Response to NRC Information Needs Related to Terrestrial Ecology (TE)

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: TERRESTRIAL ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information needs:

TE-20: Best et al-gray bat studies

TE-21: EP&P-SDP-5.7 rev 0003 Environmental Auditing Procedure

TE-26: Describe heritage audit process for transmission lines

BLN INFORMATION NEEDS: TE-20, TE-21, and TE-26

BLN RESPONSE:

During the week of March 31 through April 4, 2008, the NRC staff conducted an audit of the BLN site, including a review of the documentation supporting the BLN ER. At the site audit exit meeting, NRC Terrestrial Ecology reviewers identified additional documentation needs. These requested documents, including the document that provides a description of TVA's heritage resources audit process, are provided as Attachments A, B, and C to this enclosure.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following documents are provided as Attachments A, B, and C:

A. Best, T. L., W. S. Cvilikas, A. B. Goebel, T. D. Hass, T. H. Henry, B. A. Milam, L. R. Saidak, and D. P. Thomas, *Foraging Ecology of the Endangered Gray Bat (Myotis grisescens) at Guntersville Reservoir, Alabama*, Joint Agency Guntersville Project Aquatic Plant Management, Tennessee Valley Authority, Chattanooga, TN, and U.S. Army Corps of Engineers, 1995.

B. Tennessee Valley Authority, "Environmental Auditing Procedure," EP&P-SDP-5.7, Rev. 0003, December 15, 2005.

C. Tennessee Valley Authority, TVA Heritage Resources Review Process for TVA Transmission Rights-of-Way Vegetation Maintenance, Line and Pole Maintenance, and New Transmission Line Construction, no date.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: TERRESTRIAL ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

Price's potato-bean and Morefield's leather flower are both associated with limestone. Is limestone present within surface or shallow subsurface soils on the Bellefonte site? If so, what is the distribution of these soils (i.e., possibly a map).

BLN INFORMATION NEED: TE-22

BLN RESPONSE:

As illustrated in FSAR Figure 2.5-230, the entire BLN site is underlain by limestone of the Stones River Group (designated Osr in the figure) along the entire peninsula, with the exception of River Ridge, which is composed of sandstones and shale. The limestone at the site is overlain by 5 to 40 feet of soil, although in most areas soil does not exceed 10 feet in thickness.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None.

Foraging Ecology of the Endangered Gray Bat (Myotis grisescens) at Guntersville Reservoir, Alabama

1995

Foraging Ecology of the Endangered Gray Bat at Guntersville Reservoir, Alabama

Joint Agency
Guntersville Project
Aquatic Plant Management

TVA

US Army Corps
of Engineers

Foraging Ecology of the Endangered Gray Bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama

by Troy L. Best, Wendy S. Cvilikas, Amy B. Goebel, Tammi D. Hass, Travis H. Henry, Bettie A. Milam, Leslie R. Saidak, and David P. Thomas

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Preface

The Joint Agency Guntersville Project (JAGP) was sponsored by the Tennessee Valley Authority (TVA) and the Headquarters, U.S. Army Corps of Engineers (HQUSACE). All JAGP activities were directed by the TVA, the U.S. Army Engineer Waterways Experiment Station (WES), and the U.S. Army Engineer District, Nashville.

The TVA Vector and Plant Management Program, directed by Dr. Joseph C. Cooney, and the Aquatic Plant Management Program, directed by Mr. A. Leon Bates, served as lead programs for managing this project, with support from other organizations in TVA's Resource Group. Project funding was supported by Congressional appropriations to the TVA. The work was conducted under the management of Mr. Norman A. Zigrossi, President, Resource Group; Dr. Ralph H. Brooks, Vice President, Water Management, and Mr. Christopher D. Ungate, Clean Water Initiative.

The U.S. Army Corps of Engineers Aquatic Plant Control Research Program (APCRP) is sponsored by the HQUSACE, and is assigned to WES under the purview of the Environmental Laboratory (EL). Because of expertise developed in the APCRP, WES was designated to conduct the applied research segment of the JAGP and to participate with TVA in certain demonstrations. Funding for the APCRP is provided under Department of the Army Appropriation 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. Lewis Decell, Manager. Mr. Robert C. Gunkel, Jr., is Assistant Manager, ERRAP, for the APCRP. Program Monitor for the ARCRP is Ms. Denise White, HQUSACE. During the conduct of this study, work was under the general supervision of Dr. John W. Keeley, Director, EL; COL Bruce K. Howard, EN, Commander, WES; and Dr. Robert W. Whalin, Director, WES.

The Nashville District's involvement in the JAGP included participation in overall plan development and serving on the project management team. As part of the comprehensive project, TVA transferred funding to the Nashville District for preparation of a Master Plan and National Environmental Protection Act document for aquatic plant management on Guntersville Reservoir. This work was performed within the Planning Branch, Engineering-Planning Division, under the direction of Mr. H. Joe

Cathey. Point of contact for the project is Mr. Carl T. Swor. Commander of the Nashville District during this study was LTC J. David Norwood.

This report should be cited as follows:

Best, T. L., Cvilikas, W. S., Goebel, A. B., Haas, T. D., Henry, T. H., Milam, B. A., Saidak, L. R., and Thomas, D. P. (1995). "Foraging Ecology of the Endangered Gray Bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama," Joint Agency Guntersville Project Aquatic Plant Management.

EXECUTIVE SUMMARY: FORAGING ECOLOGY OF THE ENDANGERED GRAY BAT (*MYOTIS GRISESCENS*) AT GUNTERSVILLE RESERVOIR, ALABAMA

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Introduction.--The gray bat (*Myotis grisescens*) has a limited distribution in limestone-karst areas of the eastern and southern United States. Primarily because of habitat destruction and molestation by humans, the gray bat was listed as an endangered species by the United States Fish and Wildlife Service. Large winter colonies of the gray bat are known to hibernate in only nine caves. In early spring, winter colonies disband and leave winter hibernacula; adult females emerge from hibernation first, followed by yearlings of both sexes, and finally by adult males. The bats move to other caves where they form large transient colonies that occupy caves for several days. Gray bats then form maternity colonies, where females give birth and raise their young, and bachelor colonies, which predominantly contain males and non-reproductive females. After young become volant, sex and age segregation weakens within the home range of the population. Young-of-the-year of both sexes remain with the females in maternity colonies during July and August. Autumn migration takes place in the same order as spring emergence, with adult females leaving in early September and young-of-the-year remaining behind with the last males to leave, usually by mid-October.

During summer months, Blowing Wind and Hambrick caves, located at Guntersville Reservoir in northeastern Alabama, contain the two largest summer colonies of gray bats. The combined populations of gray bats at Blowing Wind and Hambrick caves is ca. 600,000, a doubling of their population during the past 10 years. Blowing Wind Cave (primarily a bachelor colony) and Hambrick Cave (a maternity colony) contain bats that represent a single colony, and almost all hibernate in nearby Fern Cave. Bats banded in Hambrick Cave have been found hibernating only in Fern Cave, but recoveries of hibernating bats banded at Blowing Wind Cave were more widely distributed; most hibernated in Fern Cave, but some also hibernated in Tennessee and a few as far away as Missouri. Recoveries of banded bats of all sexes and ages for all times of the year from Blowing Wind Cave indicate movements throughout northern Alabama and middle Tennessee.

Although night-flying, aquatic insects serve as the primary source of food for *M. grisescens*, little is known about the foraging and movement patterns of gray bats in Alabama. Guntersville Reservoir is large and supports a variety of aquatic habitats, but not all regions of the reservoir provide equal quantities of acceptable prey species. Gray bats probably use a variety of foraging sites throughout the active season to optimize foraging effort. In recent years, large expanses of Guntersville Reservoir have been covered with dense growths of macrophytes.

With the increasing interest in controlling or removing aquatic vegetation, it became apparent that vegetated habitats might form significant sites for production of night-flying insects, which are the primary food of endangered gray bats. To ascertain relationships of usage among the various habitats occupied by gray bats and to determine what possible effect the control or removal of aquatic vegetation might have on these bats, this study of the foraging ecology of gray bats was designed with a multifaceted approach.

1) Food habits were elucidated to verify what the bats actually were consuming, to determine patterns of variation in dietary components among hours, nights, and sample sessions, and to correlate diet with availability of prey.

2) Long-range movements were studied to ascertain how far bats ranged during nightly and seasonal forays. This provided insight into how many of the potential habitats could be visited over time.

3) Seasonal activity patterns were used to assess the duration and frequency of foraging during times of reproductive and non-reproductive activity, e.g., post-migration, gestation, lactation, mating, pre-migration. This gave an indication of the variation in intensity of foraging through the reproductive season.

4) Nightly activity patterns were studied to determine if individual bats regularly foraged in the same areas of the reservoir and to determine if they occupied an individual home range.

5) Differential use of foraging sites was measured to quantify the use of habitats as passageways and foraging areas. Because it was not possible to sample a large number of individual sites, we elected to study a few sights intensively to determine patterns of variation in use of habitats.

6) Variation in abundance and distribution of potential prey species was determined to assess which prey species were available in each habitat type. Thus, providing insight into what might attract the bats to certain habitats. These data also were used to evaluate whether the bats selected prey or if they were opportunistic in their foraging strategy.

Food habits.--The objective of this aspect of the research was to use contents of fecal pellets to document variation in dietary components among hours, nights, and sample sessions. The study site was Blowing Wind Cave, Jackson Co., Alabama, where a bachelor colony of *Myotis grisescens* resides during summer months. A sample of fecal pellets was taken every 2 h throughout the night for 1-3 nights during each of 11 sampling sessions, 19 April-20 September 1991 (total sample was 1,476 fecal pellets). Each fecal pellet was gently teased apart with a probe and identification of remains was made to taxonomic order. Remains of 14 orders of insects, two orders of arachnids, and hair of gray bats were identified. Previously, Ephemeroptera was reported as the most common order of insects in the diet of gray bats, but we found few remains of this taxon. Regarding other insect taxa, our study clearly shows that gray bats take a wider variety of prey items during their activity season than previously reported. However, we had not anticipated the significant level of variation shown between hours and sampling sessions. Apparently, availability of insects over the open-water habitats where gray bats forage is related to sporadic emergences and resultant swarms of insects. These emergences provide a temporary abundance of food represented by a few taxa of insects at any time, but a number of taxa are available at irregular intervals during the annual activity season of the bats. Our findings indicated that gray bats are very selective regarding the types of foods they consume.

Long-range movements.--The objective of this phase of the study was to use radiotelemetric monitoring to elucidate seasonal variation in movement patterns of gray bats (Myotis grisescens) at Guntersville Reservoir. Radiotransmitters were attached to female bats during July-September 1991-1992. The results of our research indicate that individual gray bats foraged over large areas of Guntersville Reservoir, there was considerable movement of bats between Blowing Wind and Hambrick caves, the average minimum size of the home range of individual gray bats at Guntersville Reservoir was ca. 7 by 24 km and covered an area of ca. 97 km^2, bats may have a greater affinity for foraging areas during and shortly after the time young become volant and during the breeding season than later in the active season as the time to enter hibernation nears, bats moved over a broader area during the time the young became volant than later in the active season, the greatest number of days a bat was detected at the same monitoring site, the greatest distances traveled by bats, and the greatest number of nights a bat was found at the same locality did not vary between sampling periods, and during 1991, the bats were located more often at about the time young became volant than later in the active season.

Seasonal activity patterns.--This aspect of the research was designed to investigate whether female bats 1) forage closer to the maternity cave during lactation than during pregnancy or after the young are weaned, 2) spend more time in maternity caves during pregnancy and lactation than after young are weaned, and 3) spend more time in non-maternity caves after the young are volant than during pregnancy and lactation. Each month from April or May through September 1993-1994, radiotransmitters were attached to female bats at Hambrick Cave or Blowing Wind Cave. A total of 107 bats was outfitted with a radiotransmitter, and each was monitored for 10 nights early in each month. Movement patterns of bats changed throughout the period of activity from April through September, but they did not fly shorter distances during the period of lactation than after lactation. Compared with periods of pregnancy and lactation, gray bats spent less time in the maternity cave immediately after lactation, but use of the maternity cave by female bats increased later in September. Females did not spend more time in non-maternity caves after the young were volant than during pregnancy and lactation.

Nightly activity patterns.—The purpose of this research was to use radiotelemetry to investigate nightly movements associated with foraging by female gray bats (*Myotis grisescens*) near Guntersville Reservoir in northeastern Alabama. Gray bats were detected at the same sites and time periods more often than expected by chance; of 141 bats equipped with radiotransmitters, 45 were located at the same site and at nearly the same time (within ≤60 min) during at least 50% of the nights they were detected. Results of this study support previous findings that some individual gray bats revisit the same foraging sites at about the same time of night. Foraging areas that receive concentrated, repeated use may represent core areas within the home range of individual gray bats. No evidence of territorial defense was observed.

Differential use of foraging sites.—The objectives of this part of the research effort were to document the use of habitats by gray bats, to determine the degree of variation in use of each habitat, and to assess differences between foraging sites located at sites located at various distances from the roost site at Blowing Wind Cave. In 1991, two terrestrial and three aquatic habits were examined within a 2-km radius of Blowing Wind Cave to verify that most foraging is done over aquatic versus terrestrial habitats. One terrestrial habitat was dominated by loblolly pine (*Pinus taeda*) and the other was characterized by grasses (*Sorghum*), goldenrod (*Solidago*), and sumac (*Rhus glabra*). One aquatic habitat contained Eurasian watermilfoil (*Myriophyllum spicatum*), another contained American lotus (*Nelumbo lutea*), and the other contained little or no vegetation. In 1992, monitoring was continued near Blowing Wind Cave at the site with watermilfoil and the site with no aquatic vegetation. Three habitats were monitored ca. 13 km from Blowing Wind Cave near the mid-channel of the Tennessee River (just downstream from B. B. Comer Bridge); these included sites dominated by no vegetation, Eurasian watermilfoil, and American lotus.

Echolocation calls emitted by gray bats were monitored simultaneously at all habitats using bat detectors and tape recorders. Recordings were made during seven 3-day sampling periods each year, yielding ca. 5,250 h of data in 1991 and 4,200 h of data in 1992. Variation in the use of habitats was assessed by counting the number of bats passing through each habitat and by counting the number of times bats foraged in each habitat (foraging attempts are distinguishable as a "buzz" on the tape recordings).

Preliminary analyses reveal that gray bats forage over aquatic habitats significantly more than terrestrial habitats. Of the two terrestrial habitats, the grassy field was visited more often than the pine forest; the bats seem to use the forest habitat as cover when traveling to and from the roost site. Of the aquatic habitats, the sites without aquatic vegetation had the most activity throughout the night, followed by the habitats with American lotus, and then the sites with Eurasian watermilfoil.

Variation in potential prey species.--The objectives of this phase of the project were to assess the diversity and abundance of insects in habitats visited by gray bats and to elucidate the pattern of variation in insect faunas among habitats. Insects were sampled at 2-h intervals during seven 3-day sampling periods at each of the sites listed above for monitoring echolocation calls, except the forest habitat where it was not possible for us to obtain samples of insects from the canopy where bats were active.

In 1991, there were no habitats that consistently contained more insects than other habitats, i.e., based on statistical analyses of abundance and biomass of insects. However, the average abundance of insects was greatest in American lotus habitat and the greatest average biomass of insects occurred in the grassy-field habitat. During 1992-1994, there were significant differences at various times among habitats in abundance or biomass of insects, but these differences were only temporary and reflected emergences of various taxa of insects. Thus, there were no consistent patterns in abundance or biomass of insects during the study. The predominant insects at any particular time or in any particular habitat seemed to be determined by emergences of a variety of insects.

Conclusions.--1) Food habits, as determined by analyses of fecal pellets, indicate that ephemeropterans were rare in the diet. This is contradictory to most previous studies, but may be explained by the total digestibility of newly-emerged mayflies. The diet varied significantly among hours and sampling sessions, verifying that the bats tend to forage almost exclusively on the emergences of insects regardless of type of insect. 2) Long-range movements indicate gray bats may move up to 75 km from the roost site during the summer activity period. All terrestrial and aquatic habitats in the vicinity of Guntersville Reservoir are within the nightly range of the bats. 3) Seasonal activity patterns indicate that adult females tend to remain closer to the maternity cave in the late stages of gestation and during lactation. Thus habitats within 20-30 km of the maternity site are used most frequently. 4) Differential use of foraging sites occurred. Overall, bats were found most often in open-water, non-vegetated, aquatic habitats. These findings are supported by previous studies of gray bats. 5) Variation in abundance and distribution of potential prey species showed that insects tend to appear as swarms of emerging insects at irregular intervals. There were no ascertainable patterns in the timing, duration, or location of insect emergences. Because the bats forage across such a large area, they apparently can detect these emergences and forage on them.

Based upon composition of diet, distances moved, seasonal variation in movement patterns, habitats visited, and availability of food, it appears that gray bats primarily forage over open-water habitats. This indicates that control or removal of aquatic vegetation would have little effect on the majority of gray bats. However, if only 5-10% of gray bats forage on emergences of insects that occur over introduced aquatic macrophytes, up to 60,000 individual bats could be effected by removal of all the introduced aquatic plants.

Project contributors and agencies involved.

This project was funded by the Tennessee Valley Authority as part of the Tennessee Valley Authority and United States Army Corps of Engineers, Joint Agency Guntersville Project. We thank J. S. Atkins, J. Bartlow, L. Bates, W. James, R. Jordan, C. P. Nicholson, B. Redman, and D. Webb of The Tennessee Valley Authority for logistical support and for their many helpful suggestions, personnel of the United States Fish and Wildlife Service, Alabama Department of Conservation and Natural Resources, and Tennessee Wildlife Resources Agency for granting permits to conduct the research, J. Shearer and H. T. Stone for assistance in the field and for permission to conduct research on Wheeler National Wildlife Refuge, K. McCutcheon of the Alabama Department of Conservation and Natural Resources for providing support facilities and access to North Sauta and Mud Creek wildlife management areas, S. Williams of the Alabama Forestry Commission for logistical support at Blowing Wind Cave, F. M. Bailey of the Tennessee Wildlife Resources Agency for logistical support at Nickajack Cave, N. R. Holler and J. Christian for administrative support from the Auburn University Cooperative Research Unit of the United States Fish and Wildlife Service, M. D. Tuttle of Bat Conservation International for advice during the early phases of this study, F. W. Anderka, E. Gardner, and B. Clark for sharing their expertise in radiotelemetry, E. H. Haas for maintaining and repairing our observation boat, T. D. Haas for entering and checking data, and especially J. L. Arnold, D. Baker, J. L. Bartig, R. S. Binkley, S. L. Burt, T. P. Carithers, N. Chadwick, W. S. Cvilikas, C. Connolley, T. Devine, F. A. Feltus, S. C. Frazier, G. L. Gardner, S. W. Gay, L. M. Gilley, A. B. Goebel, A. L. Gosser, J. Gotthelf, T. D. Haas, T. D. Hadlock, N. Hawkins, T. H. Henry, J. L. Hill, J. Holcombe, C. H. Kilgore, W. M. Kiser, N. Lawrence, K. Lewis, M. Livesay, A. McAllister, B. McCaslin, L. McDonald, B. A. Milam, L. Mitchell, K. E. Nester, J. Oakes, S. Rausch, A. Ridlehoover, J. T. Sharp, II, O. M. Smithwick, A. Stogner, A. Stonestreet, A. K. Sutherlin, L. A. Reuter, D. P. Thomas, J. C. Vaghy, J. H. Waddle, and D. M. Watts for assistance in the field and laboratory.

M.S. theses based on this research project.

Goebel, A. B. 1995. Seasonal variation in movement patterns of female gray bats (*Myotis grisescens*). M.S. thesis, Auburn University, Alabama, in preparation.

Henry, T. H. 1995. Variation in use of habitats by the gray bat (*Myotis grisescens*) in northern Alabama. M.S. thesis, Auburn University, Alabama, in preparation.

Thomas, D. P. 1994. A radiotelemetric assessment of the foraging ecology of the gray bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama. M.S. thesis, Auburn University, Alabama, 78 pp.

Technical articles that will be based on this research project.

Best, T. L., B. A. Milam, T. D. Haas, L. R. Saidak, and W. S. Cvilikas. In preparation. Variation in diet of the gray bat (*Myotis grisescens*).

Goebel, A. B., and T. L. Best. In preparation. Seasonal and nightly variation in movement patterns of female gray bats (*Myotis grisescens*) at Guntersville, Reservoir, Alabama.

Goebel, A. B., and T. L. Best. In preparation. Activity patterns of adult female gray bats (*Myotis grisescens*) in relation to reproductive status at Guntersville Reservoir, Alabama.

Henry, T. H., and T. L. Best. In preparation. Foraging ecology of *Myotis grisescens*: a comparison of numbers and types of echolocation calls in aquatic and terrestrial habitats.

Henry, T. H., A. B. Goebel, and T. L. Best. In preparation. Variation in the abundance of insects within habitats occupied by gray bats (*Myotis grisescens*) at Guntersville Reservoir, Alabama.

Thomas, D. P., and T. L. Best. 1995. Radiotelemetric assessment of movement patterns of the gray bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama. Special Publication, North Carolina State Museum of Natural History, Raleigh, in press.

Presentations of results at professional meetings.

Patterns of variation in dietary components of the gray bat (*Myotis grisescens*) in northern Alabama (T. L. Best), The Tenth International Congress on Bat Research and North American Symposium on Bat Research, Boston, Massachusetts, 11 August 1995.

Food habits of the gray bat (*Myotis grisescens*) in northern Alabama (W. S. Cvilikas), The American Society of Mammalogists, Burlington, Vermont, 24 June 1995.

Flyways and movement patterns of female gray bats (*Myotis grisescens*) in northern Alabama (T. L. Best), The Southwestern Association of Naturalists, Shreveport, Louisiana, 9 April 1995.

Movements of adult female gray bats (*Myotis grisescens*) at Guntersville Reservoir, Alabama (A. B. Goebel), Colloquium on Conservation of Mammals in the South and Central United States, Cookeville, Tennessee, 25 February 1995.

Variation in the abundance of insects within habitats occupied by gray bats (*Myotis grisescens*) at Guntersville Reservoir, Alabama (T. H. Henry), Colloquium on Conservation of Mammals in the South and Central United States, Cookeville, Tennessee, 25 February 1995.

Preliminary analysis of food habits of the gray bat (Myotis grisescens) in northern Alabama (W. S. Cvilikas), Colloquium on Conservation of Mammals in the South and Central United States, Cookeville, Tennessee, 25 February 1995.

Relationship between aquatic vegetation on Guntersville Reservoir and foraging ecology of the endangered gray bat (T. L. Best), Tennessee Valley Authority and United States Army Corps of Engineers, Joint Agency Guntersville Project, Guntersville State Park, Guntersville, Alabama, 12 April 1994.

Radiotelemetric assessment of the movement patterns of the gray bat (Myotis grisescens) in Alabama (D. P. Thomas), Colloquium on Conservation of Mammals in the South-Central United States, Athens, Georgia, 26 February 1994.

Use of echolocation calls to assess the foraging ecology of gray bats (Myotis grisescens) (T. L. Best), The American Society of Mammalogists, Bellingham, Washington, 22 June 1993.

Studies of the gray bat (T. L. Best), Tennessee Valley Authority and United States Army Corps of Engineers, Joint Agency Guntersville Project, Guntersville State Park, Guntersville, Alabama, 29 April 1993.

A radiotelemetric study of the foraging ecology of the gray bat (Myotis grisescens) at Guntersville Reservoir, Alabama (D. P. Thomas), The Southwestern Association of Naturalists, Springfield, Missouri, 16 April 1993.

A radiotelemetric study of the foraging ecology of the gray bat (Myotis grisescens) at Guntersville Reservoir, Alabama (D. P. Thomas), Colloquium on Conservation of Mammals in the South-Central United States, Mountain View, Arkansas, 26 February 1993.

Radio-telemetric assessment to determine the home range and foraging areas of the endangered gray bat (Myotis grisescens) (L. A. Reuter), North American Symposium on Bat Research, Quebec, Quebec, Canada, 23 October 1992.

Foraging ecology of Myotis grisescens: a comparison of numbers and types of echolocation calls in aquatic and terrestrial habitats (T. H. Henry), North American Symposium on Bat Research, Quebec, Quebec, Canada, 23 October 1992.

Radio-telemetric assessment to determine the home range and foraging areas of the endangered gray bat (Myotis grisescens) (T. L. Best), The American Society of Mammalogists, Salt Lake City, Utah, 16 June 1992.

Study area and methods used to assess the foraging ecology of the endangered gray bat (Myotis grisescens) in northeastern Alabama (T. L. Best), Tennessee Valley Authority, Guntersville, Alabama, 23 April 1992.

Radio-telemetric assessment to determine the home range and foraging areas of the endangered gray bat (Myotis grisescens) (L. A. Reuter), Colloquium on Conservation of Mammals in the South-Central United States, Guntersville, Alabama, 21 February 1992.

Foraging ecology of the gray bat (Myotis grisescens): determination of habitat use by recordings of vocalizations (T. H. Henry), Colloquium on Conservation of Mammals in the South-Central United States, Guntersville, Alabama, 21 February 1992.

Foraging ecology of the endangered gray bat (Myotis grisescens) in northern Alabama (T. L. Best), North American Symposium on Bat Research, Austin, Texas, 17 October 1991.

Foraging ecology of the endangered gray bat (Myotis grisescens) in aquatic habitats of northern Alabama (T. L. Best), MidSouth Aquatic Plant Management Society, Auburn University, Alabama, 3 October 1991.

I. VARIATION IN DIET OF THE ENDANGERED GRAY BAT (MYOTIS GRISESCENS) AT GUNTERSVILLE RESERVOIR, ALABAMA

Troy L. Best, Bettie A. Milam, Tammi D. Haas,

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Abstract.--Contents of fecal pellets were assessed to discern what items were ingested by the gray bat (*Myotis grisescens*), to document variation in diet among sampling sessions, among nights within sampling sessions, and among hours (1 and 2-h blocks) of nights within sampling sessions, and to compare variation in diet with variation in availability of potential prey. A total of 1,476 fecal pellets was collected at Blowing Wind Cave, Jackson Co., Alabama, 19 April-20 September 1991. Remains of 14 orders of Insecta, two orders of Arachnida, unidentified Insecta, unknown organisms, and hair from gray bats, were recovered. In decreasing order, the three most common taxa recovered were Lepidoptera, Diptera, and Coleoptera. Of the 17 food categories, 12 (71%) exhibited significant variation among sampling sessions. Three of 91 comparisons (3%) indicated significant differences among nights within sampling sessions. There was significant variation among hours within sampling sessions; more Lepidoptera usually were consumed earlier in the evening than later at night. When the amount of each food category present in the fecal pellets was compared with the quantity of prey potentially available for consumption, there was no significant correlation. We also compared contents of fecal pellets with quantity of potential prey that was available ca. 1-2 h prior to when the fecal pellets were collected; there was no significant correlation in these comparisons. There was significant variation in diet of gray bats over time, and the bats did not select prey in proportion to availability.

INTRODUCTION

Bats of the genus *Myotis* consume a variety of insects, including Coleoptera (beetles), Diptera (flies), Ephemeroptera (mayflies), Lepidoptera (moths), Neuroptera (lacewings), and Trichoptera (caddisflies--Anthony and Kunz, 1977; Barbour and Davis, 1969; Belwood and Fenton, 1976; Brack and La Val, 1985; Brigham et al., 1992; Buchler, 1976; Easterla and Whitaker, 1972; Hayward, 1970; Husar, 1976; Kunz, 1974; Ross, 1967; Whitaker, 1972; Whitaker and Black, 1976; Whitaker et al., 1981). Most previous studies of *Myotis* have been limited by duration of sampling effort and size of samples (e.g., Brigham et al., 1992; Buchler, 1976; Hayward, 1970; Lacki et al., 1995), but Brack and La

Val (1985) conducted an intensive study of the diet of the endangered Indiana bat (Myotis sodalis) in Missouri, where samples were collected at 2-week intervals from 7 June to 1 August. Their analysis of 1,272 fecal pellets provided insight into variation in diet over time. To better understand foraging requirements of a species, particularly species that may be threatened or endangered, it is highly desirable to document the full range of variability in dietary requirements.

Studies of the endangered (Greenwalt, 1976) gray bat (Myotis grisescens) have emphasized ecology, behavior, growth, and management (e.g., La Val and La Val, 1980; La Val et al., 1977; Stevenson and Tuttle, 1981; Thomas and Best, in press; Tuttle, 1975, 1976a, 1976b, 1979). M. grisescens forages over streams and reservoirs where it consumes night-flying aquatic insects (La Val et al., 1977; Rabinowitz, 1978; Rabinowitz and Tuttle, 1982; Thomas and Best, in press; Tuttle, 1976b), but there is a paucity of data on food habits of this species (Lacki et al., 1995). Guthrie (1933) reported remains of insects in the feces of a hibernating gray bat, Tuttle (1976b) noted remains of at least six species of mayflies (Ephemeroptera) under a roost, Rabinowitz (1978) and Rabinowitz and Tuttle (1982) reported remains of seven orders of insects in fecal pellets from Tennessee, and Lacki et al. (1995) identified nine orders of insects in fecal pellets obtained in Kentucky. The objectives of our research were to use contents of fecal pellets to ascertain what items were ingested by M. grisescens at intervals throughout its annual activity period, to document variation in diet among sampling sessions, nights, and hours of the night, and to compare variation in diet with variation in availability of prey.

MATERIALS AND METHODS

Blowing Wind and Hambrick caves, located at Guntersville Reservoir in northeastern Alabama, contain the two largest summer colonies of M. grisescens (Tuttle, 1976a, 1976b; United States Fish and Wildlife Service, in litt.). A total of 1,476 fecal pellets was collected at Blowing Wind Cave, Jackson Co., Alabama, 19 April-20 September 1991 (Appendix 1.1). Two linen bed sheets were spread on the ground at the lower opening of the cave to collect fecal pellets from bats entering and exiting the cave. The sheets were cleaned and repositioned after each sample was removed. For most samples, 10 fecal pellets were collected every 2 h throughout the night for 1-3 nights during each of 11 sampling sessions (Appendix 1.1). Each sample of fecal pellets was placed into a plastic bag and frozen until examined.

In the laboratory, individual fecal pellets were placed in water in a petri dish, and warmed on a slide warmer to soften and expand the contents. Then, each pellet was gently teased apart with a probe at 60X magnification. A sample of the contents of each fecal pellet was added to one drop of 90% ethyl alcohol, which had been placed on a microslide. A mixture of mounting medium and xylene (75% Permount, 25% xylene) was used to adhere the sample of contents of each fecal pellet to the microslide, which was dried on a slide warmer.

Ten fields on each microslide were examined at ≥200X magnification; an ocular grid divided each field into 100 equal-sized squares. Average percent volume of each food item based on the 10 100-unit grids was calculated by dividing the number of squares occupied by a food category by the total number of squares with food present for the fecal pellet, then multiplying this product by 100. Because we believed that Acari (chiggers) and hair of M. grisescens recovered from fecal pellets were not ingested as a source of food, these categories were quantified separately from the food categories; Acari was recorded as the total number of squares occupied in the 10 100-unit grids and bat hair was assigned values of 0 (absent in the sample), 1 ($\leq$5 hairs observed on the 10 100-unit grids), and 2 (>5 hairs observed on the 10 100-unit grids).

Identification of remains was made to taxonomic order when possible using the keys and descriptions in Whitaker (1988) and Borror et al. (1989) and by comparison of remains with specimens in the Auburn University Entomology Collection. Insects that could not be identified to taxonomic order were included in the category Insecta; structures in this category included fragments of wings, legs, head capsules, and compound eyes. Remains of organisms that could not be identified to any taxonomic unit were listed as unknown.

To quantify the relative number of prey that potentially was available for consumption by bats, 384 samples of potential prey were collected within 2 km of Blowing Wind Cave (Appendix 1.2). One terrestrial and three aquatic habitats were sampled with a 38-cm diameter, hand-held sweep net at ca. 2-h intervals during seven sampling sessions (5 June-20 September). In obtaining these sweep-net samples, the collector walked through the terrestrial habitat or was moved through aquatic habitats in a canoe; a total of 50, ca. 3 m wide, figure-8 swings was made during each sweep-net sample. The terrestrial habitat sampled was an open field adjacent to Guntersville Reservoir (characterized by grasses—Sorghum, goldenrod—Solidago, and sumac—Rhus glabra). The three aquatic habitats were: over water with no aquatic vegetation; over water with emergent Eurasian watermilfoil (Myriophyllum spicatum); over water with emergent American lotus (Nelumbo lutea). These four habitats were selected because they represented most of the habitat types available to M. grisescens at the reservoir. Contents of each sample of potential prey were identified to taxonomic order by comparison with keys in Whitaker (1988) and Borror et al. (1989). Average percent volume of each potential prey item in each sample was calculated by dividing the number of individuals of each taxon by the total number of individuals in the sample, then multiplying this product by 100. Prey taxa that could not be identified to taxonomic class were listed as unknown.

Variation among sampling sessions, nights, and hours (1 and 2-h blocks), for contents of fecal pellets and samples of potential prey, was assessed using analysis of variance and a Student-Newman-Keuls a posteriori test for multiple comparisons among means. Spearman-rank correlation coefficients were used to compare variation in each taxon between contents of fecal pellets and potential prey (Norusis, 1990; Sokal and Rohlf, 1981; Swift et al., 1985). The level of statistical significance was corrected for multiple comparisons with the sequential Bonferroni test (Rice, 1989). All times referred to herein are Central Daylight Savings Time.

RESULTS

Contents of fecal pellets.--Remains of 14 orders of Insecta (Coleoptera, Diptera, Ephemeroptera, Hemiptera--bugs, Homoptera--leafhoppers, Hymenoptera--wasps, Lepidoptera, Mecoptera--scorpionflies, Neuroptera, Odonata--dragonflies, Orthoptera--grasshoppers, Plecoptera--stoneflies, Thysanoptera--thrips, and Trichoptera), two orders of Arachnida (Araneae--spiders and Acari--chiggers), unidentified Insecta, unknown organisms, and hair from gray bats, were recovered from the 1,476 fecal pellets we analyzed (Table 1.1). The three most common taxa recovered, in decreasing order of presence, were Lepidoptera, Diptera, and Coleoptera. These three taxa represented a total of 94.4, 75.9, 88.7, 81.4, 48.5, 77.4, 68.8, 58.4, 63.5, 70.5, and 73.5% of the remains in fecal pellets collected in sampling sessions 1-11 (19 April-20 September), respectively. Small quantities (<4%/sample session) of Araneae, Hemiptera, Homoptera, Hymenoptera, Trichoptera, unidentified Insecta, and unknown organisms also were present regularly. Ephemeroptera, Mecoptera, Neuroptera, Odonata, Orthoptera, Plecoptera, and Thysanoptera occurred sporadically in the fecal pellets (Table 1.1).

Variation among sampling sessions.--Of the 17 food categories listed in Table 1.1, 12 exhibited significant ($P \leq 0.0029$) variation among sampling sessions. The largest F-value (41.674) was for unknown organisms; much of the variation in this category occurred during sampling sessions 5 and 8 (25-28 June and 5-8 August, respectively) when 30.3 and 17.7%, respectively, of the items recovered from fecal pellets could not be identified. Other than in sampling sessions 5 and 8, unknowns in the remaining sampling sessions were represented by ≤5.3% of the contents. Diptera, Insecta, Coleoptera, Ephemeroptera, and Lepidoptera had F-values >9, indicating they also were more variable than the remaining food categories. Of these five categories, Ephemeroptera was the only one that occurred sporadically. We could not discern consistent chronological patterns relative to the changes in occurrence of any food category.

Variation among nights within sampling sessions.--Variation in contents of fecal pellets was assessed among the 3 nights for sampling sessions 5 (25-28 June), 6 (8-12 July), 7 (22-26 July), 8 (5-8 August), 9 (19-22 August), 10 (3-6 September), and 11 (17-20 September; Appendices 1.3-1.9, respectively). There was no significant difference among the 3 nights sampled for any food category in sampling sessions 5, 6, 7, 9, or 10 (Appendices 1.3, 1.4, 1.5, 1.7, and 1.8). In sampling session 8, significantly more Diptera ($F = 11.027$) was present on 6-7 and 7-8 August (average = 26.3 and 22.2%, respectively), than on 5-6 August (7.9%), and more unknowns ($F = 19.506$) were present on 5-6 and 6-7 August (average = 27.3 and 25.2%, respectively) than on 7-8 August (0.8%; Appendix 1.6). In sampling session 11, significantly more Lepidoptera ($F = 38.192$) was present on 19-20 September (average = 54.6%) than on the previous 2 nights (25.1 and 19.4%, respectively; Appendix 1.9). Thus, only three of 91 comparisons (3%) indicated significant differences among nights within sampling sessions.

Variation among hours within sampling sessions.--To ascertain the degree of variation among hours (1 and 2-h blocks), we analyzed the combined data from the 3 nights within each of sampling sessions 5-11. A total of 29 of the comparisons among hours, within sampling sessions, was significant: sampling session 5, 5 significant differences among hours; 6, 6; 7, 6; 8, 4; 9, 4; 10, 1; 11, 3 (Appendices 1.10-1.16). When all 91 comparisons were considered together, the sequential Bonferroni minimum significance level was adjusted to 0.0006 (Table 1.2). At this significance level, 22 of the 91 comparisons (24%) exhibited significant differences among hours. Four food categories (Diptera, Lepidoptera, Insecta, unknown) accounted for 17 of the significant comparisons (77%), with Coleoptera, Ephemeroptera, Hemiptera, Homoptera, and Trichoptera each representing one significant difference among hours (Table 1.2).

The largest F-values (>27) were for the five significant comparisons of Lepidoptera among hours (Table 1.2); these five comparisons showed that *M. grisescens* had significantly more Lepidoptera in fecal pellets at 1930-2030 h than at other times. Three of these comparisons also indicated that, although it was significantly less than for 1930-2030 h, Lepidoptera were present in significantly greater quantities at 2030-2230 h than during the remainder of the night. Except for Lepidoptera, 1930-2030 h usually (12 of 17 comparisons or 71%) was the hour with the least amount of representation for all the food categories listed in Table 1.2.

In summary, three to five food categories showed significant variation among hours in sampling sessions 5-9 and only one food category (Insecta) differed significantly among hours in sampling sessions 10 and 11 (Table 1.2). Thus, there was significant variation among hours within sampling sessions; more Lepidoptera usually were present in fecal pellets obtained earlier in the evening than later at night, the number of food categories showing significant variation was similar among five of the seven sampling sessions, and four food categories represented 17 of the 22 (77%) significant differences among hours within sampling sessions.

Variation in presence of Acari.--Small numbers of Acari were recovered from fecal pellets in nine of the 11 sampling sessions. There were no significant differences among sampling sessions, nights, or hours within sampling sessions in incidence of Acari (Appendices 1.17-1.19). No chronological patterns in abundance of this taxon were detected.

Variation in presence of bat hair.--Hair of *M. grisescens* was present in fecal pellets collected during every sampling session, but there was significant variation in quantity of bat hair among sampling sessions (Table 1.3). Although not well-defined, there was a tendency for more bat hair to be present during sampling sessions 4-8 (8 June-8 August) than in earlier or later sampling sessions. Comparisons within sampling sessions 5-11 revealed no significant differences in presence of bat hair among nights (Appendix 1.20).

When hours within sampling sessions 5-11 were compared, there were significant differences among hours in all but sampling session 11 (Table 1.4). For all sampling sessions, fecal pellets obtained 1930-2030 h contained the most bat hair, and this hour was significantly different from all other hours in four of the seven sampling sessions. We believe the presence of bat hair in fecal pellets resulted from incidental ingestion during grooming.

Availability of potential prey.--One order of Arachnida (Araneae) and 10 orders of Insecta (Coleoptera, Diptera, Ephemeroptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, and Trichoptera) were represented in our sweep-net samples (Table 1.5). Results of analysis of variance revealed that Diptera and unknowns varied significantly among sampling sessions: more Diptera were present in samples taken during sessions 8 (5-8 August) and 10 (3-6 September) than in samples taken during session 11 (17-20 September); more unknowns (5.2%) were recorded in sampling session 5 (25-28 June) than in the six other sessions (Table 1.5). There was no significant difference within categories of potential prey among sampling hours within any of the seven sampling sessions analyzed (Appendix 1.21).

Comparison of potentially available prey with food categories represented in the fecal pellets.--Average percentage of each food category present in the fecal pellets during each sampling hour (1 and 2-h blocks) was compared with the average percentage of the respective prey category that potentially was available for consumption by *M. grisescens*. Although not significant after the Bonferroni adjustment of the P-value, the only correlation coefficient (r = 0.414; P = 0.014) approaching significance was for Coleoptera (Appendix 1.22). Because it usually takes ca. 1-2 h for most ingesta to pass through the digestive tract of similar vespertilionid bats (Anthony and Kunz, 1977; Buchler, 1975; Kunz and Whitaker, 1983; Whitaker, 1988), we also compared the contents of fecal pellets with the quantity of potential prey that was available ca. 1-2 h prior to when the fecal pellets were collected. There was no significant correlation in these comparisons after the Bonferroni adjustment of the P-value (Appendix 1.22). However, Coleoptera (r = 0.384; P = 0.044) and Ephemeroptera (r = 0.459; P = 0.014) approached statistical significance.

The third comparison of occurrence of food categories in the fecal pellets and availability of potential prey was among sampling sessions 5-11 (Appendix 1.23). Although not significant after the Bonferroni adjustment of the P-value, the only correlation coefficient (r = 0.768; P = 0.044) approaching significance was for Ephemeroptera.

Because there was no significant correlation between quantity of each food category in the fecal pellets and availability of potential prey, we examined the data in Tables 1.1 and 1.5 and looked for patterns of variation within sampling sessions 5-11 (Appendix 1.24). For Coleoptera, Diptera, and Lepidoptera there were strong indications that these food categories were not being selected in proportion to their availability. *M. grisescens* had a greater amount of Coleoptera and Lepidoptera represented in the fecal pellets during each of the seven sampling sessions than was present in the samples of potentially available prey. Conversely, Diptera was taken less frequently than available, except during sampling session 11 (17-20 September). The gray bats we studied did not select prey in proportion to availability.

DISCUSSION

As pointed out by Jones (1990), opportunistic foraging suggests that a strong positive correlation should occur between the incidence of a particular prey in the diet, and its abundance in the environment. For selective foraging, a similar comparison should result in no correlation, or even a negative correlation between dietary incorporation and abundance of less-preferred prey (Anthony and Kunz, 1977; Jones, 1990). Because there was no significant correlation between contents of fecal pellets and availability of potential prey, the population of M. grisescens we studied was selective in what it consumed. Fenton and Morris (1976) suggested that most insectivorous bats would eventually be shown to be opportunistic feeders, but our data indicated that the three primary components of the diet (Lepidoptera, Coleoptera, and Diptera) were not consumed in proportion to their availability at Guntersville Reservoir. The gray bats we studied were opportunistic only in the sense that, 1) they probably took advantage of the large emergences of these taxa and, 2) they consumed a variety of other taxa in small quantities.

Buchler (1975) showed that food moves quickly through the digestive tract of Myotis lucifugus. Because this probably is true for M. grisescens as well, we believe the samples of fecal pellets we collected usually represented food ingested within ca. 1-2 h prior to defecation. The exception would be samples collected during emergence of bats from the roost at dusk. Contents of fecal pellets voided on emergence might be more representative of what was ingested just prior to entry into the roost that morning. We were not able to test this statistically, but there usually were more Lepidoptera (five of seven sampling sessions) in samples of potential prey collected after midnight than before midnight (Appendix 1.21). Perhaps, it took longer for Lepidoptera to pass through the digestive tract of the bats, and their remains were not defecated until the evening emergence. This might account for the high incidence of this taxon in fecal pellets obtained early in the evening when Lepidoptera were rarely present in sweep-net samples.

Our study revealed that gray bats took a wider variety of prey items during their activity season than previously reported (e.g., Lacki et al., 1995; Rabinowitz, 1978; Rabinowitz and Tuttle, 1982). However, we had not anticipated the significant level of variation shown among sampling sessions and hours within sampling sessions. We expected that availability of potential prey changed through time, and that this change would be reflected in dietary components. Apparently, availability of prey over habitats where gray bats forage is related to sporadic emergences and resultant swarms of potential prey taxa. These emergences provide a temporary abundance of food represented by a few taxa at any time, but a number of taxa become available at intervals during the night, month, and annual activity season.

Araneae also was reported in small quantities in the diet of Myotis evotis and Myotis volans in eastern Oregon; both of these species are common inhabitants of forested areas (Whitaker et al., 1981). In northern Alabama, spiders often dispersed from hatching sites by ballooning, and spiders frequently were suspended in open areas that made them susceptible to capture by M. grisescens. Although a regular component of the diet, spiders were never present in large quantities.

Previously, Acari was recovered in small quantities from fecal pellets of M. volans from eastern Oregon (Whitaker et al., 1981) and from fecal pellets of M. grisescens from Tennessee (Rabinowitz and Tuttle, 1982). We theorize that the chiggers we identified in fecal pellets were incidentally ingested during grooming by M. grisescens. Kunz (1974) also noted small percentages of acarines (Mesostigmata) in stomachs of Myotis velifer from Kansas. It also is possible that these acarines crawled onto the fecal pellets during the ≤2 h when fecal pellets were on the collecting sheets at the lower opening of Blowing Wind Cave (J. O. Whitaker, Jr., pers. comm.).

A recent study by Barclay and Brigham (1994) indicated that insectivorous bats may not be as selective in what they eat as has been shown in laboratory trials. Under controlled laboratory conditions, insectivorous bats used echolocation to make detailed discriminations among targets. However, bats did not make such discriminations under natural conditions. In the field, insectivorous bats attacked any moving target of an appropriate size and appeared not to make the fine-detailed discriminations based on shape and texture of target that occurred in the laboratory. This lack of discrimination may be due to the rapid flight of bats and the short range at which prey can be detected by echolocation. Bats have only a fraction of a second between detection and capture of prey, possibly not enough time to distinguish among prey (Barclay and Brigham, 1994). Thus, the diet of insectivorous bats should change over time if diet is determined by what prey items are encountered; i.e., prey items of the proper size, shape, texture, etc. Herein, we have demonstrated that M. grisescens consumes a wide variety of prey taxa during its annual activity period and that components of the diet are significantly different over short periods of time. As might be predicted from the observations by Barclay and Brigham (1994), our findings indicated that M. grisescens encountered a variety of acceptable food taxa that varied in abundance and distribution throughout the activity season, and that components of the diet varied accordingly. Brack and La Val (1985) also noted that diversity in components of the diet of M. sodalis changed through summer months.

A criticism of analyses of fecal pellets to determine dietary components is that soft-bodied insects, i.e., small or recently emerged forms, may be digested and rendered unrecognizable, thus potentially contributing to underestimates of the number and kinds of insects actually eaten (Belwood and Fenton, 1976; Rabinowitz and Tuttle, 1982). However, the blind tests conducted by Kunz and Whitaker (1983) demonstrated that analyses of fecal pellets can yield reasonable estimates of foods eaten by insectivorous bats. In addition, Whitaker et al. (1981) reported relatively good agreement between contents of stomachs and feces of bats from eastern Oregon. Our analysis of fecal pellets revealed a variety of small and recently emerged taxa, indicating that many of these food items were well represented.

Prior to the study by Lacki et al. (1995), there were no quantitative data on foods consumed by M. grisescens. Although they examined only 58 fecal pellets, Lacki et al. (1995) demonstrated that gray bats consumed nine orders of insects in Kentucky. In addition, their samples of 24, 2, 23, and 9 fecal pellets from May, June, July, and August, respectively, indicated variation in diet among months. The predominant order of insects in the diet of M. grisescens in Kentucky was Coleoptera, but Diptera, Lepidoptera, and Trichoptera also were consumed in appreciable amounts. Conspicuously absent from the samples collected by Lacki et al. (1995) was Ephemeroptera. Previously, Rabinowitz (1978), Rabinowitz and Tuttle (1982), and Tuttle (1976b) reported that Ephemeroptera was an important component of the diet of M. grisescens. Their assertion was supported by observations of M. grisescens feeding in swarms of Ephemeroptera, but they discovered few remains of mayflies in fecal pellets of the bats. To investigate why mayflies were under represented in fecal pellets, Rabinowitz and Tuttle (1982) fed gray bats a diet containing Ephemeroptera and then examined the fecal pellets. They determined that mayflies eaten by gray bats rarely were identifiable in fecal pellets, except when wings were eaten. They concluded that body parts of mayflies, other than the usually discarded wings, were largely digested and rendered unidentifiable in the feces. Likewise, Belwood and Fenton (1976) fed mayflies to captive M. lucifugus and ascertained that no recognizable trace of ephemeropterans emerged from the digestive tract. However, other studies have been able to detect remains of mayflies in feces of M. lucifugus (Anthony and Kunz, 1977; Buchler, 1976) and Pipistrellus pipistrellus (Swift et al., 1985). On numerous occasions, we observed M. grisescens foraging at sites where there were swarms of emerging mayflies. Although our quantitative data do not support our qualitative observations of the importance of Ephemeroptera in the diet, we are confident that gray bats regularly consume mayflies, that many of these mayflies are completely digested (especially when only the body of the mayfly is ingested), and that the actual incidence of Ephemeroptera in the diet of M. grisescens is greater than quantified by us or by previous investigators. Our speculation also is supported by the presence of only pieces of the wings of mayflies in the fecal pellets where this taxon was detected.

Subadults consume a wider variety of prey than adults (Anthony and Kunz, 1977; Belwood and Fenton, 1976). Perhaps, this apparent nonselectivity is because subadults are unable to differentiate among prey types as effectively as adults. If subadult gray bats were less selective in what they consumed than adults, we would expect to see a greater variety of prey consumed during the sampling sessions after young became volant at nearby Hambrick Cave, and began to roost in Blowing Wind Cave, than during the time only adults were foraging. In addition, as females entered hibernation in September the proportion of subadults in the active population would increase, but there also was no increase in diversity of diet during September. An interesting topic for future study might be to focus on variability in diet between subadults and adults before and after adult females enter hibernation in September. Because differences in diet between sexes have been demonstrated in other species of Myotis (Husar, 1976) and because gray bats generally segregate by sex into maternity and non-maternity (primarily males and non-reproductive females) colonies (Tuttle, 1976a), it also might be informative to examine sexual differences in diet of M. grisescens.

Our study and that of Lacki et al. (1995) demonstrate that there is significant variation in diet of M. grisescens over time, but contrary to their conclusions, we have shown that gray bats are selective regarding the most common food categories they consume. It would be informative to conduct multi-year studies at the same study site to examine the degree of variation in diet among years or to examine multiple sites during the same year to quantify geographic variation in diet. We believe the degree of variability that would be elucidated in long-term or multi-site studies would demonstrate that our findings, those of Lacki et al. (1995), and those of previous researchers (Rabinowitz, 1978; Rabinowitz and Tuttle, 1982; Tuttle, 1976b) are in concordance and are indicative of the large amount of variability in the diet of this endangered species.

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Table 1.1.—Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among 11 sampling sessions used to obtain fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling sessions are listed above the average percentage of each food category as follows: 1, 19-20 April; 2, 3-4 May; 3, 24-25 May; 4, 8-9 June; 5, 25-28 June; 6, 8-12 July; 7, 22-26 July; 8, 5-8 August; 9, 19-22 August; 10, 3-6 September; 11, 17-20 September. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis										
			2	3	5	10	11	7	8	1	9	4	6
Araneae	10,1465	3.042[a]	2.1	1.7	0.7	0.5	0.3	0.2	0.2	0.2	0.1	<0.1	0.0
			3	1	2	7	6	11	8	9	5	4	10
Coleoptera	10,1465	12.021[a]	24.2	17.9	14.4	14.3	13.6	9.2	7.2	5.7	5.4	3.8	2.8
			1	10	9	11	2	6	7	4	8	3	5
Diptera	10,1465	20.026[a]	46.0	40.2	35.4	31.8	25.6	23.0	21.6	19.8	18.8	16.0	13.1
			5	8	7	1	2	3	4	6	9	10	11
Ephemeroptera	10,1465	10.590[a]	5.6	3.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			11	9	7	3	6	8	2	10	4	5	1
Hemiptera	10,1465	3.598[a]	3.4	3.3	3.0	2.0	1.9	1.5	1.5	1.3	1.1	0.1	0.0
			9	11	7	6	10	8	3	5	4	2	1
Homoptera	10,1465	5.668[a]	4.0	3.4	2.3	2.2	2.0	1.7	0.5	0.5	0.3	0.3	0.1
			10	6	9	7	11	8	1	2	4	5	3
Hymenoptera	10,1465	1.889	2.8	2.6	2.5	2.3	1.9	1.7	1.4	1.1	0.8	0.2	0.1

Table 1.1.—Continued

Lepid-			4	3	2	6	7	11	8	1	5	10	9
optera	10,1465	9.009[a]	57.8	48.5	45.6	40.8	32.9	32.5	32.4	30.5	30.0	27.5	22.4
Mecop-			8	9	1	2	3	4	5	6	7	10	11
tera	10,1465	1.407	0.3	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neurop-			11	3	7	10	5	9	4	1	2	6	8
tera	10,1465	4.231[a]	1.1	0.3	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
			7	1	2	3	4	5	6	8	9	10	11
Odonata	10,1465	0.719	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orthop-			6	7	9	11	10	1	2	3	4	5	8
tera	10,1465	0.717	0.4	0.3	0.1	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Plecop-			8	3	6	7	9	1	2	4	5	10	11
tera	10,1465	3.745[a]	1.7	0.3	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Thysanop-			11	10	1	2	3	4	5	6	7	8	9
tera	10,1465	1.112	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichop-			7	9	6	10	5	4	11	2	8	3	1
tera	10,1465	9.722[a]	13.7	10.2	4.8	4.3	4.2	3.8	3.4	2.7	1.7	1.3	0.0
			10	11	8	9	5	2	6	7	1	4	3
Insecta	10,1465	16.951[a]	18.1	12.6	12.1	10.3	9.3	6.4	5.6	3.6	3.5	2.8	2.3
			5	8	9	7	6	4	3	11	2	1	10
Unknown	10,1465	41.674[a]	30.3	17.7	5.3	5.3	5.2	4.1	2.8	0.5	0.5	0.5	0.4

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0029 for a table of 17 tests.

Table 1.2.—Selected results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 1991. Results are presented for Coleoptera, Diptera, Lepidoptera, unidentified Insecta, unknowns, and the food categories that exhibited significant variation among hours. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Sampling session and date	Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
5 25-28 June									
				4	3	2	6	5	1
	Coleoptera	5,164	4.489	4.4	10.8	4.1	2.5	2.1	0.0
				4	6	3	5	2	1
	Diptera	5,164	3.415	19.8	18.8	14.3	12.7	12.5	0.8
				1	2	3	4	5	6
	Lepidoptera	5,164	27.602[a]	81.7	35.8	17.9	14.8	13.3	12.4
				5	6	3	2	4	1
	Insecta	5,164	4.619[a]	15.6	11.2	9.6	9.4	8.7	1.2
				5	6	3	2	4	1
	Unknown	5,164	6.421[a]	50.1	46.0	27.9	22.6	21.8	12.7
6 8-12 July									
				3	6	4	5	2	1
	Coleoptera	5,174	5.303[a]	25.5	20.2	16.3	13.9	3.4	2.1
				5	4	6	3	2	1
	Diptera	5,174	16.020[a]	36.7	34.1	31.0	27.9	7.2	0.9
				3	6	5	4	1	2
	Homoptera	5,174	5.986[a]	9.1	2.6	0.7	0.5	0.4	0.0

Table 1.2.--Continued.

				1	2	5	6	4	3
	Lepidoptera	5,174	77.609[a]	93.2	79.0	24.9	18.7	14.8	14.1
				4	6	3	5	2	1
	Insecta	5,174	7.210[a]	15.3	6.5	6.2	2.9	1.3	1.3
				5	6	4	3	1	2
	Unknown	5,174	3.933[a]	12.9	7.4	6.8	3.8	0.6	<0.1
7	22-26 July								
				3	5	6	4	2	1
	Coleoptera	5,174	3.907[a]	28.6	18.2	14.0	13.0	11.4	0.8
				6	3	5	4	2	1
	Diptera	5,174	11.515[a]	39.7	29.7	28.1	14.0	13.3	4.9
				1	2	6	4	5	3
	Lepidoptera	5,174	39.119[a]	90.5	33.7	21.0	19.1	18.7	14.4
				4	2	6	3	5	1
	Trichoptera	5,174	13.386[a]	37.5	25.7	6.7	6.3	6.3	0.0
				6	3	4	2	5	1
	Insecta	5,174	1.252	5.6	4.6	4.2	3.4	2.9	1.0
				5	6	3	1	2	4
	Unknown	5,174	9.638[a]	19.1	7.1	3.4	1.0	0.9	0.1
8	5-8 August								
				3	4	2	6	5	1
	Coleoptera	5,174	3.275	17.1	9.5	6.6	4.7	4.2	1.2
				6	3	4	5	2	1
	Diptera	5,174	9.678[a]	31.7	30.4	25.0	12.8	11.2	1.7

Table 1.2.—Continued.

					5	6	1	2	3	4
		Ephemeroptera	5,174	11.866[a]	13.6	4.5	0.0	0.0	0.0	0.0
					1	2	3	4	5	6
		Lepidoptera	5,174	32.305[a]	85.0	50.1	17.9	16.1	12.9	12.5
					5	6	4	3	1	2
		Insecta	5,174	7.221[a]	22.0	20.8	12.2	8.1	5.7	4.0
					5	4	2	6	3	1
		Unknown	5,174	2.306	29.1	20.1	19.4	19.1	12.3	6.4
9	19-22 August									
					3	6	4	2	5	1
		Coleoptera	5,174	1.954	10.0	9.1	7.2	4.3	2.9	0.7
					5	4	6	2	3	1
		Diptera	5,174	8.999[a]	46.1	44.8	41.1	36.2	31.9	12.4
					3	2	4	5	6	1
		Hemiptera	5,174	4.655[a]	7.7	4.5	3.2	2.9	1.8	0.0
					1	2	3	6	5	4
		Lepidoptera	5,174	29.858[a]	67.2	21.4	18.5	10.5	8.5	8.2
					6	3	1	4	2	5
		Insecta	5,174	1.967	15.2	12.1	10.4	10.1	9.9	4.0
					5	6	4	2	1	3
		Unknown	5,174	15.826[a]	21.7	9.2	0.8	0.2	0.0	0.0
10	3-6 September									
					3	5	6	4	2	1
		Coleoptera	5,174	1.386	5.8	2.9	2.8	2.6	1.7	0.8
					5	3	4	2	6	1
		Diptera	5,174	3.600	48.4	45.2	44.9	44.0	30.4	28.3

Table 1.2.—Continued

	Lepidoptera	5,174	1.874	1	4	2	5	6	3
				38.0	29.6	27.4	27.0	24.0	19.1
	Insecta	5,174	5.442[a]	6	1	2	5	4	3
				28.3	26.7	20.6	11.8	10.6	10.5
	Unknown	5,174	0.692	4	1	5	2	3	6
				1.0	0.8	0.6	0.2	0.0	0.0
11	17-20 September								
	Coleoptera	5,170	4.284[a]	6	5	4	3	1	2
				18.2	14.3	10.3	8.3	2.2	1.2
	Diptera	5,170	4.556[a]	1	2	3	4	6	5
				45.0	41.7	35.1	28.7	22.0	19.8
	Lepidoptera	5,170	2.130	4	5	6	3	2	1
				38.5	37.2	36.9	31.6	31.0	18.0
	Insecta	5,170	6.496[a]	1	2	3	5	6	4
				28.8	13.7	10.1	8.7	8.5	8.1
	Unknown	5,170	0.480	6	5	1	2	4	3
				1.2	0.9	0.5	0.3	0.2	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0006 for a table of 91 tests.

Table 1.3.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests for presence of bat hair among 11 sampling sessions used to obtain fecal pellets of *Myotis grisescens* at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling sessions are listed above the average incidence of bat hair as follows: 1, 19-20 April; 2, 3-4 May; 3, 24-25 May; 4, 8-9 June; 5, 25-28 June; 6, 8-12 July; 7, 22-26 July; 8, 5-8 August; 9, 19-22 August; 10, 3-6 September; 11, 17-20 September. Lines beneath averages indicate nonsignificant subsets.

d.f.	F-ratio	Results of Student-Newman-Keuls analysis										
		6	4	7	5	8	2	9	3	1	11	10
10,1465	9.671[a]	0.5	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1
		—	—	—								
			—	—	—							
				—	—	—	—					
					—	—	—	—	—	—		
						—	—	—	—	—	—	
							—	—	—	—	—	—

[a]Statistically significant difference at $P < 0.05$.

Table 1.4.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests of presence of bat hair among hours of collection of fecal pellets of *Myotis grisescens* at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling hours are listed above the average incidence of bat hair in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Sampling session	and date	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
				1	2	4	5	6	3
5	25-28 June	5,164	40.663[a]	1.4	0.3	0.1	0.1	<0.1	0.0
				1	2	4	6	5	3
6	8-12 July	5,174	49.016[a]	1.5	1.3	0.2	0.1	0.1	0.1
				1	2	4	3	5	6
7	22-26 July	5,174	19.782[a]	1.4	0.5	0.5	0.1	0.1	0.1
				1	2	4	3	5	6
8	5-8 August	5,174	42.612[a]	1.2	0.4	0.1	0.1	0.0	0.0
				1	4	5	3	2	6
9	19-22 August	5,174	33.946[a]	1.0	0.2	0.1	<0.1	0.0	0.0
				1	4	2	5	3	6
10	3-6 September	5,174	3.452[a]	0.3	0.1	0.1	0.1	0.0	0.0
				1	4	5	2	3	6
11	17-20 September	5,170	0.374	0.2	0.2	0.2	0.1	0.1	0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0071 for a table of seven tests.

Table 1.5.—Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among sessions used to obtain samples of prey available at Guntersville Reservoir, Jackson Co., Alabama, 1991. Sampling sessions are listed above the average percentage of prey taxa collected in each sampling session: 5, 25-28 June; 6, 8-12 July; 7, 22-26 July; 8, 5-8 August; 9, 19-22 August; 10, 3-6 September; 11, 17-20 September. Lines beneath averages indicate nonsignificant subsets.

Prey category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis						
			5	7	6	9	8	10	11
Araneae	6,377	3.215	7.5	3.4	2.8	1.3	0.9	0.2	<0.1
			6	8	5	7	9	10	11
Coleoptera	6,377	2.293	4.0	2.1	1.5	0.8	0.0	0.0	0.0
			10	8	5	9	6	7	11
Diptera	6,377	3.497[a]	65.9	63.2	53.6	50.9	49.1	43.6	30.3
			8	5	9	7	10	6	11
Ephemeroptera	6,377	1.658	5.7	4.1	4.0	2.0	0.7	0.6	0.0
			8	5	9	6	7	10	11
Hemiptera	6,377	2.385	1.0	0.3	0.2	0.0	0.0	0.0	0.0
			5	6	8	7	9	10	11
Homoptera	6,377	1.066	2.3	2.0	1.5	1.4	0.5	0.1	0.0
			5	6	8	7	9	10	11
Hymenoptera	6,377	2.121	0.6	0.1	<0.1	0.0	0.0	0.0	0.0
			7	8	11	9	10	6	5
Lepidoptera	6,377	2.860	9.1	3.3	2.9	2.0	1.0	1.0	0.3
			9	5	6	7	8	10	11
Neuroptera	6,377	0.899	0.8	0.0	0.0	0.0	0.0	0.0	0.0
			9	7	6	8	5	11	10
Odonata	6,377	1.261	2.8	1.6	1.0	0.6	0.3	0.1	<0.1
			10	8	7	6	9	5	11
Trichoptera	6,377	3.050	6.5	1.6	1.2	1.1	0.6	0.4	0.1

Table 1.5.--Continued.

			5	11	7	9	10	8	6
Unknown	6,377	10.199[a]	5.2	1.0	0.3	0.2	0.2	0.1	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0042 for a table of 12 tests.

Appendix 1.1.—Sampling sessions, sampling days, sampling hours, dates of collection, starting times, ending times and sample sizes for fecal pellets of *Myotis grisescens* collected at Blowing Wind Cave, Jackson Co., Alabama, 1991.

Sampling session	Sampling day	Sampling hour	Sampling date	Starting and ending time	Sample size
1	1	1	19 April	1900-2330	10
1	1	2	19-20 April	2330-0030	10
1	2	1	20 April	1900-2000	10
2	3	1	3 May	1900-2015	10
2	3	3	3-4 May	2340-0200	10
2	3	4	4 May	0200-0400	10
2	3	5	4 May	0400-0600	10
2	3	6	4 May	0600-0700	10
2	4	1	4 May	1900-2015	10
3	5	1	24 May	1900-2000	10
3	5	3	24 May	2200-2400	10
3	5	4	24-25 May	0000-0200	10
3	5	5	25 May	0200-0400	10
3	5	6	25 May	0400-0600	10
3	6	1	25 May	1900-2000	10
3	7	3	27-28 May	2230-0030	10
4	8	2	8 June	2030-2230	10
4	8	3	8-9 June	2230-0030	10
4	8	4	9 June	0030-0230	10
4	8	5	9 June	0230-0430	10
4	8	6	9 June	0430-0530	10
4	8	7	9 June	0530-0730	10
4	9	2	9 June	2030-2230	10
5	10	1	25 June	2000-2100	10
5	10	2	25 June	2100-2300	10
5	10	3	25-26 June	2300-0100	10
5	10	4	26 June	0100-0300	10
5	10	5	26 June	0300-0500	10
5	10	6	26 June	0500-0700	10
5	11	1	26 June	1930-2030	10
5	11	2	26 June	2030-2230	10
5	11	3	26-27 June	2230-0030	10

Appendix 1.1.—Continued.

5	11	4	27 June	0030–0230	10
5	11	5	27 June	0230–0430	10
5	11	6	27 June	0430–0630	10
5	12	1	27 June	1930–2030	10
5	12	2	27 June	2030–2230	10
5	12	3	27–28 June	2230–0030	0
5	12	4	28 June	0030–0230	10
5	12	5	28 June	0230–0430	10
5	12	6	28 June	0430–0630	10
6	13	1	8 July	1930–2030	10
6	13	2	8 July	2030–2230	10
6	13	3	8–9 July	2230–0030	10
6	13	4	9 July	0030–0230	10
6	13	5	9 July	0230–0430	10
6	13	6	9 July	0430–0630	10
6	14	1	9 July	1930–2030	10
6	14	2	9 July	2030–2230	10
6	14	3	9–10 July	2230–0030	10
6	14	4	10 July	0030–0230	10
6	14	5	10 July	0230–0430	10
6	14	6	10 July	0430–0630	10
6	15	1	11 July	1930–2030	10
6	15	2	11 July	2030–2230	10
6	15	3	11–12 July	2230–0030	10
6	15	4	12 July	0030–0230	10
6	15	5	12 July	0230–0430	10
6	15	6	12 July	0430–0630	10
7	16	1	22 July	1930–2030	10
7	16	2	22 July	2030–2230	10
7	16	3	22–23 July	2230–0030	10
7	16	4	23 July	0030–0230	10
7	16	5	23 July	0230–0430	10
7	16	6	23 July	0430–0630	10
7	17	1	23 July	1930–2030	10
7	17	2	23 July	2030–2230	10
7	17	3	23–24 July	2230–0030	10
7	17	4	24 July	0030–0230	10
7	17	5	24 July	0230–0430	10
7	17	6	24 July	0430–0630	10
7	18	1	25 July	1930–2030	10
7	18	2	25 July	2030–2230	10
7	18	3	25–26 July	2230–0030	10

Appendix 1.1.--Continued.

7	18	4	26 July	0030-0230	10
7	18	5	26 July	0230-0430	10
7	18	6	26 July	0430-0630	10
8	19	1	5 August	1930-2030	10
8	19	2	5 August	2030-2230	10
8	19	3	5- 6 August	2230-0030	10
8	19	4	6 August	0030-0230	10
8	19	5	6 August	0230-0430	10
8	19	6	6 August	0430-0630	10
8	20	1	6 August	1930-2030	10
8	20	2	6 August	2030-2230	10
8	20	3	6- 7 August	2230-0030	10
8	20	4	7 August	0030-0230	10
8	20	5	7 August	0230-0430	10
8	20	6	7 August	0430-0630	10
8	21	1	7 August	1930-2030	10
8	21	2	7 August	2030-2230	10
8	21	3	7- 8 August	2230-0030	10
8	21	4	8 August	0030-0230	10
8	21	5	8 August	0230-0430	10
8	21	6	8 August	0430-0630	10
9	22	1	19 August	1930-2030	10
9	22	2	19 August	2030-2230	10
9	22	3	19-20 August	2230-0030	10
9	22	4	20 August	0030-0230	10
9	22	5	20 August	0230-0430	10
9	22	6	20 August	0430-0630	10
9	23	1	20 August	1930-2030	10
9	23	2	20 August	2030-2230	10
9	23	3	20-21 August	2230-0030	10
9	23	4	21 August	0030-0230	10
9	23	5	21 August	0230-0430	10
9	23	6	21 August	0430-0630	10
9	24	1	21 August	1930-2030	10
9	24	2	21 August	2030-2230	10
9	24	3	21-22 August	2230-0030	10
9	24	4	22 August	0030-0230	10
9	24	5	22 August	0230-0430	10
9	24	6	22 August	0430-0630	10
10	25	1	3 September	1930-2030	10
10	25	2	3 September	2030-2230	10
10	25	3	3-4 September	2230-0030	10

Appendix 1.1.—Continued.

10	25	4	4 September	0030-0230	10
10	25	5	4 September	0230-0430	10
10	25	6	4 September	0430-0630	10
10	26	1	4 September	1930-2030	10
10	26	2	4 September	2030-2230	10
10	26	3	4-5 September	2230-0030	10
10	26	4	5 September	0030-0230	10
10	26	5	5 September	0230-0430	10
10	26	6	5 September	0430-0630	10
10	27	1	5 September	1930-2030	10
10	27	2	5 September	2030-2230	10
10	27	3	5-6 September	2230-0030	10
10	27	4	6 September	0030-0230	10
10	27	5	6 September	0230-0430	10
10	27	6	6 September	0430-0630	10
11	28	1	17 September	1930-2030	10
11	28	2	17 September	2030-2230	10
11	28	3	17-18 September	2230-0030	10
11	28	4	18 September	0030-0230	10
11	28	5	18 September	0230-0430	10
11	28	6	18 September	0430-0630	10
11	29	1	18 September	1930-2030	10
11	29	2	18 September	2030-2230	10
11	29	3	18-19 September	2230-0030	10
11	29	4	19 September	0030-0230	10
11	29	5	19 September	0230-0430	10
11	29	6	19 September	0430-0630	10
11	30	1	19 September	1930-2030	6
11	30	2	19 September	2030-2230	10
11	30	3	19-20 September	2230-0030	10
11	30	4	20 September	0030-0230	10
11	30	5	20 September	0230-0430	10
11	30	6	20 September	0430-0630	10
Total number of fecal pellets examined					1,476

Appendix 1.2.—Sampling sessions, sampling hours, dates of collection, time of collection, and number of samples of prey available to Myotis grisescens at Guntersville Reservoir, Jackson Co., Alabama, 1991.

Sampling session	Sampling hour	Sampling date	Sampling time	Sample size
5	1	25-28 June	1930-2030	5
	2		2030-2230	10
	3		2230-0030	10
	4		0030-0230	10
	5		0230-0430	10
	6		0430-0630	5
6	1	8-12 July	1930-2030	12
	2		2030-2230	12
	3		2230-0030	12
	4		0030-0230	12
	5		0230-0430	12
7	1	22-26 July	1930-2030	12
	2		2030-2230	12
	3		2230-0030	12
	4		0030-0230	12
	5		0230-0430	12
8	1	5-8 August	1930-2030	12
	2		2030-2230	12
	3		2230-0030	12
	4		0030-0230	12
	5		0230-0430	12
9	1	19-22 August	1930-2030	12
	2		2030-2230	12
	3		2230-0030	12
	4		0030-0230	12
	5		0230-0430	12
10	1	3-6 September	1930-2030	12
	2		2030-2230	12
	3		2230-0030	11
	4		0030-0230	12
	5		0230-0430	12

Appendix 1.2.--Continued.

11	1	17-20 September	1930-2030	7
	2		2030-2230	7
	3		2230-0030	7
	4		0030-0230	7
	5		0230-0430	7
Total number of samples of prey collected				384

Appendix 1.3.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of *Myotis grisescens* at Blowing Wind Cave, Jackson Co., Alabama, 25-28 June 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 25-26 June; 2, 26-27 June; 3, 27-28 June. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
Araneae	2,167	0.359	2 1.0	1 0.6	3 0.3
Coleoptera	2,167	1.071	3 8.0	1 4.4	2 4.2
Diptera	2,167	0.819	3 15.2	1 14.1	2 10.4
Ephemeroptera	2,167	1.688	2 8.0	1 5.3	3 2.9
Hemiptera	2,167	1.238	1 0.3	2 0.0	3 0.0
Homoptera	2,167	2.018	3 1.3	1 0.2	2 0.1
Hymenoptera	2,167	1.504	3 0.6	2 0.1	1 0.1
Lepidoptera	2,167	1.410	1 33.9	3 33.2	2 23.5
Neuroptera	2,167	0.823	3 0.3	2 0.1	1 0.0
Trichoptera	2,167	0.405	2 5.6	3 3.9	1 3.2
Insecta	2,167	2.322	1 11.1	2 10.0	3 6.2
Unknown	2,167	1.828	2 37.1	1 27.0	3 26.3

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0042 for a table of 12 tests.

Appendix 1.4.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 8-12 July 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 8-9 July; 2, 9-10 July; 3, 11-12 July. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			3	2	1
Coleoptera	2,177	1.017	16.9	12.8	11.0 (one nonsignificant subset)
			2	1	3
Diptera	2,177	1.088	26.8	21.2	20.9 (one nonsignificant subset)
			3	2	1
Hemiptera	2,177	3.458	3.9	1.0	0.7 (one nonsignificant subset)
			1	3	2
Homoptera	2,177	3.918	4.6	1.2	0.8 (one nonsignificant subset)
			3	2	1
Hymenoptera	2,177	0.328	3.5	2.7	1.7 (one nonsignificant subset)
			1	2	3
Lepidoptera	2,177	0.221	43.1	40.8	38.4 (one nonsignificant subset)
			2	3	1
Orthoptera	2,177	0.946	1.2	0.1	0.0 (one nonsignificant subset)
			3	1	2
Plecoptera	2,177	1.000	0.1	0.0	0.0 (one nonsignificant subset)
			2	3	1
Trichoptera	2,177	2.309	7.3	5.0	2.0 (one nonsignificant subset)
			1	2	3
Insecta	2,177	5.218	9.4	4.2	3.1 (one nonsignificant subset)
			3	1	2
Unknown	2,177	1.831	7.0	6.3	2.5 (one nonsignificant subset)

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0046 for a table of 11 tests.

Appendix 1.5.—Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 22-26 July 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 22-23 July; 2, 23-24 July; 3, 25-26 July. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			3	1	2
Araneae	2,177	1.000	0.7	0.0	0.0
			3	2	1
Coleoptera	2,177	6.885[a]	23.3	13.6	6.1
			3	1	2
Diptera	2,177	2.233	25.3	23.0	16.5
			1	2	3
Ephemeroptera	2,177	6.526[a]	5.8	0.0	0.0
			2	3	1
Hemiptera	2,177	0.028	3.2	3.1	2.8
			2	1	3
Homoptera	2,177	2.179	3.3	2.6	1.0
			3	1	2
Hymenoptera	2,177	1.777	3.3	3.2	0.5
			2	1	3
Lepidoptera	2,177	5.649	45.4	28.3	25.1
			2	3	1
Neuroptera	2,177	0.173	0.4	0.2	0.2
			2	1	3
Odonata	2,177	1.000	0.3	0.0	0.0
			3	1	2
Orthoptera	2,177	2.133	0.7	0.0	0.0
			2	1	3
Plecoptera	2,177	1.000	0.1	0.0	0.0
			1	2	3
Trichoptera	2,177	2.500	19.5	12.2	9.6

Appendix 1.5.—Continued.

			3	1	2
Insecta	2,177	1.084	4.8	3.0	3.0
			1	3	2
Unknown	2,177	8.571[a]	11.2	3.0	1.6

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0033 for a table of 15 tests.

Appendix 1.6.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of *Myotis grisescens* at Blowing Wind Cave, Jackson Co., Alabama, 5-8 August 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 5-6 August; 2, 6-7 August; 3, 7-8 August. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			3	2	1
Araneae	2,177	0.444	0.4	0.1	0.1
			3	2	1
Coleoptera	2,177	2.572	11.3	5.2	5.1
			3	1	2
Diptera	2,177	11.027[a]	26.3	22.2	7.9
			2	3	1
Ephemeroptera	2,177	7.283[a]	6.6	2.4	0.0
			3	2	1
Hemiptera	2,177	0.328	2.0	1.5	1.0
			2	3	1
Homoptera	2,177	3.411	2.4	2.2	0.4
			2	3	1
Hymenoptera	2,177	0.669	2.4	2.1	0.8
			3	1	2
Lepidoptera	2,177	1.374	39.0	30.4	27.8
			3	1	2
Mecoptera	2,177	2.014	0.8	0.0	0.0
			2	3	1
Plecoptera	2,177	2.337	3.7	1.3	0.0
			1	2	3
Trichoptera	2,177	1.077	2.9	1.7	0.6
			2	3	1
Insecta	2,177	1.838	15.5	10.9	10.0

Appendix 1.6.--Continued.

			1	2	3
Unknown	2,177	19.506[a]	27.3	25.2	0.8

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0039 for a table of 13 tests.

Appendix 1.7.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 19-22 August 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 19-20 August; 2, 10-21 August; 3, 21-22 August. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			1	2	3
Araneae	2,177	3.283	0.2	<0.1	0.0
			1	2	3
Coleoptera	2,177	1.748	8.4	5.1	3.6
			3	2	1
Diptera	2,177	5.498	41.4	37.8	27.1
			1	2	3
Hemiptera	2,177	5.715	5.6	3.0	1.4
			1	2	3
Homoptera	2,177	1.343	5.3	4.1	2.8
			2	1	3
Hymenoptera	2,177	0.047	2.6	2.6	2.2
			1	2	3
Lepidoptera	2,177	3.984	30.0	22.7	14.5
			3	1	2
Mecoptera	2,177	1.000	<0.1	0.0	0.0
			2	3	1
Neuroptera	2,177	0.606	0.2	0.1	0.0
			1	2	3
Orthoptera	2,177	1.513	0.3	0.0	0.0
			2	1	3
Plecoptera	2,177	1.000	<0.1	0.0	0.0
			3	1	2
Trichoptera	2,177	0.881	12.8	9.4	8.4
			3	1	2
Insecta	2,177	1.725	13.1	9.1	8.6

Appendix 1.7.—Continued.

			2	3	1
Unknown	2,177	2.400	7.5	6.4	2.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0036 for a table of 14 tests.

Appendix 1.8.—Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of *Myotis grisescens* at Blowing Wind Cave, Jackson Co., Alabama, 3-6 September 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 3-4 September; 2, 4-5 September; 3, 5-6 September. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			3	2	1
Araneae	2,177	0.624	0.7	0.6	<0.1
			1	3	2
Coleoptera	2,177	1.702	4.0	3.0	1.4
			2	3	1
Diptera	2,177	1.148	43.5	40.6	36.4
			3	1	2
Hemiptera	2,177	0.564	2.0	1.2	0.6
			3	1	2
Homoptera	2,177	0.607	2.5	2.0	1.4
			3	2	1
Hymenoptera	2,177	1.173	4.0	2.7	1.6
			1	2	3
Lepidoptera	2,177	2.533	31.5	29.4	21.7
			3	2	1
Neuroptera	2,177	0.897	0.7	0.1	0.0
			2	1	3
Orthoptera	2,177	1.000	<0.1	0.0	0.0
			3	1	2
Thysanoptera	2,177	1.000	<0.1	0.0	0.0
			1	2	3
Trichoptera	2,177	2.923	6.8	5.0	1.0
			3	1	2
Insecta	2,177	2.813	23.1	15.9	15.2

Appendix 1.8.--Continued.

			3	1	2
Unknown	2,177	1.184	0.8	0.4	<0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0039 for a table of 13 tests.

Appendix 1.9.—Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests among nights of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 17-20 September 1991. Sampling nights are listed above the average percentage of each food category as follows: 1, 17-18 September; 2, 18-19 September; 3, 19-20 September. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			2	1	3
Araneae	2,173	0.219	0.4	0.2	0.2
			1	2	3
Coleoptera	2,173	6.686[a]	12.9	12.2	2.2
			1	2	3
Diptera	2,173	2.018	37.1	30.7	27.1
			2	1	3
Hemiptera	2,173	15.316[a]	7.4	2.3	0.1
			2	1	3
Homoptera	2,173	4.269	5.0	4.0	0.9
			2	1	3
Hymenoptera	2,173	0.910	2.8	1.8	0.9
			3	2	1
Lepidoptera	2,173	38.192[a]	54.6	25.1	19.4
			3	2	1
Neuroptera	2,173	2.477	1.8	1.4	0.3
			2	1	3
Orthoptera	2,173	0.966	0.1	0.0	0.0
			3	1	2
Thysanoptera	2,173	2.042	<0.1	0.0	0.0
			1	3	2
Trichoptera	2,173	0.505	4.7	3.3	2.2
			1	2	3
Insecta	2,173	3.778	17.1	12.2	8.3

Appendix 1.9.—Continued.

Unknown	2,173	0.329	2 0.7	3 0.6	1 0.2

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0039 for a table of 13 tests.

Appendix 1.10.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 25-28 June 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			5	2	6	1	3	4
Araneae	5,164	1.042	2.3	0.5	0.4	0.2	0.2	0.1
			4	3	2	6	5	1
Coleoptera	5,164	4.489[a]	14.4	10.8	4.1	2.5	2.1	0.0
			4	6	3	5	2	1
Diptera	5,164	3.415	19.8	18.8	14.3	12.7	12.5	0.8
			4	2	3	5	6	1
Ephemeroptera	5,164	3.819[a]	12.2	9.9	8.0	3.4	0.8	0.0
			2	1	3	4	5	6
Hemiptera	5,164	1.267	0.5	0.0	0.0	0.0	0.0	0.0
			6	2	4	1	3	5
Homoptera	5,164	1.803	2.2	0.4	0.1	0.0	0.0	0.0
			6	4	2	1	3	5
Hymenoptera	5,164	2.006	1.0	0.2	<0.1	0.0	0.0	0.0
			1	2	3	4	5	6
Lepidoptera	5,164	27.602[a]	81.7	35.8	17.9	14.8	13.3	12.4
			2	4	1	3	5	6
Neuroptera	5,164	0.795	0.5	0.2	0.0	0.0	0.0	0.0
			3	4	6	2	5	1
Trichoptera	5,164	2.300	11.4	7.7	4.6	3.8	0.4	0.0
			5	6	3	2	4	1
Insecta	5,164	4.619[a]	15.6	11.2	9.6	9.4	8.7	1.2

Appendix 1.10.—Continued.

			5	6	3	2	4	1
Unknown	5,164	6.421[a]	50.1	46.0	27.9	22.6	21.8	12.7

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0042 for a table of 12 tests.

Appendix 1.11.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 8-12 July 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			3	6	4	5	2	1
Coleoptera	5,174	5.303[a]	25.5	20.2	16.3	13.9	3.4	2.1
			5	4	6	3	2	1
Diptera	5,174	16.020[a]	36.7	34.1	31.0	27.9	7.2	0.9
			6	5	3	4	1	2
Hemiptera	5,174	2.791	4.9	4.5	0.9	0.8	0.0	0.0
			3	6	5	4	1	2
Homoptera	5,174	5.986[a]	9.1	2.6	0.7	0.5	0.4	0.0
			3	2	6	5	4	1
Hymenoptera	5,174	1.041	5.2	4.2	4.2	1.7	0.6	0.0
			1	2	5	6	4	3
Lepidoptera	5,174	77.609[a]	93.2	79.0	24.9	18.7	14.8	14.1
			6	5	1	2	3	4
Orthoptera	5,174	0.979	2.4	0.1	0.0	0.0	0.0	0.0
			3	1	2	4	5	6
Plecoptera	5,174	1.000	0.2	0.0	0.0	0.0	0.0	0.0
			4	3	2	6	5	1
Trichoptera	5,174	2.317	10.9	7.1	4.9	2.2	1.7	1.7
			4	6	3	5	2	1
Insecta	5,174	7.210[a]	15.3	6.5	6.2	2.9	1.3	1.3

Appendix 1.11.--Continued.

			5	6	4	3	1	2
Unknown	5,174	3.933[a]	12.9	7.4	6.8	3.8	0.6	<0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0046 for a table of 11 tests.

Appendix 1.12.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 22-26 July 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			2	1	3	4	5	6
Araneae	5,174	1.000	1.3	0.0	0.0	0.0	0.0	0.0
			3	5	6	4	2	1
Coleoptera	5,174	3.907[a]	28.6	18.2	14.0	13.0	11.4	0.8
			6	3	5	4	2	1
Diptera	5,174	11.515[a]	39.7	29.7	28.1	14.0	13.3	4.9
			6	4	1	2	3	5
Ephemeroptera	5,174	3.825[a]	9.0	2.7	0.0	0.0	0.0	0.0
			4	2	3	5	6	1
Hemiptera	5,174	2.192	6.1	5.3	3.4	2.4	1.0	0.0
			3	4	6	5	2	1
Homoptera	5,174	2.748	5.4	2.8	2.5	2.3	0.8	0.0
			2	4	6	3	1	5
Hymenoptera	5,174	0.583	4.1	3.1	2.4	2.3	1.8	0.2
			1	2	6	4	5	3
Lepidoptera	5,174	39.119[a]	90.5	33.7	21.0	19.1	18.7	14.4
			5	3	1	2	4	6
Neuroptera	5,174	1.612	1.3	0.4	0.0	0.0	0.0	0.0
			5	1	2	3	4	6
Odonata	5,174	1.000	0.6	0.0	0.0	0.0	0.0	0.0
			3	1	2	4	5	6
Orthoptera	5,174	2.176	1.5	0.0	0.0	0.0	0.0	0.0

Appendix 1.12.—Continued.

			2	1	3	4	5	6
Plecoptera	5,174	1.000	0.1	0.0	0.0	0.0	0.0	0.0
			4	2	6	3	5	1
Trichoptera	5,174	13.386[a]	37.5	25.7	6.7	6.3	6.3	0.0
			6	3	4	2	5	1
Insecta	5,174	1.252	5.6	4.6	4.2	3.4	2.9	1.0
			5	6	3	1	2	4
Unknown	5,174	9.638[a]	19.1	7.1	3.4	1.0	0.9	0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0033 for a table of 15 tests.

Appendix 1.13.--Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 5-8 August 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			6	4	1	2	3	5
Araneae	5,174	1.485	1.0	0.2	0.0	0.0	0.0	0.0
			3	4	2	6	5	1
Coleoptera	5,174	3.275	17.1	9.5	6.6	4.7	4.2	1.2
			6	3	4	5	2	1
Diptera	5,174	9.678[a]	31.7	30.4	25.0	12.8	11.2	1.7
			5	6	1	2	3	4
Ephemeroptera	5,174	11.866[a]	13.6	4.5	0.0	0.0	0.0	0.0
			4	3	6	2	5	1
Hemiptera	5,174	1.289	3.2	3.2	1.7	0.6	0.4	0.0
			5	3	6	4	2	1
Homoptera	5,174	3.247	3.3	2.9	2.7	0.8	0.4	0.0
			3	2	4	6	5	1
Hymenoptera	5,174	1.257	4.6	2.5	1.6	1.0	0.5	0.1
			1	2	3	4	5	6
Lepidoptera	5,174	32.305[a]	85.0	50.1	17.9	16.1	12.9	12.5
			4	1	2	3	5	6
Mecoptera	5,174	2.050	1.7	0.0	0.0	0.0	0.0	0.0
			4	2	3	1	5	6
Plecoptera	5,174	2.362	6.0	3.9	<0.1	0.0	0.0	0.0
			4	3	2	5	6	1
Trichoptera	5,174	0.995	3.7	3.5	1.5	1.4	0.3	0.0

Appendix 1.13.—Continued.

			5	6	4	3	1	2
Insecta	5,174	7.221[a]	22.0	20.8	12.2	8.1	5.7	4.0
			5	4	2	6	3	1
Unknown	5,174	2.306	29.1	20.1	19.4	19.1	12.3	6.4

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0039 for a table of 13 tests.

Appendix 1.14.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 19-22 August 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			5	6	3	4	1	2
Araneae	5,174	1.000	0.2	0.2	0.1	<0.1	0.0	0.0
			3	6	4	2	5	1
Coleoptera	5,174	1.954	10.0	9.1	7.2	4.3	2.9	0.7
			5	4	6	2	3	1
Diptera	5,174	8.999[a]	46.1	44.8	41.1	36.2	31.9	12.4
			3	2	4	5	6	1
Hemiptera	5,174	4.655[a]	7.7	4.5	3.2	2.9	1.8	0.0
			2	3	6	5	4	1
Homoptera	5,174	2.682	7.9	5.5	4.3	3.0	2.7	0.8
			6	5	2	3	4	1
Hymenoptera	5,174	0.841	3.6	3.4	3.3	2.9	1.8	0.0
			1	2	3	6	5	4
Lepidoptera	5,174	29.858[a]	67.2	21.4	18.5	10.5	8.5	8.2
			3	1	2	4	5	6
Mecoptera	5,174	1.000	0.1	0.0	0.0	0.0	0.0	0.0
			6	3	2	1	4	5
Neuroptera	5,174	0.750	0.4	0.2	0.1	0.0	0.0	0.0
			4	3	1	2	5	6
Orthoptera	5,174	0.900	0.4	0.1	0.0	0.0	0.0	0.0
			6	1	2	3	4	5
Plecoptera	5,174	1.000	<0.1	0.0	0.0	0.0	0.0	0.0
			4	2	3	5	1	6
Trichoptera	5,174	3.199	20.8	12.3	11.1	7.2	5.2	4.7

Appendix 1.14.—Continued.

Insecta	5,174	1.967	6 15.2	3 12.1	1 10.4	4 10.1	2 9.9	5 4.0
Unknown	5,174	15.826[a]	5 21.7	6 9.2	4 0.8	2 0.2	1 0.0	3 0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0036 for a table of 14 tests.

Appendix 1.15.--Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 3-6 September 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			6	5	1	4	3	2
Araneae	5,174	0.683	1.3	0.9	0.3	0.1	0.1	0.0
			3	5	6	4	2	1
Coleoptera	5,174	1.386	5.8	2.9	2.8	2.6	1.7	0.8
			5	3	4	2	6	1
Diptera	5,174	3.600	48.4	45.2	44.9	44.0	30.4	28.3
			3	6	5	4	2	1
Hemiptera	5,174	0.938	3.5	1.6	1.4	1.1	0.2	0.0
			3	6	4	2	1	5
Homoptera	5,174	1.380	3.6	3.0	2.4	1.3	1.1	0.5
			6	3	4	1	5	2
Hymenoptera	5,174	0.878	4.8	4.1	2.6	2.3	1.7	1.0
			1	4	2	5	6	3
Lepidoptera	5,174	1.874	38.0	29.6	27.4	27.0	24.0	19.1
			3	4	1	2	5	6
Neuroptera	5,174	0.959	1.3	0.1	0.0	0.0	0.0	0.0
			5	1	2	3	4	6
Orthoptera	5,174	1.000	0.1	0.0	0.0	0.0	0.0	0.0
			3	1	2	4	5	6
Thysanoptera	5,174	1.000	<0.1	0.0	0.0	0.0	0.0	0.0
			3	4	5	6	2	1
Trichoptera	5,174	0.454	6.8	5.0	4.7	3.9	3.7	1.7
			6	1	2	5	4	3
Insecta	5,174	5.442[a]	28.3	26.7	20.6	11.8	10.6	10.5

Appendix 1.15.--Continued.

			4	1	5	2	3	6
Unknown	5,174	0.692	1.0	0.8	0.6	0.2	0.0	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0039 for a table of 13 tests.

Appendix 1.16.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 17-20 September 1991. Sampling hours are listed above the average percentage of each food category represented in the fecal pellets as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Food category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
			6	3	4	5	1	2
Araneae	5,170	1.677	0.8	0.6	0.1	0.1	0.0	0.0
			6	5	4	3	1	2
Coleoptera	5,170	4.284[a]	18.2	14.3	10.3	8.3	2.2	1.2
			1	2	3	4	6	5
Diptera	5,170	4.556[a]	45.0	41.7	35.1	28.7	22.0	19.8
			5	6	4	2	3	1
Hemiptera	5,170	3.117	6.8	4.6	4.5	2.8	0.8	0.2
			5	2	6	4	3	1
Homoptera	5,170	1.811	6.7	4.1	3.2	3.1	2.0	1.0
			3	6	5	4	2	1
Hymenoptera	5,170	0.631	3.3	2.7	2.2	1.8	0.6	0.4
			4	5	6	3	2	1
Lepidoptera	5,170	2.130	38.5	37.2	36.9	31.6	31.0	18.0
			6	1	5	2	3	4
Neuroptera	5,170	0.520	1.8	1.4	1.3	1.0	0.9	0.3
			3	1	2	4	5	6
Orthoptera	5,170	0.973	0.1	0.0	0.0	0.0	0.0	0.0
			2	1	3	4	5	6
Thysanoptera	5,170	1.879	0.1	0.0	0.0	0.0	0.0	0.0
			3	4	2	1	5	6
Trichoptera	5,170	0.890	7.2	4.6	3.4	2.5	2.0	0.4
			1	2	3	5	6	4
Insecta	5,170	6.496[a]	28.8	13.7	10.1	8.7	8.5	8.1

Appendix 1.16.—Continued.

			6	5	1	2	4	3
Unknown	5,170	0.480	1.2	0.9	0.5	0.3	0.2	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0039 for a table of 13 tests.

Appendix 1.17.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori test for presence of Acari among 11 sampling sessions used to obtain fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling sessions are listed above the average incidence of Acari as follows: 1, 19-20 April; 2, 3-4 May; 3, 24-25 May; 4, 8-9 June; 5, 25-28 June; 6, 8-12 July; 7, 22-26 July; 8, 5-8 August; 9, 19-22 August; 10, 3-6 September; 11, 17-20 September. Lines beneath averages indicate nonsignificant subsets.

d.f.	F-ratio	Results of Student-Newman-Keuls analysis										
		1	9	7	5	11	6	3	8	10	2	4
10,1465	2.047	1.3	0.9	0.8	0.8	0.4	0.4	0.3	0.2	0.1	0.0	0.0

[a]Statistically significant difference at $P < 0.05$.

Appendix 1.18.--Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests for Acari among nights of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling nights are listed above the average incidence of Acari. Lines beneath averages indicate nonsignificant subsets.

Sampling session	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			27-28 Jun	26-27 Jun	25-26 Jun
5	2,167	3.307	2.0	0.5	0.0
			9-10 Jul	11-12 Jul	8-9 Jul
6	2,177	0.947	0.7	0.3	0.2
			22-23 Jul	25-26 Jul	23-24 Jul
7	2,177	0.554	1.2	0.8	0.4
			5-6 Aug	7-8 Aug	6-7 Aug
8	2,177	1.050	0.3	0.2	0.0
			21-22 Aug	20-21 Aug	19-20 Aug
9	2,177	3.681	1.8	0.6	0.3
			4-5 Sep	3-4 Sep	5-6 Sep
10	2,177	0.005	0.2	0.1	0.1
			17-18 Sep	18-19 Sep	19-20 Sep
11	2,173	0.778	0.6	0.5	0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0071 for a table of seven tests.

Appendix 1.19.--Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests of Acari among hours of collection of fecal pellets of Myotis grisescens at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling hours are listed above the average incidence of Acari as follows: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h; 6, 0430-0630 h. Lines beneath averages indicate nonsignificant subsets.

Sampling session	and date	d.f.	F-ratio	Results of Student-Newman-Keuls analysis					
				2	1	5	4	3	6
5	25-28 June	5,164	1.122	2.2	1.1	0.6	0.5	0.0	0.0
				3	4	6	1	2	5
6	8-12 July	5,174	1.496	1.1	0.9	0.3	0.0	0.0	0.0
				3	2	4	1	5	6
7	22-26 July	5,174	1.617	1.9	1.8	1.1	0.0	0.0	0.0
				4	2	3	1	5	6
8	5-8 August	5,174	0.811	0.4	0.4	0.3	0.0	0.0	0.0
				3	2	4	1	5	6
9	19-22 August	5,174	2.460	2.2	1.4	1.2	0.3	0.0	0.0
				4	3	1	2	5	6
10	3-6 September	5,174	1.464	0.6	0.3	0.0	0.0	0.0	0.0
				2	4	6	3	1	5
11	17-20 September	5,170	0.999	1.0	0.8	0.4	0.2	0.0	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0071 for a table of seven tests.

Appendix 1.20.—Results of one-way analysis of variance[a] and Student-Newman-Keuls a posteriori tests for bat hair among nights of collection of fecal pellets of *Myotis grisescens* at Blowing Wind Cave, Jackson Co., Alabama, 1991. Sampling nights are listed above the average incidence of bat hair. Lines beneath averages indicate nonsignificant subsets.

Sampling session	d.f.	F-ratio	Results of Student-Newman-Keuls analysis		
			27-28 Jun	25-26 Jun	26-27 Jun
5	2,167	2.619	0.5	0.3	0.2
			8-9 Jul	9-10 Jul	11-12 Jul
6	2,177	0.552	0.6	0.5	0.5
			23-24 Jul	22-23 Jul	25-26 Jul
7	2,177	4.849	0.6	0.5	0.2
			5-6 Aug	7-8 Aug	6-7 Aug
8	2,177	0.728	0.4	0.3	0.3
			21-22 Aug	19-20 Aug	20-21 Aug
9	2,177	0.639	0.3	0.2	0.2
			4-5 Sep	3-4 Sep	5-6 Sep
10	2,177	2.356	0.2	0.1	0.1
			17-18 Sep	19-20 Sep	18-19 Sep
11	2,173	1.953	0.2	0.2	0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0071 for a table of seven tests.

Appendix 1.21.—Results of one-way analyses of variance[a] and Student-Newman-Keuls a posteriori tests among hours within each sampling session for potential prey available to *Myotis grisescens* at Guntersville Reservoir, Jackson Co., Alabama, 1991. Sampling hours are listed above the average percentage of prey collected in each prey category: 1, 1930-2030 h; 2, 2030-2230 h; 3, 2230-0030 h; 4, 0030-0230 h; 5, 0230-0430 h. Lines beneath averages indicate nonsignificant subsets.

Sampling session and date	Prey category	d.f.	F-ratio	Results of Student-Newman-Keuls analysis				
5 25-28 June								
				5	3	4	2	1
	Araneae	4,40	0.295	12.0	9.5	7.1	6.7	0.0
				3	4	2	1	5
	Coleoptera	4,40	0.618	2.9	2.3	0.6	0.0	0.0
				2	1	4	3	5
	Diptera	4,40	0.689	67.2	54.5	54.5	53.1	36.0
				1	4	3	2	5
	Ephemeroptera	4,40	1.405	17.6	9.4	1.7	0.5	0.0
				4	1	2	3	5
	Hemiptera	4,40	0.864	1.3	0.0	0.0	0.0	0.0
				4	3	1	2	5
	Homoptera	4,40	1.084	6.9	2.5	1.2	0.0	0.0
				2	1	3	4	5
	Lepidoptera	4,40	0.864	1.4	0.0	0.0	0.0	0.0
				4	1	2	3	5
	Odonata	4,40	0.864	1.7	0.0	0.0	0.0	0.0
				3	4	2	1	5
	Trichoptera	4,40	0.604	0.7	0.6	0.4	0.0	0.0
				3	1	4	2	5
	Unknown	4,40	0.782	9.7	6.7	6.3	3.2	2.0
6 8-12 July								
				2	4	5	1	3
	Araneae	4,55	0.666	5.7	5.1	2.1	0.9	0.0
				3	4	5	2	1
	Coleoptera	4,55	1.626	9.0	7.9	2.1	1.0	0.0

Appendix 1.21.—Continued.

Diptera	4,55	5.222	2	1	3	4	5
			80.8	55.5	52.1	46.8	10.4
Ephemeroptera	4,55	2.010	1	2	3	4	5
			3.1	0.0	0.0	0.0	0.0
Homoptera	4,55	0.425	3	4	5	1	2
			4.2	2.8	2.1	1.1	0.0
Hymenoptera	4,55	1.000	1	2	3	4	5
			0.3	0.0	0.0	0.0	0.0
Lepidoptera	4,55	0.934	4	1	2	3	5
			4.2	0.7	0.0	0.0	0.0
Odonata	4,55	1.848	2	1	3	4	5
			4.2	1.0	0.0	0.0	0.0
Trichoptera	4,55	1.670	1	3	2	4	5
			4.1	1.4	0.0	0.0	0.0
7 22-26 July							
Araneae	4,55	0.820	5	3	4	1	2
			8.3	4.2	4.2	0.4	0.0
Coleoptera	4,55	1.756	2	1	3	4	5
			3.8	<0.1	0.0	0.0	0.0
Diptera	4,55	1.182	2	1	4	5	3
			58.3	54.2	47.2	29.2	28.9
Ephemeroptera	4,55	1.019	1	3	2	4	5
			8.7	1.4	0.0	0.0	0.0
Homoptera	4,55	1.601	3	2	1	4	5
			5.8	1.0	<0.1	0.0	0.0
Lepidoptera	4,55	1.142	5	4	1	3	2
			20.8	12.5	6.7	5.6	0.0
Odonata	4,55	0.590	3	4	2	1	5
			2.8	2.8	2.4	0.0	0.0
Trichoptera	4,55	0.737	1	3	2	4	5
			3.6	1.4	1.0	0.0	0.0
Unknown	4,55	1.000	1	2	3	4	5
			1.4	0.0	0.0	0.0	0.0

Appendix 1.21.—Continued.

8	5-8 August							
				4	2	1	3	5
	Araneae	4,55	0.766	2.1	1.9	0.3	0.0	0.0
				3	4	1	2	5
	Coleoptera	4,55	0.874	8.3	2.1	0.1	0.0	0.0
				1	3	2	5	4
	Diptera	4,55	1.351	76.0	73.8	70.2	50.0	46.1
				4	5	1	2	3
	Ephemeroptera	4,55	1.754	16.9	8.3	3.4	0.0	0.0
				2	4	1	3	5
	Hemiptera	4,55	1.653	3.3	1.7	0.2	0.0	0.0
				4	2	1	3	5
	Homoptera	4,55	1.166	6.3	0.7	0.6	0.0	0.0
				1	2	3	4	5
	Hymenoptera	4,55	1.000	0.1	0.0	0.0	0.0	0.0
				5	4	2	1	3
	Lepidoptera	4,55	0.757	8.3	5.4	2.6	0.0	0.0
				2	4	1	3	5
	Odonata	4,55	2.395	2.3	0.6	0.1	0.0	0.0
				1	4	2	3	5
	Trichoptera	4,55	0.407	2.5	2.1	2.1	1.2	0.0
				2	1	3	4	5
	Unknown	4,55	0.785	0.4	0.2	0.0	0.0	0.0
9	19-22 August							
				5	2	1	3	4
	Araneae	4,55	0.785	4.2	2.4	0.0	0.0	0.0
				1	3	2	5	4
	Diptera	4,55	1.666	68.1	61.5	58.4	37.5	29.2
				1	3	2	4	5
	Ephemeroptera	4,55	4.008	17.5	2.4	0.0	0.0	0.0
				2	1	3	4	5
	Hemiptera	4,55	1.000	1.2	0.0	0.0	0.0	0.0
				1	2	3	4	5
	Homoptera	4,55	0.861	1.4	1.2	0.0	0.0	0.0

Appendix 1.21.—Continued.

	Lepidoptera	4,55	0.447	4 4.2	3 2.8	1 2.4	2 0.7	5 0.0
	Neuroptera	4,55	1.000	2 4.2	1 0.0	3 0.0	4 0.0	5 0.0
	Odonata	4,55	0.870	3 8.3	2 5.6	1 0.1	4 0.0	5 0.0
	Trichoptera	4,55	1.611	2 1.5	1 1.4	3 0.0	4 0.0	5 0.0
	Unknown	4,55	1.361	1 0.9	2 0.0	3 0.0	4 0.0	5 0.0
10	3–6 September							
	Araneae	4,54	0.924	1 1.0	3 0.1	2 0.0	4 0.0	5 0.0
	Diptera	4,54	4.527	1 91.3	2 72.8	4 71.2	3 69.4	5 25.0
	Ephemeroptera	4,54	2.420	1 2.4	4 0.8	2 0.0	3 0.0	5 0.0
	Homoptera	4,54	1.403	1 0.5	2 0.0	3 0.0	4 0.0	5 0.0
	Lepidoptera	4,54	1.268	3 3.2	4 2.1	1 0.1	2 0.0	5 0.0
	Odonata	4,54	0.978	1 0.1	2 0.0	3 0.0	4 0.0	5 0.0
	Trichoptera	4,54	1.534	2 18.9	3 9.1	1 3.7	4 0.9	5 0.0
	Unknown	4,54	0.978	1 0.8	2 0.0	3 0.0	4 0.0	5 0.0
11	17–20 September							
	Araneae	4,30	1.000	1 0.1	2 0.0	3 0.0	4 0.0	5 0.0
	Diptera	4,30	1.210	2 42.9	3 42.9	1 41.7	4 23.8	5 0.0

Appendix 1.21.—Continued.

			4	1	2	3	5
Lepidoptera	4,30	1.000	14.3	0.0	0.0	0.0	0.0
			1	2	3	4	5
Odonata	4,30	1.000	0.3	0.0	0.0	0.0	0.0
			1	2	3	4	5
Trichoptera	4,30	2.242	0.7	0.0	0.0	0.0	0.0
			4	1	2	3	5
Unknown	4,30	1.000	4.8	0.0	0.0	0.0	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0008 for a table of 62 tests.

Appendix 1.22.—Spearman-rank correlation coefficients[a] calculated between the occurrence of food categories in fecal pellets and availability of potential prey at the time fecal pellets were collected and availability of potential prey 2 h prior to the time fecal pellets were collected at Guntersville Reservoir, Jackson Co., Alabama, 1991; an asterisk indicates $P \leq 0.05$.

Food category	Number of potential prey available		Number of potential prey available 2 h previously	
	n	r	n	r
Araneae	35	-0.010	28	-0.204
Coleoptera	35	0.414*	28	0.384*
Diptera	35	-0.300	28	0.124
Ephemeroptera	35	0.185	28	0.459*
Hemiptera	35	-0.067	28	-0.117
Homoptera	35	-0.257	28	-0.233
Lepidoptera	35	-0.014	28	-0.040
Odonata	35	-0.134	28	0.255
Trichoptera	35	-0.184	28	0.003

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0028 for a table of 18 tests.

Appendix 1.23.—Spearman-rank correlation coefficients[a] calculated between occurrence of food categories in fecal pellets and availability of potential prey among sampling sessions 5-11 at Guntersville Reservoir, Jackson Co., Alabama, 1991; an asterisk indicates $P \leq 0.05$.

Food category	Number of potential prey available[a]	
	n	r
Araneae	7	-0.054
Coleoptera	7	0.371
Diptera	7	0.036
Ephemeroptera	7	0.768*
Hemiptera	7	-0.394
Homoptera	7	-0.643
Lepidoptera	7	0.306
Odonata	7	0.412
Trichoptera	7	0.107

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0056 for a table of nine tests.

Appendix 1.24.--Summary of the average percentage occurrence of food categories in fecal pellets and average percentage availability of potential prey among sampling session 5-11 at Guntersville Reservoir, Jackson Co., Alabama.

Sampling session	Date	Occurrence and availability	ARA[a]	COL	DIP	EPH	HEM	HOM	LEP	ODO	TRI
5	25-28 June	Occurrence	0.7	5.4	13.1	5.6	0.1	0.5	30.0	0.0	4.2
		Availability	7.5	1.5	53.6	4.1	0.3	2.3	0.3	0.3	0.4
6	8-12 June	Occurrence	0.0	13.6	23.0	0.0	1.9	2.2	40.8	0.0	4.8
		Availability	2.8	4.0	49.1	0.6	0.0	2.0	1.0	1.0	1.1
7	22-26 June	Occurrence	0.2	14.3	21.6	1.9	3.0	2.3	32.9	0.1	13.7
		Availability	3.4	0.8	43.6	2.0	0.0	1.4	9.1	1.6	1.2
8	5-8 August	Occurrence	0.2	7.2	18.8	3.0	1.5	1.7	32.4	0.0	1.7
		Availability	0.9	2.1	63.2	5.7	1.0	1.5	3.3	0.6	1.6
9	19-22 August	Occurrence	0.1	5.7	35.4	0.0	3.3	4.0	22.4	0.0	10.2
		Availability	1.3	0.0	50.9	4.0	0.2	0.5	2.0	2.8	0.6
10	3-6 September	Occurrence	0.5	2.8	40.2	0.0	1.3	2.0	27.5	0.0	4.3
		Availability	0.2	0.0	65.9	0.7	0.0	0.1	1.0	<0.1	6.5
11	17-20 September	Occurrence	0.3	9.2	31.8	0.0	3.4	3.4	32.5	0.0	3.4
		Availability	<0.1	0.0	30.3	0.0	0.0	0.0	2.9	0.1	0.1

Food-prey category spans ARA through TRI.

[a]Abbreviations are as follows: ARA, Araneae; COL, Coleoptera; DIP, Diptera; EPH, Ephemeroptera; HEM, Hemiptera; HOM, Homoptera; LEP, Lepidoptera; ODO, Odonata; TRI, Trichoptera.

II. RADIOTELEMETRIC ASSESSMENT OF MOVEMENT PATTERNS OF THE GRAY BAT (*MYOTIS GRISESCENS*) AT GUNTERSVILLE RESERVOIR, ALABAMA

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Abstract.--The objective of this study was to use radiotelemetric monitoring to elucidate seasonal variation in movement patterns of individual gray bats (*Myotis grisescens*) at Guntersville Reservoir. The results of our research indicate that individual gray bats foraged over large areas of Guntersville Reservoir, there was considerable movement of bats between Blowing Wind and Hambrick caves, the average minimum size of the home range of individual gray bats at Guntersville Reservoir was ca. 7 by 24 km and covered an area of ca. 97 km^2, bats may have a greater affinity for foraging areas during and shortly after the time young become volant and during the breeding season than later in the active season as the time to enter hibernation nears, bats moved over a broader area during the time the young became volant than later in the active season, the greatest number of days a bat was detected at the same monitoring site, the greatest distances traveled by bats, and the greatest number of nights a bat was found at the same locality did not vary between sampling periods, and during 1991, the bats were found more often at about the time young became volant than later in the active season.

INTRODUCTION

The gray bat (*Myotis grisescens*) has a limited distribution in limestone-karst areas of the eastern and southern United States (Hall, 1981; Hall and Wilson, 1966; Rabinowitz and Tuttle, 1980). Primarily because of habitat destruction and molestation by humans (Barbour and Davis, 1969; Tuttle, 1979*a*, 1979*b*), the gray bat was listed as an endangered species by the United States Fish and Wildlife Service (Greenwalt, 1976). Large winter colonies of the gray bat are known to hibernate in only nine caves. In early spring, winter colonies disband and leave winter hibernacula; adult females emerge from hibernation first, followed by yearlings of both sexes, and finally by adult males. The bats move to other caves where they form large transient colonies that occupy caves for several days. Gray bats then form maternity colonies, where females give birth and raise their young, and bachelor colonies, which predominantly contain males and non-reproductive females. After young become volant, sex and age segregation weakens within the home range of the population.
Young-of-the-year of both sexes remain with the females in maternity colonies during July and August. Autumn migration takes place in the same order as

spring emergence, with adult females leaving in early September and young-of-the-year remaining behind with the last males to leave, usually by mid-October (Elder and Gunier, 1978; Tuttle, 1976a, 1979a).

Movement patterns among summer caves, as well as movement patterns between summer caves and hibernacula, are relatively well understood (Elder and Gunier, 1978; Hall and Wilson, 1966; Tuttle, 1976a, 1979a). Gray bats generally occur as relatively discrete populations that occupy a series of summer caves associated with one or a few hibernacula (Elder and Gunier, 1978; Hall and Wilson, 1966; Tuttle, 1976a). For example, gray bats associated with a large hibernaculum in Kentucky occupy summer caves in that area (Hall and Wilson, 1966), those associated with a large hibernaculum in southwestern Missouri occupy nearby summer caves (Elder and Gunier, 1978), and those associated with a large hibernaculum in northeastern Alabama also occupy nearby summer caves (Tuttle, 1976a). However, this affiliation between summer caves and winter hibernacula also may involve long-distance movements by relatively few individuals (Elder and Gunier, 1978; Hall and Wilson, 1966; Tuttle, 1976a) or by whole populations, e.g., gray bats from northwestern Florida regularly migrate to a winter hibernaculum in northeastern Alabama (Tuttle, 1976a).

During summer months, Blowing Wind and Hambrick caves, located at Guntersville Reservoir in northeastern Alabama, contain the two largest summer colonies of gray bats (Tuttle, 1976a; United States Fish and Wildlife Service, in litt.). The combined populations of gray bats at Blowing Wind and Hambrick caves is ca. 600,000, a doubling of their population during the past 10 years (The Tennessee Valley Authority, in litt.). Blowing Wind Cave (primarily a bachelor colony) and Hambrick Cave (a maternity colony) contain bats that represent a single colony, and almost all hibernate in nearby Fern Cave. Bats banded in Hambrick Cave have been found hibernating only in Fern Cave, but recoveries of hibernating bats banded at Blowing Wind Cave were more widely distributed; most hibernated in Fern Cave, but some also hibernated in Tennessee and a few as far away as Missouri. Recoveries of banded bats of all sexes and ages for all times of the year from Blowing Wind Cave indicate movements throughout northern Alabama and middle Tennessee (Tuttle, 1976a).

Although large-scale movement patterns among caves inhabited by single colonies of gray bats is well documented, smaller-scale movement patterns are not well known. During the active season of gray bats, movements patterns associated with foraging require forays from summer caves. At Norris Reservoir, Tennessee, Rabinowitz (1978) found that gray bats foraged at some sites more than others; this foraging pattern may be correlated with the abundance of prey species, e.g., mayflies (Ephemeroptera--Rabinowitz, 1978; Rabinowitz and Tuttle, 1982; Tuttle, 1976b). Previous research has shown that gray bats may forage 15-35 km from the roost each night and that foraging activities are restricted to the home range of the population, which may be 50 km across (Tuttle, 1976a). Although night-flying, aquatic insects serve as the primary source of food for M. grisescens, little is known about the foraging and movement patterns of gray bats in Alabama. Guntersville Reservoir is large and supports a variety of aquatic habitats, but not all regions of the reservoir provide equal quantities of acceptable prey species. Gray bats probably use a variety of foraging sites throughout the active season to optimize foraging effort. The only previous study of movement patterns of *M. grisescens* at Guntersville Reservoir was conducted during the 1960s and early 1970s, a time when the population of gray bats was decreasing (Tuttle, 1975, 1976*a*, 1976*b*, 1979*a*, 1979*b*).

Historically, various methods have been used to study the biology and movement patterns of *M. grisescens*. Banding and recovery has been the method most widely employed (Elder and Gunier, 1978, 1981; Gunier and Elder, 1971; La Val et al., 1977; Stevenson and Tuttle, 1981; Tuttle, 1975, 1976*a*, 1976*b*; Tuttle and Robertson, 1969; Tuttle and Stevenson, 1977), but this technique may involve capturing bats several times, it may be critically disturbing to a colony, and at times it has been necessary to use a shotgun to sacrifice bats to recover bands (Tuttle, 1976*b*). Attached chemiluminescent capsules make dispersing *M. grisescens* more easily detectable, and when observed from a helicopter, the bats can be followed relatively easily (La Val et al., 1977). Observations using night-vision equipment also have been successful (Rabinowitz, 1978). Because they are swift fliers (18-39 km/h—Kennedy and Best, 1972; La Val et al., 1977; Tuttle, 1976*a*), gray bats can disappear from sight quickly, often crossing open water or traveling overland to reach their destinations (La Val et al., 1977), but radiotelemetry eliminates the need to maintain visual contact with the bats. The technology to monitor movements of small bats by radiotelemetry was not available in the 1960s and 1970s when most of the previous studies of *M. grisescens* were conducted in Alabama. Radiotelemetry may provide answers to questions about the foraging ecology and movement patterns of this species, and provide additional information that will be useful in its protection and management. The objective of our study was to use radiotelemetric monitoring to elucidate seasonal variation in movement patterns of individual *M. grisescens* at Guntersville Reservoir.

METHODS AND MATERIALS

This study was conducted at Guntersville Reservoir, a 27,479-ha impoundment of the Tennessee River in northeastern Alabama and southern Tennessee. The reservoir was constructed ca. 50 years ago for commercial navigation, flood control, and hydroelectric generation. It is bounded downstream by Guntersville Dam and upstream by Nickajack Dam in Tennessee. An abundance of ecologically diverse aquatic habitats are supported by Guntersville Reservoir (The Tennessee Valley Authority, in litt.). The area surrounding Guntersville Reservoir consists of a mixture of pine-hardwood forests and open pastures. Limestone caves suitable for *M. grisescens* are situated near the reservoir and its tributary systems, and three caves, Blowing Wind, Hambrick, and Nickajack, are used each summer by large colonies of gray bats. Two of these caves, Nickajack (located on Nickajack Reservoir, Tennessee) and Hambrick, open directly onto the water, but Blowing Wind Cave is separated from the reservoir by a distance of ca. 100 m. Entrances of these three caves have been fenced or gated to prevent disturbance of the bats by humans.

During the summer of 1991 (8 July-17 September), gray bats were captured using a harp trap (Tuttle, 1974) as they emerged from Blowing Wind Cave, Jackson Co., Alabama, and in the summer of 1992 (9 July-14 September) as they emerged from Blowing Wind Cave and Hambrick Cave, Marshall Co., Alabama. Bats were aged as young-of-the-year or adult; young-of-the-year were differentiated by the prominent vascularization present at the wrist (Anthony, 1988; Barbour and Davis, 1969). While most females in the population of gray bats at Guntersville Reservoir gave birth and raised their young at Hambrick Cave, a nursery colony containing >2,000 young also was present in Blowing Wind Cave; the mothers of these young-of-the-year were the primary focus of research efforts.

Radiotransmitters were attached to 6 adult males and 21 post-lactating, adult females in 1991 and to 34 post-lactating adult females in 1992. Hair was partially removed from a 1-cm^2 area on the back with scissors, and a radiotransmitter (0.8 g, model BD-2A with reed switch, Holohil Systems Ltd., Ontario, Canada) was attached using non-toxic "Skin-Bond" cement. Transmission distance for these radiotransmitters is ca. 3-5 km, but may be >10 km over open water with no physical obstructions. No apparent distress was caused to the bats by these procedures.

Five teams of two persons each monitored the bats throughout the night (1930-0600 h CDT) using TRX-2000S radioreceivers (Wildlife Materials, Inc., Carbondale, IL) and collapsible three and five-element Yagi antennae. When possible, walkie-talkies were used to communicate among teams of observers concerning the movements of individual bats. During 1991, bats were monitored from >30 sites; the number and location of which varied throughout the summer (Fig. 2.1, Appendix 2.1). In 1992, the number of monitoring sites was reduced to seven (Fig. 2.2, Appendix 2.1), chosen for their wide vantage points and because information gathered in 1991 indicated that these were areas frequently used by bats. Each radiotransmitter frequency usually was monitored on a 1-min rotational basis throughout the night. As in 1991, five teams of two observers each monitored the bats throughout the night. The entrance of Blowing Wind Cave was monitored throughout all sampling periods in 1991 and 1992.

Six parameters were used to assess movement patterns, roost fidelity, and home ranges of individual bats. To provide an estimate of how long individual bats remained in the vicinity of Guntersville Reservoir, we examined the number of days between receipt of the first and last radiotransmission from a bat and the number of successful attempts to locate each bat. To provide an estimate of size of home range, roost-site fidelity, and foraging-site fidelity, we examined the total number of sites where each bat was located, the number of times each bat was located (i.e., ≥15 min between each time the bat was detected), the greatest distance each bat traveled from where the radiotransmitter was attached (measured along a straight line in kilometers), and the greatest number of nights each bat was found at the same locality. To assess variation of these parameters within years, we divided each year into early and late-season sampling periods (8 July-5 August and 19 August-3 September in 1991, 9 July-7 August and 21 August-4 September in 1992, respectively). The early season sampling period generally corresponded to when the young became volant and to the premigratory time for adult females, and the late-season period generally corresponded to when adult females began to migrate to hibernacula, the time of copulation, and to the premigratory time for young-of-the-year and adult males (Tuttle, 1975, 1976a, 1976b). One-way analysis of variance was used to assess differences between sexes and sampling periods. To provide an estimate of the minimum size of the home range of individual bats, we plotted localities where bats with radiotransmitters were detected, connected the points with straight lines, measured the greatest length and width (90^{o} to length) of the home range, and overlaid a grid to estimate the minimum area of the home range. All statistical analyses were conducted using SPSS/PC+ (Norusis, 1990).

RESULTS

During 1991, 38,771 attempts (81,452 min) were made to locate the 27 bats with radiotransmitters attached to them (Table 2.1). Unknown electrical sources near monitoring sites interfered with radiotransmissions at some lower frequencies (150.000-150.300); thus, data for 11 bats were omitted from analyses. Of the remaining 16 bats, radiotransmissions were received from 10 of them (3 males, 7 females), and six (3 males, 3 females) were not located after release. Activity areas of bats generally were near Blowing Wind and Hambrick caves. Of the 10 bats detected after release, six remained within ca. 10 km of Blowing Wind Cave, one (150.578) was located ca. 20 km downstream at Guntersville State Park, and three (150.370, 150.418, 150.517) were located in the Hambrick Cave-Guntersville Dam area, ca. 30 km from the release site (Appendix 2.1).

In 1991, four bats with radiotransmitters were detected on two or more occasions at the same monitoring site (Table 2.2), indicating that bats may have areas where they regularly forage (i.e., an individual home range). Data obtained in 1991 indicated the average home range of individual bats was ca. 4 by 17 km and covered an area of ca. 50 km^2 (Table 2.2). Generally, the home ranges of the four bats that showed greatest movement from Blowing Wind Cave coincided with the area between Blowing Wind and Hambrick caves and reflected movements between the two caves. Limited observations of these four bats indicated one-way movements from Blowing Wind Cave to Hambrick Cave and Guntersville State Park; none of these bats returned to Blowing Wind Cave (Appendix 2.1).

During 1992, 67,885 attempts (103,216 min) were made to locate the 34 bats with radiotransmitters (all females). Sixteen of these bats were not detected after release, but radiotransmissions were received from 18 of them at least once after release (Table 2.1). Excluding the release site, no individual bat was located at more than three monitoring sites (Table 2.2). Greatest activity of bats occurred near Blowing Wind Cave, Hambrick Cave, and Guntersville State Park, with 15 of the 18 bats being found two or more times at the same monitoring site (Table 2.2). A functioning radiotransmitter, which had been placed on a bat at Blowing Wind Cave 2 days previously, was recovered from a cave in Guntersville State Park, indicating the bats used roost sites other than Blowing Wind and Hambrick caves.

Of the 13 bats found after they were released at Blowing Wind Cave in 1992, one (172.888) was detected only at Blowing Wind Cave, two (172.550 and 172.650) traveled to Guntersville State Park (ca. 20 km) and returned, and one (172.950) went to Guntersville State Park, back to Blowing Wind Cave, then to Brown's Creek and Guntersville State Park (Appendix 2.1). Once they left Blowing Wind

Cave, none of the remaining nine bats with radiotransmitters were detected there again; two bats (172.591 and 172.770) went to Guntersville State Park and Brown's Creek, one (172.830) moved between Brown's Creek, Guntersville State Park, and Hambrick Cave, two (172.640 and 172.791) went to Guntersville State Park, two (172.671 and 172.729) went to Brown's Creek, one (172.809) went to Guntersville State Park, Brown's Creek, and Hambrick Cave, and one (172.691) that was released at Blowing Wind Cave on 24 July was located at Brown's Creek on 26 July and outside Nickajack Cave, Tennessee, on 28 and 29 July, ca. 75 km upriver from the capture site and >100 km from Brown's Creek (Fig. 2.1, Appendix 2.1). The five bats with radiotransmitters attached to them at Hambrick Cave were found only at the release site, Brown's Creek, and Guntersville State Park (Table 2.2, Appendix 2.1). Data obtained in 1992 indicated the average home range was ca. 9 by 28 km and covered an area of ca. 135 km^2. When combined with the 1991 data, the average minimum size of the home range of gray bats at Guntersville Reservoir was ca. 7 by 24 km and covered an area of ca. 97 km^2 (Table 2.2).

When the amount of effort made to locate bats in 1991 was examined statistically, there was no significant difference between the sampling periods of 8 July-5 August and 19 August-3 September for number of attempts to locate bats ($\underline{F}$-value = 0.575, $\underline{d.f.}$ = 1,14, $\underline{P}$ = 0.461; 8 July-5 August, $\underline{n}$ = 3, $\underline{X}$ = 1,491 attempts/bat, range = 225-2,322; 19 August-3 September, $\underline{n}$ = 13, $\underline{X}$ = 1,177 attempts/bat, range = 269-1,809), but there was a significant difference between sampling periods for the number of minutes spent attempting to locate bats in 1991 ($\underline{F}$-value = 4.927, $\underline{d.f.}$ = 1,14, $\underline{P}$ = 0.044; 8 July-5 August, $\underline{n}$ = 3, $\underline{X}$ = 3,482 min attempted/bat, range = 1,068-5,212; 19 August-3 September, $\underline{n}$ = 13, $\underline{X}$ = 1,937 min attempted/bat, range = 432-2,889). For 1992, there were significant differences between sampling periods for number of attempts to locate bats ($\underline{F}$-value = 40.202, $\underline{d.f.}$ = 1,32, $\underline{P} \leq 0.001$; 9 July-7 August, $\underline{n}$ = 20, $\underline{X}$ = 2,686 attempts/bat, range = 1,955-3,978; 21 August-4 September, $\underline{n}$ = 14, $\underline{X}$ = 1,218 attempts/bat, range = 442-1,719) and number of minutes spent attempting to locate bats ($\underline{F}$-value = 20.143, $\underline{d.f.}$ = 1,32, $\underline{P} \leq 0.001$; 9 July-7 August, $\underline{n}$ = 20, $\underline{X}$ = 4,185 min attempted/bat, range = 2,431-8,195; 21 August-4 September, $\underline{n}$ = 14, $\underline{X}$ = 1,394 min attempted/bat, range = 442-2,199). Thus, subsequent analyses of the six parameters used to assess movement patterns were conducted after data recorded for each bat was divided by the number of minutes we attempted to locate the bat, then multiplied by 100.

Statistical analyses of the number of days between receipt of first and last radiotransmission indicated no significant differences between sexes or between sampling periods during 1991, but in 1992, the number of days that radiotransmissions were received were significantly greater in the 9 July-12 August sampling period than in the 21 August-10 September period (Table 2.3). Thus, bats remained in the vicinity of monitoring sites for more days in the sampling period of 9 July-12 August than 21 August-10 September 1992. This indicates that bats may have a greater affinity for foraging areas during and shortly after the time young become volant and during the breeding season than later in the active season as the time to enter hibernation nears.

In 1991, the number of successful attempts to locate a bat did not differ between sexes, but a significant difference was present between sampling periods; there was a greater number of successful attempts to locate bats for 8 July-14 August than for 19 August-18 September (Table 2.3). There were no significant differences between sampling periods in 1992. Thus, during 1991, the bats were found more often at about the time the young became volant than later in the active season. This may indicate that bats tend to lose their affinity for foraging areas after the time the young become volant.

The number of sites where a bat was detected after release did not differ between sexes, but in 1991 and 1992 there were significant differences between sampling periods (Table 2.3). In 1991 and 1992, bats were more likely to be detected in the sampling periods of 8 July-14 August and 9 July-12 August, than in the sampling periods of 19 August-18 September and 21 August-10 September, respectively. In 1991, seven bats were detected beginning 19 August, but the average number of sites was less than for the three bats detected in the earlier sampling period (Table 2.3). Beginning 21 August 1992, only one bat was located after it was released (172.640). This bat was flying over the reservoir north (average direction from observers = 335°, range = 250-40°, where north = 360 and 0°) of the hotel facilities at Guntersville State Park and was detected at varying intervals during the time periods of 0350-0440 h 7 September, 2013-2344 h 7 September, 0206-0448 h 8 September, 1945-2357 h, 2004-2126 h, and 2326-2400 h 9 September, and 2405-0308 h 10 September (Appendix 2.1). Thus, bats moved among more sites during the time the young became volant than later in the active season. This indicates that the bats moved over a broader area around the reservoir during the earlier sampling periods.

There were no differences in number of times a bat was located after release, in greatest distance a bat traveled from where a radiotransmitter was attached, or in greatest number of nights a bat was found at the same locality between sexes or between sampling periods during 1991 or 1992 (Table 2.3). Thus, number of times detected, greatest distances traveled, and greatest number of nights a bat was found at the same locality were similar throughout the sampling periods.

DISCUSSION

It generally is assumed that addition of a radiotransmitter weighing 4-10% of body mass has a negligible effect on movement patterns of bats. A study by Aldridge and Brigham (1988) has shown, however, that maneuverability decreased proportionally to increase in mass of the radiotransmitter and recommended radiotransmitters of ≤5% of body mass with animals <70 g. Because body mass of pregnant bats may increase >30%, an absolute upper limit of 30% was suggested, but this upper limit should be used only when food is abundant. Although the bat can forage with this load, its behavior will be modified (Aldridge and Brigham, 1988). Because body mass of the gray bats we studied usually was 8-11 g, radiotransmitters (0.8 g) were ≤10% of body mass. Judging from the distances bats traveled and the length of time that radiotransmissions were received, the bats apparently were unaffected by the radiotransmitters.

Based on earlier studies, the foraging range of *M. grisescens* was assumed to be <35 km (Tuttle, 1976a), and the majority of forays to be <12 km (range 1-35 km—La Val et al., 1977). Accordingly, monitoring sites were established around North Sauta Creek, a large, shallow-water tributary of Guntersville Reservoir, near the roost at Blowing Wind Cave (Fig. 2.1). Our initial plan was to maintain radiocontact among observers using walkie-talkies and attempt to triangulate locations of any bats detected, but this was not successful. During summer months, Blowing Wind Cave was home to 200,000-300,000 M. grisescens (The Tennessee Valley Authority, in litt.). Upon emergence from the roost, these bats dispersed in several directions, quickly moving out of sight and outside the range of radioreceivers. While large numbers of M. grisescens were observed foraging in the area of North Sauta Creek, a population density of this magnitude required many of the bats to forage in areas beyond the region of the reservoir being monitored. When an attempt was made to reconcile the situation by moving some of the monitoring sites farther away from the roost, we lost the ability to maintain radiocommunications with each other. The great distance between monitoring sites made attempts to triangulate the location of bats impossible.

M. D. Tuttle (in litt.) suggested that bats with radiotransmitters be followed by boat directly from the roost and observed with night-vision scopes to determine location and exact size of their territories, but this was not feasible. Blowing Wind Cave has two entrances, and neither opens directly onto the water. While most of the bats emerged from the largest entrance and went directly to North Sauta Creek, the nearest water, a significant number of bats flew overland at great heights for a distance of several kilometers to the broader expanses of Guntersville Reservoir. It would be nearly impossible to locate a specific bat at the cave entrance and follow it to its foraging territory, because the bats frequently alternate between land and water in route to their destinations.

Data from 1991 indicated that most bats initially captured at Blowing Wind Cave remained in the vicinity of the cave (Appendix 2.1). Gray bats tended to be transient, however, and more than one bat was detected near the Guntersville Dam-Hambrick Cave area, ca. 30 km away from Blowing Wind Cave. One bat was located near Guntersville State Park, at least 20 km from the capture site. There also is reason to believe that more bats were traveling farther than shown by the data presented herein. During 1991, several bats with radiotransmitters were detected at Nickajack Cave, Tennessee, but because portions of the data became suspect when it was discovered that false readings were being obtained on some of the lower radiofrequencies, the information was disregarded. Apparently, Tuttle (1976a) did not include Nickajack Cave, Tennessee, in his study of large-scale movement patterns of gray bats. However, our data indicate that Nickajack Cave probably is within the home range of the same population that inhabits Blowing Wind and Hambrick caves, and it is likely that most bats from Nickajack Cave hibernate in Fern Cave with other members of this population. Although bats from Nickajack Cave possibly hibernate elsewhere, none of 43 banded at Nickajack Cave, was recovered in the hibernating colony in Coach-James Cave, Edmonson Co., Kentucky (Hall and Wilson, 1966).

In addition to early or late migration, a few bats, most often yearlings or adults without young, may make lengthy trips to other places within their summer home range (Tuttle, 1976a). It was evident from information gathered during both years of our study that gray bats were using alternate roost sites (Table 2.2). There always was a monitoring team stationed at the capture site (i.e., Blowing Wind Cave), and while it initially was expected that bats with radiotransmitters would return to this site on a regular basis, they returned only sporadically or not at all. One bat from Blowing Wind Cave was recorded at Brown's Creek and at Nickajack Cave, Tennessee (ca. 75 km from the capture site and >100 km from Brown's Creek--Fig. 2.1, Appendix 2.1). This long-range movement pattern is consistent with other studies. An adult female M. grisescens from a colony in Tennessee was found 205 km distant on 7 August, at a cave outside the home range of the colony, and returned to the original colony site within 4 nights (Tuttle, 1976a), and bats in Kentucky also are known to travel ≤75 km between summer caves (Hall and Wilson, 1966).

There was further evidence that gray bats were using roost sites other than those where bats originally were captured. A radiotransmitter, which had been used in our study, was found in a cave at Guntersville State Park during the summer of 1992. Tuttle (United States Fish and Wildlife Service, 1982, in litt.) suggested that gray bats were territorial, and depending on abundance of prey, foraging territories may be occupied by 1-15 bats. He also suggested that females in reproductive condition seemed to control these territories, which are located in the same places and used by the same bats year after year. If this assumption is true, M. grisescens probably is most territorial at critical times of the year, e.g., when it is caring for its young. During our study, which was conducted after the young became volant each year, some bats repeatedly returned to the same foraging sites. This suggests that bats have individual home ranges and that these home ranges are large, i.e., because many bats were detected repeatedly and at several locations during our study (Table 2.2, Appendix 2.1).

La Val et al. (1977) observed gray bats from a helicopter in Missouri and found that bats flew rapidly and directly to foraging areas. In most instances, the flight path of bats that flew cross-country took them over water again within a few minutes. Bats foraged over water, with brief forays into riparian vegetation. The gray bats they observed tended to be concentrated in groups of two or three adjacent to heavily wooded bluffs and hillsides. When subsequent passes were made along the river in the helicopter, foraging bats, assumed to be the same individuals, often were observed in the same places as on the previous pass (La Val et al., 1977). In Tennessee, Rabinowitz and Tuttle (1982) reported that gray bats sometimes fed continuously at feeding territories for several hours before returning to their roosts. Like La Val et al. (1982), we also found that bats tended to be concentrated in groups in foraging areas, but groups or individual bats rarely stayed >1 h before leaving. Based upon our radiotelemetry data, none of the bats continuously fed in any location for several hours. We suspect that Rabinowitz and Tuttle (1982) and La Val et al. (1982) observed different individuals or groups of bats that were passing through a foraging area instead of the same bats remaining for long periods to time. Qualitative observations of bats in foraging areas indicated that several bats foraged over the water followed by times when no bats were present. Our observations of short-term foraging times at particular sites by individuals or small groups of bats also are supported by observations of La Val et al. (1982) in Missouri. They reported that one female was followed by helicopter for 63 min on 19 May. During this time, she foraged continuously above the water along a 0.5-km section of the river. Occasional forays were made into riverbank trees, but these were of brief duration. She foraged from just above the water to treetop level, but most commonly remained 2-10 m above the water. At the end of the observation period, she returned to the cave from which she had been released. Another female on 18 May was observed foraging for 21 min during which she flew at a height <2 m over the water for much of the time, within a 0.6-km section of the river (La Val et al., 1977). We do not believe that individual bats returned to roost sites after short foraging forays, but we believe our observations indicate that foraging bats move on to foraging sites their predecessors have vacated. Because we never detected a bat in any foraging area for a long period of time in the same night, we believe that foraging areas were visited at irregular intervals throughout the night by different individuals or groups of bats. Further, individual bats may return to the same foraging site on subsequent nights and often at about the same time.

While we have shown that 1) individual gray bats foraged over large areas of Guntersville Reservoir, 2) there was considerable movement of bats between Blowing Wind and Hambrick caves, 3) the average minimum size of the home range of individual gray bats at Guntersville Reservoir was ca. 7 by 24 km and covered an area of ca. 97 km^2, 4) bats may have a greater affinity for foraging areas during and shortly after the time young become volant and during the breeding season than later in the active season as the time to enter hibernation nears, 5) during 1991, the bats were found more often at about the time young became volant than later in the active season, 6) bats moved over a broader area during the time the young became volant than later in the active season, and 7) the greatest number of days at the same monitoring site, the greatest distances traveled, and the greatest number of nights a bat was found at the same locality did not vary between sampling periods, further studies are needed to determine the precise microhabitats that are most important to _M. grisescens_ at Guntersville Reservoir. Data acquisition in our radiotelemetric study was limited because of the great distances traveled by gray bats and the inability to determine which microhabitats the bats were foraging over. The use of alternate techniques of study or modification of our radiotelemetric techniques, e.g., radiotelemetric monitoring with the aid of aircraft or satellites, or developing methods to quantify rates of visitation by bats to specific microhabitats, might prove to be more precise in determining specific microhabitats used by gray bats during their nightly forays.

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Table 2.1.—Gender of gray bats (Myotis grisescens), frequency of radiotransmitter, date radiotransmitter was attached, date of receipt of last radiotransmission, total number of attempts to locate the bat, number of minutes spent attempting to locate the bat, and number of minutes the bat was located at Guntersville Reservoir, Alabama, in 1991 and 1992. Radiotransmitters were attached to bats at Hambrick (indicated by an asterisk) and Blowing Wind caves.

Year	Gender of bat	Transmitter frequency	Begin date	End date	Number of attempts	Minutes attempted	Minutes located
1991							
	F	150.458	8 Jul	10 Jul	225	1,068	40
	F	150.016	9 Jul	N/A	3,176	9,590	N/A
	F	150.038	22 Jul	N/A	2,101	4,925	N/A
	F	150.418	22 Jul	14 Aug	1,927	5,212	43
	F	150.138	22 Jul	N/A	2,103	4,972	N/A
	F	150.080	23 Jul	N/A	2,047	4,997	N/A
	F	150.157	19 Aug	N/A	714	1,359	N/A
	F	150.178	5 Aug	N/A	1,396	2,836	N/A
	F	150.057	5 Aug	N/A	1,428	2,892	N/A
	F	150.247	5 Aug	N/A	1,490	3,061	N/A
	F	150.266	5 Aug	N/A	1,469	3,062	N/A
	F	150.308	5 Aug	N/A	2,234	6,499	N/A
	F	150.370	5 Aug	14 Aug	2,322	4,167	4
	F	150.220	19 Aug	N/A	844	1,636	N/A
	F	150.349	19 Aug	19 Aug	1,809	2,889	0
	M	150.756	19 Aug	19 Aug	1,657	2,669	0
	M	150.398	19 Aug	23 Aug	1,687	2,728	8
	M	150.439	19 Aug	19 Aug	677	1,341	0
	F	150.328	23 Aug	23 Aug	592	1,912	0
	F	150.497	3 Sep	3 Sep	1,413	2,284	1
	F	150.517	3 Sep	6 Sep	1,365	2,040	14
	F	150.578	3 Sep	7 Sep	1,417	2,289	1
	F	150.657	3 Sep	4 Sep	1,368	2,016	9
	F	150.697	3 Sep	3 Sep	1,368	2,036	0
	M	150.738	3 Sep	18 Sep	1,403	2,109	10
	M	150.637	17 Sep	17 Sep	270	431	0
	M	150.537	17 Sep	18 Sep	269	432	2
			Total		38,771	81,452	132

Table 2.1.—Continued.

1992							
	F	172.650	9 Jul	15 Jul	3,978	8,080	54
	F	172.550	9 Jul	15 Jul	3,949	8,048	25
	F	172.950	9 Jul	14 Jul	3,931	8,195	22
	F	172.888	9 Jul	15 Jul	3,902	7,997	5
	F*	172.849	11 Jul	27 Jul	3,162	3,468	88
	F	172.969	24 Jul	24 Jul	2,883	3,404	0
	F	172.770	24 Jul	9 Aug	2,267	2,790	40
	F	172.591	24 Jul	8 Aug	2,878	3,403	10
	F	172.691	24 Jul	29 Jul	2,221	2,744	26
	F	172.729	24 Jul	12 Aug	2,132	2,689	2
	F	172.809	24 Jul	7 Aug	2,898	7,177	5
	F	172.830	24 Jul	8 Aug	2,139	2,696	13
	F*	172.572	6 Aug	11 Aug	2,147	2,952	1
	F*	172.631	6 Aug	9 Aug	3,178	4,344	12
	F*	172.872	6 Aug	12 Aug	2,154	2,737	14
	F*	172.909	6 Aug	12 Aug	2,146	2,783	7
	F	172.927	7 Aug	7 Aug	1,955	2,735	0
	F	172.671	7 Aug	8 Aug	1,956	2,510	1
	F	172.791	7 Aug	9 Aug	1,878	2,431	9
	F	172.989	7 Aug	9 Aug	1,971	2,524	0
	F	172.382	21 Aug	21 Aug	1,636	1,895	0
	F	172.020	21 Aug	21 Aug	1,705	2,191	0
	F	172.109	21 Aug	21 Aug	1,719	2,199	0
	F	172.259	21 Aug	21 Aug	1,635	1,894	0
	F	172.540	21 Aug	21 Aug	1,636	1,899	0
	F	172.710	21 Aug	21 Aug	1,696	2,004	0
	F	172.751	21 Aug	21 Aug	1,701	2,015	0
	F	172.168	4 Sep	4 Sep	776	776	0
	F	172.211	4 Sep	4 Sep	442	442	0
	F	172.304	4 Sep	4 Sep	722	724	0
	F	172.353	4 Sep	4 Sep	722	722	0
	F	172.431	4 Sep	4 Sep	724	739	0
	F	172.501	4 Sep	4 Sep	876	876	0
	F	172.640	4 Sep	10 Sep	1,068	1,133	80
			Total		67,885	103,216	414

Table 2.2.—Number of times gray bats (Myotis grisescens) were located after release (≥15 min between each time of location), number of sites where they were located after release (does not include the site of release), and estimates of the minimum size of home range at Guntersville Reservoir, Alabama, 1991 and 1992.

Year	Frequency of transmitter	Number of locations	Number of sites	Minimum size of home range		
				Length (km)	Width (km)	Area (km^2)
1991						
	150.370	2	2	29	3	44
	150.398	1	2	3	3	5
	150.418	12	6[a]	29	9	193
	150.458	3	7[a]	7	4	15
	150.497	1	1			
	150.517	5	3[a]	29	5	73
	150.537	1	1			
	150.578	1	1	22		
	150.657	3	3	5	1	3
	150.738	4	3[a]	11	2	11
	Average	3.3	2.9	17.3	3.9	49.1
1992						
	172.550	9	2[a]	22		
	172.572	1	1			
	172.591	4	2	31	9	140
	172.631	8	2[a]	15	9	68
	172.640	15	1[a]	22		
	172.650	13	2[a]	22		
	172.671	1	1	28		
	172.691	5	2[a]	89	5	223
	172.729	2	1[a]	28		
	172.770	25	3[a]	31	16	248
	172.791	3	1[a]	22		
	172.809	5	2[a]	31	16	248
	172.830	10	3[a]	31	9	140
	172.849	3	2[a]	15	9	68
	172.872	8	3[a]	15	9	68
	172.888	5	1[a]			
	172.909	5	1[a]	15		
	172.950	5	3[a]	29	7	102
	Average	7.1	1.8	27.8	9.1	134.6
Overall Average		5.7	2.2	24.2	6.9	97.2

[a]Radiotransmissions received at the same site ≥2 nights.

Table 2.3.--Results of one-way analysis of variance between sexes and times radiotransmitters were attached for variables examined in a radiotelemetric assessment of the foraging patterns of gray bats (*Myotis grisescens*) at Guntersville Reservoir, Alabama, 1991-1992. One asterisk indicates $P \leq 0.05$ and two asterisks indicate $P \leq 0.001$.

Variable and date	n	$\bar{X}$	range	Results of ANOVA		
				d.f.	F	P
Number of days between receipt of first and last radiotransmission/number of minutes attempted X 100						
1991						
Males	6	0.234	0-0.759			
Females	10	0.150	0-0.461	1,14	0.525	0.481ns
8 July-14 August	3	0.327	0.240-0.461			
19 August-18 September	13	0.148	0-0.759	1,14	1.661	0.218ns
1992						
9 July-12 August	20	0.240	0-0.744			
21 August-10 September	14	0.044	0-0.618	1,32	7.893	0.008*
Number of successful attempts to locate each bat/number of minutes attempted X 100						
1991						
Males	6	0.205	0-0.474			
Females	10	0.589	0-3.745	1,14	0.633	0.439ns
8 July-14 August	3	1.555	0.096-3.745			
19 August-18 September	13	0.189	0-0.686	1,14	7.781	0.015*
1992						
9 July-12 August	20	0.450	0-2.538			
21 August-10 September	14	0.504	0-7.061	1,32	0.015	0.904ns

Table 2.3.--Continued.

Total number of sites where each bat was located/number of minutes attempted X 100						
1991						
Males	6	0.075	0-0.232			
Females	10	0.120	0-0.655	1,14	0.279	0.606ns
8 July-14 August	3	0.273	0.048-0.655			
19 August-18 September	13	0.064	0-0.231	1,14	5.043	0.041*
1992						
9 July-12 August	20	0.044	0-0.111			
21 August-10 September	14	0.006	0-0.088	1,32	12.770	0.001**
Number of times each bat was located/number of minutes attempted X 100						
1991						
Males	6	0.077	0-0.232			
Females	10	0.104	0-0.281	1,14	0.238	0.633ns
8 July-14 August	3	0.186	0.048-0.281			
19 August-18 September	13	0.072	0-0.245	1,14	3.181	0.096ns
1992						
9 July-12 August	20	0.152	0-0.896			
21 August-10 September	14	0.097	0-1.324	1,32	0.370	0.548ns
Greatest distance (km) each bat traveled from where the radiotransmitter was attached/number of minutes attempted X 100						
1991						
Males	3	0.211	0-0.522			
Females	7	0.648	0-1.422	1,8	2.236	0.173ns
8 July-14 August	3	0.636	0.556-0.696			
19 August-18 September	7	0.466	0-1.422	1,8	0.271	0.617ns
1992						
9 July-12 August	17	0.746	0-3.243			
21 August-10 September	1	1.942	---	1,16	2.414	0.140ns

Table 2.3.—Continued.

Greatest number of nights each bat was found at the same locality/number of minutes attempted X 100						
1991						
Males	6	0.107	0–0.463			
Females	10	0.045	0–0.098	1,14	1.112	0.310ns
8 July–14 August	3	0.071	0.024–0.096			
19 August–18 September	13	0.068	0–0.463	1,14	0.003	0.961ns
1992						
9 July–12 August	20	0.074	0–0.219			
21 August–10 September	14	0.025	0–0.353	1,32	3.300	0.079ns

Fig. 2.1.—Sites monitored for gray bats (Myotis grisescens) at Guntersville Reservoir, Alabama, and Nickajack Reservoir, Tennessee, in 1991: 1) Blowing Wind Cave; 2) Jackson County Highway 114 (south of US 72); 3) Island in North Sauta Creek; 4) Goose Pond Colony (boat ramp); 5) Jackson County Sportsman's Club (boat ramp); 6) B. B. Comer Bridge (boat ramp); 7) South Sauta Creek (boat ramp); 8) Guntersville Dam; 9) Hambrick Cave; 10) Guntersville State Park; 11) Mink Cove; 12) Nickajack Cave. In addition, ca. 18 other sites were monitored at irregular intervals.

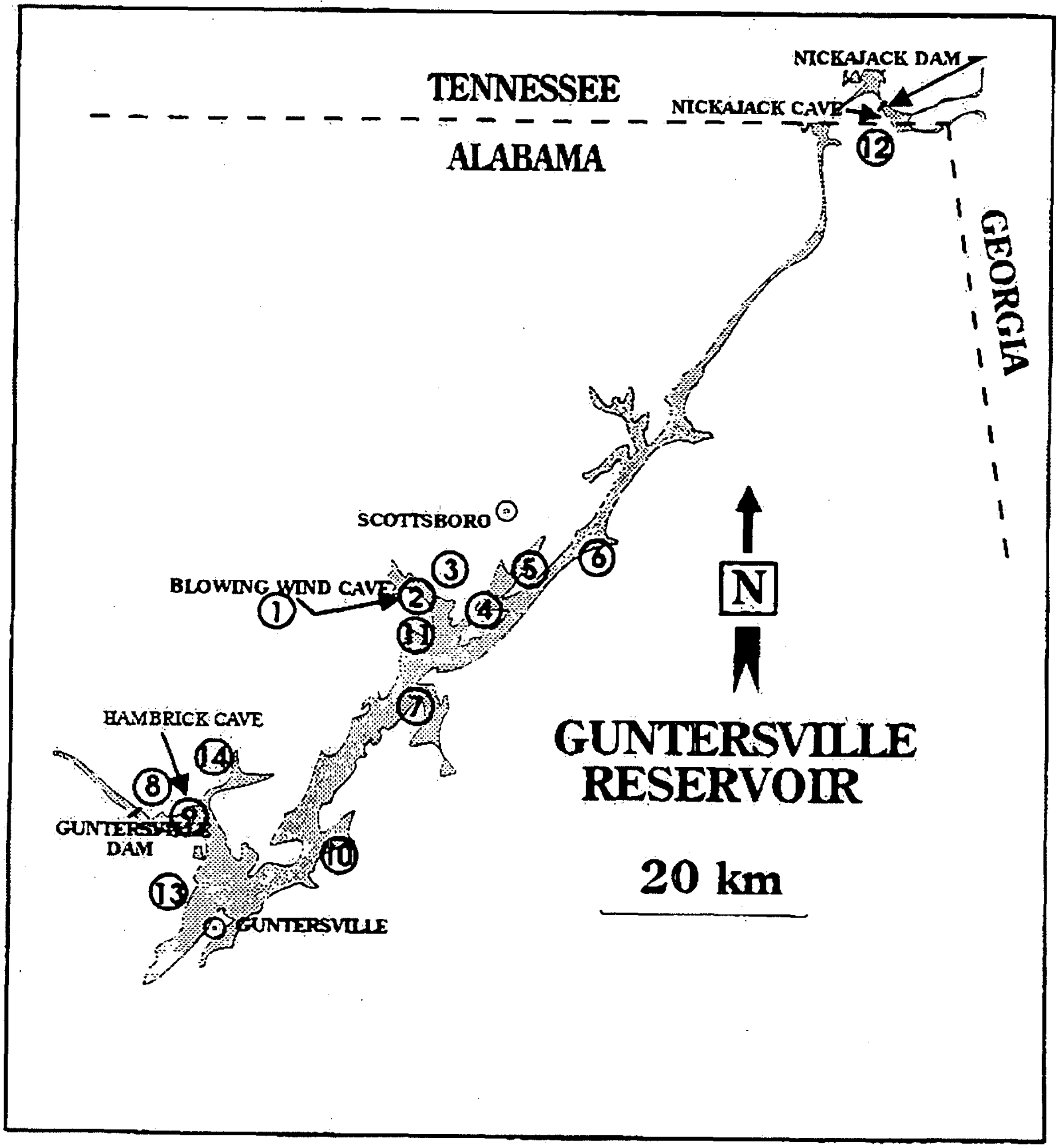
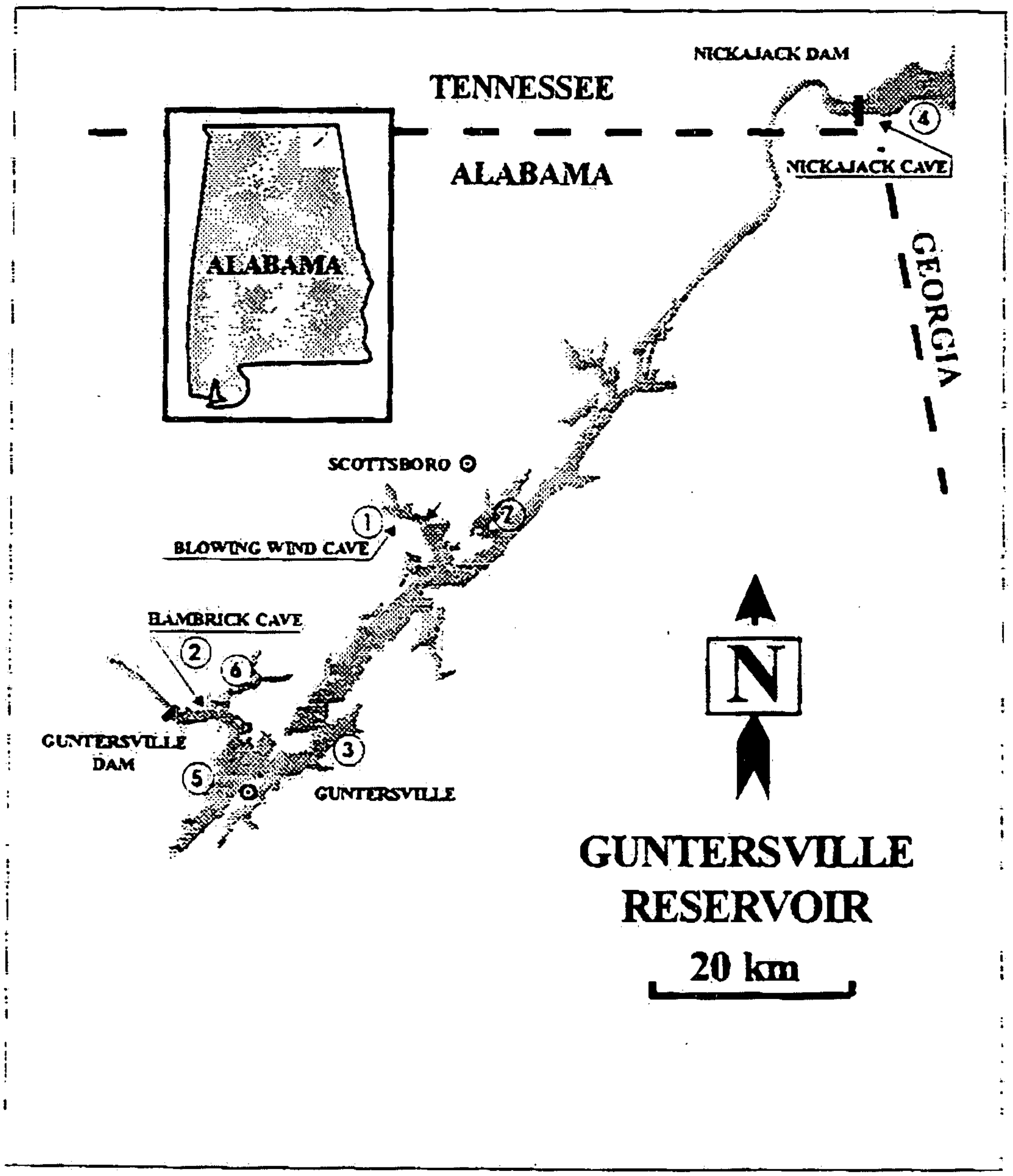


Fig. 2.2.—Sites monitored for gray bats (Myotis grisescens) at Guntersville Reservoir, Alabama, and Nickajack Reservoir, Tennessee, in 1992: 1) Blowing Wind Cave; 2) Hambrick Cave; 3) Guntersville State Park; 4) Nickajack Cave; 5) Brown's Creek; 6) Honeycomb Creek Campground; 7) Jackson County Sportsman's Club (boat ramp).



