Estimated entrainment of freshwater drum eggs at SQN in 1982 (41.3 percent) exceeded the estimate of 21.8 percent in 1981 although hydraulic entrainment (12.6 percent) decreased slightly from 13.4 percent in 1981 (TVA, 1982a). As in 1980 and 1981, greater densities of fish eggs were collected in skimmer wall samples than at the plant transect causing estimated entrainment of freshwater drum eggs to be higher than hydraulic entrainment. Similarly, greatest seasonal density of freshwater drum eggs was again recorded from samples at the downstream diffuser transect (table 5-5) suggesting substantial reproduction occurring at or just downstream of the plant site and not vulnerable to entrainment.

Estimated entrainment of total fish larvae in 1982 (2.2 percent) was consistent with 1981 (2.25 percent) and again lower than hydraulic entrainment (12.5 percent). Larval shad, the most abundant taxon, were entrained at a rate of 1.5 percent. Freshwater drum larvae were estimated to have the highest entrainment of 25.6 percent. Seasonal density of larval freshwater drum was nearly three times higher at the skimmer wall than at the other three transects. During all three years (1980-1982) of plant operation, seasonal densities of larval freshwater drum have been highest at the skimmer wall and relatively uniform at the other three transects. Analysis by sample depth (figures 5-4 and 5-5) indicates that at the plant, diffuser, and Dallas Bay transects, freshwater drum larvae are most abundant in the deep stratum. Because all samples at the skimmer wall are taken in front of the intake opening at a depth of 9 to 13 meters (at full pool), average densities should be higher than those from other transects where samples from shallow strata contain fewer freshwater drum larvae and tend to decrease average densities. If total transport of freshwater drum larvae were estimated from only deep stratum samples, percentage entrainment would obviously be lower. Therefore, vertical distribution of freshwater drum larvae serves to increase their vulnerability to entrainment. The five-fold increase in percentage entrainment of freshwater drum larvae transported past SQN in 1982, warrants concern with respect to plant impact on the population of freshwater drum in Chickamauga Reservoir.

Larval Percichthyidae (white and yellow bass) was the only other taxon with entrainment (2.7 percent) higher than that of total larvae. Entrainment of these increased from 1981 (1.7 percent). Estimated entrainment of catfish larvae decreased from 8.4 percent in 1981 to 7.7 percent in 1982. Although collected in low numbers, densities of larval catfish were similar at all transects (table 5-5).

With the exception of estimated entrainment of one-fourth of the freshwater drum larvae passing SQN, overall abundance and distribution of fish eggs and larvae in the vicinity and downstream of SQN in 1982 suggests no detectable impact to the fish community as a result of plant entrainment.

Due to vertical distribution patterns of fish eggs and larvae observed in 1982, estimated transport for 1983 should be weighted according to percentage of reservoir flow in individual compartments across the plant transect. This would require field collection of hydrodynamic data for several reservoir flow levels.

Table 5-1. Reservoir (Q_r) and Intake (Q_i) Flow Volumes ($m^3 \times 10^6$/day) at Sequoyah Nuclear Plant for Each Larval Fish Sample Period in 1980 thrugh 1982

Sample Period	1980			1981			1982		
	Q_r	Q_i	Q_i/Q_r	Q_r	Q_i	Q_i/Q_r	Q_r	Q_i	Q_i/Q_r
1	133.10	2.12	0.016	15.17	4.92	0.324	159.29	3.78	0.024
2	228.00	0.11	0.0004	14.43	4.92	0.341	79.29	6.06	0.076
3	91.01	0.15	0.002	20.31	2.95	0.145	29.36	6.06	0.206
4	89.79	0.15	0.002	23.00	1.97	0.086	14.93	4.92	0.329
5	68.01	2.12	0.031	15.17	2.95	0.195	23.98	6.06	0.253
6	77.07	2.08	0.027	45.02	2.95	0.066	32.05	2.95	0.092
7	68.01	0.09	0.001	76.09	2.95	0.039	54.56	6.06	0.111
8	67.77	2.12	0.031	55.54	2.95	0.053	55.79	6.06	0.109
9	81.47	2.08	0.026	74.13	2.95	0.039	66.55	6.06	0.091
10	83.18	2.09	0.025	46.24	4.92	0.106	73.16	6.06	0.083
11	72.42	2.12	0.029	59.21	4.92	0.083	106.19	6.06	0.057
12	56.76	3.12	0.055				73.40	6.06	0.083
13	58.47	2.16	0.037						
Mean seasonal hydraulic entrainment			0.022			0.134			0.126

Table 5-2. Sample Period, Dates, Number of Samples, and Mean Temperatures for Larval Fish Samples Collected Near Sequoyah Nuclear Plant 1980-1982

Sample Period	Date		Number Samples	Mean Water Temperature (°C)
1980				
1	3/12/80		44	7.9
2	3/25/80		44	9.9
3	4/07/80		44	13.5
4	4/21/80		44	15.1
5	5/07/80		44	17.8
6	5/20/80		44	22.4
7	6/03/80		44	23.4
8	6/18/80		44	27.4
9	6/30/80		44	28.5
10	7/14/80		44	30.4
11	7/29/80		44	28.8
12	8/11/80		44	28.6
13	8/27/80		44	29.1
		Total	572	
1981				
1	4/06/81		44	16.0
2	4/13/81		44	17.7
3	5/04/81		44	19.4
4	5/12/81		44	19.4
5	5/26/81		44	20.7
6	6/01/81		36	22.1
7	6/16/81		41	26.7
8	7/01/81		44	26.3
9	7/15/81		44	27.5
10	7/29/81		44	28.4
11	8/27/81		43	27.8
		Total	472	
1982				
1	3/18/82		22	12.5
2	3/31/82		44	13.5
3	4/14/82		44	15.1
4	4/28/82		44	16.9
5	5/12/82		44	21.3
6	5/26/82		29	21.6
7	6/09/82		44	24.2
8	6/23/82		44	26.9
9	7/06/82		44	29.7
10	7/20/82		44	29.3
11	8/03/82		44	28.5
12	8/17/82		44	27.4
		Total	491	

Table 5-3. List of Scientific and Common Names for Fish Egg and Larval Taxa Collected in Chickamauga Reservoir Near Sequoyah Nuclear Plant in 1979 through 1982

Taxon	Common Name
Eggs	
Unidentifiable fish eggs	
Cyprinus carpio eggs	Carp eggs
Aplodinotus grunniens eggs	Freshwater drum eggs
Larvae	
Unidentifiable fish larvae*	
Polyodontidae	
Polyodon spathula	Paddlefish
Clupeidae	
Unidentifiable clupeids	Unidentifiable herrings and shad
Alosa chrysochloris	Skipjack herring
Dorosoma sp.	Mixed shad
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Hiodontidae	
Hiodon tergisus	Mooneye
Cyprinidae	
Unidentifiable cyprinids	Unidentifiable minnows and carps
Cyprinus carpio	Carp
Hybopsis storeriana	Silver chub
Notropis sp.	Unidentifiable shiners
Notropis atherinoides	Emerald shiner
Notropis buchanani	Ghost shiner
Notropis volucellus	Mimic shiner
Pimephales sp.	Unidentifiable minnow
Pimephales notatus	Bluntnose minnow
Pimephales vigilax	Bullhead minnow
Catostomidae	
Unidentifiable catostomids	Unidentifiable suckers
Ictiobinae	Unidentifiable buffalo and carpsuckers
Ictiobus sp.	Unidentifiable buffalo
Ictaluridae	
Ictalurus furcatus	Blue catfish
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Atherinidae	
Labidesthes sicculus	Brook silverside
Percicthyidae	
Morone sp.	Unidentifiable temperate bass
Morone (not *saxatilis*)	Unidentifiable temperate bass (not striped bass)
Morone chrysops	White bass
Morone mississippiensis	Yellow bass

Table 5-3. (Continued)

Taxon	Common Name
Centrarchidae	
Unidentifiable centrarchids	Unidentifiable sunfish, crappie or black bass
Lepomis or *Pomoxis*	Unidentifiable sunfish or crappie
Lepomis sp.	Unidentifiable sunfish
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear sunfish
Micropterus (not *dolomieui*)	Black bass (not smallmouth bass)
Pomoxis sp.	Unidentifiable crappie
Pomoxis annularis	White crappie
Percidae	
Unidentifiable percid (not *Stizostedion* sp.)	Unidentifiable perch (not *Stizostedion*)
Unidentifiable darter	Unidentifiable darter
Perca flavescens	Yellow perch
Stizostedion sp.	Unidentifiable sauger or walleye
Stizostedion canadense	Sauger
Sciaenidae	
Aplodinotus grunniens	Freshwater drum

*Usually mutilated.

Table 5-4. List of Taxa, Total Number Collected, and Period of Occurrence of Fish Eggs and Larvae Collected near Sequoyah Nuclear Plant, 1982

Taxon	Total Collected	Percent Composition	1	2	3	4	5	6	7	8	9	10	11	12
		Fish Eggs												
Unidentifiable fish eggs	69	0.42				+	+	+	+		+	+		
Aplodinotus grunniens (eggs)	16439	99.58				+	+	+	+	+	+	+	+	+
	16508	100												
		Fish Larvae												
Unidentifiable fish larvae	61	0.07		+		+	+	+	+	+	+	+		
Unidentifiable Clupeids	59512	68.10			+	+	+	+	+	+	+	+	+	+
Alosa chrysochloris	1	T*							+					
Dorosoma sp.	41	0.05						+	+					
Dorosoma cepedianum	5192	5.94						+	+	+	+	+		
Dorosoma petenense	705	0.81						+	+	+	+	+	+	+
Unidentifiable Cyprinids	1218	1.39				+	+	+	+	+	+	+	+	+
Cyprinus carpio	9	0.01					+	+	+				+	
Notropis sp.	39	0.04							+	+	+			
Notropis atherinoides	11	0.01							+	+				
Notropis volucellus	164	0.19							+	+	+	+	+	+
Pimephales sp.	1	T												+
Pimephales notatus	1	T										+		
Pimephales vigilax	2	T												+
Unidentifiable Ictiobinae	16	0.02		+		+	+							
Ictiobus sp.	1	T					+							
Ictalurus furcatus	19	0.02								+	+	+	+	+
Ictalurus punctatus	49	0.06							+	+	+	+	+	+
Pylodictis olivaris	1	T									+			
Labidesthes sicculus	35	0.04						+	+	+				
Morone sp.	1935	2.21				+	+	+	+	+				

Table 5-4. (Continued)

Taxon	Total Collected	Percent Composition	Occurrence by Sample Period 1	2	3	4	5	6	7	8	9	10	11	12
Morone chryops	1	T								+				
Morone mississippiensis	5	0.01							+					+
Morone sp. (not *saxatilis*)	1693	1.94		+	+	+	+	+	+					
Lepomis sp.	11243	12.87					+	+	+	+	+	+	+	+
Lepomis macrochirus	66	0.08								+	+	+	+	+
Micropterus sp. (not *dolomieui*)	1	T						+						
Pomoxis sp.	2698	3.09				+	+	+	+	+	+			
Pomoxis annularis	7	0.01							+		+	+		+
Unidentifiable Percids	9	0.01		+	+	+	+							
Perca flavescens	64	0.07		+	+	+								
Stizostedion canadense	4	0.01		+			+							
Aplodinotus grunniens	2581	2.95					+	+	+	+	+	+	+	+
	87385	100												

* Less than 0.01 percent composition.

Table 5-5. Seasonal Densities (No./1,000 m^3) for Dominant Taxa of Fish Larvae and Eggs Collected at Transects Near Sequoyah Nuclear Plant, 1982

Taxon	Transect: Dallas Bay	Diffuser	Plant	Skimmer Wall
Shad (Clupeidae)	973.22	252.36	2,359.49	205.70
Sunfish (*Lepomis*)	89.67	207.03	333.95	44.14
White, Yellow Bass (*Morone*)	61.03	35.31	107.32	15.14
Crappie (*Pomoxis*)	49.07	13.95	86.26	12.87
Catfish (*Ictalurus*)	1.44	1.30	1.08	0.88
Freshwater drum larvae (*A. grunniens*)	37.45	31.46	35.57	108.59
Total larvae	1,225	564	2,973	405
Freshwater drum eggs	66.12	967.77	13.06	53.10

Table 5-6. Peak Larval Density, Sample Date and Period, and Mean Water Temperature Recorded for each Transect Sampled Near Sequoyah Nuclear Plant, Chickamauga Reservoir, in 1980 through 1982

Transect	Peak* Larval Density	Date	Sample Period	Mean Water Temp. (°C)
1980				
Dallas Bay	5,546	June 18	8	27.4
Diffuser	4,406	June 18	8	27.4
Plant	8,846	June 18	8	27.4
Skimmer wall	2,110	June 30	9	28.5
1981				
Dallas Bay	3,961	June 16	7	26.7
Diffuser	6,026	June 1	6	22.1
Plant	5,955	May 4	3	19.4
Skimmer wall	2,371	July 1	8	26.3
1982				
Dallas Bay	8,710	May 12	5	21.3
Diffuser	4,145	May 26	8	21.6
Plant	16,002	May 12	5	21.3
Skimmer Wall	1,347	June 9	7	24.2

*Number per 1000 m^3.

Table 5-7. Estimated Percentage Entrainment by Family and Sample Period of Fish Eggs and Larvae by Sequoyah Nuclear Plant from March 18, 1982 through August 27, 1982

Family	Sample Period 1	2	3	4	5	6	7	8	9	10	11	12	Season Total
Sciaenidae eggs	0.00	0.00	0.00	0.00	47.33	2.76	66.48	14.01	41.35	461.27	53.31	*	41.37
Unidentifiable fish larvae	0.00	0.00	0.00	0.00	0.00	4.55	0.00	0.00	44.63	0.00	0.00	0.00	7.71
Clupeidae	0.00	0.00	0.00	5.18	0.43	0.92	4.86	7.37	2.48	1.34	*	*	1.45
Cyprinidae	0.00	0.00	0.00	20.64	5.52	2.27	3.39	9.66	5.93	2.71	3.40	4.37	4.24
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	18.01	11.26	0.00	0.00	0.00	0.00	7.67
Percichthyidae	0.00	6.70	20.83	6.68	2.53	0.86	1.91	0.00	0.00	0.00	0.00	0.00	2.70
Centrarchidae	0.00	0.00	0.00	0.56	0.43	0.61	3.97	6.83	2.36	1.03	0.91	2.17	1.78
Percidae	*	0.00	0.00	16.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60
Sciaenidae	0.00	0.00	0.00	0.00	3.31	45.91	16.34	14.54	42.53	41.01	14.35	8.55	25.60
Atherinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*Individuals collected only in skimmer wall samples, estimates of entrainment not valid.

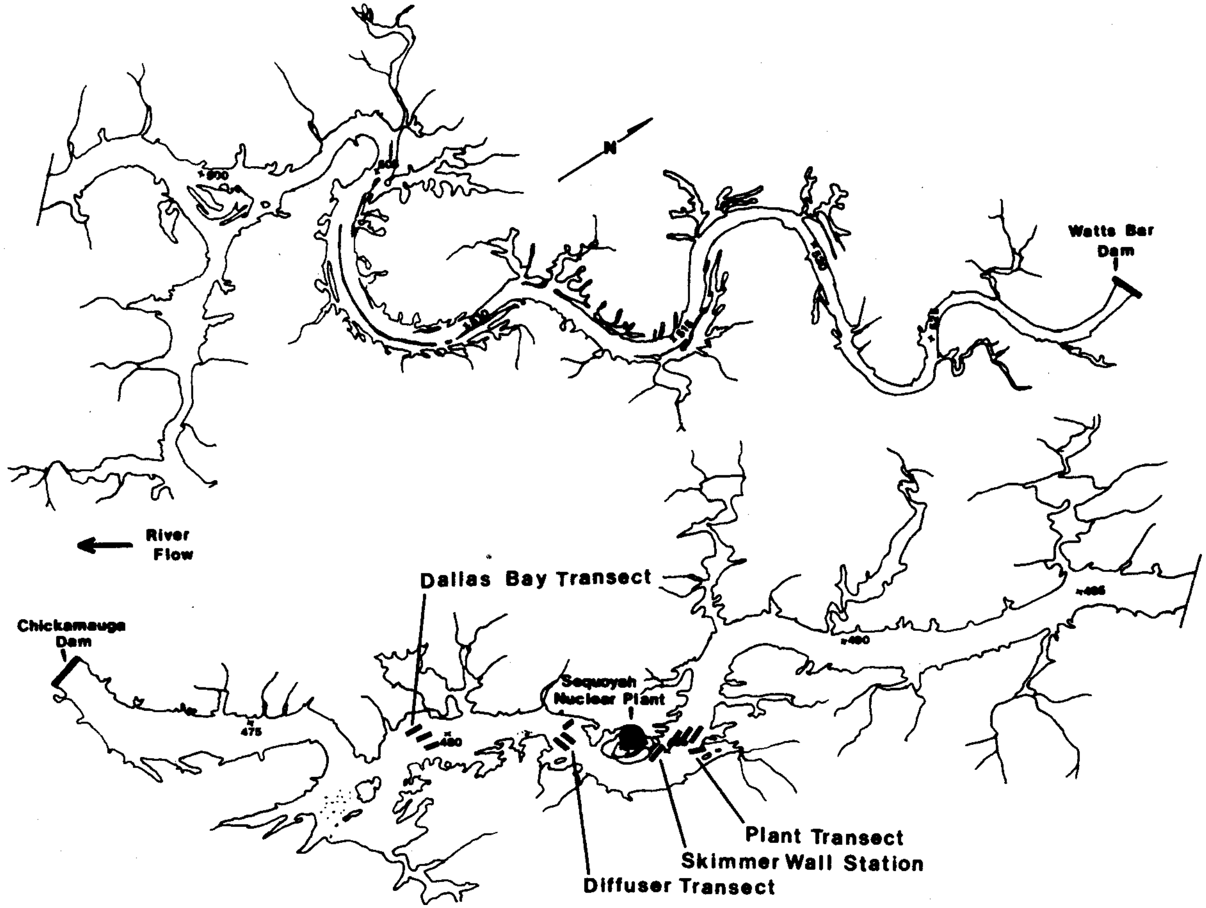

Figure 5-1. Chickamauga Reservoir Showing Location of Larval Fish Transects and Individual Sample Stations Within a Transect in Relation to Sequoyah Nuclear Plant.

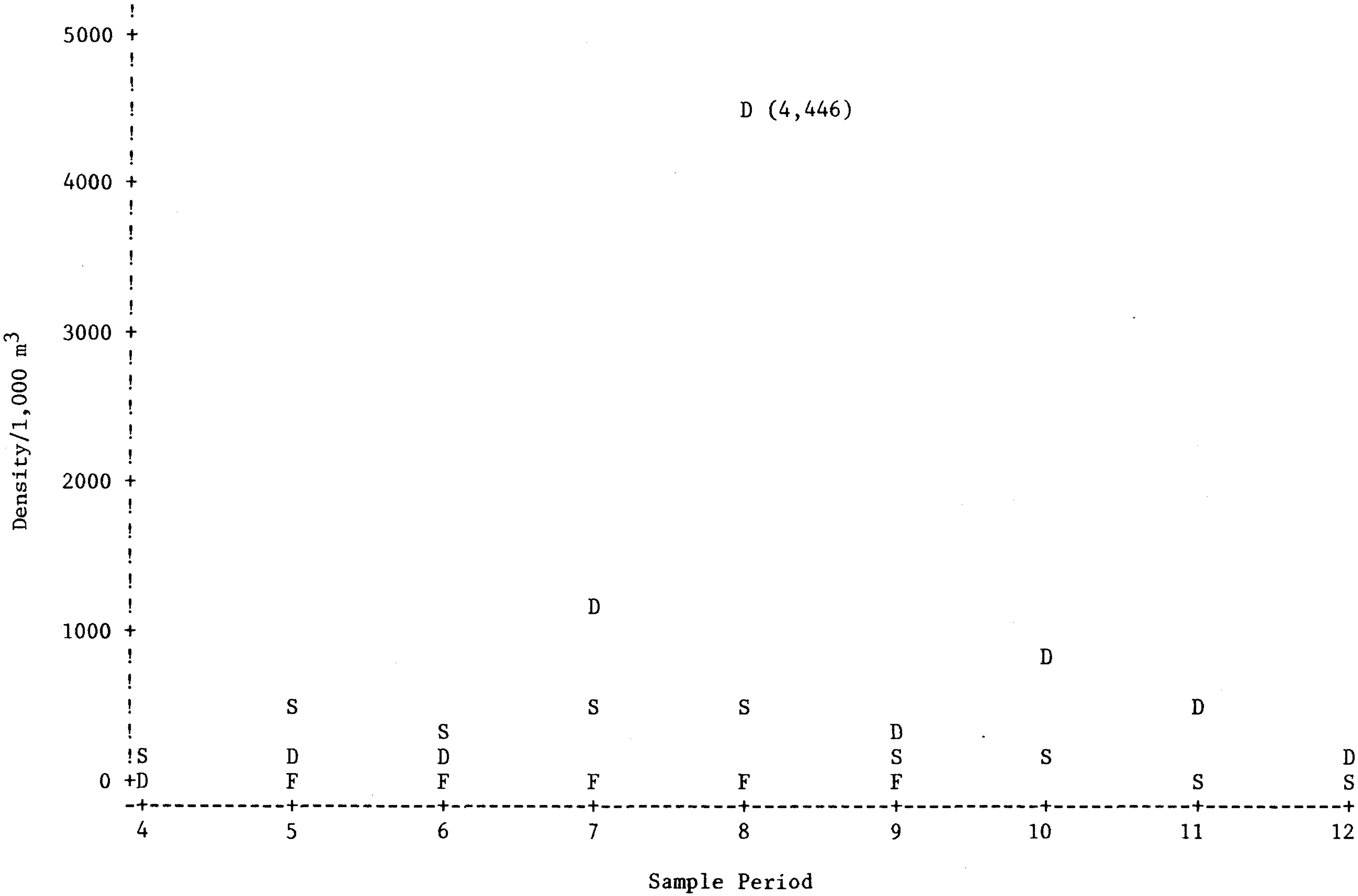

Figure 5-2. Densities (No./1,000 m^3) of Drum Eggs by Sample Period (March 18, 1982-August 17, 1982) for Each Stratum Sampled (Average of Three Reservoir Transects) at SQN, 1982. D = Deep Stratum (Channel), S = Shallow Stratum (Channel), F = Full Stratum (Near Shore).

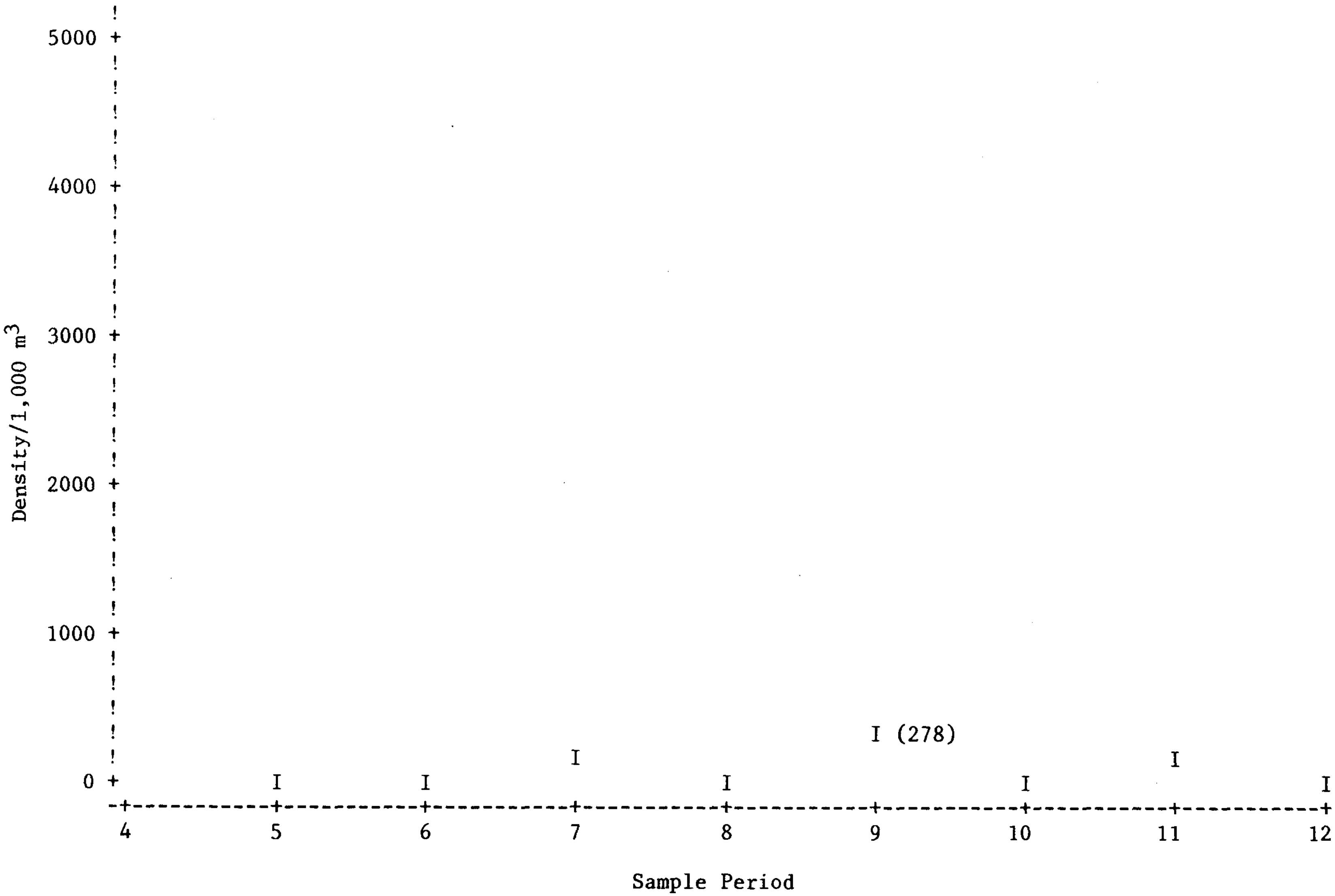

Figure 5-3. Densities (No./1,000 m^3) of Drum Eggs by Sample Period (March 18, 1982-August 17, 1982) Estimated from Samples Collected at Intake Skimmer Wall Opening (9-13 m Stratum), SQN, 1982. I = Intake.

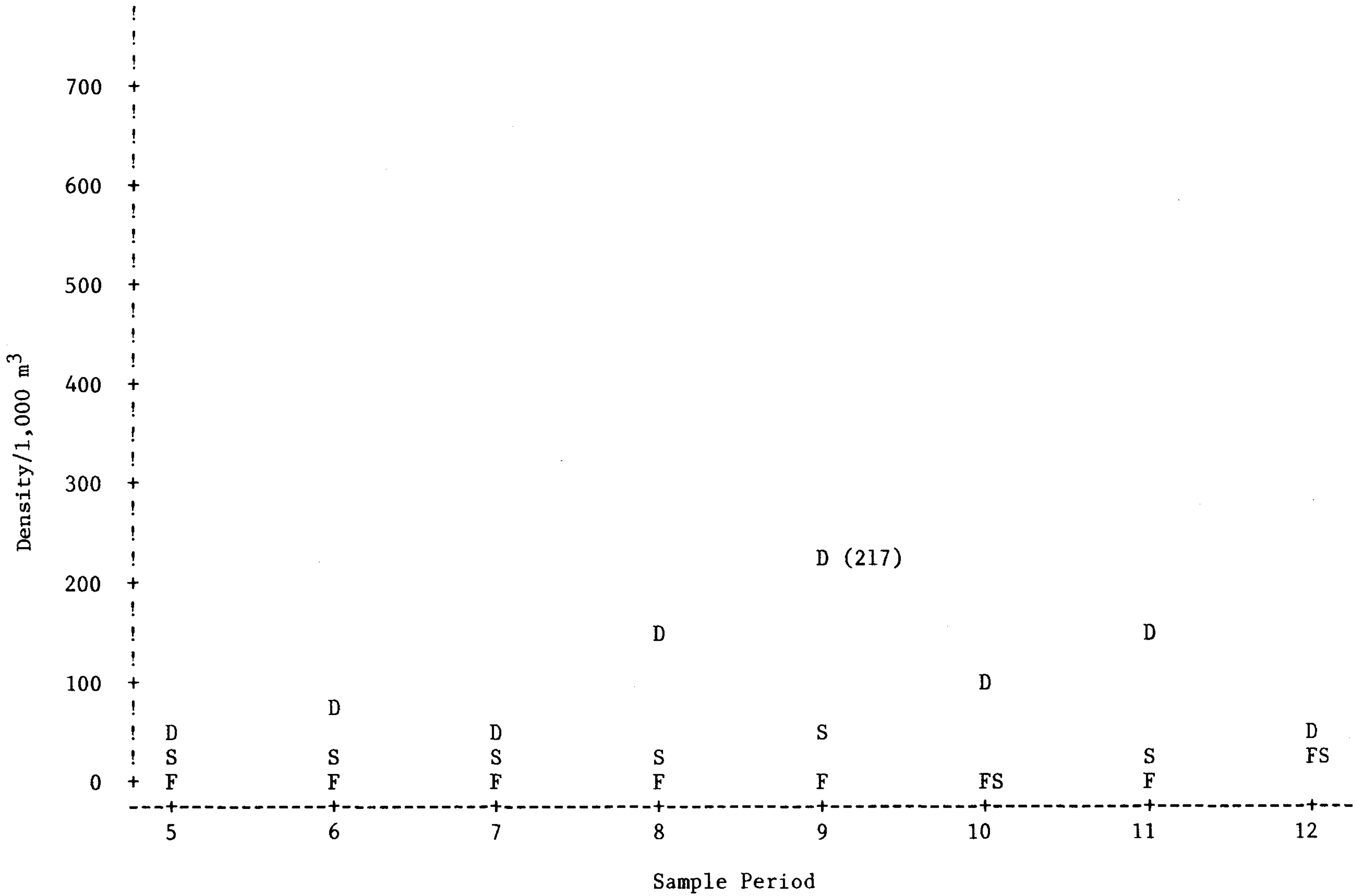

Figure 5-4. Densities (No./1,000 m^3) of Drum Larvae Near SQN by Sample Stratum at Three Reservoir Transects (Combined Average) Sample Period March 18, 1982-August 17, 1982. D = Deep (Channel), S = Shallow (Channel), F = Full Stratum (Near Shore).

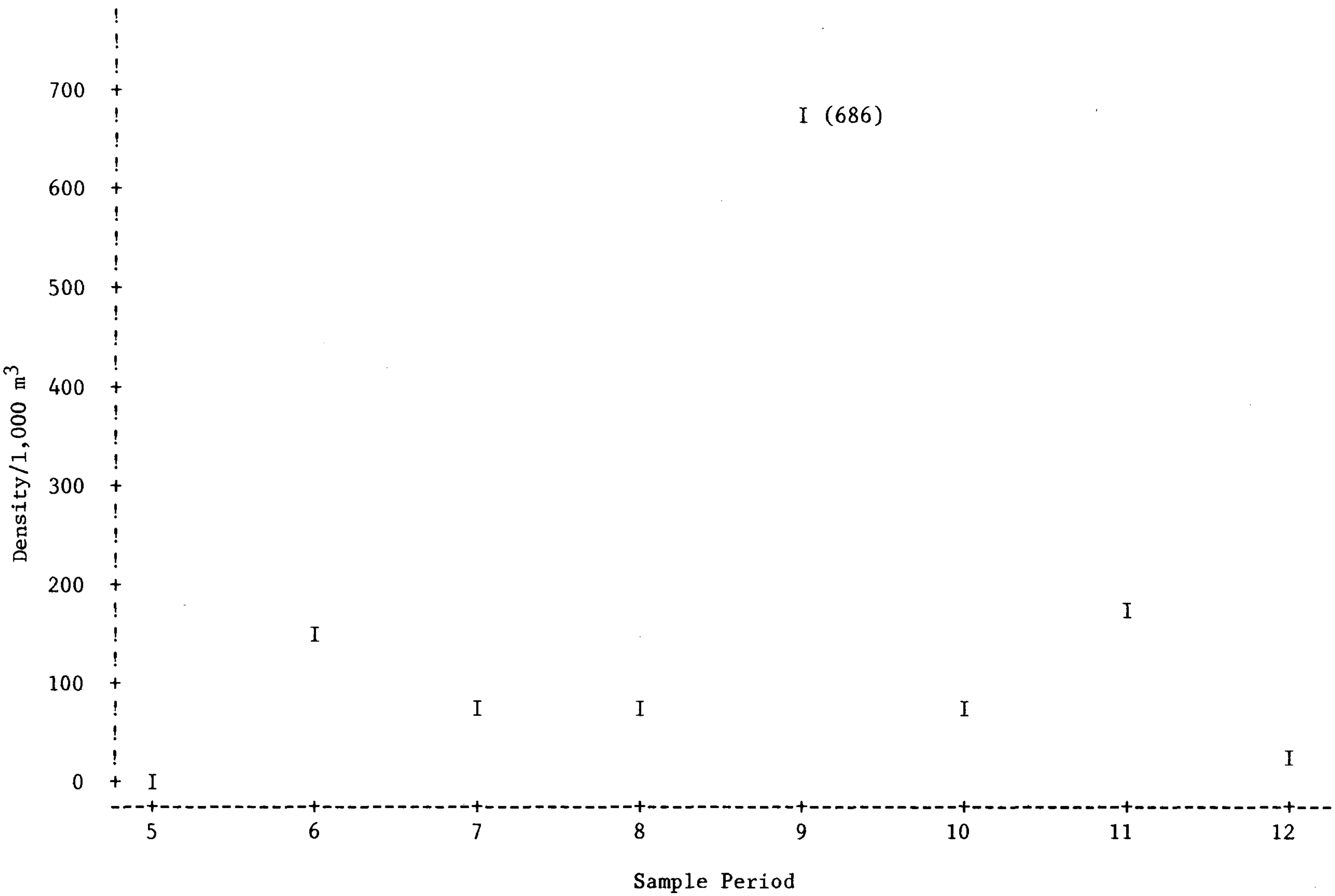

Figure 5-5. Densities (No./1,000 m^3) of Drum Larvae Collcted at SQN Intake Skimmer Wall (9-13 m depth) by Sample Period (March 18, 1982-August 17, 1982).