Appendix 2.1.—Monitoring sites and radiotelemetry data for gray bats (Myotis grisescens): ALABAMA—Jackson Co.: Blowing Wind Cave, T5S R5E, Burns Reservation; Goodyear Plant on US Highway 72, T5S R5E NW 1/4 Sec. 10; Goose Pond Colony (boat ramp), T5S R5E SE 1/4 Sec. 22; Island in North Sauta Creek, T5S R5E, Burns Reservation; Jackson County Highway 114, T5S R5E NW 1/4 Sec. 16; Jackson County Sportsman's Club (boat ramp), T5S R6E NW 1/4 Sec. 17; Highways 72 & 114, T5S R5E NW 1/4 Sec. 8; Zion's Rest Cemetery, T5S R5E NW 1/4 Sec. 7. Marshall Co.: Brown's Creek, T8S R3E NW 1/4 Sec. 5; Guntersville Dam, T7S R2E NE 1/4 Sec. 14; 0.5 mile below Guntersville Dam, T7S R2E NE 1/4 Sec. 15; Guntersville State Park, T7S R4E SE 1/4 Sec. 27; Hambrick Cave, T7S R2E NE 1/4 Sec. 14; Honeycomb Creek Campground, T7S R3E NW 1/4 Sec. 8; South Sauta Creek (boat ramp), T6S R5E NE 1/4 Sec. 15. TENNESSEE—Marion Co.: Nickajack Cave, 85°36'36"W 34°59'01"N.

Frequency	Date (d-m-yr)	Start CDT	Stop CDT	Total (min)	Locality	Direction (degrees)
150.370	100891	2013	2015	2	Hambrick Cave	190
	140891	2145	2147	2	Guntersville Dam	60
150.398	230891	0524	0529	5	Jackson County Highway 114	0
	230891	0527	0530	3	Island in North Sauta Creek	120
150.418	230791	0125	0131	6	Goose Pond Colony	300-360
	230791	0132	0134	2	Jackson County Highway 114	150
	240791	2459	0101	2	Goose Pond Colony	80-140
	240791	0116	0118	2	Goose Pond Colony	160-180
	280791	2007	2011	4	Hambrick Cave	emerging
	290791	2012	2014	2	Hambrick Cave	emerging
	290791	2349	2352	3	Guntersville Dam	270
	300791	2403	2404	1	Guntersville Dam	270
	300791	2004	2012	8	Hambrick Cave	260
	300791	2212	2214	2	0.5 mile below Guntersville Dam	0-360
	310791	2225	2227	2	Guntersville Dam	240
	070891	2009	2013	4	Guntersville Dam	260
	120891	2044	2046	2	South Sauta Creek	40
	140891	1957	2000	3	Guntersville Dam	40
150.458	080791	0121	0127	6	Blowing Wind Cave	110
	080791	2230	2235	5	Blowing Wind Cave	160
	080791	2240	2242	2	Jackson County Highway 114	48
	080791	2242	2247	5	Highways 72 & 114	120-165
	080791	2255	2258	3	Goodyear Plant	250-280
	080791	2258	2300	2	Jackson County Highway 114	110
	080791	2300	2307	7	Blowing Wind Cave	20-140
	100791	2405	2415	10	Zion's Rest Cemetery	260
150.497	030991	2025	2026	1	Blowing Wind Cave	140

Appendix 2.1.—Continued.

150.517	030991	2214	2216	2	Jackson County Highway 114	30
	040991	2033	2035	2	Goose Pond Colony	140
	060991	2142	2144	2	Guntersville Dam	80
	070991	1935	1941	6	Guntersville Dam	100
	070991	0502	0504	2	Guntersville Dam	100
150.537	180991	2315	2317	2	Blowing Wind Cave	80
150.578	070991	1941	1942	1	Guntersville State Park	100
150.657	030991	2115	2117	2	Blowing Wind Cave	220
	040991	2007	2010	3	Jackson County Highway 114	90
	040991	2008	2010	2	Goose Pond Colony	270
	040991	2031	2033	2	Goose Pond Colony	220
150.738	080991	0426	0428	2	Jackson County Sportman's Club	160
	130991	0329	0330	1	Blowing Wind Cave	20
	130991	0333	0334	1	Blowing Wind Cave	0
	180991	2254	2256	2	Jackson County Highway 114	60
	180991	2311	2314	3	Blowing Wind Cave	100–170
	180991	2314	2315	1	Jackson County Highway 114	240
172.550	110792	2050	2052	2	Blowing Wind Cave	150
	110792	2236	2248	12	Blowing Wind Cave	100
	120792	2032	2036	4	Blowing Wind Cave	120
	130792	2032	2033	1	Blowing Wind Cave	300
	140792	2050	2051	1	Blowing Wind Cave	80
	140792	2305	2306	1	Blowing Wind Cave	310
	140792	0253	0255	2	Guntersville State Park	345
	140792	0332	0333	1	Blowing Wind Cave	180
	150792	2039	2040	1	Blowing Wind Cave	60
172.572	110892	1947	1948	1	Hambrick Cave	110
172.591	250792	2032	2033	1	Guntersville State Park	0
	250792	2054	2058	4	Guntersville State Park	340
	250792	2113	2114	1	Guntersville State Park	0
	250792	2128	2130	2	Guntersville State Park	0
	250792	2143	2144	1	Guntersville State Park	0
	080892	2435	2436	1	Brown's Creek	80
172.631	070892	0225	0226	1	Brown's Creek	20
	070892	0247	0248	1	Brown's Creek	70
	070892	0258	0259	1	Brown's Creek	40
	070892	2109	2110	1	Guntersville State Park	260
	070892	2113	2114	1	Brown's Creek	40
	080892	0224	0225	1	Guntersville State Park	290
	080892	2021	2022	1	Guntersville State Park	270
	080892	2031	2032	1	Brown's Creek	90

Appendix 2.1.—Continued.

	090892	0210	0211	1	Guntersville State Park	300
	090892	0217	0218	1	Brown's Creek	30
	090892	0247	0248	1	Brown's Creek	60
	090892	2306	2307	1	Brown's Creek	60
172.640	070992	0350	0356	6	Guntersville State Park	270
	070992	0410	0411	6	Guntersville State Park	270-330
	070992	0426	0428	2	Guntersville State Park	330
	070992	0435	0440	5	Guntersville State Park	250-340
	070992	2013	2017	4	Guntersville State Park	300-30
	070992	2031	2032	1	Guntersville State Park	300-30
	070992	2045	2047	2	Guntersville State Park	320
	070992	2108	2109	1	Guntersville State Park	350
	070992	2122	2124	2	Guntersville State Park	350
	070992	2138	2139	1	Guntersville State Park	330
	070992	2156	2157	1	Guntersville State Park	10
	070992	2251	2252	1	Guntersville State Park	320
	070992	2305	2306	1	Guntersville State Park	290-310
	070992	2329	2330	1	Guntersville State Park	330
	070992	2343	2344	1	Guntersville State Park	340
	080992	0206	0207	1	Guntersville State Park	340
	080992	0219	0220	1	Guntersville State Park	350
	080992	0340	0341	1	Guntersville State Park	320
	080992	0353	0354	1	Guntersville State Park	330
	080992	0406	0407	1	Guntersville State Park	330
	080992	0432	0435	3	Guntersville State Park	340
	080992	0447	0448	1	Guntersville State Park	340
	080992	1945	1947	2	Guntersville State Park	340
	080992	1959	2000	1	Guntersville State Park	320
	080992	2028	2029	1	Guntersville State Park	340
	080992	2225	2226	1	Guntersville State Park	350
	080992	2238	2239	1	Guntersville State Park	340
	080992	2304	2305	1	Guntersville State Park	340
	080992	2317	2318	1	Guntersville State Park	340
	080992	2330	2331	1	Guntersville State Park	340
	080992	2343	2344	1	Guntersville State Park	340
	080992	2356	2357	1	Guntersville State Park	350
	090992	2004	2005	1	Guntersville State Park	330
	090992	2017	2018	1	Guntersville State Park	10
	090992	2030	2031	1	Guntersville State Park	350
	090992	2045	2046	1	Guntersville State Park	330-010
	090992	2058	2059	1	Guntersville State Park	340
	090992	2111	2112	1	Guntersville State Park	340
	090992	2119	2120	1	Guntersville State Park	340
	090992	2125	2126	1	Guntersville State Park	340
	090992	2326	2327	1	Guntersville State Park	10
	090992	2339	2340	1	Guntersville State Park	350
	090992	2352	2353	1	Guntersville State Park	350
	090992	2422	2423	1	Guntersville State Park	340

Appendix 2.1.--Continued.

	100992	2405	2406	1	Guntersville State Park	340
	100992	2418	2419	1	Guntersville State Park	340
	100992	2431	2432	1	Guntersville State Park	340
	100992	2444	2445	1	Guntersville State Park	340
	100992	2457	2458	1	Guntersville State Park	350
	100992	0110	0111	1	Guntersville State Park	350
	100992	0123	0124	1	Guntersville State Park	340
	100992	0136	0137	1	Guntersville State Park	340
	100992	0149	0150	1	Guntersville State Park	40
	100992	0202	0203	1	Guntersville State Park	340
	100992	0215	0216	1	Guntersville State Park	350
	100992	0254	0255	1	Guntersville State Park	340
	100992	0307	0308	1	Guntersville State Park	340
172.650	100792	0245	0248	3	Blowing Wind Cave	0-320
	100792	2053	2054	1	Blowing Wind Cave	180
	100792	2228	2231	3	Guntersville State Park	180-220
	100792	2237	2238	1	Guntersville State Park	240
	110792	0218	0234	16	Guntersville State Park	280-330
	110792	0401	0405	4	Blowing Wind Cave	300
	110792	2212	2216	4	Guntersville State Park	20-25
	110792	2247	2255	8	Guntersville State Park	220-260
	120792	0153	0157	4	Guntersville State Park	270-280
	120792	0335	0338	3	Blowing Wind Cave	120
	120792	2140	2142	2	Blowing Wind Cave	300
	130792	2025	2026	1	Blowing Wind Cave	120
	140792	0139	0140	1	Blowing Wind Cave	110
	140792	0303	0304	1	Blowing Wind Cave	180
	140792	2021	2022	1	Blowing Wind Cave	310
	150792	0141	0143	2	Blowing Wind Cave	310
172.671	080892	2437	2438	1	Brown's Creek	80
172.691	260792	2254	2255	1	Brown's Creek	30
	280792	0253	0310	17	Nickajack Cave	340-190
	280792	2031	2033	2	Nickajack Cave	10
	290792	0300	0302	2	Nickajack Cave	80-170
	290792	0419	0423	4	Nickajack Cave	120-170
172.729	120892	0139	0140	1	Brown's Creek	50
	280792	2027	2028	1	Brown's Creek	300
172.770	270792	2425	2426	1	Guntersville State Park	290
	270792	2439	2440	1	Guntersville State Park	300
	270792	2455	2456	1	Guntersville State Park	340
	270792	0124	0125	1	Guntersville State Park	320
	270792	2316	2317	1	Guntersville State Park	20
	280792	2203	2204	1	Guntersville State Park	350
	280792	2217	2218	1	Guntersville State Park	330

Appendix 2.1.—Continued.

	280792	2230	2231	1	Guntersville State Park	320
	280792	2316	2317	1	Guntersville State Park	310
	280792	2346	2347	1	Guntersville State Park	270
	290792	2402	2403	1	Guntersville State Park	320
	290792	2442	2443	1	Guntersville State Park	320
	290792	0108	0109	1	Guntersville State Park	340
	290792	0121	0122	1	Guntersville State Park	340
	060892	2200	2201	1	Brown's Creek	50
	060892	2211	2212	1	Brown's Creek	110
	060892	2251	2252	1	Guntersville State Park	280
	060892	2316	2317	1	Guntersville State Park	300
	060892	2327	2328	1	Guntersville State Park	320
	060892	2351	2352	1	Guntersville State Park	290
	070892	0200	0201	1	Brown's Creek	320
	070892	0200	0201	1	Guntersville State Park	340
	070892	0211	0212	1	Brown's Creek	340
	070892	0255	0256	1	Brown's Creek	70
	070892	0306	0307	1	Brown's Creek	70
	070892	0317	0318	1	Brown's Creek	90
	070892	0324	0325	1	Guntersville State Park	280
	070892	0328	0329	1	Brown's Creek	50
	070892	2013	2014	1	Hambrick Cave	130
	070892	2117	2118	1	Guntersville State Park	320
	080892	2434	2435	1	Brown's Creek	340
	080892	0347	0348	1	Guntersville State Park	280
	080892	2013	2014	1	Hambrick Cave	100
	080892	2014	2015	1	Guntersville State Park	320
	080892	2035	2036	1	Brown's Creek	80
	080892	2044	2045	1	Guntersville State Park	270
	080892	2132	2133	1	Guntersville State Park	300
	090892	0136	0137	1	Brown's Creek	80
	090892	0206	0207	1	Brown's Creek	40
	090892	0221	0222	1	Brown's Creek	320
172.791	080892	2237	2238	1	Guntersville State Park	290
	080892	2322	2323	1	Guntersville State Park	310
	080892	2353	2354	1	Guntersville State Park	330
	090892	2407	2408	1	Guntersville State Park	300
	090892	2422	2423	1	Guntersville State Park	260
	090892	2437	2438	1	Guntersville State Park	320
	090892	2452	2453	1	Guntersville State Park	340
	090892	0107	0108	1	Guntersville State Park	220
	090892	0122	0123	1	Guntersville State Park	300
172.809	290792	2438	2439	1	Guntersville State Park	320
	060892	2449	2450	1	Brown's Creek	100
	070892	0122	0123	1	Brown's Creek	90
	070892	0241	0242	1	Guntersville State Park	260
	070892	0332	0333	1	Guntersville State Park	280

Appendix 2.1.—Continued.

172.830	260792	2227	2228	1	Brown's Creek	20
	280792	2353	2354	1	Brown's Creek	320
	290792	0203	0204	1	Brown's Creek	20
	290792	2156	2157	1	Guntersville State Park	350
	300792	0232	0234	2	Hambrick Cave	130
	070892	0257	0258	1	Brown's Creek	340
	070892	0333	0334	1	Guntersville State Park	290
	070892	0357	0358	1	Guntersville State Park	330
	070892	2017	2018	1	Hambrick Cave	230
	080892	0142	0143	1	Brown's Creek	340
	080892	0157	0158	1	Brown's Creek	20
	080892	0242	0243	1	Brown's Creek	340
172.849	110792	0240	0241	1	Guntersville State Park	320
	120792	0149	0151	2	Guntersville State Park	300
	120792	0159	0200	1	Guntersville State Park	340
	120792	0208	0235	27	Guntersville State Park	60-80
	120792	0239	0300	21	Guntersville State Park	350-70
	120792	0356	0422	26	Guntersville State Park	330-20
	120792	0427	0434	7	Guntersville State Park	340-20
	120792	0438	0442	4	Guntersville State Park	0-10
	270792	2342	2343	1	Brown's Creek	20
172.872	060892	2124	2126	2	Guntersville State Park	250
	060892	2133	2134	1	Guntersville State Park	270
	060892	2146	2147	1	Guntersville State Park	260
	060892	2157	2158	1	Guntersville State Park	280
	080892	2133	2134	1	Guntersville State Park	350
	080892	2148	2149	1	Guntersville State Park	220
	090892	0242	0243	1	Brown's Creek	40
	090892	0316	0317	1	Guntersville State Park	340
	100892	2119	2110	1	Guntersville State Park	300
	110892	0220	0221	1	Guntersville State Park	280
	110892	2115	2116	1	Guntersville State Park	280
	120892	0139	0140	1	Guntersville State Park	300
	120892	2437	2438	1	Hambrick Cave	120
172.888	100792	2133	2134	1	Blowing Wind Cave	80
	110792	0206	0207	1	Blowing Wind Cave	40
	130792	2023	2024	1	Blowing Wind Cave	50
	140792	2014	2015	1	Blowing Wind Cave	360
	150792	2014	2015	1	Blowing Wind Cave	300
172.909	080892	2431	2432	1	Guntersville State Park	330
	080892	2446	2447	1	Guntersville State Park	310
	080892	0104	0105	1	Guntersville State Park	300
	080892	0121	0122	1	Guntersville State Park	310
	120892	2410	2411	1	Guntersville State Park	300
	120892	2440	2441	1	Guntersville State Park	300

Appendix 2.1.—Continued.

	120892	2455	2456	1	Guntersville State Park	340
172.950	090792	2148	2150	2	Guntersville State Park	270
	100792	2255	2301	6	Guntersville State Park	290-320
	110792	2442	2445	3	Blowing Wind Cave	300
	120792	2244	2250	6	Brown's Creek	20
	140792	0152	0155	3	Guntersville State Park	335-340
	140792	0204	0206	2	Guntersville State Park	340

III. SEASONAL VARIATION IN MOVEMENT PATTERNS OF THE ENDANGERED GRAY BAT (MYOTIS GRISESCENS) AT GUNTERSVILLE RESERVOIR, ALABAMA

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Abstract.—The purposes of this study were to use radiotelemetry to record patterns of movement of female gray bats (*Myotis grisescens*) throughout their annual period of activity, and to determine if these patterns were affected by reproductive status. Each of the 107 bats outfitted with a radiotransmitter was monitored for 10 nights early in each month from May to September at Guntersville Reservoir, Alabama. Movement patterns of bats changed throughout the period of activity from April through September, but they did not fly shorter distances during the period of lactation than after lactation. Compared with periods of pregnancy and lactation, gray bats spent less time in the maternity cave immediately after lactation, but use of the maternity cave by female bats increased later in September.

INTRODUCTION

Animals forage to obtain energy resources needed for metabolism, thermoregulation, growth, and reproduction (Speakman and Racey, 1987). However, foraging activities are costly in terms of time and energy. Foraging requires a temporal investment that reduces time available for mating, protecting territories, or avoiding predators (Schoener, 1971). Furthermore, because quality and availability of food resources often are variable, animals must expend energy to search for and pursue prey before energy can be assimilated (Norberg, 1977; Schoener, 1971).

A net gain of energy from foraging is secured most efficiently when the rate of energy intake per unit time is maximized (Norberg, 1977). The optimal-foraging theory predicts that natural selection should result in foraging habits that maximize energy gain per unit time (Norberg, 1977; Pyke, 1984; Schoener, 1971). For females, maximizing gain of energy may be most critical during gestation and lactation, when a great deal of energy must be allocated to producing and rearing offspring.

During gestation and lactation, small terrestrial mammals typically compensate for rising energetic demands by increasing consumption of food (Glazier, 1985; Hanwell and Peaker, 1977; Migula, 1969; Racey and Speakman, 1987). However, while insectivorous bats experience similar energetic needs during reproduction as other small mammals, bats are able to respond to energetic demands differently (Racey and Speakman, 1987).

When gains of energy from food resources are inadequate, bats are able to reduce total expenditure of energy by becoming heterothermic (Anthony et al., 1981; Racey, 1982; Racey and Speakman, 1985). A torpid bat decreases its rate of energy expenditure to ca. 5-10% of the homeothermic rate (Racey and Speakman, 1987). Because bats are able to balance energetic needs either by increasing intake of energy or by decreasing use of energy, bats are likely to cope with energetic demands differently than other small mammals.

The gray bat, Myotis grisescens, is thought to select roosts, foraging areas, and food items in response to energetic needs. Throughout its range in the southeastern United States (Hall, 1981), the gray bat minimizes time spent foraging by selecting roost caves that are near bodies of water (Meyers, 1964; Saugey, 1978; Tuttle, 1976a, 1976b; Tuttle and Stevenson, 1977). This provides gray bats with rapid access to their prey, nocturnal flying insects, which often are abundant over lakes and streams (Tuttle, 1976b). Gray bats may maximize energetic gains from foraging by selecting profitable foraging sites (Rabinowitz, 1978). When density of prey is low, temperate vespertilionid bats usually feed opportunistically, but as prey becomes more abundant, bats may increase net intake of energy by selecting high-energy food items. (Anthony and Kunz, 1977; La Val and La Val, 1980; Rabinowitz, 1978; Ross, 1967).

While selection of roosts, foraging areas, and food items have been documented, little is known about how M. grisescens modifies its foraging patterns to cope with changing energy needs. Aspects of foraging, such as duration of feeding bouts, distance to foraging areas, and number of feeding bouts per night may be adjusted to alter the net amount of energy that results from foraging.

Modification of foraging patterns may have a significant impact on the total energy budget of the gray bat because flight is an energetically costly mode of locomotion (Thomas, 1985). Minimizing the number or duration of foraging flights significantly reduces costs of foraging in some cases (Racey and Speakman, 1987; Tuttle, 1976b). Bats may remain quiescent at the roost if a net energy gain from active foraging is not possible (Anthony et al., 1981; Audet, 1990).

To achieve a net gain of energy, not only must gray bats balance costs and gains of foraging behaviors, but they must cope with seasonal abundance of prey. In nearly all parts of the range of the gray bat, food resources are seasonally limited. In most temperate regions, abundance of insects peaks during July, and usually is low in early spring and late summer (Anthony and Kunz, 1977; Rabinowitz, 1978; Speakman and Racey, 1987). In winter, during months of low abundance of insects, gray bats reduce energetic costs of foraging and thermoregulation by hibernating (French, 1992; Kunz, 1974; Schoener, 1971). During the 6-month period of activity, foraging behaviors may be adjusted to monthly or nightly fluctuations in abundance and distribution of prey.

For M. grisescens, adjusting foraging patterns to achieve a net gain of energy may be most critical during gestation and lactation, a 4-month interval of intense energetic demands. Total respiratory costs increase gradually throughout pregnancy and culminate during lactation (Kurta et al., 1989; Racey and Speakman, 1987; Studier et al., 1973). Throughout gestation and lactation, variation in energy demands, costs of locomotion, and availability of food cause changes in the total energy requirements of females. It seems reasonable to expect that changes in energetic demands associated with reproductive status will affect foraging patterns of female M. grisescens. Furthermore, modifications of foraging patterns should be indicated by variation in patterns of visitation to roost caves, as well as by changes in patterns of excursions outside the caves.

The purpose of this study was to record patterns of movement of female gray bats throughout their annual period of activity and to determine if these patterns are affected by reproductive status. Specifically, I predicted that female M. grisescens would fly shorter distances during lactation than during the post-lactation period. Also, female M. grisescens should spend more time in the maternity cave during pregnancy and lactation than after the young are weaned and volant. Finally, female M. grisescens should spend more time in non-maternity caves in the post-lactation period than during pregnancy or lactation. Alternatively, the null hypotheses would suggest that these elements of foraging strategy would not be significantly different among the reproductive stages.

MATERIALS AND METHODS

Colonies of gray bats selected for this study were located near Guntersville Reservoir in northeastern Alabama (Fig. 3.1). The reservoir is a 27,479-ha impoundment of the Tennessee River, between Nickajack and Guntersville dams, which was constructed ca. 50 years ago for flood control, commercial navigation, and generation of hydroelectric power. The reservoir provides water for several growing municipalities as well as seasonal recreation (Thomas and Best, in press).

The Tennessee River system drains the Cumberland Plateau region, in which limestone caves are plentiful (Tarkington et al., 1965). Although bats may use many of the caves in this region, Hambrick and Blowing Wind caves are particularly important to summer colonies of M. grisescens. Hambrick Cave, Marshall Co., is used by female M. grisescens as a maternity roost (Tuttle, 1975). The cave opens directly onto Guntersville Reservoir, and the interior floor often is submerged. Portions of the interior are elevated above the entrance, which promotes conservation of heat (Tuttle, 1975). Hambrick Cave is relatively small, but frequently houses ca. 60,000 gray bats (M. K. Hudson, in litt.). The entrance to Hambrick Cave is protected by a chain-link fence (Brady et al., 1982).

About 45 km upstream from Hambrick Cave, is Blowing Wind Cave, Jackson Co. From April through September, it primarily is used by a bachelor colony consisting of ca. 190,000 M. grisescens (M. K. Hudson, in litt.). Blowing Wind Cave is located on Wheeler National Wildlife Refuge, ca. 100 m from North Sauta Creek, a tributary of the Tennessee River. The surrounding area primarily is forested with oak (Quercus) and hickory (Carya) trees. The cave has two large entrances that are gated to minimize disturbance of the bats by humans (Brady et al., 1982).

Throughout the project, great care was taken to minimize any impact on the bats. The guidelines of the Gray Bat Recovery Team were followed; the maternity caves were not entered between April and July, trapping was limited to a small section of the cave entrance, and only a small proportion of the colony was captured (Brady et al., 1982). Also, trapped bats were released as soon as possible. Lights and activity at the mouth of the caves were minimized so as not to influence the emerging or returning bats.

During 1993 (31 April-14 September) and 1994 (9 April-11 September), emerging M. grisescens were caught using a modified harp trap (Tuttle, 1974). Trapping occurred at Hambrick Cave, except in April 1994, when bats were captured at Blowing Wind Cave.

Captured bats were identified as juveniles or adults by examining the vascularization of wrist joints (Anthony, 1988; Barbour and Davis, 1969). Gender also was determined and all but 10 adult females were released immediately. The remaining 10 bats were weighed to the nearest 0.5 g with a Pesola spring scale and external measurements were recorded. Reproductive status was ascertained visually, Timing of reproductive events was coincident with previous studies (La Val and La Val, 1980; Meyers, 1964; Saugey, 1978; Tuttle, 1975). On each bat, an 0.8-g radiotransmitter (model BD-2A with reed switch, Holohil Systems, Ltd., Ontario, Canada) was attached dorsally as described by Thomas and Best (in press). Each bat was identified by the last three digits of the radiofrequency of the transmitter carried by the bat.

In 1993, bats outfitted with radiotransmitters were monitored for 10 nights early in each month from May to September. A pair of assistants used a portable radioreceiver (Model TRX-2000S, Wildlife Materials Inc., Carbondale, IL) and a collapsible 3-element Yagi antenna to receive radiotransmissions. The antenna was placed about 1.5 m above the ground to facilitate reception of radiotransmissions. Monitoring was continuous throughout the night beginning ca. 15 min before sunset and ending ca. 15 min after sunrise. Each frequency was monitored ca. 1 min in a 10-min cycle. The time and duration of all attempts to locate radiotransmissions were recorded. When a radiotransmission was detected, the direction of the strongest signal also was recorded. A bat located in several consecutive cycles was considered present throughout each cycle until the last time that frequency was detected. Likewise, failure to detect a frequency indicated the bat was absent during the 10-min cycle.

In May and June, monitoring took place from only one site at Guntersville Reservoir. The balcony of the lodge at Guntersville State Park was chosen for its high elevation (Fig. 3.1). This site was ca. 18 km from the release site at Hambrick Cave. From this site, a portion of the main body of the reservoir was monitored.

To determine distances flown by bats with radiotransmitters, two additional monitoring sites were operative in July, August, and September. Following the established procedures for monitoring, radiofrequencies were monitored from

Riverview Campground, Marshall Co., and from the amphitheater of Goose Pond Colony, Jackson Co. (Fig. 3.1). At each of these sites, research assistants were situated as close to the shore of the reservoir as possible, with the widest area of the reservoir in view. Riverview Campground was ca. 6 km directly across the reservoir from the release site. Goose Pond Colony was ca. 32 km from Hambrick Cave. The site at Goose Pond Colony allowed access not only to the main body of the reservoir, but to a tributary, North Sauta Creek, that extends into the mouth of Blowing Wind Cave.

Along with observation from sites near the reservoir, an attempt was made to collect data on use of maternity and non-maternity caves by M. grisescens. An automatic datalogging unit was designed to scan the appropriate frequencies and record presence or absence of radiosignals inside Hambrick (maternity) and Blowing Wind (non-maternity) caves. Unfortunately, despite repeated repairs and modifications, no reliable data were obtained. Therefore, no data regarding frequency of activity in caves were available from 1993.

From April to September 1994, radiotelemetric monitoring was conducted from four sites using methods similar to those used in 1993. To maintain uniformity of data collection, clocks used at all sites were synchronized and the same pattern of monitoring radiotransmissions was followed at each site.

Two of the sites, Riverview Campground and Guntersville State Park Campground, allowed observation of activity of bats outside caves (Fig. 3.1). At Riverview Campground, monitoring was conducted from the shore of the reservoir, just as in 1993. However, rather than use the elevated site at the lodge of Guntersville State Park, monitoring was done at Guntersville State Park Campground because that site was close to the reservoir and would allow more control of elevation on distance of reception. From here, potential foraging areas over the main body of the reservoir were monitored.

One reason for selecting these sites was to determine relative distances traveled by the bats. Previous studies have used triangulation among multiple monitoring sites. For the present study, triangulation was impractical for two reasons. First, the topography, location of roads, and thick forests prevented access to sites suitable for triangulation. Second, the gray bat is a swift flyer and will routinely fly many kilometers from roost caves (Kennedy and Best, 1972; La Val and La Val, 1980; Thomas and Best, in press; Tuttle, 1976a). If radioreceivers had been clumped for the purpose of triangulation, the chance of locating even one bat would have been reduced dramatically. Over a clear area, such as over water, a radiosignal may be received for 20-30 km (Sahley et al., 1993). Therefore, determining the exact location of the radiotransmitter from the receiver is impossible without triangulation.

To estimate distance traveled by the bats, I determined whether a bat was present within a 5-km radius of the radioreceiver. Before actual monitoring began, a radiotransmitter was placed 5 km across the reservoir from Riverview Campground. Tuning the gain until the signal was barely audible allowed all radioreceivers to be calibrated to receive only signals originating within the 5-km distance. The process was then repeated at Guntersville State Park

Campground. I was able to determine when a particular signal was ≤5 km of the monitoring site.

Two additional sites, at Hambrick Cave and Blowing Wind Cave, were established to monitor activity of bats at roosts within the caves (Fig. 3.1). Stationary Yagi antennas were mounted in each cave and aimed at the roost area. Roost areas were identified by stained patches on the ceiling with large, fresh piles of guano beneath. In Hambrick Cave, 133 m of coaxial cable was stretched from the entrance gate to a location beneath the roost. In Blowing Wind Cave, a cable reached 260 m from the gate at the upper entrance to an antenna that was aimed at the main roost. Radioreceivers were plugged into the cable outside the gates of both caves. Activity in the roosts was monitored nightly following a schedule identical to that at the other sites.

Along with monitoring of the internal cave area, assistants periodically used hand-held antennas to listen for radiotransmissions originating from outside the caves. As soon as a signal from inside the cave was lost, the external antenna was activated. The purpose of this external monitoring was two-fold. First, monitoring outside the entrance helped confirm whether a bat had exited the cave. This confirmation was necessary as intrusion of rocks and cave topography between the antenna and the transmitter can block radiosignals. Second, external monitoring helped record activity of bats near Hambrick and Blowing Wind caves.

For analysis, all times were converted to central standard time. Four parameters were used to determine variation in movement patterns as reproductive status of the bats changed. Percentage of time each radioequipped bat was heard was determined for each month. The percentage was calculated by dividing the total number of minutes during the month that a radiofrequency was received by the total number of minutes spent monitoring during the month, then multiplying by 100.

Next, the number of trips each radioequipped bat made past each site was counted and the duration of each trip determined. A trip began the minute a signal was located, continued as long as the signal was received in consecutive cycles of monitoring, and ended the last minute the signal was detected.

Finally, for radioequipped bats detected at two or more sites, movement among sites was assessed. Although gray bats are believed to forage primarily over water, they also have been observed traveling and foraging over land (La Val et al., 1977; Thomas and Best, in press; Tuttle, 1975). Thus, it was impossible to determine the exact routes flown between sites by individual bats. To determine distance traveled by a bat between two sites, I measured the shortest, straight-line distance between two sites.

Location of sites permitted simultaneous detection of a radiofrequency from two sites (especially from the elevated site at Guntersville State Park Lodge). Therefore, to confirm that a radioequipped bat actually had traveled between two sites at which it had been detected, I calculated the minimum expected time for travel between the two sites. From three reports of rates of flight for _M. grisescens_, I calculated an average speed of 23.3 km/h (Kennedy and Best, 1972;

La Val et al., 1977; Tuttle, 1976a). By dividing this average speed into the minimum distance between two sites, then multiplying by 60, I obtained the minimum time (min) expected for travel by a gray bat between those two sites. If a radiotransmission was detected at two sites only within the minimum expected time, I assumed that the radioequipped bat was located between the two sites and had not actually traveled the minimum distance between sites.

For each of the four variables, movements of bats were compared among months. In 1993, as two sites were not operational until July, two groups of comparisons among months were made. In the first group, only data from Guntersville State Park Lodge were used to determine variation among May-September. In the second comparison, data from the sites at Guntersville State Park Lodge, Riverview Campground, and Goose Pond Colony were combined to determine variation among July-September. Both groups were used to determine how activity of bats outside caves changed among months. In 1994, three groups of comparisons among months were made for each of the four variables. The first group included combined data from Riverview Campground, Guntersville State Park Campground, and the vicinity of Hambrick Cave. Second, data from inside Hambrick Cave were compared among months. Finally, data from inside Blowing Wind Cave were compared among months.

One-way analysis of variance was used to determine differences among months. For analysis of percentage of time and number of trips made by bats, samples included one observation per bat for each site. In cases where individual bats made multiple trips to a site, each trip was considered in the analyses of duration of trips and distances flown by bats. In all comparisons, zeros were entered for bats that were not detected again after release. Several comparisons were used to analyze data from one site, which could elevate the probability of observing a significant difference among months by chance. Thus, significance levels were calculated using the sequential Bonferroni method (Rice, 1989). A Student-Newman-Keuls a posteriori test for multiple comparisons among means was used to identify significantly different subsets of months (SAS Institute, Inc., 1985).

RESULTS

During 1993 and 1994, data were obtained from a total of 107 female M. grisescens (Table 3.1). Examination of females indicated changes in reproductive status. Pregnancy was not detected by external examination by 2 May. However, the 10 females examined in June 1993, and eight of 10 females examined in June 1994 showed evidence of lactation. Two of 10 females equipped with radiotransmitters in June 1994 were heavily pregnant, as indicated by greatly distended abdomens. In July, all females equipped with radiotransmitters had bare mammae, indicating lactation. In August and September, post-lactating females were recognized by bare mammae or new growth of pelage around mammae. Bats lacking these features were classified as non-lactating.

From May through September 1993, a total of 53,376 min was spent searching for radioequipped bats. Of the 49 bats equipped with radiotransmitters, signals were received from 31 of them. From April through September 1994, a total of

150,902 min was spent monitoring radiofrequencies. Transmissions were received from 53 of 58 bats equipped with radiotransmitters.

For each year, total number of minutes spent attempting to locate each bat at each site was analyzed statistically. In both years there was a significant difference in the amount of effort devoted to monitoring individual bats ($\underline{P} > 0.001$). To standardize effort of monitoring among bats, minutes of activity of each bat were determined as a percentage of total minutes spent monitoring from each site during each month.

In 1993, 21 radioequipped bats were detected at two or more sites. The average distance flown by bats did not differ among months (Table 3.2). There was no significant difference among months in percentage of time bats were detected near Guntersville State Park Lodge (Table 3.3). The number and duration of trips made by bats near Guntersville State Park Lodge were not significantly different among months. From July through September 1993, when minutes of signal reception from Riverview Campground, Goose Pond Colony, and Guntersville State Park Lodge were combined, the percentage of time radioequipped bats were located near these sites, as well as number and duration of trips made by bats past these sites, were similar among months (Table 3.3).

In 1994, 31 radioequipped bats traveled to two or more sites. The average distance flown by bats with radiotransmitters was not significantly different among months (Table 3.2). In 1994, data from inside the maternity cave (Hambrick Cave) were obtained from a total of 41 radioequipped bats. Statistical analysis showed that average percentage of time spent by radioequipped bats inside the maternity cave was not significantly different among months (Table 3.3). Radioequipped bats made a significantly greater number of trips into the maternity cave in June than in April and in August ($\underline{P} = 0.009$). Duration of trips made by radioequipped bats into the maternity cave each month were not significantly different among months.

Data from inside Blowing Wind Cave, a non-maternity cave, were obtained from a total of five radioequipped bats in June, July, and August. No radioequipped bats were detected inside Blowing Wind Cave in April, May, or September. There were no differences among months in percentage of time, number of trips, or duration of trips that radioequipped bats were detected inside Blowing Wind Cave (Table 3.3).

The average percentage of time and average number of trips that bats with radiotransmitters were located outside caves (i.e., near Guntersville State Park Campground, Hambrick Cave, and Riverview Campground) were not significantly different among months (Table 3.3). In May, the average duration of trips near Guntersville State Park Campground, Riverview Campground, and Hambrick Cave was significantly greater than average duration of trips near these sites in other months ($\underline{P} < 0.001$).

When all comparisons were re-analyzed using only data from radioequipped bats that were detected on one or more occasion after release, patterns of movement of gray bats were similar, but the magnitude of differences among months increased in several cases. When bats with radiotransmitters from which no signals were received were excluded from analysis, distances flown by radioequipped bats in 1993 were significantly greater in July and August than in September ($\underline{P} = 0.006$). Also, distance flown by bats in 1994 was significantly greater in April and July than in other months ($\underline{P} < 0.001$). Individual tests indicated that number of trips made by radioequipped bats near Guntersville State Park Lodge in 1993 was significantly greater in September than in all other months ($\underline{P} = 0.028$), and number of trips taken into the maternity cave in 1994 was significantly greater in May than in April ($\underline{P} = 0.029$). However, these differences were insignificant with P-values calculated by the sequential Bonferroni method (Rice, 1989).

DISCUSSION

Radiotelemetric monitoring has been used to study many species of bats, especially individuals with large body mass (Audet, 1990; Brigham, 1991; Charles-Dominique, 1991). This technique is useful particularly for bats such as Corynorhinus townsendii, which can be radiotracked nearly continuously; usually these bats travel only 1-5 km between roosts and foraging areas (Clark et al., 1993). However, M. grisescens may travel to foraging areas 15-35 km from the roost and may occupy a home range of ≥ 70 km^2 (La Val et al., 1977; Thomas and Best, in press; Tuttle, 1976a). Thus, in studies of gray bats, continuous radiotelemetric monitoring and triangulation are difficult. Only two previous attempts have been made to use radiotelemetric techniques to investigate movement patterns of gray bats. In those studies, rate of success of detecting radiotransmissions after bats were released was 50-63% (T. L. Best and M. K. Hudson, in litt.; Thomas and Best, in press). In the current study, 63% of the bats equipped in 1993 and 91% of the bats equipped in 1994 were detected at least one time after release. Although considerable effort may yield only a small amount of data, radiotelemetric monitoring offers a longer period of data collection on individual bats than marking bats with luminescent capsules (La Val et al., 1977; Racey and Swift, 1985). Also, radiotelemetric techniques require less handling of individuals and disturbance of colonies than banding and recapture methods (Meyers, 1964; Tuttle, 1975).

Attaching a radiotransmitter to the back of a bat may influence the behavior of the bat. For bats weighing <70 g, a radiotransmitter weighing $\leq 5\%$ of the body mass of the bat is believed to have a negligible effect on maneuverability of the bat in flight (Aldridge and Brigham, 1985). Yet, the mass of some vespertilionid bats may increase by 30% during pregnancy, without preventing foraging. Therefore, weight added to a bat should not exceed 30% of the body mass of the bat (Aldridge and Brigham, 1985).

In my study, body mass of bats equipped with radiotransmitters ranged from 7.5 to 14.0 g ($\bar{X} = 10.1$ g; Table 3.1). Attachment of a 0.8-g radiotransmitter represented $\leq 11\%$ of the body weight of the bat. Signals were detected from 42 of the 107 transmitters ≥ 7 days after release of the radioequipped bats. One bat (191) weighing 7.5 g was released at Hambrick Cave on 30 August and was located 18 km away at Guntersville State Park Lodge on 5 May. Thomas and Best (1994) found that gray bats were able to fly ≤ 75 km when equipped with radiotransmitters identical to those used in my study. Thus, it is probable that addition of radiotransmitters did not impede foraging movements of the bats.

In 1994, an effort was made to conduct radiotelemetric monitoring in April so that the beginning of the active period of the gray bats could be observed. However, by 8 April, few bats had arrived at Hambrick Cave from hibernation, and trapping an adequate sample for radiotelemetry was impossible. Many bats had returned to Blowing Wind Cave by that time, so capture, attachment of radiotransmitters, and release of bats was conducted at Blowing Wind Cave on 9 April.

Evidence from radiotelemetric monitoring confirmed that the maternity colony at Hambrick Cave had not been established by mid-April. During 9-18 April, activity of radioequipped bats was minimal both inside the maternity cave and near sites adjacent to the reservoir (Figs. 3.2 and 3.3). Short average duration of trips made by radioequipped bats inside the maternity cave indicated little activity of bats inside Hambrick Cave (Fig. 3.4).

As radioequipped bats were located near but not inside Blowing Wind Cave, these bats may have been traveling to alternate caves in the vicinity. Among the two radioequipped bats that were detected, average distance of flights between sites did not suggest broad excursions (Fig. 3.5). Yet, because no other radioequipped bats were observed travelling among monitoring sites, it is questionable whether this small sample was representative of the activities of the majority of the colony. In Arkansas a maternity colony of gray bats was settled by 1 April (Saugey, 1978), other evidence suggests that female M. grisescens move frequently among "transitional" caves just after leaving hibernation in early spring (La Val and La Val, 1980; Myers, 1964). In the Ozark region, Myers (1964) documented movement of gray bats through 30 April, after which the maternity period began.

For female M. grisescens, reproduction is a period of intense energy investment to the development of offspring. To allocate more energy to respiration and biosynthesis, gray bats may modify foraging patterns either to assimilate more energy or to reduce energy expenditures on non-reproductive activities (Speakman and Racey, 1985; Studier and O'Farrell, 1980).

Observations made in my study suggest that pregnant gray bats combine periods of foraging and periods of torpor in mid-spring. During 30 April-8 May 1993, activity of radioequipped bats detected outside caves was high, yet not different from other months (Table 3.2, Figs. 3.2, 3.3, and 3.4). Relatively high average percentage of time that bats were located (3.8 min), long average duration of trips (37.9 min), and low average number of trips (3.4) indicate that bats spent long periods flying, and probably foraging, near Guntersville State Park, Riverview Campground, and Goose Pond Colony. During 2-11 May 1994, activity of bats outside caves increased from levels of activity observed in April (Table 3.2, Figs. 3.2, 3.3, and 3.4). Higher average percentage of time radioequipped bats were detected (0.7 min), average number of trips (1.8), and average duration of trips (19.1 min) suggested that radioequipped bats were increasing the length and number of foraging bouts near the localities being monitored.

Similarly, Racey and Swift (1985) reported that pregnant Pipistrellus pipistrellus foraged throughout the night and occasionally flew farther to feed than lactating individuals. Pregnant Myotis myotis also were observed to spend a longer time foraging than lactating females, males, or juveniles (Audet, 1990).

However, evidence from other investigations fails to show extensive foraging. During May, Tuttle and Stevenson (1977) observed that female M. grisescens often remained inside the maternity cave and only foraged for short periods. In Sweden, the foraging periods of female Eptesicus nilssonii became shorter as the date of parturition approached (Rydell, 1993). In my study, average percentage of time radioequipped bats were located (1.7 min) and average number of trips (5.2) made by bats inside the maternity cave not only increased from activity observed there in April but were more than twice levels of activity at sites outside caves in May (P = 0.232; Table 3.2). Also, average distance flown by bats was small in May (7.3 km; Fig. 3.3). These data suggest that radioequipped bats were spending time inside the maternity cave at night in early May.

During pregnancy, decreasing non-reproductive costs may be sufficient to balance energy supplies and demands, because costs of biosynthesis are moderate during gestation. Growth of the fetus in M. grisescens proceeds slowly until ca. 35 days prior to parturition (Saugey, 1978). During slow rates of development of the fetus, production of tissues requires only a small proportion of the total metabolic cost (Anthony and Kunz, 1977; Kurta et al., 1989; Racey, 1982; Racey and Speakman, 1987; Studier et al., 1973).

Merely increasing foraging during pregnancy probably would not fulfill energetic needs because efficiency of foraging is likely to be poor in May. Abundance of insects typically is low in early spring. Costs of flight increase as body mass increases, thus efficiency of foraging flights by pregnant females is poor (Kunz, 1974; Racey, 1982; Thomas, 1980; Thomas and Suthers, 1972; Tucker, 1970). In pregnant Myotis lucifugus, foraging flights may account for 61% of daily energy metabolism (Kurta et al., 1989). In early May, although abundance of insects may have been low, it is likely that maneuverability of the bats in flight had not yet decreased significantly. Pregnancy was not visibly evident in bats captured at this time, and body mass of bats captured in May 1994 was not significantly different from masses of bats captured in April 1994 (April, $\bar{X}$ = 9.3 g; May, $\bar{X}$ = 9.6 g; d.f. = 17, t-value = 1.73, $P > 0.05$; Table 3.1). Thus, mass of the fetus may not have caused significant increase in the mass of the mother by this date. These data show that during gestation, females were periodically making forays from the maternity cave, but bats also were remaining inside the maternity cave, probably to conserve energy during periods of heterothermy.

While heterothermy may allow bats to balance energetic costs during pregnancy, field studies show little evidence that lactating bats habitually compensate energetic costs by heterothermy (Racey, 1982; Tuttle, 1975, 1976b). Research on food habits of lactating mammals including bats indicates that consumption of food is greatest during lactation (Hanwell and Peaker, 1977; Kunz, 1974;

Migula, 1969). Lactating *Eptesicus fuscus* foraged almost twice as long as pregnant and post-lactating bats (Brigham, 1989). Likewise, *M. grisescens* is expected to increase foraging activity during June and July to support high energetic costs of lactation.

Results of this study do not indicate an increase in foraging activities during lactation. However, activity of radioequipped bats outside caves decreased from May to June (Table 3.2, Figs. 3.2, 3.3, and 3.4). In June, average percentage of time radioequipped bats were detected (0.4 min), as well as average number (2.6) and average duration of trips (7.3 min) outside caves decreased from levels recorded in May (P = 0.820, Table 3.2). In 1994, activity of bats near Riverview, Guntersville State Park Campground, and Hambrick Cave also was less in June than in May, although these differences are not significant. Differences in activity of bats between May and June may reflect influences of small samples, or differences among individual bats.

It is possible that radioequipped bats had not begun foraging extensively in early June. Two of the bats captured on 2 June were pregnant (Table 3.1). At a particular locality, parturition is synchronous over ca. 2 weeks (Saugey, 1978; Tuttle, 1975). Thus, for lactating bats, parturition had occurred only recently.

During lactation, energetic demands are intense due to production of milk and maintenance of mammary glands (Hanwell and Peaker, 1977; Racey and Speakman, 1987). Yet, costs associated with lactation are lowest after parturition and peak prior to weaning (Racey and Speakman, 1987). In laboratory studies that subdivided lactation into early and late periods, evidence suggests that *Myotis thysanodes* and *M. lucifugus* enter torpor just after parturition, which may allow greater allocation of maternal energy to production of milk (Studier et al., 1973). Tuttle's (1975) observations of thermoregulation in lactating *M. grisescens* occurred on 11-12 July (just 6 days before some young were able to fly), which could be considered late in the period of lactation. Thus, the energetic requirements of lactating bats may be different immediately following parturition than later during lactation.

Early in the period of lactation, *M. grisescens* may be foraging only intermittently and spending much of the remaining time each night in heterothermy inside the maternity cave. The average percentage of time radioequipped *M. grisescens* were detected inside Hambrick Cave in June was 30X greater than the average percentage of time bats were heard outside the cave (P = 0.232, Table 3.2; Fig. 3.2). In July, later in the period of lactation, radioequipped bats were detected for a smaller average percentage of time (0.7 min) inside the maternity cave (Table 3.2).

In 1993, radioequipped bats were detected for an average percentage of 3.0 min outside caves in July whereas in June bats were detected an average percentage of 0.4 min outside caves (Table 3.2). Average number and duration of trips made by bats outside caves in July were greater than trips made outside caves in June (P = 0.10, P = 0.114, respectively). In 1994, activity of bats outside caves did not increase in July, but activity of radioequipped bats detected in Blowing Wind Cave was greater in July than in other months (Figs.

3.2, 3.3, and 3.4). Although none of the differences in activity of bats between June and July was significant, these data may suggest that lactating gray bats spent more time inside the maternity cave at the onset of lactation than later in the period of lactation.

Greater activity of females inside than outside the maternity cave also may be related to maternal behavior; the mother must periodically fly back to the roost to provide milk and warmth to her young (Anthony and Kunz, 1977; Racey, 1982; Racey and Swift, 1985; Studier et al., 1973; Swift, 1980). The number of trips made by radioequipped gray bats into Hambrick Cave is significantly greater in June than in other months ($\underline{P} = 0.009$), while average duration of these trips is short (6.2 min). This suggests that radioequipped bats made frequent, brief trips into the maternity cave, which is consistent with the requirement to periodically nurse the young.

Repeated returns to the maternity cave potentially increase the cost of locomotion for lactating females. Foraging in areas near maternity caves could conserve energy allocated to foraging flights. However, in both years, the average distances flown by M. grisescens during lactation did not seem to support my prediction. In June 1993, one-half of the radioequipped bats were detected at Guntersville State Park Lodge (17.6 km from the maternity cave), and average distance flown by radioequipped bats was greater in July than other months ($\underline{P} = 0.467$; Table 3.3). A similar pattern was seen in 1994; the distances flown by radioequipped bats in June and July were greater than average distances flown in other months ($P = 0.057$; Table 3.3).

This evidence could be affected by the number or location of sites from which monitoring occurred. Yet, in several other studies, it is unclear if lactating bats chose foraging sites primarily for the conservation of energy. In certain areas, lactating P. pipistrellus foraged in areas closer to the roost than pregnant bats. However, in the same study, P. pipistrellus feeding in other habitats foraged the same distance from the cave during pregnancy and lactation (Racey and Swift, 1985). Barclay (1989) proposed that Lasiurus cinereus did not forage closer to roosts during lactation than during pregnancy or post-lactation because the bats can fly rapidly, thereby reducing energetic and temporal costs of selecting distant foraging sites. Furthermore, as insects generally are abundant in June and July, bats often are most selective for high-energy food items during these months (Anthony and Kunz, 1977; La Val and La Val, 1980; Rabinowitz, 1978). Thus, bats may increase gains from foraging by traveling to areas where quality or abundance of insects is high rather than reducing foraging costs by remaining in the proximity of the maternity roost (Anthony and Kunz, 1977; Racey and Swift, 1985; Swift, 1980).

Lactation ends in early August, by which time most juvenile M. grisescens are fully weaned (La Val and La Val, 1980; Meyers, 1964, Tuttle, 1976a, 1976b; Saugey, 1978). As young become independent, adult female M. grisescens often expand duration and distance of forays; fidelity of female gray bats to the maternity roost declines in August (La Val and La Val, 1980; Meyers, 1964; Tuttle, 1976a). Increased roaming of adult female gray bats may be related to mating or foraging behavior. Additionally, others have suggested that adult females leave the maternity cave soon after weaning to prevent competition with juveniles for food near the cave (Kunz, 1974; Racey, 1982).

Contrary to my prediction, female M. grisescens do not seem to fly greater distances in August and September than in other months. In fact, average distances flown by radioequipped bats were shorter in August and September than in the period of lactation ($P = 0.467$ in 1993, $P = 0.057$ in 1994; Table 3.3). However, it is difficult to determine variation in distances flown by bats using radiotelemetric monitoring at fixed sites as only flights between monitoring sites can be analyzed.

Activity of radioequipped bats inside the maternity cave was less in August than in the previous 3 months, although these differences were not significant (Figs. 3.2, 3.3, and 3.4). This may suggest that females were less loyal to the maternity roost in August. However average duration of time spent by radioequipped bats inside the maternity cave was more than eight times longer in September than in August ($P = 0.145$; Table 3.2). While adult females may have returned to Hambrick Cave for another reason, it is possible that the bats equipped with radiotransmitters in September were not adults but were young of the year. As adult females often enter hibernation in early September, before males or juveniles, many of the adult females may have left Hambrick Cave (Elder and Gunier, 1978; Ewing et al., 1970; Tuttle, 1976a). Assessing age of bats by examining vascularization of the wrist joints is only possible until late August because epiphyses close at ca. 3 months of age (Anthony, 1988; Kunz, 1974; Saugey, 1978).

More activity of female gray bats inside a non-maternity cave (Blowing Wind Cave) was not observed in the period of post-lactation. Only one radioequipped bat was detected inside Blowing Wind Cave in August, and none was detected there in September. While female gray bats with radiotransmitters did not seem to spend more time inside Blowing Wind Cave, it is possible that the bats increased use of other non-maternity caves in the area. Tuttle (1976a) noted that the home range of M. grisescens may include up to six caves. Several studies show that gray bats visit caves other than their primary roost, particularly before entering hibernation (Meyers, 1964; Thomas and Best, in press).

CONCLUSIONS

Movement patterns of radioequipped female M. grisescens changed throughout the period of activity from April through September. Although samples were small in proportion to the size of the colony, movement patterns of radioequipped M. grisescens should be consistent with movement patterns of other gray bats because samples were taken randomly.

None of the three predictions were supported by data. Female gray bats did not fly shorter distances during the period of lactation than after lactation. Compared with periods of pregnancy and lactation, gray bats spent less time in the maternity cave, immediately after lactation. However, use of the maternity cave by female bats increased later in September. Finally, no increase in the time spent by adult females inside Blowing Wind Cave was observed after young were weaned.

Caution must be used when interpreting these data for several reasons. Only two comparisons indicated a statistically significant difference among months; other variations among months were too small to indicate a difference in behavior of the bats. Also, sources of variation, such as variation among individual bats and variation among nights in abundance of prey or temperature may have affected the foraging patterns of the bats.

When performing radiotelemetric monitoring from fixed sites, the probability of receiving radiotransmissions may change if average distance flown by radioequipped bats changes. Thus, in some cases, average percentage of time bats were detected outside caves may underestimate actual activity of bats outside caves. Likewise, average distances flown by bats may be underestimated if bats flew to localities farther apart than monitoring sites.

Future studies are needed that employ techniques capable of acquiring more data from individual bats. Perhaps radiotelemetric monitoring from low-flying aircraft or from satellites could be used to increase amount of time each bat is detected. In addition, radiotransmitters capable of transmitting physiological information (e.g., body temperature) could promote understanding of the influence of factors such as heterothermy on the energy budget of free-ranging bats.

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Table 3.1.—Date of release of gray bats (Myotis grisescens) used for radiotelemetric monitoring at Guntersville Reservoir, Alabama, 1993-1994. Also listed are frequency of radiotransmitter, reproductive condition, body mass, and last date radiosignal was received. Radiotransmitters were attached to bats at Blowing Wind (indicated by asterisks) and Hambrick caves.

Date of release	Frequency (Mhz) of transmitter	Reproductive condition	mass(g)	Last day located
29 April 1993	172.038	no sign of pregnancy	8.5	29 April
	172.088	no sign of pregnancy	9.5	29 April
	172.130	no sign of pregnancy	10.5	6 May
	172.148	no sign of pregnancy	10.0	6 May
	172.191	no sign of pregnancy	7.5	5 May
	172.228	no sign of pregnancy	7.5	29 April
	172.278	no sign of pregnancy	10.0	29 April
	172.451	no sign of pregnancy	9.5	6 May
	172.480	no sign of pregnancy	9.5	7 May
2 June 1993	172.332	pregnant	12.0	9 June
	172.468	pregnant	12.0	9 June
	172.562	pregnant	12.5	5 June
	172.601	pregnant	12.0	2 June
	172.643	pregnant	12.0	2 June
	172.702	pregnant	12.0	2 June
	172.783	pregnant	12.5	2 June
	172.862	—	—	4 June
	172.907	pregnant	12.0	11 June
	172.953	pregnant	12.5	5 June
6 July 1993	172.500	lactating	10.0	13 July
	172.531	lactating	10.0	6 July
	172.582	lactating	9.5	6 July
	172.624	lactating	9.5	12 July
	172.661	lactating	9.0	6 July
	172.680	lactating	9.0	11 July
	172.742	lactating	9.5	16 July
	172.822	lactating	9.0	8 July
	172.882	lactating	8.5	8 July
	172.969	lactating	10.0	13 July
4 August 1993	172.023	post-lactating	9.0	11 August
	172.180	post-lactating	8.0	9 August
	172.313	post-lactating	9.0	12 August
	172.441	post-lactating	9.0	11 August
	172.519	post-lactating	10.5	12 August
	172.722	post-lactating	10.0	4 August
	172.761	post-lactating	10.5	4 August
	172.802	post-lactating	11.0	4 August

Table 3.1.—Continued.

	172.843	post-lactating	8.0	4 August
	172.933	post-lactating	9.5	13 August
3 September 1993	172.044	no sign of lactation	11.0	3 September
	172.083	no sign of lactation	14.0	4 September
	172.120	no sign of lactation	10.0	10 September
	172.210	no sign of lactation	11.5	12 September
	172.273	no sign of lactation	12.5	9 September
	172.330	no sign of lactation	12.0	3 September
	172.370	no sign of lactation	11.0	11 September
	172.461	no sign of lactation	12.5	9 September
	172.502	no sign of lactation	12.0	8 September
	172.542	no sign of lactation	11.5	10 September
9 April 1994	173.021*	no sign of pregnancy	9.0	18 April
	173.041*	no sign of pregnancy	8.5	10 April
	173.062*	no sign of pregnancy	9.5	9 April
	173.101*	no sign of pregnancy	10.0	10 April
	173.383*	no sign of pregnancy	10.0	12 April
	173.399*	no sign of pregnancy	9.5	18 April
	173.431*	no sign of pregnancy	8.5	10 April
	173.452*	no sign of pregnancy	9.5	—
2 May 1994	172.142	no sign of pregnancy	10.0	2 May
	172.232	no sign of pregnancy	8.5	—
	172.293	no sign of pregnancy	9.0	11 May
	172.350	no sign of pregnancy	10.0	—
	172.412	no sign of pregnancy	10.0	—
	172.482	no sign of pregnancy	9.5	11 May
	172.769	no sign of pregnancy	10.0	11 May
	172.831	no sign of pregnancy	9.0	11 May
	172.910	no sign of pregnancy	9.5	2 May
	172.977	no sign of pregnancy	10.5	3 May
2 June 1994	173.000	lactating	9.5	7 June
	173.060	lactating	9.5	7 June
	173.119	lactating	9.5	10 June
	173.189	pregnant	12.5	8 June
	173.391	lactating	10.0	10 June
	173.479	pregnant	12.0	3 June
	173.603	lactating	10.0	6 June
	173.750	lactating	9.5	11 June
	173.862	lactating	9.5	6 June
	173.920	lactating	9.0	3 June
6 July 1994	173.019	lactating	9.5	9 July
	173.080	lactating	10.0	14 July
	173.150	lactating	10.5	12 July
	173.339	lactating	9.0	14 July

Table 3.1.--Continued.

	173.428	lactating	8.0	13 July
	173.502	lactating	9.0	10 July
	173.640	lactating	8.5	---
	173.801	lactating	9.5	13 July
	173.881	lactating	9.0	7 July
	173.940	lactating	10.5	13 July
3 August 1994	172.231	post-lactating	9.0	12 August
	172.273	post-lactating	9.0	9 August
	172.313	post-lactating	9.5	5 August
	172.350	post-lactating	8.5	---
	172.392	post-lactating	9.5	5 August
	172.789	post-lactating	9.0	4 August
	172.809	post-lactating	8.5	5 August
	172.869	post-lactating	9.0	4 August
	172.929	post-lactating	8.5	3 August
	172.959	post-lactating	9.5	3 August
1 September 1994	172.212	no sign of lactation	11.5	6 September
	172.250	no sign of lactation	11.5	11 September
	172.292	no sign of lactation	11.0	11 September
	172.329	no sign of lactation	10.5	6 September
	172.370	no sign of lactation	12.0	10 September
	172.571	no sign of lactation	11.5	4 September
	172.600	no sign of lactation	11.0	10 September
	172.629	no sign of lactation	11.5	10 September
	172.658	no sign of lactation	10.5	2 September
	172.679	no sign of lactation	11.0	2 September

Table 3.2.—Average and standard deviation of percentage of time, number of trips, and duration of trips for which female gray bats (Myotis grisescens) were located at Guntersville Reservoir, Alabama, 1993-1994; degrees of freedom (d.f.), F-values, and P-values from one-way analysis of variance are listed.

Site (year)	Month	Percentage of time X (SD)	Number of trips X (SD)	Duration of trips (min) X (SD)
Guntersville State Park Lodge (1993)	May	3.8(10.7)	3.4(6.5)	37.9(57.7)
	June	0.4(1.2)	2.6(3.7)	7.3(15.2)
	July	3.0(8.2)	5.3(5.7)	25.6(65.3)
	August	1.9(3.0)	4.8(5.7)	19.1(28.9)
	September	4.2(10.5)	12.1(14.8)	20.8(47.8)
d.f.		4,48	4,48	4,301
F-value		0.38	2.06	1.88
P-value		0.820	0.10	0.114
Guntersville State Park Lodge, Riverview Campground, and Goose Pond Colony (1993)	July	1.7(5.7)	3.1(6.6)	25.2(55.6)
	August	0.7(1.9)	2.1(3.9)	15.0(26.2)
	September	1.8(6.2)	5.6(10.3)	19.9(44.4)
d.f.		2,89	2,89	2,338
F-value		0.49	1.78	1.07
P-value		0.617	0.175	0.344
Hambrick Cave (1994)	April	0.1(0.2)	0.3(0.5)	5.5(15.2)
	May	1.7(2.4)	5.2(7.8)	18.3(34.9)
	June	0.9(0.6)	8.4(4.4)	6.2(9.2)
	July	0.7(0.8)	5.2(4.7)	7.3(11.4)
	August	0.2(0.4)	2.3(3.1)	3.8(10.6)
	September	1.5(3.1)	3.7(2.8)	24.5(99.4)
d.f		5,57	5,57	5,270
F-value		1.42	3.43	1.66
P-value		0.232	0.009[a]	0.145
Blowing Wind Cave (1994)	April	0.0	0.0	0.0
	May	0.0	0.0	0.0
	June	0.1(0.2)	0.2(0.6)	2.9(9.3)
	July	0.2(0.3)	0.7(1.3)	6.5(11.8)
	August	0.0	0.1(0.3)	0.1(0.3)
	September	0.0	0.0	0.0
d.f.		5,59	5,59	5,34
F-value		2.04	2.17	1.47
P-value		0.088	0.07	0.245

Table 3.2.—Continued

Guntersville State Park Campground, Riverview Campground, and vicinity of Hambrick Cave (1994)	April	0.0(0.1)	0.5(1.5)	1.8(4.0)
	May	0.7(3.1)	1.8(5.5)	19.1(40.0)
	June	0.0(0.1)	0.7(1.3)	1.7(4.2)
	July	0.0(0.1)	0.6(1.2)	1.0(2.3)
	August	0.1(0.2)	0.6(1.4)	2.4(5.9)
	September	0.1(0.2)	1.1(2.2)	3.9(10.6)
d.f.		5,173	5,173	5,284
F-value		1.32	0.94	7.04
P-value		0.257	0.455	<0.001[a]

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0100 for a table of five tests.

Table 3.3.--Average and standard deviation of distances flown by female gray bats (Myotis grisescens) among sites at Guntersville Reservoir, Alabama, 1993-1994; degrees of freedom (d.f.), F-values, and P-values from one-way analysis of variance are provided.

Year	Month	Distance flown (km) X (SD)	Results of one-way ANOVA d.f.	F-value	P-value
1993	July	14.7(7.9)			
	August	14.0(7.9)			
	September	12.4(4.5)			
			5,74	0.77	0.467
1994	April	7.7(13.5)			
	May	7.3(6.8)			
	June	8.1(7.5)			
	July	14.3(14.9)			
	August	7.8(8.3)			
	September	5.2(1.7)			
			5,118	2.22	0.057

Fig. 3.1.--Sites at Guntersville Reservoir, Alabama, where radiotelemetric monitoring of female gray bats (Myotis grisescens) took place in 1993 and 1994: 1) Guntersville State Park (lodge and campground); 2) Goose Pond Colony; 3) Riverview Campground; 4) Blowing Wind Cave; 5) Hambrick Cave.

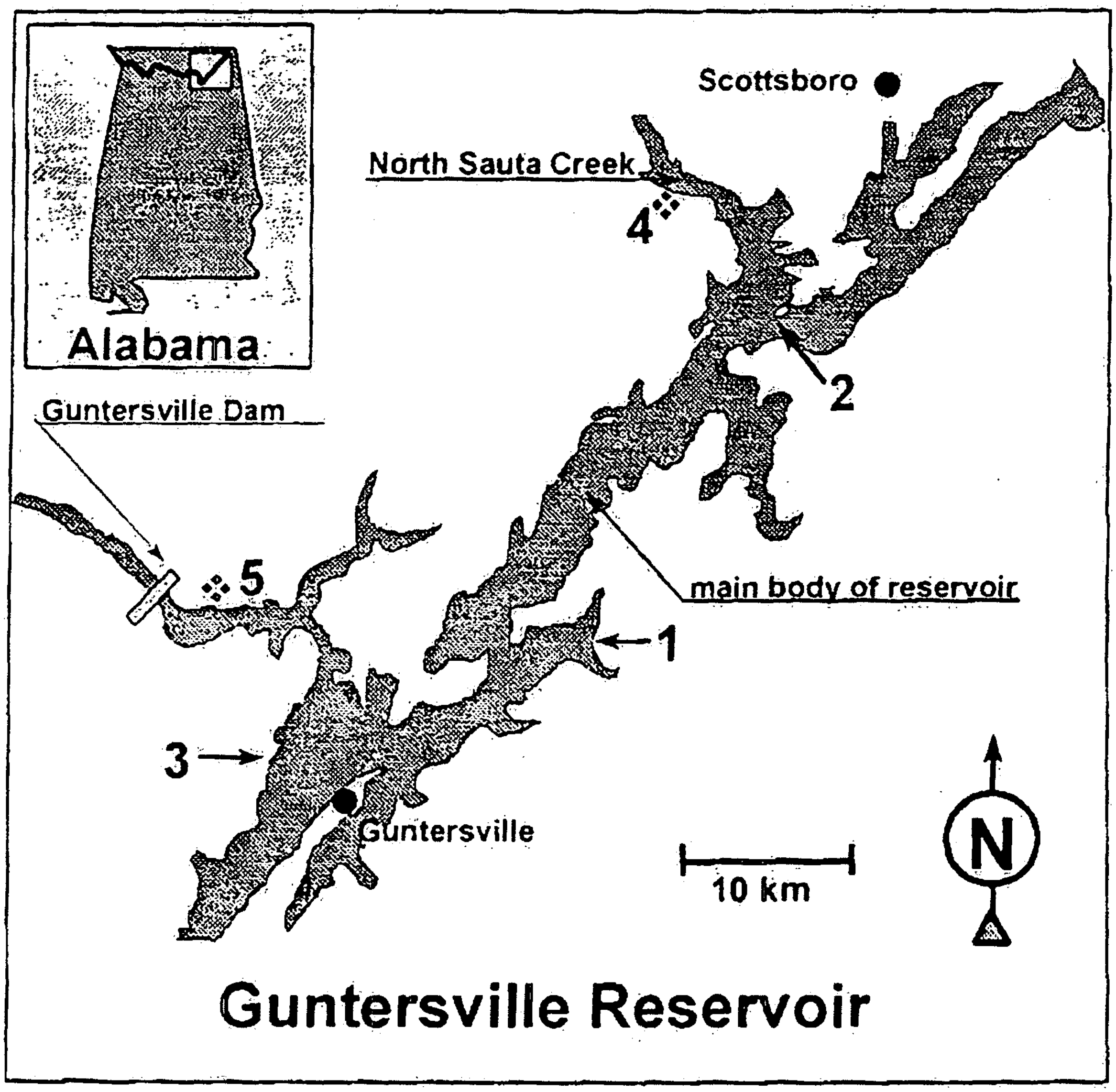


Fig. 3.2.—Average percentage of time that female gray bats (Myotis grisescens) were detected at Guntersville Reservoir, Alabama, 1993-1994.

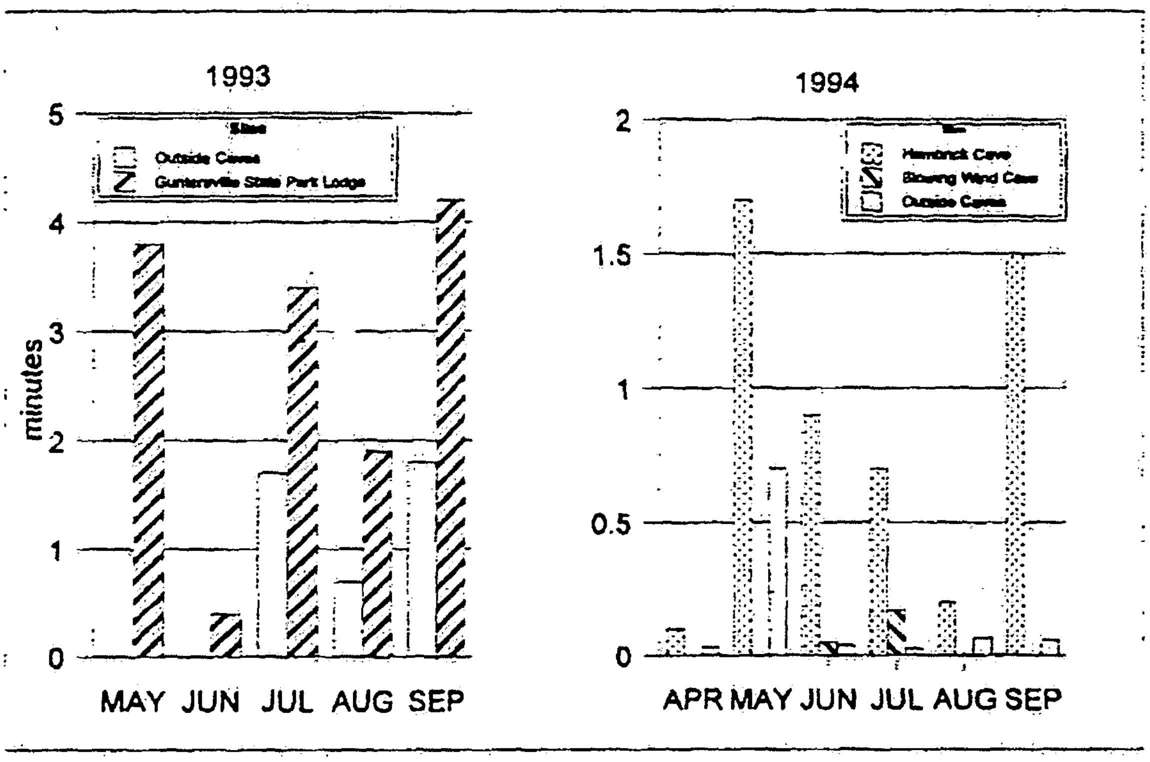


Fig. 3.3.—Average number of trips taken by radioequipped gray bats (Myotis grisescens) at Guntersville Reservoir, Alabama, 1993-1994.

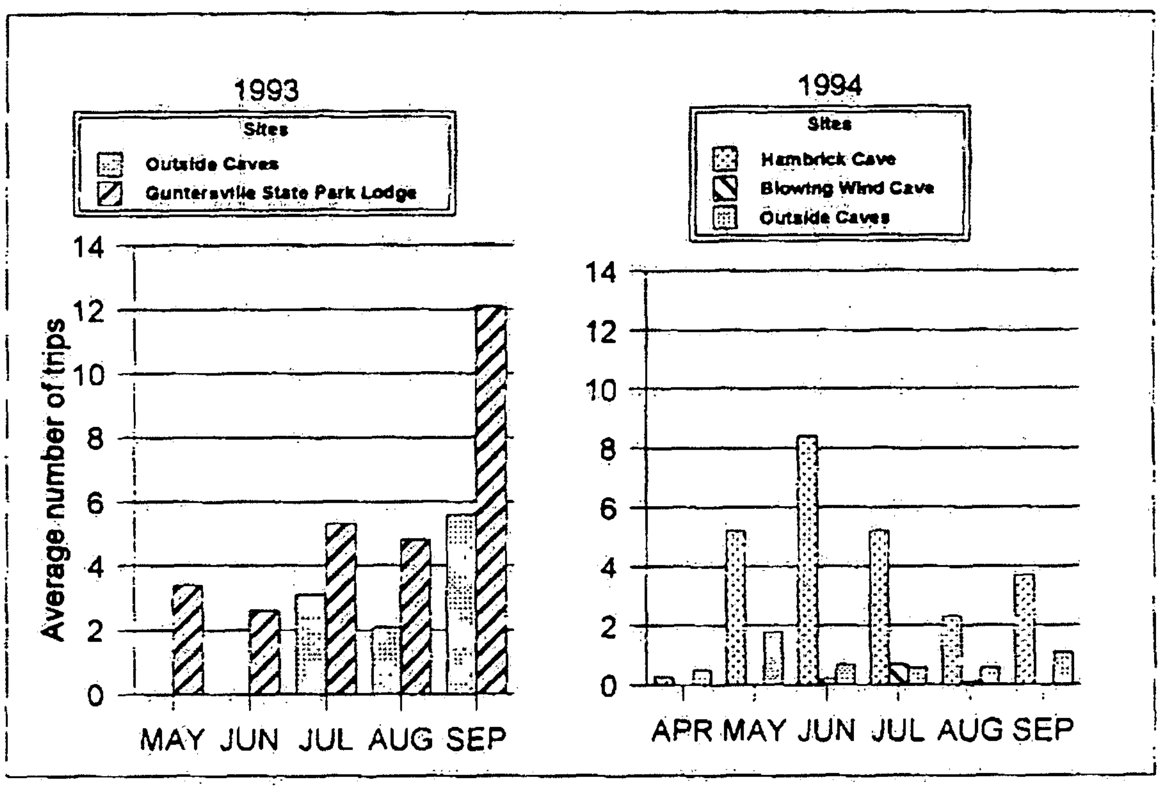


Fig. 3.4.—Average duration of trips made by gray bats (Myotis grisescens) at Guntersville Reservoir, Alabama, 1993-1994.

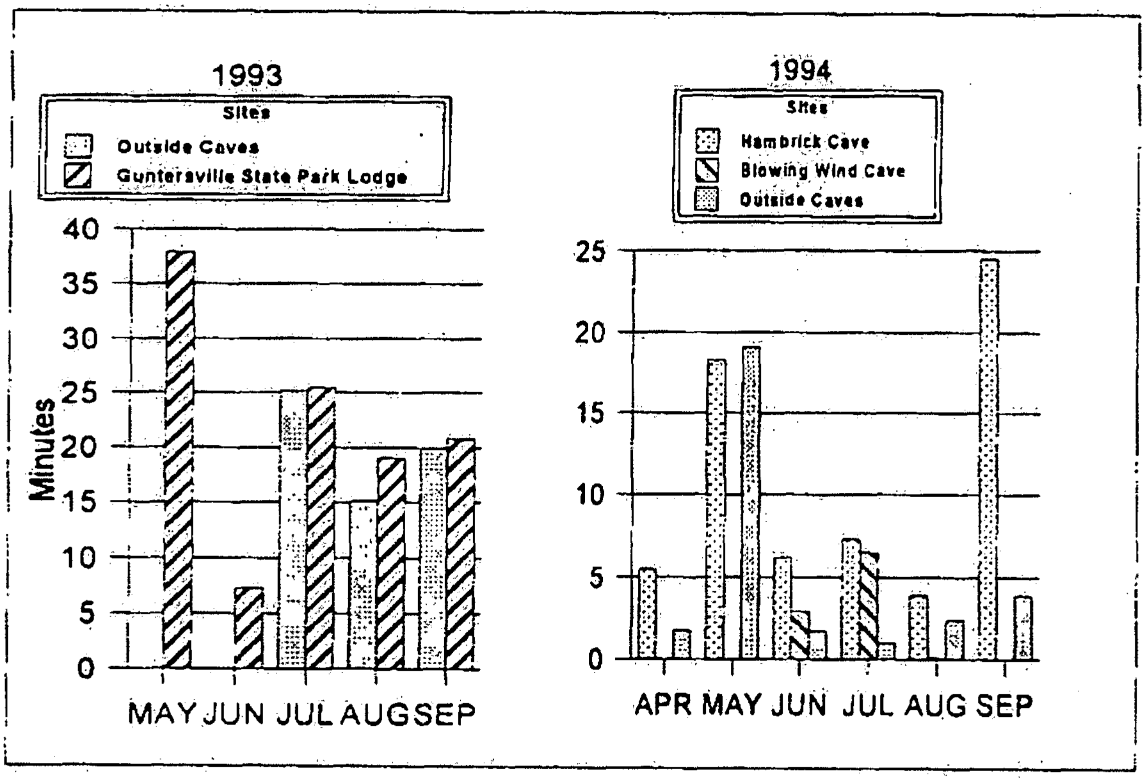
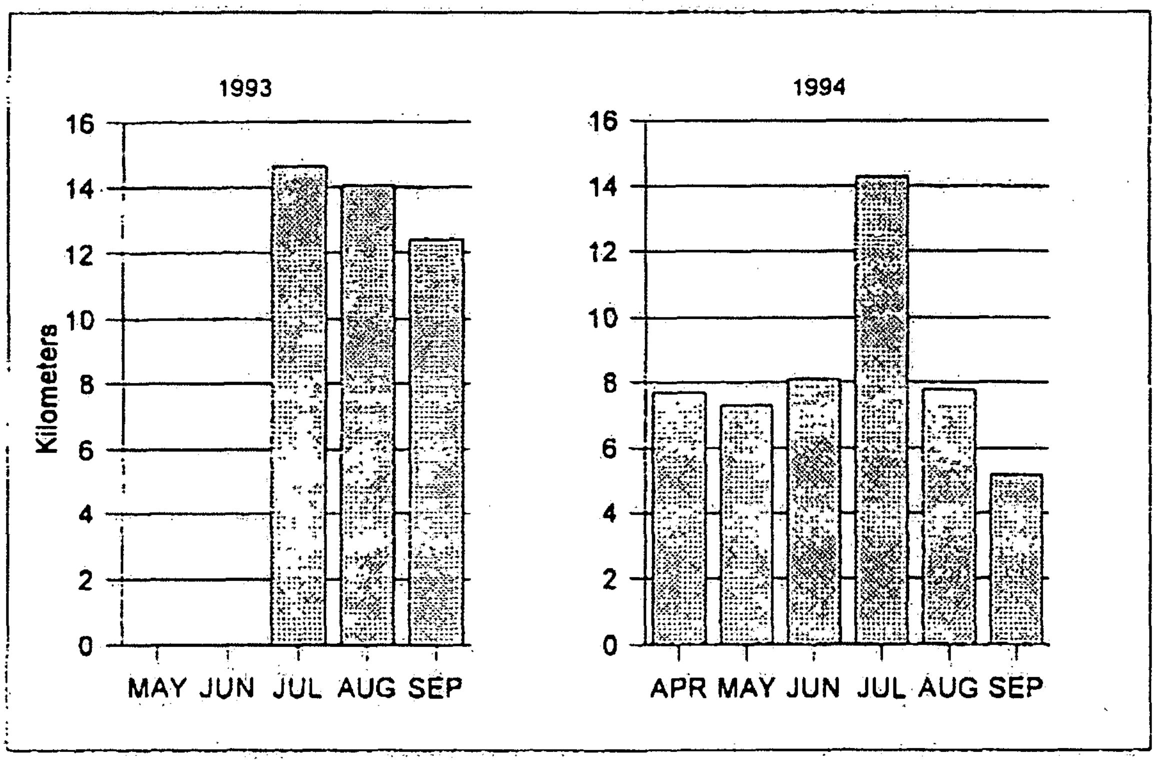


Fig. 3.5.—Distances flown by gray bats (*Myotis grisescens*) among sites at Guntersville Reservoir, Alabama, 1993-1994.



IV. NIGHTLY MOVEMENT PATTERNS OF FEMALE ENDANGERED GRAY BATS (*MYOTIS GRISESCENS*) AT GUNTERSVILLE RESERVOIR, ALABAMA

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Abstract.--The purpose of this research was to use radiotelemetry to investigate nightly movements associated with foraging by female gray bats (*Myotis grisescens*) near Guntersville Reservoir in northeastern Alabama. Gray bats were detected at the same sites and time periods more often than expected by chance; of 141 bats equipped with radiotransmitters, 45 were located at the same site and at nearly the same time (within ≤60 min) during at least 50% of the nights they were detected. Results of this study support previous findings that some individual gray bats revisit the same foraging sites at about the same time of night. Foraging areas that receive concentrated, repeated use may represent core areas within the home range of individual gray bats. No evidence of territorial defense was observed.

INTRODUCTION

The ordinary activities of animals usually are carried out in a limited area, or home range. The home range often is described as the space traveled by the animal while mating, rearing young, and foraging (Burt, 1943; Samuel et al., 1985). Foraging activities may be particularly important in establishing size of the home range, as the animal must find enough food to satisfy energetic needs (Jewell, 1966; McNab, 1963). Size and location of the home range may also be influenced by specificity of habitat requirements of the animal.

Habitat requirements of the gray bat (*Myotis grisescens*) limit the species to parts of the southeastern United States that provide suitable roost caves and riparian foraging areas (Brady et al, 1982). Gray bats exhibit strong philopatry to summer and winter home ranges, both throughout a season and from year to year (Tuttle, 1976). Recovery of banded gray bats indicates that a colony may range up to 70 km along a river or reservoir (Brady et al., 1982; Tuttle, 1976). The home range of an individual gray bat is 15-35 km in length (24 km--Thomas and Best, in press; Tuttle, 1976). Gray bats, especially juveniles, will make occasional distant forays not associated with migratory movements (Thomas and Best, in press; Tuttle, 1976). However, these exploratory travels should not be included in the size of the home range (Burt, 1943).

While the size of the home range of the gray bat has been estimated, little is known about the activities of gray bats inside the home range. Within the range of M. grisescens, distribution of food (nocturnal flying insects) is heterogenous in time and space. Thus, the entire home range is not uniformly exploited by gray bats (Rabinowitz, 1978). To obtain sufficient energy resources, gray bats are believed to select foraging areas that provide abundant prey (Rabinowitz, 1978). It is not known if individual bats repeatedly select the same forging areas within the home range.

For other animals, areas of repeated use, called core areas, have been identified within the home range. Core areas often are situated close to roosts and dependable food sources (Samuel et al., 1985). Exploitation of core areas may be related to the patchiness of resources (Schoener, 1971). It is unclear whether individual gray bats regularly use core areas within a home range.

The purpose of this study was to use radiotelemetry to investigate movements associated with foraging of female gray bats near Guntersville Reservoir in northeastern Alabama. I attempted to determine whether gray bats were detected at sites and time periods more often than expected by chance.

MATERIALS AND METHODS

Colonies of M. grisescens selected for this study were located near Guntersville Reservoir in northeast Alabama (Fig. 4.1). Two caves near the reservoir, Hambrick and Blowing Wind caves, are crucial roosts for gray bats. The many ecologically diverse habitats supported by the reservoir provide foraging areas for gray bats (Tennessee Valley Authority, in litt.).

During 1993 (31 April-14 September) and 1994 (9 April-11 September), 107 adult female M. grisescens were captured and equipped with radiotransmitters as described previously (Chapter I; Thomas and Best, in press). Individual bats were identified by the last three digits of the frequency of the radiotransmitter attached to the bat. Teams of research assistants monitored transmitter frequencies from up to five sites along the reservoir, as described (Chapter I). Each frequency was observed for ca. 1 min every 10 min throughout the night.

Data obtained from Guntersville State Park (lodge and campground), Riverview Campground, Hambrick Cave, Blowing Wind Cave, and Goosepond Colony were included (Fig. 4.2). Effort of monitoring was similar from these sites, thus the chance of detecting individual bats from each site was similar.

My analysis also included data recorded during a similar study conducted 1991-1992 in which 34 female M. grisescens were equipped with radiotransmitters (Thomas and Best, in press). The method of monitoring was similar to the procedure followed in 1993 and 1994. However, in 1991, locations of monitoring sites were changed frequently and effort of monitoring individual radiofrequencies differed (P = 0.044--Thomas and Best, in press). Because effort of monitoring was different among bats and among sites, the chance of detecting individual bats at each site was different. Thus, data obtained in 1991 were omitted from this analysis.

Data obtained in 1992 from Guntersville State Park Campground, Brown's Creek Campground, Hambrick Cave, Blowing Wind Cave, and Nickajack Cave (Fig. 4.3) were included in this analysis because number of hours spent monitoring from these sites was similar. Sites from which monitoring was intermittent were excluded from this analysis as the chance of detecting bats at each site was different.

For analysis, all times were converted to central standard time. Radiosignals detected at two or more sites were used to determine if each bat visited one site more often than expected. As bats released from Hambrick and Blowing Wind caves were detected at each site, I assumed that all sites were available to each bat. Because effort of monitoring was similar at all sites, detection of a bat was possible at each site. For each bat, a Chi-square goodness-of-fit test was calculated to determine if sites visited by the bat were visited with similar frequency.

A Chi-square test of independence was performed on observations for each bat to determine if a bat was detected more often than expected at a site and during a time period. The hours of monitoring were divided into a first (1830-0000 h) and a second (0001-0530 h) time period. A contingency table was constructed for each bat using variables of site and time period. Only sites at which the bat was detected were considered. In instances where observations formed a two-by-two table and cell frequencies were small (≤ 15), a Fisher's exact test was performed instead of a Chi-square test (Steel and Torrie, 1980). To avoid committing a Type 1 error, Bonferroni table-wide significance levels were calculated by dividing the *P*-value by the number of individuals tested (Rice, 1989).

RESULTS

Of 141 female *M. grisescens* equipped with radiotransmitters, 102 were detected on at least one occasion after release. For 45 individuals, the radiofrequency was located at the same site and at nearly the same time (within ≤ 60 min) during at least 50% of the days it was detected (Table 4.1). Eight bats were detected at the same site during more than one period of ≤ 60 min on at least 50% of the days each bat was detected. Fifty percent of the days that bat 293 was detected, it was located at Hambrick Cave at nearly the same time. The same bat was detected at Riverview Campground between 1930-2030 h during 10 days that monitoring occurred.

Forty-seven bats were located at two or more sites. Using the Bonferroni table-wide significance level of $P < 0.0011$, only 11 bats were located at one site more often than expected (Table 4.2). Of the 11 bats, seven were detected most frequently at Guntersville State Park, two inside Hambrick Cave, and two at Riverview Campground.

The test of independence showed that five bats with radiotransmitters were detected more than expected ($P < 0.0011$) at the same site and during the same period during the night more often than expected by chance (Table 4.2). Of these bats, no two individuals were detected at the same site and during the same time period. For bat 769, 48% of the observations occurred from

Guntersville State Park during the first time period (1830-0000 h). Fifty-four percent of detections of bat 293 occurred at Riverview Campground during the first time period. Sixty-four percent of observations of bat 370 were from within Hambrick Cave during the first time period. Bat 502 was located 60% of the time from Riverview Campground during the second time period (0001-0530 h). Bat 210 was detected frequently from two sites; 36% of observations occurred from Guntersville State Park during the first time period, while 35% of observations occurred from Riverview Campground during the second time period.

DISCUSSION

Techniques of radiotelemetry can be used to gather much information about species such as the Ozark big-eared bat (Corynorhinus townsendii), which travel short distances from roosts to foraging areas (Clark et al., 1993). However, as gray bats often travel 20-35 km from the roost cave each night, small amounts of data can be obtained with considerable effort in radiotelemetric tracking. Because the number of observations are small for some individuals in this study, results are interpreted with caution.

Results of the Chi-square goodness-of-fit tests indicate that some bats visited one of the sites more often than expected by chance. Sites visited more often than others may represent core areas for these individuals. Hambrick Cave, the maternity cave from which these bats were captured, was expected to be a core area. In two instances, bats visited Hambrick Cave more often than any other site. However, because monitoring occurred during hours bats were expected to be foraging, frequency of visits to the cave during the night probably does not represent actual use of the maternity cave.

Nine of the bats visited the area near Guntersville State Park more often than expected. This area is likely to contain many foraging areas that are suitable for the gray bat. It also is located between the maternity and bachelor caves. Thus, the area near Guntersville State Park may represent a core area for gray bats. The area near Riverview Campground also contains suitable foraging areas for gray bats; bats were observed foraging near security lights on docks and piers.

The tests of independence indicated that a few bats visited the same sites at nearly the same period during the night. This suggests that some bats maintain a foraging route night after night. Several species of bats have been observed returning to the same foraging location at about the same time of night. Northern bats (Eptesicus nilssoni) in Sweden exhibited fidelity to foraging areas throughout 3 months (Rydell, 1986). Each E. nilssoni used several 100-m^2 foraging areas per night, and bats often returned to the same sites several times each night (Rydell, 1986). During a period of 2 weeks, Racey and Swift (1985) observed individual Pipistrellus pipistrellus returning to the same foraging sites at nearly the same time of night. Furthermore, the same foraging areas were visited successively by different individuals (Racey and Swift, 1985). Gray bats showed fidelity to foraging areas, and would revisit sites that were previously occupied by other gray bats (Thomas and Best, in press). As these foraging areas often are revisited throughout the night or on successive nights, they may represent core areas for individual bats.

Maintaining core areas may be energetically advantageous for the gray bat. Core areas in which bats forage are likely chosen for high abundance of insects (Rabinowitz, 1978). Searching for food is energetically and temporally costly (Norberg, 1977; Schoener, 1971). Thus, bats may regularly visit sites that previously have been successful foraging areas to reduce time spent searching for prey. Likewise, if foraging success at a site has been poor, the bat should discontinue visiting that site (Pyke, 1984). Revisiting a successful site may increase chances that current foraging efforts will be successful.

Observations of aggression in bats at regularly visited foraging sites may indicate that bats sometimes are territorial. Territoriality occurs when an area within the home range is defended by the animal (Davies and Houston, 1984). Hawaiian hoary bats (Lasiurus cinereus semotus) appeared to defend individual, circular patterns of flight while foraging under street lamps (Belwood and Fenton, 1984). When another bat intruded in an established circuit, the foraging bat sometimes emitted an audible agonistic call and chased the intruder away. Aggressive chases and audible vocalizations among foraging bats were observed in E. nilssoni (Rydell, 1986) and in Myotis daubentoni (Wallin, 1961).

Defense of particular foraging sites would be advantageous when insect prey is not abundant. Territoriality may prevent depletion of prey by a competitor, yet defense of the territory requires time and energy that could otherwise be spent foraging (Schoener, 1971). The advantage of defending a foraging territory is reduced when prey is either superabundant or extremely low (Davies and Houston, 1984).

Evidence suggests that territorial behavior occurs when the density of prey is low. Reduction of aggressive interactions among foraging E. nilssoni in July may be related to increased availability of food (Rydell, 1986). The number of agonistic calls among L. cinereus semotus decreased as density of insects increased (Belwood and Fenton, 1984). Brady et al. (1982) assert that male and non-reproductive female M. grisescens are excluded from territories when abundance of insects is low. The number of bats foraging in an area without intraspecific aggression was related to density of insects in the area (Brady et al., 1982; Racey and Swift, 1985). If bats are territorial, this behavior probably is dependent on abundance of food.

While foraging behavior of bats may change as abundance of insects changes, whether bats are territorial is unclear. Aggression among bats at foraging sites may not prove that bats are territorial. Although red bats (Lasiurus borealis) chased intruders from individual foraging circuits, these chases did not successfully exclude the intruder from the foraging site (Hickey and Fenton, 1990). The number of times foraging bats chased intruders was not related to the abundance of food. The aggressive behavior of red bats did not illustrate territoriality as defined by Davies and Houston (1984).

No evidence of territoriality was observed in my study. However, methods other than radiotelemetry would be more instructive in assessing territoriality in gray bats. Results of this study support previous findings that some individual gray bats revisit foraging sites and often visit the same site at about the same time of night (T. L. Best and M. K. Hudson, in litt; Thomas and Best, in press). Foraging areas that receive concentrated, repeated use represent core areas within the home range of the individual gray bat.

Further studies are needed to determine how use of core areas is related to short- and long-term changes in abundance of food. Marking bats with reflective wing bands to facilitate long-term identification of individual bats would allow better determination of fidelity to foraging sites as well as territorial defense of these sites.

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Table 4.1.—Gray bats (Myotis grisescens) located at sites near Guntersville Reservoir, Alabama, within a 60-min period on >50% of the days the radiosignal was detected.

Frequency (Mhz)	Site	Time (h)	No. days detected at site	Total no. days detected	Percent of days detected at site
173.000	Guntersville State Park	0215-0315	4	5	80.0
173.019	Hambrick Cave	0235-0236	2	2	100
172.023	Guntersville State Park	1930-2030	5	6	83.3
172.148	Guntersville State Park	1856-1956	2	2	100
172.210	Riverview Campground	1830-1840	5	9	55.9
172.210	Riverview Campground	0320-0420	7	9	77.8
173.212	Hambrick Cave	1800-1830	3	3	100
173.231	Hambrick Cave	1855-1955	4	7	57.1
173.250	Riverview Campground	0330-0430	4	8	50.0
173.292	Hambrick Cave	1800-1830	2	3	66.7
172.293	Hambrick Cave	1830-1930	5	10	50.0
172.293	Riverview Campground	1930-2030	10	10	100
172.313	Guntersville State Park	2030-2130	4	8	50.0
173.313	Hambrick Cave	0430-0530	2	3	66.7
172.332	Guntersville State Park	1924-1951	5	5	100
173.370	Riverview Campground	0400-0500	5	8	62.5
173.391	Hambrick Cave	0330-0430	4	8	50.0
173.392	Riverview Campground	0330-0400	2	3	66.7
173.430	Hambrick Cave	1900-2000	3	4	75.0
172.441	Guntersville State Park	2000-2100	3	4	75.0
172.441	Guntersville State Park	0100-0200	3	4	75.0
172.451	Guntersville State Park	0215-0216	2	2	100
172.461	Guntersville State Park	1820-1920	6	7	85.7
172.461	Guntersville State Park	2330-0030	5	7	71.4
172.461	Guntersville State Park	0300-0400	7	7	100
172.468	Guntersville State Park	1935-2035	2	3	66.7
172.480	Guntersville State Park	1930-2030	6	6	100
172.480	Guntersville State Park	0150-0250	3	6	50.0
172.482	Hambrick Cave	0330-0430	3	5	60.0
172.500	Riverview Campground	0144-0154	3	5	60.0
172.502	Guntersville State Park	0130-0230	3	6	50.0
172.550[a]	Blowing Wind Cave	2030-2050	5	5	100
172.562	Guntersville State	1900-2000	3	3	100
172.603	Hambrick Cave	0400-0430	3	5	60.0
172.624	Guntersville State Park	2120-2220	5	6	83.3
172.624	Guntersville State Park	0140-0240	6	6	100
172.640[a]	Guntersville State Park	2000-2100	3	4	75.0
172.640[a]	Guntersville State Park	0350-0450	2	4	50.0
172.650[a]	Blowing Wind Cave	0301-0401	3	6	50.0
172.680	Guntersville State Park	0100-0200	3	4	75.0

Table 4.1.—Continued.

172.691[a]	Nickajack Cave	0300–0400	2	3	66.7
172.742	Riverview Campground	2000–2100	6	10	60.0
172.742	Riverview Campground	2300–0000	6	10	60.0
172.742	Riverview Campground	0150–0250	5	10	50.0
173.750	Hambrick Cave	1902–1903	4	6	66.7
172.769	Guntersville State Park	1930–2030	5	8	62.5
172.770[a]	Guntersville State Park	2330–0030	3	6	50.0
172.830[a]	Brown's Campground	0203–0243	3	5	50.0
172.831	Hambrick Cave	1830–1930	4	7	57.1
172.831	Hambrick Cave	0330–0430	4	7	57.1
172.849[a]	Guntersville State Park	0420–0430	2	4	50.0
172.862	Guntersville State Park	1917–2017	2	3	66.7
173.862	Hambrick Cave	0403–0404	2	3	66.7
172.872[a]	Guntersville State Park	2110–2130	4	4	100
172.888[a]	Blowing Wind Cave	2010–2030	3	4	75.0
172.909[a]	Guntersville State Park	0030–0130	3	3	100
172.969	Guntersville State Park	0115–0215	4	5	80.0

aData obtained in 1992 (Thomas and Best, in press).

Table 4.2. Results of statistical tests to determine if individual Myotis grisescens were detected at sites and times more often than expected by chance. Values include X^2 and P-value for Chi-square goodness-of-fit tests, X^2 and P-values for Chi-square test of independence, and P-value for Fisher's exact test.

Frequency (Mhz)	No. of Observa-tions	Number of sites	Chi-square goodness-of-fit test d.f.	X^2	P-value	Chi-square test of independence X^2	P-value	Fisher's exact test P-value
173.000	24	2	1	16.667	0.000*	1.125	0.289	
173.021	9	2	1	1.000	0.317			0.333
172.023	30	2	1	16.133	0.000*			
173.060	25	3	2	21.440	0.000*	8.339	0.016	
172.180	9	2	1	0.600	0.439			0.333
173.189	9	2	1	0.600	0.439			0.063
172.210	87	2	1	0.012	0.915	14.075	0.000*	
173.231	9	2	1	0.600	0.439			1.000
173.250	80	2	1	48.050	0.000*	7.120	0.008	
172.273	7	3	2	2.000	0.368	0.875	0.646	
173.273	5	2	1	1.800	0.180			1.000
172.293	174	2	1	14.368	0.000*			0.000*
172.313	20	2	1	12.400	0.002	2.222	0.136	
172.370	29	3	2	36.690	0.000*	1.661	0.436	
173.370	22	2	1	2.909	0.088	3.747	0.000*	
173.392	9	2	1	5.444	0.020			1.000
173.399	5	2	1	1.800	0.180			0.200
172.441	69	2	1	65.058	0.000*	0.828	0.363	
172.500	14	2	1	4.571	0.033			0.330
172.502	78	2	1	4.154	0.042	36.325	0.000*	
173.503	14	2	1	7.000	0.032			0.378
172.519	19	3	2	14.000	0.001*	4.961	0.084	
172.542	38	2	1	2.632	0.105	0.069	0.793	
172.550[a]	9	2	1	5.444	0.020			0.222
173.571	3	2	1	0.333	0.564			
172.591[a]	6	2	1	2.667	0.103			0.167
173.603	15	2	1	3.267	0.071			0.282
172.624	138	2	1	134.029	0.000*			0.295
172.631[a]	12	2	1	1.333	0.248			1.000
172.650[a]	16	2	1	1.000	0.317	0.004	0.950	
172.680	11	2	1	4.455	0.035			0.109
172.691[a]	6	2	1	2.667	0.102			0.333
172.742	150	3	2	155.640	0.000*	4.624	0.099	
172.769	67	2	1	0.134	0.714	19.563	0.000*	
172.770[a]	39	3	2	18.615	0.000*	6.044	0.049	
173.789	11	2	1	0.812	0.366			0.491
173.802	6	2	1	2.667	0.103			0.667
172.809[a]	5	2	1	0.200	0.655			
172.830[a]	12	3	2	3.500	0.174	0.321	0.852	

Table 4.2.—Continued.

172.849[a]	13	2	1	9.308	0.002			0.769
173.862	12	2	1	0.333	0.564			0.558
172.882	3	2	1	0.333	0.564			1.000
172.872[a]	12	3	2	13.500	0.001*	2.933	0.231	
172.933	15	2	1	0.600	0.439			0.229
173.941	12	2	1	0.000	1.000			0.699
172.950[a]	5	2	1	0.180	0.180			1.000
172.969	15	2	1	3.267	0.071			0.026

[a]Data obtained from Thomas and Best (in press).

*Significance at $P \leq 0.001$.

Fig. 4.1.—Two caves located near Guntersville Reservoir, Alabama, which are roosts for gray bats (Myotis grisescens) during summer: 1) Blowing Wind Cave is primarily a roost for male and non-reproductive female gray bats; 2) Hambrick Cave is primarily a roost for reproductive female gray bats.

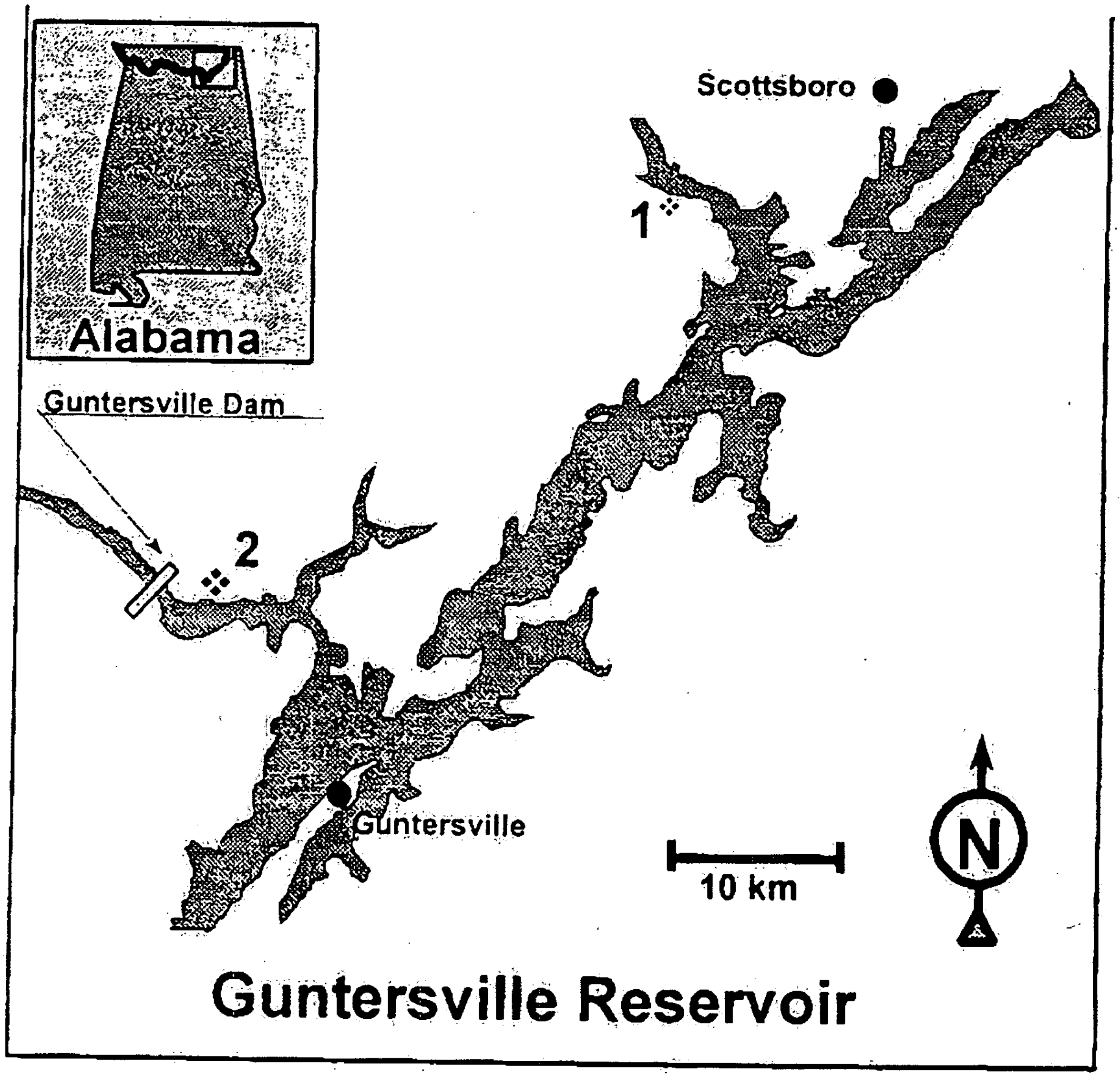


Fig. 4.2.—Sites at Guntersville Reservoir, Alabama, where radiotelemetric monitoring of female gray bats (Myotis grisescens) took place in 1993 and 1994: 1) Guntersville State Park (lodge and campground); 2) Goose Pond Colony; 3) Riverview Campground; 4) Blowing Wind Cave; 5) Hambrick Cave.

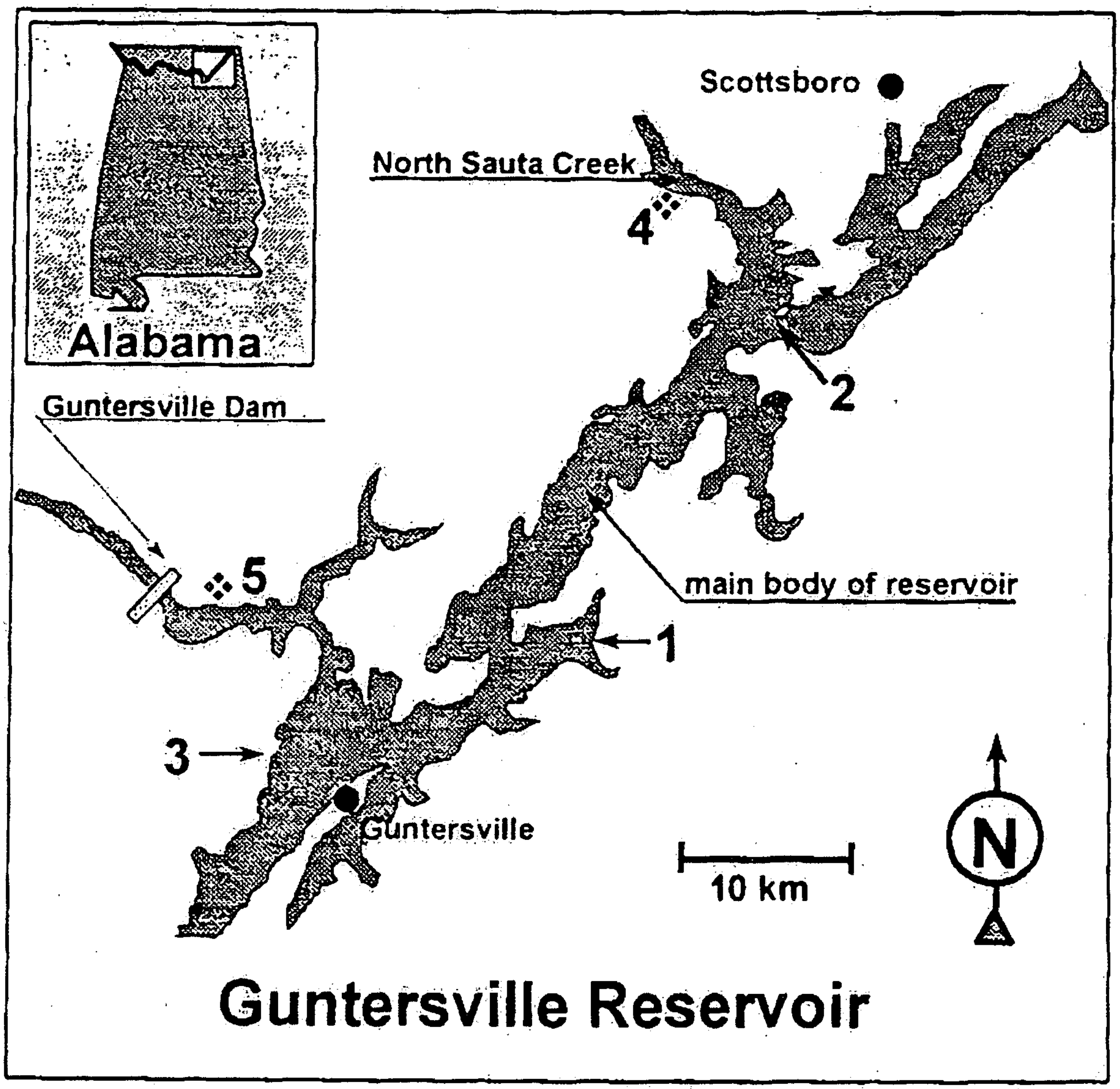
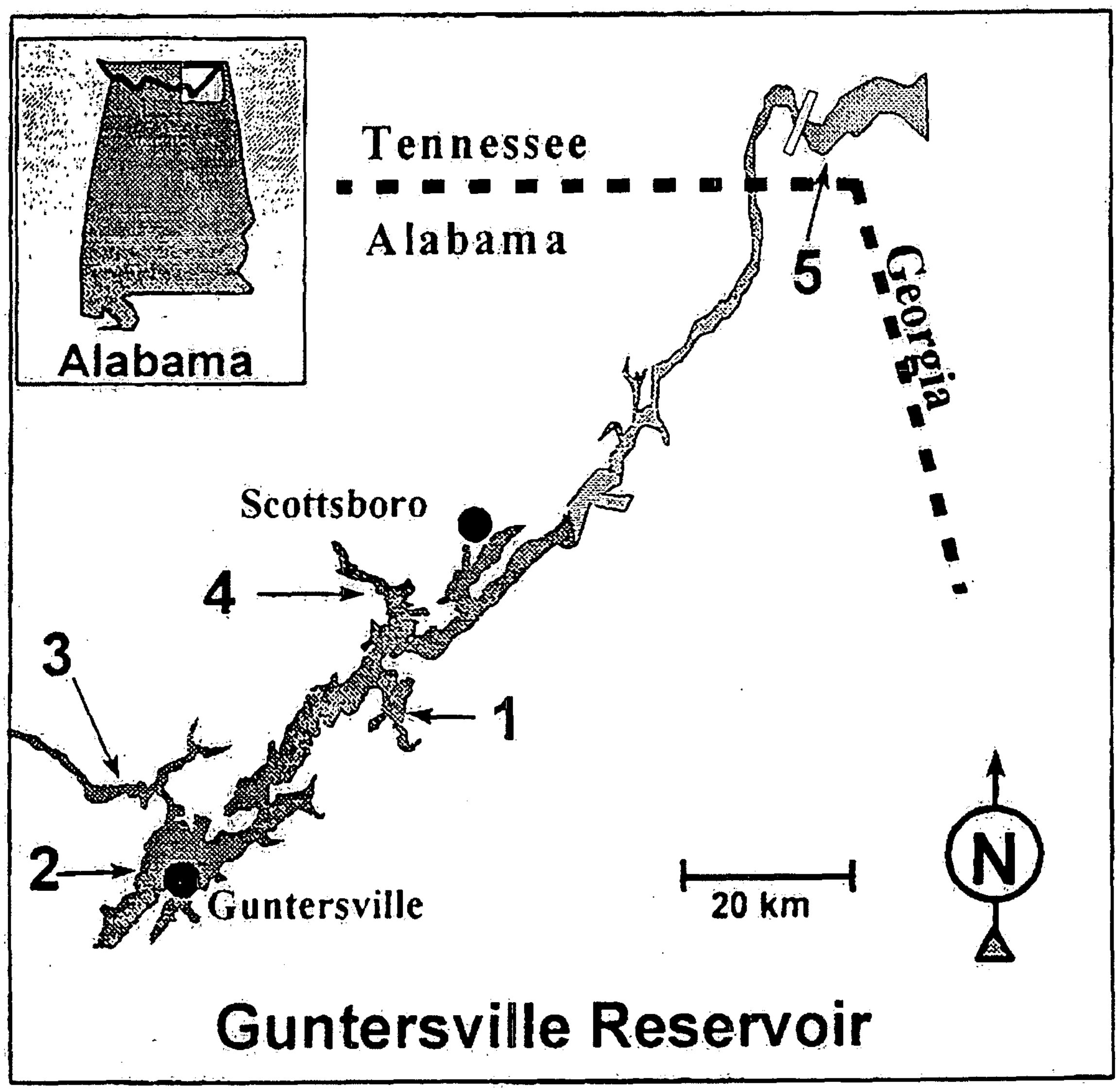


Fig. 4.3.—Sites at Guntersville Reservoir, Alabama, where radiotelemetric monitoring of gray bats (Myotis grisescens) took place in 1992: 1) Guntersville State Park; 2) Brown's Creek Campground; 3) Hambrick Cave; 4) Blowing Wind Cave; 5) Nickajack Cave.



V. VARIATION IN USE OF HABITATS BY THE ENDANGERED GRAY BAT (*MYOTIS GRISESCENS*) AT GUNTERSVILLE RESERVOIR, ALABAMA

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Abstract.—The temporal and spatial effects of foraging patterns of *Myotis grisescens* were studied near Blowing Wind Cave, Jackson Co., Alabama, 1991-1992. More gray bats foraged over open-water and *Nelumbo* habitats than any other habitat and would often switch from one to another within the same night. More bats were present in aquatic habitats than in terrestrial habitats. Although gray bats foraged throughout the night, most activity was recorded at 0200-0600 h. Throughout the summer, most activity of bats was from July through August. From June to August, most activity of bats was recorded among habitats within 2 km of Blowing Wind Cave. During August, activity of bats increased in habitats 13 km from Blowing Wind Cave as activity of bats decreased among habitats 2 km from Blowing Wind Cave. Greatest levels of foraging activity were recorded during September in the *Nelumbo* (22.8 buzzes/hr in 1991) and *Myriophyllum* (21.9 buzzes/hr in 1992) habitats within 2 km of Blowing Wind Cave. This emphasizes the importance of aquatic habitats containing vegetation to gray bats during September; a period when gray bats are beginning to migrate to hibernacula.

INTRODUCTION

Foraging in optimal habitats provides greater intake of energy and increases the foraging efficiency of organisms. Therefore, habitats with greater profitability for a forager, i.e., intake of energy per unit effort, should be chosen over poorer habitats (Guillemette et al., 1993). The distribution of many types of vertebrates can be related to habitats having maximum production of prey items (Goss-Custard, 1970). For example, density of songbirds within riparian habitats was highly correlated with emergences of insects from streams (Grey, 1993), and waterfowl (Sjöberg and Danell, 1982) quickly locate and forage in habitats containing high densities of chironomid insects and synchronize their nesting with peaks in abundance of insects.

Different habitats have varying rates of emergence of insects (Krull, 1970). These rates can be affected by factors such as intensity of light, temperature, and presence or absence of aquatic vegetation (Dvořak and Best, 1982; Flannagan and Cobb, 1991; Gray, 1989; Krull 1970). Aquatic invertebrates are more abundant in vegetated habitats than non-vegetated habitats (Krull, 1970).

The quality of a given habitat can fluctuate over time causing shifts in use by predators from one habitat to another (Werner et al., 1981). By sampling multiple habitats, insectivores can take advantage of changing densities of prey within habitats. This has been shown in birds (Zach and Falls, 1977), fishes (Persson and Greenberg, 1990; Werner et al., 1981), and bats (Bell, 1980).

For organisms having short annual foraging periods, such as bats, choice of habitats is important. Most bats in temperate regions spend 6-8 months hibernating each year. Selection of optimum habitats in which to forage may be especially important to obtain adequate nutrition for reproduction and to provide reserves of fat crucial for surviving hibernation (Davis, 1970).

Some bats are highly opportunistic and forage in many types of habitats. Geggie and Fenton (1985) observed that Eptesicus fuscus will take advantage of insect emergences in different habitats. Bell (1980) reported similar observations for desert ecosystems containing many species of bats. However, some bats are selective in their use of habitats. Euderma maculatum (Leonard and Fenton, 1983; Woodsworth et al., 1981), Myotis myotis (Audet, 1990), and Myotis grisescens (Tuttle, 1976a) have been observed foraging in specific habitats.

To better understand habitat requirements of bats, use of habitats, both temporally and spatially, must be considered. Not only can foraging vary within and among nights, seasons, and years (Fenton et al., 1983; O'Farrell and Bradley, 1970), but also may change according to distance from roosting areas. Furlonger et al. (1987) and Barclay (1984) observed that bats of the genus Myotis were influenced by the proximity of their hibernacula and day roosts to foraging area. Partridge (1978) stated that when population densities are high, intraspecific competition can force organisms to forage in habitats that are less than optimal. As colonial bats disperse from the roost, competition among individuals for foraging areas may decrease, causing these bats to use habitats differently.

The gray bat (Myotis grisescens) is an insectivorous species primarily occurring in riparian habitats (Brady et al., 1982; La Val et al., 1977; Tuttle, 1976a, 1976b). The gray bat was placed on the United States Fish and Wildlife Service listing of endangered species due to the large percentage of the population that was restricted to a few caves (Greenwalt, 1976). Although restricted to foraging in riparian zones (Rabinowitz, 1978; Tuttle, 1976a), the gray bat may cover a range of up to 75 km (Thomas and Best, in press). Throughout this range, the gray bat actually has a number of habitats available to forage over, i.e., aquatic areas dominated by different communities of plants and adjacent terrestrial communities. The quality of these habitats may vary due to periodic emergences of insects. This may cause the gray bat to select different habitats during different times of the night and over a period of several nights, making it an ideal species to test whether use of habitats as foraging areas varies temporally. The colonial behavior of the gray bat also makes it an ideal species to test spatial differences in use of habitats.

The purpose of the research reported herein was to study temporal and spatial variation in the foraging ecology of gray bats at Guntersville Reservoir, Jackson Co., Alabama. This was achieved by investigating variation in the activity of bats: 1) among habitats; 2) throughout the night; and 3) throughout the summer. Additionally, activity of bats in terrestrial and aquatic habitats were compared to verify reports (Tuttle, 1976a) of the tendency of gray bats to forage over aquatic areas. Aquatic habitats were compared to test for differential use based upon the presence or absence of vegetation in the water. Finally, habitats at different distances from Blowing Wind Cave were studied to determine if use of habitats by bats differs as distance from the summer roost increases.

MATERIALS AND METHODS

This 2-year study differed among years. In 1991, habitats were surveyed to establish temporal patterns used by gray bats when foraging among habitats near their summer roost. During 1992, both temporal and spatial use of habitats by gray bats were investigated.

The study area is located at Guntersville Reservoir, a 27,479-ha lake in northeastern Alabama and southcentral Tennessee. Most habitats were in the vicinity of Blowing Wind Cave, a large limestone cavern located in Jackson Co., Alabama. From April to late September, this cave can contain up to 300,000 gray bats (Tuttle, 1976b).

In 1991, temporal studies were initiated among habitats within 2 km of Blowing Wind Cave. Five habitats, two terrestrial and three aquatic (Table 5.1), were examined. Both terrestrial habitats (forest and field) were adjacent to the reservoir. The forest habitat contained a loblolly pine (*Pinus taeda*) overstory, a midstory composed of sweetgum (*Liquidambar styraciflua*) and dogwood (*Cornus florida*), and an understory made up of poison ivy (*Rhus radicans*), greenbriars (*Smilax*), and japanese honeysuckle (*Lonicera japonica*). The field habitat consisted primarily of grasses (*Sorghum*), herbaceous (*Solidago*, *Vernonia*), and woody vegetation (*Rhus glabra*). Of the three aquatic habitats selected, two contained macrophytes (Eurasian watermilfoil, *Myriophyllum spicatum*; American lotus, *Nelumbo lutea*) and one open-water habitat contained little or no vegetation.

Echolocation calls of foraging bats were monitored simultaneously in each habitat at three recording stations. Each recording station on each end of a transect contained two recording units oriented in opposite directions to provide two non-overlapping signal-reception areas 30° in width. An additional recording station housing one recording unit was placed in the center of the transect. A recording unit consisted of a QMC Mini II bat detector (QMC Instruments Ltd., London, UK) to make echolocation calls audible and a Realistic Mini Recorder (Radio Shack, Fort Worth, TX) to record the calls. These recording units were placed within boxes to protect them from the weather. Each transect was 100 m in length and consisted of five recording units. From observations of bats flying through habitats, I determined that QMC Mini II bat detectors had an effective range of ca. 25 m and that placing recording units 50 m apart insured that no detectors picked up the same bat simultaneously.

In the five habitats, direct observations and captures of bats provided positive identification of species. Recording units in the field habitat were placed upon plywood platforms to insure that no vegetation blocked echolocation signals. Units in the forest habitat were hoisted ca. 10 m into the canopy using antenna masts and pulleys. Recording units at aquatic sites were placed on plywood platforms attached to inner-tubes from truck tires. Vegetation adjacent to recording units that may have interfered with reception of echolocation calls was removed.

Samples were collected on 3 nights during each sampling session. There were 7 sampling sessions, each separated by ca. 14 days. Sampling sessions began on 25 June, 8 July, 22 July, 5 August, 20 August, 3 September, and 17 September; respectively (Appendix 5.1).

Monitoring began within ca. 15 min before sunset and ended within 30 min after sunrise. Tapes in recorders were replaced or turned over every hour; each unit recorded ca. 10 h/night. A total of ca. 250 h of data/night was collected.

During 1992, I studied temporal and spatial use of habitats by gray bats. Two aquatic habitats within 2 km of Blowing Wind Cave (open water and Myriophyllum) were compared with three aquatic habitats (open water, Myriophyllum, and Nelumbo) ca. 13 km from the cave. This comparison allowed me to determine if bats selected habitats differently as they foraged further from the cave. Habitats within 2 km and 13 km of Blowing Wind Cave were classified as backwater and river-channel habitats, respectively. Backwater habitats were located at North Sauty, a shallow cove on the northern section of Guntersville Reservoir. The river-channel habitats were located on a shallow sand-bar adjacent to the primary navigation channel used by commercial and recreational boats to move throughout the reservoir (Fig. 5.1).

Because activity of bats was similar among recording units within a habitat during 1991 (data presented below; Table 5.2), I reduced the number of recording units within a habitat to four. One floating station, containing two recording units, was placed in each habitat at each end of a 100-m transect. I used the same sampling procedure as in 1991. However, samples were recorded twice monthly (except for 3 nights in July). Sampling sessions started on 26 June, 7 July, 8 July, 20 July, 3 August, 19 August, 31 August, and 15 September; respectively (Appendix 5.2).

Fluctuation in the use of habitats by gray bats was determined by counting the number of passes (echolocation calls without feeding buzzes) and feeding buzzes (increased rates in repetition of pulses associated with attacks on insects—Griffin et al., 1960) that were recorded per habitat per minute. Counting passes alone determined levels of activity of bats, while feeding buzzes indicated actual foraging activity. Species of bats other than the gray bat were grouped into the "other" category.

Numbers of passes and feeding buzzes were tabulated for 1-min intervals. All observations were blocked into 2-h units and a mean was tabulated by averaging the observations of the five recording units per habitat. Values were divided by number of minutes observed in each 2-h block and multiplied by 100, resulting in a value representing numbers of passes, buzzes, and other species of bats observed per 2-h block. This adjustment accounted for any unequal recording times among samples.

Statistical comparisons were made among habitats to determine variation in number of passes and feeding buzzes of gray bats and passes of other species of bats during each night, among nights, within annual activity periods. A three-way analysis of variance was used for comparisons to determine the interactions of time, sampling period, and habitats (SAS Institute, Inc., 1985). Habitat was the independent variable while number of passes and buzzes over time were dependent variables. This allowed nightly and monthly comparisons to be made. By contrasting river and backwater habitats, I determined spatial effects. One-way analysis of variance with sequential Bonferroni adjustments (Rice, 1989) were used to identify differences among habitats over time and sampling periods. A Tukey's multiple-comparison test was used to determine where this difference occurred (Day and Quinn, 1989).

RESULTS

Results of activity of bats during 1991.

In 1991, 197,507 minutes of data were collected. A total of 223,644 passes and 8,547 buzzes of gray bats were recorded (Appendix 5.3).

Differences among recording units.--Only one comparison out of 15 showed any difference among recording units within habitats. The only exception was recording units within the forest habitat (Table 5.2). More passes were recorded by units near the edge of the habitat. Among remaining habitats, no differences were present among recording units.

Activity of bats among habitats.--Numbers of passes of gray bats were different among all habitats. *M. grisescens* was recorded most often in the open-water habitat (n = 394.9 passes/2-h block) followed by *Nelumbo*, *Myriophyllum*, field, and forest habitats (Table 5.3). More gray bats were recorded in aquatic than in terrestrial habitats.

Foraging activity of bats differed among habitats (P < 0.001; Table 5.4). More feeding buzzes of gray bats were recorded in open-water and *Nelumbo* habitats than the *Myriophyllum* habitat (Table 5.3). Additionally, gray bats foraged more in aquatic than terrestrial habitats with the least amount of buzzes recorded in the forest habitat (n = 0.2 buzzes/2-h block).

Activity of *M. grisescens* was not correlated with other species of bats (r^2 = 0.003). Although 15,069 passes by other species of bats were recorded in 1991, they were outnumbered by gray bats 15:1. Differential use of habitats also was observed in other species of bats (P < 0.001). Most passes by other species of bats were recorded in the *Nelumbo* (n = 14.9 passes/2-h block) and open-water (n

= 10.9 passes/2-h block) habitats (Table 5.3). With the exception of the *Myriophyllum* habitat, activity of other species of bats was greater among aquatic than terrestrial habitats.

Activity of bats throughout the night.—Variation in activity of bats throughout the night was observed (Table 5.5). At 2000-2200 h, most passes of gray bats were recorded in the *Nelumbo* and open-water habitats (Fig. 5.2). Most foraging activity was recorded in *Nelumbo* habitat. This pattern was maintained until 0000 h, when most gray bats were present in the open-water habitat. At this time most bats foraged equally among all aquatic habitats. Throughout the remainder of the night, gray bats foraged within the open-water habitat. Few gray bats were recorded among the terrestrial habitats throughout the night. Most activity of bats was recorded here at 0400-0600 h.

At 2000-2200 h, other species of bats were most common in the *Nelumbo* and open-water habitats (Table 5.5). As activity dropped among these habitats at 2200 h, activity increased in the *Myriophyllum* habitat. All aquatic habitats were then used equally until to 0400 h. By 0600 h, most activity of other bats was within the open-water habitat. From 2000 to 0400 h, other species of bats were most active in the *Nelumbo* habitat (Fig. 5.4). During 2000-0200 h terrestrial habitats had fewer passes than other habitats. However, for the remainder of the night, number of passes of gray bats increased among terrestrial habitats reaching the peak at 0400-0600 h (46.3 and 22.1 passes/2-h block in the field and forest habitats, respectively).

Nightly differences in activity of bats.—The number of gray bats often varied nightly among sampling sessions (Appendices 5.4-5.10). Differences from one night to the next within a sampling session in the number of passes of gray bats were observed in July and late September. Secondly, nightly differences in the number of buzzes within a sampling session were observed in June, July, and late September. Yet, throughout the summer, the number of passes by other species of bats did not differ among sample nights within a sampling session.

Variation in hourly activity of bats throughout the summer.—On average, most activity of gray bats was at the 2000-2200 and 0400-0600 h (Table 5.6). However, in late July, early August, and early September, there were no differences among sampling hours.

In terms of actual foraging, only three of seven comparisons showed any differences among sampling hours. When differences were observed (early July, late August, and late September), most foraging activity was at 2000-2200 and 0400-0600 h.

Throughout the summer, activity of other species of bats was consistent throughout the night. The only exception was in late August, when most activity was at 2000-0000 h.

Activity of bats throughout the summer.—Gray bats were most active during early July ($\underline{n}$ = 519.2 passes/2-h block) and least active during late September ($\underline{n}$ = 119.8 passes/2-h block). In 6 of 7 comparisons, more bats were found in the open-water habitat than any other habitat (Table 5.7). The only exception was in early September, when most gray bats were present in the Nelumbo and open-water habitats. Activity decreased in the open-water habitat throughout 1991, and increased in the Nelumbo habitat (Fig. 5.5). The number of passes of gray bats was greatest in the Myriophyllum habitat during June and July and gradually decreased throughout the summer.

Similar trends in foraging by gray bats were observed throughout 1991 (Fig. 5.6). On average, more foraging attempts by gray bats were recorded initially in the open-water habitat (Table 5.7). However, during the second one-half of summer, more gray bats foraged in the Nelumbo habitat.

Activity of other species of bats increased throughout 1991 (Fig. 5.7). Most activity occurred in early August and early September. Throughout summer, more activity was recorded in aquatic than in terrestrial habitats.

Results of activity of bats during 1992.

In 1992, 62,227 min of data were collected. A total of 133,480 passes and 4,949 buzzes of gray bats were recorded (Appendix 5.11).

Activity of bats among habitats—Differential use of habitats by bats was observed ($P \leq 0.001$; Table 5.8). Gray bats were recorded most often within backwater habitats. Most passes were recorded in the open-water habitat and fewest in the Myriophyllum habitat. Of the river-channel habitats, there were no differences among habitats. In terms of feeding buzzes, similar patterns were observed (Table 5.9). On average, bats foraged most among open-water habitats.

Although 8,794 passes by other species of bats were recorded, gray bats outnumbered other bats 13:1. Most passes were recorded among backwater habitats (Table 5.9). On average, other species of bats usually were found over the Myriophyllum habitat, in both backwater and river-channel areas.

Activity of bats throughout the night.—Myotis grisescens was most active at 2000-2200 and 0200-0400 h (Table 5.10). At these periods of time, most gray bats were recorded in the open-water habitat. However, throughout the remainder of the night, most gray bats were recorded in Myriophyllum and open-water habitats. Throughout the night, more bats were recorded among backwater habitats than river habitats. Among the river habitats, activity of gray bats was greatest at 0000-0400 h (Fig. 5.8).

Gray bats foraged most at 2000-2200 h (Fig 5.9). On average, most feeding activity was recorded among Myriophyllum and open-water habitats (Table 5.10). After a decline at 2200-0000 h, foraging activity increased throughout the night. Among river-channel habitats, no differences in the number of buzzes among sample times were observed.

As foraging by gray bats decreased at 2200-0000 h, number of passes of other species increased (Fig. 5.10). On average, other species of bats were recorded most in the Myriophyllum during the first one-half of the night, then gradually switched to the open-water habitat. No difference in the number of other species of bats was observed river-channel habitats.

Variation in hourly activity of bats throughout the summer.—On average, most activity of gray bats was at 0200-0600 h (Table 5.11). However, in late July, late August, and early September, there were no differences among sampling hours.

In terms of feeding buzzes, there were few differences among hours throughout the summer. In late June, more feeding buzzes were recorded at 0200-0400 h and 0400-0600 h (39.1 and 29.1 feeding buzzes/2-h block, respectively) and in late September during 2000-2200 h (5.5 feeding buzzes/2-h block). There were no differences in the numbers of other passes by other species recorded among hours within any sampling sessions.

Activity of bats among habitats throughout the summer.—Most gray bats were observed during the first one-half of 1992 (Table 5.12). Most passes were recorded during early July through early August among the backwater habitats (Fig. 5.11). As activity in backwater habitats decreased throughout August, an increase in activity was observed among river-channel habitats. Throughout the summer, gray bats used the open-water habitat more than any other, with the exception of early September, when numbers of bats were, on average, higher in the *Myriophyllum* habitat.

Most buzzes were recorded from late June through early August within the backwater habitats (Fig. 5.12). However, buzzes increased substantially in early September (Table 5.12). Among river-channel habitats, feeding activity of gray bats was greatest in late August. This coincides with a decrease in feeding buzzes among backwater habitats (Table 5.12).

Activity of other species fluctuated throughout summer (Fig. 5.13). Most passes were recorded in late June, early August, and early September. Activity increased throughout summer.

DISCUSSION

Numerous investigators have used recordings of vocalizations of bats to better understand the foraging requirements of bats (Bell, 1980; Fenton, 1970; Fenton et al., 1983; Furlonger et al., 1987; Geggie and Fenton, 1985; Leonard and Fenton, 1983; O'Farrell and Bradley, 1970; Thomas, 1988; Woodsworth et. al., 1981). Although many studies have used this unobtrusive technique, few (Bell, 1980; Fenton, 1970; Thomas, 1988) have recorded movements of bats continuously over long periods of time.

Differential use of habitats was observed. Gray bats passed through open-water habitats more than other habitats. However, gray bats often foraged equally among aquatic habitats.

Gray bats rarely were detected among terrestrial habitats. *M. grisescens* primarily used the forest canopy as cover when traveling to habitats to forage. These findings are similar to those observed by La Val et al. (1977) and Tuttle

(1976a). In most habitats, gray bats were restricted to treelines during twilight periods. However, at dusk, most bats became active among aquatic habitats. In addition to foraging on localized hatches of insects, I observed gray bats gleaning insects from the surface of open-water habitats. Upon exhausting this food source, the number of bats dropped as they dispersed from the area.

Throughout the night, gray bats exhibited a bimodal pattern of foraging in most habitats (Fig. 5.3). This behavior was noted in other species of bats (Bell, 1980; Erkert, 1982; Fenton, 1970; Rydell, 1993), but others forage primarily just after dusk (Furlonger et al., 1987; Thomas, 1988). These patterns may coincide with emergences of insects at different types of habitats. Often, most bats foraged among one habitat during the first one-half of the night and switched to another habitat later in the night. This suggests that as quality of one habitat decreased, bats switched to more profitable habitats.

There was little variation in the number of gray bats from one night to the next within sampling sessions. Most variation was observed in June, July, and September. This could be due to fluctuating numbers of insects during these times. However, it is more likely that these periods of the year coincide with changes in population dynamics of gray bats. In July, young-of-the-year become volant. This sudden increase in the number of inexperienced bats could account for fluctuations in the number of bats among habitats. In September, gray bats are beginning to move to nearby hibernacula (Tuttle, 1976b). The number of gray bats would increase among habitats in response to these movements.

Throughout the summer, fluctuations in the number of passes was least among backwater habitats and greatest among river-channel habitats. Intraspecific competition may be less in river-channel habitats and bats are able to detect subtle changes in abundance of insects may not be perceived among the more crowded backwater habitats. However, this trend could indicate changing environmental components effecting distribution of aquatic insects may be greater in the main river than in backwater habitats, thus causing more variability in the emergences of insects among different habitats.

Because of the constraints of reproduction, female gray bats must stay near the summer cave during earlier summer months (Tuttle, 1976b). Adam et al. (1994) and Clark et al. (1993) observed that the home range of Corynorhinus townsendii increased as summer progressed. Data suggest a similar occurrence with gray bats. More gray bats were detected among aquatic habitats near Blowing Wind Cave. As summer progressed, the number of gray bats decreased among backwater habitats and increased among river habitats. Perhaps, as constraints of reproduction lessened, gray bats foraged farther from the roost; resulting in a decrease in the number of gray bats among backwater habitats and an increase among river habitats. Lowered intraspecific competition for food resulting from these extended forays would greatly benefit gray bats as they prepare for migration to hibernacula.

The number of passes and buzzes increased among backwater habitats during early September in 1991 and 1992. Tuttle (1976b) noted a similar increase in the number of gray bats at Blowing Wind Cave during this time. September probably is a crucial period for gray bats as they replenish fat reserves needed to maintain them through winter. This increase in activity was observed only in aquatic habitats containing vegetation emphasizing the importance of these habitats to gray bats.

The interactions of gray bats with other species of bats were minimal. La Val et al. (1977) noted that gray bats probably excluded Myotis sodalis from habitats having better food resources. Although we saw no direct evidence of competitive exclusion, mutual avoidance may be taking place. Throughout the night, other species of bats were more active among habitats when presence of gray bats was lowest. On average, most passes of other species were recorded among Nelumbo and Myriophyllum habitats. However, in September both populations of bats increased in the same habitats (Nelumbo in 1991; Myriophyllum in 1992). This increase in bats probably marks a substantial increase in insects among these habitats allowing greater numbers of bats to use this resource.

CONCLUSIONS

From June to August, gray bats foraged primarily over open-water habitats in both backwater and river-channel habitats. However in September, more bats were observed among habitats containing aquatic vegetation. This activity was only observed in backwater habitats indicating that habitats containing aquatic vegetation in close proximity of Blowing Wind Cave may be crucial for gray bats. This emphasizes the need for a diversity of habitats over which the bats can forage. It is apparent that a variety of habitats within this community ensure that gray bats will have a continuous food supply throughout the summer.

Additional temporal and spatial studies of the foraging ecology of gray bats are necessary. Assessing abundance of insects among similar habitats and parameters affecting this abundance would identify factors controlling the quality of habitats used by gray bats. Additionally, investigating foraging areas of individual gray bats and how these areas change over time would identify important regions of Guntersville Reservoir and allow better management of these habitats.

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Table 5.1. Study sites used to investigate variation in use of habitats by the gray bat (*Myotis grisescens*) at Guntersville Reservoir, Jackson Co., Alabama, 1991-1992.

Year	Habitat	Location	Classification
1991			
	Open water	North Sauty Creek, 1.9 km south of US highway 72	Backwater
	Myriophyllum spicatum	North Sauty Creek, 1.4 km north of US highway 72	Backwater
	Nelumbo lutea	North Sauty Creek, 1.6 km of US highway 72	Backwater
	Forest	Adjacent to county road 114, 1.9 km south of US highway 72.	Terrestrial
	Field	0.7 km north of US highway 72.	Terrestrial
1992			
	Open water 1	Adjacent to county road 114, 1.9 km south of US highway 72.	Backwater
	Myriophyllum spicatum 1	Adjacent to county road 114, 1.9 km south of US highway 72.	Backwater
	Open water 2	1.6 km west of bridge on US highway 35.	River-channel
	Myriophyllum spicatum 2	1.6 km west of bridge on US highway 35.	River-channel
	Nelumbo lutea 2	1.9 km west of bridge on US highway 35.	River-channel

[1]Habitats ca. 2 km from Blowing Wind Cave.
[2]Habitats ca. 13 km from Blowing Wind Cave.

Table 5.2.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison test for differences among five recording units within each habitat at Guntersville Reservoir, Jackson Co., Alabama, 1991. Lines beneath averages indicate nonsignificant subsets.

Habitat	Activity	d.f.	F-ratio	Results of Tukey's analysis				
Forest								
				3	5	4	2	1
	Passes	4,422	4.08[a]	20.0	12.1	9.2	5.7	5.5
				3	5	4	2	1
	Buzzes	4,422	1.25	0.3	0.2	0.2	0.1	0.1
				3	2	5	4	1
	Passes (Other)	4,422	3.32	1.0	0.4	0.1	0.1	0.0
Field								
				5	3	1	2	4
	Passes	4,480	0.27	19.6	19.2	19.0	17.3	15.9
				5	3	1	4	2
	Buzzes	4,480	0.50	1.0	0.7	0.6	0.6	0.5
				2	3	1	5	4
	Passes (Other)	4,480	1.97	4.7	2.9	2.0	2.0	1.2
Nelumbo								
				1	2	3	5	4
	Passes	4,505	3.24	180.9	152.2	118.9	101.0	91.4
				1	2	3	5	4
	Buzzes	4,505	0.59	9.8	8.2	7.6	6.8	5.9
Nelumbo								
				4	5	3	1	2
	Passes (Other)	4,505	2.38	23.4	20.1	17.7	6.9	5.8

Table 5.2.—Continued.

<u>Myriophyllum</u>								
				1	2	5	4	3
	Passes	4,504	1.86	104.9	104.9	86.7	79.1	77.2
				1	2	3	4	5
	Buzzes	4,504	0.46	4.8	4.6	3.6	3.1	2.9
				5	4	2	3	1
	Passes (Other)	4,504	1.81	13.0	11.6	7.6	6.5	6.3
Open-water								
				4	2	1	3	5
	Passes	4,448	3.03	445.2	349.4	336.6	331.0	267.2
				4	2	1	3	5
	Buzzes	4,448	2.15	13.6	9.5	8.4	7.8	7.6
				2	4	3	1	5
	Passes (Other)	4,448	0.95	21.0	13.4	8.8	6.3	5.3

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0033 for a table of 15 tests.

Table 5.3.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison test among five habitats to determine primary activity of *Myotis grisescens* and other species of bats[b] at Guntersville Reservoir, Jackson Co., Alabama, 1991. Habitats are listed above the average number of each type of activity as follows: 1, Open-water; 2, *Nelumbo*; 3, *Myriophyllum*; 4, Field; 5, Forest. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis				
			1	2	3	4	5
Passes	174,2,363	21.80[a]	344.9	128.6	90.4	18.2	10.5
			———				
				———			
					———		
						———	
							———
			1	2	3	4	5
Buzzes	174,2,363	6.76[a]	9.4	7.6	3.8	0.7	0.2
			———	———			
					———		
						———	———
			2	1	3	4	5
Passes (Other)	174,2,363	2.42[a]	14.8	10.9	9.0	2.6	0.3
			———	———	———		
					———	———	
						———	———

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.
[b]Passes by bats other than *Myotis grisescens*.

Table 5.4.—Results of three-way analysis of variance comparing passes and buzzes of Myotis grisescens and presence of other species of bats[b] with habitats sampled, sampling time, and sampling session at Guntersville Reservoir, Jackson Co., Alabama, 1991.

Source of variation	d.f.	F-values Passes	Buzzes	Other bats
Habitat	4	409.8[a]	56.1[a]	10.3[a]
Time	4	40.5[a]	9.5[a]	1.2
Habitat by time	16	42.2[a]	11.8[a]	1.5
Sampling session	6	24.6[a]	13.6[a]	8.6[a]
Habitat by sampling session	24	14.5[a]	7.1[a]	5.2[a]
Time by sampling session	24	6.4[a]	2.6[a]	1.1
Habitat by time by sampling session	96	5.1[a]	3.8[a]	1.2

[a] $P \leq 0.001$.
[b] Passes by bats other than *Myotis grisescens*.

Table 5.5.—Results of one-way analysis of variance and Tukey's multiple-comparison test for differences of numbers of Myotis grisescens among habitats throughout the night at Guntersville Reservoir, Jackson, Alabama, 1991. Habitats sampled are listed above average number of bats as follows: 1, open-water; 2, Nelumbo; 3, Myriophyllum; 4, field; 5, forest. Lines beneath averages indicate nonsignificant subsets.

Time	Activity	d.f.	F-ratio	Results of Tukey's analysis				
2000-2200 h								
				2	1	3	4	5
	Passes	4,470	42.85[a]	283.6	237.6	127.6	16.7	8.6
				______	______			
						______		
							______	______
				2	1	3	4	5
	Buzzes	4,470	16.34[a]	16.6	8.5	6.8	0.3	0.2
				______				
					______	______		
						______	______	
							______	______
				2	1	3	4	5
	Passes (Other)	4,470	7.16[a]	25.8	13.6	6.9	5.5	0.5
				______	______			
					______	______	______	______
2200-0000 h								
				1	2	3	4	5
	Passes	4,496	28.42[a]	172.8	143.6	84.2	6.9	4.1
				______	______			
						______		
							______	______
				2	1	3	4	5
	Buzzes	4,496	13.05[a]	11.0	4.6	3.4	0.3	0.0
				______				
					______	______	______	______
2200-0000 h								
				3	2	1	4	5
	Passes (Other)	4,496	3.00	11.8	9.9	9.1	1.6	0.1
				______	______	______	______	______

Table 5.5.—Continued.

0000–0200 h								
	Passes	4,485	62.23[a]	1	3	2	4	5
				245.1	64.0	60.8	9.6	3.7
	Buzzes	4,485	5.50[a]	1	2	3	4	5
				7.2	4.7	3.8	0.2	0.1
	Passes (Other)	4,485	5.03[a]	2	3	1	4	5
				17.4	15.4	6.8	2.5	0.2
0200–0400 h								
	Passes	4,478	94.44[a]	1	3	2	5	4
				477.3	59.2	55.3	15.4	15.0
	Buzzes	4,478	26.79[a]	1	2	3	4	5
				7.2	2.7	1.8	0.4	0.2
	Passes (Other)	4,478	4.77[a]	2	1	3	4	5
				17.4	7.7	5.2	1.3	0.1
0400–0600 h								
	Passes	4,430	160.64[a]	1	3	2	5	4
				639.2	119.7	95.0	46.3	22.1

Table 5.5.—Continued.

0400-0600 h								
				1	3	2	4	5
	Buzzes	4,430	37.73[a]	20.7	3.1	2.5	2.2	0.5
				1	3	2	4	5
	Passes (Other)	4,430	1.38	18.4	5.3	2.5	1.9	0.6

[a] Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0033 for a table of 15 tests.

Table 5.6.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison test among sampling hours used to record vocalizations of Myotis grisescens and other species of bats[b] at Guntersville Reservoir, Jackson Co., Alabama, 1991. Sampling hours are listed above the average of each type of activity as follows: 1, 2000-2200 h; 2, 2200-0000 h; 3, 0000-0200 h; 4, 0200-0400 h; 5, 0400-600 h. Lines beneath averages indicate nonsignificant subsets.

Date	Activity	d.f.	F-ratio	Results of Tukey's analysis				
25-28 June								
				4	5	3	1	2
	Passes	4,314	4.63[a]	287.2	167.1	152.7	138.6	81.3
				1	3	4	5	2
	Buzzes	4,314	2.12	9.1	7.3	4.5	3.9	2.7
				3	2	5	1	4
	Passes (Other)	4,314	0.71	4.7	4.4	2.8	1.7	1.3
8-12 July								
				5	1	4	2	3
	Passes	4,326	9.79[a]	321.5	212.1	135.6	74.9	73.0
				1	5	2	4	3
	Buzzes	4,326	6.52[a]	10.1	8.6	2.5	2.3	2.0
8-12 July								
				3	1	2	4	5
	Passes (Other)	4,326	3.01	12.2	6.6	3.7	2.9	0.9
22-27 July								
				5	4	1	2	3
	Passes	4,336	4.10	238.0	131.7	115.6	113.9	93.3
				5	1	2	3	4
	Buzzes	4,336	1.73	5.9	4.3	2.6	1.9	1.5

Table 5.6.—Continued.

Passes (Other)	4,336	2.07	1	2	5	3	4
			9.3	5.3	4.9	2.1	1.9
5-8 August							
Passes	4,348	2.76	1	5	4	2	3
			178.7	160.8	149.5	106.7	74.7
Buzzes	4,348	1.10	1	5	4	2	3
			5.8	5.1	4.5	4.4	2.4
Passes (Other)	4,348	0.23	5	4	1	3	2
			21.2	20.1	18.3	17.9	10.7
20-23 August							
Passes	4,365	6.40[a]	5	1	4	2	3
			146.1	103.9	57.2	46.9	41.1
Buzzes	4,365	5.51[a]	1	5	2	4	3
			5.0	3.3	1.7	1.1	0.5
Passes (Others)	4,365	4.71[a]	1	2	5	4	3
			16.6	5.8	1.9	1.2	1.0
3-6 September							
Passes	4,372	2.02	1	2	5	4	3
			155.2	147.9	134.9	92.9	73.5
Buzzes	4,372	2.27	2	3	1	5	4
			13.2	9.0	8.9	8.6	2.6
Passes (Other)	4,372	1.66	3	1	2	4	5
			22.7	18.3	14.9	14.8	1.4

(Underlines: for 20-23 August rows, one line spans the first two sites and a second line spans the second through fifth sites; all other rows have a single line spanning all five sites.)

Table 5.6.—Continued.

17-20 September

			5	1	2	4	3
Passes	4,296	8.08[a]	93.9	62.6	22.9	21.9	17.3
			5	1	2	4	3
Buzzes	4,296	5.38[a]	3.9	2.3	0.9	0.6	0.2
			5	1	2	4	3
Passes (Other)	4,296	3.04	3.2	2.6	1.9	1.5	0.6

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0024 for a table of 21 tests.

[b] Passes by bats other than *Myotis grisescens*.

Table 5.7.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison test for differences of numbers of *Myotis grisescens* among habitats throughout the summer at Guntersville Reservoir, Jackson, Alabama, 1991. Habitats sampled are listed above average number of bats as follows: 1, open-water; 2, *Nelumbo*; 3, *Myriophyllum*; 4, field; 5, forest. Lines beneath averages indicate nonsignificant subsets.

Date	Activity	d.f.	F-ratio	Results of Tukey's analysis				
25-29 June								
	Passes	4,314	45.27[a]	1	3	2	5	4
				433.1	115.2	53.3	23.3	16.0
				———				
					———	———	———	———
	Buzzes	4,314	6.49[a]	1	3	2	4	5
				11.1	8.2	2.4	1.1	0.4
				———	———	———		
					———	———	———	———
	Passes (Other)	4,314	2.15	1	2	4	3	5
				6.8	2.5	1.7	1.0	0.0
				———	———	———	———	———
8-12 July								
	Passes	4,326	62.02[a]	1	2	3	5	4
				519.2	117.2	116.5	24.3	22.5
				———				
					———	———	———	———
	Buzzes	4,326	13.17[a]	1	2	3	4	5
				13.6	6.6	3.6	0.6	0.3
				———				
					———	———		
						———	———	———
8-12 July								
	Passes (Other)	4,326	4.80[a]	3	1	2	4	5
				11.8	11.1	4.6	0.7	0.0
				———	———	———		
						———	———	———
22-27 July								
	Passes	4,336	41.39[a]	1	3	2	4	5
				434.0	152.4	131.5	29.6	12.3
				———				
					———	———		
							———	———

Table 5.7.--Continued.

				1	2	3	4	5
	Buzzes	4,336	4.65[a]	8.0	4.9	3.1	0.7	0.3
				2	3	1	4	5
	Passes (Other)	4,336	6.10[a]	10.8	8.0	1.9	0.8	0.0
5-8 August								
				1	2	3	4	5
	Passes	4,348	54.68[a]	381.6	215.6	97.6	23.3	6.0
				1	2	3	4	5
	Buzzes	4,348	20.34[a]	10.9	9.8	2.1	1.2	0.3
				1	3	2	4	5
	Passes (Other)	4,348	2.54	34.6	25.6	23.4	6.6	1.0
20-23 August								
				1	2	3	4	5
	Passes	4,365	30.11[a]	224.6	97.9	64.5	14.2	6.0
20-23 August								
				2	1	3	4	5
	Buzzes	4,365	8.37[a]	4.9	4.5	1.8	0.5	0.1
				1	3	2	4	5
	Passes (Other)	4,365	5.93[a]	19.1	5.2	2.6	1.5	0.1

Table 5.7.--Continued.

3-4 September							
			1	2	3	4	5
Passes	4,372	39.16[a]	288.6	240.0	56.9	12.5	6.0
			2	1	3	4	5
Buzzes	4,372	16.38[a]	22.8	12.6	6.7	0.2	0.0
			2	3	1	4	5
Passes (Other)	4,372	17.21[a]	56.5	10.2	3.5	1.6	0.6
17-20 September							
			1	2	3	4	5
Passes	4,296	19.53[a]	119.8	29.0	26.0	11.5	6.8
			1	2	3	4	5
Buzzes	4,296	7.81[a]	4.3	1.1	1.0	0.3	0.0
			3	1	2	4	5
Passes (Other)	4,296	11.66[a]	4.5	2.2	0.9	0.8	0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0024 for a table of 21 tests.

Table 5.8.—Results of three-way analysis of variance comparing passes and buzzes of gray bats and presence of other species of bats[b] with interactions of habitats sampled, sampling time, and sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, 1992.

Source of variation	d.f.	F-values		
		Passes	Buzzes	Other bats
Habitat	4	78.4[a]	25.7[a]	14.9[a]
Time	4	18.6[a]	3.5[a]	0.5
Habitat by time	16	5.0[a]	1.2	3.3[a]
Sampling session	6	24.8[a]	8.3[a]	7.6[a]
Habitat by sampling session	20	5.8[a]	3.4[a]	4.5[a]
Time by sampling session	24	4.6[a]	3.7[a]	1.2
Habitat by time by sampling session	79	1.8[a]	2.1[a]	1.7[a]

[a] $P \leq 0.001$.
[b] Passes by bats other than *Myotis grisescens*.

Table 5.9.—Results of three-way analysis of variance[a] and Tukey's multiple-comparison test among five habitats to determine primary activity of *Myotis grisescens* and other species of bats[b] at Guntersville Reservoir, Jackson Co., Alabama, 1992. Habitats are listed above the average number of each type of activity as follows: 1, open-water[c]; 2, *Myriophyllum*[c]; 3, *Nelumbo*[d]; 4, open-water[d]; 5, *Myriophyllum*[d]. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	*F*-ratio	Results of Tukey's analysis				
			1	2	3	4	5
Passes	153,687	7.81[a]	447.9	301.8	92.2	91.3	80.9
			1	2	4	3	5
Buzzes	153,687	3.91[a]	15.8	13.2	3.7	2.6	2.0
			2	1	5	4	3
Passes (Other)	153,687	2.66[a]	30.1	22.3	4.9	4.0	2.6

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.
[b]Passes by bats other than *Myotis grisescens*.
[c]Habitats ca. 2 km from Blowing Wind Cave.
[d]Habitats ca. 13 km from Blowing Wind Cave.

Table 5.10.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison test for differences of numbers of Myotis grisescens among habitats throughout the night at Guntersville Reservoir, Jackson, Alabama, 1992. Habitats sampled are listed above average number of bats as follows: 1, open-water[b]; 2, Myriophyllum[b]; 3, open-water[c]; 4, Myriophyllum[c]; 5, Nelumbo[c]. Lines beneath averages indicate nonsignificant subsets.

Time	Activity	d.f.	F-ratio	Results of Tukey's analysis					Lines beneath averages
2000-2200 h									
				1	2	3	4	5	
	Passes	4,136	16.12[a]	438.8	257.0	106.4	58.5	37.4	(1); (2, 3); (3, 4, 5)
				1	2	3	4	5	
	Buzzes	4,136	7.15[a]	21.9	14.4	4.5	2.7	1.9	(1, 2); (2, 3, 4, 5)
				2	3	1	5	4	
	Passes (Other)	4,136	4.93[a]	19.1	14.1	9.5	0.7	0.4	(2, 3, 1); (3, 1, 5, 4)
2200-0000 h									
				2	1	3	5	4	
	Passes	4,138	14.95[a]	225.4	205.5	53.4	51.8	33.7	(2, 1); (3, 5, 4)
				2	1	3	5	4	
	Buzzes	4,138	5.01[a]	9.8	6.4	4.7	1.9	1.8	(2, 1, 3); (1, 3, 5, 4)
2200-0000 h									
				2	1	3	4	5	
	Passes (Other)	4,138	7.92[a]	57.3	6.5	1.8	1.6	0.8	(2); (1, 3, 4, 5)
0000-0200 h									
				1	2	4	3	5	
	Passes	4,138	5.21[a]	353.0	238.1	185.8	152.1	148.0	

Table 5.10.--Continued.

				1	2	3	5	4
	Buzzes	4,138	4.10	14.9	10.6	3.8	3.4	3.2
				2	1	4	5	3
	Passes (Other)	4,138	2.97	27.5	24.4	10.7	4.4	3.0
0200-0400 h								
				1	2	5	3	4
	Passes	4,136	17.02[a]	677.0	403.5	193.7	136.5	112.5
				1	2	3	5	4
	Buzzes	4,136	7.40[a]	18.4	16.0	4.9	4.8	2.1
				2	1	4	4	3
	Passes (Other)	4,136	3.88	31.4	29.9	10.2	6.0	1.8
0400-0600 h								
				1	2	5	3	4
	Passes	4,135	31.20[a]	573.3	385.2	29.1	12.7	8.9
				1	2	5	3	4
	Buzzes	4,135	13.07[a]	17.6	15.3	0.9	0.8	0.4
0400-0600 h								
				1	2	5	4	3
	Passes (Other)	4,135	2.22	42.1	15.1	1.4	1.3	0.4

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0033 for a table of 15 tests.
[b]Habitats ca. 2 km from Blowing Wind Cave.
[c]Habitats ca. 13 km from Blowing Wind Cave.

Table 5.11.--Results of one-way analysis of variance[a] and Tukey's multiple-comparison test among sampling hours used to record vocalizations of *Myotis grisescens* and other species of bats[b] at Guntersville Reservoir, Jackson Co., Alabama, 1992. Sampling hours are listed above the average of each type of activity as follows: 1, 2000-2200 h; 2, 2200-0000 h; 3, 0000-0200 h; 4, 0200-0400 h; 5, 0400-600 h. Lines beneath averages indicate nonsignificant subsets.

Date	Activity	d.f.	F-ratio	Results of Tukey's analysis				
26-27 June								
				4	5	1	3	2
	Passes	4,39	9.11[a]	747.2	691.1	330.3	257.0	101.5
				5	4	3	1	2
	Buzzes	4,39	2.12[a]	39.1	29.1	14.1	10.6	6.9
				3	2	1	4	5
	Passes (Other)	4,39	0.71	48.7	33.2	33.1	20.7	7.8
7-9 July								
				4	3	1	5	2
	Passes	4,191	5.42[a]	448.5	380.8	256.0	238.1	175.4
				1	4	3	5	2
	Buzzes	4,191	0.80	12.3	11.6	10.2	7.9	7.7
7-9 July								
				4	3	1	5	2
	Passes (Other)	4,191	4.26	16.4	7.0	4.2	3.4	2.3
20-21 July								
				5	1	4	3	2
	Passes	4,78	1.13	325.5	323.7	318.2	210.2	134.3

Table 5.11.—Continued.

				1	5	3	4	2
	Buzzes	4,78	1.94	15.1	9.1	7.3	4.0	2.4
				3	4	1	2	5
	Passes (Other)	4,78	1.11	20.5	14.8	14.8	4.0	3.3
3-4 August								
				4	5	3	1	2
	Passes	4,94	4.89[a]	525.4	261.0	253.5	130.1	120.0
				4	3	5	2	1
	Buzzes	4,94	3.27	22.6	14.5	5.6	5.1	4.5
				2	5	4	3	1
	Passes (Other)	4,94	0.19	44.5	40.4	31.2	29.4	20.7
19-20 August								
				4	3	5	2	1
	Passes	4,85	4.17	218.8	192.4	145.0	115.6	60.7
				5	4	3	2	1
	Buzzes	4,85	0.58	6.1	4.9	4.4	3.9	3.5
				5	4	3	2	1
	Passes	4,85	2.46	29.5	19.3	8.1	4.2	3.3
31 August-1 September								
				5	1	4	2	3
	Passes	4,99	0.53	178.1	168.4	123.1	115.9	90.6
				1	2	5	4	3
	Buzzes	4,99	1.80	16.0	6.7	5.8	4.4	3.2
				2	4	3	5	1
	Passes (Other)	4,99	1.19	42.3	22.5	19.9	17.6	5.2

Table 5.11.--Continued.

15-16 September

Passes	4,95	6.23[a]	1	5	2	3	4
			122.6	45.8	42.2	38.1	12.2
Buzzes	4,95	9.58[a]	1	2	3	5	4
			5.5	1.5	0.7	0.7	0.3
Passes (Other)	4,95	1.35	1	5	3	2	4
			0.9	0.3	0.2	0.1	0.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0024 for a table of 21 tests.

[b] Passes by bats other than *Myotis grisescens*.

Table 5.12.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison test for differences of numbers of Myotis grisescens among habitats throughout the summer at Guntersville Reservoir, Jackson, Alabama, 1992. Habitats sampled are listed above average number of bats as follows: 1, open-water[b]; 2, Myriophyllum[b]; 3, open-water[c]; 4, Myriophyllum[c]; 5, Nelumbo[c]. Lines beneath averages indicate nonsignificant subsets.

Date	Activity	d.f.	F-ratio	Results of Tukey's analysis				
26-27 June								
				1	2			
	Passes	1,39	5.94	555.0	295.9			
				———	———			
				1	2			
	Buzzes	1,39	0.42	22.0	17.9			
				———	———			
				1	2			
	Passes (Other)	1,39	5.17	39.6	17.8			
				———	———			
7-9 July								
				1	2	5	4	3
	Passes	4,191	35.94	647.9	390.3	153.6	148.0	125.8
				———				
					———			
						———	———	———
				1	2	3	5	4
	Buzzes	4,191	24.83	23.6	15.8	3.4	3.2	2.4
				———				
					———			
						———	———	———
7-9 July								
				2	1	5	4	3
	Passes (Other)	4,191	4.33	12.7	12.5	3.4	3.0	0.8
				———	———	———	———	
					———	———	———	———
20-21 July								
				1	2	5	4	
	Passes	3,78	17.58	560.9	342.8	72.6	60.5	
				———				
					———			
						———	———	

Table 5.12.—Continued

			1	2	5	4	
Buzzes	3,78	3.92	13.9	11.6	2.4	2.0	
			2	4	1	5	
Passes (Other)	3,78	9.67	37.0	4.4	4.0	0.3	
3-4 August							
			1	2	5	3	4
Passes	4,94	9.55	528.2	440.3	112.7	109.3	85.2
			1	2	3	5	4
Buzzes	4,94	3.77	22.6	15.8	6.5	4.8	2.4
			1	2	3	5	4
Passes (Other)	4,94	3.04	83.0	51.3	18.4	4.0	3.3
19-20 August							
			1	3	5	2	4
Passes	4,85	4.61	241.7	153.3	135.6	124.6	78.2
			3	1	2	5	4
Buzzes	4,85	1.73	8.5	5.7	4.3	3.5	3.1
			1	4	2	5	3
Passes (Other)	4,85	3.35	33.2	8.9	6.8	5.5	0.6
31 August-1 September							
			2	1	3	5	4
Passes	4,99	9.67	331.2	219.5	60.1	33.6	31.8
			2	1	3	4	5
Buzzes	4,99	6.62	21.9	9.7	2.8	1.1	0.7

Table 5.12.—Continued.

			2	1	4	3	5
Passes (Other)	4,99	9.37	79.3	11.8	11.7	2.5	2.1
15–16 September							
			1	2	4	3	5
Passes	4,95	16.47	135.0	99.5	15.1	11.6	9.6
			1	2	4	3	5
Buzzes	4,95	2.84	3.7	2.7	1.0	0.9	0.7
			3	1	2	4	5
Passes (Other)	4,95	2.18	4.5	2.2	0.9	0.8	0.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0024 for a table of 21 tests.
[b]Habitats ca. 2 km from Blowing Wind Cave.
[c]Habitats ca. 13 km from Blowing Wind Cave.

Fig. 5.1.—Sites at Guntersville Reservoir where vocalizations of foraging <u>Myotis</u> <u>grisescens</u> were recorded during 1991 and 1992: A, North Sauty north of Highway 72 (1991); B, North Sauty south of Highway 72 (1991 and 1992); C, historical channel of Tennessee River (1992).

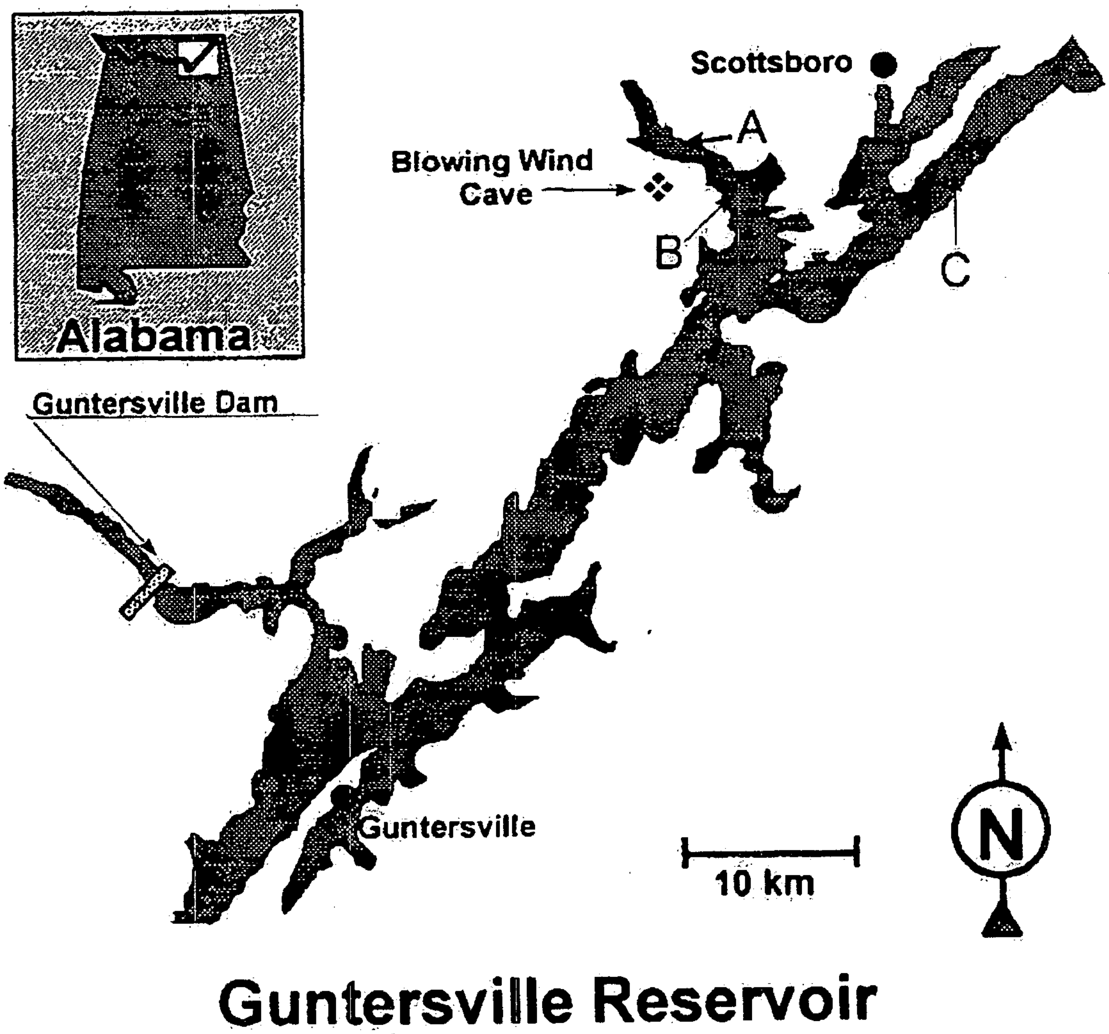


Fig. 5.2.—Average number of passes of gray bats (Myotis grisescens) recorded among five habitats throughout the night at Guntersville Reservoir, Jackson Co., Alabama, 1991.

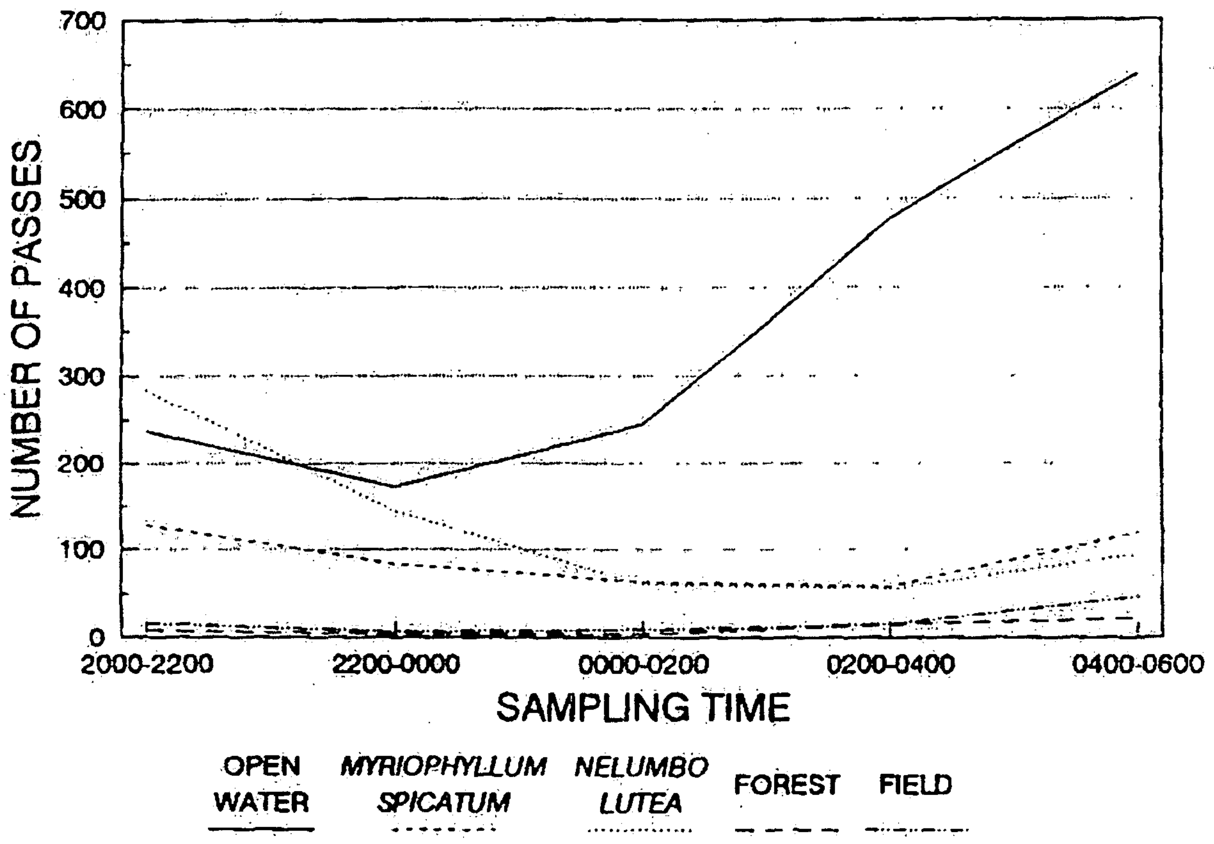


Fig. 5.3.—Average number of buzzes of gray bats (Myotis grisescens) recorded among five habitats throughout the night at Guntersville Reservoir, Jackson Co., Alabama, 1991.

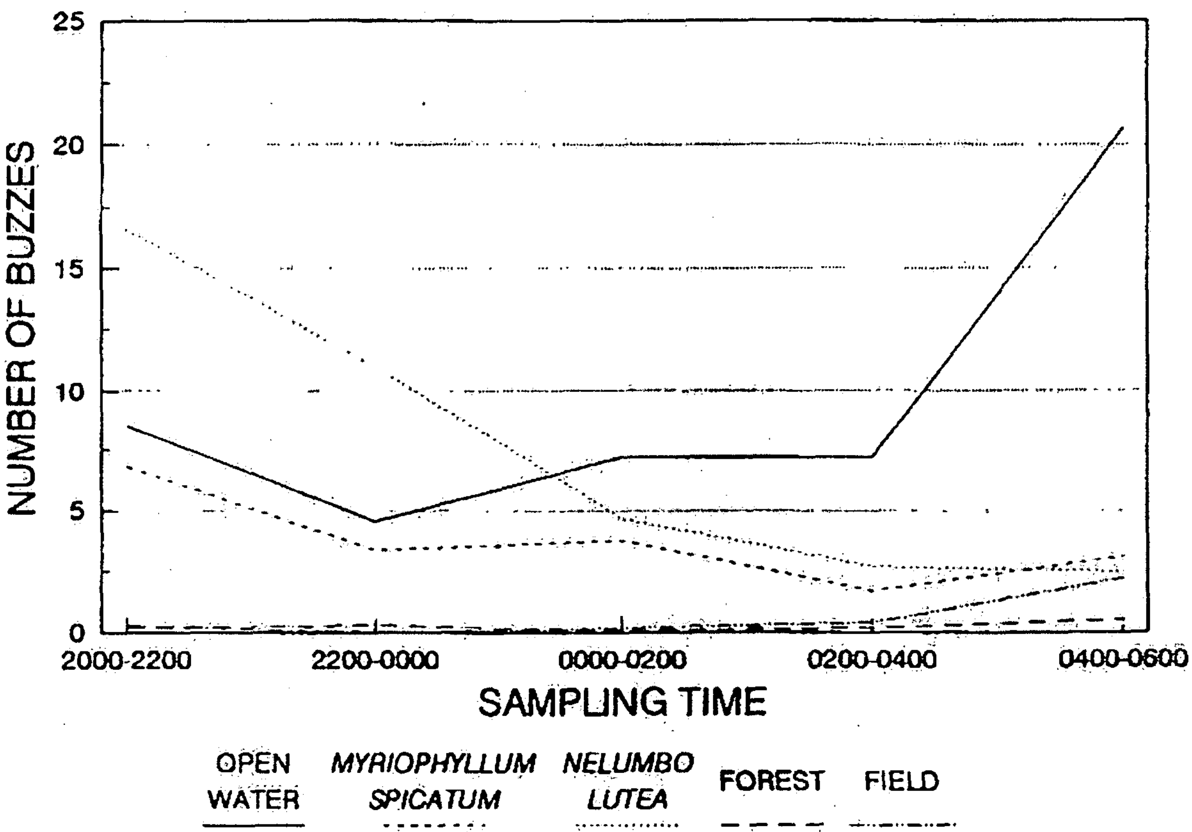


Fig. 5.4.—Average number of passes of species of bats, other than Myotis grisescens, that were recorded among five habitats throughout the night at Guntersville Reservoir, Jackson Co., Alabama, 1991.

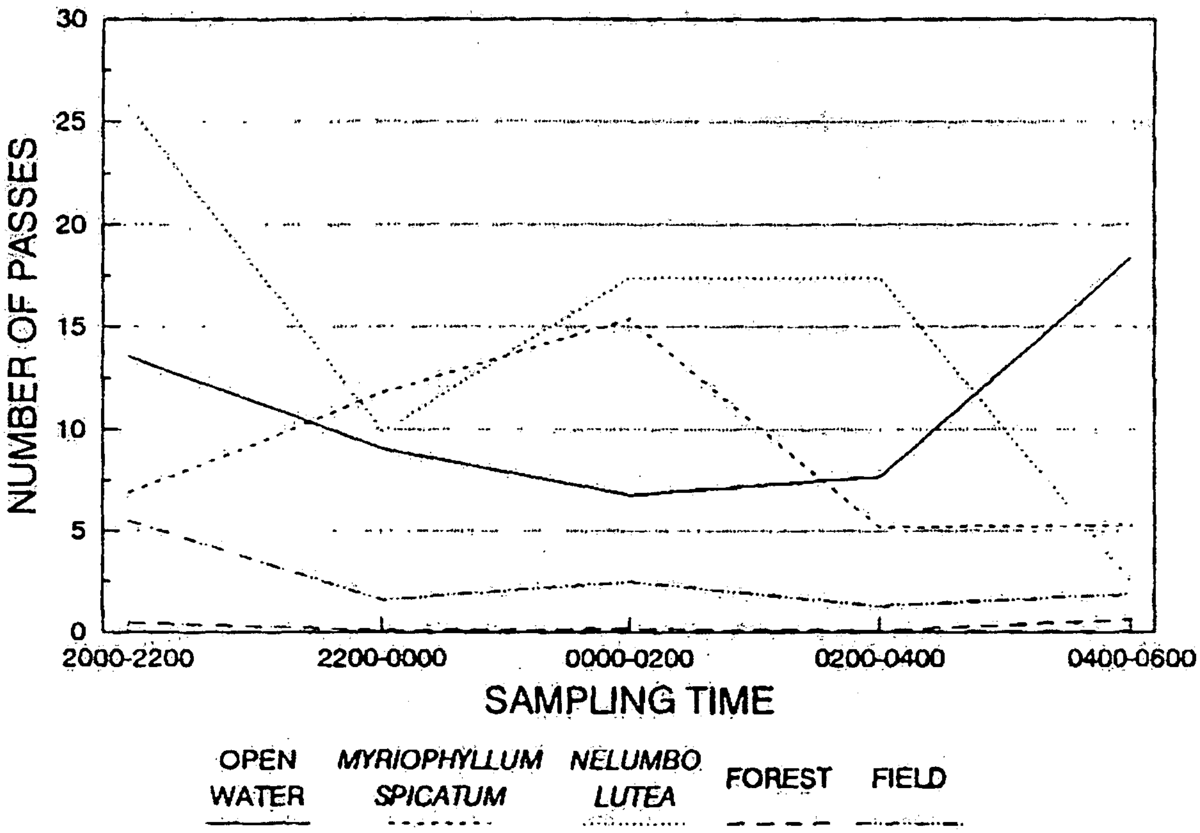


Fig. 5.5.—Average number of passes of gray bats (Myotis grisescens) recorded among five habitats throughout the summer during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, 1991.

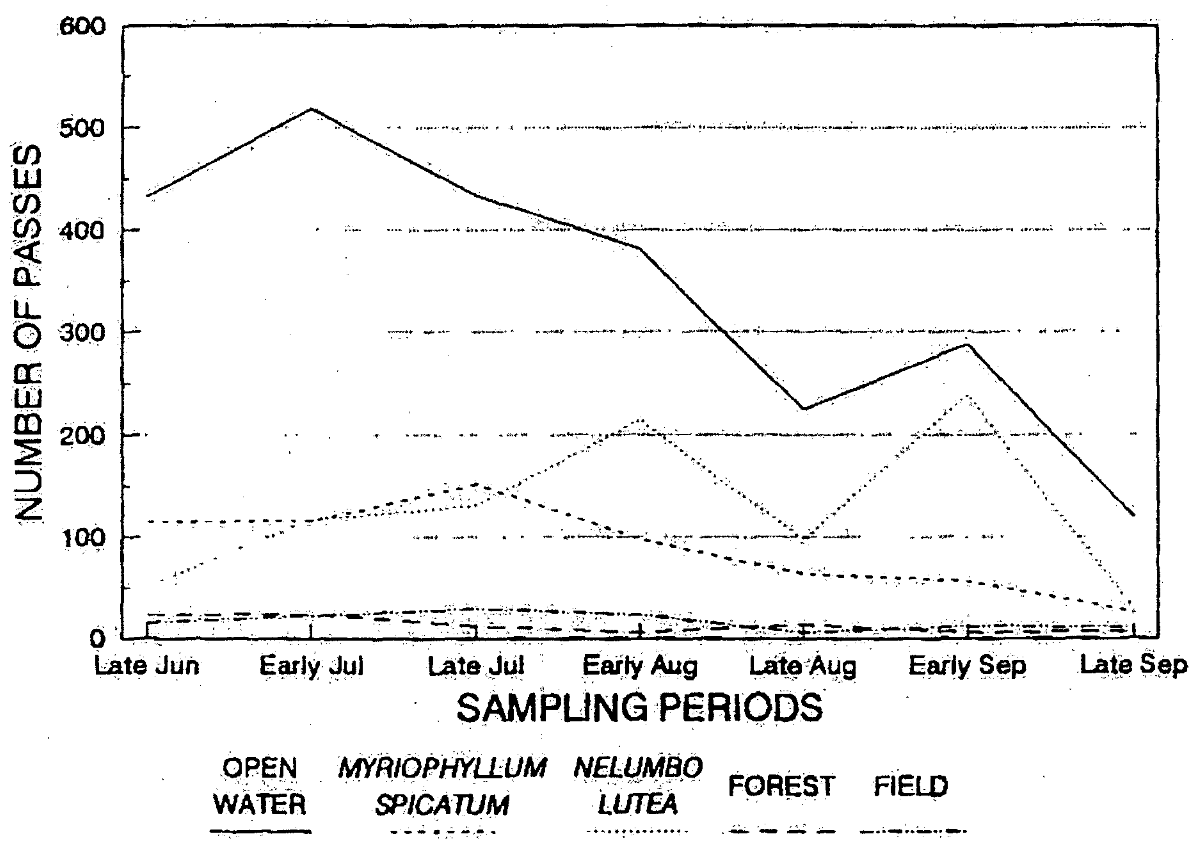


Fig. 5.6.—Average number of buzzes of gray bats (Myotis grisescens) recorded among five habitats throughout the summer during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, 1991.

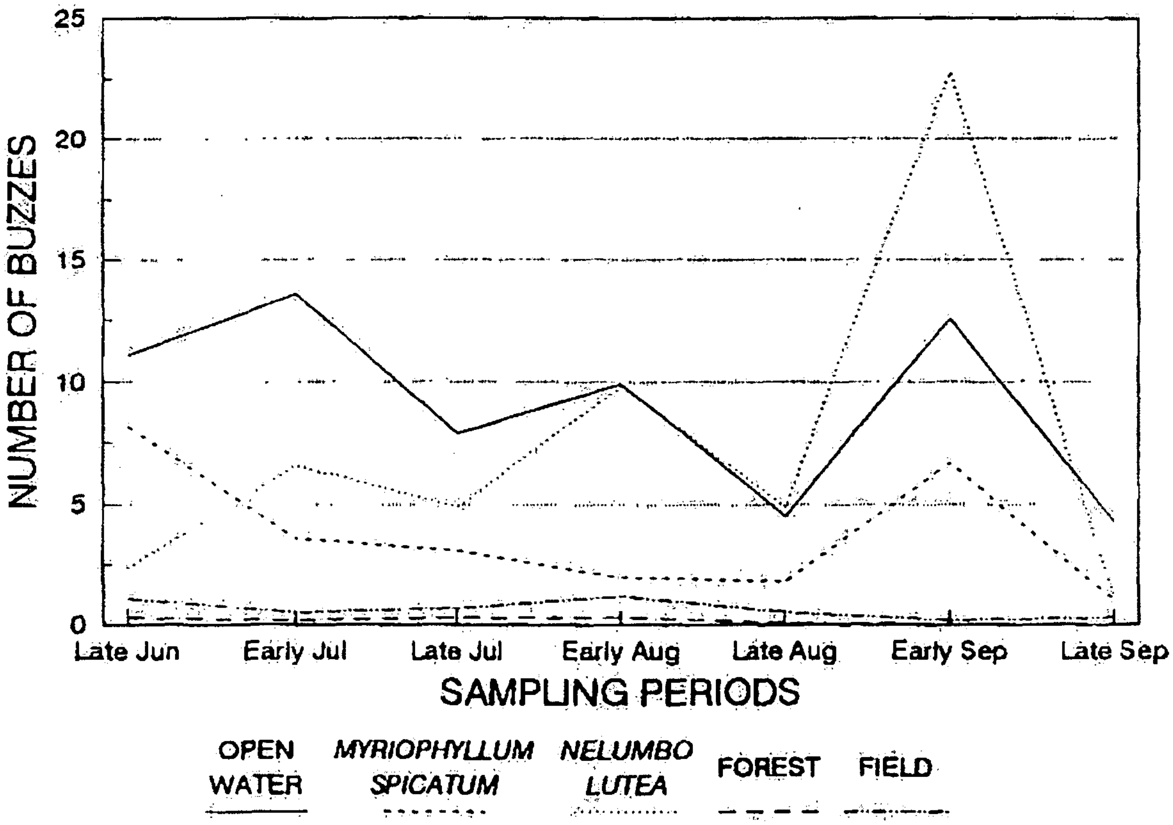


Fig. 5.7.—Average number of passes of species of bats, other than Myotis grisescens, that were recorded among five habitats during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, summer 1991.

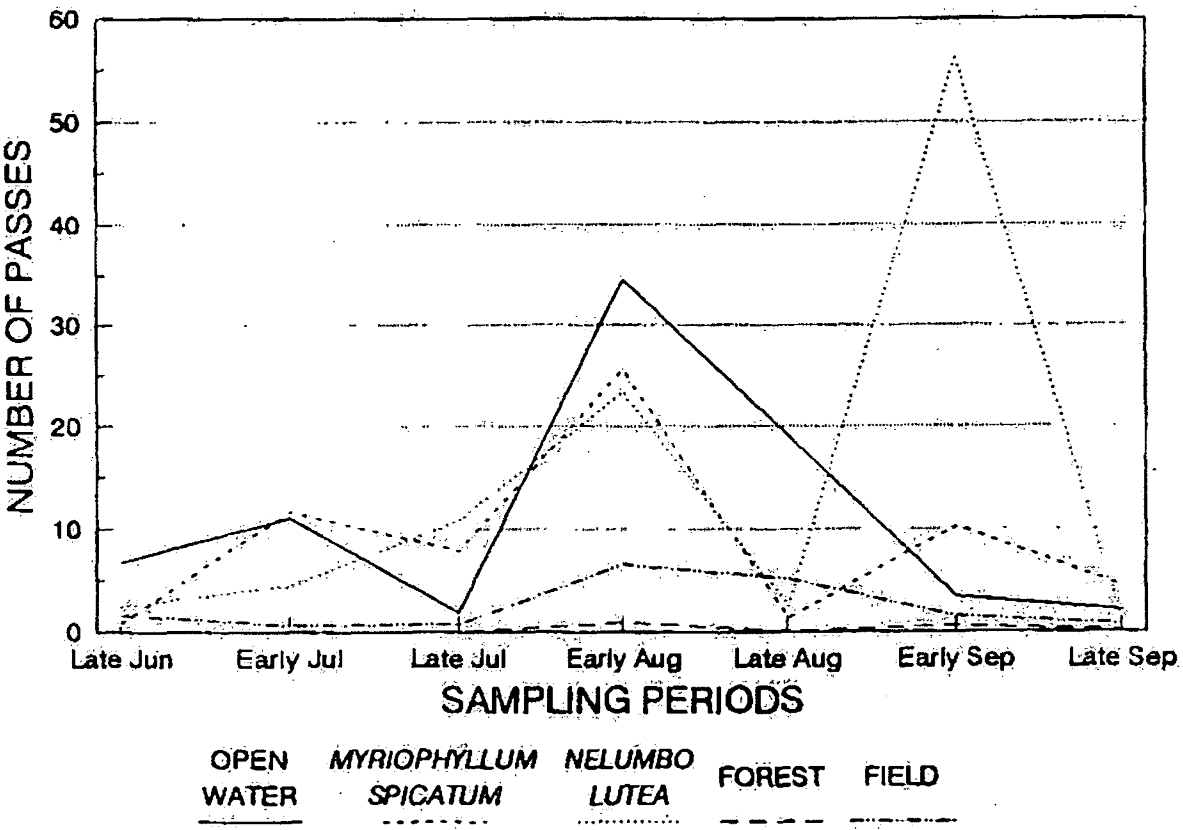


Fig. 5.8.—Average number of passes of gray bats (Myotis grisescens) recorded among five habitats throughout the night at Guntersville Reservoir, Jackson Co., Alabama, 1992.

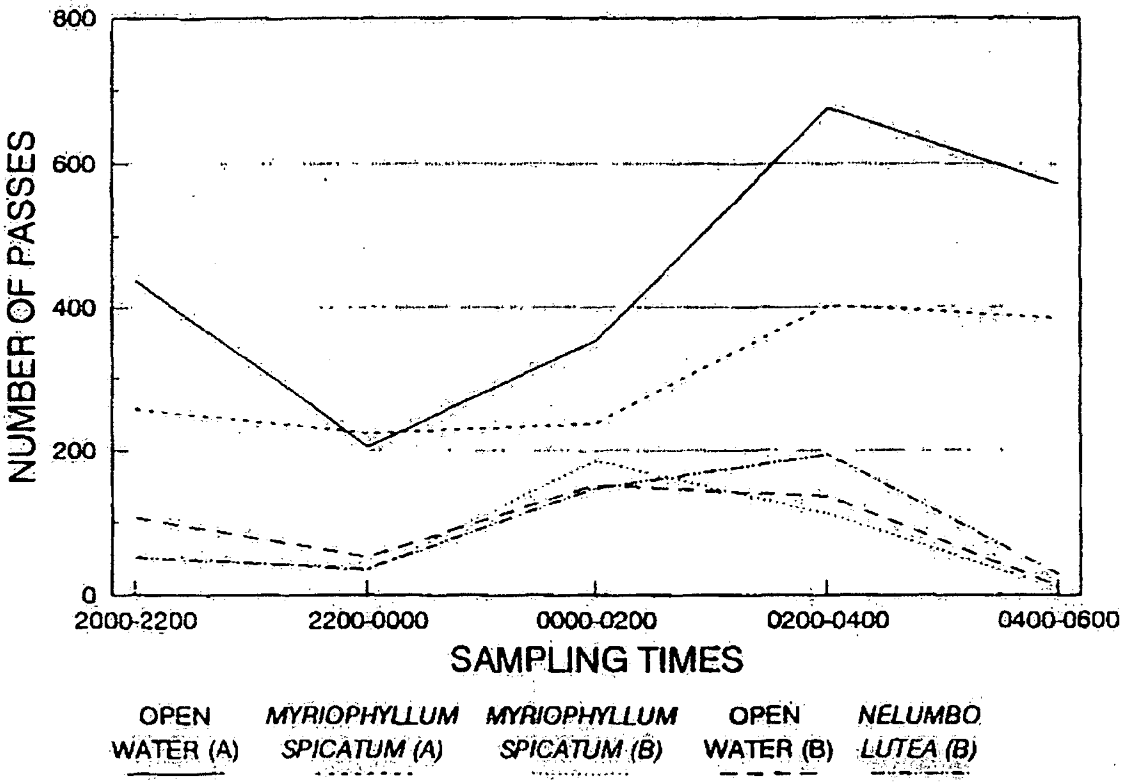


Fig. 5.9.—Average number of buzzes of gray bats (Myotis grisescens) recorded among five habitats throughout the night at Guntersville Reservoir, Jackson Co., Alabama, 1992.

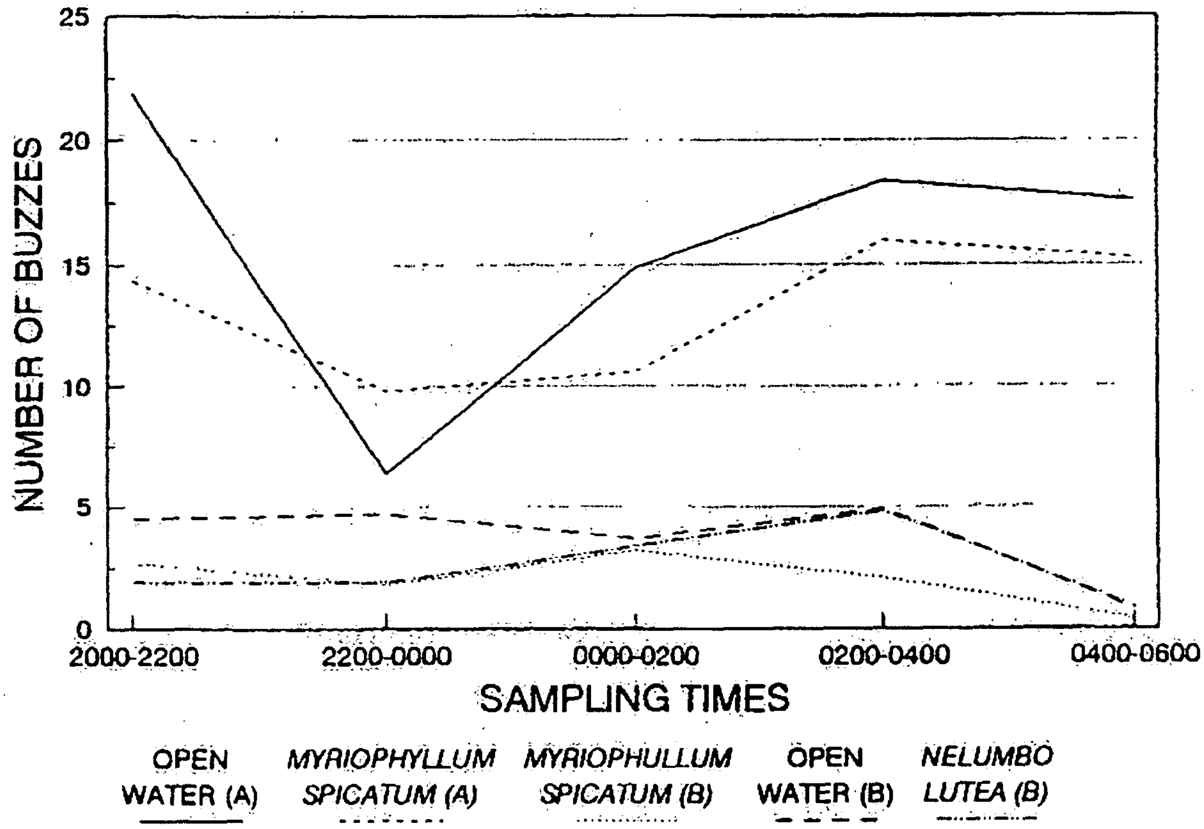


Fig. 5.10.—Average number of passes by species of bats, other than Myotis grisescens, recorded among five habitats throughout the night at Guntersville Reservoir, Jackson Co., Alabama, 1992.

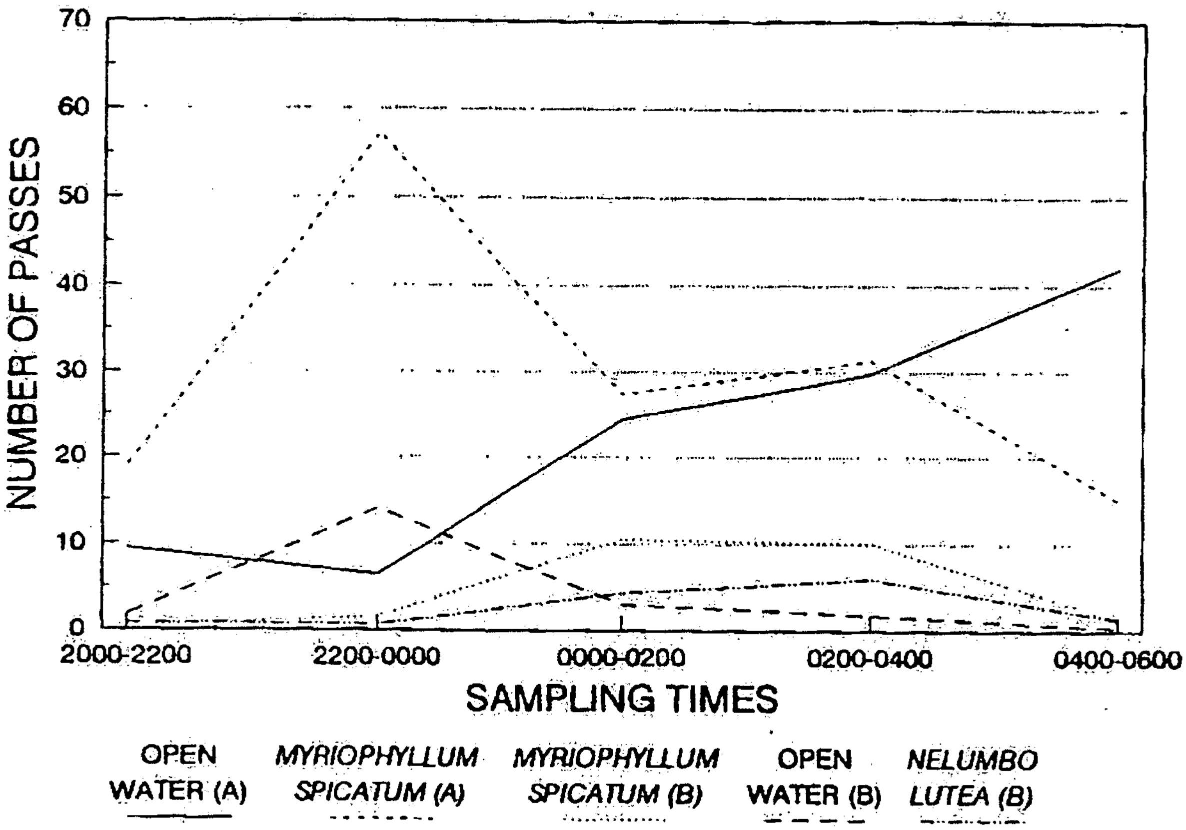


Fig. 5.11.—Average number of passes of gray bats (Myotis grisescens) recorded among five habitats during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, summer 1992.

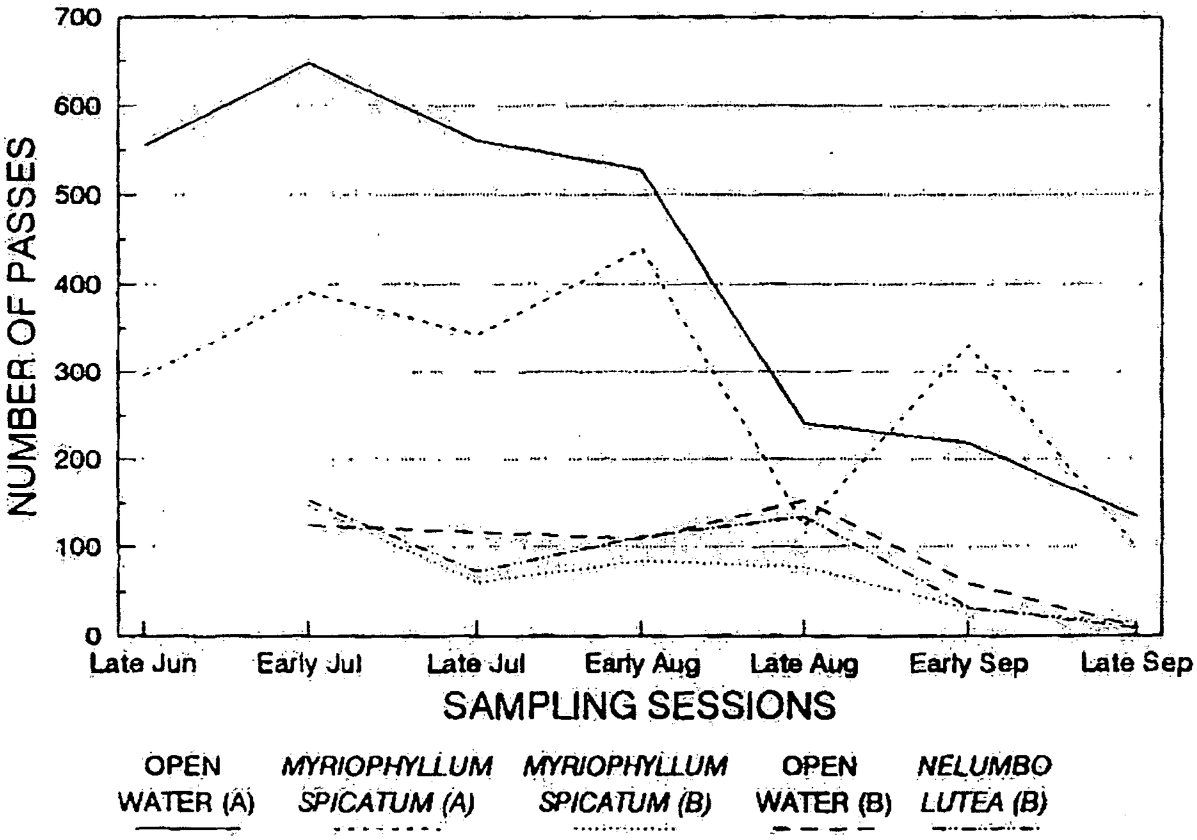


Fig. 5.12.—Average number of buzzes of gray bats (Myotis grisescens) recorded among five habitats during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, summer 1992.

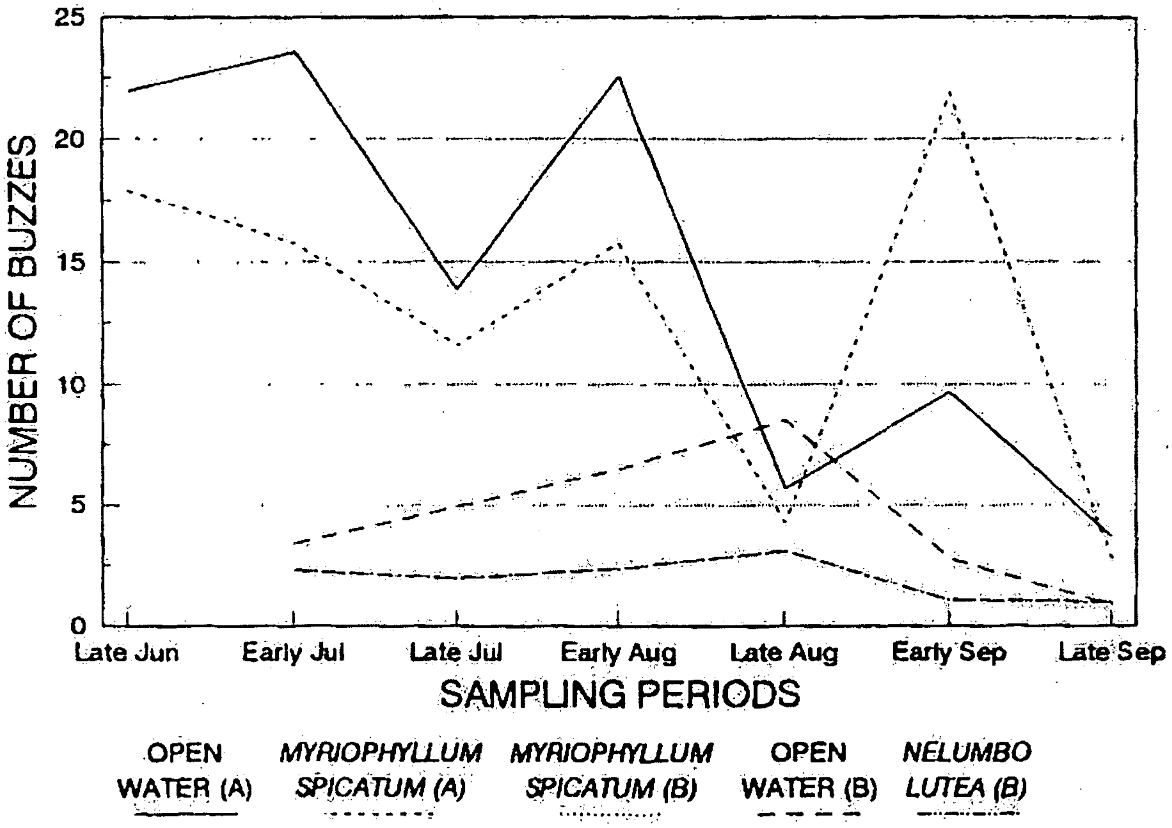
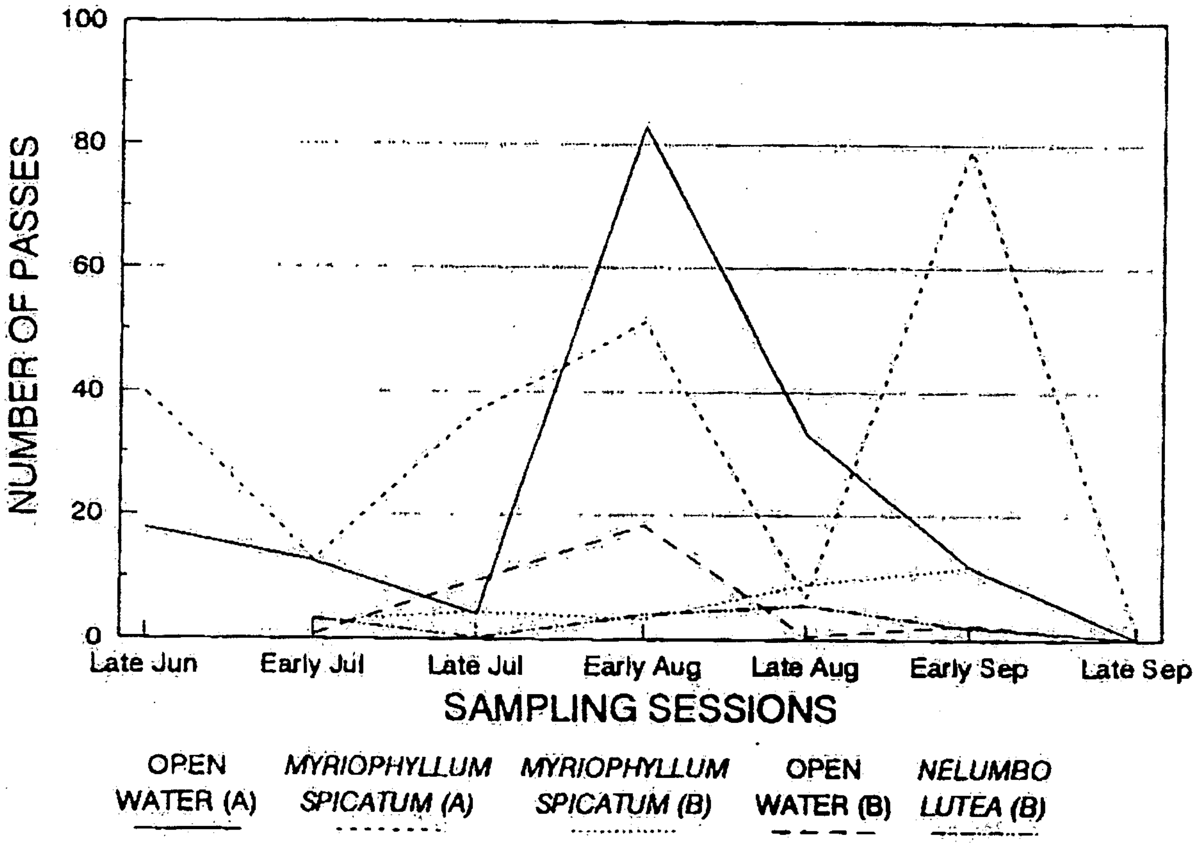


Fig. 5.13. Average number of passes of species of bats, other than Myotis grisescens, recorded among five habitats during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, summer 1992.



Appendix 5.1.--Sampling sessions, sampling dates, sampling times, and samples sizes used to record vocalizations of Myotis grisescens among five habitats within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991. Habitats sampled are as follows: 1, open-water; 2, Myriophyllum; 3, Nelumbo; 4, forest; 5, field.

Sampling session	Date	Sampling time	Habitats				
			1	2	3	4	5
1	25-26 June	2000-2200	5	5	4	1	4
1	25-26 June	2200-0000	5		4	2	
1	25-26 June	0000-0200					
1	25-26 June	0200-0400					
1	25-26 June	0400-0600					
1	26-27 June	2000-2200	5	5	4	1	5
1	26-27 June	2200-0000	5	5	4	1	5
1	26-27 June	0000-0200	5	5	5	1	4
1	26-27 June	0200-0400	5	5	5		5
1	26-27 June	0400-0600	5	4	5		2
1	27-28 June	2000-2200	5	5	5	1	5
1	27-28 June	2200-0000	5	5	5	1	5
1	27-28 June	0000-0200	4	4	4	2	5
1	27-28 June	0200-0400	5	1	1	2	5
1	27-28 June	0400-0600	5	2	2	2	2
1	28-29 June	2000-2200	5	5	5		4
1	28-29 June	2200-0000	5	5	5		5
1	28-29 June	0000-0200	5	5	5		5
1	28-29 June	0200-0400	5	5	5	1	5
1	28-29 June	0400-0600	5	5	5	1	5
2	8-9 July	2000-2200	1	5	5	3	4
2	8-9 July	2200-0000	4	5	5	3	5
2	8-9 July	0000-0200	5	5	5	3	5
2	8-9 July	0200-0400	1	5	5	3	5
2	8-9 July	0400-0600					
2	9-10 July	2000-2200	4	5	5	5	5
2	9-10 July	2200-0000	4	5	5	5	5
2	9-10 July	0000-0200	5	5	5	5	5
2	9-10 July	0200-0400	5	5	5	5	5
2	9-10 July	0400-0600	5	5	5	5	5
2	11-12 July	2000-2200	5	4	5	5	4
2	11-12 July	2200-0000	5	4	5	5	5
2	11-12 July	0000-0200	5	5	5	5	5
2	11-12 July	0200-0400	5	5	5	5	5

Appendix 5.1.--Continued.

2	11-12 July	0400-0600	5	5	5	5	5
3	22-23 July	2000-2200		5	5	5	4
3	22-23 July	2200-0000	2	5	5	5	4
3	22-23 July	0000-0200	1	5	5	5	4
3	22-23 July	0200-0400		5	5	5	4
3	22-23 July	0400-0600	5	5	5	5	3
3	23-24 July	2000-2200	1	5	5	5	3
3	23-24 July	2200-0000	5	5	5	5	
3	23-24 July	0000-0200	5	5	5	5	5
3	23-24 July	0200-0400	5	5	5	5	5
3	23-24 July	0400-0600	5	5	5	5	5
3	26-27 July	2000-2200	5	5	5	5	5
3	26-27 July	2200-0000	5	5	5	5	3
3	26-27 July	0000-0200	5	5	5	5	3
3	26-27 July	0200-0400	5	5	5	5	5
3	26-27 July	0400-0600	5	5	5	5	5
4	5-6 August	2000-2200	3	5	5	5	5
4	5-6 August	2200-0000	5	5	5	5	5
4	5-6 August	0000-0200	5	5	5	4	5
4	5-6 August	0200-0400	5	5	5	5	5
4	5-6 August	0400-0600	5	5	5	4	5
4	6-7 August	2000-2200	5	5	5	5	5
4	6-7 August	2200-0000	5	5	5	5	5
4	6-7 August	0000-0200	2	5	5	5	5
4	6-7 August	0200-0400	5	5	5	5	5
4	6-7 August	0400-0600	5	5	5	5	5
4	7-8 August	2000-2200		5	5	5	4
4	7-8 August	2200-0000	5	5	5	5	4
4	7-8 August	0000-0200		5	5	5	4
4	7-8 August	0200-0400	1	5	5	5	4
4	7-8 August	0400-0600	5	5	5	5	4
5	20-21 August	2000-2200	5	5	5	5	5
5	20-21 August	2200-0000	3	5	5	5	5
5	20-21 August	0000-0200	5	5	5	5	5
5	20-21 August	0200-0400	4	5	5	5	5
5	20-21 August	0400-0600		5	5	5	5
5	21-22 August	2000-2200	5	5	5	5	5
5	21-22 August	2200-0000	5	5	5	5	5
5	21-22 August	0000-0200	5	5	5	5	5
5	21-22 August	0200-0400	5	5	5	5	5
5	21-22 August	0400-0600	5	5	5	5	5

Appendix 5.1.—Continued.

5	22-23 August	2000-2200	5	5	5	5	5
5	22-23 August	2200-0000	5	5	5	5	5
5	22-23 August	0000-0200	5	5	5	5	5
5	22-23 August	0200-0400	5	5	5	5	5
5	22-23 August	0400-0600	3	5	5	5	5
6	3-4 September	2000-2200	5	5	5	5	4
6	3-4 September	2200-0000	5	5	4	5	5
6	3-4 September	0000-0200	5	5	5	5	5
6	3-4 September	0200-0400	5	5	5	5	5
6	3-4 September	0400-0600	5	5	5	5	5
6	4-5 September	2000-2200	5	5	5	5	5
6	4-5 September	2200-0000	5	5	5	5	5
6	4-5 September	0000-0200	5	5	5	5	5
6	4-5 September	0200-0400	5	5	5	5	5
6	4-5 September	0400-0600	5	5	5	5	5
6	5-6 September	2000-2200	5	5	5	5	5
6	5-6 September	2200-0000	5	5	5	5	5
6	5-6 September	0000-0200	5	5	5	5	5
6	5-6 September	0200-0400	5	5	5	5	5
6	5-6 September	0400-0600	5	5	5	5	5
7	17-18 September	2000-2200	5	5	5	5	5
7	17-18 September	2200-0000	5	5	5	5	5
7	17-18 September	0000-0200	5	5	5	5	5
7	17-18 September	0200-0400	5	5	5	5	5
7	17-18 September	0400-0600	5	5	5	3	3
7	18-19 September	2000-2200					
7	18-19 September	2200-0000	5	5	4	3	5
7	18-19 September	0000-0200	5	5	5	3	5
7	18-19 September	0200-0400	5	5	5	3	5
7	18-19 September	0400-0600		1			2
7	19-20 September	2000-2200	5	5	5	3	5
7	19-20 September	2200-0000	5	5	5	3	5
7	19-20 September	0000-0200	5	5	5	3	5
7	19-20 September	0200-0400		5	5	3	5
7	19-20 September	0400-0600		5	5	3	5

Appendix 5.2.—Sampling sessions, sampling dates, sampling times, and samples sizes used to record vocalizations of Myotis grisescens among five habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1992. Habitats sampled are as follows: 1, open-water[a]; 2, Myriophyllum[a]; 3, open-water[b]; 4, Myriophyllum[b]; 5, Nelumbo[b].

Sampling session	Date	Sampling time	Habitats 1	2	3	4	5
1	26-27 June	2000-2200	4	4			
1	26-27 June	2200-0000	4	4			
1	26-27 June	0000-0200	4	4			
1	26-27 June	0200-0400	4	4			
1	26-27 June	0400-0600	4	4			
2	7-8 July	2000-2200	4	4	4	4	4
2	7-8 July	2200-0000	4	4	4	4	4
2	7-8 July	0000-0200	4	4	4	4	3
2	7-8 July	0200-0400	4	4	4	4	3
2	7-8 July	0400-0600	4	4	4	4	3
2	8-9 July	2000-2200	4	4	4	4	3
2	8-9 July	2200-0000	4	4	4	4	3
2	8-9 July	0000-0200	4	4	4	4	3
2	8-9 July	0200-0400	4	4	4	4	3
2	8-9 July	0400-0600	4	4	4	4	3
3	20-21 July	2000-2200	1	4		4	4
3	20-21 July	2200-0000	1	4		4	4
3	20-21 July	0000-0200	1	4		4	4
3	20-21 July	0200-0400	1	4		4	4
3	20-21 July	0400-0600	1	4		4	3
4	3-4 August	2000-2200	4	4	3	3	4
4	3-4 August	2200-0000	4	4	3	3	4
4	3-4 August	0000-0200	4	4	4	4	4
4	3-4 August	0200-0400	4	4	4	4	4
4	3-4 August	0400-0600	4	4	4	3	4
5	19-20 August	2000-2200	4	4	1	4	4
5	19-20 August	2200-0000	4	4	2	4	4
5	19-20 August	0000-0200	4	4	2	4	4
5	19-20 August	0200-0400	4	4	2	4	4
5	19-20 August	0400-0600	4	4		4	3
6	31 August-1 September	2000-2200	4	4	4	4	4
6	31 August-1 September	2200-0000	4	4	4	4	4

Appendix 5.2.—Continued.

6	31 August-1 September	0000-0200	4	4	4	4	4
6	31 August-1 September	0200-0400	4	4	4	4	4
6	31 August-1 September	0400-0600	4	4	4	4	4
7	15-16 September	2000-2200	4	4	3	4	4
7	15-16 September	2200-0000	4	4	4	4	4
7	15-16 September	0000-0200	3	4	4	4	4
7	15-16 September	0200-0400	3	4	4	4	4
7	15-16 September	0400-0600	3	4	4	4	4

[a]Habitats ca. 2 km from Blowing Wind Cave.
[b]Habitats ca. 13 km from Blowing Wind Cave.

Appendix 5.3.—Sampling dates, sampling times, number of minutes recorded among each sampling time (n), and total number of passes and buzzes of Myotis grisescens and passes of other species of bats[a] among five habitats within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991.

Habitat	Date	Sampling time	n	Passes	Buzzes	Other
Open-water						
	25-26 June	2000-2200	464	572	11	1
		2200-0000	231	120	1	10
		0000-0200				
		0200-0400				
		0400-0600				
	26-27 June	2000-2200	419	1,107	39	0
		2200-0000	423	550	30	8
		0000-0200	473	2,470	19	0
		0200-0400	468	6,925	101	3
		0400-0600	467	2,631	28	5
	27-28 June	2000-2200	423	318	9	3
		2200-0000	445	399	26	114
		0000-0200	266	1,177	133	5
		0200-0400	469	3,281	43	4
		0400-0600	463	1,333	25	70
	28-29 June	2000-2200	468	1,356	42	2
		2200-0000	468	2,327	33	71
		0000-0200	472	2,939	204	217
		0200-0400	436	3,476	61	4
		0400-0600	457	2,037	6	1
	8-9 July	2000-2200	46	411	12	15
		2200-0000	185	164	7	21
		0000-0200	264	700	31	45
		0200-0400	47	136	1	0
		0400-0600				
Open-water						
	9-10 July	2000-2200	187	397	13	15
		2200-0000	235	474	5	43
		0000-0200	376	1,056	12	113
		0200-0400	464	2,893	36	155
		0400-0600	408	3,421	37	3

Appendix 5.3.--Continued.

11-12 July	2000-2200	421	3,398	155	0
	2200-0000	459	1,241	17	0
	0000-0200	417	998	24	0
	0200-0400	472	3,272	64	0
	0400-0600	330	4,450	177	0
22-23 July	2000-2200				
	2200-0000	96	191	11	1
	0000-0200	47	95	0	0
	0200-0400				
	0400-0600	235	1,783	89	1
23-24 July	2000-2200	45	22	0	0
	2200-0000	237	1,102	13	0
	0000-0200	262	1,598	14	0
	0200-0400	400	3,897	22	0
	0400-0600	399	3,935	21	0
26-27 July	2000-2200	236	159	1	1
	2200-0000	442	324	8	24
	0000-0200	420	774	42	1
	0200-0400	440	521	1	16
	0400-0600	233	667	25	24
5-6 August	2000-2200	138	344	15	7
	2200-0000	228	399	4	7
	0000-0200	465	1,327	12	18
	0200-0400	461	2,025	49	168
	0400-0600	229	1,074	12	569
6-7 August	2000-2200	466	1,280	37	65
	2200-0000	208	345	15	34
	0000-0200	4	7	0	0
	0200-0400	467	3,122	52	179
	0400-0600	181	784	24	33
7-8 August	2000-2200				
	2200-0000	237	734	19	21
	0000-0200				
	0200-0400	47	369	6	7
	0400-0600	468	2,812	137	6
Open-water					
20-21 August	2000-2200	190	365	12	169
	2200-0000	213	231	2	221
	0000-0200	74	174	1	1
	0200-0400	278	427	6	20
	0400-0600				

Appendix 5.3.—Continued.

21-22 August	2000-2200	301	802	29	2
	2200-0000	230	175	0	0
	0000-0200	169	74	0	0
	0200-0400	67	233	4	0
	0400-0600	402	2,399	61	12
22-23 August	2000-2200	534	934	20	21
	2200-0000	446	424	7	12
	0000-0200	342	163	1	1
	0200-0400	347	504	15	13
	0400-0600	196	1,390	33	16
3-4 September	2000-2200	249	261	12	2
	2200-0000	189	186	13	5
	0000-0200	237	305	4	0
	0200-0400	471	1,451	18	3
	0400-0600	385	1,624	74	6
4-5 September	2000-2200	492	1,130	42	5
	2200-0000	447	1,221	62	2
	0000-0200	450	864	7	0
	0200-0400	428	885	12	0
	0400-0600	357	2,643	151	0
5-6 September	2000-2200	481	1,162	63	106
	2200-0000	418	968	20	18
	0000-0200	461	928	18	30
	0200-0400	448	1,144	39	29
	0400-0600	371	2,667	204	36
17-18 September	2000-2200	545	1,785	61	28
	2200-0000	453	593	12	1
	0000-0200	472	558	8	1
	0200-0400	441	458	5	0
	0400-0600	300	1,803	88	2
18-19 September	2000-2200				
	2200-0000	306	144	14	28
	0000-0200	418	75	1	2
	0200-0400	384	106	3	16
	0400-0600				
Open-water					
19-20 September	2000-2200	435	83	0	8
	2200-0000	388	99	7	11
	0000-0200	319	18	0	0
	0200-0400				
	0400-0600				

Appendix 5.3.—Continued.

Myriophyllum

25-26 June	2000-2200	449	1,978	332	21
	2200-0000				
	0000-0200				
	0200-0400				
	0400-0600				
26-27 June	2000-2200	463	1,581	81	0
	2200-0000	450	267	6	0
	0000-0200	455	550	4	0
	0200-0400	417	281	2	0
	0400-0600	278	158	12	0
27-28 June	2000-2200	222	56	0	0
	2200-0000	425	195	7	5
	0000-0200	233	59	0	0
	0200-0400	47	14	1	0
	0400-0600	84	25	0	0
28-29 June	2000-2200	462	637	11	4
	2200-0000	445	338	9	6
	0000-0200	471	362	1	10
	0200-0400	429	235	12	16
	0400-0600	25	17	3	0
8-9 July	2000-2200	441	505	4	53
	2200-0000	512	387	11	41
	0000-0200	468	176	4	49
	0200-0400	236	166	4	5
	0400-0600				
9-10 July	2000-2200	398	540	17	48
	2200-0000	475	737	33	32
	0000-0200	444	243	8	164
	0200-0400	443	258	11	7
	0400-0600	321	551	13	1
11-12 July	2000-2200	240	630	13	33
	2200-0000	328	528	26	16
	0000-0200	467	164	4	242
	0200-0400	468	229	4	1
	0400-0600	356	657	25	17

Appendix 5.3.—Continued.

Myriophyllum

22-23 July	2000-2200	336	469	18	11
	2200-0000	491	1,231	24	88
	0000-0200	422	182	6	13
	0200-0400	465	411	15	22
	0400-0600	421	458	12	6
23-24 July	2000-2200	468	912	3	20
	2200-0000	423	632	0	56
	0000-0200	464	521	5	51
	0200-0400	464	970	16	42
	0400-0600	422	845	7	1
26-27 July	2000-2200	444	491	4	4
	2200-0000	461	370	23	4
	0000-0200	462	838	32	20
	0200-0400	470	795	22	0
	0400-0600	461	1,082	19	159
5-6 August	2000-2200	509	476	12	18
	2200-0000	379	426	13	13
	0000-0200	455	284	7	56
	0200-0400	446	254	5	1
	0400-0600	448	279	0	5
6-7 August	2000-2200	451	516	11	14
	2200-0000	468	285	3	151
	0000-0200	388	196	2	349
	0200-0400	445	317	16	125
	0400-0600	439	423	2	78
7-8 August	2000-2200	511	441	11	278
	2200-0000	451	790	38	289
	0000-0200	454	701	8	284
	0200-0400	448	574	10	82
	0400-0600	446	639	1	36
20-21 August	2000-2200	449	258	7	8
	2200-0000	463	436	26	0
	0000-0200	482	232	15	4
	0200-0400	459	154	5	3
	0400-0600	472	1,584	47	1
21-22 August	2000-2200	459	196	3	19
	2200-0000	460	70	0	0
	0000-0200	398	39	0	0
	0200-0400	463	52	2	0
	0400-0600	454	483	6	0

Appendix 5.3.—Continued.

Myriophyllum

22-23 August	2000-2200	497	145	2	40
	2200-0000	456	140	4	30
	0000-0200	471	77	1	1
	0200-0400	427	57	1	2
	0400-0600	439	542	7	0
3-4 September	2000-2200	447	151	11	33
	2200-0000	469	578	49	252
	0000-0200	480	498	59	145
	0200-0400	464	128	8	95
	0400-0600	448	130	13	3
4-5 September	2000-2200	386	211	10	11
	2200-0000	474	133	14	22
	0000-0200	463	105	11	36
	0200-0400	453	68	3	21
	0400-0600	451	212	3	16
5-6 September	2000-2200	506	418	47	8
	2200-0000	478	231	19	27
	0000-0200	466	738	201	50
	0200-0400	497	148	13	0
	0400-0600	449	278	15	0
17-18 September	2000-2200	460	333	3	26
	2200-0000	444	93	5	5
	0000-0200	464	70	3	5
	0200-0400	448	85	0	13
	0400-0600	459	291	2	5
18-19 September	2000-2200				
	2200-0000	270	36	1	8
	0000-0200	483	40	0	3
	0200-0400	450	57	0	3
	0400-0600	3	6	0	1
19-20 September	2000-2200	482	68	6	39
	2200-0000	419	83	8	26
	0000-0200	388	7	1	7
	0200-0400	442	25	6	22
	0400-0600	404	134	21	68

Appendix 5.3.--Continued.

Nelumbo

25-26 June	2000-2200	288	636	58	25
	2200-0000	78	38	6	5
	0000-0200				
	0200-0400				
	0400-0600				

Nelumbo

26-27 June	2000-2200	289	348	10	0
	2200-0000	365	167	1	7
	0000-0200	350	148	1	6
	0200-0400	464	133	0	9
	0400-0600	204	60	0	11
27-28 June	2000-2200	168	38	0	0
	2200-0000	452	220	4	5
	0000-0200	212	68	1	0
	0200-0400	54	26	2	0
	0400-0600	93	0	0	0
28-29 June	2000-2200	412	465	9	0
	2200-0000	439	372	26	16
	0000-0200	372	122	1	7
	0200-0400	387	59	1	8
	0400-0600	499	82	3	34
8-9 July	2000-2200	466	691	19	137
	2200-0000	447	128	6	39
	0000-0200	414	91	2	19
	0200-0400	253	107	3	2
	0400-0600				
9-10 July	2000-2200	452	1,241	96	35
	2200-0000	467	135	3	0
	0000-0200	445	114	1	23
	0200-0400	451	146	1	1
	0400-0600	278	395	6	0
11-12 July	2000-2200	410	1,992	168	0
	2200-0000	484	477	43	10
	0000-0200	487	136	2	19
	0200-0400	441	186	11	7
	0400-0600	277	667	22	1

Appendix 5.3.--Continued.

22-23 July	2000-2200	432	1,598	180	121
	2200-0000	454	450	32	81
	0000-0200	463	122	2	44
	0200-0400	362	142	2	19
	0400-0600	241	333	25	35
23-24 July	2000-2200	446	1,440	3	22
	2200-0000	467	815	1	7
	0000-0200	435	262	1	0
	0200-0400	479	331	0	0
	0400-0600	391	1,110	10	0
Nelumbo					
26-27 July	2000-2200	441	683	27	322
	2200-0000	477	246	4	0
	0000-0200	471	89	1	1
	0200-0400	461	56	0	4
	0400-0600	382	479	7	29
5-6 August	2000-2200	467	2,672	71	183
	2200-0000	479	1,206	118	50
	0000-0200	480	549	38	86
	0200-0400	433	712	23	4
	0400-0600	469	415	25	5
6-7 August	2000-2200	401	2,536	129	328
	2200-0000	411	443	23	12
	0000-0200	469	455	11	4
	0200-0400	476	232	14	638
	0400-0600	449	467	11	1
7-8 August	2000-2200	473	1,851	41	6
	2200-0000	470	750	18	2
	0000-0200	454	512	54	197
	0200-0400	464	1,061	82	49
	0400-0600	462	691	15	12
20-21 August	2000-2200	430	385	35	66
	2200-0000	480	103	3	0
	0000-0200	478	155	7	3
	0200-0400	470	214	6	9
	0400-0600	450	352	7	2
21-22 August	2000-2200	476	1,046	97	1
	2200-0000	459	287	12	0
	0000-0200	460	94	0	0
	0200-0400	458	133	2	0
	0400-0600	389	295	2	2

Appendix 5.3.—Continued.

22-23 August	2000-2200	464	1,984	103	81
	2200-0000	467	958	49	16
	0000-0200	468	115	2	0
	0200-0400	469	146	3	3
	0400-0600	456	399	12	0
3-4 September	2000-2200	413	1,491	34	351
	2200-0000	355	3,161	200	490
	0000-0200	474	741	92	734
	0200-0400	468	449	42	513
	0400-0600	467	83	2	3
<u>Nelumbo</u>					
4-5 September	2000-2200	462	3,053	288	325
	2200-0000	449	892	75	163
	0000-0200	467	434	22	542
	0200-0400	463	97	17	339
	0400-0600	466	184	7	13
5-6 September	2000-2200	449	948	103	398
	2200-0000	449	2,472	412	13
	0000-0200	451	1,299	211	10
	0200-0400	462	335	21	6
	0400-0600	450	204	3	9
17-18 September	2000-2200	458	571	40	3
	2200-0000	476	111	0	3
	0000-0200	467	155	1	9
	0200-0400	470	193	2	7
	0400-0600	465	137	0	0
18-19 September	2000-2200				
	2200-0000	192	24	0	2
	0000-0200	474	53	0	0
	0200-0400	437	58	4	1
	0400-0600				
19-20 September	2000-2200	463	51	0	3
	2200-0000	451	37	1	4
	0000-0200	445	22	0	6
	0200-0400	472	115	11	4
	0400-0600	456	165	8	8

Appendix 5.3.—Continued.

Forest

25-26 June	2000-2200	83	98	3	0
	2200-0000	61	11	0	0
	0000-0200				
	0200-0400				
	0400-0600				
26-27 June	2000-2200	96	6	0	0
	2200-0000	48	1	0	0
	0000-0200	96	1	0	0
	0200-0400				
	0400-0600				
27-28 June	2000-2200	48	3	1	0
	2200-0000	47	0	0	0
	0000-0200	192	9	0	0
	0200-0400	144	12	0	0
	0400-0600	192	10	0	0

Forest

28-29 June	2000-2200				
	2200-0000				
	0000-0200				
	0200-0400	96	34	0	0
	0400-0600	96	91	0	0
8-9 July	2000-2200	181	21	1	0
	2200-0000	267	16	1	0
	0000-0200	287	22	0	0
	0200-0400	139	3	0	0
	0400-0600				
9-10 July	2000-2200	451	66	2	0
	2200-0000	438	43	0	0
	0000-0200	461	38	0	0
	0200-0400	461	160	2	0
	0400-0600	451	99	0	0
11-12 July	2000-2200	467	159	3	0
	2200-0000	456	23	0	0
	0000-0200	467	61	2	0
	0200-0400	439	429	4	0
	0400-0600	357	170	0	0

Appendix 5.3.—Continued.

22-23 July	2000-2200	461	26	0	0
	2200-0000	459	3	0	0
	0000-0200	458	8	0	0
	0200-0400	465	20	0	0
	0400-0600	406	44	0	0
23-24 July	2000-2200	461	55	0	0
	2200-0000	470	22	0	0
	0000-0200	451	16	2	0
	0200-0400	426	154	5	0
	0400-0600	458	341	5	0
26-27 July	2000-2200	413	53	0	0
	2200-0000	491	5	0	0
	0000-0200	456	2	0	0
	0200-0400	389	3	0	0
	0400-0600	396	50	5	0
5-6 August	2000-2200	402	6	0	11
	2200-0000	353	3	0	0
	0000-0200	245	10	0	1
	0200-0400	487	3	0	0
	0400-0600	286	4	0	1
Forest					
6-7 August	2000-2200	457	2	0	0
	2200-0000	425	0	0	0
	0000-0200	372	0	0	0
	0200-0400	455	6	0	0
	0400-0600	426	12	1	0
7-8 August	2000-2200	429	0	0	0
	2200-0000	400	28	0	0
	0000-0200	453	11	0	18
	0200-0400	407	201	8	2
	0400-0600	231	60	8	17
20-21 August	2000-2200	349	4	0	0
	2200-0000	375	8	0	0
	0000-0200	475	2	0	0
	0200-0400	346	6	0	0
	0400-0600	337	21	2	1
21-22 August	2000-2200	409	19	0	0
	2200-0000	424	1	0	0
	0000-0200	462	4	0	0
	0200-0400	482	19	0	0
	0400-0600	416	102	0	0

Appendix 5.3.—Continued.

22-23 August	2000-2200	500	9	0	0
	2200-0000	504	10	0	0
	0000-0200	444	2	0	0
	0200-0400	438	16	0	0
	0400-0600	413	120	1	6
3-4 September	2000-2200	471	28	0	6
	2200-0000	481	48	0	1
	0000-0200	445	42	0	0
	0200-0400	486	22	0	0
	0400-0600	375	32	0	0
4-5 September	2000-2200	448	24	0	14
	2200-0000	450	10	0	3
	0000-0200	461	5	0	0
	0200-0400	482	73	0	3
	0400-0600	340	44	0	0
5-6 September	2000-2200	477	8	0	12
	2200-0000	401	2	0	0
	0000-0200	486	8	0	0
	0200-0400	424	5	0	0
	0400-0600	424	40	0	0
Forest					
17-18 September	2000-2200	481	17	1	0
	2200-0000	440	0	0	0
	0000-0200	373	0	0	0
	0200-0400	443	8	0	0
	0400-0600	246	44	0	0
18-19 September	2000-2200				
	2200-0000	154	2	0	0
	0000-0200	243	4	0	0
	0200-0400	227	0	0	1
	0400-0600				
19-20 September	2000-2200	296	36	0	0
	2200-0000	236	35	0	0
	0000-0200	252	41	0	0
	0200-0400	274	34	0	2
	0400-0600	242	52	0	1

Appendix 5.3.—Continued.

Field

25-26 June	2000-2200	365	156	3	47
	2200-0000				
	0000-0200				
	0200-0400				
	0400-0600				
26-27 June	2000-2200	326	8	1	9
	2200-0000	471	3	0	17
	0000-0200	362	12	0	7
	0200-0400	420	4	0	6
	0400-0600	139	1	0	1
27-28 June	2000-2200	452	27	2	1
	2200-0000	456	4	0	1
	0000-0200	406	15	0	3
	0200-0400	409	37	0	14
	0400-0600	152	433	45	0
28-29 June	2000-2200	354	24	0	0
	2200-0000	468	11	1	0
	0000-0200	443	31	2	0
	0200-0400	410	11	0	0
	0400-0600	488	102	2	0
8-9 July	2000-2200	374	56	2	0
	2200-0000	467	34	0	1
	0000-0200	463	56	0	0
	0200-0400	236	72	0	0
	0400-0600				

Field

9-10 July	2000-2200	393	125	1	20
	2200-0000	417	32	0	0
	0000-0200	457	56	0	0
	0200-0400	467	87	0	2
	0400-0600	382	163	3	5
11-12 July	2000-2200	252	49	3	5
	2200-0000	410	24	0	0
	0000-0200	479	57	1	1
	0200-0400	466	112	1	0
	0400-0600	319	218	15	4

Appendix 5.3.—Continued.

22-23 July	2000–2200	349	36	0	5
	2200–0000	368	8	2	0
	0000–0200	368	16	0	0
	0200–0400	361	36	0	0
	0400–0600	115	53	1	0
23-24 July	2000–2200	213	119	1	9
	2200–0000				
	0000–0200	382	44	2	2
	0200–0400	466	117	8	4
	0400–0600	437	487	13	9
26-27 July	2000–2200	460	67	1	0
	2200–0000	275	15	0	0
	0000–0200	172	21	0	2
	0200–0400	467	39	1	4
	0400–0600	431	351	7	0
5-6 August	2000–2200	505	261	8	209
	2200–0000	451	68	2	25
	0000–0200	480	78	2	25
	0200–0400	482	103	5	38
	0400–0600	458	158	7	28
6-7 August	2000–2200	476	83	1	1
	2200–0000	457	23	4	22
	0000–0200	403	24	5	36
	0200–0400	461	178	3	0
	0400–0600	453	157	4	13
7-8 August	2000–2200	410	55	1	0
	2200–0000	366	38	3	8
	0000–0200	335	37	6	7
	0200–0400	348	63	6	7
	0400–0600	357	187	21	12
Field					
20-21 August	2000–2200	487	72	1	106
	2200–0000	414	36	0	29
	0000–0200	379	28	0	36
	0200–0400	472	37	1	20
	0400–0600	399	73	0	9
21-22 August	2000–2200	491	57	3	62
	2200–0000	458	36	13	4
	0000–0200	479	52	1	21
	0200–0400	328	49	2	5
	0400–0600	384	82	1	30

Appendix 5.3.—Continued.

22-23 August	2000-2200	459	40	0	2
	2200-0000	476	14	0	3
	0000-0200	430	42	0	1
	0200-0400	462	56	4	3
	0400-0600	431	197	11	3
3-4 September	2000-2200	398	53	0	9
	2200-0000	412	76	4	4
	0000-0200	422	118	0	69
	0200-0400	479	92	3	5
	0400-0600	455	68	3	1
4-5 September	2000-2200	476	27	0	3
	2200-0000	438	44	0	6
	0000-0200	472	41	0	2
	0200-0400	365	66	0	4
	0400-0600	420	29	2	1
5-6 September	2000-2200	479	17	0	0
	2200-0000	426	13	0	0
	0000-0200	476	28	0	0
	0200-0400	436	29	0	0
	0400-0600	443	98	1	1
17-18 September	2000-2200	460	40	0	0
	2200-0000	426	15	0	2
	0000-0200	464	39	0	5
	0200-0400	418	55	2	2
	0400-0600	140	94	3	0
18-19 September	2000-2200				
	2200-0000	268	13	1	3
	0000-0200	457	18	1	3
	0200-0400	476	44	1	11
	0400-0600	3	0	0	0

Appendix 5.3.--Continued.

Field

19-20 September	2000-2200	476	40	0	13
	2200-0000	404	29	0	7
	0000-0200	389	13	0	0
	0200-0400	453	62	1	2
	0400-0600	467	105	4	0
Total		Minutes	Passes	Buzzes	Other[a]
		197,507	223,664	8,547	15,069

[a]Passes of bats other than *Myotis grisescens*.

Appendix 5.4.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of Myotis grisescens and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 25-28 June, 1991. Sampling nights are listed above the average of each activity as follows: 1, 25-26 June; 2, 26-27 June; 3, 27-28 June; 4, 28-29 June. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis			
			2	4	1	3
Passes	3,314	1.95	202.9	166.5	146.9	105.1
			1	4	3	2
Buzzes	3,314	6.27[a]	16.8	5.0	4.4	4.0
			1	4	3	2
Passes (Other)	3,314	1.00	5.1	4.3	2.9	1.1

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.5.--Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of *Myotis grisescens* and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 8-11 July, 1991. Sampling nights are listed above the average of each activity as follows: 1, 8-9 July; 2, 9-10 July; 3, 11-12 July. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis		
			3	2	1
Passes	2,326	8.17[a]	221.7	136.2	73.0
			3	2	1
Buzzes	2,326	8.30[a]	8.4	2.9	2.2
			1	2	3
Passes (Other)	2,326	1.17	7.0	6.8	3.3

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.6.--Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of Myotis grisescens and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 22-26 July, 1991. Sampling nights are listed above the average of each activity as follows: 1, 22-23 July; 2, 23-24 July; 3, 26-27 July. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis		
			2	1	3
Passes	2,336	12.27[a]	227.9	111.8	82.6
			2	3	1
Buzzes	2,336	4.17[a]	6.0	2.4	1.8
			3	1	2
Passes (Other)	2,336	1.17	5.8	5.4	2.7

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.7.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of *Myotis grisescens* and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 5-8 August, 1991. Sampling nights are listed above the average of each activity as follows: 1, 5-6 August; 2, 6-7 August; 3, 7-8 August. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis		
			3	1	2
Passes	2,348	0.05	139.4	134.4	130.3
			3	2	1
Buzzes	2,348	0.62	5.3	4.1	4.1
			2	1	3
Passes (Other)	2,348	0.20	19.8	18.6	14.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.8.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of *Myotis grisescens* and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 20-23 August, 1991. Sampling nights are listed above the average of each activity as follows: 1, 20-21 August; 2, 21-22 August; 3, 22-23 August. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis		
			2	3	1
Passes	2,365	0.19	81.7	80.9	70.8
			3	2	1
Buzzes	2,365	0.21	2.5	2.5	2.0
			1	3	2
Passes (Other)	2,365	6.78	12.8	2.2	1.6

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.9.—Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of Myotis grisescens and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 3-5 September, 1991. Sampling nights are listed above the average of each activity as follows: 1, 3-4 September; 2, 4-5 September; 3, 5-6 September. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis			
			3	2	1	
Passes	2,372	0.13	129.0	117.2	116.0	(line beneath 3, 2, 1)
			3	2	1	
Buzzes	2,372	3.23	12.5	6.8	6.1	(line beneath 3, 2, 1)
			1	2	3	
Passes (Other)	2,372	3.37	23.8	13.2	6.4	(line beneath 1, 2, 3)

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.10.--Results of one-way analysis of variance[a] and Tukey's multiple-comparison tests among nights of recording activity of Myotis grisescens and other species of bats at Guntersville Reservoir, Jackson Co., Alabama, 17-20 September, 1991. Sampling nights are listed above the average of each activity as follows: 1, 17-18 September; 2, 18-19 September; 3, 19-20 September. Lines beneath averages indicate nonsignificant subsets.

Activity	d.f.	F-ratio	Results of Tukey's analysis		
			1	2	3
Passes	2,296	16.43[a]	71.1	15.7	14.4
			1	3	2
Buzzes	2,296	4.04[a]	2.3	0.8	0.5
			3	2	1
Passes (Other)	2,296	3.55	2.5	2.1	1.0

[a]Significant based on sequential Bonferroni minimum table-wide significance level set at 0.0167 for a table of three tests.

Appendix 5.11.--Sampling dates, sampling times, number of minutes recorded among each sampling time (n), and total number of passes and buzzes of Myotis grisescens and passes of other species of bats[a] among five habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1992. Habitats sampled are as follows: 1, open-water[b]; 2, Myriophyllum[b]; 3, open-water[c]; 4, Myriophyllum[c]; 5, Nelumbo[c].

Habitat	Date	Sampling time	n	Passes	Buzzes	Other
Open-water[b]						
	26-27 June	2000-2200	369	1,565	47	105
		2200-0000	360	310	18	41
		0000-0200	392	1,130	58	150
		0200-0400	316	3,715	142	34
		0400-0600	350	2,907	124	6
	7-8 July	2000-2200	281	1,631	148	11
		2200-0000	418	1,367	61	16
		0000-0200	374	1,432	65	25
		0200-0400	381	2,450	69	133
		0400-0600	349	1,307	51	18
	8-9 July	2000-2200	373	3,463	144	19
		2200-0000	376	2,469	88	13
		0000-0200	381	3,245	85	63
		0200-0400	372	3,360	38	138
		0400-0600	318	2,572	79	26
	20-21 July	2000-2200	324	2,627	109	1
		2200-0000	392	884	9	14
		0000-0200	378	1,122	14	14
		0200-0400	360	2,560	28	39
		0400-0600	310	2,195	80	1
	3-4 August	2000-2200	329	1,011	36	80
		2200-0000	372	517	15	67
		0000-0200	369	2,013	191	341
		0200-0400	375	4,107	158	360
		0400-0600	373	2,117	15	712
Open-water[b]						
	19-20 August	2000-2200	283	224	6	28
		2200-0000	386	354	2	36
		0000-0200	334	846	10	77
		0200-0400	363	1,517	31	103
		0400-0600	326	1,288	55	356

Appendix 5.11.—Continued.

31 August- 1 September	2000-2200	285	379	15	17
	2200-0000	380	260	3	8
	0000-0200	326	182	5	31
	0200-0400	350	1,079	45	52
	0400-0600	298	2,003	61	131
15-16 September	2000-2200	535	1,423	58	2
	2200-0000	311	163	2	0
	0000-0200	298	240	3	0
	0200-0400	243	119	4	0
	0400-0600	298	617	8	2
Myriophyllum[b]					
26-27 June	2000-2200	378	892	32	143
	2200-0000	367	427	32	201
	0000-0200	376	844	50	225
	0200-0400	376	1,327	61	120
	0400-0600	317	1,699	134	41
7-8 July	2000-2200	360	212	14	56
	2200-0000	375	472	39	40
	0000-0200	383	901	59	29
	0200-0400	368	1,729	93	92
	0400-0600	316	1,229	65	52
8-9 July	2000-2200	379	1,608	61	53
	2200-0000	377	1,154	42	7
	0000-0200	331	1,956	61	27
	0200-0400	374	2,577	97	107
	0400-0600	242	1,563	38	0
20-21 July	2000-2200	339	1,266	56	218
	2200-0000	269	494	6	37
	0000-0200	326	727	49	213
	0200-0400	374	1,398	25	147
	0400-0600	297	1,384	36	41
3-4 August	2000-2200	405	228	4	17
	2200-0000	350	733	28	597
	0000-0200	397	1,059	24	88
	0200-0400	384	4,121	177	205
	0400-0600	352	2,165	64	13

Appendix 5.11.—Continued.

Myriophyllum[b]

19-20 August	2000-2200	422	295	16	20
	2200-0000	396	1,156	25	20
	0000-0200	355	230	11	1
	0200-0400	352	244	7	2
	0400-0600	225	301	16	52
31 August-1 September	2000-2200	313	1,291	176	37
	2200-0000	347	1,393	99	685
	0000-0200	320	602	27	164
	0200-0400	336	529	21	261
	0400-0600	410	1,292	47	214
15-16 September	2000-2200	518	1,192	33	18
	2200-0000	360	453	14	2
	0000-0200	288	214	6	2
	0200-0400	323	36	0	0
	0400-0600	457	254	6	2

Open-water[c]

7-8 July	2000-2200	362	183	13	0
	2200-0000	379	396	46	1
	0000-0200	372	617	13	1
	0200-0400	381	544	5	12
	0400-0600	360	9	0	0
8-9 July	2000-2200	374	772	12	6
	2200-0000	378	111	3	0
	0000-0200	325	794	11	1
	0200-0400	357	1,153	23	10
	0400-0600	355	12	0	0
3-4 August	2000-2200	251	465	15	189
	2200-0000	214	170	9	18
	0000-0200	260	325	15	46
	0200-0400	381	550	55	4
	0400-0600	339	119	10	2
19-20 August	2000-2200	92	114	14	0
	2200-0000	93	78	18	0
	0000-0200	187	782	20	4
	0200-0400				
	0400-0600	186	27	3	0

Appendix 5.11.—Continued.

31 August– 1 September	2000–2200	353	181	7	13
	2200–0000	358	215	16	13
	0000–0200	376	374	15	4
	0200–0400	367	254	10	8
	0400–0600	557	113	4	10
Open-water[c]					
15–16 September	2000–2200	329	93	17	0
	2200–0000	275	21	0	0
	0000–0200	382	83	1	0
	0200–0400	369	16	0	0
	0400–0600	492	11	0	0
Myriophyllum[c]					
7–8 July	2000–2200	330	98	0	5
	2200–0000	378	128	2	1
	0000–0200	328	790	13	1
	0200–0400	357	525	11	1
	0400–0600	380	4	0	0
8–9 July	2000–2200	371	553	12	0
	2200–0000	355	123	4	1
	0000–0200	327	1,694	22	64
	0200–0400	327	1,144	22	31
	0400–0600	322	10	0	4
20–21 July	2000–2200	371	207	19	0
	2200–0000	368	127	11	0
	0000–0200	370	454	5	57
	0200–0400	314	247	0	23
	0400–0600	367	23	2	0
3–4 August	2000–2200	293	140	4	1
	2200–0000	178	125	8	2
	0000–0200	360	631	8	44
	0200–0400	237	271	11	0
	0400–0600	268	37	3	0
19–20 August	2000–2200	412	128	13	0
	2200–0000	372	180	11	15
	0000–0200	372	712	29	11
	0200–0400	364	368	3	119
	0400–0600	343	69	3	15

Appendix 5.11.—Continued.

31 August- 1 September	2000-2200	415	199	11	5
	2200-0000	363	86	2	21
	0000-0200	364	175	5	92
	0200-0400	363	83	3	86
	0400-0600	447	74	1	16
15-16 September	2000-2200	485	215	15	1
	2200-0000	342	59	5	0
	0000-0200	391	35	0	0
	0200-0400	375	9	1	0
	0400-0600	453	11	0	0
Nelumbo[c]					
7-8 July	2000-2200	373	92	1	1
	2200-0000	372	212	1	0
	0000-0200	278	473	9	31
	0200-0400	278	774	14	10
	0400-0600	225	12	0	0
8-9 July	2000-2200	239	99	0	0
	2200-0000	283	157	1	8
	0000-0200	275	1,090	25	4
	0200-0400	270	1,466	37	48
	0400-0600	275	81	3	0
20-21 July	2000-2200	276	114	10	0
	2200-0000	367	119	7	0
	0000-0200	320	533	13	4
	0200-0400	284	317	6	1
	0400-0600	276	19	0	0
3-4 August	2000-2200	353	180	9	11
	2200-0000	391	377	23	11
	0000-0200	318	566	28	17
	0200-0400	366	796	25	23
	0400-0600	353	83	4	6
19-20 August	2000-2200	401	205	9	2
	2200-0000	370	248	10	2
	0000-0200	358	536	2	32
	0200-0400	357	990	28	53
	0400-0600	267	366	12	3
31 August- 1 September	2000-2200	414	98	6	1
	2200-0000	368	127	1	1
	0000-0200	352	208	3	10
	0200-0400	362	125	1	6
	0400-0600	544	88	2	28

Appendix 5.11.—Continued.

15-16 September	2000-2200	469	93	8	0
	2200-0000	360	75	6	0
	0000-0200	383	9	0	1
	0200-0400	372	12	0	0
	0400-0600	470	7	0	3
Total		Minutes	Passes	Buzzes	Other
		62,227	133,480	4,949	8,794

[a]Passes of bats other than Myotis grisescens.
[b]Habitats ca. 2 km from Blowing Wind Cave.
[c]Habitats ca. 13 km from Blowing Wind Cave.

VI. TEMPORAL VARIATION IN PRESENCE OF INSECTS AMONG HABITATS AT GUNTERSVILLE RESERVOIR, ALABAMA

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Abstract.--During summers of 1991 and 1992, and spring and summers of 1993 and 1994, insects were collected at 2-h intervals from sites on or adjacent to Guntersville Reservoir in northern Alabama. Taxonomic order, number, and weight of insects in each sample were recorded. We investigated relationships between abundance of insects and hour of the night, night of the month, sampling period and type of habitat. More insects, especially Diptera, were present just after dusk than during other hours of the night. Abundance of insects usually was greatest from June through early August. Few significant differences in abundance of insects and insect biomass were observed among hours of the night, nights of the month, and sampling periods. Habitats containing American lotus often produced greater mass of insects than other habitats.

INTRODUCTION

The area around Guntersville Reservoir is home to several large colonies of the endangered gray bat (*Myotis grisescens*). Numerous caves suitable for roosting have been documented in the area, and the reservoir and its tributaries provide productive foraging areas for gray bats. The insectivorous gray bat primarily eats aerial insects and restricts its foraging to these riparian areas (Tuttle, 1976*a*, 1976*b*).

As most insects are active only during spring and summer months, foraging activity of the gray bat also is limited seasonally. Foraging activities of the gray bat may be further limited by short-term variations in abundance of insects. Studies of birds and bats have shown that flying insectivores are limited to foraging in specific areas and at specific times relative to abundance of prey (Anthony and Kunz, 1977; Gray, 1993; Kunz, 1973; Rabinowitz, 1978). It is unknown how abundance of insects varies over time and among habitats at Guntersville Reservoir. Furthermore, it is unknown whether bats adjust patterns of foraging in response to variation in abundance of insects.

The abundance and composition of assemblages of aerial insects in riparian habitats are influenced by temporal factors, quality of habitats, and environmental conditions. Many investigators have attempted to explain distribution of aquatic, subadult insects (Dvorak and Best, 1982; Keast, 1984; Krecker, 1939; Rosine, 1955; Zwick, 1984). A few recent studies have focused on distribution of winged adult insects (Corbet, 1964; Jackson, 1988; Jackson and Fisher, 1986; McGeachie, 1989). The mature stage of insects often is brief, but certain factors may significantly alter populations of aerial insects (Williams and Feltmate, 1992).

Many insects live only for a single season. Thus, events in the lifecycle of an insect must take place in relatively rapid succession (Johnson, 1969). Therefore, hatching, emergence, dispersal, and mating may cause the abundance and composition of insect communities to fluctuate dramatically over time. The timing and duration of lifecycle events often are flexible in response to environmental factors, such as air and water temperature or photoperiod (Ward, 1992; Wolf and Zwick, 1989).

Variation in abundance of insects also may be linked to quality of habitats. Prior to emergence, distribution of aquatic nymphs may be affected by quality and characteristics of submerged vegetation, water flow, oxygenation, and substrate (Flannagan and Cobb, 1991; Ward, 1992). Greater diversity of macroinvertbrates typically corresponds to greater diversity of habitats (Keast, 1984; Krecker, 1939; Rosine, 1955; Zwick, 1984). During emergence, teneral adults usually are abundant near habitats occupied by nymphs. Thus, habitats occupied by nymphs will affect the initial distribution of winged adult insects.

Along with emergence, swarming, and dispersal, environmental factors may influence nightly abundance of aerial insects. McGeachie (1989) found that brighter lunar illumination and stronger windspeed decreased nightly catches of lepidopterans. Conversely, warmer air temperature increased nightly catches in traps.

The goal of our 4-year study was to investigate variation in assemblages of aerial insects over Guntersville Reservoir, an impoundment of the Tennessee River in northern Alabama. Comprehensive sampling allowed analysis of variation on hourly, nightly, and seasonal levels. Variation among different aquatic and terrestrial habitats also was evaluated.

MATERIALS AND METHODS

Guntersville Reservoir is a 27,479-ha impoundment of the Tennessee River in northeastern Alabama and southcentral Tennessee. It is characterized by warm waters, slow currents, and an extensive littoral zone (Tennessee Valley Authority, in litt.). The 12,141-ha of shallow water along with fertile hydrosoil promote growth of aquatic plants; both submergent and emergent macrophytes flourish in the reservoir (Tennessee Valley Authority, in litt.).

In 1991, insects were sampled in aquatic and terrestrial habitats. Because this project was part of a broader project studying the foraging ecology of *Myotis grisescens*, habitats were selected based on their proximity to Blowing Wind Cave, Jackson Co., Alabama. This large limestone cavern located adjacent to Guntersville Reservoir, is the summer roost of up to 300,000 gray bats (Tuttle, 1976*b*). Three aquatic habitats were selected in shallow coves within 2 km of Blowing Wind Cave. One habitat was characterized by an introduced macrophyte, Eurasian watermilfoil (*Myriophyllum spicatum*). This submerged plant occurs in dense groves in ≤1.5 m of water (Tennessee Valley Authority, in litt.). Fronds of Myriophyllum are visible at the surface of the water from late June through October. The density of stands of Eurasian watermilfoil can reduce circulation of water in this habitat, establishing gradients of water density, temperature, and concentration of dissolved oxygen (Tennessee Valley Authority, in litt.). A second vegetated habitat consisted of groves of American lotus (Nelumbo lutea). From July through October, stalks of Nelumbo, topped with large flat leaves, emerge from the water. Flowers of American lotus bloom in early July, and large seed pods develop in subsequent months. Like Eurasian watermilfoil, American lotus grows in shallow areas of the reservoir. The third aquatic habitat was an open-water area that contained little or no vegetation. The final area sampled was a field habitat adjacent to the reservoir. The field was dominated by grasses (Sorghum), herbaceous (Solidago), and woody growth (Rhus glabra).

In each of the four habitats, insects were collected along a 50-m transect. A mesh sweep-net was held near shoulder height and swung in a figure-8 pattern 50 times per sample. In the field habitat, samples were taken while walking through the vegetation. In the open-water habitat and habitats containing Myriophyllum and Nelumbo, collections were made while canoeing through the transects. In each habitat, five samples were taken per night. Collection occurred every 2 h beginning at 2000 h and ending at 0600 h. Insects were collected for 3 nights, every 2 weeks, for 7 sampling periods. The first period began on 26 June, and the following six periods began on 8 July, 22 July, 5 August, 20 August, 3 September, and 17 September, respectively (Appendix 6.1). Collected specimens were killed using ethyl acetate and hourly samples were stored individually in 70% ethyl alcohol. Insects were identified to order. All flying insects were included; ticks, wingless ants, springtails, and insect larvae were excluded from analyses. Spiders were included due to their ability to balloon and drift in the air. For each sample, the total number of flying insects captured, as well as the number of each order present were recorded. To record an index of biomass, insects were dried ≥12 h and weighed to the nearest mg on a Sartorius balance.

Beginning in 1992, collection of insects in the terrestrial habitat were terminated. While sampling continued in the same open-water habitat as 1991, four new study sites were established. Instead of using the Eurasian watermilfoil habitat sampled in 1991, a similar Myriophyllum habitat in a more accessible area near the open-water habitat was examined. In addition, three new habitats were located ca. 13 km from Blowing Wind Cave in the main navigation channel of the reservoir. The depth of the main channel is maintained between ca. 2.7 and 10.6 m to allow for heavy commercial and recreational navigation. Currents typically are stronger in the main channel than in the backwater areas. Two vegetated habitats, one Myriophyllum and one Nelumbo, were established in a relatively shallow sand-bar adjacent to the main channel. The fourth new locality was an open-water habitat (Or) located on the edge of the deep navigation lane.

In 1992, insects were collected using the same methods and time table as in 1991. The first of six twice-monthly sampling periods began on 6 July. Five subsequent periods began on 20 July, 3 August, 17 August, 31 August, and 14 September, respectively (Appendix 6.2).

In 1993 and 1994, the five habitats established in 1992 were examined, but samples were collected on 1 day each month for 6 sampling periods. In 1993, the first period began 10 April, and subsequent sampling periods were 7 May, 11 June, 10 July, 1 August, and 13 September (Appendix 6.3). In 1994, the sampling periods began 7 April, and following periods started 1 May, 1 June, 5 July, 6 August, and 7 September (Appendix 6.4). Procedures for storing and analyzing samples remained the same throughout the 4 years.

Because habitats and sampling schedules were changed during the 4-year study, each year was analyzed separately. Temporal variation in the presence of insects over each habitat was analyzed among hours, days, and sampling sessions. For each habitat and each of the 3-day sample periods of 1991 and 1992, corresponding samples were arranged in five groups by time of collection (2000-2159 h, 2200-2359 h, 0000-0159 h, 0200-0359 h, and 0400-0559 h) and the average number of all insects caught was calculated. Due to sample sizes < 5, the five groups of hours were compared using the non-parametric Kruskall-Wallace test (SAS Institute, Inc., 1985; Steel and Torrie, 1980). This procedure was repeated for each habitat, substituting averages of mass of insects caught. Next, for each habitat and each sample period in 1991 and 1992, the three nightly averages of total insects caught were compared using the Kruskall-Wallace test. Again, this test was repeated for each habitat, using averages of mass of insects collected during each of the 3 nights within a sampling period. Additionally, for each habitat throughout the 4 years, one-way analysis of variance (ANOVA) was used to detect differences among sampling periods measured by total numbers and mass of insects collected. Finally, for each sampling period throughout the 4 years, one-way analysis of variance was used to determine variation among habitats measured by total numbers and mass of insects collected during the sampling period.

RESULTS

From June 1991 to September 1994, 1,071 samples of insects were collected and analyzed. More than 1,800 arthropods representing Arachnida and 10 orders of Insecta were collected. Of insects collected each year, 80-90% were Diptera. Other prevalent orders included Ephemeroptera, Trichoptera, Araneida (spiders), and Lepidoptera. Occasionally, insects from the orders Coleoptera, Hemiptera, Homoptera, Hymenoptera, Odonata, and Orthoptera were captured (Table 6.1). While yearly collections of insects were similar in composition, individual samples were variable in orders of insects, number of insects, and mass of insects collected. When means were calculated for number of insects and mass of samples, standard deviations typically were large, often exceeding the mean (Appendices 6.5-6.8). Due to considerable variation among individual samples, regular patterns of abundance of insects were almost non-existent at any level.

Comparisons of total number and mass of insects among hours.—Few differences between abundance of insects and hour of the night were observed. In 1991 only nine of 26 comparisons of total number of insects and four of 26 comparisons of mass of samples differed among hours (Appendix 6.5). On average, number of insects and mass of samples were greatest at 2000 h and decreased throughout the night. When differences in number of insects occurred, they were often extreme. For example, the greatest difference among hours occurred in the field habitat during early August. The average number of insects dropped from 398.3 at 2000 h to 9.0 at 2200 h. These differences among hours occurred from late July till early September.

In 1992, five of 30 comparisons of total number and one of 30 comparisons of mass of samples differed among hours (Appendix 6.6). In most comparisons where a difference was found among hours, samples collected at 2000 h had more insects or mass than other samples during the night. In addition, in contrast to 1991, the number of insects collected often increased at 0400 h in 1992. However, these trends were not evident in all habitats during a sampling period or in one habitat throughout all sampling periods. Thus, no definite pattern of abundance of insects was evident among hours.

Comparisons of total number and mass of insects among nights.—Few differences in number and mass of insects were observed among nights. Although there often was prominent variation among the 3 nights in numbers or mass of insects captured, the great variation in individual samples precluded statistical significance (Appendix 6.7). During 1991, differences did occur during late July, early August, and late September in the field, *Myriophyllum*, and open-water habitats, respectively. In 1992, differences only occurred in total number of insects from one night to the next. Most differences were during late August and late September among *Nelumbo* and *Myriophyllum* habitats, respectively (Appendix 6.8). However, no significant pattern of variation in abundance or mass of insects among nights either among habitats or sampling sessions was evident.

Comparison of total number and mass of insects among habitats within sampling sessions.—From 1991 through 1994, number of insects and weight of samples were compared among sampling periods for each habitat. As with previous comparisons, there was much variation in abundance of insects among sampling sessions, yet fluctuations were random and sporadic (Appendix 6.9–6.12).

There were no differences in habitats throughout the year in 1991 (Appendix 6.9). On average, most insects occurred among the field and *Nelumbo* habitats. Greater numbers of insects in the field habitat occurred during early August (average = 83.2) and early September and greatest weight of samples was in June, early July, and early September (15.2, 14.5, and 20.6 mg; respectively). In the *Nelumbo* habitat numbers of insects increased throughout the summer. Greatest levels of insects were observed in early September (average = 67.4).

During 1992, differences in the total number of insects throughout the summer were observed in the *Nelumbo* (13 km from Blowing Wind Cave) and *Myriophyllum* (2 km from Blowing Wind Cave) habitats (Appendix 6.10). Differences in mass of samples were observed in both *Myriophyllum* habitats. No differences in total number or mass of insects were observed in 1993 or 1994 (Appendices 6.11–6.12).

Differences among habitats within each sampling session.—When abundance of insects was compared among habitats in each sampling period, there was much variation among habitats, although few relationships between abundance of insects and habitat were found. When significant differences in abundance of insects occurred among habitats, Nelumbo (near navigation channel) habitat usually exceeded other habitats in number of insects or mass of insects (Appendix 6.13-6.16). During 1991 and 1993, no differences were found among habitats. In 1992, differences were observed in late July, late August, and late September. In 1994, differences in mass of samples were observed in September. When habitats are ranked in order of total number of insects and total weight of samples, Nelumbo habitat has the greatest total mass of samples for 3 years. During the same 3 years, open-water (river-channel habitat) had the smallest number of insects and the smallest mass of insects each year (Table 6.2).

DISCUSSION

Our purpose was to document variation in abundance of aerial insects over time and among riparian habitats. Considerable variation in number of insects captured occurred among individual samples. Variation among samples also was present in measurements of mass. However, there was little variation in abundance at any level of comparison that could not be attributed to chance. Thus, there was almost no statistical relationship between either number of insects or mass of insects and hour, night, sampling period, or habitat. Rapid and erratic changes in abundance of insects are not unusual and may result from emergence of adults, swarming behavior, or change in environmental condition (Corbet, 1964; Jackson, 1988; Jackson and Fisher, 1986; McClure, 1938; McGeachie, 1989). Timing of emergence and swarming may differ among species of insects and may be influenced by several variables (Ward, 1992; Wolf and Zwick, 1989).

Although few statistical differences were observed, trends in abundance of insects were evident among hours, sampling periods, and habitats. Within a night, the greatest number of insects often was captured at 2000 h. This trend is especially obvious from July through August (Appendix 6.5-6.6). In 1992, number of insects collected often seemed to follow a bimodal pattern; capture usually was greatest at 2000 h and 0400 h. A number of studies have reported a great abundance of insects just after dusk, and a few have noted a second peak in abundance of insects just before dawn (Anthony and Kunz, 1977; Gray, 1993; Racey and Swift, 1985). Racey and Swift (1985) also reported that bats adjusted foraging habits in response to changes in insect density throughout the night.

Although there are few statistical differences among sampling periods, there generally were more insects in all habitats during June, July, and early August of each year. Likewise, Anthony and Kunz (1977) collected large numbers of insects during mid-summer, yet abundance of insects often fluctuated sharply. For many insectivorous bats, foraging is most intense during mid-summer, as they are raising young and depositing fat in preparation for hibernation (Racy and Swift, 1985).

Finally, comparisons among habitats often indicated a greater abundance of insects in the Nelumbo habitats than in other habitats. This trend was particularly clear in 1992. Except for 1991, total mass of insects collected each year in Nelumbo habitats was greater than samples from other habitats (Table 6.2). In several years, we observed massive emergences of large, Hexagenia mayflies (Ephemeroptera) in the Nelumbo habitat near the primary navigation channel of Guntersville Reservoir. Coleoptera and Odonata also were observed more often in the Nelumbo habitats. Insects may prefer qualities of the habitat containing American lotus, including food, oviposition sites, or shelter offered by emergent leaves (Ward, 1992).

In conclusion, wide variation in abundance of insects was noticed, regardless of hour, night, sampling period, or habitat. It is unknown how insectivorous bats respond to this variation in abundance of prey. Further analyses considering taxonomic composition of samples are necessary, as some bats are selective for specific sizes or taxa of prey (Rabinowitz, 1978; Ross, 1967). Continued investigation of availability of prey among habitats, as well as preference of gray bats for specific foraging habitats, will improve efforts to conserve essential habitat for the endangered gray bat.

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Table 6.1.—Total numbers of each order of insects collected at Guntersville Reservoir, Jackson Co., Alabama, 1991-1994. The percentage of each order in the total number of insects collected each year is shown in parenthesis.

		Orders						
Year	Total	Diptera	Ephemeroptera	Trichotera	Araneae	Lepidoptera	Coleoptera	Others[a]
1991	6,991	6,215 (88.9)	266 (3.8)	233 (3.3)	62 (0.9)	47 (0.6)	22 (0.3)	146 (2.1)
1992	6,100	5,387 (88.3)	298 (2.9)	174 (4.9)	50 (0.8)	32 (0.5)	30 (0.5)	129 (2.1)
1993	2,623	2,417 (92.1)	93 (3.5)	87 (3.3)	11 (0.4)	5 (0.2)	2 (0.1)	8 (0.3)
1994	2,395	2,298 (95.9)	24 (1.0)	37 (1.3)	10 (0.4)	5 (0.2)	7 (0.3)	14 (0.6)

[a]Includes Hemiptera, Homoptera, Hymenoptera, Odonata, Orthoptera, unidentifiable specimens

Table 6.2.—Total number of insects and mass of insects collected among habitats at Guntersville Reservoir, Jackson Co., Alabama, 1991-1994.

Year	Habitat	Number of insects	Habitat	Mass of sample (mg)
1991				
	Nelumbo[a]	2,558	Field[a]	99.1
	Field[a]	1,813	Nelumbo[a]	44.6
	Myriophyllum[a]	1,417	Open-water[a]	18.9
	Open-water[a]	1,203	Myriophyllum[a]	17.1
1992				
	Myriophyllum[a]	1,695	Nelumbo[b]	108.0
	Nelumbo[b]	1,526	Open-water[a]	21.7
	Open-water[a]	1,357	Myriophyllum[a]	17.2
	Myriophyllum[b]	944	Myriophyllum[b]	12.7
	Open-water[b]	587	Open-water[b]	9.8
1993				
	Myriophyllum[a]	1,020	Nelumbo[b]	25.8
	Open-water[a]	751	Myriophyllum[b]	20.8
	Myriophyllum[b]	378	Myriophyllum[a]	10.4
	Nelumbo[b]	260	Open-water[a]	6.7
	Open-water[b]	214	Open-water[b]	2.4
1994				
	Open-water[a]	754	Nelumbo[b]	14.4
	Myriophyllum[b]	718	Myriophyllum[b]	11.7
	Myriophyllum[a]	419	Open-water[a]	10.6
	Nelumbo[b]	378	Myriophyllum[a]	4.1
	Open-water[b]	126	Open-water[b]	1.6

[a]Habitats ca. 2 km from Blowing Wind Cave.
[b]Habitats ca. 13 km from Blowing Wind Cave.

Appendix 6.1.—Sampling sessions, dates of collection, and samples sizes used to collect insects among five habitats within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991. Habitats sampled are as follows: 1, open-water; 2, Myriophyllum; 3, Nelumbo; 4, field.

Sampling session	Sampling day	Date	Habitats 1	2	3	4
1	1	26-27 June	5	5	5	5
1	2	27-28 June	5	5	5	5
1	3	28-29 June	5	5	5	5
2	4	8-9 July	5			5
2	5	9-10 July	5	5	5	5
2	6	11-12 July	5	5	5	6
3	7	22-23 July	5	5	5	4
3	8	23-24 July	5	6	5	6
3	9	26-27 July	5	5	5	6
4	10	5-6 August	5	5	5	6
4	11	6-7 August	5	5	5	6
4	12	7-8 August	5	5	5	6
5	13	20-21 August	5	5	5	6
5	14	21-22 August	5	5	5	6
5	15	22-23 August	5	5	5	6
6	16	3-4 September	5	5	5	6
6	17	4-5 September	5	5	5	5
6	18	5-6 September	6	5	5	6
7	19	17-18 September		5	5	
7	20	18-19 September	6	6	5	
7	21	19-20 September		6	5	

Appendix 6.1.—Sampling sessions, dates of collection, and samples sizes used to collect insects among five habitats within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991. Habitats sampled are as follows: 1, open-water; 2, Myriophyllum; 3, Nelumbo; 4, field.

Sampling session	Sampling day	Date	Habitats			
			1	2	3	4
1	1	26-27 June	5	5	5	5
1	2	27-28 June	5	5	5	5
1	3	28-29 June	5	5	5	5
2	4	8-9 July	5			5
2	5	9-10 July	5	5	5	5
2	6	11-12 July	5	5	5	6
3	7	22-23 July	5	5	5	4
3	8	23-24 July	5	6	5	6
3	9	26-27 July	5	5	5	6
4	10	5-6 August	5	5	5	6
4	11	6-7 August	5	5	5	6
4	12	7-8 August	5	5	5	6
5	13	20-21 August	5	5	5	6
5	14	21-22 August	5	5	5	6
5	15	22-23 August	5	5	5	6
6	16	3-4 September	5	5	5	6
6	17	4-5 September	5	5	5	5
6	18	5-6 September	6	5	5	6
7	19	17-18 September		5	5	
7	20	18-19 September	6	6	5	
7	21	19-20 September		6	5	

Appendix 6.2.—Sampling sessions, dates of collection, and samples sizes used to collect insects among five habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1992. Habitats sampled are as follows: 1, open-water[a]; 2, Myriophyllum[a]; 3, open-water[b]; 4, Myriophyllum[b]; 5, Nelumbo[b].

Sampling session	Sampling day	Date	Habitats				
			1	2	3	4	5
1	1	26-27 June			5		
2	2	6-7 July	5	5	5	5	5
2	3	7-8 July	5	5	5	6	5
2	4	8-9 July	5	5	5	5	5
3	5	20-21 July	5	5	5	3	5
3	6	22-23 July	5	5			
3	7	23-24 July	5	5	5	5	5
4	8	3-4 August	5	5	5	5	5
4	9	4-5 August	5	5	5	5	5
4	10	5-6 August	5	5	5	5	5
5	11	17-18 August	5	5	5	5	4
5	12	18-19 August	4	4	5	5	5
5	13	19-20 August	5	5	5	5	5
6	14	31 August-1 September	5	5	5	5	5
6	15	31 August-1 September	5	5	5	5	5
7	16	14-15 September	5	5	5	5	5
7	17	15-16 September	5	5	5	5	5
7	18	16-17 September	5	5	5	5	5

[a]Habitats ca. 2 km from Blowing Wind Cave.
[b]Habitats ca. 13 km from Blowing Wind Cave.

Appendix 6.3.—Sampling sessions, dates of collection, and samples sizes of insects from five habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1993. Habitats sampled are as follows: 1, open-water[a]; 2, Myriophyllum[a]; 3, open-water[b]; 4, Myriophyllum[b]; 5, Nelumbo[b].

Sampling session	Sampling day	Date	Habitats 1	2	3	4	5
1	1	10-11 April	6	6	5	5	5
2	2	7-8 May	5	5	5	5	5
3	3	7-8 June	5	5	5	5	5
4	4	8-9 July	5	5	5	5	5
5	5	1-2 August	5	5	5	5	5
6	6	13-14 September	5	5	5	5	5

[a]Habitats ca. 2 km from Blowing Wind Cave.
[b]Habitats ca. 13 km from Blowing Wind Cave.

Appendix 6.4.--Sampling sessions, dates of collection, and samples sizes of insects from five habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1994. Habitats sampled are as follows: 1, open-water[a]; 2, Myriophyllum[a]; 3, open-water[b]; 4, Myriophyllum[b]; 5, Nelumbo[b].

Sampling session	Sampling day	Date	Habitats				
			1	2	3	4	5
1	1	1-2 May	5	5	5	5	5
2	2	1-2 June	5	5	5	5	5
3	3	5-6 July	5	5	5	5	5
4	4	6-7 August	5	5	5	5	5
5	5	7-8 September	5	5	5	5	5

[a]Habitats ca. 2 km from Blowing Wind Cave.
[b]Habitats ca. 13 km from Blowing Wind Cave.

Appendix 6.5.—Results of Kruskal-Wallace nonparametric test comparing hours within habitats during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, 1991. Mean total number and mass (±1 SD) of insects captured are reported along with sample size (n), degrees of freedom (d.f.), and probability values (P). An asterisk indicates P ≤ 0.05.

Sampling session	Habitat	Hour	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
26-28 June					
	Field	2000	3	8.7 (7.6)	2.1 (2.3)
		2200	3	4.0 (3.5)	0.5 (0.9)
		0000	3	7.3 (11.0)	36.3 (62.5)
		0200	3	7.3 (8.1)	35.2 (49.2)
		0400	3	4.7 (1.5)	2.1 (2.7)
		X = 0.826			X = 1.938
		d.f. = 4			d.f. = 4
		P = 0.935			P = 0.747
	Nelumbo	2000	2	8.0 (11.3)	9.8 (13.8)
		2200	2	7.0 (0.0)	2.1 (3.0)
		0000	2	8.0 (5.7)	6.3 (8.8)
		0200	2	0.0 (0.0)	0.0 (0.0)
		0400	2	6.0 (1.4)	0.3 (0.4)
		X = 3.669			X = 1.731
		d.f. = 4			d.f. = 4
		P = 0.453			P = 0.785
	Myriophyllum	2000	2	45.0 (63.6)	2.8 (3.9)
		2200	2	22.0 (28.3)	1.2 (1.7)
		0000	2	9.0 (8.5)	0.1 (0.1)
		0200	2	4.0 (4.2)	0.0 (0.0)
		0400	2	0.5 (0.7)	0.0 (0.0)
		X = 3.009			X = 2.642
		d.f. = 4			d.f. = 4
		P = 0.556			P = 0.619

Appendix 6.5.—Continued.

26-28 June

Open-water	2000	3	4.7 (5.7)	0.8 (1.4)
	2200	3	18.0 (18.3)	0.4 (0.1)
	0000	3	11.7 (16.1)	1.3 (2.3)
	0200	3	7.7 (8.0)	1.2 (1.7)
	0400	3	1.7 (2.9)	0.0 (0.0)
	X = 4.234			X = 4.219
	d.f. = 4			d.f. = 4
	P = 0.375			P = 0.377

8-11 July

Field	2000	3	15.0 (13.8)	3.5 (4.1)
	2200	3	4.3 (2.1)	4.3 (5.0)
	0000	3	0.7 (1.2)	1.1 (1.9)
	0200	3	1.7 (0.6)	3.9 (4.1)
	0400	3	1.3 (2.3)	59.4 (102.9)
	X = 5.186			X = 1.609
	d.f. = 4			d.f. = 4
	P = 0.269			P = 0.807
Nelumbo	2000	3	20.3 (23.5)	5.7 (8.8)
	2200	3	15.3 (9.5)	2.5 (2.1)
	0000	3	6.3 (2.5)	14.0 (11.8)
	0200	3	4.7 (3.8)	9.8 (8.5)
	0400	3	1.0 (1.7)	0.2 (0.4)
	X = 6.451			X = 4.805
	d.f. = 4			d.f. = 4
	P = 0.168			P = 0.308
Myriophyllum	2000	3	43.7 (38.4)	7.3 (6.5)
	2200	3	7.3 (3.1)	1.7 (0.9)
	0000	3	2.0 (2.0)	0.9 (1.6)
	0200	3	1.7 (1.5)	0.5 (0.9)
	0400	3	0.0 (0.0)	0.0 (0.0)
	X = 7.299			X = 5.755
	d.f. = 4			d.f. = 4
	P = 0.121			P = 0.218

Appendix 6.5.--Continued.

Open-water	2000	3	10.7 (13.6)	3.1 (4.8)
	2200	3	1.7 (2.1)	3.3 (5.7)
	0000	3	0.7 (0.6)	0.0 (0.0)
	0200	3	0.0 (0.0)	0.0 (0.0)
	0400	3	0.0 (0.0)	0.0 (0.0)
			X = 6.336	X = 5.689
			d.f. = 4	d.f. = 4
			P = 0.175	P = 0.224
22-26 July				
Field	2000	3	9.3 (12.1)	16.8 (25.3)
	2200	3	2.0 (3.5)	0.2 (0.3)
	0000	3	2.7 (3.1)	8.2 (11.8)
	0200	3	1.3 (1.2)	3.3 (2.9)
	0400	3	1.7 (1.2)	1.8 (2.3)
			X = 1.180	X = 2.898
			d.f. = 4	d.f. = 4
			P = 0.881	P = 0.575
Nelumbo	2000	3	99.7 (114.9)	15.9 (23.0)
	2200	3	9.7 (3.5)	1.7 (1.2)
	0000	3	1.7 (2.9)	0.2 (0.3)
	0200	3	2.7 (1.5)	1.1 (1.1)
	0400	3	3.3 (1.5)	1.1 (0.3)
			X = 11.218	X = 8.921
			d.f. = 4	d.f. = 4
			P = 0.024*	P = 0.063
Myriophyllum	2000	3	38.0 (55.4)	3.3 (5.1)
	2200	3	7.3 (1.2)	3.2 (1.0)
	0000	3	3.0 (3.0)	1.2 (1.7)
	0200	3	0.7 (0.6)	0.0 (0.0)
	0400	3	0.3 (0.6)	0.0 (0.0)
			X = 10.200	X = 8.353
			d.f. = 4	d.f. = 4
			P = 0.037*	P = 0.080

Appendix 6.5.—Continued.

Open-water	2000	3	2.0 (3.5)	0.4 (0.7)
	2200	3	1.0 (1.7)	1.5 (2.5)
	0000	3	0.7 (1.2)	0.0 (0.0)
	0200	3	0.3 (0.6)	0.1 (1.7)
	0400	3	0.0 (0.0)	0.0 (0.0)
			X = 1.373	X = 2.367
			d.f. = 4	d.f. = 4
			P = 0.849	P = 0.669

5-7 August

Field	2000	3	398.3 (338.5)	28.7 (18.2)
	2200	3	9.0 (3.6)	2.3 (2.1)
	0000	3	2.0 (2.7)	0.0 (0.0)
	0200	3	5.0 (1.0)	6.7 (7.6)
	0400	3	1.7 (1.5)	2.9 (4.7)
			X = 11.562	X = 10.326
			d.f. = 4	d.f. = 4
			P = 0.021*	P = 0.035*

5-7 August

Nelumbo	2000	3	97.3 (26.0)	17.1 (8.7)
	2200	3	21.7 (9.7)	6.3 (4.5)
	0000	3	8.0 (8.7)	1.0 (1.5)
	0200	3	5.7 (6.7)	7.0 (8.1)
	0400	3	8.3 (11.0)	1.6 (2.2)
			X = 9.292	X = 7.588
			d.f. = 4	d.f. = 4
			P = 0.054	P = 0.108
Myriophyllum	2000	3	33.7 (39.9)	2.3 (3.8)
	2200	3	15.3 (5.5)	3.5 (1.3)
	0000	3	4.0 (2.7)	0.2 (0.3)
	0200	3	4.7 (1.2)	0.9 (1.0)
	0400	3	2.3 (2.1)	0.2 (0.4)
			X = 8.984	X = 6.356
			d.f. = 4	d.f. = 4
			P = 0.062	P = 0.174

Appendix 6.5.—Continued.

	Open-water	2000	3	42.3 (73.3)	5.8 (10.1)
		2200	3	0.3 (0.6)	0.0 (0.0)
		0000	3	0.7 (0.6)	1.1 (2.0)
		0200	3	5.0 (5.6)	0.8 (1.4)
		0400	3	0.7 (1.2)	0.0 (0.0)
		X = 1.790			X = 2.367
		d.f. = 4			d.f. = 4
		P = 0.774			P = 0.669
20-22 August					
	Field	2000	3	4.0 (3.6)	1.5 (2.5)
		2200	3	3.3 (3.2)	2.0 (1.6)
		0000	3	1.0 (1.7)	0.0 (0.0)
		0200	3	0.7 (1.2)	3.1 (5.3)
		0400	3	0.0 (0.0)	0.0 (0.0)
		X = 5.972			X = 6.179
		d.f. = 4			d.f. = 4
		P = 0.201			P = 0.186
	Nelumbo	2000	3	141.7 (157.1)	10.5 (10.9)
		2200	3	5.7 (6.0)	4.8 (8.0)
		0000	3	2.7 (2.1)	0.2 (0.2)
		0200	3	0.3 (0.6)	0.0 (0.0)
		0400	3	1.7 (0.6)	0.4 (0.4)
		X = 9.530			X = 8.129
		d.f. = 4			d.f. = 4
		P = 0.049*			P = 0.087
20-22 August					
	Myriophyllum	2000	3	45.0 (22.7)	4.0 (1.1)
		2200	3	12.0 (3.6)	0.7 (0.4)
		0000	3	8.3 (6.4)	0.5 (0.9)
		0200	3	3.0 (3.0)	0.2 (0.2)
		0400	3	1.3 (1.5)	0.0 (0.0)
		X = 10.601			X = 10.663
		d.f. = 4			d.f. = 4
		P = 0.031*			P = 0.031*

Appendix 6.5.--Continued.

Open-Water	2000	3	184.7 (203.1)	30.0 (34.8)
	2200	3	0.3 (0.6)	0.0 (0.0)
	0000	3	8.7 (9.6)	0.1 (0.2)
	0200	3	0.0 (0.0)	0.0 (0.0)
	0400	3	0.0 (0.0)	0.0 (0.0)
	X = 10.436 d.f. = 4 P = 0.034*			X = 11.859 d.f. = 4 P = 0.018*

3-5 September

Field	2000	3	75.3 (107.2)	96.3 (163.4)
	2200	3	13.3 (17.1)	0.9 (1.6)
	0000	3	2.3 (2.5)	1.2 (1.7)
	0200	3	13.7 (11.9)	5.3 (6.4)
	0400	3	2.0 (3.5)	0.2 (0.4)
	X = 7.244 d.f. = 4 P = 0.124			X = 4.560 d.f. = 4 P = 0.336
Nelumbo	2000	3	261.7 (125.7)	22.9 (30.3)
	2200	3	26.0 (21.6)	1.1 (10.1)
	0000	3	26.7 (38.4)	6.2 (107.4)
	0200	3	22.7 (22.1)	1.1 (14.0)
	0400	3	0.0 (0.0)	0.0 (0.0)
	X = 11.057 d.f. = 4 P = 0.026*			X = 9.000 d.f. = 4 P = 0.061
Myriophyllum	2000	3	76.3 (46.3)	14.7 (10.8)
	2200	3	22.0 (15.7)	1.3 (0.8)
	0000	3	47.0 (51.3)	3.3 (3.7)
	0200	3	10.3 (5.5)	0.6 (0.6)
	0400	3	2.3 (3.2)	0.1 (0.2)
	X = 9.776 d.f. = 4 P = 0.044*			X = 10.883 d.f. = 4 P = 0.028*

Appendix 6.5.—Continued.

3-5 September

Open-water	2000	3	89.3 (77.5)	12.0 (13.1)
	2200	3	7.0 (11.3)	0.6 (1.1)
	0000	3	2.0 (2.8)	0.6 (0.9)
	0200	3	0.0 (0.0)	0.0 (0.0)
	0400	3	0.0 (0.0)	0.0 (0.0)
	X = 9.946			X = 9.132
	d.f. = 4			d.f. = 4
	P = 0.041*			P = 0.059

17-19 September

Field	2000	1	0.0 (0.0)	0.0 (0.0)
	2200	1	0.0 (0.0)	0.0 (0.0)
	0000	1	0.0 (0.0)	0.0 (0.0)
	0200	1	2.0 (0.0)	2.2 (0.0)
	0400	1	0.0 (0.0)	0.0 (0.0)
Nelumbo	2000	3	35.0 (56.4)	3.9 (6.3)
	2200	3	2.3 (4.0)	0.2 (0.4)
	0000	3	1.3 (2.3)	0.1 (0.2)
	0200	3	0.0 (0.0)	0.0 (0.0)
	0400	3	0.0 (0.0)	0.0 (0.0)
	X = 4.831			X = 4.831
	d.f. = 4			d.f. = 4
	P = 0.305			P = 0.305
Myriophyllum	2000	3	17.3 (30.0)	3.4 (5.9)
	2200	3	4.7 (6.4)	0.3 (0.5)
	0000	3	3.3 (4.9)	0.2 (0.3)
	0200	3	1.7 (1.5)	0.0 (0.0)
	0400	3	0.0 (0.0)	0.0 (0.0)
	X = 2.957			X = 2.367
	d.f. = 4			d.f. = 4
	P = 0.565			P = 0.669
Open-water	2000	0		
	2200	0		
	0000	0		
	0200	0		
	0400	0		

Appendix 6.6.—Results of Kruskal-Wallace nonparametric test comparing hours within habitats during seven sampling sessions at Guntersville Reservoir, Jackson Co., Alabama, 1992. Mean total number and mass (+ SD) of insects captured are reported along with sample size (n), degrees of freedom (d.f.), and probability values (P). An asterisk indicates $P \leq 0.05$.

Sampling session	Habitat	Hour	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
6-8 July					
	Nelumbo[b]	2000	3	40.7 (54.1)	10.5 (16.6)
		2200	3	16.7 (7.5)	25.3 (8.5)
		0000	3	5.0 (3.6)	3.7 (4.5)
		0200	3	4.3 (4.0)	7.6 (12.7)
		0400	3	43.3 (32.6)	84.8 (132.4)
		X = 6.425			X = 5.134
		d.f. = 4			d.f. = 4
		P = 0.170			P = 0.274
	Myriophyllum[a]	2000	3	45.3 (41.7)	6.0 (6.2)
		2200	3	26.7 (9.1)	3.9 (2.8)
		0000	3	8.3 (4.6)	1.0 (0.9)
		0200	3	3.3 (0.6)	0.7 (0.3)
		0400	3	27.0 (17.7)	3.8 (3.0)
		X = 9.249			X = 8.223
		d.f. = 4			d.f. = 4
		P = 0.055			P = 0.084
	Myriophyllum[b]	2000	3	85.3 (68.7)	8.5 (5.8)
		2200	3	11.7 (6.0)	3.7 (1.4)
		0000	3	1.7 (2.9)	0.4 (0.8)
		0200	3	1.0 (1.0)	0.2 (0.3)
		0400	3	26.7 (12.9)	12.7 (18.0)
		X = 12.120			X = 10.962
		d.f. = 4			d.f. = 4
		P = 0.017*			P = 0.027*

Appendix 6.6.—Continued.

6-8 July

Open-water[a]	2000	3	37.0 (11.5)	4.0 (3.2)
	2200	3	11.7 (4.2)	1.1 (1.1)
	0000	3	4.7 (3.5)	0.7 (0.6)
	0200	3	5.3 (5.8)	1.6 (2.8)
	0400	3	23.7 (8.1)	5.9 (5.8)
			X = 11.616	X = 5.103
			d.f. = 4	d.f. = 4
			P = 0.020*	P = 0.277
Open-water[b]	2000	3	30.0 (18.7)	12.7 (14.6)
	2200	3	15.0 (14.1)	4.3 (4.5)
	0000	3	6.0 (8.7)	0.5 (0.6)
	0200	3	1.7 (2.1)	0.4 (0.4)
	0400	3	10.3 (8.0)	1.1 (1.1)
			X = 6.954	X = 8.165
			d.f. = 4	d.f. = 4
			P = 0.138	P = 0.086

20-23 July

Nelumbo[b]	2000	2	35.5 (29.0)	9.1 (10.3)
	2200	2	30.5 (26.2)	4.1 (3.9)
	0000	2	32.5 (34.7)	24.4 (34.5)
	0200	2	17.5 (21.9)	8.9 (12.6)
	0400	2	141.0 (24.0)	14.6 (9.9)
			X = 5.127	X = 1.509
			d.f. = 4	d.f. = 4
			P = 0.275	P = 0.825
Myriophyllum[a]	2000	3	30.0 (8.5)	2.2 (0.7)
	2200	3	8.3 (5.8)	0.5 (0.8)
	0000	3	7.3 (7.6)	0.6 (0.6)
	0200	3	3.0 (1.7)	0.1 (0.1)
	0400	3	5.7 (3.8)	1.4 (1.5)
			X = 8.766	X = 6.927
			d.f. = 4	d.f. = 4
			P = 0.067	P = 0.140

Appendix 6.6.—Continued.

Myriophyllum[b]	2000	2	88.0 (113.1)	6.9 (8.6)
	2200	2	1.5 (2.1)	0.0 (0.0)
	0000	1	0.0 (0.0)	0.0 (0.0)
	0200	2	0.5 (0.7)	0.0 (0.0)
	0400	1	2.0 (0.0)	0.3 (0.0)
	X = 5.163			X = 6.891
	d.f. = 4			d.f. = 4
	P = 0.271			P = 0.142
20-23 July				
Open-water[a]	2000	3	33.7 (22.1)	1.9 (1.6)
	2200	3	7.3 (2.5)	17.7 (30.4)
	0000	3	3.7 (3.8)	1.2 (2.0)
	0200	3	2.7 (2.1)	0.0 (0.0)
	0400	3	33.7 (5.8)	3.6 (0.7)
	X = 11.323			X = 7.501
	d.f. = 4			d.f. = 4
	P = 0.023*			P = 0.112
Open-water[b]	2000	2	13.5 (14.9)	1.2 (0.5)
	2200	2	9.5 (6.4)	1.1 (0.3)
	0000	2	3.0 (2.8)	0.8 (0.1)
	0200	2	2.5 (2.1)	0.3 (0.4)
	0400	2	1.0 (1.4)	0.0 (0.0)
	X = 4.942			X = 7.903
	d.f. = 4			d.f. = 4
	P = 0.293			P = 0.095
3-5 August				
Nelumbo[b]	2000	3	78.3 (124.4)	8.6 (6.7)
	2200	3	8.3 (14.4)	0.7 (1.2)
	0000	3	3.0 (2.7)	0.4 (0.3)
	0200	3	2.7 (2.1)	9.9 (16.5)
	0400	3	6.7 (4.6)	3.7 (5.0)
	X = 5.104			X = 5.842
	d.f. = 4			d.f. = 4
	P = 0.277			P = 0.211

Appendix 6.6.—Continued.

Myriophyllum[a]	2000	3	31.0 (13.9)	3.6 (0.5)
	2200	3	4.0 (1.7)	0.8 (0.7)
	0000	3	1.3 (2.3)	0.3 (0.5)
	0200	3	3.0 (1.7)	0.6 (0.6)
	0400	3	15.0 (6.3)	2.0 (2.1)
			X = 11.904	X = 7.724
			d.f. = 4	d.f. = 4
			P = 0.018*	*P* = 0.102
Myriophyllum[b]	2000	3	56.3 (30.1)	6.8 (3.8)
	2200	3	16.3 (19.9)	0.7 (1.2)
	0000	3	3.3 (1.2)	0.2 (0.3)
	0200	3	1.7 (1.2)	0.3 (0.5)
	0400	3	3.0 (3.0)	0.7 (1.2)
			X = 8.628	X = 7.593
			d.f. = 4	d.f. = 4
			P = 0.071	*P* = 0.108
3-5 August				
Open-water[a]	2000	3	26.0 (11.4)	2.9 (2.0)
	2200	3	7.7 (7.1)	0.7 (1.2)
	0000	3	2.0 (1.7)	0.5 (0.5)
	0200	3	4.0 (4.0)	0.7 (0.9)
	0400	3	7.3 (4.9)	1.2 (0.6)
			X = 7.629	X = 4.718
			d.f. = 4	d.f. = 4
			P = 0.106	*P* = 0.318
Open-water[b]	2000	3	38.7 (39.9)	3.5 (3.5)
	2200	3	3.7 (0.6)	0.0 (0.1)
	0000	3	5.3 (9.2)	0.4 (0.8)
	0200	3	0.7 (0.6)	0.1 (0.2)
	0400	3	3.0 (1.7)	0.8 (1.3)
			X = 8.369	X = 5.804
			d.f. = 4	d.f. = 4
			P = 0.079	*P* = 0.214

Appendix 6.6.—Continued.

17-19 August

Nelumbo[b]

2000	2	19.5 (0.7)	6.5 (2.1)
2200	3	11.0 (8.2)	9.4 (5.8)
0000	3	9.3 (7.6)	10.8 (9.9)
0200	3	16.7 (10.7)	85.3 (87.8)
0400	3	6.7 (5.1)	6.5 (5.2)

X = 4.305; d.f. = 4; P = 0.366 | X = 7.410; d.f. = 4; P = 0.116

Myriophyllum[a]

2000	3	60.7 (18.5)	3.2 (1.1)
2200	3	34.0 (33.8)	1.4 (2.0)
0000	3	18.0 (24.3)	0.8 (1.4)
0200	3	6.0 (3.6)	0.0 (0.0)
0400	2	2.5 (2.1)	0.0 (0.0)

X = 6.529; d.f. = 4; P = 0.163 | X = 7.931; d.f. = 4; P = 0.094

Myriophyllum[b]

2000	3	12.3 (9.3)	0.9 (0.6)
2200	3	3.3 (2.5)	0.2 (0.4)
0000	3	4.3 (3.5)	1.1 (1.5)
0200	3	3.0 (1.0)	0.1 (0.2)
0400	3	0.7 (1.2)	0.0 (0.0)

X = 6.019; d.f. = 4; P = 0.198 | X = 6.730; d.f. = 4; P = 0.151

17-19 August

Open-water[a]

2000	3	25.0 (29.5)	4.7 (5.5)
2200	3	7.3 (4.5)	0.3 (0.3)
0000	3	3.0 (1.0)	0.1 (0.2)
0200	3	0.3 (0.6)	0.0 (0.0)
0400	2	3.5 (5.0)	0.0 (0.0)

X = 9.482; d.f. = 4; P = 0.050 | X = 9.262; d.f. = 4; P = 0.055

Appendix 6.6.—Continued.

Open-water[b]	2000	3	18.0 (7.0)	1.2 (0.3)
	2200	3	7.0 (2.7)	0.1 (0.2)
	0000	3	6.0 (6.2)	0.3 (0.6)
	0200	3	2.0 (1.7)	0.2 (0.3)
	0400	3	1.3 (1.5)	0.0 (0.0)
			X = 10.118 d.f. = 4 P = 0.039	X = 8.400 d.f. = 4 P = 0.078

31 August-1 September

Nelumbo[b]	2000	2	7.0 (4.2)	2.3 (2.6)
	2200	2	9.0 (5.7)	28.8 (21.8)
	0000	2	7.0 (7.1)	8.9 (2.7)
	0200	2	3.0 (2.8)	0.3 (0.4)
	0400	2	2.0 (1.4)	0.7 (0.9)
			X = 4.114 d.f. = 4 P = 0.391	X = 7.381 d.f. = 4 P = 0.117
Myriophyllum[a]	2000	2	23.0 (21.2)	1.6 (2.0)
	2200	2	5.0 (0.0)	0.3 (0.3)
	0000	2	0.5 (0.7)	0.0 (0.0)
	0200	2	3.0 (2.8)	0.0 (0.0)
	0400	2	0.5 (0.7)	0.0 (0.0)
			X = 7.702 d.f. = 4 P = 0.103	X = 8.446 d.f. = 4 P = 0.077
Myriophyllum[b]	2000	2	12.5 (3.5)	1.7 (0.3)
	2200	2	0.5 (0.7)	0.0 (0.0)
	0000	2	0.5 (0.7)	0.0 (0.0)
	0200	2	2.0 (2.8)	0.0 (0.0)
	0400	2	0.5 (0.7)	0.0 (0.0)
			X = 4.947 d.f. = 4 P = 0.293	X = 8.889 d.f. = 4 P = 0.064

31 August-1 September

Appendix 6.6.--Continued.

Open-water[a]	2000	2	15.0 (11.3)	1.1 (1.1)
	2200	2	13.0 (5.7)	1.0 (0.3)
	0000	2	4.5 (3.5)	1.7 (2.4)
	0200	2	1.0 (1.4)	0.0 (0.0)
	0400	2	1.0 (1.4)	0.0 (0.0)
			X = 7.189	X = 5.338
			d.f. = 4	d.f. = 4
			P = 0.126	P = 0.254
Open-water[b]	2000	2	12.0 (5.7)	3.5 (2.6)
	2200	2	3.0 (0.0)	0.0 (0.0)
	0000	2	0.0 (0.0)	0.0 (0.0)
	0200	2	0.5 (0.7)	0.0 (0.0)
	0400	2	0.0 (0.0)	0.0 (0.0)
			X = 8.375	X = 8.889
			d.f. = 4	d.f. = 4
			P = 0.079	P = 0.064
14-16 September				
Nelumbo[b]	2000	3	20.3 (23.6)	5.4 (4.6)
	2200	3	8.3 (2.5)	2.4 (3.1)
	0000	3	6.3 (4.5)	8.8 (6.9)
	0200	3	9.7 (6.0)	3.5 (4.5)
	0400	3	8.3 (3.8)	0.8 (0.5)
			X = 1.165	X = 5.976
			d.f. = 4	d.f. = 4
			P = 0.884	P = 0.201
Myriophyllum[a]	2000	3	30.0 (22.1)	1.8 (1.5)
	2200	3	13.0 (2.0)	0.8 (0.1)
	0000	3	5.0 (2.7)	3.4 (6.0)
	0200	3	2.3 (2.1)	0.0 (0.0)
	0400	3	2.3 (0.6)	0.7 (0.6)
			X = 10.956	X = 5.514
			d.f. = 4	d.f. = 4
			P = 0.027*	P = 0.239

Appendix 6.6.—Continued.

Myriophyllum[b]	2000	3	1.7 (2.9)	0.0 (0.0)
	2200	3	3.0 (3.6)	0.0 (0.0)
	0000	3	3.0 (2.7)	0.0 (0.0)
	0200	3	2.7 (3.1)	0.0 (0.0)
	0400	3	2.3 (2.1)	0.0 (0.0)
			X = 0.581	X = 0.000
			d.f. = 4	d.f. = 4
			P = 0.965	P = 0.999
14-16 September				
Open-water[a]	2000	3	57.0 (23.6)	4.2 (0.8)
	2200	3	10.3 (9.6)	0.4 (0.4)
	0000	3	4.3 (3.8)	0.6 (0.7)
	0200	3	5.0 (2.0)	0.1 (0.2)
	0400	3	4.3 (2.3)	0.5 (0.4)
			X = 7.462	X = 8.171
			d.f. = 4	d.f. = 4
			P = 0.113	P = 0.086
Open-water[b]	2000	3	3.0 (1.7)	0.2 (0.2)
	2200	3	3.4 (3.2)	0.3 (0.4)
	0000	3	2.3 (2.5)	1.8 (2.6)
	0200	3	1.3 (0.6)	0.0 (0.0)
	0400	3	3.7 (4.0)	0.1 (0.2)
			X = 1.267	X = 4.194
			d.f. = 4	d.f. = 4
			P = 0.867	P = 0.380

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.7.—Results[a] of Kruskal-Wallace analysis comparing total number and mass of insects among nights within each sampling session among habitats within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991. Chi-square values (X^2), degrees of freedom (d.f.), and probability levels (P) are given. An asterisk indicates $P \leq 0.05$.

Habitat	Sampling session	Date	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
Field					
	1	26 June	5	8.6 (8.7)	25.6 (46.7)
	1	27 June	5	6.0 (6.6)	19.2 (40.5)
	1	28 June	5	4.6 (3.4)	1.0 (0.7)
				X = 0.250	X = 0.805
				d.f. = 2	d.f. = 4
				P = 0.882	P = 0.747
	2	8 July	5	6.2 (11.7)	2.4 (3.4)
	2	9 July	5	5.0 (7.6)	4.3 (4.6)
	2	11 July	5	2.6 (2.4)	36.7 (79.2)
				X = 0.069	X = 0.341
				d.f. = 2	d.f. = 2
				P = 0.966	P = 0.843
	3	22 July	5	8.0 (8.6)	6.3 (8.9)
	3	23 July	5	1.6 (2.1)	10.6 (19.8)
	3	24 July	5	0.6 (0.9)	1.2 (2.3)
				X = 8.038	X = 1.381
				d.f. = 2	d.f. = 2
				P = 0.018*	P = 0.501
	4	5 August	5	18.0 (32.5)	2.4 (4.6)
	4	6 August	5	154.6 (333.4)	12.2 (19.7)
	4	7 August	5	77.0 (162.7)	9.7 (12.2)
				X = 0.383	X = 0.922
				d.f. = 2	d.f. = 2
				P = 0.826	P = 0.631

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(46.7)
(40.5)
(0.7)

= 0.805
= 4
= 0.747

(3.4)
(4.6)
(79.2)

= 0.341
= 2
= 0.843

(8.9)
(19.8)
(2.3)

= 1.381
= 2
= 0.501

(4.6)
(19.7)
(12.2)

= 0.922
= 2
= 0.631

Appendix 6.7.—Continued.

Field					
	5	20 August	5	2.4 (3.4)	0.3 (0.7)
	5	21 August	5	2.0 (2.9)	2.9 (4.0)
	5	22 August	5	1.0 (1.4)	0.8 (1.7)
				X = 0.307 d.f. = 2 P = 0.858	X = 2.580 d.f. = 2 P = 0.275
	6	3 September	5	54.0 (82.0)	58.8 (126.5)
	6	4 September	5	4.6 (4.6)	0.2 (0.4)
	6	5 September	5	5.4 (7.7)	3.4 (5.4)
				X = 5.251 d.f. = 2 P = 0.072	X = 5.824 d.f. = 2 P = 0.054
	7	18 September	5	0.4 (0.9)	44.0 (1.0)
Nelumbo					
	1	26 June	5	6.8 (5.9)	4.0 (8.7)
	1	27 June	5	4.8 (5.1)	3.3 (5.4)
				X = 0.287 d.f. = 1 P = 0.592	X = 0.000 d.f. = 1 P = 0.999
	2	7 July	5	17.8 (18.2)	7.4 (7.7)
	2	9 July	5	7.4 (7.1)	8.8 (10.8)
	2	11 July	5	3.4 (2.6)	3.0 (6.4)
				X = 2.805 d.f. = 2 P = 0.246	X = 2.676 d.f. = 2 P = 0.262
	3	22 July	5	50.6 (101.4)	9.6 (18.4)
	3	23 July	5	10.0 (17.5)	0.9 (1.1)
	3	26 July	5	9.6 (10.3)	1.5 (1.2)
				X = 0.910 d.f. = 2 P = 0.635	X = 1.643 d.f. = 2 P = 0.440

Appendix 6.7.—Continued.

	4	5 August	5	41.0 (46.3)	9.2 (8.9)
	4	6 August	5	24.0 (41.5)	5.1 (6.7)
	4	7 August	5	19.6 (30.4)	5.4 (8.5)
				X = 3.126	X = 2.075
				d.f. = 2	d.f. = 2
				P = 0.210	P = 0.354
Nelumbo					
	5	20 August	5	65.2 (144.1)	4.8 (10.2)
	5	21 August	5	12.4 (22.8)	1.1 (2.3)
	5	22 August	5	13.6 (20.3)	3.6 (5.9)
				X = 1.029	X = 1.494
				d.f. = 2	d.f. = 2
				P = 0.598	P = 0.474
	6	3 September	5	56.2 (54.2)	8.1 (9.9)
	6	4 September	5	62.2 (108.8)	5.5 (10.9)
	6	5 September	5	83.8 (171.9)	5.1 (10.7)
				X = 0.671	X = 0.867
				d.f. = 2	d.f. = 2
				P = 0.715	P = 0.648
	7	17 September	5	21.4 (44.0)	2.3 (4.9)
	7	18 September	5	0.8 (1.8)	0.1 (0.2)
	7	19 September	5	1.0 (2.2)	0.1 (0.2)
				X = 1.219	X = 1.219
				d.f. = 2	d.f. = 2
				P = 0.544	P = 0.544
Myriophyllum					
	1	26 June	5	30.8 (36.7)	1.6 (2.4)
	1	27 June	5	1.4 (1.1)	0.0 (0.1)
				X = 2.827	X = 0.809
				d.f. = 1	d.f. = 1
				P = 0.093	P = 0.368

Appendix 6.7.—Continued.

2	7 July	5	17.4 (30.8)	2.9 (5.3)
2	9 July	5	12.6 (26.0)	2.3 (4.2)
2	11 July	5	2.8 (3.3)	1.0 (1.4)
			X = 1.050	X = 0.159
			d.f. = 2	d.f. = 2
			P = 0.592	P = 0.924
3	22 July	5	22.2 (44.7)	2.3 (3.9)
3	23 July	5	3.6 (3.8)	1.2 (1.7)
3	26 July	5	3.8 (2.6)	1.1 (1.8)
			X = 0.067	X = 0.077
			d.f. = 2	d.f. = 2
			P = 0.967	P = 0.963
Myriophyllum				
4	5 August	5	19.0 (33.7)	2.2 (2.7)
4	6 August	5	6.8 (7.0)	0.7 (1.6)
4	7 August	5	10.2 (7.2)	1.4 (1.9)
			X = 1.002	X = 2.752
			d.f. = 2	d.f. = 2
			P = 0.606	P = 0.253
5	20 August	5	13.0 (17.2)	1.1 (2.1)
5	21 August	5	12.2 (8.3)	1.2 (1.9)
5	22 August	5	16.6 (29.5)	1.0 (1.1)
			X = 0.972	X = 0.594
			d.f. = 2	d.f. = 2
			P = 0.615	P = 0.743
6	3 September	5	52.0 (60.4)	7.2 (11.5)
6	4 September	5	24.0 (23.0)	2.3 (3.4)
6	5 September	5	18.8 (16.8)	2.4 (3.5)
			X = 0.561	X = 0.197
			d.f. = 2	d.f. = 2
			P = 0.755	P = 0.906
7	17 September	5	15.0 (21.3)	2.3 (4.4)
7	18 September	5	0.6 (1.3)	0.0 (0.0)
7	19 September	5	0.6 (0.9)	0.0 (0.0)
			X = 5.164	X = 6.898
			d.f. = 2	d.f. = 2
			P = 0.076	P = 0.032*

Appendix 6.7.—Continued.

Open-water

1	26 June	5	8.2 (6.1)	1.2 (1.5)
1	27 June	5	15.8 (17.5)	1.0 (1.7)
1	28 June	5	2.2 (3.0)	0.1 (0.2)
			X = 3.288	X = 3.293
			d.f. = 2	d.f. = 2
			P = 0.193	P = 0.193
2	7 July	5	6.2 (11.2)	3.7 (5.1)
2	9 July	5	0.0 (0.0)	0.0 (0.0)
2	11 July	5	1.6 (2.5)	0.1 (0.3)
			X = 4.393	X = 2.647
			d.f. = 2	d.f. = 2
			P = 0.111	P = 0.266

Open-water

3	22 July	5	0.6 (0.9)	0.1 (0.1)
3	23 July	5	1.8 (2.7)	1.1 (1.9)
3	26 July	5	0.0 (0.0)	0.0 (0.0)
			X = 2.602	X = 2.647
			d.f. = 2	d.f. = 2
			P = 0.272	P = 0.266
4	5 August	5	0.0 (0.0)	0.0 (0.0)
4	6 August	5	1.2 (1.6)	0.7 (1.5)
4	7 August	5	28.2 (55.4)	4.0 (7.6)
			X = 6.531	X = 2.299
			d.f. = 2	d.f. = 2
			P = 0.038*	P = 0.317
5	20 August	5	85.6 (180.4)	13.7 (30.6)
5	21 August	5	28.4 (59.7)	4.2 (9.2)
5	22 August	5	2.2 (4.9)	0.2 (0.4)
			X = 1.629	X = 0.428
			d.f. = 2	d.f. = 2
			P = 0.443	P = 0.807

Appendix 6.7.—Continued.

6	3 September	5	5.0 (8.5)	0.5 (0.7)
6	4 September	4	43.3 (86.5)	6.7 (13.3)
6	5 September	5	19.0 (32.5)	1.9 (3.4)
			X = 0.170	X = 0.151
			d.f. = 2	d.f. = 2
			P = 0.919	P = 0.927

Appendix 6.8.—Results of Kruskal-Wallace analysis comparing total number and mass of insects among nights within each sampling session among habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1992. Chi-square values (X^2), degrees of freedom (d.f.), and probability levels (P) are given. An asterisk indicates $P \le 0.05$.