5.2 JUVENILE AND ADULT FISH

5.2.1 Impingement

Data from weekly SQN impingement samples for the period May 1980 through December 1981 were presented in TVA (1982a). Between early January 1982 and late December 1982, 49 additional weekly impingement samples were taken.

Materials and Methods

To start a sample at each pumping station (ERCW and CCW) all screens were rotated and sprayed simultaneously to remove all fish and debris. Screens were then left stationary for 24 hours. To end the sample each screen in use during the 24 hour period was individually rotated and sprayed to remove impinged fish. These fish were collected from the screen wash water as the water passed through a retrieval basket. Impinged fish were identified to species and separated into 25 mm length classes. Number and total weight of fish in each length class were recorded and later entered into the computer. Estimates of monthly and annual total impingement were made by multiplying average number of fish impinged per sample by number of days in each month and year.

Results and Discussion

In 1982, 29 species totalling 5,497 fish were collected in samples from both pumping stations (table 5-8). Threadfin shad and gizzard shad accounted for 63 percent of fish impinged. Next were freshwater drum and bluegill (13.9 and 8.7 percent, respectively). None of the species impinged were listed as threatened, endangered, or of special concern by the State of Tennessee or the U.S. Fish and Wildlife Service.

Of the four ERCW screens, an average of 3.53 were in operation on sample days in 1982. Only 308 fish (5.6 percent of total numbers impinged) were collected at the ERCW intake. This is not surprising since these four screens account for only 0.7 percent (0.5 m^3/s) of total pumping capacity of the two intakes.

Estimate total number of fish impinged in 1982 (both intakes combined) was approximately 41,000; this compares to an estimated 70,000 fish in 1981 (table 5-9). The larger number of fish impinged in 1981 was likely due to greater plant generation during the winter season in 1981 compared to 1982 (figure 5-6).

Seasonal trends in monthly estimated impingement for 1981 and 1982 were largely masked by the influence of number of screens sampled (figure 5-6). For example, in 1981 greatest numbers of fish were impinged in December when number of CCW screens in operation was near the maximum and when impingement is often greatest at other plants. In December 1982, however, impingement of very few fish was obviously due largely to low level CCW pump operation. SQN experienced a maintenance outage throughout December; thus only a minimal amount of water was taken into the plant.

Length class frequency of impinged fish was almost identical to that observed in 1981 (TVA 1982); nearly all individuals were between 51 and 100 mm total length. Freshwater drum was an exception in both years, evidenced by approximately 50 percent of individuals larger than 176 mm.

Estimated annual impingement at SQN continued to be low relative to impingement in past years at most other TVA electric generating plants (table 5-10). Only two of TVA's 13 other plants showed lower impingement totals in past years than SQN in 1982.

Estimated numbers of fish impinged in 1982 were also low relative to estimated numbers of fish present in Chickamauga Reservoir based on summer cove rotenone samples in 1982. Percentage of standing stock removed by impingement in 1982 and hectares of standing stock (numbers) removed by impingement appeared insignificant for all fish except white bass (table 5.11). White bass standing stock was likely underestimated in cove samples, owing to the pelagic nature of this species. Impingement of 782 young-of-year white bass would not have an adverse impact on the reservoir-wide population.

To some extent number of fish impinged at SQN was underestimated because of several lost or questionable samples. Failure to obtain accurate data occurred in several instances when icing conditions or heavy accumulation of trash precluded 24 hour samples, when high water in the fish basket and return channel hampered removing impinged fish from the screen wash water, and when communication breakdown between plant and field personnel resulted in lost samples. Excessive accumulations of water-milfoil throughout August 1982 required that the screens be rotated almost continuously. As a result, no samples were obtained that month even though the plant operated at 96 percent capacity. In those cases where the problem could have been avoided, measures have been taken or are planned to avoid recurrence. Once high water problems in the catch basket are corrected, more reliable impingement estimates can be made. Assuming the present error in estimating impingement losses is low, it is unlikely these losses have significantly affected the Chickamauga Reservoir fish community.

Summary and Conclusion

Impingement losses of fish at Sequoyah Nuclear Plant are low relative to most TVA electric generating plants and to numbers of fish in Chickamauga Reservoir. Although there are some questionable data, impingement losses as presently estimated are judged to have no significant adverse impact on the reservoir-wide populations of the 29 species impinged.

Table 5-8. Numbers of Fish Impinged at Sequoyah Nuclear Plant Between January 4, 1982 and December 29, 1982 in 49 Weekly Samples of 24-hour Duration

Common Name	CCW* Intake	ERCW Intake	Total	Percentage Composition
Skipjack herring	20	0	20	0.4
Gizzard shad	1,336	2	1,338	24.3
Threadfin shad	2,024	101	2,125	38.7
Mooneye	8	0	8	0.1
Carp	1	0	1	<0.1
Silver chub	4	0	4	0.1
Golden shiner	2	0	2	<0.1
Emerald shiner	1	0	1	<0.1
Bluntnose minnow	31	1	32	0.6
Bullhead minnow	47	0	47	0.9
Blue catfish	17	0	17	0.3
Black bullhead	1	0	1	<0.1
Yellow bullhead	1	0	1	<0.1
Channel catfish	24	0	24	0.4
Flathead catfish	12	1	13	0.2
White bass	98	7	105	1.9
Yellow bass	248	2	250	4.5
Unidentified sunfish	5	0	5	0.1
Warmouth	4	2	6	0.1
Redbreast sunfish	12	1	13	0.2
Green sunfish	10	0	10	0.2
Bluegill	318	159	477	8.7
Redear sunfish	27	2	29	0.5
Spotted bass	88	2	90	1.6
Largemouth bass	7	2	9	0.2
White crappie	13	0	13	0.2
Yellow perch	52	0	52	0.9
Logperch	15	21	36	0.7
Sauger	1	0	1	<0.1
Freshwater drum	762	4	766	13.9
Unidentified fish	0	1	1	<0.1
	5,189	308	5,497	

* Condenser Cooling Water or Main Intake.

† Essential Raw Cooling Water Intake.

Table 5-9. Estimated Total Impingement of Fishes at Sequoyah Nuclear Plant

Common Name	1981*	1982†
Unidentified fish	.	7
Chestnut lamprey	29	.
Skipjack herring	73	149
Gizzard shad	453	9,967
Threadfin shad	56,582	15,829
Mooneye	37	60
Unidentified minnow	.	7
Silver chub	102	30
River chub	7	.
Golden shiner	153	15
Emerald shiner	22	7
Bluntnose minnow	22	238
Bullhead minnow	110	350
Spotted sucker	7	.
Blue catfish	102	127
Black bullhead	.	7
Yellow bullhead	7	7
Channel catfish	387	179
Flathead catfish	58	97
Mosquitofish	7	.
White bass	51	782
Yellow bass	212	1,862
Unidentified sunfish	.	37
Warmouth	153	45
Redbreast sunfish	51	97
Green sunfish	2,759	74
Bluegill	4,672	3,553
Longear sunfish	110	.
Redear sunfish	256	216
Spotted bass	117	670
Largemouth bass	44	67
White crappie	190	97
Logperch	22	268
Sauger	22	7
Freshwater drum	2,759	5,706
Total	70,021	40,944

*January 5, 1981-December 28, 1981.
†January 4, 1982-December 29, 1981.

Table 5-10. Estimated Annual Impingement at TVA Steam-Electric Generating Plants

Plant	Maximum Cooling Water Used (m3/s)	Study Period	Number of 24-hr samples	Estimated Annual* Impingement
Fossil fuel				
Allen	21.7	Aug 74-Jul 76	103	761,960
Bull Run	21.5	Aug 74-Jul 75	45	23,157
Colbert	54.6	Aug 74-Mar 76	93	889,018
Cumberland	101.9	Aug 74-Jul 76	89	1,728,483
Gallatin	42.7	Aug 74-Jul 79	222	184,482
John Sevier	28.6	Aug 74-Jul 75	45	138,870
Johnsonville	70.8	Jul 74-Mar 76	80	1,028,616
Kingston	61.0	Aug 74-Jul 75	51	344,606
Paradise	48.8	Aug 74-Jul 75	42	235,590
Shawnee	72.0	Sep 74-Aug 76	93	1,737,733
Watts Bar	17.7	Aug 74-Jul 75	42	21,752
Widows Creek	68.9	Aug 74-Apr 75	35	95,721
Nuclear				
Browns Ferry	113.5	Apr 74-Mar 75	150	5,263,546
		Apr 75-Mar 76	152	2,688,498
		Sep 76-Aug 77	54	6,673,488
Sequoyah	71.3	May 80-Dec 82	82	100,218
		Jan 82-Dec 82	49	40,944

$$^{*}\text{Estimated Annual Impingement} = \frac{\text{Total Fish Impinged in all samples}}{\text{Number of samples}} \times 365$$

Table 5-11. Estimated Percentage of Standing Stock and Number of Hectares of Standing Stock Removed from Chickamauga Reservoir by 12 Months Impingement at Sequoyah Nuclear Plant.

Common Name	1982 Mean Standing Stock (No./ha)	Percentage of Standing Stock (Numbers) Impinged† during 1982	No. of ha of Standing Stock (Numbers) Removed by Impingement
Skipjack herring	7.31	<0.01	20.38
Gizzard shad	9,443.80	0.01	1.06
Threadfin shad	370.40	0.30	42.73
Mooneye	0.00	NA‡	NA
Carp	7.02	0.01	1.00
Silver chub	0.00	NA	NA
Golden shiner	173.11	<0.01	0.09
Emerald shiner	161.84	<0.01	0.04
Bullhead minnow	554.76	<0.01	0.63
Blue catfish	0.00	NA	NA
Black bullhead	0.87	0.06	8.05
Yellow bullhead	179.13	<0.01	0.04
Channel catfish	7.12	0.18	25.14
Flathead catfish	1.74	0.39	55.75
White bass	2.38	2.29	328.57
Yellow bass	276.05	0.05	6.75
Warmouth	1,458.55	<0.01	0.03
Redbreast sunfish	2,212.50	<0.01	0.04
Green sunfish	198.78	<0.01	0.37
Bluegill	11,364.68	<0.01	0.31
Redear sunfish	4,166.23	<0.01	0.05
Spotted bass	316.28	0.01	2.12
Largemouth bass	442.69	<0.01	0.15
White crappie	126.79	<0.01	0.77
Yellow perch	65.12	0.01	5.94
Logperch	61.62	0.03	4.35
Sauger	0.00	NA	NA
Freshwater drum	223.10	0.18	25.58

*Estimated total impingement in 1982 was extrapolated from 49 weekly samples.

†Based on surface area of 14,326 ha for Chickamauga Reservoir.

‡Not applicable.

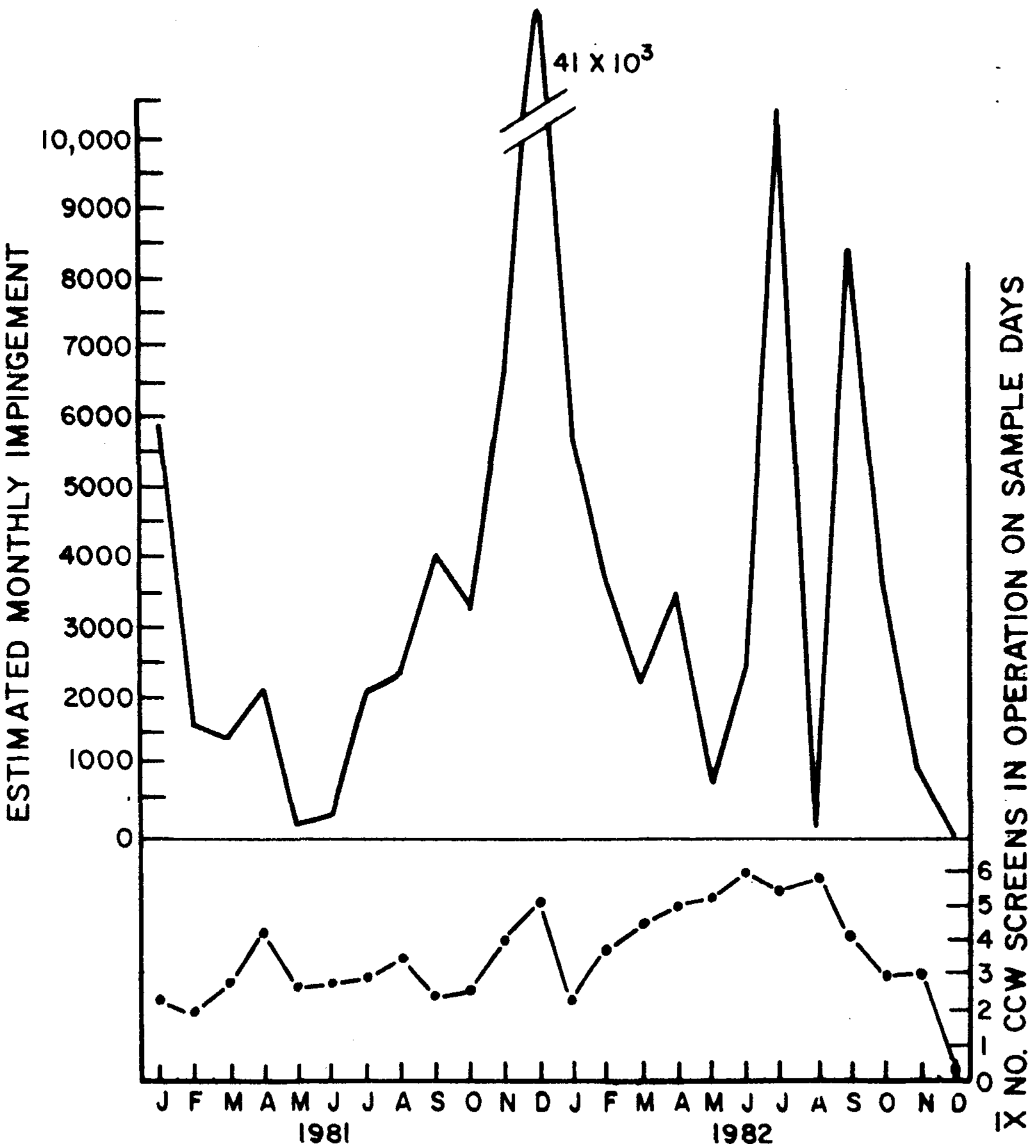

Figure 5-6. Estimated Monthly Impingement (ERCW and CCW Intakes) and Mean Number of CCW Screens in Operation During Impingement Sample Days at Sequoyah Nuclear Plant During 1981 and 1982. Note that while the plant operated at 96 percent capacity in August 1982, no samples were obtained from the CCW screens because of excessive accumulation of watermilfoil which required the intake screens be rotated continuously.

5.2.2 Gill Net

Materials and Methods

Preoperational gill net sampling at 3 stations was conducted from 1971 through early 1978 (TVA, 1978b). Gill net sampling for operational monitoring began in April 1980; data collected through November 1981 were included in the first annual operational monitoring report (TVA, 1982a). This report incorporates data from preoperational sampling and operational sampling through October 1982. Dates of operational gill net sampling at each station are in table 5-12.

Field Procedures--Ten gill nets daily were set perpendicular to the shoreline at each of three stations for one week (four nights) in each quarter (total of 120 net nights per quarter) from April 1980 through October 1982. Each net was fished approximately 24 hours before being retrieved. All nets were cleared of debris, aquatic macrophytes, etc., before being reset. Occasionally nets were lost, stolen, or clogged with debris to the point that data were useful only for qualitative information (e.g., species presence).

Sample Areas--Station 1 (TRM 473.0) was located along the right shoreline of the reservoir in an overbank area approximately 18 km (11 mi) downstream of the plant discharge (figure 5-7). Water velocity is usually low in this area. Gently sloping clay-silt substrate was predominant near the upstream end of the station with clay and rock in the downstream portion. Shoreline vegetation was composed primarily of trees and shrubs along a steep slope. Relatively few aquatic plants were present during preoperational studies; however, aquatic macrophyte infestation has become rather heavy near the water's edge since preoperational monitoring was conducted. Nets were set in depths of 2 to 5 m at this site.

At station 2 (TRM 483.6), 5 gill nets were fished along the right bank on the channel side of a partially submerged island. This area was characterized by gently sloping clay-silt substrate, slow currents, and a few scattered stumps. Riparian vegetation along the upstream portion of the island was shrubs, small trees, and grass. Emergent aquatic vegetation was the dominant cover near the downstream end. Depths in this area ranged from 1.5 to 2.5 m. The remaining five gill net sites at station 2 were on the left bank near a small island. Shoreline in this area ranged from small rocky bluffs upstream to gently sloping overbank area downstream; substrate was predominantly smooth clay, although numerous rocks and submerged trees were present near the upstream end. Shoreline vegetation was primarily shrubs and small trees rooted in shallow water. Aquatic macrophytes were present near shore and appeared to have increased in density since preoperational monitoring was completed. Water velocity was relatively low near the lower end of the station but greater in the upstream portion. Nets were set at depths of 3 to 10 m.

At station 3 (TRM 495.0), approximately 18km (11 mi) upstream of the SQN discharge, sample sites were between the right bank and a submerged island. The area was characterized by clay-silt substrate, slow current, and submerged stumps near the upstream end of the station. Small trees and shrubs were the primary riparian vegetation, and shoreline areas ranged from rock bluffs (downstream) to a gently sloping bank at the upstream end of the station. Nets were set at depths of 1 to 4.5 m.

<u>Data Analysis</u>--Gill net data were computerized for analyses. Calculations were performed to determine numbers of each fish species caught

per gill net night (c/f), species percent occurrence and composition, seasonal abundance, and spatial and temporal relative abundance. To evaluate gill net data, important species were determined according to the following criteria:

1. Must occur in 50 percent or more of all operational monitoring samples; and
2. Must comprise at least 1 percent of the total number of fish collected during operational monitoring.

Temporal Comparisons--To determine temporal trends from 1971 through 1981, a linear regression model with time as the independent variable and c/f as the dependent variable was used to test catch at each station during each of the 4 seasons. Twelve tests (4 quarters x 3 stations) were conducted for each important species.

Results and Discussion

Species Occurrence--Operational monitoring gill net samples (1980 through 1982) contained a total of 39 fish species (10 families) plus one hybrid (table 5-13). Seven species (shortnose gar, goldfish, black bullhead, brown bullhead, redbreast sunfish, orangespotted sunfish, and longear sunfish) were collected in 1982 that had not been collected during the first 2 years (1980 and 1981) of operational monitoring (TVA, 1982a). Nine species (chestnut lamprey, paddlefish, brown trout, river carpsucker, quillback, bigmouth buffalo, river redhorse, pumpkinseed, and smallmouth bass) collected during preoperational gill net sampling have not yet been collected in operational gill netting. Conversely, four species (goldfish, yellow bullhead, brown bullhead, and orangespotted sunfish) plus hybrid white bass x striped bass collected during operational sampling, were not found in preoperatonal gill net samples. None of these occurrence differences are thought to be related to operation of SQN because all, except goldfish and hybrid white x striped bass, are present in very low numbers (i.e., comprise $\leq$ 0.1 percent of total catch) and can be considered incidental in the catch. Typically, number of species collected increases with increasing number of samples. Both goldfish and hybrid white bass x striped bass are introduced species; goldfish are sold as bait and hybrid white bass x striped bass are stocked by the Tennessee Wildlife Resources Agency in some reservoirs.

Species Composition--Gizzard shad and skipjack herring were the only species which constituted 10 percent or more of the total number of fish at stations 1 and 2 from spring 1980 through fall 1982 (table 5-14). At station 3, only gizzard shad comprised $\geq$10 percent of the total catch. Results from preoperational monitoring were similar, with only 1 other species (mooneye) comprising $\geq$10 percent of the preoperational catch at any station.

Total catch during operational monitoring was similar between stations 2 and 3, with catch at station 1 approximately one-third less than at either of the other stations (table 5-14). Species appreciably more abundant at stations 2 and 3 than at station 1 were: spotted gar, longnose gar, gizzard shad, mooneye, spotted sucker, channel catfish, redear sunfish, yellow perch, and freshwater drum. Skipjack herring, white bass, hybrid white bass x striped bass, spotted bass, and white crappie were noticeably more abundant in samples from station 1 than from stations 2 or 3. Carp and blue catfish were most abundant at station 2.

At station 1, mean c/f for fall quarters was highest in each of the 3 years of operational monitoring (table 5-15). Winter quarter catches were consistently lower than in any other quarter at station 1.

Similar to station 1, station 2 c/f was also lowest in winter (table 5-16). However, at station 2, fall quarter c/f was highest only in 1980, while in 1981 and 1982, summer quarter c/f was greatest.

At station 3, highest c/f in 1981 occurred during winter quarter, whereas in 1982, summer quarter values were highest (table 5-17). Most of the large catch during winter quarter 1981 is attributable to relatively large numbers of gizzard shad at station 3 (16.23 fish/net night) compared to stations 1 and 2 (0.33 and 0.07 fish/net night, respectively). A similar pattern was evident in winter 1982; gizzard shad c/f was 0.30, 0.46, and 8.53 at stations 1, 2, and 3, respectively. Lowest c/f at station 3 was recorded in fall 1981.

Important species--Each of the following important species is discussed in terms of spatial comparisons, temporal trends, and preoperational vs operational differences in gill net catch.

Skipjack herring--Fall quarter catches at skipjack herring at station 1 (downstream of SQN) were consistently highest among the three stations in operational monitoring (figure 5-8). During preoperational monitoring (summer of 1973 through spring of 1977), highest catches were usually observed at station 2 (TVA, 1978b). Operational data to this point did not indicate this trend, however, as station 2 showed highest c/f in only 3 of 11 quarters of operational monitoring. Since 1971, skipjack herring catches have shown neither increasing nor decreasing trends (in a statistically identifiable sense) at any station during any season.

Gizzard shad--With the exception of unusually high catches of gizzard shad at station 3 in winters of 1981 and 1982, operational monitoring c/f followed similar seasonal patterns among stations (figure 5-9). As noted in the preoperational report (TVA, 1978b), summer quarter catches during operational monitoring were consistently highest at station 2 (immediately downstream of the diffuser). There has been no evidence of avoidance of this area since operation of SQN commenced. Fall quarter catches at station 2 were also frequently higher than at other stations.

Linear regression analyses over the period 1971 through 1982 indicated winter and spring quarter c/f values for gizzard shad exhibited an increasing trend at station 3 through time (table 5-18). Most of these increases occurred in 1981 and 1982 (since plant operation began) (table 5-19). However, because both of these statistically significant trends occurred upstream of SQN only, it is unlikely they are related to plant operation.

Mooneye--Consistent with preoperational monitoring, mooneye were most abundant at station 3 and did not consistently exhibit any trends in seasonal abundance (figure 5-10). Linear regression analyses indicated no significant c/f trends since 1971 at any station during any of the 4 seasons.

Spotted sucker--Similar to preoperational monitoring, spotted sucker c/f was consistently highest at station 3 during winter quarter (figure 5-11). Also, lowest c/f values usually occurred at station 1. Linear regression analyses failed to indicate significant trends at any station during any of the 4 seasons.

Blue catfish--As during preoperational monitoring, blue catfish were frequently most abundant at station 2 with peak annual c/f at this station in spring or summer quarters (figure 5-12). Linear regression analyses failed to reveal any significant trends.

Channel catfish--Preoperational monitoring generally showed highest catches of this species during summer quarter and lowest catches during the winter. Operational monitoring to date has shown peak catches to occur in either spring, summer, or fall with lowest catches consistently during winter (figure 5-13).

Statistical analyses showed summer quarter catch at station 2 declined through time (table 5-18). Table 5-19 reveals 1980 through 1982 catches at station 2 were approximately half those of the first 3 years of preoperational monitoring. However, declines to current levels occurred by 1977, three years prior to fuel loading. Because channel catfish are very tolerant of warm temperatures, it is unlikely that this declining trend immediately downstream of the diffuser is related to operation of SQN, even during summer months. No other statistically significant trends were found.

White bass--During preoperational monitoring, except for 3 periods of unusually high catches, c/f of white bass was low (generally less than 0.5 fish/net night), with no seasonal pattern of abundance evident. Operational monitoring from 1980 through 1982 revealed similar results (figure 5-14), with only 3 unusually high catches (1 at each station during either summer or fall quarters) and no discernable pattern of seasonal abundance.

Only 1 of 12 linear regression analyses showed a statistically significant trend (table 5-18). White bass were found to be increasing at station 2 (immediately downstream of the diffuser) during summer (table 5-19). White bass is a schooling species, and attraction to the diffuser discharge area is a possible explanation.

Yellow bass--Yellow bass was not identified as an important species in preoperational gill net samples. During the period of operational monitoring no seasonal patterns or consistent station differences could be discerned, with the possible exception of relatively high c/f at all stations during spring quarter (figure 5-15).

Only one of twelve linear regression analyses revealed a statistically significant trend. Yellow bass catches were found to be increasing at station 1 during summer quarters (tables 5-18 and 5-19). Although not statistically identifiable, catches during all quarters appeared to be increasing at most stations. This may reflect a general increase in yellow bass abundance in Chickamauga Reservoir.

Bluegill--During preoperational monitoring c/f of bluegill was generally low at all stations (≤0.6 fish per net night). Catches were often higher at station 3 than at other stations, and a general seasonal pattern occurred with highest c/f in spring or summer and lowest c/f in fall or winter. Figure 5-16 shows this seasonal pattern still apparent during operational monitoring from 1980 through 1982. In addition, c/f at station 3 remained generally higher than at the other 2 stations.

Eight of the twelve linear regression analyses showed statistically significant increasing trends (table 5-18). Spring and summer quarter catches of bluegill increased significantly at all stations (table 5-19), while fall quarter catches increased only at stations 1 and 2 (table 5-19). These increases probably reflect a general increase in bluegill abundance, most likely associated with increased abundance of aquatic macrophytes in Chickamauga Reservoir, rather than any influence on bluegill abundance caused by SQN.

Redear sunfish--Similar to preoperational monitoring results, in operational samples redear sunfish were usually least abundant at station 1 with catches similar between the other 2 stations (figure 5-17). Seasonal abundance patterns showed consistently low catches during winter and relatively high catches during the other three seasons. Linear regression analyses did not reveal any significant trends.

Spotted bass--During preoperational monitoring, c/f values were similar among stations and, with the exception of one quarter, were less than 0.4 throughout the study. Operational monitoring results differed with catches at station 3 usually lower than at either of the other two stations (figure 5-18). Further, c/f has exceeded 0.4 at one or more stations during five of the 11 quarters of operational sampling, including 3 of the 4 quarters in 1982.

Linear regression analyses showed summer quarter catches of this species at station 1 increased from 1971 through 1982 (tables 5-18 and 5-19). No other statistically significant increasing or decreasing trends were found at any station during any of the four quarters.

White crappie--During preoperational monitoring, catches of white crappie were erratic with relatively low c/f values (generally less than 1.0) at all stations. It was also noted that populations of white crappie appeared to have decreased in Chickamauga Reservoir since 1971. Operational monitoring from 1980 through 1982 indicated that, with the exception of fall 1980, c/f of white crappie remained low (figure 5-19).

Linear regression analyses did not confirm that c/f of white crappie declined in Chickamauga Reservoir. No statistically significant trends were found.

Sauger--Sauger were not addressed as an important species in preoperational gill netting results. During operational monitoring, relative abundance of this species did not differ greatly among stations, and no pattern of seasonal abundance was apparent (figure 5-20).

Of the 12 linear regression analyses, only 1 showed a statistically significant trend. Summer quarter catches of sauger (table 5-18 and 5-19) declined at station 2 (immediately downstream of the diffuser). Avoidance of elevated temperatures in this area by sauger during summer is an effect of SQN.

Freshwater drum--In preoperational monitoring this species was more abundant at stations 2 and 4 (Hiwassee River Mile 1.0) than at stations 1 and 3. The Hiwassee River station was not sampled during operational monitoring. However, results to date indicate no consistent relationship among catches at various stations (figure 5-21). Large peaks occurred at station 2 in summer 1981 and at station 3 in summer 1982. Linear regression analyses did not reveal statistically significant trends at any station during any season.

Summary and Conclusions

Eleven quarters of gill net sampling have been conducted since fuel load of unit one. Results of these samples were compared with 28 quarters of preoperational monitoring conducted from 1971 through 1977. Of 39 fish species and one hybrid collected during operational gill netting, gizzard shad and skipjack herring were the most abundant species.

Comparisons of total annual catch among stations during operational monitoring revealed total catch at stations 2 and 3 were similar, whereas catch at station 1 was approximately one-third lower than at stations 2 or 3. Species composition at station 1 also differed from that at stations 2 and 3 with several game species most abundant at station 1.

Comparisons of preoperational and operational observations of important species revealed that for eight species (gizzard shad, mooneye, spotted sucker, blue catfish, white bass, bluegill, redear sunfish, and white crappie), seasonal abundance patterns and relative abundance among stations were not appreciably different between the two monitoring periods. In preoperational monitoring, skipjack herring were usually most abundant at station 2 (immediately downstream of the diffuser), whereas during operational monitoring this was seldom the case. During preoperational monitoring, channel catfish abundance was lowest during winter quarters and highest during summer quarters. In operational sampling, winter quarter catches of channel catfish were still lowest, but peak catches occurred during any of the other three seasons. Preoperational catches of spotted bass were similar among stations, but c/f during operational monitoring was lower at station 3 than at either stations 1 or 2. Further, peak catches of spotted bass appeared to be increasing, possibly reflecting increased abundance of spotted bass in Chickamauga Reservoir. Freshwater drum were more abundant at station 2 during preoperational monitoring than at stations 1 and 3. In operational monitoring no consistent relationship in catches of freshwater drum existed among stations.

Linear regression analyses performed on each important species detected no significant trends at any station during any of the four quarters for seven species (skipjack herring, mooneye, spotted sucker, blue catfish, redear sunfish, white crappie, and freshwater drum). Catches increased at one or more stations during one or more quarters for five species (gizzard shad, white bass, yellow bass, bluegill, and spotted bass). Catches decreased at one or more stations during one or more quarters for two species (channel catfish and sauger). Both species showed declines occurring at station 2 during summer. For channel catfish this was probably not a response to plant operation because it was first observed in 1977 (three years prior to fuel load) and because channel catfish are one of the fish species in Chickamauga least likely to avoid high temperatures. On the other hand, avoidance of elevated temperatures by sauger is to be expected during summer months and was due to operation of SQN. White bass abundance at station 2 increased during summer seasons and may have been the result of attraction to the SQN discharge area during operation.

Gill net samples during operational monitoring to date have revealed few differences from preoperational observations. Only two of the changes seen in gill netting results appear to be related to operation of SQN. Sauger were avoiding the diffuser area during summer months, and white bass were attracted to this area during the same period.

Table 5-12. Dates of Operational Gill Net Sampling near Sequoyah Nuclear Plant, Spring 1980 through Fall 1982

Quarter	Station 1*	Station 2†	Station 3‡
Spring 1980	04/7-11/80	04/14-18/80	04/21-25/80
Summer 1980	06/23-27/80	06/23-27/80	07/7-11/80
Fall 1980	09/22-26/80	09/29/80 to 10/03/80	10/6-10/80
Winter 1981	01/12-16/81	01/26-30/81	01/26-30/81
Spring 1981	04/6-10/81	04/13-17/81	04/20-24/81
Summer 1981	07/6-10/81	07/6-10/81	07/20-24/81
Fall 1981	10/5-9/81	10/5-9/81	10/5-9/81
Winter 1982	02/1-5/82	02/1-5/82	02/1-5/82
Spring 1982	04/19-23/82	04/19-23/82	04/19-23/82
Summer 1982	07/19-23/82	07/19-23/82	07/19-23/82
Fall 1982	10/18-22/82	10/18-22/82	10/18-22/82

* Tennessee River Mile (TRM) 473.0.