Habitat	Sampling session	Date	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
Nelumbo[b]					
	1	6 July	5	43.2 (43.8)	16.3 (15.9)
	1	7 July	5	10.8 (17.2)	57.4 (101.1)
	1	8 July	5	12.0 (7.0)	5.5 (9.6)
				X = 3.429 d.f. = 2 P = 0.180	X = 1.117 d.f. = 2 P = 0.572
	2	20 July	5	38.4 (48.8)	5.7 (7.4)
	2	23 July	5	64.4 (57.0)	18.7 (18.8)
				X = 0.884 d.f. = 1 P = 0.347	X = 1.098 d.f. = 1 P = 0.295
	3	3 August	5	2.8 (2.8)	4.4 (5.4)
	3	4 August	5	5.0 (4.6)	6.3 (12.7)
	3	5 August	5	51.6 (95.7)	3.3 (5.8)
				X = 2.124 d.f. = 2 P = 0.346	X = 0.060 d.f. = 2 P = 0.970
	4	17 August	4	4.0 (2.2)	12.3 (9.5)
	4	18 August	5	11.8 (6.8)	42.2 (80.4)
	4	19 August	5	19.0 (5.4)	17.7 (17.0)
				X = 8.353 d.f. = 2 P = 0.015*	X = 0.1430 d.f. = 2 P = 0.931

Appendix 6.8.—Continued.

Nelumbo[b]					
	5	31 August-	5	6.6 (4.7)	5.3 (5.2)
	5	1 September	5	4.6 (4.5)	11.1 (19.1)
				X = 0.707 d.f. = 1 P = 0.401	X = 0.538 d.f. = 1 P = 0.463
	6	14 September	5	7.4 (3.8)	4.8 (5.1)
	6	15 September	5	15.4 (18.0)	3.5 (5.1)
	6	16 September	5	9.0 (5.3)	4.3 (4.9)
				X = 0.198 d.f. = 2 P = 0.906	X = 1.591 d.f. = 2 P = 0.451
Myriophyllum[a]					
	1	6 July	5	16.8 (10.1)	1.9 (1.1)
	1	7 July	5	15.6 (15.5)	1.5 (1.5)
	1	8 July	5	34.0 (36.2)	5.9 (5.0)
				X = 0.923 d.f. = 2 P = 0.630	X = 2.710 d.f. = 2 P = 0.258
	2	20 July	5	16.8 (12.6)	1.5 (1.1)
	2	22 July	5	7.2 (7.8)	0.6 (0.8)
	2	23 July	5	8.6 (12.6)	0.7 (1.3)
				X = 3.984 d.f. = 2 P = 0.136	X = 3.026 d.f. = 2 P = 0.220
	3	3 August	5	14.6 (20.2)	1.7 (2.3)
	3	4 August	5	8.2 (9.6)	1.3 (1.1)
	3	5 August	5	9.8 (7.7)	1.4 (1.3)
				X = 0.463 d.f. = 2 P = 0.793	X = 0.189 d.f. = 2 P = 0.910

Appendix 6.8.—Continued.

	4	17 August	5	18.6 (33.8)	0.9 (1.0)
	4	18 August	4	34.3 (36.3)	1.7 (2.0)
	4	19 August	5	26.2 (18.7)	1.0 (1.2)
				X = 0.852 d.f. = 2 P = 0.653	X = 0.736 d.f. = 2 P = 0.692
Myriophyllum[a]					
	5	31 August-	5	8.8 (16.5)	0.7 (1.3)
	5	1 September	5	4.0 (3.0)	0.1 (0.1)
				X = 0.563 d.f. = 1 P = 0.452	X = 0.222 d.f. = 1 P = 0.638
	6	14 September	5	9.8 (11.3)	2.6 (4.3)
	6	15 September	5	16.0 (21.3)	1.1 (1.4)
	6	16 September	5	5.8 (4.0)	0.3 (0.4)
				X = 0.469 d.f. = 2 P = 0.791	X = 2.811 d.f. = 2 P = 0.245
Myriophyllum[b]					
	1	6 July	5	23.4 (31.9)	2.9 (3.0)
	1	7 July	5	42.2 (66.6)	10.2 (14.3)
	1	8 July	5	10.2 (8.6)	2.1 (1.6)
				X = 0.322 d.f. = 2 P = 0.851	X = 0.341 d.f. = 2 P = 0.843
	2	20 July	3	57.3 (95.8)	4.3 (7.5)
	2	23 July	5	2.0 (3.5)	0.2 (0.4)
				X = 1.890 d.f. = 1 P = 0.169	X = 0.029 d.f. = 1 P = 0.864
	3	3 August	5	11.4 (19.9)	2.2 (4.9)
	3	4 August	5	20.2 (39.1)	1.3 (2.8)
	3	5 August	5	16.8 (17.3)	1.8 (1.1)
				X = 1.531 d.f. = 2 P = 0.465	X = 3.889 d.f. = 2 P = 0.143

Appendix 6.8.—Continued.

4	17 August	5	2.0 (1.6)	0.1 (0.2)
4	18 August	5	6.8 (7.6)	1.1 (1.1)
4	19 August	5	5.4 (6.2)	0.2 (0.3)
			X = 1.933	X = 4.580
			d.f. = 2	d.f. = 2
			P = 0.381	P = 0.101
5	31 August	5	2.4 (4.3)	0.4 (0.9)
5	1 September	5	4.0 (6.4)	0.3 (0.7)
			X = 0.107	X = 0.022
			d.f. = 1	d.f. = 1
			P = 0.743	P = 0.882
Myriophyllum[b]				
6	14 September	5	0.4 (0.9)	0.0 (0.0)
6	15 September	5	4.2 (1.9)	0.0 (0.0)
6	16 September	5	3.0 (2.8)	0.0 (0.0)
			X = 6.099	X = 0.000
			d.f. = 2	d.f. = 2
			P = 0.047*	P = 0.999
Open-water[a]				
	6 July	5	18.8 (19.1)	3.8 (2.9)
	7 July	5	12.2 (9.4)	1.0 (1.0)
	8 July	5	18.4 (14.6)	3.3 (5.1)
			X = 0.422	X = 2.679
			d.f. = 2	d.f. = 2
			P = 0.810	P = 0.262
	20 July	5	23.6 (23.1)	12.6 (22.5)
	22 July	5	13.0 (13.4)	1.0 (1.5)
	23 July	5	12.0 (15.0)	1.0 (1.9)
			X = 1.833	X = 2.634
			d.f. = 2	d.f. = 2
			P = 0.399	P = 0.268

Appendix 6.8.--Continued.

	3 August	5	9.4 (3.8)	0.8 (0.6)
	4 August	5	8.0 (13.0)	1.1 (1.5)
	5 August	5	10.8 (14.1)	1.7 (1.8)
			X = 1.479	X = 0.653
			d.f. = 2	d.f. = 2
			P = 0.478	P = 0.722
	17 August	5	3.4 (3.9)	2.2 (4.8)
	18 August	4	18.8 (27.3)	0.9 (1.2)
	19 August	5	4.4 (3.2)	0.1 (0.2)
			X = 1.469	X = 2.608
			d.f. = 2	d.f. = 2
			P = 0.480	P = 0.272
	31 August	5	7.2 (9.5)	0.5 (0.8)
	1 September	5	6.6 (6.6)	1.0 (1.4)
			X = 0.000	X = 0.310
			d.f. = 1	d.f. = 1
			P = 0.999	P = 0.578
Open-water[a]				
	14 September	5	9.2 (17.3)	0.9 (1.7)
	15 September	5	22.4 (34.6)	1.3 (2.1)
	16 September	5	17.0 (17.7)	1.3 (1.4)
			X = 3.984	X = 1.520
			d.f. = 2	d.f. = 2
			P = 0.136	P = 0.468
Open-water[b]				
	6 July	5	11.8 (13.1)	8.2 (12.5)
	7 July	5	11.2 (20.0)	1.7 (2.9)
	8 July	5	14.8 (11.0)	1.6 (1.1)
			X = 0.424	X = 1.594
			d.f. = 2	d.f. = 2
			P = 0.809	P = 0.451
	20 July	5	9.4 (9.6)	0.8 (0.6)
	23 July	5	2.4 (1.7)	0.5 (0.5)
			X = 1.590	X = 0.281
			d.f. = 1	d.f. = 1
			P = 0.207	P = 0.596

Appendix 6.8.—Continued.

	3 August	5	5.6 (9.8)	0.4 (0.9)
	4 August	5	18.4 (36.7)	1.5 (3.3)
	5 August	5	6.8 (5.9)	1.0 (0.9)
			X = 1.385	X = 2.582
			d.f. = 2	d.f. = 2
			P = 0.500	P = 0.275
	17 August	5	6.2 (7.6)	0.4 (0.7)
	18 August	5	7.2 (10.0)	0.3 (0.5)
	19 August	5	7.2 (5.1)	0.4 (0.5)
			X = 0.339	X = 0.000
			d.f. = 2	d.f. = 2
			P = 0.844	P = 0.999
	31 August	5	3.8 (6.9)	1.1 (2.4)
	1 September	5	2.4 (3.4)	0.3 (0.7)
			X = 0.050	X = 0.022
			d.f. = 1	d.f. = 1
			P = 0.823	P = 0.882
Open-water[b]				
	14 September	5	0.4 (0.6)	0.0 (0.0)
	15 September	5	4.6 (2.5)	0.2 (0.2)
	16 September	5	3.4 (1.7)	1.2 (2.1)
			X = 9.063	X = 5.441
			d.f. = 2	d.f. = 2
			P = 0.011*	P = 0.066

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.9.—Results of analysis of variance comparing total number and mass of insects among sampling sessions among habitats within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991. Dates of sampling sessions were: 1, 26-28 June; 2, 8-11 July; 3, 22-26 July; 4, 5-7 August; 5, 20-22 August; 6, 3-5 September; 7, 17-19 September. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates $P \leq 0.05$.

Habitat	Sampling session	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
Field				
	1	15	6.4 (6.4)	15.2 (34.7)
	2	15	4.6 (7.7)	14.5 (45.5)
	3	15	3.4 (5.8)	6.0 (12.3)
	4	15	83.2 (207.3)	8.1 (13.3)
	5	15	1.8 (2.6)	1.3 (2.6)
	6	15	21.3 (50.2)	20.6 (73.2)
	7	5	0.4 (0.9)	0.4 (1.0)
			F = 1.77 d.f. = 6 P = 0.114	F = 0.50 d.f. = 6 P = 0.804
Nelumbo				
	1	10	5.8 (5.3)	3.7 (6.8)
	2	15	9.5 (12.3)	6.4 (8.2)
	3	15	23.4 (58.8)	4.0 (10.7)
	4	15	28.2 (38.2)	6.6 (7.7)
	5	15	30.4 (82.8)	3.2 (6.6)
	6	15	67.4 (113.2)	6.3 (9.9)
	7	15	7.7 (25.6)	0.8 (2.8)
			F = 1.71 d.f. = 6 P = 0.127	F = 1.07 d.f. = 6 P = 0.388

Appendix 6.9.—Continued.

<u>Myriophyllum</u>

1	10	16.1 (29.0)	0.8 (1.8)
2	15	10.9 (22.5)	2.1 (3.8)
3	15	9.9 (25.7)	1.5 (2.5)
4	15	12.0 (19.5)	1.4 (2.1)
5	15	13.9 (18.9)	1.1 (1.6)
6	15	31.6 (38.8)	4.0 (7.1)
7	15	5.4 (13.4)	0.8 (2.6)
		$F = 1.68$	$F = 1.37$
		d.f. = 6	d.f. = 6
		$P = 0.135$	$P = 0.234$

Open-water

1	15	8.7 (11.6)	0.7 (1.3)
2	15	2.6 (6.7)	1.3 (3.2)
3	15	0.8 (1.7)	0.4 (1.2)
4	15	9.8 (32.5)	1.6 (4.5)
5	15	38.7 (107.8)	6.0 (18.1)
6	14	20.9 (48.2)	2.8 (7.2)
		$F = 1.19$	$F = 0.94$
		d.f. = 5	d.f. = 5
		$P = 0.322$	$P = 0.460$

Appendix 6.10.—Results of analysis of variance comparing total number and mass of insects among sampling sessions among habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1992. Dates of sampling sessions were: 1, 26 June; 2, 6-8 July; 3, 20-23 July; 4, 3-5 August; 5, 17-19 August; 6, 31 August-1 September; 7, 14-16 September. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates P ≤ 0.05.

Habitat	Sampling session	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
Nelumbo[b]				
	1	15	22.0 (29.8)	26.4 (59.6)
	2	10	51.4 (51.9)	12.2 (15.1)
	3	15	19.8 (56.3)	4.6 (8.1)
	4	14	12.1 (7.9)	24.9 (47.8)
	5	10	5.6 (4.5)	8.2 (13.5)
	6	15	10.6 (10.8)	4.2 (4.7)
			F = 2.47 d.f. = 5 P = 0.040*	F = 1.23 d.f. = 5 P = 0.305
Myriophyllum[a]				
	1	15	22.1 (23.4)	3.1 (3.5)
	2	15	10.9 (11.1)	0.9 (1.1)
	3	15	10.9 (12.0)	1.5 (1.5)
	4	14	25.8 (28.4)	1.2 (1.6)
	5	10	6.4 (11.4)	0.4 (0.9)
	6	15	10.5 (13.8)	1.3 (2.6)
			F = 2.35 d.f. = 5 P = 0.048*	F = 2.43 d.f. = 5 P = 0.042*
Myriophyllum[b]				
	1	15	25.3 (42.0)	5.1 (8.7)
	2	8	22.8 (58.8)	1.8 (4.5)
	3	15	16.1 (25.5)	1.7 (3.1)
	4	15	4.7 (5.7)	0.5 (0.8)
	5	10	3.2 (5.2)	0.3 (0.7)
	6	15	2.5 (2.5)	0.0 (0.0)
			F = 1.65 d.f. = 5 P = 0.158	F = 2.71 d.f. = 5 P = 0.027*

Appendix 6.10.—Continued.

Open-water[a]

1	15	16.5 (14.1)	2.7 (3.4)
2	15	16.2 (17.3)	4.9 (13.4)
3	15	9.4 (10.5)	1.2 (1.3)
4	14	8.1 (15.1)	1.1 (2.9)
5	10	6.9 (7.7)	0.8 (1.1)
6	15	16.2 (23.4)	1.2 (1.6)
		F = 1.09	F = 0.97
		d.f. = 5	d.f. = 5
		P = 0.375	P = 0.440

Open-water[b]

1	15	12.6 (14.2)	3.8 (7.6)
2	10	5.9 (7.5)	0.7 (0.5)
3	15	10.3 (21.4)	1.0 (2.0)
4	15	6.9 (7.3)	0.4 (0.5)
5	10	3.1 (5.2)	0.7 (1.7)
6	15	2.8 (2.5)	0.5 (1.3)
		F = 1.45	F = 2.08
		d.f. = 5	d.f. = 5
		P = 0.218	P = 0.077

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.11.—Results of analysis of variance comparing total number and mass of insects among sampling sessions among habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1993. Dates of sampling sessions were: 1, 10-11 April; 2, 7-6 May; 3, 11-12 June; 4, 10-11 July; 5, 1-2 August; 6, 13-14 September. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates P ≤ 0.05.

Habitat	Sampling session	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
Nelumbo[b]				
	1	5	0.0 (0.0)	0.0 (0.0)
	2	5	2.6 (5.8)	0.4 (0.9)
	3	5	25.2 (18.9)	22.2 (41.1)
	4	5	19.0 (24.5)	25.4 (31.4)
	5	5	4.4 (6.1)	2.3 (3.9)
	6	5	0.8 (0.8)	1.3 (1.9)
			F = 3.33	F = 1.57
			d.f. = 5	d.f. = 5
			P = 0.020*	P = 0.207
Myriophyllum[a]				
	1	5	0.4 (0.9)	0.1 (0.2)
	2	5	21.6 (42.2)	3.1 (7.0)
	3	5	80.0 (141.9)	8.3 (14.6)
	4	5	6.8 (12.0)	1.1 (2.2)
	5	5	48.4 (71.0)	5.4 (8.0)
	6	5	46.8 (39.2)	2.9 (2.4)
			F = 0.95	F = 0.79
			d.f. = 5	d.f. = 5
			P = 0.470	P = 0.566
Myriophyllum[b]				
	1	5	0.0 (0.0)	0.0 (0.0)
	2	5	0.8 (1.3)	0.0 (0.0)
	3	5	33.8 (37.4)	7.6 (9.4)
	4	5	37.2 (70.5)	31.3 (40.5)
	5	5	3.6 (3.4)	2.7 (4.7)
	6	5	0.2 (0.4)	0.0 (0.0)
			F = 1.49	F = 2.59
			d.f. = 5	d.f. = 5
			P = 0.229	P = 0.052

Appendix 6.11.—Continued.

Open-water[a]

1	5	1.2 (2.7)	0.0 (0.0)
2	5	7.6 (13.6)	1.3 (2.3)
3	5	55.8 (61.9)	3.5 (2.3)
4	5	8.8 (13.3)	2.7 (4.4)
5	5	8.4 (5.1)	1.0 (1.5)
6	5	68.4 (106.7)	4.9 (7.6)
		F = 1.63 d.f. = 5 P = 0.191	F = 1.09 d.f. = 5 P = 0.389

Open-water[b]

1	5	0.0 (0.0)	0.0 (0.0)
2	5	0.4 (0.9)	0.0 (0.0)
3	5	26.6 (53.4)	3.5 (7.4)
4	5	14.4 (26.4)	1.2 (2.3)
5	5	1.4 (1.3)	0.0 (0.0)
6	5	0.0 (0.0)	0.0 (0.0)
		F = 1.03 d.f. = 5 P = 0.420	F = 1.00 d.f. = 5 P = 0.441

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.12.—Results of analysis of variance comparing total number and mass of insects among sampling sessions among habitats within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1994. Dates of sampling sessions were: 1, 1-2 May; 2, 1-2 June; 3, 5-6 July; 4, 6-7 August; 5, 7-6 September. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates P ≤ 0.05.

Habitat	Sampling session	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
Nelumbo[b]				
	1	2	0.5 (0.7)	0.0 (0.0)
	3	5	46.4 (58.4)	10.2 (16.2)
	4	5	17.2 (11.5)	12.3 (18.1)
	5	5	4.4 (4.1)	0.9 (1.6)
	6	5	7.4 (5.3)	5.3 (5.3)
			F = 1.81	F = 0.83
			d.f. = 4	d.f. = 4
			P = 0.173	P = 0.525
Myriophyllum[a]				
	1	5	0.6 (0.5)	0.0 (0.0)
	2	5	1.8 (1.9)	0.4 (0.7)
	3	5	63.6 (101.4)	6.3 (11.9)
	4	4	4.0 (4.5)	0.5 (1.1)
	5	5	12.6 (11.5)	0.8 (0.9)
	6	5	2.0 (2.8)	0.2 (0.3)
			F = 1.66	F = 1.20
			d.f. = 5	d.f. = 5
			P = 0.184	P = 0.340
Myriophyllum[b]				
	1	2	0.0 (0.0)	0.0 (0.0)
	3	5	126.2 (232.9)	22.0 (44.6)
	4	5	2.4 (4.3)	0.2 (0.5)
	5	5	7.4 (14.3)	0.5 (1.1)
	6	5	7.6 (10.6)	0.7 (0.7)
			F = 1.11	F = 0.96
			d.f. = 4	d.f. = 4
			P = 0.386	P = 0.453

Appendix 6.12.—Continued.

Open-water[a]

1	5	0.0 (0.0)	0.0 (0.0)
2	5	3.6 (6.4)	0.4 (0.7)
3	5	136.8 (219.5)	20.3 (40.0)
4	4	0.8 (0.5)	0.0 (0.0)
5	5	8.8 (15.3)	0.4 (0.9)
6	5	1.0 (1.4)	0.1 (0.2)
		F = 1.77	*F* = 1.20
		d.f. = 5	*d.f.* = 5
		P = 0.160	*P* = 0.338

Open-water[b]

1	2	0.0 (0.0)	0.0 (0.0)
3	5	17.0 (21.8)	2.1 (3.8)
4	5	3.8 (5.0)	0.5 (0.5)
5	5	2.0 (2.0)	0.1 (0.3)
6	5	2.4 (3.2)	0.3 (0.3)
		F = 1.74	*F* = 0.98
		d.f. = 4	*d.f.* = 4
		P = 0.188	*P* = 0.447

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.13.—Results[a] of analysis of variance comparing total number and mass of insects among habitats within sampling sessions at sites within 2 km of Blowing Wind Cave, Jackson Co., Alabama, 1991. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates P ≤ 0.05.

Date	Habitat	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
26-28 June				
	Field	15	6.4 (6.4)	15.3 (34.7)
	Nelumbo	10	5.8 (5.3)	3.7 (6.8)
	Myriophyllum	10	16.1 (29.0)	0.8 (1.8)
	Open-water	15	8.7 (11.6)	0.7 (1.3)
			F = 1.06	F = 1.78
			d.f. = 3	d.f. = 3
			P = 0.376	P = 0.164
8-11 July				
	Field	15	4.6 (7.7)	14.5 (45.5)
	Nelumbo	15	9.5 (12.2)	6.4 (8.2)
	Myriophyllum	15	10.9 (22.5)	2.1 (3.8)
	Open-water	15	2.6 (6.7)	1.3 (3.2)
			F = 1.24	F = 1.01
			d.f. = 3	d.f. = 3
			P = 0.305	P = 0.394
22-26 July				
	Field	15	3.4 (5.8)	6.0 (12.3)
	Nelumbo	15	23.4 (58.8)	4.0 (10.7)
	Myriophyllum	15	9.9 (25.7)	1.5 (2.6)
	Open-water	15	0.8 (1.7)	0.4 (1.2)
			F = 1.48	F = 1.40
			d.f. = 3	d.f. = 3
			P = 0.231	P = 0.253

Appendix 6.13.—Continued.

5-7 August

Field	15	83.2 (207.3)	8.1 (13.3)
Nelumbo	15	28.2 (38.2)	6.6 (7.7)
Myriophyllum	15	12.0 (19.5)	1.4 (2.1)
Open-water	15	9.8 (32.6)	1.6 (4.5)
		F = 1.54	F = 2.71
		d.f. = 3	d.f. = 3
		P = 0.215	P = 0.054

20-22 August

Field	15	1.8 (2.6)	1.3 (2.6)
Nelumbo	15	30.4 (82.8)	3.2 (6.6)
Myriophyllum	15	13.9 (18.9)	1.1 (1.6)
Open-water	15	38.7 (107.8)	6.0 (18.1)
		F = 0.87	F = 0.83
		d.f. = 3	d.f. = 3
		P = 0.461	P = 0.485

3-5 September

Field	15	21.3 (50.2)	20.8 (73.2)
Nelumbo	15	67.4 (113.2)	6.3 (9.9)
Myriophyllum	15	31.6 (38.8)	4.0 (7.1)
Open-water	14	20.9 (48.2)	2.8 (7.2)
		F = 1.48	F = 0.73
		d.f. = 3	d.f. = 3
		P = 0.230	P = 0.537

17-19 September

Field	5	0.4 (0.9)	0.4 (1.0)
Nelumbo	15	7.7 (25.6)	0.8 (2.8)
Myriophyllum	15	5.4 (13.4)	0.8 (2.6)
		F = 0.28	F = 0.05
		d.f. = 2	d.f. = 2
		P = 0.759	P = 0.955

[a] $P \leq 0.05$.
* Significant at 0.05 level.

Appendix 6.14.—Results of analysis of variance comparing total number and mass of insects among habitats within sampling sessions at sites within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1992. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates P ≤ 0.05.

Date	Habitat	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
6-8 July				
	Nelumbo[b]	15	22.0 (29.8)	26.4 (59.6)
	Myriophyllum[a]	15	22.1 (23.4)	3.1 (3.5)
	Myriophyllum[b]	15	25.3 (42.0)	5.1 (8.7)
	Open-water[a]	15	16.5 (14.1)	2.7 (3.4)
	Open-water[b]	15	12.6 (14.2)	3.8 (7.1)
			F = 1.48	F = 0.73
			d.f. = 3	d.f. = 3
			P = 0.230	P = 0.537
20-23 July				
	Nelumbo[b]	10	51.4 (51.9)	12.2 (15.1)
	Myriophyllum[a]	15	10.9 (11.3)	0.9 (1.1)
	Myriophyllum[b]	8	22.8 (58.8)	1.8 (4.5)
	Open-water[a]	15	16.2 (17.3)	4.9 (3.4)
	Open-water[b]	10	5.9 (7.5)	0.7 (0.5)
			F = 3.23	F = 2.75
			d.f. = 4	d.f. = 4
			P = 0.019*	P = 0.038*
3-5 August				
	Nelumbo[b]	15	19.8 (56.3)	4.6 (8.1)
	Myriophyllum[a]	15	10.9 (13.0)	1.5 (1.5)
	Myriophyllum[b]	15	16.1 (25.5)	1.7 (3.1)
	Open-water[a]	15	9.4 (10.5)	1.2 (1.3)
	Open-water[b]	15	10.3 (21.4)	1.0 (2.0)
			F = 0.33	F = 2.04
			d.f. = 4	d.f. = 4
			P = 0.856	P = 0.098

Appendix 6.14.—Continued.

17-19 August

Nelumbo[b]	14	12.1 (7.9)	24.9 (47.8)
Myriophyllum[a]	14	25.9 (28.4)	1.2 (1.6)
Myriophyllum[b]	15	4.7 (5.7)	0.5 (0.8)
Open-water[a]	14	8.1 (15.1)	1.1 (2.9)
Open-water[b]	15	6.9 (7.3)	0.4 (0.5)
		F = 4.37	F = 3.70
		d.f. = 4	d.f. = 4
		P = 0.003*	P = 0.009*

31 August-1 September

Nelumbo[b]	10	5.6 (4.5)	8.2 (13.5)
Myriophyllum[a]	10	6.4 (11.4)	0.4 (0.9)
Myriophyllum[b]	10	3.2 (5.2)	0.3 (0.7)
Open-water[a]	10	6.9 (7.7)	0.8 (1.1)
Open-water[b]	10	3.1 (5.2)	0.4 (1.7)
		F = 0.61	F = 3.09
		d.f. = 4	d.f. = 4
		P = 0.661	P = 0.025*

14-16 September

Nelumbo[b]	15	10.6 (10.8)	4.2 (4.7)
Myriophyllum[a]	15	10.5 (13.8)	1.3 (2.6)
Myriophyllum[b]	15	2.5 (2.5)	0.0 (0.0)
Open-water[a]	15	16.2 (23.4)	1.2 (1.6)
Open-water[b]	15	2.8 (2.5)	0.5 (1.3)
		F = 2.94	F = 5.91
		d.f. = 4	d.f. = 4
		P = 0.026*	P = 0.001*

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.15.--Results of analysis of variance comparing total number and mass of insects among habitats within sampling sessions at sites within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1993. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates $P \leq 0.05$.

Date	Habitat	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
10-11 April				
	Nelumbo[b]	5	0.0 (0.0)	0.0 (0.0)
	Myriophyllum[a]	5	0.4 (0.9)	0.1 (0.2)
	Myriophyllum[b]	5	0.0 (0.0)	0.0 (0.0)
	Open-water[a]	5	1.2 (2.7)	0.0 (0.0)
	Open-water[b]	5	0.0 (0.0)	0.0 (0.0)
			F = 0.85	F = 1.00
			d.f. = 4	d.f. = 4
			P = 0.510	P = 0.431
7-8 May				
	Nelumbo[b]	5	2.6 (5.8)	0.4 (0.9)
	Myriophyllum[a]	5	21.6 (42.2)	3.1 (7.0)
	Myriophyllum[b]	5	0.8 (1.3)	0.0 (0.0)
	Open-water[a]	5	7.6 (13.6)	1.3 (2.3)
	Open-water[b]	5	0.4 (0.9)	0.0 (0.0)
			F = 0.98	F = 0.78
			d.f. = 4	d.f. = 4
			P = 0.440	P = 0.551
11-12 June				
	Nelumbo[b]	5	25.2 (18.9)	22.2 (41.1)
	Myriophyllum[a]	5	80.0 (141.9)	8.3 (14.6)
	Myriophyllum[b]	5	33.8 (37.4)	7.6 (9.4)
	Open-water[a]	5	55.8 (61.9)	3.5 (2.3)
	Open-water[b]	5	26.6 (53.4)	3.5 (7.4)
			F = 0.48	F = 0.73
			d.f. = 4	d.f. = 4
			P = 0.750	P = 0.583

Appendix 6.15.--Continued.

10-11 July			
Nelumbo[b]	5	19.0 (24.5)	25.4 (31.4)
Myriophyllum[a]	5	6.8 (12.1)	1.1 (2.2)
Myriophyllum[b]	5	37.2 (70.5)	31.3 (40.5)
Open-water[a]	5	8.8 (13.3)	2.7 (4.4)
Open-water[b]	5	14.4 (26.4)	1.2 (2.3)
		$F = 2.06$	$F = 0.56$
		d.f. = 4	d.f. = 4
		$P = 0.124$	$P = 0.695$
1-2 August			
Nelumbo[b]	5	4.4 (6.1)	2.3 (3.9)
Myriophyllum[a]	5	48.4 (71.0)	5.4 (8.0)
Myriophyllum[b]	5	3.6 (3.4)	2.7 (4.7)
Open-water[a]	5	8.4 (5.1)	1.0 (1.5)
Open-water[b]	5	1.4 (1.3)	0.0 (0.0)
		$F = 1.92$	$F = 0.99$
		d.f. = 4	d.f. = 4
		$P = 0.146$	$P = 0.434$
13-14 September			
Nelumbo[b]	5	0.8 (0.9)	1.4 (1.9)
Myriophyllum[a]	5	46.8 (39.2)	2.9 (2.4)
Myriophyllum[b]	5	0.2 (0.4)	0.0 (0.0)
Open-water[a]	5	68.4 (106.7)	4.9 (7.6)
Open-water[b]	5	0.0 (0.0)	0.0 (0.0)
		$F = 2.02$	$F = 1.63$
		d.f. = 4	d.f. = 4
		$P = 0.131$	$P = 0.206$

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Appendix 6.16.--Results of analysis of variance comparing total number and mass of insects among habitats within sampling sessions at sites within 2 and 13 km of Blowing Wind Cave, Jackson Co., Alabama, 1994. F-values (F) degrees of freedom (d.f.) and probability levels (P) are given. An asterisk indicates P ≤ 0.05.

Date	Habitat	n	Total number of insects Mean (SD)	Mass (mg) of insects Mean (SD)
7-8 April				
	Nelumbo[b]	2	0.5 (0.7)	0.0 (0.0)
	Myriophyllum[a]	5	0.6 (0.5)	0.0 (0.0)
	Myriophyllum[b]	2	0.0 (0.0)	0.0 (0.0)
	Open-water[a]	5	0.0 (0.0)	0.0 (0.0)
	Open-water[b]	2	0.0 (0.0)	0.0 (0.0)
			F = 2.10 d.f. = 4 P = 0.149	
1-2 May				
	Myriophyllum[a]	5	1.8 (1.9)	0.4 (0.7)
	Open-water[a]	5	3.6 (6.4)	0.4 (0.7)
			F = 0.36 d.f. = 1 P = 0.560	F = 0.00 d.f. = 1 ---
1-2 June				
	Nelumbo[b]	5	46.4 (58.4)	10.2 (16.2)
	Myriophyllum[a]	5	63.6 (101.4)	6.3 (11.9)
	Myriophyllum[b]	5	126.2 (232.9)	22.0 (44.6)
	Open-water[a]	5	136.8 (219.5)	20.3 (40.0)
	Open-water[b]	5	17.0 (21.8)	2.1 (3.8)
			F = 0.57 d.f. = 4 P = 0.685	F = 0.47 d.f. = 4 P = 0.756

Appendix 6.16.--Continued.

5-6 July

Nelumbo[b]	5	17.2 (11.5)	12.3 (18.1)
Myriophyllum[a]	5	4.0 (4.5)	0.5 (1.1)
Myriophyllum[b]	5	2.4 (4.3)	0.2 (0.5)
Open-water[a]	5	0.8 (0.5)	0.0 (0.0)
Open-water[b]	5	3.8 (5.0)	0.5 (0.5)
		F = 4.93	F = 1.92
		d.f. = 4	d.f. = 4
		P = 0.007*	P = 0.151

6-7 August

Nelumbo[b]	5	4.4 (4.1)	0.9 (1.6)
Myriophyllum[a]	5	12.6 (11.5)	0.8 (0.9)
Myriophyllum[b]	5	7.4 (14.3)	0.5 (1.1)
Open-water[a]	5	8.8 (15.3)	0.4 (0.9)
Open-water[b]	5	2.0 (2.0)	0.1 (0.3)
		F = 0.70	F = 0.46
		d.f. = 4	d.f. = 4
		P = 0.599	P = 0.766

7-8 September

Nelumbo[b]	5	7.4 (5.3)	5.3 (5.3)
Myriophyllum[a]	5	2.0 (2.8)	0.2 (0.3)
Myriophyllum[b]	5	7.6 (10.6)	0.7 (0.7)
Open-water[a]	5	1.0 (1.4)	0.1 (0.2)
Open-water[b]	5	2.4 (3.2)	0.3 (0.3)
		F = 1.57	F = 4.37
		d.f. = 4	d.f. = 4
		P = 0.221	P = 0.011*

[a]Habitats located ca. 2 km from Blowing Wind Cave.
[b]Habitats located ca. 13 km from Blowing Wind Cave.

Tennessee Valley Authority Environmental Auditing Procedure EP&P-SDP-5.7, Rev. 0003

December 15, 2005

TVA EPP Standard Department Procedure	TITLE **Environmental Auditing Procedure**	**EP&P-SDP-5.7** **Rev. 0003** **Page 1 of 35** Effective Date 12-15-05

Prepared by:	Environmental Auditing	
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Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0	10-01-01	All	Initial issue
1	12-09-02	All	Deleted reference to rotational auditors, defined open findings, and added requirement to use the Temporary PER Form until COO Corrective Action Program is issued, added Office of the General Counsel to distribution list for Unannounced Audits, and other minor editorial changes.
2	10-01-03	All	Revised in response to self-assessment report EP&P-EMS-EA&ERAL-04-01-03. Changes include: • Statement Corporate Environmental Auditing meets the guidelines of ISO 19001 • Additional information on the format, content and transmittal of audit reports • Additional information on audit guides, tracking of audit findings, and maintenance of audit records • Statement the VP-EP&P may certify lead auditors • Other minor editorial changes
3	12-15-05	All	Revised to address self-assessment areas for improvement, update titles and references, and incorporate other minor editorial changes.

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1.0 PURPOSE

TVA-SPP-5.14 Environmental Auditing Process directs Environmental Auditing to conduct audits of agency facilities, activities, and contractors. This implementing procedure provides guidance for conducting such audits and helps ensure that audits are comprehensive, systematic, objective, and independent.

2.0 SCOPE

A. Environmental Auditing provides TVA corporate management and operations managers with thorough, timely, and accurate information on the effectiveness of the facility's environmental program, implementation of the TVA EMS at the facility level and the facility's compliance with environmental laws, regulations, and the TVA EMS. The audit will focus on the time period since the previous audit of the same facility/region.

B. Environmental Auditing meets the guidelines and provisions of:

1. ISO 14001 Environmental Management System - Specification with Guidance for Use (2004)

2. ISO 19011S Guidelines for Quality and/or Environmental Management Systems Auditing - U.S. Version with Supplemental Guidance Added (2004ISO 19001)

3. Environmental Protection Agency's (EPA's) Environmental Auditing Policy Statements, Federal Register, Vol. 51, July 9, 1986 and Vol. 59, July 28, 1994

4. The Auditing Roundtable's Standards for Performance of Environmental, Health, and Safety Audits, February 1993

5. EPA's Generic Protocol for Conducting Environmental Audits of Federal Facilities, December 1996

2.2 Environmental Management System (EMS) Audits

TVA EMS audits are comprehensive, addressing the implementation and effectiveness of the EMS at the facility level and the facility's compliance with the TVA EMS and with regulations governing air, water, toxic substances, solid and hazardous wastes, and other environmental areas. These audits also address compliance with TVA environmental policies.

2.3 Unannounced Audits

The scope of unannounced audits is limited to one regulatory area (e.g., hazardous waste, air, PCBs, solid waste) and will focus only on compliance issues. The audit will include records review, interviews, and site inspections.

2.4 Program Audits

Program audits assess environmental issues such as SBU/BU level implementation of the TVA EMS or TVA-wide issues that cannot be adequately addressed in facility-level audits.

2.5 Environmental Restricted Awards List (ERAL) Audits

ERAL audits assess environmental and financial risks of companies currently on or being considered for TVA's ERAL. These include vendors responsible for managing and disposing of TVA's wastes as defined in TVA-SPP-5.17 Environmental Restricted Awards List (ERAL) Procedure.

3.0 PROCEDURE

3.1 Roles and Responsibilities

Audit Steering Team

A. The Audit Steering Team is comprised of members from the SBUs/BUs, EP&P Staff (Team Lead Environmental Auditing) and the Office of the General Counsel (OGC). Participation from front-line employees is encouraged. The Team:

1. Participates in the annual Team meeting
2. Provides input on TVA-SPP-5.14 and EP&P's implementing procedures
3. Provides input for facilities and programs to be audited
4. Reviews draft audit schedule and identifies scheduling conflicts and solutions
5. Evaluates the process indicator data and addresses any process issues

B. The Team meets annually in the fourth quarter of the fiscal year and periodically during the year as needed. Issues may be communicated by the Audit Steering Team Lead to the Environmental Peer Team (ENVPT) for guidance.

Environmental Auditing Manager

The Environmental Auditing Manager is responsible for the following:

A. Ensure development and maintenance of the audit procedure

B. Ensure development and maintenance of the audit schedule, in collaboration with Audit Steering Team, and arrange for necessary resources

C. Assign audit teams

D. Perform lead auditor or auditor duties

E. Ensure proper format, accuracy, clarity, consistency, and thoroughness of audit reports

F. Ensure audit data is provided for quarterly status reports

G. Ensure issuance of reports on audit process indicators

H. Manage Environmental Auditing's budget

I. Ensure professional conduct of audits

3.1 Roles and Responsibilities (continued)

J. Certify lead auditors

K. Ensure training of lead auditors and auditors

L. Ensure maintenance of audit guides, issues lists, and other audit tools

M. Ensure maintenance of environmental audit files (e.g., audit reports)

Lead Auditor

Lead auditors are responsible for the following:

A. Assist Environmental Auditing Manager in preparing schedules, assigning audit teams, developing budget documents, maintaining the audit procedure, preparing audit process indicator and quarterly status reports, maintaining audit guides and issues lists, and maintaining audit files

B. Lead the assessment of the effectiveness of the environmental program at the facility, and the evaluation of the facility's implementation of and compliance with the TVA EMS

C. Ensure professional conduct of audits

D. Certify auditors in each regulatory area

E. Prepare facility audit announcement

F. Make specific arrangements for conducting audits

G. Communicate specific assignments to audit team members

H. Prepare pre-audit information package for team members

I. Direct conduct of audits

J. Direct preparation and peer review of audit reports

K. Ensure proper format, accuracy, clarity, consistency and thoroughness of audit reports

L. Sign final audit reports

M. Present audit results to facility management

N. Ensure that the EP&P Learning Development Representative enters audit results into the audit tracking system

O. Distribute final audit reports

P. Complete pre-job and post-job safety checklists

3.1 Roles and Responsibilities (continued)

Environmental Auditor

A. Environmental auditors are responsible for the following:

1. Prepare for assigned audits

2. Complete assignments in accordance with this procedure

3. Prepare audit report input

4. Participate in the peer review of audit reports

5. Develop and maintain audit guides and issues lists, as assigned

B. Environmental auditors must have the following qualifications and skills:

1. Experience and skill in interpersonal relations

2. Good oral and written communication skills

3. Understanding of environmental management systems

4. Experience in and knowledge of techniques for organizing complex activities and motivating people to achieve goals and objectives

5. Overall knowledge and understanding of environmental laws and regulations

6. Understanding of TVA operations and environmental practices

7. Understanding of quality assurance

Clerical Support

EP&P clerical staff provides secretarial and administrative services to the Environmental Auditing staff, as needed.

Learning Development Representative (LDR)

The EP&P LDR provides support for lead auditors and audit team by tracking and analyzing audit findings and corrective actions, distributing audit reports, and providing other services as needed.

3.1 Roles and Responsibilities (continued)

Audit Assistant/Observer

A. Staff from other TVA organizations may accompany the audit team as Audit Assistants/Observers. There are no specific qualifications or responsibilities for an Audit Assistant/Observer. They may observe one or more regulatory area during an audit and/or assist the audit team by reviewing records or performing other routine tasks. The assistance is done under the direct supervision of an auditor. Approval to accompany the audit team must be obtained from Environmental Auditing and the audited facility before the audit. The Audit Assistant/Observer's organization is responsible for their travel, per diem, and salary expenses.

B. Persons from other agencies or companies may occasionally accompany audit teams as observers. Arrangements for such a visit must be approved by the Environmental Auditing Manager and the management of the audited facility.

3.2 Auditor Training, Certification, and Development

3.2.1 Auditor Training

Upon joining Environmental Auditing, a new auditor and the Environmental Auditing Manager develop a training plan. This plan is designed to get the auditor certified in as many regulatory areas as practical and to help the new auditor become familiar with auditing methods and techniques. The training plan generally consists of:

A. An introductory course in environmental auditing taken within six months after joining Environmental Auditing.

B. Self-study and/or formal training in each regulatory area (e.g., Clean Water Act, Resource Conservation and Recovery Act, and Toxic Substances Control Act).

C. ISO 14001 EMS introductory course taken within one year after joining Environmental Auditing.

3.2.2 Lead Auditor Certification

A. An auditor must become certified before leading an audit. To be certified as a lead auditor, knowledge and understanding of the following must be demonstrated:

1. Auditing principles and standards

2. TVA operations, including experience in dealing with environmental issues at TVA facilities and an understanding of how regulations apply to TVA operations

3. Federal, state, and local environmental regulations, and TVA environmental policies and procedures

4. Controls needed to maintain compliance in various TVA operations

5. Auditing techniques

B. Detailed requirements for certification are shown in Appendix B.

3.2.2 Lead Auditor Certification (continued)

C. Lead auditors are also required to obtain EMS and Compliance certification from the Board of Environmental Auditor Certification (BEAC) or an equivalent certification.

3.2.3 Regulatory Area Certification

A. Auditors and lead auditors are to become certified in all regulatory areas in accordance with their training plan.. Certification means that the auditor understands the regulatory requirements and is able to apply that knowledge in an audit. An auditor or lead auditor certified in a regulatory area may certify a new auditor.

B. A new auditor first becomes knowledgeable of applicable federal, state, and local regulations, Environmental Auditing audit guides, and other materials. They then participate in an audit where they observe the certified auditor conduct that portion of the audit. In a subsequent audit, a new auditor has complete responsibility for the regulatory area and is observed by the trainer and then certified. Certification is documented. The Environmental Auditing Manager may waive the certification requirement if it is determined the auditor has thorough knowledge of the regulatory requirements and is able to apply that knowledge in an audit.

C. Regulatory areas certifications include:

1. Air
2. Asbestos
3. Drinking Water
4. Emergency Planning and Community Right to Know Act (EPCRA)
5. Hazardous Wastes
6. National Environmental Policy Act (NEPA)
7. Oil Pollution Prevention
8. Pesticides
9. Polychlorinated Biphenyls (PCBs)
10. Solid Waste
11. Underground Storage Tanks
12. Used Oil
13. Water

3.2.4 Professional Development

A. Lead auditors and auditors should take at least 80 hours of training each year. Training may address any of the following elements:

1. Environmental regulations
2. EMS auditing techniques
3. Internal audit methods and standards
4. Interpersonal skills
5. Oral and written communications
6. Industry developments in environmental compliance and controls

B. The Environmental Auditing Manager discusses training opportunities and needs with each auditor. Specific training assignments are made a part of each auditor's personal goals and objectives for the next fiscal year. Training may include TVA and non-TVA courses. Training progress is reviewed quarterly.

3.3 Audit Scheduling

3.3.1 EMS Audits

A. Environmental Auditing, based on input from SBUs and the Audit Steering Team, identifies and maintains a list of all TVA facilities and activities to be audited. Environmental Auditing prepares an annual schedule and presents it to the Audit Steering Team for review by July 1. Environmental Auditing finalizes and distributes the schedule to the Audit Steering Team by August 1. The schedule may be adjusted during the year if conflicts develop. Any schedule revisions will be coordinated with affected operating organizations. Unannounced audits are not shown on the schedule.

B. Given the large number of TVA facilities that potentially pose environmental risk, an important issue facing the environmental audit program is how to make best use of available audit resources. A quantitative systematic risk-based process to select and schedule audits is used to ensure available audit resources are used effectively. Appendix A describes the procedure used in risk-based scheduling.

3.3.2 Unannounced Audits

A. A limited number of unannounced regulatory compliance audits will be conducted each year. These audits will help verify that facilities are prepared for unannounced regulatory inspections.

B. The decision on which facilities will receive unannounced audits is based on such factors as:

1. Closure time for previous findings
2. Likelihood of a regulatory inspection

3.3.2 Unannounced Audits (continued)

3. Compliance history

4. Implementation and effectiveness of EMS

5. Time since the last audit

6. Regulatory or organizational changes since the last audit

C. The audit will generally consist of two auditors and be completed in one day.

3.3.3 Program Audits

A limited number of program audits may be conducted each year. Selection of program audits is based on input from the Audit Steering Team, the EMS Steering Team, the ENVPT, and TVA management.

3.3.4 ERAL Audits

Approximately 12 ERAL audits will be scheduled and conducted each year in accordance with TVA-SPP-5.17 Environmental Restricted Awards List (ERAL) Procedure.

3.4 Audit Protocol

The following describes the protocol for conducting EMS audits. There are minor variations when conducting unannounced, program and ERAL audits. For example, no announcement memo is issued for unannounced audits. Specific guidelines for unannounced, program and ERAL audits are maintained on the Environmental Auditing's networked computer system.

3.4.1 Audit Identification

Each audit is assigned an identification number. The audit number consists of a set of letters followed by a set of numbers. The letters identify the facility to be audited. Six numbers are used to identify the scheduled date of the audit entrance meeting. For example, CUF-02-03-06 identified an audit of Cumberland Fossil Plant with a scheduled entrance meeting date of March 6, 2002. Audit numbers for unannounced audits will identify the media audited; for example, CUF(HW)-02-03-06 for a hazardous waste audit.

3.4.2 Pre-site Visit

A. Audit Preparation

1. About four weeks before a scheduled audit, the lead auditor should begin preparation by referring to the lead auditor package. This package is maintained on Environmental Auditing's networked computer system and includes, among other things:

   a. A detailed list of lead auditor responsibilities for each audit phase: pre-site, onsite, and post-site visit

   b. An announcement memorandum, audit documents checklist, audit coordination form, and environmental audit information handout

3.4.2 Pre-site Visit (continued)

c. A pre-audit questionnaire to be completed by facility staff before the audit

d. Entrance, pre-exit, and exit meeting outlines

e. Entrance and exit meeting attendance forms

f. Audit interview schedule form

g. Standard audit report format

h. Audit Quality questionnaire

2. The lead auditor or designee contacts the audited Lead Manager and/or environmental contact to discuss the audit and to confirm entrance meeting arrangements. At this time, the pre-audit questionnaire is sent to the environmental contact to complete and return. The environmental contact of the audited facility is informed that an onsite work area equipped with a telephone will be needed by the auditors, and that certain records and file materials will be needed in the work area when the audit team arrives at the site.

3. The lead auditor or designee should prepare the announcement memorandum and audit documents checklist for transmittal to the Lead Manager of the audited facility. Copies of the memorandum are sent to off-site management of the audited operation, OGC, Environmental Auditing staff, and others as appropriate.

4. Approximately one week before the entrance meeting, the lead auditor should confirm work area and document review arrangements with the environmental contact.

5. The lead auditor is responsible for preparing the audit coordination form and environmental audit information handout. If outside expertise is needed, the lead auditor is responsible for coordinating necessary arrangements. The lead auditor or designee makes travel arrangements for the audit team.

6. Auditors are generally assigned to a specific audit when the annual audit schedule is prepared. The lead auditor is responsible for coordinating auditor selection changes when schedule conflicts occur or specific technical expertise is needed.

B. Gathering Background Information

1. The lead auditor is responsible for ensuring that audit information is provided to each audit team member about two weeks before the audit. The package includes:

a. Audit announcement memorandum and attachments

b. Audit coordination form

c. Environmental audit information sheet

3.4.2 Pre-site Visit (continued)

d. Completed pre-audit questionnaire

2. Auditors prepare by reviewing the audit information package, EMS audit protocols, applicable regulations (federal, state, and local), facility environmental procedures, and Environmental Auditing files. Auditors also obtain audit guides and issues lists for assigned regulatory areas. These are maintained by Environmental Auditing staff on the networked computer system.

C. Audit Team Meeting

The lead auditor should meet with the audit team approximately one week before the entrance meeting to confirm final audit arrangements and ensure that computer equipment, manuals, regulations, safety equipment, and other items are available for the audit. The lead auditor should ensure assignments are clear for completing the EMS review. The pre-job safety checklist is usually completed during this meeting. After this meeting, the lead auditor should call the environmental contact or Lead Site Manager to confirm arrangements for the entrance meeting.

3.4.3 Onsite Activities

A. Entrance Meeting

1. The entrance meeting is scheduled and conducted at the convenience of the Lead Manager of the audited facility. The audit team should arrive at the site 15-30 minutes before the time of the meeting.

2. The lead auditor conducts the entrance meeting and distributes an attendance form. An environmental audit information sheet is provided to each attendee for reference. The lead auditor offers to have the audit team meet with the manager and environmental contact each day to summarize results.

3. Consistent with the pre-job safety checklist, the lead auditor will:

a. Confirm audit team work room or space location

b. Confirm work hours and restrictions on working past the normal shift hours

c. Review safety equipment needs (shoes, hard-hats, safety glasses, hearing protection)

d. Verify whether there are any areas at the facility undergoing construction, maintenance, or outage activities

e. Request facility staff to come to the team work room for audit interviews and to escort auditor for site inspections

3.4.3 Onsite Activities (continued)

B. EMS Overview Meeting and Site Tour

1. After the entrance meeting, the lead auditor facilitates a meeting with the entire audit team and the facility environmental contact to obtain EMS overview information. The audit team poses questions regarding how the EMS is implemented and functions at the facility.

2. The audit team may take a guided tour of the site with the environmental contact.

C. Gathering Information

D. Audit information is gathered by interviewing, observing, records review, and sampling.

1. Interviewing

a. Whenever possible, interviews will be scheduled and conducted in an area free from distraction. The auditor has discretion on who should be included in the interview. The auditor defines the topics to be covered before the interview begins.

b. Standard audit interview techniques, including use of open-ended questions, are used. "How does this work?", "How do you know?" or "How do you ensure?" types of questions are preferred in determining the effectiveness of the facility environmental program and EMS implementation. Auditors are discouraged from relying on checklists during the interview and take only brief notes to identify key information from the interview. As soon as practical following each interview the auditor prepares expanded notes to more completely summarize the information from the interview. Tape recorders are not used during interviews.

2. Observation

Observation involves inspecting the facility and various EMS implementation and compliance activities. For example, if a facility is required to take water samples or conduct inspections, these activities may be observed by the auditor. If no activities are scheduled, the auditor may request a demonstration of activities unless it involves impractical startup and operation of equipment. All potential issues (findings and observations) are noted and discussed with the appropriate personnel at the time of discovery. Pictures may be used to document observations for the exit meeting.

3. Records Review

Records review consists of examining documentation to ensure accuracy and to compare practices against EMS and compliance requirements. This activity verifies the existence of documents which provide evidence that the EMS is being effectively implemented and that the facility is in compliance with the TVA EMS and regulatory requirements.

3.4.3 Onsite Activities (continued)

4. Sampling

Sampling is a process where evidence is gathered by examining only a portion of a broad array of items. Because of time constraints, it is often necessary to use sampling in interviews, observations, and records review. Sampling methods that may be used include random sampling, block sampling, and stratified sampling. The criteria to be used in selecting the size of the sample are:

a. The importance of the information in evaluating the effectiveness of the facility's environmental program

b. Risk of overlooking a finding

c. Probability of a finding

d. Available time

E. Documentation of Auditor Work

1. Documentation of information collected during an audit should be sufficient, reliable, relevant, and useful to provide a sound basis for reporting on the effectiveness of the facility's environmental program, implementation of the TVA EMS, findings, and observations. Written notes, along with memoranda, reports, letters, pictures and other documents constitute documentation. Each subject reviewed in the audit is to be documented sufficiently so that the lead auditor or another auditor of similar skill could confirm the conclusions of the first auditor. The auditor's written notes need to be legibly written or printed in ink with date, page number, auditor's initials, and facility name on each page.

2. Auditor notes are discarded after all corrective actions have been closed. Notes from ERAL audits are discarded after the decision is made on whether to include the facility on the ERAL.

F. Evaluating Results

Before daily briefings and the pre-exit and exit meetings, each auditor and the team evaluates information gathered from interviews, observation, and records review. The information is compared to regulatory and EMS requirements. The lead auditor is in contact with the audit team members throughout the audit to determine how the information collected is to be included in the report.

G. Pre-exit Meetings

It is important for the audit team to have a well-organized presentation of audit results prepared for the exit meeting. This is accomplished by initially conducting an audit team peer review and then a meeting with the facility's staff.

3.4.3 Onsite Activities (continued)

1. Audit Team Peer Review

   Each auditor prepares input for the audit report and provides it to the lead auditor. The lead auditor completes the overall assessment of the effectiveness of the environmental program, and implementation of the TVA EMS based on input from the audit team. The lead auditor compiles a draft report. The audit team then meets to discuss and revise the report. Each auditor presents the details of his or her EMS assessment and proposed findings and/or observations. Each EMS assessment, finding, and observation and the interrelationships are subjected to a team peer review and a decision is made as to whether and how the information will be included in the report and how it will be used. The team jointly prepares the Executive Summary. The lead auditor is responsible for resolving differences of opinion among the team and preparing a revised draft report.

2. Facility Meeting

   After the audit team peer review, a pre-exit meeting is held with the audited facility environmental contact and other appropriate managers and staff to discuss the EMS assessment, findings, and observations. The draft audit report is presented at that time, and the EMS assessment and all findings and observations are thoroughly discussed. It is important either to reach a consensus on identified issues or identify any areas of disagreement during this meeting. After this meeting, the final audit report is prepared and signed by the lead auditor.

H. Exit Meeting

The exit meeting is held with the Lead Manager (or designee) and appropriate staff. The final audit report is provided and serves as the basis for discussion at the meeting. The lead auditor discusses the executive summary and the results of the team's assessment of the effectiveness of the facility's environmental program and EMS implementation. Then each audit team member (or lead auditor) presents the audit findings and observations identified in their assigned areas. The level of discussion of the audit results is at the discretion of the Lead Manager. At the end of the exit meeting, the Lead Manager or designee is given an audit quality questionnaire to evaluate the performance of the audit. They and others from the facility that were involved in the audit are asked to complete the questionnaire and return it to the Vice President of EP&P (VP-EP&P). If all appropriate managers and staff were present at the pre-exit briefing, the Lead Manager may elect not to have an exit meeting.

3.5 Audit Report

3.5.1 Report Content and Format

A. Audit reports should be prepared in accordance with modern, professional business writing standards and include findings as well as observations. The report must be marked "Environmental Audit Report: Privileged Document" and contain the statement "To ensure legal audit confidentiality, distribution of the report must be limited to persons within TVA who need to see the report in connection with their responsibilities. Audit reports must not be distributed outside TVA." The lead auditor is responsible for preparing a final audit report, including any changes agreed upon in the pre-exit meetings. The lead auditor signs and dates the final report.

B. To ensure consistency in audit reports, report templates are used for EMS, unannounced and ERAL audit reports. These templates are maintained in the Environmental Auditing's networked computer system. Because of the varied nature of program audits, a set format is not established.

C. Audit reports typically include an executive summary, findings, and observations. EMS audits also include an EMS assessment.

D. Executive Summary

1. The executive summary provides an overview of the audit results. It may include:

a. A statement on the effectiveness of the environmental program

b. TVA EMS and regulatory areas where findings were identified

c. EMS strengths and areas for improvement

d. Commendable practices

e. Status of findings from the previous audit

f. Repeat findings

E. Assessment of the Effectiveness of the EMS

An assessment of the effectiveness of the environmental program at the facility level is based on how well the EMS is implemented and functioning. Components of an effective EMS are defined in the ISO 14000 Standards (upon which the TVA EMS is based) and the EPA protocol for conducting EMS assessments. Environmental Auditing developed a protocol for conducting EMS audits at TVA facilities based on the information provided in the ISO 14000 and EPA protocol documents. This protocol is used when evaluating the EMS. Examples of EMS strengths and areas for improvement are provided as appropriate. A summary of the criteria used in assessing the effectiveness of facility EMS implementation is available on the Environmental Information Center.

3.5.1 Report Content and Format (continued)

F. Findings

1. Regulatory Findings

A regulatory finding is a condition that is not in compliance with:

a. Federal, state, or local regulation, law, or permit

b. Procedure or plan required by such a regulation, law, or permit

c. TVA environmental policies

2. EMS Findings

An EMS finding is a condition not in compliance with a requirement of the TVA EMS.

3. Repeat Findings

a. A repeat finding is a condition that is not in compliance with a regulatory or EMS requirement identified as a finding in the previous audit report (announced or unannounced) of the same facility. See Appendix C for repeat finding criteria for regional operations.

b. A repeat finding will usually have the same regulatory or TVA EMS citation as the finding in the previous audit.

4. Open Findings

Open findings are findings from the previous audit of the facility or region (see above) which have not been closed in accordance with the COO Corrective Action Program.

5. Self-Identified Nonconformances

Nonconformances identified prior to an audit through self-assessments, inspections, regulatory inspections or other means are not included as findings in an audit report provided the nonconformances are addressed in accordance with TVA-SPP-5.12 Corrective and Preventive Action Process and the COO Corrective Action Program. Self-identified nonconformances must be documented and corrective actions documented and tracked in order to be excluded as findings. Self-identified nonconformances which are still in a non-complying condition may be included as observations in the audit report.

G. Observations

Observations may include:

1. Noteworthy or positive accomplishments

2. Conditions that could develop into findings

3.5.1 Report Content and Format (continued)

3. Activity status

4. Compliance improvement opportunities

5. Nonconformances observed during an unannounced audit which are outside the media area covered in that audit will be identified as observations in unannounced audit reports.

3.5.2 Report Transmittal

A. The lead auditor provides a copy of the EMS and unannounced audit reports to EP&P management following the audit. After the facility Management Review Committee has met to discuss the audit report, but no later than five business days after the exit meeting, Environmental Auditing distributes the audit report to OGC and the facility's representatives on the Executive Committee and ENVPT. Environmental Auditing may on occasion provide copies of specific audit reports or corrective action plans to other organizations (e.g., Office of the Inspector General (OIG), TVA Board) upon request or if needed in connection with their duties. Additional distribution of the audit report is at the discretion of the facility or SBU. To ensure legal audit confidentiality, distribution of the report must be limited to persons within TVA who need to see the report in connection with their responsibilities. Audit reports must not be distributed outside TVA.

B. ERAL audit reports are provided to Research & Technology Applications with copies to Finance, EP&P, OGC and others as appropriate.

C. Program audit reports are provided to TVA's Environmental Executive, VP-EP&P, OGC and others depending on the scope of the audit.

3.5.3 Report Revision

If the auditors, in consultation with the audited facility and OGC, determine after an audit exit meeting that an audit finding was in error, a revised audit report will be issued to the Lead Manager, deleting the finding (provided the determination can be made before the corrective action plan is reported as compete). The revised report may note the item as an observation. A revised report is clearly marked as a revision which supersedes the original. Copies of the revised report are also distributed to the original recipients.

3.6 Corrective Action And Follow-Up

3.6.1 Corrective Action

Findings that are not corrected in a timely manner present TVA and its management with risk. Management of the audited organization is responsible for correcting findings identified in the audit. In some cases, another organization may also be responsible for correcting findings. The audited Lead Manager is responsible for developing and implementing a corrective action plan according to TVA-SPP-5.12 Corrective and Preventive Action Process and COO Corrective Action Program. Effective January 20, 2006, A and B level Problem Evaluation Reports (PERs) must be addressed individually under different PER numbers. C and D level PERs may be combined into a single PER provided they have the same apparent cause, the same responsible organization, and the same affected environmental media.

3.6.2 Tracking and Closing Findings

A. TVA-SPP-5.12 Corrective and Preventive Action Process and the COO Corrective Action Program describe the audited organizations' responsibilities for tracking and closing findings.

1. PERs for all environmental audit findings must be entered as potential environmental issues.

2. The facility is requested to notify the lead auditor when the CAP is prepared. This will allow the lead auditor to review the PER and bring to the facility's attention any closure plans that appear to be inadequate.

3. The facility is to notify the lead auditor by email when each PER is closed. The lead auditor may request supporting information to document closure of the finding. In order for a finding to be considered closed, the facility must have completed corrective action. Corrective action solutions must be fully implemented and documented and the noncomplying situation eliminated before the finding is closed.

4. The lead auditor will review the PER closure for auditor concurrence. If it is determined closure is ineffective, the lead auditor contacts the facility to ensure understanding. If the lead auditor's determination does not change, a new PER is created.

B. During the next audit of the facility, open items from the previous audit are checked to determine their status. If the auditors determine during an audit that any open findings have been addressed and should be closed, the status of these findings is reported in the new audit report.

C. Repeat findings are highlighted for management attention.

D. The EP&P LDR maintains computer files for tracking closure of audit findings.

3.6.3 Quarterly Performance Reports

Operating organizations are required to regularly update the status of findings in the COO Corrective Action Program. Audit results and trending analyses are included in quarterly environmental performance reports. These reports are prepared by EP&P in accordance with TVA-SPP-5.11 Performance Monitoring and Reporting Process. Environmental Auditing provides audit, EMS indicator data, and a compilation of audit issues to PA&R in accordance with EP&P-SDP-5.5 Performance Monitoring and Reporting Procedure.

3.7 Audit Quality Assurance

A. Quality assurance (QA) consists of systematic activities which provide the user of a product or a service the assurance that defined quality standards are being met. It consists of five separate but related activities:

1. Controls
2. Assessments
3. Corrective actions
4. Periodic process review
5. Continuous improvements

B. The purpose of the audit QA program is to provide reasonable assurance that the audit process and products conform to applicable standards and procedures.

3.7.2 Audit Quality Control

Audit quality control is a system of activities which assists an audit organization in meeting its mission and objectives. The following are quality control activities for Environmental Auditing products and services:

A. Audit Standards

Environmental Auditing follows the provisions of the standards and guidelines listed in Section 2.0.

B. Audit Procedures

The audit procedures assist Environmental Auditing in meeting its responsibilities outlined in TVA-SPP-5.14 Environmental Auditing Process.

C. Training and Certification

Auditor training and certification requirements have been established and incorporated into the audit procedure (see Section 3.2).

3.7.3 Audit Assessments

Audit assessments provide assurance that the quality control activities are effective. For Environmental Auditing, such assessments involve the routine evaluation of performance in light of TVA's needs. Environmental Auditing's assessment activities include oversight, internal reviews, and external reviews.

A. Oversight

1. Oversight of auditors is carried out continually to assure conformance to audit standards and procedures. The Environmental Auditing Manager provides oversight of individual audits. The Environmental Auditing Manager should meet with the lead auditor and with team members periodically to review and discuss audit performance.

2. The VP-EP&P and TVA Environmental Executive provide oversight through periodic reviews of the audit process and monitoring the process indicators.

B. Internal Reviews

The purpose of internal reviews is to verify the effectiveness of the audit program. These internal reviews include:

1. Customer Appraisal

   At the completion of each audit, an audit quality questionnaire is provided to the Lead Site Manager or designee. The form is to be completed by that manager (and others they may designate) and returned to the VP-EP&P after the audit.

2. Corporate Management Input

   Environmental Auditing annually receives feedback from senior and line management via representatives on the Audit Steering Team.

3. Self-Assessment

   EP&P will conduct self-assessments in accordance with EP&P-SDP-5.4 Self-Assessment Procedure to evaluate compliance with TVA-SPP-5.14 Environmental Auditing Process and this procedure.

C. External Reviews

External reviews are performed to appraise the quality of the audit process. These reviews are performed by qualified persons who are trained in environmental management systems and environmental auditing. The following are some examples of different types of external reviews.

3.7.3 Audit Assessments (continued)

1. External Audits of the Process

   a. External audits are designed to evaluate the effectiveness of the audit process. These reviews seek to determine whether audits are complete and suitably designed by the audit team and if corrective actions are being taken by the auditees. Reviews also seek to determine if quality control policies and procedures are adequately documented, communicated to the auditors and auditees, and effectively complied with so as to provide reasonable assurance that TVA is meeting appropriate standards.

   b. External reviews are to be carried out by qualified peers. People outside the environmental auditing profession do not always have the technical education, training, and perspective to evaluate Environmental Auditing professional practices.

   c. External reviews should be conducted every three to five years. The Audit Steering Team recommends an external auditor. Upon completion of the review, a formal, written report is issued. The report expresses an opinion as to the effectiveness of the process and TVA's compliance with the process. It may also include recommendations for improvement.

2. External Audit of an Audited Facility

   Consultants with environmental auditing experience could be hired to perform an independent audit of a facility recently audited by Environmental Auditing.

3. Qualified Observers

   Consultants could be hired to observe an audit and write a report to describe strengths and areas for improvement of the audit process, including recommendations for improvement.

4. Benchmarking

   Environmental Auditing keeps abreast of how other organizations conduct environmental audits. This is accomplished through membership in organizations such as The Auditing Roundtable, the Edison Electric Institute Environmental Auditing Task Force, and through working relationships with audit groups from other agencies and corporations. Environmental Auditing also keeps current on state-of-the-art approaches through audit training courses.

3.7.4 Corrective Actions

As part of its effort to continuously improve the audit process, the Audit Steering Team can take the following actions concerning each issue identified during quality assessments:

A. Determine cause of the issue

B. Identify appropriate solutions

C. Recommend changes

3.7.5 Annual Review of Process

During the fourth quarter of each fiscal year, the Audit Steering Team typically discusses internal and external feedback on the audit process and any improvements that could be made to enhance effectiveness. Audit issues may be communicated by the Team Lead to the ENVPT for guidance. The Team Lead submits requests for revisions to TVA-SPP-5.14 Environmental Auditing Process and TVA-SPP-5.17 Environmental Restricted Awards List (ERAL) Procedure to the Team Lead of the EMS Steering Team.

3.8 Miscellaneous Activities

3.8.1 Procedure Revision

Revisions to this procedure are approved by the Environmental Auditing Manager and VP-EP&P. Proposed substantive revisions are provided to the Audit Steering Team and EP&P Performance Analysis and Reporting Manager for comment. Audited organizations are notified of substantive revisions. Environmental Auditing may prepare minor revisions without additional coordination provided such revisions do not materially change the procedure. A revision log is maintained as part of this procedure.

3.8.2 Reporting Evidence of Fraud or Willful Violation

If there is evidence of fraudulent activities, repeated serious violations, or findings likely to cause imminent adverse impacts to human health or the environment, the audit team will bring these immediately to the attention of the facility's manager. The team may also bring these matters to the attention of its manager and OGC. EP&P makes all audit reports available to the OIG. EP&P and SBUs advise the OIG when they believe there is sufficient evidence of intentional wrongdoing or serious harm to the environment such that the violation would likely be considered a crime.

3.8.3 Regulatory Review

Auditors must maintain current knowledge of regulatory requirements. Various sources of information are used to maintain this awareness, including the Code of Federal Regulations, Federal Register, state regulations, and Bureau of National Affairs publications. Each auditor is assigned responsibility for keeping abreast of new and amended state, federal, and local regulations in several regulatory areas. When a new or amended regulation becomes final, the responsible auditor informs the other auditors and revises the audit guides accordingly.

3.8.4 Audit Guides

Audit guides are developed to provide guidance to the auditors on how to approach auditing an assigned regulatory or EMS area. The guides enable the auditors to be consistent in the EMS assessments and compliance evaluations. Audit guides are not a substitute for the regulations or EMS documents. The auditor responsible for each area determines the format that works best for his/her area(s). Guides are updated as needed. The responsible auditor may also provide information to other auditors through meetings, e-mails, handouts, guidance from regulators, etc. A network computer file of the guides is maintained by Environmental Auditing. Audit guides are not to be distributed outside Environmental Auditing.

4.0 RECORDS

A. Audit reports and correspondence are maintained in accordance with TVA-SPP-5.13 Records Management Process. Access to audit reports and correspondence is restricted per EP&P requirements.

B. Environmental Auditing maintains an electronic working file for each audited facility. These files contain copies of the audit reports and documentation relative to the audit. Auditor certification records (lead auditor and media) shall be maintained by Environmental Auditing.

5.0 DEFINITIONS

Audit - Systematic, independent and documented process for obtaining records, statements of fact or other information, and evaluating it objectively to determine the extent to which policies, procedures or requirements are fulfilled.

The following terms are defined in TVA-SPP-5.14 Environmental Auditing Process:

A. Corrective Action Plan

B. EMS Finding

C. Environmental Management System (EMS) Audit

D. Environmental Audit Steering Team

E. ERAL Audit

F. Program Audit

G. Regulatory Compliance Audit

H. Repeat Finding

I. Unannounced Compliance Audit

Appendix A
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Risk-Based Audit Scheduling

As described below, a two-step process is used for determining when TVA facilities should be audited:

A. The first step involves assigning an audit frequency range for all TVA facilities based on their size and complexity and available audit resources.

B. The second step involves an annual assessment of risk for each facility to determine which facilities will be audited in the next year.

First, an average audit frequency is assigned based on benchmarking data from other companies and the available audit staff resources. Each TVA facility is placed into one of four categories and assigned an audit frequency based on the following criteria.

Category	Large and Complex	Medium to Large	Small to Medium	Small and Simple
Description	Large facility, numerous complex environmental issues.	Medium sized facility several complex environmental issues.	Medium sized facility or group of facilities, some moderately complex environmental issues.	Small facility or group of facilities, very few environmental issues.
Average Audit Frequency	2.0 years	2.5 years	3.0 years	4.0 years
Range of Audit Frequency	1.0 to 2.5 years	1.5 to 3.0 years	2.0 to 4.0 years	3.0 to 5.0 years

Thus, the largest most complex facilities would be audited an average of every two years with the highest risk facilities in this category audited as often as annually and all facilities in this category audited at least every two and one-half years.

The following regions include many smaller facilities and are audited by region:

- Hydro Production Regions
- Resource Stewardship Watersheds
- Ground and Property Maintenance Regions
- Transmission Operations & Maintenance Regions

Audits of these regions may be scheduled more frequently than the above size and complexity matrix would indicate to ensure adequate coverage of each region. However, individual facilities within these regions would not be audited more frequently than the size and complexity matrix would indicate. The second step is to rank the risk of each facility for each of the following six criteria:

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Risk-Based Audit Scheduling

Category	High Risk	Medium-High Risk	Medium-Low Risk	Low Risk
Ranking Criteria	4	3	2	1
Weaknesses in the EMS Implementation	Numerous significant weaknesses in the EMS in last audit.	Several weakness in the EMS, one or more significant, in last audit.	One or no significant weaknesses and a few minor weaknesses in the EMS in the last audit.	No significant weaknesses and two or less minor weaknesses in the EMS in the last audit.
The impact of regulatory changes on the facility	Regulatory changes greatly impact facility.	Regulatory changes provide moderate effect.	Regulatory changes have slight effect on facility.	Regulatory changes would not affect facility.
Findings in last audit	Numerous significant findings in last audit and/or >3 repeat findings in last audit.	Several findings, one or more significant, in last audit and/or 2-3 repeat findings in last audit.	A few minor findings in last audit and/or 1-2 repeat findings in last audit.	No findings in last audit and/or no repeat findings in last Environmental Auditing audit.
Compliance history, Reportable Environmental Events (REEs), EPA/State Notices of Violation (NOVs) and/or a history of negative self assessment results and corrective action progress	History of findings and/or REEs (EPA - State NOVs and releases) and self-assessment results and corrective action progress.	Several findings or several REEs (EPA - State NOVs and releases) and/or several negative self-assessment results and corrective action progress.	A few findings and/or a few REEs (EPA - State NOVs and releases) and/or some negative self-assessment results and corrective action progress.	No recent findings and/or no recent REEs (EPA - State NOVs and releases) and/or mostly positive self-assessment results and corrective action progress.
Organizational changes that could impact the facility's Environmental Compliance (For example, new plant manager; new environmental manager.)	Numerous changes since last audit.	Changes to several key personnel since last audit.	Only a few changes since last audit.	No changes since last audit.
Time since last audit	4 years	3 years	2 years	1 year

The sum of the numerical rankings of each of these six risk categories is tabulated to determine a "Total Risk Score." This total risk score is used to determine which facilities within each of the four size and complexity groups poses the most risk to TVA. Those with the highest score are given the highest priority for audits in the following year. These scores are reevaluated each year based on available data and used to determine the audit schedule for the next year.

Appendix B
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Lead Auditor Certification

1.0 PURPOSE

To describe the method used by TVA to certify Environmental Auditing lead auditors.

2.0 REFERENCE

EPA Environmental Auditing Policy Statements - Federal Register, Vol. 51, July 9, 1986 and Vol. 59, July 28, 1994

3.0 RESPONSIBILITIES

The Environmental Auditing Manager shall be responsible for:

A. Administering lead auditor certification process

B. Ensuring lead auditor training

C. Verifying qualifications for lead auditor certification

D. Awarding lead auditor certification

4.0 CERTIFICATION REQUIREMENTS

4.1 General Requirements

A. Lead auditor candidates must demonstrate knowledge and understanding of:

1. Basic auditing principles and standards

2. Auditing techniques for examining, interviewing, evaluating, preparing work papers, and reporting

3. Environmental operations and practices

4. ISO 14001 Environmental management systems

5. Federal, State, and local environmental laws and regulations

6. TVA environmental policies and procedures

B. A lead auditor candidate must be certified as a Professional Environmental Auditor (Compliance and Environmental Management Systems) by BEAC or the equivalent as determined by the Environmental Auditing Manager.

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Lead Auditor Certification

4.1 General Requirements (continued)

C. In addition, lead auditor candidates shall have participated as an audit team member in a minimum of four facilities audits within two years before the date of certification. At least one of the required audits must have been completed within the previous 12 months. Candidates for lead auditor certification shall demonstrate to the Environmental Auditing Manager a thorough, sound understanding of the material referenced in Section 2.0 of this appendix. The Environmental Auditing Manager or VP-EP&P shall make the final determination of lead auditor certification.

4.2 Specific Requirements

Candidates for lead auditor certification shall, in addition to the above, have verifiable evidence that a minimum of 10 points has been scored under the criteria noted below:

4.2.1 Education (Three Points Maximum; Must Be From Accredited School)

A. Bachelors' Degree (Two Points)

B. Masters' Degree in engineering, physical or biological science or other discipline directly related to quality assurance or environmental compliance (One Additional Point)

4.2.2 Environmental Compliance Experience (Six Points Maximum)

A. Applied experience in environmental compliance, pollution control equipment design and maintenance, or pollution control engineering (One Point/Year, Two Points Maximum)

B. Experience in compliance auditing (Two Points/Year, Four Points Maximum)

4.2.3 ISO14001 EMS Experience (Three Points Maximum)

A. Experience in ISO 14001 EMS auditing

B. Knowledge and understanding of ISO 14001 EMS

4.2.4 Auditing Skills and Experience (Six Points Maximum)

A. Communication and leadership skills

B. Analytical abilities

C. Interpersonal skills

D. Team-oriented approach to solving problems

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Lead Auditor Certification

5.0 MAINTENANCE OF LEAD AUDITOR CERTIFICATION

A. Lead auditors shall maintain their proficiency through the following:

1. Regular, active participation in conducting audits.

2. Leading a minimum of six audits every two years.

3. Ongoing review and understanding of statutes, standards, regulations, procedures, instructions, and other documents related to ISO 14001 environmental management systems, environmental compliance, quality assurance, and auditing.

4. Annual participation in management/employee development programs; attendance at professional environmental compliance, EMS, and auditing training programs, conferences, or seminars.

B. The Environmental Auditing Manager or VP-EP&P shall annually assess the status of lead auditor proficiency and determine if each lead auditor maintains his/her certification. This is done in conjunction with the annual employee service review.

6.0 RECERTIFICATION OF LEAD AUDITORS

Lead auditors who lose their certification must demonstrate to the Environmental Auditing Manager or VP-EP&P their competency in the requirements outlined in Section 4.0 of this appendix. They must also participate as an audit team member in the audit of three facilities within a 12-month period before they may be recertified.

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Lead Auditor Certification

6.0 RECERTIFICATION OF LEAD AUDITORS (continued)

Lead Auditor Certification Form			
Lead Auditor:			
Lead Auditor Requirements (10 Points Required):			
		Points Earned	
1.	Education -- 3 Points Maximum		
2.	Environmental Compliance Experience -- 6 Points Maximum		
3.	ISO 14001 EMS Experience -- 3 Points Maximum		
4.	Auditing Skills -- 6 Points Maximum		
	TOTAL POINTS (18 Points Maximum)		
Certified By:		Date:	
	Environmental Auditing Manager		

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Repeat Findings Criteria for Regional Operations

Facility[1]	Repeat Finding is based on last audit of:
Fossil Power	**Fossil Power**
Distributed Generation Projects Coal mining and Reclamation Sites[5]	Any Distributed Generation Project Any Coal mining and Reclamation Site[5]
RSO&E	**RSO&E**
Resource Stewardship and Lands Holston-Cherokee-Douglas, Watts Bar-Clinch, Little Tennessee, and Chickamauga[2]-Hiwassee, Guntersville-Tims Ford, Pickwick-Wheeler, and Kentucky Watershed Teams	**Resource Stewardship and Lands** Any Watershed Team Area
Nonpower Dams Tellico, Normandy, Upper Bear Creek, Bear, Little Bear, Cedar Creek, Cedar, Dogwood, Lost Creek, Pin Oak, Pine, Redbud, Sycamore, Beaver Creek, Clear Creek, Nolichucky and other non-power dams owned by TVA	**Nonpower Dams** Any Nonpower Dam
Power Dams Watts Bar family (Watts Bar, Great Falls) Hiwassee family (Hiwassee, Apalachia, Chatuge, Blue Ridge, Nottely) Ocoee family (Ocoee #1, Ocoee #2, Ocoee #2) Chickamauga family (Chickamauga, Nickajack, Tims Ford) Boone family (Boone, Ft. Patrick Henry, South Holston, Watauga, Wilbur) Cherokee family (Cherokee, Douglas, Norris) Ft. Loudoun family (Ft. Loudoun, Melton Hill, Fontana)	**Power Dams** Any facility in the family
Kentucky Pickwick Wilson Wheeler Guntersville Raccoon Mountain	Last audit of this facility

Appendix C
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Repeat Findings Criteria for Regional Operations

Facility[1]	Repeat Finding is based on last audit of:
Power Systems Operations[5]	**Power Systems Operations[5]**
New Construction Projects[6] Transmission Line Construction - TVA Substation Construction - TVA Telecommunications Construction - TVA	**New Construction Projects[6]** Any Transmission Line Construction - TVA - Project Any Substation Construction - TVA - Project Any Telecommunications Construction - TVA - Project
Contractor Construction Transmission Line - Contractor Substation/Telecommunication Sites - Contractor	**Contractor Construction** Any Transmission Line or Substation/ Telecommunication Sites - Contractor - Project Any Transmission Line or Substation/ Telecommunication Sites - Contractor - Project
System Applied Maintenance (SAM)	**Any SAM Project**
Existing Transmission Lines and Substations[3] - East Transmission Service Centers (TSCs) in Existing Transmission Lines and Substations[3] - East Area Includes: Johnson City TSC, Knoxville TSC[4]; Chattanooga TSC[2]; Cleveland TSC; Huntsville TSC	**Existing Transmission Lines and Substations[3] - East** Any TSC in Existing Transmission Lines and Substations[3] - East Area
Existing Transmission Lines and Substations[3] - North TSCs in Existing Transmission Lines and Substations[3] - North Area Includes: Bowling Green TSC; Columbia TSC; Mayfield TSC; Murfreesboro TSC; Nashville TSC	**Existing Transmission Lines and Substations[3] - North** Any TSC in Existing Transmission Lines and Substations[3] - North Area
Existing Transmission Lines and Substations[3] - West TSCs in Existing Transmission Lines and Substations[3] - West Area Includes: Jackson TSC; Memphis TSC Tupelo TSC; Starkville TSC; Muscle Shoals TSC[2]	**Existing Transmission Lines and Substations[3] - West** Any TSC in Existing Transmission Lines and Substations[3] - West Area

Appendix C
(Page 3 of 3)

Repeat Findings Criteria for Regional Operations

Facility[1]	Repeat Finding is based on last audit of:
Administrative Services[5]	**Administrative Services[5]**
Grounds Maintenance Bases	**Grounds Maintenance Bases**
Stand alone Maintenance Bases	Any stand alone Maintenance Base (any maintenance base not contiguous with a hydro reservation
Facilities	**Facilities**
Knoxville area facilities Includes: Norris, Greenway[4], and Singleton	Any Knoxville area facility
Chattanooga area facilities	Any Chattanooga area facility
Muscle Shoals area facilities	Any Muscle Shoals area facility

1. Facility includes all of the contiguous property and operations on this site.
2. See maps of Chickamauga, Watts Bar, and Muscle Shoals reservations attached to "TVA Environmental Roles and Responsibilities" list for site boundaries and lead.
3. Includes crew maintenance facilities in each Transmission Service Center area.
4. At Greenway, TPS has lead on properties north of Greenway Drive and building and storage area south of the Railroad tracks. Facilities has the lead on all other properties.
5. Includes all properties except those at fossil plants, where the plant manager is the lead.
6. Sites outside existing Transmission Lines and Substations.

TVA Heritage Resources Review Process for TVA Transmission Rights-of-Way Vegetation Maintenance, Line and Pole Maintenance, and New Transmission Line Construction

[redacted]

TVA Heritage Resources review process for TVA transmission rights-of-way vegetation maintenance, line and pole maintenance, and new transmission line construction

This document briefly summarizes the environmental compliance review process TVA Heritage Resources use for maintenance and modifications of transmission lines and proposed construction of new transmission lines. The review processes are presented below by resource area.

Overview of environmental compliance process for transmission line maintenance and modifications

The TVA Power System Operations organization routinely conducts maintenance activities on transmission lines in the TVA Power Service Area (PSA). These activities include, but are not restricted to, right-of-way reclearing (removal of vegetation), pole and crossarm replacements, installation of lightning arrestors and counterpoise, and upgrading of existing equipment. Regular vegetation maintenance activities are conducted on a cycle of 3-5 years. Prior to these maintenance activities, the transmission line area including the right-of-way (ROW) is reviewed by technical specialists in the TVA Regional Natural Heritage Project to identify any natural resource issues that may occur along that transmission line. The TVA Regional Natural Heritage Project maintains a database of some 35,000+ (as of November 2005) occurrence records for protected plants, animals, caves, heronries, eagle nests, and natural areas for the entire TVA PSA, including 201 counties in a seven state area. The TVA Heritage database is dynamic, with updates and additions taking place throughout the year. Only credible records are included in the database, and the sources include the results of field surveys by TVA biologists, publications, museum and herbarium specimens, unpublished reports from biologists outside TVA, data exchanges with the seven state heritage programs overlapped by TVA's coverage area (AL, GA, KY, MS, NC, TN, and VA), and data exchanges with five offices of U.S. Fish & Wildlife Service (Cookeville, TN, Asheville, NC, Athens, GA, Daphne, AL, and Jackson, MS).

Wetland information is maintained by TVA Heritage Resources and includes National Wetland Inventory wetland maps for the entire TVA PSA. Soil survey maps are also used to identify potential wetland areas. All records of listed plants or animals, caves, wetlands, or natural areas that are present, or are potentially present, in the transmission line right-of-ways are taken into consideration when conducting these transmission line reviews. Other sources of considered in reviews include county lists of federally protected species, the TVA Natural Heritage database described above, aerial photographs and USGS topographical maps. In addition high quality videos taken during low-altitude flyovers of the transmission corridors are used to estimate the ecological community types present on the ROW. Using these available data sources, Heritage biologists identify sensitive habitats where rare plants or animals are known or likely to occur.

If potential impacts of maintenance activities to plants or animals on the federal Endangered Species Act are identified, field surveys may be conducted to document presence of the listed species in the ROW, especially if the proposed actions include pole replacement or some other action that would result in ground disturbance. However, in many other cases where the available data indicate the possibility of listed species being present on the ROW, Heritage specialists assume the species is present and work with PSO staff to avoid impacts to the listed species. For example, if maintenance activities in the ROW could affect a cave inhabited during part of the year by a bat colony a restriction may be indicated for the time of year the maintenance activities could take place. Within streamside management zones, hand clearing or backpack herbicide application reduce impacts to streams and listed aquatic species. The width of the streamside management zones vary according to the slope of the surrounding area, the type of stream, and the particular resources that may be present in the stream (listed species). However, if avoidance is not possible, Heritage specialists consult, as appropriate, with the U.S. Fish & Wildlife Service.

Also included in this document is the explanation of Class Definitions and associated table of mapping polygon colors and the restrictions indicated by those designations used in the GIS product transmitted to PSO.

(Managed Area) Managed areas, ecologically significant sites, and National Rivers Inventory for maintenance activities in TVA transmission line rights-of-way

Managed Areas (MA) are lands held in public ownership that are managed to protect and maintain certain ecological features. Ecologically Significant Sites (ESS) are tracts of privately owned land that are identified by resource biologists as containing significant environmental resources. National River Inventory (NRI) streams are free-flowing river segments that are recognized by the National Park Service as possessing remarkable natural or cultural values. The TVA Natural Heritage Project maintains a database of all such lands and streams occurring within the seven-state TVA PSA. As described above, this information is added to and updated frequently.

ROW maintenance activity reviews for MA's, ESS's, and NRI streams are completed by utilizing computerized mapping ArcMap graphics software. If a MA, ESS, and/or NRI stream is located within the 0.5-mile buffer of the subject transmission line, a a polygon designating the known or likely extent of that occurrence is drawn on an ArcMap electronic topographic map, and appropriate class restrictions are applied (see table of Class Definitions and Associated Polygon Colors of Sensitive Areas.") that represents the area's boundaries within the buffer. A description of the area that includes contact information for the manager of the natural area and also for the appropriate TVA contact, restrictions for maintenance methods, and the subject transmission line name is listed in the corresponding attribute table.

Right-of-way (ROW) vegetation maintenance and transmission line maintenance are reviewed for potential of these activities to affect natural areas. If all or any portion of a MA, ESS, and/or NRI stream lies within the buffer of the subject transmission line, a polygon is drawn depicting the boundary of such areas. Restrictions on proposed activities (See Table 1) are determined by the type and location of the MA, ESS, and/or NRI streams as well as consultation with the area manager or resource specialist. The class and contact restrictions, definitions, and polygon color for both activities are listed in the included table.

After determining the particular class restriction associated with the area, special instructions or comments are added to indicate the importance of the restriction and why it was assigned. For example, when a portion of a national forest is within the 0.5-mile buffer or crossed by the subject transmission line, a Class 3 restriction is assigned and a comment is added indicating the area manager must be contacted and herbicide use is restricted.

Table 2 provides the types of restrictions assigned to transmission line maintenance projects for Natural Areas. Under Categorical Exclusions, transmission line projects such as lightning mitigation, counterpoise activities, conveyances, line relocations for state highway department work, and providing delivery points and switches for substations are separate projects and are reviewed for potential impacts to MA's, ESS's, and NRI streams based on the amount and type of disturbance required. A three mile radius of the project site(s) is reviewed for MA's, ESS's, and NRI streams that might be affected by the proposed activity.

(Botany) - State and federal protect plant restrictions for maintenance activities in TVA transmission line rights-of-way

Botanical assessments are performed for proposed ROW vegetation maintenance and transmission line maintenance activities. During the review botanists identify state and federally listed plants or rare plant community types that occur, or are likely to occur on or near the transmission line ROW. Identifying the occurrences gives TVA the ability to identify habitats within a proposed project area that are sensitive and potentially require restrictions for particular vegetation management activities. To identify rare plant and sensitive habitat locations we utilize the U.S. Fish and Wildlife Service's county lists of protected plants, the TVA Natural Heritage database, aerial photographs and USGS topographical maps. In addition, we also have access to videos taken during low-altitude flyovers of the transmission corridors. These high quality videos are used to determine the type of plant habitats available on the ROW.

The review process for ROW vegetation maintenance and transmission line maintenance activities is different since they potentially impact vegetation in different ways. ROW vegetation maintenance consists of vegetation clearing with both herbicides (unless otherwise specified) and mechanical methods. Any vegetation present in the ROW that is sprayed by herbicides could be adversely affected. Mechanical clearing has less of an impact since many plants can usually tolerate being cut. Transmission line maintenance projects like pole replacements potentially impact vegetation when vehicles and equipment drive on and in the vicinity of the ROW and the soil and the vegetation are disturbed. If sensitive plants are likely, field work is often required to confirm the presence. Frequently, however, we assume the presence and make recommendations for different access routes to be taken and we notify appropriate staff about sensitive areas to avoid. Restrictions are determined by our knowledge of the habitat requirements for rare plants and rare plant communities that occur within the vicinity of the ROW. Once a sensitive area is located a polygon designating the known or likely extent of that occurrence is drawn on an ArcMap electronic topographic map, and appropriate class restrictions are applied (see table of Class Definitions and Associated Polygon Colors of Sensitive Areas).

(Terrestrial Animals) - State and federal protected terrestrial animal restrictions for maintenance activities in TVA transmission line rights-of-way

The TVA Regional Natural Heritage Program keeps track of state and federal protected species reported from the seven state region.. The terrestrial animal portion of the data base includes all listed birds (breeding and large wintering aggregations), mammals, reptiles, and amphibians, and some invertebrates (land snails, insects and cave obligate invertebrates). In addition to certain species of animals, the terrestrial portion of the database also includes records of heronries and caves as they often are used by multiple species, and thus are sensitive habitats.

Each transmission line maintenance project is reviewed for the presence of protected terrestrial animals, heronries, and caves.. A database search of the listed animals known from the county (or counties) included in the project area is performed. The zoologists, using these county lists and animal occurrences from the TVA Heritage database, look for habitats appropriate for these species in their review of the ROW videos. For state likely occurrences of federal and state listed species, heronries, and caves, within a 3-mile radius from the ROW, restrictions will be listed as appropriate for the species of concern. A polygon designating the known or likely extent of that occurrence is drawn on an ArcMap electronic topographic map and appropriate restrictions are applied (Tables 1 and 2). Special comments or instructions accompany each entry, as appropriate. For instance, if a cave is located along a powerline corridor schedule for vegetative maintenance, a 200-foot buffer is indicated around the opening of the cave and a "Hand Clearing Only" restriction is applied within the buffer. If the cave is used by a summer or hibernating colony of bats, appropriate time restrictions, as designated in specific recovery plans for each species, may also be applied.

(Aquatic Animals) - State and federal protected aquatic animal restrictions for maintenance activities in TVA transmission line rights-of-way

Each proposed transmission line maintenance or ROW vegetation maintenance project is reviewed for the known or likely occurrence of protected aquatic animals in streams in or adjacent to the transmission line right-of-way or in a stream drained by the ROW corridor. A database search of the listed aquatic animals known from the county (or counties) included in the project area is performed. The aquatic biologists, using these county lists and animal occurrences from the TVA Heritage database, look for habitats appropriate for these species in their review of the ROW videos. Once an occurrence or likely occurrence is identified, class restrictions are applied and the appropriate colored polygon is drawn around the resource area on an ArcMap electronic topographic map (Tables 1 and 2). All transmission line maintenance activities are currently conducted using Best Management Practices as outlined in Muncy (1999). Special comments or instructions (including designation of specific Streamside Management Zones, as identified by Muncy 1999) accompany each entry as appropriate.

(Wetlands) - Wetlands review for maintenance activities in TVA transmission line rights-of-way

Prior to the performance of any maintenance activities in TVA transmission line ROWs, office-level reviews are conducted by Natural Heritage wetland biologists. This review includes review of the National Wetland Inventory (NWI) map, county soil surveys, and TVA photos and videos of transmission line structures and rights of way. Potential wetland areas, not indicated on the NWI map, are identified based on interpretation of topographic features, water bodies, soils information, TVA photos and videos and proximity to NWI features. All NWI wetlands or potential wetland areas are superimposed as layers on an ArcMap electronic topographic map (see included maps). These ArcMap images are sent to PSO, and are accompanied by the Excel spread sheet which lists areas that have been included with the NWI data as areas of potential wetlands and what specific guidelines are to be used in each situation to avoid adverse impacts.

The NWI wetlands are indicated on the ArcMap drawings for both the ROW and a 1-mile diameter buffer area around the ROW. Potential wetland areas are identified in the ROW, but are not identified in the buffer area, parts of which may be used for ROW access. If the access route follows an existing road that does not require any repair or upgrading, no further wetland reviews are needed. Repair and upgrading includes, but is not limited to grading, fill addition, new or upgraded stream crossings, and vegetation removal. If a new or upgraded access route is necessary, environmental reviews of those particular access areas are conducted as required by the National Environmental Policy Act (NEPA).

The National Wetland Inventory (NWI) data was compiled using high-altitude aerial photography, some of which is now over 15 years old, with very limited field verification. Because of this, some of the NWI data may be inaccurate. The limitations of the NWI data are considered in the performance of transmission line maintenance and ROW vegetation maintenance projects to avoid accidental wetland impacts. Since there could be wetlands present for which no map evidence or other data currently exists, maintenance crews remain alert to such things as water on the surface of the ground, soil saturation, the type of vegetation growing in an area, and evidence of present, seasonal or temporary flooding.

In the absence of a ground survey by a wetlands specialist to determine wetland presence and location for ROW vegetation maintenance and transmission line maintenance projects, Best Management Practices, as described in Muncy (1999) are implemented to avoid and minimize potential impacts (see Tables 1 & 2). These techniques would be implemented in all locations where NWI wetlands and potential wetland areas are indicated on the project maps submitted by the TVA Natural Heritage staff.

Site-specific recommendations for ROW vegetation maintenance and transmission line maintenance projects are provided when needed (see Tables 1 & 2).
In addition, certain activities that may occur during pole replacement in wetlands are regulated under Sections 404 and 401 of the Clean Water Act. U.S. Army Corps of Engineers (USACE) Nationwide General Permit (NWP) #12 authorizes certain activities related to utility line construction and contains conditions to ensure that impacts to wetlands are minimal. Section 401 gives states the authority to certify whether activities permitted under Section 404 are in

accordance with state water quality standards (Strand, 1997). A qualified TVA or TVA contract wetlands specialist would be required to delineate the wetland(s) and provide the wetland determination data forms which are required for inclusion in the permit application. TVA also follows Executive Order 11990 which requires all federal agencies to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands, in carrying out the agency's responsibilities.

Potential impacts to wetlands resulting from ROW vegetation maintenance and transmission line maintenance activities include vegetation damage, soil compaction and erosion, sedimentation, and hydrologic alterations. These impacts are avoided or minimized during TVA maintenance operations by following the recommendations of the guidelines presented above and implementing all relevant Best Management Practices. In addition, the appropriate permits are obtained if required for the specific activity.

Overview of Environmental Compliance Process for New Transmission Line Construction

Prior to selection of potential routes for new transmission lines PSO identifies the geographic "study area" that includes all potential routes. Heritage database records of listed plants and animals, caves, natural areas, and (NWI) wetlands in this study area are provided to PSO at this stage in the planning process. These and other data are used to support development of specific route alternatives for the new line. Procedures for environmental review of proposed alternative routes developed with this preliminary information may include field surveys, depending on resource area (briefly discussed by resource) below. Data obtained from field surveys for new construction projects are used to update the Heritage and wetlands databases so that it is available for future maintenance projects.

If potential construction impacts to plants or animals on the federal Endangered Species Act are identified, Heritage and PSO staffs will make every effort to avoid these impacts. If avoidance is not possible, Heritage specialists consult, as appropriate, with the U.S. Fish & Wildlife Service.

(Managed Areas) - Managed Areas, Ecologically Significant Sites, and National Rivers Inventory review of New TVA Transmission Line Construction

A desktop level review of the proposed route alternatives identifies MA, ESS, and/or NRI streams that could be impacted by new transmission line construction. The TVA Natural Areas Coordinator might contact managers of any non-TVA areas that might be affected to confirm boundaries of the area and management objectives. Natural Areas input to the NEPA document prepared for this new construction line project includes the commitment for any mitigation that might be appropriate to protect managed areas from any adverse impacts of construction activities. Field surveys are not usually required, but may be appropriate in some cases.

(Botany) - State and Federal listed plant restrictions for Construction of New TVA Transmission Lines

A desktop level review of the proposed route alternatives is performed to identify state and federally listed plants known from within the counties included in the construction line route alternatives. If this initial review indicates the project may impact a listed plant, field surveys are made of the proposed routes. The PSO process for line construction normally allows for reroute negotiations to avoid potential impacts to listed plants. These reroutes are worked out in cooperation between Heritage and PSO staffs, and are contingent upon environmental review results for other disciplines. The botanical input to the NEPA document prepared for this new construction line project includes the commitment for any mitigation that might be appropriate to listed plants from any adverse impacts of construction activities, and also make recommendations about ROW maintenance activities specific to maintain populations of listed plants identified.

(Terrestrial Animals) - State and Federal Protected Animal reviews of new TVA Transmission Line construction

A desktop level review of the proposed route alternatives is performed to identify state and federally listed animals known to occur within the counties included in the construction line route alternatives. If this initial review indicates the project may impact a listed animal, field surveys are made of the proposed routes. The results of these field surveys are conservative, in that confirmation of the species presence is not required for a determination that construction of the new line may affect the species. The presence of appropriate habitat for the listed animals along the proposed route could result in route negotiations and/or specifically recommended mitigation. As mentioned above, the PSO process for line construction normally allows for reroute negotiations to avoid potential impacts to listed animals. These reroutes are worked out in cooperation between Heritage and PSO staffs, and are contingent upon environmental review results for other disciplines. The zoological input to the NEPA document prepared for this new construction line project includes the commitment for any mitigation that might be appropriate to protect listed animals or their habitats from any adverse impacts of construction activities, and also make recommendations about future ROW vegetation and transmission line maintenance activities specific to maintain populations of listed animals identified.

(Aquatic Animals) - State and federal protected animal review of proposed new TVA transmission line construction.

A desktop level review of the proposed route alternatives is performed to identify state and federally listed animals known to occur within the counties and watersheds included in the geographic areas potentially affected by construction line route alternatives. Because topographic maps are not always accurate, and aquatic habitats can be more accurately described by seeing them, field surveys are required for all proposed routes. Field surveys provide information to support recommendations for streamside management zones (Muncy 1999) appropriate for the streams encountered along the route. These field surveys will be conservative in that biological samples are not normally taken, and confirmation of the species presence is not required for a determination that the construction may affect the species. The presence of appropriate aquatic habitat for the listed animals along the proposed route could result in route negotiations and/or specifically recommended mitigation. As mentioned above, the PSO process for line construction normally allows for reroute negotiations to avoid potential impacts to listed animals. These reroutes are worked out in cooperation between Heritage and PSO staffs, and are contingent upon environmental review results for other disciplines. Streamside management zones for all waterbodies crossed by the proposed routes are flagged in the field and also documented with polygons designating the known or likely extent of that occurrence on an ArcMap electronic topographic map delineated using sub-meter accuracy GPS units. The aquatic animal input to the NEPA document prepared for this new construction line project includes specification of streamside management zones for each stream crossed by the proposed routes, and also includes commitment for any mitigation that might be appropriate to protect listed animals or their habitats from any adverse impacts of construction activities. Recommendations for future ROW vegetation and transmission line maintenance activities that would maintain populations of listed animals are also identified in the NEPA document.

(Wetlands) - Wetlands review of proposed new TVA transmission line construction

A desktop level review of the proposed route alternatives is performed to identify areas where NWI, soil survey maps and data indicate wetlands present in the geographic areas potentially affected by construction line route alternatives. Field surveys for wetlands are required for all proposed routes. Any wetlands encountered are delineated with standard wetlands delineation techniques, and the ecological condition is also evaluated using a TVA-developed wetland rapid assessment protocol. Wetlands crossed by the proposed routes are flagged in the field, and also mapped using sub-meter accuracy GPS units. The presence of wetlands along the proposed route could result in route negotiations and/or specifically recommended mitigation. As mentioned above, the PSO process for line construction normally allows for reroute negotiations to avoid potential impacts to wetlands. These reroutes are worked out in cooperation between Heritage and PSO staffs, and are contingent upon environmental review results for other disciplines and the practicability of the suggested reroutes. The wetlands input to the NEPA document prepared for this new construction line project includes documentation (size and type of wetland, for example) for each wetland crossed by the proposed routes, and also includes commitment for any mitigation that might be appropriate to protect these wetlands from adverse impacts of construction activities. Recommendations for future ROW vegetation and transmission line maintenance activities are also identified in the NEPA document.

Literature Cited

Muncy, J.A. 1999. A guide for environmental protection and best management practices for Tennessee Valley Authority transmisssion construction and maintenance activities (revised). Technical note TVA/LR/NRM 92/1. TVA, Norris, TN. (Chris Austin, Chris Brewster, Alicia Lewis, Kenton Smithson, Tina Broyles, Tom Wojtalik, editors).

Strand, M.N. 1997. *Wetland Deskbook*, 2nd edition. The Environmental Law Reporter, Environmental Law Institute, Washington, D.C.

Table 1. Class Definitions for vegetation management of TVA Transmission ROW's

Terrestrial Plants (A), Terrestrial Animals (D), and Aquatic Animals (E)			
Class	Restriction if Sensitive area in ROW	Restriction for Sensitive Areas Potentially Affected	Polygon Color
1	No broadcast spraying. Use one of the three following alternatives: 1) Hand or mechanical clearing, 2) Request field surveys by TVA Heritage staff to determine if suitable habitat for these species exists in the subject area, 3) Selective spraying of herbicides to shrubs or tree saplings less than 12 feet in height.	Not Applicable	Yellow
2	Hand-clearing only. Vehicles and equipment restricted from area unless confined to existing access road.	Vehicles and equipment restricted from area unless confined to existing access road.	Red
3	Special circumstance (specified by documentation accompanying that ROW review). **Botany:** listed plant recorded from within ROW. Please contact Heritage botanist prior to entering or conducting maintenance activities in subject area. **Terrestrial Animals:** if project occurs during the breeding season (March to mid-July), a Heritage terrestrial zoologist must be contacted prior to conducting the work. If outside this time period, no restrictions are necessary.		Orange
Wetlands* (C)			
-	Wetlands obtained from National Wetland Inventory data. Refer to "Wetlands ROW and Pole Replacement Guidelines" for restrictions.		Blue Outline
1	Potential wetlands identified by Natural Heritage wetland biologists based on interpretation of topographic features, water bodies, soil surveys and proximity to NWI features. Wetlands biologists will make recommendations specific to the situation		Pink Outline

Natural Areas (B)			
Class	**Call***	**Definition**	**Color**
1	No	Same as Class 1 definition above.	Yellow
2	No	Same as Class 2 definition above.	Red
1	Yes	Same as Class 1 definition above, and must contact area manager prior to	Yellow hatching
2	Yes	Same as Class 2 definition above, and must contact area manager prior to entering or conducting maintenance in subject area.	Red hatching
3	Yes	Must contact area manager prior to entering or conducting maintenance in subject area.	Neon Green
4		Special circumstance (specified by documentation accompanying that ROW review).	Green

* Refer to Wetlands Statement included in this package.
** The "Call" column on the accompanying datasheets is used by Natural Area specialists only.
A blank in the column indicates no call is necessary.

Table 2. Class Definitions and Associated Polygon Colors of Sensitive Areas for line or pole maintenance on TVA transmission lines.

All Resources Areas (Plants, Natural Areas, Wetlands, Terrestrial Animals, and Aquatic Animals)		
Class	Restriction	Color
I	**Botany:** Sensitive Botanical resources are known from the area. Details of proposed activities should be submitted to TVA Heritage staff to determine if the proposed activities require restrictions. **Natural Areas:** Refer to table accompanying project for restrictions. **Wetlands:** Potential wetlands identified by Natural Heritage wetland biologists based on interpretation of topographic features, water bodies, soil surveys and proximity to NWI features. Refer to wetlands ROW and pole replacement guidelines (below) for restrictions. **Terrestrial Animals:** Refer to table accompanying project for restrictions. **Aquatic Animals:** Refer to table accompanying project for restrictions.	Pink
Wetlands		
-	Wetlands obtained from National Wetland Inventory data. Wetlands biologists will make recommendations specific to the situation.	Blue Outline

Response to NRC Information Needs Related to Aquatic Ecology (AQ)

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information needs:

AQ-01: Section 2.4.2.5.3. Is there a commercial fishery on Guntersville Reservoir, including any commercial mussel fishery? Are there commercial or recreational fisheries below Guntersville dam or in Wheeler Lake?

AQ-13: Page 2.4-23 Historical harvest of striped bass, spotted bass, and genus *Lepomis* from sport fishery.

BLN INFORMATION NEEDS: AQ-01 and AQ-13

BLN RESPONSE:

As of 2005, five commercial fishing licenses were distributed in Marshall County and six in Jackson County. Commercial anglers on Guntersville Reservoir are only allowed to take rough fish such as carp, gar, and sucker species. Although some game fish are inadvertently caught, it is unlawful for commercial netters to keep or sell game fish. Mussel densities adjacent to the BLN are too low to support commercial or recreational uses.

Wheeler Reservoir downstream of Guntersville Reservoir supports a recreational fishery. TVA conducts annual sport fishery surveys on Guntersville and Wheeler Reservoirs each spring for largemouth bass, spotted bass, smallmouth bass, and crappie; surveys do not include monitoring for the genus *Lepomis* (sunfish). Twelve sites at four locations are electro-shocked to determine sport fish composition within each reservoir. Total shock time during the 2002 and 2003 survey on Guntersville Reservoir was 30 hours. From 2004 to 2007, total shock time decreased to 24 hours for each survey. Total shock time for each survey year on Wheeler Reservoir ranged from 22 hours in 2002 to 18 hours in 2007. Species abundance from 2002 to 2007 is displayed in Table 2.4-X7.

ASSOCIATED BLN COL APPLICATION REVISIONS:

1. Revise ER Chapter 2, Subsection 2.4.2.5.3, to insert new second and third paragraphs as follows:

   As of 2005, five commercial fishing licenses were distributed in Marshall County and six in Jackson County. Commercial anglers on Guntersville Reservoir are only allowed to take rough fish such as carp, gar, and sucker species. Although some game fish are inadvertently caught, it is unlawful for commercial netters to keep or sell game fish. Mussel densities adjacent to the BLN are too low to support commercial or recreational uses.

Wheeler Reservoir downstream of Guntersville Reservoir also supports a recreational fishery. The TVA conducts annual sport fishery surveys on Guntersville and Wheeler Reservoirs each spring. Twelve sites at four locations are electro-shocked to determine sport fish composition within each reservoir. Total shock time during the 2002 and 2003 survey on Guntersville Reservoir was 30 hours. From 2004 to 2007, total shock time decreased to 24 hours for each survey. Total shock time for each survey year on Wheeler Reservoir ranged from 22 hours in 2002 to 18 hours in 2007. Species abundance from 2002 to 2007 is displayed in Table 2.4-X7.

2. Revise COLA Part 3, ER Chapter 2, by adding **Table 2.4.X7,** Sport Fish Species Abundance in Guntersville and Wheeler Reservoirs 2002 – 2007, as indicated below.

Table 2.4-X7
Sport Fish Species Abundance in
Guntersville and Wheeler Reservoirs 2002 – 2007

	2002		**2003**		**2004**		**2005**		**2006**		**2007**	
	GR	**WR**	**GR**	**WR**	**GR**	**WR**	**GR**	**WR**	**GR**	**WR**	**GR**	**WR**
Largemouth bass	792	1171	880	1234	979	1628	1004	1390	888	797	594	1265
Spotted bass	142	0	50	2	71	0	52	4	68	5	89	5
Smallmouth bass	0	113	0	64	1	94	0	64	0	108	0	35
Crappie (black and white)	76	0	29	8	247	23	132	6	171	78	67	100

Note: Values indicate total number of fish caught within the yearly spring survey of Guntersville Reservoir (GR) and Wheeler Reservoir (WR).

ATTACHMENTS:

None.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information needs:

AQ-02: Page 2.4-18 and 19. Provide the basis for the statement that "Because the fish community is substantially similar at these locations [TRM 375.2 and TRM 424.0] and no unique reservoir habitat exists adjacent to the BLN, it is reasonable to assume the fish community adjacent to the BLN (TRM 391.0) is similar to the fish community determined for river miles 375.2 and 424.0.

AQ-03: Pages 2.4-18 and 19. Does the assumption of similarity in the fish community apply to the fish community inhabiting the intake canal and the area adjacent to the intake canal? If so, provide the basis for the assumption that this fish community would be substantially similar to those at locations TRM 375.2 and TRM 424.0. Otherwise, provide a list of species likely to inhabit in the intake canal or that are likely to be pulled into the canal during operations.

BLN INFORMATION NEEDS: AQ-02 and AQ-03

BLN RESPONSE:

By correspondence dated May 2, 2008, TVA provided responses to comments made by the NRC reviewers during the sufficiency review of the BLN COLA, including the Applicant's Environmental Report. In response to comment ER50 and ER52, TVA addressed the NRC reviewer's questions regarding the similarity of the fish community at Tennessee River miles (TRMs) 375.2 and 424.0 (as well as at TRMs 350.0, 405.0, and 410.0). This similarity of the fish community at these five locations supports the assumption that the fish community in the area of the intake canal is similar, as the BLN intake canal is located within this stretch (TRM 350.0 to TRM 424.0) of the Tennessee River (Guntersville Reservoir). Because NRC Information Needs AQ-02 and AQ-03 request the same information as that provided in response to ER50 and ER52, TVA refers the reviewers to the response provided in TVA's May 2, 2008 letter.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

> Page 2.4-17 states that "Aquatic communities have been extensively studied within Guntersville Reservoir and Town Creek". Provide the results of studies of the aquatic communities in Town Creek, including species list and habitat type.

BLN INFORMATION NEED: AQ-06

BLN RESPONSE:

By correspondence dated May 2, 2008, TVA provided responses to comments made by the NRC reviewers during the sufficiency review of the BLN COLA, including the Applicant's Environmental Report. In response to comment ER49, TVA addressed the NRC reviewer's questions regarding studies of the aquatic communities in Town Creek by providing species lists and habitat information for Town Creek, and also demonstrating that the aquatic fauna identified in Town Creek are similar to those identified in studies of aquatic communities in Guntersville Reservoir. Because NRC Information Need AQ-6 requests the same information as that provided in response to ER49, TVA refers the reviewers to the response provided in TVA's May 2, 2008 letter.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

> Page 2.4-19. Provide data and analysis from the benthic macroinvertebate sampling (1974 to 1984) that occurred adjacent to BLN during a preoperational biological assessment of Guntersville Reservoir. Specifically the identity, frequency and general habitat location of the surveyed mussels.

BLN INFORMATION NEED: AQ-09

BLN RESPONSE:

During the week of March 31 through April 4, 2008, the NRC staff conducted an audit of the BLN site, including a review of the documentation supporting the BLN ER. At the site audit exit meeting, NRC Aquatic Ecology reviewers identified documentation needed to provide the data and analysis from benthic macroinvertebrate sampling that occurred adjacent to the BLN from the mid-1970s to the mid-1980s. The requested document, "Preoperational Assessment of Water Quality and Biological Resources of Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant, 1974-1984," dated 1985, is provided as Attachment A to this enclosure. The attachment provides detail related to frequency and general habitat location of the surveyed mussels. In providing the preoperational assessment report, TVA understands that the NRC staff considers these comments resolved and no additional documentation is required in response to these information requests.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following document is provided as Attachment A to this enclosure:

A. Tennessee Valley Authority, *Preoperational Assessment of Water Quality and Biological Resources of Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant, 1974-1984*, 1985.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

Page 2.4-19. Provide the results of the 1995 and 2007 mussel survey including the locations of the survey with respect to the site.

BLN INFORMATION NEED: AQ-10

BLN RESPONSE:

By correspondence dated May 2, 2008, TVA provided responses to comments made by the NRC reviewers during the sufficiency review of the BLN COLA, including the Applicant's Environmental Report. In response to comment ER58, TVA addressed the NRC reviewer's question regarding the 2007 mussel survey adjacent to the BLN site and information on recreationally important species. The 2007 mussel survey report and the results of the 1995 mussel survey (also conducted adjacent to the BLN) were provided as attachments to the May 2, 2008 letter. The transect location and orientation details are included in the survey reports. Because NRC Information Need AQ-10 requests the same information as that provided in response to ER58, TVA refers the reviewers to the response provided in TVA's May 2, 2008 letter.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

Page 5.6-4. Provide the procedures used to minimize impact to aquatic ecosystems from ROW maintenance.

BLN INFORMATION NEED: AQ-18

BLN RESPONSE:

By correspondence dated May 2, 2008, TVA provided responses to comments made by the NRC reviewers during the sufficiency review of the BLN COLA, including the Applicant's Environmental Report. In response to comment ER-07, TVA addressed the NRC reviewers' questions regarding TVA procedures that provide guidance for right-of-way (ROW) maintenance near aquatic ecosystems. Because NRC Information Need AQ-18 requests the same information as that provided in response to ER07, TVA refers the reviewers to the response provided in TVA's May 2, 2008 letter.

In addition, at the BLN site audit held March 31 through April 4, 2008, the following document, referred to as the "Muncy Manual," was provided to the NRC Ecology reviewers:

Muncy, J. A., *A Guide for Environmental Protection and Best Management Practices for Tennessee Valley Authority Transmission Construction and Maintenance Activities* (revised), Technical Note TVA/LR/NRM 92/1, TVA, Norris, TN, (Chris Austin, Chris Brewster, Alicia Lewis, Kenton Smithson, Tina Broyles, Tom Wojtalik, editors), 1999.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information needs:

AQ-20: Page 4.3-7 refers to the installation of riprap as a measure of bank stabilization. Page 4.2-3 discusses the installation of riprap, stemwalls or other appropriate means to stabilize the banks of the embayment. Are there any plans to install riprap on the banks along the reservoir? Provide a copy of the TVA requirements for installing riprap, stemwalls and other means to stabilize the banks of the embayment.

AQ-21: Page 4.3-7 states that "Because intake and discharge structures are already in place, new construction is not expected to occur near the banks of the reservoir. However, pages 4.2-1 and 4.2-2 lists proposed construction activities that could result in impacts to the hydrology at the BLN site including construction or modification of the existing cooling water intake structure and discharge structure and construction of new and/or potential modification of docking facilities for barges/vessels. Will construction occur on the banks of the reservoir?

BLN INFORMATION NEEDS: AQ-20 and AQ-21

BLN RESPONSE:

By correspondence dated May 2, 2008, TVA provided responses to comments made by the NRC reviewers during the sufficiency review of the BLN COLA, including the Applicant's Environmental Report. In response to certain elements of comments ER04, 11, 43, 44, and 45, TVA addressed the NRC reviewers' questions regarding measures to stabilize banks of the intake canal embayment and provided clarification that no new construction is planned. Also, as stated during the site audit, riprap installation for river bank stabilization was completed as part of Bellefonte Units 1 and 2 construction activities. There are no plans for installation of additional riprap or any stemwalls. Any refurbishment of existing structures such as the intake canal or barge docking area, during Units 3 and 4 construction, would be more accurately characterized as a maintenance activity. Changes to the BLN ER to clarify maintenance characterization for activities described on ER pages 4.2-1 and 4.2-2, and riprap installation were provided as part of the response to comments ER04, 11, 43, 44, and 45.

As applicable to developments for which TVA is issuing a permit under Section 26a of the TVA Act, TVA requirements, guidelines and best management practices (BMPs) for installing riprap, stemwalls, and other means to stabilize embankments are described in two documents: "Regulation_1304.208" and "GS_Conditions (General and Standard Conditions – Sections 3 and 6)." These documents are provided as Enclosure 2, Attachments B and C, respectively. As modified for site-specific application, TVA typically identifies similar conditions and BMPs for implementation in TVA-initiated projects. However, as stated above, riprap installation is complete; there are no plans for installation of additional riprap or stemwalls.

Because NRC Information Needs AQ-20 and AQ-21 request the same information as that provided in response to ER4, 11, 43, 44, and 45, and procedures for installing bank stabilization measures are attached, TVA refers the reviewers to the response provided in TVA's May 2, 2008 letter and to Attachments B and C to this enclosure.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following documents are provided as Attachments B and C to this enclosure:

B. 18 CFR 1304.208, Shoreline Stabilization on TVA-Owned Residential Access Shoreland.

C. Tennessee Valley Authority, Form TVA 17416[5-2005], General and Standard Conditions, Section 26a and Land Use.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

Page 4.2-8. Provide the TVA regulations related to dredging operations.

BLN INFORMATION NEED: AQ-24

BLN RESPONSE:

During the week of March 31 through April 4, 2008, the NRC staff conducted an audit of the BLN site, including a review of the documentation supporting the BLN ER. At the site audit exit meeting, NRC Aquatic Ecology reviewers identified additional documentation needs. This document, "General and Standard Conditions, Section 26a and Land Use," is provided in response to Information Need AQ-20 and AQ-21 and provided as Attachment C to this enclosure. In addition to this document, clarification on TVA regulations related to dredging is provided below.

TVA's proposed activities at the BLN site include possible maintenance dredging needed to desilt the intake canal to return it to its originally constructed contour or capacity. Desilting or dredging procedures, guidelines, and BMPs are not specifically outlined in TVA regulations. In the State of Alabama, if a permit is needed, the requirements for such activities would typically fall under the requirements of either a general or site-specific U.S. Army Corps of Engineers (USACE) permit. If a USACE permit is not required, TVA would stipulate general conditions and BMPs similar to those established in Section 6 of TVA's General and Standard Conditions, which is attached to this enclosure. The types of BMPs implemented would be dependent upon where the desilting or maintenance dredging operation were to take place (intake, discharge, river); how the operation would be conducted (e.g., hydraulic dredge, clam shell removal, or other less intrusive methodologies); and where the material was to be placed. For other previous agency desilting or dredging projects, and depending upon site-specificity, TVA has 1) pumped or dredged materials into geotec filterbags/socks to filter out sediment as the water is returned to the river; 2) used sediment curtains; 3) used visual monitoring and ceased activities if sediment is stirred up and may enter the plant intake; 4) placed a dredge cell with a berm and allowed to de-water; and 5) explored and utilized other less-intrusive methods, if such activities of less extensive scope and potential for impacts warranted them.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None. In response to AQ-20 and AQ-21, the document titled "General and Standard Conditions, Section 26a and Land Use" as cited above, was provided as Attachment C to this enclosure.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information needs:

AQ-25: Page 5.3-4 and 5.3-5. Provide the data from the 2005-2006 and 2006-2007 study of impingement and entrainment at Widows Creek.

AQ-26: Page 5.3-4 and 5.3-5. Provide a more complete description of how the Widows Creek data compares with the potential for entrainment at BLN. Are the designs of the intake systems, the size and orientation of canals, withdrawal rates from river, and velocities of water in the canal sand through the screens comparable between the two plants? Will the entrainment rates at BLN be higher or lower than at Widows Creek and why?

BLN INFORMATION NEEDS: AQ-25 and AQ-26

BLN RESPONSE:

By correspondence dated May 2, 2008, TVA provided responses to comments made by the NRC reviewers during the sufficiency review of the BLN COLA, including the Applicant's Environmental Report. In response to comments ER54 and ER55, TVA addressed the NRC reviewer's questions by illustrating that the intake system at Widows Creek Fossil Plant (WCF) and the system for BLN are essentially similar regarding intake structure equipment, intake canals parameters, and measured and estimated water velocities. The similarity between the WCF Plant A and BLN intake systems provide the basis for TVA's assertion that WCF may be considered as a surrogate for impingement, not entrainment, at BLN. Impingement at the BLN intake structure is expected to be of a similar composition, but reduced magnitude, from that shown for WCF Plant A, due to a difference in water velocity at the BLN intake compared to the velocity at WCF. Because NRC Information Need AQ-26 requests the same information as that provided in response to ER54 and ER55, TVA refers the reviewers to the response provided in TVA's May 2, 2008, letter. (Note: In the response to ER54 and ER55, TVA corrected a discrepancy in ER Subsection 5.3.1.2.1, which inappropriately referred to "entrainment" in a paragraph that was actually discussing impingement.)

At the site audit exit meeting, NRC Aquatic Ecology reviewers identified additional documentation needs that included TVA's report on the 316(b) monitoring program fish impingement study at WCF, from 2005 through 2007. A copy of this study is provided as Attachment D to this enclosure.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following document is provided as Attachment D to this enclosure:

D. Tennessee Valley Authority, Environmental Stewardship and Policy, *Widows Creek Plant A & B, NPDES Permit No. AL0003875 316(b) Monitoring Program, Fish Impingement at Widows Creek Fossil Plants A & B During 2005 through 2007,* 2007.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

Page 6.5-4. Provide the basis for the decision that the current Vital Signs monitoring program locations will be adequate to determine if there are any operational impacts from the BLN site.

BLN INFORMATION NEED: AQ-27

BLN RESPONSE:

TVA's long-term Vital Signs Program is used to track trends of ecological reservoir health in Guntersville Reservoir. These ecological health parameters are used in TVA's self assessment of environmental stewardship and are expected to continue to satisfy TVA's mandate in the TVA Act. BLN is situated at approximately Tennessee River mile (TRM) 391. TVA has established Vital Signs sampling sites upstream of BLN at TRM 424.0, 410.0, and 405.0, and downstream of BLN at TRM 375.2 and 350.0, so that sampling reveals near- and far-field effects of BLN to the resident aquatic communities of Guntersville Reservoir. To satisfy National Pollutant Discharge Elimination System (NPDES) permit requirements, two sites upstream (TRM 408 and 410) and two sites downstream (TRM 405 and 406) of Widows Creek Fossil Plant are sampled once every two years at TRM 405.0 and 410.0 in accordance with TVA's Vital Signs monitoring program. The sampling results have provided long-term reservoir fish and benthic macroinvertebrate population trends since 2000. A TVA white paper, Attachment E to this enclosure, on the TVA Vital Signs monitoring program provides further details, and demonstrates the depth and expected long-term capacity for the program to follow trends.

At the April 4, 2008, site audit exit meeting, NRC Aquatic Ecology reviewers identified additional documentation needs that included TVA's report on the 316(b) monitoring program fish impingement study at Widows Creek Fossil Plant from 2005 through 2007. In response to AQ-25 and AQ-26, this document is attached to this enclosure for inclusion in Attachment D.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following document is provided as Attachment E to this enclosure:

E. Tennessee Valley Authority, *TVA's Reservoir Ecological Health Monitoring Function*, White Paper.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

> Hartsville - Page 9.3-25, provide reference and data from the January 2001 study on the Cumberland River mussel survey that stated that "a once-thriving population of endangered mussels could no longer be found." Provide list of species and abundance from the September 1992 through January 1993 gill net and electrofishing samples. Have other studies of the aquatic ecosystem been conducted?

BLN INFORMATION NEED: AQ-28

BLN RESPONSE:

During the week of March 31 through April 4, 2008, the NRC staff conducted an audit of the BLN site, including a review of the documentation supporting the BLN ER. The documentation provided to the staff included a TVA report titled, "A Survey of the Dixon Island Mussel Bed adjacent to the Hartsville Nuclear Plant Site, Cumberland River, Smith and Trousdale Counties, TN – Input for the Hartsville Land Sale EA," dated 2001. Fish species and abundance data from the September 1992 through January 1993 sampling at the Hartsville site are provided in Table 3, "Fish Collected in Monthly Netting and Electrofishing Samples at the Hartsville Site, September 1992 through January 1993," of this survey report. A copy of Table 3 of the Dixon Island Mussel Bed survey report is provided as Attachment F to this enclosure.

At the site audit exit meeting, NRC Aquatic Ecology reviewers identified additional documentation needs. In response to the staff's request for aquatic ecosystem studies, TVA identified a report of monitoring that was conducted in the vicinity of Gallatin Fossil Plant during autumn 2007 in support of a continued 316(a) thermal variance. This monitoring report, dated April 2008, is provided as Attachment G to this enclosure.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following documents are provided as Attachments F and G to this enclosure:

F. Tennessee Valley Authority, "Table 3. Fish Collected in Monthly Netting and Electrofishing Samples at the Hartsville Site, September 1992 Through January 1993," in *Environmental Assessment and Finding of No Significant Impact – Hartsville Nuclear Plant Site, Trousdale and Smith Counties, Tennessee, Transfer of TVA Property for Industrial Park*, 2002.

G. Tennessee Valley Authority, Aquatic Monitoring and Management, *Results of Fish Community Monitoring in the Vicinity of Gallatin Fossil Plant During Autumn 2007 in Support of a Continued 316(a) Thermal Variance*, April 2008.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information need:

> Provide reference 4 on page 9.3-40 (Tennessee Valley Authority, Environmental Report - Phipps Bend Nuclear Plant, Units 1 and 2, Revision 6, 1977)

BLN INFORMATION NEED: AQ-31

BLN RESPONSE:

During the week of March 31 through April 4, 2008, the NRC staff conducted an audit of the BLN site, including a review of the documentation supporting the BLN ER. Although the Phipps Bend Nuclear Plant (PBN) Environmental Report, dated 1977, is cited as Reference 4 for Section 9.3 of the BLN ER, NRC reviewers indicated that a copy of the PBN Final Environmental Statement (FES), also dated 1977, was preferable. The PBN FES, as listed below, was provided to NRC staff. Based on discussions with the NRC's Aquatic Ecology reviewers and subsequent confirmation at the audit exit meeting, TVA understands that the NRC staff considers this comment resolved and no additional documentation is required in response to this information request.

The following document was provided to the NRC reviewers:

> Tennessee Valley Authority, *Final Environmental Statement – Phipps Bend Nuclear Plant, Units 1 and 2*, 1977.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

None.

Tennessee Valley Authority

Preoperational Assessment of Water Quality and Biological Resources of Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant 1974 - 1984

1985

TENNESSEE VALLEY AUTHORITY

Office of Natural Resources and Economic Development
Division of Air and Water Resources

PREOPERATIONAL ASSESSMENT OF WATER QUALITY AND BIOLOGICAL RESOURCES OF GUNTERSVILLE RESERVOIR IN THE VICINITY OF BELLEFONTE NUCLEAR PLANT, 1974 THROUGH 1984

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October 1985

TVA/ONRED/WRF-86/1

PREFACE

By nature of the large amount of information contained in this report (approximately nine years of data collected monthly), several adjustments were required to limit size of this document. Large data summaries listing either individual sample values and/or sample statistics are not included. However, these may be purchased at reproduction costs or examined at the Fisheries and Aquatic Ecology Branch's (FAEB) office located at the Summer Place Building, Knoxville, Tennessee.

Organizationally, materials contained in this report have been grouped into three volumes:

Volume I:	Text and Figures (figures following each chapter)
Volume II:	Tabular data summaries
Volume III:	Appendices (limited to tabular presentations of important data too extensive or inclusive for volume II)

Only limited copies of volume III were made to limit costs. Additional copies may also be purchased at reproduction costs or examined at FAEB offices either in Knoxville, Tennessee (Summer Place Building) or Muscle Shoals, Alabama (E & D Building).

Abstract

Baseline aquatic conditions in the vicinity of TVA's Bellefonte Nuclear Plant (BLN) are described for the period 1974 through 1984 with regard to spatial, seasonal, and temporal observations. Results from all instream preoperational monitoring activities are presented. Included are assessments of physical reservoir data, water quality data, and descriptions of aquatic flora (phytoplankton, periphyton, aquatic macrophytes) and fauna (zooplankton, benthic macroinvertebrates, planktonic, juvenile and adult fish).

Spatial analyses indicated greater abundance of planktonic organisms from habitat along the left descending overbanks than in the mainstream river channel. An opposite trend was indicated for periphyton. Phytoplankton abundance and relative amounts of blue-green algae were greatest at overbank and channel stations downstream of BLN. Greatest zooplankton abundance (both habitats) occurred opposite the BLN site with significantly fewer organisms at the upstream control station. Ichthyoplankton data identified the Tennessee River upstream of BLN as an important spawning area for Polyodon spathula (paddlefish) and Stizostedion canadense (sauger). High densities of freshwater drum eggs were also observed in the vicinity of BLN and upstream. Consistent spatial trends were not observed for aquatic macrophytes and most fish species.

Temporal analyses identified several trends indicating substantial change over the 10-year monitoring period. Several water quality parameters (BOD, TOC, Org-N) began to increase during 1982 and 1983. Aquatic macrophytes approximately doubled after 1979 with a new pervasive species, Hydrilla verticillata, occurring for the first time in 1982. Periphyton changes included increasingly greater relative amounts of chlorophytes over the study period in addition to a general increase in phaeophytin a and autotrophic index values, indicating a shift toward more heterotrophic growth. Macroinvertebrate taxa and abundance increased throughout the study period, with a change in dominant genera observed in 1982. Number or biomass of one or more size classes for 8 of 11 dominant fish species collected in rotenone surveys showed significant decreasing trends over the period 1974-1983. Gill netting also identified a decline in white bass populations during the last three years of data collection. Abundance trends for several communities (phytoplankton, zooplankton, and periphyton) were more cyclic than linear, indicating that monitoring activities may have observed close to a full range of conditions occurring in the vicinity of BLN under normal flow and climatic conditions.

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1.0 INTRODUCTION

In May 1973 the Tennessee Valley Authority (TVA) filed with the Atomic Energy Commission (AEC), now the Nuclear Regulatory Commission (NRC), an application to construct the Bellefonte Nuclear Plant (BLN) in Jackson County, Alabama. In accordance with the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. sections 4331 et seq), TVA prepared a Draft Environmental Impact Statement which was sent to the Council of Environmental Quality (CEQ), State of Alabama and Federal agencies, and made available to the public in March 1973. TVA's Final Environmental Impact Statement (FEIS) was sent to the CEQ and made available to the public May 24, 1974. The FEIS for the BLN, units 1 and 2, served as the licensing document. Construction permits for the facility were issued by the AEC and received by TVA on December 24, 1974.

In February 1974, a combined preoperational/construction effects monitoring program was initiated in Guntersville Reservoir for the BLN. On August 15, 1975, detailed procedures were finalized and distributed: Nonradiological Environmental Monitoring Procedures for the Water Quality and Ecology Branch Responsibilities at the Bellefonte Nuclear Plant. Larval fish sampling also was begun in 1974 to assess entrainment potential for the BLN ERCW intake and cove rotenone sampling began in 1974 to provide long-term baseline data on fishstocks near BLN. On April 28, 1980, TVA submitted its construction assessment report (TVA 1980a) to the Alabama Water Improvement Commission (AWIC), now the Alabama Department of Environmental Management (ADEM), along with a recommendation to discontinue instream construction effects monitoring. AWIC concurred with this recommendation on October 9, 1980, and the construction assessment phase of the instream monitoring program was terminated. Persuant to requirements of the National Pollutant Discharge Elimination System (NPDES) Permit (AL0024635) for BLN, issued by the AWIC, TVA submitted a preoperational monitoring study plan on June 3, 1980. This plan as ammended on February 5 and November 17, 1981, continued the revised Water Quality and Ecology Branch's procedures and also included fishery components for monitoring preoperational conditions in the vicinity of the plant.

In October 1980, TVA completed its first written preoperational assessment which evaluated water quality and non-fish (phytoplankton, periphyton, zooplankton, macroinvertebrates, and aquatic macrophytes) data collected during the period 1974 through 1979. On June 9, 1982, TVA submitted a report entitled "Predicted Effects for Mixed Temperatures Exceeding 30°C (86°F) in Guntersville Reservoir, Alabama, in the Vicinity of the Diffuser Discharge, Bellefonte Nuclear Plant (TVA 1982a)." This predictive assessment which utilized data collected from Guntersville Reservoir, observations from other studies, and results from the Browns Ferry Biothermal Research Facility, was written to satisfy requirements contained in Part III.J. of the BLN NPDES permit.

The present preoperational assessment of all instream water quality and biological data collected at BLN from February 1974 through February 1984 does not completely satisfy NPDES reporting commitments for preoperational monitoring at BLN. Fuel loading for units 1 (July 1993) and 2 (July 1995) has been extended perhaps beyond the usefulness of these data for making accurate assessments of operational conditions. Therefore, additional update preoperational monitoring will be required for at least two years immediately before fuel loading of unit 1.

1.1 Purpose and Objective

The purpose of preoperational studies is to establish an aquatic baseline (fisheries, limnology, water quality) for subsequent operational evaluation of aquatic impacts. When operational studies are completed, results of preoperational studies allow evaluation of project impacts and provide protection from liability for existing aquatic conditions.

More specifically the objective of preoperational monitoring is to describe both spatially and temporally the biological/limnological/ water quality variability existing in the vicinity of BLN, including a baseline description of habitat diversity, trends, pre-existing reservoir conditions, and cause/effect relationships between biological communities and environmental factors. Descriptions contained in this report regarding data from 1974 through 1984 will be re-evaluated and supplemented in a final preoperational report following additional data collection preceeding fuel loading of unit 1.

1.2 Description of Study Area

BLN is located on a peninsula formed by the Town Creek embayment on the western shore of Guntersville Reservoir at Tennessee River Mile (TRM) 391.5 (figure 1-1), and about 11.3 km (7 mi) northeast of Scottsboro in Jackson County, Alabama. A low-lying floodplain between the BLN site and the old river channel and along the shore of the reservoir opposite the site was flooded by impoundment of Guntersville Reservoir in 1939. These areas now exist as backwater sloughs and embayments which are protected to a degree from wave and current action of the main river by strip islands and bars formed by higher portions of the old river bank. Four large tributary creeks which enter Guntersville

Reservoir upstream of BLN (Town Creek - TRM 393.4R; Mud Creek - TRM 394.3R; Raccoon Creek - TRM 393.9L; and Crow Creek - TRM 401.4R) also provide extensive shallow backwater habitats as does Jones Creek which enters Guntersville Reservoir downstream of BLN at TRM 388.1L. Drainage area of the Tennessee River upstream of BLN is 60,451 km^2 (23,340 mi^2). At Nickajack Dam, 53.1 km (33 mi) upstream, the drainage area is 56,643 km^2 (21,870 mi^2), and at Guntersville Dam, 69.2 km (43 mi) downstream, the drainage area is 63,326 km^2 (24,450 mi^2). Other morphometric features are summarized in table 1-1.

1.3 Summary of Aquatic Monitoring and Reporting

Several aquatic studies have been conducted on Guntersville Reservoir, including those relating to BLN. In 1973-1975 (TVA 1978a) and 1978-1979 (TVA 1981), 316(a and b) studies were made in the vicinity of TVA's Widows Creek Steam Plant (TRM 407.5) to evaluate entrainment and impacts of the thermal discharge. An assessment of Guntersville Reservoir trophic status and assimilative capacity (TVA 1982b) was made in support of the proposed Murphy Hill Coal Gasification Project (TRM 368.5). A preoperational monitoring program involving water quality, fisheries, phytoplankton, zooplankton, macrobenthos, aquatic macrophytes, and periphyton also was conducted at the Murphy Hill site during 1981 and 1982 (TVA 1983a).

In 1974 a combined preoperational/construction effects monitoring program was initiated at BLN. This program incorporated water quality (quarterly), biological (monthly), and those water quality parameters which specifically support biological monitoring (monthly). Biological and support water quality samples were collected February through October. The fish community was not expected to be substantially harmed by construction; therefore, broad-spectrum fish studies were not implemented in 1974. Larval fish sampling was implemented in 1974 to address entrainment potential and intake design for the BLN facility. Initially, sampling of biological communities was conducted in the mainstream channel and right downstream overbank habitats until 1978, when a change in design for the BLN diffuser redirected the plant effluent from the right (or BLN) side of the river to the opposite shore. Additional preoperational sampling stations were established along the opposite shore effective March 15, 1978. Right overbank stations downstream of BLN and in Town Creek (upstream) were retained to monitor construction effects until 1980 when AWIC allowed TVA to discontinue instream contruction effects monitoring.

Several delays in the construction schedule and fuel load date for unit 1 contributed to changes in the monitoring schedule at BLN. Effective February 12, 1979, sampling was reduced at several mainstream channel stations where a large data base existed. All sampling was suspended after the October 1979 survey. Water quality and biological monitoring was reinstated in February 1982 and continued through October 1983. A full scale fisheries preoperational monitoring program was initiated March 1981 and continued without a break through February 1984. A data base for cove rotenone sampling was collected somewhat sporadically dating back to 1949. Intensity of cove rotenone sampling improved over the years such that data collected since 1971 are sufficient for inclusion into this report. A listing of various written aquatic assessments relating to Guntersville Reservoir is provided in table 1-2.

1.4 Plant Description

BLN is a two-unit plant with the nuclear steam supply systems designed and supplied by Babcock and Wilcox. Each of the two pressurized water reactors is rated at 3600 MW core thermal power. The station operating life is expecting to be 40 years. Waste heat will be dissipated by natural draft cooling towers (one/unit) together with the main condenser and circulating system.

The essential raw cooling water (ERCW) pumps are the largest pumps which take suction from the river. They provide cooling water to safety-related plant components and supply the raw cooling water system pumps. Eight verticle turbine pumping units are located in the intake pumping station. These pumping units are completely redundant and normally only four will be operating with the remaining four on standby for emergency use. Flow rates for these pumps will vary with demand; however, under normal conditions, each of the four operating pumps will provide 1.1 m^3/sec (37.9 cfs) or less, for a total of 4.2 m^3/sec (151.5 cfs) for the plant.

The intake channel which connects the intake structure to the reservoir has a 7.6 meter wide (25 ft) trench excavated below the surface of the rock to connect to the original river channel, such that the intake will withdraw approximately 85 percent of its demand from the main river channel (and approximately 15 percent from the upstream overbank habitat). The intake pumping station is located approximately 365.8 m (1200 ft) from the existing shoreline. A floating trash boom will be located at the shoreline to protect the intake channel and pumping station from floating debris. Maximum cross sectional water velocity within the intake channel will be about 0.02 m/sec (0.06 ft/sec) for a water surface elevation of 593, minimum normal pool.

The intake pumping station has four openings slightly over three meters (10 ft) wide and approximately 11 meters (36 ft) high. Maximum water velocity will be less than 0.03 m/sec (0.10 ft/sec) through each opening at maximum normal pool elevation of 595. The openings are followed by 2.7 meter-wide (9 ft) vertical traveling screens which have 0.9 cm (3/8 in) opening mesh. Maximum average velocity through clean screens is estimated to be 0.07 m/sec (0.24 ft/sec) at maximum normal pool elevation of 595. Screen backwash water will be returned to Guntersville Reservoir via a concrete sluice.

The primary purpose of the BLN discharge system is to disperse cooling tower blowdown into the receiving water to limit concentration of dissolved solids in the heat rejection system. Normal discharge from the natural draft towers will be directed into Guntersville Reservoir through a diffuser at a rate of about 1.4 m^3/sec (50 cfs). The maximum blowdown rate (4.2 m^3/sec or 150 cfs) would occur when both units are down and neither cooling tower is operating. Maximum blowdown temperature is expected to be 35°C (95°F).

An oblique multiport diffuser was designed to achieve adequate mixing of the discharge during low and reverse river flow. Positioning of two diffuser sections 22.9 m and 13.7 m long at an angle to the shoreline will remove the heated effluent from the vicinity of the diffuser and direct it toward the opposite shore.

Potential impacts to the aquatic ecosystem in Guntersville Reservoir would occur primarily through the intake and heat dissipation systems. Intake impacts would involve entrainment of reservoir plankton including phytoplankton, zooplankton, fish eggs, and larval fish in addition to impingement of larger fish upon the intake pump screens. The heat dissipation system's potential for impacts would be through the thermal/chemical discharge of blowdown into the river. Bottom scouring is not expected to be a significant factor because of the design of the multiport diffuser pipes.

Figure 1-1. Area map showing location of Bellefonte Nuclear Plant relative to other land and reservoir features.

2.0 PHYSICAL RESERVOIR CONDITIONS IN THE VICINITY OF BLN

Physical conditions within and affecting Guntersville Reservoir play an important role in determining its biological potential. Many physical factors have been shown to influence aquatic ecosystems, including light and/or temperature (Ward and Karaki 1973; Kimmel and Lind 1972; Lund 1965; Mackenthun 1968; Moed and Hoogveld 1982); day-length and rainfall (Lund 1965); river flow (Pennak 1946); water retention (or replacement) times (Hynes 1969; Wrobel and Bombowna 1976); reservoir depth, basin contour, surface area, and surface winds (Mackenthun 1968), and basin geology (Wade, et al. 1981). Degree of influence exerted by a single factor is many times uncertain because of the large number of factors involved, their interrelation with one another, the rapidity with which the environment changes, and the diversity of aquatic organisms themselves.

It was beyond the scope of this project to decribe a large number of factors known to regulate reservoir conditions. However, several major factors and conditions are described in this chapter (especially as they relate to times on or just before collection of biological samples) which are considered important to a flow-through water body such as Guntersville Reservoir. These include: (1) flow patterns in the vicinity of the BLN site, (2) temperature and mixing, (3) monthly flows and temperatures during monitoring activities, (4) discharge from upstream and downstream dams, (5) solar radiation, (6) travel times for water masses, and (7) rainfall events. These factors are characterized by seasonal and annual trends.

2.1 Flow Patterns

Flow past the BLN site is controlled by operation of Nickajack Dam (TRM 425.0), upstream of the BLN site, and Guntersville Dam (TRM 407.6), downstream. Past studies have shown the highly variable nature of flow at the BLN site. Figure 2-1 illustrates the flow regime at BLN for typical operation of Nickajack Dam and Guntersville Dam. Nickajack consists of four hydropower units which discharge approximately 1,246 m^3/sec (44,000 cfs) when all are operating; Guntersville also has four units which discharge approximately 1,416 m^3/sec (50,000 cfs) total. Both dams have a much higher spill capacity for flood control. The maximum discharge at each dam since closure was in March 1973 at peak rates of 7,142 m^3/sec (252,200 cfs) at Nickajack Dam and 8,897 m^3/sec (314,200 cfs) at Guntersville Dam.

Upstream of the BLN site, Guntersville Reservoir is contained mainly within the original river channel. Immediately upstream of the site is Bellefonte Island (approximately TRM 392.3 to 394.7) which divides the reservoir longitudinally. Also immediately upstream of the BLN site, the reservoir begins to widen beyond the original channel into relatively shallow backwater and overbank areas. These areas are protected from wind and current action by a chain of strip islands and bars. These strips extend from above BLN to approximately TRM 385.0, and are broken periodically, which allows some exchange between the overbank areas and the main channel. These overbank areas are significant in considering biological response, offering plankton source areas and fish habitat which are different from that of the main channel. Exchanges between the overbank areas and the main channel are most significant during periods of rapid water surface elevation change.

2.2 Temperature and Mixing

Previous studies have indicated that temperatures at the BLN site are primarily affected by releases from Nickajack Dam. There is generally a lack of stratification, indicating a fully mixed flow-through reservoir with short detention times.

Effects from Widows Creek Steam Plant (WCF) on temperatures at the BLN site are negligible during moderate to high flows. During low flows, the thermal discharge from WCF mixes in a surface layer 1.5 to 3 m (5 to 10 feet) deep, across the width of the reservoir. The effects of this thermal discharge during low flows are difficult to differentiate from solar heating of the surface layer (TVA, 1982).

2.3 Monthly Flows and Temperatures During Monitoring Activities

Maximum average daily flows during the period of monitoring were on the order of 4,248 m^3/sec (150,000 cfs) and 5,663 m^3/sec (200,000 cfs) at Nickajack Dam and Guntersville Dam, respectively. These higher flows occurred generally during late winter and spring. Plankton samples were taken during periods of high average daily flow in 1974, 1975, and 1982.

Minimum average daily flows during the monitoring period were on the order of 283 m^3/sec (10,000 cfs) or less. These generally occurred in late summer. Plankton samples were taken during low flow in 1975, 1976, 1978, 1982, and 1983. Average daily flows with sample date indicators are displayed in figures 2-2 through 2-9. Monthly average discharges for Nickajack Dam and Guntersville Dam are shown in table 2-1, along with yearly averages, for the period of monitoring (including non-sample months). Estimated occurrence and duration or river flows less than 0 are shown in table 2-2. Average dam discharges for the entire monitoring period at Nickajack Dam and Guntersville Dam were 1,141 m^3/sec (40,300 cfs) and 1,368 m^3/sec (48,300 cfs), respectively.

Travel times within Guntersville Reservoir are governed by the operation of Nickajack and Guntersville Dams. Travel times for the Nickajack to BLN and BLN to Comer Bridge reaches were calculated for each sample date. Travel time from Nickajack to BLN ranged from 21 hours to 5.1 days. Travel time from BLN to Comer Bridge, which is approximately the end of the strip islands, ranged from seven hours to 2.1 days. Daily average flows on plankton sample dates and for the five days prior to samples, and travel time on the same date, are shown in figures 2-10 through 2-45.

Temperatures on the plankton sample date and the five days prior are also in figures 2-10 through 2-45. Table 2-3 shows the monthly average maximum and minimum temperatures for the monitored period. During this time, average temperatures ranged from a low of 5.6°C (42°F) to a high of 30.6°C (87°F). The adjusted temperatures should be used with some caution in this analysis, but should adequately display annual and seasonal trends.

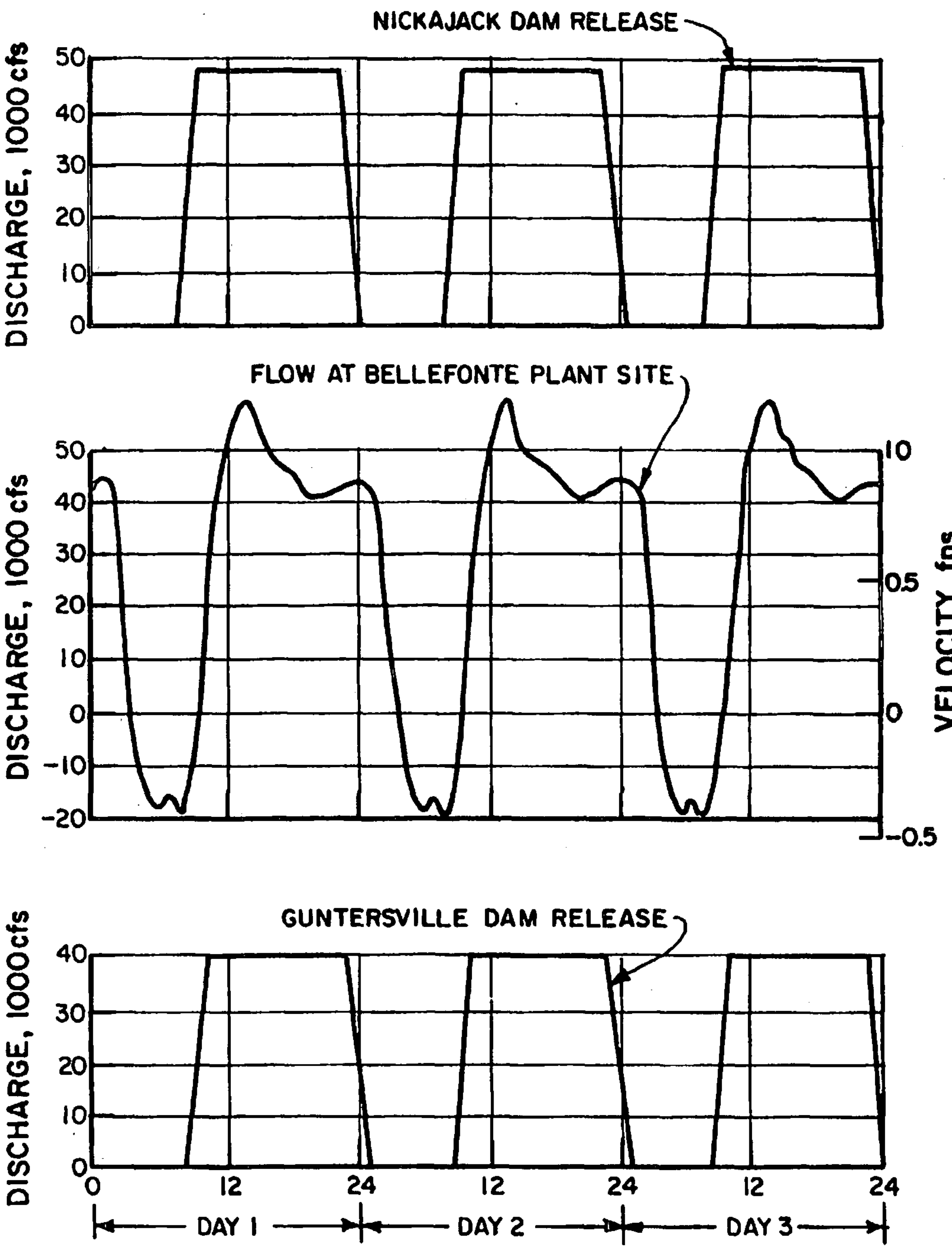

Figure 2-1. Typical Tennessee River Flows in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, Alabama.

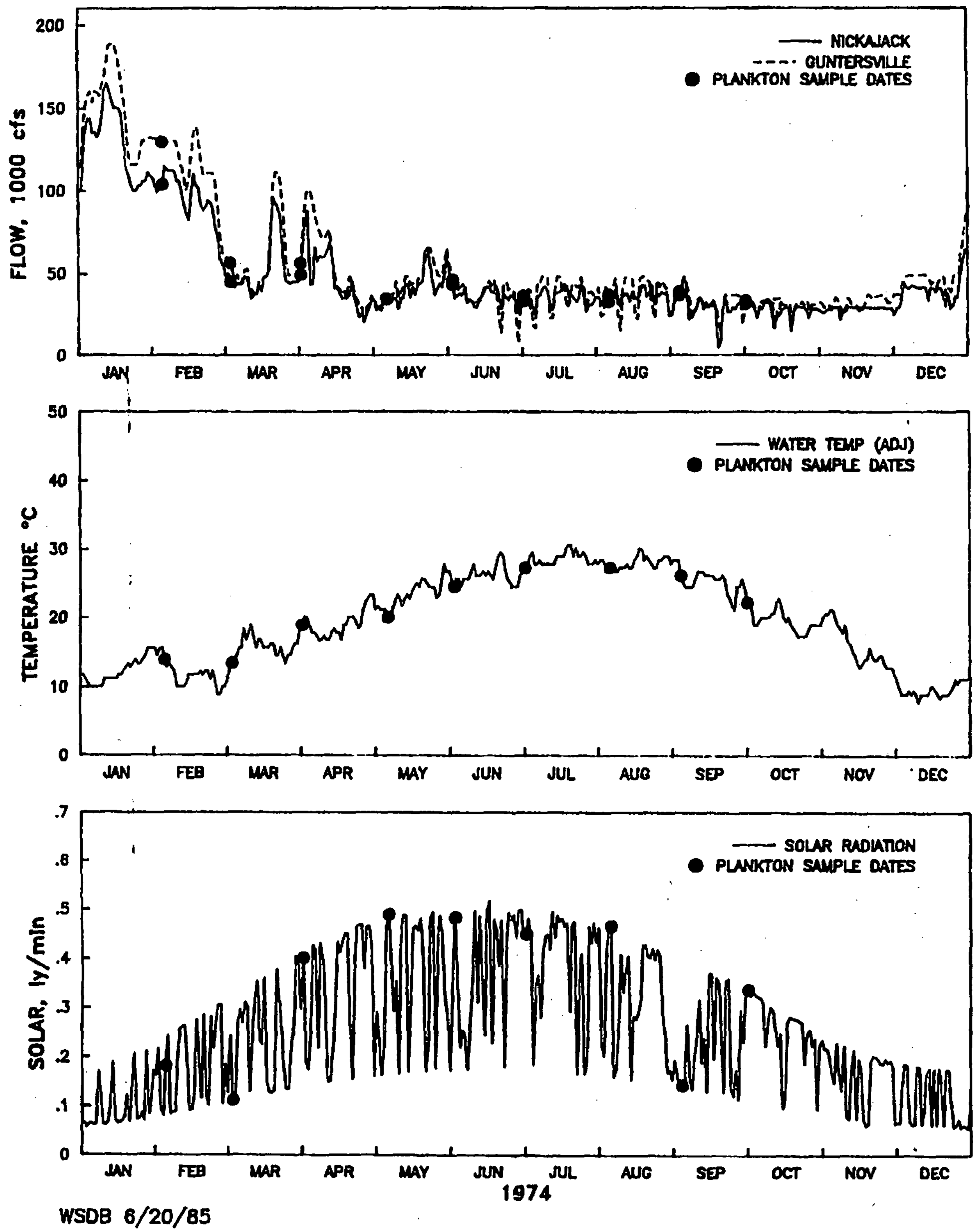

Figure 2-2 .Daily average flows & temperatures near Bellefonte Nuclear Plant, Guntersville Reservoir, 1974.

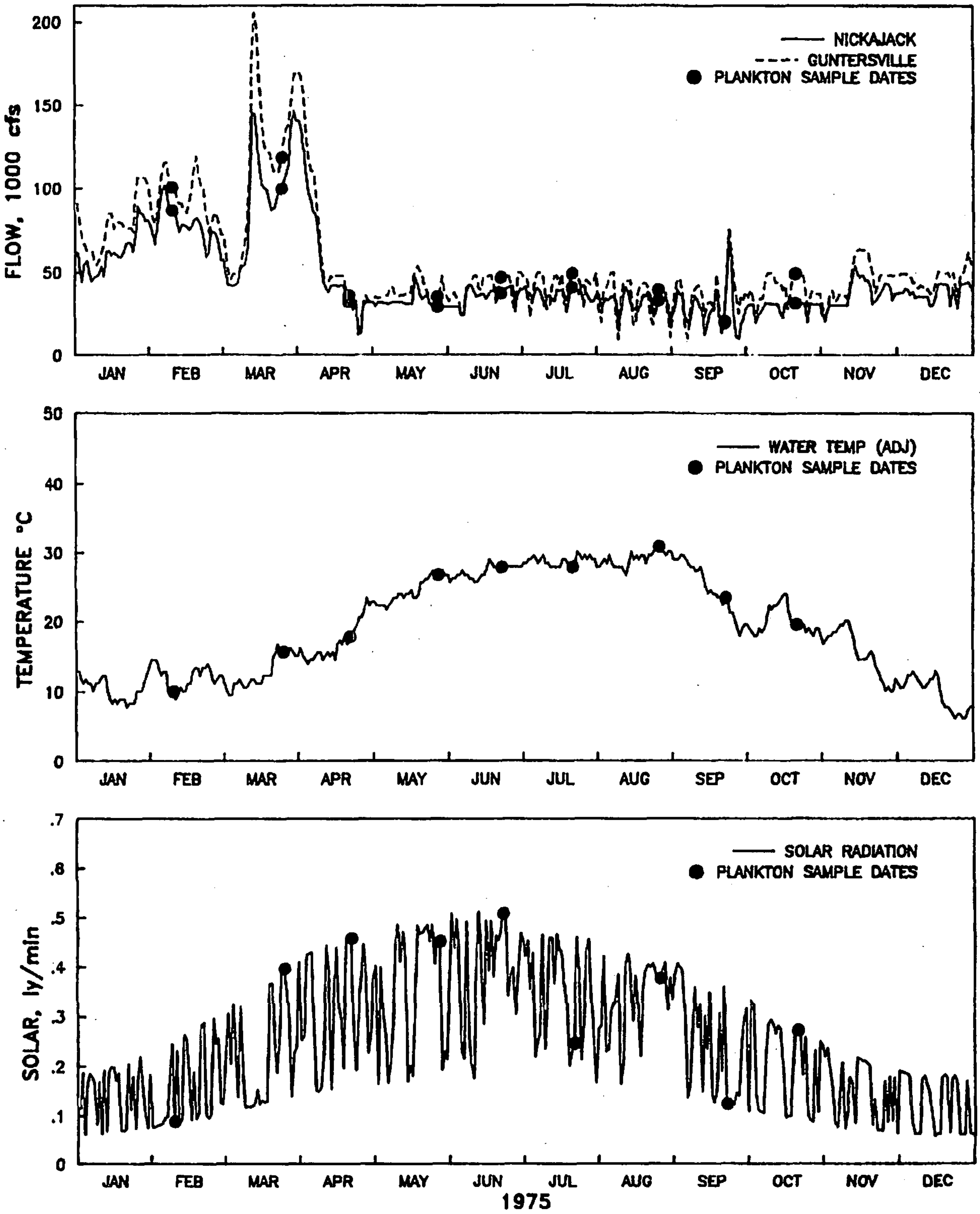

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Figure 2-3 .Daily average flows & temperature near Bellefonte Nuclear Plant, Guntersville Reservoir, 1975.

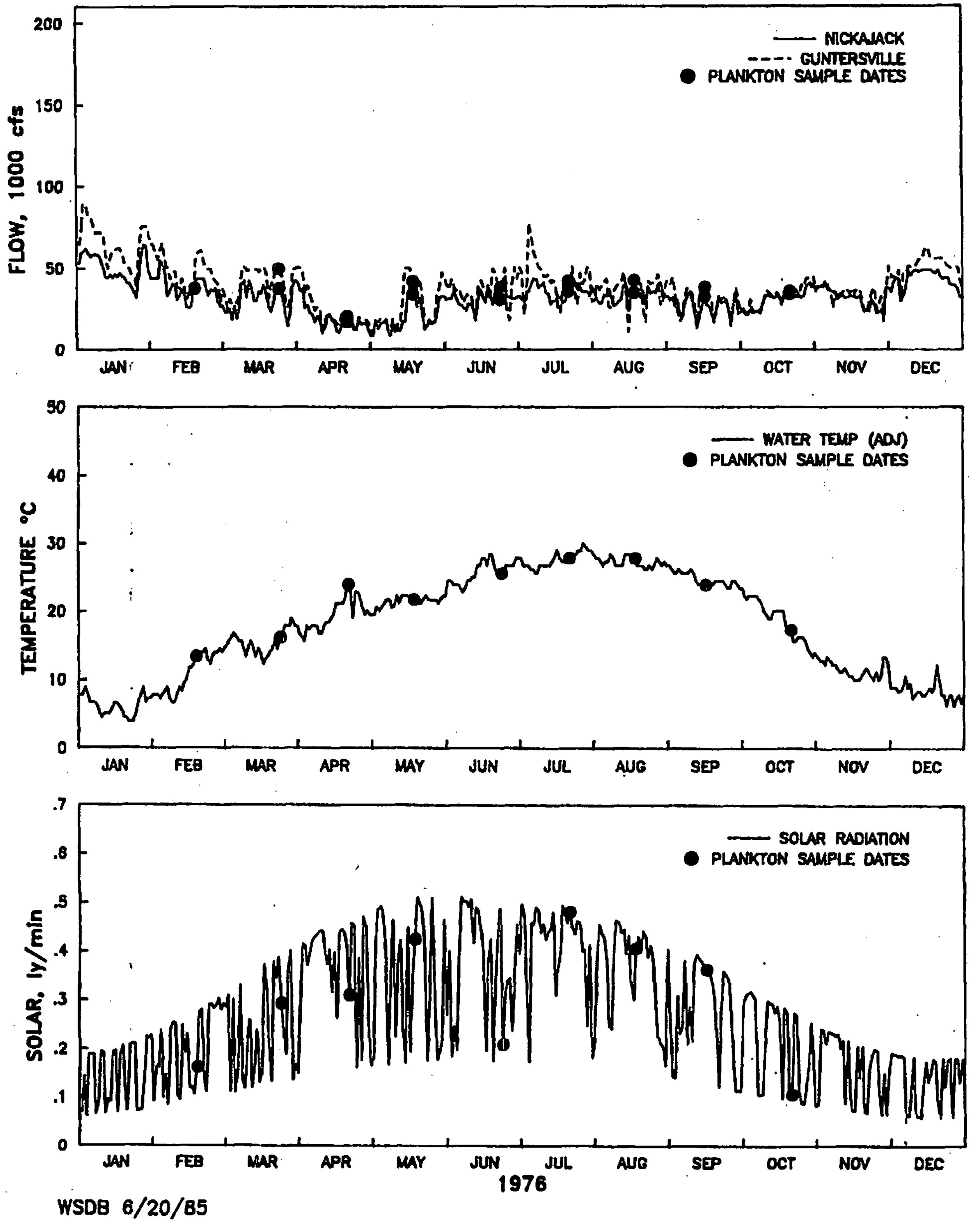

Figure 2-4 .Daily average flows & temperatures near Bellefonte Nuclear Plant, Guntersville Reservoir, 1976.

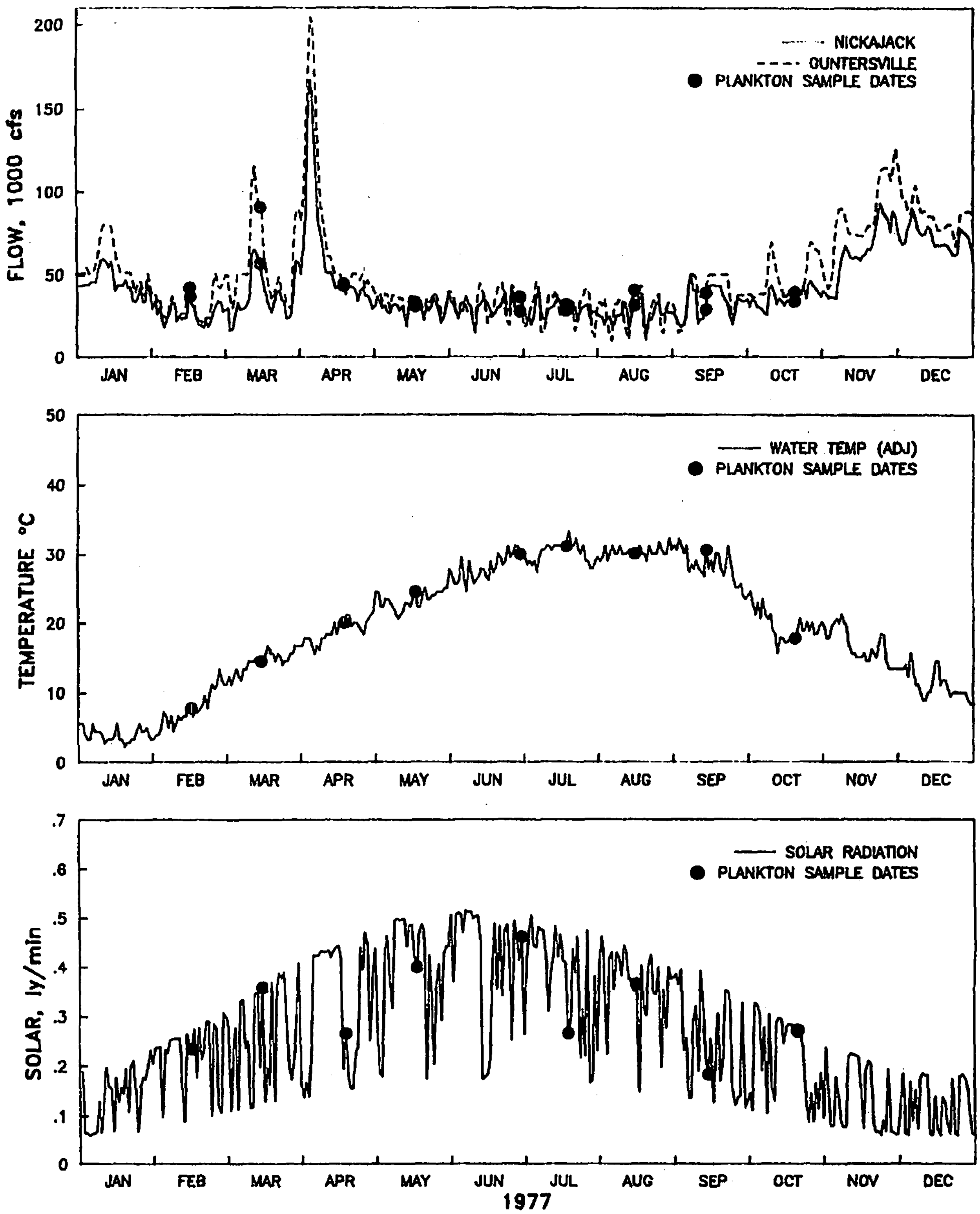

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Figure 2-5 .Daily average flows & temperatu,es near Bellefonte Nuclear Plant, Guntersville Reservoir, 1977.

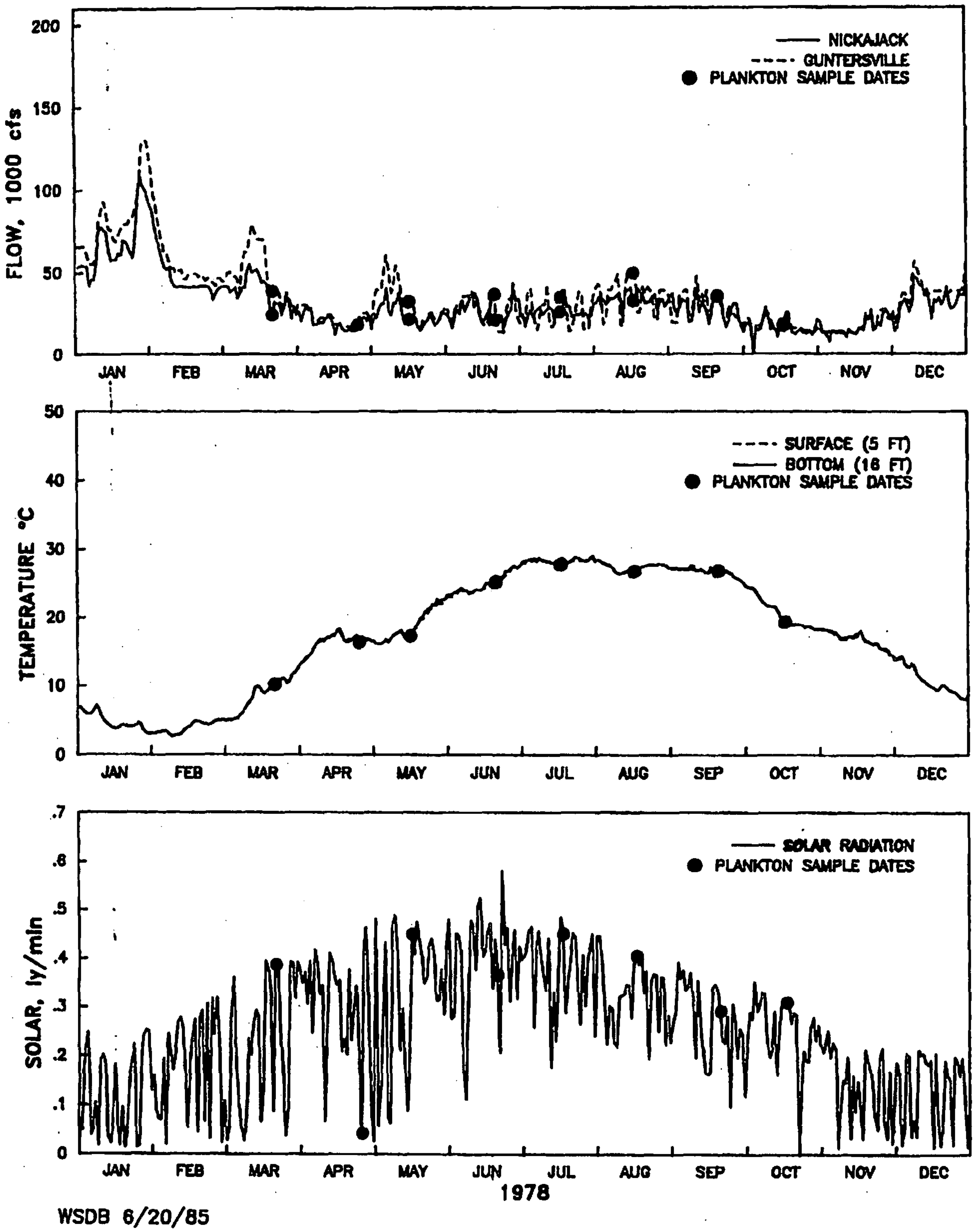

Figure 2-6 .Daily average flows & temperatures near Bellefonte Nuclear Plant, Guntersville Reservoir, 1978.

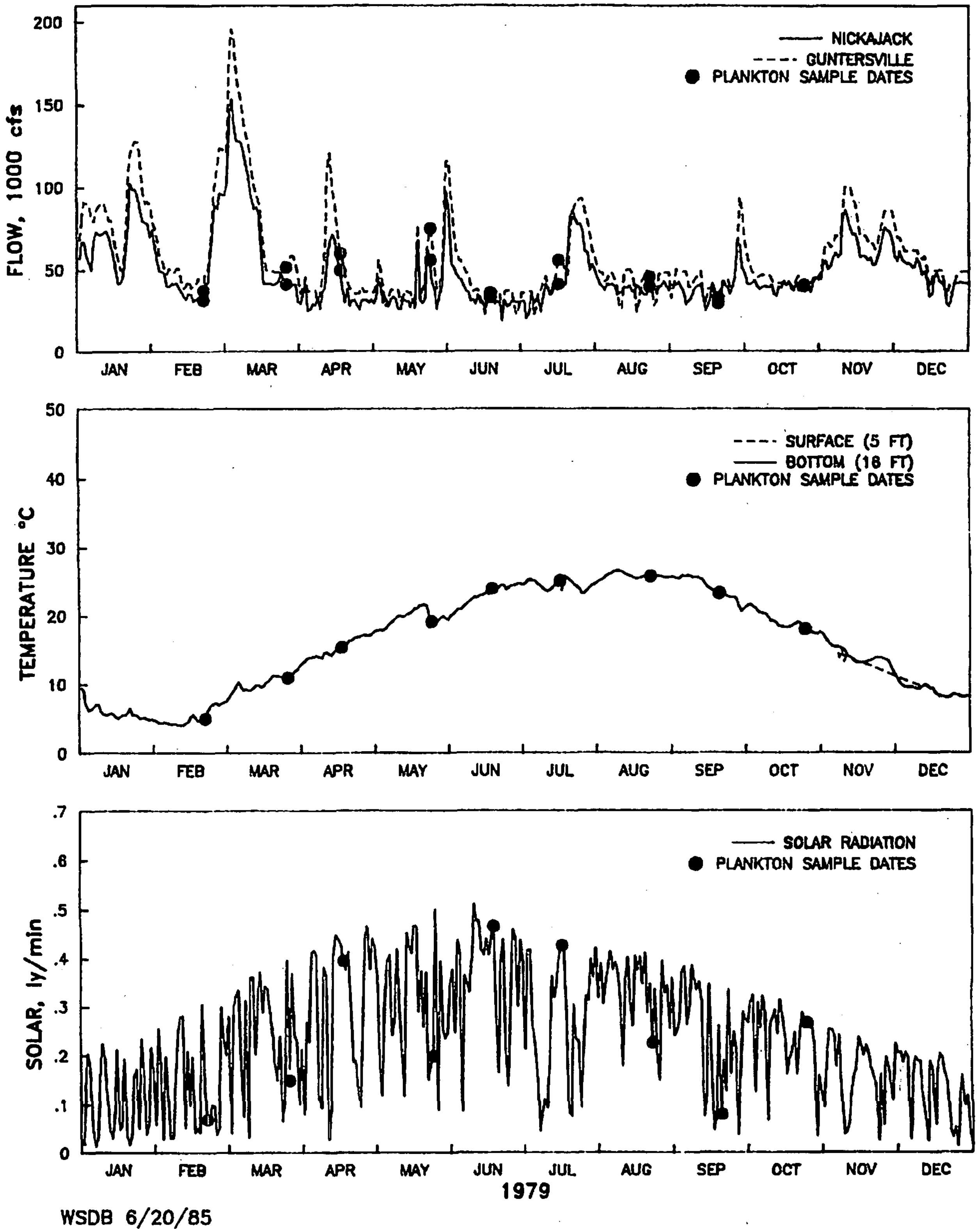

Figure 2-7 .Daily average flows & temperatures near Bellefonte Nuclear Plant, Guntersville Reservoir, 1979.

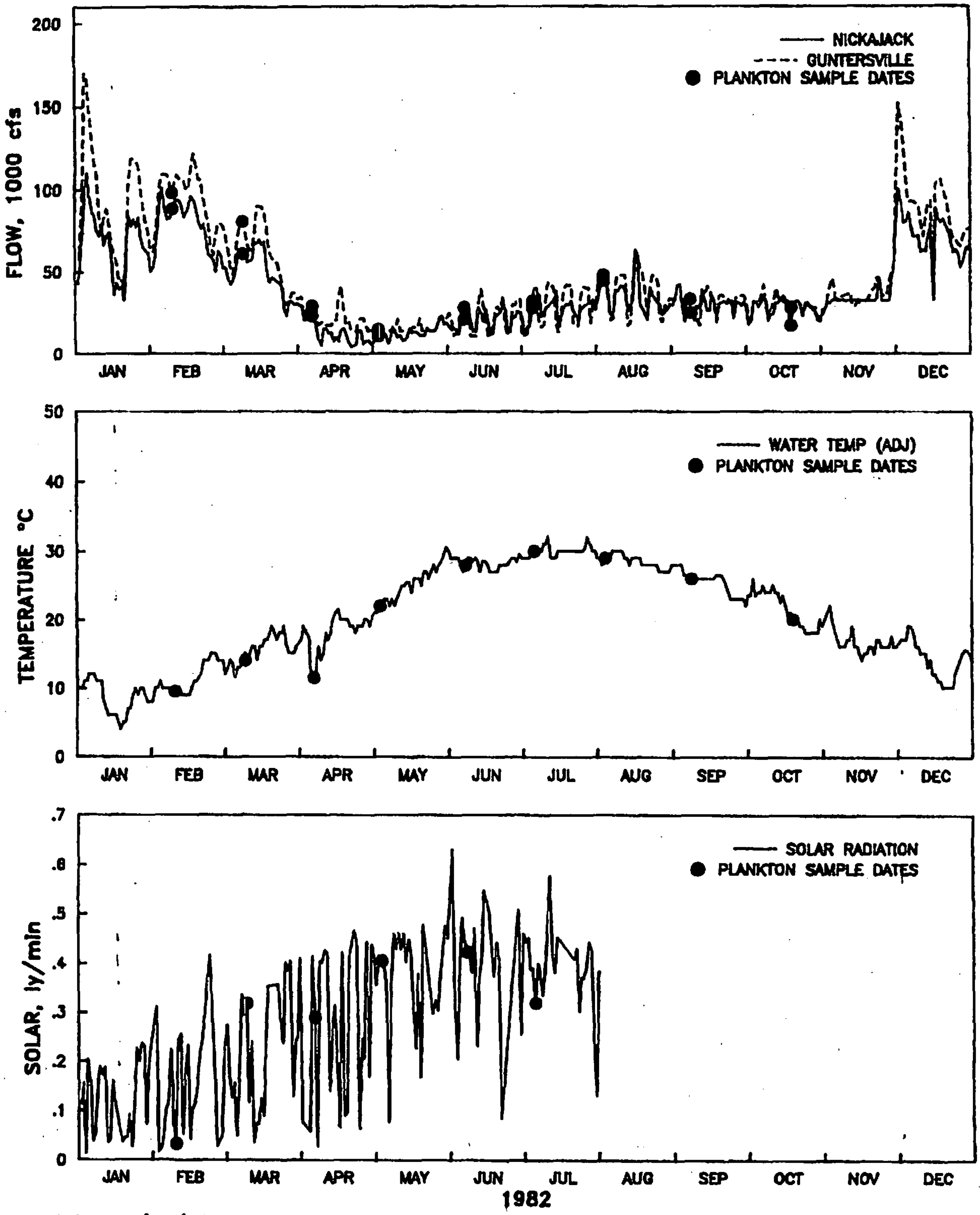

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Figure 2-8 .Daily average flows & temperatures near Bellefonte Nuclear Plant, Guntersville Reservoir, 1982.

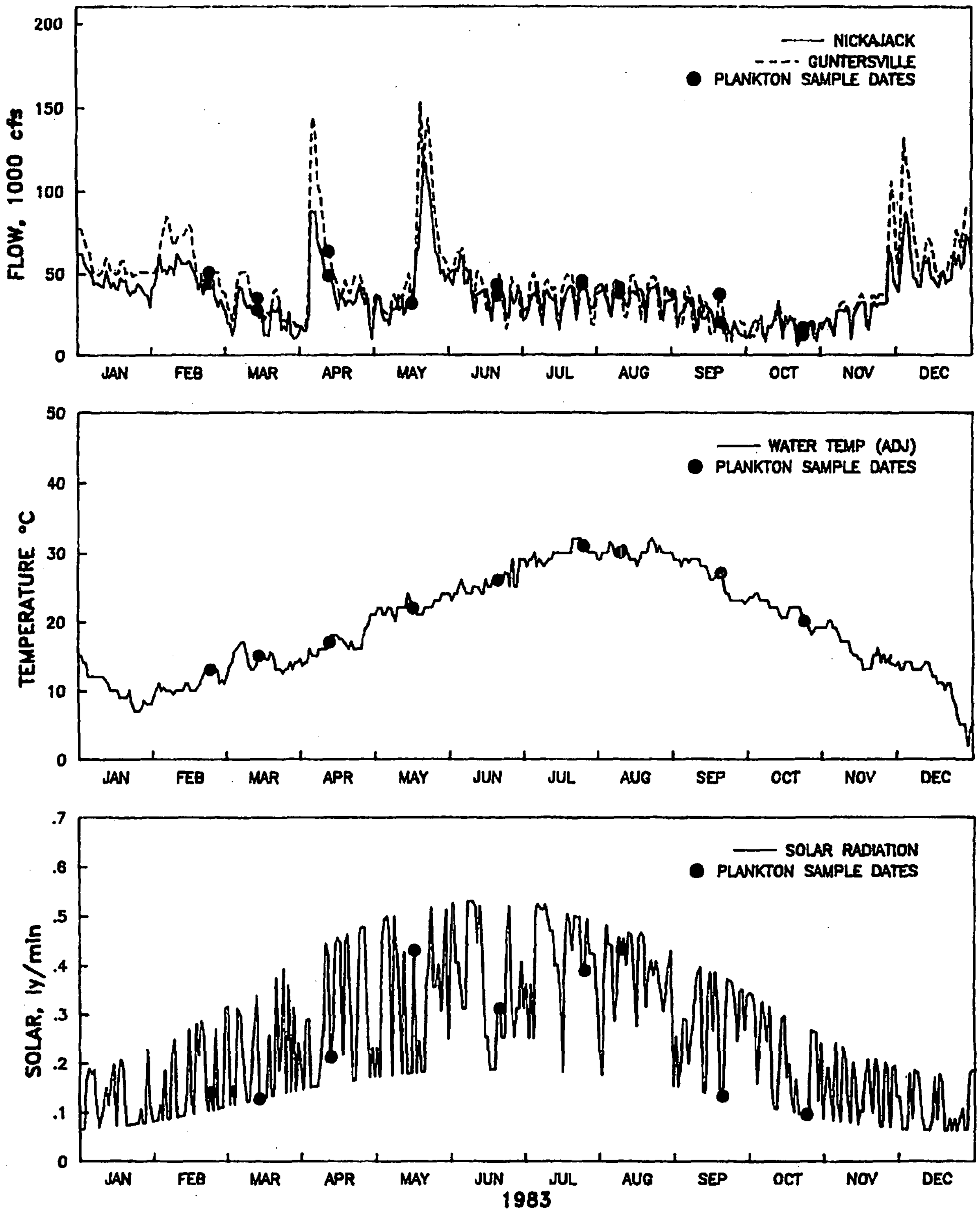

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Figure 2-9 .Daily average flows & temperatures near Bellefonte Nuclear Plant, Guntersville Reservoir, 1983.

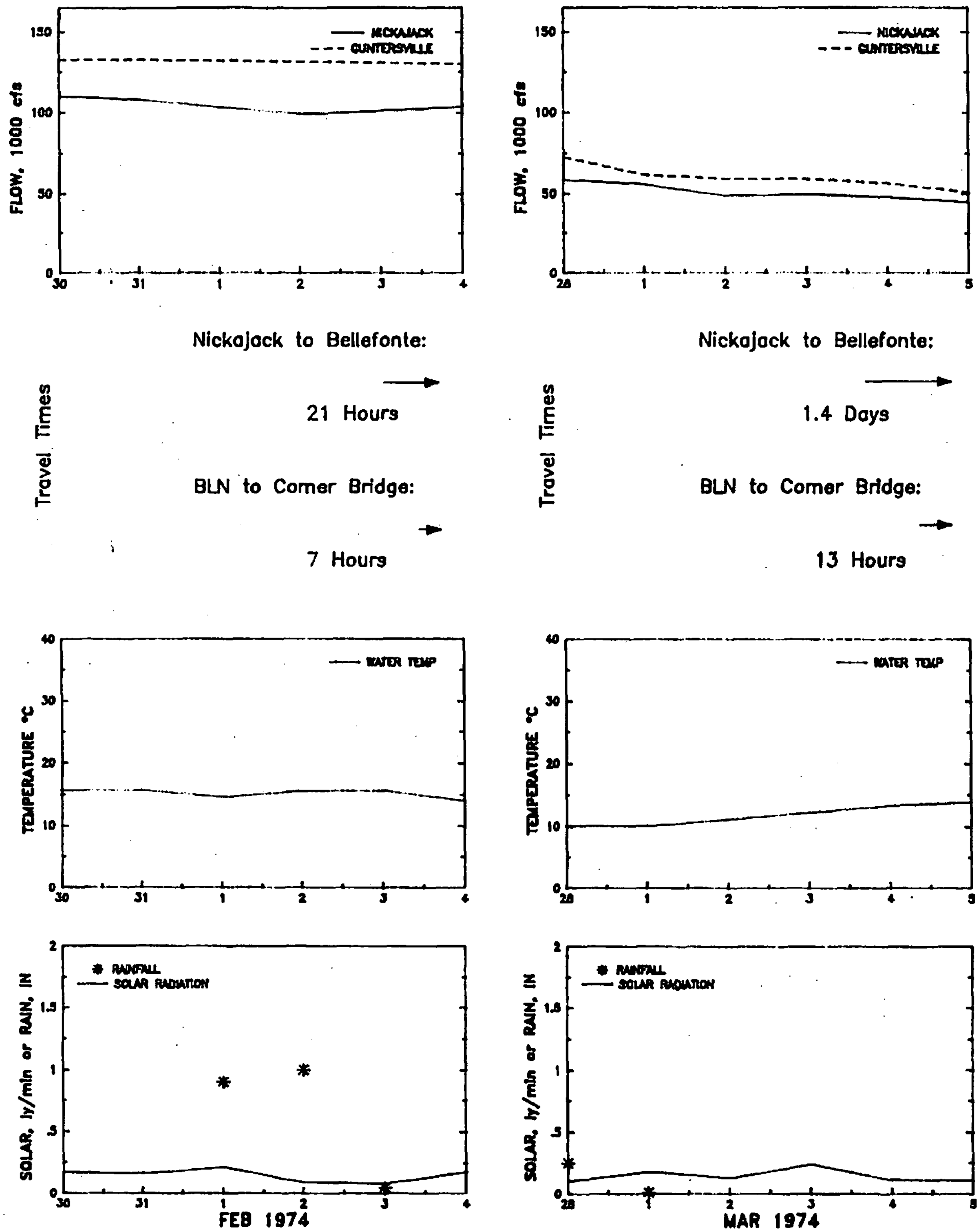

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Figure 2-10 .Conditions prior to Plankton Sampling on Feb. 4 and Mar. 5, 1974 for Preoperational Monitoring of Bellefonte Nuclear Plant.

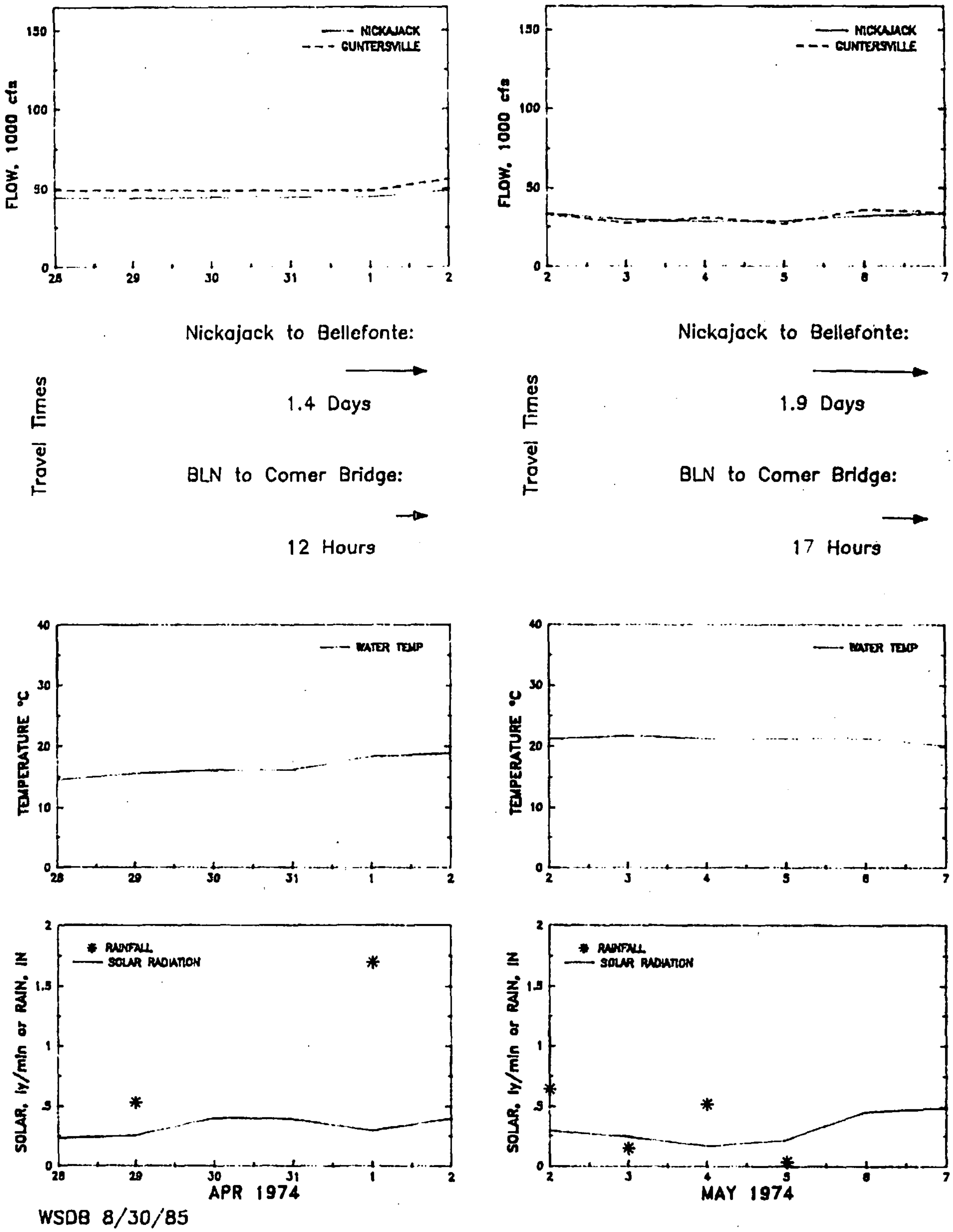

Figure 2-11 .Conditions prior to Plankton Sampling on April 2 and May 7, 1974 for Preoperational Monitoring of Bellefonte Nuclear Plant.

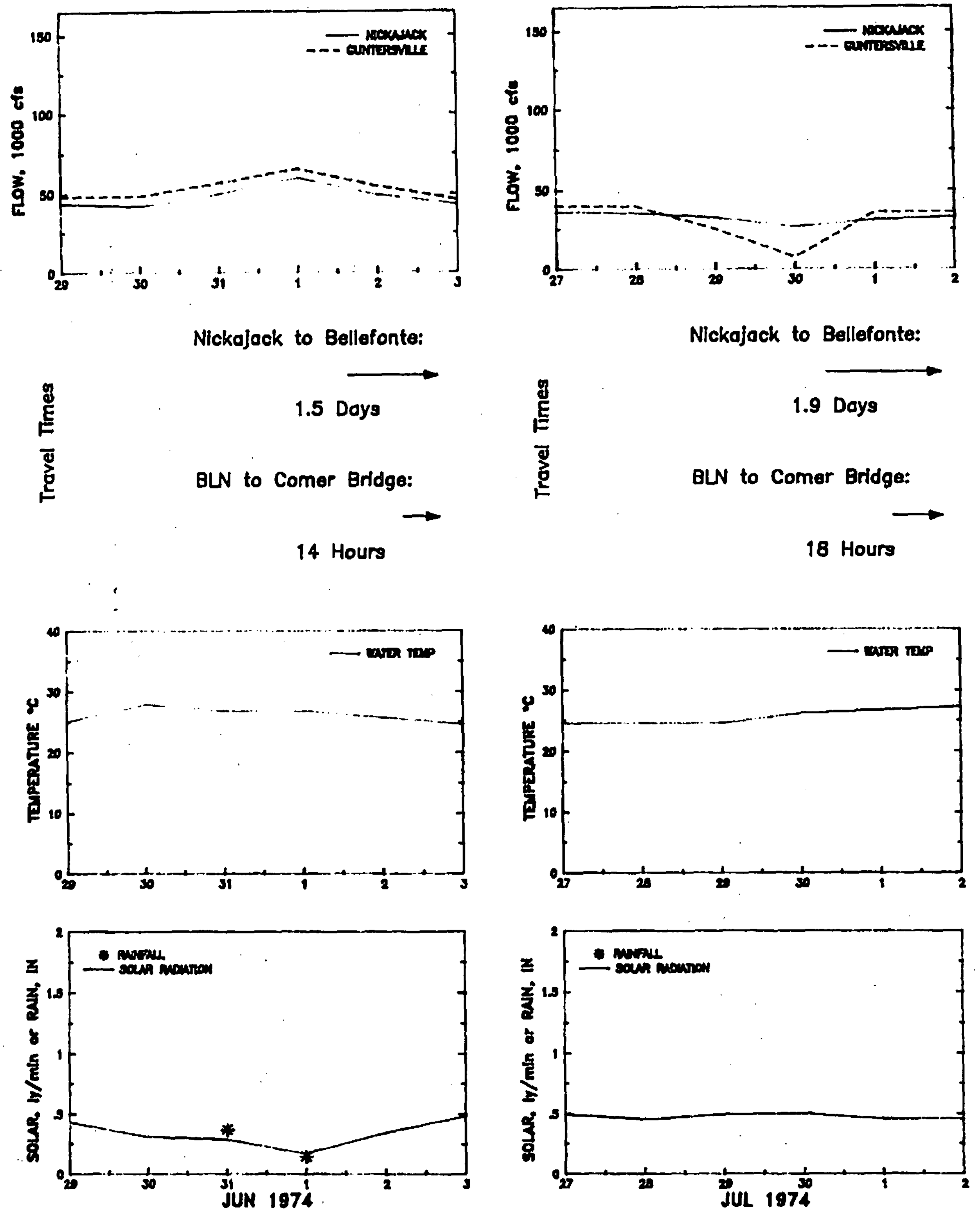

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Figure 2-12 .Conditions prior to Plankton Sampling on June 3 and July 2, 1974 for Preoperational Monitoring of Bellefonte Nuclear Plant.

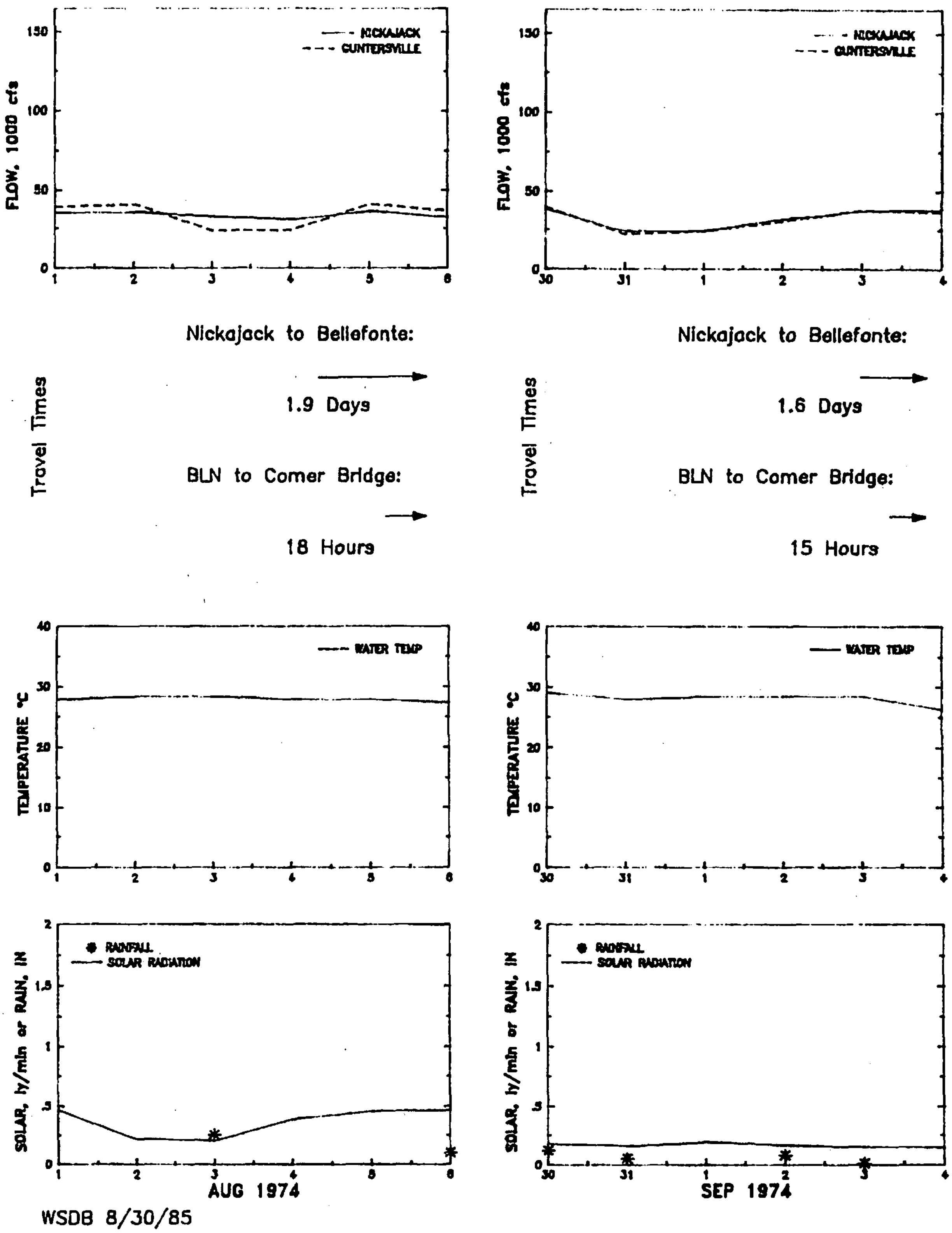

Figure 2-13 .Conditions prior to Plankton Sampling on Aug. 6 and Sep. 4, 1974 for Preoperational Monitoring of Bellefonte Nuclear Plant.

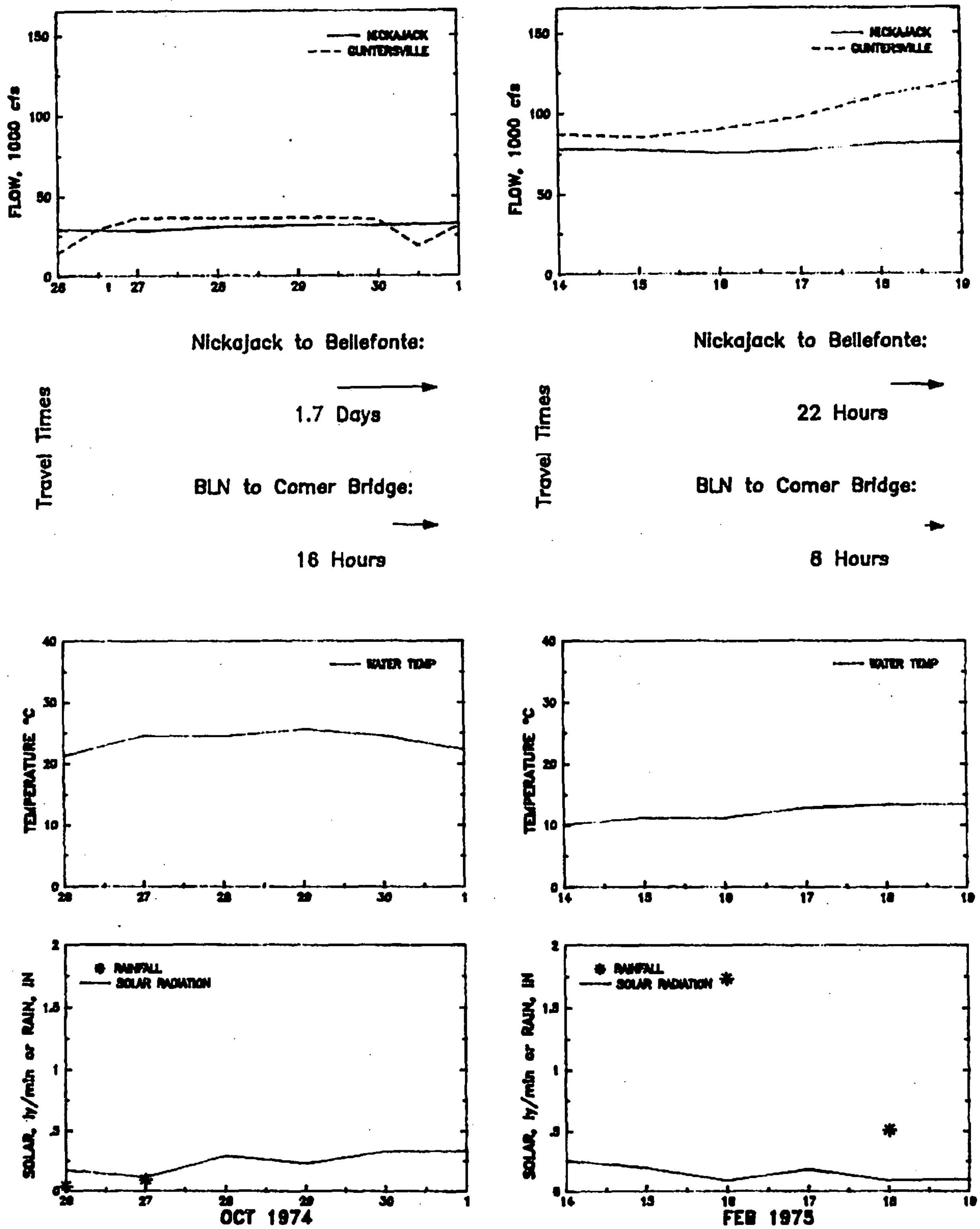

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Figure 2-14 .Conditions prior to Plankton Sampling on Nov. 1, 1974 and Feb. 19, 1975 for Preoperational Monitoring of Bellefonte Nuclear Plant.

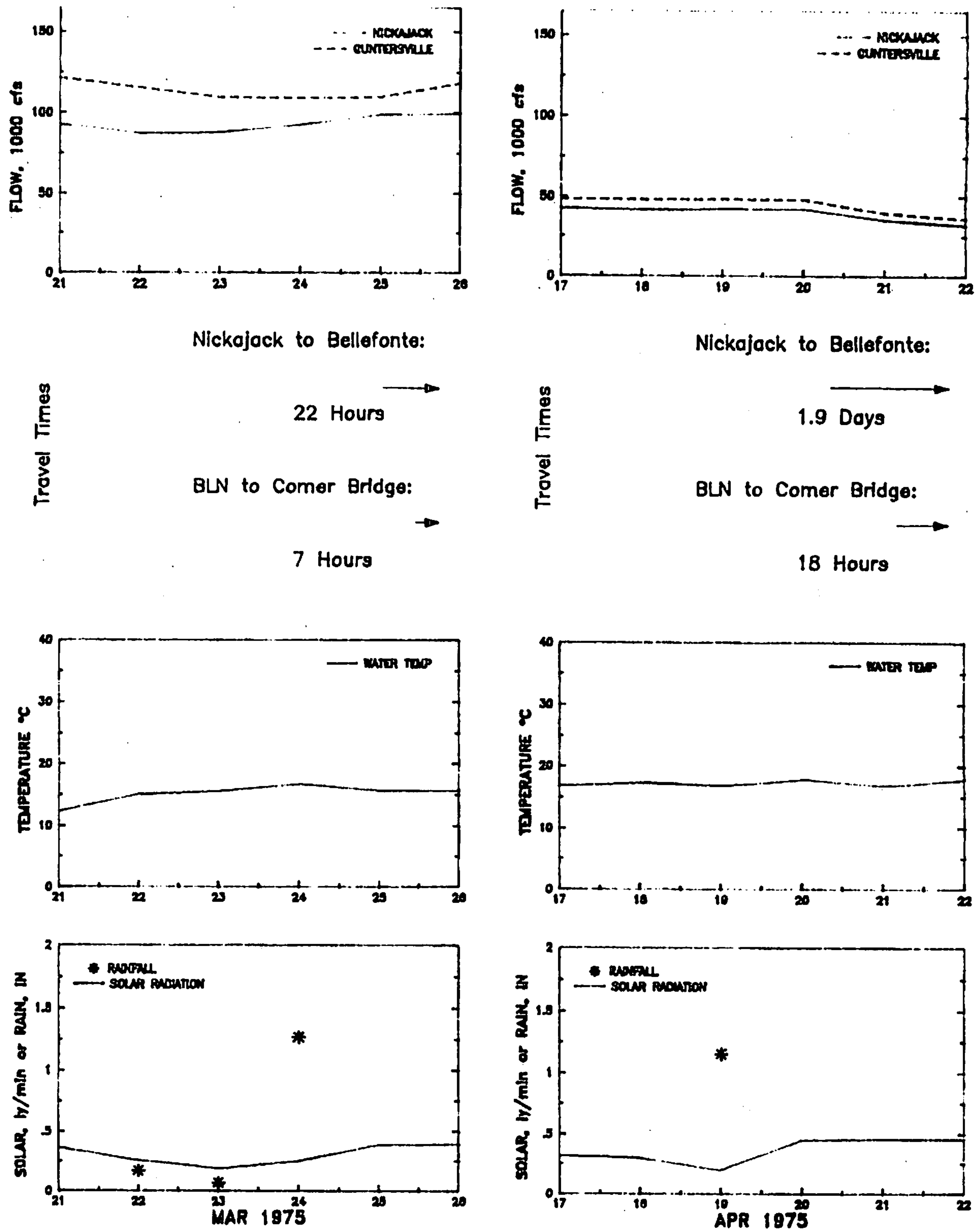

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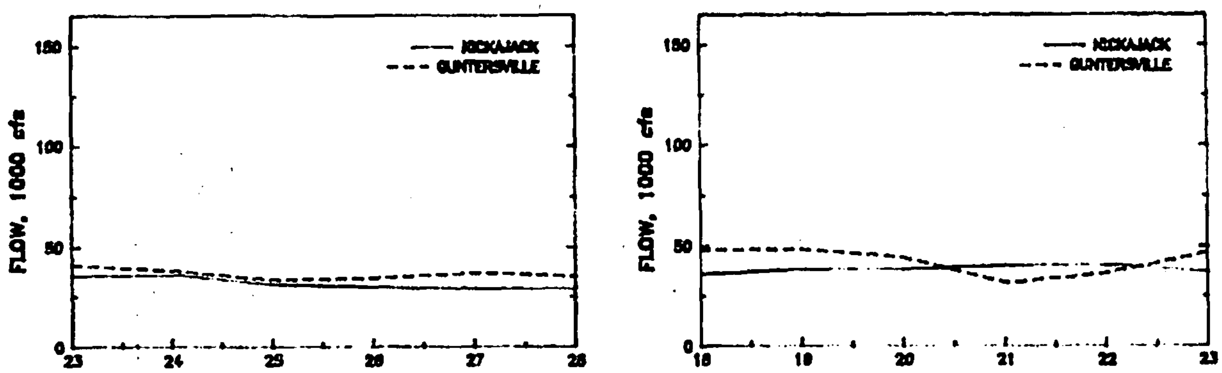
Figure 2-15 .Conditions prior to Plankton Sampling on Mar. 26 and Apr. 22, 1975 for Preoperational Monitoring of Bellefonte Nuclear Plant.



Travel Times

Nickajack to Bellefonte: → 2.2 Days

BLN to Comer Bridge: → 20 Hours

Travel Times

Nickajack to Bellefonte: → 1.8 Days

BLN to Comer Bridge: → 16 Hours

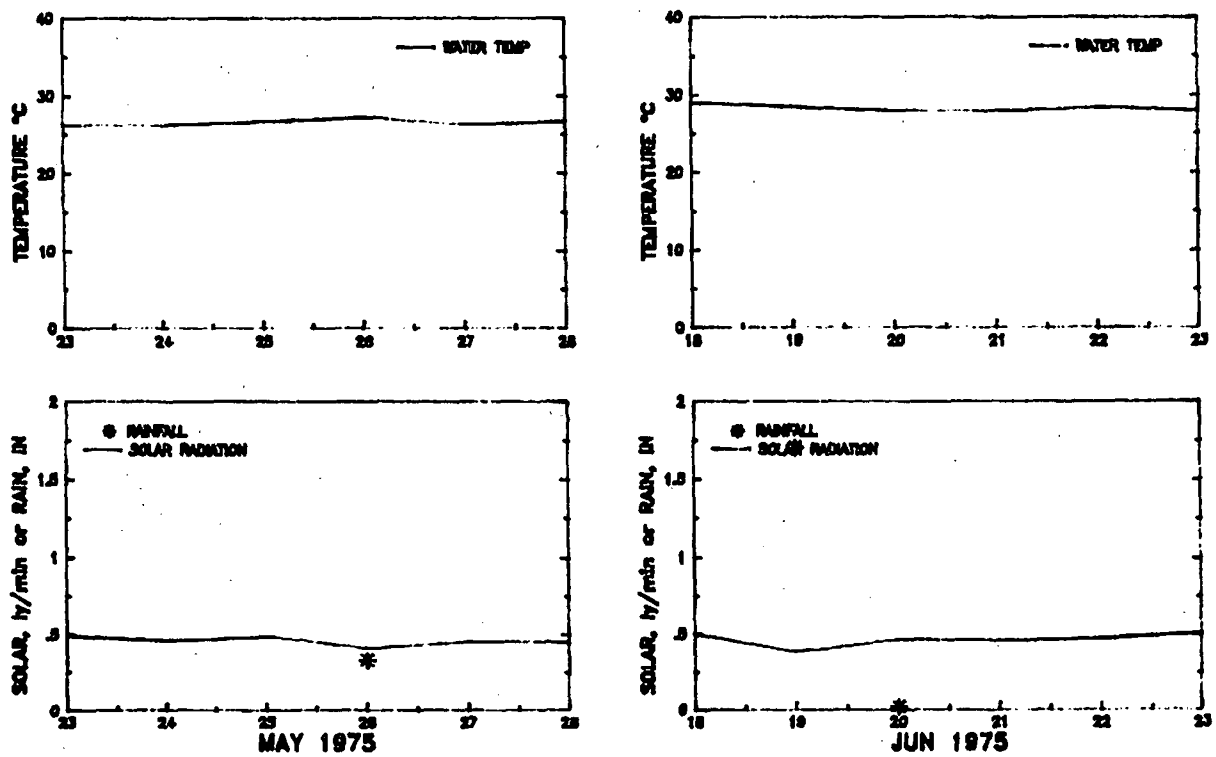


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Figure 2-16 .Conditions prior to Plankton Sampling on May 28 and June 23, 1975 for Preoperational Monitoring of Bellefonte Nuclear Plant.

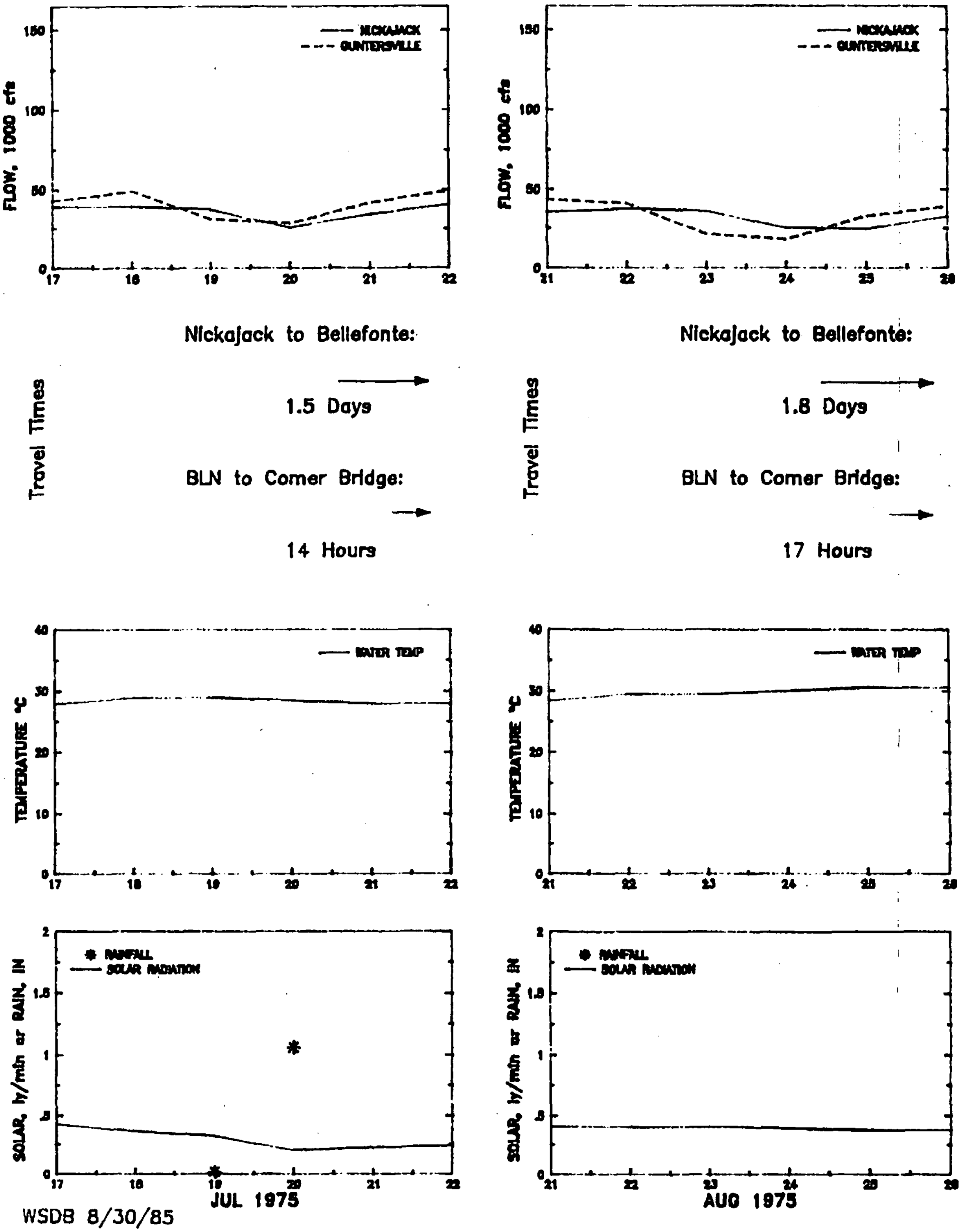

Figure 2-17 .Conditions prior to Plankton Sampling on July 22 and Aug. 26, 1975 for Preoperational Monitoring of Bellefonte Nuclear Plant.

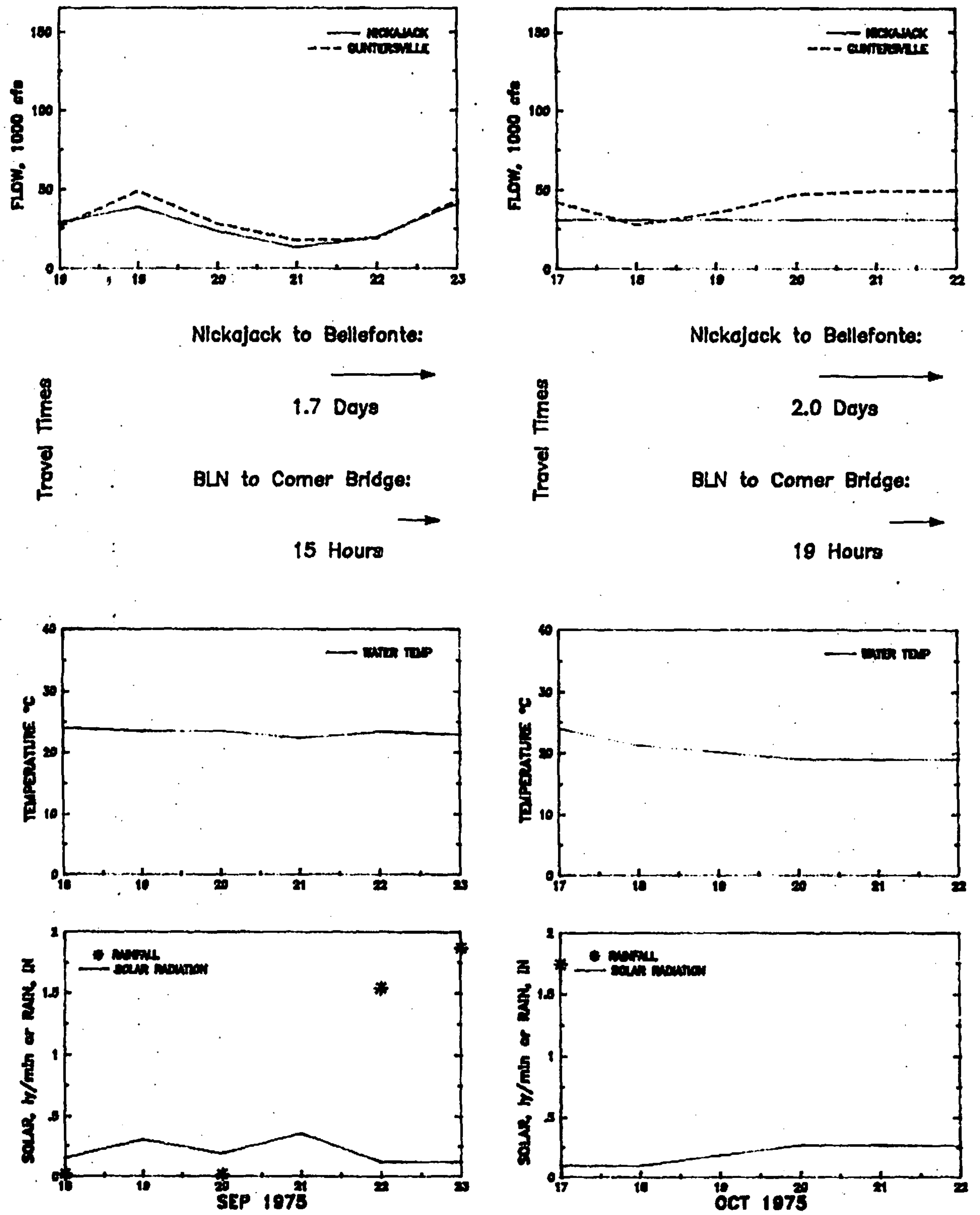

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Figure 2-18 .Conditions prior to Plankton Sampling on Sep. 23 and Oct. 22, 1975 for Preoperational Monitoring of Bellefonte Nuclear Plant.

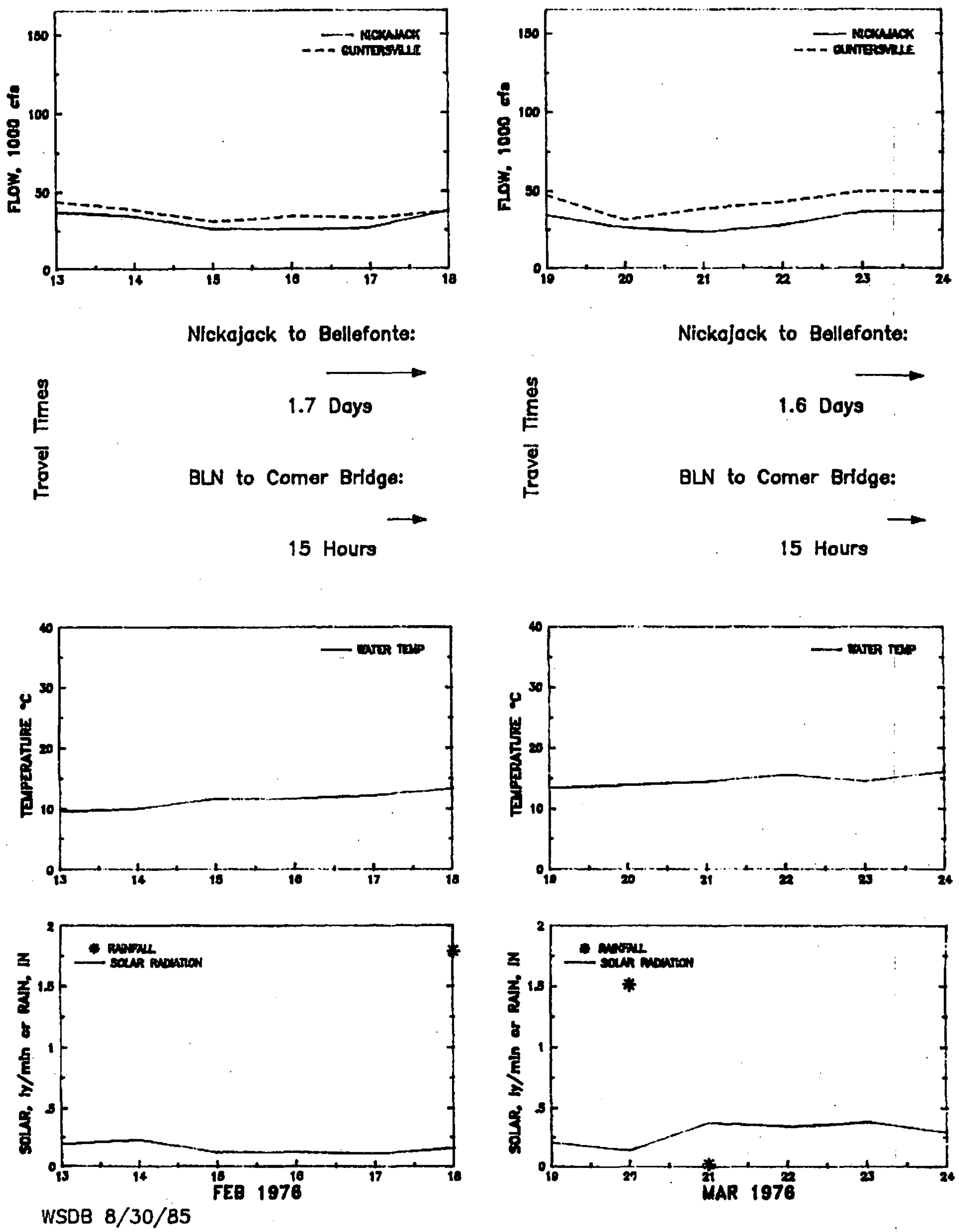

Figure 2-19 .Conditions prior to Plankton Sampling on Feb. 18 and Mar. 24, 1976 for Preoperational Monitoring of Bellefonte Nuclear Plant.

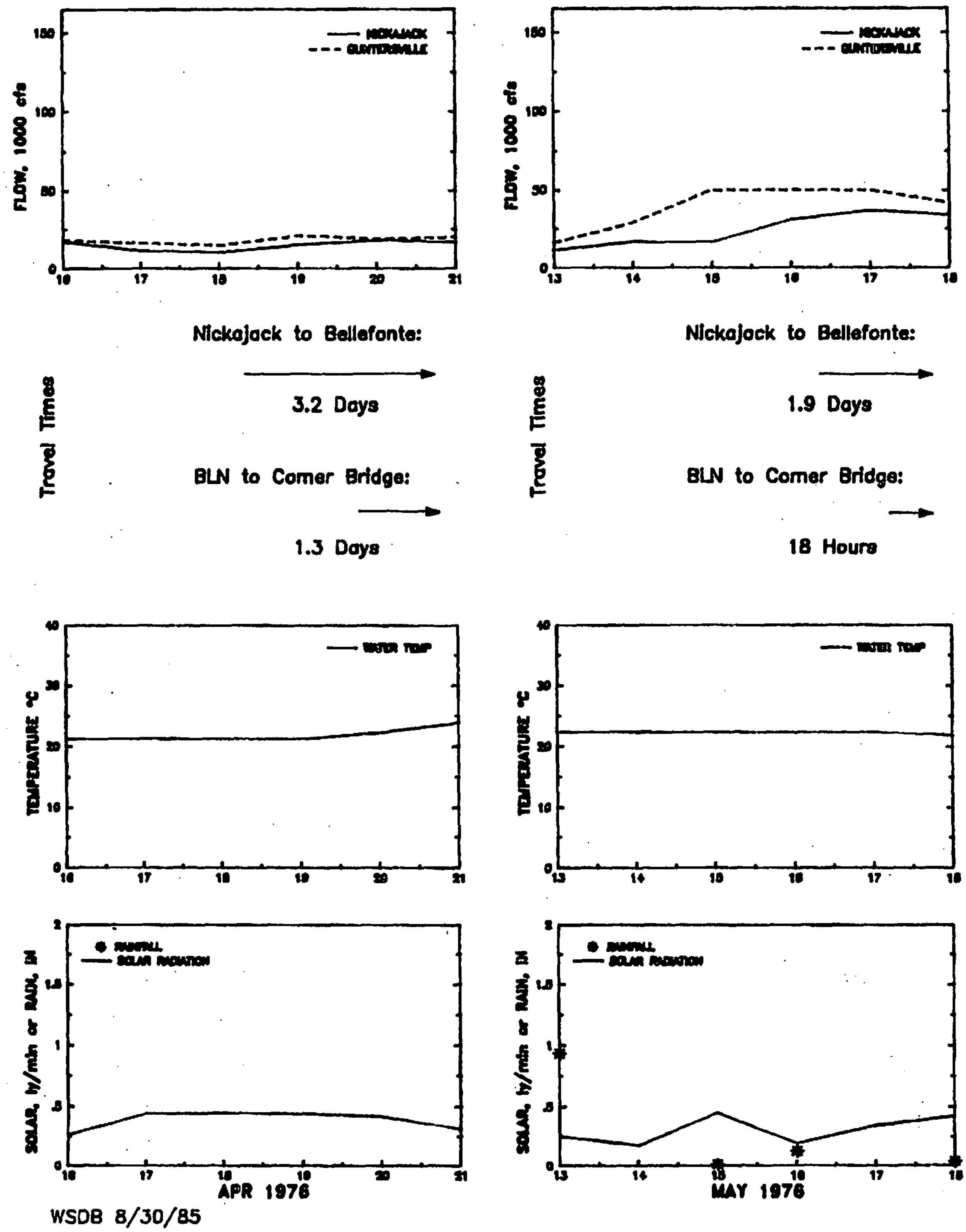

Figure 2-20 .Conditions prior to Plankton Sampling on Apr. 21 and Mar. 18, 1976 for Preoperational Monitoring of Bellefonte Nuclear Plant.

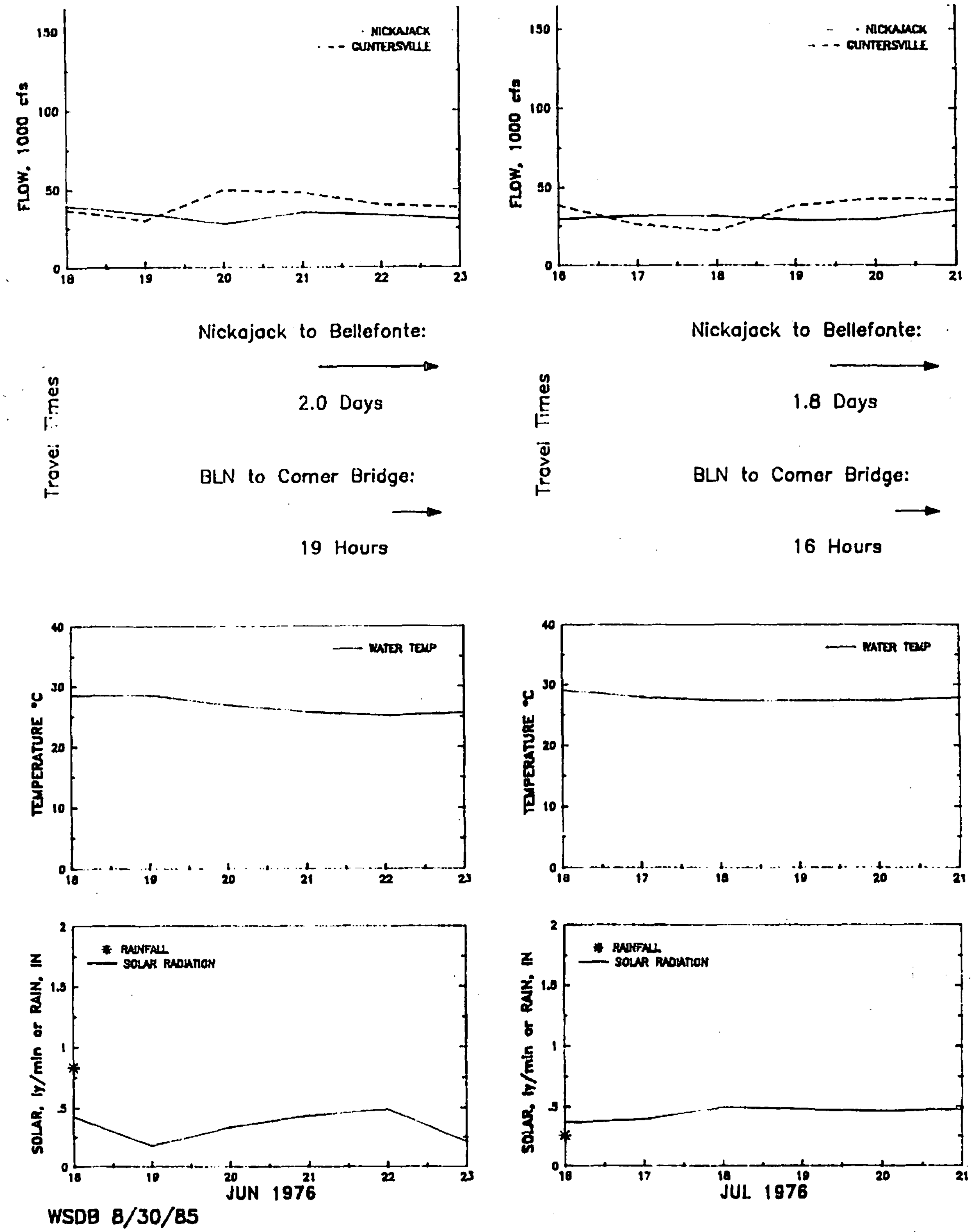

Figure 2-21 .Conditions prior to Plankton Sampling on June 23 and July 21, 1976 for Preoperational Monitoring of Bellefonte Nuclear Plant.

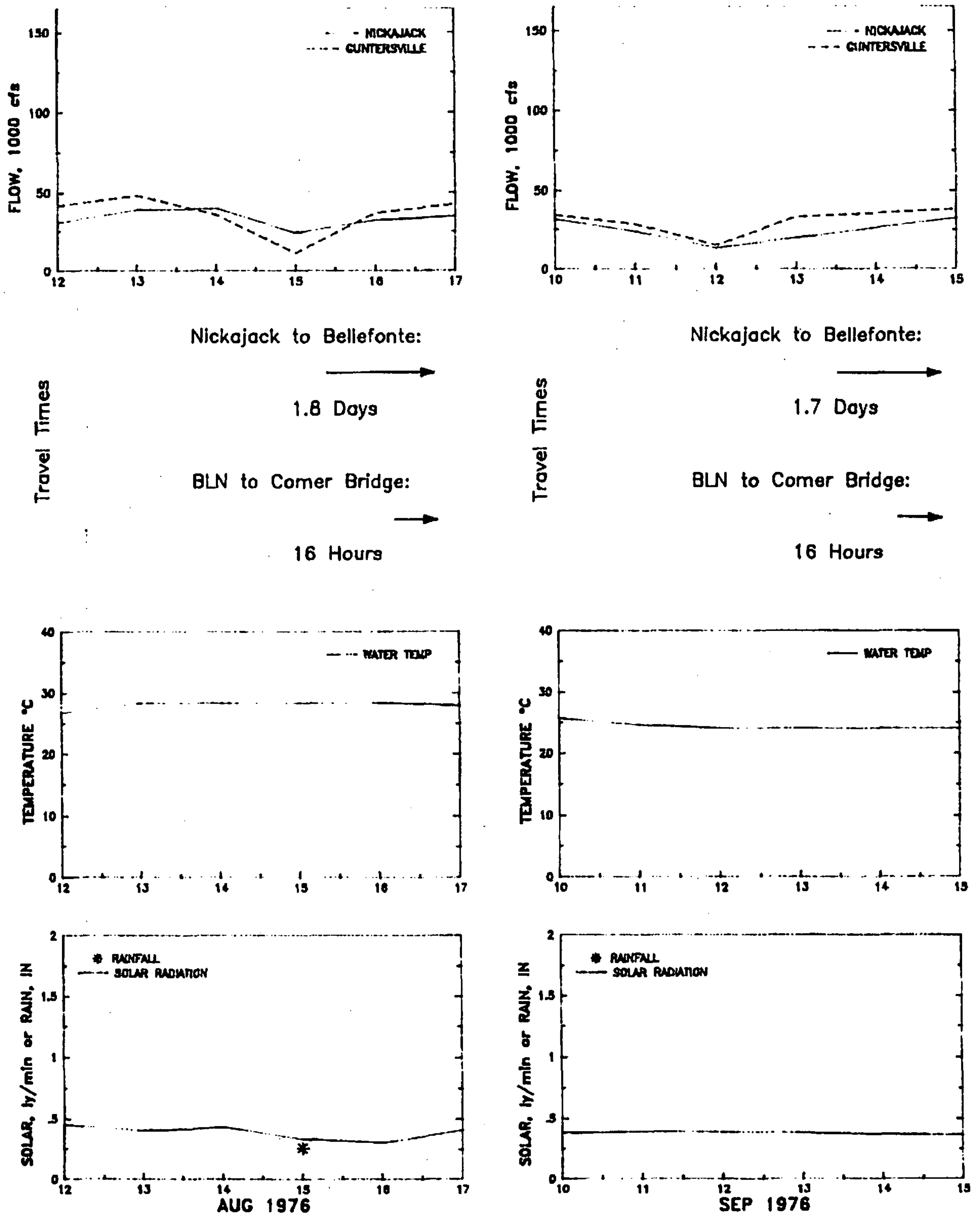

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Figure 2-22 .Conditions prior to Plankton Sampling on Aug. 17 and Sep. 15, 1976 for Preoperational Monitoring of Bellefonte Nuclear Plant.

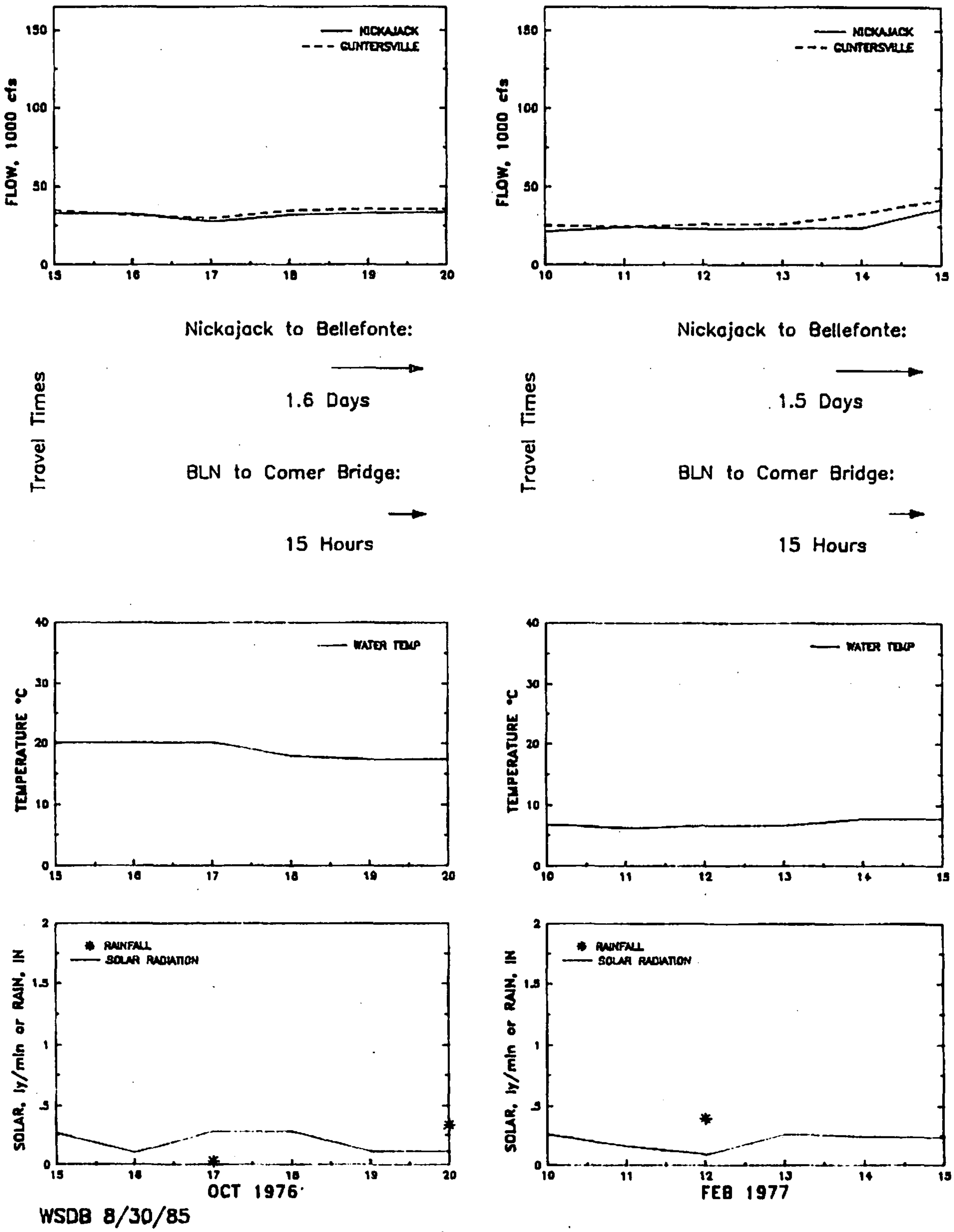

Figure 2-23 .Conditions prior to Plankton Sampling on Oct. 20, 1976 and Feb. 15, 1977 for Preoperational Monitoring of Bellefonte Nuclear Plant.

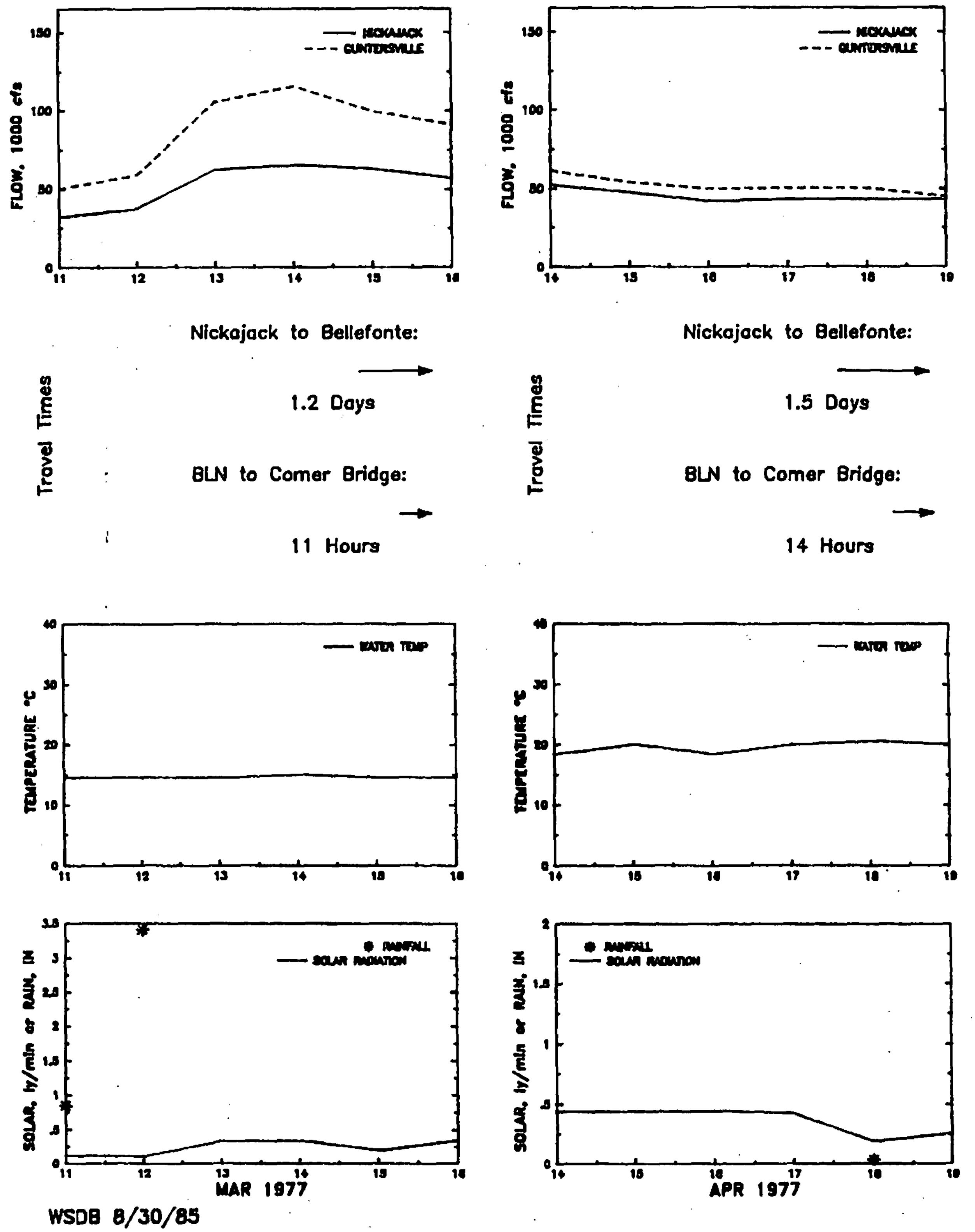

Figure 2-24 .Conditions prior to Plankton Sampling on Mar. 16 and Apr. 19, 1977 for Preoperational Monitoring of Bellefonte Nuclear Plant.

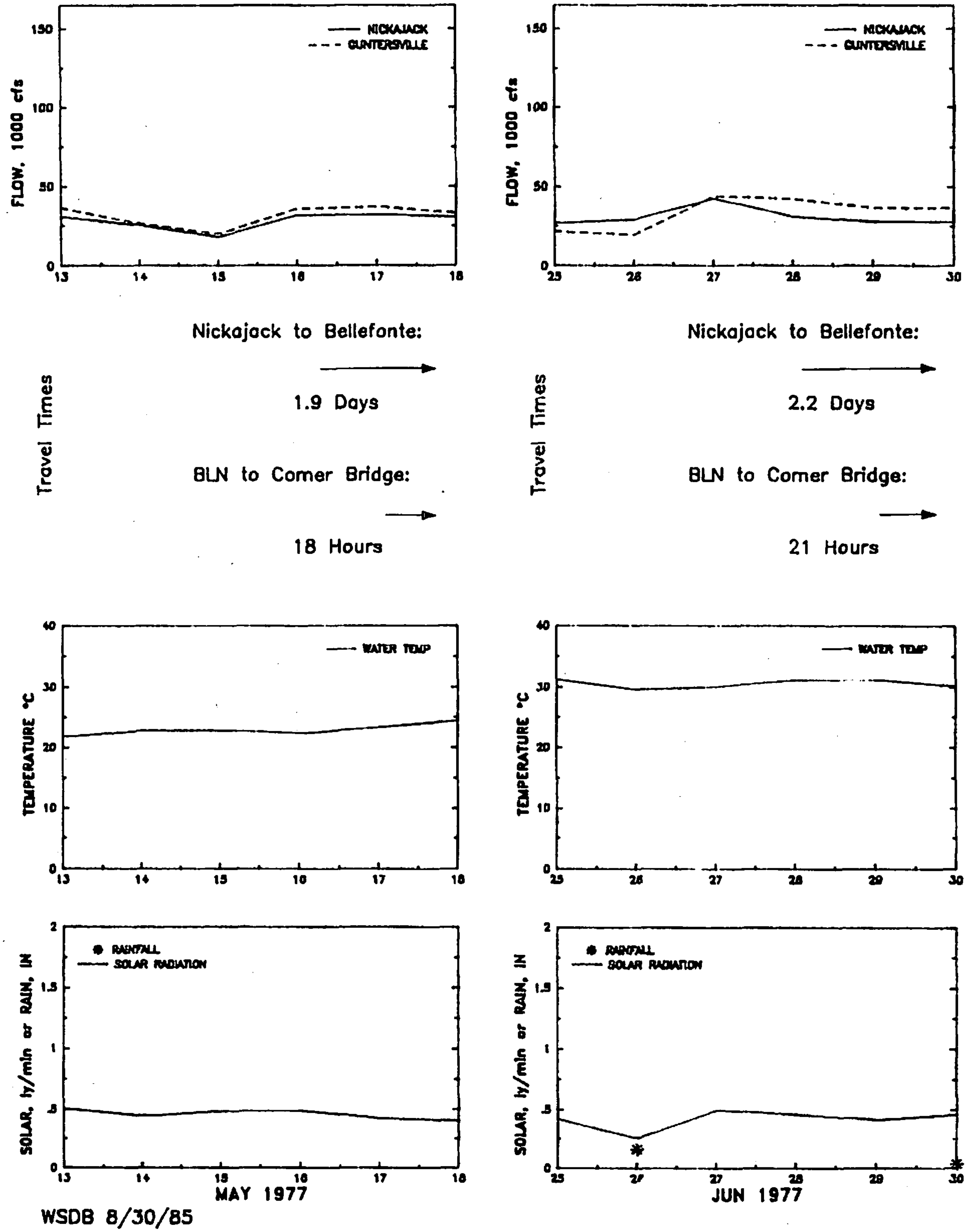

Figure 2-25 .Conditions prior to Plankton Sampling on May 18 and June 30, 1977 for Preoperational Monitoring of Bellefonte Nuclear Plant.

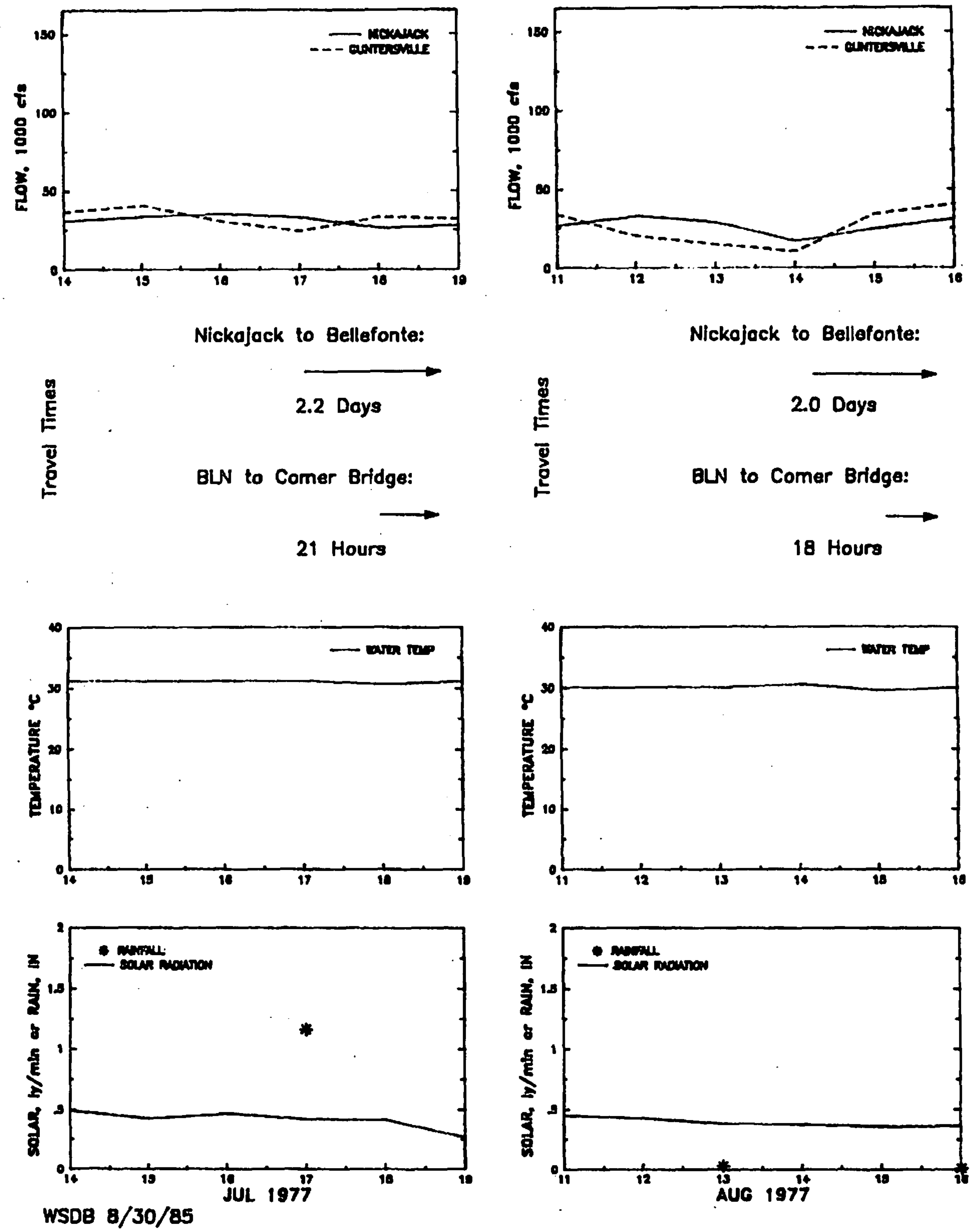

Figure 2-26 .Conditions prior to Plankton Sampling on July 19 and Aug. 16, 1977 for Preoperational Monitoring of Bellefonte Nuclear Plant.

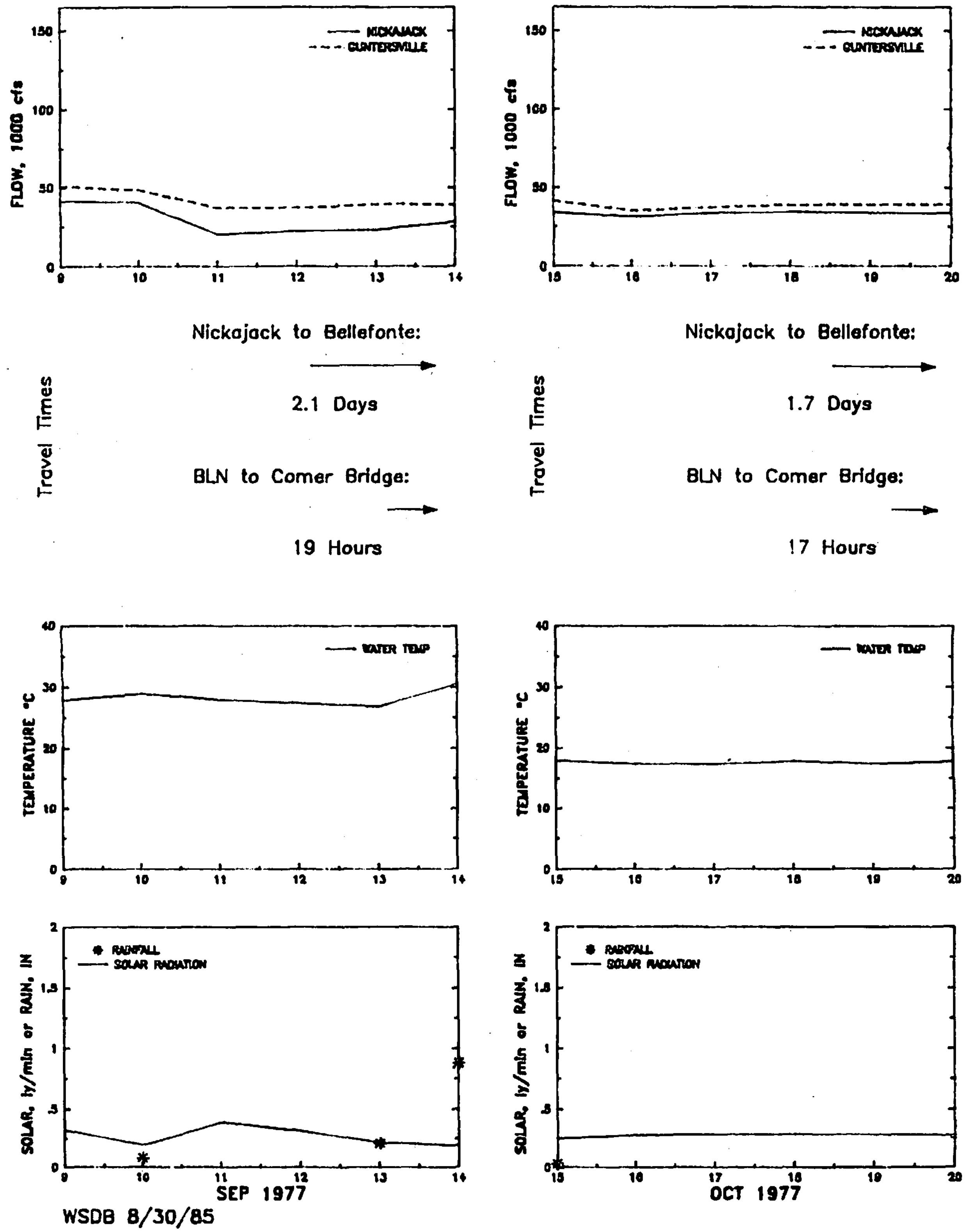

Figure 2-27 .Conditions prior to Plankton Sampling on Sep. 14 and Oct. 20, 1977 for Preoperational Monitoring of Bellefonte Nuclear Plant.

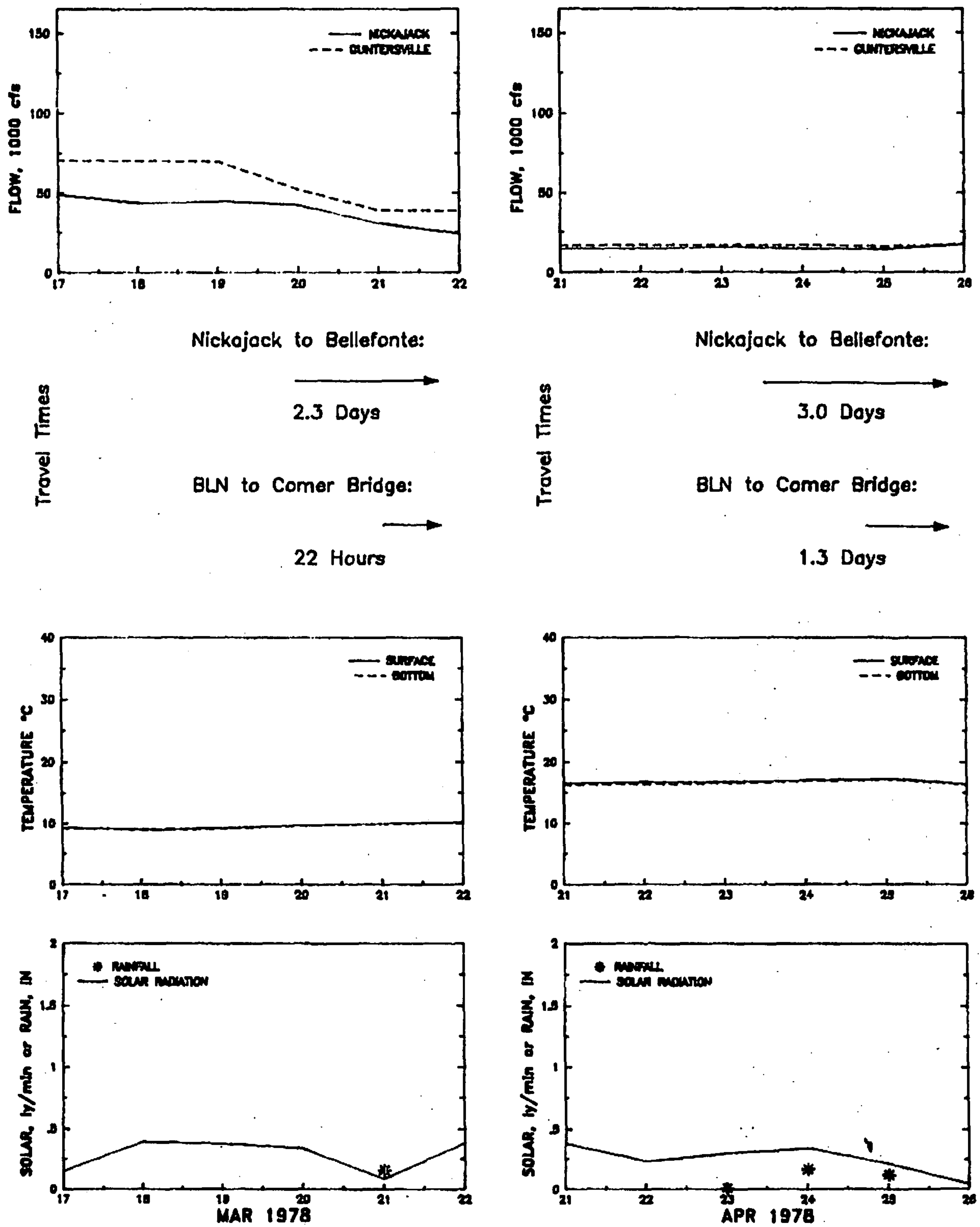

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Figure 2-28 .Conditions prior to Plankton Sampling on Mar. 22 and Apr. 26, 1978 for Preoperational Monitoring of Bellefonte Nuclear Plant.

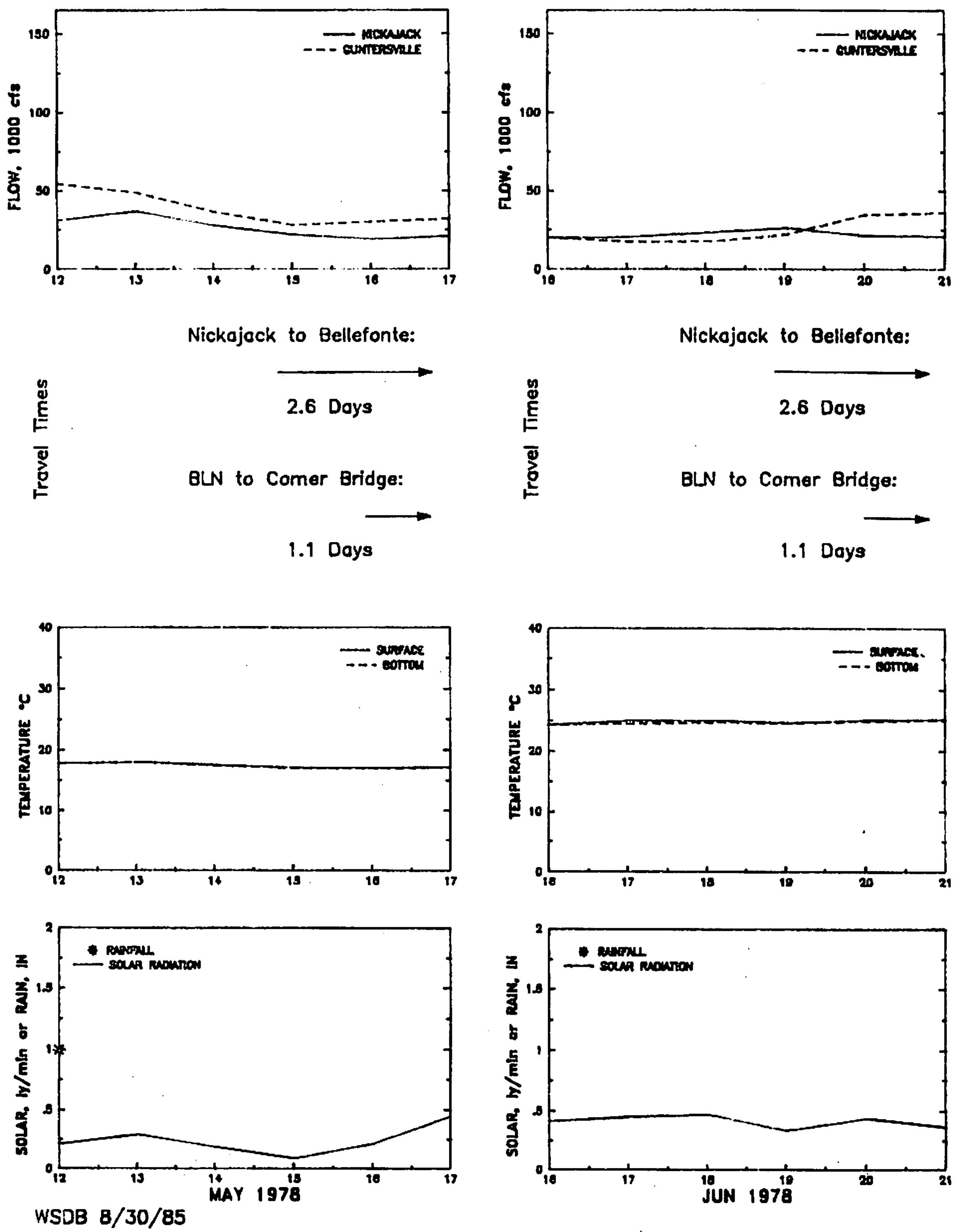

Figure 2-29 .Conditions prior to Plankton Sampl ing on May 17 and June 21, 1978 for Preoperational Monitoring of Bellefonte Nuclear Plant.

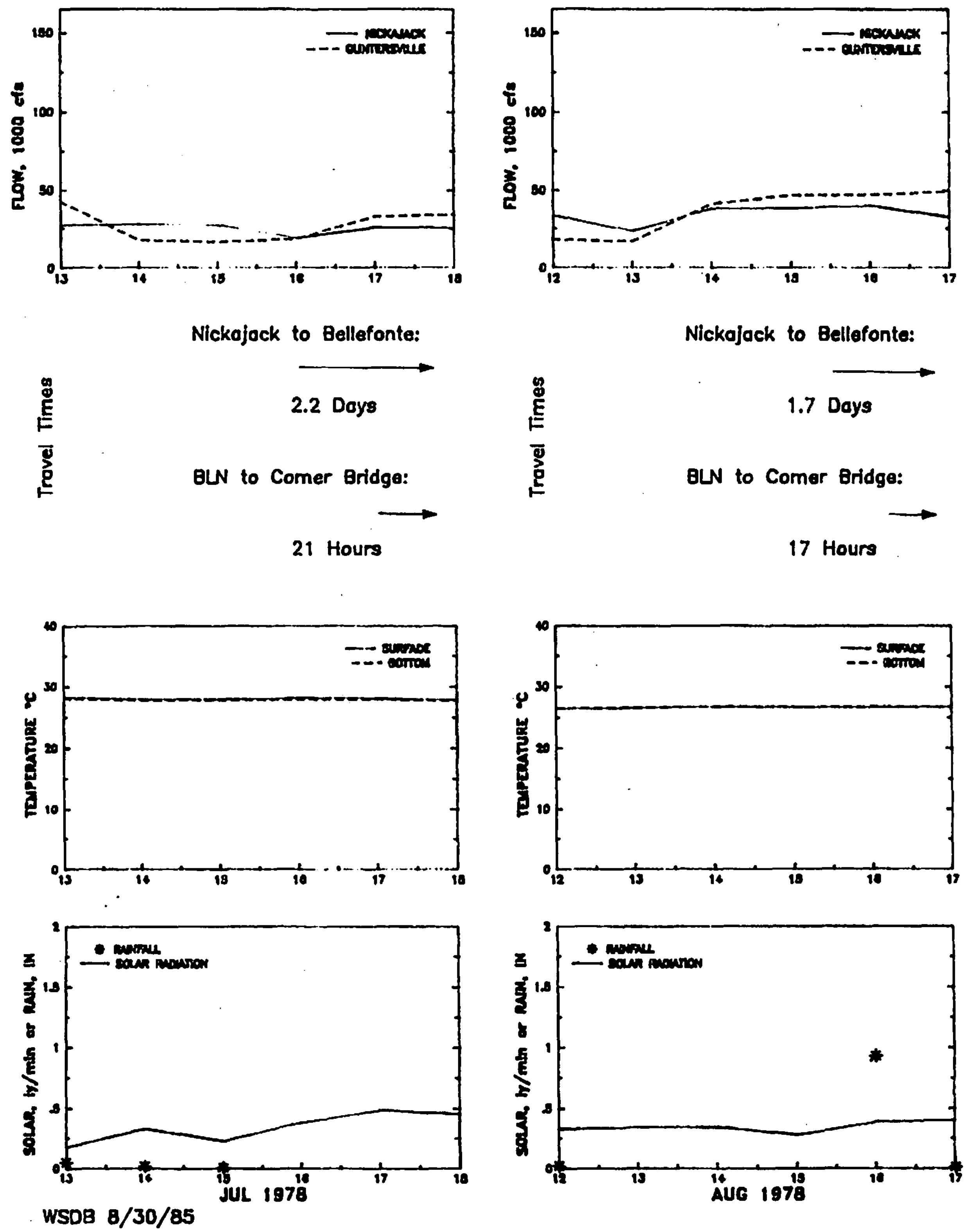

Figure 2-30 .Conditions prior to Plankton Sampling on July 18 and Aug. 17, 1978 for Preoperational Monitoring of Bellefonte Nuclear Plant.

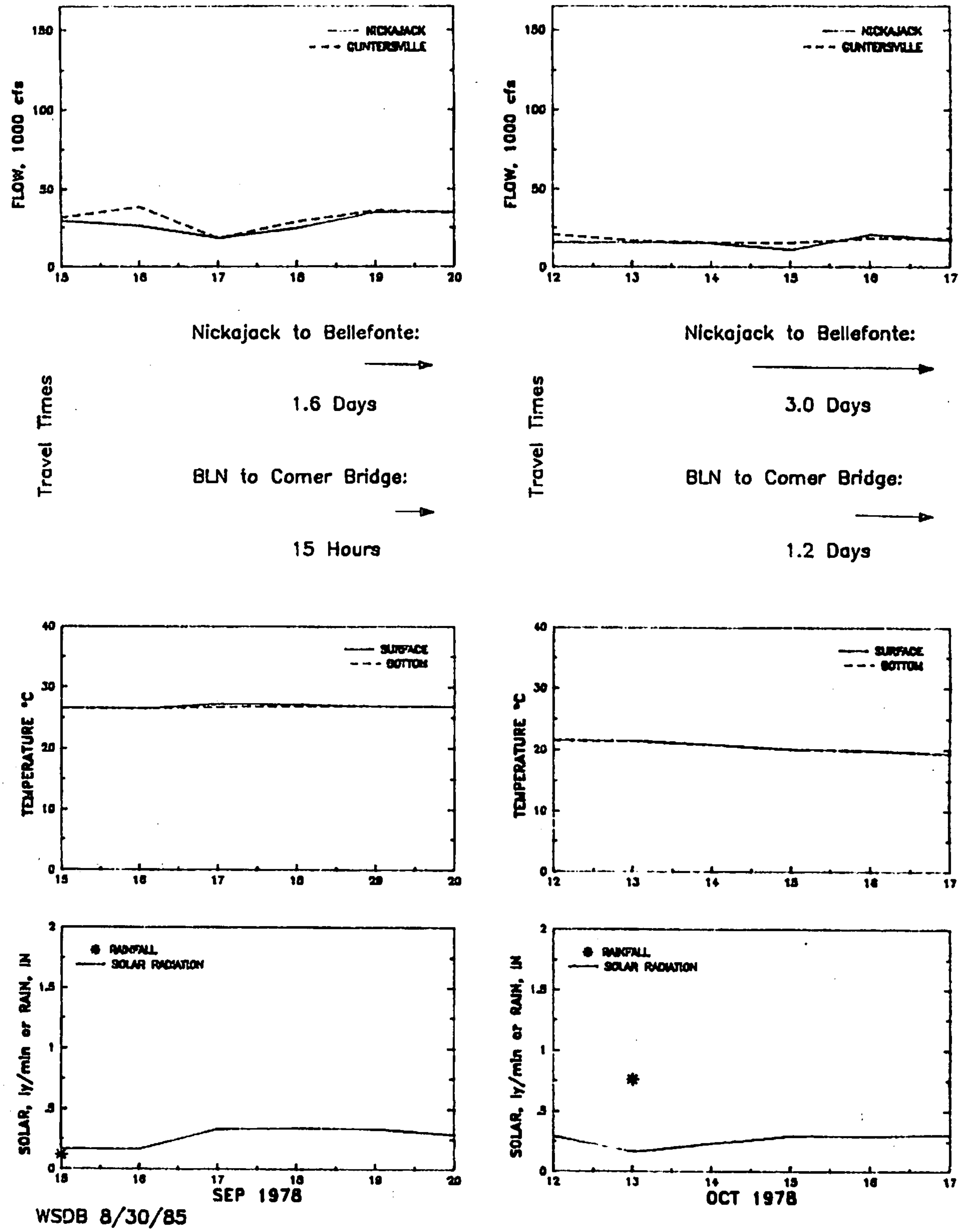

Figure 2-31 .Conditions prior to Plankton Samp ing on Sep. 20 and Oct. 17, 1978 for Preoperational Monitoring of Bellefonte Nuclear Plant.

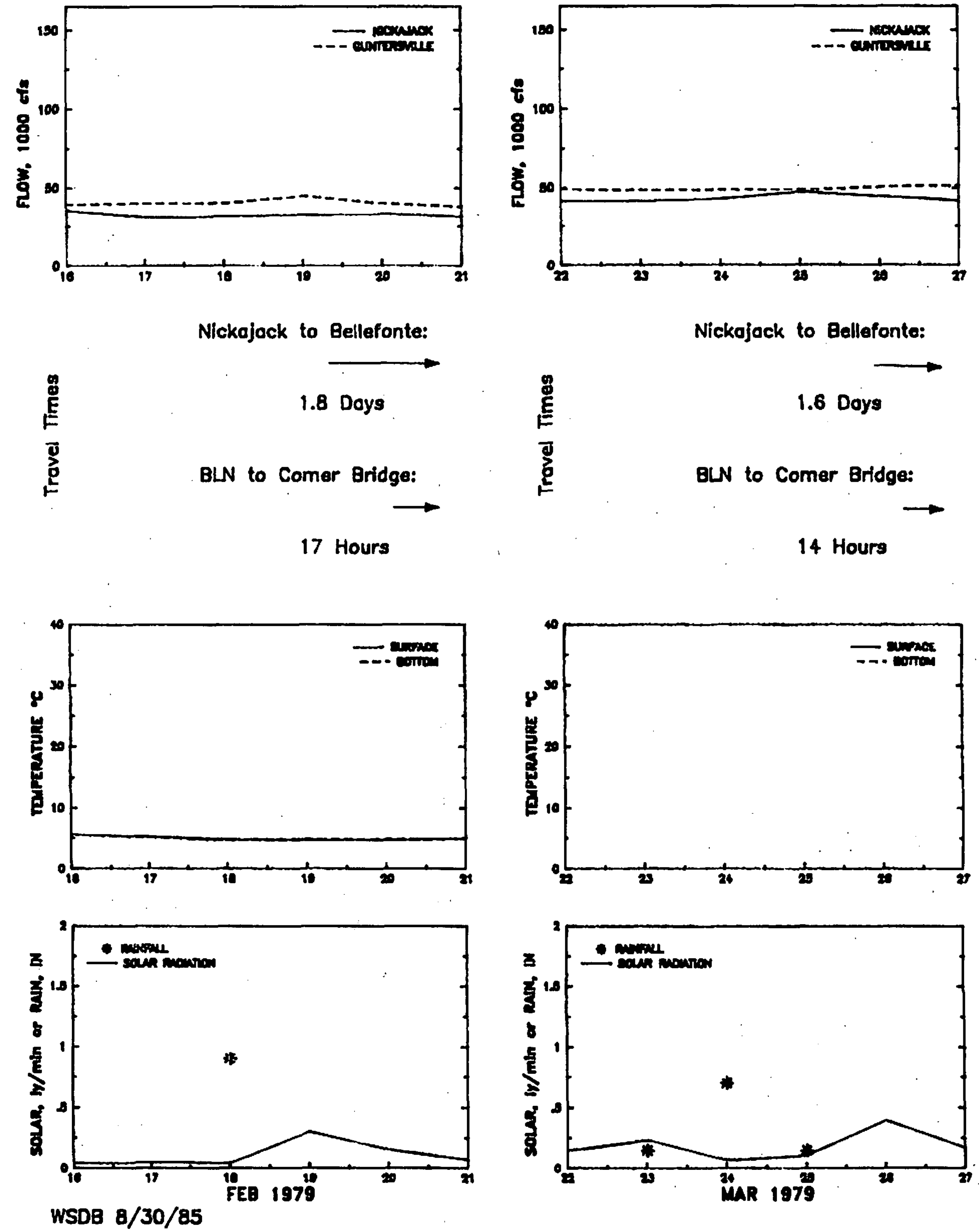

Figure 2-32 .Conditions prior to Plankton Sampling on Feb. 21 and Mar. 27, 1979 for Preoperational Monitoring of Bellefonte Nuclear Plant.

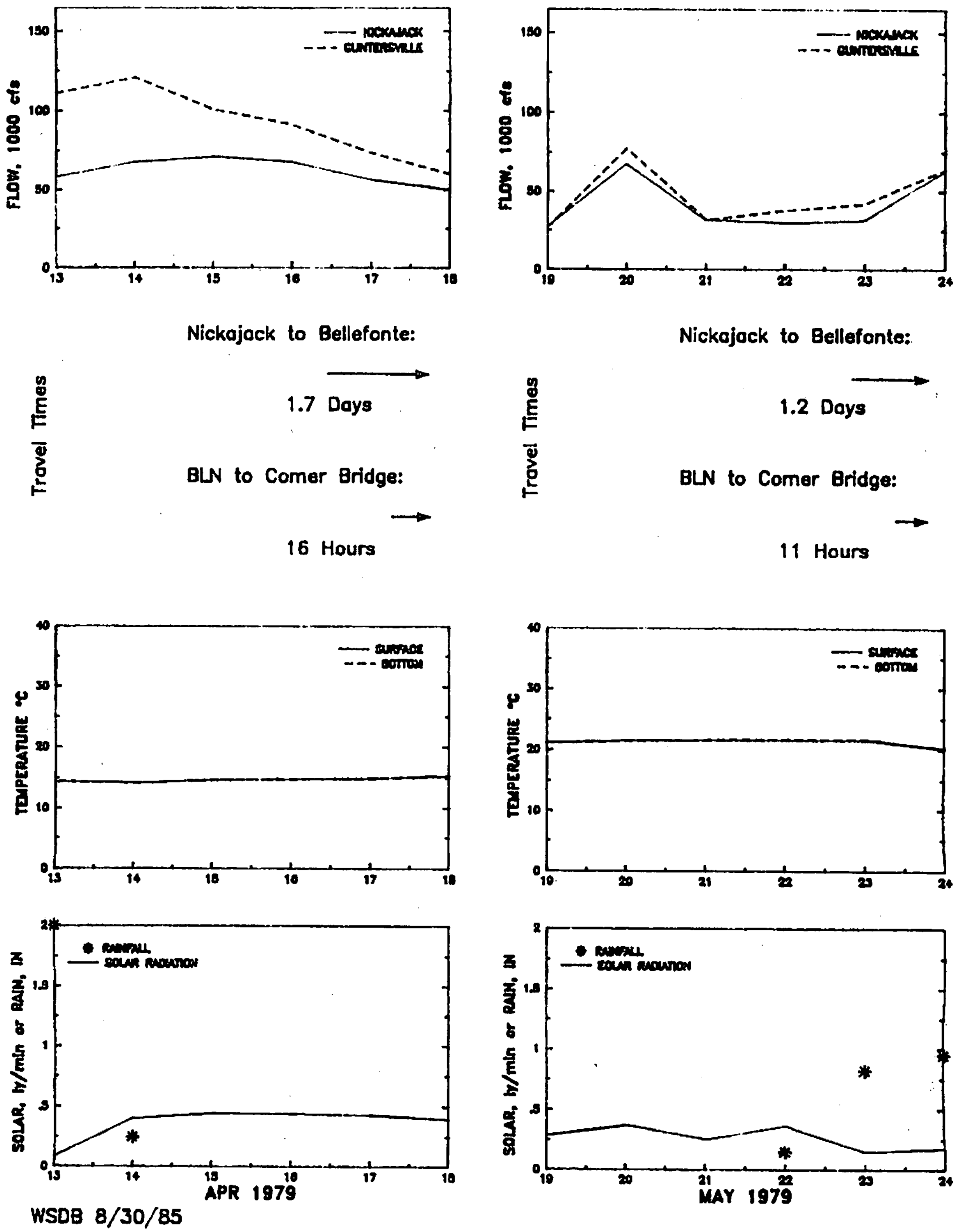

Figure 2-33 .Conditions prior to Plankton Sampling on Apr. 18 and May 24, 1979 for Preoperational Monitoring of Bellefonte Nuclear Plant.

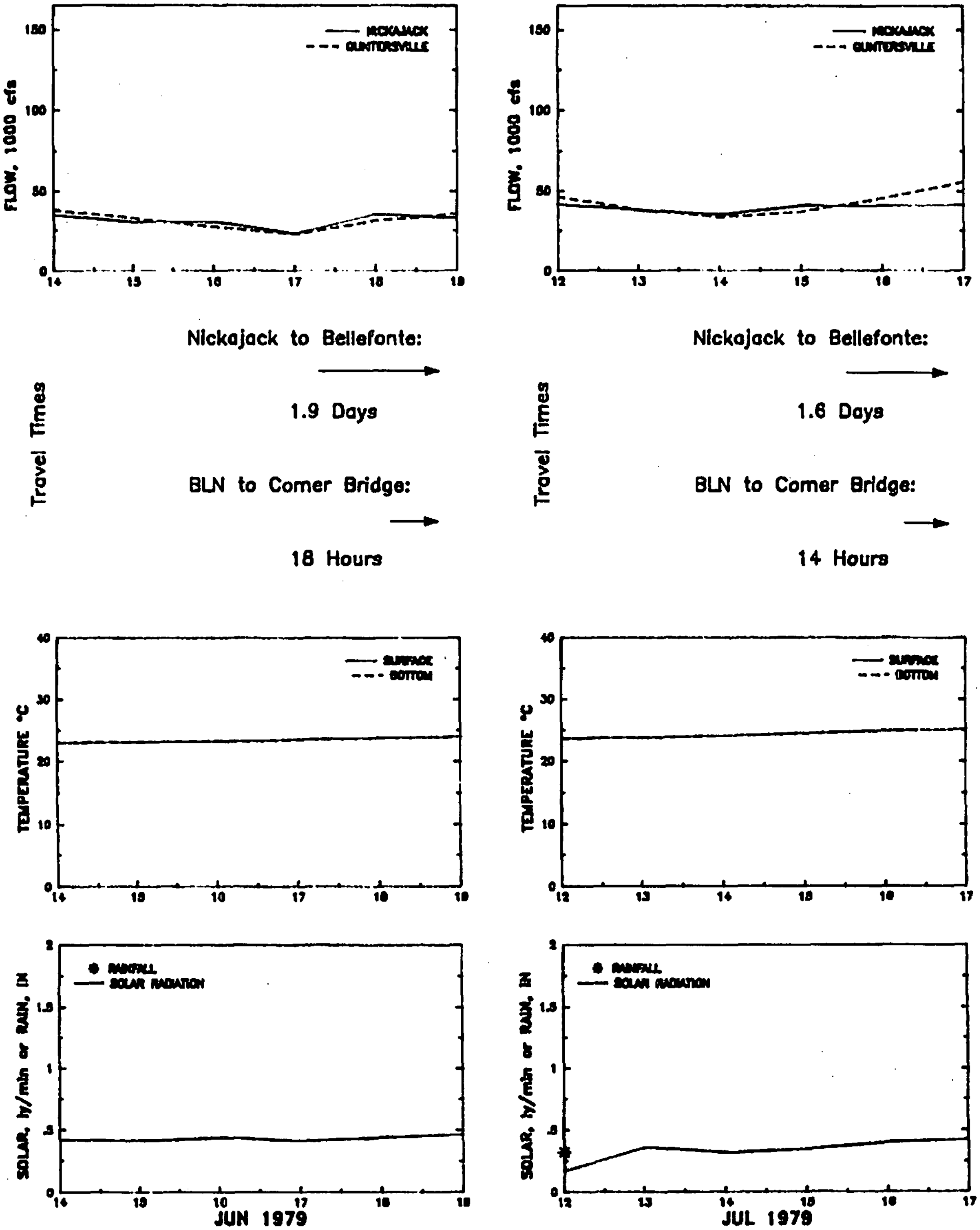

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Figure 2-34 .Conditions prior to Plankton Sampling on June 19 and July 17, 1979 for Preoperational Monitoring of Bellefonte Nuclear Plant.

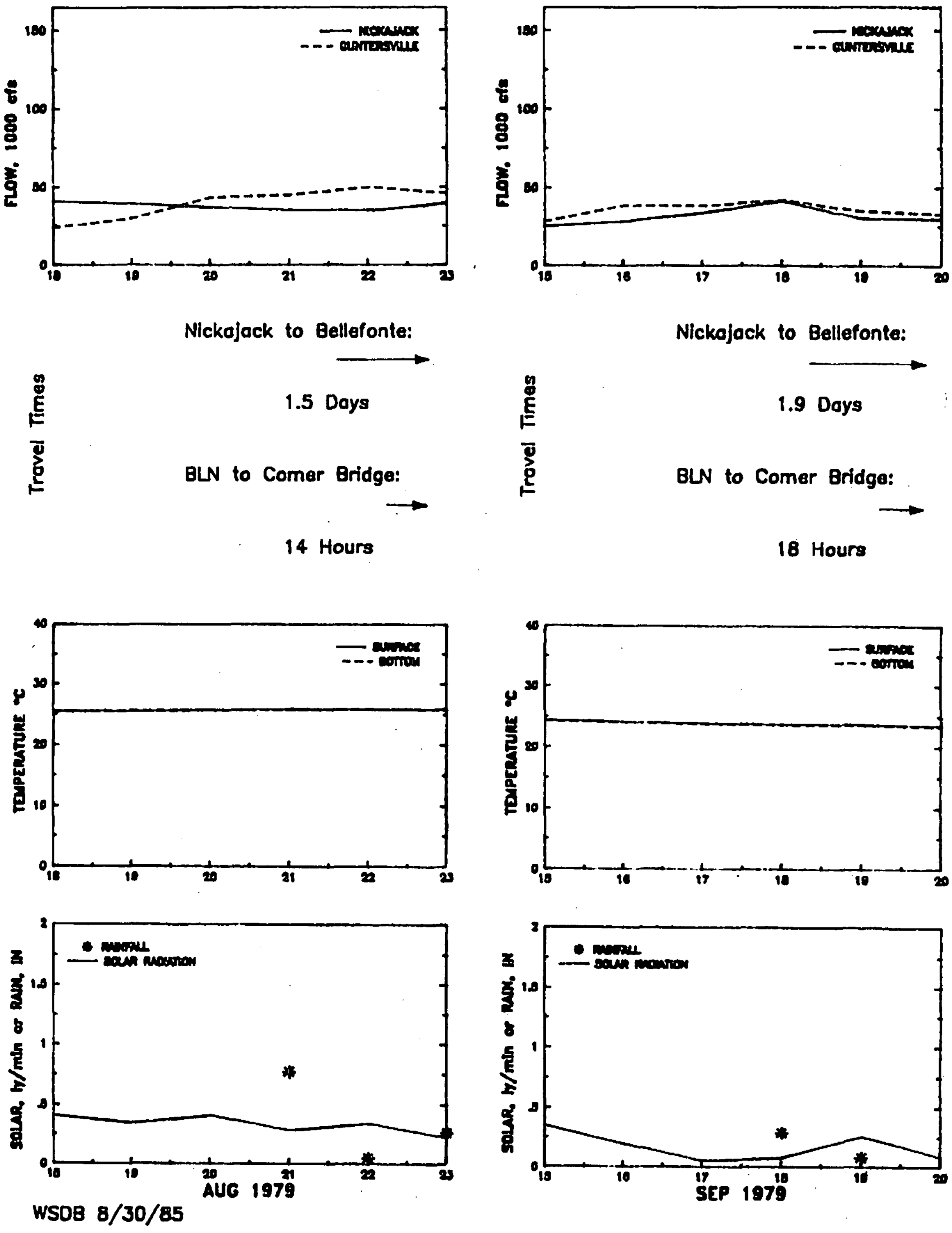

Figure 2-35 .Conditions prior to Plankton Samp.ing on Aug. 23 and Sep. 20, 1979 for Preoperational Monitoring of Bellefonte Nuclear Plant.

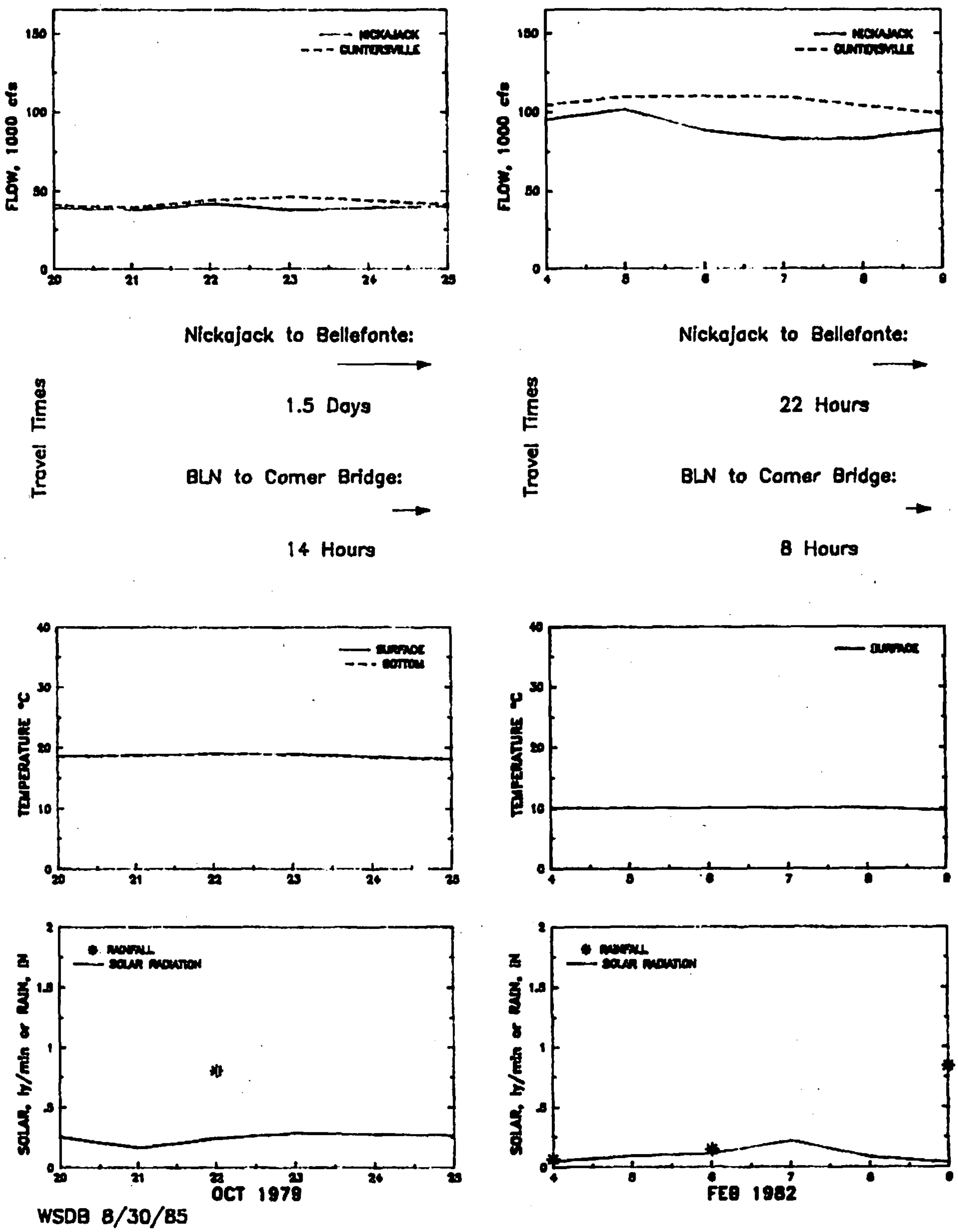

Figure 2-36 .Conditions prior to Plankton Sampling on Oct. 25, 1979 and Feb.9, 1982 for Preoperational Monitoring of Bellefonte Nuclear Plant.

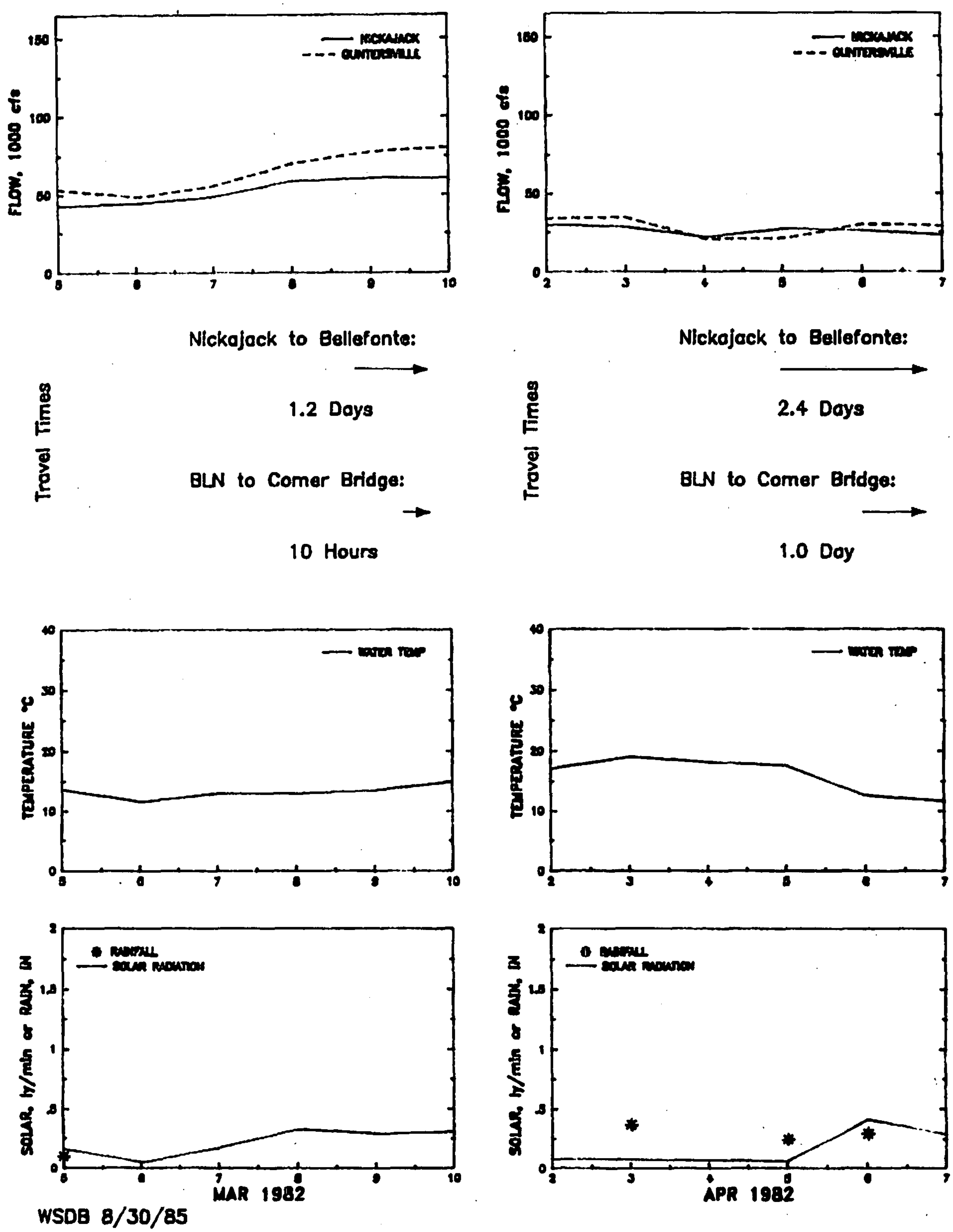

Figure 2-37 .Conditions prior to Plankton Sampling on Mar. 10 and Apr. 7, 1982 for Preoperational Monitoring of Bellefonte Nuclear Plant.

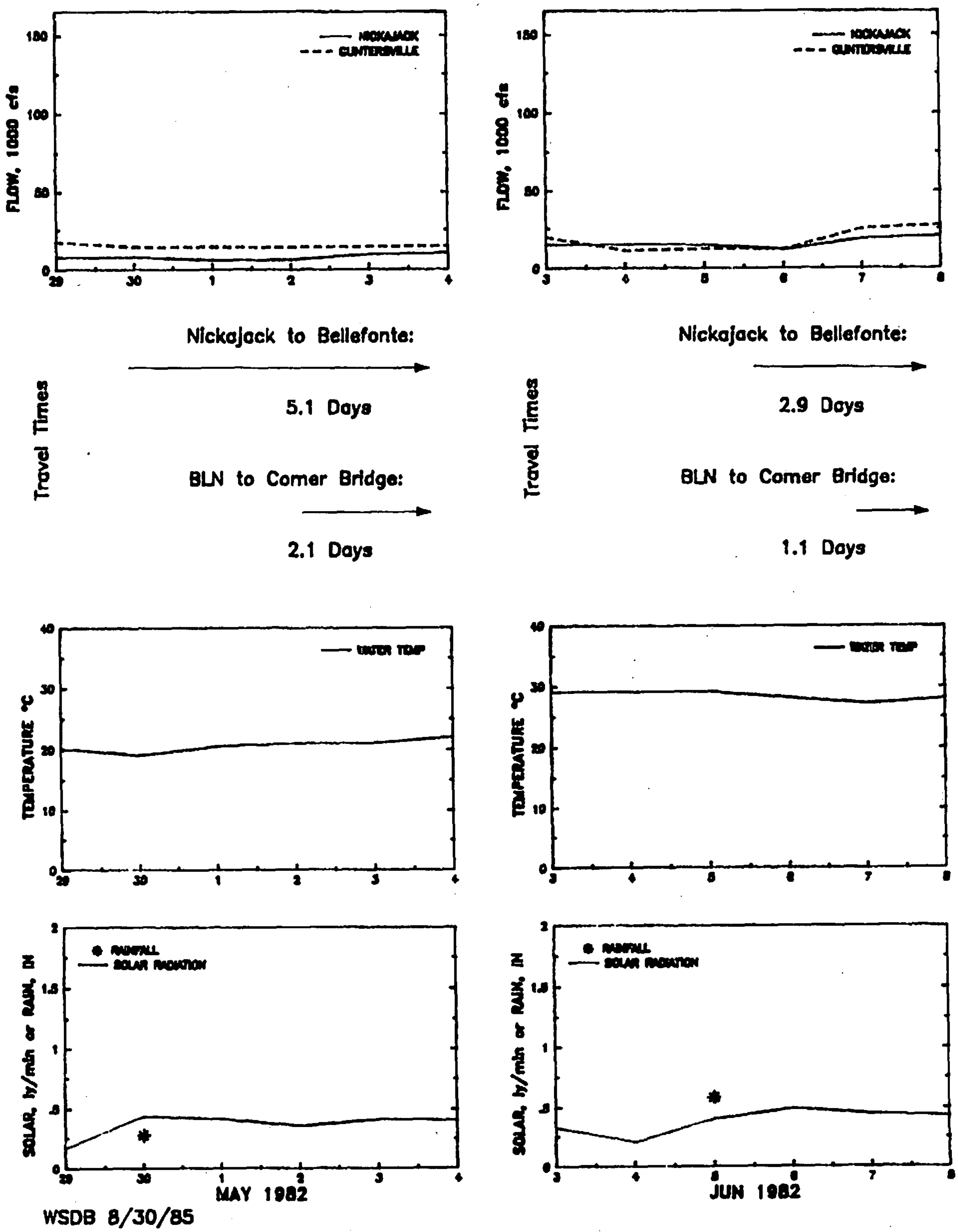

Figure 2-38 .Conditions prior to Plankton Sampling on May 4 and June 8, 1982 for Preoperational Monitoring of Bellefonte Nuclear Plant.

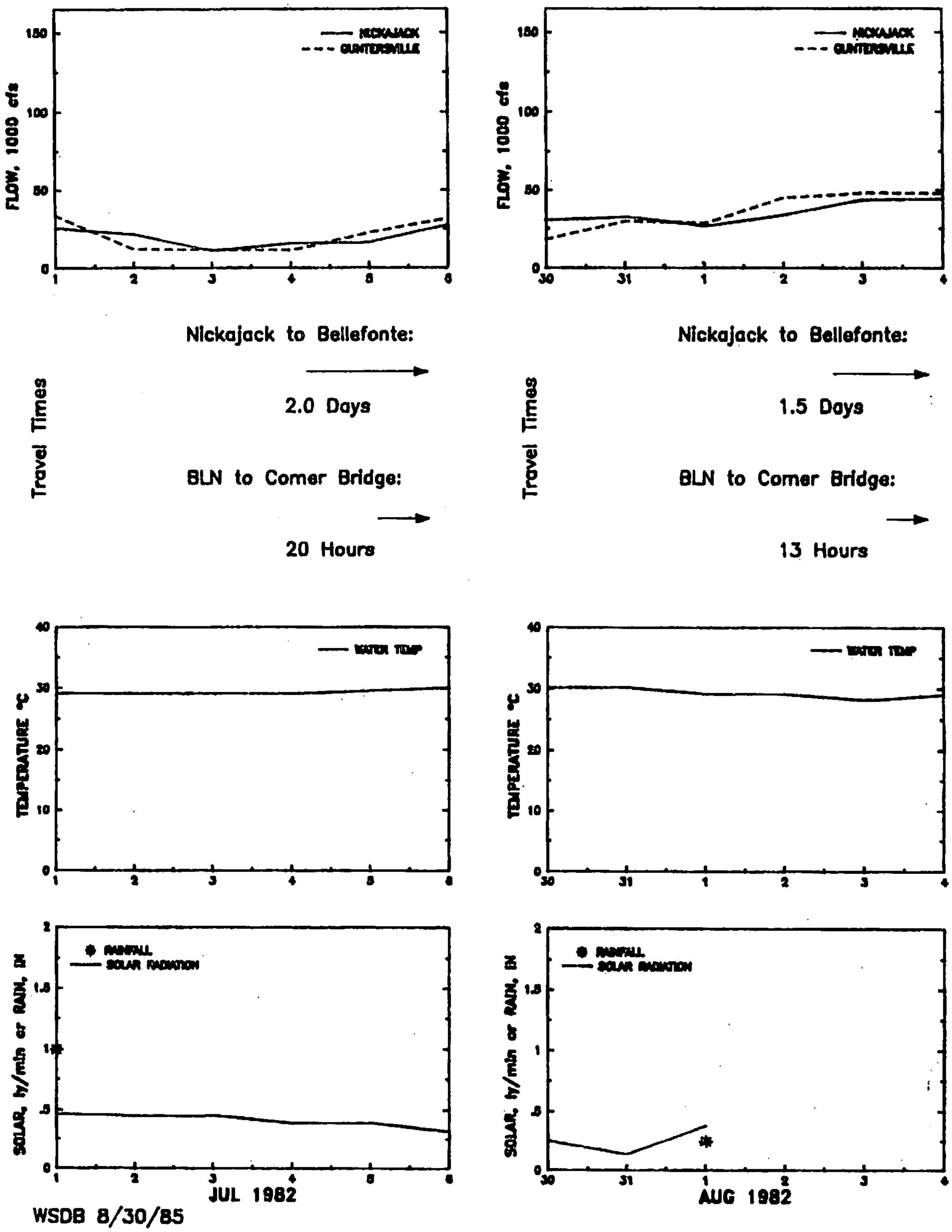

Figure 2-39 .Conditions prior to Plankton Sampling on July 6 and Aug. 4, 1982 for Preoperational Monitoring of Bellefonte Nuclear Plant.

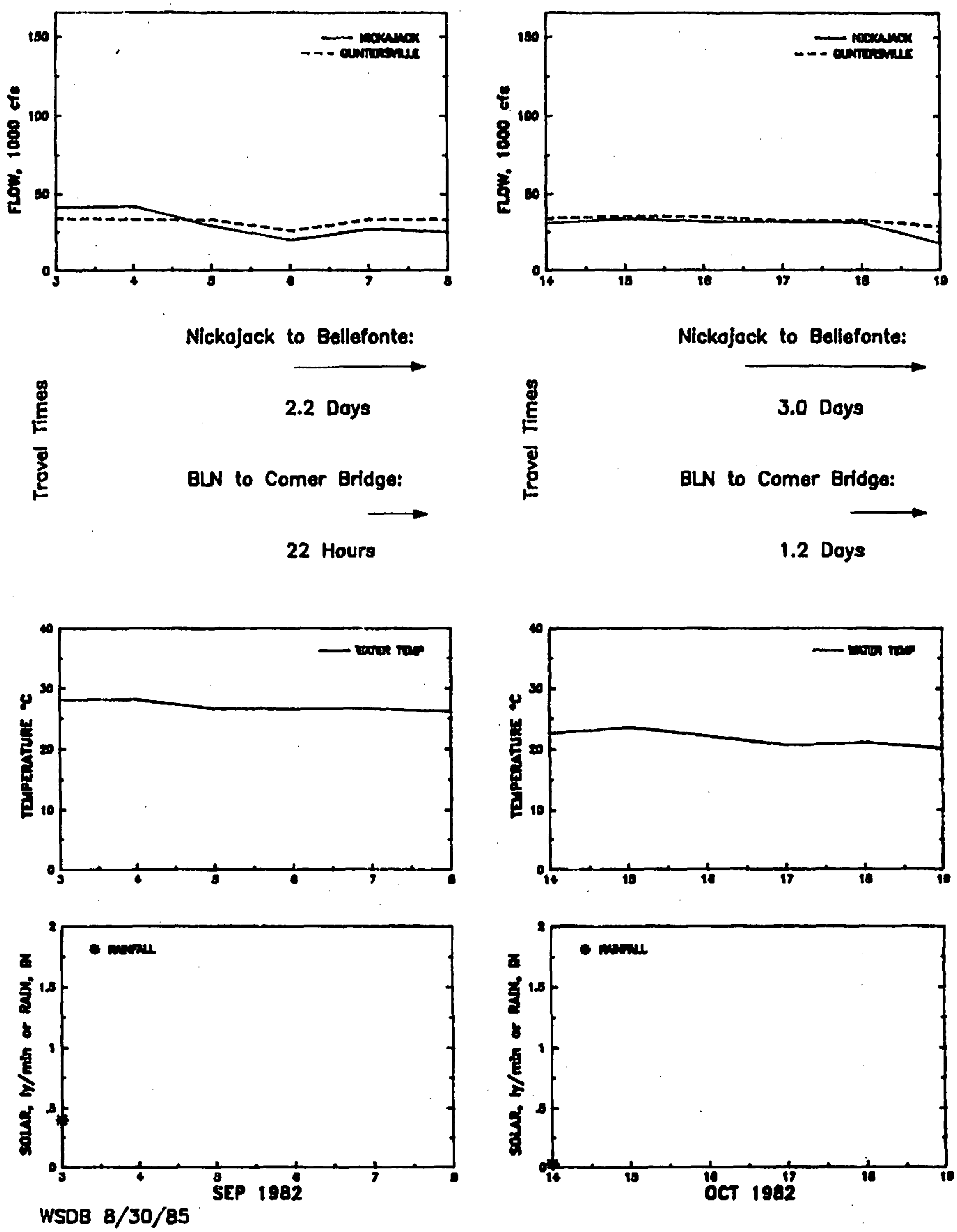

Figure 2-40 .Conditions prior to Plankton Sampling on Sep. 8 and Oct. 19, 1982 for Preoperational Monitoring of Bellefonte Nuclear Plant.

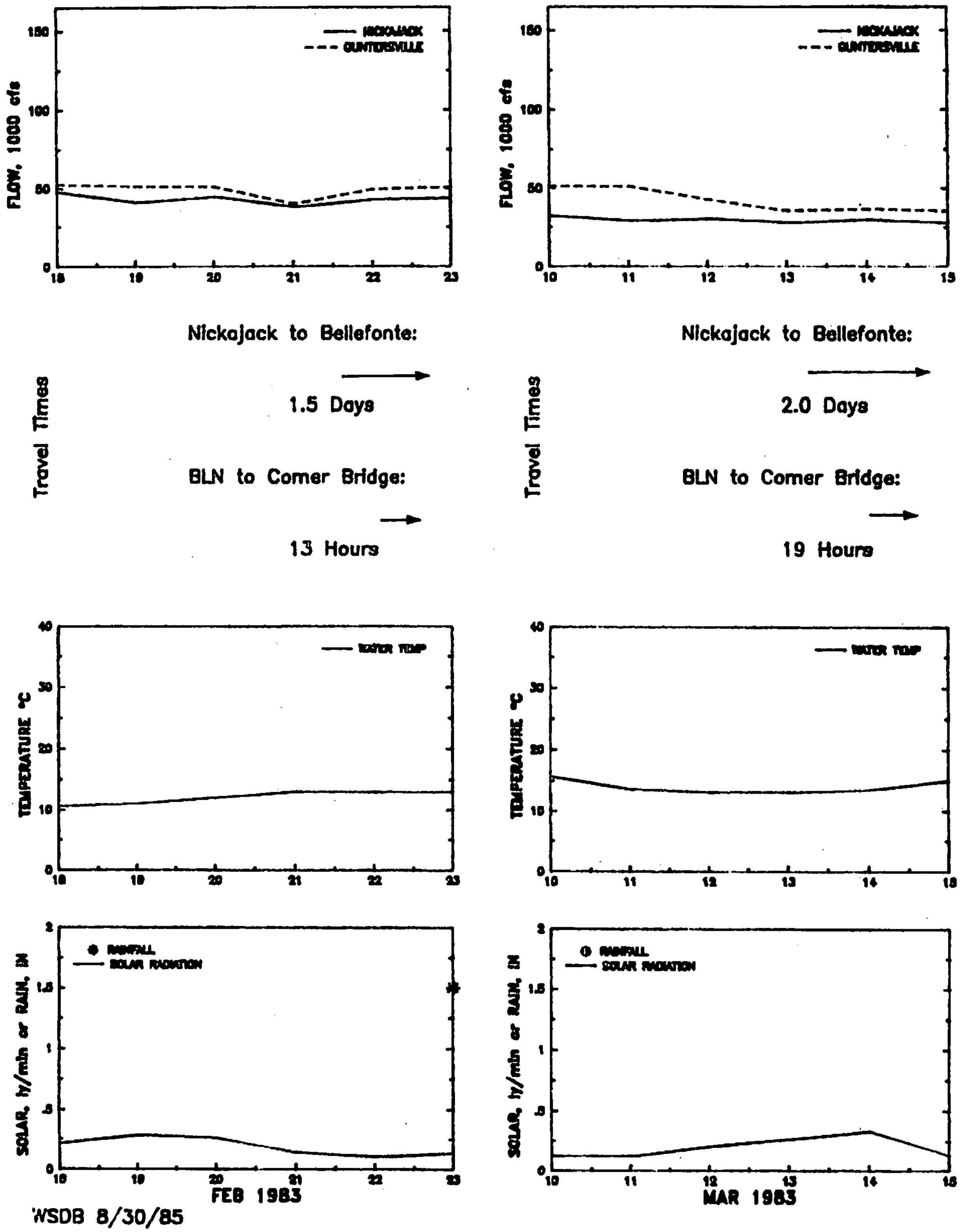

Figure 2-41 .Conditions prior to Plankton Sar.,ling on Feb. 23 and Mar 15, 1983 for Preoperational Monitoring of Bellefonte Nuclear Plant.

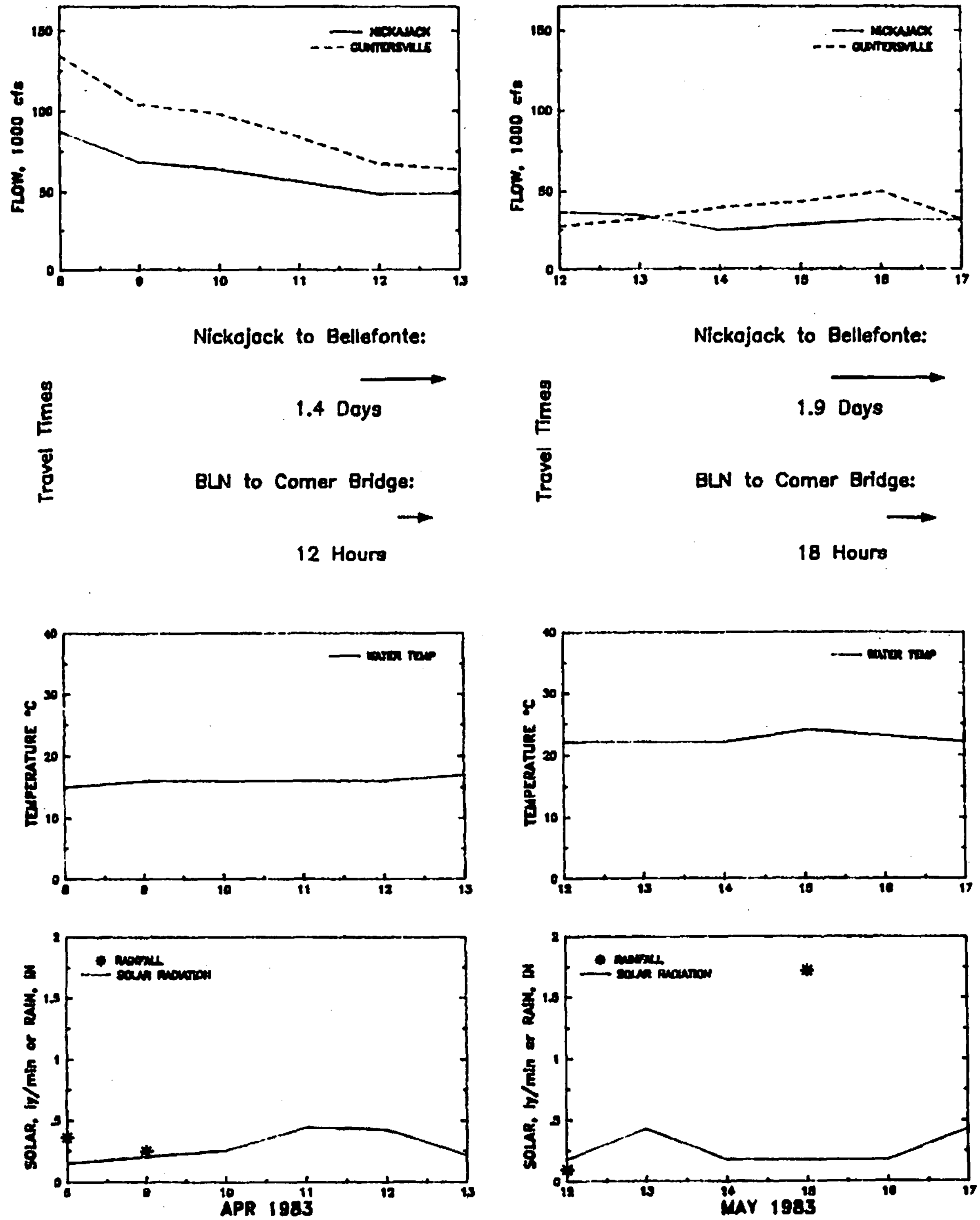

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Figure 2-42 .Conditions prior to Plankton Sampling on Apr. 13 and May 17, 1983 for Preoperational Monitoring of Bellefonte Nuclear Plant.