† TRM 483.6.

‡ TRM 495.0.

Table 5-13. A List of Species Collected with Gill Nets During Operational Sampling in Chickamauga Reservoir near Sequoyah Nuclear Plant, Spring 1980 through Fall 1982

Family	Species	Common Name
Lepisosteidae	*Lepisosteus oculatus*	Spotted gar
	Lepisosteus osseus	Longnose gar
	Lepisosteus platostomus	Shortnose gar
	Unidentified *Lepisosteus* sp.	Unidentified gar
Clupeidae	*Alosa chrysochloris*	Skipjack herring
	Dorosoma cepedianum	Gizzard shad
	Dorosoma petenense	Threadfin shad
Hiodontidae	*Hiodon tergisus*	Mooneye
Cyprinidae	*Carassius auratus*	Goldfish
	Cyprinus carpio	Carp
	Notemigonus crysoleucas	Golden shiner
Catostomidae	*Catostomus commersoni*	White sucker
	Hypentelium nigricans	Northern hog sucker
	Ictiobus bubalus	Smallmouth buffalo
	Minytrema melanops	Spotted sucker
	Moxostoma erythrurum	Golden redhorse
Ictaluridae	*Ictalurus furcatus*	Blue catfish
	Ictalurus melas	Black bullhead
	Ictalurus natalis	Yellow bullhead
	Ictalurus nebulosus	Brown bullhead
	Ictalurus punctatus	Channel catfish
	Pylodictis olivaris	Flathead catfish
Percichthyidae	*Morone chrysops*	White bass
	Morone mississippiensis	Yellow bass
	Morone saxatilis	Striped bass
	Hybrid *Morone* (*chrysops* x *saxatilis*)	Hybrid white x striped bass
Centrarchidae	*Ambloplites rupestris*	Rock bass
	Lepomis auritus	Redbreast sunfish
	Lepomis gulosus	Warmouth
	Lepomis humilis	Orangespotted sunfish
	Lepomis macrochirus	Bluegill
	Lepomis megalotis	Longear sunfish
	Lepomis microlophus	Redear sunfish
	Micropterus punctulatus	Spotted bass
	Micropterus salmoides	Largemouth bass
	Pomoxis annularis	White crappie
	Pomoxis nigromaculatus	Black crappie

Table 5-13. (Continued)

Family	Species	Common Name
Percidae	Perca flavescens	Yellow perch
	Stizostedion canadense	Sauger
	Stizostedion vitreum vitreum	Walleye
Sciaenidae	Aplodinotus grunniens	Freshwater drum

Table 5-14. Total Number, Percent Composition, and Percent Occurrence For Species of Fish Collected with Gill Nets at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant, Spring 1980 through Fall 1982

	Station 1*			Station 2†			Station 3‡		
	No.	% Comp.	% Occur.**	No.	% Comp.	% Occur.	No.	% Comp.	% Occur.
Spotted gar	0	0.00	0.00	12	0.24	45.46	7	0.14	27.27
Longnose gar	2	0.06	18.18	10	0.20	36.36	7	0.14	27.27
Shortnose gar	0	0.00	0.00	0	0.00	0.00	1	0.02	9.09
Unidentified gar	3	0.09	18.18	1	0.20	9.09	0	0.00	0.00
Skipjack herring	826	24.22	100.00	566	11.49	100.00	328	6.60	100.00
Gizzard shad	1,395	40.90	100.00	2,380	48.32	100.00	2,667	53.67	100.00
Threadfin shad	6	0.18	27.27	0	0.00	0.00	3	0.06	9.09
Mooneye	24	0.70	45.56	168	3.41	100.00	366	7.37	90.91
Goldfish	0	0.00	0.00	9	0.18	9.09	0	0.00	0.00
Carp	3	0.09	27.27	16	0.32	54.54	8	0.16	36.36
Golden shiner	0	0.00	0.00	5	0.10	36.36	12	0.24	45.46
White sucker	1	0.03	9.09	1	0.02	9.09	2	0.04	9.09
Northern hog sucker	0	0.00	0.00	0	0.00	0.00	2	0.04	18.18
Smallmouth buffalo	0	0.00	0.00	1	0.02	9.09	5	0.10	27.27
Spotted sucker	11	0.32	27.27	41	0.83	90.91	253	5.09	81.82
Golden redhorse	4	0.12	18.18	4	0.08	36.36	18	0.36	63.64
Blue catfish	82	2.40	63.64	391	7.94	90.91	24	0.48	45.46
Black bullhead	0	0.00	0.00	0	0.00	0.00	1	0.02	9.09
Yellow bullhead	0	0.00	0.00	0	0.00	0.00	5	0.10	27.27
Brown bullhead	0	0.00	0.00	0	0.00	0.00	1	0.02	9.09
Channel catfish	181	5.31	81.82	316	6.42	90.91	252	5.07	90.91
Flathead catfish	16	0.47	63.64	16	0.32	54.54	9	0.18	45.46
White bass	152	4.46	63.64	112	2.27	72.73	64	1.29	81.82
Yellow bass	171	5.01	90.91	145	2.94	90.91	208	4.19	90.91
Striped bass	2	0.06	18.18	2	0.04	18.18	1	0.02	9.09
Hybrid white x striped bass	20	0.59	18.18	0	0.00	0.00	1	0.02	9.09
Rock bass	3	0.09	9.09	1	0.02	9.09	11	0.02	18.18
Redbreast sunfish	3	0.09	27.27	1	0.02	9.09	0	0.00	0.00

Table 5-14. (Continued)

	Station 1*			Station 2†			Station 3‡		
	No.	% Comp.	% Occur.**	No.	% Comp.	% Occur.	No.	% Comp.	% Occur.
Warmouth	6	0.18	18.18	5	0.10	27.27	13	0.26	45.46
Orangespotted sunfish	0	0.00	0.00	1	0.02	9.09	0	0.00	0.00
Bluegill	113	3.31	81.82	137	2.78	90.91	246	4.95	100.00
Longear sunfish	0	0.00	0.00	1	0.02	9.09	1	0.02	9.09
Redear sunfish	6	0.18	36.36	128	2.60	81.82	123	2.48	00.00
Spotted bass	127	3.72	90.91	68	1.38	81.82	17	0.34	54.54
Largemouth bass	11	0.32	63.64	29	0.59	72.73	23	0.46	72.73
White crappie	119	3.49	90.91	85	1.73	90.91	61	1.23	90.91
Black crappie	3	0.09	9.09	1	0.02	9.09	2	0.04	18.18
Yellow perch	4	0.12	27.27	9	0.18	36.36	38	0.76	36.36
Sauger	52	1.52	100.00	76	1.54	100.00	57	1.15	81.82
Walleye	0	0.00	0.00	3	0.06	18.18	3	0.06	9.09
Freshwater drum	65	1.91	90.91	185	3.76	100.00	129	2.60	90.91
Total	3,411			4,926			4,969		

*Station 1 - Tennessee River Mile (TRM) 473.0.

†Station 2 - TRM 483.6.

‡Station 3 - TRM 495.0.

**Percentage of quarters in which a species occurred.

Table 5-15. Mean Quarterly Catch per Gill Net Night for Fish Species Collected at Station 1 (Tennessee River Mile 473.0) Located Downstream of Sequoyah Nuclear Plant Discharge on Chickamauga Reservoir, Spring 1980 through Fall 1982

Species	Sampling Quarter										
	Spring 1980	Summer 1980	Fall 1980	Winter 1981	Spring 1981	Summer 1981	Fall 1981	Winter 1982	Spring 1982	Summer 1982	Fall 1982
Longnose gar	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Unidentified gar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.00	0.00
Skipjack herring	0.08	0.83	6.27	0.13	1.45	1.94	8.00	0.08	0.43	1.62	2.64
Gizzard shad	1.85	6.23	4.15	0.33	5.25	5.91	3.30	0.30	2.18	3.12	5.35
Threadfin shad	0.00	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Mooneye	0.00	0.09	0.54	0.00	0.05	0.09	0.00	0.00	0.00	0.04	0.00
Carp	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
White sucker	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spotted sucker	0.03	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.05	0.00	0.00
Golden redhorse	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.00	0.00
Blue catfish	0.88	0.20	0.35	0.00	0.23	0.26	0.00	0.00	0.00	0.27	0.08
Channel catfish	0.63	0.54	0.88	0.00	0.68	1.11	0.15	0.00	0.62	0.27	0.13
Flathead catfish	0.05	0.11	0.00	0.00	0.00	0.03	0.08	0.00	0.05	0.04	0.02
White bass	0.00	0.00	0.62	0.00	0.03	0.09	2.83	0.00	0.05	0.23	0.15
Yellow bass	0.13	0.06	0.12	0.00	0.83	0.43	0.05	0.05	1.98	0.65	0.03
Striped bass	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Hybrid white x striped bass	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.03
Rock bass	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Redbreast sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.03
Warmouth	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.03
Bluegill	0.03	0.37	0.15	0.00	0.45	0.69	0.18	0.00	0.82	0.35	0.10
Redear sunfish	0.05	0.06	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Spotted bass	0.08	0.09	0.65	0.03	0.45	0.00	0.08	0.15	0.28	0.96	0.64
Largemouth bass	0.00	0.03	0.00	0.03	0.08	0.00	0.03	0.08	0.02	0.00	0.00
White crappie	0.05	0.03	1.65	0.00	0.43	0.94	0.20	0.11	0.08	0.15	0.05
Black crappie	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yellow perch	0.00	0.00	0.04	0.00	0.00	0.03	0.00	0.05	0.00	0.00	0.00
Sauger	0.20	0.06	0.15	0.03	0.10	0.14	0.18	0.20	0.12	0.15	0.10
Freshwater drum	0.05	0.11	0.23	0.00	0.20	0.43	0.25	0.03	0.05	0.23	0.28
Totals	4.20	8.84	16.00	0.58	10.61	12.09	15.81	1.10	6.96	8.12	9.82

Table 5-16. Mean Quarterly Catch per Gill Net Night for Fish Species Collected at Station 2 (Tennessee River Mile 483.6) Located Immediately Downstream of the Sequoyah Nuclear Plant Discharge on Chickamauga Reservoir, Spring 1980 through Fall 1982

	Sampling Quarter										
Species	Spring 1980	Summer 1980	Fall 1980	Winter 1981	Spring 1981	Summer 1981	Fall 1981	Winter 1982	Spring 1982	Summer 1982	Fall 1982
Spotted gar	0.00	0.00	0.03	0.00	0.00	0.00	0.08	0.00	0.10	0.03	0.11
Longnose gar	0.00	0.08	0.00	0.00	0.00	0.03	0.00	0.00	0.13	0.03	0.00
Unidentified gar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Skipjack herring	0.11	1.34	2.94	0.03	1.00	4.95	1.20	0.03	0.36	2.64	0.56
Gizzard shad	1.76	6.39	7.89	0.07	7.27	11.33	5.13	0.46	7.23	10.42	6.59
Mooneye	0.05	0.08	1.64	0.23	0.11	1.10	0.03	0.22	0.41	0.44	0.26
Goldfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00
Carp	0.05	0.03	0.06	0.00	0.00	0.00	0.05	0.00	0.10	0.00	0.18
Golden shiner	0.03	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.03	0.00	0.00
White sucker	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smallmouth buffalo	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spotted sucker	0.34	0.08	0.08	0.13	0.27	0.03	0.10	0.00	0.03	0.03	0.04
Golden redhorse	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00
Blue catfish	2.32	0.24	1.33	0.00	3.11	0.87	0.25	0.03	0.44	1.42	0.63
Channel catfish	0.58	0.61	3.44	0.03	0.49	0.82	0.13	0.00	1.51	0.58	0.30
Flathead catfish	0.00	0.05	0.03	0.00	0.11	0.08	0.05	0.00	0.00	0.08	0.00
White bass	0.00	0.00	0.31	0.03	0.00	0.56	0.15	0.05	0.05	1.75	0.18
Yellow bass	0.34	0.00	0.06	0.07	0.59	0.23	0.08	0.24	1.64	0.47	0.07
Striped bass	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Rock bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Readbreast sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.04
Orangespotted sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Bluegill	0.16	0.16	0.22	0.03	0.43	0.59	0.23	0.00	0.77	0.86	0.18
Longear sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Redear sunfish	0.47	0.45	0.44	0.00	0.51	0.46	0.18	0.00	0.15	0.39	0.48
Spotted bass	0.03	0.08	0.47	0.20	0.22	0.13	0.00	0.03	0.59	0.00	0.15
Largemouth bass	0.00	0.00	0.03	0.03	0.43	0.08	0.03	0.00	0.05	0.08	0.07
White crappie	0.32	0.00	0.47	0.03	0.49	0.41	0.10	0.05	0.13	0.14	0.18

Table 5-16. (Continued)

Species	Sampling Quarter										
	Spring 1980	Summer 1980	Fall 1980	Winter 1981	Spring 1981	Summer 1981	Fall 1981	Winter 1982	Spring 1982	Summer 1982	Fall 1982
Black crappie	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yellow perch	0.00	0.00	0.00	0.03	0.03	0.00	0.10	0.00	0.08	0.00	0.00
Sauger	0.13	0.26	0.14	0.30	0.30	0.21	0.13	0.05	0.31	0.17	0.07
Walleye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07
Freshwater drum	0.21	0.24	0.11	0.10	0.54	1.44	0.53	0.38	0.41	0.44	0.52
Totals	6.96	10.12	19.78	1.31	16.06	23.32	8.63	1.54	14.87	20.03	10.68

Table 5-17. Mean Quarterly Catch per Gill Net Night for Species Collected at Station 3 (Tennessee River Mile 495.0) Located Upstream of the Sequoyah Nuclear Plant Discharge on Chickamauga Reservoir, Spring 1980 through Fall 1982

	Sampling Quarter										
Species	Spring 1980	Summer 1980	Fall 1980	Winter 1981	Spring 1981	Summer 1981	Fall 1981	Winter 1982	Spring 1982	Summer 1982	Fall 1982
Spotted gar	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.03	0.00	0.05	0.00
Longnose gar	0.00	0.00	0.03	0.00	0.13	0.03	0.00	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Skipjack herring	0.05	0.38	1.38	0.33	0.18	2.18	0.63	0.13	0.30	2.90	0.24
Gizzard shad	0.68	4.25	3.90	16.23	6.20	6.03	2.23	8.53	10.90	3.59	7.69
Threadfin shad	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Mooneye	0.10	1.13	1.20	3.03	0.65	0.82	0.00	1.26	0.95	0.15	0.07
Carp	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.05	0.07
Golden shiner	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.21	0.02	0.00	0.00
White sucker	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northern hog sucker	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Smallmouth buffalo	0.00	0.00	0.05	0.00	0.00	0.06	0.00	0.03	0.00	0.00	0.00
Spotted sucker	1.30	0.45	0.38	2.13	0.85	0.38	0.10	0.53	0.30	0.00	0.00
Golden redhorse	0.00	0.10	0.08	0.08	0.05	0.00	0.00	0.05	0.05	0.05	0.00
Blue catfish	0.15	0.33	0.00	0.00	0.05	0.06	0.00	0.00	0.00	0.02	0.00
Black bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Yellow bullhead	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.08	0.00	0.00
Brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Channel catfish	0.40	1.18	0.88	0.03	0.78	1.56	0.08	0.00	0.95	0.64	0.14
Flathead catfish	0.00	0.03	0.03	0.00	0.05	0.12	0.00	0.00	0.00	0.00	0.03
White bass	0.03	0.03	0.08	0.00	0.00	0.15	0.15	0.03	0.02	0.18	1.34
Yellow bass	0.35	0.28	0.03	0.90	0.38	0.09	0.00	1.60	0.80	0.31	0.79
Striped bass	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Hybrid white x striped bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Rock bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.20	0.00	0.00
Warmouth	0.00	0.00	0.08	0.03	0.15	0.00	0.03	0.00	0.00	0.00	0.07
Bluegill	0.55	0.30	0.13	0.53	0.88	1.59	0.05	0.18	1.00	1.15	0.10

Table 5-17. (Continued)

	Sampling Quarter										
Species	Spring 1980	Summer 1980	Fall 1980	Winter 1981	Spring 1981	Summer 1981	Fall 1981	Winter 1982	Spring 1982	Summer 1982	Fall 1982
Longear sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Redear sunfish	0.20	0.48	0.55	0.25	0.40	0.47	0.08	0.10	0.10	0.36	0.24
Spotted bass	0.00	0.05	0.23	0.00	0.08	0.03	0.03	0.00	0.00	0.00	0.03
Largemouth bass	0.00	0.00	0.03	0.13	0.05	0.00	0.05	0.21	0.02	0.02	0.10
White crappie	0.13	0.20	0.33	0.23	0.15	0.21	0.00	0.05	0.10	0.15	0.03
Black crappie	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yellow perch	0.00	0.00	0.00	0.35	0.00	0.00	0.20	0.34	0.08	0.00	0.00
Sauger	0.15	0.10	0.28	0.05	0.38	0.24	0.10	0.00	0.05	0.00	0.17
Walleye	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Freshwater drum	0.03	0.38	0.43	0.00	0.23	0.24	0.10	0.05	0.40	1.31	0.21
Totals	4.20	9.70	10.13	24.33	11.86	14.38	3.99	13.41	16.39	10.93	11.41

Table 5-18. Regression Analysis of Mean Quarterly Catch per Gill Net Night for each Important Species by Sampling Quarter and Station, Sequoyah Nuclear Plant, Chickamauga Reservoir, 1971-1982

Species	Quarter	Station*	Slope	F-Value	PR>F†
Gizzard shad	Winter	3	0.68	7.24	0.0361
Gizzard shad	Spring	3	0.53	5.18	0.0489
Channel catfish	Summer	2	-0.07	9.88	0.0119
White bass	Summer	2	0.11	5.83	0.0464
Yellow bass	Summer	1	0.23	24.01	0.0392
Bluegill	Spring	1	0.05	6.47	0.0345
Bluegill	Summer	1	0.04	5.60	0.0455
Bluegill	Fall	1	0.01	13.53	0.0062
Bluegill	Spring	2	0.04	5.42	0.0484
Bluegill	Summer	2	0.05	10.07	0.0131
Bluegill	Fall	2	0.02	6.44	0.0348
Bluegill	Spring	3	0.07	24.85	0.0011
Bluegill	Summer	3	0.08	6.06	0.0392
Spotted bass	Summer	1	0.05	5.50	0.0470
Sauger	Summer	2	-0.04	22.11	0.0424

*Station 1 - Tennessee River Mile (TRM) 473.0.
Station 2 - TRM 483.6.
Station 3 - TRM 495.0.

†Probability of obtaining a value greater than F. Only those values with a probability level of 0.05 or less are listed.

Table 5-19. Mean Quarterly Catch per Gill Net Night (c/f) Values for Species Showing Significant Trends, Sequoyah Nuclear Plant, Chickamauga Reservoir, 1971-1982

Species	Quarter	Station*	Year	c/f
Gizzard shad	Winter	3	1972	0.48
	Winter	3	1973	1.70
	Winter	3	1974	1.62
	Winter	3	1975	5.60
	Winter	3	1976	5.02
	Winter	3	1977	6.42
	Winter	3	1978	1.35
	Winter	3	1981	16.23
	Winter	3	1982	8.53
Gizzard shad	Spring	3	1971	2.08
	Spring	3	1972	0.70
	Spring	3	1973	0.98
	Spring	3	1974	2.05
	Spring	3	1975	2.32
	Spring	3	1976	13.40
	Spring	3	1977	5.20
	Spring	3	1979	2.80
	Spring	3	1980	0.68
	Spring	3	1981	6.20
	Spring	3	1982	10.90
Channel catfish	Summer	2	1971	1.45
	Summer	2	1972	1.55
	Summer	2	1973	1.25
	Summer	2	1974	0.72
	Summer	2	1975	0.50
	Summer	2	1976	0.98
	Summer	2	1977	0.58
	Summer	2	1979	0.60
	Summer	2	1980	0.61
	Summer	2	1981	0.82
	Summer	2	1982	0.58
White bass	Summer	2	1971	0.21
	Summer	2	1972	0.20
	Summer	2	1973	0.48
	Summer	2	1974	0.22
	Summer	2	1975	0.02
	Summer	2	1976	0.08
	Summer	2	1977	1.40
	Summer	2	1979	0.07
	Summer	2	1980	0.00
	Summer	2	1981	0.56
	Summer	2	1982	1.75

Table 5-19. (Continued)

Species	Quarter	Station*	Year	c/f
Yellow bass	Summer	1	1971	0.00
	Summer	1	1972	0.00
	Summer	1	1973	0.03
	Summer	1	1974	0.00
	Summer	1	1975	0.00
	Summer	1	1976	0.11
	Summer	1	1977	0.43
	Summer	1	1979	0.02
	Summer	1	1980	0.06
	Summer	1	1981	0.43
	Summer	1	1982	0.65
Bluegill	Spring	1	1971	0.15
	Spring	1	1972	0.00
	Spring	1	1973	0.05
	Spring	1	1974	0.14
	Spring	1	1975	0.00
	Spring	1	1976	0.05
	Spring	1	1977	0.12
	Spring	1	1979	0.05
	Spring	1	1980	0.02
	Spring	1	1981	0.45
	Spring	1	1982	0.82
Bluegill	Summer	1	1971	0.05
	Summer	1	1972	0.10
	Summer	1	1973	0.42
	Summer	1	1974	0.05
	Summer	1	1975	0.02
	Summer	1	1976	0.22
	Summer	1	1977	0.60
	Summer	1	1979	0.08
	Summer	1	1980	0.37
	Summer	1	1981	0.69
	Summer	1	1982	0.35
Bluegill	Fall	1	1971	0.00
	Fall	1	1972	0.00
	Fall	1	1973	0.05
	Fall	1	1974	0.00
	Fall	1	1975	0.02
	Fall	1	1976	0.00
	Fall	1	1977	0.00
	Fall	1	1980	0.15
	Fall	1	1981	0.18
	Fall	1	1982	0.10

Table 5-19. (Continued)

Species	Quarter	Station*	Year	c/f
Bluegill (cont.)	Spring	2	1971	0.32
	Spring	2	1972	0.10
	Spring	2	1973	0.05
	Spring	2	1974	0.07
	Spring	2	1975	0.05
	Spring	2	1976	0.15
	Spring	2	1977	0.15
	Spring	2	1980	0.16
	Spring	2	1981	0.43
	Spring	2	1982	0.77
Bluegill	Summer	2	1971	0.11
	Summer	2	1972	0.05
	Summer	2	1973	0.28
	Summer	2	1974	0.02
	Summer	2	1975	0.05
	Summer	2	1976	0.08
	Summer	2	1977	0.28
	Summer	2	1979	0.05
	Summer	2	1980	0.16
	Summer	2	1981	0.59
	Summer	2	1982	0.86
Bluegill	Fall	2	1971	0.08
	Fall	2	1972	0.08
	Fall	2	1973	0.08
	Fall	2	1974	0.03
	Fall	2	1975	0.00
	Fall	2	1976	0.00
	Fall	2	1977	0.02
	Fall	2	1979	0.02
	Fall	2	1980	0.22
	Fall	2	1981	0.23
	Fall	2	1982	0.18
Bluegill	Spring	3	1971	0.00
	Spring	3	1972	0.35
	Spring	3	1973	0.22
	Spring	3	1974	0.20
	Spring	3	1975	0.18
	Spring	3	1976	0.40
	Spring	3	1977	0.18
	Spring	3	1979	0.15
	Spring	3	1980	0.55
	Spring	3	1981	0.88
	Spring	3	1982	1.00

Table 5-19. (Continued)

Species	Quarter	Station*	Year	c/f
Bluegill	Summer	3	1971	0.50
	Summer	3	1972	0.12
	Summer	3	1973	0.38
	Summer	3	1974	0.18
	Summer	3	1975	0.45
	Summer	3	1976	0.12
	Summer	3	1977	0.32
	Summer	3	1979	0.08
	Summer	3	1980	0.30
	Summer	3	1981	1.59
	Summer	3	1982	1.15
Spotted bass	Summer	1	1971	0.12
	Summer	1	1972	0.05
	Summer	1	1973	0.02
	Summer	1	1974	0.05
	Summer	1	1975	0.02
	Summer	1	1976	0.05
	Summer	1	1977	0.20
	Summer	1	1979	0.13
	Summer	1	1980	0.09
	Summer	1	1981	0.00
	Summer	1	1982	0.96
Sauger	Summer	2	1971	0.00
	Summer	2	1972	0.00
	Summer	2	1973	0.08
	Summer	2	1974	0.05
	Summer	2	1975	0.10
	Summer	2	1976	0.18
	Summer	2	1977	0.15
	Summer	2	1979	0.27
	Summer	2	1980	0.26
	Summer	2	1981	0.21
	Summer	2	1982	0.16

*Station 1 - Tennesse River Mile (TRM) 473.0.
Station 2 - TRM 483.6.
Station 3 - TRM 495.0.

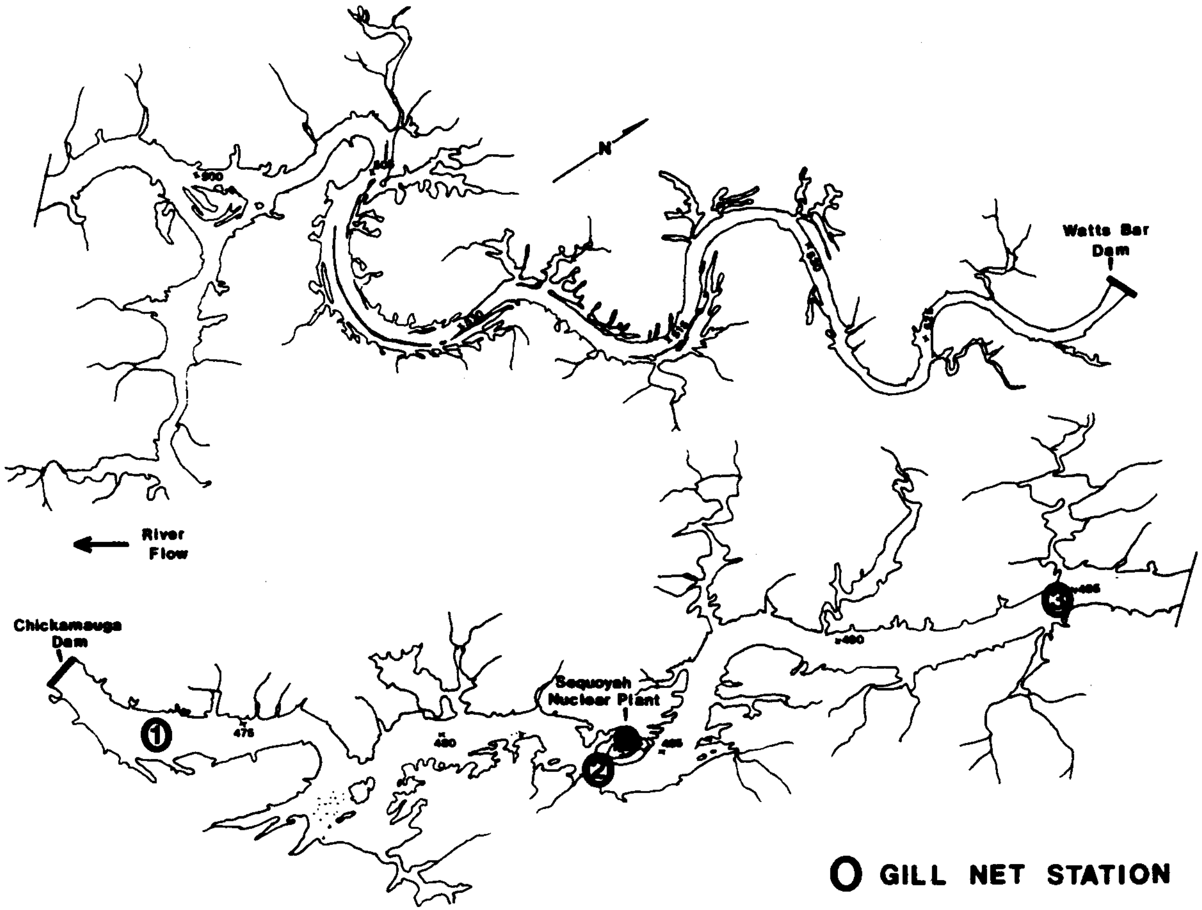

Figure 5-7. Location of Gill Net Sampling Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant.

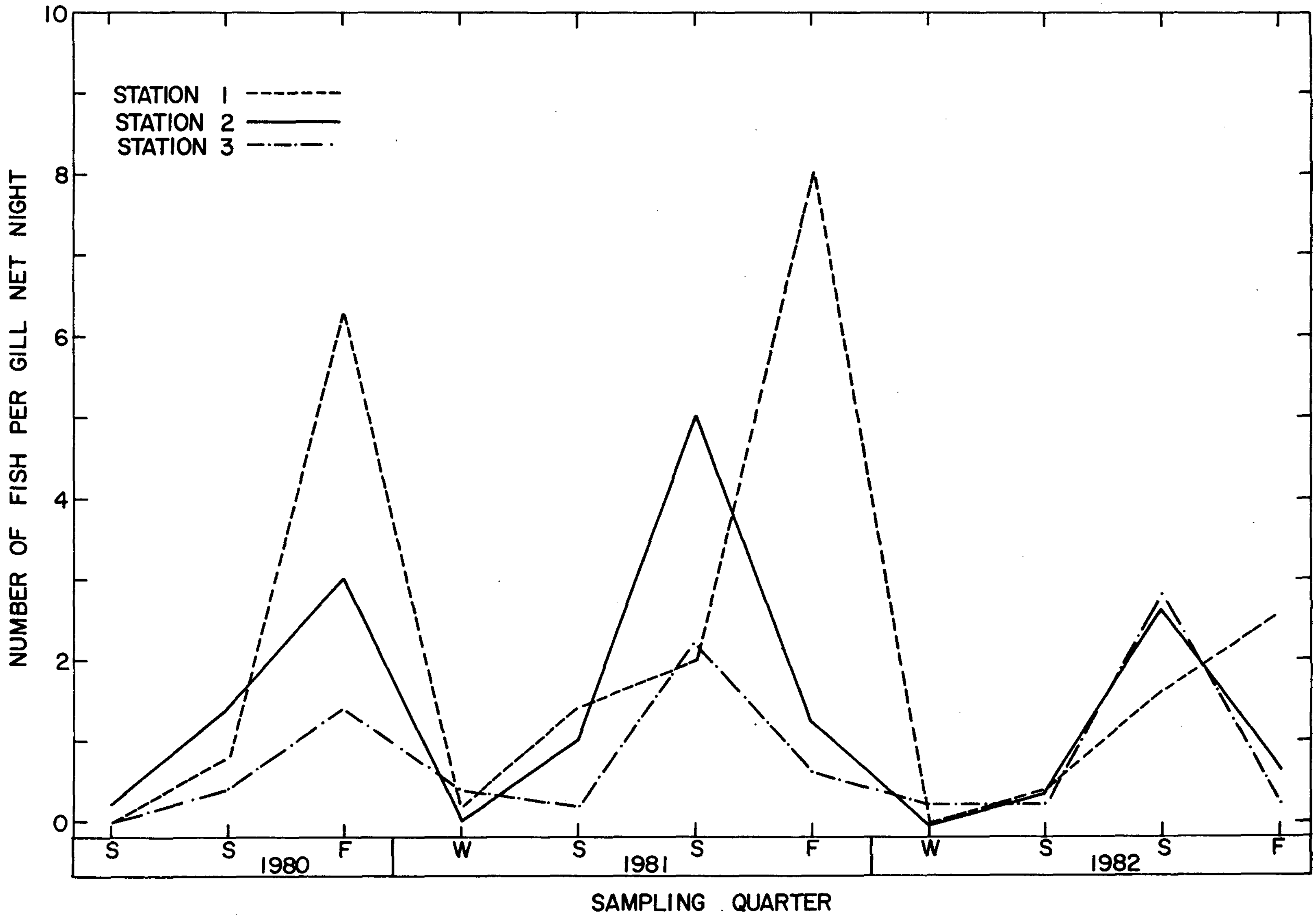

Figure 5-8. Mean Quarterly Catch per Gill Net Night for Skipjack Herring (Alosa chrysochloris) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

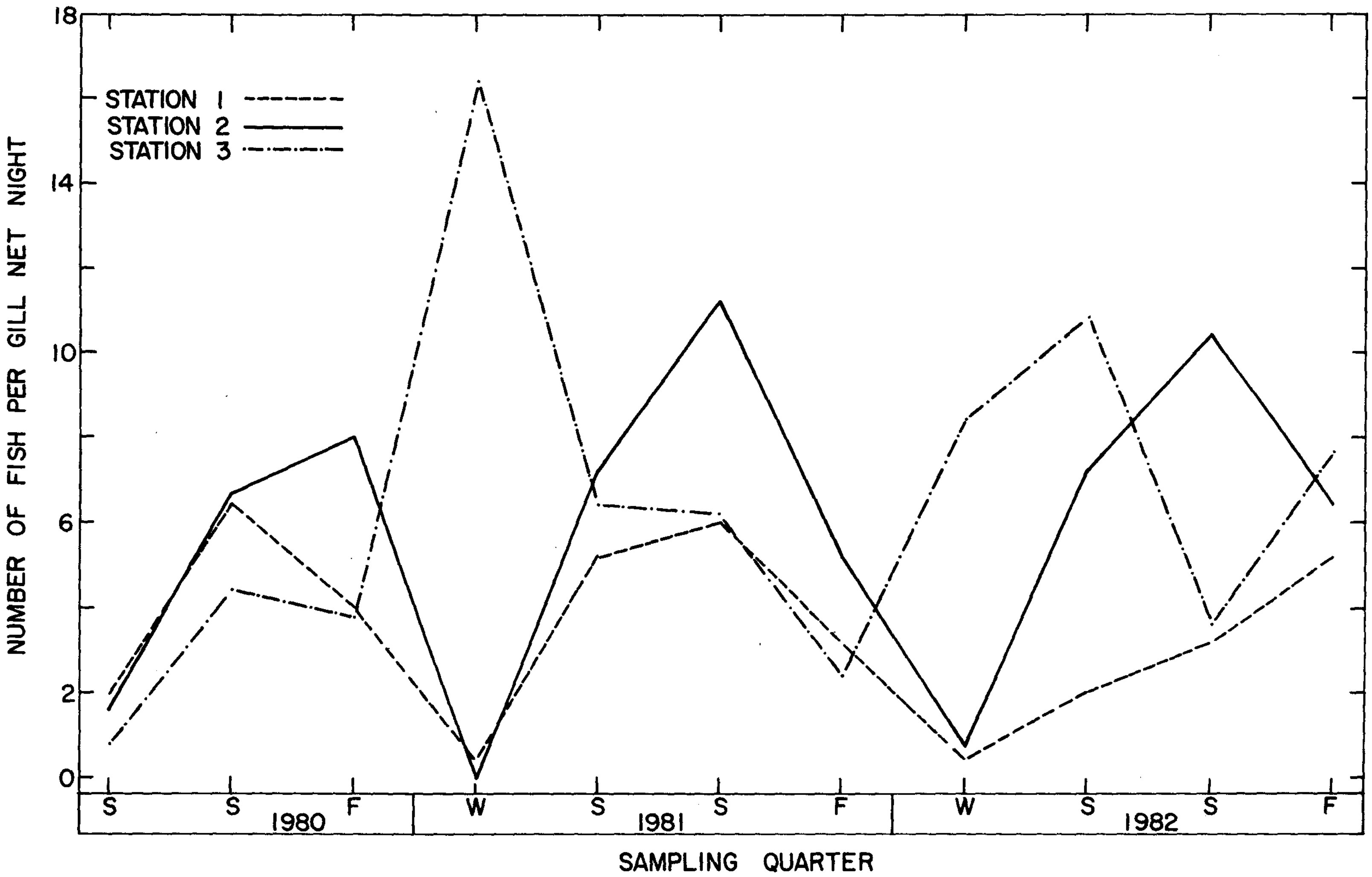

Figure 5-9. Mean Quarterly Catch per Gill Net Night for Gizzard Shad (Dorosoma cepedianum) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

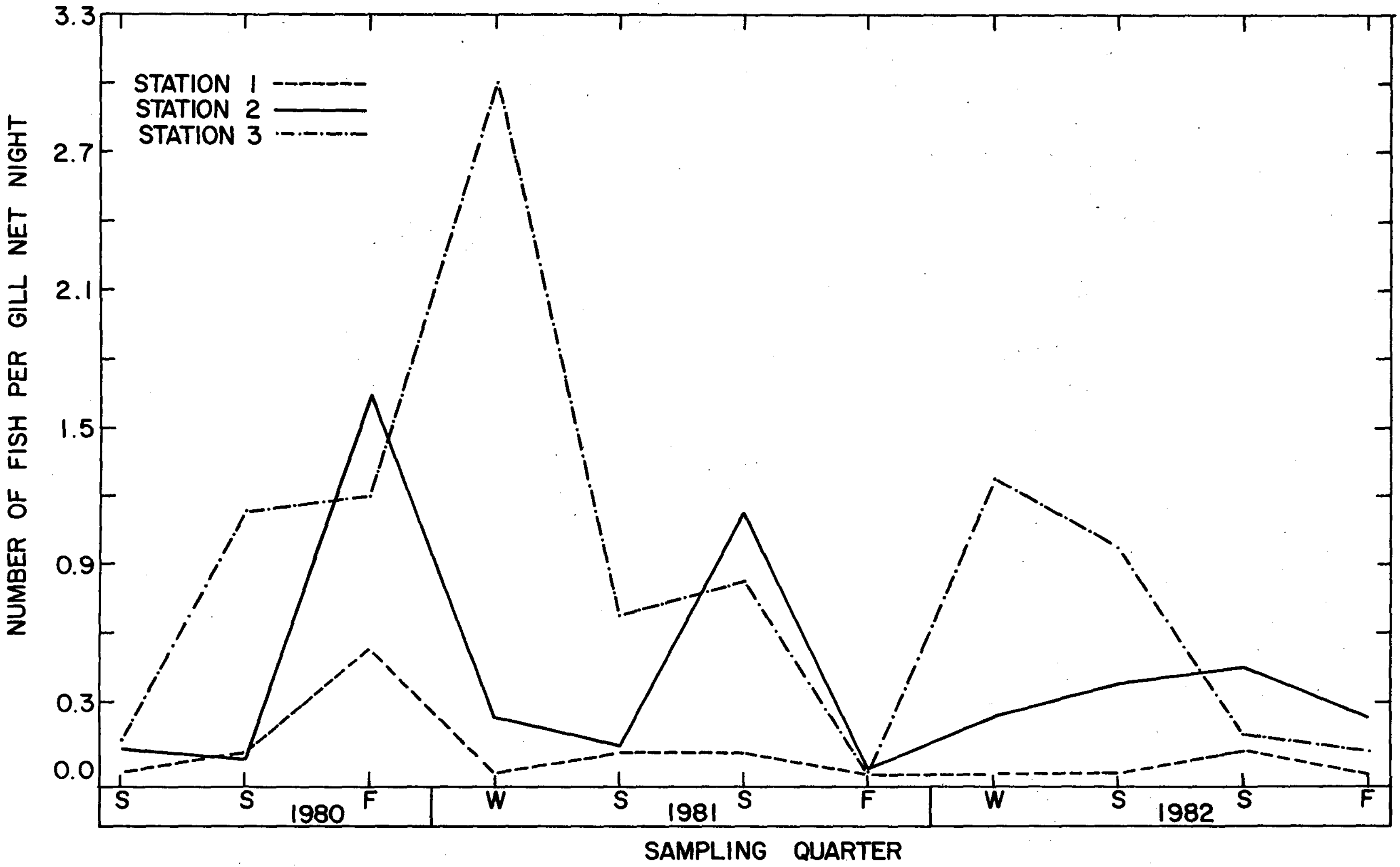

Figure 5-10. Mean Quarterly Catch per Gill Net Night for Mooneye (Hiodon tergisus) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

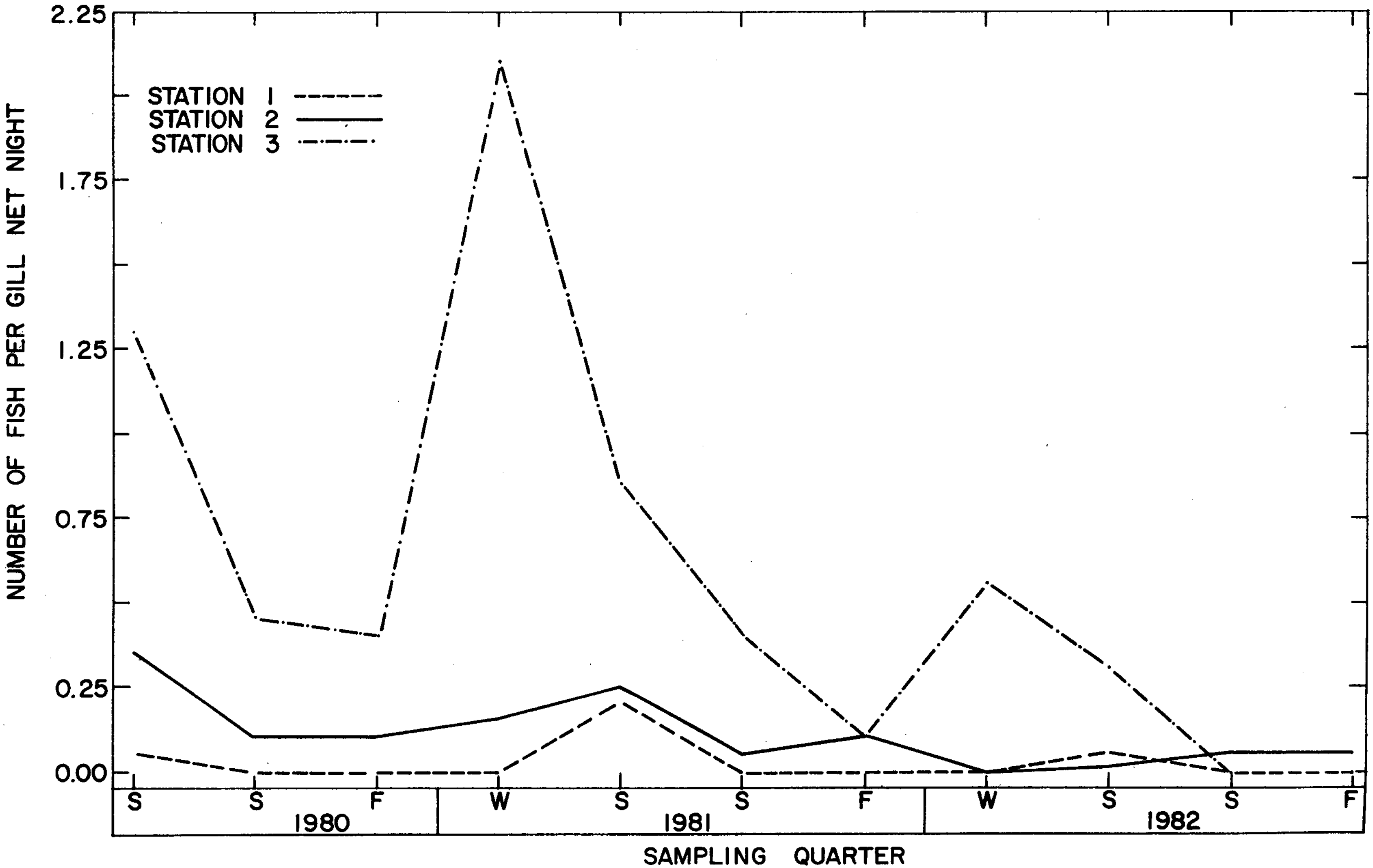

Figure 5-11. Mean Quarterly Catch per Gill Net Night for Spotted Sucker (*Minytrema melanops*) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

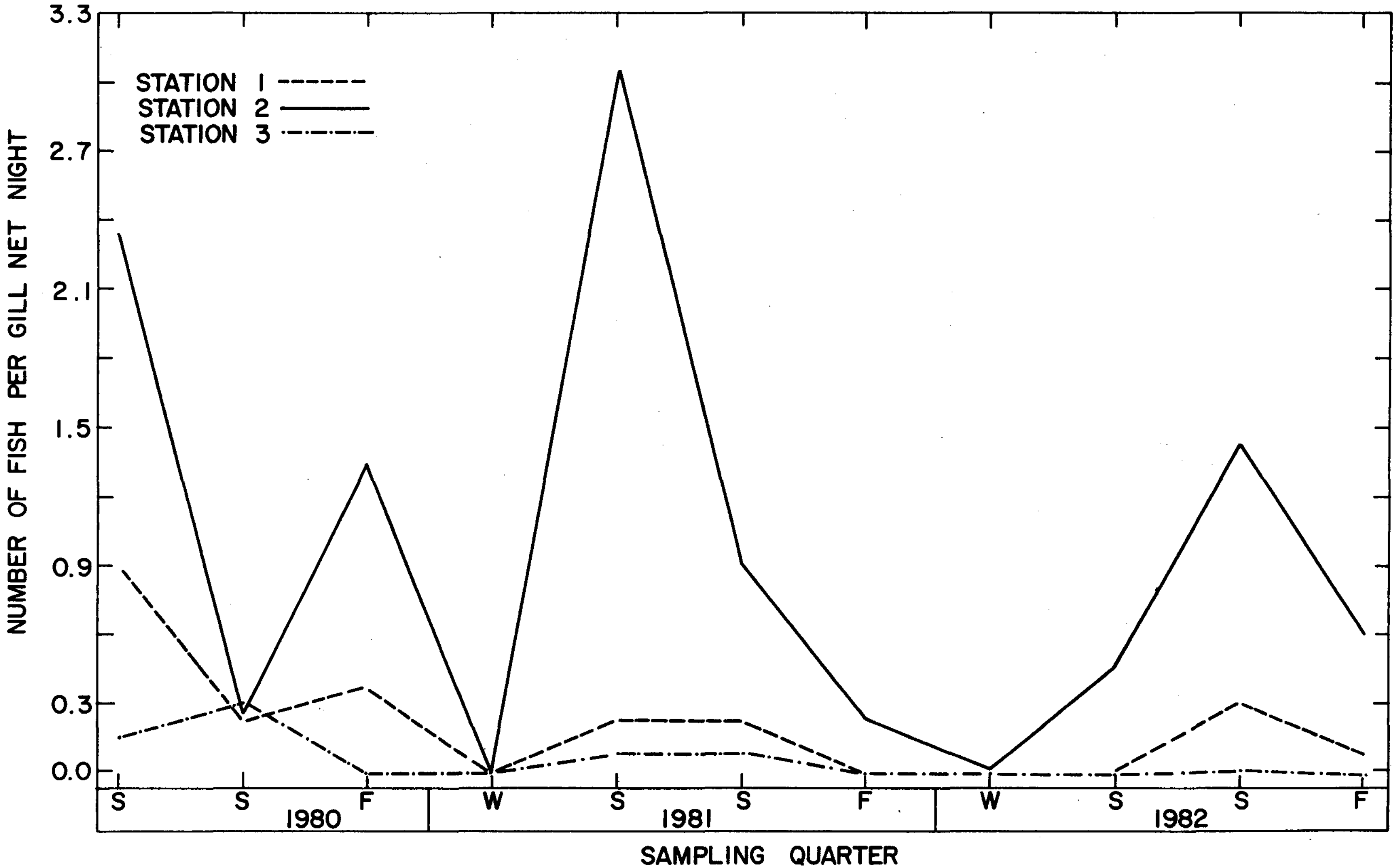

Figure 5-12. Mean Quarterly Catch per Gill Net Night for Blue Catfish (Ictalurus furcatus) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

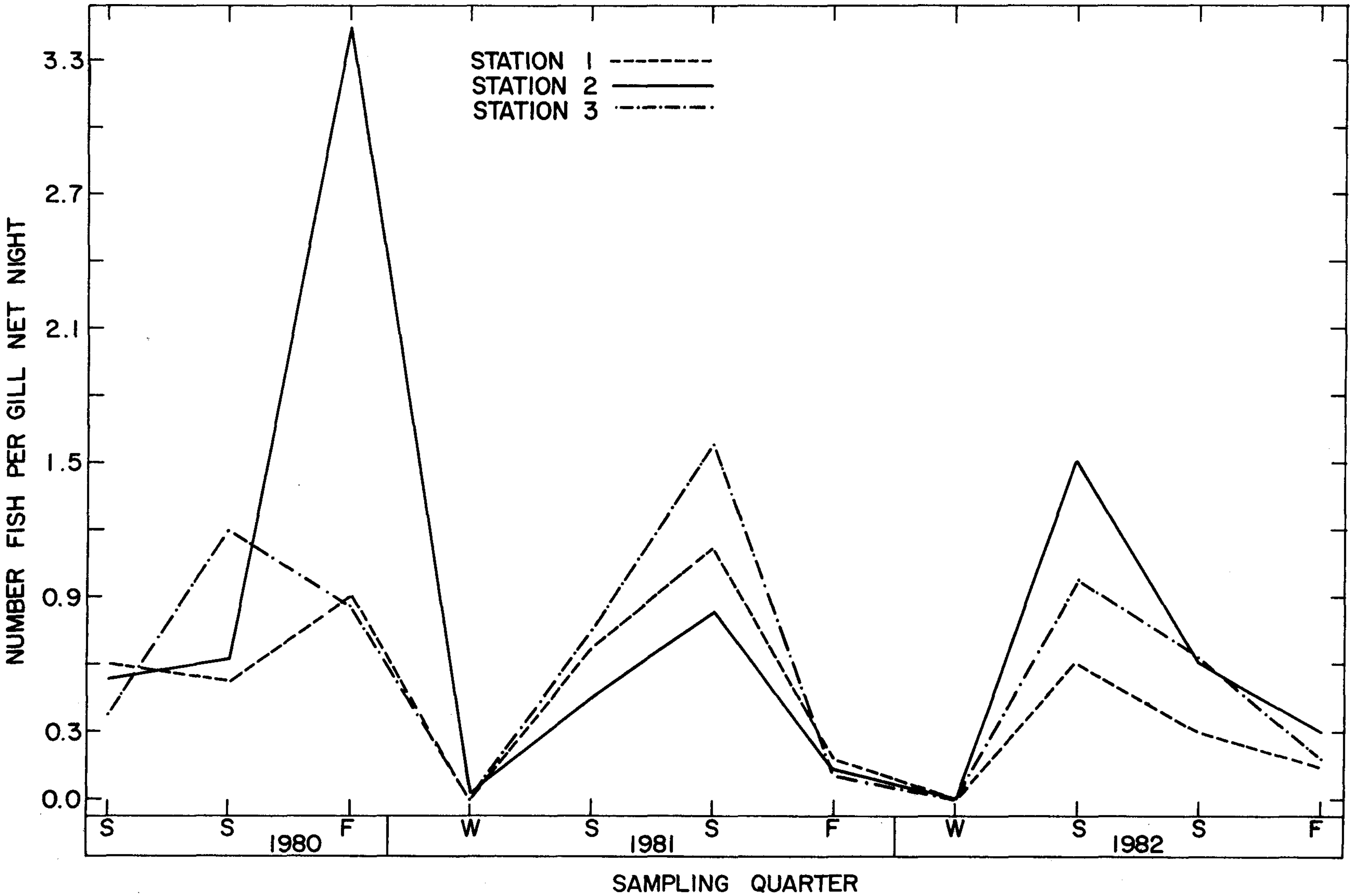

Figure 5-13. Mean Quarterly Catch per Gill Net Night for Channel Catfish (Ictalurus punctatus) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

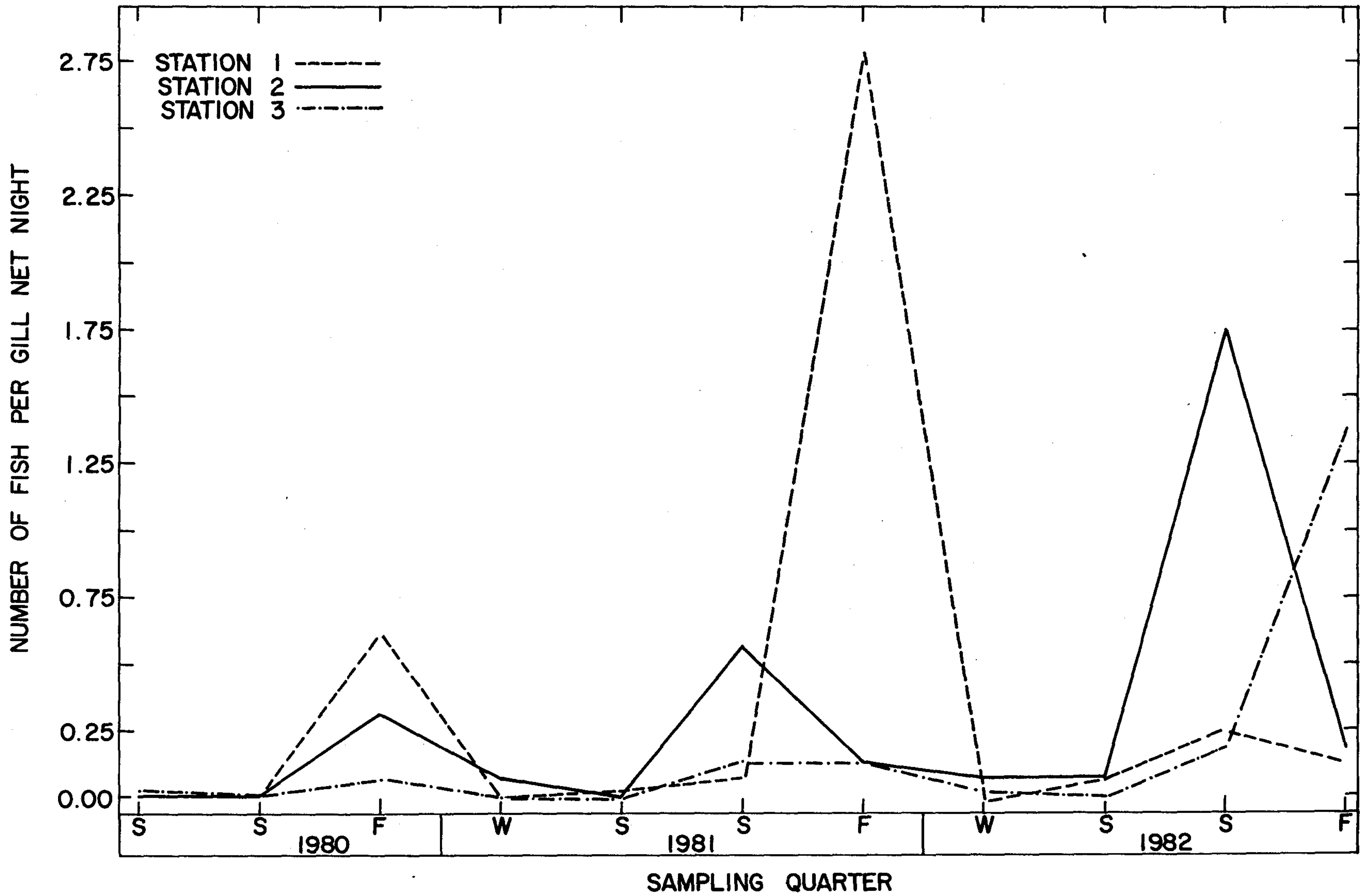

Figure 5-14. Mean Quarterly Catch per Gill Net Night for White Bass (Morone chrysops) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

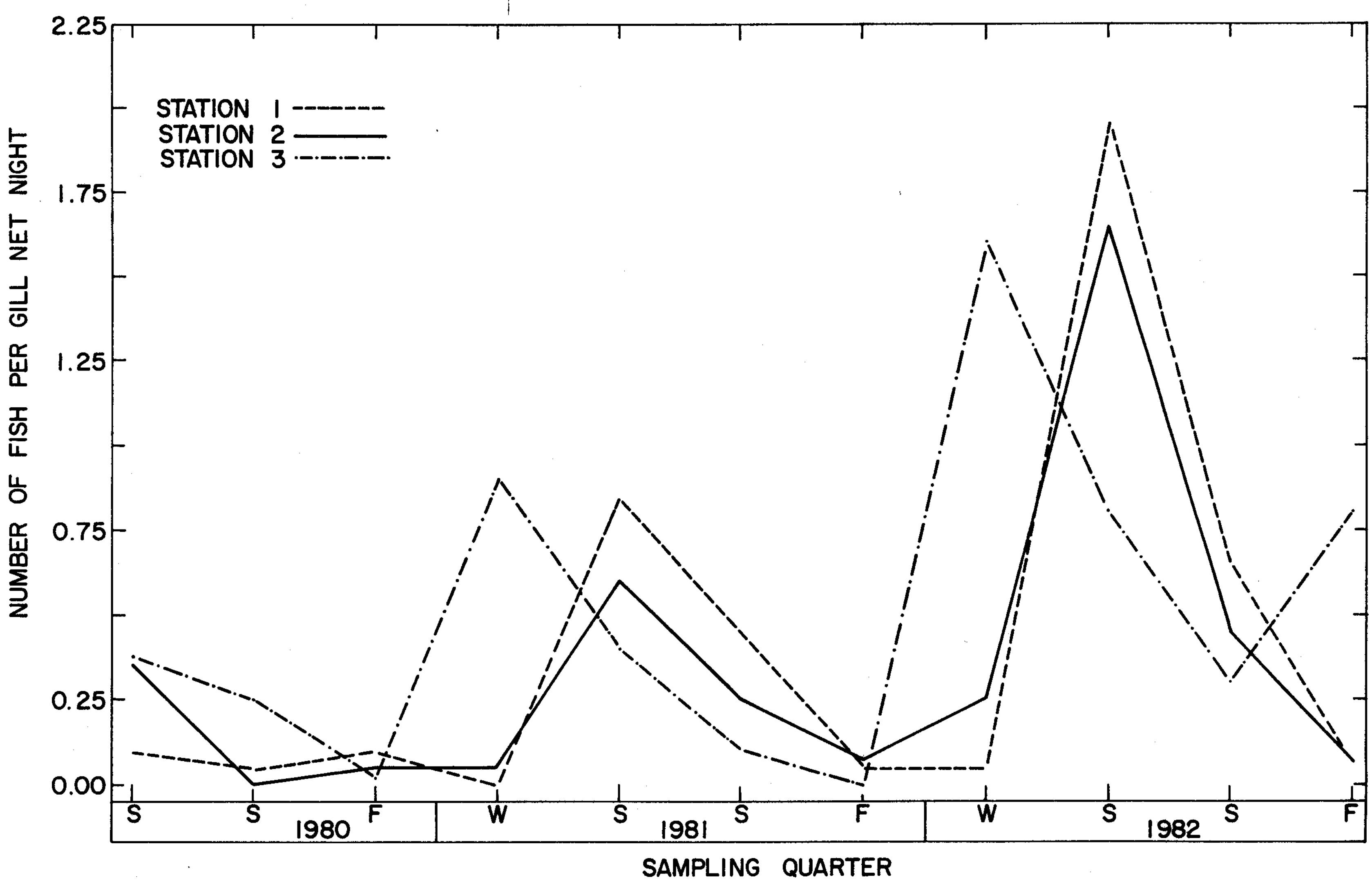

Figure 5-15. Mean Quarterly Catch per Gill Net Night for Yellow Bass (Morone mississippiensis) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

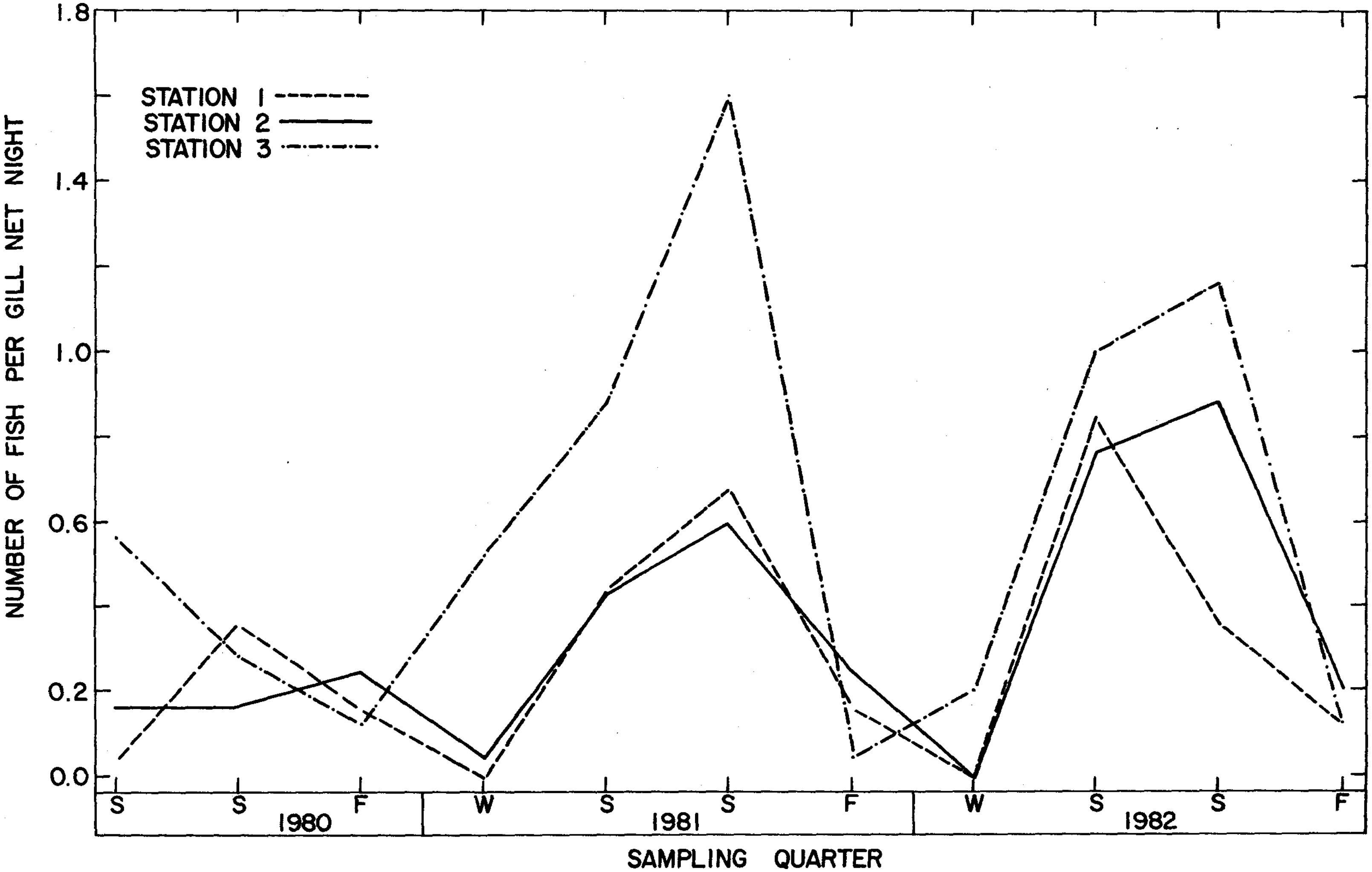

Figure 5-16. Mean Quarterly Catch per Gill Net Night for Bluegill (Lepomis macrochirus) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