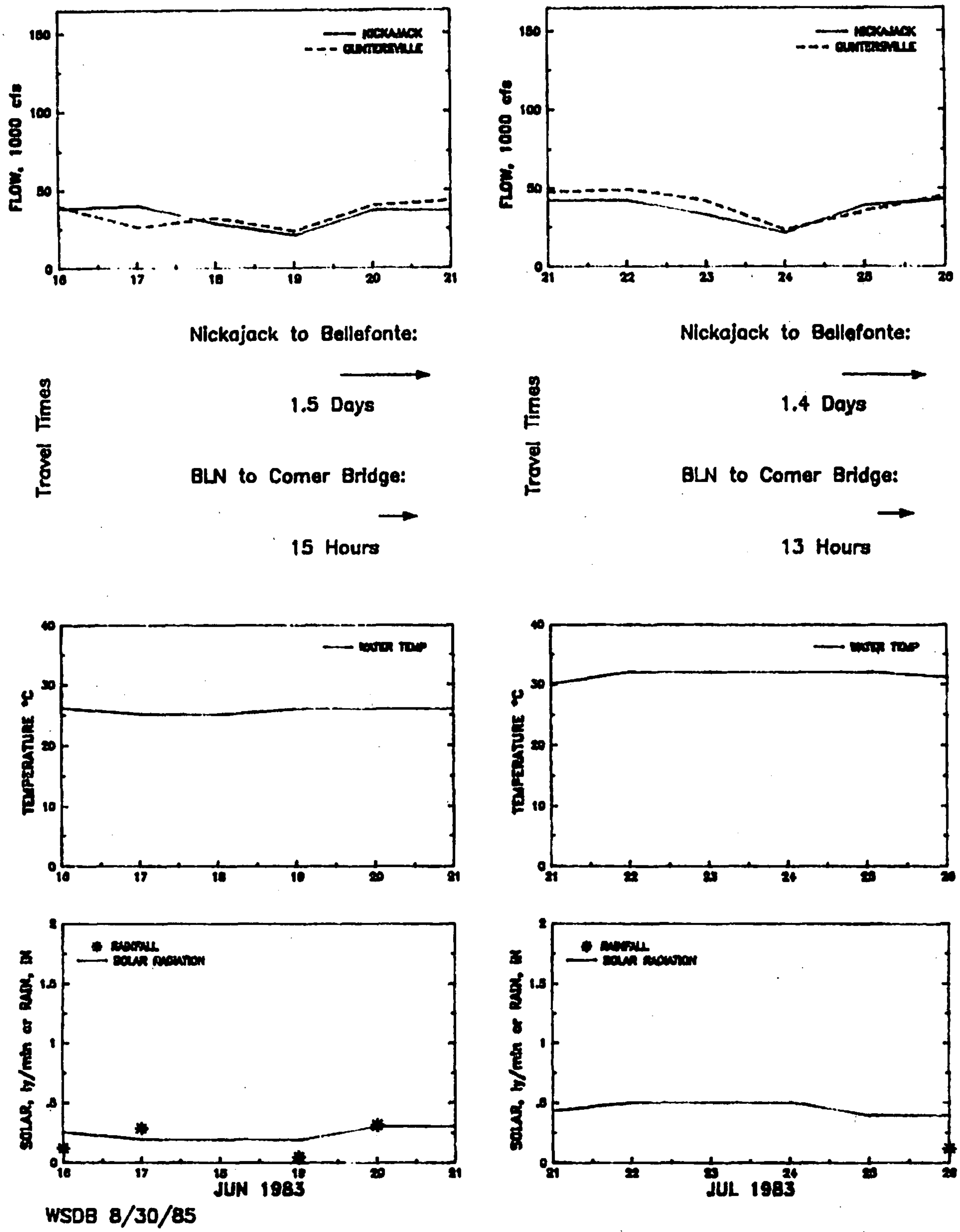


Figure 2-43 .Conditions prior to Plankton Sampling on June 21 and July 26, 1983 for Preoperational Monitoring of Bellefonte Nuclear Plant.

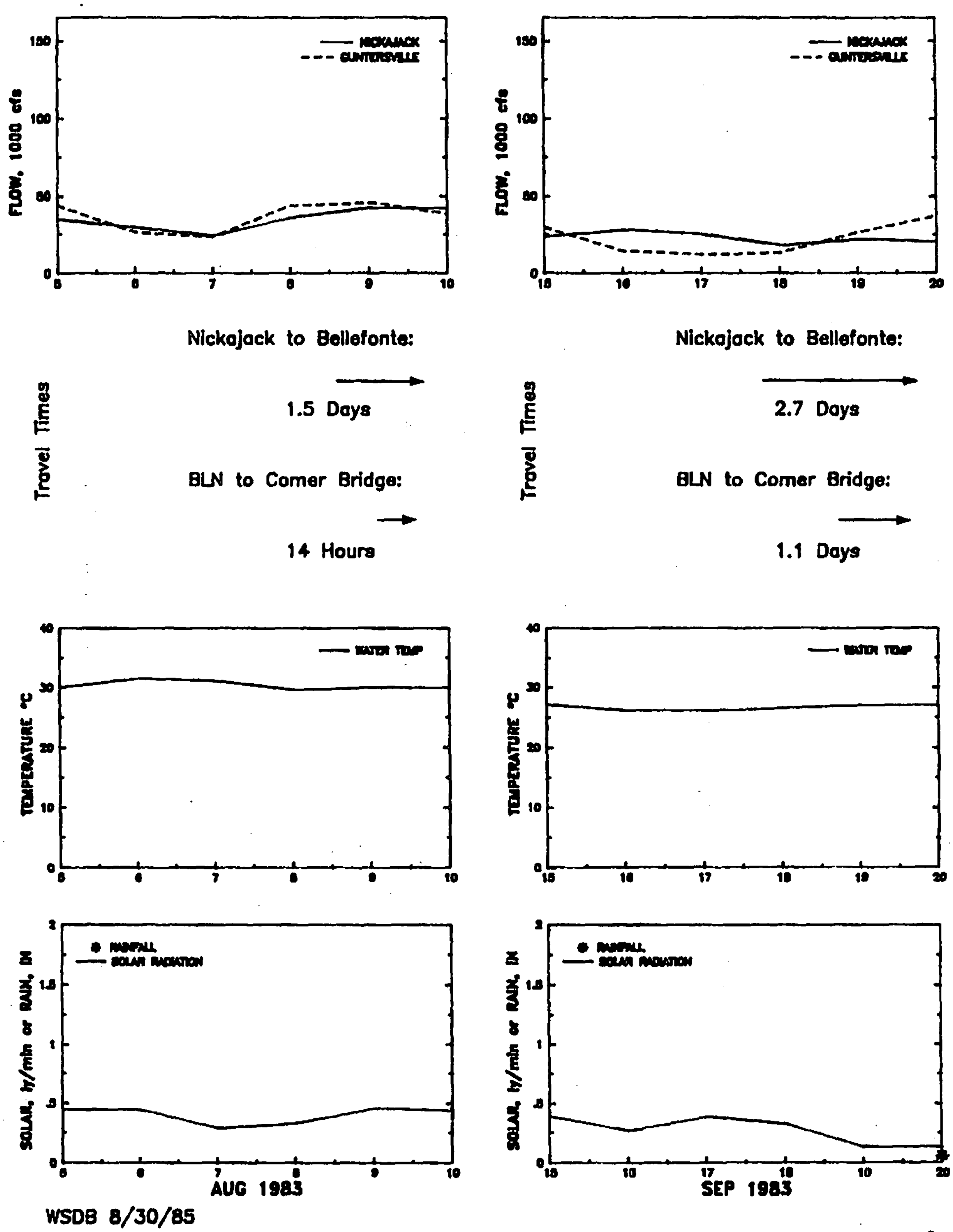


Figure 2-44 .Conditions prior to Plankton Sampling on Aug. 10 and Sep. 20 1983 for Preoperational Monitoring of Bellefonte Nuclear Plant.

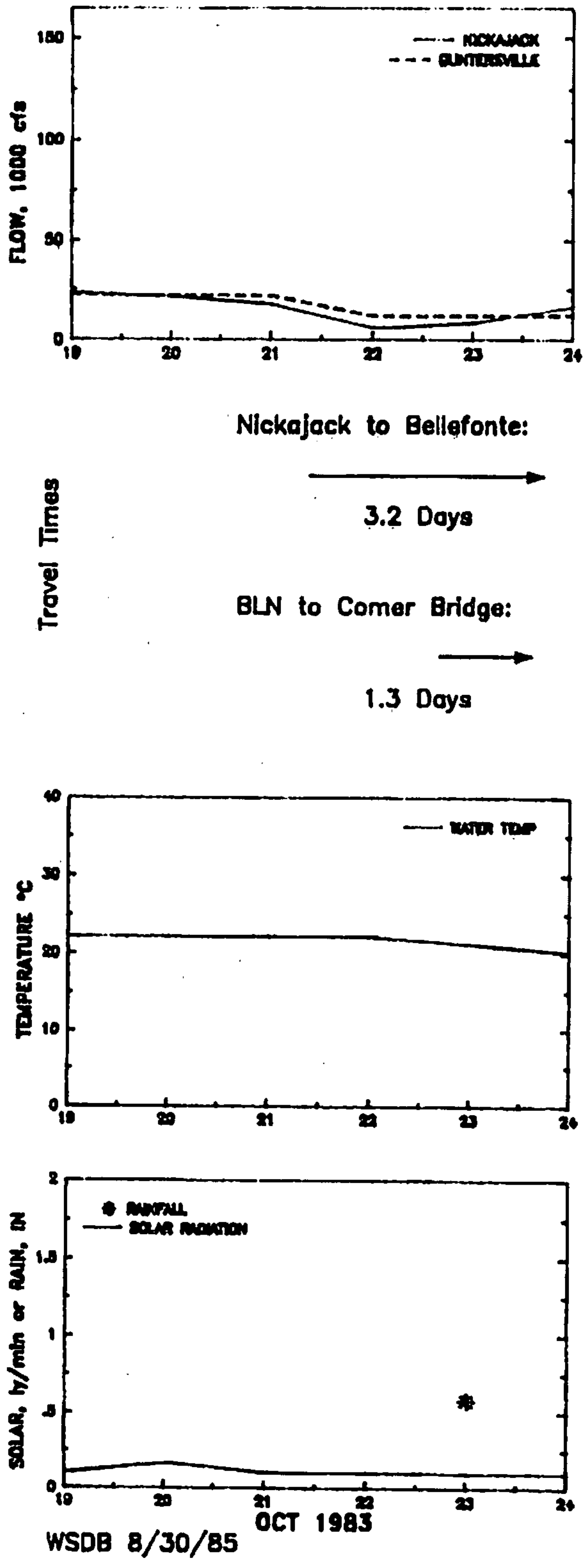


Figure 2-45 .Conditions prior to Plankton Sampling on Oct. 24, 1983 for Preoperational Monitoring of Bellefonte Nuclear Plant.

3.0 FACTORS AFFECTING WATER QUALITY AND BIOLOGICAL CONDITIONS

A preoperational baseline assessment must consider events occurring within the reservoir with potential for influencing the data base. Several events occurred during the 1974-1984 period of data collection which had potential for altering conditions in the vicinity of BLN. Some of these events are continuing and may become a factor in future BLN assessments. These events included the following.

1. Upgrading of sewage treatment at the Moccasin Bend plant in Chattanooga, Tennessee, which resulted in partial and total by-pass of sewage wastes into Nickajack Reservoir upstream of BLN from January 29, 1982 to April 15, 1983.
2. Operation of Widows Creek Steam Plant and the discharge of condenser cooling water into Guntersville Reservoir approximately 24.9 km (15.5 miles) upstream of BLN (continuing).
3. Herbicide treatments of aquatic habitats in Guntersville Reservoir and the immediate vicinity of BLN to reduce growth of aquatic macrophyte species (continuing).
4. Pesticide treatments of aquatic habitats in the vicinity of BLN to reduce mosquito infestations, but also having potential of affecting other aquatic insect species (continuing).
5. Operation of a commercial gravel and sand dredge in the immediate vicinity of BLN and downstream in Guntersville Reservoir (continuing).

3.1 Moccasin Bend Sewage Treatment Plant

It was necessary to reduce treatment of sewage wastes from the city of Chattanooga, Tennessee, in order to upgrade the Moccasin Bend Sewage Treatment facility. On January 29, 1982, aeration systems at the plant were suspended. During renovation, the main pump station into the Moccasin Bend Plant was shut down, resulting in a total by-pass of the treatment facility for seven days, beginning March 8, 1983 and ending March 15, 1983. Reduced waste treatment continued until manual operation of the secondary treatment facility on April 15, 1983.

Prior to renovation, the Moccasin Bend Plant discharged 151,400 m^3/day (40 mgd) of treated effluent to the upper end of Nickajack Reservoir which extends from Chickamauga Dam (TRM 471.0) downstream to TRM 424.7. One result of renovation increased the capacity of the facility which is now capable of discharging up to 302,800 m^3/day (80 mgd) of treated effluent. Overall result should be a marked improvement in quality of discharges entering Nickajack Reservoir from the city of Chattanooga.

Preliminary estimates had indicated an extremely low assimilative capacity for the Nickajack Reservoir and indicated that the Chattanooga plant would require additional treatment beyond secondary. However, an assimilative capacity study (Clark 1975) showed reareation within the reservoir is much higher than predicted and deemed secondary treatment sufficient to protect water quality within the reservoir. It was also felt that wastes by-passed during renovation would be assimilated within the reservoir with no significant change in nutrients or oxygen consuming wastes discharged into upper Guntersville Reservoir.

Therefore, by-pass operations were not expected to have a measurable impact upon the Guntersville biological communities monitored during this preoperational period.

To evaluate this prediction, selected water quality parameters were collected in Nickajack tailrace (upper Guntersville Reservoir) in conjunction with regularly scheduled sampling at BLN during 1982 and 1983. The additional samples which were collected monthly (February through October) intensified data collection from Nickajack tailrace waters (only limited sampling had occurred previously). Parameters evaluated included temperature, DO, pH, alkalinity, total-P, organic-N, NH_3 and NH_4-N, NO_2 + NO_3-N, BOD_5, and TOC. Ortho-P and SOC data were available only for 1982 and 1983. Data were reported to correspond as closely as possible with data collected from BLN from 1974 through 1983 (table 3-1).

A one-way Analysis of Variance (ANOVA) was used to determine if the period of by-pass (1982 and part of 1983) affected quality of water entering Guntersville Reservoir (table 3-2). If a significant difference among treatments (years) was demonstrated, yearly means were ordered and ranked (Duncan's New Multiple Range Test) to determine if values for 1982 and/or 1983 were different from previous years (table 3-3). A significant difference among years was demonstrated only for total alkalinity ($\alpha = 0.05$). Alkalinity for 1982 was higher than other years, but not significantly different from 1978. Alkalinity in 1983 was lower than other years, but not different from 1974, 1975, 1976, and 1977. Failure to clearly separate alkalinity for 1982 or 1983 from other years or demonstrate differences among yearly means for other parameters indicates that water entering Guntersville Reservoir during by-pass at Moccasin Bend Sewage Treatment Plant was unaffected for those parameters tested and should not have affected the data base collected at BLN.

Nickajack tailrace data also were evaluated to look for any significant trends during the years of preoperational monitoring at BLN. Scatter plots and a regression line were developed for each parameter (figures 3-1 through 3-14). Trend lines were not drawn for SOC and ortho-P (figures 3-13 and 3-14) because only two years of data were collected for those parameters. Regression analysis (table 3-4) identified a significant increase ($\alpha = 0.05$) in total-P (figure 3-1) and a highly significant decrease ($\alpha = 0.01$) in NO_2+NO_3-N (figure 3-2) and summer (June-September) DO concentrations (figure 3-3). In addition to determining significant trends in waters entering Guntersville Reservoir, these data also will serve to evaluate changes in water quality in the upstream portion of the reservoir (between Nickajack Dam and BLN). Data from Nickajack tailrace for 1974-1979 were chosen to correspond as closely as possible to sampling dates at BLN and data for 1982 and 1983 corresponded exactly to BLN sampling (were collected the same day).

3.2 Widows Creek Steam Plant

Widows Creek Steam Plant (WCF), located approximately 24.9 km (15.5 mi) upstream of BLN, is rated at 5,350 MW and at full capacity discharges cooling water at a rate of 69 m^3/sec (2,437 cfs) with a maximum temperature rise of 8.3°C (14.9°F). An alternate thermal limitation of 38.9°C (102°F) (daily maximum) was established for this discharge based upon a successful 316(a) demonstration. During summer, water travel time from WCF to BLN averages about two days, but annually can vary from under one day to over five days. During this time heat exchange with the atmosphere can remove excess heat from the river. During a hot month (August 1978 was selected for use in a modeling study), it was estimated that the average temperature rise of 0.33°C at WCF decayed to 0.27°C at BLN. The 0.33°C rise at WCF represents the difference between average temperatures recorded at the intake and downstream of the discharge at WCF. Temperatures at WCF intake normally approach and sometime exceed Alabama's 30°C upper limit during summer. Effects of WCF discharges are to increase downstream temperatures slightly, causing exceedance of 30°C to occur more frequently, and prolonging duration of these exceedances (TVA 1982). A comparison of maximum temperatures at WCF intake and the BLN site (TRM 391.3) during July and August 1977 and 1980 is provided in table 3-5.

Water temperatures upstream of BLN are affected primarily by releases from the upstream dam. Water temperature profiles in fall and winter are nearly uniform, indicating that Guntersville Reservoir is primarily a flow-through system. Water temperature surveys of the WCF discharge conducted August 1967 indicate that, for periods of moderate to high river flow, the WCF thermal discharge would have a negligible effect on water temperatures at BLN (TVA, 1974). However, for periods of extended low river flows, WCF discharges mix in a surface layer 1.5-3.0 meters deep and across the width of the reservoir within one mile of the plant (WCF) (Waldrop et al. 1975). When stratified conditions develop in the reservoir due to solar heating during low flow conditions, it is difficult to differentiate between WCF-induced and naturally-induced temperature increases downstream of WCF. Typical seasonal profiles of water temperature in Guntersville are provided in figure 3-15.

Since suspension of monitoring at BLN in 1984, power generation at WCF has been reduced. Effect of WCF on preoperational monitoring data from 1974-1984 has been minor and should not constitute a significant influence (due to decreased generation load) during the scheduled year of monitoring prior to fuel loading of unit 1.

3.3 Aquatic Macrophyte Control

Submersed aquatic macrophytes have created conflicts with reservoir use since the 1960's when Eurasian watermilfoil (*Myriophyllum spicatum* L.) became widespread in several TVA mainstream reservoirs. Eurasian watermilfoil is the dominant species on Guntersville Reservoir; however, several other species such as spinyleaf naiad (*Najas minor* All.), southern naiad (*N. guadalupensis* [Spreng.] Magnus), American pondweed (*Potamogeton nodosus* Poir.), coontail (*Ceratophyllum demersum* L.), narrow-leaved pondweed (*P. pusillus* L.) and muskgrass (*Chara* spp.) have caused problems in some areas. A particularly noxious species, hydrilla (*Hydrilla verticillata* [L.f.] Royle), was discovered on Guntersville Reservoir in 1982 and is expected to cause major problems within the decade.

Guntersville Reservoir is the most severely infested reservoir in the TVA system. Since 1980 from 15 to 21 percent of the surface area of Guntersville Reservoir has been infested with aquatic macrophytes (Burns et al., 1984). In an effort to reduce reservoir-use conflicts, aquatic macrophytes around high-priority ar as receive herbicide treatment at varying intervals during the growing seasons. High-priority treatment areas are reservoir sites that receive the greatest social and economic benefits following treatment and generally include (1) high-use recreation and public access sites, (2) reservoir areas adjacent to lakeside residences, resorts, camps, and recreational marinas, (3) water intakes around TVA power facilities and industrial sites, (4) small expanding colonies of noxious weeds such as hydrilla, and (5) colonies of dense weeds that support mosquito populations that show tolerance to conventional mosquito larvicides.

All herbicide treatments in the study area from the period 1974 to 1983 have been confined to TRM 385.8 to 391.5 including Jones Creek embayment. No herbicide treatments occurred in the area from TRM 395 to TRM 397 including Raccoon Creek embayment. The areas receiving herbicide treatment from 1974 to 1983 are shown in figures 3-16 through 3-25. Several of the areas received more than one treatment per growing season. The dates of treatment, area treated, herbicide, gallons applied, and acreage treated are listed in table 3-6.

Four herbicides (2,4-D, diquat, Cutrine®, endothall) have been used to control aquatic macrophytes and are listed in table 3-7. All are approved for aquatic use and were applied at label rates. Of the four herbicides, 2,4-D has the longest history of use in the Tennessee Valley and specifically controls Eurasian watermilfoil. By the late 1970's several other species of submersed macrophytes caused problems in priority areas, resulting in using other herbicides in the aquatic weed control program. Cutrine® with algicide/herbicide properties and diquat have been used on a limited scale. Endothall, in conjunction with 2,4-D, are the primary herbicides currently used in TVA's aquatic plant management program.

In most instances, herbicides were applied with a conventional flat-bottomed boat powered by an outboard motor or more recently with airboats using a spray system with subsurface injection. An exception was a helicopter treatment of approximately 80 acres in Sublett Ferry Slough (TRM 389.1R to TRM 390.1R) in September 1982. This treatment was made in an effort to eradicate a large hydrilla colony that would have served as a propagule source for downstream spread of this noxious weed.

For the most part, herbicide treatments have not occurred at stations sampled during preoperational monitoring at BLN. Left overbank stations at TRM's 386.4 and 391.9 may have been impacted in 1974 (figure 3-16); however, sampling at these locations was not begun until 1978. Treatment of areas near the sampling station at TRM 386.4 in 1978 and especially 1979 (figures 3-20 and 3-21) may have impacted that sampling location; however, records do not indicate that the exact point of sampling was treated. Treatments in Sublett Ferry (1982, figure 3-24) impacted one of several stations sampled to evaluate baseline aquatic macrophyte colonization in the vicinity of BLN.

3.4 Larvicide Treatments

Several complaints were registered concerning severe mosquito annoyance to construction workers at the site during the summer of 1975. A survey revealed that most of the mosquito breeding at that time was occurring in a construction holding pond. The pond was treated with 30 pounds of 1 percent Dursban granular larvicide at the rate of 0.05 pound active ingredient per acre. Malathion insecticide was also applied as an adulticide to those areas (22.8 acres) of the construction site where adult mosquitoes were causing annoyance. Adult mosquitoes again became annoying in late July. An inspection revealed significant number of Anopheles quadrimaculatus larvae in an extensive band of uncontrolled Eurasian watermilfoil in Guntersville Reservoir in the immediate vicinity of the construction site. Adult mosquito counts were also unusually high at index stations located in this vicinity. It was recommended that the area be included in the operational larvicide program. No treatments were made until reviews were completed and approvals were granted by TVA technical staff responsible for the site monitoring zone. Abate, which was the routine mosquito larvicide used, can produce mortality in Chironomus, which is one of the dominant macrobenthic organisms in the vicinity of the site. However, under actual field conditions, this effect should be minor since Abate was applied only to the water surface and not bottom sediments, the habitat of benthic organisms. Abate degrades so rapidly in water, that is is unlikely that sufficient amounts of toxicant would remain long enough to significantly impact sediment inhabitating organisms.

Beginning with July 1975, Abate larvicide was applied by helicopter at the rates of 0.004 and 0.012 pound active ingredient per acre to mats of aquatic plants, predominately Eurasian watermilfoil in the vicinity of the Bellefonte site. Due to the development of mosquito resistance to Abate, it was replaced with Altosid SR-10® (methoprene) as the routine larvicide used in the spring of 1983. Methoprene is an insect growth regulator that produces morphogenetic effects on mosquitoes rather than direct toxic effects as do conventional insecticides. Methoprene is very specific for mosquito larvae. Methoprene was applied by helicopter at the rate of four fluid ounces of 0.025 pound active ingredient per acre. A summary of larvicide treatments (1975-1984) is given in table 3-8.

Observations made in the vicinity of field bioassay sites on Guntersville Reservoir have indicated no acute mortality of nontarget arthropods by Abate or methoprene insecticide applications. In addition, analysis of Abate water samples collected from bioassay sites on Guntersville Reservoir indicated that insecticide concentrations were below detectable levels for laboratory equipment (0.1 parts per billion) four hours after treatment. Therefore, it appears that larvicide applications had no major impact on preoperational results collected for BLN.

3.5 Sand and Gravel Dredging

Throughout much of the preoperational monitoring period, a commercial sand and gravel company which operates out of Chattanooga, Tennessee, has been dredging the main river channel in the vicinity of BLN sampling stations. The BLN construction assessment evaluation (TVA, 1980) identified a change in sediment composition and benthic macroinvertebrates at the downstream channel station. This change was attributed to the sand and gravel dredge which had operated in the immediate vicinity of the BLN station for 83 days before initiation of the 1978 year of sample collections. Impacts of dredging which included significant increases in the relative amounts of silt and clay and macroinvertebrate abundance (Oligochaeta, *Corbicula manilensis*, *Hexagenia*, Chironomidae) are not considered to have been deleterous, although the data base for preoperational monitoring at that station was substantially altered. Dredging logs supplied by the sand and gravel company do not indicate any direct impact to other preoperational monitoring stations. However, sand and gravel dredging has occurred upstream of the monitoring station immediately downstream of the BLN diffuser for a total of 40 days during 1975. Impacts from this dredging were not observed in the TVA construction assessment report.

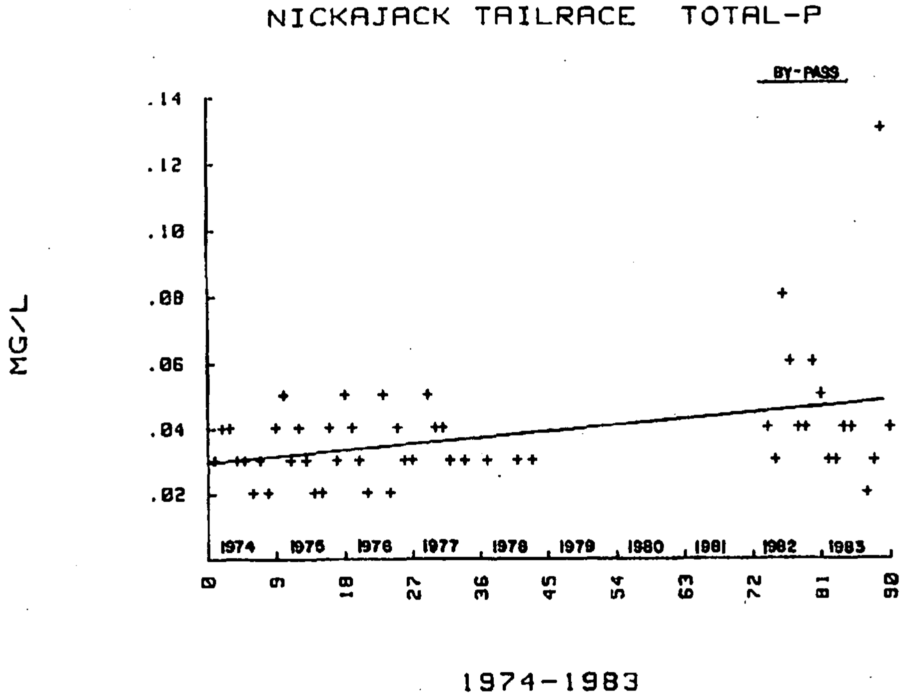


Figure 3-1. Total-P Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

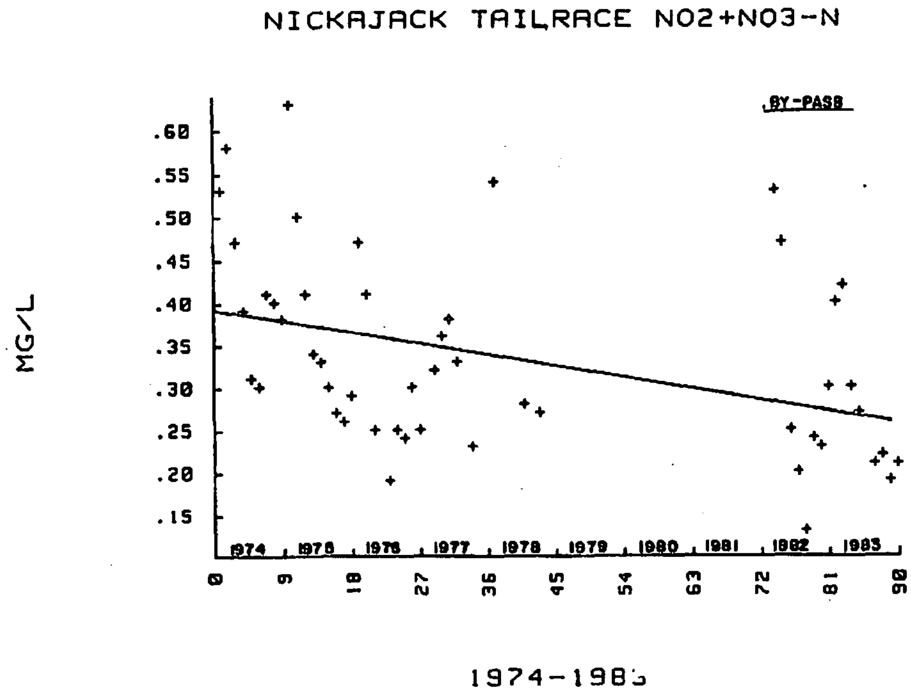


Figure 3-2. $NO_2 + NO_3$-N Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

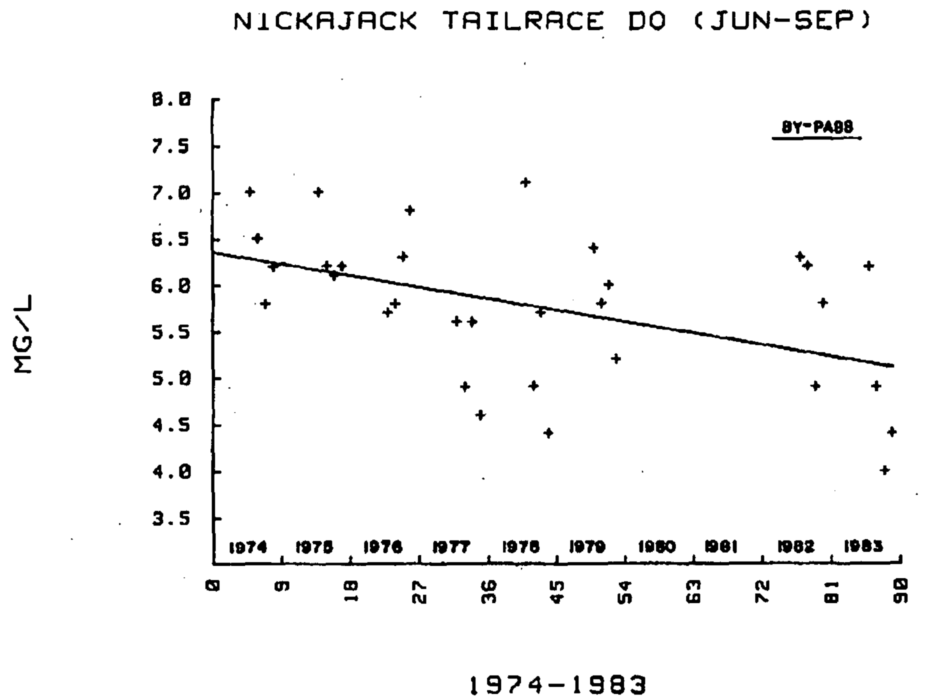


Figure 3-3. Summer DO Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

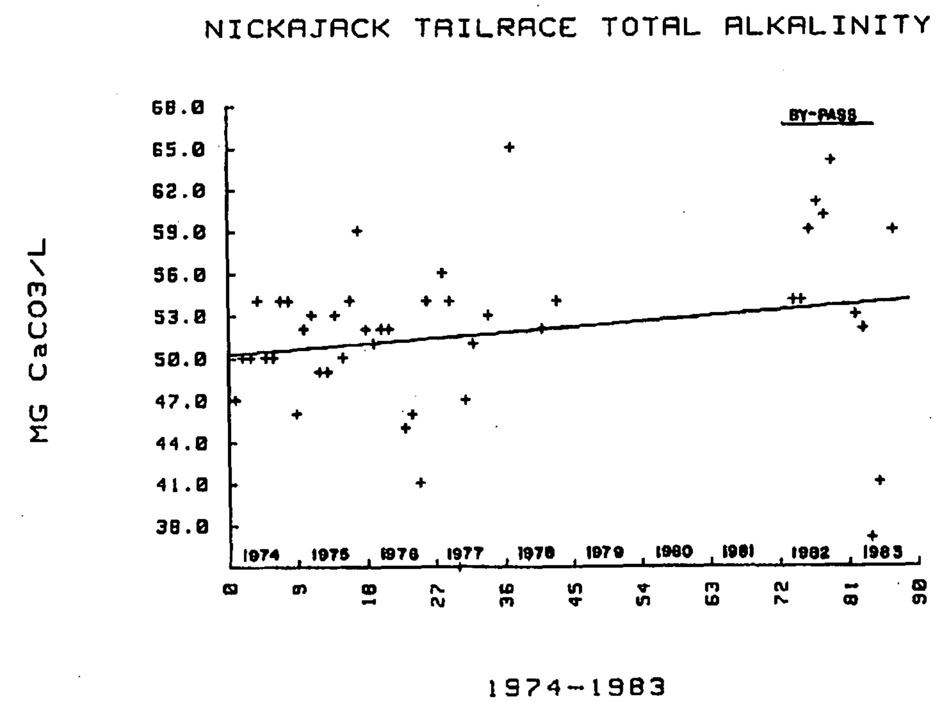


Figure 3-4. Total Alkalinity of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

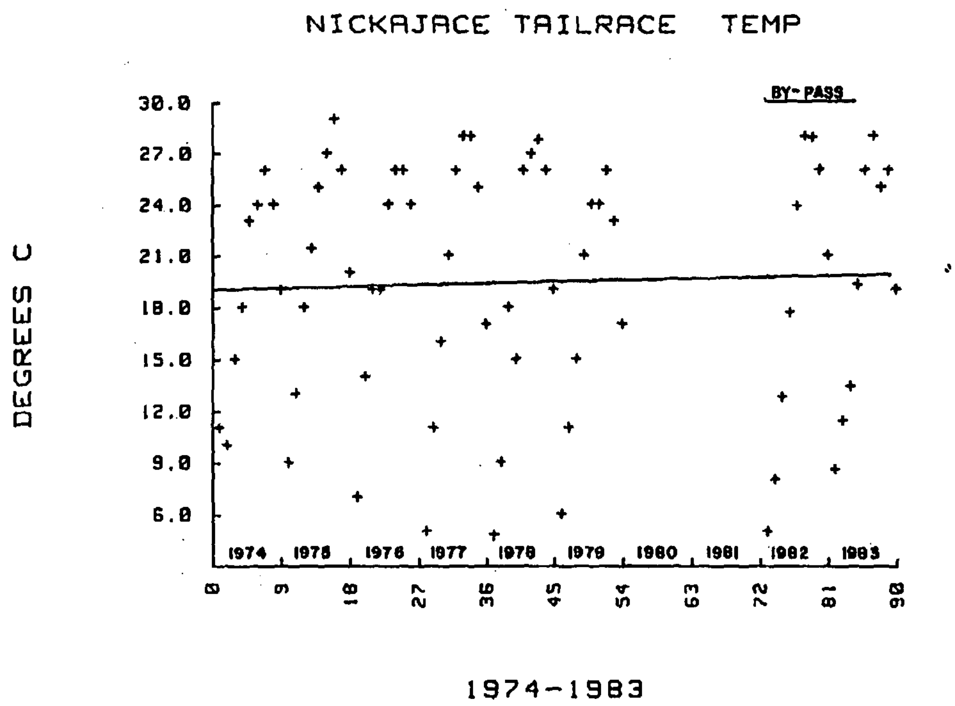


Figure 3-5. Temperature of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

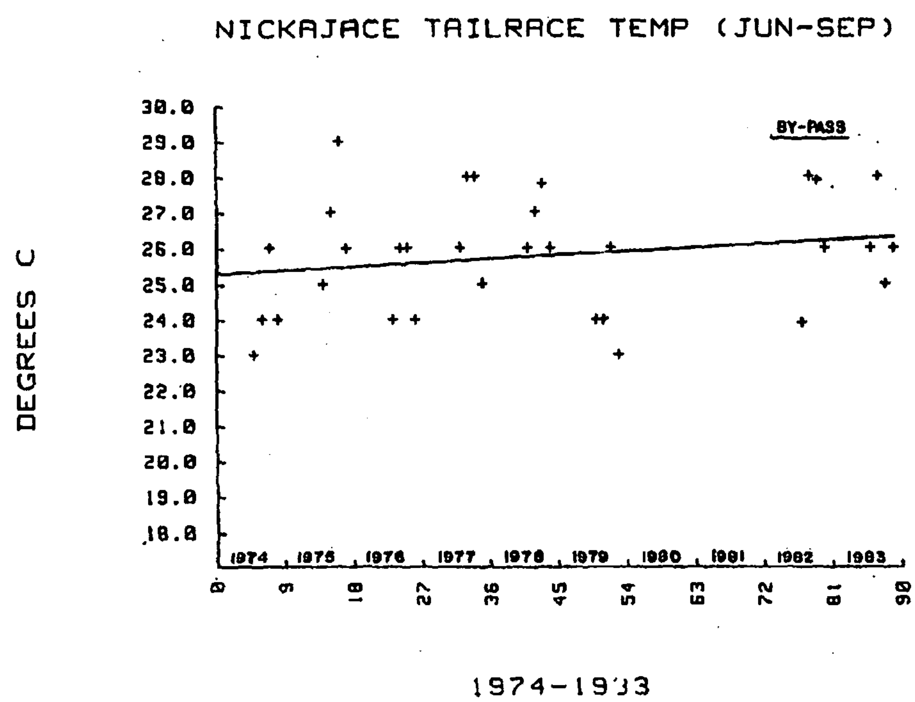


Figure 3-6. Summer Temperatures of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

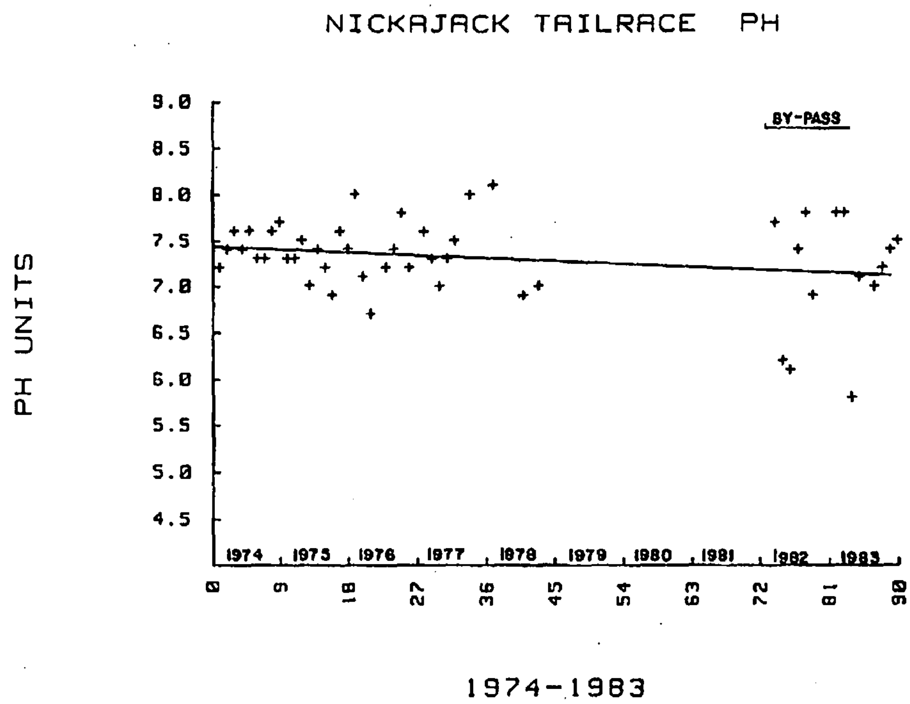


Figure 3-7. pH of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

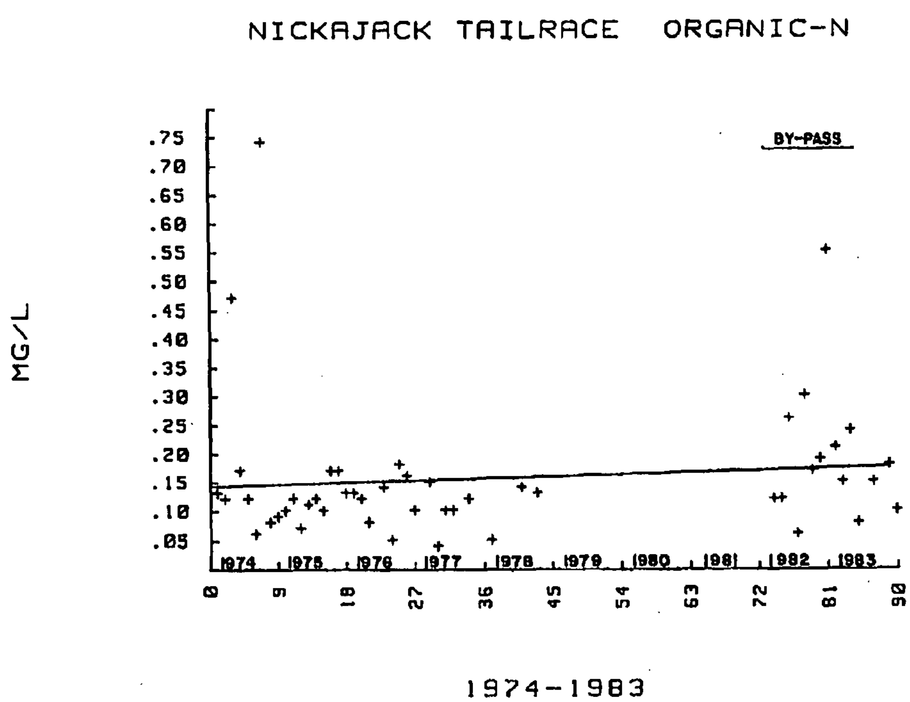


Figure 3-8. Organic-N Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

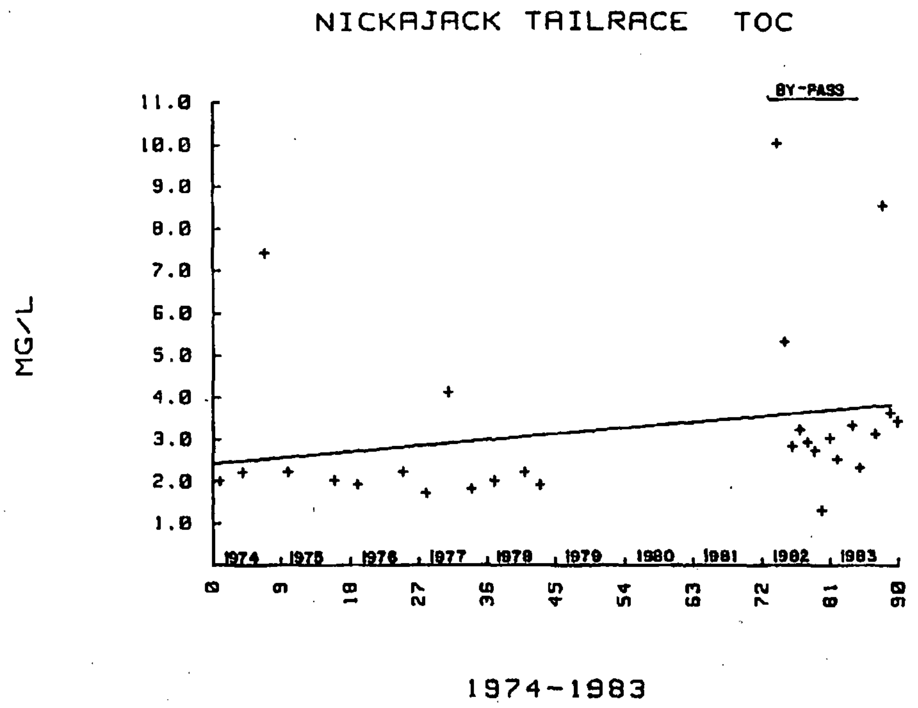


Figure 3-9. Total Organic Carbon Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

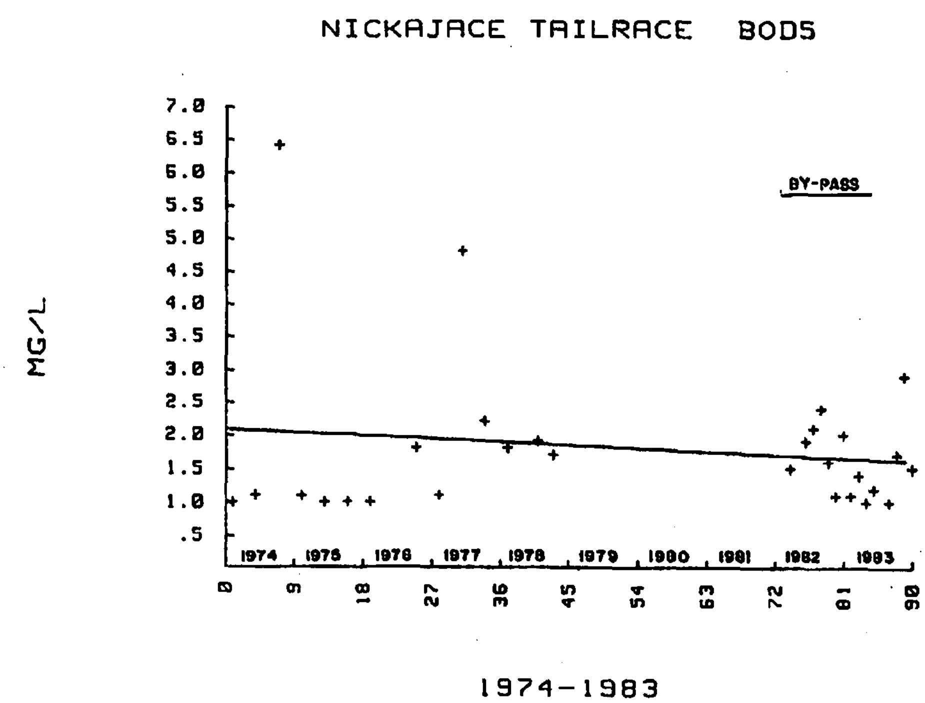


Figure 3-10. BOD (five day) of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

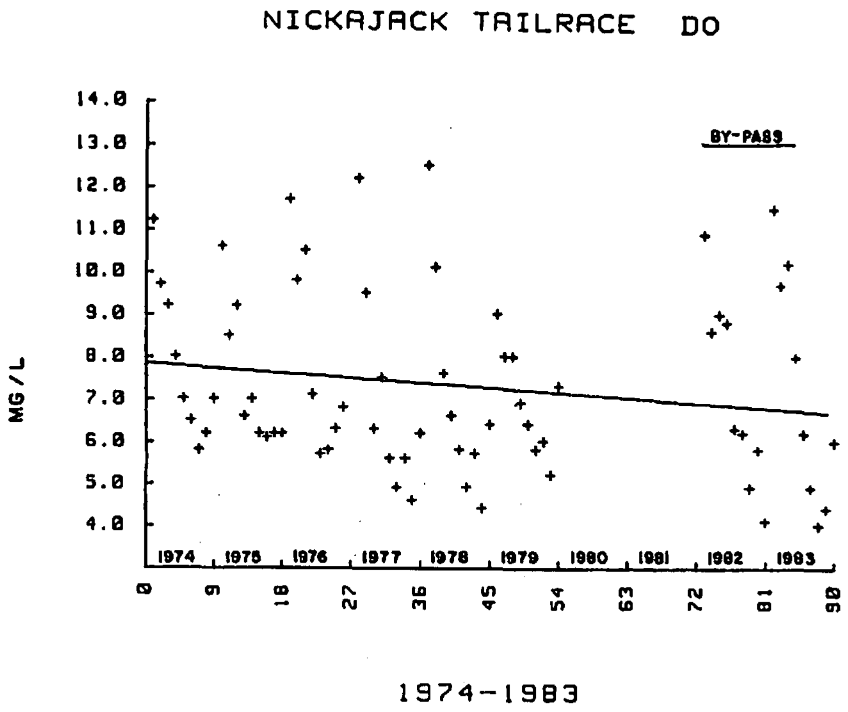


Figure 3-11. DO Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

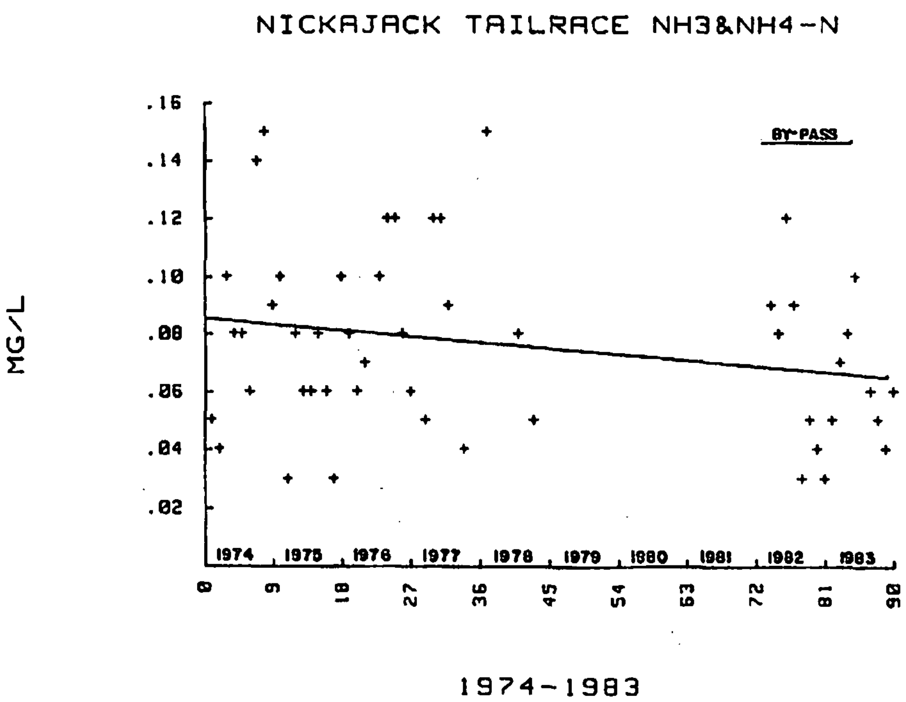


Figure 3-12. NH_3 & NH_4-N Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

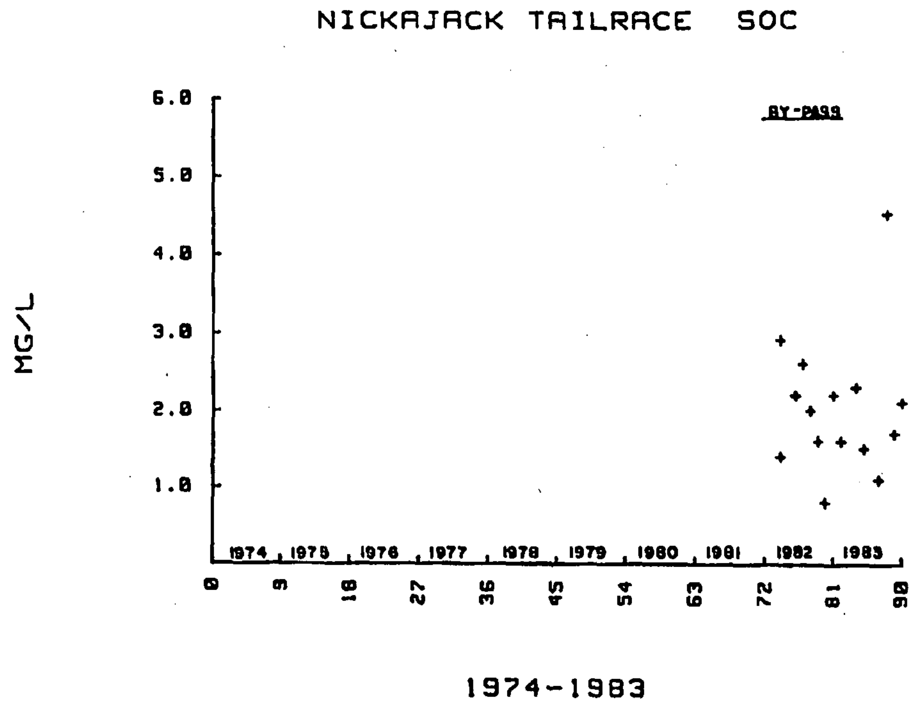


Figure 3-13. SOC Concentrations of Waters Entering Guntersville Reservoir, Nickajack Tailrace (TRM 424.68).

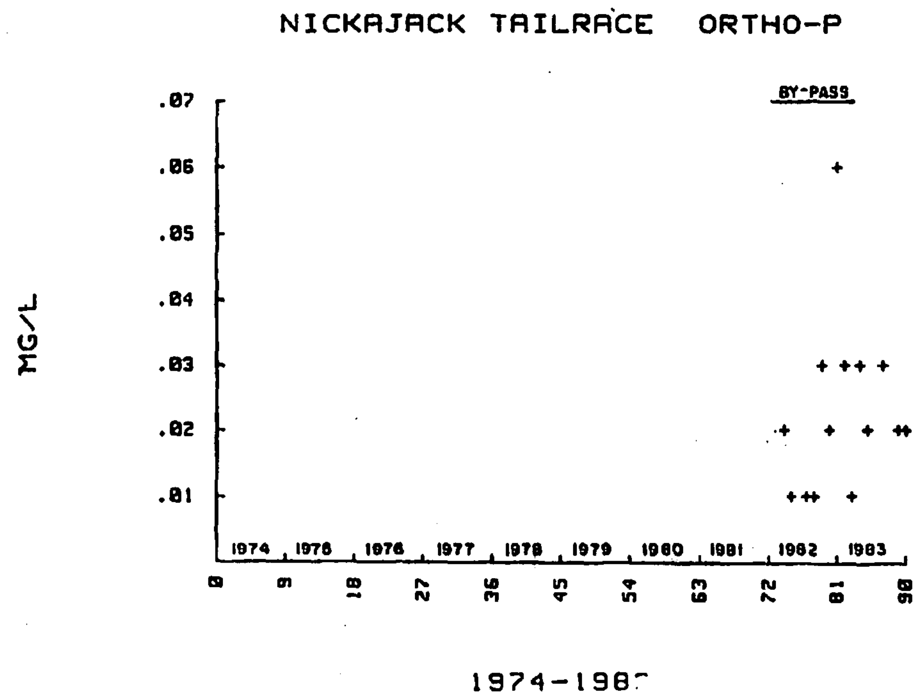


Figure 3-14. Ortho-P Concentrations of Waters Entering Guntersville Reservoir, Nickajack Reservoir (TRM 424.68).

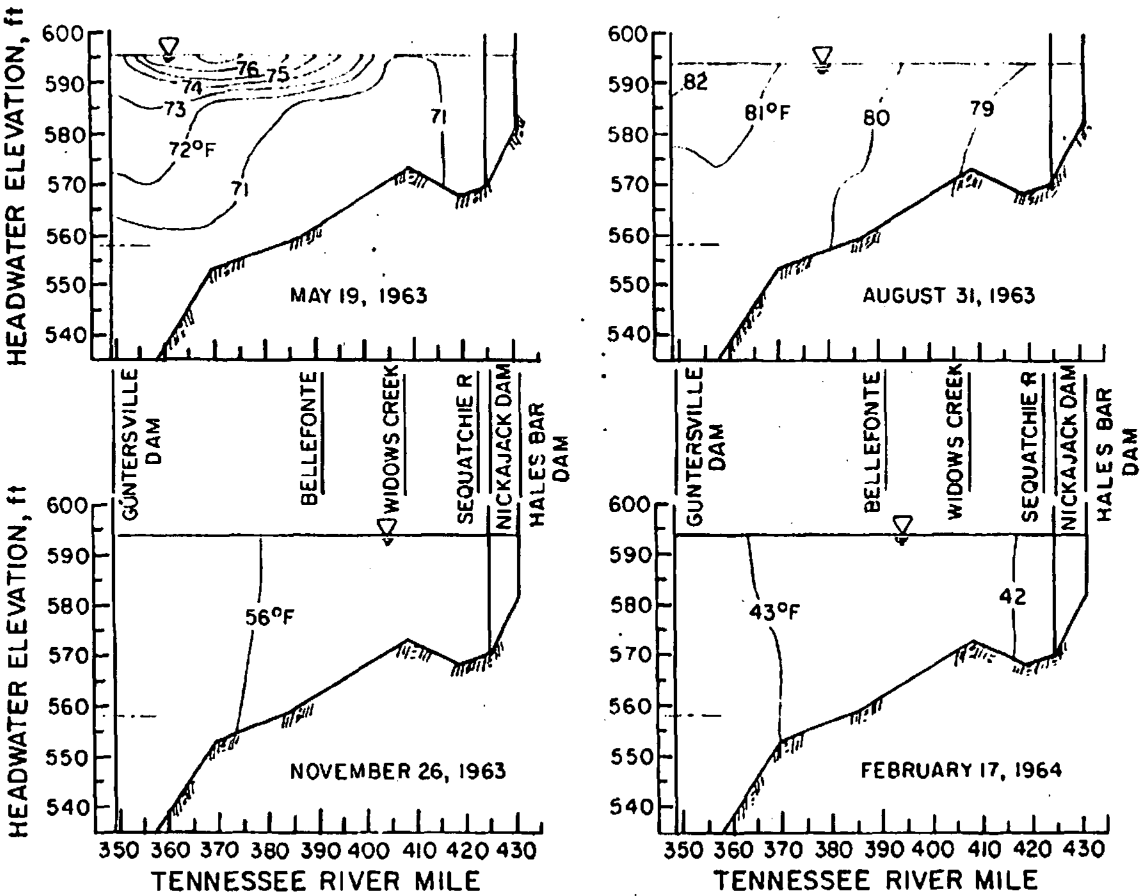


Figure 3-15. Seasonal Water Temperature Profile in Guntersville Reservoir, Tennessee River, Alabama.

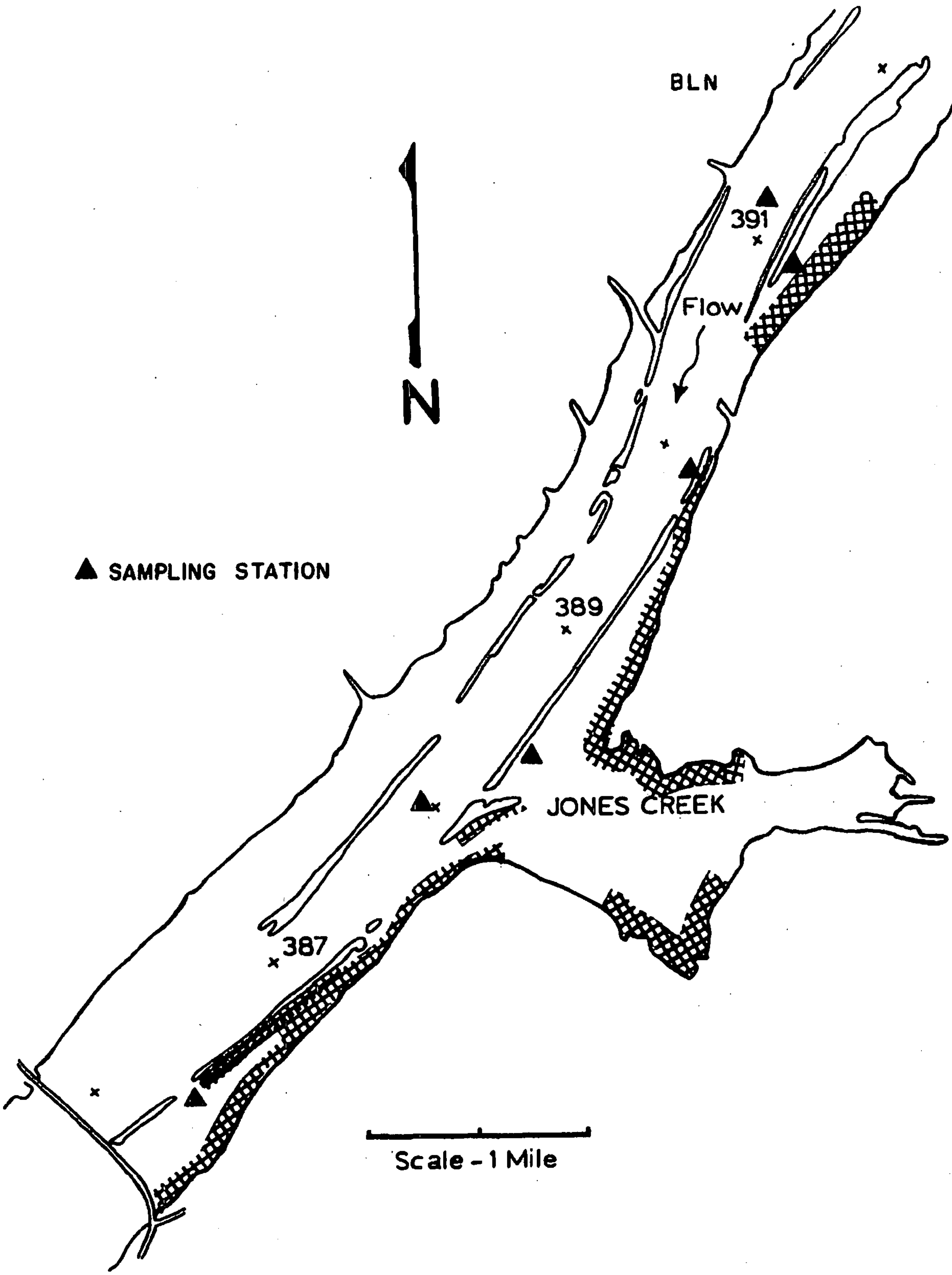


Figure 3-16. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 197ʰ

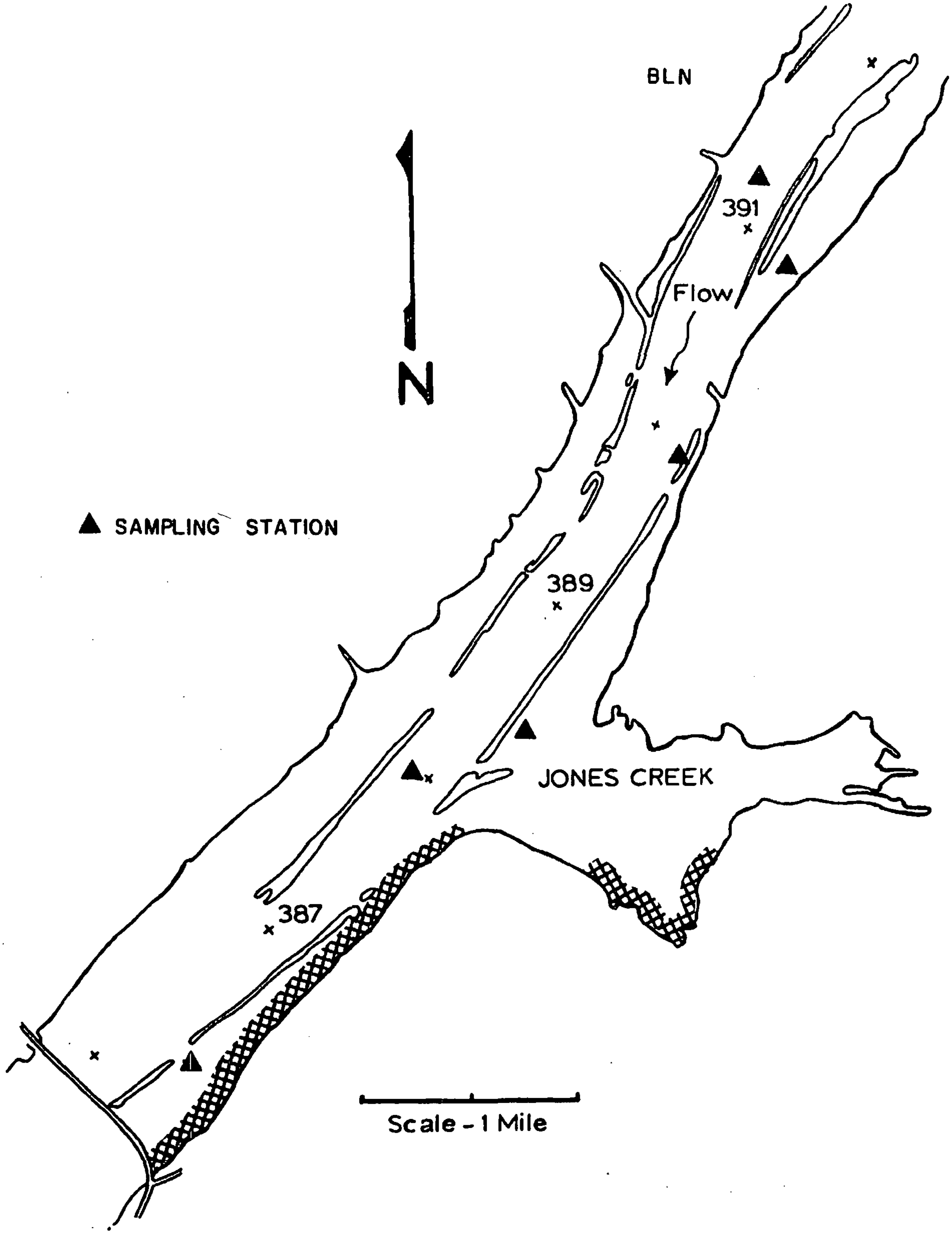


Figure 3-17. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1975.

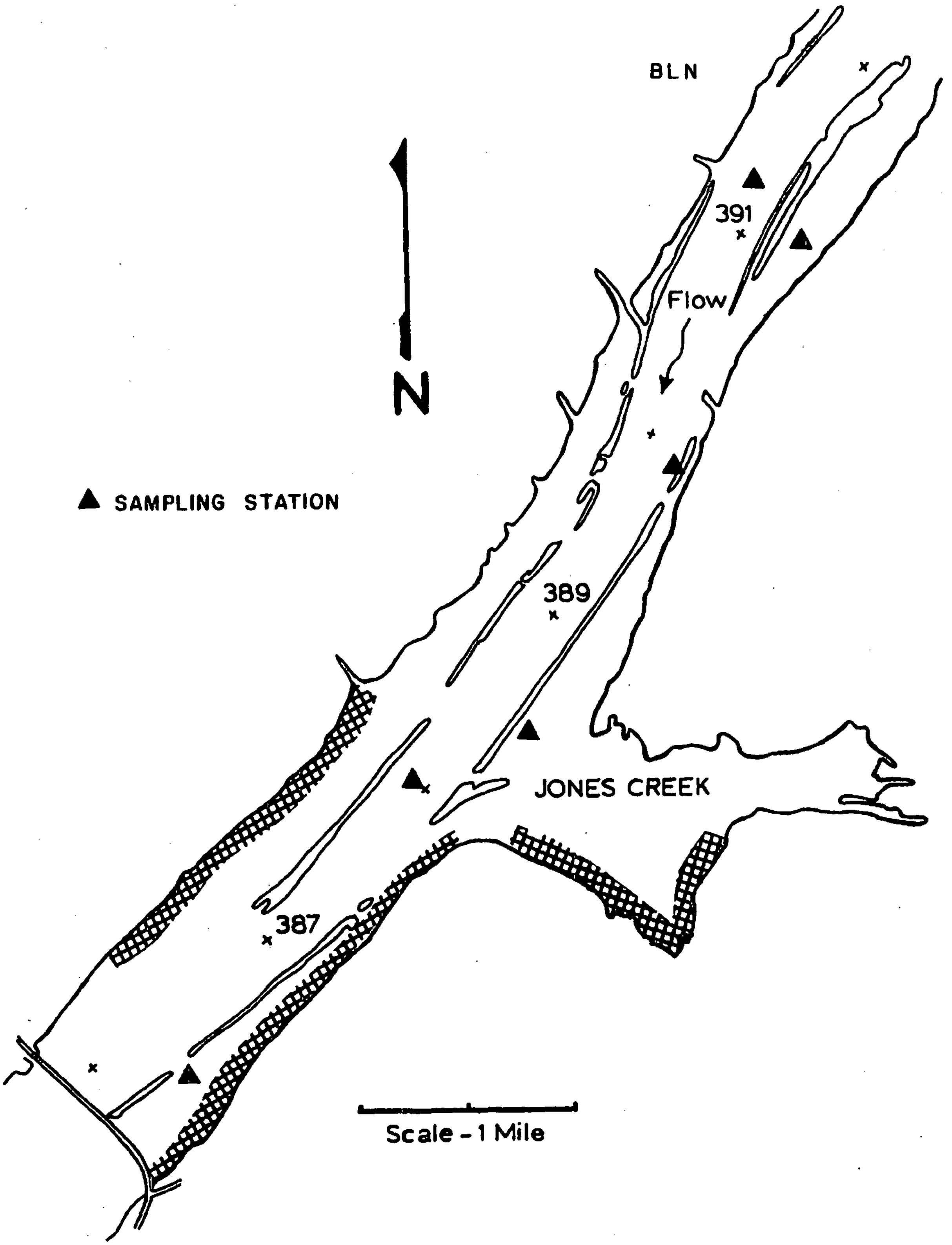


Figure 3-18. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1[illegible].

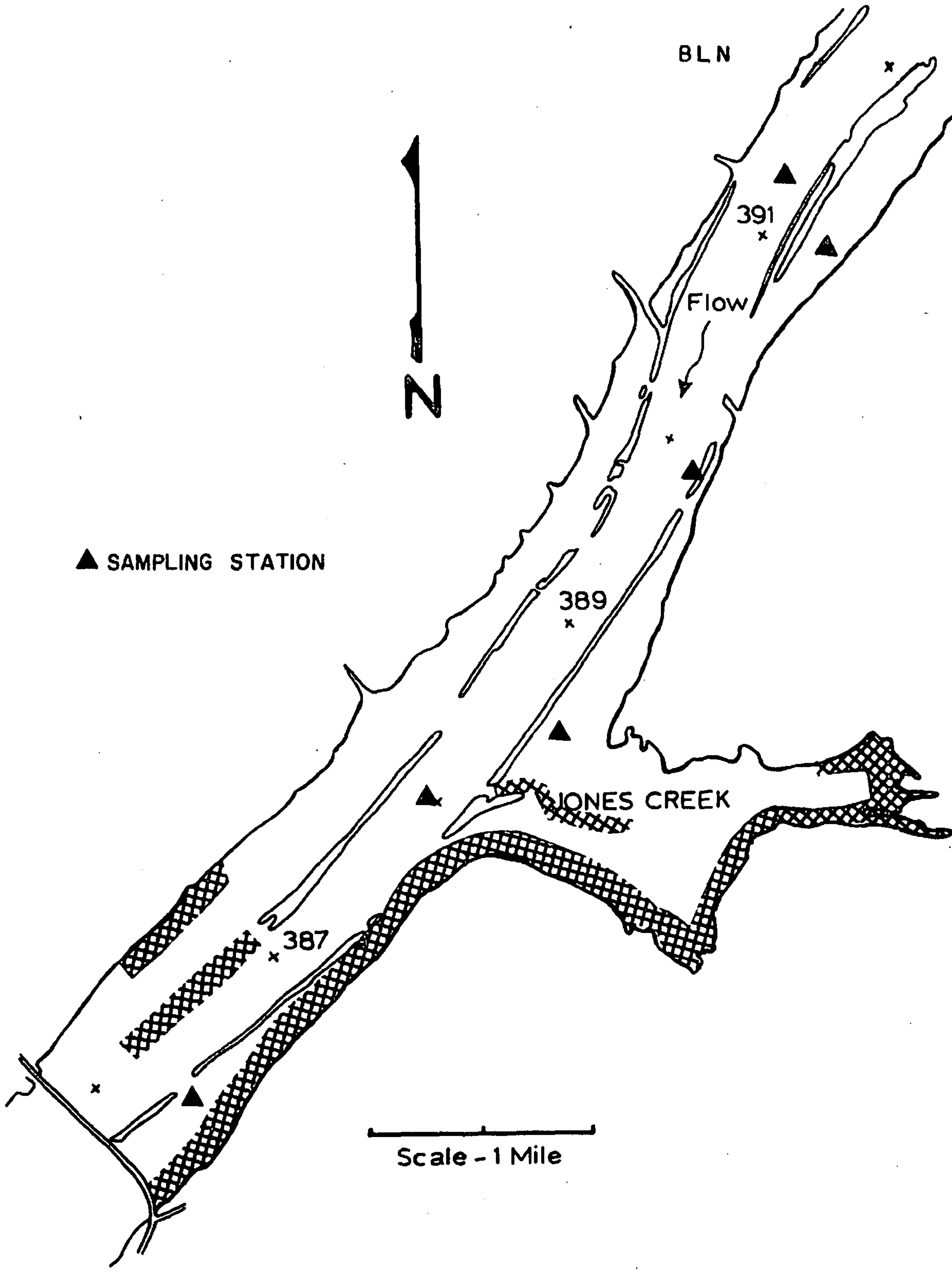


Figure 3-19. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1977.

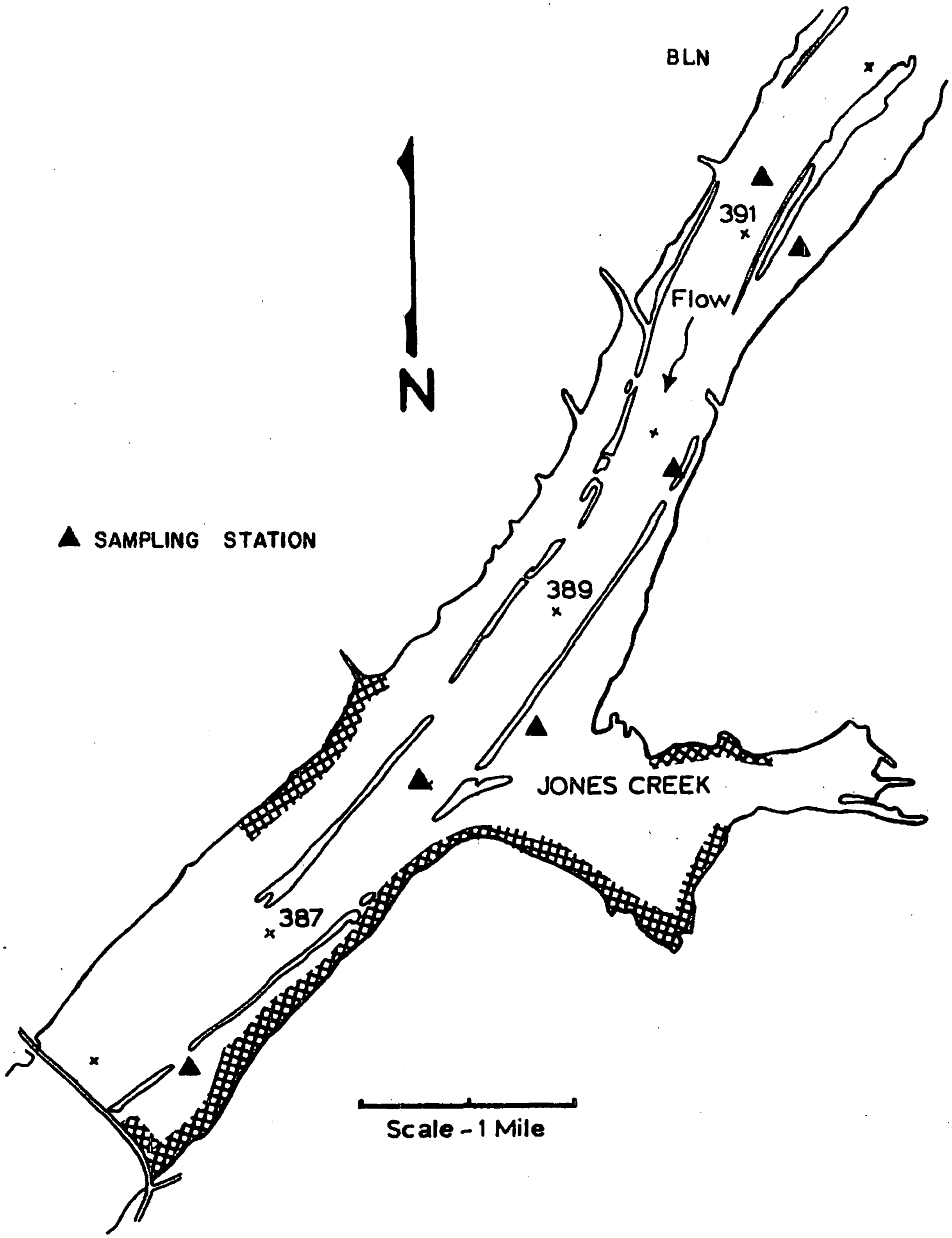


Figure 3-20. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1978.

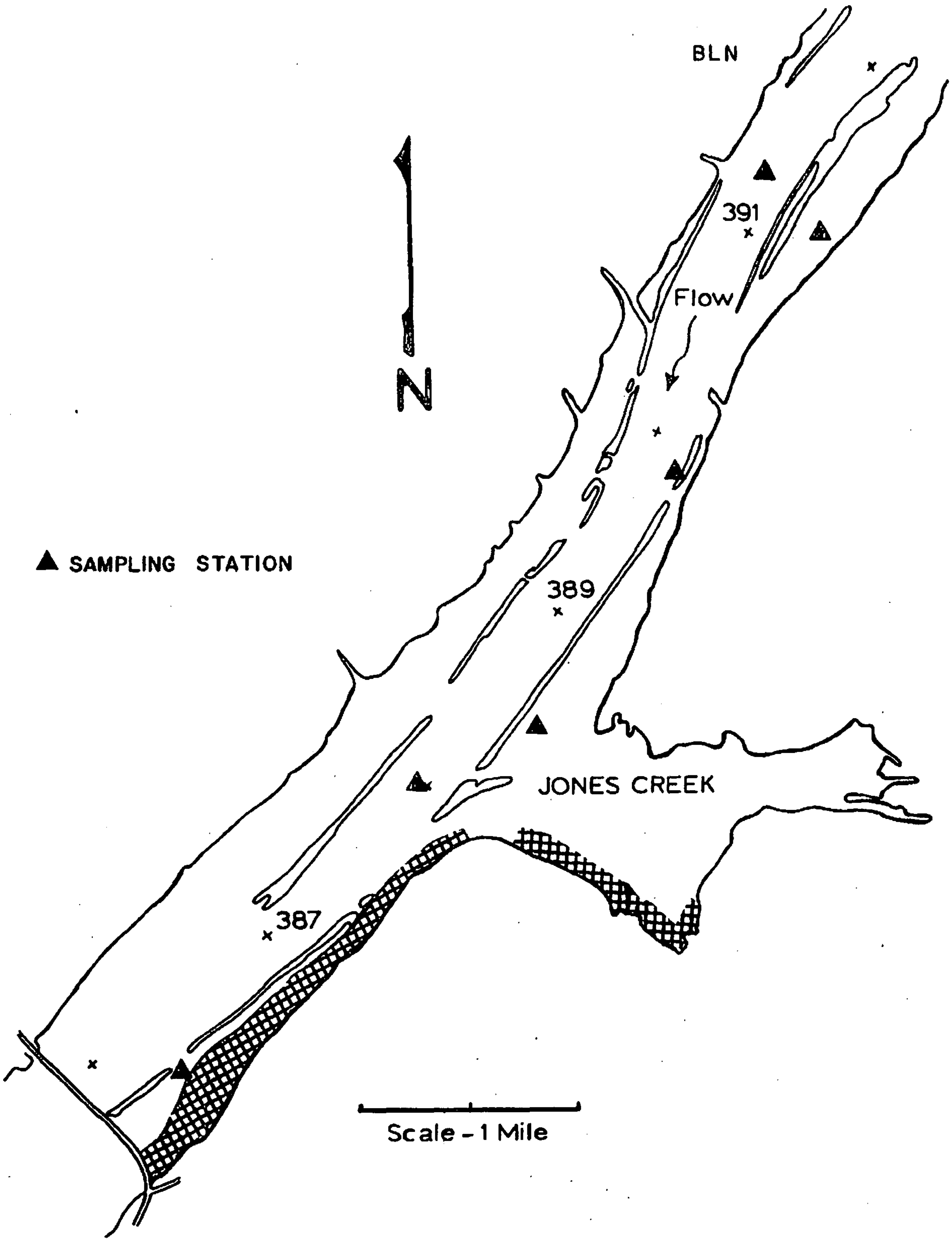


Figure 3-21. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1979.

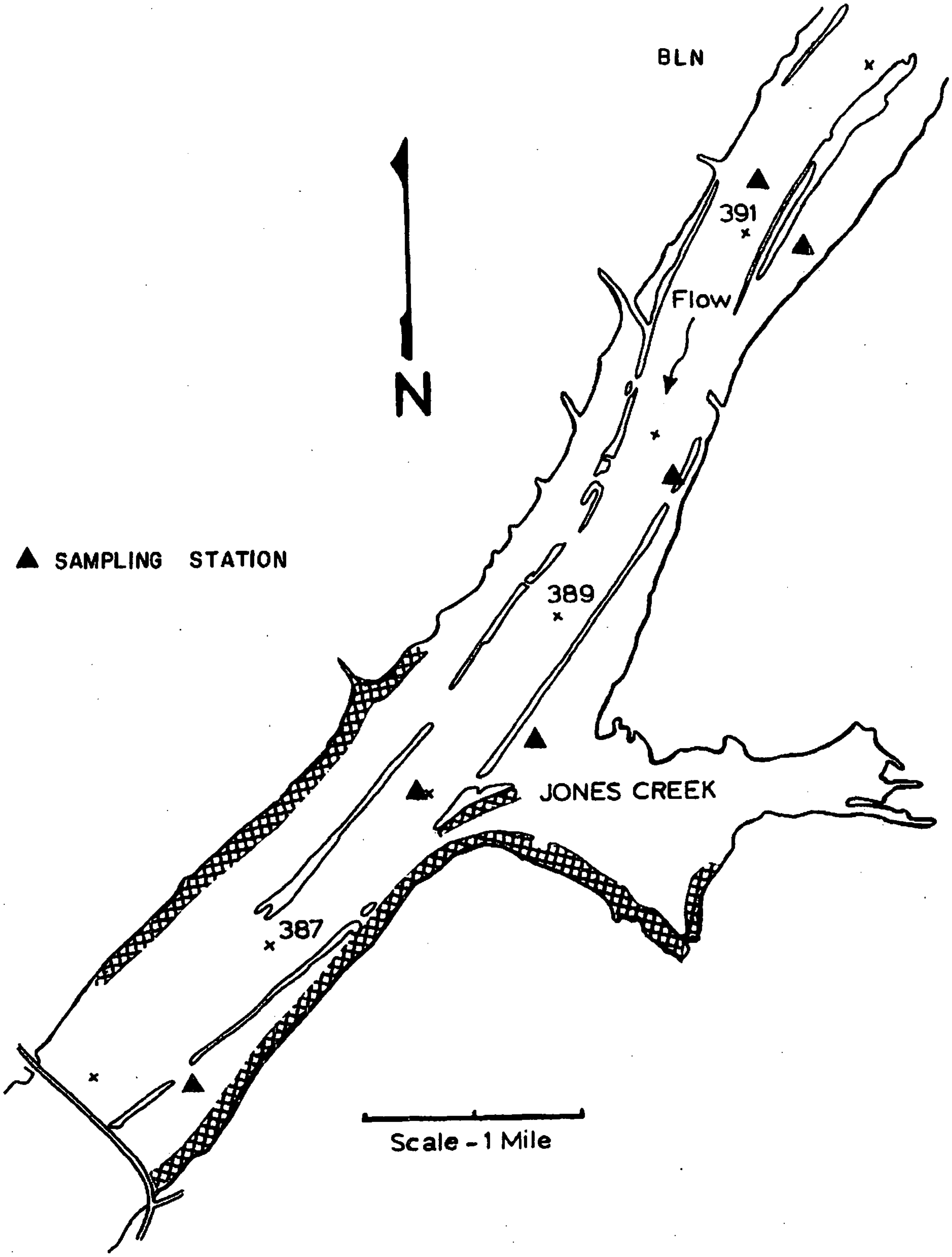


Figure 3-22. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1980.

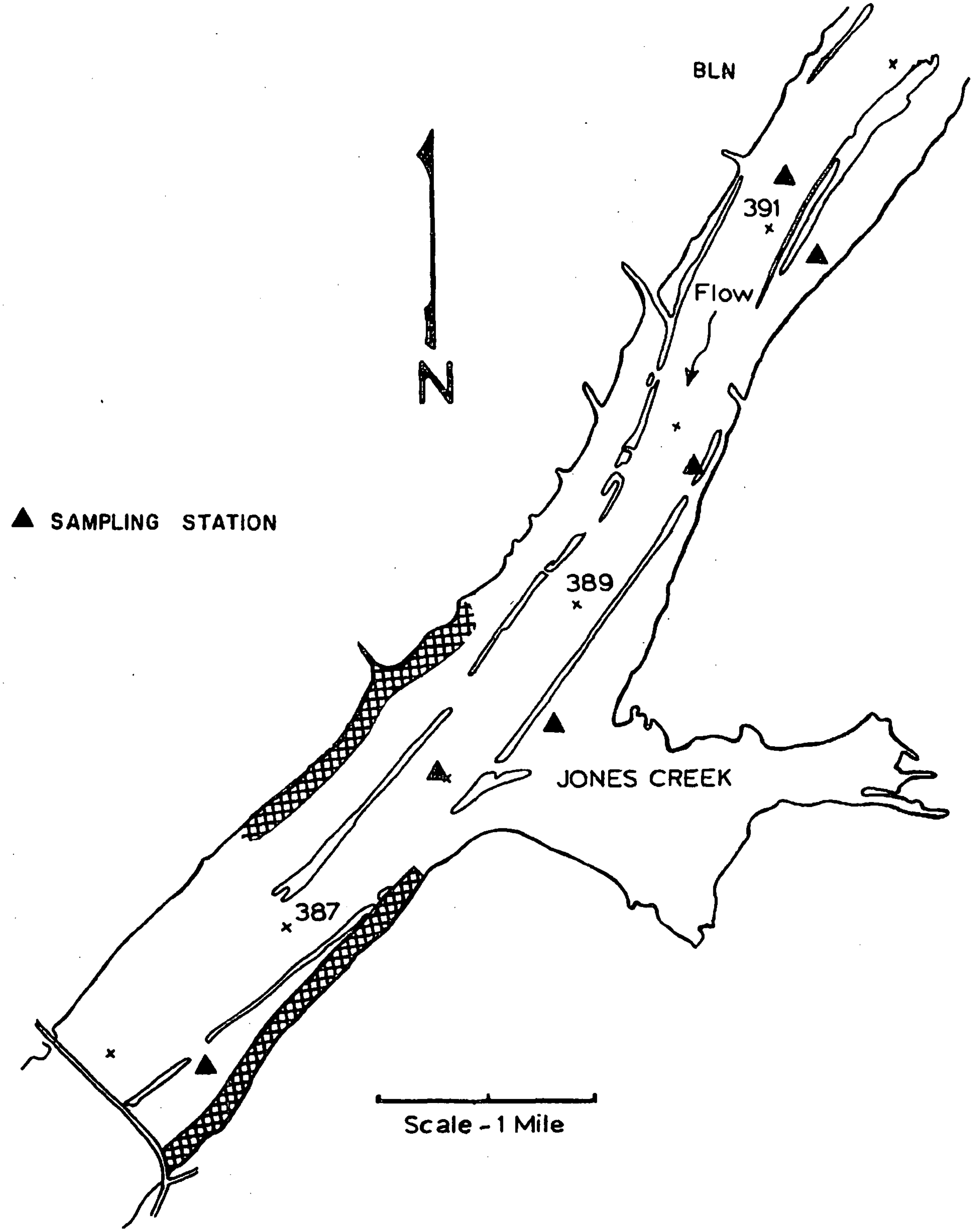


Figure 3-23. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1981.

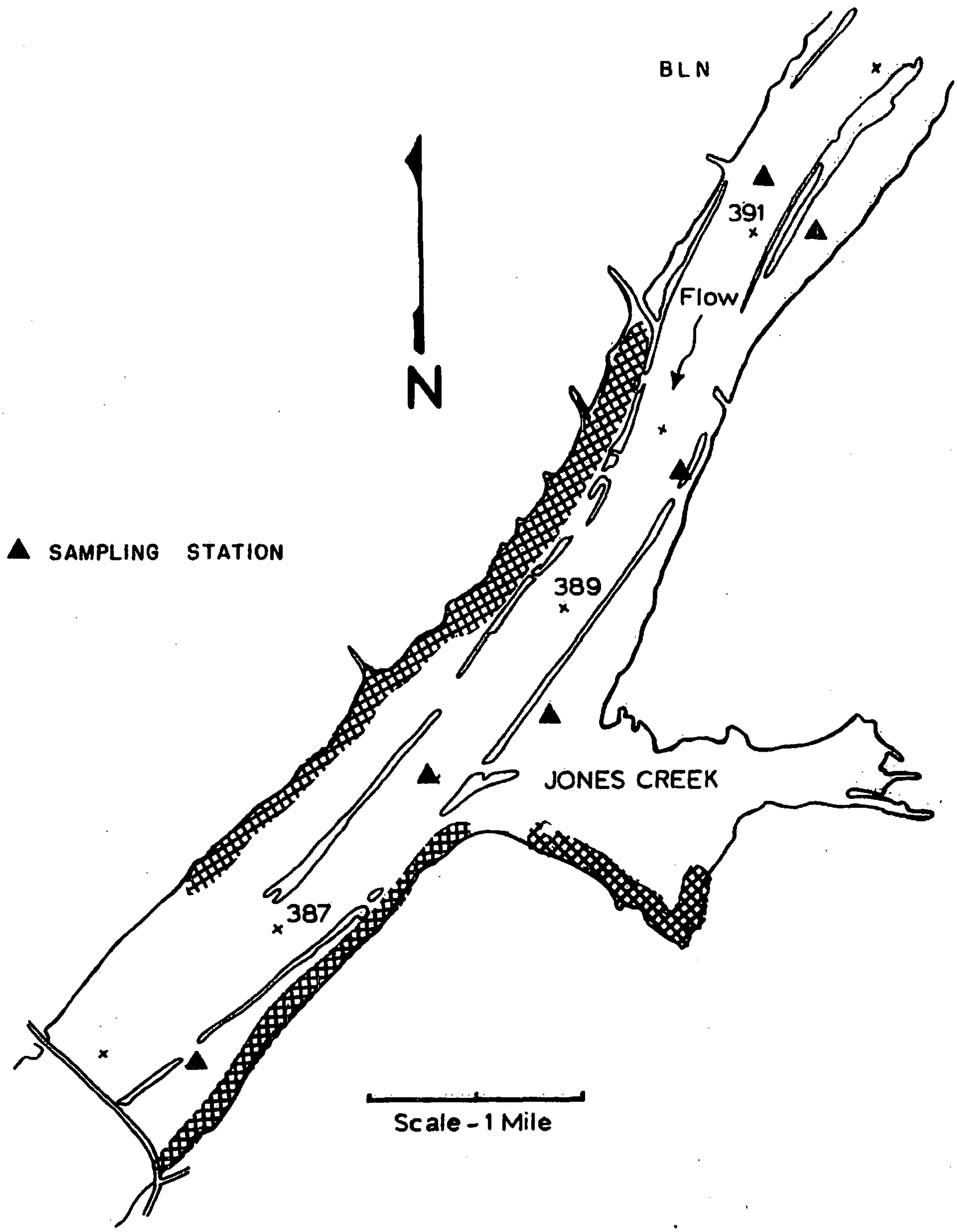


Figure 3-24. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1982.

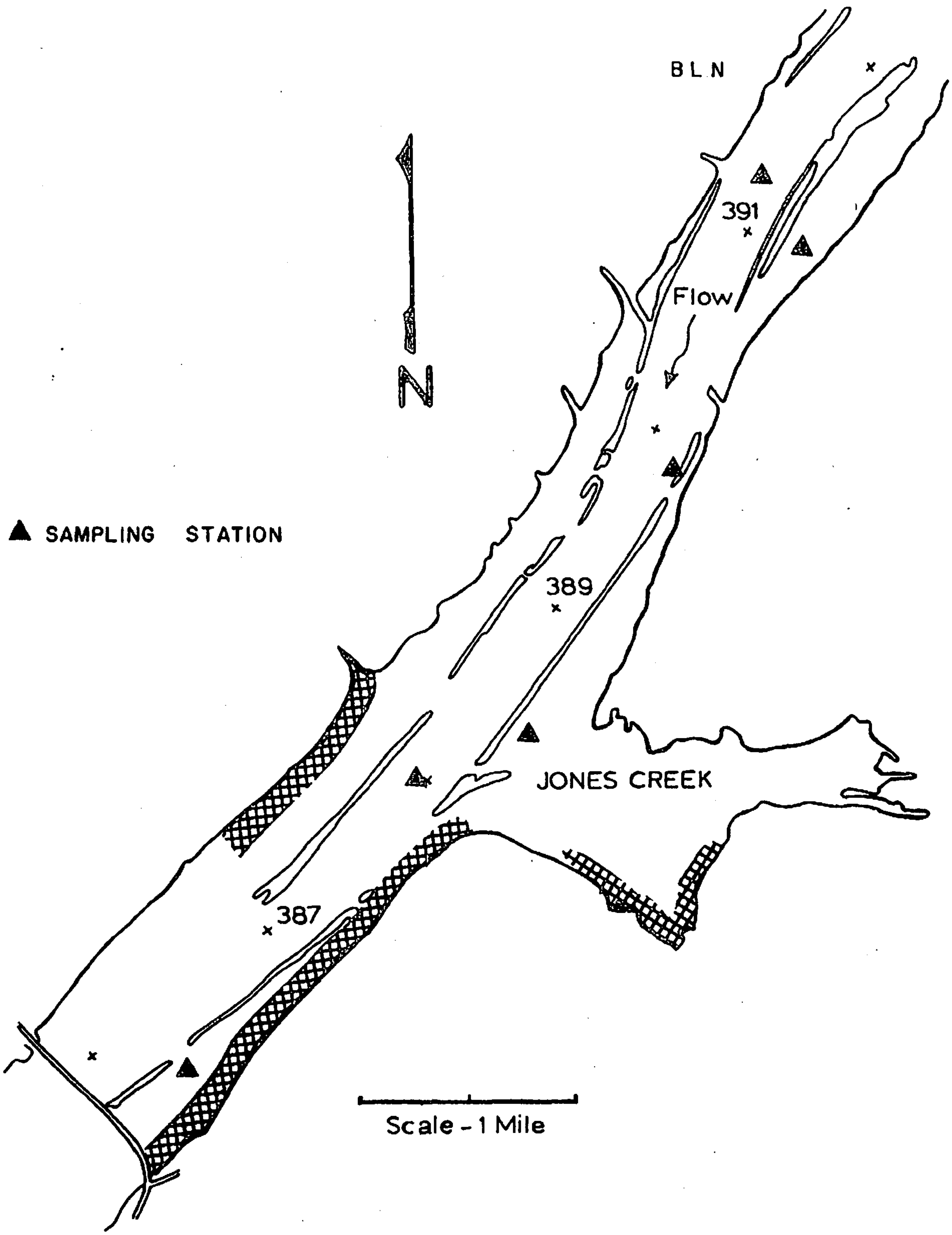


Figure 3-25. Areas Receiving Herbicide Treatments on Guntersville Reservoir from TRM 385.8 to 391.5 in 1983.

4.0 INSTREAM WATER QUALITY

The Tennessee River in the vicinity of BLN is an "effluent limited" stream. An effluent limited stream is one where stream standards are met by requiring normal levels of wastewater treatment (i.e., secondary treatment for municipalities and best practicable treatment for industries). From TRM 382.4 (Roseberry Creek) to TRM 416.5 (Alabama-Tennessee State line), the Tennessee River is classified by the State of Alabama as suitable for public water supply, swimming, and other whole body water contact sports, and fish and wildlife. However, that portion of Guntersville Lake in the immediate vicinity of the sewage discharge from the city of Bridgeport, TRM 412.9, is not considered suitable for use as a source of public water supply nor for swimming and other whole body water contact sports.

4.1 Materials and Methods

Field Procedures--Since the inception of the BLN nonradiological, preoperational water quality monitoring program in 1974, samples have been collected and analyzed in accordance with established TVA and EPA procedures (TVA 1980b, 1983b; EPA 1982; EPA 40 CFR 136). Two components of this program evaluated water quality data: (1) to support biological investigations (monthly) and (2) to provide baseline descriptions of a more comprehensive list of parameters (quarterly). Samples used for the biological evaluation were collected at TRMs 388.0 and 391.2 (1974-1978, 1982-1983); TRM 396.8 (1974-1979, 1982-1983); and TRMs 386.4, 388.4, and 391.1 (1978-1979, 1982-1983), as shown in figure 4-1. These samples were analyzed for the following parameters: temperature, dissolved oxygen, pH, alkalinity, conductivity, turbidity, TOC, BOD, organic nitrogen, nitrate plus nitrite nitrogen, ammonia nitrogen, and total and dissolved phosphorous. The more extensive list of quarterly parameters for the water quality evaluation is shown in appendix A. Table 4-1 summarizes the entire water quality monitoring program.

The nonradiological, preoperational water quality monitoring program for BLN was begun in February 1974 with the exception of one set of data collected in December 1983, at TRMs 388.0 and 391.2. Water quality monitoring surveys were performed on a quarterly (February, May, August, and October) frequency at six locations at which a rather comprehensive list of physical and chemical measurements were made. Supplemental measurements for temperature, dissolved oxygen, pH, and alkalinity were also made at these six locations in March, April, June, July, and September.

In May 1975 the BLN preoperational monitoring program was largely revised. Sampling was discontinued at one of the six locations (Mud Creek), and monitoring activities were expanded at the remaining five locations. The list of water quality parameters collected on a quarterly frequency remained the same; however, additional physical-chemical measurements, including nutrients, were made on monthly (March, April, June, July, and September) surveys. In addition, Ekman dredge sediment samples for chemical analysis of metals were collected in August 1975 and August 1976 at five locations.

In March 1978 four additional locations were established along the left overbank (looking downstream) to help evaluate impacts of the thermal and chemical plume from plant blowdown. These four new locations were monitored on a monthly frequency (February through October) for temperature, pH, dissolved oxygen, conductivity, and nutrients.

Collection of water quality samples at four of the original five locations was discontinued at the end of 1978. At the fifth original location (TRM 396.8), physical-chemical measurements were reduced to monthly surveys for temperature, pH, dissolved oxygen, conductivity, and nutrients in 1979. All monitoring was discontinued in October 1979.

The BLN nonradiological, preoperational water quality monitoring program was reinstated in 1982 at eight of the previous nine locations, with sampling eliminated at TRM 391.6. Details relating to the physical-chemical measurements made at each location and the frequency of each sampling survey can be found in table 4-1. Monitoring was again stopped in February 1984 due to the construction schedule slippage.

Laboratory--All analytical and sample preservation methods used for chemical water quality characterizations (TVA NRS 1980; EPA 1980; TVA NR OPS 1983;) are approved by EPA

Data Analysis--All water quality data are entered into the EPA water quality data Storage and Retrieval (STORET) system and are available from TVA's Data Services Branch, Chattanooga, Tennessee. Data contained in STORET has been amended to reflect any changes in sampling or analytical procedures which have occurred during the sampling period. Data reduction and statistical evaluation procedures used standard statistical routines available through the STORET system. Data collected specifically to support the biological evaluation was averaged by month and the monthly averages were plotted against time. Both the biological support data and the other water quality data were compared to the criteria and standards listed in appendix A.

All data collected during the preoperational monitoring period was used for the water quality analysis. A one-way Analysis of Variance Test

(ANOVA) (SAS 1982) was used to determine significant differences with regard to depth and year for water quality parameters collected at each station. Duncan's New Multiple Range Test (SAS 1982) was used to separate significantly different (α=0.05) depths and years. A linear regression analysis (SAS 1982) was run on the parameters which had significant differences among years to identify linear trends (significant change over time).

4.2 Results and Discussion

All water samples collected between 1974 and 1983 for both the biological support and the more comprehensive water quality data are identified in table 4-1. For purposes of this report, the data used for biological support has been evaluated separately, and also included in the more comprehensive statistical evaluation of the entire data base.

Biological Support Water Quality Data--The data base used to support biological evaluations contained data which was averaged for specific river miles without consideration of depth (table 4-2). Biological support data was compared against the criteria concentrations listed in appendix A. The few exceedances which were found were identified by asterisks in table 4-2. Values for pH, organic nitrogen, TOC, and BOD were higher during the 1982-1983 sampling period than they were during the 1974-1979 sampling period, (figures 4-2 through 4-13).

Temperature and Dissolved Oxygen--Individual temperature values rarely exceeded the State of Alabama criterion of 30°C, but values between 28°C and 30°C occurred frequently throughout the summer. A temperature of 31.7°C was recorded at TRM 391.6 in May 1975. A mean temperature (table 4-2) of 30.3°C was recorded at TRM 386.4 in August 1983. Weak thermal stratification was occasionally observed in late summer when river flow was low.

Dissolved oxygen concentrations below 5 mg/L were measured at six out of seven stations during August, 1982 and July, 1983, as noted in table 4-2. Lowest average DO concentrations measured during the study occurred in July 1977 at TRMs 391.2 (2.3 mg/L) and 396.8 (3.3 mg/L). Average DO concentrations represented data collected at all depths. Since the 5 mg/L minimum DO criteria applies to measurements collected at a water depth of five feet, only a few samples related directly to the five-foot depth minimum criteria. DO values from the five-foot depth which were below the minimum criteria were measured in the summer of 1975 (TRM 391.2, 4.6 mg/l), 1976 (TRM 396.8, 4.9 mg/l), 1977 (TRM 396.8; 4.0, 4.2, and 4.9 mg/l; TRM 391.2; 2.6 and 3.1 mg/l), 1978 (TRM 386.4, 4.6 mg/l), 1982 (TRM 389.8, 4.5 mg/l; TRM 391.1, 3.6 mg/l, TRM 388.4, 4.1 mg/l; TRM 391.2, 3.7 mg/l) and in 1983 (TRM 396.8, 3.6 mg/l; 391.2, 3.3 mg/l). DO values greater than 10 mg/l usually occurred during February and March.

pH--An average pH value greater than 8.5 occurred once (TRM 388.4, 10/78) and individual values ranged between 5.9-8.9. Values lower than the EPA aquatic life criteria of 6.5 were recorded at TRM 388.0 (12 samples), TRM 391.2 (10 samples) and 396.8 (18 samples). The highest averages occurred at stations TRM 388.4 and 386.4 for the 1978-1979 and 1982-1983 sampling periods.

Alkalinity and Conductivity--Total alkalinity ranged from 14 to 69 mg/l as $CaCO_3$. The mean was 45 mg/l, which indicates moderate buffering capacity. No phenolphthaline alkalinity was measured. Average conductivity ranged between 130 and 200 μmhos/cm 93 percent of the time, which is typical for Tennessee River water.

Turbidity--Turbidity was only measured in the 1982-1983 sampling program, for stations 386.4, 388.4 and 391.1, but was measured during all years for stations 388.0, 391.2 and 396.8. None of the values measured were exceedingly high, but the higher values (20-34 JTU) were usually measured in the spring while the lower values (2-8 JTU) were measured in the late summer. This reflects the effect of spring runoff. TRM 391.1 had higher peak turbidities than other overbank stations.

TOC and BOD_5--Approximately 73 percent of the total organic carbon (TOC) values measured from 1974-1979 were below 3 mg/l, whereas 75 percent of the TOC values measured in 1982 and 1983 were between 3 and 6 mg/l, indicating an increase over time. BOD_5 values were also higher in 1982-1983 than in the samples collected between 1974-1979. All stations had BOD_5 values below 2 mg/l in 1974-1979. TOC increased at channel stations beginning in 1979 (figure 4-8) such that 1982 and 1983 concentrations were greater than during earlier years. BOD_5 concentrations also increased at all mainstream channel stations during 1982 and 1983 (figure 4-9). Since similar trends were not observed for waters entering Guntersville Reservoir through Nickajack Dam (section 3.1), increases of these parameters likely were related to changes occurring within Guntersville Reservoir. These changes apparently were related to low DO concentrations (<5 mg/L) which occurred at almost all stations in August 1982 and July 1983.

Phosphorous & Nitrogen--Total and dissolved phosphorous concentrations as well as organic nitrogen, nitrate + nitrite nitrogen and ammonia nitrogen concentrations were also determined for use in the biological support information. Neither phosphorous nor nitrogen concentrations were low enough to be limiting factors to aquatic life. Total phosphorous concentrations were between 0.02 to 0.06 mg/l and dissolved phosphorous ranged from 0.01 to 0.03 mg/l (values of dissolved phosphorous which were greater than the total phosphorous were not considered since these values were probably due to contamination of the sample). Both total and dissolved phosphorous values remained constant throughout the sampling period. Average organic nitrogen concentrations ranged from 0.04 to 0.74 mg/l. All values over 0.30 mg/l occurred in 1982-1983.

Nitrate plus nitrite nitrogen concentrations were consistently higher in the spring (up to 0.88 mg/l) and were depleted in the summer (down to 0.01 mg/l). The highly significant decreasing trend in $NO_2 + NO_3$ data for waters downstream of Nickajack Dam (section 3.1) was not apparent in the vicinity of BLN. Ammonia nitrogen values consistently averaged below 0.2 mg/l for the samples collected between 1974-1979. Concentrations as high as 0.58 mg/l were measured in 1982 (TRM 396.8), but this was below the maximum allowed concentration for ammonia based on temperature and pH.

Trace Metals and Other Water Quality Data--The mean values for the trace metals measured at TRMs 388.0, 391.2, and 396.8 (appendix B) were compared to the average water quality criteria listed in appendix A. Copper, total iron, total manganese, lead, and mercury average concentrations for the entire sampling period exceeded the water quality criteria, but these concentrations are, however, typical of the Tennessee River in the site vicinity and have been observed in other studies (TVA 1979; TVA 1983). Exceedances of the copper and total iron criteria occurred frequently at all stations. Copper concentrations averaged between 30-34 µg/l which was approximately four times the 7.4 µg/l criterior for aquatic life. Most samples contained copper in concentrations .bove the detection limit. The Secondary Drinking Water Standard for total iron is 300 µg/l and the average concentrations of iron ranged from 425 to 467 µg/l. However, these concentrations were well below the aquatic life criterion for iron of 1000 of µg/L. Average mercury and total manganese concentrations were close to the criteria. Total manganese concentrations averaged from 55-59 µg/l which was relatively close to the 50µg/l. Mercury, which has a 0.2 µg/l criteria, averaged between 0.2-0.4 µg/l. Lead concentrations were higher than the average criteria of 1.4 µg/l. Average values for lead were between 12 and 13 µg/l. Many of the lead values were below the detection limit. The average values of 12 and 13 µg/l were worst case and assumed that all values recorded below the detection limit equaled the detection limit. When these values were assumed to be zero in order to represent the best conditions, the mean values ranged from 4 to 6 µg/l, which was still above the criteria.

All individual analyses were compared against the maximum allowable aquatic life criteria. Concentrations of most parameters were below the maximum criteria. The only parameters which had measured concentrations exceeding the maximum criteria at all stations were lead and copper. Only a few values recorded for lead exceeded the maximum criteria of 36.6 µg/l, but at least 70 percent of the copper values exceeded the average criteria of 10.8 µg/l. Chromium data at TRM 388.0 and 391.2 exceeded the maximum criteria (11 µg/l) once and twice, respectively. The maximum criteria of 2.8 µg/l for cadmium was exceeded once at TRM 391.2 and twice at TRM 396.8. The maximum criteria for zinc (228 µg/l) was exceeded once at 391.2, and the maximum criteria of 1.1 µg/l for mercury was exceeded once at TRM 396.2. All of these exceedances are marked with an asterisk in appendix B.

The sediment trace metals data are summarized in appendix C for TRM's 388.0, 391.2, 391.6 and 396.8. Since no State or EPA criteria have been established for sediment trace metals, concentrations of these metals from a 1982 survey of TVA reservoir forebay sediments were used for comparison purposes. The average sediment concentration listed in appendix C as the "typical value" was the mean of the 1982 values collected in Wheeler, Guntersville and Nickajack reservoir forebays. Average concentrations of As, Al, Cd, Ni, and Hg were somewhat higher than the typical value in all cases except As at TRM 391.2 and Hg at TRM 391.6. Mean concentrations of the other metals were less than the measured in the 1982 survey.

The first ANOVA was run at each station to identify significant differences in measurements with water depth (table 4-3). The only parameters which were statistically different were TOC (TRM 396.8), TDS (TRM 388.0), and organic nitrogen (TRM 388.0). Table 4-4 shows the yearly means for these parameters which were ordered and ranked by depth using Duncan's New Multiple Range Test. No clear differentiation of depths was obvious. Separation of TDS data at 15 feet should be discounted because of the extreme unbalance (1 sample vs. 29 and 53 samples) in the analysis.

The data collected at all depths were combined for the ANOVA comparing differences among years, since there were essentially no variations with depth. Significant results of this ANOVA (table 4-5) were ordered and ranked (table 4-6) showing the data grouped according to the differences in the means. Changes in the analytical detection limit affected the results of some parameters. Beryllium, nickel, and titanium appeared to have decreased over time, but in actuality they had lower limits of detection in 1982-1983, so the Duncan Test was not valid for those parameters. Even though there were significant differences between the yearly data collected for SO_4, flouride, dissolved oxygen, pH, selenium, dissolved phosphorous, and conductivity, these differences showed no consistent pattern. An example would be SO_4. There was no chronological order to the data when listed from high values to low values, and the highest value for SO_4 at TRM 391.2 occurred in 1982, but occurred in 1973 at TRM 388.0 and 396.8.

Many differences were observed between the data collected during the 1982-1983 sampling period and the previously collected data. BOD, TOC and organic nitrogen were significantly higher in 1982-1983 than in 1974-1979, whereas chromium, dissolved silica, and barium were lower in 1982-1983 than in 1974-1979. COD and total phosphorous were high in 1973 and 1983, with low values during the middle of the sampling period.

A third ANOVA was run for the mid-channel stations (TRMs 388.0, 391.2, 396.8) to evaluate changes occurring from station to station. No significant differences were present.

Linear regression analysis (table 4-7) showed that values recorded for four parameters (Dissolved Si, Ti, Be, and As) had decreasing patterns at TRM 396.8, 388.0, and 391.2. High R-Squared values in combination with high F-values indicate that a linear regression accurately represented the data. The R-Squared values for titanium ranged from 0.56 to 0.58 which means that at least 56 percent of the titanium data were represented by a linear regression with a slope ranging between -0.26 to -0.30. The regression for beryllium data showed a slope of -0.003 for up to 69 percent of the data. Between 57 percent and 77 percent of the data, based on R-Squared values, for D SI and AS fit regression lines with each having a slope of -0.001. Parameters which showed increasing regressions were TOC,

NH_3, Organic N, BOD, COD, and NI (TRM 396.8); TOC, N, COND, and BOD (TRM 388); and Cl_2 (TRM 391.2). Organic nitrogen, TOC, and BOD values were larger in 1982-1983 than in 1974-1978 but the increase could not significantly be represented by a linear pattern, as shown by low R-Squared values in table 4-7. However, the increase over time for these parameters (figures 4-8, 4-9, and 4-11) was real and appeared better suited to some standard curvilinear model; i.e. exponential, $y = ae^{bx}$.

4.3 Summary & Conclusions

Few parameters changed significantly during the sampling period, which would indicate that the study area is relatively stable. Differences which were observed were generally between the data collected during the 1974-1979 sampling period and data collected during the 1982-1983 study. Of particular interest was the increase in BOD, TOC and Organic Nitrogen in 1982-1983. It also should be noted that the DO occasionally dropped below 5.0 mg/l during the summer months. Other changes in the data during the sampling period were either not statistically significant or were one time occurrences. The comparison to the water quality criteria showed that copper and lead concentrations frequently exceeded the average criteria, and lead also exceeded the maximum criteria at all mid-channel sampling stations.

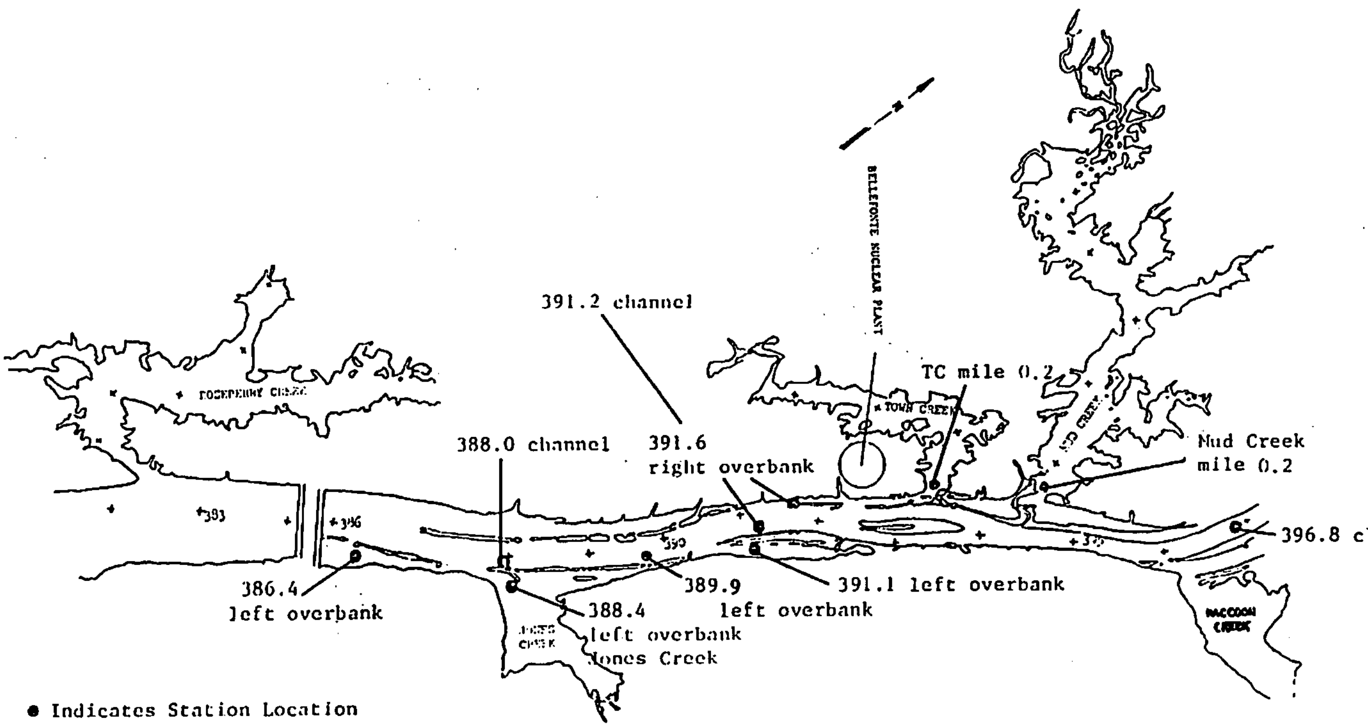


Figure 4-1 Water Quality Sampling Locations in the Vicinity of Bellefonte Nuclear Plant for the Preoperational Monitoring Program (1974-1983), Guntersville Reservoir.

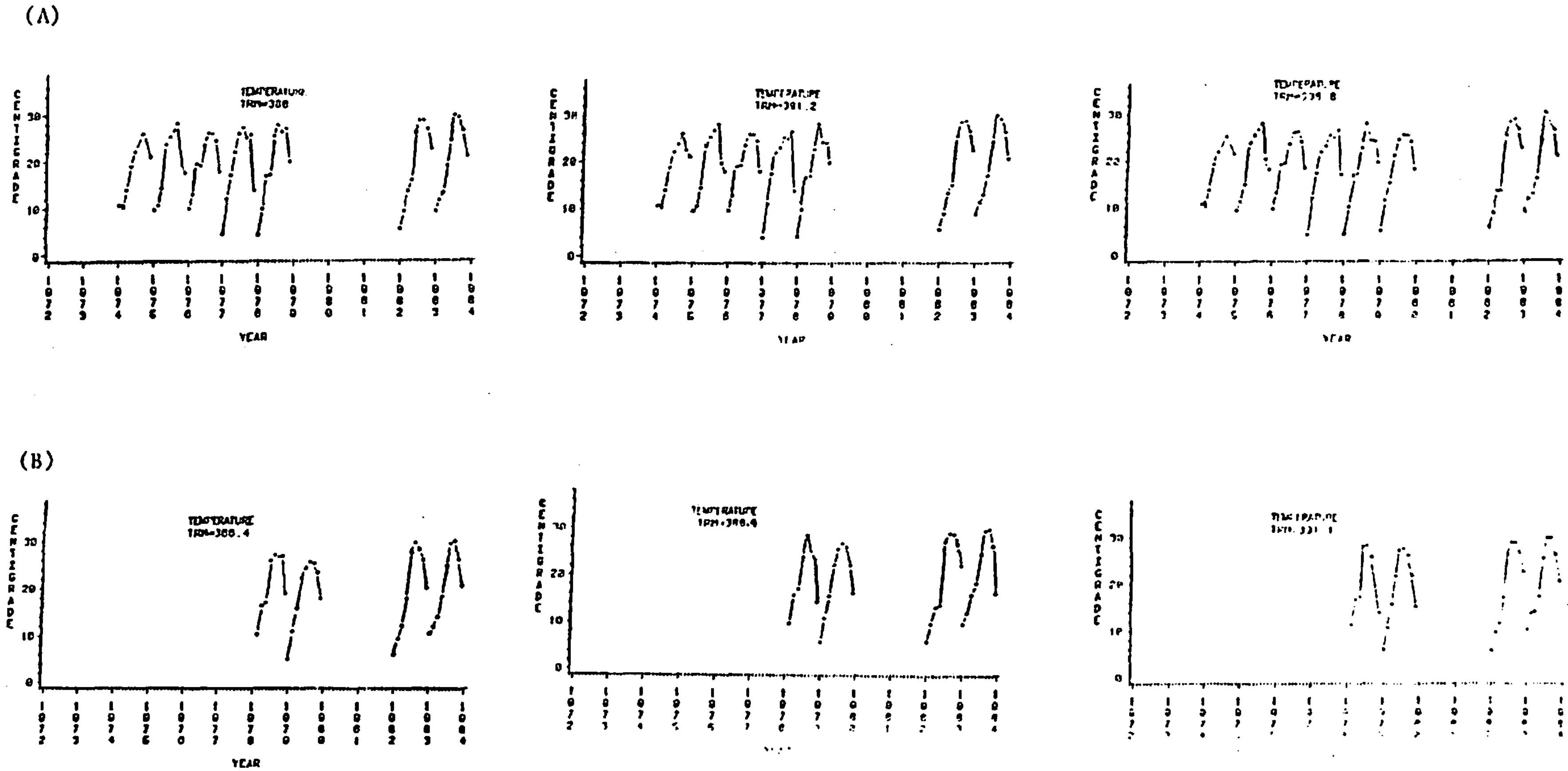


Figure 4-2. Mean Monthly Temperatures at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

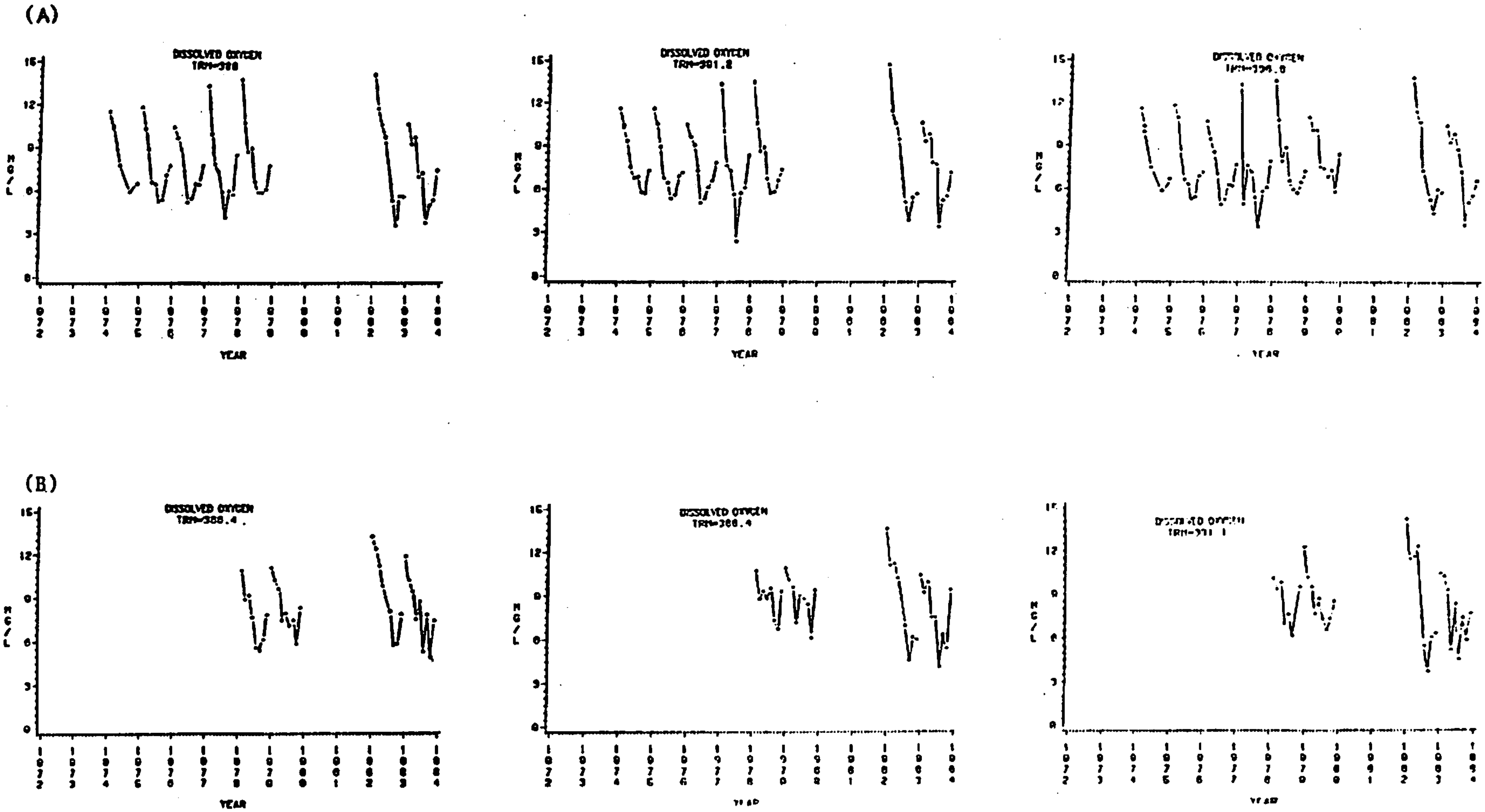


Figure 4-3. Mean Monthly Concentrations of Dissolved Oxygen at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

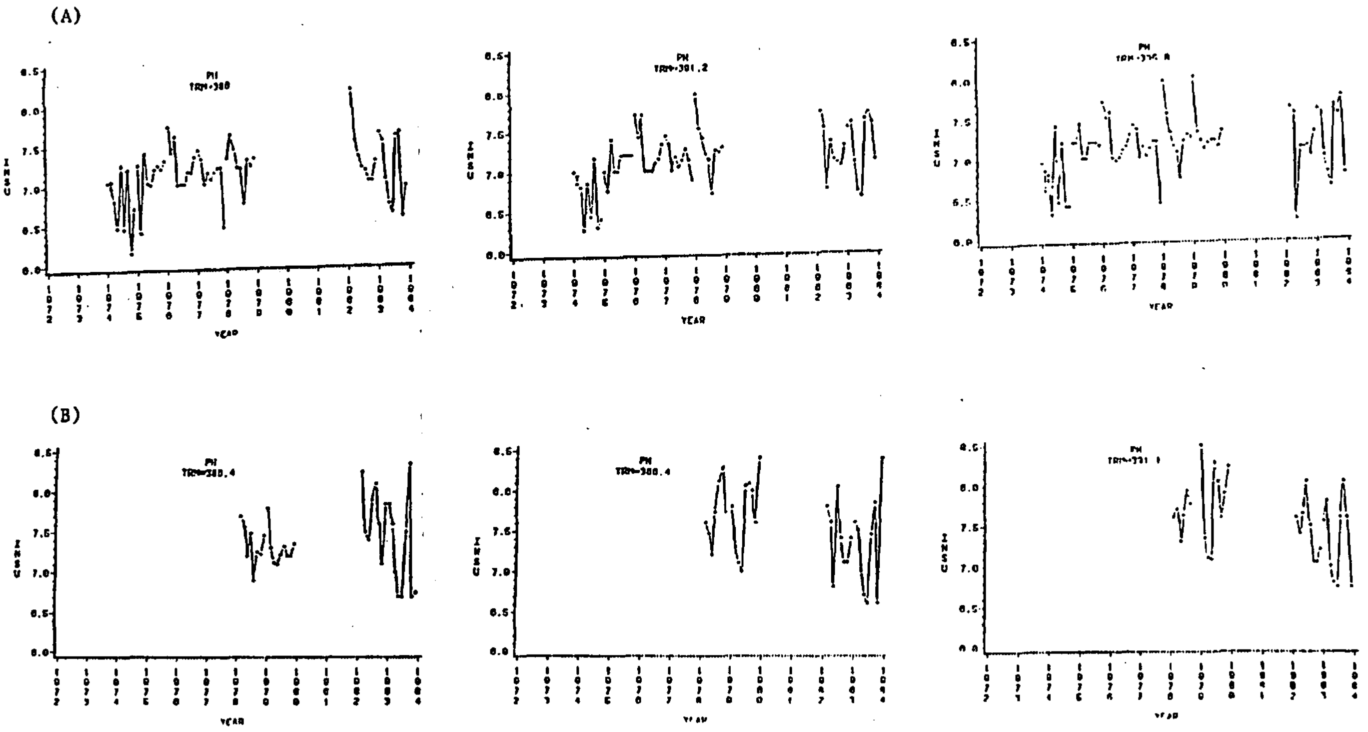


Figure 4-4. Mean Monthly pH Values at Mainstream Channel (A) and Overbank (B) Stations in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

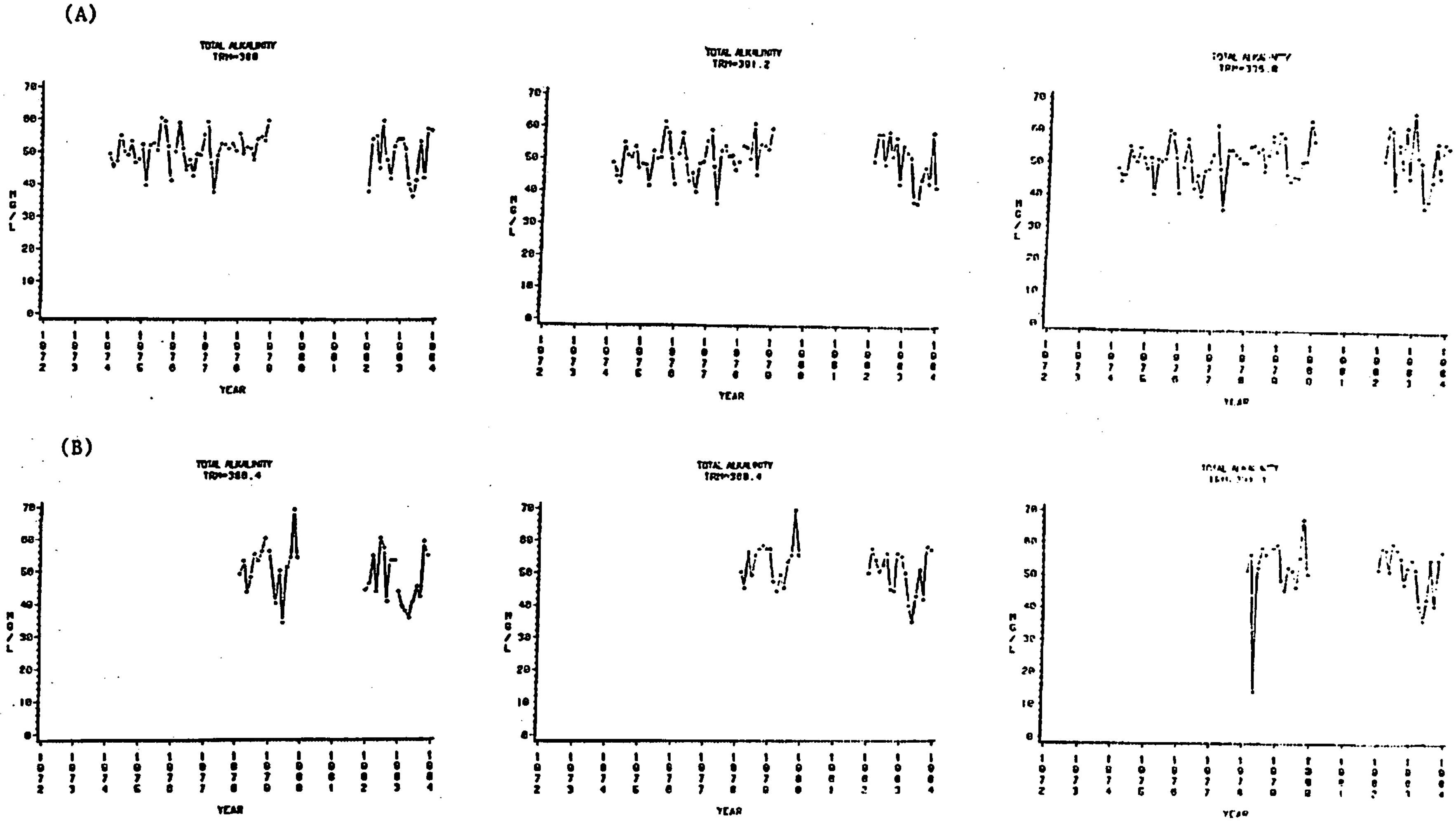


Figure 4-5. Mean Monthly Concentrations of Total Alkalinity (mg/L as $CaCO_3$) at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

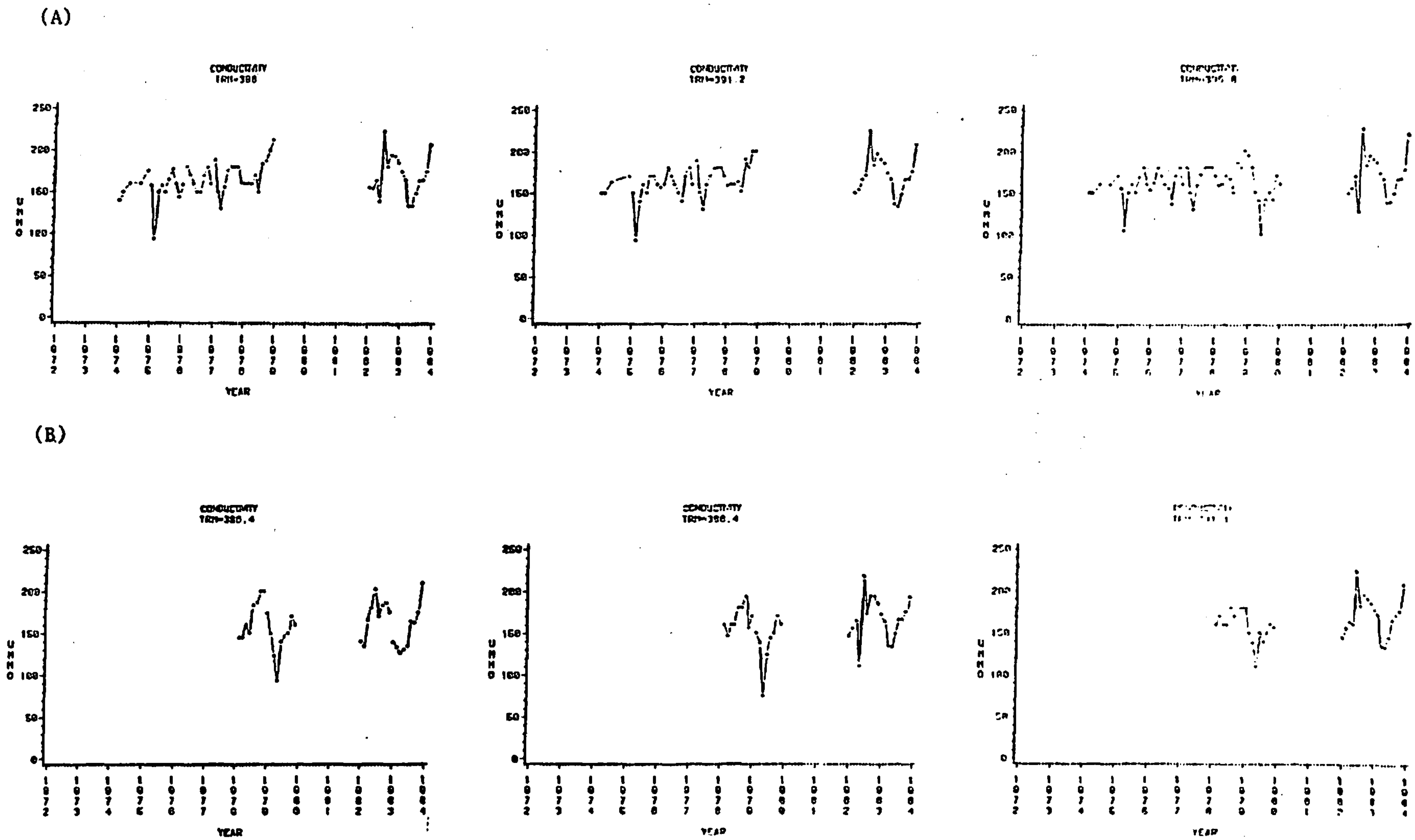


Figure 4-6. Mean Monthly Conductivity levels at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

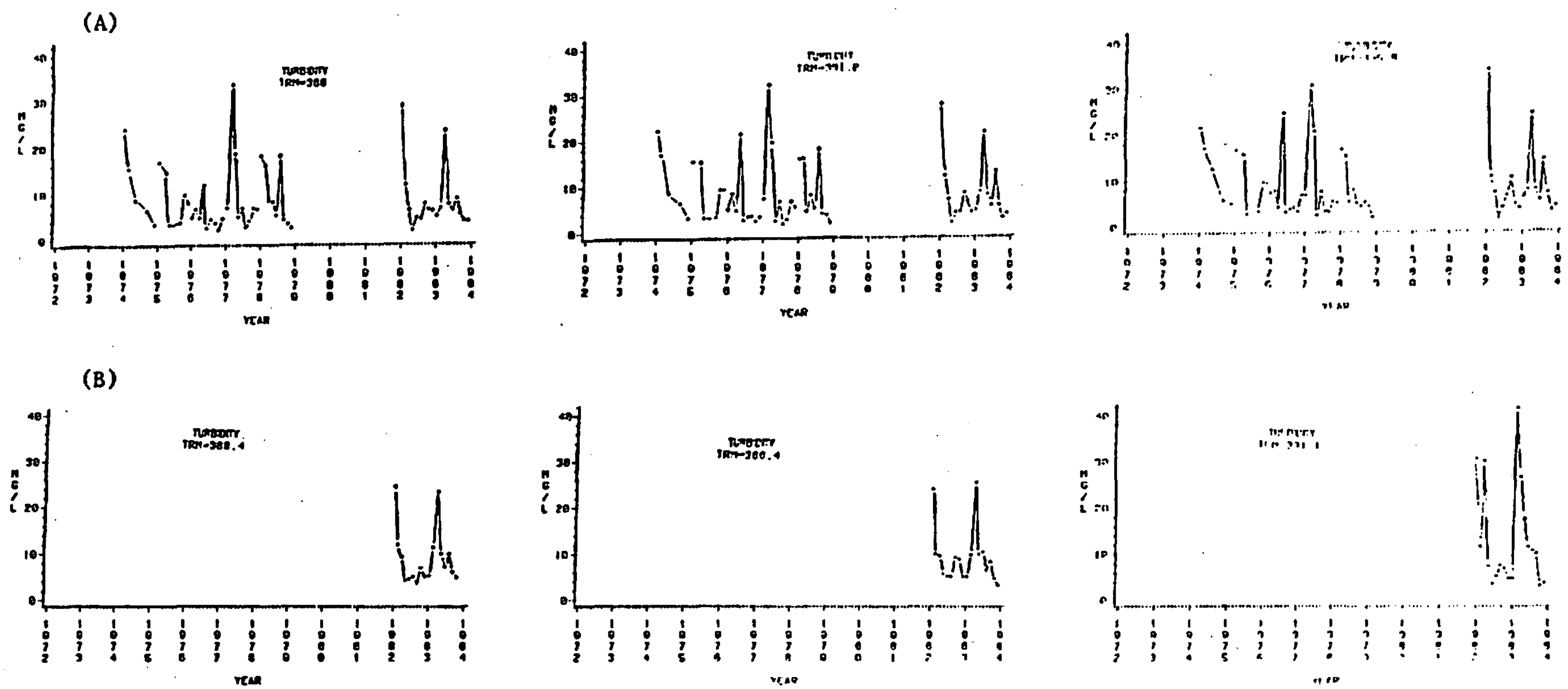


Figure 4-7. Mean Monthly Turbidity levels at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

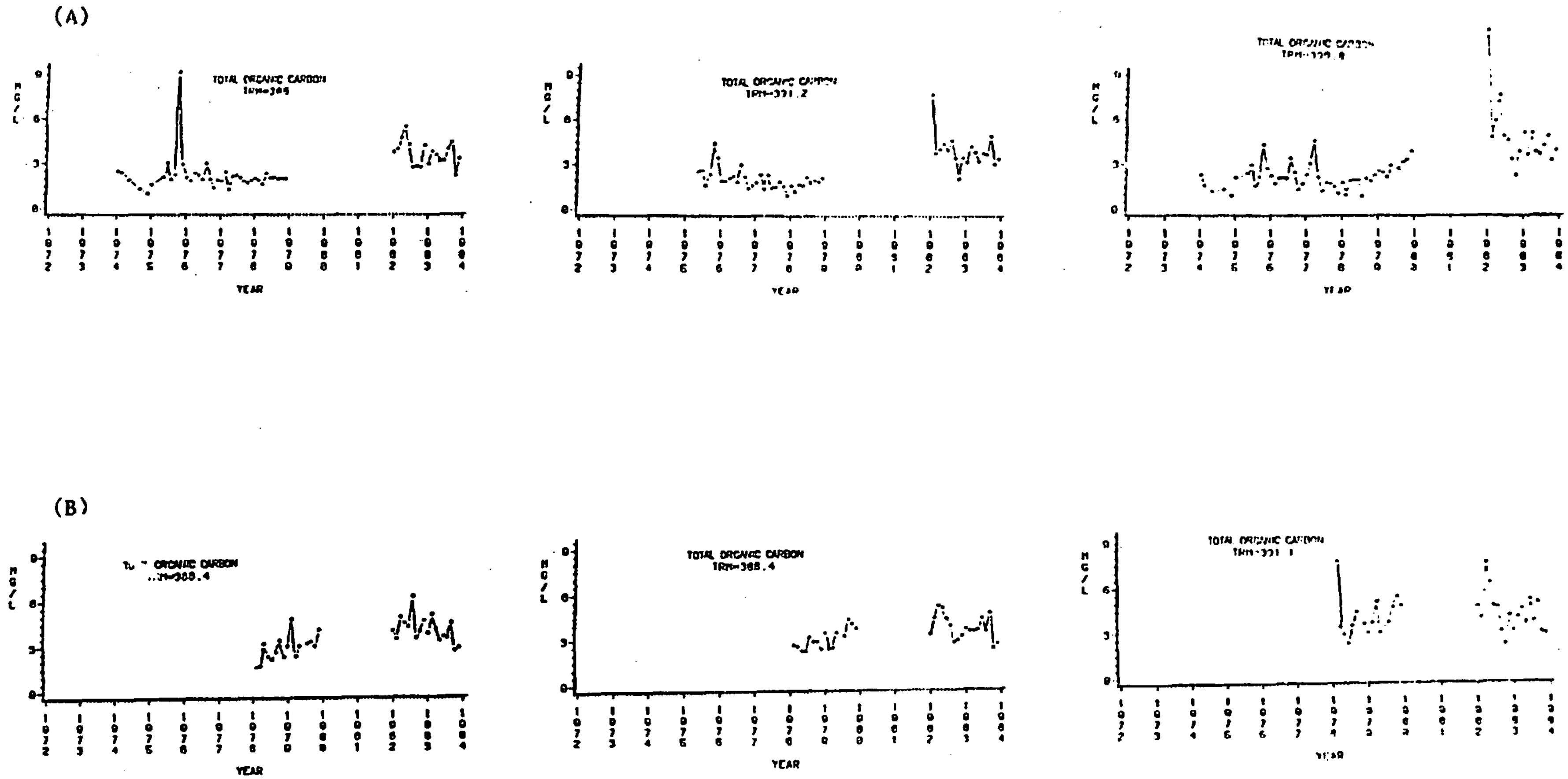


Figure 4-8. Mean Monthly Concentrations of Total Organic Carbon at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plnat, Guntersville Reservoir, 1973-1983.

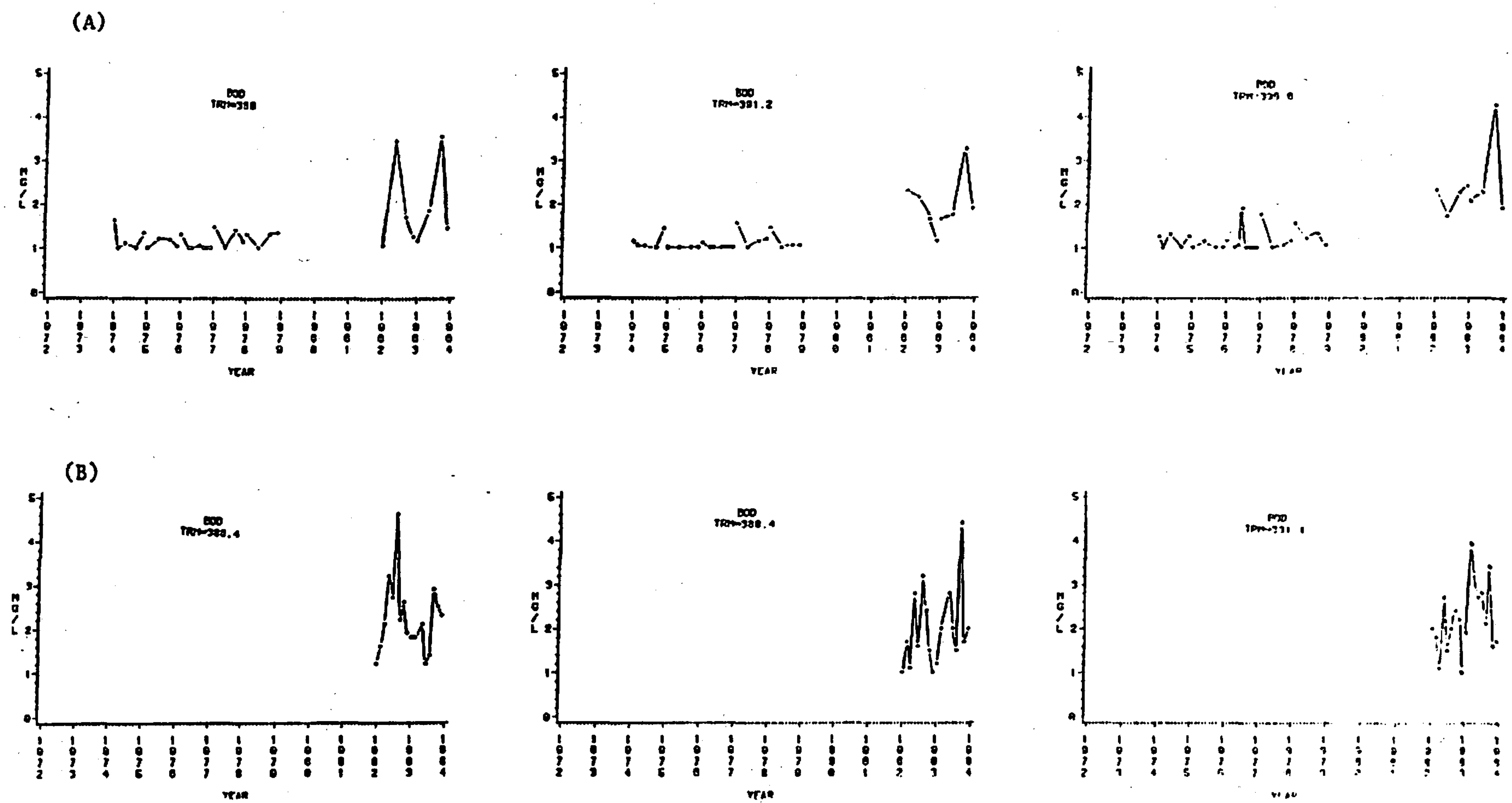


Figure 4-9. Mean Monthly Concentrations of BOD_5 at mainstream channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

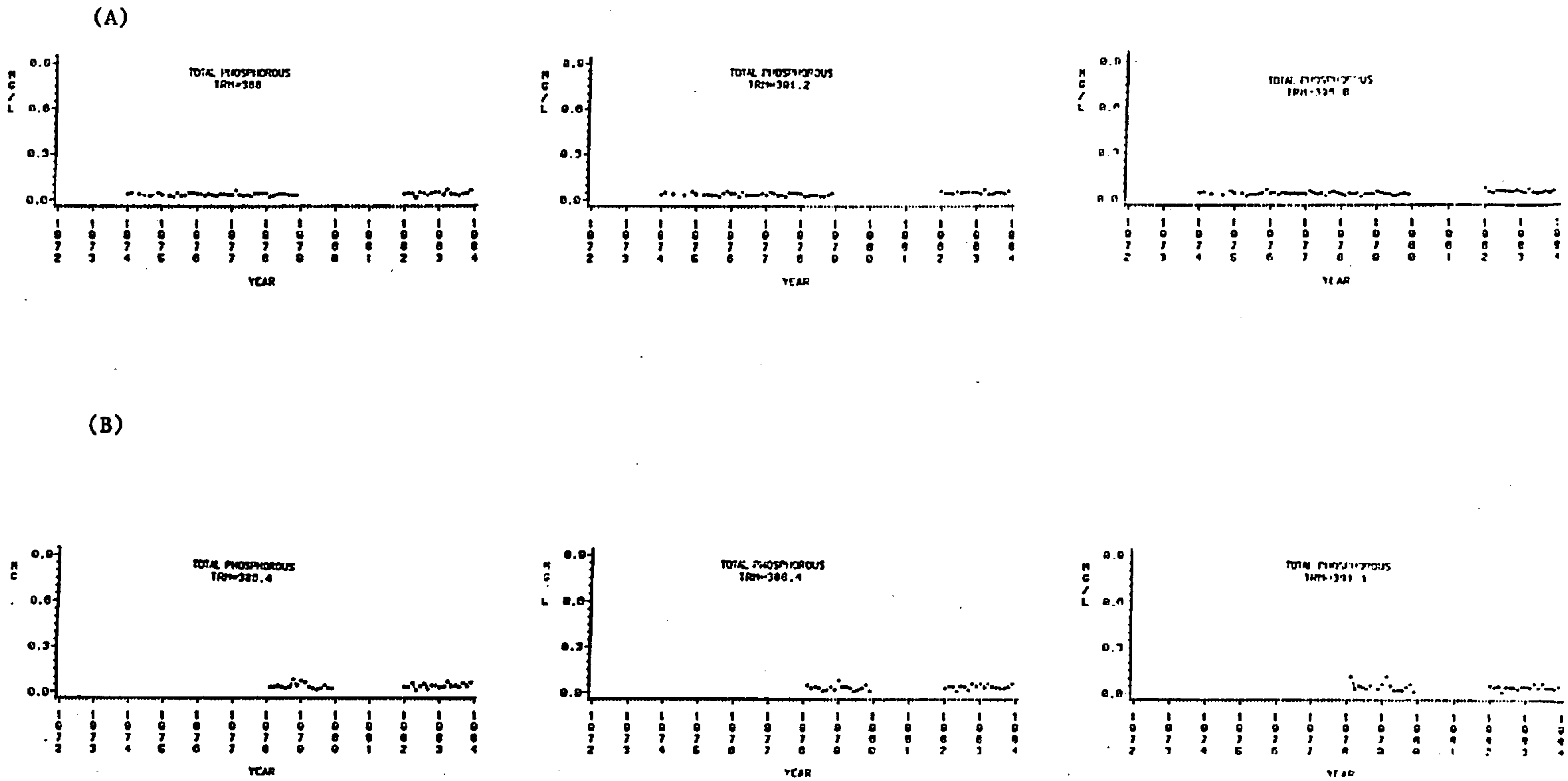


Figure 4-10. Mean Monthly Concentrations of Total Phosphorous at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

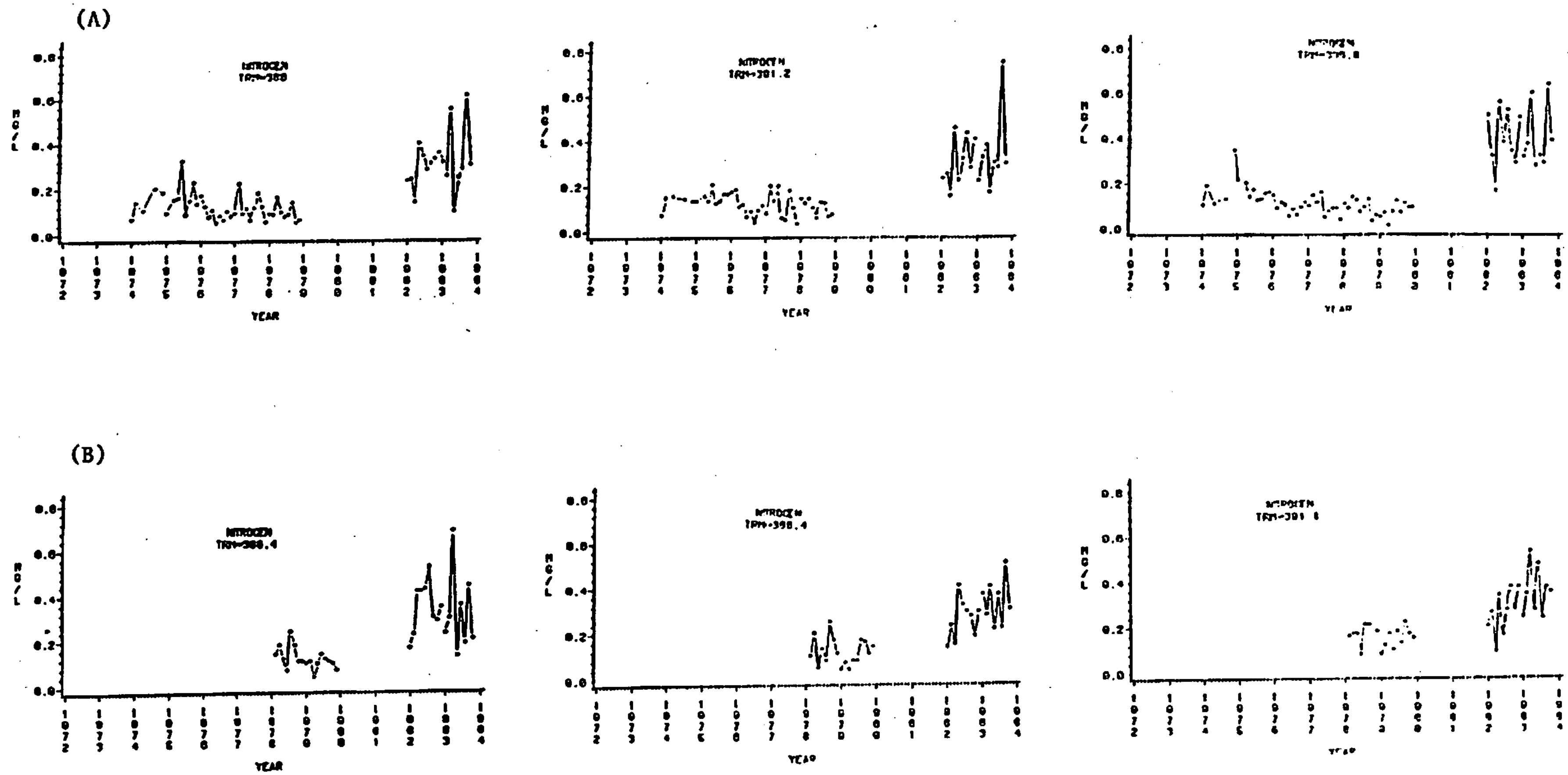
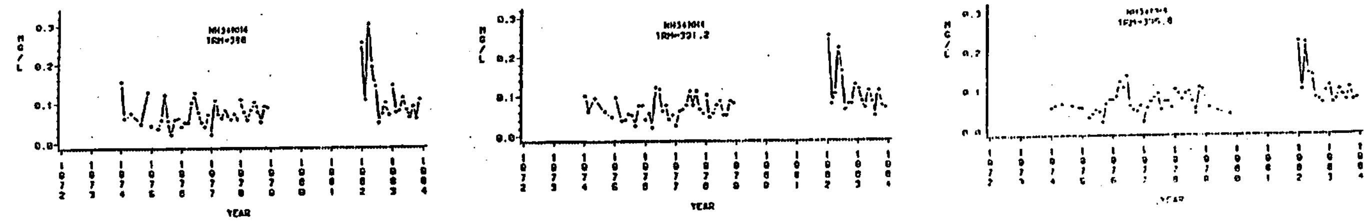


Figure 4-11. Mean Monthly Concentrations of Organic Nitrogen at Mainstream Channel (A) and Overbank (B) Stations in the vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

(A)



(B)

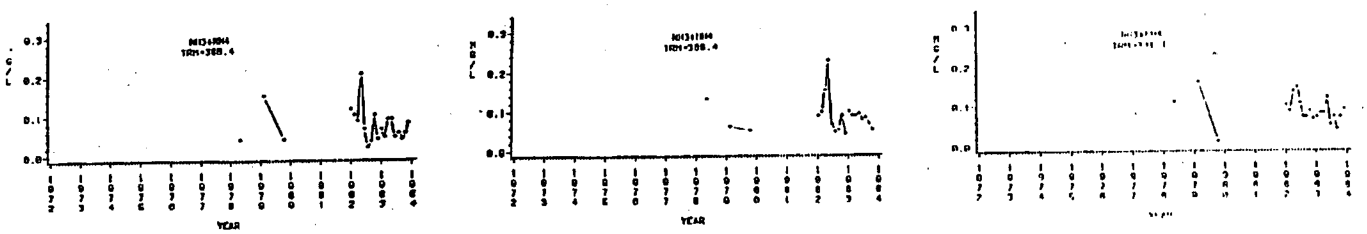


Figure 4-12. Mean Monthly Concentrations of NH_3 + NH_4-N at Mainstream Channel (A) and Overbank (B) Stations in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

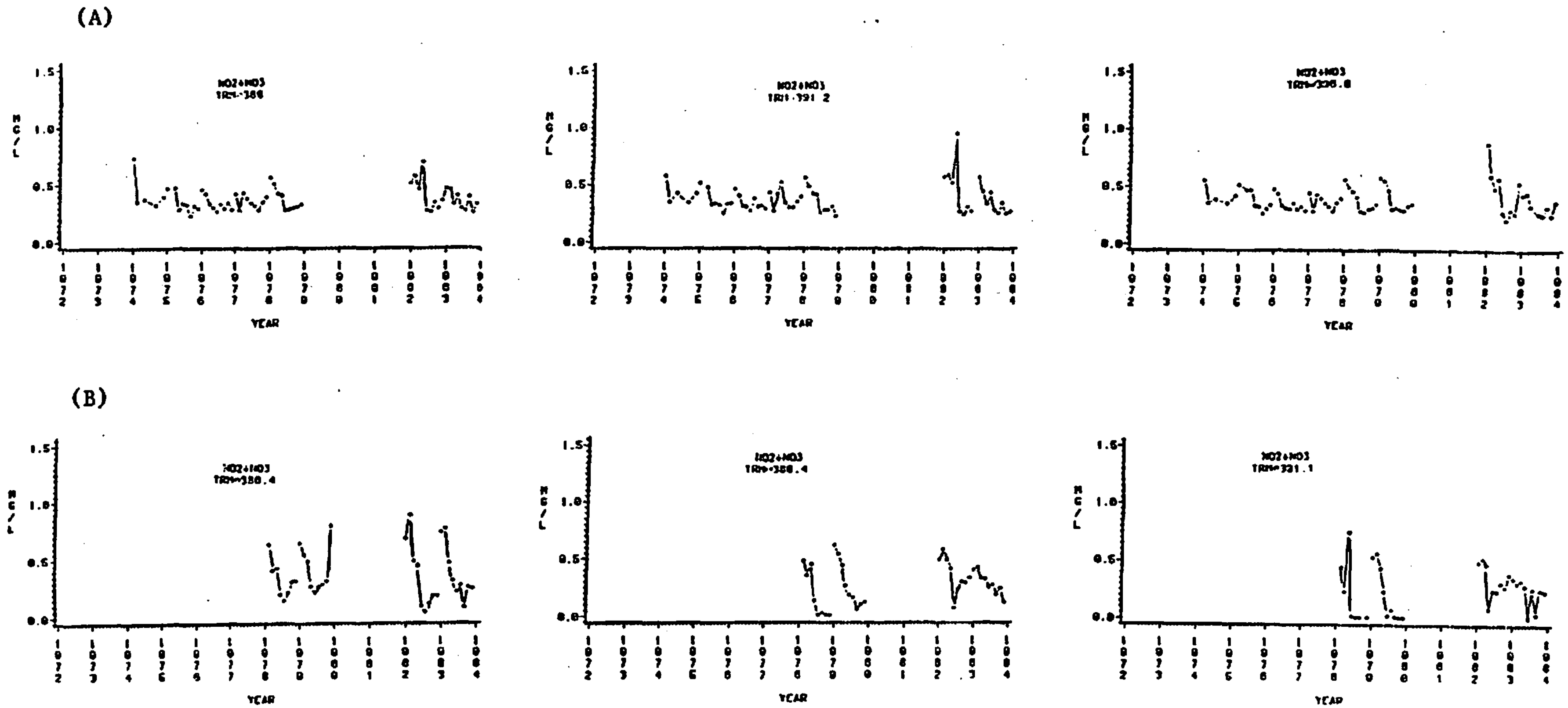


Figure 4-13. Mean Monthly Concentrations of NO2 + NO3-N at Mainstream channel (A) and Overbank (B) Stations in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, 1973-1983.