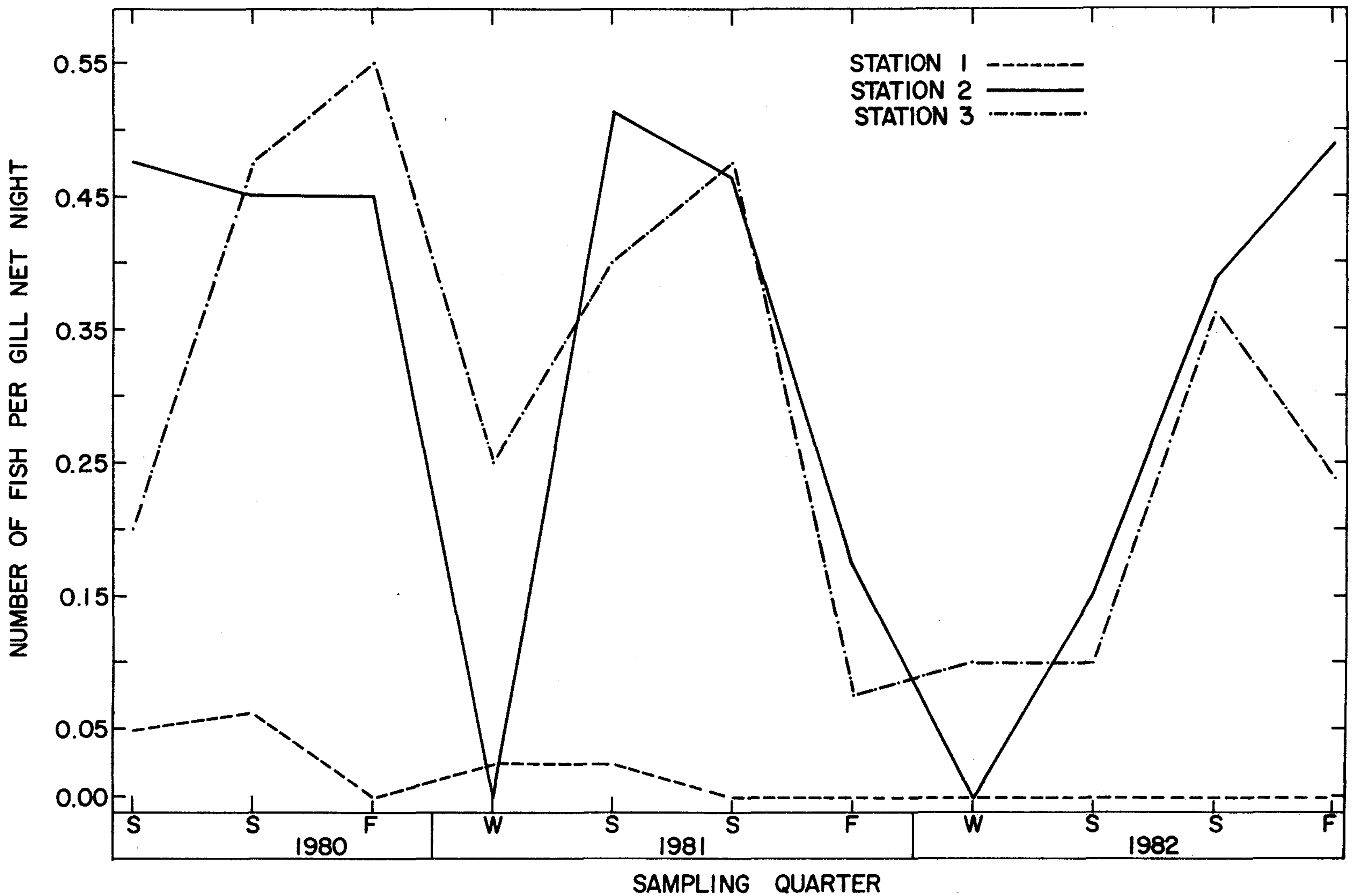

Figure 5-17. Mean Quarterly Catch per Gill Net Night for Redear Sunfish (Lepomis microlophus) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

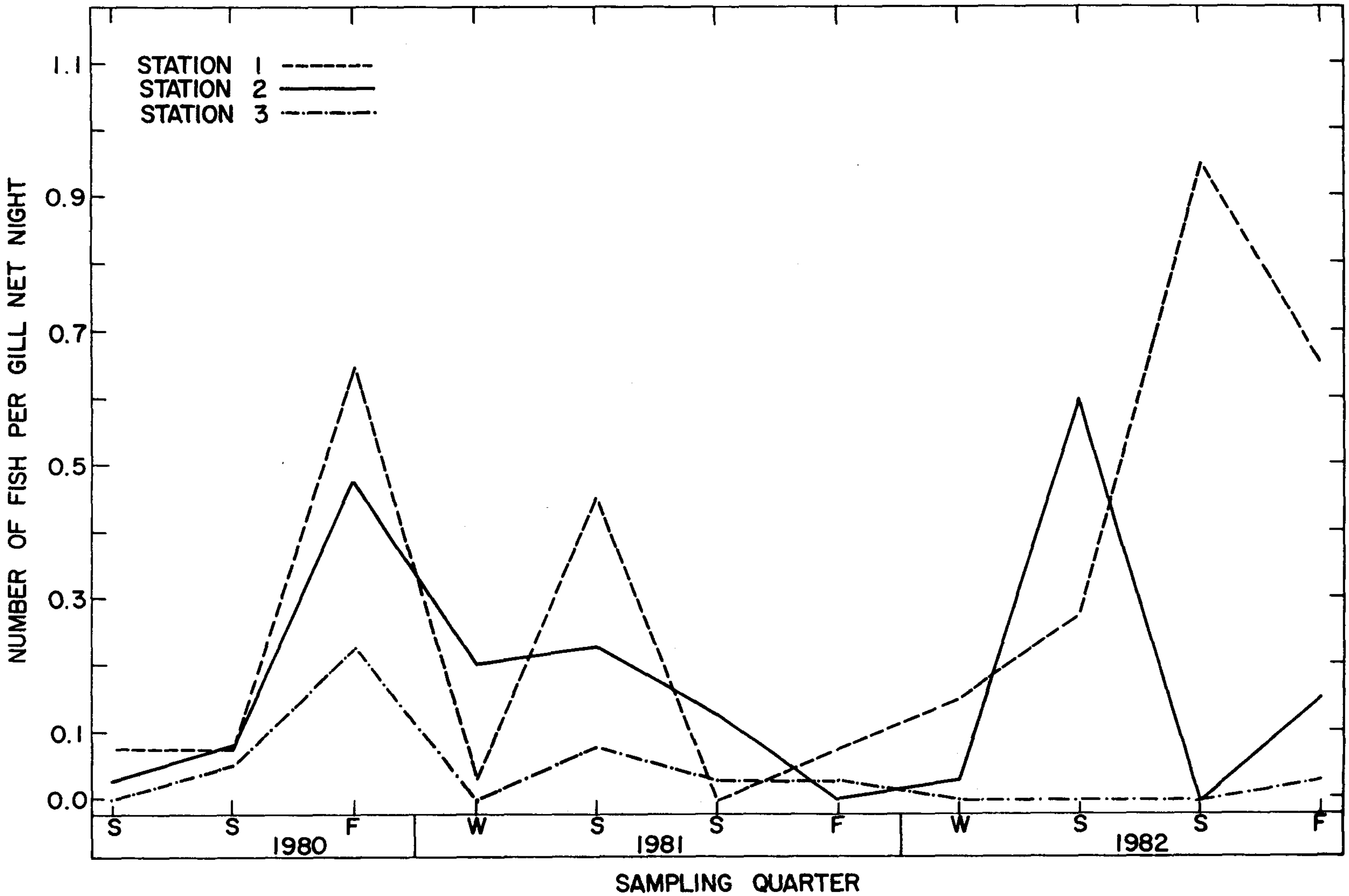

Figure 5-18. Mean Quarterly Catch per Gill Net Night for Spotted Bass (*Micropterus punctulatus*) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

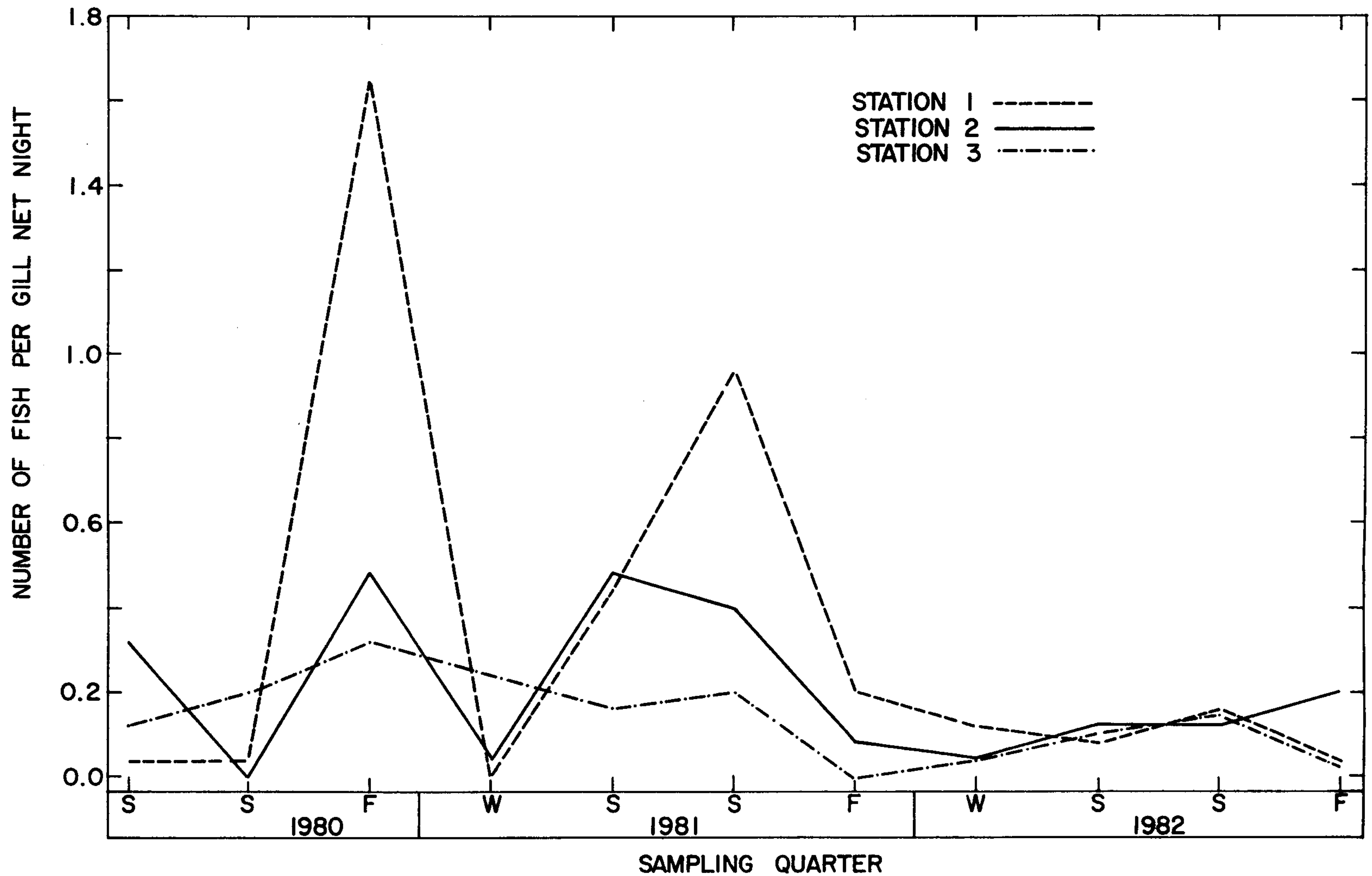

Figure 5-19. Mean Quarterly Catch per Gill Net Night for White Crappie (Pomoxis annularis) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

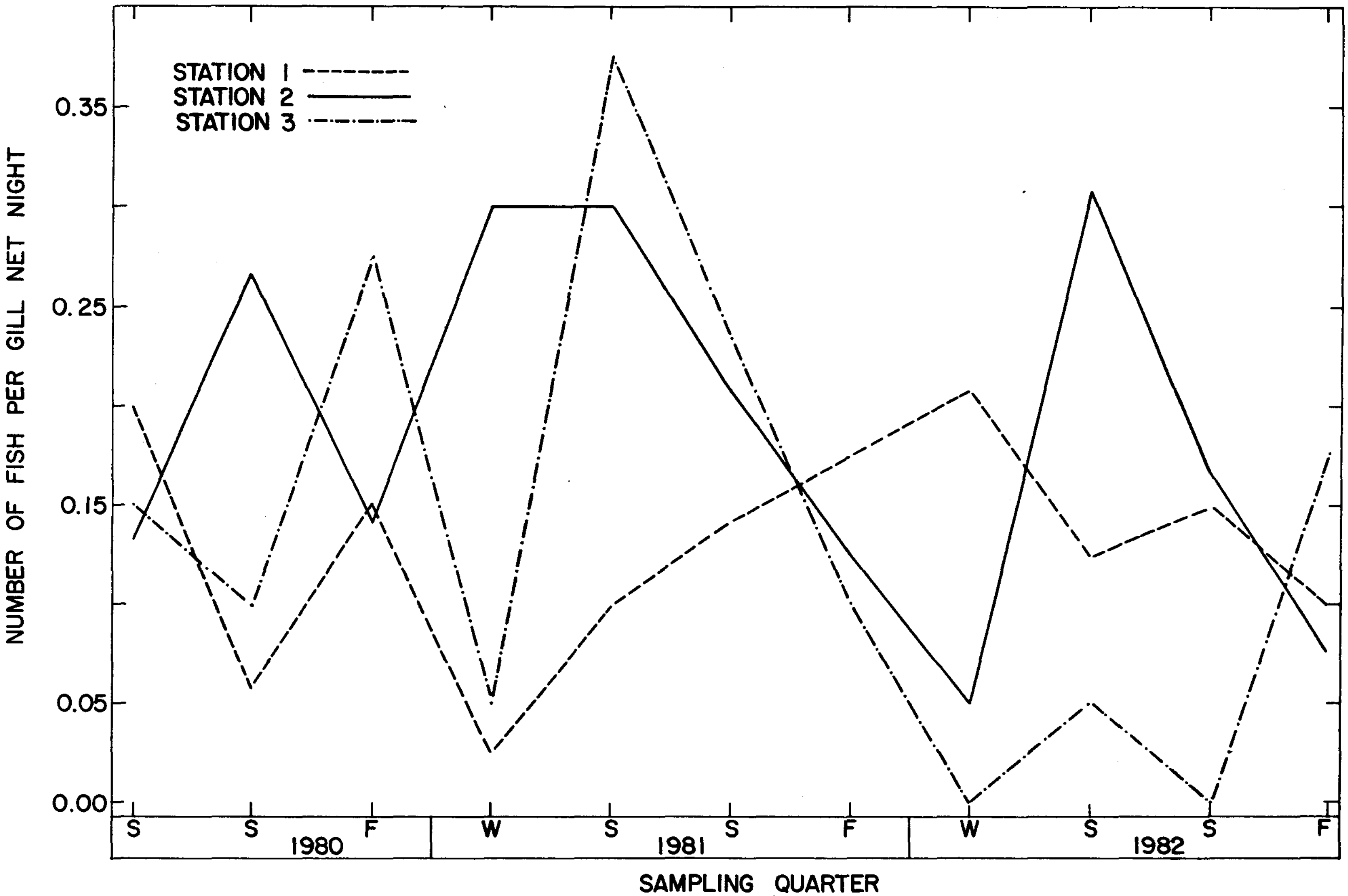

Figure 5-20. Mean Quarterly Catch per Gill Net Night for Sauger (Stizostedion canadense) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

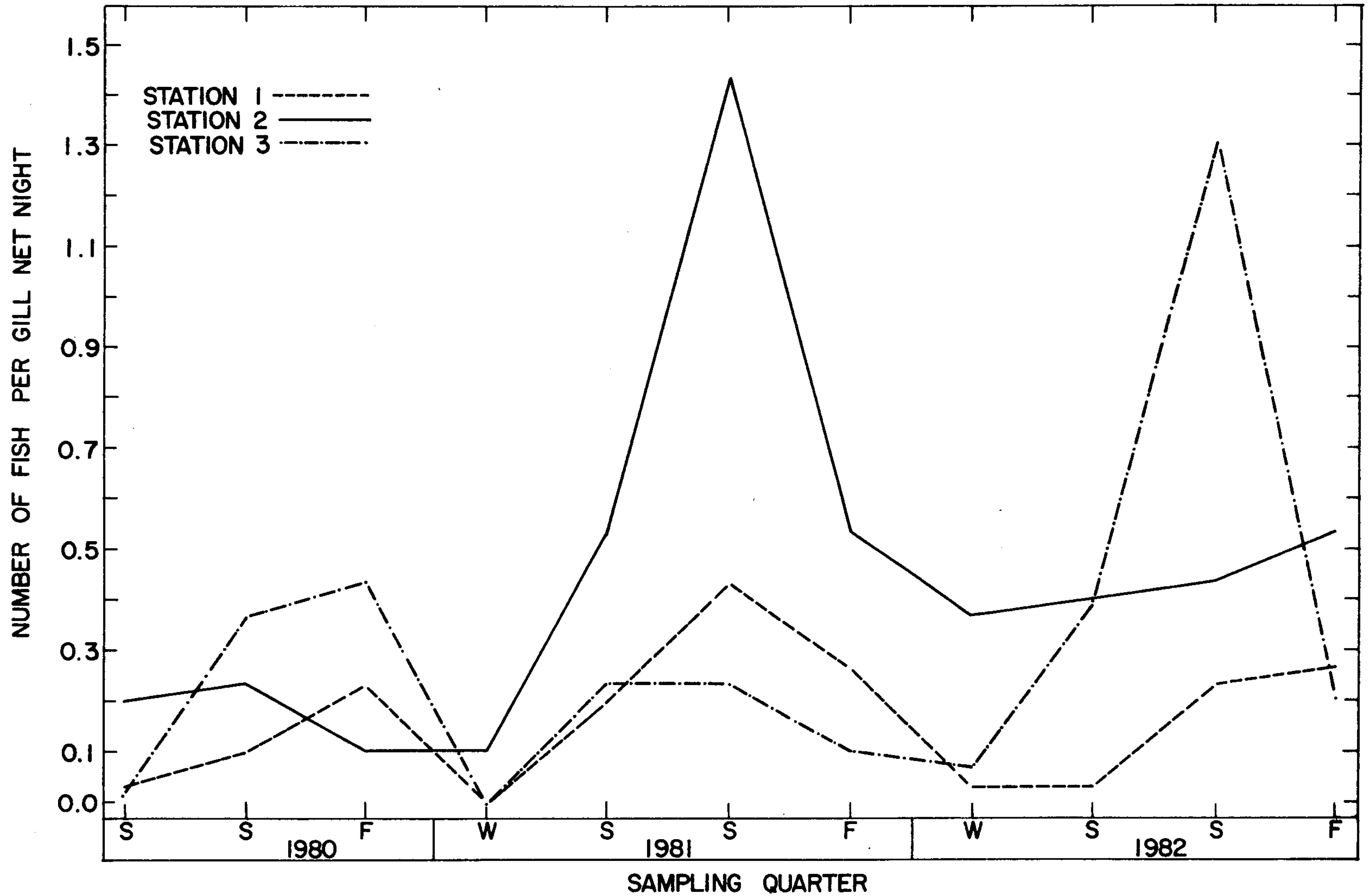

Figure 5-21. Mean Quarterly Catch per Gill Net Night for Freshwater Drum (*Aplodinotus grunniens*) Collected at Three Stations in Chickamauga Reservoir near Sequoyah Nuclear Plant (Spring 1980 through Fall 1982).

5.2.3 Cove Rotenone

Materials and Methods

Fish sampling with rotenone was initiated in Chickamauga Reservoir in 1947 to determine standing stock (numbers/ha and kg/ha) of game, prey, and commercial fish species. Samples were taken at various locations, primarily in coves, annually through 1959 (with the exception of 1948 and 1953). In addition to standing stock information, these data provided species occurrence and composition information and characterized the overall fish community of the reservoir. Sampling was discontinued after 1959 but was resumed in 1970 to collect preoperational data for monitoring possible impacts from operation of SQN.

Rotenone sampling procedures were standardized for use in Tennessee Valley reservoirs after 1960 to include use of block nets and standard survey techniques. Prior to this, techniques varied from year to year and from one reservoir to another. Sampling in Chickamauga Reservoir from 1947 through 1960 included: (1) use of varying techniques for determining area and volume of the sample site, (2) some samples conducted without the use of block nets, and (3) undescribed subsampling techniques. In addition to 21 cove samples, two samples were conducted in open water areas.

Field--Cove rotenone sampling since 1970 was designed to eliminate certain biases through establishment of criteria for sample sites and standardization of field techniques. Criteria for an acceptable rotenone site were: (1) surface area at least 0.4 ha; (2) depth not more than 7.5 m where block net is set; (3) location not adjacent to or within the same cove as housing developments, boat docks, or other recreation areas; (4) absence of streams or other sensitive habitats; and (5) easy access by boat. During operational monitoring five coves were sampled each year in Chickamauga Reservoir. These coves were located at TRM 476.2, 478.0, 495.0, 508.0, and 524.6 (figure 5-22). Descriptions of sample sites (1947-1982) are in table 5-21.

Standardized field techniques for rotenone sampling include: (1) sampling when water temperature is $\geq$ 20° C; (2) accurate surveying of surface area within one day prior to conducting sample; (3) block net set on the afternoon prior to sampling; (4) scuba-diver check of block net to ensure isolation of sample area; (5) determination of physical and chemical properties of the sample area; (6) application of rotenone to attain a 1.0 mg/l concentration of toxicant; (7) pick up of all visible fish on two consecutive days; and (8) specified sorting, counting, weighing, subsampling, and data recording procedures.

Physical properties measured were surface area, maximum depth, and mean depth (obtained through a systematic series of depth soundings). Mean depth and surface area were used to determine the volume of the cove and, thereby, the amount of toxicant necessary to achieve a concentration of 1.0 mg/l.

Rotenone was applied with a pump and a weighted, perforated hose to distribute the toxicant evenly at all depths. Initially a curtain of rotenone was applied adjacent to the block net to prevent small fish from escaping. Following this, rotenone was distributed by operating the boat in a zigzag pattern throughout the cove. Finally, shallow shoreline areas were surface sprayed with rotenone to ensure complete coverage of the area. All visible fish were picked up the day of application and sorted by species. Small fish (e.g., Notropis sp.) were preserved in a 10 percent formalin solution and returned to the laboratory for identification. Each remaining species was then sorted into groups by 25 mm length increments. Each size group was counted and the aggregate weight recorded. Occasionally, some length groups were so numerous that it was not practical to count each fish. In these cases a subsample of that length group was counted and weighed. Remainder of the size class was then weighed collectively and numbers estimated by the relationship:

$$\text{Numbers in subsample} : \text{Weight of subsample} = \text{Numbers in remainder} : \text{Weight of remainder}$$

Fish collected the second day were processed in the same way, except that numbers only were recorded for each size class of each species. Weights of second-day fish were calculated from length-weight relationships derived from first-day fish. Fish were grouped into game, commercial, and prey species and classified as young, intermediate, and adults, based on total length (table 5-22).

Data Analyses--Cove rotenone data were computer stored for analysis and standing stocks of each species were calculated by size class. Standing stocks of young, intermediate, and adult size classes of "important" species were analyzed using a linear regression model to determine statistically significant trends over the period 1970 through 1982. Important species were determined by the following criteria:

1. Must occur in at least 50 percent of samples since 1970, and
2. Must comprise one percent of either the total number or total biomass collected.

In addition to species meeting the above criteria, certain species of special interest were included for analysis because of their importance as sport or commercial species. For each important species, Kruskal-Wallis rank sums analyses as modified by Dunn (Hollander and Wolfe 1973) were used to determine significant standing stock differences among three areas of

Chickamauga Reservoir for the preoperational period (1970-1979) and operational period (1980-1982). Areas of the reservoir were defined as: (1) downstream area (TRM 471.0 to TRM 484.5), (2) middle area (TRM 484.5 to TRM 500.0), and (3) upstream area (TRM 500.0 to 529.9).

Also, an additional statistical procedure, principal components analysis (PCA), was employed in 1982 to examine spatial and temporal characteristics of the cove rotenone data. This procedure summarizes the important patterns in a data set in terms of a few basic trends (components) which may account for a large portion of the variation. Hypotheses about the nature of the major sources of variation can then be formulated. Densities (no./ha) were normalized using base 10 logarithms. The PCA was based on the covariance matrix.

Results and Discussion

In 1982, 38 species representing 12 families were collected in cove rotenone samples in Chickamauga Reservoir (table 5-23). All species collected in 1982 previously had occurred in cove rotenone samples for preoperational and operational monitoring in this reservoir (table 5-24). Numerically, bluegill was the most abundant species (31 percent), followed by gizzard shad (26 percent). However, gizzard shad constituted 56 percent of the total biomass sampled, whereas biomass of bluegill was 9 percent. Freshwater drum also made up about 9 percent of total biomass, but this species only comprised 0.6 percent of the total number.

Mean annual standing stock of all young, intermediate, and harvestable size classes of fish in Chickamauga Reservoir in 1982, determined by five cove rotenone samples, was 36,534 fish/ha with a biomass of 288 kg/ha (table 5-25). Young-of-year fish represented 92 percent of the standing stock by number and about 19 percent of the biomass. Whereas harvestable size fish comprised 73 percent of the biomass, numerically this size class only was 5 percent of the standing stock.

Based on the general classification of game, commercial, and prey species, biomass in 1982 was dominated by prey species, 164 kg/ha (57 percent) (table 5-26). Game and commercial fish comprised 23 percent (67 kg/ha) and 20 percent (57 kg/ha) of the biomass, respectively. About 65 percent of the game fish populations by number were young of year, primarily bluegill and other sunfish. Young of year comprised 10 percent of the game fish biomass.

Temporal and Spatial Trends--Seventy-one species encompassing 15 families were collected in cove rotenone samples in Chickamauga Reservoir from 1970 through 1982 (table 5-24). During this period 67 samples were taken from 15 locations (table 5-21). Mean numbers per hectare by species and location are shown in appendix T, whereas mean biomass estimates are shown in appendix U. Bluegill was the predominant species, comprising 41 percent of the total number of fish collected (appendix V). Only three species (gizzard shad, bluegill, and freshwater drum) were present in all cove samples from 1970 through 1982 (appendix W). Appendices X and Y show annual mean number and biomass, respectively, of each species collected in rotenone samples.

Numbers of young fish and biomass of harvestable fish were highest in 1981 (table 5-25). Table 5-26 shows a general increase in numbers and biomass of game fish from 1970 through 1982, with no apparent trend for either commercial or prey fish groups.

Important Species--A total of 19 species was classified as important in cove rotenone samples (table 5-27). Numerical abundance and biomass of young, intermediate, and adult size classes of each species through time are discussed below. Spatial differences among the three areas of the reservoir are also noted.

Gizzard shad--From 1970 through 1982, statistically significant increasing or decreasing trends were not found for either numbers or biomass of young and adult gizzard shad in Chickamauga Reservoir. Similar results were noted in SQN preoperational monitoring (TVA, 1978b). However, in the Watts Bar Nuclear Plant (WBN) preoperational fisheries monitoring report (TVA, 1980) a statistically significant trend was observed, wherein numbers of adult gizzard shad were increasing through time. SQN preoperational monitoring analyses covered the period 1970 through 1977, whereas WBN preoperational monitoring employed data from the same coves in Chickamauga each year but incorporated two additional years (1978 and 1979). Results of linear regression analysis (table 5-34) can be considerably influenced by the most recent values for a given species, particularly if the species exhibits large year class variability as is the case with gizzard shad.

Analyses of spatial distributions of gizzard shad during preoperational monitoring (1970-1979) indicated greater numerical abundance in the upstream area of Chickamauga Reservoir than in either middle or downstream areas (table 5-29b). No statistically significant differences in biomass were found among the three areas nor were spatial differences found in either the SQN or WBN preoperational monitoring analyses. Also, analyses of operational monitoring data (1980-1982) showed no significant spatial differences in numbers or biomass of gizzard shad. Biomass of young of year increased substantially in 1982 (table 5-31).

Threadfin shad--Over the period 1970 through 1982, numbers and biomass of young of year showed a significant decline (table 5-28). No significant differences in numbers or biomass were found among the three areas of Chickamauga Reservoir during the preoperational or operational phase. Because no statistically significant trends were identified through 1981, the linear regression analysis was influenced by the 1982 estimates (see discussion for gizzard shad). Estimated total biomass of threadfin shad in 1982 was about 1 kg/ha (table 5-32).

Carp--Young carp increased (both numbers and biomass) in Chickamauga Reservoir (table 5-28) over the period of study (1970 through 1982). No statistically significant trend was observed for numbers or biomass of intermediate or adult carp. In previous analyses (TVA, 1978b and 1980) no significant trends were observed. However, in these reports it was noted that cove rotenone probably does not adequately sample smaller size classes of this species. Young and intermediate carp are relatively uncommon in cove rotenone samples, and statistically significant increasing or decreasing trends should be interpreted with caution.

Biomass and numbers of carp were significantly higher in the upstream portion of Chickamauga Reservoir (TRM 500 to TRM 529.9) than in other areas during preoperational monitoring (tables 5-29b and 5-30b). However, results of cove rotenone samples for operational monitoring indicate no significant differences for biomass or numbers of carp among the three areas of the reservoir.

Bullhead minnow--Bullhead minnow occurrence prior to 1971 was sporadic but may have been due to misidentification of this species. Since 1971, stocks have been relatively high (table 5-34) and have shown an increasing trend through time (table 5-28). No significant differences in standing stocks were found among the three areas of the reservoir.

Smallmouth buffalo--Over the period 1970 through 1982, both numbers and biomass of all size classes of this species have declined significantly (table 5-28). However, total number (7/ha) and biomass (11 kg/ha) of smallmouth buffalo in 1982 were the highest recorded in the last five years and were similar to levels observed in 1977 and 1974 (table 5-35). No significant differences in standing stocks (numbers or biomass) of this species among the three areas of Chickamauga Reservoir have occurred under preoperational (1970-1979) or operational conditions (tables 5-29a and b and 5-30a and b).

Spotted sucker--Biomass and numbers of adult spotted sucker have increased, 1970 through 1982, and this trend was statistically significant (table 5-28). Spotted sucker was not identified in rotenone samples in Chickamauga Reservoir prior to 1959. As noted in the previous report (TVA, 1982a) this species may be nearing the end of an expansion phase. A decrease (6 kg/ha) in total biomass in 1982 (table 5-36), and a significant numerical decline for young spotted sucker (table 5-28) supports this observation. Since operation began, significant differences in standing stocks of spotted sucker among the three areas of the reservoir have not been noted, whereas in preoperational analyses biomass of this species was significantly greater in the upper area than in the middle area (table 5-30b).

Channel catfish--Intermediate size channel catfish continued to decrease (both numbers and biomass) through time, whereas adults increased (biomass) through time (table 5-28). A declining trend was also noted for intermediate size channel catfish in previous reports (TVA, 1978b; 1980; and 1982a). Total biomass of this species declined in 1982 (table 5-37). No significant differences were noted among the 3 reservoir areas during either preoperational (table 5-29b) or operational monitoring (table 5-29a) for SQN. However, preoperational data for WBN (TVA, 1980) showed this species to be least abundant in the middle portion of the reservoir.

Flathead catfish--For the first time a declining trend for numbers of harvestable flathead catfish was indicated, but no significant trend for biomass of this size class was determined (table 5-28). For the preoperational period, numbers of this species were significantly higher in the middle area of the reservoir (table 5-29b). Operational monitoring numbers were not significantly different among the three areas; however, biomass in the middle area was significantly greater than in the upper and downstream areas (table 5-30a). Total biomass estimates for flathead catfish since 1970 have seldom exceeded 1.0 kg/ha (table 5-38).

White bass--With the exception of number of young of year, no significant trends were determined for white bass in Chickamauga Reservoir cove rotenone samples. Numbers of young white bass declined (table 5-28). Also, no significant stock differences were found among the three reservoir areas. These results are similar to those reported earlier (TVA, 1978b; 1980; and 1982a). Total biomass estimates for this species have been consistently below 1.0 kg/ha (table 5-39).

Yellow bass--All size classes of this species increased significantly (both numbers and biomass) since 1971 when this species was first recorded in cove rotenone samples (table 5-28). This trend was first documented in the WBN preoperational monitoring report (TVA, 1980). During preoperational monitoring, yellow bass were most abundant (both numbers and biomass) in the upstream portion of Chickamauga (tables 5-29b and 5-30b). The WBN preoperational report (TVA, 1980) showed no significant differences among the 3 areas of the reservoir. Also, since operation began, no significant differences in the standing stock among the three reservoir areas were detected. Total biomass for this species was highest (10 kg/ha) in 1981, and total numbers were highest in 1982 (table 5-40).

Warmouth--All three size classes of this species increased significantly (both numbers and biomass) through time (table 5-28). Warmouth did not meet criteria for "important species" status when SQN preoperational studies were analyzed (TVA, 1978b). When data were analyzed for the WBN preoperational report, warmouth abundance had increased to meet these criteria. Linear regression analyses for WBN preoperational monitoring revealed that, with the exception of numbers of young warmouth, all size groups were increasing significantly. Numbers of young warmouth per hectare had increased but the trend was not statistically significant. Similar to previous results (TVA, 1980 and 1982a), no significant differences were found among the three areas of the reservoir. For the past three years total numbers have exceeded 100/ha (table 5-41).

Bluegill--Numbers and biomass of young of year and numbers of harvestable bluegill increased significantly through time (table 5-28). A significant increasing or decreasing trend for other size groups was not determined. However, estimated total biomass for this species declined about 15 kg/ha in 1982 compared to 1981 (table 5-42). During the preoperational period for SQN (TVA, 1978b) only numbers of young bluegill exhibited a significant (increasing) trend. Preoperational data analyses for WBN (TVA, 1980) indicated numbers of all three size classes increased while biomass of only the young size class showed a similar trend. Based on recent results, it appears that a formerly stable bluegill population in Chickamauga has recently started increasing. It remains to be seen if this trend will continue or if this merely represents a fluctuation or cyclic phenomenon. In contrast to previous analyses (TVA, 1982a), significant differences were found among the 3 areas of the reservoir (tables 5-29a and 5-30a). Numbers and biomass were significantly less in the upper area relative to the downstream area.

Longear sunfish--Neither numbers nor biomass of any size group was found to be increasing or decreasing. Previous analyses (TVA, 1978b and 1980) showed increases for young and intermediate sizes, although adult numbers and biomass exhibited no trend. Both numbers and biomass of this species were significantly lower upstream than in either of the other two reservoir areas in both the operational and preoperational periods (tables 5-29a, 5-30a, and 5-30b). Previous analyses showed numbers and biomass were higher in the downstream area than in the upstream area. The past three years total biomass was less than 2 kg/ha (table 5-43).

Redear sunfish--As in previous analyses, biomass and numbers of young redear sunfish showed a significant increasing trend (table 5-28). Although the adult size class had an increasing trend through 1981 (TVA, 1982a), no significant increasing or decreasing trend was indicated in the current analyses. Total biomass for this species in 1982 was 10 kg/ha (table 5-44). No significant difference in standing stocks was found among the three areas of the reservoir for preoperation or operation.

Largemouth bass--Biomass of young and numbers of intermediate largemouth bass continued to show an increasing trend (table 5-28). This varies somewhat from previous analyses in which both numbers and biomass of young bass increased significantly (TVA, 1982a). For preoperation, no significant difference in abundance among the three areas of the reservoir was determined, but under operation, biomass has been significantly higher in the downstream area relative to the upstream area (table 5-30a). Since 1978, total biomass of this species has exceeded 10 kg/ha (table 5-45).

Increasing abundance of young and intermediate largemouth bass may be directly related to increases in young bluegill and other centrarchids.

Sauger--As in previous analyses, sauger showed neither increasing nor decreasing trends for any size class, although this species has not been collected in rotenone samples since 1979 (table 5-46). No significant differences were found among the three areas of the reservoir during preoperation or operation. This species is seldom collected in large numbers in coves.

Yellow perch--Both numbers and biomass of intermediate and adult sizes of yellow perch showed increasing trends through time (table 5-28). This species invaded Chickamauga Reservoir sometime after 1959 and first appeared in cove rotenone samples in 1970. Adults were first collected in cove rotenone samples in 1978. At the time data analyses were performed for the SQN preoperational report (TVA, 1978b), only young had been collected, and no trend could be determined. At the time data analyses were performed for WBN preoperational report (TVA, 1980), intermediate and adult size classes had only been collected for two years, and linear regression analyses showed increasing trends. Most recent results confirm that this species has gained a foothold in Chickamauga, and the population is expanding although total biomass has not exceeded 4 kg/ha (table 5-47). For the operational and preoperational periods, significant spatial differences in abundance of this species were determined (table 5-29a, 5-29b, 5-30a, and 5-30b). During preoperation, biomass and numbers were higher in both the middle and downstream areas than in the upstream area. Since operation began, biomass and numbers in the middle area continue to be significantly higher than those upstream.

Freshwater drum--Both numbers and biomass of young and intermediate size freshwater drum have decreased with time in Chickamauga Reservoir (table 5-28). Data analyses performed for the SQN preoperational report (TVA, 1978b) did not reveal these trends; however, analyses for the WBN preoperational report (TVA, 1980) documented declining trends (both no./ha and kg/ha) of young and intermediate size freshwater drum. In section 5.1.2 it was noted that entrainment percentage of freshwater drum eggs amd larvae at SQN exceeded hydraulic entrainment percentage. Whereas this provides a possible explanation of declining stocks of young and intermediate size classes of this species, entrainment effect is not considered likely because (1) statistically significant decreasing trends were first documented from data collected through 1979 (before unit 1 fuel load at SQN), and (2) substantial numbers of freshwater drum eggs and larvae were present downstream of SQN diffusers where they are not subject to entrainment. Even if declining stocks of young and intermediate size classes are plant related, effects to Chickamauga Reservoir would not necessarily be considered adverse. Declining stock levels have not been manifested in the adult size class of freshwater drum (table 5-48). In preoperational analyses this species was found to be most abundant (both numbers and biomass) in the upstream portion of Chickamauga (tables 5-29b and 5-30b). Analyses of samples since operation began show no significant differences. Previous analyses (TVA, 1978b and 1980) also did not reveal significant differences among areas.

White crappie--Neither increasing nor decreasing trends were found for number or biomass of young and adults of this species. Biomass of the intermediate size class showed a decreasing trend (table 5-28). Although data analyses for the SQN preoperational report revealed declining numbers and biomass of adults (TVA, 1978b), more recent analyses performed for the WBN preoperational report (TVA, 1980) showed neither increasing nor decreasing trends. White crappie were significantly more abundant (both numbers and biomass) in the upstream area of Chickamauga Reservoir than in the middle and downstream areas during preoperation (tables 5-29b and 5-30b). Since operational monitoring began, no significant differences in abundance among areas of the reservoir were noted. Since 1970, total biomass of white crappie estimated by cove rotenone has not exceeded 5 kg/ha (table 5-49).

Principal Components Analysis--Interrelationships among the cove rotenone samples were examined using principal component analysis (PCA). The first component, PC I (figure 5-23), accounted for 35 percent of the total variation. PC I appeared to reflect the increase in aquatic vegetation beginning in the mid-1970s. Golden shiner, spotfin shiner, warmouth, redbreast sunfish, bluegill, redear sunfish, largemouth bass, yellow perch, logperch, and brook silverside had high positive loadings on PC I, while threadfin shad and freshwater drum had high negative loadings.

Before 1975 PC I scores were low. Between 1975 and 1977, when aquatic weeds increased in Chickamauga Reservoir, scores began to increase annually. After 1977, scores remained high. Scores from TRM 508 increased at a slower rate than the 3 downstream locations. Increased weed growth apparently occurred about a year or two later than in the areas downstream. The sample scores from TRM 524.6 remained low throughout the period (1976-1982). Concurrently, aquatic weeds have not increased at this site.

The secondary component, PC II (figure 5-24), accounted for an additional 15 percent of the variation. This component may reflect the effects of 2 extremely cold winters (1977-1978 and 1978-1979). Threadfin shad, bullhead minnow, longear sunfish, spotted bass, and logperch had high positive loadings; while longnose gar, carp, and yellow bullhead had high negative loadings. Extensive winter kills of threadfin shad were observed during both winters. However, the other species with high positive loadings would not be expected to be directly affected by low temperature.

PC II scores for samples collected from TRM 475.7 to TRM 495.0 increased annually through 1977. Samples from TRM 508.0 remained relatively constant during this period. From 1977 through 1980, PC II scores from each site decreased, then began to rise again.

Summary and Conclusions

Cove rotenone samples collected in 1982 as part of operational monitoring for SQN were analyzed along with those collected from 1970 through 1979 (preoperation) and with those from 1980 and 1981 (operation). All species (38) collected in 1982 previously had occurred in cove rotenone samples for preoperational or operational monitoring in this reservoir. Mean annual standing stock of all size classes of fish in Chickamauga Reservoir in 1982 was 36,434 fish/ha with a biomass of 288 kg/ha. Numerically, bluegill was the most abundant species (31 percent), followed by gizzard shad (26 percent). However, biomass of gizzard shad was 56 percent of the total standing stock, whereas biomass of bluegill was 9 percent.

Since 1978 there has been a general increase in numbers and biomass of game fish but no apparent trend for commercial or prey fish groups. Further examination of the data base in 1982 (principal component analysis) indicated that the general increase in game fish species, particularly centrarchids (e.g., bluegill, redear sunfish, and largemouth bass), may be attributed to an increase in aquatic vegetation in this reservoir. The second major factor (component) which probably influenced the variation in fish stocks during this period was 2 extremely cold winters in 1977-1978 and 1978-1979. For example, extensive winter kills of threadfin shad occurred.

Nineteen species were classified as important in cove rotenone samples. Of these, neither increasing nor decreasing trends (numbers or biomass) were found for any size group of three species (gizzard shad, longear sunfish, and sauger). Increasing numbers and/or biomass of at least one size class were found for ten species (carp, bullhead minnow, spotted sucker, channel catfish, yellow bass, warmouth, bluegill, redear sunfish, largemouth bass, and yellow perch). For two species (yellow bass and warmouth) both numbers and biomass of all three size groups increased. Adults of seven species (spotted sucker, channel catfish, yellow bass, warmouth, bluegill, redear sunfish, and yellow perch) were increasing either in numbers or biomass. Decreasing stocks (both numbers and biomass) of one or more size classes of four species (threadin shad, smallmouth buffalo, channel catfish, and freshwater drum) were determined.

Comparison of present trends to those determined in preoperational data anlyses for SQN (TVA, 1978b) and WBN (TVA, 1980) revealed that (1) smallmouth buffalo, previously decreasing in cove rotenone samples, no longer met criteria for important species; (2) three species (bullhead minnow, yellow bass, and warmouth) which did not meet criteria for important species consideration at the time of SQN preoperational analyses have increased to the point they now meet these criteria; (3) two species (gizzard shad and longear sunfish) which showed increases for at least one size class in preoperational analyses no longer show any trend, (4) of seven species which presently show increasing numbers or biomass of adults, only one species (channel catfish) showed no increasing trend for either adult numbers or biomass in preoperational analyses for SQN and/or WBN, and (5) one species (white crappie) which showed declining adult numbers and biomass in preoperational data analyses for SQN no longer shows such a trend.

Of those spatial or temporal trends determined, only declining stocks of young and intermediate size freshwater drum might to be related to operation of SQN. However, it was unlikely that entrainment of eggs and larvae was the primary cause of declining stocks in Chickamauga Reservoir since (1) declining trends were first documented prior to unit 1 fuel load and (2) substantial numbers of freshwater drum eggs and larvae were present downstream of the diffusers where they are not subject to entrainment. If this were plant effect, it would not presently be considered adverse. Rank sum analysis for abundance (numbers and biomass) of important species in three areas of Chickamauga Reservoir showed that significant differences in abundance among the three areas have generally declined since operation began. During preoperation, numbers of seven species were significantly different among areas. Since operation began, only numbers of three species (bluegill, longear sunfish, and yellow perch) were significantly different. For these species, abundance was higher in the downstream or middle area than in the upstream area. For biomass, significant differences among areas were noted for seven species during preoperation (gizzard shad, carp, spotted sucker, white bass, longear sunfish, yellow perch, and freshwater drum). Since operation began, biomass for five species (flathead catfish, bluegill, longear sunfish, largemouth bass, and yellow perch) was significantly different. As for numbers, biomass was higher in the downstream or middle area than in the upstream area.

Table 5-21. Characteristics of Rotenone Sites in Chickamauga Reservoir, 1947 through 1982 (Chickamauga Dam Located at TRM 471.0, and Sequoyah Nuclear Plant Located at TRM 484.5)

Tennessee River Mile	Date	Area (Hectares)	Mean Depth (m)	Maximum Depth (m)	Surface Temperature (C^o)
471.7	9/ 9/54	0.81	2.7	-	26.7
472.8	10/12/49	0.61	-	6.1	22.2
472.8	4/26/50	0.40	-	9.2	16.1
472.8	10/17/50	0.61	-	6.1	18.9
472.8	10/16/51	0.61	-	6.1	18.9
475.0	5/ 8/47	0.81	2.4	4.0	15.6
475.0	5/24/50	0.81	2.4	-	22.2
475.0	6/21/50	0.81	1.8	-	27.3
475.0	7/26/50	0.81	2.4	-	27.8
475.2	8/ 3/70	0.90	1.5	3.2	29.5
475.7	8/ 4/70	0.89	1.8	-	29.4
475.7	9/14/71	1.26	2.0	-	25.5
475.7	9/19/72	1.26	2.0	-	-
475.7	9/18/73	1.26	-	6.4	24.8
475.7	9/16/74	1.26	2.0	4.6	25.0
475.7	9/16/75	1.33	2.0	6.1	23.5
475.7	9/14/76	0.93	1.9	4.9	23.5
476.2	9/ 1/77	0.49	1.1	1.9	28.1
476.2	8/22/78	0.29	0.7	1.5	28.5
476.2	8/21/79	0.74	1.2	2.8	28.5
476.2	8/19/80	0.65	0.7	2.2	30.0
476.2	9/ 1/81	0.75	1.1	2.8	27.5
476.2	8/31/82	0.42	0.8	1.4	27.5
478.0	9/11/56	1.81	2.3	4.0	23.3
478.0	9/10/57	1.21	1.9	4.3	25.5
478.0	8/ 5/70	0.45	1.7	-	28.6
478.0	9/16/71	0.97	0.5	-	26.7
478.0	9/21/72	0.97	0.5	-	28.5
478.0	9/20/73	0.97	-	4.0	23.7
478.0	9/18/74	0.97	0.5	1.8	25.0
478.0	9/18/75	0.97	1.4	4.3	23.6
478.0	9/16/76	0.56	1.2	2.4	23.0
478.0	8/30/77	0.35	1.0	2.2	27.0
478.0	8/24/78	0.58	0.9	2.2	30.0
478.0	8/23/79	0.43	1.2	2.5	28 5
478.0	8/21/80	0.65	1.3	2.9	31.0
478.0	9/ 3/81	0.61	1.3	2.8	27.5
478.0	9/ 2/82	0.43	1.0	2.3	28.0
484.7	7/ 6/70	0.49	1.6	-	26.0
487.5	9/20/50	0.40	-	7.0	22.2
487.5	9/ 7/54	0.81	-	5.5	27.8
487.5	9/12/57	0.93	2.5	6.4	25.6
487.5	9/ 9/58	1.05	2.6	6.7	25.6
487.5*	9/11/58	0.40	5.5	11.6	25.6
487.5	8/27/59	1.05	2.6	6.5	27.8

Table 5-21. (Continued)

Tennessee River Mile	Date	Area (Hectares)	Mean Depth (m)	Maximum Depth (m)	Surface Temperature (C°)
489.6*	10/28/52	0.40	-	4.6	15.6
489.6	10/29/52	0.41	-	3.7	12.2
492.6	7/ 7/70	0.28	1.4	-	-
495.0	10/21/52	0.61	-	-	14.4
495.0	7/10/70	0.61	1.3	-	-
495.0	9/23/71	0.93	1.4	-	24.4
495.0	9/28/72	0.93	1.4	-	-
495.0	9/27/73	0.93	-	4.0	24.6
495.0	9/23/74	0.93	1.4	3.7	22.0
495.0	9/23/75	0.93	1.4	3.7	22.8
495.0	9/21/76	0.47	1.2	3.7	22.2
495.0	9/13/77	0.39	1.8	5.2	23.4
495.0	8/31/78	0.46	1.3	3.4	29.7
495.0	9/ 5/79	0.52	1.4	3.7	27.5
495.0	8/26/80	0.58	1.6	3.7	30.0
495.0	8/20/81	0.46	1.2	3.1	24.0
495.0	8/19/82	0.46	1.4	3.4	29.0
1.2†	7/27/70	0.55	1.2	3.4	25.3
2.5†	9/13/56	0.81	1.7	3.1	21.7
2.5†	7/28/70	0.96	1.3	-	29.8
3.5†	7/29/70	0.69	1.2	2.5	30.7
505.4	7/14/70	0.18	1.3	-	27.5
506.0	7/13/70	0.28	1.1	-	28.0
507.3	7/14/70	0.27	1.0	2.1	27.3
508.0	9/20/71	0.43	0.9	-	23.9
508.0	9/27/72	0.43	-	-	-
508.0	9/25/73	0.43	-	2.0	24.9
508.0	9/25/74	0.43	0.9	3.1	21.0
508.0	9/25/75	0.42	0.9	3.1	22.3
508.0	9/23/76	0.43	0.9	2.0	22.2
508.0	9/15/77	0.43	0.9	2.2	23.3
508.0	8/29/78	0.57	1.0	1.8	30.5
508.0	8/23/79	0.43	0.9	1.9	27.3
508.0	8/28/80	0.51	0.9	1.7	30.0
508.0	8/18/81	0.48	1.0	1.9	27.0
508.0	8/17/82	0.46	0.9	1.8	27.0
524.6	9/ 8/76	0.33	0.3	1.0	25.2
524.6	9/ 7/77	0.33	0.5	1.2	26.6
524.6	8/29/78	0.29	0.4	0.6	31.0
524.6	8/21/79	0.38	0.6	1.2	30.0
524.6	9/ 3/80	0.48	0.4	0.8	27.0
524.6	9/ 9/81	0.32	0.2	0.5	-
524.6	9/ 8/82	0.44	0.4	0.9	26.5

* Open water sample.

† Hiwassee River Mile (confluence at TRM 500.0).

Table 5-22. Size Classes* of Fish Species in Rotenone Surveys on Chickamauga Reservoir, 1947-1982

Species	Young Millimeters (inches)	Intermediate Millimeters (inches)	Adult Millimeters (inches)
Game			
White bass	Less than 150 (5.9)	151-200 (5.9- 7.9)	201 (7.9) and over
Yellow bass	" " 150 (5.9)	151-200 (5.9- 7.9)	201 (7.9) " "
Striped bass	" " 175 (6.9)	176-375 (6.9-14.8)	376 (14.8) " "
Rock bass	" " 75 (3.0)	76-125 (3.0- 4.9)	126 (5.0) " "
Bluegill	" " 75 (3.0)	76-125 (3.0- 4.9)	126 (5.0) " "
Other sunfish	" " 75 (3.0)	76-125 (3.0- 4.9)	126 (5.0) " "
Smallmouth bass	" " 100 (3.9)	101-200 (4.0- 7.9)	201 (7.9) " "
Spotted bass	" " 100 (3.9)	101-200 (4.0- 7.9)	201 (7.9) " "
Largemouth bass	" " 100 (3.9)	101-225 (4.0- 8.9)	226 (8.9) " "
Crappie	" " 75 (3.0)	76-175 (3.0- 6.9)	176 (6.9) " "
Sauger	" " 200 (7.9)	201-275 (7.9-10.8)	276 (10.9) " "
Walleye	" " 200 (7.9)	201-275 (7.9-10.8)	276 (10.9) " "
Commercial			
Lamprey	Less than 50 (2.0)	51-125 (2.0- 4.9)	126 (5.0) and over
Paddlefish	" " 300 (11.8)	301-450 (11.9-17.7)	451 (17.8) " "
Gar	" " 300 (11.8)	301-475 (11.9-18.7)	476 (18.7) " "
Bowfin	" " 200 (7.9)	201-300 (7.9-11.8)	301 (11.9) " "
Skipjack herring	" " 150 (5.9)	151-275 (5.9-10.8)	276 (10.9) " "
Mooneye	" " 150 (5.9)	151-300 (5.9-11.8)	301 (11.9) " "
Carp	" " 200 (7.9)	201-300 (7.9-11.8)	301 (11.9) " "
Goldfish	" " 150 (5.9)	151-250 (5.9- 9.8)	251 (9.9) " "
Buffalo	" " 200 (7.9)	201-300 (7.9-11.8)	301 (11.9) " "

Table 5-22. (Continued)

Species	Young Millimeters (inches)	Intermediate Millimeters (inches)	Adult Millimeters (inches)
Commercial (continued)			
Carpsucker	Less than 175 (6.9)	176-250 (6.9- 9.8)	251 (9.9) and over
Redhorses	" " 175 (6.9)	176-250 (6.9- 9.8)	251 (9.9) " "
Other suckers	" " 175 (6.9)	176-250 (6.9- 9.8)	251 (9.9) " "
Blue catfish	" " 125 (4.9)	126-225 (5.0- 8.9)	226 (8.9) " "
Channel catfish	" " 125 (4.9)	126-225 (5.0- 8.9)	226 (8.9) " "
Bullheads	" " 100 (3.9)	101-175 (4.0- 6.9)	176 (6.9) " "
Flathead catfish	" " 125 (4.9)	126-275 (5.0-10.8)	276 (10.9) " "
Freshwater drum	" " 125 (4.9)	126-200 (5.0- 7.9)	201 (7.9) " "
Grass pickerel	" " 175 (6.9)	176-300 (6.9-11.8)	301 (11.9) " "
Forage†			
Gizzard shad	Less than 125 (4.9)	-	126 (5.0) and over
Threadfin shad	" " 125 (4.9)	-	126 (5.0) " "
Orangespotted sunfish	" " 50 (2.0)	51- 75 (2.0- 3.0)	76 (3.0) " "
Miscellaneous prey species	All sizes	-	-

* The size class divisions are arbitrary but are based on knowledge of growth rates and information from creel census and commercial harvest records.

† Shad are recorded as young or harvestable; sizes of other forage fish, except orangespotted sunfish, were not differentiated.

Table 5-23. Species composition of cove populations, Chickamauga Reservoir 1982, determined by rotenone samples.

Species	Percent of Total numbers	Percent of Total weight
Bluegill	31.11	8.95
Gizzard shad	25.85	55.67
Redear sunfish	11.40	3.49
Unidentified sunfish	10.99	0.69
Redbreast sunfish	6.06	1.05
Warmouth	3.99	1.08
Bullhead minnow	1.52	0.14
Largemouth bass	1.21	4.47
Brook silverside	1.06	0.14
Threadfin shad	1.01	0.36
Spotted bass	0.87	0.40
Yellow bass	0.76	1.69
Freshwater drum	0.61	8.66
Green sunfish	0.54	0.18
Spotfin shiner	0.51	0.08
Yellow bullhead	0.49	0.36
Golden shiner	0.47	0.41
Emerald shiner	0.44	0.10
White crappie	0.35	0.30
Longear sunfish	0.25	0.39
Yellow perch	0.18	0.45
Logperch	0.17	0.11
Carp	0.03	3.18
Skipjack herring	0.02	0.07
Smallmouth buffalo	0.02	3.82
Channel catfish	0.02	2.09
Spotted sucker	0.02	1.21
Unidentified shiner	0.01	T
Longnose gar	T	0.07
White bass	T	0.05
Flathead catfish	T	0.22
Ghost shiner	T	T
Shortnose gar	T	0.07
Black bullhead	T	T
Blackspotted topminnow	T	T
Brown bullhead	T	0.02
Black redhorse	T	0.06
Central stoneroller	T	T
Common shiner	T	T
Mosquitofish	T	T
	100.00	100.00

T = Less than 0.01 percent.

Table 5-24. List of Fish Species Collected in Cove Rotenone Samples During Preoperational and Operational Fisheries Monitoring for Sequoyah Nuclear Plant, Chickamauga Reservoir, 1970 through 1982

Species	Common Name	Fish Group
Icthyomyzon castaneus	Chestnut lamprey	Commercial
Polyodon spathula	Paddlefish	Commercial
Lepisosteus oculatus	Spotted gar	Commercial
Lepisosteus osseus	Longnose gar	Commercial
Lepisosteus platostomus	Shortnose gar	Commercial
Alosa chrysochloris	Skipjack herring	Commercial
Dorosoma cepedianum	Gizzard shad	Prey
Dorosoma petenense	Threadfin shad	Prey
Dorosoma sp.	Unidentified shad	Prey
Mixed Dorosoma spp.	Mixed shad	Prey
Hiodon tergisus	Mooneye	Commercial
Campostoma anomalum	Stoneroller	Prey
Carassius auratus	Goldfish	Prey
Cyprinus carpio	Carp	Commercial
Hybopsis storeriana	Silver chub	Prey
Notemigonus crysoleucas	Golden shiner	Prey
Notropis atherinoides	Emerald shiner	Prey
Notropis buchanani	Ghost shiner	Prey
Notropis chrysocephalus	Striped shiner	Prey
Notropis cornutus	Common shiner	Prey
Notropis emiliae	Pugnose minnow	Prey
Notropis galacturus	Whitetail shiner	Prey
Notropis spilopterus	Spotfin shiner	Prey
Notropis volucellus	Mimic shiner	Prey
Notropis whipplei	Steelcolor shiner	Prey
Notropis sp.	Unidentified shiner	Prey
Pimephales notatus	Bluntnose minnow	Prey
Pimephales vigilax	Bullhead minnow	Prey
Pimephales promelas	Flathead minnow	Prey
Pimephales sp.	Unidentified minnow	Prey
Cyprinidae	Mixed & unidentified minnows	Prey
Cyprinidae	Minnow, carp	Prey
Carpiodes carpio	River carpsucker	Commercial
Carpiodes cyprinus	Quillback carpsucker	Commercial
Carpiodes sp.	Unidentified carpsucker	Commercial
Catostomus commersoni	White sucker	Commercial
Hypentelium nigricans	Northern hogsucker	Commercial
Ictiobus bubalus	Smallmouth buffalo	Commercial
Ictiobus cyprinellus	Bigmouth buffalo	Commercial
Ictiobus niger	Black buffalo	Commercial
Ictiobus sp.	Unidentified buffalo	Commercial
Minytrema melanops	Spotted sucker	Commercial

Table 5-24. (Continued)

Species	Common Name	Fish Group
Moxostoma carinatum	River redhorse	Commercial
Moxostoma duquesnei	Black redhorse	Commercial
Moxostoma erythrurum	Golden redhorse	Commercial
Moxostoma macrolepidotum	Shorthead redhorse	Commercial
Moxostoma sp.	Unidentified redhorse	Commercial
Ictalurus furcatus	Blue catfish	Commercial
Ictalurus melas	Black bullhead	Commercial
Ictalurus natalis	Yellow bullhead	Commercial
Ictalurus nebulosus	Brown bullhead	Commercial
Ictalurus punctatus	Channel catfish	Commercial
Pylodictis olivaris	Flathead catfish	Commercial
Fundulus notatus	Blackstripe topminnow	Prey
Fundulus olivaceus	Blackspotted topminnow	Prey
Cyprinodontidae	Killifish	Prey
Gambusia affinis	Mosquitofish	Prey
Labidesthes sicculus	Brook silverside	Prey
Morone chrysops	White bass	Game
Morone mississippiensis	Yellow bass	Game
Morone sp.	Unidentified temperate bass	Game
Ambloplites rupestris	Rock bass	Game
Lepomis auritus	Redbreast sunfish	Game
Lepomis cyanellus	Green sunfish	Game
Lepomis gulosus	Warmouth	Game
Lepomis humilis	Orangespotted sunfish	Prey
Lepomis macrochirus	Bluegill	Game
Lepomis megalotis	Longear sunfish	Game
Lepomis microlophus	Redear sunfish	Game
Lepomis sp.	Hybrid sunfish	Game
Lepomis sp.	Unidentified sunfish	Game
Micropterus dolomieui	Smallmouth bass	Game
Micropterus punctulatus	Spotted bass	Game
Micropterus salmoides	Largemouth bass	Game
Pomoxis annularis	White crappie	Game
Pomoxis nigromaculatus	Black crappie	Game
Etheostoma asprigene	Mud darter	Prey
Etheostoma caeruleum	Rainbow darter	Prey
Etheostoma kennicotti	Stripetail darter	Prey
Etheostoma spectabile	Orangethroat darter	Prey
Etheostoma sp.	Unidentified darter	Prey
Percidae	Unidentified darter	Prey
Perca flavescens	Yellow perch	Game
Percina caprodes	Logperch	Prey
Stizostedion canadense	Sauger	Game
Aplodinotus grunniens	Freshwater drum	Commercial

Table 5-25. Number of Samples and Mean Annual Standing Stock (no./ha and kg/ha) of all Young, Intermediate, and Harvestable Size Fish Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970 through 1982

Year	No. Samples	Young		Intermediate		Harvestable		Total	
		Number	kg	Number	kg	Number	kg	Number	kg
1970	12	7,353	12.61	534	24.80	931	182.49	8,819	219.91
1971	4	7,018	17.27	724	97.95	863	168.04	8,604	283.26
1972	4	12,872	63.06	932	30.96	1,394	271.21	15,199	365.23
1973	4	13,092	72.52	955	36.44	1,572	290.20	15,619	399.16
1974	4	9,737	34.23	673	21.98	1,263	194.91	11,673	251.13
1975	4	12,684	37.18	443	14.94	1,364	187.09	14,491	239.21
1976	5	14,662	37.20	1,179	26.39	1,400	272.84	17,241	336.43
1977	5	33,121	96.18	1,164	26.41	1,441	223.97	35,727	346.56
1978	5	19,883	31.70	960	19.98	2,584	184.51	23,427	236.19
1979	5	17,973	22.91	1,375	27.41	2,872	209.04	22,220	259.36
1980	5	34,424	44.71	537	10.08	1,020	132.58	35,981	187.37
1981	5	53,515	66.21	1,590	34.14	2,278	327.68	57,383	428.03
1982	5	33,638	53.84	977	24.37	1,919	209.96	36,534	288.17
TOTAL	67								

Table 5-26. Mean Annual Standing Stock (no./ha and kg/ha) of Game, Commercial, and Forage Fish Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970 through 1982

	Game Fish		Commercial Fish		Prey Fish	
Year	Number	Kg	Number	Kg	Number	Kg
1970	2,288.22	27.42	548.18	109.55	5,982.24	82.93
1971	2,778.21	41.27	421.52	165.43	5,404.62	76.57
1972	3,764.61	58.53	769.14	140.99	10,665.19	165.72
1973	4,427.42	59.13	979.55	158.12	10,212.52	181.92
1974	2,637.81	33.32	396.25	79.74	8,638.84	138.07
1975	5,489.16	37.06	269.92	78.42	8,731.57	123.73
1976	8,624.39	57.53	474.81	147.02	8,141.71	131.88
1977	22,477.22	72.79	443.34	94.65	12,805.99	179.13
1978	18,340.44	57.57	228.17	52.31	4,859.39	126.30
1979	18,590.09	69.87	281.76	92.03	3,347.66	97.46
1980	33,026.90	80.19	225.13	66.67	2,728.00	40.51
1981	51,074.50	116.51	504.41	131.19	5,804.83	180.33
1982	24,734.60	66.80	451.4	57.10	11,347.80	164.30

Table 5-27. List of Important Fish Species Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970-1982*

Species	Frequency (%)	Percent Composition (number)	Percent Composition (biomass)
Gizzard shad	100.00	12.95	37.61
Threadfin shad	91.04	13.13	4.40
Carp	83.58	0.07	8.85
Bullhead minnow	65.67	2.20	0.18
Smallmouth buffalo	70.14	0.07	7.90
Spotted sucker	91.04	0.18	2.67
Channel catfish	94.03	0.12	3.90
Flathead catfish†	76.12	0.02	0.25
White bass†	44.78	0.07	0.06
Yellow bass†	73.13	0.39	0.57
Warmouth	94.03	2.12	0.54
Bluegill	100.00	41.06	9.50
Longear sunfish	73.13	1.71	0.73
Redear sunfish	97.01	7.23	2.83
Largemouth bass	97.51	1.73	3.31
Sauger†	34.33	0.01	0.08
Freshwater drum	100.00	1.42	8.98
Yellow perch†	79.10	0.36	0.39
White crappie†	98.50	0.34	0.88

*Based on a total of 67 samples.

†Species of special interest.

Table 5-28. Linear Regression Analyses of numbers/ha and kg/ha of Each Size Group of Each Important Fish Species Collected in Cove Rotenone Samples from Chickamauga Reservoir, 1970-1982

Species	Group*	Slope	F-Value	PR>F†
Threadfin shad	YNG-NO.	-0.15	18.88	0.0001
Threadfin shad	YNG-WT.	-0.05	7.11	0.0097
Carp	YNG-NO.	0.06	23.34	0.0001
Carp	YNG-WT.	0.01	8.85	0.0041
Bullhead minnow	YNG-NO.	0.12	11.39	0.0013
Smallmouth buffalo	YNG-NO.	-0.02	4.61	0.0356
Smallmouth buffalo	INT-NO.	-0.05	14.01	0.0004
Smallhouth buffalo	INT-WT.	-0.04	10.09	0.0023
Smallmouth buffalo	HAR-NO.	-0.06	10.15	0.0022
Smallmouth buffalo	HAR-WT.	-0.06	8.37	0.0052
Spotted sucker	YNG-NO.	-0.05	5.67	0.0202
Spotted sucker	HAR-NO.	0.04	6.81	0.0112
Spotted sucker	HAR-WT.	0.04	12.93	0.0006
Channel catfish	INT-NO.	-0.07	26.68	0.0001
Channel catfish	INT-WT.	-0.02	24.37	0.0001
Channel catfish	HAR-WT.	0.03	5.04	0.0282
Flathead catfish	HAR-NO.	-0.02	4.46	0.0386
White bass	YNG-NO.	-0.07	14.42	0.0003
Yellow bass	YNG-NO.	0.11	23.21	0.0001
Yellow bass	YNG-WT.	0.02	14.99	0.0003
Yellow bass	INT-NO.	0.08	22.96	0.0001
Yellow bass	INT-WT.	0.03	21.27	0.0001
Yellow bass	HAR-NO.	0.06	32.19	0.0001
Yellow bass	HAR-WT.	0.02	29.89	0.0001
Warmouth	YNG-NO.	0.18	49.42	0.0001
Warmouth	YNG-WT.	0.03	30.89	0.0001
Warmouth	INT-NO.	0.05	7.83	0.0068
Warmouth	INT-WT.	0.01	15.42	0.0002
Warmouth	HAR-NO.	0.07	25.73	0.0001
Warmouth	HAR-WT.	0.02	23.75	0.0001
Bluegill	YNG-NO.	0.09	19.33	0.0001
Bluegill	YNG-WT.	0.04	14.09	0.0004
Bluegill	HAR-NO.	0.02	4.51	0.0375
Redear sunfish	YNG-NO.	0.22	64.68	0.0001
Redear sunfish	YNG-WT.	0.05	39.46	0.0001
Largemouth bass	YNG-WT.	0.03	17.67	0.0001
Largemouth bass	INT-NO.	0.04	4.49	0.0380
Yellow perch	YNG-NO.	0.06	5.94	0.0175
Yellow perch	INT-NO.	0.07	9.01	0.0038
Yellow perch	INT-WT.	0.01	5.13	0.0268
Yellow perch	HAR-NO.	0.08	16.35	0.0001
Yellow perch	HAR-WT.	0.03	18.85	0.0001
Freshwater drum	YNG-NO.	-0.16	68.42	0.0001
Freshwater drum	YNG-WT.	-0.03	25.38	0.0001

Table 5-28. (Continued)

Species	Group	Slope	F-Value	PR>F
Freshwater drum	INT-NO.	-0.06	22.57	0.0001
Freshwater drum	INT-WT.	-0.05	24.37	0.0001
White crappie	INT-WT.	-0.02	7.84	0.0068

*YNG-NO. = Young (numbers/ha) YNG-WT. = Young (kg/ha)
INT-NO. = Intermediate (numbers/ha) INT-WT. = Intermediate (kg/ha)
HAR-NO. = Harvestable (numbers/ha) HAR-WT. = Harvestable (kg/ha)

†Probability of obtaining a value ≥F. Only those values with a probability level of 0.05 or less are listed.