5.0 PLANKTON

This chapter evaluates both phytoplankton and zooplankton components of the plankton community in the vicinity of BLN. An evaluation of ichthyoplankton (larval fish and eggs) is included in Chapter 9.0.

5.1 Materials and Methods

5.1.1 Phytoplankton

Field--Preoperational phytoplankton studies were conducted 1974 through 1979, 1982, and 1983. Samples were collected monthly, February through October, except in 1978 when February samples were not collected. In March 1978, phytoplankton monitoring was expanded beyond the main river channel to include the descending left overbank habitat because it was felt that this area could be exposed to the thermal/ chemical plume from BLN under low-flow and reverse-flow conditions. Mainstream (channel) stations were located at TRMs 388.0, 391.2, and 396.8 (figure 5-1). Left overbank stations were located on the shoreward side of the narrow strip islands which separate channel and overbank habitats at TRMs 386.4, 388.4, and 391.1. Sampling was suspended in 1979 at TRMs 388.0 and 391.2, but reinstated in February 1982.

Phytoplankton measurements included in the preoperational study were organism abundance, phytopigment concentrations (chlorophyll) or biomass, and primary productivity (carbon-14). An 8-L nonmetallic Van Dorn water sampler was used to collect sufficient water for all three phytoplankton parameters--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 phytoplankton parameter were collected from 0.3, 1.0, 3.0, and 5.0 m at mainstream channel stations and 0.3 and 1.0 m at left overbank stations.

Samples for determination of organism abundance (enumeration) were preserved immediately after collection with 2 ml of 37 percent formalin from 1974 through 1978 and M_3 (Meyer 1971) during 1982 and 1983. Phytopigment samples were processed in the field by filtering 500 ml of river water through cellulose ester filter pads in 1974 and through glass fiber filter pads after 1974. From 1974-1977, each filter was folded, enclosed by an absorbant pad, and placed within a light-excluding field dessicator which was kept chilled in a chest of ice. During 1978 filters were stored within the field dessicator on dry ice. During 1982 and 1983, 1 ml of magnesium carbonate suspension was added as the sample was filtered and each filter pad was placed in 5.0 ml of 90 percent buffered acetone. Samples were immediately placed on dry ice in a light-excluding container and stored frozen until laboratory analysis.

Primary productivity samples were spiked with 1 ml of approximately 2µCi sodium bicarbonate radioisotope (C-14) in pyrex (125 ml) bottles, attached to metered nylon lines, and suspended from a common incubation site (TRM 386.0) at their respective collection depths. A dark bottle (light excluding) was attached to compensate for nonphotosynthetic assimilation of the labeled sodium bicarbonate. Following an approximately three-hour incubation period, 125 ml of the sample was filtered through a 0.45 μm membrane filter and rinsed with 0.1N HCl and water. Through 1982 filters were glued to stainless steel planchets, and during 1983 filters were placed in scintillation vials and returned to the laboratory.

In support of the primary productivity studies, daily solar radiation energy was measured from sunrise to sunset on each sampling date at the BLN meteorological station. Beginning in 1975, light penetration into the water column was measured at each station for depths corresponding to sample collections. On April 13, 1983, primary productivity samples were lost from the incubation site. These samples were recollected on April 25, 1983.

Selected water quality samples also were measured from each phytoplankton station to provide supportive information for interpreting results. These data are described in Chapter 4.0 as Biological Support parameters.

Laboratory--Each abundance sample was agitated, a 15 ml aliquot removed, placed in a counting chamber, and allowed to settle for a minimum of 12 hours. Algal cells were enumerated at the genus level using an inverted microscope (320X). References and publications used in identification varied for individual algal groups. Sometimes several references were utilized to identify genera within an algal group, but usually a single reference comprised the major taxonomic authority. Major (x) and infrequently used (✓) references were as follows.

Reference	Algal Group Chlo	Chry	Cyano	Crypto	Eugleno	Pyrro
Cocke (1967)			x			
Desikachary (1959)			✓			
Drouet (1973)			x			
Drouet & Daily (1973)			x			
Forest (1954)	✓	✓	✓		x	✓
Hustedt (1930)		x				
Patrick & Reimer (1966)		x				
Prescott (1964)	x			x	x	x
Tiffany & Britton (1971)	✓	✓			✓	✓
Whitford & Schumacher (1969)	✓					

From 1974 through 1978, chlorophyll was extracted by steeping the algae-laden filters in 90 percent acetone for 24 hours in the dark at 4°C. When glass fiber filters were used (after 1974), samples were filtered again immediately preceeding spectrophotometric analysis. When using cellulose ester filters (1974), samples were centrifuged before analysis. During 1982 and 1983, samples were allowed to reach room temperature, ground with a glass rod, and subjected to ultrasonic vibrations to rupture algal cell walls and enhance the extraction process. Samples then were clarified by centrifugation and analyzed spectrophotometrically. In 1974, optical densities at 750, 663, 645, and 630 nm were determined and substituted into the UNESCO (1966) equations to calculate chlorophyll a, b, and c concentrations. Beginning in 1975 the Jeffrey-Humphrey (1975) equations were used to determine chlorophyll concentrations. The new equations required that optical densities be determined at 750, 664, 647, and 630 nm. Beginning in 1978 each sample was acidified with two drops of 0.1N HCl after determining initial optical density values, allowed to steep for one minute, and then reread at 750 and 664 nm. These values were used to correct chlorophyll a concentrations for phaeophytin, determine phaeophytin concentrations (Lorezen, 1967), and calculate phaeophytin index values (ratio of chlorophyll a to phaeophytin a) according to Weber (1973).

C-14 activity (primary productivity samples) was determined from 1974 through 1978 and 1982 by using a thin window, low-background, gas-flow proportional counter with a counting efficiency of approximately 10 percent. In 1983 activity was determined by using liquid scintillation counting techniques, which produced a higher counting efficiency (approximately 50 percent). Using the conversions of Saunders, et al. (1962), total inorganic carbon available at each station was determined by using pH, temperature, and alkalinity values. Mean Carbon-14 activity incorporated into algal cells from light bottles minus that absorbed by materials from dark bottles resulted in estimates of net photosynthetic activity.

Date Analyses--Data analyses addressed four related areas of assessment used to evaluate the phytoplankton community. Specific analytical approaches are summarized below for each type assessment.

1. Community Structure

   Analysis of numerically important genera (>10 percent total abundance)
   Sorenson's Quotient of Similarity (SQS)
   Pielou's Percentage Similarity (PS)
   Diversity ($\bar{d}$)
   Percentage composition by station
   Percentage composition by habitat (stations averaged), presented as figures
   Listing of dominant genera
   Five-way Analysis of Variance (ANOVA) of percentage composition data for the mainstream channel habitat (main effects = group, station, depth, month, and year)

2. Abundance

   Four-way ANOVA for channel stations (station, depth, month, year)
   Four-way ANOVA for overbank stations (station, depth, month, year)
   Four-way ANOVA for channel and overbank (habitat, depth, month, year)
   Regression analysis of abundance over time (total phytoplankton and each of the three dominant groups). Also presented as figures.

3. Biomass Estimates (Chlorophyll)

   Presentation of phytopigment concentrations (chlorophyll a, b, and c)
   Graphical presentation of chlorophyll a by station, month, and year
   Chlorophyll a/Phaeophyton a relationship

4. Primary Productivity

   Graphical presentation of productivity (mg C/m^2/day) by station month, and year
   Graphical presentation of productivity (mg C/m^2/day) plotted over time.

In addition to the above, solar radiation for each day of sample collection and light penetration into the water column at each station was provided to supplement understanding of community observations.

Similarity of algal communities between stations was determined using a two-step approach. Sorenson's Quotient of Similarity, SQS (McCain 1975), was calculated to determine similarity based solely on presence/absence of genera (qualitative dimension of community structure). A percentage similarity (PS) index (Pielou 1975) was calculated to determine similarities based on both qualitative and quantitative dimensions of community structure. In both cases, values of 70 percent or greater were assumed to indicate 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

PS index was calculated as follows.

$$PS = 200 \sum_{i=1}^{s} \min (P_{ix}, P_{iy})$$

Where, P_{ix} and P_{iy} are the quantities of genus i at stations x and y as proportions of the quantities of all s genera at the two stations combined.

Phytoplankton community structure also was analyzed using a diversity index applying the following formula (Patten 1962).

$$\bar{d} = -\sum_{1}^{s} (n_i/n) \log_2 (n_i/n)$$

Where, s = number of genera;
n_i = number of individuals belonging to the i^{th} genus;
n = total number or organisms

Diversity index was used only as a reference to evaluate change.

Pie graphs were developed for each month sampled and combined into a figure for each year to illustrate change in channel and overbank community structure (succession) for the three major phytoplankton groups (Chrysophyta, Cyanophyta, and Chlorophyta) and for Euglenophyta, Pyrrophyta, and Cryptophyta combined as an unlebeled percentage. An average of the three channel and three over ,ank stations was used to construct these figures for each respective habitat type.

Percentage composition data, transformed using the Arcsine Square Root transformation (reported in radians), were used in a five-way ANOVA to evaluate differences in community structure (phytoplankton group) among channel stations, years, months, and depths. The data base for phytoplankton abundance was log transformed (base 10) and utilized to characterize abundance with regard to station, year, month, depth, and habitat (i.e., channel vs. overbank). Since it was not known how phytoplankton abundance would vary with regard to habitat, station, year, month, and depth (or any combination of these parameters), data were organized in four-way ANOVA layouts for a fixed effect cross-over design. Three layouts were planned, i.e., (1) channel stations only, (2) overbank stations only, and (3) combined channel versus combined overbank stations.

Unfortunately, each data set evaluated by the multi-way ANOVA layouts for both community structure (five-way) and abundance (four-way) was incomplete or statistically unbalanced. Specifically, information with regard to month, year, station, and depth was totally lacking, at worst, or only single observations were missing. Analysis of linear models that are unbalanced are very complex and little understood. Therefore, computer software programs usually do not handle unbalanced data sets at all beyond a two-way layout. Fortunately, the BLN data sets could be balanced in some fashion. Specifically for channel analyses, the data set was balanced over six of the seven years (excluding 1978 - February missing), for all three stations, for all four depths, for all nine months, and using single replication for each treatment combination (where two replicates were available, the first was selected for the analysis). For the overbank analysis, the data set was balanced over three of the four years (excluding 1978) for all three river miles, for both depths, for eight months (excluding February), and using two replications for each treatment combination.

Variance ratios were calculated as follows for the four-way and five-way ANOVAs which had only one replicate for treatment combinations (channel habitat). The residual term used to determine variance ratios for the main effects and primary interactions consisted of the mean square of the combined (summed) four-way and three-way (or five- and four-way) terms. The residual mean square used to determine F-statistics for the secondary interactions consisted of the mean square of the four-way (or five-way) term. Significance of the tests was determined by probabilities exceeding the F-statistic at the 0.005 level to lessen chances of making a type I error. The Least Significance Difference (LSD) Test at the 99 percent significance level was used to locate differences between means for each significant F-test.

Regression analysis (Snedecor and Cochran 1967) was run on data from each station to evaluate the relationships of phytoplankton abundance (total and major groups) and primary productivity with time. These data also were plotted for the total sampling period to enhance interpretation of regression results and to visualize short-term (yearly) periodicity.

Chlorophyll a and phaeophytin a relationships, including phaeophytin index values, were calculated according to Weber (1973). Index values should vary between 1.0 (indicating no chlorophyll a) and 1.7 (indicating no pheophytin a); however, values less than 1.0 and greater than 1.7 occasionally occur and should be interpreted cautiously.

Total carbon assimilated by algal cells were expressed as milligrams carbon per cubic meter per hour (mg C/m^3/hour). 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 water column with a surface area of 1 m^2 and to the lowest depth of incubation, which was 5 m at the channel stations and 1 m at the overbank stations (mg C/m^2/day).

5.1.2 Zooplankton

Field--Two-replicate zooplankton samples were collected monthly, February through October, at channel stations located at TRM 388.0 (station 1 downstream from BLN), TRM 391.2 (station 2 at BLN site) and TRM 396.8 (station 3 upstream from BLN) during the period 1974- 1977 (figure 5-1). Beginning in March 1978 (no February samples were collected) two-replicate samples were collected at the channel stations and also at three left overbank stations. These were TRM 386.4 (station 4) located behind a strip island on the left side of the reservoir in an area increasingly affected by American Lotus (Nelumbo sp.), TRM 388.4 (station 5) behind a strip island barrier and in the mouth of Jones Creek, and TRM 391.1 (station 6) directly across from BLN and also behind a land barrier (figure 5-1). Two replicates per month were collected at only one channel station (station 3, TRM 396.8) and at the three overbank stations from February through October of 1979. No zooplankton samples were collected in 1980 and 1981; however, monthly sampling (February-October) at all six stations was reinstated in 1982 and continued through 1983.

Zooplankton samples were collected by a 50 cm-diameter net (80 μm mesh) equipped with a digital flowmeter suspended in the throat and with an opening device. The net was lowered to the bottom in a closed position, opened, and pulled to the surface (Dycus and Wade 1977). Samples were preserved with formalin immediately after collection.

Laboratory--Samples were diluted or concentrated, depending upon the abundance of detritus and organisms. Four 1-ml subsamples were removed from the magnetically stirred sample using a 1-ml Hensen-Stempel pipette, and each subsample was placed in a Sedgwick Rafter cell. Organisms were enumerated at the lowest practical taxonomic level, usually species, on a compound microscope at 35X or 50X. After subsample enumeration, the remainder of the sample was scanned under a dissecting microscope for additional taxa not encountered in subsampling. Resultant counts were extrapolated to numbers per cubic meter.

A variety of references and publications was used in making zooplankton identifications. Major (x) and infrequently used (✓) references were as follows:

Reference	Zooplankton Group		
	Rotifera	Cladocera	Copepoda
Ahlstrom (1940)	x		
Ahlstrom (1943)	x		
Borutskii (1964)			✓
Brooks (1957)		x	
Brooks (1959)		x	
Deevey and Deevey (1971)		✓	
Donner (1956)	✓		
Edmonson (1959)	x		
Goulden (1968)		x	
Harring and Myers (1926)	x		
Pennak (1978)	✓	✓	✓
Ruttner-Kolisko (1974)	x		
Wilson and Yeatman (1959)			x

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

Total and group abundance data were transformed ($\log_{10}$) and tested for statistical differences among stations for each sample date and for each sample year 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 the diversity index (immature forms excluded), SQS, and PS with analyses based primarily on species.

5.2 Results and Discussion

5.2.1 Phytoplankton

Phytoplankton dynamics respond rapidly to changing environmental conditions and are capable of demonstrating impressive variations in abundance and/or physiological state within a very short period of time, i.e., a week or even days (Wade 1984). Therefore, discussion of observations made on any particular monthly survey has only limited value in describing baseline conditions, because those observations may not be truly representative of even that month. Phytoplankton data, therefore, are best discussed with regard to yearly patterns (approximately nine months/year), repeated from year to year, or otherwise stated, with regard to short-term (yearly) and long-term (the entire 1974-1983 study period) periodicity. That is not to say that monthly observations are unimportant because information regarding community cause/response mechanisms can be gained by evaluating phytoplankton and conditions measured just prior to each sampling period (presented in Chapters 2.0 and 4.0).

Presentation and discussion of phytoplankton results will follow analytical approaches summarized in the Materials and Methods section, i.e., community structure, abundance, biomass, and productivity. Although discussion will follow short and long-term periodicity, data are presented in tables and figures to allow examination of individual sample dates which can be compared with the presentation of physical factors and water quality parameters in Chapters 2.0 and 4.0, respectively.

Community Structure--During preoperational monitoring, 137 phytoplankton genera were identified from the channel and overbank habitats in the vicinity of BLN (table 5-1). Taxonomic distribution of these genera were as follows.

Group	No. Genera
Chlorophyta	66
Chrysophyta	35
Cryptophyta	3
Cyanophyta	25
Euglenophyta	4
Pyrrophyta	4

Several genera were unique to channel (13 genera) or overbank (8 genera) habitats:

Group	Channel	Overbank
Chlorophyta	Cladophora Microspora Palmellococcus Stigeoclonium Tetraspora Ulothrix	Hyalotheca Lobomonas Nephrocytiun Netrium
Chrysophyta	Caloneis Tabellaria	Amphiprora
Cyanophyta	Arthrospira Phormidium Plectonema Rhabdoderma Spirulina	Calothrix Coccochloris Coelosphaerium

Twenty-two of the 137 genera accounted for 90 percent of total phytoplankton abundance during one or more collection periods. These genera, therefore, comprised the numerically important or dominant segment of the phytoplankton community:

Chlorophyta

Ankistrodesmus (overbank only)
Carteria (overbank only)
Chlamydomonas
Chlorella
Chlorococcum
Dactylococcus
Eudorina (overbank only)
Micractinium
Pandorina (overbank only)
Scenedesmus

Chrysophyta

Asterionella
Chaetoceros
Cyclotella (overbank only)
Melosira
Stephanodiscus
Synedra

Cyanophyta

Anabaenopsis (overbank only)
Anacystis
Chroococcus
Dactylococcopsis
Merismopedia
Oscillatoria

Abundance of each genus by location and collection period is provided in appendix D.

Comparison of the three channel stations showed a high degree of similarity from 1974-1982 based upon genera presence/absence (SQS) (84 percent of all possible channel comparisons were similar, table 5-2). However, less than one half (48 percent) of possible comparisons were similar in 1983. Community similarity of channel stations was lower than SQS comparisons when based upon both genera presence/absence and abundance (PS), with 52 percent of the possible combinations similar, 1974-1983. Similarity of channel stations based upon PS showed a declining trend over the study period with 70 percent of all possible comparisons similar in 1974 and 33 percent similar in 1983. These data are summarized by year as follows.

Channel

	SQS		PS	
Year	No. Comparisons Similar/Possible	%	No. Comparisons Similar/Possible	%
1974	24/27	89	19/27	70
1975	22/27	81	16/27	59
1976	22/27	81	16/27	59
1977	22/27	81	16/27	59
1978	21/24	88	9/24	38
1982	23/27	85	12/27	44
1983	13/27	48	9/27	33
Overall	147/186	79	97/186	52

Lowest degree of similarity (PS) normally occurred in late summer (August through October).

Over one half (66 percent) of all possible comparisons of overbank stations based upon SQS were similar (table 5-2). Number of similar comparisons in 1982 (56 percent) was less than calculated for the mainstream channel habitat (85 percent) for the same year. Similarity among overbank stations was expected to be less than similarity among channel stations because overbank stations are flow isolated and subject to developing their own unique communities. Flow isolation was also a factor in PS comparisons of overbank stations where only 26 percent of all possible comparisons were similar. These data are summarized below.

Overbank

Year	SQS No. Comparisons Similar/Possible	SQS %	PS No. Comparisons Similar/Possible	PS %
1978	20/24	83	5/24	21
1979	20/27	74	6/27	22
1982	15/27	56	9/27	33
1983	14/27	52	7/27	26
Overall	69/105	66	27/105	26

Like channel stations, lowest similarity (PS) normally occurred in late summer.

A large number of comparisons was possible between channel and overbank stations (table 5-2). Channel and overbank comparisons were similar 58 percent of the time based upon SQS and only 20 percent of the time based upon PS. PS comparisons between channel (TRM 396.8) and overbank stations were especially low in 1979 when every comparison was less than 70 percent. These data are summarized as follows.

Channel vs. Overbank

Year	SQS No. Comparisons Similar/Possible	SQS %	PS No. Comparisons Similar/Possible	PS %
1978	52/72	72	8/72	11
1979	13/27	48	0/27	0
1982	54/81	67	21/81	26
1983	32/81	40	23/81	28
Overall	151/261	58	52/261	20

Similarity between channel and overbank stations would be expected to occur sporadically and usually when reservoir operations were of a nature to mix flow between the two habitats. On some occasions it appeared (based upon PS data) that the overbank station at TRM 386.4 was more isolated from channel waters than overbank TRMs 388.4 and 391.1 (see table 5-2, 1982, June, August, and October). On other occasions overbank station TRM 391.1 appeared more isolated from channel waters than TRMs 388.4 and 386.4 (1978, March, September, and October).

Diversity index values for mainstream channel phytoplankton (depths combined) ranged from 0.60 in April 1976 to 4.00 in September 1975 and March 1979 (table 5-3). Range of overbank diversity was from 1.32 in October 1982 to 4.62 in August 1983 (overbank samples were not collected 1974-1977). Lowest diversity occurred early or late in the year while greatest diversity normally occurred during the summer. Diversity was especially low during 1976 and 1977. Overbank diversity values were as high or usually higher than those in the channel. Greatest number of genera occurred for channel (62) and overbank (71) during 1978. These data are summarized as follows.

	Channel			Overbank		
	Range			Range		
Year	No. Genera	Diversity	(months)	No. Genera	Diversity	(months)
1974	13-34	2.44-3.80	(May/Apr)	-	-	-
1975	17-44	2.03-4.00	(Feb/Sep)	-	-	-
1976	19-50	0.60-3.83	(Apr/Sep)	-	-	-
1977	16-59	0.70-3.55	(Mar/Sep)	-	-	-
1978	18-62	2.14-3.84	(Jul/Jul)	14-71	2.14-4.39	(May/Aug)
1979	22-44	2.26-4.00	(Feb/Mar)	10-55	1.83-4.46	(Feb/Sep)
1982	16-55	1.31-3.81	(Oct/Apr)	12-67	1.32-3.81	(Oct/Mar)
1983	10-30	1.16-3.07	(Apr/May)	9-55	1.33-4.62	(Oct/Aug)

Phytoplankton community structure and monthly succession of the three dominant phytoplankton groups (Chrysophyta, Chlorophyta, and Cyanophyta) are illustrated for channel stations in figures 5-2 through 5-9 for sampling years 1974 through 1983. These percentage composition data represent average abundance of all three channel stations. These data are further defined by sampling location in table 5-4. Data were fairly consistent for all stations through 1979. In 1982 and especially 1983, sporadic occurrence of Cyanophyta at one or two (but not all) stations introduced a greater degree of variability within the data shown in figures 5-8 and 5-9 than was found in previous years.

In 1974 Chrysophyta dominated the mainstream channel phytoplankton assemblage every month except August and September, when Chrysophyta and Chlorophyta became co-dominants (figure 5-2). Melosira was the dominant genus every month, accounting for 21-53 percent of the total phytoplankton abundance (table 5-5). Cyanophyta comprised only 4-20 percent of the assemblage. Beginning in 1975 and continuing through 1978, Chrysophyta was again dominant early in the year (February-May). But in June, Cyanophyta became the dominant phytoplankton group, prevailing for the remainder of each sampling year. Cyanophyta comprised especially large segments of the total assemblage in 1975 (77 percent, August); 1976 (81 percent, August); 1977 (83 percent, July; 76 percent, September; and 73 percent, October); and 1978 (77 percent, August). Dominant Cyanophyta genera were Anacystis and Merismopedia which comprised up to 69 percent of the total assemblage (i.e., September 1978, TRM 391.1) (table 5-5). Beginning in 1979 and continuing through 1983, Cyanophyta dominance became more sporadic during each year (figures 5-7 through 5-9).

In 1979 Cyanophyta was dominant in February (52 percent) and September (51 percent) (Anacystis). Chlorophyta and/or Chrysophyta were dominant the remaining months. By 1983, Chrysophyta had again become the dominant phytoplankton group, except for March when Cyanophyta (Oscillatoria) was dominant (50 percent). Also, by 1983 Oscillatoria had become the most important Cyanophyta genus, although its occurrence (dominance) was variable throughout the study reach. Years 1982 and 1983 were different from other years in that Cyanophyta was not represented in the phytoplankton assemblage during October. Chlorophyta comprised over 50 percent of phytoplankton abundance during June and July 1979.

Patterns of algal succession on the left overbank (figures 5-10 through 5-13) were similar to the mainstream channel, except (1) Cyanophyta dominance began one month earlier on the overbank (June) than in the channel (July) in 1978; (2) the large percentage of Cyanophyta (Anacystis) in the channel during February 1979 did not occur on the overbank; and (3) Cyanophyta dominance was greater on the overbank during July-October 1979; June, August, and October 1982; and August 1983. Both habitats were totally lacking in Cyanophyta during October 1983.

The greatest amount of phytoplankton data is from the four depths and three stations in the mainstream channel. The five-way ANOVA summarizing phytoplankton groups, stations, depths, months, and years (table 5-6) identified highly significant (α = 0.005) main effects and interactions involving percentage composition of phytoplankton groups. All years, months, stations, and depths considered, Chrysophyta comprised significantly greater proportions of the assemblage (mean = 52.7 percent) than Chlorophyta and Cyanophyta which were alike (table 5-7, comparison I). However, station and group showed significant interaction (table

5-6) such that, when analyzed separately by station, differences were observed for subdominant groups (table 5-7, comparison II). Chlorophyta and Cyanophyta comprised similar segments of the assemblage at TRM 396.8 (upstream of BLN) but were significantly different at TRM 391.2 (Chlorophyta greater than Cyanophyta) and TRM 388.0 (Cyanophyta greater than Chlorophyta) downstream of BLN. This indicates an overall downstream increase in relative abundance of Cyanophyta.

Further analysis of significant interactions (comparison III) indicated Chlorophyta comprised a greater amount of the phytoplankton assemblage in 1974 (29.8 percent) than in other years. Similarly, greater relative amounts of Chrysophyta (66.8 percent) occurred in 1983, Cyanophyta (32.0 percent) in 1977, and Euglenophyta in 1974 (2.0 percent) and 1975 (1.1 percent). Months with greatest group abundance (comparison IV) were June, July, and September for Chlorophyta; February through April for Chrysophyta; and July and August for Cyanophyta. Comparisons (V-IX of table 5-7) illustrating ranked means for various other interactions are provided to further refine analysis of group percentage composition data; but are not discussed individually because of the level of detail they present. It is worth noting that analysis of groups by year and depth (comparison VIII) indicated that percentage composition was usually alike at all depths. Two well defined exceptions in 1983 occurred when significantly smaller proportions of Chrysophyta occurred at the 0.3 m depth which also contained relatively more Cyanophyta than other depths. Proportionally more Cyanophyta also occurred at 0.3 meters than at 5.0 meters in 1982.

Abundance--Total phytoplankton abundance in the mainstream channel exhibited significant differences (table 5-8) for all main effects (station, year, month, and depth). Significant interactions also occurred between station and month, year and month, and station, year and month. TRM 388.0 (farthest downstream of BLN) contained significantly (α = 0.001) more phytoplankton cells (376 x 10^3 cells/L) than either TRM 391.2 (immediately downstream of BLN) and TRM 396.8 (upstream) which were similar (330 x 10^3 and 305 x 10^3 cells/L, respectively) (table 5-9). Total abundance was greater in 1976 (781 x 10^3 cells/L) and 1977 (770 x 10^3 cells/L) than other years (1978 not included in the four-way ANOVA). Abundance in 1983 (94 x 10^3 cells/L) was significantly lower than any other year. Combining all years, July had more phytoplankton (351 x 10^3 cells/L) than other months; October had fewer cells (101 x 10^3 cells/L) than other months. Significantly more phytoplankton were collected at the 0.3 and 1.0 m depths than at 3.0 and 5.0 meters (table 5-8, comparison IV).

Significant interaction between station and month (comparison V) identified more phytoplankton during June and July at TRM 388.0, July at TRM 391.2, and July and February at TRM 396.8. Abundance in February was high in 1976 and 1977 (comparison VII) at all three channel stations (79-90 percent Chrysophyta).

A similar analysis for overbank stations (1979-1983) also demonstrated highly significant differences for main effects (table 5-10). TRM 386.4 had more phytoplankton (663 x 10^3 cells/L) than TRM 388.4 (601 x 10^3 cells/L), which was in turn greater than TRM 391.1 (383 x 10^3 cells/L) (table 5-11, comparison I). Differences were also found among years, ranging from 862 x 10^3 cells/L in 1982 to 285 x 10^3 cells/L in 1983. More phytoplankton cells occurred on the left overbank in August (2,480 x 10^3/L) than any other month (February excluded from the analysis). Cell numbers were lower in October (128×10^3/L) than other months. Significantly more phytoplankton also occurred at the 0.3 m depth than at 1.0 m.

Interaction between stations and years (table 5-11, comparison V) indicated abundance at TRM 388.4 was not significantly different during 1979 and 1982. Plankton abundance was greatest at TRM 386.4 in 1982 and at TRM 391.1 in 1979. Abundance was lowest at all stations during 1983. Also more phytoplankton were collected at the 0.3 m depth than at 1.0 m.

August had significantly more phytoplankton (comparison VI) than other months at TRM's 386.4 and 391.1. Abundance in June, July, and August were similar at TRM 388.4 and higher than other months. Abundance data,, stratified by year and month (comparison VII) indicated more phytoplankton in June and July during 1979, July and August during 1982, and August during 1983 than other months. Greatest phytoplankton abundance in overbank habitat was $56,676 \times 10^3$ cells/L at TRM 386.4 in August 1982 (comparison VIII).

Channel and overbank phytoplankton abundance was compared by habitat (combining stations) for 1982 and 1983 only because of unbalance in 1978 and 1979 data sets (refer to Data Analysis section of Materials and Methods). All main effects (habitat, year, month, and depth) showed significant differences (table 5-12). Interaction also occurred between habitat and year, habitat and month, year and month, and habitat, year, and month.

Abundance on the left overbank was significantly greater than in the channel (table 5-13). Other significant differences (combined habitats) included greater abundance in 1982 compared with 1983, more phytoplankton at 0.3 m than at 1.0 m, and greater abundance during June, July, and August than other months.

Abundance of phytoplankton by group is shown in figures 5-14 through 5-21 for each year of sampling, including 1978 which was omitted from the ANOVA procedures. Compared to other years, 1978 (figure 5-18) was very productive in terms of overbank phytoplankton abundance. Cyanophyta dominated the 1978 phytoplankton assemblage from June through September, with a maximum of 27 x 10^6 Cyanophyte cells/L recorded in September at TRM 391.1. Very high abundance of Cyanophyta also occurred in 1982 (figure 5-20) at TRM 386.4 in June (15 x 10^6 cells/L) and August (47 x 10^6 cells/L).

Maximum yearly abundance occurred mid-year in 1974 and 1975 (figures 5-14, 5-15), early in the year in 1976 (figure 5-16), early and again in mid-year in 1977 (figure 5-17), and mid-year from 1978-1983 (figures 5-18 through 5-21). Large abundances early in some years resulted from Chrysophyta production, while mid-year abundance resulted from large numbers of Cyanophyta, except in 1974 when Chrysophyta and Chlorophyta were dominant. Abundance was very low during 1983, except for June and August (figure 5-21).

Temporal trends for total phytoplankton (figures 5-22 and 5-23), Chrysophyta (figures 5-24 and 5-25), Cyanophyta (figures 5-26 and 5-27), and Chlorophyta (figures 5-28 and 5-29) indicated both long-term and short-term periodicity. Abundance in the mainstream channel during the approximate 10-year monitoring period indicated a cyclic pattern: beginning low in 1974, increasing through 1977, and declining during 1982 and 1983 to abundance levels at or below those measured in 1974. Most of these data did not fit the regression model, $y = a + bx$, indicating no linear increase or decrease over time (table 5-14). Only Cyanophyta (which accounted for much of the 1975-1977 abundance increase and then declined to zero levels of abundance in late 1982 and several months in 1983) showed a significant decrease in abundance over the study period. This decline was significant at TRM's 396.8 and 391.2, but not at TRM 388.0.

Overbank abundance also declined from 1978 through 1983. Since the overbank was not sampled during early years of the study which represented increasing (channel) abundance, overbank trends adhered better to the regression model. The only overbank station which did not demonstrate a significant decrease over time was TRM 384.6 (table 5-14). A large degree of short-term (yearly) periodicity in 1982 and 1983 at this station (figures 5-23, 5-25, 5-27, and 5-29) prevented the decrease.

Short-term periodicity usually coincided with annual temperature curves (Chapter 2.0), with low abundance in February, increasing abundance during warmest months, and declining abundance in October. Exceptions occurred in 1976 and 1977 when February abundance was highest (>80 percent Chrysophyta). These two years did not have the high January and February reservoir flows demonstrated for other years (figures 2-2 through 2-9). Therefore short-term periodicity appeared related to temperature and flow.

Chlorophyll Biomass--Because of changes in field and laboratory techniques, chlorophyll data were not comparable over time. Within years these data were variable in regard to monthly biomass production (table 5-15). Minimum and maximum mean values for channel and overbank habitats are summarized below for the three major phytopigments.

Channel

Year	Chl a (Months)	Chl b (Months)	Chl c (Months)
1974	1.07- 3.52 (Apr/Jun)	0.00-1.37 (Apr/Jun)	0.04-4.89 (Apr/Jun)
1975	0.09- 2.42 (Oct/Feb)	0.05-2.63 (May/Jul)	1.05-6.23 (Feb/Jul)
1976	1.15- 6.10 (Mar/Feb)	0.00-2.66 (* /Aug)	0.37-6.89 (Mar/Feb)
1977†	6.83-13.64 (Mar/Feb)	0.00-0.00 (Mar/Feb)	0.11-2.88 (Mar/Feb)
1978†	4.47- 5.74 (Oct/Jul)	3.49-5.07 (Jul/Sep)	3.86-6.50 (Jul/Oct)
1982	0.99- 3.39 (Oct/May)	0.34-2.88 (Oct/Aug)	0.48-4.34 (Oct/Aug)
1983	1.04- 2.43 (Aug/Sep)	0.06-0.59 (Aug/Sep)	0.12-1.12 (Aug/Sep)

Overbank

Year	Chl a (Months)	Chl b (Months)	Chl c (Months)
1982	2.91- 8.12 (Feb/May)	0.28-2.86 (Oct/Sep)	2.19-4.29 (Feb/Sep)
1983	1.89-12.46 (Oct/Jun)	0.23-0.87 (Oct/Aug)	0.42-1.33 (Jul/Jun)

Chlorophyll a is the primary photosynthetic pigment for all phytoplankton; chlorophyll b is associated only with Chlorophyta and Euglenophyta; and chlorophyll c is found in Chrysophyta and Cryptophyta (Chang and Rossman 1982). Pigment extraction has been shown to be more difficult for Cyanophyta and Chlorophyta (Marker 1972) than other phytoplankton groups. Throughout the BLN preoperational study, months with maximum chlorophyll a, b, and c concentrations showed only occasional agreement with maximum abundance peaks for phytoplankton groups during each year.

Maximum channel chlorophyll a during the study occurred the first two months sampled in 1977 and the last four months of 1978 (figure 5-30). Relative concentration of chlorophyll a in figure 5-30 shows good agreement with total phytoplankton abundance for each year (ref. table 5-9, comparison II).

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*March, April, June
†1977: February and March only; 1978: July-October only

Chlorophyll a concentrations on the left overbank during 1982 and 1983 (figure 5-31) were much greater than corresponding channel amounts. The large amount of within-month variability among overbank stations (flow isolated) showed good agreement with abundance data (compare figure 5-31 with figures 5-20 and 5-21). The maximum single-sample chlorophyll a concentration measured during the study (channel and overbank) was 23.40 mg/m³ at TRM 391.1 in June 1983. Maximum single-sample values recorded each year are summarized as follows.

Year	Channel			Overbank		
	Chl a (mg/m³)	TRM	Month	Chl a (mg/m³)	TRM	Month
1974	6.47	396.8	Aug	-	-	-
1975	3.92	391.2	Feb	-	-	-
1976	11.53	388.0	Sep	-	-	-
1977	16.22	388.0	Feb	-	-	-
1978	10.21	396.8	Jul	-	-	-
1982	6.54	391.2	May	15.23	386.4	Jul
1983	3.58	388.0	Sep	23.40	391.1	Jun

While some of the above maximum concentrations were within the 10-30 mg/m³ range indicating potentially eutrophic conditions (Vincent 1981), mean concentrations (table 5-15) normally were much lower. Chlorophyll a concentrations measured in the vicinity of BLN during 1982 were also lower than concentrations measured during the same period in Wilson Reservoir, although large weekly variations in Wilson Reservoir occurred (Wade 1984). Maximum mean chlorophyll a concentration in Wilson Reservoir was 81.24 mg/m³ on April 17, 1982. Differences in habitat and water retention time between the BLN site on Guntersville Reservoir and Wilson Reservoir (forebay area) likely accounted for the lower concentrations at BLN.

Relationship between chlorophyll a and phaeophytin a (degradation product of chlorophyll a) is expressed as a phaeophytin index (PI) value which indicates physiological state of the community. PI values close to 1.7 indicate algal populations consisting of mostly intact, nondecaying organisms (Weber 1973). Except for only an occasional high PI value, relatively large amounts of phaeophytin a (PI <1.60) were present at all stations and depths (channel and overbank) the first eight months of 1982 (tables 5-16 and 5-17). By contrast, October 1982 and several months in 1983 (February, March, April, and August) had at least 50 percent of their PI values equal to or greater than 1.60, indicating healthy, viable phytoplankton populations. However, 100 percent of the PI values during June and September 1983 were low.

Primary Productivity--Productivity data were expressed as mg C/m^3/hour, and mg C/m^2/hour, and mg C/m^2/day (table 5-18). The most meaningful expression of these data in regard to productivity of Guntersville Reservoir in the vicinity of BLN is in terms of the amount of carbon incorporated into the phytoplankton under a square meter (five meters deep) for an entire day. This expression not only considers amounts of light available during sample incubation and for the day, but also integrates depths within the euphotic zone, defined as the depth to which 1 percent of surface light penetrates (Jasper, et al. 1983).

Daily productivity depends largely upon abundance and physiological state of the phytoplankton during sampling. In turn, abundance and physiological state depends largely upon temperature, nutrients, rainfall, flow, and especially upon the quantity and quality of light present on and several days before sampling. Because of the complex interactions of these factors, explanation of variability in productivity estimates among months and years (figures 5-32 and 5-33) is uncertain. However, periods of reduced and/or variable solar radiation on and especially several days before sampling (figures 2-2 through 2-9) appear important in reducing phytoplankton productivity. Variability within a sampling period was related to total abundance of algal cells. Productivity ranged from 7-2,930 mg C/m^2/day in the channel and 7-3,231 mg C/m^2/day on the left overbank for the period 1974-1982 (table 5-18). Maximum productivity from both habitats occurred in July 1982. Significant questions regarding validity of 1983 results prevented discussion of that year's productivity estimates. Because relative amounts of solar radiation were similar during most surveys in 1982 and 1983 (figures 5-34 and 5-35), analytical problems regarding liquid scintillation counting are suspected.

Phytoplankton productivity demonstrated considerable short-term periodicity (figure 5-36). Productivity usually was very low during winter and autumn months and high during late spring and early summer. There were no apparent long-term changes from 1974 through 1978. An overall increase may be indicated, based upon 1982 monthly (June-October) productivity estimates which were much greater than corresponding monthly estimates for the period 1974-1978. Overbank productivity was also very high in 1982, especially at TRM 386.4 (figure 5-37).

Productivity in the channel was much greater at the 0.3 and 1.0 m depths than at 3.0 and 5.0 m depths (table 5-18). Overbank productivity was occasionally higher at the 1.0 m (bottom) depth than near the surface (i.e., May 1982). Depth differences in productivity are best evaluated by comparing light penetration data shown in tables 5-19 and 5-20 for channel and overbank stations, respectively.

5.2.2 Zooplankton

In Guntersville Reservoir, zooplankton are represented predominantly by two phyla: Rotifers (Rotatoria) and Arthropods (Cladocera and Copepoda). These organisms are subject to reservoir currents, hence are not randomly distributed in the system but discontinuous (i.e., patchy) in their occurrence. This patchiness is further compounded by vertical migrations in response to diel changes in light intensity. Density and distribution of zooplankton in the vicinity of BLN are affected by water movement, season, localized habitat conditions, and the incidence of spates. These and other more subtle factors acting in concert produce an assemblage which in the short term (< 1 year) is inherently variable both temporally and spatially. However, when several years of data are analyzed, either concurrently or year by year, trends in zooplankton community structure become more apparent. This section addresses temporal and spatial changes in the zooplankton assemblage, based on approximately 300 two-replicate samples, in Guntersville Reservoir near BLN.

Results for Each Sample Year--Samples were collected from February through October to represent the biologically active period for each year. Because of the inherent instability among months, year became the first level of comparison with significant meaning. Important yearly observations, therefore, are described first, before evaluating overall trends representing the entire preoperational study period.

1974--During 1974 zooplankton collections were generally dominated by cladocerans at the three channel stations although rotifers were frequently dominant during the first part of the year (table 5-21) (there were no overbank stations prior to 1978). Abundances by month were consistently low, less than $8.5 \times 10^3/m^3$, at all stations except during May when total abundance ranged between 63.1×10^3 (station 1) and $122.1 \times 10^3/m^3$ (station 2) (table 5-21). The May assemblage was predominantly Bosmina longirostris (a cladoceran) which comprised more than 50 percent of total numbers (table 5-22). The rotifer, Conochilus unicornis was the second most prevalent taxon making up 12 to 20 percent of numbers collected. These two taxa were responsible for the significant increase in zooplankton densities shown in figure 5-38.

The entire study series (1974-1983) showed the cladoceran B. longirostris is typically becoming the dominant taxon in late spring (April-May) and generally dominant or subdominant until the end of the sample year in October. Such was the case in 1974, when B. longirostris was either first or second in abundance in 63 percent of all samples collected from the mainstream channel near BLN (table 5-23). The reason for the single prolific sample period (May) is unclear, however such a phenomenon was documented during other years in this study (see for example February 1977, all stations, and station 2 in 1978) (table 5-21) and other studies on upper Guntersville Reservoir (TVA 1978, 1979).

A particular note of interest is that beginning in July and continuing to the end of the year, Leptodora kindtii was most numerous at one site and second in eight others. Generally, this particular cladoceran was only sparsely present relative to other zooplankton species and, with the exception of three samples in September and October 1975, ranked lower than tenth in abundance in all samples collected in the period 1975-1983. The population expansion of this relatively minor species (i.e., generally present in mid to late summer but in small numbers) suggests a syndrome of favorable conditions which occurred in 1974 or earlier and may have carried over into 1975. However, population levels of L. kindtii since that time indicated proper conditions have not reoccurred. The fact that L. kindtii (1) was the sub-dominant taxon at all stations in August 1974; (2) was either dominant or sub-dominant at two of three stations during July, September, and October 1974 (appendix B); and (3) was collected regularly leads to the inference: L. kindtii responded in 1974 to hydrologic and physicochemical factors which were not duplicated in the remaining sample years.

The early portion of 1974 was dominated by larval copepods (nauplii) with rotifers sub-dominant. While this larval group tended to dominate the spring period, identifiable copepods (copopedids and adults) were quite sparse at all stations and, nauplii included, exceeded 1,000/m^3 only during February and May (appendix E). This suggests copepods, and for that matter cladocerans and rotifers, shifted from a "maintenance" level to the relatively high "summer" productivity level during May 1974 but did not continue the seasonal expansion of numbers into the summer.

The three channel stations were analyzed via one-way Analysis of Variance (ANOVA) by groups within months and by total zooplankton density at each station to determine whether the samples were drawn from a common assemblage. Of the 36 ANOVA's, 31 did not show enough difference to permit rejection of the null hypothesis at the $\alpha = 0.05$ level. Station mean densities of the five ANOVA which were significantly different at the $\alpha = 0.05$ level were further compared using the Student, Newman, Keuls (SNK) Multiple Range Test (table 5-25). While no clear pattern of differences was established, station 1 (downstream from BLN) generally had fewer organisms than station 3 (upstream) and station 2 at the plant (table 5-21).

With the exception of May, the 1974 zooplankton assemblage in the vicinity of BLN showed little variation among stations with respect to species composition and abundance. The month of May was characterized by large increases in Cladocera (B. longirostris) and rotifers (C. unicornis), which masked concommitant increases in larval copepods. During the latter part of the sample year L. kindtii (Cladocera) showed an increase in abundance, relative to the remainder of the assemblage, of a magnitude not observed during other sample years.

The channel assemblage of zooplankton near BLN had nine taxa as dominant or sub-dominant during 1974 (table 5-23). Of these two taxa were cladocerans (B. longirostris and L. kindtii), one copepod "taxon" (naupii larvae), and the remainder rotifers (table 5-23). Neither number of taxa nor diversity index values (table 5-24) showed a clear advantage of one channel station over the others. Number of taxa was lowest (14) at station 3 (TRM 396.8) in March and highest (35) at station 1 (TRM 388.0) in

May; however, the average number of taxa collected each month was 22 (range 14-35) and was similar for each station (table 5-24). Diversity values ranged between 0.98 (station 3, October) and 3.54 (station 2, TRM 391.2, July) with a 1974 median diversity index of 2.60. The only time all diversity indices were over 3.0 was during April when diversity index values of 3.41, 3.19, and 3.44 were recorded at stations 1, 2, and 3, respectively (table 5-24).

Based on the criterion that Sorensen's Quotient of Similarity (SQS) values > 70 indicate similarity, comparable taxa were present in 25 of 27 comparisons (table 5-26). In the two instances when the SQS values were less than 70 (stations 1-2, SQS = 65, February; and stations 2-3, SQS = 68, October) they were not greatly divergent from the standard. This test is a qualitative comparison and does not include organism abundance as does the Percentage Similarity (PS) coefficient proposed by Pielou (1976). Percentage Similarity compares densities of each taxon at two locations providing a dimension not included in SQS. Sixty-three percent of the PS comparisons (17 of 27) were above the 70 percent criterion and were considered similar (table 5-27).

1975--The zooplankton assemblage present at BLN channel stations in 1975 resembled that of 1974 in community composition by monthly interval; however, total density was reduced by about an order of magnitude in 1975 (figure 5-39). The May samples showed highest densities ranging from $7.0 \times 10^3/m^3$ to $8.2 \times 10^3/m^3$ (table 5-21) with B. longirostris (Cladocera) as the dominant taxon (table 5-23). The rotifer, Synchaeta sp., was second in abundance and together with other rotifers made this taxonomic group dominant in this month.

The cyclic change in abundance of zooplankton by group was similar to that observed in 1974 (table 5-22). Copepods (primarily nauplii) dominated February, March, and April, with rotifers (Synchaeta sp. and Keratella sp.) occupying the sub-dominant positions (table 5-23). Beginning in May, B. longirostris was either dominant or sub-dominant throughout the remainder of the sample year. Community structure, based on dominant and sub-dominant taxa, showed 1975 was remarkably similar to 1974 at all stations (table 5-23).

The cladoceran, L. kindtii, once again increased in relative abundance during the latter part of the year. This species was second in abundance at station 2 and third at station 3 in September. It was fourth in abundance at station 3 in October and in all cases comprised, 7 percent or more of total zooplankton density.

The channel assemblage of zooplankton near BLN was composed mainly of eight taxa during 1975 (table 5-23). The 1975 sample year was consistent among stations with respect to numbers of taxa present and diversity. Number of taxa was lowest (8) at station 1 during February with the next lowest values (11 and 13) at station 2 and 3, respectively, also during February. The greatest number of taxa (32) was collected during August at station 2, while the average number of taxa per sample was 21 (range 8-32) and was similar for each station. Diversity index values ranged between 0.98 (station 1, August) and 3.35 at the same location (station 1) during the following month (September) (table 5-24).

SQS and PS showed 21 (SQS) (table 5-26) and 15 (PS) (table 5-27) instances in 27 possible combinations where the stations had comparable community structure. The PS values showed lowest degree of comparability among all stations during June, ranging from 34 to 50 percent.

In 28 of 36 one-way ANOVA, the hypothesis of no difference was accepted at the $\alpha = 0.05$ level. Station means of the eight ANOVA which were significantly different were examined by SNK (table 5-25). While station 2 was median in abundance, stations 1 and 3 showed no pattern. The trend of station 1 having the lowest density observed in 1974 did not occur in 1975.

Generally, the zooplankton assemblage at the three channel stations near BLN showed little difference with respect to species composition and abundance. Although the entire sample year was relatively light with respect to total densities and densities within groups (table 5-21), the frequency of occurrence of dominant and sub-dominate taxa (table 5-23) suggests a normal, albeit relatively sparse, community. The cladoceran, L. kindtii, comprised a large portion of the late summer/early fall assemblage but not to the degree observed in 1974. This suggests that those factors which elicited large numbers of this species in 1974 were diminished in 1975.

1976--February of 1976 showed an assemblage dominated by rotifers with Synchaeta sp. and Keratella sp. being the dominant and subdominant taxa, respectively, at each of the three channel stations. Copepods (primarily nauplii) comprised the second most prevalent group, while cladocerans were present at a "maintenance" level (< 1,000/m^3) (table 5-21). Overall densities were drastically reduced in March (from about 48.0 x $10^3/m^3$ to near 4.0 x $10^3/m^3$). Rotifers (primarily Keratella sp.) were again dominant at stations 1 and 2 (appendix E), and copepods (nauplii) continued as the sub-dominant category. At the up stream station (3) the dominant and sub-dominant roles were reversed for nauplii and Keratella sp.

During April overall zooplankton densities increased to levels intermediate between February and March; however, community structure changed (figure 5-40). The cladoceran, B. longirostris, dominated the group and the assemblage at all stations, while rotifers were subdominant (Synchaeta sp. at stations 1 and 3, and Keratella sp. at station 2) (appendix E). In May overall numbers dropped again to near 9.0 x $10^3/m^3$ with rotifers (Keratella sp. dominant and Synchaeta sub-dominant) comprising more than 70 percent of the assemblage (table 5-22).

In June B. longirostris once more became the dominant zooplankter at all channel stations and continued as the most prevalent form throughout the remainder of 1976. This single taxon dominance coupled with strong rotifer representation by two taxa (Keratella sp. and Synchaeta sp.) was evidenced by the occurrence of only six taxa as either first or second in abundance in the 1976 channel at stations at BLN (table 5-23).

Overall densities by taxonomic group were quite low in the latter part of the year, suggesting only maintenance levels of zooplankton production (table 5-21). This was particularly evident in August and October.

The 1976 assemblage was characterized by the presence of more taxa per sample (average 29, range 18-41) than were recorded in the previous years. Neither number of taxa nor diversity values showed a clear pattern for any particular channel station. Numbers of taxa were lowest

(18) at station 1 (October) and station 3 (August), whereas station 2 had the greatest number (41) in June of 1976 (table 5-24). Diversity indices were less than 2.0 in February, April, and September and were greater than 3.0 only during June (station 3) (table 5-24). Relatively low diversity index values in February and April, the two months of highest total densities, were due to samples being almost totally dominated by one or two taxa. Synchaeta sp. and Keratella sp. comprised approximately 70 percent of total density at all staions in February, while B. longirostris made up 53-64 percent of the total assemblage in April (appendix E).

In 32 of 40 one-way ANOVA tests, there were no significant differences (α = 0.05 level) among stations. Station mean densities of the eight ANOVA which were significantly different showed no clear pattern of abundances; however, station 1 was generally in the median position of the three channel areas (table 5-25).

The 1976 assemblage showed more variability of composition based on SQS indices than was indicated by the PS index of similarity. Nine of 27 SQS values were less than the 70 percent level, with the lowest degree of similarity occurring late in the year (table 5-26). The Percent Similarity (PS) index based on both numbers of taxa present and their relative abundance showed 22 of 27 comparisons (81 percent) were similar (table 5-27).

In summary, the 1976 zooplankton assemblage near BLN was dominated in the late winter and early spring by rotifers (primarily Synchaeta sp. and Keratella sp.); however, the cladoceran, B. longirostris, became the most prevalent form in April. With the exception of May, when the rotifers again dominated the assemblage, B. longirostris dominated the remainder of the sample year at all sites. While each of the three channel stations was specifically identified by one or more of the analyses as different, there was no clear pattern of differentation. The three channel sample stations showed more similarities than differences throughout 1976.

1977--Greatest overall densities in 1977 occurred in February and March (figure 5-41), but varied considerably between the two months at station 1 (February total density = 86.6 x $10^3/m^3$; March density = 32.6 x $10^3/m^3$). The February assemblage was dominated by rotifers with Synchaeta sp. and Keratella sp. being either dominant or subdominant at each channel station and comprising more than 75 percent of the zooplankton assemblage (table 5-21). March was also dominated by rotifers (table 5-22), however, a new genus, Polyarthra sp., was sub-dominant (stations 2 and 3) for the first time (appendix E).

During April plankton densities decreased to less than 3.7 x $10^3/m^3$ at all stations (table 5-21) and were dominated by rotifers; however, cladocerans and copepods increased in relative abundance (table 5-22). This was due to drastic reduction in numbers of rotifers (table 5-21). Beginning in June and continuing through the remainder of 1977, the assemblage was dominated by nauplii, B. longirostris, Brachionus angularis, and Synchaeta sp. Brachionus angularis, a rotifer, comprised from 18 to 41 percent of the total assemblage during June. This was the first appearance of this species as either a dominant or sub-dominant in BLN samples. After early (February, March) peaks, zooplankton densities were moderate during the late spring and summer, and then dropped to low levels in October (table 5-21).

The zooplankton assemblage was characterized by an average of 31 taxa (range 17-45) per sample and had no diversity index values which were less than 1.0 (table 5-24). Diversity indices were less than 2.0 on only six occasions during 1977. These lower values were due to the assemblage being dominated to a large extent by one or two taxa (Keratella sp. and Synchaeta sp. in February, and B. longirostris in May and August. Numbers of taxa were lowest (17) at station 3 in April and highest (42) at station 2 in September. Station 3 generally had fewer taxa than either stations 1 or 2 (table 5-24).

One-way ANOVA within months by taxonomic groups and total zooplankton densities at each station showed 10 of 36 instances when the null hypothesis (no difference among stations) was refuted at the α = 0.05 level. Station mean densities of those ANOVA which were significantly different showed no clear pattern of station differences was demonstrated (table 5-25). The overall trend was station 3 < station 2 < station 1.

The 1977 zooplankton assemblage showed considerably more variability of composition based on PS than were indicated by SQS values. Four of 27 SQS values were less than the 70 percent similarity level, with station 3 being different than station 1 in April and all stations being different in October (table 5-26). This relatively high level of similarity using SQS was not supported by PS indices where all comparisons during May, June, September, and October were less than 70 percent (table 5-27). Station 3 was involved in [illegible] of 16 instances where 1977 PS values were less than 70 percent, suggesting the community composition of this station was different during this sample year.

The 1977 zooplankton assemblage near BLN was dominated by relatively large numbers of rotifers (Synchaeta sp. and Keratella sp.) in February and March, which persisted, at reduced densities, into May. Nauplii were moderately abundant (≈ 6-8 x $10^3/m^3$) in February and March and at lower densities during the remainder of the sample year; however, copepod adults did not comprise a large portion of the assemblage. Only one species, Diaptomus reighardi, was present at more than 250 individuals per cubic meter ($251/m^3$ at station 3 in July) (appendix B). These observations were consistent with zooplankton samples collected in 1974, 1975, and 1976 (appendix E).

Only six taxonomic forms including nauplii occurred as either dominant or sub-dominant in 1977 (table 5-23), and two of these, Polyarthra sp. and Brachionus angularis had not previously occurred as a dominant form. In general, the three channel stations were not statistically different during 1977; however station 3 had lower diversity indices, lower PS values and fewer taxa than either stations 1 or 2.

1978--Beginning in March, three new sample sites--all in overbank areas--were added to the sample regime at BLN (figure 5-1). These new stations differed considerably from channel stations both hydrologically and biologically. In this report they will be discussed separately and then compared to describe those factors unique to either system.

The March 1978, zooplankton assemblage at channel stations near BLN was dominated by rotifers and copepods (figure 5-42). Rotifers were dominant with Synchaeta sp. being the major taxon and copepods (nauplii) the second most numerous group at each station. Cladocera were present at maintenance levels (< 0.7 x $10^3/m^3$) during this sample month (table 5-21). This changed considerably during April when B. longirostris dominated the assemblage at all stations, comprising 65 percent or more of total densities with nauplii second in abundance (table 5-22). In May, nauplii were dominant at stations 1 and 3, while Asplanchna sp. (rotifer) was most numerous at station 2 (appendix E). Sub-dominant taxa in May were Conochilus unicornis (rotifer) at station 1, Synchaeta sp. at station 2 and B. longirostris at station 3. Percentage composition (table 5-22) and presence absence data (appendix E) suggested an equitable distribution of numbers among taxa. This was supported by the fact that five forms were either dominant or subdominant among the three stations (table 5-23).

Beginning in June and continuing throughout the remainder of 1978, channel stations were dominated by either B. longirostris, Synchaeta sp., Brachionus angularis or nauplii (appendix E) with one exception. At station 3 in September, the cladoceran Alonella sp. comprised 50 percent of the total assemblage (table 5-22); however, total densities were quite low at the time (1.9 x $10^3/m^3$ at station 3). This was the first appearance of the taxon in the BLN zooplankton assemblage. Alonella sp. was identified at station 6 (overbank) in September of 1978 and again at station 5 (overbank) in 1979 (appendix E). The fact that this organism was collected in significant numbers (> $300/m^3$) only in September 1978 (the 1979 sample had only 10 specimens) suggested it was rare and that proper conditions for a celerated production occurred only in autum 1978. This is not an unlikely phenomena for several of the Chydorinae, including this genus (Pennak 1978).

Population densities were moderate during the period March through August except at station 2 in June when rotifer density, especially, Brachionus sp., was very high (figure 5-42). B. angularis, the dominant species was represented by 140.3 x $10^3/m^3$ individuals at this station (appendix E), with overall rotifer densities exceeding 285.4 x $10^3/m^3$ (figure 5-42). While B. angularis frequently was the most numerous species at channel stations, this density was the highest of any channel station during the entire preoperational sampling period. September and October samples were relatively sparse (table 5-21) when compared with densities during the earlier part of the year. Total densities ranged between 1.4 x $10^3/m^3$ at station 2 in September and 5.2 x $10^3/m^3$ at the same location station in October.

The 1978 channel assemblage had the highest average number of taxa for any channel series during all years of preoperational sampling (32 taxa per sample, range 21-41). Numbers of taxa were lowest (21) at station 3 in April and highest (41) at stations 1 and 2 during August (table 5-24). The station trend with respect to numbers of taxa per sample was station 3 < station 1 < station 2. While diversity indices showed no pattern among channel stations, the lowest diversity index value (0.96) occurred at station 3 in April, also the site of fewest taxa per sample in 1978 (table 5-24). Seasonally the lowest diversity indices (< 2.0) were in March and April (all stations) and in September (station 1) and October (station 2); otherwise all diversity indices were greater than 2.0 (table 5-24).

One-way ANOVA showed no significant differences among stations in 23 of 32 tests. Station mean densities of the nine ANOVA which were significantly different were subsequently analyzed using SNK tests (table 5-25). Taxonomic groups were quite variable, and although the stations were significantly different, no station pattern could be discerned. When all groups were combined, station 3 had fewer organisms than either of the others but was significantly lower (P > 0.001) only in May (table 5-25).

Sorenson's Quotient of Similarity showed station 3 to be different from station 1 in May and different from stations 1 and 2 in September; otherwise based on taxa present, the stations were similar at the SQS = 70 percent level or better (table 5-26). However, PS indicated few similarities; March, April, and October were similar (PS > 70 percent) at all stations, stations 3 and 1 were similar in June, and stations 1 and 2 in July (table 5-27). All others were different and station 2 was extremely poor (8-10 percent) in June. This occurred because of the very large numbers of rotifers (figure 5-42) at station 2.

The 1978 channel zooplankton stations were moderately productive and, except for two anomalies, were consistent with previous years. The anomalies were the peak abundance of rotifers, primarily <u>B</u>. <u>angularis</u>, during June (station 2) and the occurrence of the cladoceran genus <u>Alonella</u> sp. as the dominant taxon at station 3 in September. These were first occurrences for both events during channel zooplankton sampling at BLN.

Overbank stations had a different community structure and were much more productive than BLN channel sta'ıons (figure 5-42). There were nine taxonomic forms which were either dominant or sub-dominant at overbank stations, while only six forms were so designated at the channel stations (table 5-23). Generally, overbank stations had much larger populations than their channel counterparts during each sample period (table 5-21). The exceptions were during March (no difference, stations 4 and 5), May (stations 5 and 6 less than station 1) and October (station 4 similar to stations 1, 2, and 3) (table 5-21). In June, station 2 densities were much higher than any other site. Overall differences in community structure were evident in that B. longirostris was dominant only twice (station 5, August and station 4, September) in overbank stations, whereas in 1978 it dominated channel samples 14 times (appendix E).

In March the overbank samples were similar to channel collections with respect to both dominant forms (Synchaeta sp. and nauplii) and density (range $10.0 \times 10^3/m^3$--station 3 to $15.6 \times 10^3/m^3$--station 6). In April rotifers (Asplanchna sp. and Synchaeta sp.) dominated the overbank assemblage and production was much higher than that observed in the channel (appendix E). This was not due to an absence of Cladocera (they were still present in numbers comparable to channel stations) rather it represents an expansion of rotifers (table 5-21).

Copepod density was relatively low ($2.2 \times 10^3/m^3$ to $26.0 \times 10^3/m^3$) but consistent throughout the year. The one exception was station 4 ($0.2 \times 10^3/m^3$) in September when only maintanence levels were observed (table 5-21). As was the case in earlier years, copepod numbers were primarily larval (nauplii) and could not be identified to either genus or species.

Figure 5-42 shows rotifers dominated the overbank zooplankton assemblage near BLN. Beginning early in the year dominance by *Synchaeta* sp. augmented by *Asplanchna* sp. in April, a relatively consistent pattern of rotifer domination of 1978 overbank stations was apparent (appendix E). As the year progressed, these taxa were supplanted by the genus *Brachionus* (*B*. *angularis* and *B*. *budapestinensis*) along with the genus *Conochilus* (*C*. *unicornis* and *C*. *hippocrepis*) until late summer when *Conochilus* sp. (predominately *C*. *unicornis*) dominated the overbank assemblage (appen- dix B). At irregular intervals, other rotifer taxa were either dominant or sub-dominant for one sample period at one station. These included: *Platyias* *patulus* (22 percent, Station 5) and *Hexarthra* sp. (16 percent, station 6) both in July (appendix E).

One-way ANOVA identified significant differences in 18 of 32 overbank tests at $\alpha = 0.05$. SNK Multiple Range Tests showed station 5 had fewer organisms than stations 4 and 6 and station 6 was the overbank location with the greatest overall zooplankton densities (table 5-25). Station 4 was quite variable, but was usually median particularly during March, June, and August. For one analysis (September, copepods) ANOVA was significant (F = 11.25, P > F = 0.04[illegible]) and subsequent SNK test was not. This statistical anomaly occurs because the SNK test is an *a posteriori* test of differences which *appear* to be contributing to the significance of the ANOVA. When the decision is near the borderline for a given probability level, an *a priori* test is more sensitive and in this case probably would have shown September copepods to be significantly different. The less sensitive *a posteriori* test (SNK) did not; however, when SNK shows significant differences among stations, one can be sure *a priori* tests would also have been significant (Sokol and Rohlf 1969).

The 1978 overbank assemblage had an average number of taxa per sample of 34 (range 25-43) and had only one sample (April, station 6) with a diversity index less than 1.0 (table 5-24). Diversities less than 2.0 occurred during March (station 4) and October (station 6) and all others ranged between diversity index = 2.12 (station 4, September) and 4.05 (station 5, August).

Results of SQS and PS comparisons of community similarity very graphically demonstrate the effects of abundance (PS) versus species presence-absence (SQS) on the respective indices. Five of 24 SQS values were less than 70 percent suggesting considerable similarity among overbank stations (table 5-26). When abundance was included (PS) only 2 of 24 similarity indices were greater than 70 percent (table 5-27). In all other cases, PS indices were less than 70 percent and in one instance dropped to only 5 percent similarity (stations 4 and 6 in September). These low PS values were due to the diversity of taxa present and the variability of abundance among taxa and among stations (appendix E).

When channel and overbank stations were compared, several differences became apparent. For example all the dominant and sub-dominant taxa found at channel stations were also found at overbank stations but not vice-versa (table 5-23). This coupled with more taxa per sample in overbank stations (34, range 25-43) than in channel stations (32, range 21-41) suggested some stimulating factor at overbank stations that was either missing or attenuated in the channel area. Two possibilities were (1) the reduction in overbank flow [because overbank areas are behind strip (barrier) islands, which allow limited exchange of water between the two areas but ameliorates wind and current action] and (2) solar heating of the more shallow backwater areas, especially in the early spring. Both these parameters are discussed in sections 2.1 and 2.2 of this report. Reduced current with associated increased water residence time at the shallow overbank stations probably accounted for the overall greater production in overbank areas when compared to channel areas (figure 5-42). Also, because overbank stations would be flow isolated (each developing a more resident, unique assemblage than channel communities), larger differences among overbank stations were possible.

Analysis of variance and subsequent SNK tests showed the channel stations had fewer organisms (by taxonomic group and by total density) than did the overbank stations. The density array by station was structured 3 < 1 < 2 < 5 < 4 < 6 with stations 3, 1, and 2 being different from the remaining stations at a significance level of 0.0001. This coupled with differences in species composition and species dominance indicated aspects of the zooplankton community that can not be measured by examining only one of the habitat types.

1979--The 1979 main channel series of zooplankton samples was discontinued except for one station (station 3, TRM 396.8) which was retained for comparative purposes. Because only one channel station was examined it will be considered along with the overbank stations instead of being analyzed separately.

During February, March, and April the zooplankton assemblage was dominated by Rotifera and/or Copepoda, with mean monthly densities ranging between 42.2 x $10^3/m^3$ at station (channel) in February and

$1.2 \times 10^3/m^3$ at the same station in April (table 5-21). Rotifers and copepods comprised from 84 percent to 98 percent of the assemblage during the same period (table 5-22). Dominant taxonomic forms at all stations during the first three months of 1979 were either Synchaeta sp. or nauplii (table 5-23). The four dominant or sub-dominant forms observed at the channel station (number 3) were included among the twelve forms which were most numerous at the three overbank stations (table 5-23).

In February, zooplankton production was moderate with total densities ranging between $23.0 \times 10^3/m^3$ and $42.2 \times 10^3/m^3$ and were dominated by Synchaeta sp., except at station 6, where nauplii were comprised more than 50 percent of the assemblage (table 5-22). Although the dominant taxa remained the same, densities dropped appreciably during March and April at both channel and overbank sites (table 5-21). The channel station had more individuals than overbank areas only once--February. Throughout the remainder of the sample year overbank stations were several times more productive than the channel stations. Except for June, nauplii (young copepoda) were either the dominant or sub-dominant at one or more sample sites during the entire sample year (appendix E). This indicates continued copepod reproduction although mature copepod domination of the assemblage was rare (table 5-23).

Total densities varied between moderate and maintainence levels throughout most of the sample year. The exception was station 6 during June, July and August when densities, relative to the remainder of the year, were quite high (figure 5-43), being $123.4 \times 10^3/m^3$, $124.2 \times 10^3/m^3$ and $167.6 \times 10^3/m^3$, respectively, for the three periods. In each instance of high zooplankton densities, Rotifera were predominant (table 5-22). Asplanchna sp., and Brachionus angularis dominated the June sample at station 6; however these two taxa only comprised 40 percent the rotifer population. This suggests several other rotifer species were well represented in the sample and the diversity index supports this (table 5-24, diversity index = 3.51). During July at station 6 rotifers were represented by the family Conochiloidae (primarily Conochilus unicornis) which comprised over half the rotifer density of $107.4 \times 10^3/m^3$. The Conochilus sp. population peaked in August at station 6 (appendix E), when the group made up 80 percent of the total rotifers (table 5-22) and accounted for $121.2 \times 10^3/m^3$ of $167.6 \times 10^3/m^3$ total zooplankton at the site.

In spite of large densities in February at station 3 (channel), numerical abundance of zooplankton in 1979 was clearly greater in all overbank stations than at channel stations. Based on mean densities over the year by station the trend was station $3 < 4 \simeq 5 << 6$.

The 1979 overbank assemblage had fewer taxa per sample than observed in 1978 (1978; 34 taxa, range 25-43 versus 1979; 32 taxa, range 19-41), while station 3 (channel) showed an average of 29 taxa (range 23-35) (table 5-24). Diversity indices were generally good with a median of 2.88 and a range of 1.03 to 4.14 at overbank stations and a median of 2.32 (range 1.01-2.77) at the single channel station. There were no diversity index values less than 1.0; however, lower diversities tended to occur either early (February and March) or late (September and October) in the sample year (table 5-24).

One-way analysis of variance (overbank stations only) showed 24 of 36 ANOVA significantly different at the $\alpha = 0.05$ level. However SNK

Multiple Range Tests showed only 22 of the 24 ANOVAS to be significantly different based on the conservative a posteriori determination (table 5-25). ANOVA for June showed Clodocera ($F = 9.99$, $P > F = 0.05$) and, Rotifera for all of 1979 ($F = 3.54$, $P > F = 0.045$) to be different, however their densities did not permit separation of distinct stations using SNK. Based on the SNK tests which were significant, the overall pattern of difference was $\underline{4 < 5} \underline{\leq 6}$ and was generally consistent throughout the sample year (table 5-25).

Results of SQS and PS comparisons showed a series of highly variable sample stations (table 5-26 and table 5-27). In 1979, 15 of 27 SQS comparisons involving overbank stations showed values $\geq$ 70 percent whereas in only 5 of 27 tests was the channel station (3) similar to overbank stations at the SQS $\geq$ 70 percent level (table 5-26). In June SQS levels for all station comparisons were equal to or greater than 70 percent indicating a well mixed assemblage throughout the reservoir in the vicinity of BLN (table 5-26). When numerical abundance was incorporated into the test (PS) it was apparent that little overall similarity existed (table 5-27). In only seven of fifty-four instances were PS values $\geq$ 70 percent. In 26 of 27 possible PS station comparisons, station 6 was less than the preferred percentage similarity of 70 percent, indicating this station was distinctly different from the others.

In summary, the 1979 overbank zooplankton assemblage near BLN showed considerable variability with respect to both taxonomic structure and relative abundance. While stations 4 and 5 were not significantly different when overall plankton densities were considered, 8 of 15 SNK tests showed station 4 to have fewer organisms per taxonomic group than other sites (table 5-25). Station 6 had 11 occasions when taxonomic groups were significantly more numerous than stations 4 and 5. Based on these 1979 results the overbank assemblage in the vicinity of BLN should be ranked 4 < 5 < 6.

When the channel station was compared with overbank stations there was little evidence the two areas were similar. With the exception of February, total density at the channel station was several times less than at overbank stations during the same period.

When station 3 was compared with data from all three channel stations during previous years, the average number of taxa per sample in 1979 (29, range 23-35) was equal to the median value for the years 1974-1978. Only in 1975 were mean zooplankton densities in channel stations consistently lower than those observed at station 3 in 1979. This suggests station 3, the most upstream site (TRM 396.8) may not have been the most appropriate site for relating previous channel samples to the 1979 group.

1982--After a hiatus of two years, zooplankton sampling was resumed at channel and overbank stations in February 1982. Zooplankton densities were moderate ($< 16.0 \times 10^3/m^3$) to maintainence level ($< 2.0 \times 10^3/m^3$) at channel stations throughout the sample year (table 5-21), and during February and March, populations were dominated by Copepoda (nauplii) and Rotifera (Synchaeta sp.) (appendix E). In April, B. longirostris, nauplii, Asplanchna sp., Synchaeta sp., and Brachionus calyciflorus became a significant part of the zooplankton assemblage (appendix E) but varied from station to station with regard to dominant and sub-dominant forms. April was the last time, except station 2 in July, that rotifers comprised more than 10 percent of the channel zooplankton assemblage in 1982 (table 5-22). In May the assemblage was almost completely dominated by Cladocera (Bosmina longirostris) (table 5-22 and appendix E). In June the entire channel assemblage was dominated by copepods (table 5-22). These were either larval (nauplii) or sub-adult (calanoid) forms and at no time were enough adults present to materially affect the mature zooplankton assemblage (appendix E). Beginning in July and continuing through October the channel zooplankton assemblage was dominated by the cladoceran, B. longirostris. With the exception of station 2 (July), when the rotifer Conochiloides sp. was second in abundance, the second most prevalent form was copepod nauplii (immatures, station 3 July) (appendix E).

The 1982 sample year showed more variety among channel station dominant taxa than previous years with nine forms being either dominant or sub-dominant at some period (table 5-23). However, as in the past three forms: Cladocera, B. longirostris; Copepoda, nauplii; and Rotifera, Synchaeta sp., were the primary constituients of the channel group (table 5-23). Samples in 1982 had an average of 20 taxa (range 9-31) per two-replicate sample (table 5-24). This was equal to the lowest number of taxa found in previous years (20, range 8-32, 1975).

Community diversity (diversity index) values were relatively low with six instances when diversity index was less than 1.0 and only 4 diversity index values $\geq$ 3.0 (table 5-24). Those diversity indices less than 1.0 occurred when a single taxon (in all cases B. longirostris) made up more than two-thirds the total assemblage at a given station (appendix E).

In 1975, 96 percent of the two-replicate samples had a CV $\leq$ 40 percent indicating consistent sampling within the same zooplankton community. In 1982 only 76 percent of the CV's were equal to or less than 40 percent, suggesting considerably more variability among replicates. Except for February, Guntersville Reservoir flow regimes were generally lower than normal and should not have affected replicapability (figures 2-36 through 2-40). At present there are no obvious reasons why coefficients of variation were high in 1982.

One-way ANOVA used to test for differences in zooplankton abundance (either by taxonomic group or total density) at channel stations showed 14 of 36 instances when the hypothesis of no difference in mean density was rejected at the $\alpha = 0.05$ level. When these significantly different ANOVA were treated by SNK analysis 13 continued to be different (table 5-25). Although there were exceptions, the general trend among channel stations was $1 < 2 < 3$ with respect to zooplankton densities.

The 1982 channel assemblage showed considerable variability of composition based on SQS and PS indices. In 15 of 27 SQS tests the zooplankton community did not achieve the 70 percent similarity index expected for samples taken from similar assemblages (table 5-26). In February, March, and October all comparisons among stations showed differences. During July and August, all channel stations were similar at the SQS $\geq$ 70 percent (table 5-26). This mid-summer congruence between stations as evaluated by SQS did not persist when percentage similarity

(PS) determinations were made (table 5-27). In July the channel assemblage was nearly at 70 percent similarity level (stations 1 and 2 were 68 percent PS and the others $\geq$ 70 percent PS); otherwise PS indices showed a taxon/abundance similarity that was $\geq$ 70 percent just five times for the year (table 5-27). This degree of dissimilarity was unu- sual in channel stations where hydrologic conditions tend to be more con- sistent than in overbank areas. The relatively high taxonomic and abun- dance variability may have been the result of those factors which lead to high coefficients of variation between replicates.

In 1982, overbank stations were generally more productive than channel areas (table 5-21); however, community structure between channel and overbank stations did not vary as much as in prior years. Percentage composition by taxonomic group showed differences at stations 5 and 6 in May, and station 4 in June when rotifer abundance was greater than at other locations (table 5-22). Rotifers continued to dominate at station 4 throughout the remainder of the year (figure 4-44); however, at other overbank stations there was a more equitable mix of major groups (table 5-22). There were twelve taxonomic forms which were either dominant or sub-dominant at overbank stations in 1983 (table 5-23). One rotifer, Brachionus caudatus, was second in abundance at station 4 in August. While this species occured routinely as a part of the rotifer assemblage, this is the only time during these studies that it was numerous enough ($16.8 \times 10^3/m^3$) to be classified as sub-dominant (appendix E).

Zooplankton densities in overbank areas were generally moderate throughout the year except at station 4 during August, September and

October (table 5-21 and appendix E). Beginning in August, rotifer and copepod (nauplii) densities at station 4 were several times greater than observed at other stations (figure 5-44). While stations 5 and 6 showed the cladoceran, *B. longirostris* and nauplii as the dominant forms during August, September, and October, as did the channel stations, the assemblage at station 4 was quite different (appendix E). Seven rotifer taxa at station 4 were more abundant than *B. longirostris*, suggesting some factor, not present at other stations, was promoting rotifer production at this site. This high rotifer production relative to other overbank stations continued at station 4 during the remainder of the sample year (table 5-21, figure 5-44).

Average number of taxa per sample in overbank stations was the same as at channel stations (20, range 9-32). This was quite low compared to 1978 (34 taxa, range 25-43) and 1979 (32 taxa, range 19-41). Because no samples were taken during 1980-1981, it was not possible to determine whether this represented a natural fluctuation (see 1975 data) or an aberation related to sampling. Three diversity values were less than 1.0 in 1982 (table 5-24), compared with only one value less than 1.0 (1978, station 6, April) at overbank stations in 1978 and 1979 combined (table 5-24).

In 12 of 36 one-way ANOVA either group or total density was significantly different ($\alpha = 0.05$) among overbank stations. When these 12 were subjected to SNK Multiple Range Tests all were significantly different. Only Cladocera was not significantly different among overbank stations throughout the sample year (table 5-25). When total densities were tested over all months in 1982, results were significantly different among the P > F = 0.0009 level. The SNK array was stations 6 < 5 < 4 (table 5-25). This was not unexpected in view of the dis- parity of zooplankton densities at the three stations (figure 5-44).

Sorenson's Quotient of Similarity showed the overbank stations were similar at the 70 percent level in May and July of 1983 (table 5-26). No station comparisons met the criterion of 70 percent similarity (SQS) during March, September, and October. One or more station pairs were similar during February, April, June, and August, but no discernible pattern was evident (table 5-26). Generally overbank stations were similar to channel stations in that the greatest degree of congruence based on SQS occurred May through August of 1983. Only 7 of of 36 percentage similarily (PS) values were above 70 percent and these showed no meaningful pattern (table 5-27). The fact that September and October of 1982 had only two instances (SQS, channel, stations 2-3 and PS, channel, stations 1-2) among 24 comparisons where channel similarity indices were $\geq$ 70 percent and none for overbank stations, confirms considerable aberation in taxonomic structure of the zooplankton community near BLN (table 5-26 and table 5-27).

When channel and overbank stations were compared, their overall similarities were greater than their differences. Synchaeta sp. and nauplii dominated the assemblage in both areas during February, March, and April (appendix E). May and June patterns of dominance showed Bosmina longirostris and nauplii, respectively, at all stations. However, in July and August, Cladocera were most prevalent at channel stations, whereas rotifers dominated the overbank areas (table 5-22). This trend persisted throughout the remainder of the sample year at channel stations and at overbank station 4. Overbank stations 5 and 6 were generally similar to each other particularly with respect to dominant or sub-dominant taxa (B. longirostris or nauplii) during the period July through October 1982.

An analysis of variance on total densities over all months by station (stations were not nested by channel and overbank treatments) was significantly different at the 0.0001 level. SNK tests of mean zooplankton densities by station showed $\underline{2 < 1 < 6 < 5 < 3}$ $\underline{< 4}$ with station 4 being different because of the high rotifer densities during August September, and October of 1982.

1983--The 1983 channel zooplankton assemblage in the vicinity of BLN was charactrized by low densities in February, March, and April at all stations (table 5-21). Densities, increased by an order of magnitude in May (table 5-21) and shifted from rotifer domination to a system that was comprised primarily of Cladocera (table 5-22). The shift in percentage was due to an increase in B. longirostris at all stations with no concommitant change in copepod or rotifer numbers (table 5-21). Total zooplankton densities dropped back to maintenance levels at all stations in June and remained low until October when once again Cladocera (B. longirostris) densities increased (table 5-21, figure 5-45).

Taxonomically the 1983 channel stations followed the trend that was shown in earlier sample years, with rotifers (usually Synchaeta sp.) and copepods (nauplii) dominating the spring assemblage (appendix E). In February a different rotifer (Epiphanes macrouras) was the dominant at station 1 and was sub-dominant at station 2. This species had previously occurred in the zooplankton assemblage; however its numbers were usually less than $100/m^3$, whereas in February, E. macroura density was approximately $1.2 \times 10^3/m^3$ at stations 1 and 2 (appendix E).

Beginning in May, Cladocera dominated the channel assemblage and, with nauplii, remained most numerous throughout the sample year except at station 1 in September when rotifers comprised 31 percent of the community (table 5-22). The sample year had nine taxonomic forms which, at one or more times, were either first or second in abundance (table 5-23). Three taxa were reported as either dominant or subdominate for the first time at channel stations. They were: Epiphanes macroura, a rotifer; Diaptomus reighhardi, a copepod; and Diphanosoma leuchtenbergianum, a cladoceran. However, D. leuchtenbergianum was second in abundance at overbank station 4 in August 1979. The remaining dominant forms have occurred regularly throughout the sample series and constitute a normal channel assemblage in the area. Fewer taxa were collected during 1983 than in any previous year (average number of taxa = 16, range 9-24), and overall replicate variability as measured by coefficient of variation (CV) was poor. Only 70 percent of replicates had CV $\leq$ 40, whereas the CV was less than 40 in more than 89 percent of samples taken during 1974 through 1979. It is not known whether the fewer taxa collected in 1983 are due to variability in sampling or to some difference in the zooplankton assemblage evidenced during 1983, and to some degree in 1982.

The channel assemblage had eight community diversity indices less than 1.0. These occurred primarily during May (stations 1 and 2), September (stations 2 and 3) and October (all channel stations) (table 5-24). Diversities ranged between 0.14 (station 2 in October) and

3.36 (station 2 in July). In all instances where diversity values were less than 1.0 the assemblage was dominated by one species (*B. longirostris*) which made up more than 85 percent of total zooplankton density (appendix E).

One-way ANOVA used to test for differences in zooplankton densities showed 5 of 36 tests where the hypothesis of no difference in mean density among channel station was rejected. When these were examined by SNK, four of the five ANOVA showed significant station differences based on this *a posteriori* test (table 5-25). Although no clear pattern was evidenced for stations 1 and 2, station 3 had the fewest individuals. Station ranking by abundance was station 3 < 1 < 2.

Like the 1982 assemblage, zooplankton in 1983 showed considerable variation between stations based on SQS and PS values. In 16 of 27 SQS comparisons between channel stations the similarity quotient was less than the preferred criterion of 70 percent similarity (table 5-26). In two months (April and June) all channel station comparisons either met or exceeded the 70 percent criterion, and in two months (September and October) all stations comparisons were less than 70 percent (table 5-26). Stations 1 and 3 showed the greatest degree of similarity, especially during the first half of the sample year, whereas stations 1 and 2 differed in taxonomic similarity in 7 of 9 months sampled (table 5-26). When adjusted for abundance (i.e., Percentage Similarity), PS comparisons showed 15 of 27 instances when station comparisons were less than 70 percent (table 5-27). In only one month (March) was there a 70 percent congruence among all channel sites. The PS values showed station 1 versus station 2 to have the highest degree of similarity (5 of 9 months), whereas this pairing showed the best similarity using SQS index. This suggests that while the two stations were quite dissimilar taxonomically, abundances of taxa in common were relatively similar. Both SQS and PS tests are in agreement with the inference that a low degree of similarity with respect to both taxonomic structure and relative abundance within taxa was evidenced among channel zooplankton assemblages near BLN in 1983.

Relatively low similarities were expected in areas where flow is slight (e.g., overbanks), thus allowing one or a few taxa to expand their numbers and produce a "patch" that would not resemble neighboring patches. Conversely in sample areas of moderate discharge effect (e.g., channel), one expects the assemblage to be relatively well mixed hence have a good degree of similarity. Discharges at Nickajack Dam (upstream) and Guntersville Dam (downstream) in 1983 (table 2-1) do not suggest long periods of little or no flow in the vicinity of BLN. Relatively low densities and reduced numbers of taxa were documented in 1974 and 1975 so this may be a periodic cycle in the zooplankton community.

In 1983, as was the case in prior years, the overbank assemblage indicated more production than in channel areas (table 5-21). Based on group composition, overbank areas were similar to the main channel with rotifers and copepods dominating the assemblage early in the year (February, March, and April) and Cladocera at the end of the sample year (September and October) (table 5-22). Contrary to channel stations, rotifers continued to dominante the overbank assemblage throughout the summer except for July (very low abundance at all stations) when copepods (nauplii) comprised 87 percent, 57 percent, and 78 percent of the zooplankton at stations 4, 5, and 6, respectively (table 5-22).

Generally, zooplankton densities at overbank stations were approximately five times greater than at channel stations. Stations 4, 5, and 6 had 13 taxonomic forms which were either dominant or subdominant one or more times during the year (table 5-23), with three taxa classified as first or second in abundance for the first time in the monitoring period. They were: Bosminopsis sp. (Cladocera--station 4, September), and the rotifers Monostyla sp. (station 5, July) and Trichotria sp. (station 5, February) (table 5-23). In each instance overall densitites were low ($\leq 2.7 \times 10^3/m^3$), therefore these may be instances when relatively minor but consistently present taxa became dominant due to absence of a more normal assemblage (appendix E).

Densities were quite variable among overbank stations and throughout the sample year (figure 5-45). June samples had the highest overall densities, as well as the highest individual station value (station 6), while July samples yielded the least overall numbers of any sample month in 1983. Synchaeta sp. ($231.7 \times 10^3/m^3$) accounted for more than 69 percent of total plankton abundance ($334.4 \times 10^3/m^3$) at station 6 in June (appendix E). Further evidence of overbank density variability in 1983 occurred in March when station 6 had the lowest total zooplankton density ($0.47 \times 10^3/m^3$) of any overbank sample. This nadir was surpassed by only one other sample (station 3, October 1977, total density = $0.4 \times 10^3/m^3$) during the entire investigation.

Average number of taxa per sample in overbank stations was the lowest reported for the four years (19, r nge 8-31). In previous sample years, the trend had been for overbank and channel samples to have about the same average number of taxa per sample within a particular year. However the average number of taxa varied considerably from year to year. Although overank stations were not sampled in 1974 and 1975, the taxonómic composition of channel stations was comparable to 1982-1983 (table 5-24). This cyclic trend should be considered when zooplankton samplîng is resumed at BLN.

Very low diversity indices (diversity index $\leq$ 0.25) were observed in October at all overbank stations (table 5-24). These occurred because the cladoceran B. longirostris made up 88 percent to 94 percent of total zooplankton density (total density range 15.4 x $10^3/m^3$ to 23.4 x $10^3/m^3$) at overbank stations (tables 5-22 and appendix E). Diversity indices ranged between 0.18 (station 6, October) and 3.95 (station 6, March) with 17 of 27 diversity indices greater than 2.0 (table 5-24).

One-way analysis of variance showed 9 of 36 instances when the null hypothesis (i.e., no difference among stations) was rejected (table 5-25). When these were tested by SNK all were significant (table 5-25). Station 4 as generally had significantly greater abundances than either stations 5 or 6; however, no consistent pattern was established because of replicate variability. Rotifers in June were not significantly different at station 6 (density = 289.5 x $10^3/m^3$) from other overbank stations because of high coefficients of variation (CV) at station 4 (CV = 136) and station 6 (CV = 61). If replicates within samples had been in the preferred range of CV $\leq$40, station 6 would have been significantly different from stations 4 and 5.

Based on the 70 percent SQS criterion, only in June were assemblages comparable at all sites (table 5-26). In total, only 9 of 27 comparisons met the 70 percent criterion (table 5-26). PS indices also showed a poor degree of similarity. When zooplankton densities were included in the analysis, stations 5 and 6 were similar at the PS $\geq$ 70 percent level in May and all three overbank stations were similar in October (table 5-27). The October sample series was totally dominated ($\geq$ 88 percent of total numbers) by B. longirostris at each station, therefore high PS similarities were expected. Otherwise, 23 of 27 PS simmilarity tests showed the assemblages to be different among stations (table 5-21).

In 1983 the zooplankton assemblage near BLN was characterized by extremes at both channel and overbank stations. For example, station 6 had the greatest (334.4 x $10^3/m^3$, June) and least (0.5 x $10^3/m^3$, March) overbank zooplankton density estimates of the entire investigation (appendix E). Also community similarity based on SQS and PS indicators showed both channel and overbank sites to be only occasionally similar to each other. When SQS values for channel stations in 1983 were compared with those from 1975, only 11 of 27 stations were comparable in 1983, whereas in 1975, 21 of 27 comparisons were similar at the 70 percent level or greater (table 5-26). Though different in degree of station similarity, the two years were similar with respect to average number of taxa per sample, total zooplankton densities, species diversity, and numbers of dominant and sub-dominant forms. They were also similar in that the early part of both sample years (February-May) was dominated by rotifers (primarily Synchaet sp.) and immature copepods (nauplii) with B. longirostris increasing in density in early summer (May-June) and dominating the assemblage during the remainder of the sample year. SQS and PS values in 1983 seem to be due to station differences with respect to less abundant taxa and to inconsistencies among replicates. Because of these inconsistencies and the lack of zooplankton samples in 1980-1981, it is possible to hypothesize (conjecture) but not demonstrate a relatively long-term periodicity (ca. 7-8 years) of cyclical zooplankton production in Guntersville Reservoir in the vicinity of BLN. Other investigations in the reservoir have shown similar phenomena (TVA 1983a).

Seasonal Variations in Zooplankton Assemblages--Figures 5-38 through 5-45 demonstrate temporal and numerical instability of the zooplankton assemblage. However, in spite of these fluctuations certain seasonal trends were established over the span of the investigation.

Certain taxonomic forms were ubiquitous in their occurrence throughout the sample year (B. longirostris, nauplii, Synchaeta sp. and except for August of some years, Keratella sp.) as either dominant or sub-dominant in abundance at channel and/or overbank sites. However the periods of dominance and the number of dominant taxa varied with season. In the period February-April rotifers (Synchaeta sp. and Keratella sp.) were generally the most prevalent taxa with immature copepods (nauplii) second in abundance (table 5-22 and appendix E). Numbers of taxa were also reduced in the overwintering populations in both channel (average number of taxa = 21, range 8-35) and overbank (average number of taxa = 22, range 11-41) stations during February-April when compared to annual averages of 25 taxa, range 9-45 (channel) and 26 taxa, range 8-43 (overbank). This was particularly evident in February (table 5-24) when overwintering forms were either rarely present in the water column or still in the "resting" egg stage and thus were missing from the samples. However when conditions were favorable for a group (e.g., rotifers in February and March, 1976) they produced considerable densities ($\simeq$ 48 x $10^3/m^3$) early in the sample year (table 5-21). The two dominant taxa during this expansion were Synchaeta sp. and Keratella sp. (appendix E). While these two taxa established the pattern for the early season, other rotifers on occasion contributed significantly to early season zooplankton densities. Two taxa, one in channel samples (Epiphanes macroura) and a second in overbank samples (Trichotria sp.), showed early season cycles of abundance in 1983.

Although rotifers usually continued to dominate the assemblage in April, Cladocera (B. longirostris) typically began their increasing in density and by May were co-dominant with larval copepods (nauplii) as the most numerous forms; especially in channel areas. Even with these sample sites (channel) being generally dominated by nauplii and B. longirostris, the summer zooplankton assemblage could best be characterized as diverse with respect to abundance of taxa and community dominance (appendix E). Channel stations had one unique sub-dominant taxon among summer zooplankton, the copepod, Diaptomus reighardi (July, station 1). This was one of only two instances when mature copepods were either dominant or sub-dominant in a sample (appendix E). Overbank stations in summer had five taxa occurring as dominant forms in the area (overbank) and season (May-July). They were all rotifers and included, Brachionus quadridentatus, Conochilus hippocrepis, Hexarthra sp., Monostyla sp., and Platyias patulus (table 5-23).

Beginning in May and continuing through August several taxa of Conochilidae were at peak production in the reservoir near BLN. While both channel and overbank stations had substantial numbers of these organisms they were generally more prevalent in overbank areas (table 5-23) where they were occasionally either dominant or second in abundance throughout the remainder of the sample year (September-October). This trend was not observed at channel stations.

The genus Brachionus, another rotifer, began to dominate the assemblage during June of most sample years and was a major part of the community throughout the remainder of the year. There were five species (B. angularis, B. budapestinensis, B. calyciflorus, B. caudatus, and B. quadridentatus) which were either dominant or sub-dominant at one or more stations. Although some taxa were quite abundant at both channel and overbank sites (e.g., B. angularis), when weighted by years sampled, representatives of the genus Brachionus were more than twice as prevalent at overbank stations than in channel areas (table 5-23).

The months of August through October, particularly October, were characterized by a diminished number of taxa collected, as well as a general reduction in productivity, (table 5-24 and figures 5-38 through 5-45). Two taxa were unique to channel stations as dominant (Alonella sp.) and sub-dominant (Diaptomus pallidus) during this season. Documentation of the copepod D. pallidus as sub-dominant (August, station 3) represented the second time during this entire investigation that a mature copepod contributed significantly to the community assemblage. As a group, the copepods, were always well represented by nauplii (larval forms) in these investigations but were sparsely present as mature adults (<7 percent overall) in the assemblage. At present, it is not known whether this was due to cropping of the larger organisms by predators or to adults being poorly sampled because of their proximity to the substrate during daylight hours or if this is the natural population dynamics of this reservoir. Pennak (1978) notes that copepods frequently migrate much further than other plankters, moving vertically through depths ranging from 10 to 15 meters, whereas rotifers only range between one and five meters. In Guntersville Reservoir vertical migratory ranges of 15 meters or less would place most calenoid and cyclopoid forms near the substrate, and thus easily missed during sampling. Another factor which must be considered is that while harpacticoid copepods have a free-swimming larval form, adults are generally substrate (detritus) dwellers, hence not subject to samples extracted from the water column (see section 5.1.2).

Occasionally a taxon dominated the late summer/early fall assemblage during one year, but not be evident in ensuing years. This was demonstrated by the cladoceran, Leptodora kindtii in 1974 (appendix B). This large (ca. 1 cm length) predaceous species was generally present in summer and autumn assemblages at both channel and overbank stations, but was abundant only in 1974. The presence of this particular species as a dominant form within the 1974 assemblages demonstrated the variety of taxa, which given the proper conditions can change the zooplankton community composition in the vicinity of BLN. However, these fluctuations were usually transitory, with the autumnal channel assemblage being composed primarily of B. longirostris, nauplii, and several rotifers (Synchaeta, sp. an B. angularis).

The same general pattern (B. longirostris and nauplii codominant, supported by several species of rotifers) was evident in overbank areas. However, in overbank samples the rotifer group was composed of four species within the genus Brachionus and three in the family Conochiloidae which were rarely abundant at channel stations. Synchaeta sp., regularly a part of the dominant fauna at channel stations, was not included as a dominant taxon in any of the autumnal (August-October) overbank samples in this investigation.

In summary zooplankton assemblages near BLN were dominated by four taxonomic forms which persisted throughout the sample year. They were Bosmina longirostris (Cladocera), nauplii (larval copepods) and two rotifers (Synchaeta sp. and Keratella sp.). In the early part of the year (February-April) rotifers and nauplii dominated both channel and overbank areas. In mid-season (May-July) Cladocera became dominant, especially in channel areas, with rotifers and nauplii sub-dominant. Variety was provided by different species of rotifers in both channel and overbank areas when Asplanchna sp., Brachionus angularis and Conochilus unicornis begin to increase in density in May-June and continued through the rest of the year. Overbank stations had more variety of taxa (especially species of Brachionus and Conochilus) than were found in the channel. Zooplankton diversity and density was generally highest in mid-year. The fall season was characterized by reduced density overall and a shift toward rotifer domination in channel stations. Synchaeta sp. rarely dominated the late season samples at overbank sites.

On a year-by-year basis, channel stations were least productive and had fewest average taxa per sample in 1975. Both total densities and number of taxa per sample increased through 1978 and then decreased to 1982. In 1983, average number of taxa per sample improved slightly; however total densities continued to be depressed.

In 1978, the first year of overbank sampling total densities and average number of zooplankton taxa per sample were the highest recorded for the study. Both parameters then declined with lowest overbank densities occurring in 1982 and fewest average taxa per sample in 1983. Although overbank stations were more productive, they generally followed the trend established by channel stations in regard to yearly changes in abundance and numbers of taxa per sample.

Spatial Variations in Zooplankton Assemblages--Overall station diffferences within channel and overbank areas were few in number yet differences between channel and overbank areas were great. In this section, channel station variations are examined first, then overbank areas, and finally the two groups will be compared.

Channel station 3 (TRM 396.8) is intended to be the upstream "control" when BLN begins operating. It was found to be generally the poorest of the three channel stations. Although few analyses showed significance at the 0.05 level, this station was consistently lowest in average number of taxa per sample (24, range 9-38), had poorest diversity, was low in low total density (10.6 x $10^3/m^3$) except for 1983, and was represented by the fewest dominant taxa (12) of any channel station. While these trends were not statistically significant they were documented in this preoperational report. They also show the need for another "control" station closer to the BLN site than station 3 which is over five miles upstream from BLN.

Channel station 2 (TRM 391.2) was the richest of the channel sites. Located at the BLN diffuser area, station 2 had an average number of taxa of 25 (range 10-45), good species diversity, and the highest total density ($16.2 \times 10^3/m^3$) of channel stations. Fourteen taxonomic forms were either dominant or subdominant during one or more of the sample years.

Channel station 1 (TRM 388.0) results were generally between those of the other two sites with respect to most of the measured parameters. Total density ($10.7 \times 10^3/m^3$) was comparable to station 3; community diversity was good, and like station 2, had an average number of taxa per sample of 25 (range 8-42). In one category, number of taxa present as either dominant or sub-dominant, station 1 was clearly highest with 17 taxonomic forms. This was the largest number reported for this parameter at either channel and overbank stations, and implies a greater diversity of fauna and habitat than observed eleswhere in this study.

Based on the entire series of zooplankton studies no clear pattern of statistically significant differences could be established among channel stations near BLN; however, the stations were generally ranked station 3 < station 1 < station 2.

Overbank stations were located at TRM 386.4 (station 4), TRM 388.4 (station 5), and TRM 391.1. All overbank stations were generally more productive than were channel stations. This was due in part to the reduced current behind the barrier islands which limited flushing of plankters from the environs.

Overbank station 4 was the most downstream of the three sites and like channel station 3 (also downstream), had a relatively high number of taxa present as dominant or sub-dominant (15) components of the overbank assemblage. In part this may have been due to an influx of zooplankton from the Jones Creek embayment (TRM 388.0) which is along the left shore (facing downstream) with a portion of its flow remaining behind a continuous barrier island to a point downstream from station 4. Average number of taxa per sample for station 4 was 26 (range 10-41), community diversity was approximately equivalent to that observed for channel station 2, and total density ($36.1 \times 10^3/m^3$) was the median for three overbank stations.

Overbank station 5 (TRM 388.4) was located behind a barrier island just upstream from the month of Jones Creek (TRM 388.0). During the perod 1978-1983 this site was subjected to considerable encroachment from aquatic macrophytes. This may explain the fact that, although not statistically significant, station 5 was generally the poorest overbank station sampled. Total density was $21.9 \times 10^3/m^3$ less than half that of station 6, the most productive site. Average number of taxa per sample (27 range 10-43) and community diversity were the highest observed; however, only eleven taxonomic forms were listed as dominant or subdominant in abundance. This was the fewest representatives for this category in either channel or overbank stations. Figures 5-42 through 5-45 show station 5 to have the fewest organisms in 15 of 35 monthly comparisons among overbank stations.

Overbank station 6 (TRM 391.1) had the highest average total density ($53.4 \times 10^3/m^3$) of any sample site studied. SQS and PS indices throughout the study showed station 6 to be frequently dissimilar to other stations (table 5-26 and table 5-27). Community diversity was good, second only to station 5, and 12 taxonomic forms were either dominant or sub-dominant during the study. In spite of, or perhaps because of its high productivity, station 6 had fewer average taxa per sample (25 range 8-42) than other overbank stations. This may have occurred when large numbers of one or two taxa utilized habitat which might have otherwise been occupied by other species.

When all overbank station parameters were considered in concert, station 5 ranked less than station 4 which ranked less than station 6.

When dominant and sub-dominant taxa at channel and overbank stations were combined by sample type and compared, there were five ubiquitous taxonomic forms (Bosmina longirostris, nauplii, Asplanchna sp., Brachionus angularis, and Synchaeta sp.) (table 5-23). Total numbers of abundant taxa showed 20 taxa plus nauplii in channel areas and 21 taxa plus nauplii at overbank stations. Overbank stations had more unique (i.e., occurred only in one sample type) taxa (8) than channel stations (6).

Zooplankton diversity indices and average number of taxa per sample consistently showed the overbank stations to be slighlty more diverse with have more species than channel stations. None of these differences were statistically significant, although they were consistent. Diversity measures showed station 3 $\simeq$ station 1 $<$ station 4 $\simeq$

station 2 < station 6 < station 5 while ranking by average taxa per sample provided an array of station 3 < station 1 $\simeq$ station 2 $\simeq$ station 6 < station 4 < station 5.

During the three sample year period (1978, 1982, and 1983) when both channel and overbank stations densities were tested using ANOVA and SNK (table 5-25) certain patterns became evident. Channel stations ranked station 3 < station 1 < station 2 in 1978 and 1983 and station 1 < station 2 < station 3 in 1982. Overbank stations during the same period showed station 5 < station 4 < station 6 (1978, 1983) and station 6 < station 5 < station 4 in 1982. However, when all six stations were examined simultaneously the very high zooplankton densities at station 6 (1978, 1979, 1983) and station 4 (1978, 1982) affected the analysis such that station 3 < station 1 < station 2 < station 5 < station 4 < station 6, with channel stations at the low end of the array and overbank stations at the high end.

These observations suggested that, while channel and overbank sample sites shared the same zooplankton species mix, habitats differed such that communities were somewhat different. Also, within sample areas there existed a trend which although not statistically significant, consistently showed the upstream control station (station 3) to be less productive than other channel stations. Overbank stations showed a similar trend with station 5 being the least productive site. The two most productive sites (station 2, channel at TRM 391.2 and station 6, overbank at TRM 391.1) were in close proximity to each other and to the diffuser outlet of BLN.

5.3 Summary and Conclusions

5.3.1 Phytoplankton

Phytoplankton assemblages of the mainstream channel and left overbank habitats near BLN were diverse, consisting of 137 phytoplankton genera. Most of these genera comprised the groups Chlorophyta (66), Chrysophyta (35), and Cyanophyta (25). Twenty-two genera were important with regard to abundance, representing at least 10 percent of total abundance during one or more collection periods.

Comparisons of community structure in the mainstream channel indicated 79 percent of all possible SQS and 52 percent of PS comparisons were similar. Similarity of overbank phytoplankton communities occurred less frequently with 66 percent of all possible SQS comparisons similar and only 26 percent of possible PS comparisons similar. The low degree of similarity among overbank stations was the result of flow isolation which allowed development of distinct and separate communities, whereas, channel stations were contiguous with regard to flow. Lowest similarity (PS) among both overbank and channel stations occurred in late summer. Comparisons of community structure between channel and overbank stations were usually dissimilar with regard to PS where only 52 of 261 possible comparisons (20 percent) were similar.

Phytoplankton diversity was greater on the left overbank (range of d values = 1.32-4.62) than in the mainstream channel (d = 0.60 4.00). Maximum number of genera identified for a single collection date occurred for the overbank (71, September) and channel (62, July) during 1978.

Patterns of algal succession changed during the preoperational study period. Chrysophyta and Chlorophyta dominated the phytoplankton assemblage every collection period in 1974 and Chrysophyta was again dominant every collection period (except March) in 1983. During 1975-1982 Cyanophyta became the most abundant phytoplankton group, comprising especially large segments of the total assemblage in August 1975 (77 percent), August 1976 (81 percent), and July (83 percent), September (76 percent), and October (73 percent) in 1977. Dominant Cyanophyta genera were Anacystis and Merismopedia during 1975-1982, but changed to Oscillatoria in 1983. The dominant genus occurring most often during the study was a chrysophyte, Melosira. Cyanophyta dominance was usually greater on the overbank habitat than in the river channel. October 1982 and several months in 1983 were unique in that Cyanophyta was not represented in the phytoplankton community.

Combining channel percentage composition data for all years, month, stations, and depths indicated Chrysophyta composed significantly greater proportions of the assemblage than other groups. Stratifying data by station indicated a downstream increase in relative Cyanophyta abundance. Greater relative abundance occurred for Chlorophyta in 1974, Chrysophyta in 1983, Cyanophyta in 1977, and Euglenophyta in 1974 and 1975.

Phytoplankton abundance was greater for the overbank habitat than the mainstream channel. The most productive stations with regard to cell numbers were TRM 388.0 in the channel and TRM 386.4 on the left overbank, indicating a downstream increase in phytoplankton abundance. Combining abundance data for years indicated, overall, that July (channel) and August (overbank) had significantly more phytoplankton than other months. Lowest abundances occurred in October for both habitats.

Greatest phytoplankton abundance measured during the monitoring period exceeded 56 million cells/L at TRM 386.4 in August 1982.

Temporal evaluation of phytoplankton indicated a cyclic abundance pattern for the channel habitat, beginning low in 1974, increasing through 1977, and declining during 1982 and 1983 to abundance levels at or below those measured in 1974. Two overbank stations (TRMs 391.1 and 388.4) exhibited a significant decrease in phytoplankton abundance over time (1978-1983).

Short-term periodicity usually coincided with annual temperature curves, with low abundance in February which increased during warmest months and declined in October. Exceptions occurred in 1976 and 1977 when large abundance in February appeared related to absence of high January/February reservoir flows demonstrated for other years.

Average chlorophyll a concentrations normally were below the 10-30 mg/m^3 range indicating potentially eutrophic conditions; however, maximum single-sample concentrations occasionally fell within that range. Maximum chlorophyll concentrations on the left overbank were much greater than corresponding channel concentrations. Estimates of phytoplankton community health, based upon relative amounts of phaeophytin a, indicated healthy, viable populations during much of 1983 in contrast to a somewhat less viable assemblage in 1982.

Primary productivity data were extremely variable from month-to-month, ranging from 7 to 2,930 mg C/m^2/day in the channel and 7 to 3,231 mg C/m^2/day on the left overbank. Maximum productivity for both habitats occurred in July 1982. Reduced and/or changing solar radiation several days before sampling appeared to reduce productivity.

Over time, phytoplankton productivity appeared to increase based upon greater photosynthetic activity during 1982. As expected because of decreasing penetration of light into the water column, maximum productivity occurred at the surface and 1-m depths.

In summary, phytoplankton data were quite variable within stations, months, and years such that spatial trends were seldom obvious. However, there was a trend indicated for greatest total phytoplankton abundance and Cyanophyta dominance on the left overbank and at downstream sampling locations.

5.3.2 Zooplankton

During the period 1974-1978 channel stations were remarkably similar with respect to numbers of zooplankton taxa present, species diversity, and frequency of occurrence of dominant and sub-dominant taxonomic forms. However, this overall similarity did not include either total zooplankton densities or densities by species, which showed considerable inequality, with no reliable pattern by either station or sample period. For example, February, and to some extent March were usually periods of reduced abundance, except for 1977 when the highest production during the year was in February and March. Similar anomalies occurred frequently, but never predictably, throughout the investigation.

Larval copepods (nauplii) were the most consistent component of the zooplankton assemblage, but adult copepods were only rarely (twice) present as a major component of the community. The second most prevalent form was the cladoceran, Bosmina longirostris which generally dominated channel zooplankton from May to the end of the sample year.

Total zooplankton densities and average number of taxa per sample increased at all stations during the period 1974-1978 and then decreased in 1979, 1982, and 1983. Several other parameters examined during the study supported the conjecture that zooplankton in Guntersville had a long-term ($\simeq$ 7-8 years) cycle of increasing and decreasing numbers. This phenomenon may have been more evident if variability among two-replicate samples collected in 1982-1983 had been less. The high degree of within sample variability tended to obliterate inferences which may have supported the long-term periodicity concept. Within each of the two habitat types sampled, highest overall densities were at channel station 2 and overbank station 6, both located immediately in front of the plant, while lowest zooplankton numbers at channel stations were at the upstream control (station 3, TRM 396.8) and at overbank station 5 (TRM 388.4). Overbank stations were much more productive than channel sites. This probably resulted from amelioration of river flows due to the presence of barrier islands.

Several conclusions can be made from zooplankton data collected during the period 1974-1979 and 1982-1983. These include:

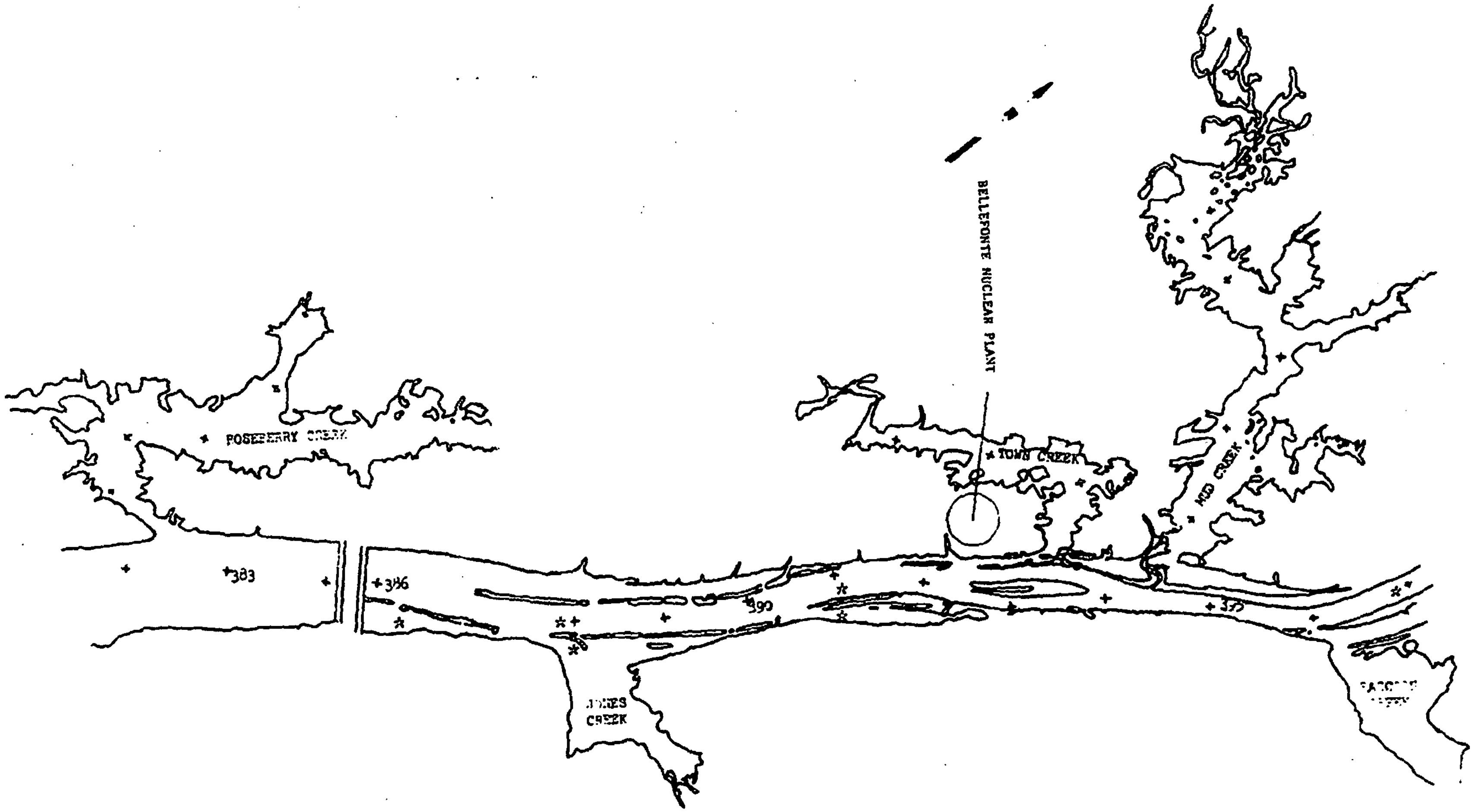
1. Short-term fluctuations ($\leq$one year) in the zooplankton assemblage (both in terms of occurrence and relative abundance) occur frequently near BLN.

2. Based on the occurrence of taxa, the three sample stations in the channel group were more similar than different.

3. Overbank stations showed a greater degree of variability with respect to total density and similarity indices (SQS and PS) than channel stations. This was probably due to a more "patchy" distribution of zooplankton in overbank areas, and less mixing enabling communities to develop in separate overbank areas.

4. Number of taxa present, species diversity, and total zooplankton densities were usually lower at the beginning (February) and end (October) of the sample year than in the summer season.

5. The most productive channel station (station 2) and overbank station (station 6) are nearest the BLN diffuser, whereas the least productive station (station 3) represents the upstream "control".



* - Plankton Stations

Figure 5-1. Location of Plankton Stations for the Preoperational Monitoring Program in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir.

CHANNEL - 1974

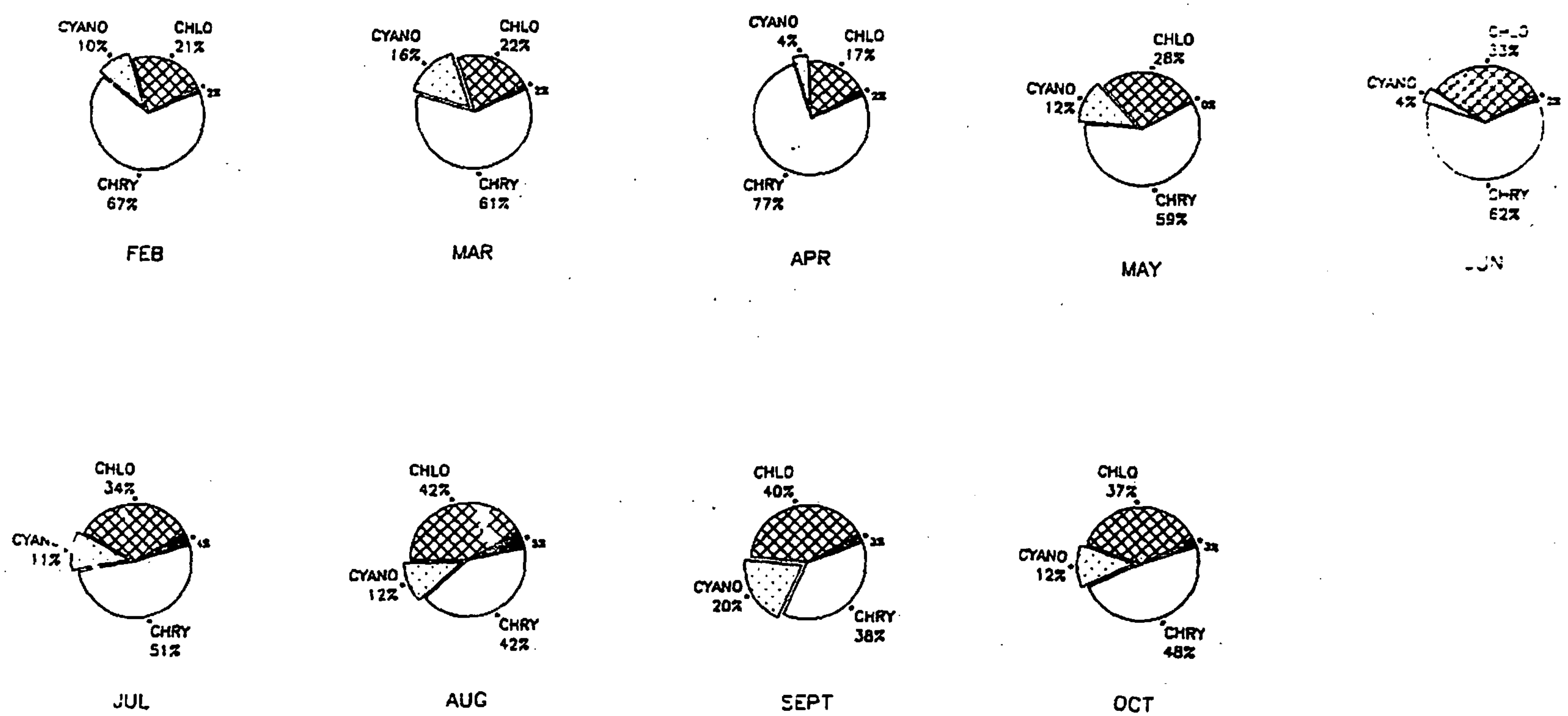


Figure 5-2. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1974.

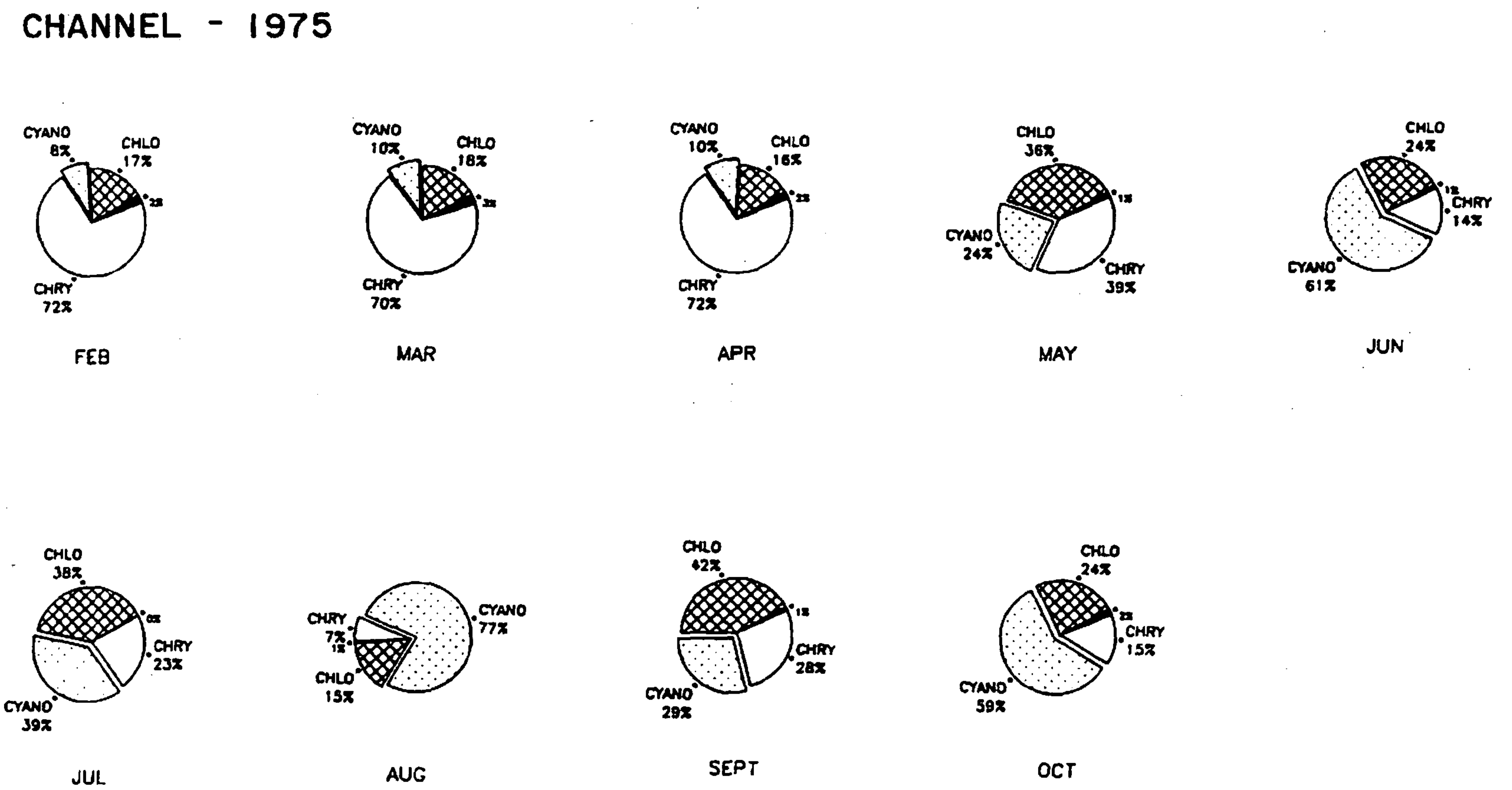


Figure 5-3. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1975.

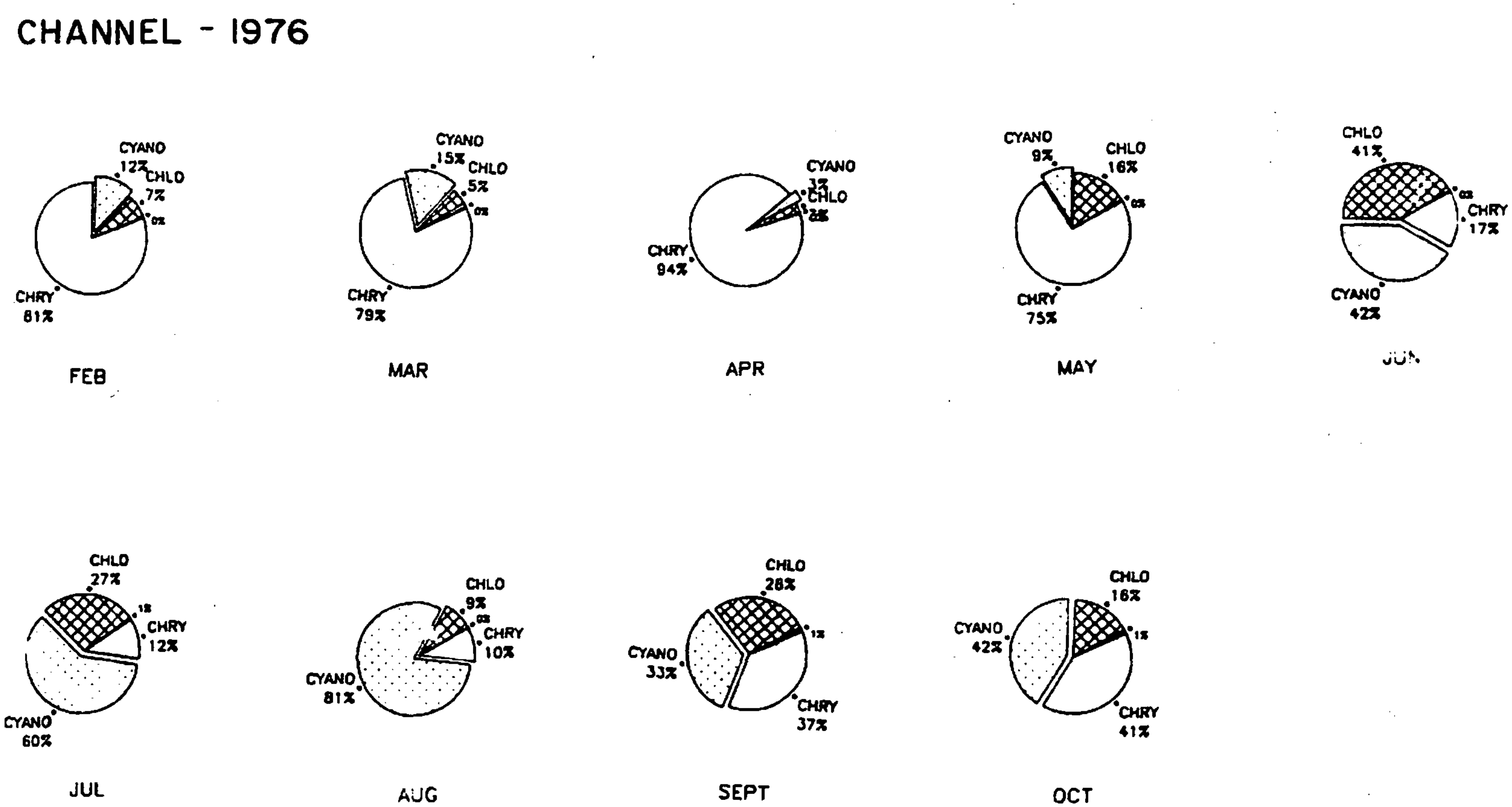


Figure 5-4. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1976.

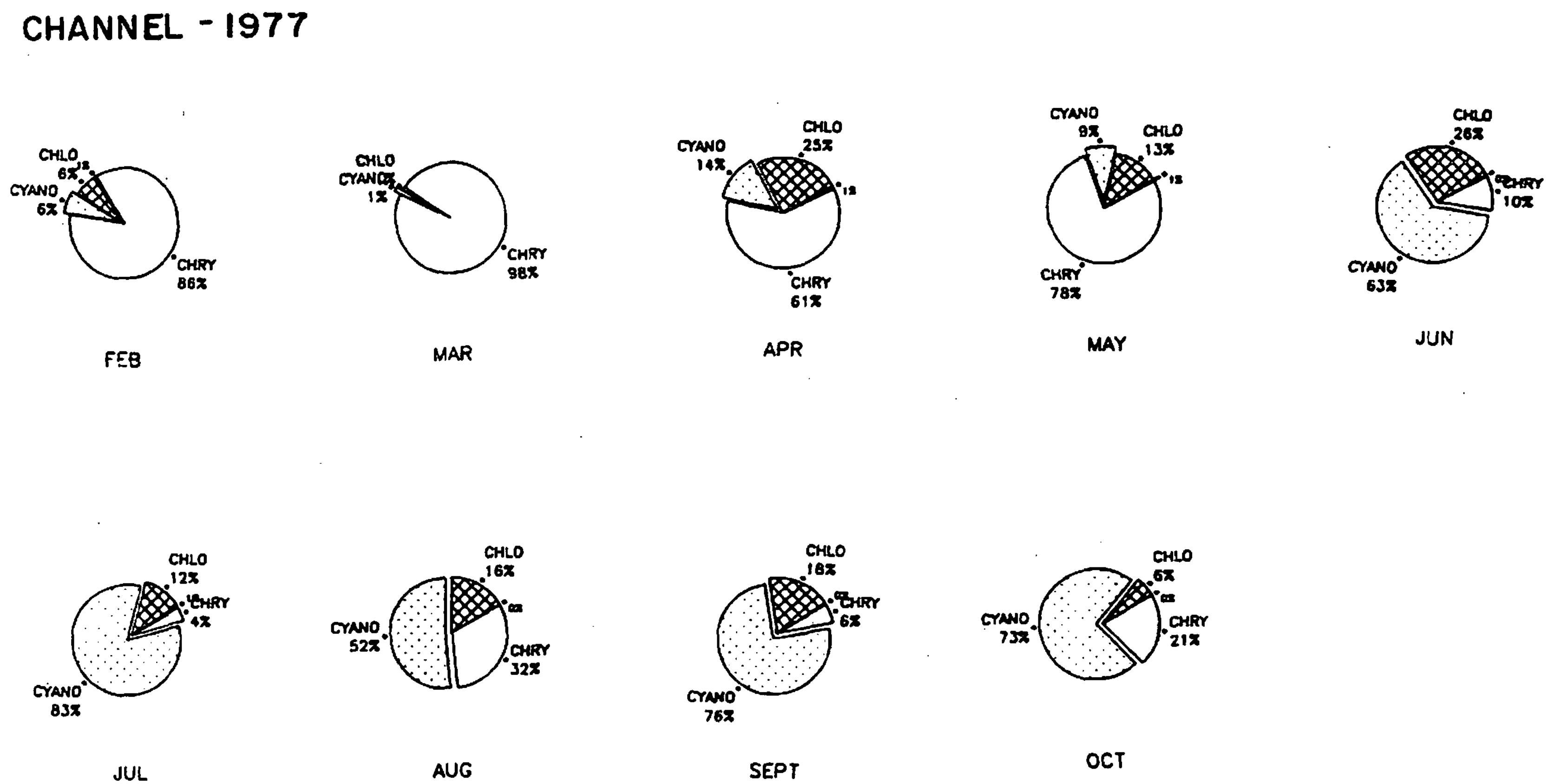


Figure 5-5. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1977.

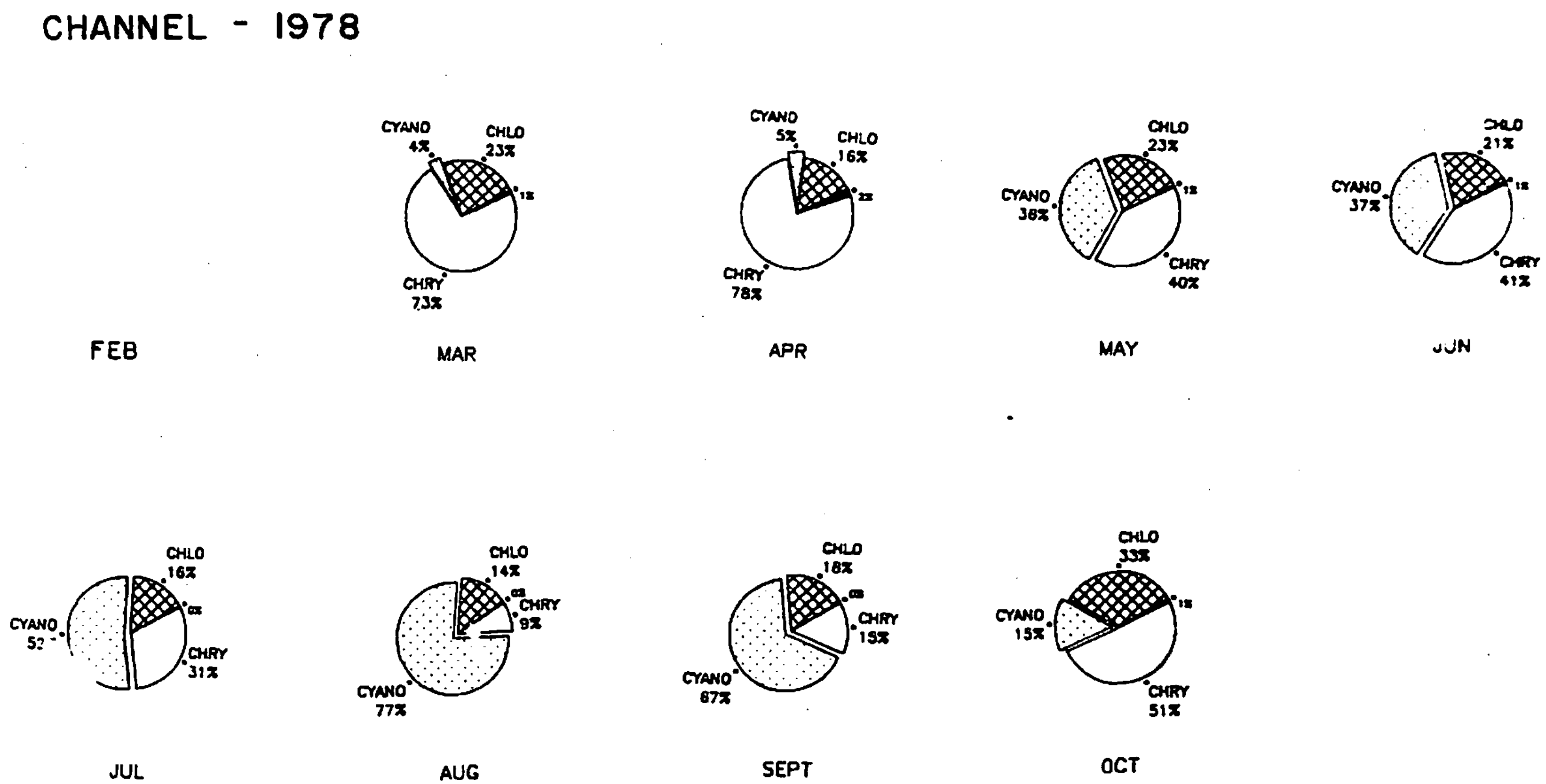


Figure 5-6. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1978.

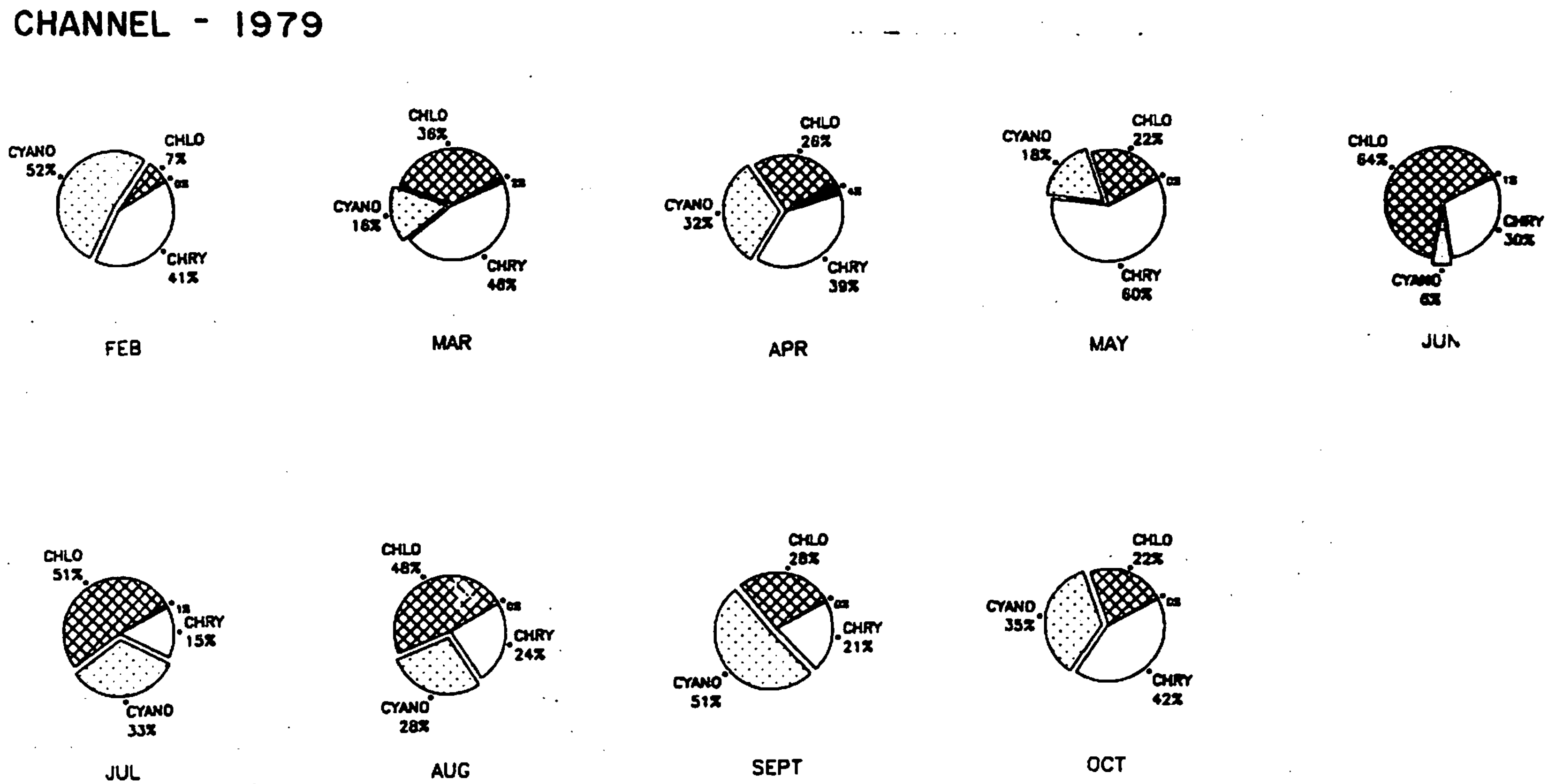


Figure 5-7. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1979.

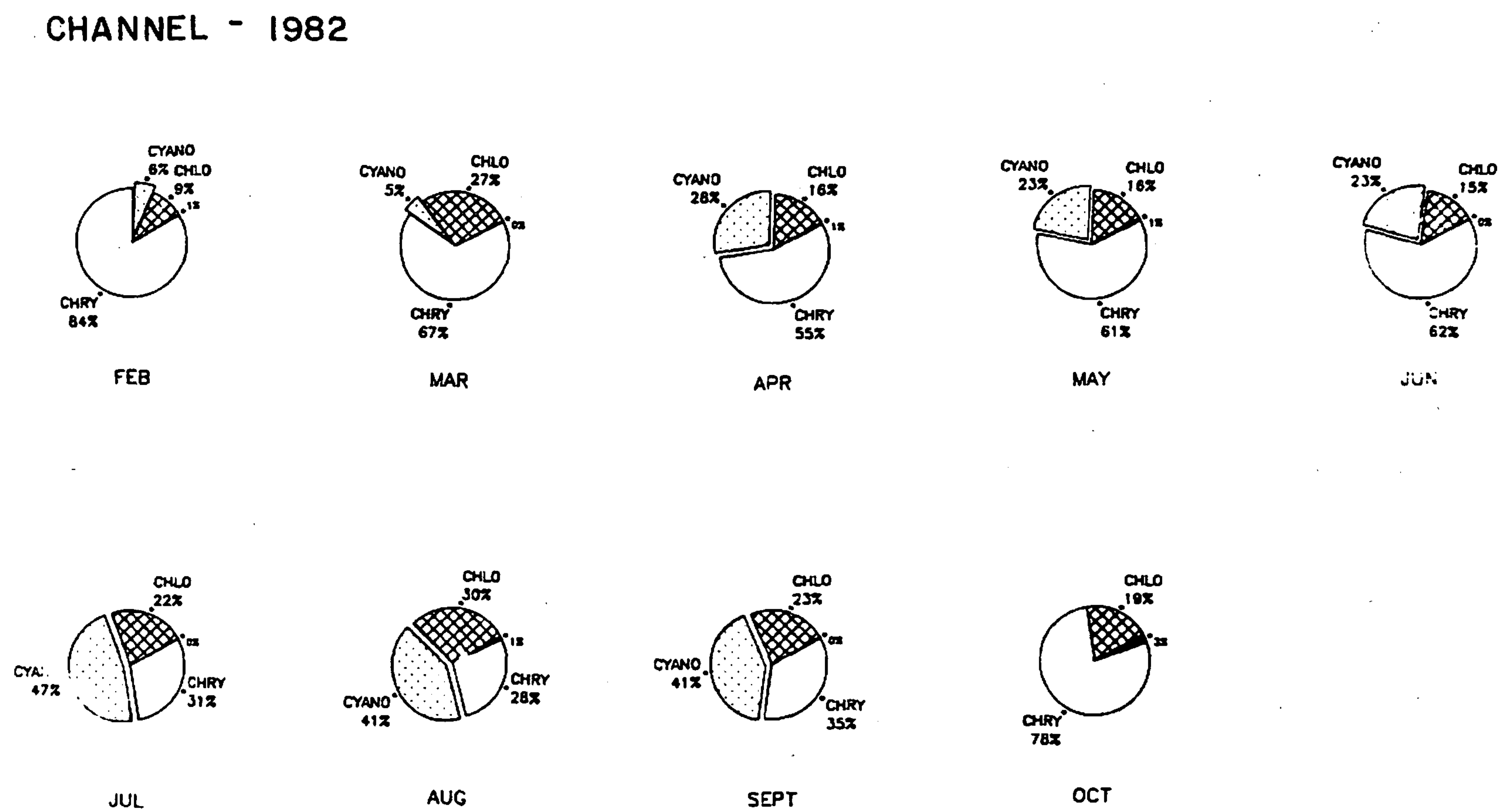


Figure 5-8. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1982.

CHANNEL - 1983

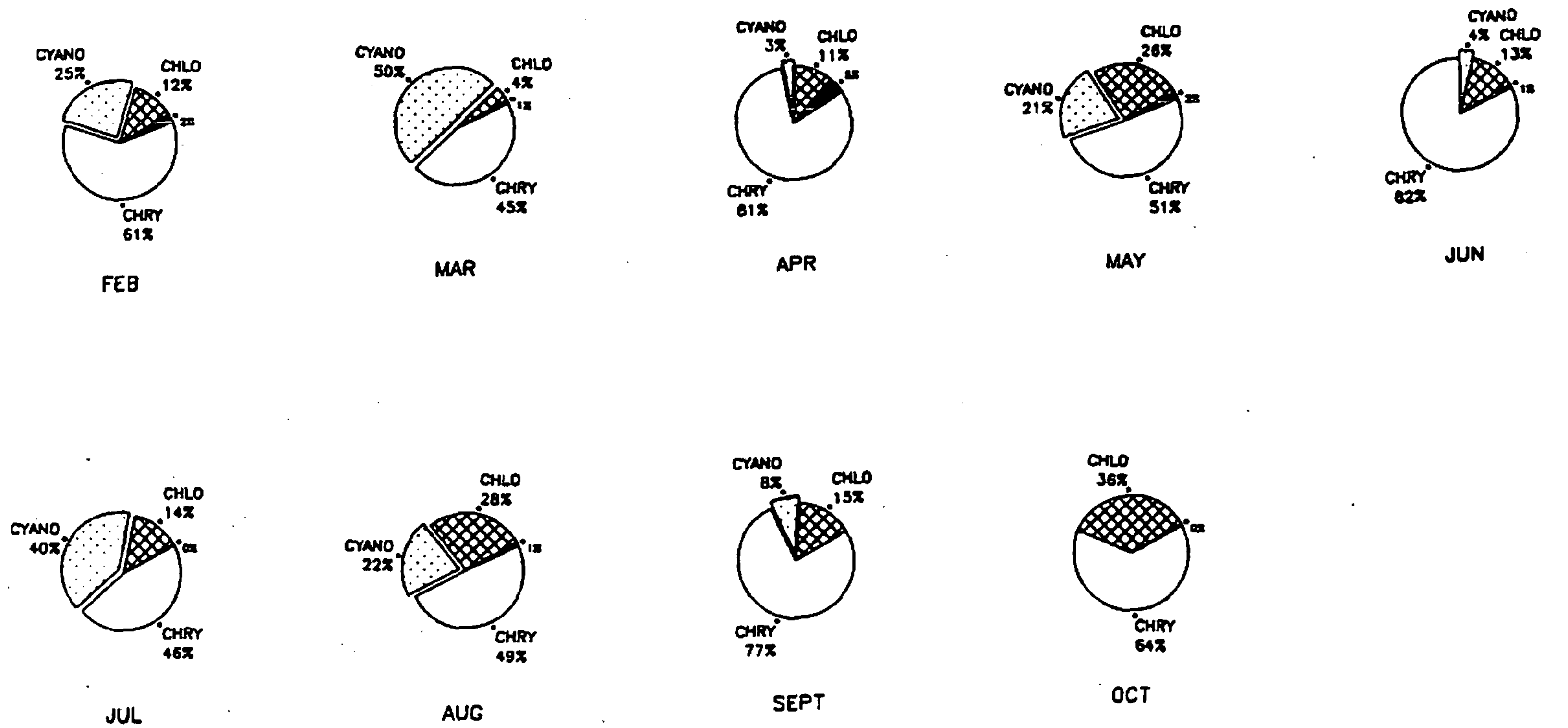


Figure 5-9. Monthly Succession of Major Phytoplankton Groups from the Mainstream Channel Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1983.

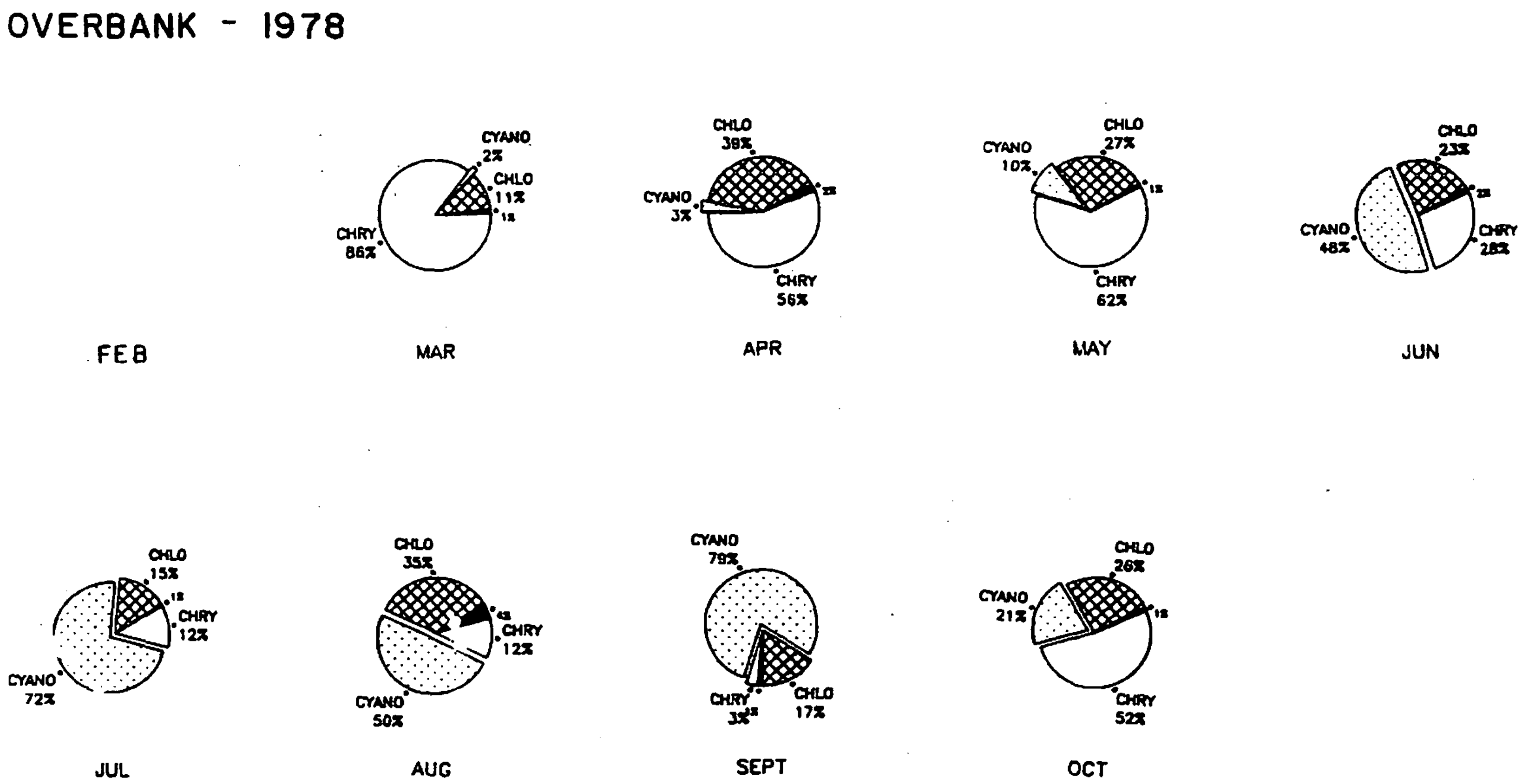


Figure 5-10. Monthly Succession of Major Phytoplankton Groups from the Left Overbank Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1978.

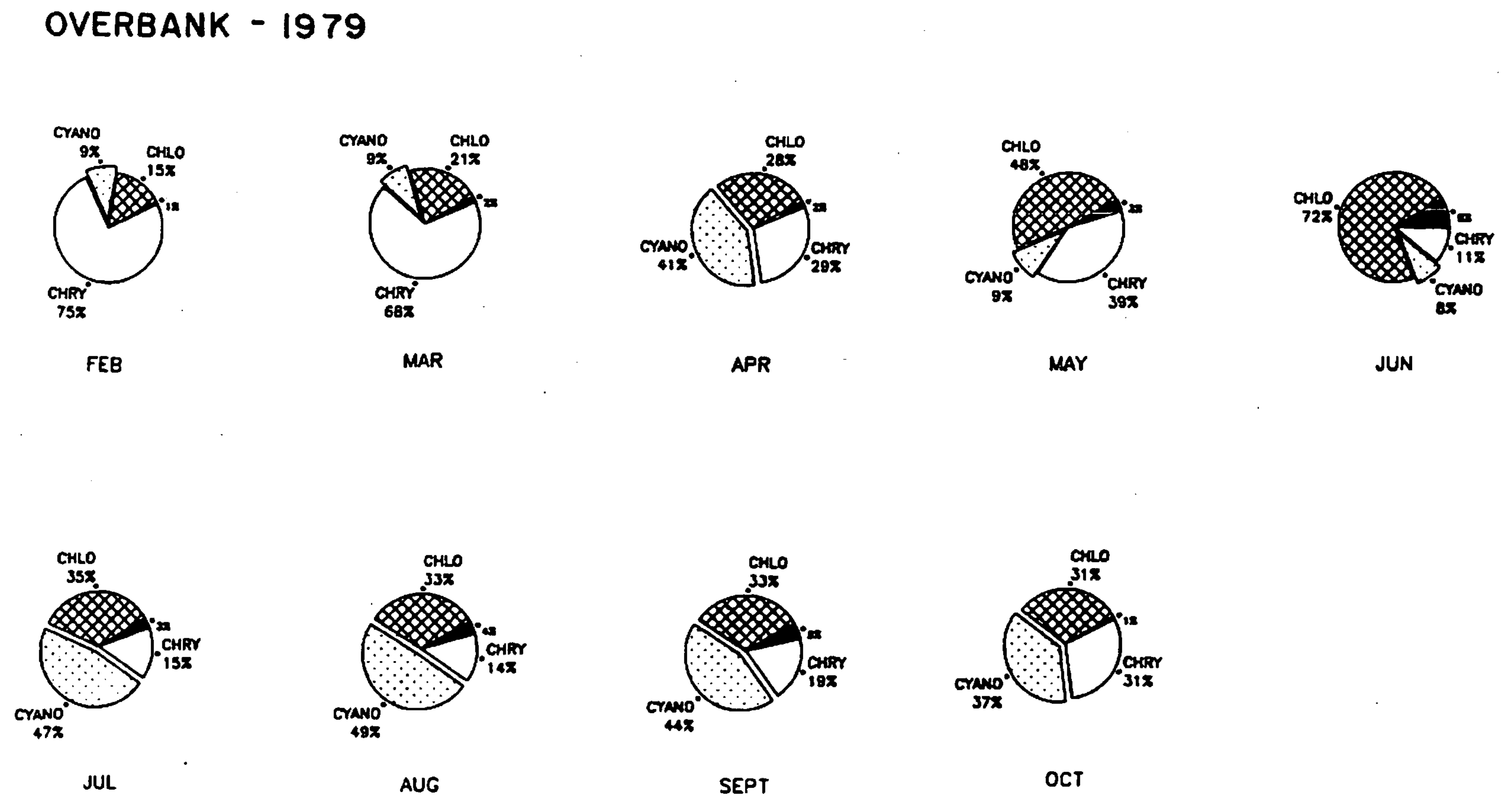


Figure 5-11. Monthly Succession of Major Phytoplankton Groups from the Left Overbank Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1979.