Table 5-29a. Kruskal-Wallis Rank Sum Analyses (as Modified by Dunn) for Numbers (no./ha) of Important Species Collected in Cove Rotenone Samples from Three Areas of Chickamauga Reservoir* During Operation of SQN (1980 through 1982)

Species	Chi-Square Value	Prob. > Chi-Square†	Reservoir Areas Showing Significant Differences	Mean of Ranks‡ U	M	D
Bluegill	7.42	0.0245	- U-D -	4.17	10.00	10.83
Longear sunfish	10.35	0.0057	U-M U-D -	3.50	12.00	10.50
Yellow perch	9.52	0.0085	U-M - -	4.17	13.67	9.00

* Reservoir areas are defined as follows: Downstream (D) - TRM 471.0 to TRM 484.5; Middle (M) - TRM 484.5 to TRM 500; Upstream (U) - TRM 500 to TRM 529.9.

† Probability of obtaining value equal to or greater than chi-square. Only those species with a probability level of 0.05 or less are listed.

‡ Indicates relative abundance between areas.

Table 5-29b. Kruskal-Wallis Rank Sum Analyses (as Modified by Dunn) for Numbers (no./ha) of Important Species Collected in Cove Rotenone Samples from Three Areas of Chickamauga Reservoir[*] Prior to Operation of SQN (1970 through 1979)

Species	Chi-Square Value	Prob. > Chi-Square[†]	Reservoir Areas Showing Significant Differences	Mean of Ranks[‡]		
				U	M	D
Gizzard shad	12.17	0.0023	U-M U-D -	37.44	22.73	20.86
Carp	18.82	0.0001	U-M U-D -	38.44	14.87	25.71
Flathead catfish	7.60	0.0224	U-M - M-D	23.78	35.53	22.12
White bass	6.30	0.0429	- U-D -	32.94	28.00	20.52
Longear sunfish	31.87	0.0001	U-M U-D M-D	10.47	26.30	38.86
Yellow perch	17.00	0.0002	U-M U-D -	13.62	30.53	33.43
Freshwater drum	11.88	0.0026	U-M U-D -	37.19	23.60	20.43
White crappie	15.82	0.0004	U-M U-D -	38.81	23.26	19.42

[*] Reservoir areas are defined as follows: Downstream (D) - TRM 471.0 to TRM 484.5; Middle (M) - TRM 484.5 to TRM 500; Upstream (U) - TRM 500 to TRM 529.9.

[†] Probability of obtaining value equal to or greater than chi-square. Only those species with a probability level of 0.05 or less are listed.

[‡] Indicates relative abundance between areas.

Table 5-30a. Kruskal-Wallis Rank Sum Analyses (as Modified by Dunn) for Biomass (kg/ha) of Important Species Collected in Cove Rotenone Samples from Three Areas of Chickamauga Reservoir* During Operation of SQN (1980 through 1982)

Species	Chi-Square Value	Prob. > Chi-Square†	Reservoir Areas Showing Significant Differences	Mean of Ranks‡ U	M	D
Flathead catfish	6.04	0.0489	U-M - M-D	6.42	13.67	6.75
Bluegill	8.40	0.0150	- U-D -	4.00	9.33	11.33
Longear sunfish	10.75	0.0046	U-M U-D -	3.50	12.67	10.17
Largemouth bass	7.68	0.0215	- U-D -	4.17	9.33	11.17
Yellow perch	8.77	0.0125	U-M - -	4.67	14.00	8.33

* Reservoir areas are defined as follows: Downstream (D) - TRM 471.0 to TRM 484.5; Middle (M) - TRM 484.5 to TRM 500; Upstream (U) - TRM 500 to TRM 529.9.

† Probability of obtaining value equal to or greater than chi-square. Only those species with a probability level of 0.05 or less are listed.

‡ Indicates relative abundance between areas.

Table 5-30b. Kruskal-Wallis Rank Sum Analyses (as Modified by Dunn) for Biomass (kg/ha) of Important Species Collected in Cove Rotenone Samples from Three Areas of Chickamauga Reservoir* Prior to Operation of SQN (1970 through 1979)

Species	Chi-Square Value	Prob. > Chi-Square†	Reservoir Areas Showing Significant Differences			Mean of Ranks‡		
						U	M	D
Gizzard shad	7.67	0.0215	U-M	-	-	34.81	20.27	24.62
Carp	16.10	0.0003	U-M	U-D	-	38.16	16.67	24.64
Spotted sucker	7.72	0.0210	U-M	-	-	33.09	18.10	27.48
White bass	9.67	0.0079	-	U-D	-	34.81	27.73	19.28
Longear sunfish	32.26	0.0001	U-M	U-D	M-D	10.66	25.63	39.19
Yellow perch	21.07	0.0001	U-M	U-D	-	12.75	28.33	35.67
Freshwater drum	13.55	0.0011	-	U-D	-	36.94	26.67	18.43
White crappie	13.61	0.0011	U-M	U-D	-	37.68	24.53	19.38

* Reservoir areas are defined as follows: Downstream (D) - TRM 471.0 to TRM 484.5; Middle (M) - TRM 484.5 to TRM 500; Upstream (U) - TRM 500 to TRM 529.9.

† Probability of obtaining value equal to or greater than chi-square. Only those species with a probability level of 0.05 or less are listed.

‡ Indicates relative abundance between areas.

Table 5-31. Numbers and Biomass (kg) Per Hectare of Each Size Group of Gizzard Shad in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate*		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	1,129.74	2.24	0.00	0.00	645.34	75.49	1,775.08	77.73
1971	329.03	2.27	0.00	0.00	561.91	65.51	890.94	67.78
1972	0.52	0.01	0.00	0.00	836.35	119.52	836.87	119.53
1973	0.65	0.01	0.00	0.00	1,034.97	127.41	1,035.63	127.42
1974	5.23	0.07	0.00	0.00	912.33	107.61	917.56	107.69
1975	109.44	1.44	0.00	0.00	946.20	90.71	1,055.64	92.15
1976	1,140.28	9.83	0.00	0.00	844.93	105.62	1,985.21	115.45
1977	8,624.47	44.57	0.00	0.00	928.02	112.60	9,552.49	157.17
1978	1,894.39	7.74	0.00	0.00	2,177.57	115.17	4,071.96	122.92
1979	54.15	0.68	0.00	0.00	2,315.58	92.12	2,369.73	92.80
1980	953.30	2.63	0.00	0.00	503.02	34.73	1,456.32	37.36
1981	507.50	1.73	0.00	0.00	1,484.11	164.41	1,991.61	166.14
1982	7,913.77	20.23	0.00	0.00	1,530.03	140.19	9,443.80	160.42

*No intermediate size class considered.

Table 5-32. Numbers and Biomass (kg) Per Hectare of Each Size Group of Threadfin Shad in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate*		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	2,732.68	2.94	0.00	0.00	0.31	0.01	2,732.99	2.95
1971	3,351.72	7.19	0.00	0.00	0.00	0.00	3,351.72	7.19
1972	8,094.18	41.72	0.00	0.00	52.33	1.46	8,146.51	43.18
1973	7,248.00	50.51	0.00	0.00	6.21	0.20	7,254.21	50.72
1974	6,916.67	28.02	0.00	0.00	3.10	0.13	6,919.78	28.16
1975	3,906.97	23.05	0.00	0.00	122.96	4.07	4,029.94	27.12
1976	3,401.95	11.75	0.00	0.00	0.00	0.00	3,401.95	11.75
1977	1,566.42	17.31	0.00	0.00	0.00	0.00	1,566.42	17.31
1978	53.10	0.34	0.00	0.00	0.00	0.00	53.10	0.34
1979	363.60	0.80	0.00	0.00	0.47	0.01	364.06	0.81
1980	448.09	0.79	0.00	0.00	0.00	0.00	448.09	0.79
1981	3,294.25	8.29	0.00	0.00	0.00	0.00	3,294.25	8.29
1982	368.97	1.00	0.00	0.00	1.43	0.03	370.40	1.03

*No intermediate size class considered.

Table 5-33. Numbers and Biomass (kg) Per Hectare of Each Size Group of Carp in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	0.84	0.00	0.15	0.06	4.77	7.04	5.77	7.09
1971	0.00	0.00	0.20	0.05	27.46	53.85	27.66	53.89
1972	0.00	0.00	0.00	0.00	14.66	31.59	14.66	31.59
1973	0.00	0.00	0.00	0.00	21.49	48.42	21.49	48.42
1974	0.00	0.00	0.52	0.09	8.28	20.18	8.79	20.27
1975	0.00	0.00	0.00	0.00	12.65	28.93	12.65	28.93
1976	0.00	0.00	0.22	0.05	22.16	46.72	22.37	46.77
1977	0.00	0.00	0.00	0.00	14.26	31.39	14.26	31.39
1978	2.09	0.11	2.16	0.31	5.21	14.43	9.46	14.86
1979	0.54	0.01	0.00	0.00	16.93	38.02	17.47	38.04
1980	4.21	0.13	0.31	0.04	7.98	24.01	12.49	24.18
1981	34.52	2.02	3.79	0.61	4.04	11.94	42.35	14.57
1982	7.02	0.14	0.48	0.12	4.92	8.91	12.41	9.16

Table 5-34. Numbers and Biomass (kg) Per Hectare of Each Size Group of Bullhead Minnow in Cove Rotenone Samples, Chickamauga Reservoir, 1971-1982

	Young of Year		Intermediate*		Adult*		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1971	1.05	0.00	0.00	0.00	0.00	0.00	1.05	0.00
1972	72.67	0.15	0.00	0.00	0.00	0.00	72.67	0.15
1973	0.65	0.00	0.00	0.00	0.00	0.00	0.65	0.00
1974	734.76	0.81	0.00	0.00	0.00	0.00	734.76	0.81
1975	3,397.45	3.72	0.00	0.00	0.00	0.00	3,397.45	3.72
1976	1,974.17	1.75	0.00	0.00	0.00	0.00	1,974.17	1.75
1977	418.03	0.67	0.00	0.00	0.00	0.00	418.03	0.67
1978	148.19	0.14	0.00	0.00	0.00	0.00	148.19	0.14
1979	118.98	0.09	0.00	0.00	0.00	0.00	118.98	0.09
1980	65.01	0.09	0.00	0.00	0.00	0.00	65.01	0.09
1981	20.46	0.01	0.00	0.00	0.00	0.00	20.46	0.01
1982	554.76	0.41	0.00	0.00	0.00	0.00	554.76	0.41

*All minnows grouped in young-of-year size class.

Table 5-35. Numbers and Biomass (kg) Per Hectare of Each Size Group of Spotted Sucker in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	18.02	0.10	0.68	0.07	0.47	0.23	19.17	0.40
1971	21.16	0.30	0.00	0.00	8.76	2.76	29.92	3.06
1972	38.06	0.81	2.00	0.32	19.79	6.68	59.85	7.82
1973	162.46	3.28	7.13	1.08	17.56	5.95	187.14	10.32
1974	23.71	0.36	26.16	3.54	39.10	13.07	88.97	16.96
1975	10.71	0.17	10.98	1.41	19.72	8.84	41.42	10.42
1976	15.29	0.28	3.15	0.51	35.12	17.17	53.55	17.96
1977	18.19	0.30	2.84	0.37	23.23	11.41	44.26	12.08
1978	6.23	0.09	5.25	0.64	14.85	7.48	26.33	8.21
1979	8.99	0.07	6.05	0.80	11.20	5.73	26.23	6.60
1980	3.09	0.02	0.31	0.05	10.61	7.24	14.01	7.31
1981	0.00	0.00	0.00	0.00	12.47	9.34	12.47	9.34
1982	0.43	0.02	0.43	0.03	5.83	3.45	6.70	3.50

Table 5-36. Numbers and Biomass (kg) Per Hectare of Each Size Group of Smallmouth Buffalo in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	1.96	0.01	3.04	0.75	23.28	34.87	28.28	35.64
1971	0.58	0.02	36.05	71.13	0.00	0.00	36.63	71.15
1972	8.68	0.64	2.53	0.98	26.48	41.51	37.69	43.14
1973	1.74	0.15	1.39	0.40	21.21	40.84	24.34	41.39
1974	0.00	0.00	0.00	0.00	6.40	12.52	6.40	12.52
1975	1.79	0.15	0.78	0.16	6.39	18.86	8.96	19.17
1976	0.61	0.01	0.00	0.00	12.41	28.93	13.02	28.94
1977	2.33	0.16	1.82	0.72	7.49	9.93	11.64	10.82
1978	0.00	0.00	0.00	0.00	0.35	1.84	0.35	1.84
1979	0.00	0.00	0.00	0.00	3.31	4.57	3.31	4.57
1980	0.31	0.01	0.00	0.00	1.67	3.35	1.97	3.35
1981	0.00	0.00	0.43	0.15	1.58	2.75	2.01	2.90
1982	0.00	0.00	0.45	0.17	6.85	10.83	7.31	11.00

Table 5-37. Numbers and Biomass (kg) Per Hectare of Each Size Group of Channel Catfish in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	3.27	0.02	10.10	0.62	5.71	2.35	19.07	2.98
1971	0.99	0.01	12.73	0.86	20.19	9.89	33.91	10.76
1972	1.05	0.01	12.32	0.79	23.20	7.33	36.57	8.12
1973	1.23	0.01	12.07	0.71	29.68	9.64	42.98	10.36
1974	0.52	0.01	3.21	0.19	8.41	3.92	12.14	4.12
1975	1.03	0.01	2.39	0.11	10.27	4.13	13.69	4.25
1976	1.63	0.00	6.26	0.32	17.67	12.11	25.56	12.43
1977	2.75	0.02	4.55	0.27	12.14	7.12	19.44	7.40
1978	1.38	0.00	0.35	0.01	13.45	4.17	15.18	4.18
1979	1.05	0.01	1.40	0.04	22.35	14.19	24.80	14.24
1980	2.90	0.01	0.42	0.02	11.34	7.70	14.65	7.73
1981	6.41	0.06	4.17	0.12	67.02	59.00	77.60	59.17
1982	0.00	0.00	0.91	0.03	6.21	5.98	7.12	6.01

Table 5-38. Numbers and Biomass (kg) Per Hectare of Each Size Group of Flathead Catfish in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	3.51	0.01	0.43	0.07	1.36	0.51	5.30	0.60
1971	2.89	0.01	1.92	0.32	0.47	0.20	5.27	0.53
1972	0.78	0.00	1.06	0.08	1.65	0.98	3.49	1.06
1973	1.03	0.01	0.77	0.13	4.10	2.12	5.91	2.26
1974	0.00	0.00	0.74	0.08	2.40	1.23	3.14	1.31
1975	0.77	0.00	1.57	0.24	0.86	0.36	3.20	0.60
1976	1.21	0.00	0.00	0.00	1.50	0.81	2.70	0.81
1977	3.51	0.01	0.98	0.12	1.21	0.70	5.70	0.83
1978	1.12	0.00	1.74	0.18	1.22	0.40	4.08	0.58
1979	0.00	0.00	0.77	0.12	1.12	0.43	1.89	0.55
1980	0.34	0.00	0.00	0.00	0.00	0.00	0.34	0.00
1981	20.00	0.14	1.23	0.12	0.00	0.00	21.23	0.26
1982	0.87	0.00	0.00	0.00	0.87	0.63	1.74	0.63

Table 5-39. Numbers and Biomass (kg) Per Hectare of Each Size Group of White Bass in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	47.30	0.20	0.12	0.01	0.00	0.00	47.42	0.21
1971	4.07	0.08	0.00	0.00	0.00	0.00	4.07	0.08
1972	3.30	0.06	0.27	0.02	0.00	0.00	3.57	0.08
1973	13.96	0.15	1.33	0.07	1.12	0.22	16.42	0.44
1974	2.61	0.04	0.00	0.00	0.85	0.16	3.46	0.20
1975	0.00	0.00	0.00	0.00	0.27	0.06	0.27	0.06
1976	3.86	0.08	1.40	0.10	0.47	0.06	5.72	0.24
1977	35.48	0.38	2.79	0.16	0.00	0.00	38.27	0.54
1978	11.03	0.03	0.00	0.00	0.00	0.00	11.03	0.03
1979	3.16	0.05	0.00	0.00	0.00	0.00	3.16	0.05
1980	11.25	0.05	0.00	0.00	0.00	0.00	11.25	0.05
1982	1.43	0.03	0.48	0.03	0.48	0.08	2.38	0.14

Table 5-40. Numbers and Biomass (kg) Per Hectare of Each Size Group of Yellow Bass in Cove Rotenone Samples, Chickamauga Reservoir, 1971-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1971	0.91	0.00	0.27	0.02	0.00	0.00	1.18	0.02
1972	21.90	0.15	0.26	0.02	0.54	0.06	22.70	0.23
1973	16.65	0.19	4.65	0.28	0.00	0.00	21.30	0.47
1974	6.63	0.11	1.92	0.14	0.00	0.00	8.55	0.25
1975	19.37	0.33	12.01	0.95	2.01	0.26	33.39	1.54
1976	48.09	0.19	8.76	0.59	3.82	0.47	60.67	1.26
1977	238.76	0.94	6.52	0.56	2.62	0.30	247.91	1.80
1978	106.99	0.29	5.90	0.45	2.70	0.33	115.59	1.06
1979	3.84	0.05	0.38	0.03	0.38	0.04	4.61	0.13
1980	121.22	0.48	5.46	0.50	1.18	0.15	127.85	1.13
1981	187.95	4.29	69.19	4.56	10.23	1.26	267.37	10.11
1982	232.81	1.15	37.20	2.94	6.04	0.77	276.05	4.86

Table 5-41. Numbers and Biomass (kg) Per Hectare of Each Size Group of Warmouth in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	7.18	0.03	4.44	0.11	2.30	0.17	13.92	0.30
1971	37.62	0.09	10.65	0.23	0.00	0.00	48.27	0.32
1972	39.04	0.13	14.26	0.38	1.88	0.15	55.18	0.66
1973	195.94	1.09	9.40	0.25	8.17	0.65	213.51	2.00
1974	8.92	0.02	3.79	0.07	0.98	0.07	13.68	0.16
1975	38.28	0.06	4.67	0.08	2.82	0.27	45.77	0.41
1976	54.55	0.07	12.34	0.26	5.68	0.41	72.57	0.74
1977	233.55	0.41	9.93	0.15	6.12	0.46	249.60	1.02
1978	313.63	0.31	26.19	0.54	9.05	0.79	348.87	1.64
1979	844.05	0.95	34.19	0.65	18.29	1.55	896.53	3.15
1980	1,282.81	1.67	13.77	0.32	7.42	0.64	1,304.00	2.64
1981	1,690.82	2.15	56.63	1.12	32.43	2.21	1,779.88	5.48
1982	1,402.57	1.59	45.06	0.77	10.92	0.76	1,458.55	3.12

Table 5-42. Numbers and Biomass (kg) Per Hectare of Each Size Group of Bluegill in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	1,243.26	2.46	193.31	5.27	70.03	5.28	1,506.60	13.01
1971	1,669.92	3.18	345.20	8.84	94.88	6.68	2,110.00	18.70
1972	2,296.39	10.96	495.25	9.53	171.22	11.80	2,962.87	32.30
1973	2,214.82	5.97	374.95	7.81	186.17	12.13	2,775.94	25.91
1974	1,447.34	1.77	296.85	4.90	105.55	5.68	1,849.74	12.36
1975	4,073.41	4.83	237.89	4.18	108.32	5.96	4,419.62	14.97
1976	5,812.86	6.67	674.71	10.08	186.81	11.33	6,674.38	28.09
1977	18,963.39	20.64	519.75	7.96	185.11	11.21	19,668.26	39.81
1978	15,302.81	15.89	552.57	7.87	119.50	7.06	15,974.88	30.82
1979	13,121.79	11.47	953.28	13.59	213.18	12.11	14,288.25	37.16
1980	26,776.07	27.42	257.12	4.01	231.35	16.66	27,264.54	48.08
1981	12,800.94	7.49	979.89	15.16	277.70	19.30	14,058.54	41.94
1982	10,772.44	12.91	497.85	6.96	94.39	5.91	11,364.68	25.79

Table 5-43. Numbers and Biomass (kg) Per Hectare of Each Size Group of Longear Sunfish in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	47.16	0.32	24.34	0.58	2.71	0.17	74.21	1.07
1971	126.30	0.51	57.59	1.45	2.48	0.08	186.37	2.03
1972	171.57	0.63	76.93	1.46	5.84	0.51	254.34	2.60
1973	312.19	0.79	59.20	1.20	3.29	0.20	374.69	2.19
1974	321.73	0.47	73.49	1.19	3.70	0.17	398.92	1.84
1975	488.19	0.75	48.23	0.86	0.64	0.04	537.07	1.65
1976	867.52	1.46	188.92	2.84	4.73	0.23	1,061.16	4.53
1977	393.78	0.94	194.22	2.92	1.96	0.09	589.96	3.95
1978	191.00	0.28	75.90	1.18	7.42	0.33	274.31	1.79
1979	1,013.24	1.06	112.07	1.72	5.14	0.25	1,130.45	3.03
1980	324.67	0.53	35.93	0.67	8.80	0.42	369.40	1.62
1981	18.59	0.08	64.02	1.06	9.15	0.51	91.75	1.65
1982	41.71	0.16	44.42	0.75	3.59	0.20	89.72	1.12

Table 5-44. Numbers and Biomass (kg) Per Hectare of Each Size Group of Redear Sunfish in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	9.09	0.02	15.23	0.40	16.65	1.69	40.97	2.11
1971	80.79	0.25	25.28	0.65	33.08	4.52	139.14	5.42
1972	46.02	0.26	40.65	1.14	62.42	6.90	149.09	8.30
1973	614.75	3.64	36.64	0.89	43.59	5.35	694.98	9.88
1974	66.12	0.19	62.88	1.39	61.86	6.80	190.86	8.37
1975	160.80	0.53	17.09	0.40	62.77	6.86	240.66	7.79
1976	187.48	0.53	62.79	1.46	93.81	9.28	344.09	11.28
1977	851.95	3.03	49.23	1.10	77.90	8.60	979.08	12.73
1978	361.20	0.53	31.23	0.60	72.46	6.41	464.89	7.54
1979	1,017.73	1.26	92.27	2.13	50.44	4.57	1,160.45	7.95
1980	2,650.56	4.17	9.33	0.21	52.48	5.90	2,712.38	10.29
1981	10,762.80	7.20	40.38	0.87	62.62	5.51	10,865.80	13.58
1982	4,012.28	5.85	118.54	1.59	35.41	2.63	4,166.23	10.06

Table 5-45. Numbers and Biomass (kg) Per Hectare of Each Size Group of Largemouth Bass in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	263.10	0.69	22.41	2.05	9.58	2.89	295.09	5.63
1971	64.88	0.35	35.72	1.89	20.59	6.67	121.20	8.90
1972	21.16	0.17	60.90	4.08	14.62	4.94	96.68	9.18
1973	66.45	0.43	69.09	4.86	26.93	6.71	162.46	12.01
1974	27.57	0.11	20.43	1.73	19.07	4.91	67.08	6.76
1975	65.56	0.23	23.82	1.68	17.35	6.32	106.74	8.23
1976	38.80	0.19	34.59	1.36	13.53	5.86	86.92	7.41
1977	251.89	1.07	130.99	3.77	16.76	3.92	399.64	8.76
1978	506.83	1.91	54.77	1.82	19.98	4.96	581.58	8.69
1979	784.76	2.25	27.21	2.00	22.44	7.40	834.42	11.65
1980	863.78	3.82	101.05	1.78	12.01	5.47	976.84	11.08
1981	468.11	2.98	219.40	5.76	28.02	8.13	715.53	16.87
1982	321.76	1.08	91.40	5.62	29.53	6.18	442.69	12.88

Table 5-46. Numbers and Biomass (kg) Per Hectare of Each Size Group of Yellow Perch in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	11.81	0.04	4.92	0.04	0.21	0.01	16.94	0.10
1971	0.00	0.00	28.77	0.29	4.26	0.28	33.03	0.57
1972	0.00	0.00	26.89	0.30	5.37	0.27	32.25	0.57
1973	0.00	0.00	7.68	0.09	15.73	0.76	23.41	0.85
1974	0.00	0.00	2.08	0.03	6.22	0.41	8.30	0.44
1975	0.27	0.00	3.18	0.03	0.91	0.06	4.36	0.09
1976	0.00	0.00	28.35	0.28	3.84	0.21	32.19	0.49
1977	42.99	0.11	89.64	0.54	15.01	0.61	147.65	1.25
1978	195.38	0.50	96.60	0.56	36.33	1.67	328.31	2.72
1979	0.38	0.00	26.80	0.19	43.06	2.11	70.25	2.31
1980	95.76	0.26	65.24	0.38	31.77	2.39	192.76	3.03
1981	39.05	0.12	56.11	0.36	25.35	1.17	120.50	1.64
1982	26.96	0.06	18.87	0.11	19.30	1.11	65.12	1.28

Table 5-47. Numbers and Biomass (kg) Per Hectare of Each Size Group of Sauger in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	0.00	0.00	0.00	0.00	0.75	0.23	0.75	0.23
1972	0.54	0.03	0.81	0.07	0.27	0.09	1.61	0.19
1973	2.23	0.13	0.58	0.09	2.59	0.60	5.40	0.82
1974	1.39	0.07	0.26	0.02	0.85	0.19	2.50	0.28
1975	0.27	0.02	1.46	0.21	0.19	0.03	1.92	0.26
1976	0.00	0.00	0.00	0.00	3.39	0.78	3.39	0.78
1977	6.52	0.25	0.41	0.03	0.00	0.00	6.93	0.28
1978	0.00	0.00	0.79	0.10	0.69	0.14	1.48	0.24
1979	0.00	0.00	1.40	0.14	0.47	0.08	1.86	0.23
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5-48. Numbers and Biomass (kg) Per Hectare of Each Size Group of Freshwater Drum in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass	Numbers	Biomass
1970	109.45	0.76	211.63	12.38	96.91	16.34	417.99	29.48
1971	72.45	0.93	139.24	8.21	58.07	8.40	269.77	17.54
1972	305.07	3.72	153.91	9.71	127.07	25.45	586.05	38.88
1973	228.57	1.87	307.13	15.63	125.75	21.71	661.45	39.21
1974	27.10	0.21	165.60	7.68	62.02	10.33	254.72	18.22
1975	33.86	0.29	68.26	3.96	37.15	8.09	139.26	12.35
1976	77.81	0.52	125.65	7.08	119.88	19.32	323.34	26.92
1977	62.65	0.60	116.64	6.73	127.61	17.95	306.90	25.28
1978	0.34	0.00	73.93	4.46	82.26	11.23	156.54	15.70
1979	5.87	0.06	68.65	4.15	100.96	13.30	175.47	17.51
1980	2.76	0.02	27.73	1.74	116.01	15.76	146.50	17.51
1981	6.31	0.04	57.13	3.52	247.53	38.22	310.97	41.78
1982	1.39	0.02	68.89	3.96	152.82	20.98	223.10	24.96

Table 5-49. Numbers and Biomass (kg) Per Hectare of Each Size Group of White Crappie in Cove Rotenone Samples, Chickamauga Reservoir, 1970-1982

	Young of Year		Intermediate		Adult		Total	
Year	Numbers	Weight	Numbers	Weight	Numbers	Weight	Numbers	Weight
1970	89.00	0.11	28.51	1.19	20.68	3.09	138.18	4.39
1971	7.90	0.05	13.69	1.04	17.95	3.14	39.54	4.23
1972	29.80	0.10	13.33	0.48	12.55	2.52	55.68	3.11
1973	24.31	0.07	15.29	0.69	16.30	2.94	55.90	3.70
1974	0.60	0.00	2.14	0.07	7.15	1.15	9.88	1.22
1975	1.13	0.00	4.31	0.27	7.80	1.07	13.25	1.35
1976	26.53	0.06	14.70	0.24	7.65	1.25	48.88	1.55
1977	66.00	0.18	16.16	0.18	8.59	1.20	90.75	1.56
1978	116.93	0.27	26.24	0.98	12.34	1.46	155.50	2.71
1979	57.10	0.12	26.41	0.59	28.16	2.87	111.67	3.58
1980	9.31	0.02	8.42	0.09	12.86	1.74	30.59	1.85
1981	10.43	0.02	14.13	0.15	5.59	0.99	30.16	1.17
1982	118.97	0.21	4.57	0.05	3.25	0.60	126.79	0.86

Table 5-50. Loading of Fish Species on Two Components (PCA), Cove Rotenone Samples Chickamauga Reservoir, 1970 Through 1982

Species	Principal Component I	Principal Component II
Spotted gar	-.13	-.32
Longnose gar	.10	-.51
Skipjack herring	-.20	.34
Gizzard shad	-.19	.12
Threadfin shad	-.50	.56
Mooneye	-.04	.09
Central stoneroller	.46	.10
Carp	-.32	-.52
Silver chub	-.01	.30
Golder shiner	.78	-.36
Emerald shiner	.37	.46
Common shiner	.34	.13
Spotfin shiner	.54	.49
Mimic shiner	.18	.34
Bullhead minnow	.35	.50
Northern hogsucker	.19	.38
Smallmouth buffalo	-.42	.24
Spotted sucker	-.06	.09
Black redhorse	-.05	.23
Golden redhorse	-.29	.12
Blue catfish	.02	-.15
Black bullhead	.25	-.20
Yellow bullhead	.42	-.52
Channel catfish	-.24	-.12
Flathead catfish	.01	.11
Blackspotted topminnow	.31	.37
Mosquitofish	-.31	-.22
White bass	-.42	.05
Yellow bass	.11	-.05
Warmouth	.74	-.39
Redbreast sunfish	.50	-.25
Green sunfish	.42	-.23
Orangespotted sunfish	-.15	-.05
Bluegill	.87	.05
Longear sunfish	.46	.57
Redear sunfih	.77	-.13
Spotted bass	.03	.54
Largemouth bass	.74	-.23
White crappie	.01	-.34
Black crappie	.37	-.21
Rainbow darter	.19	.20
Yellow perch	.76	.08
Logperch	.51	.62
Sauger	-.02	.31
Freshwater drum	-.63	.09
Brook silverside	.76	.32

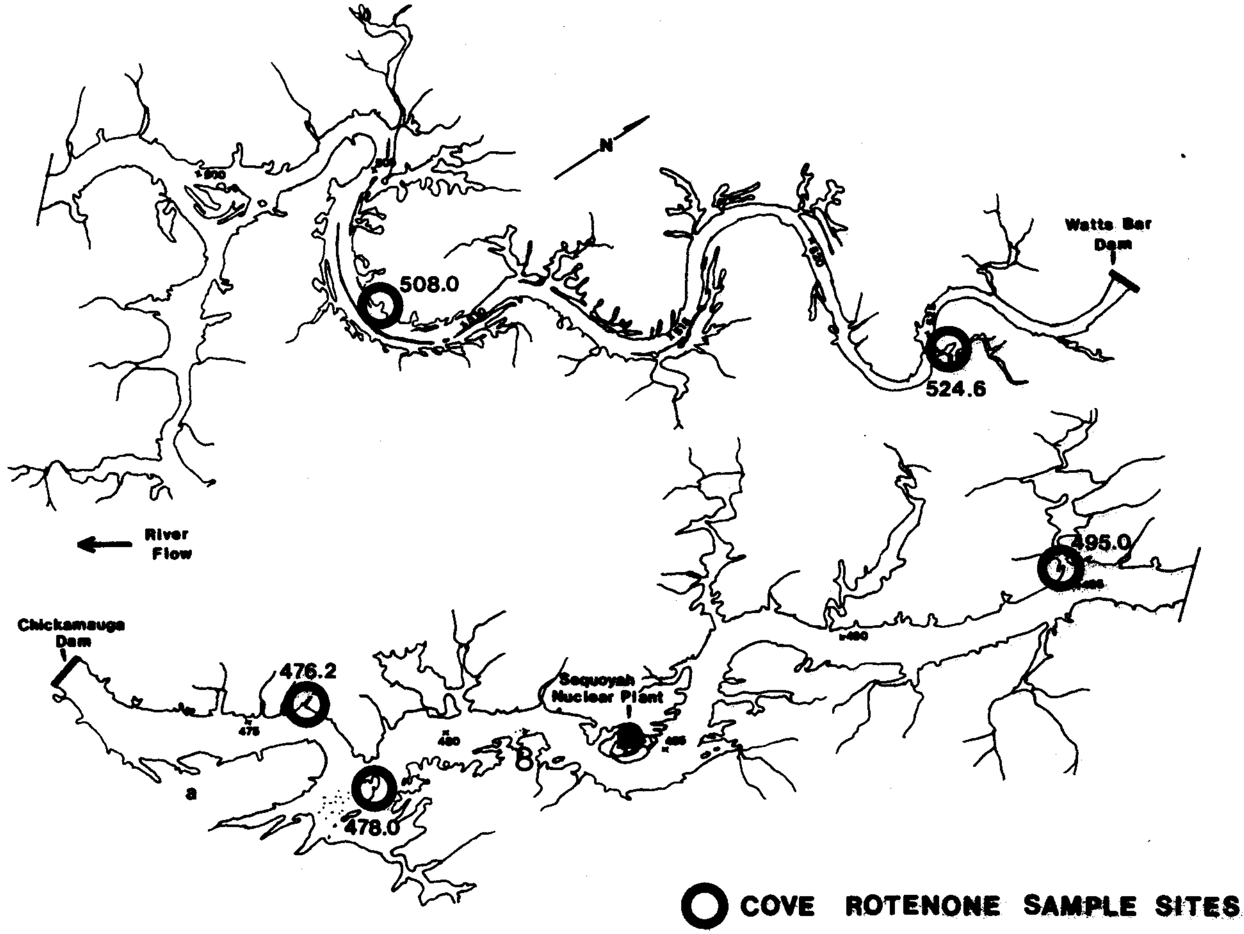

Figure 5-22. Location of Cove Rotenone Sample Sites in Chickamauga Reservoir, 1970 through 1982.

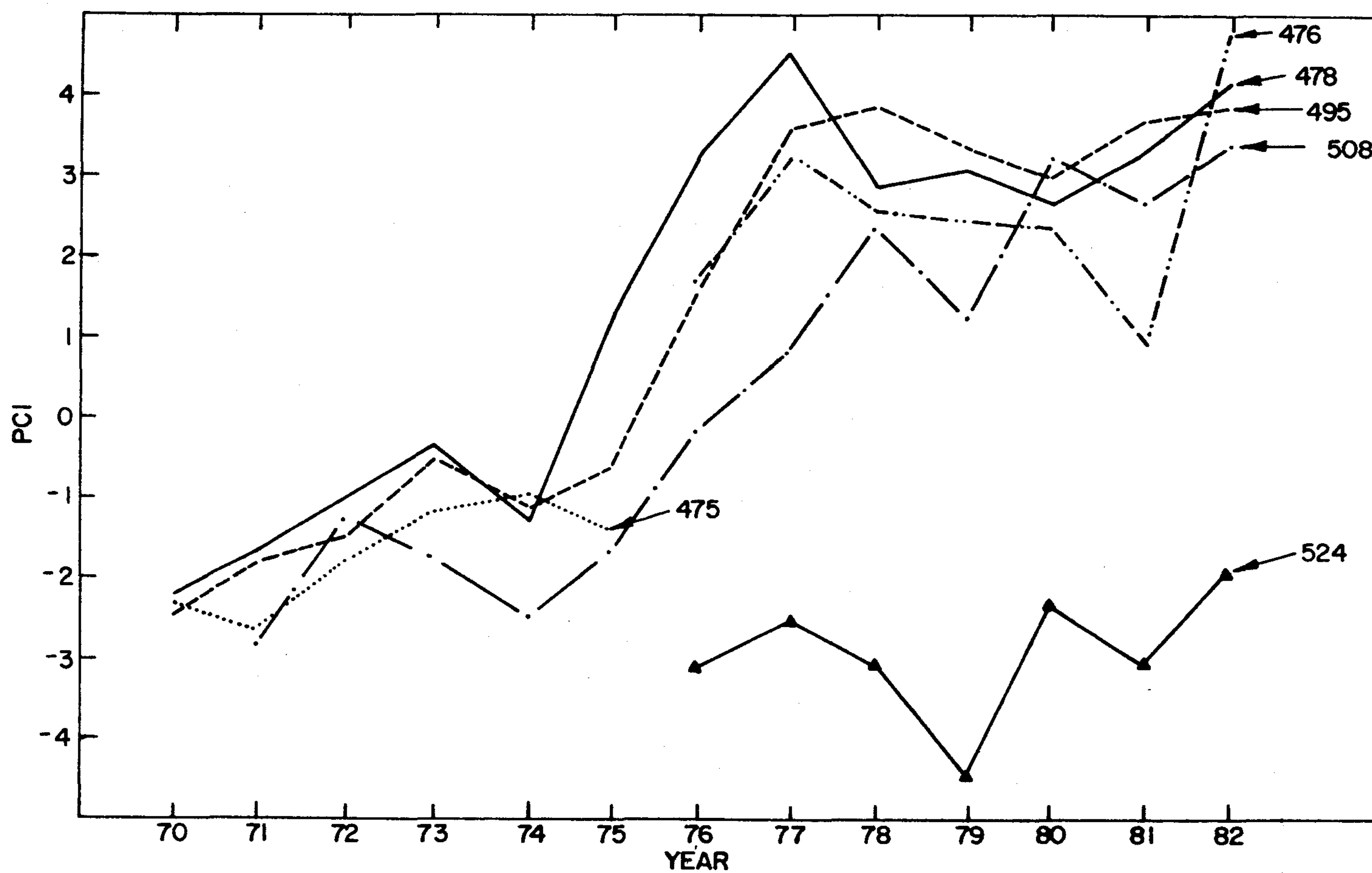

Figure 5-23. Principal Component Scores (PCI) for Cove Rotenone Samples from Chickamauga Reservoir, 1970 through 1982. Numbers Indicate Tennessee River Mile (TRM).

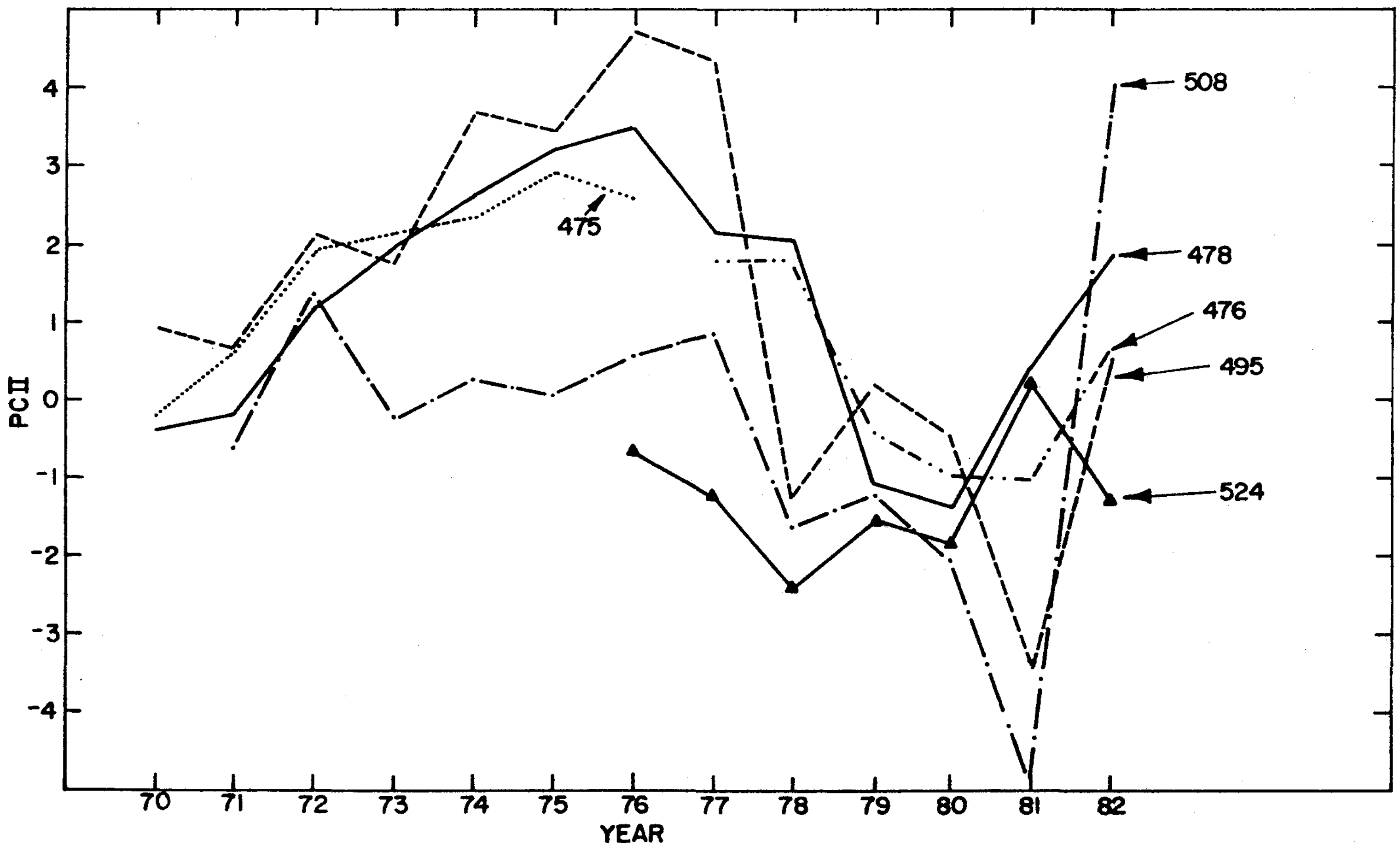

Figure 5-24. Principal Component Scores (PCII) for Cove Rotenone Samples from Chickamauga Reservoir, 1970 through 1982. Numbers Indicate Tennessee River Mile (TRM).

5.2.4 Creel

Materials and Methods

This survey procedure was formulated by personnel of the Tennessee Wildlife Resources Agency (TWRA) and TVA following closely a design prepared for Tennessee by Dr. D. W. Hayne of the Institute of Statistics at Raleigh, North Carolina. Collection of field data and data processing was performed by TVA and TWRA personnel.

This survey was of the roving clerk-uneven probability type, with day, work area, and time of day randomly selected. Workdays were drawn, with replacement, until enough days had been selected to fill out the prescribed five-day, weekly work load for the clerk; a record was kept of the number of times each weekday was drawn. After the workdays for a week had been selected, the work area and time for each day were chosen. The reservoir was divided into areas just large enough to be covered in a boat in one work period. Each day was divided into two work periods, from sunrise until noon and from noon until sunset (except during Daylight Savings Time when the division was at 1:00 p.m.). After the time of day had been selected, the given time for making instantaneous counts was chosen at random from all quarter hour segments in the work period. At this preselected time, the clerk counted the number of persons fishing in the work area. During the rest of the work day, the clerk collected information on the number of each species of fish caught, the weights of individual fish, hours fished, and related data from each fishing party interviewed. Estimates of fishing success were made from the interviews and estimates of fishing pressure from the counts of fishermen; total catch was estimated as the product of success and pressure.

A separate estimate of the weekly fishing pressure in fisherman hours (P) was made for each work period by use of the following formula:

$$P = \frac{a \times c}{b \times d \times e}$$

where

a = work area count

b = probability of drawing this work area

c = number of hours in work period

d = probability of drawing this work day

e = probability of drawing this work time (a.m. or p.m.)

Probabilities for work days, areas, and times were assigned using information on fishing pressure provided by TVA personnel from previous knowledge of fisherman activity. Each day's estimate of weekly pressure was weighted by the number of times that particular day was drawn in setting up the original sampling schedule and used to calculate a mean ($\bar{P}$) for the week.

Estimated weekly harvest (number) of each species was the average catch per hour of that species from the clerk's total interviews for the week multiplied by mean pressure ($\bar{P}$). The weekly harvest of a particular species multiplied by its average weight in the creel provided the weekly weight of each species caught. Estimated total number and weight of all fish caught each week were summations of estimates for individual species. Total number of fishing trips was derived from the average length of completed fishing trips in hours divided into the total estimated fisherman hours.

Supplemental fisherman interviews were made one (1) day per week in the immediate vicinity of SQN. Annual data summaries represent data collections in a creel year, beginning July 1 each year and ending June 30 of the following year.

All tabulations and calculations used in this survey were made by IBM 360-20 computer using programs developed and written by William L. Turner, Tennessee Game and Fish Commission. The computer program printed the creel clerk's work schedule, expanded the counts into estimated pressure and, employing catch data, made harvest estimates by month and year.

Results and Discussion

Creel information contained in this report represent three years of data collection (interim sampling) between SQN preoperational data collection and two years of operational data collection. Summary data from these surveys are compared to those derived from the SQN preoperational creel surveys conducted from 1972 through 1976.

Creel information collected during the period July 1977 to June 1982 shows 24 species of game fish have been consistently harvested by anglers. Of these, nine have been shown to be important (i.e., comprising at least one percent of the total biomass or numbers harvested each year).

Numbers--A total of 253,248 fish were harvested by anglers in the 1981 creel year (July 1981 through June 1982). This was a 25 percent decrease from 1980 (table 5-51). The 1981 catch is reasonable compared to previous years. The average annual catch in the interim period was 255,173 fish with an expected variation of 24 percent among the years. The six-year preoperational average was 175,645 fish (cv = 54).

In terms of numbers, white crappie was the dominant species harvested, contributing 53.8 percent of the total harvest in 1981. Largemouth bass, bluegill and white bass were the next highest species harvested averaging 11.5, 10.7, and 10.3 percent respectively. Other species contributing at least one percent of the total harvest were channel catfish, blue catfish, black crappie, sunfish, and sauger.

Total catch in the 1980 creel year was 337,392 fish. The three dominant species were white crappie, bluegill, and channel catfish. White crappie catch contributed 64 percent, while bluegill and channel catfish combined accounted for 17 percent. White crappie catch, although lower in 1981 than 1980, is larger than estimates from earlier creel surveys and continues to reflect high reproductive success during recent years.

Biomass--Estimated total biomass of game fish harvested was 68,536 kg in 1977, 86,540 kg in 1978, and 78,947 kg in 1979. The three-year average was 78,007 kg (cv = 12). The six-year preoperational average was 68,575 kg (cv = 26).

White crappie was generally the biggest contributor with 34.8 percent in 1977, 22.0 percent in 1978, 20.8 percent in 1979 and 40.0 percent in 1980 (table 5-52). Biomass of white bass in 1978 exceeded that of white crappie by 3.5 percent. Over the three years, white bass and blue catfish were the second and third highest biomass harvests with averages of 15.2 and 14.0 percent respectively. Of the remaining species, both largemouth bass and channel catfish contributed more than one percent of the estimated total biomass in each of the survey years.

Total biomass harvested during the 1981 survey was 82,170 kg. White crappie accounted for 35.0 percent of the harvest, followed by largemouth bass at 21.0 percent. The third largest contributor was white bass at 11.4 percent.

Harvest Rates--Rates of harvest (catch per hour) and catch per unit surface area) for three interim survey years (1977-79) and two operational years (1980-1981) are in table 5-53. Number of fish harvested per hour of fishing ranged from 0.58 fish in 1979 and 1981 to 1.18 fish in 1978. The operational period average was 0.73 fish/hr (cv = 29), compared to the interim period average of 0.86 fish/hr (cv = 35) and the preoperational period average of 0.75 fish/hr (cv = 22). Biomass of fish harvested showed a similar pattern with a low of 0.20 kg/hr in 1981 and a high of 0.31 kg/hr in 1978. The 1980-81 average was 0.21 kg/hr (cv = 1) compared to the interim average of 0.25 kg/hr (cv = 20), and the six-year preoperational average of 0.22 (cv = 43). Harvest rates per unit of water surface in Chickamauga Reservoir (summer pool) showed a two-year operational average of 18.73 fish/ha (cv = 20) and 4.10 kg/ha (cv = 61) compared to the three-year averages of 16.18 fish/ha (cv = 24) and 4.94 kg/ha (cv = 12). Averages for the preoperational period were 16.30 (cv = 18) and 4.74 (cv = 30), respectively.

Annual rates of number of fish and biomass per hour of fishing were 0.58 fish/hr and 0.20 kg/hr, respectively in 1981 and 0.87 fish/hr and 0.21 kg/hr, respectively in 1980. Rates of harvest per hectare of reservoir surface area in 1980 exceeded the estimates from interim surveys, but dropped in 1981 to 16.06 fish/ha and 2.33 kg (table 5-53). These estimates are within one standard deviation of the seven-year averages calculated from preoperational study data.

Fishing Pressure--Fishing pressure during two years of operational monitoring followed the expected seasonal pattern in which angler activity is lowest in the colder months and highest in spring (table 5-54). The two-year operational fishing pressure average was 477,427 hours (cv = 4).

Since 1977, the lowest annual pressure observed was 289,066 hours in 1977 and the highest, 491,171 hours, in 1981. The six-year preoperational average was 336,897 hours (cv = 30) with a 12-month low of 216,868 hours in 1974 and a high of 463,855 in 1975.

Fishing pressure in 1981 showed an increase over previous years. Most noteworthy were monthly estimates of 82,000 hours for April and 54,000 hours for July, indicating that weather and other fishing conditions were excellent in spring and early summer.

Summary and Conclusions

White crappie is the primary contributor to the creel on Chickamauga Reservoir; bluegill, white bass, channel catfish, largemouth bass, and sauger provide most of the remainder of both number and biomass of fish harvested. The top three species combined in any given year contribute more than 60 percent of the creel.

Although estimates of individual species harvests and total fishing pressure vary from year to year as shown in tables 5-51 through 5-54, the overall fishery appears reasonably stable. The only noteworthy findings were that catfish biomass exceeded white crappie biomass in 1976 and 1977 and that biomass of white bass harvest exceeded that of white crappie in 1978.

Variation among interim period estimates for total biomass harvested was 12 percent. Estimates of total numbers of fish harvested over the three-year period varied 24 percent and estimated fishing pressure varied 20 percent.

The moderately low estimates of variation in harvest per hectare in both the preoperational study period and interim period indicate a relatively constant supply of catchable sized game fish. In 1981 biomass harvested per fishing hour and per unit surface area were similar to previous years, however, corresponding rates for number of fish caught were depressed. This indicates that the average size of fish caught in 1981 was generally larger than previous years.

Review of the composition of sport fish harvested from Chickamauga Reservoir in the preoperational and interim periods shows that reasonable variation can be expected from year to year. Comparison of the 1980 and 1981 creel estimates to that of the previous eleven years do not indicate any detrimental effect of SQN on sport fish harvest.

Table 5-51. Estimated numbers harvested by anglers, July 1, 1977 through June 30, 1982, Chickamauga Reservoir, Tennessee

Species	Number				
	1977	1978	1979	1980*	1981*
White crappie	85,425	108,716	87,831	215,764	136,069
Bluegill	34,886	46,694	25,137	29,520	25,547
White bass	17,700	67,692	20,819	16,562	26,556
Channel catfish	20,461	22,392	18,227	25,051	8,391
Drum	17,719	4,891	2,894	1,529	1,221
Largemouth bass	6,441	23,936	20,536	18,850	29,094
Skipjack herring	134	-	-	-	-
Blue catfish	5,132	4,164	4,875	8,924	3,928
Redear sunfish	2,330	1,862	893	3,788	291
Spotted bass	1,212	1,211	848	265	597
Smallmouth bass	1,180	444	330	265	1,494
Black crappie	1,705	3,313	4,105	3,204	4,502
Sauger	20,772	34,704	20,200	9,115	3,054
Other sunfish†	289	-	5,286	341	9,364
Yellow perch	1,737	756	1,946	1,771	1,208
Yellow bass	997	3,009	1,201	57	1,141
Flathead catfish	1,397	218	1,464	861	303
Rock bass	192	62	-	-	77
Bullhead	875	-	-	-	-
Carp	481	-	148	-	98
Walleye	-	215	78	591	-
Smallmouth buffalo	58	-	-	-	-
Striped bass	844	756	1,381	508	303
Mooneye	105	-	-	-	-
Total	222,056	325,035	218,429	337,392	253,248

* Operational studies.

† Includes longear sunfish, green sunfish, warmouth, etc.

Table 5-52. Estimated biomass harvested by anglers, July 1, 1977 through June 30,1982, Chickamauga Reservoir, Tennessee

Species	Biomass (kg)				
	1977	1978	1979	1980*	1981*
White crappie	23,886	19,080	16,423	36,765	28,874
Bluegill	4,591	4,839	2,450	2,817	3,129
White bass	6,537	22,151	8,569	7,299	9,452
Channel catfish	11,773	11,481	9,404	16,891	6,255
Drum	5,495	1,300	1,316	862	471
Largemouth bass	3,609	10,207	10,902	10,780	17,326
Skipjack herring	31	-	-	-	-
Blue catfish	1,707	2,090	3,064	6,656	6,352
Redear sunfish	350	245	117	480	56
Spotted bass	469	488	721	175	310
Smallmouth bass	693	196	415	107	1,123
Black crappie	517	892	974	669	1,271
Sauger	4,766	10,972	8,501	3,320	1,635
Other sunfish†	53	-	929	108	1,751
Yellow perch	153	118	275	402	352
Yellow bass	178	433	130	10	130
Flathead catfish	740	58	6,491	2,073	543
Rock bass	23	10	-	-	25
Bullhead	112	-	-	-	-
Carp	1,470	-	558	-	405
Walleye	-	193	57	310	-
Smallmouth buffalo	171	-	-	-	-
Striped bass	1,193	1,787	7,651	2,815	2,694
Mooneye	19	-	-	-	-
Total	68,536	86,540	78,947	92,539	82,170

*Operational studies.

†Includes longear sunfish, green sunfish, warmouth, etc.

Table 5-53. Harvest rates of sport fish, July 1, 1977 through June 30, 1982, Chickamauga Reservoir, Tennessee

Year	Harvest per hour of fishing		Harvest per hectare	
	Number	Biomass(kg)	Number	Biomass(kg)
1977	0.82	0.23	14.08	4.34
1978	1.18	0.31	20.61	5.48
1979	0.58	0.21	13.85	5.00
1980*	0.87	0.21	21.39	5.87
1981*	0.58	0.20	16.06	5.21

*Operational studies

[illegible] Fishing pressure by months, July 1, 1977 through June 30, 1982, Chickamauga Reservoir, Tennessee

	Hours of Fishing				
	1977	1978	1979	1980*	1981*
J	38,872	41,957	47,513	37,513	53,846
Au	24,479	49,263	37,466	47,852	52,011
Se	18,146	20,356	27,004	36,831	35,918
Oct	-†	16,224	15,459	47,776	29,688
Nov	5,614	23,264	13,403	19,847	13,069
Dece	5,106	14,983	10,061	19,424	10,084
Janu	551	4,997	6,825	11,212	5,535
Febru	2,470	6,189	15,579	18,868	8,820
March	21,997	28,881	14,371	35,025	60,322
April	66,376	26,863	68,705	71,207	81,896
May	45,007	42,818	58,733	67,011	64,134
June	45,264	56,192	101,482	51,117	75,848
Total	289,066	329,297	424,231	463,683	491,171

* Operatio dies.

† No Estima

6.0 CONCLUSIONS

TVA initiated loading nuclear fuel in the first of two units at SQN on March 1, 1980 and in the second unit on July 3, 1981. Testing of unit 1 was completed and 100 percent power was reached early in 1981. Testing of unit 2 was initiated during November and December 1981 and the 100 percent power level reached early in 1982. Testing and operation of pumping structures were initiated early in 1980 with continual operational since that time.

The NPDES permit for SQN requires monitoring the aquatic environment following initiation of plant operation. This is the second operational monitoring report and summarizes data collected in 1982 and compares these with preoperational data, as well as data summarized in the first operational monitoring report (TVA, 1982a).

6.1 Abiotic Parameters

1. Flows at SQN are dominated by releases from Watts Bar Dam, with approximately ten percent of the water originates from the Hiwassee River basin. In 1982 river flows during March and from June through November were normal, while flows during January, February, and December were higher than normal. Flows during April and May were very low.

2. Plant operation was much greater in 1982 than in 1981, as both units 1 and 2 operated for a significant period of 1982. Combined output of units 1 and 2 was fairly low in January and February, increased to about 50 percent capacity in March, and remained at about 70 percent capacity during spring and summer months (April through August). Unit generation coincided with plankton sampling on three of four operational sample periods.

3. Diffuser water quality is comparable to that of the intake suggesting operation of SQN has had little, if any, effect on the chemical composition of water withdrawn from and discharged back to Chickamauga Reservoir. An increase in average sulfate concentration of 2.0 mg/ℓ was the only statistically significant

increase in a chemical constituent that could be attributed to the operation of SQN. Because sulfate concentrations in the intake were well below levels recommended for water quality criteria, the slight increase should not cause any adverse environmental problem in Chickamauga Reservoir or impair any water uses.

4. Water quality of Chickamauga Reservoir is primarily influenced by the relatively high flow of the Tennessee River. Operational monitoring data to date show no adverse alteration of water quality in Chickamauga Reservoir due to operation of SQN.

6.2 Biotic Parameters

1. Phytoplankton and zooplankton data for winter and fall 1982 sample periods revealed almost no differences between up- and downstream stations; indicating SQN had very little influence on plankton during these periods in 1982. Very high river flows during winter and normal flows with no plant generation during fall probably accounted for plankton similarity among stations.

   Data for spring 1982 indicated significant differences among stations for both phyto- and zooplankton. Various explanations were postulated, but relative contribution of potential causes to observed differences could not be determined. Plant effect was one possible cause because SQN entrained about 30 percent of the river flow during this sample period.

   Phytoplankton and zooplankton exhibited increases from up- to downstream stations during the summer 1982 sample period. Although stimulation from plant operation cannot be ruled out, it appeared that plant operation had less effect on plankton during this period than did other physical conditions.

   When operational data were compared to preoperational data, trends which were apparent in preoperational monitoring and the first year of operational monitoring (increases in phytoplankton parameters) were not apparent during this second year of operational sampling. Rather, data for 1982 were more similar to mesotrophic conditions of the early 1970's. SQN has apparently had little influence on trophic conditions in Chickamauga Reservoir because similar trends were apparent both upstream and downstream of the plant.

   A comparison of preoperational and operational zooplankton data indicated trends which were apparent in preoperational monitoring (increases in zooplankton densities over time) were not apparent during three of the four sample periods in both years of operational sampling. Only during May of each operational year did trends observed during preoperational monitoring continue.

   Data for this operational period indicated that SQN had little influence on the plankton community during winter, summer, and fall. However, the relative contribution of SQN in combination with physical factors in Chickamauga Reservoir to differences in plankton among stations during spring could not be determined.

2. Seasonal comparisons based upon macroinvertebrate diversity, community similarity, and abundance in 1982 indicate that the station located immediately downstream of SQN was different from other stations. In August, only five taxa were collected from this station and in November number of specimens declined to a yearly low in contrast to increases in macroinvertebrate abundance at other stations. Based upon 1982 data, close proximity of this station to SQN and the simultaneous occurrence of macroinvertebrate community reductions with increased plant load (spring and summer) make SQN a likely contributing factor.

   Compared to other years (1971-1981), however, changes observed immediately downstream of SQN in 1982 were similar to conditions observed at that station during preoperational monitoring, indicating that factors other than operation of SQN may be responsible for observed differences. Because factors such as depth, substrate composition, and scouring action of reservoir currents affect the macroinvertebrate community and because these factors were observed to be different at the station immediately downstream of SQN, this study is inconclusive regarding impact of SQN. Investigations are continuing to locate a station within the nearfield area similar to the control station.

   Bioaccumulation data indicated concentrations of copper and cadmium increased seasonally above background levels (i.e., source population) downstream of SQN during both 1981 and 1982 and were statistically higher than upstream concentrations during 1982 (upstream data not available for 1981). Concentrations of zinc were also elevated downstream of SQN in *Amblema plicata* (a freshwater mussel), although high variability among downstream replicate samples precluded determination of statistical significance. Other metals such as iron and aluminum were also greater than background concentrations at both control and experimental stations and are thought to represent gut contents rather than true bioaccumulation. Failure to purge gut contents of test organisms before analyses made it impossible to determine if metals were incorporated into mollusk tissues downstream of SQN. However, it does appear that copper, cadmium, and zinc are being increased seasonally in the trophic system downstream of SQN.

3. Estimated entrainment of freshwater drum eggs at SQN in 1982 was higher than in 1981, although hydraulic entrainment decreased slightly. As in 1980 and 1981, larger densities of freshwater drum eggs were collected in skimmer wall samples than at the plant transect causing estimated entrainment of freshwater drum eggs to be higher than hydraulic entrainment. However, greatest seasonal density of freshwater drum eggs was recorded at the diffuser transect (downstream from the plant) where they would not be vulnerable to entrainment.

Estimated entrainment of total fish larvae in 1982 was consistent with 1981 and again lower than hydraulic entrainment. Larval shad, the most abundant taxon, were entrained at a rate of 1.5 percent, while freshwater drum larvae had the highest entrainment percentage (25.6 percent). Seasonal density of larval drum was nearly three times higher at the skimmer wall than at the other three transects. Freshwater drum larvae were most abundant in the deep sample strata. Thereby, increasing their vulnerability to entrainment. The five-fold increase (over 1981 level) in percentage entrainment of freshwater drum larvae transported past SQN in 1982 warrants concern with respect to plant impact on this population in Chickamauga Reservoir. Larval Percichthyidae (white and yellow bass) was the only other taxon with entrainment (2.7 percent) higher than that of total larvae and which increased in percentage entrainment from 1981 (1.7 percent).

With the exception of estimated entrainment of one-fourth of freshwater drum larvae passing SQN, no detectable impact to the fish community as a result of plant entrainment was apparent.

4. Impingement losses of fish at SQN were low relative to most other TVA electric generating plants and to cove rotenone stock estimates of fish in Chickamauga Reservoir. Although there are some questionable data, impingement losses as presently estimated are judged to have no significant adverse impact on reservoir-wide populations of the 29 species impinged.

5. Of 39 fish species and one hybrid collected during operational gill netting, gizzard shad and skipjack herring were the most abundant species. Gill net samples during operational monitoring to date have revealed few differences from preoperational observations. Only two of the changes seen in gill netting results appear to be related to operation of SQN. Sauger were likely avoiding the diffuser area during summer months, and white bass were likely attracted to the same area during the same period.

6. Bluegill was the predominant species in cove rotenone samples from Chickamauga Reservoir from 1970 through 1982. There has also been a general increase in numbers and biomass of other game fish but no apparent trend for commercial or prey fish groups. Increases in game fish species, especially centrarchids, are probably related to increased aquatic vegetation in Chickamauga Reservoir.

   Of numerous trends determined for important species, only declining stocks of young and intermediate size freshwater drum might be related to operation of SQN. However, entrainment of eggs and larvae may not be the primary cause of declining stocks in Chickamauga Reservoir because (1) declining trends were first documented prior to unit 1 fuel load and (2) substantial numbers of freshwater drum eggs were present downstream of the diffusers where they were not subject to entrainment. Even if this were plant effect, it would not presently be considered adverse. None of the other trends or differences from preoperational data appear related to operation of SQN.

7. White crappie is the primary contributor to creel on Chickamauga Reservoir. Bluegill, white bass, channel catfish, largemouth bass, and sauger provide most of the remainder of both number and biomass of fish harvested. The top three species harvested in any given year contributed more than 60 percent of the creel. Comparison of creel estimates during the operational period to that of the previous eleven years do not indicate that operation of SQN has detrimentally affected game fish harvest.

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