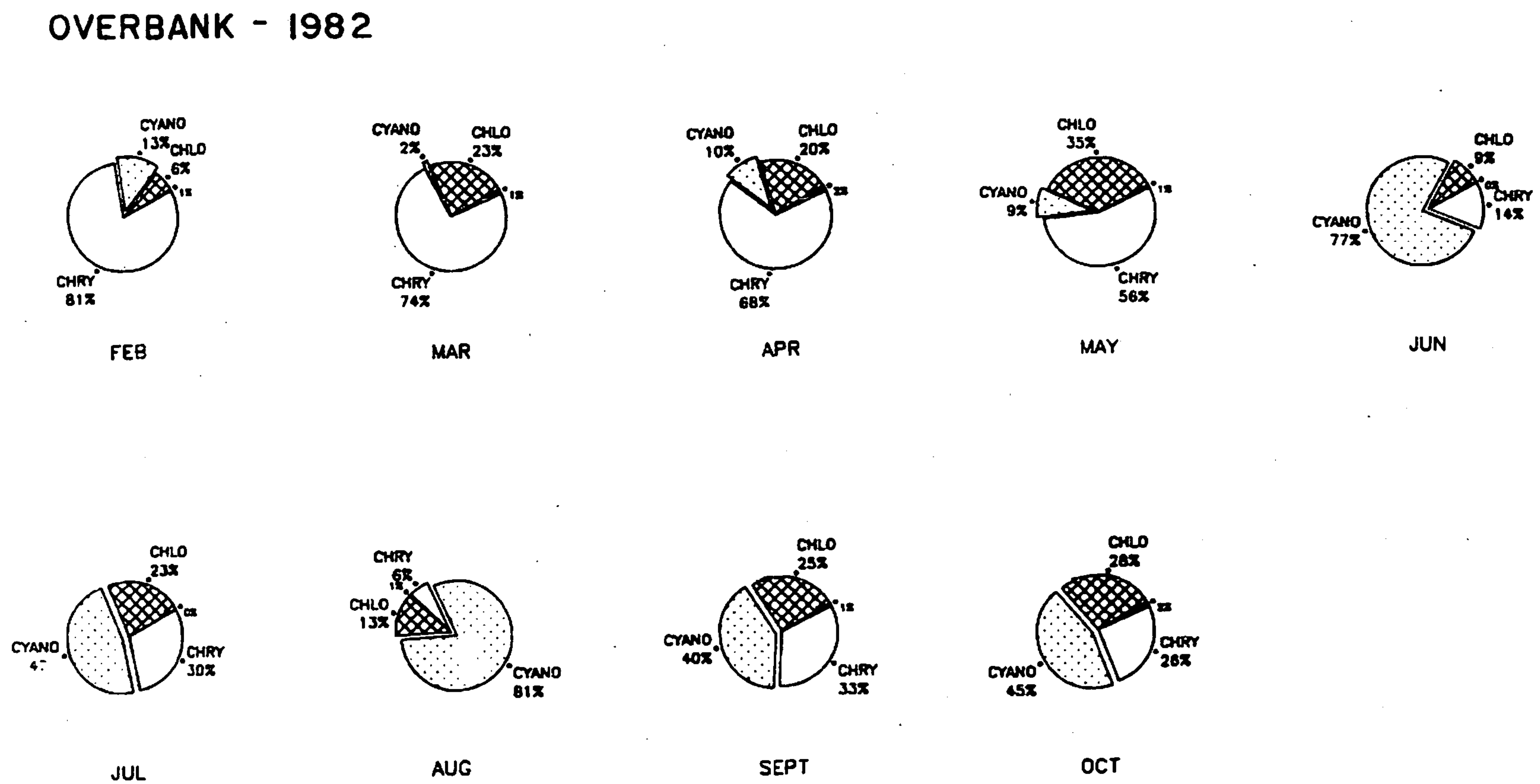


Figure 5-12. Monthly Succession of Major Phytoplankton Groups from the Left Overbank Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1982.

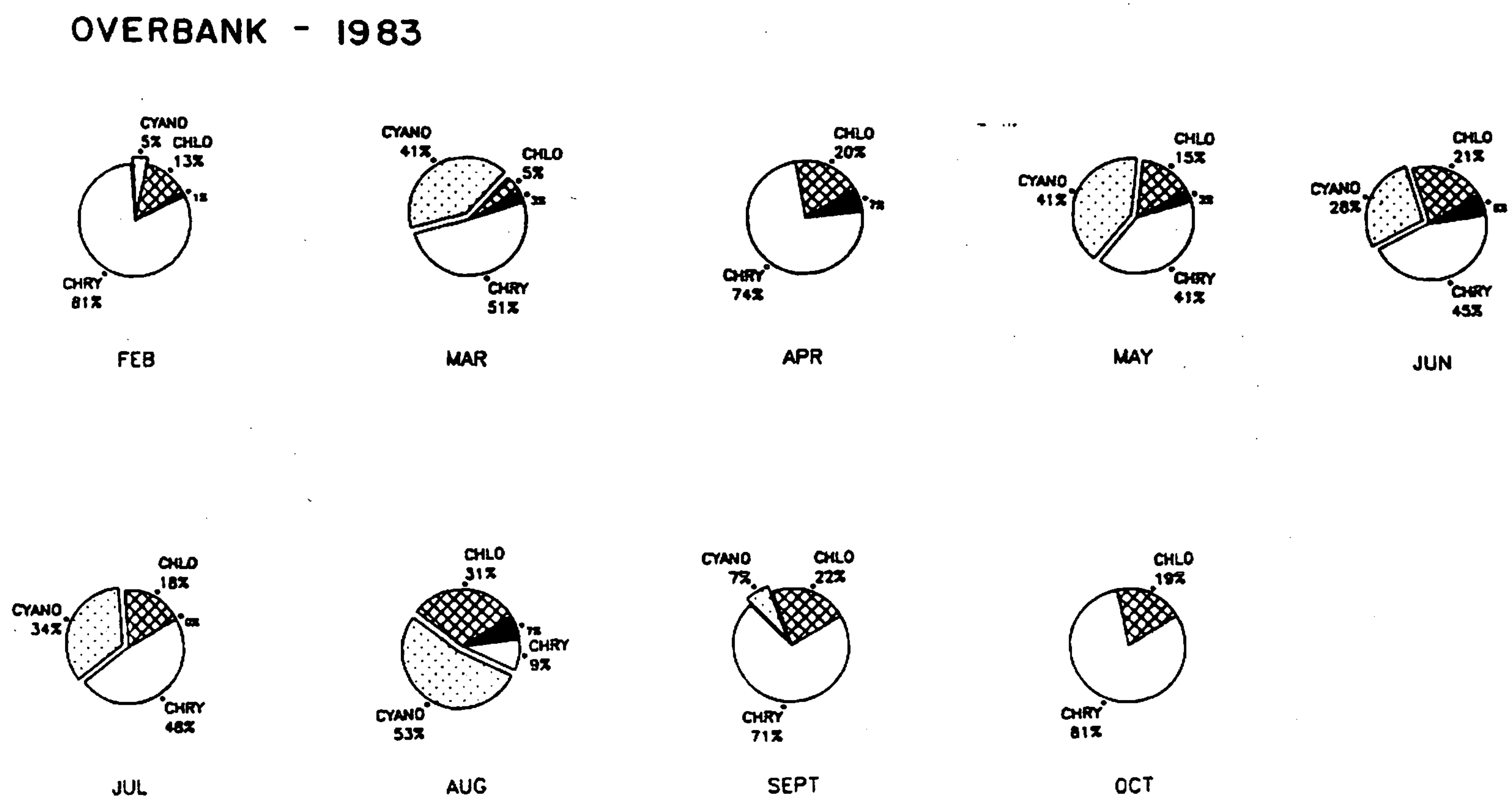


Figure 5-13. Monthly Succession of Major Phytoplankton Groups from the Left Overbank Habitat near Bellefonte Nuclear Plant, Guntersville Reservoir, 1983.

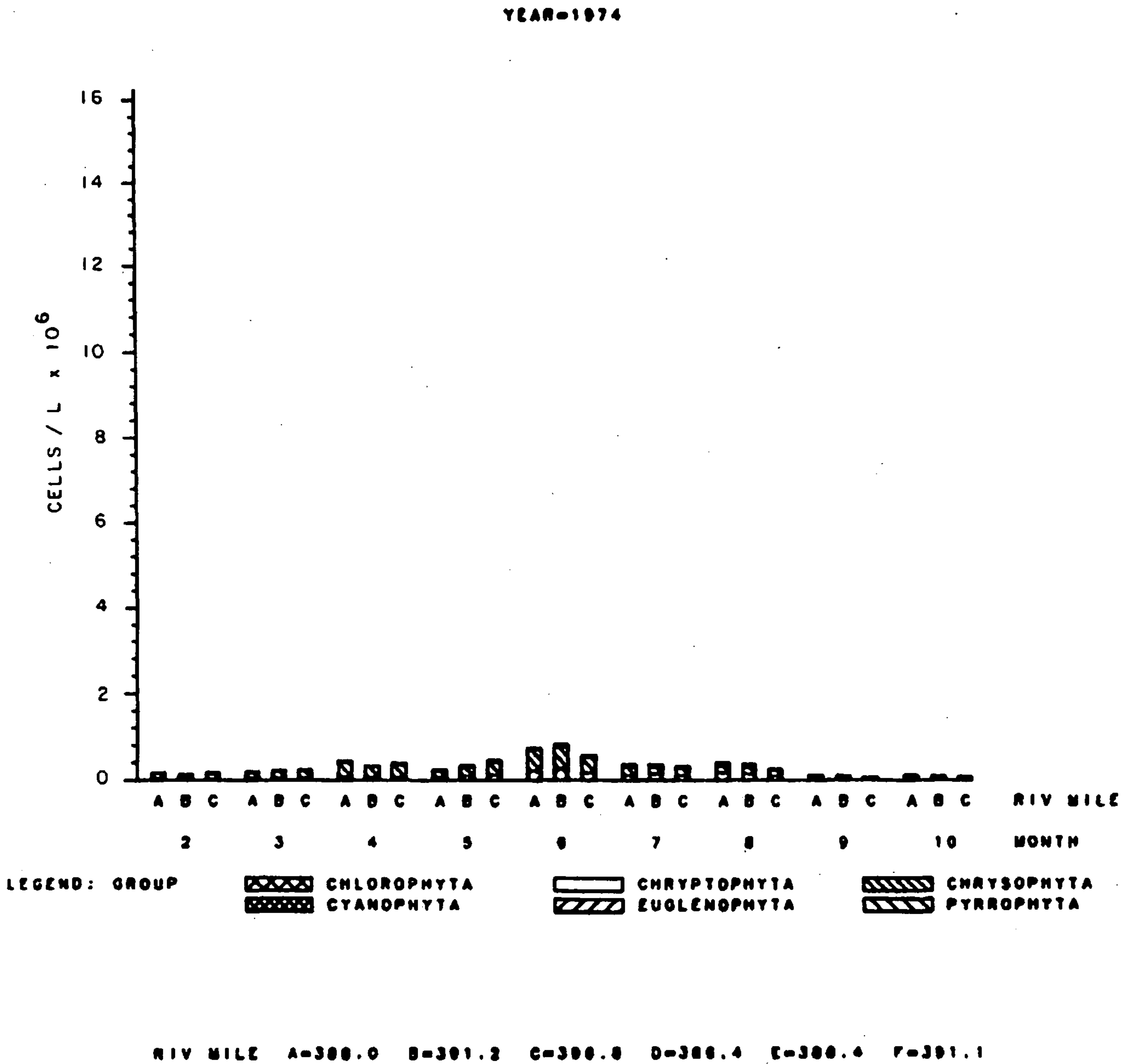


Figure 5-14. Abundance of Phytoplankton by Group for each Mainstream Channel Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1974.

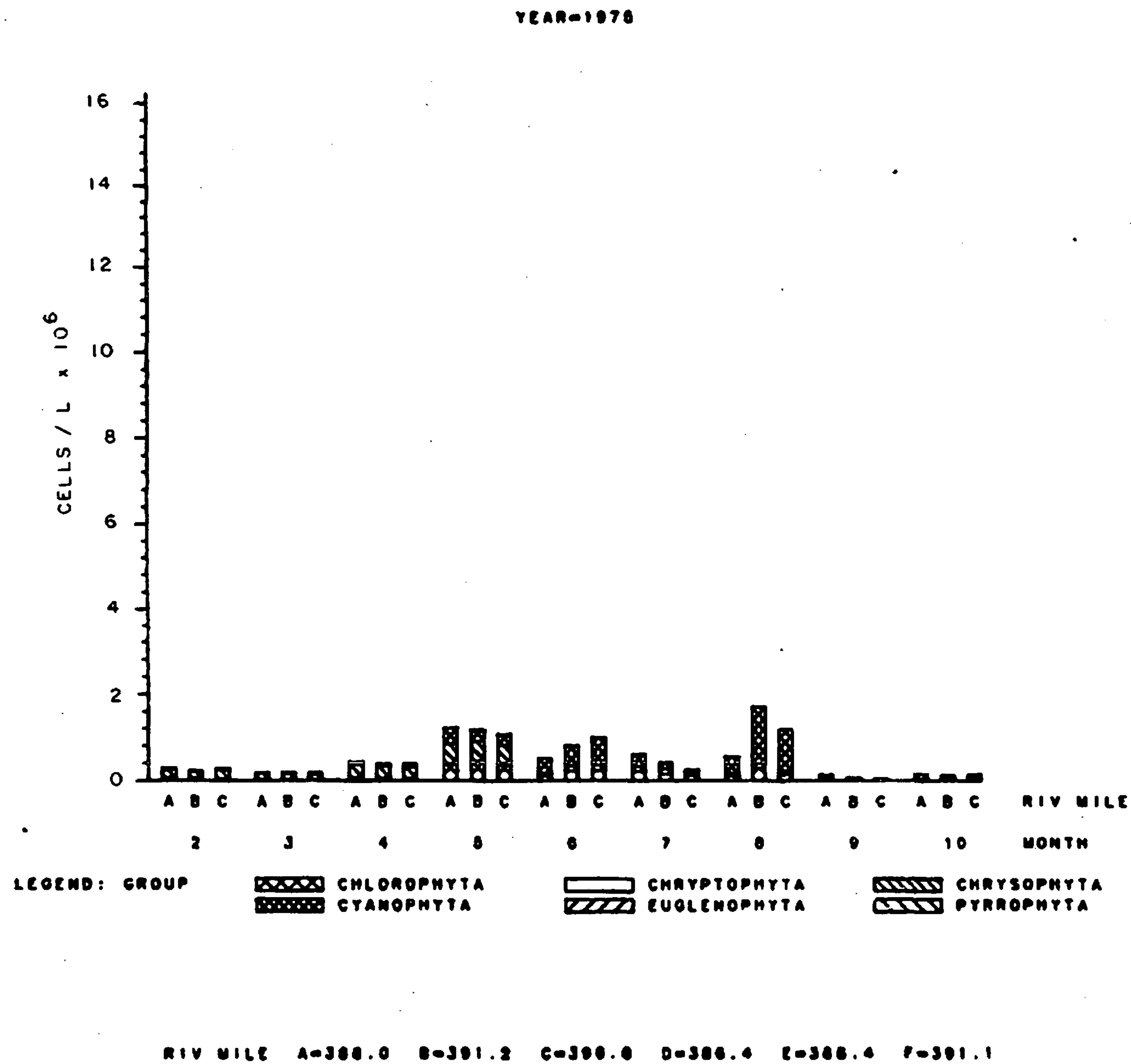


Figure 5-15. Abundance of Phytoplankton by Group for each Mainstream Channel Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1975.

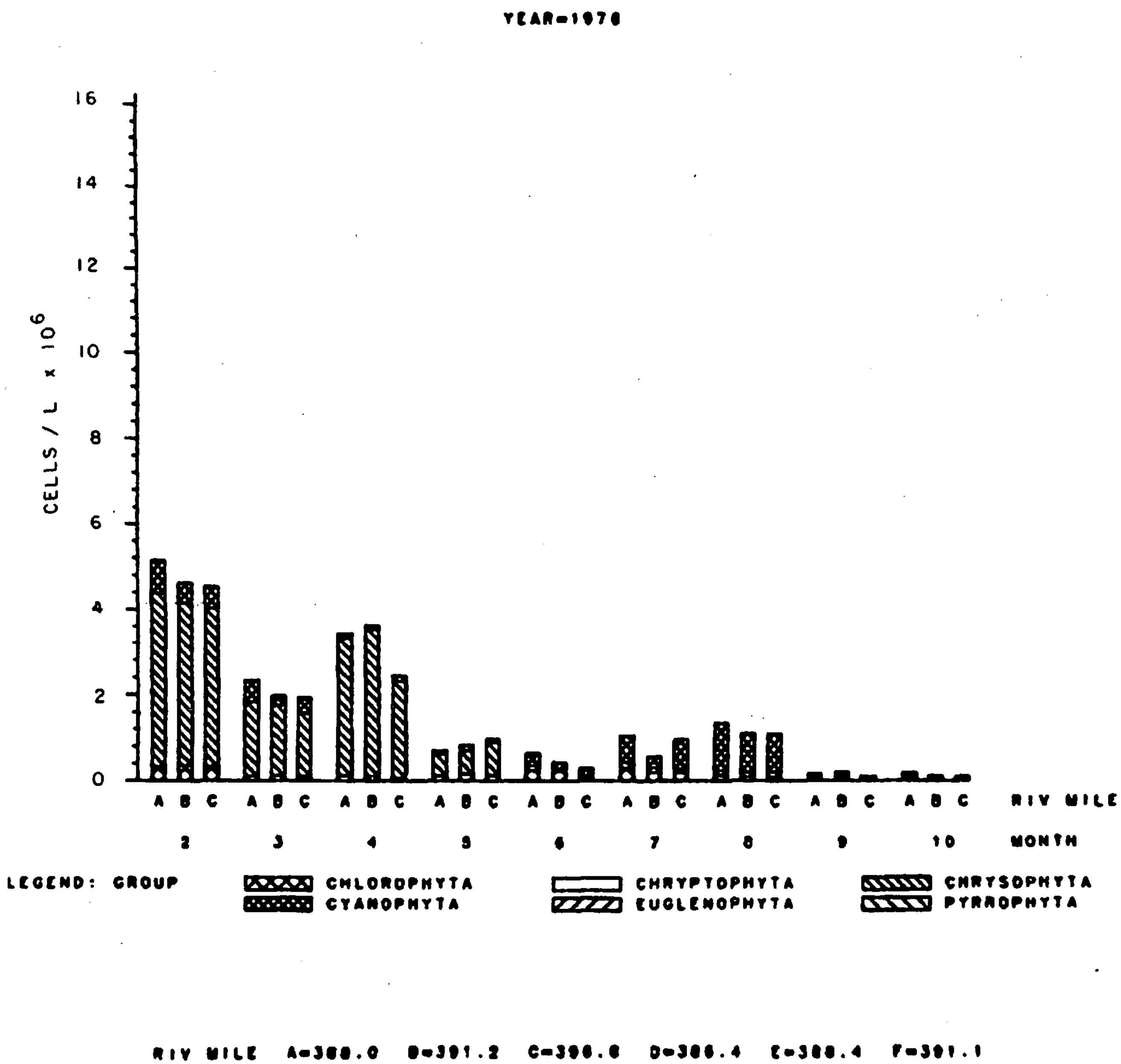


Figure 5-16. Abundance of Phytoplankton by Group for each Mainstream Channel Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1976.

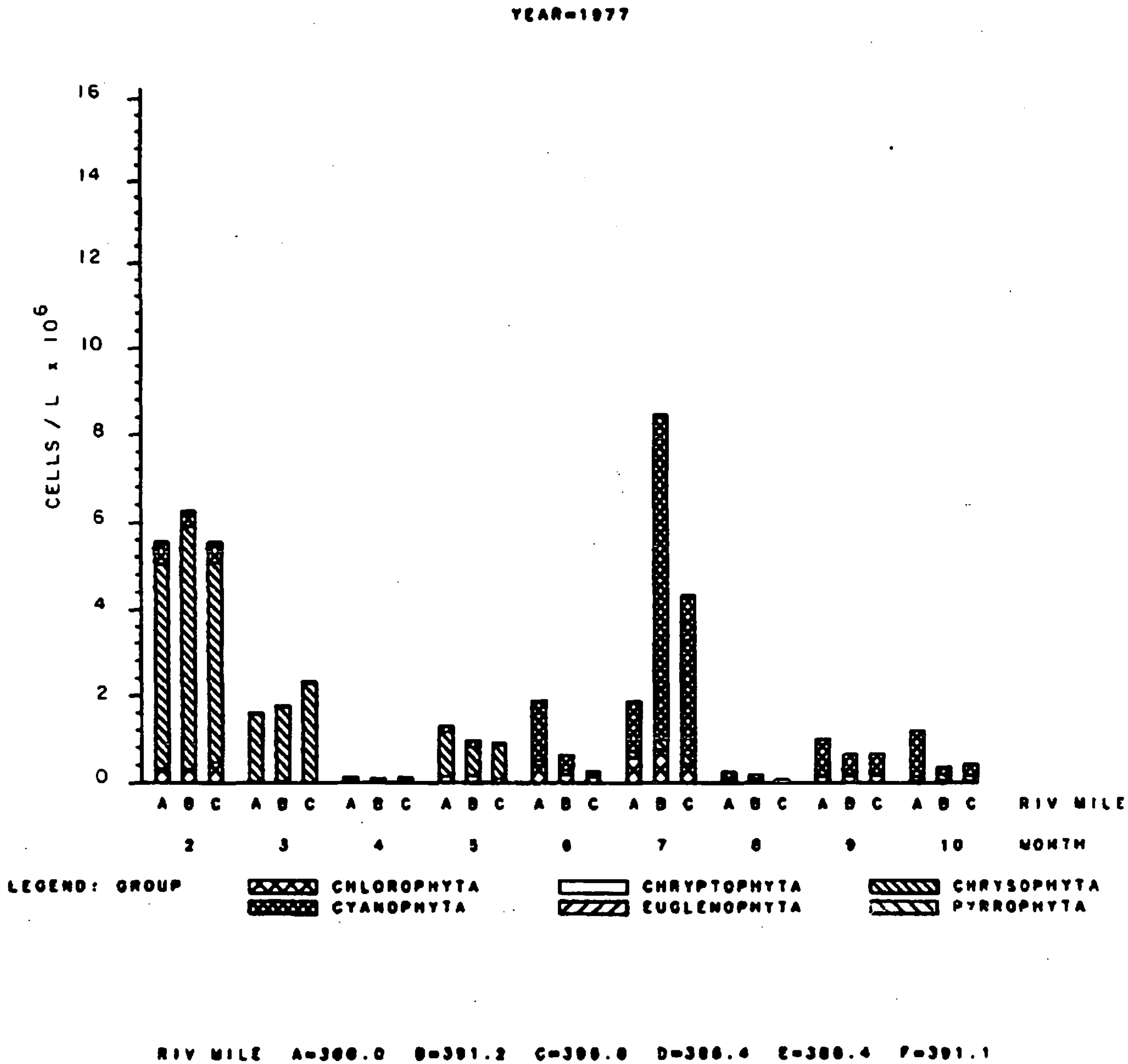
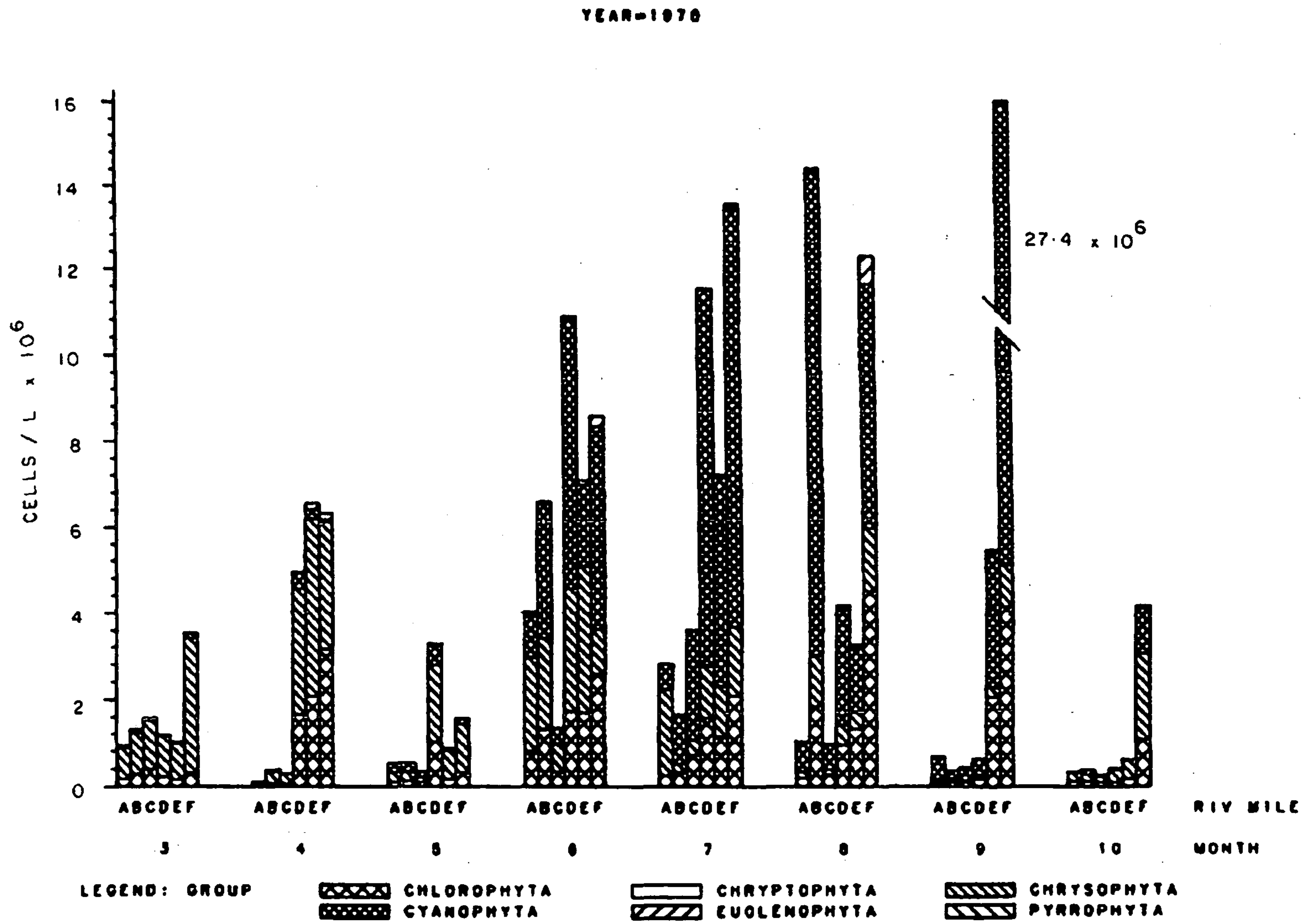


Figure 5-17. Abundance of Phytoplankton by Group for each Mainstream Channel Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1977.



RIV MILE A=388.0 B=391.2 C=390.8 D=388.4 E=388.4 F=391.1

Figure 5-18. Abundance of Phytoplankton by Group for each Mainstream Channel and Left Overbank Station near Bellefonte Nuclear Plant, Guntersville Reservoir, March through October, 1978.

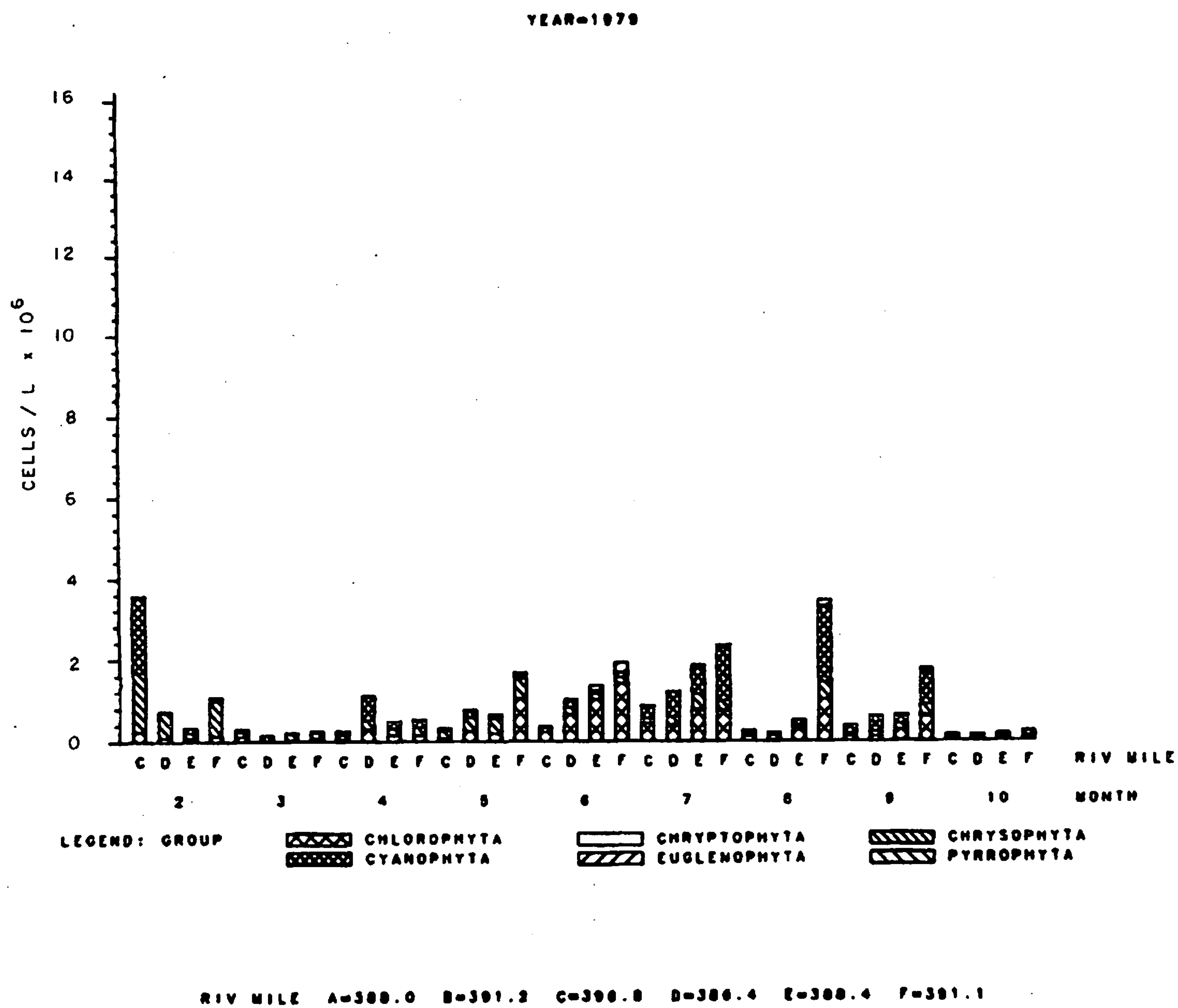


Figure 5-19. Abundance of Phytoplankton by Group for each Mainstream Channel and Left Overbank Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1979.

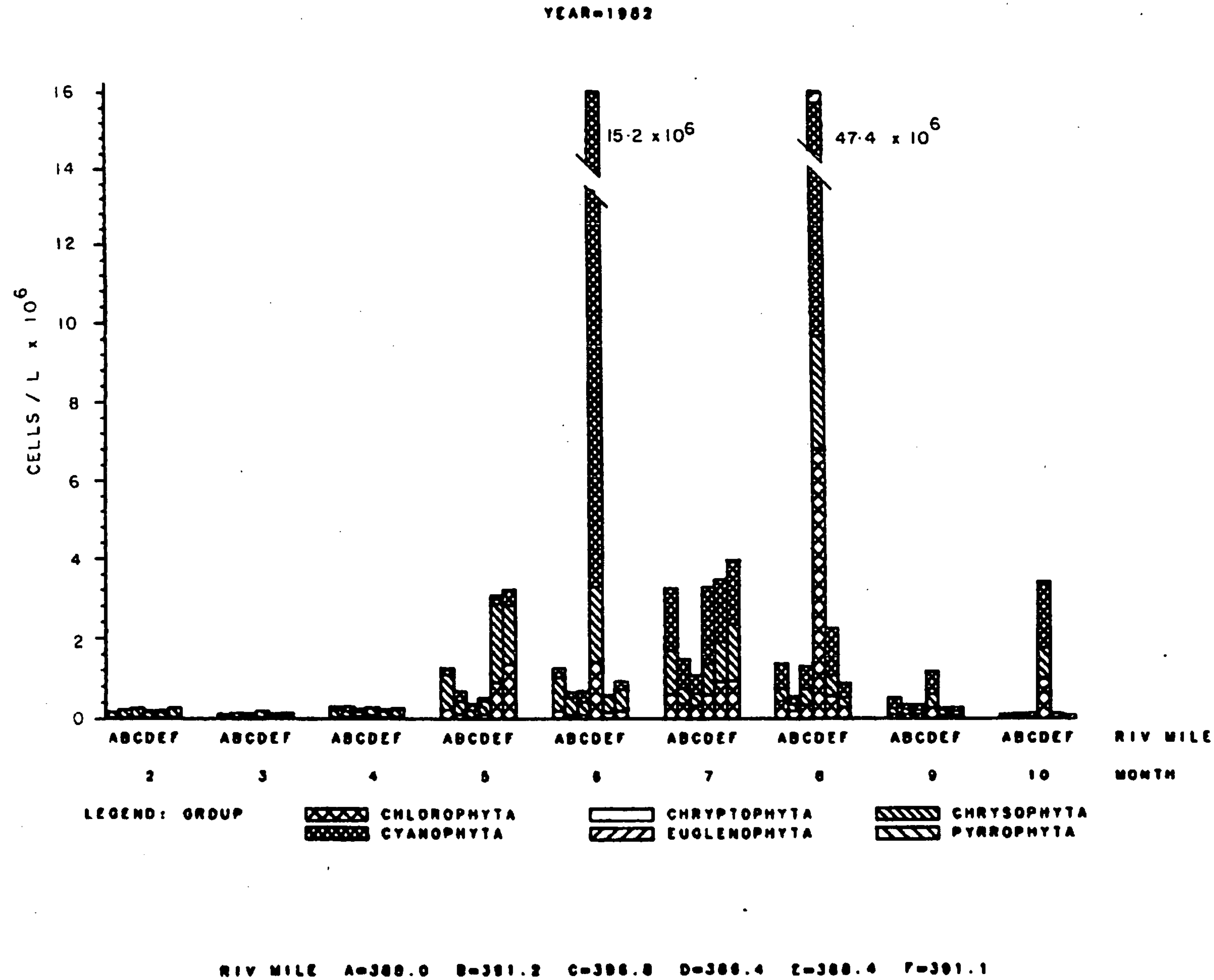


Figure 5-20. Abundance of Phytoplankton by Group for each Mainstream Channel and Left Overbank Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1982.

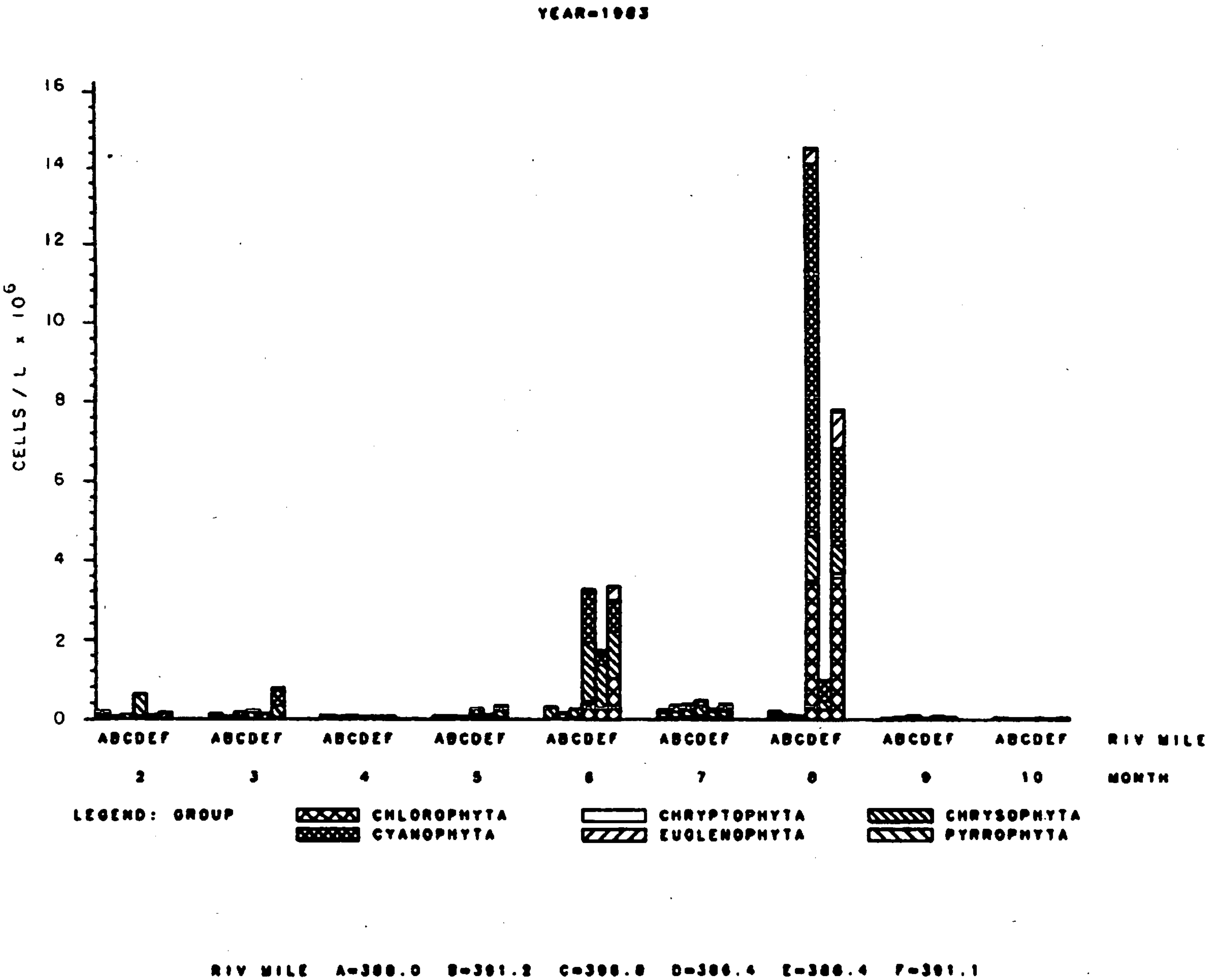


Figure 5-21. Abundance of Phytoplankton by Group for each Mainstream Channel and Left Overbank Station near Bellefonte Nuclear Plant, Guntersville Reservoir, February through October, 1983.

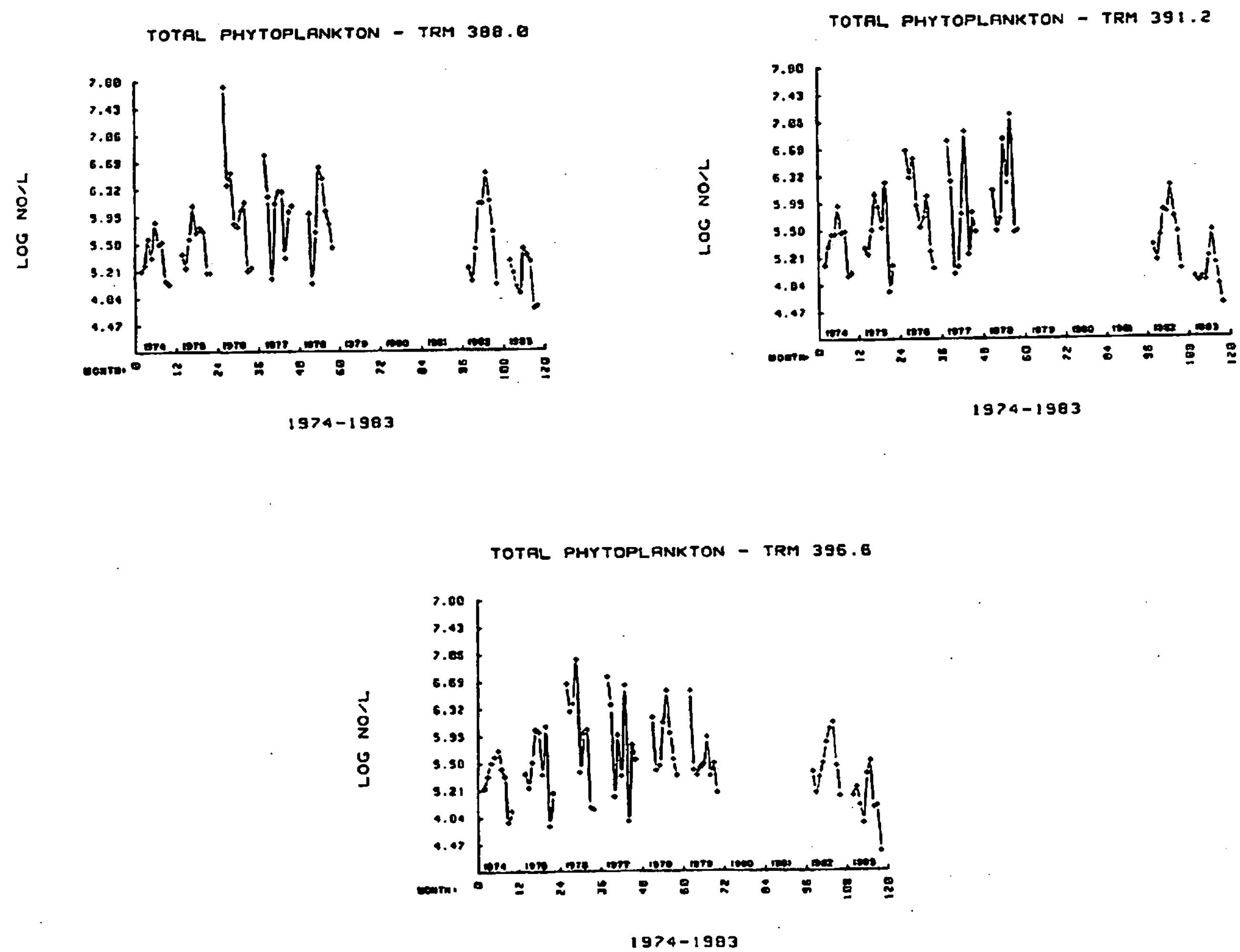


Figure 5-22. Total Phytoplankton Abundance at Mainstream Channel Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

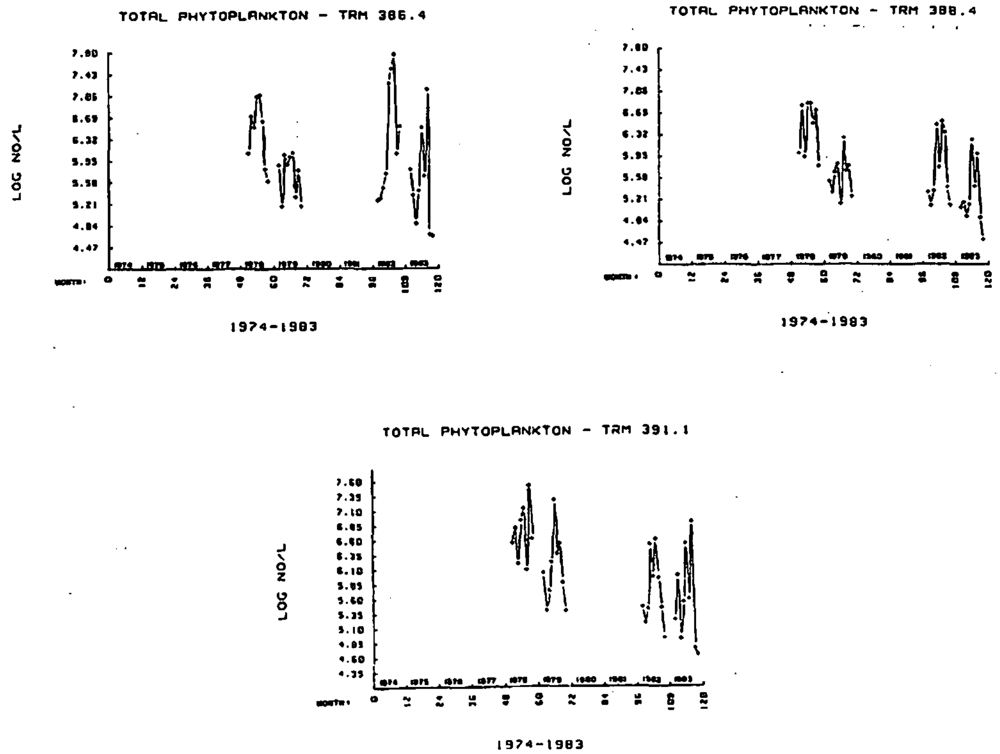


Figure 5-23. Total Phytoplankton Abundance at Left Overbank Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

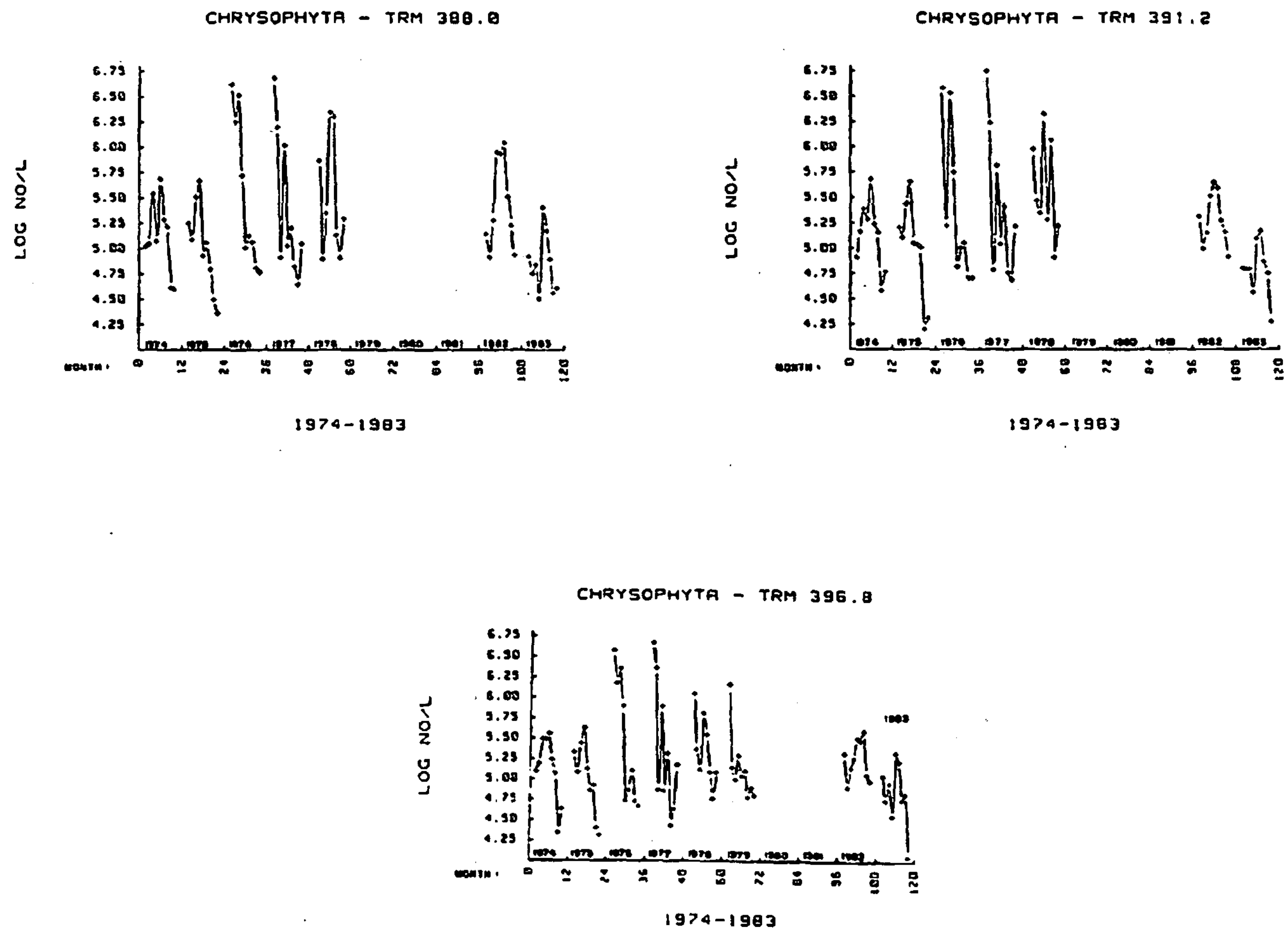


Figure 5-24. Abundance of Chrysophyta at Mainstream Channel Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

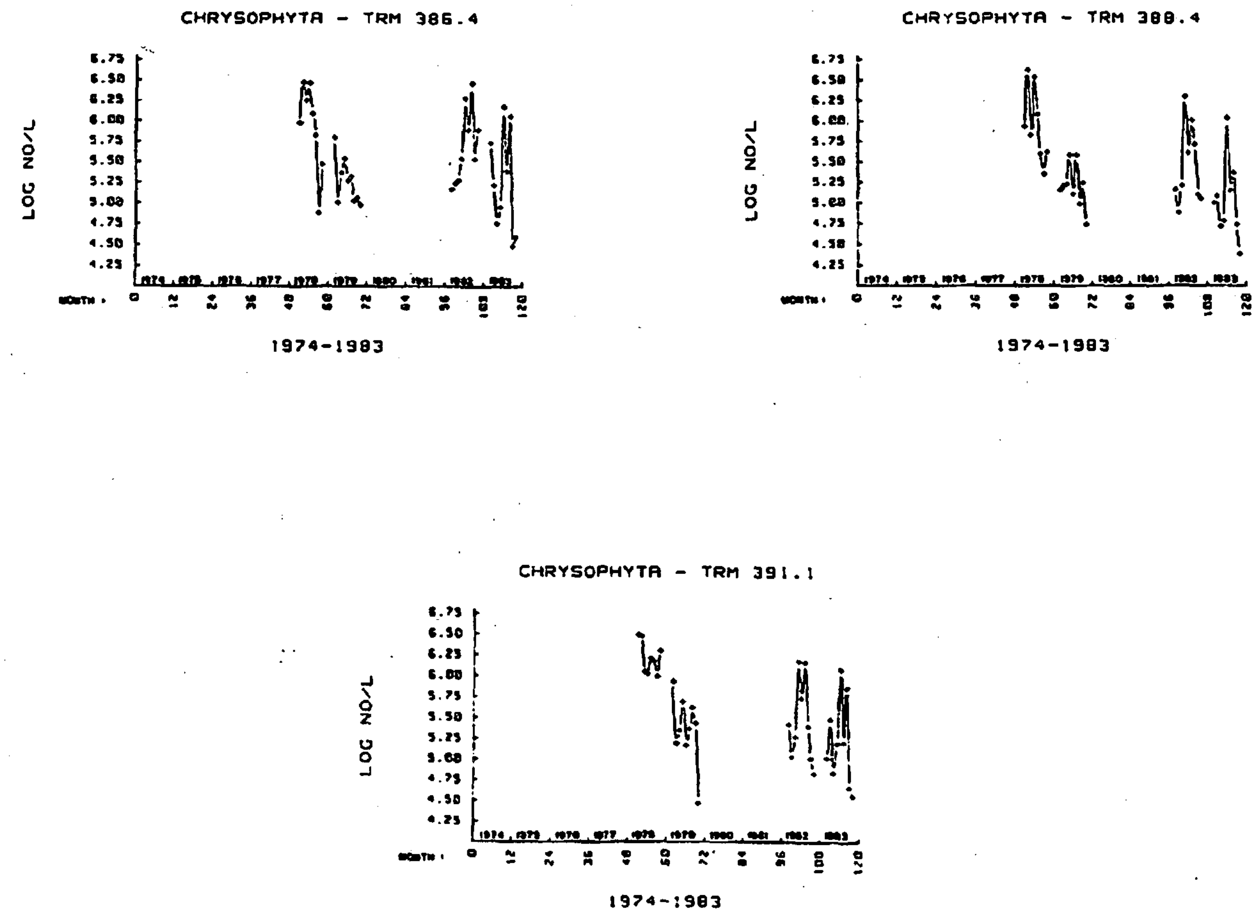


Figure 5-25. Abundance of Chrysophyta at Left Overbank Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

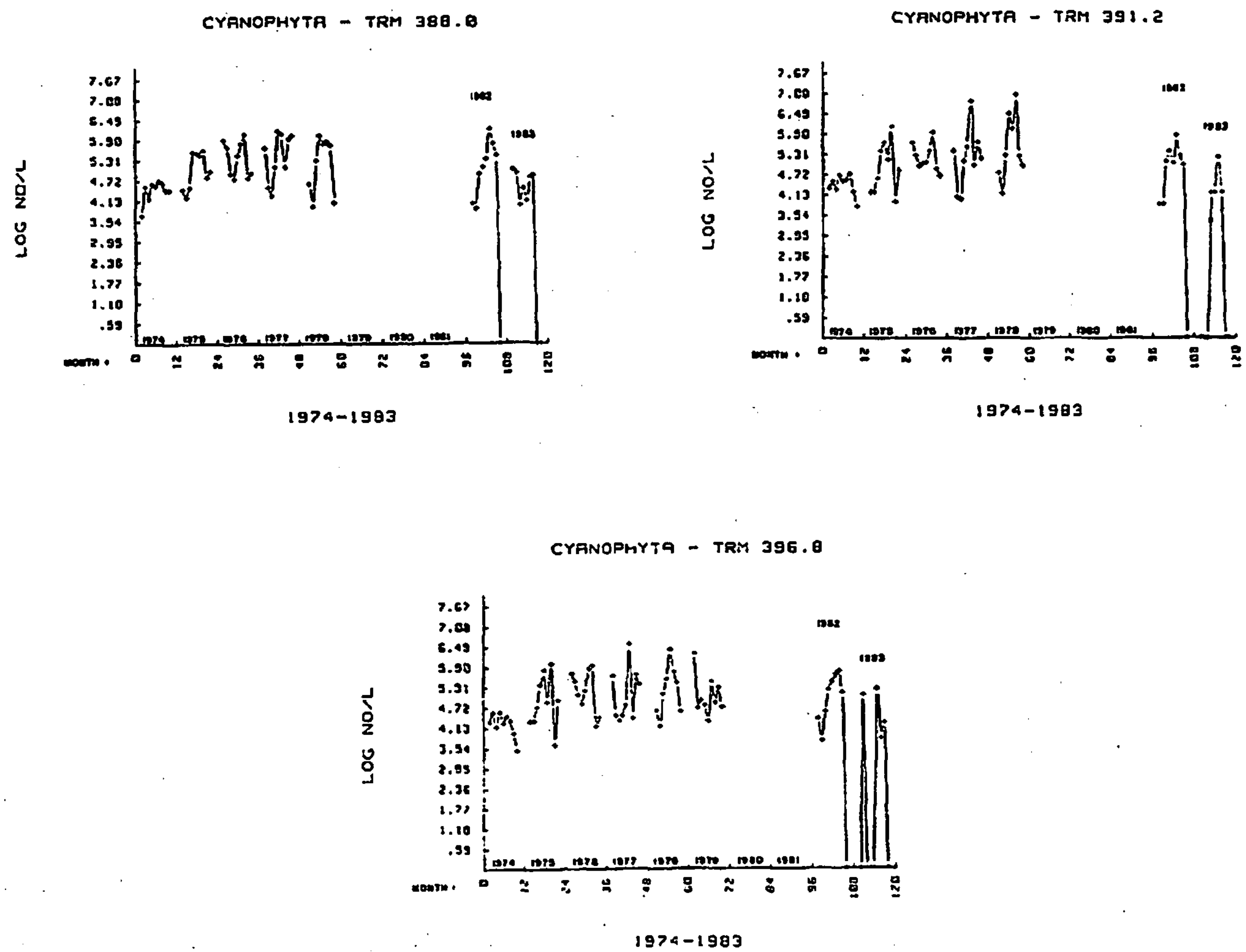


Figure 5-26. Abundance of Cyanophyta at Mainstream Channel Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

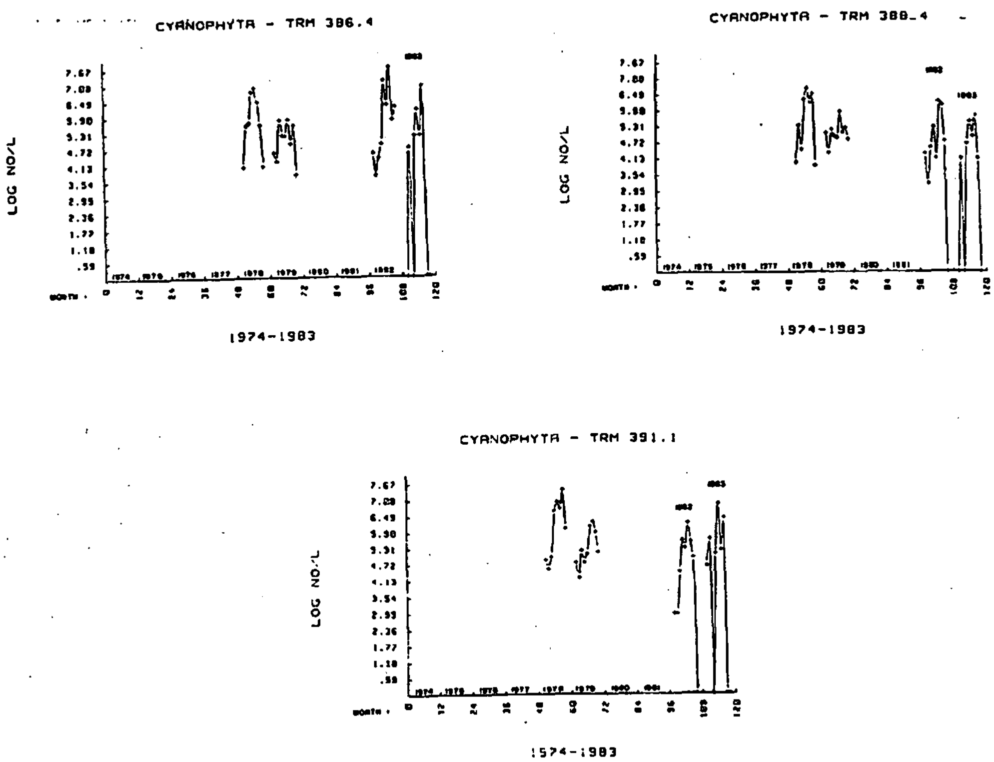


Figure 5-27. Abundance of Cyanophyta at Left Overbank Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

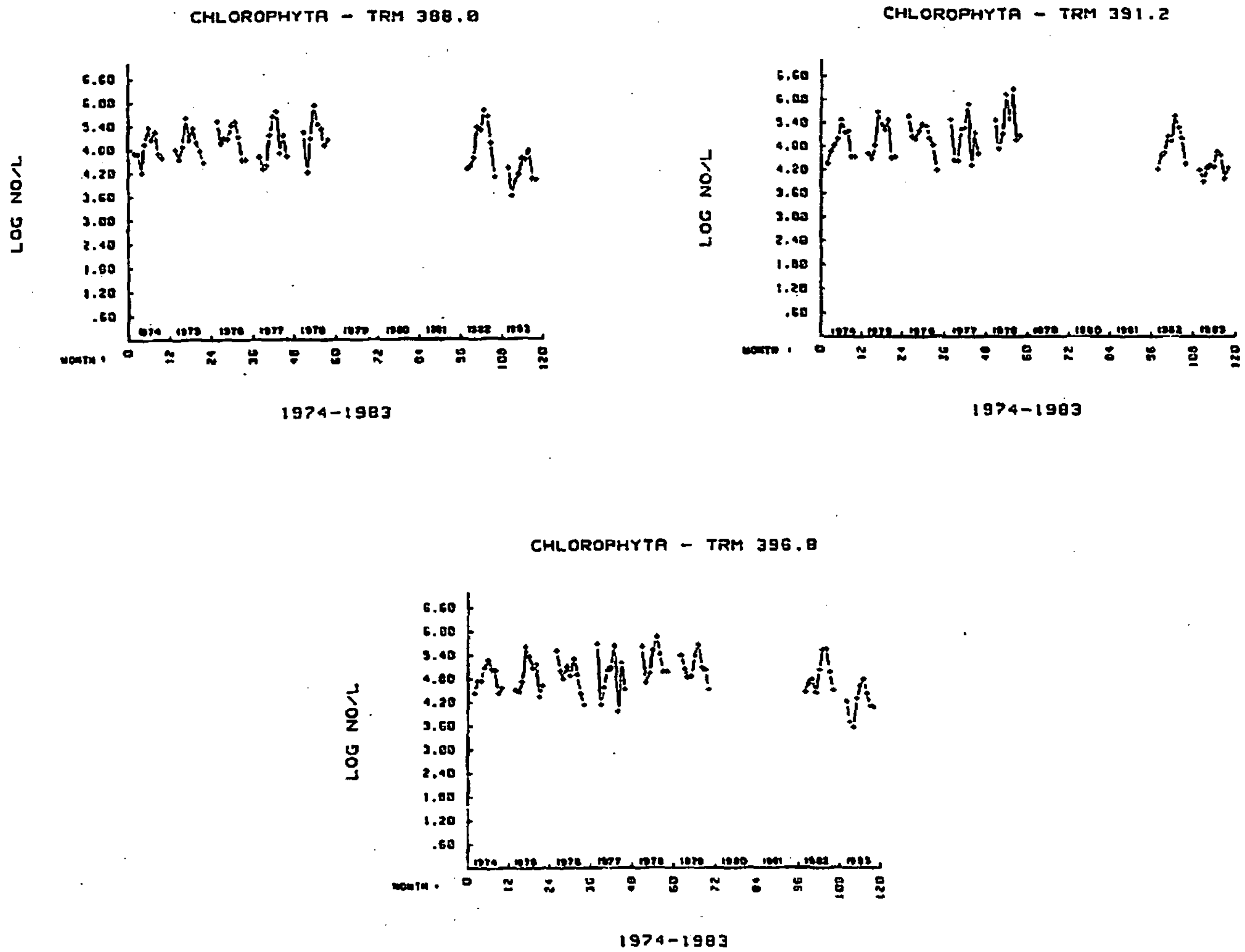


Figure 5-28. Abundance of Chlorophyta at Mainstream Channel Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

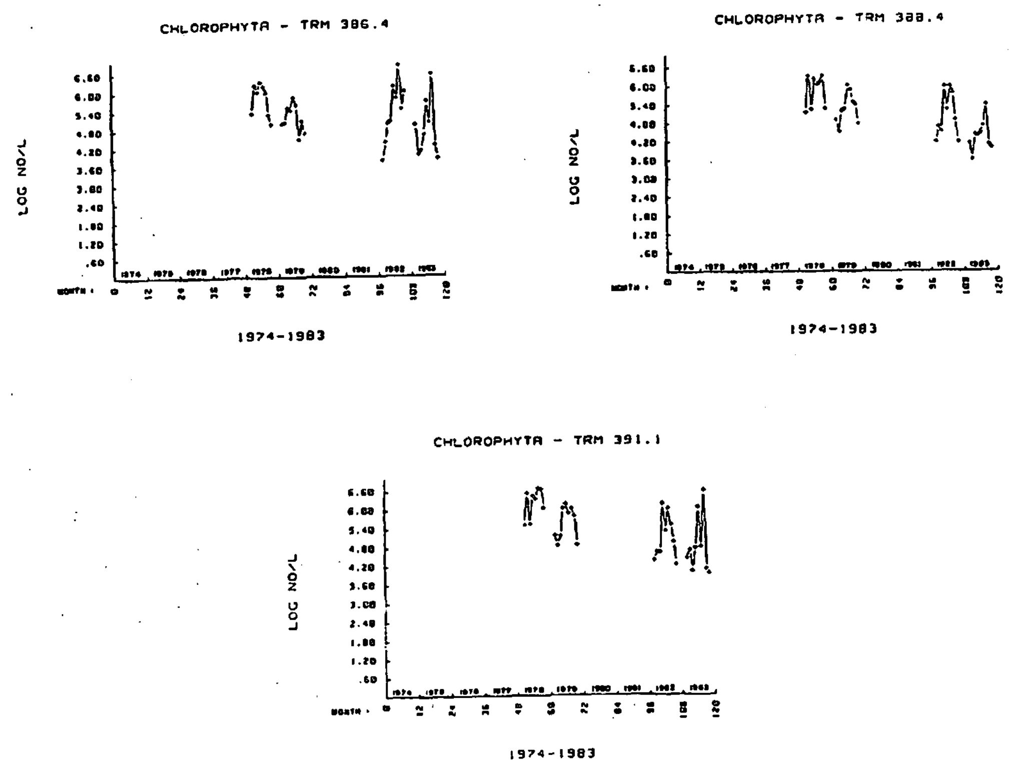


Figure 5-29. Abundance of Chlorophyta at Left Overbank Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

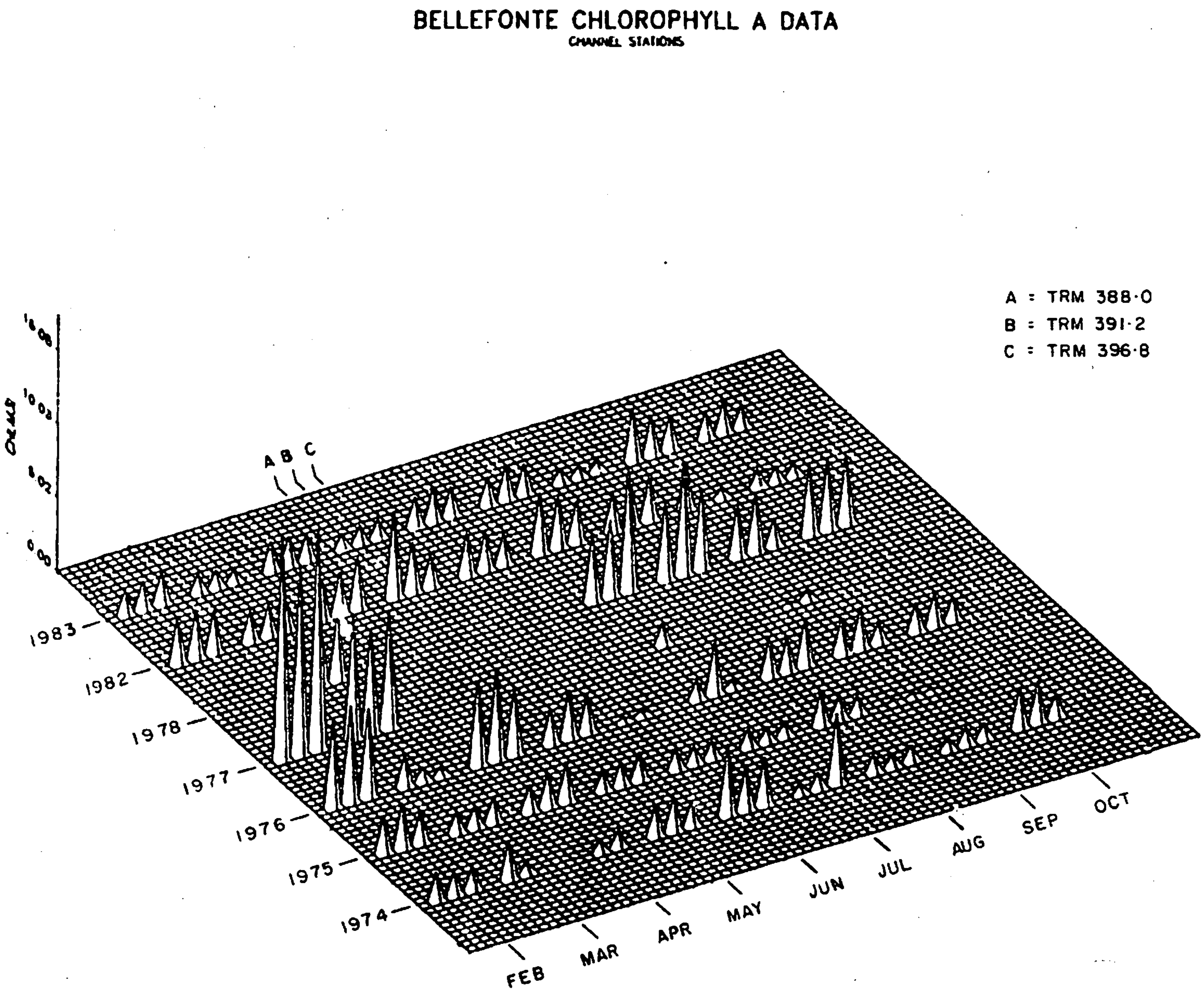


Figure 5-30. Phytoplankton Biomass (mg Chl $\underline{a}/m^3$) for Mainstream Channel Stations near Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

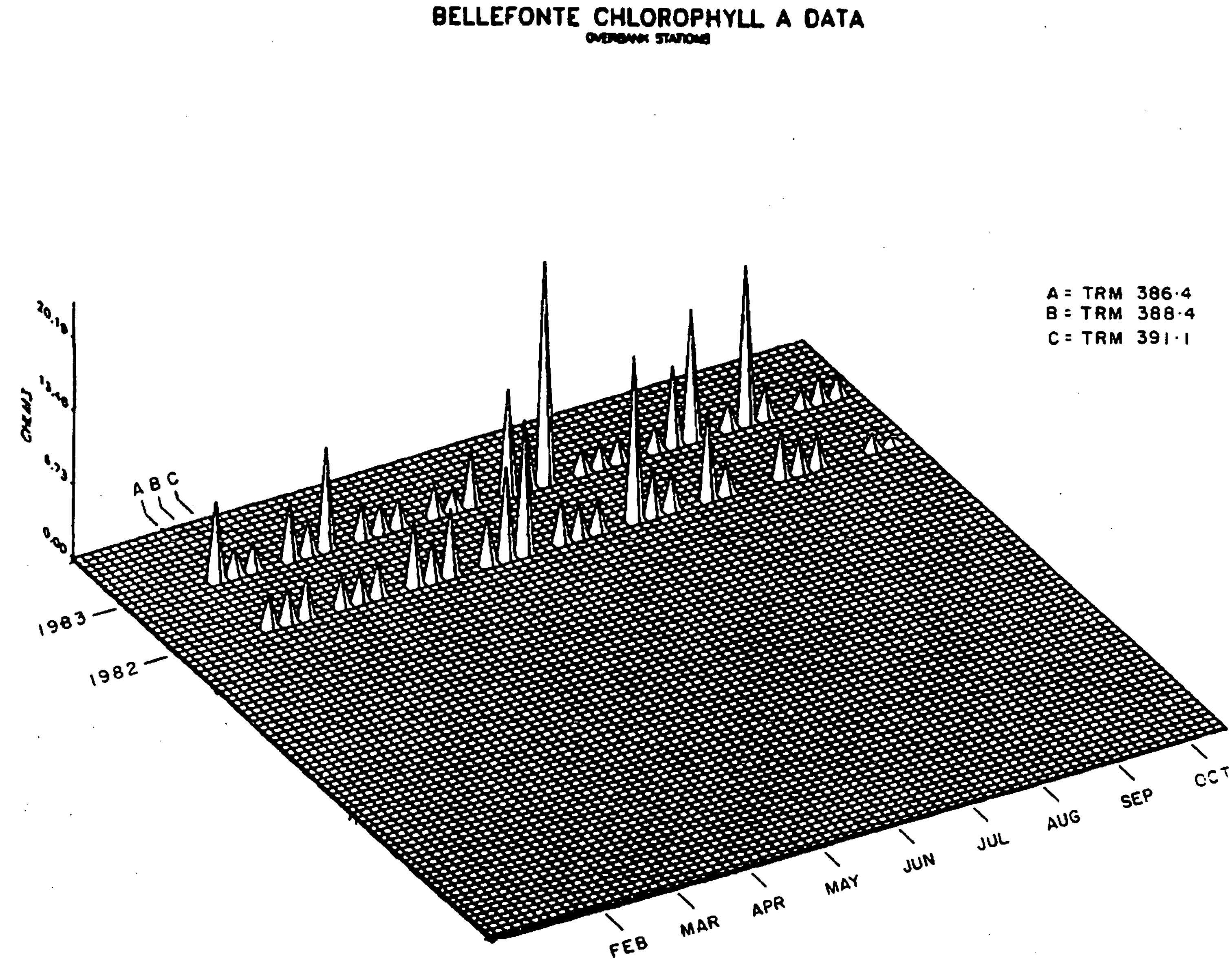


Figure 5-31. Phytoplankton Biomass (mg Chl a/m³) for Left Overbank Stations near Bellefonte Nuclear Plant, Guntersville Reservoir, 1982 and 1983.

CARBON-14 DATA

CHANNEL STATIONS

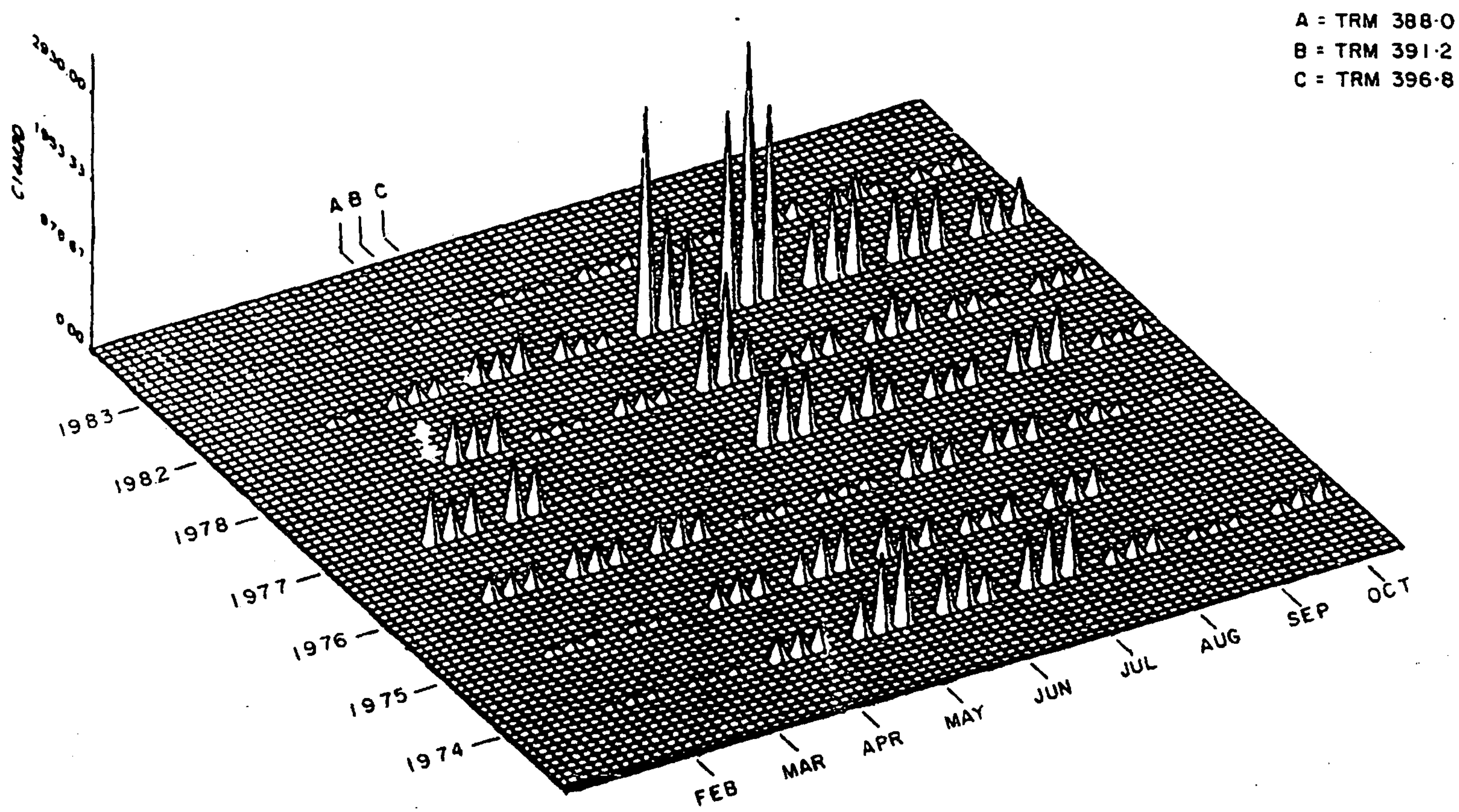


Figure 5-32. Phytoplankton Productivity (mg C/m²/Day) for Mainstream Channel Stations near Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

CARBON-14 DATA
OVERBANK STATIONS

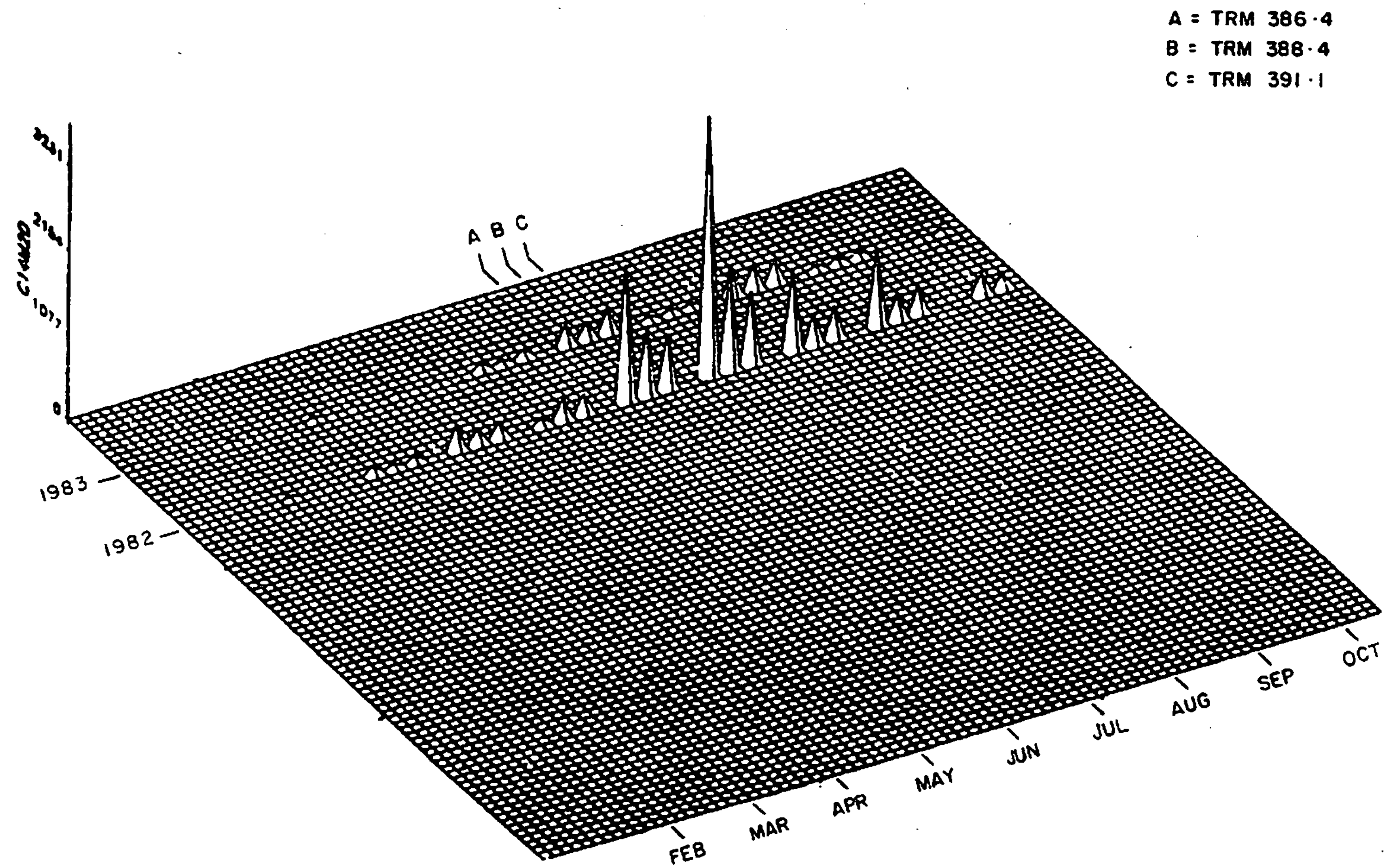


Figure 5-33. Phytoplankton Productivity (mg C/m²/Day) for Left Overbank Stations near Bellefonte Nuclear Plant, Guntersville Reservoir, 1982 and 1983.

1982

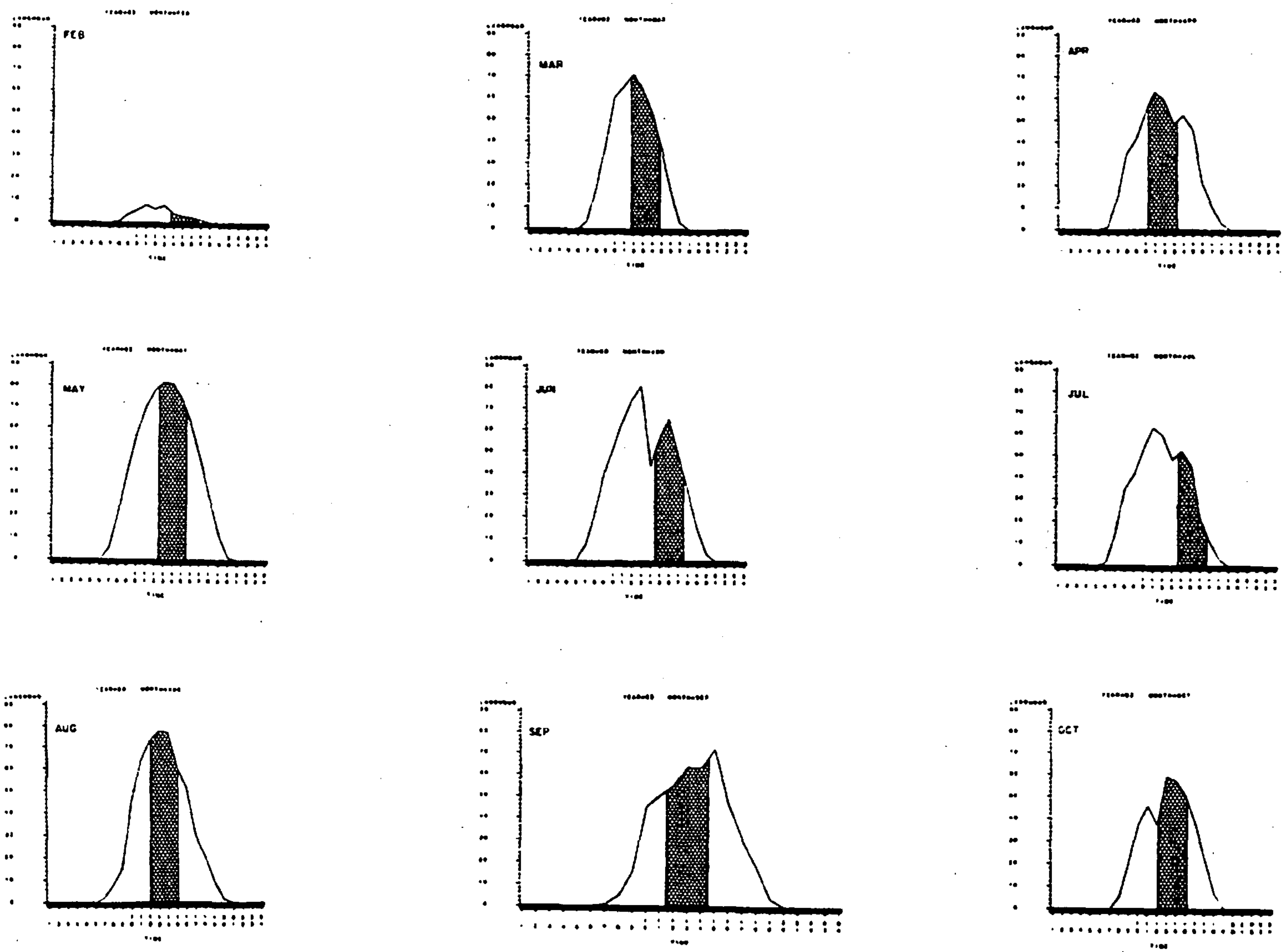


Figure 5-34. Total Surface Available Light for Each Day and Approximate Three-Hour Period of Measured Phytoplankton Productivity (Hatched) at Bellefonte Nuclear Plant, Guntersville Reservoir, During 1982.

1983

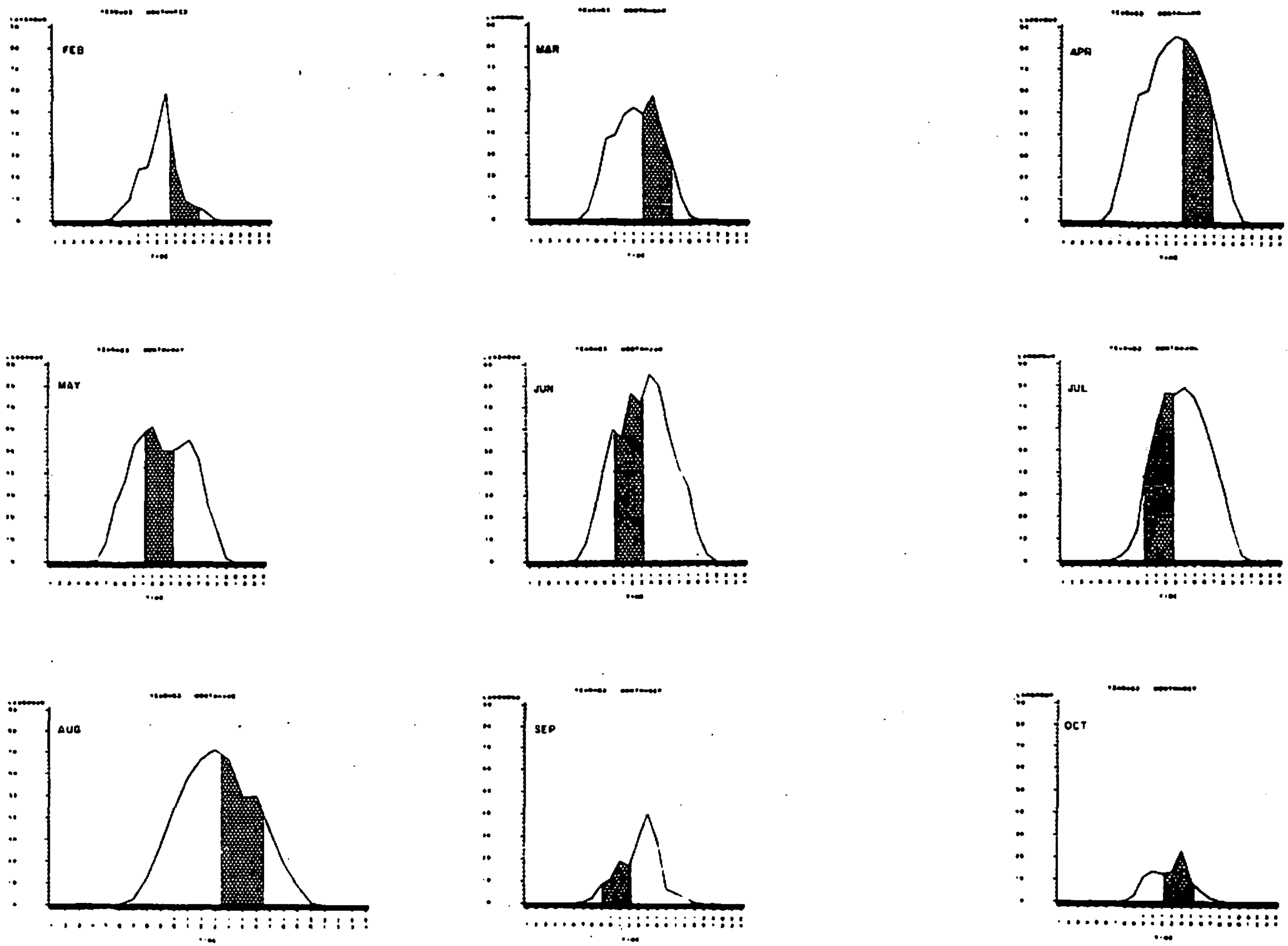
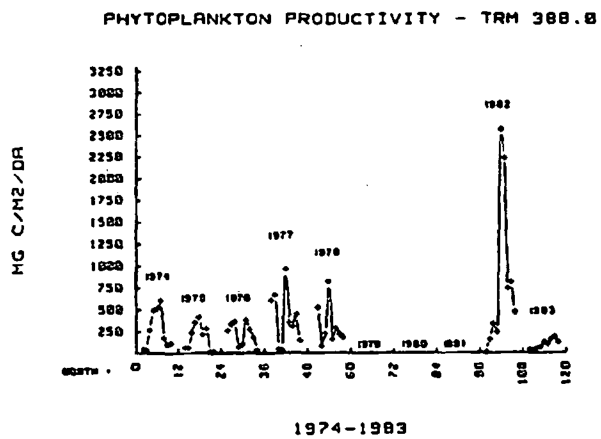
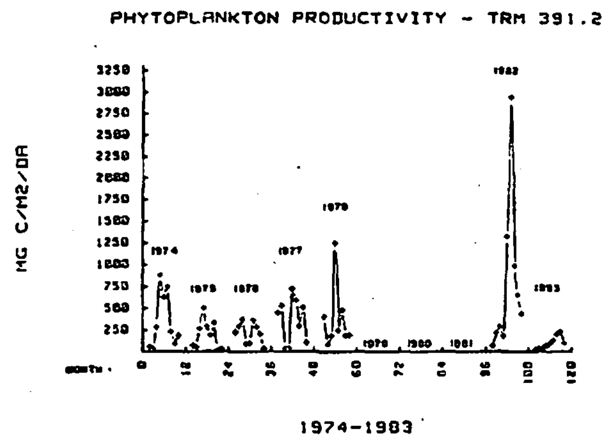


Figure 5-35. Total Surface Available Light for Each Day and Approximate Three-Hour Period of Measured Phytoplankton Productivity (Hatched) at Bellefonte Nuclear Plant, Guntersville Reservoir, During 1983.





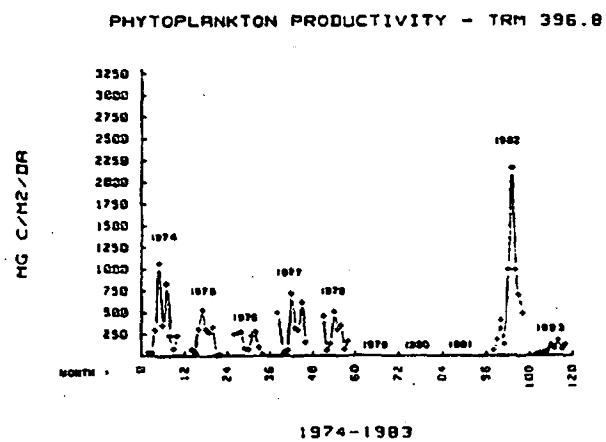


Figure 5-36. Phytoplankton Productivity at Mainstream Channel Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.

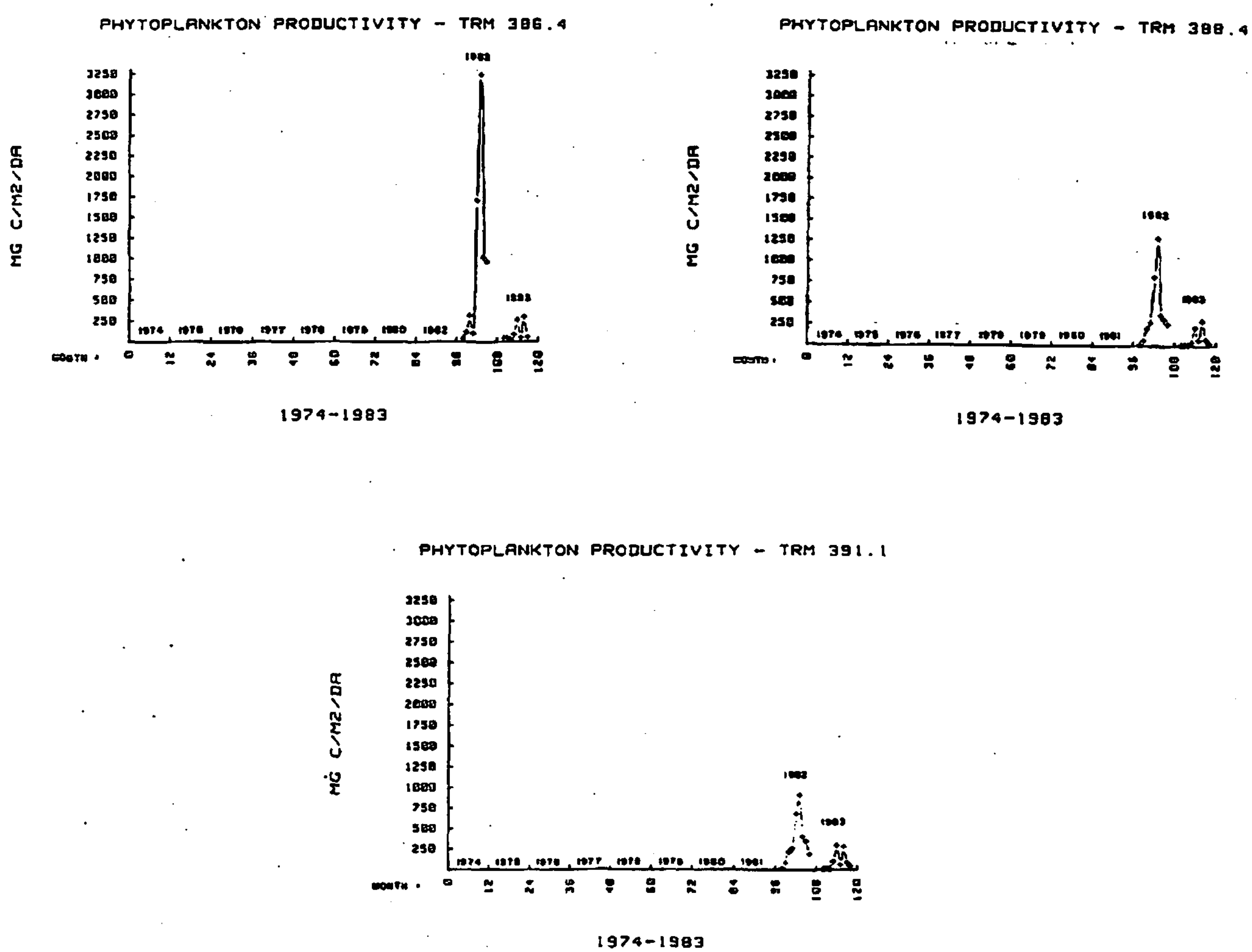
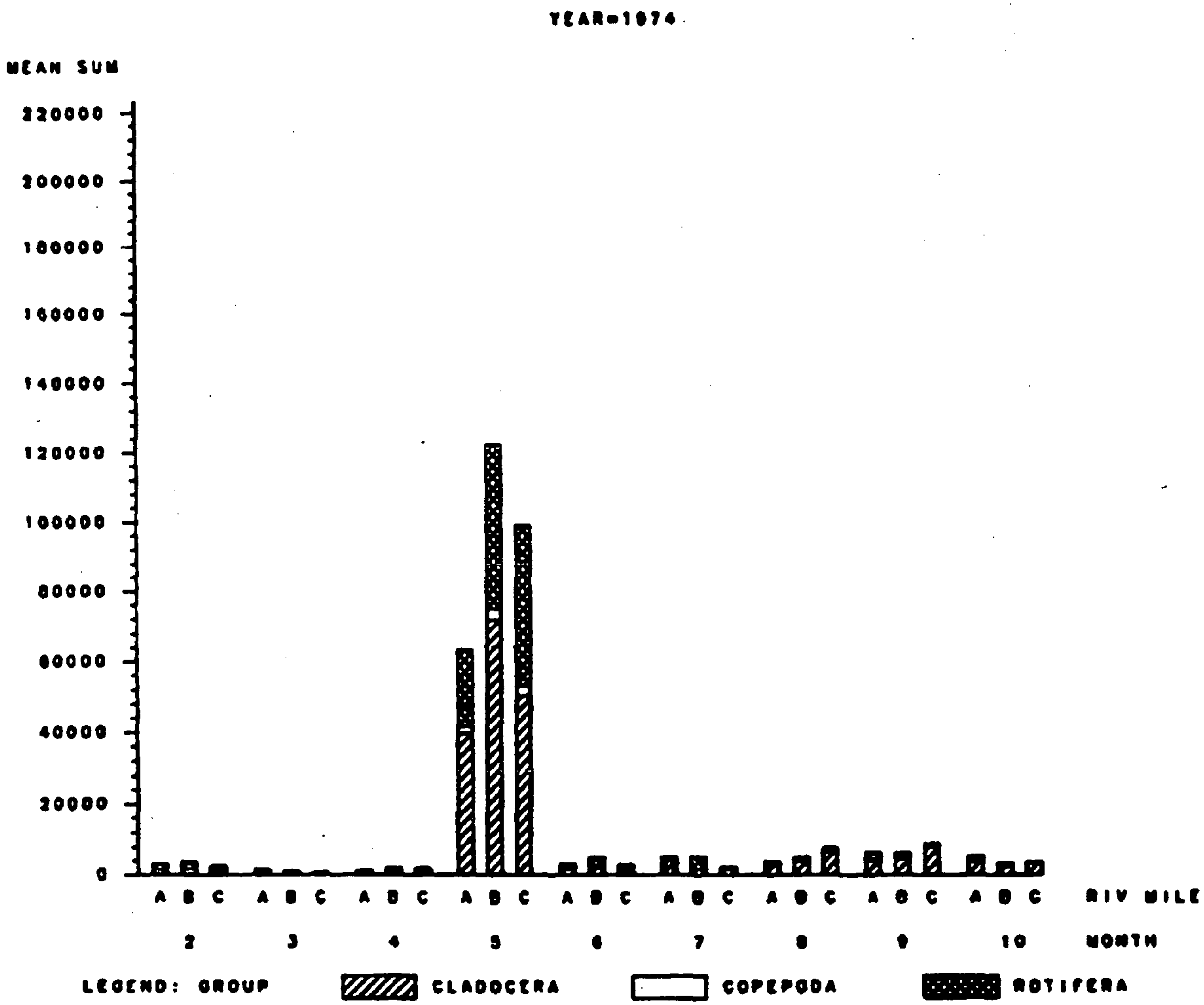


Figure 5-37. Phytoplankton Productivity at Left Overbank Stations During Preoperational Monitoring at Bellefonte Nuclear Plant, Guntersville Reservoir, 1974 through 1983.



RIV MILE A=388.0 B=391.2 C=390.8 D=388.4 E=388.4 F=391.1

Figure 5-38. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel Stations During 1974, Bellefonte Nuclear Plant.

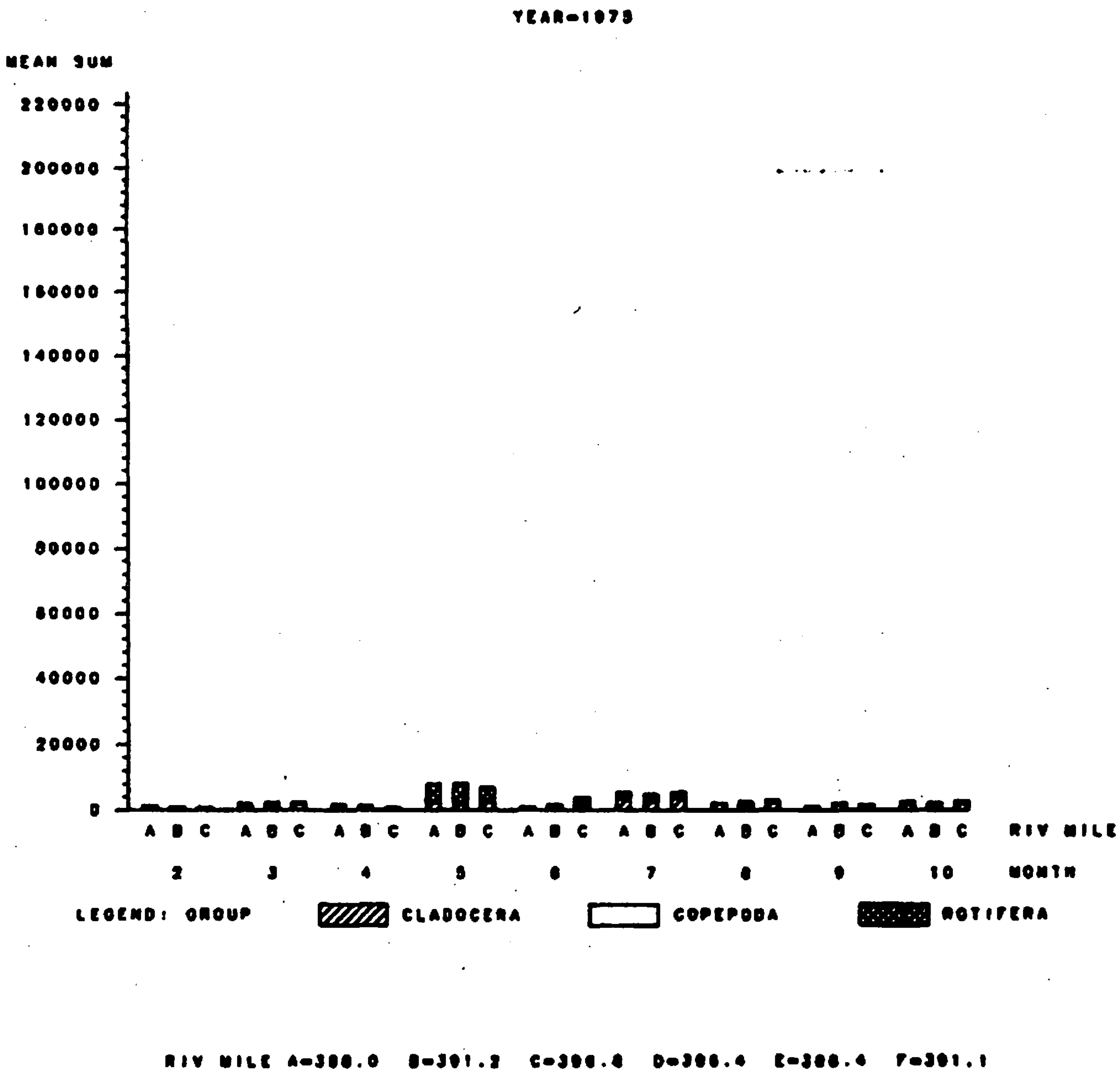


Figure 5-39. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel Stations During 1975, Bellefonte Nuclear Plant.

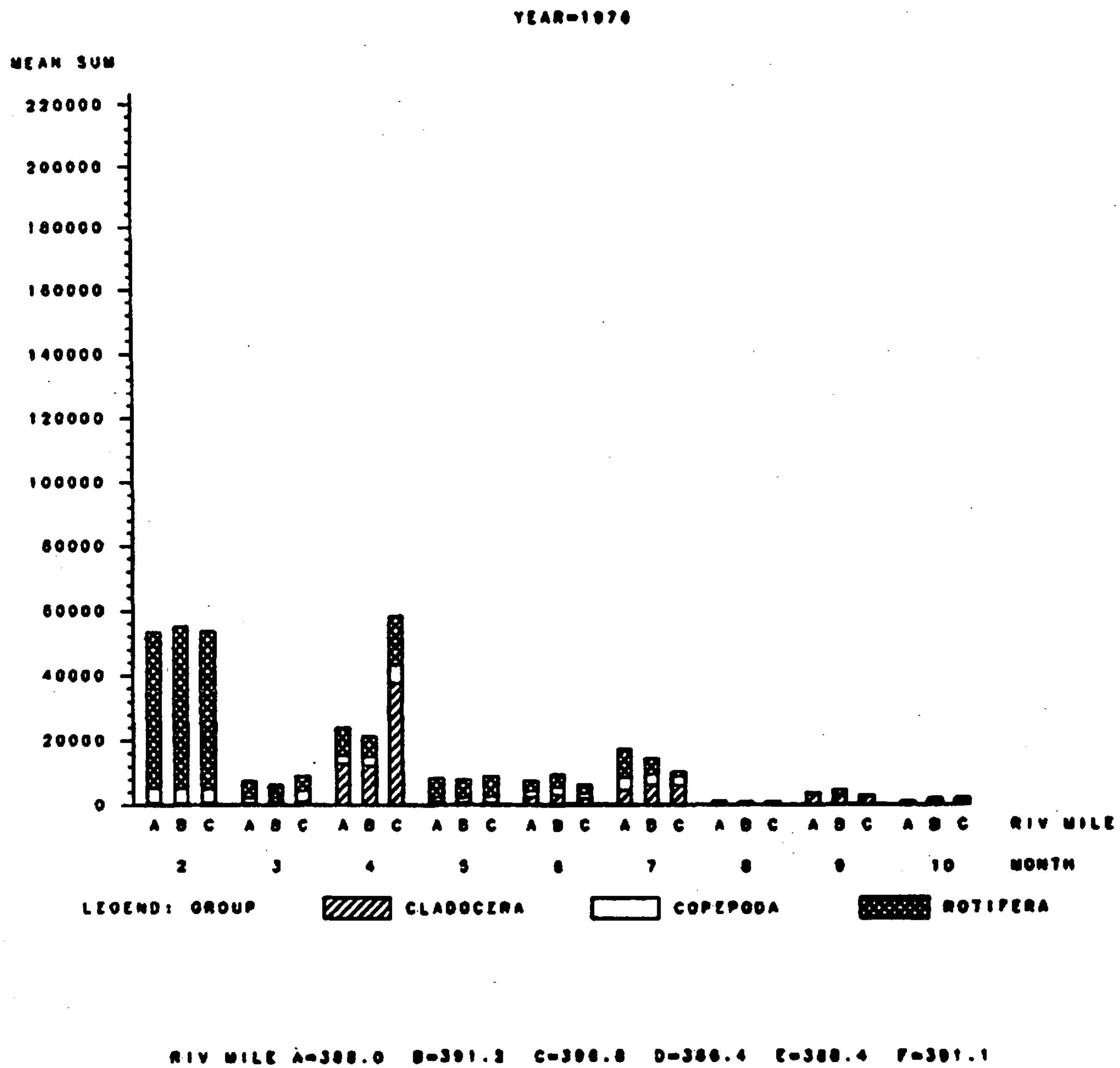


Figure 5-40. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel Stations During 1976, Bellefonte Nuclear Plant.

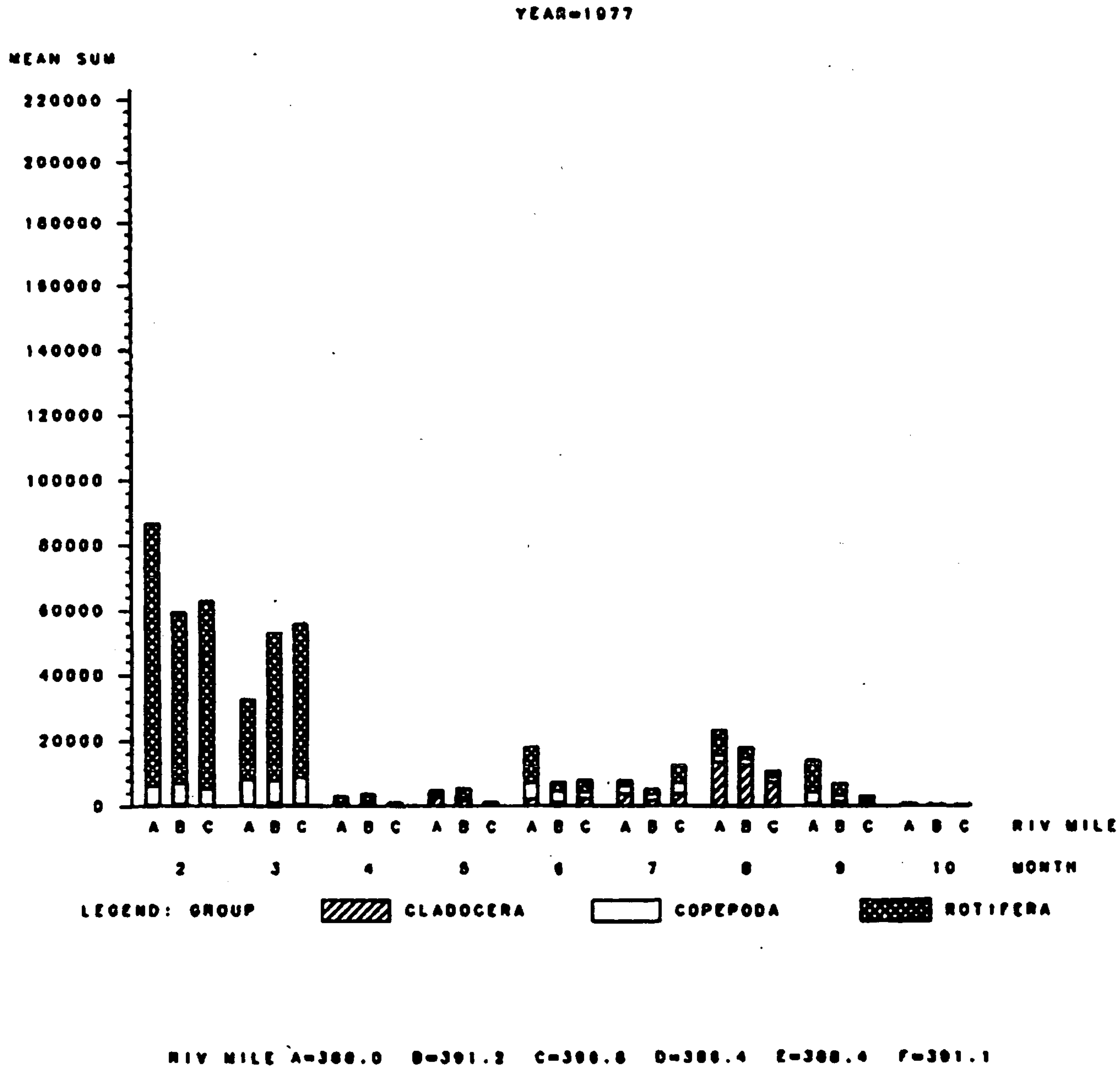


Figure 5-41. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel Stations During 1977, Bellefonte Nuclear Plant.

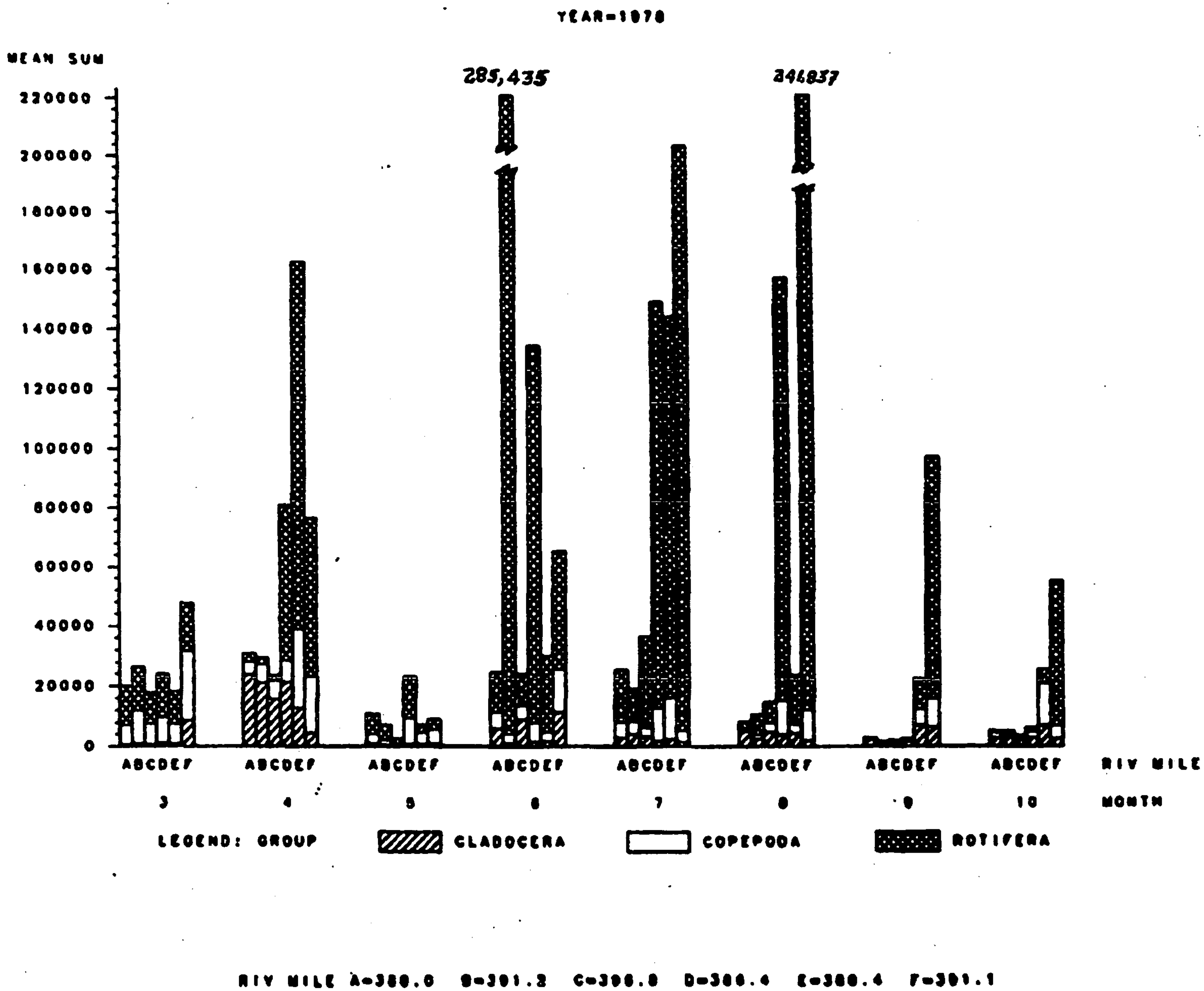


Figure 5-42. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel and Three Overbank Stations During 1978, Bellefonte Nuclear Plant.

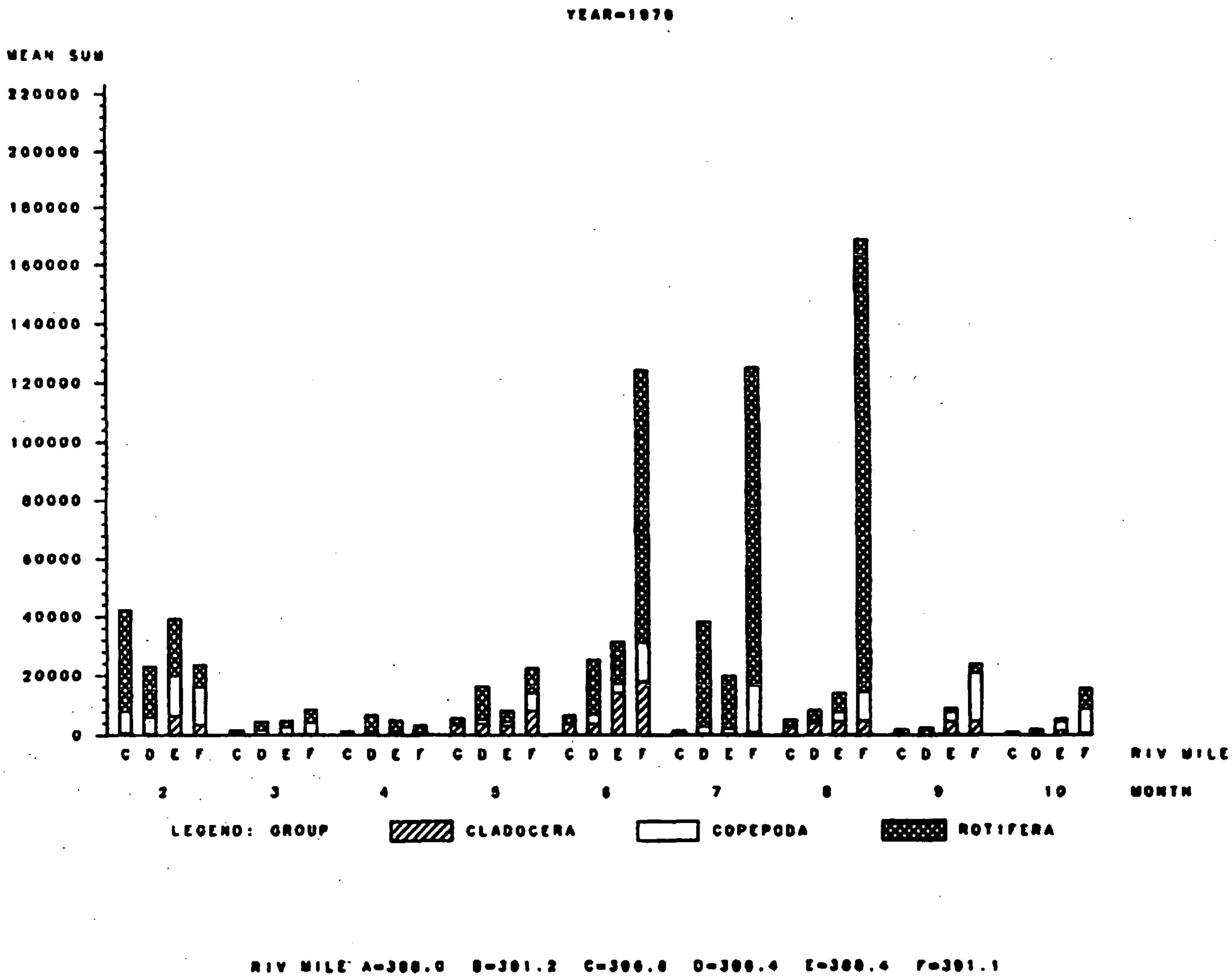


Figure 5-43. Zooplankton Densities Per Cubic Meter by Taxonomic Group at One Channel and Three Overbank Stations During 1979, Bellefonte Nuclear Plant.

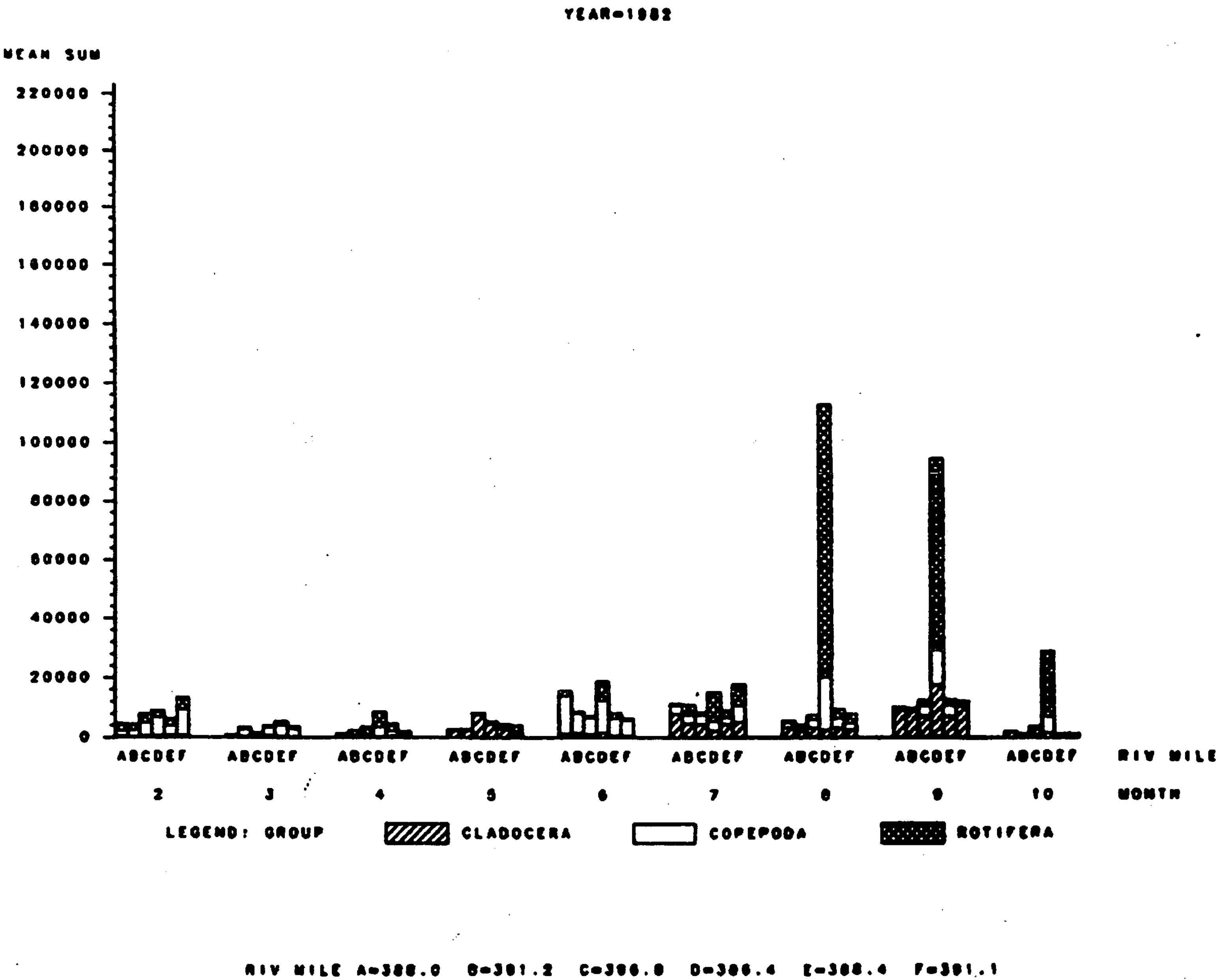


Figure 5-44. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel and Three Overbank Stations During 1982, Bellefonte Nuclear Plant.

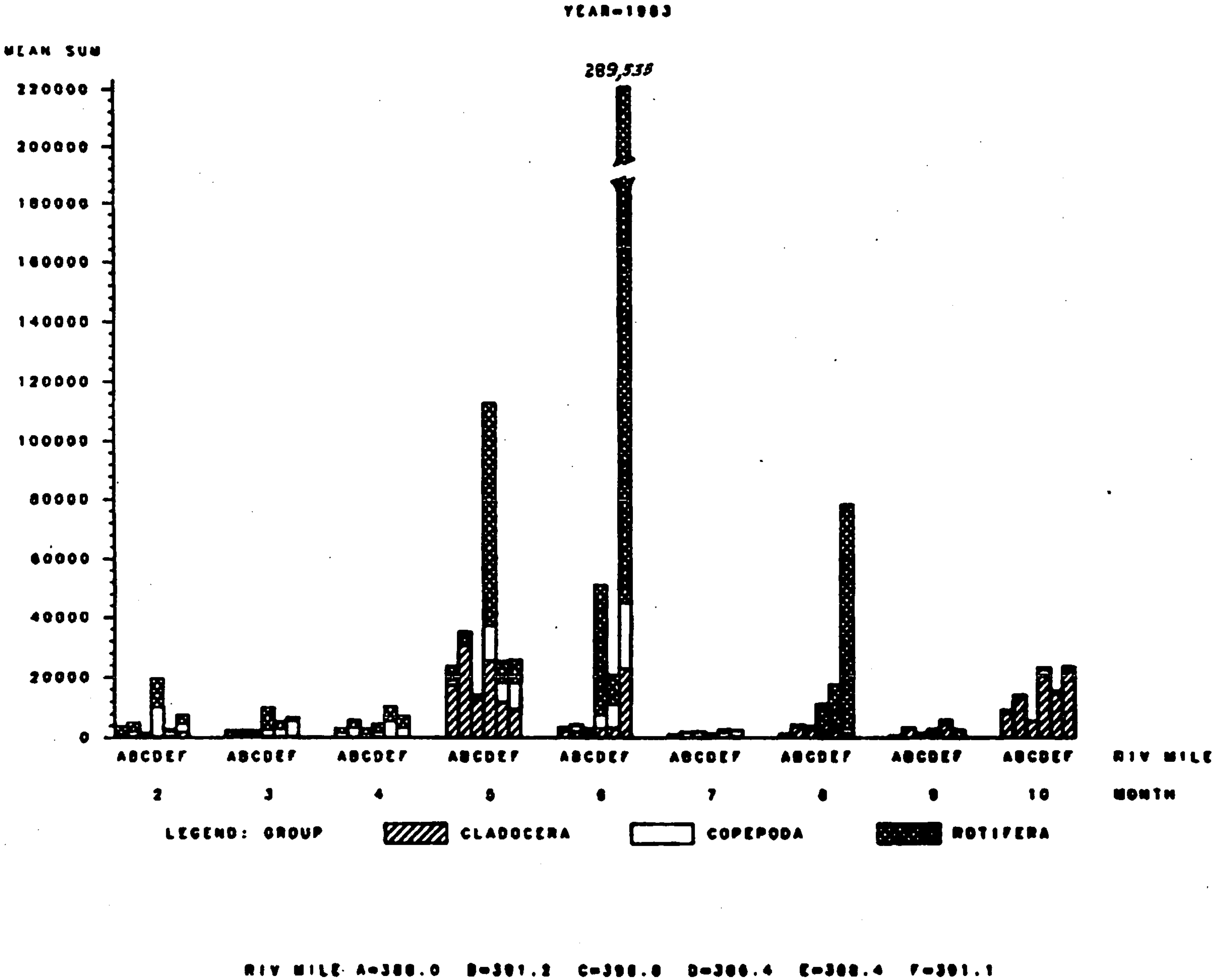


Figure 5-45. Zooplankton Densities Per Cubic Meter by Taxonomic Group at Three Channel and Three Overbank Stations During 1983, Bellefonte Nuclear Plant.

6.0 PERIPHYTON

6.1 Materials and Methods

6.1.1 Field

Preoperational monitoring of the periphyton community in the vicinity of BLN was conducted from 1974 through 1978 for channel stations TRM 388.0, 391.2, and 396.8 and resumed in 1982 and 1983 with the addition of left (facing downstream) overbank stations TRM 386.4, 388.4, 389.9, and 391.1. Stations on the left overbank below the plant site were added in 1982 because the potential plume exposure from BLN existed in these areas for low or no flow conditions after the diffuser was redesigned.

Five plexiglass plates, having an 1.5 dm^2 exposed area, were placed in a metal or PVC support rack and suspended 0.5 m from the water surface. Two racks were placed at each sampling location throughout the 1974-1983 study period. The plates were collected after being incubated for approximately one month. Upon collection, each plate was placed in an individual plastic bag and labelled. One plate from each rack was designated for algal enumeration (ID) and the remaining plates were designated for autotrophic index (AI) analyses. After labelling, all plates were placed on ice, returned to the laboratory, and stored frozen.

Artificial substrates for periphyton colonization were placed monthly March through September and retrieved approximately one month later in April through October of each sampling year. High flow conditions, floating debris, or vandalism caused loss of substrates or entire samplers. Listed below are the sampling dates and locations when entire samplers for a particular analyses were lost and no data are therefore available. In April 1974 both enumeration (ID) and autotrophic index (AI) samples were collected from TRM 388.0, 391.2, and 396.8 and analyzed but the data were lost.

Date	Location (TRM)	Analysis
June 1974	388.0, 391.2	ID, AI
August 1974	396.8	ID, AI
September 1974	396.8	ID, AI
October 1974	388.0, 391.2, 396.8	ID
April 1975	388.0, 391.2, 396.8	ID
June 1975	388.0	ID, AI
August 1975	388.0	ID, AI
April 1976	396.8	ID, AI
April 1977	388.0, 391.2	ID, AI
September 1977	391.2, 396.8	ID, AI
October 1977	391.2	ID, AI
May 1978	388.0	ID, AI
April 1982	386.4	ID, AI
June 1982	391.2, 388.4, 391.1	ID, AI
July 1982	391.1	ID, AI
September 1982	391.2, 396.8, 386.4, 388.4, 389.9	ID, AI
October 1982	391.2, 391.1	ID, AI
April 1983	388.0, 396.8, 386.4	ID, AI
May 1983	389.9, 391.1	ID, AI
August 1983	386.4	ID, AI
September 1983	388.0, 391.2, 396.4	ID, AI
October 1983	386.4, 388.4	ID, AI

6.1.2 Laboratory

Enumeration--During the 1974-1978 phase of the study, there were occasions when the prescribed number of plates from each station were not recovered because of vandalism, high flows which tore the plates from the racks, etc. This created situations when there were not enough plates to do both the enumeration and autotrophic indices analyses. Beginning in 1982, if the prescribed number of plates were not recovered to do both enumeration and autotrophic indices analyses, some plates (one or two) designated for autotrophic indices analyses were taken for enumeration analyses.

Plates designated for algal enumeration were thawed for up to one hour and periphyton from a known area was scraped from the plates. If the periphytic growth was, in the opinion of the analyst, moderate to heavy, a small area (usually 25 cm^2) was scraped. If the growth was light to moderate, the entire plate was scraped into a beaker containing a small amount of 10 percent formalin.

The scraped material was diluted and a subsample withdrawn. Volumes of the diluted sample and the subsample which would allow expeditious and thorough enumeration, were dependent upon the abundance of organisms and the quantity of detritus. This subsample was placed in a sedimentation chamber similar to an Uthermohl cylinder and allowed to settle for at least 12 hours. Classification and enumeration were conducted at the generic level with an inverted microscope at a magnification of approximately 320X. References and publications used in identification varied for individual algal groups. Sometimes several references were utilized to identify genera within an algal group, but usually a single reference comprised the major taxonomic authority. Major (x) and infrequently (✓) used references were as follows:

Reference	Algal Group					
	Chlo	Chry	Cyano	Crypto	Eugleno	Pyrro
Cocke (1967)			x			
Desikachary (1959)			✓			
Drouet (1973)			x			
Drouet & Daily (1973)			x			
Forest (1954)	✓	✓	✓		x	✓
Hustedt (1930)		x				
Patrick & Reimer (1966)		x				
Prescott (1964)	x			x	x	x
Tiffany & Britton (1971)	✓	✓			✓	✓
Whitford & Schumacher (1969)	✓					

Autotrophic Index--Slides selected for autotrophic indices were thawed and large organisms (chironomids, caddisflies, etc.) were removed and discarded. All periphytic growth was scraped from the slide and placed in 90 percent acetone to extract the phytopigments. The scraped material was placed in up to 50 ml of solvent, homogenized, and steeped for at least 12 hours.

After extraction the sample was filtered onto a preweighed filter pad. The chlorophyll concentrations were determined using the filtrate as described below. Biomass estimate was calculated using data from the residue manipulations. The filter with residue was placed in a preweighed crucible and dried at 105°C for at least 12 hours; incinerated in a muffle furnace at 600°C for 1 hour; cooled in a dessicator; and weighed. This ash-free dry weight provided an estimate of total organic matter or biomass.

To estimate phytopigment concentrations, the filtrate was analyzed spectrophotometrically. In 1974, chlorophyll concentrations were originally calculated from the Parsons and Strickland (1963) modification of the Richards and Thompson (1952) equations. From 1975 to 1978 the optical densities were read at 750, 663, 645, and 630 nm. Each sample was then acidified with two drops of 0.1 N HCl, allowed to steep for one minute, then reread at 750 and 663 nm. Chlorophyll a, b, and c concentrations were originally calculated using the 1966 UNESCO equations for chlorophylls and the Lorenzen (1967) equations for phaeophytin a. However, for this report all values have been recalculated using the Jeffrey-Humphrey (1975) equations.

In 1982 and 1983, optical densities of each sample were read at 750, 664, 647, and 630 nm. Again the samples were acidified with two drops of 0.1 N HCl, allowed to steep for one minute, then reread at 750 and 664 nm. Phytopigment concentrations were calculated using the Jeffrey-Humphrey (1975) equations, and phaeophytin a concentration was calculated again using the Lorenzen (1967) equations.

For all samples from 1975 to 1983 the phaeophytin index values were determined (Weber 1973) as shown:

$$PI = Chl\ \underline{a}_b / Chl\ \underline{a}_a$$

where Chl $\underline{a}_a$ = corrected optical density for chlorophyll $\underline{a}$ after acidification;

Chl $\underline{a}_b$ = corrected optical density for chlorophyll $\underline{a}$ before acidification.

The autotrophic index (AI) value for the sample was calculated according to Weber (1973) as shown:

$$AI = \frac{\text{Ash free dry weight/m}^2\ (\text{mg/m}^2)}{\text{Chlorophyll } \underline{a} \text{ concentration/m}^2\ (\text{mg/m}^2)}$$

6.1.3 Data Analyses

Periphyton enumeration and autotrophic index data for each sampling date were tested for station differences using a one-way Analysis of Variance after the data were transformed ($\log_{10}$). If there were significant differences among stations, a Student, Newman, Keuls (SNK) Multiple Range Test (Sokal and Rohlf, 1969) was applied to the data. However, this was done only for those sampling dates which had replicate samples for every station.

In an effort to look for general trends in the enumeration data, the data were transformed ($\log_{10}$) and pooled by years and by stations. Two-way analyses of variance were done on these pooled data sets with station and time (both year and month) as the variables. Means were further compared using an SNK multiple range test.

Periphyton community structure was analyzed using a diversity index applying the following formula (Patten, 1962):

$$\bar{d} = -\sum_1^s (n_i/n) \log_2 (n_i/n)$$

where, s = number of genera;

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

n = total number of organisms;

$\bar{d}$ = diversity per individual.

Similarity of periphytic communities among stations was determined using a two-step approach. Sorenson's Quotient of Similarity, SQS (McCain, 1975), was calculated to determine similarities based solely on presence/absence of genera (qualitative characteristics of community composition). A percentage similarity (PS) index (Pielou, 1975) was calculated, also 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:

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

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

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, 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 compositions, relative abundance of genera present, and absolute cell number.

Correlation coefficients (Snedecor and Cochran, 1967) were calculated on untransformed data to test for possible relationships between total abundance and selected chemical parameters.

6.2 Results and Discussion

Periphyton is most commonly defined as the community of bacteria, fungi, algae, and animals, as well as organic and inorganic detritus attached to submerged substrata, with the substrata being inorganic, organic, alive or dead (Weitzel 1983). It includes additionally, free living microorganisms which swim or become entangled among the attached forms. However, for this study only the algal portion of that community was considered.

Plankton, by its nature, being transported by flow and currents, often does not respond entirely to pertubations in the environment for a considerable distance downstream. Periphyton, on the other hand, being attached can show immediate responses to these perturbations at the source and thus can be useful as an indicator of water quality.

Periphyton taxa are somewhat selective to substrate type. Because of this, to avoid introducing the variable of differing substrata in this study, artificial substrates were used to provide uniform substrate type, orientation, and size.

Community Structure--During the six years of preoperational monitoring, a total of 62 periphyton taxa were found in the vicinity of BLN. These included 26 chlorophytes, 26 chrysophytes, 7 cyanophytes, and 3 euglenophytes (table 6-1). Temporal, spatial, and abundance information on these taxa are presented in Appendix F.

Several of these taxa had only single temporal occurrences during the study period and are shown below.

Division	Genus	Date	Location C=Channel OB=Overbank
Chlorophyta	Chlorella	APR 78	388.0 C, 396.8 C
	Chodatella	MAY 75	391.2 C, 396.8 C
	Golenkinia	JUN 78	396.8 C
	Gonium	APR 78	388.0 C, 391.2 C
	Pandorina	SEP 78	396.8 C
	Closteridium	AUG 83	391.2 C
	Rhizoclonium	SEP 78	396.8 C
	Tetraedron	JUN 78	396.8 C
	Trochiscia	APR 78	388.0 C
Chrysophyta	Asterionella	APR 82	389.9 OB
	Dichotomococcus	MAY 82	388.4 OB
	Pleurosigma	MAY 74	391.2 C
Cyanophyta	Anabaena	OCT 76	388.0 C
Euglenophyta	Phacus	AUG 83	388.4 OB, 389.9 OB

Most of these taxa are planktonic forms which probably became entrapped in the filamentous algal periphyton, a common phenomenon in habitats similar to those surrounding BLN.

Additionally, there were a few genera which occurred several times during the study period but only in one habitat type. These are given below.

Division	Channel	Overbank
Chlorophyta	Carteria	
Chrysophyta	Fragilaria	Epithemia
	Pinnularia	
	Rhiocosphaenia	

There were 10 genera (table 6-2) which occurred as the single dominant taxa throughout the study period. As the dominant genus, these taxa accounted for 19.8 to 91.9 percent of the total periphyton community in any sample. As the dominant form, these genera individually accounted for over 40 percent of the total abundance in 68.9 percent of the samples.

Division	Genus	No. of Times as Dominant/Possible	Range of Mean Percentage of Total Abundance
Chlorophyta	Spirogyra	1/141	45.4%
	Stigeoclonium	46/141	30.8-91.9%
	Staurastrum	1/141	30.2%
Chrysophyta	Achnanthes	58/141	19.8-86.3%
	Cocconeis	22/141	28.6-75.0%
	Gomphonema	4/141	26.6-48.1%
	Melosira	5/141	20.2-51.1%
	Navicula	1/141	31.6%
	Synedra	2/141	24.6-30.8%
Cyanophyta	Oscillatoria	1/141	32.5%

During the period 1974-1978 Achnanthes, a rheophilic chrysophyte, was the dominant genus in 51 percent of the channel samples and Stigeoclonium, a rheophilic filamentous chlorophyte, was dominant in 21 percent of the samples. This was reversed to some extent during the 1982-1983 study period when Achnanthes was dominant in 28 percent of the samples and Stigeoclonium 48 percent.

The total number of taxa by each location over the study period is shown in figures 6-1 through 6-7. At the channel stations, which were the only ones studied throughout the entire 1974-1983 period, there was a general increase in the number of taxa from 1974 to 1978 than a decline in 1982-1983 to levels similar to 1974-1975. The minimum number of taxa occurring at any location for a collection period was five taxa. This occurred primarily in 1982 at several locations in June, at TRM 396.8 in August, and at TRM 388.4 in October, as well as TRM 391.2 in June 1983. The maximum number of taxa was found during September 1978 when 24 genera were found at TRM 396.8. The number of taxa at overbank stations varied between 5 at TRM 386.4 and TRM 389.9 in June 1982 to 17 at TRM 389.9 in August 1983. As with the channel stations, June had the lowest number of taxa in both 1982 and 1983.

The frequency of similar community structure among channel stations was high (table 6-3) when considering only taxa (SQS) ranging from 68 percent in 1976 to 100 percent in 1974, 1977, and 1983 as shown below. When both taxa and abundance are considered (PS) the frequency of similarity was lower, ranging from 25 percent in 1983 to 88 percent in 1974. There appears to be no periodicity in the similarity of communities over time but TRM 396.8 frequently (43 percent frequency in the period 1974-1978 and 75 percent frequency in 1982-1983 period) is dissimilar to the other channel stations according to the PS. When only taxa are considered (SQS) the frequency of dissimilarity decreases to 15 percent in the 1974-1978 period and 13 percent in the 1982-1983 period. This suggests that the taxa comprising this upper channel station were similar to those of the lower stations, although there are station differences in abundance of those taxa.

	SQS		PS		Either > 70%	
Year	No./Possible	%	No./Possible	%	No./Possible	%
			Channel			
1974	8/8	100	7/8	88	8/8	100
1975	8/11	73	5/11	45	8/11	73
1976	13/19	68	11/19	58	16/19	84
1977	13/13	100	6/13	46	13/13	100
1978	18/19	95	11/19	27	18/19	95
			Channel			
1982	9/11	82	3/11	27	9/11	82
1983	12/12	100	3/12	25	12/12	100
Overall	81/93	87	46/93	49	84/93	90
			Overbank			
1982	13/16	81	5/16	31	14/16	88
1983	19/20	95	4/20	20	19/20	95
Overall	32/36	89	9/36	25	33/36	92
			Channel vs Overbank			
1982	33/40	83	9/40	23	34/40	85
1983	32/36	89	13/36	36	33/36	92
Overall	65/76	86	22/76	29	67/76	88

A high percentage of the overbank station comparisons were similar in 1982 and 1983 (81 and 95 percent, respectively) when genera presence/absence is considered. The frequency, as with the channel stations, lowers when abundance is also considered and ranges from 20 percent in 1983 to 31 percent in 1982. This again suggests that the taxa in the algal portion of the periphyton communities were similar but differed in abundance. There were no discernable trends in the overbank community structure similarities over time or by location.

When channel community structures were compared with overbank community structures, the results were basically the same. The frequency of similarity based on taxa comparisons were high (83 to 89 percent). When abundance was also considered the frequency again decreased (23 to 36 percent) further suggesting a possible difference based only on cellular abundance.

Diversity index values for the channel stations ranged from 0.80 in July 1974 at TRM 388.0 and TRM 391.2 to 2.99 in September 1976 at TRM 391.2 (table 6-4). The diversity index values for overbank stations varied from 0.57 at TRM 391.1 in April 1983 to 3.17 also at TRM 391.1 in April 1982. Diversities at both the channel and overbank stations were usually high in April (occasionally May), decreased to a low in June and then increased again through August or September. In three years (1974, 1976, and 1983), there was a slight decline in the October channel station diversities. The remaining years had October channel station diversities similar to or higher than September. The October decline occurred in both 1982 and 1983 at the overbank stations. Although the range of overbank stations was larger than that of the channel stations, the indices at the overbank stations were similar. Overall diversities were highest during 1976 and lowest in 1974.

Percentage composition of the periphyton communities by the three major groups, chlorophytes, chrysophytes, and cyanophytes, is shown by year in table 6-5. Channel stations were dominated by chrysophytes during 1974-1976 with the exception of TRM 388.0 in September 1974 when the filamentous green alga, Stigeoclonium comprised 61.9 percent of the total community. For this period of almost total chrysophyte dominance, the dominant chrysophyte genera were Cocconeis and Achnanthes. During 1974 and 1975, Cocconeis was frequently (>50 percent of the samples) the dominant chrysophyte, and comprised between 36.2 (September 1975) and 75 percent (July 1975) of the total community. However, during 1976 it was never dominant, giving way to Achnanthes which made up between 26.1 (August) and 72.0 percent (May) of the community.

Beginning in 1977 and continuing through 1983, the channel stations were dominated by chrysophytes early in the study year (April and May). Chlorophytes began to dominate some channel stations in June and continued to sporadically dominate or together with the chrysophytes codominate the channel periphyton community through the end of the sample year (October). Frequency of chlorophyte dominance at channel stations ranged from 0 percent in 1976 and 1977 to 46 percent in 1983. Frequency for chrysophyte dominance ranged from 46 percent in 1983 to 100 percent in 1975 and 1976. When chlorophytes dominated the community, the dominant genus was Stigeoclonium in all but one set. Only in August 1977 at TRM 396.8 was another chlorophyte, Spirogyra, the prevalent chlorophyte at channel stations.

The predominant chrysophyte at channel stations from 1977 to 1983 was usually (71 percent frequency) Achnanthes. Other chrysophytes, which were infrequently dominant, include Melosira (at all channel stations on April 1978 and at TRM 396.8 on August 1978), Cocconeis (TRM 388.0 on September and October 1977 and September 1982), Gomphonema (April 1977 at TRM 396.8, May 1978 at TRM 388.0, and April 1982 at TRM 388.0), and Synedra (April 1982 at TRMs 391.2 and 396.8).

Only once during the entire study was bluegreen (cyanophytes) abundance large enough to numerically dominate the periphyton community. This occurred at TRM 391.2 in May 1983 when together Lyngbya and Oscillatoria comprised 37 percent of the community. The single numerically dominant genus for this sample however was Stigeoclonium which made up 34.6 percent of the cellular abundance.

Overbank stations exhibited similar community percentage composition changes except that chlorophytes were predominant at all overbank stations sampled in April 1983. The frequency of chlorophyte dominance was less (19 percent) in 1982 than in 1983 (39 percent). Cyanophytes were never the dominant group at overbank stations but tended to form a larger portion of the periphyton abundance than at channel stations, particularly in 1983. Cyanophytes occurred in 19 percent of channel station samples in 1982-1983 and 34 percent of overbank station samples.

Abundance--Because of the large number of sample sets with only one replicate, the data were pooled as discussed in section 6.1 to allow some statistical evaluation. Results of the two-way ANOVA's (tables 6-6 and 6-7) indicate there were significant differences in the periphyton communities studied over the entire preoperational monitoring period . Significant interactions occurred between year and month as well as station and month. Over the entire monitoring period when years are pooled (table 6-6), two channel stations (TRM 388.0 and TRM 396.8) had significantly higher total and chrysophyte abundances than all other stations. Additionally, the third channel station (TRM 391.2) had significantly higher abundances than the overbank stations but was significantly lower in total and chrysophyte abundances than other channel stations but similar chlorophyte abundances. For the overbank stations TRM 388.4 had significantly lower total, chlorophyte, and chrysophyte abundances than other overbank stations and was lowest overall. The overbank station adjacent to the river channel, TRM 389.9, had significantly greater abundance (total and chrysophyte) than overbank stations which were isolated from the channel by strip of islands. These stations with higher abundances, TRMs 388.0, 396.8, 391.2, and 389.9, are stations which would experience higher flows. This would tend to stimulate rheophilic taxa abundances which is typical for periphyton communities.

When stations were pooled (table 6-7), total abundance was highest in 1977 and 1978 (1,651-59,110/cm^2) and lowest in 1974 (380-3,083/cm^2). This trend was also true for chlorophyte and chrysophyte abundances. Over the entire sampling period, there were increasing significantly different total abundances from 1974 to 1976. The total abundances continued to be significantly higher than preceeding years in 1977 and 1978. The trend reversed in 1982 and 1983 with total abundances for these years being similar to each other and significantly higher than 1974-1976.

Throughout the sampling years (when pooled), highest total abundances occurred in June and July (mean abundance 8,043/cm^2, lowest mean abundance 45/cm^2). As expected, chrysophyte abundances were higher earlier in the year and declined through the end of the sampling year, while chlorophyte densities tended to increase through the year.

When stations were compared by months with all years combined, channel stations were higher in total densities than overbank stations and were usually significantly different from overbank stations. However, except for April, May, and July, there were also significant differences among channel stations. Significant differences were also exhibited among overbank stations. In July there were no overbank samples retrievable and the channel stations exhibited no significant differences.

When the stations were combined and months were compared for each year, total abundances were highest in June for 1976, 1977, 1978, and 1982; in April for 1983; in May for 1975; and in July for 1974. Total densities were lowest in September for 1975, 1982, and 1983 and in August for 1974, 1976, and 1978. In April for 1977 (when samples from only one station were collected), the mean density ranked lowest (3,978/cm^2). However, the lowest single density actually occurred in August 1977 (1,651/cm^2 with a range to 4,343/cm^2).

Table 6-8 presents the results of the one-way ANOVA's and SNK multiple range tests for each month alone when there were sufficient replicates (i.e., 2). With the pooled data described above, no significant differences for total or chlorophyte abundances were found among channel stations in July 1974, 1976-1978 (July 1975 did not have sufficient replicate numbers and no samples were collected in July 1982 and 1983). There was a significant difference found in July 1974 Chrysophyta abundances when TRM 391.2 was significantly higher than TRM 388.0 and TRM 396.8. Additionally, no significant differences for total abundances were found in May 1976-1978 and June 1978.

In 1982 channel stations tended to be higher in abundances than overbank stations but not consistently. However, in 1983 the tendency was reversed with channel station being lower (except August). In June 1983 total abundances at all stations were significantly different.

The total densities for major groups by river mile are graphically shown by each sampling date in figures 6-8 through 6-50. Figures 6-51 through 6-57 show total densities for all years at each station for each sampling month. A comparison of mean densities (all stations combined) for total numbers, chrysophytes and chlorophytes is given in figure 6-58 and mean periphyton densities (all years combined) by river mile for total numbers, chrysophytes and chlorophytes is given in figure 6-59.

Several of the trends identified through the SNK multiple range tests discussed previously are further illustrated in these figures. Total abundance continually increased from 1974 through 1978 then began to decline in 1982 and 1983 to levels somewhat higher than 1976 (figure 6-58). Beginning in 1976, chlorophytes became an increasing larger part of the periphyton community through 1983, except for a slight decline in 1977. Except for April 1983, the chlorophytes did not start to predominate in the community each year until June. In most of the sampling years cyanophytes did not constitute a large portion of the community. There was an increase in the proportion of cyanophytes in 1976 and in 1983 when they predominated at TRM 391.2 in May and were present in larger than usual proportions for the entire year.

Channel stations usually had higher total abundances than overbank stations (figure 6-59). Chlorophytes constituted a larger portion of the community on the overbank stations while chrysophyte constituted a larger portion in channel stations.

When abundance data were compared with physical and chemical information (chapters 1.0 and 4.0) several apparent relationships could be seen (see below). There was a general increase in abundance as water temperatures increased. This parallel increase usually continued until the periphyton community had a late summer decline then increased again. This was true except for 1983 when the abundance in April was highest for the year. Total numbers exhibited a slight inverse relationship with both pH and DO with these parameters increasing as total numbers decreased. These were not consistently strong relationships with pH exhibiting the relationship most strongly in 1974-1976 (correlation coefficients of -0.33, -0.96, and -0.40, respectively) but DO exhibiting these relationships best in 1976 and 1982 (-0.39 and -0.56, respectively) but having a direct relationship in 1983 (0.62). Parameters which did not exhibit any trends with total abundance included total organic carbon, alkalinity, turbidity, nitrogen (both elemental and NO_2-NO_3) as well as total and dissolved phosphorus. The strongest relationship with chemical factors existed between total abundance and NH_3-NH_4 with correlation coefficients varying from 0.22 in 1983 to 0.83 in 1978. There was an inverse relationship in 1982 with a correlation coefficient of -0.68.

Correlation Coffecients of Total Abundance With

Year	TOC	Nitrogen	Dissolved Oxygen	Ammonia Nitrogen	pH
1974					-0.33
1975	-0.54	-0.14	0.26	0.47	-0.96
1976	0.00	-0.10	-0.39	0.56	-0.40
1977	0.53	-0.71	0.24	0.64	0.44
1978	0.20	-0.39	-0.24	0.83	-0.24
1982	-0.04	0.55	-0.56	-0.68	-0.29
1983	0.11	0.21	0.62	0.22	0.19

Total abundance also seemed to exhibit relationships with the physical parameter of flow and solar irradiation. Highest total abundances occurred in years of lowest flow and vice versa. As shown below, except for 1976 and 1977 this was true for the mean total abundance and the mean yearly flow.

	Mean Total Abundance Increasing						
Year	1974	1975	1976	1982	1983	1977	1978

	Mean Yearly Flow Decreasing						
Year	1974	1975	1977	1982	1983	1976	1978

In the years 1977 and 1978, there were longer periods of higher solar irradiation (figures 2-5 and 2-6) during the sampling years (March-October) than in other years. These were the two years of highest total abundance for the periphyton communities. Since light is necessary for growth of this community these periods of higher total amount of irradiation and less flow (probably less scouring) may have significantly affected the communities.

Autotrophic Indices--Chlorophyll a being the primary photosynthetic pigment for green plants is useful as an index of the productivity of the periphyton community. The ratio of ash free dry weight to chlorophyll, i.e., autotrophic index (AI), has been increasingly used to indicate periphyton community structure (Weitzel 1979). Additionally, it has been used to indicate changes in the ratio of the primary producing portion (autotrophic) to the consuming portion (heterotrophic) of the community in response to environmental perturbations. Theoretically, an organic influx to the system, for example, will shift the community from a producing (autotrophic) phase to a consumptive (heterotrophic) phase, causing an increase in the AI. Normal AI values range from 50 to 200 with larger values generally assumed to indicate a decline or poor water quality (Standard Methods, 1985). However, a problem with this index is the presence of nonviable organic material. Large amounts, which may be normal for the community in a particular location or growth habit, will increase the amount of ash-free dry weight, thereby, greatly increasing the AI value (Grzenda and Brehener 1960).

Chlorophyll a degrades into several by-products, the major one being phaeophytin a. Because phaeophytin a absorbs in the same spectral region as chlorophyll a, the concentration of chlorophyll a can be overestimated, if not corrected for this. Additionally, the ratio of active pigment, chlorophyll a to degradation product, phaeophytin a can be useful in assessing the health of the community. Therefore, beginning in 1975, the chlorophyll a concentrations were corrected for phaeophytin a and the phaeophytin index was calculated. Also beginning in 1975 the autotrophic indices were calculated using chlorophyll a which had been corrected for the concentration of phaeophytin a.

The ash-free dry weight (AFDW) and phytopigment information for individual samples are in Appendix G. Mean values for each sampling location by sampling dates for AFDW, corrected chlorophyll a, AI's and phaeophytin indices are in Appendix H.

Because of the large number of replicate autotrophic samples taken at each sampling site each collection period, unlike the abundance data there were no problems in subjecting the data to one-way ANOVA's and SNK multiple range tests. Results of these tests are in table 6-9. From 1974 to 1978, 18 out of the 31 (58 percent) sampling dates had no significant difference among channel stations for AI values, two sampling dates (6 percent) had significant differences among all channel stations and the remainder (36 percent) had two channel stations similar which were significantly different from one other channel station. During the 1982-1983 sampling period, channel and overbank stations were not significantly different on six (50 percent) sampling dates, April, June, and September, 1982; May, June, and October 1983. In the remainder of cases when both channel and overbank stations were collected, there were significantly different AI values but there were no consistent trends among stations. There were fewer occasions of similar corrected chlorophyll a (CCA) and ash-free dry weight data for all channel stations. Between 1974-1978, 42 percent of the CCA and 35 percent of the AFDW sample sets had no significant differences. As with the AI values, in 1982-1983 there were no consistent trends for differences among channel and overbank stations.

Over the study period, mean corrected chlorophyll a values for channel stations were lowest in 1982 ranging from 0.6 to 43.9 mg/m² in October and April, respectively. Highest mean values were found in 1978 when mean corrected chlorophyll a varied from 9.5 to 143.8 mg/m² in May and June, respectively. Mean values for the overbank stations were both lowest and highest in 1983 when concentrations were 1.0 to 89.3 mg/m² in October and April, respectively. Ranges for these and remaining years are shown below.

Mean Corrected Chlorophyll a (mg/m^2)

	Channel		Overbank	
Year	Range	Months	Range	Months
1974	7.8-150.8	May/Jun		
1975	2.3- 63.5	May/Jun		
1976	1.5- 51.5	Oct/Aug		
1977	20.0-138.5	Apr/Oct		
1978	9.5-143.8	May/Jun		
1982	0.6- 43.9	Oct/Apr	1.5-55.9	Aug/Apr
1983	1.4- 62.0	Jun/Apr	1.0-89.3	Oct/Apr

There were no consistent periodic trends by year for the corrected chlorophyll a data, i.e., no month was consistently highest or lowest. However, May and June were the low and peak, respectively, of chlorophyll a concentrations in 1974, 1975, and 1978 while April was the month of lowest concentration for both channel and overbank stations during 1982 and 1983. Except for 1974 when chlorophyll levels were highest and total abundance was lowest these two parameters are in good agreement. As total abundance increases so do the corrected chlorophyll a concentrations. This is also true for the decreases in total abundance.

Mean ash-free dry weights were somewhat more consistent with lowest weights occurring early in the year (April, May, or June) and highest weights occurring later in the year. This was reversed for the overbank stations in 1982. Mean ash-free dry weights for channel stations were lowest in 1974 ranging from a low of 948.6 to a peak of 6,482.9 mg/m^2 in May and June respectively, while 1982 AFDW values were similarly low ranging from 300.2-6,019.6 mg/m^2 in April and September, respectively. Mean values for AFDW were highest overall in 1976 ranging from 2,100.4 to 10,525.3 mg/m^2 in May and June, respectively. There were occurrences of single-sample values higher than these, e.g., mean AFDW of 211,808.2 mg/m^2 in August of 1983 at TRM 388.0. Mean AFDW values for overbank stations ranged from 646.4 mg/m^2 in August 1982 to 22,202.4 mg/m^2 in May of the same year as shown below.

Mean Ash-Free Dry Weight (mg/m^2)				
	Channel		Overbank	
Year	Range	Months	Range	Months
1974	948.6- 6,482.9	May/Aug		
1975	462.3- 7,801.7	Apr/Jun		
1976	2,100.4-20,525.3	May/Jun		
1977	2,424.5-11,441.8	Jun/Oct		
1978	1,532.5-11,824.2	May/Jun		
1982	300.2- 6,019.6	Apr/Sep	646.4-22,202.4	Aug/May
1983	554.3-72,855.5	Jun/Aug	1,014.5-10,036.3	Jun/Aug

The ratio of the preceeding parameters constitutes the autotrophic index which, as mentioned earlier, varies between 50 and 200 for natural waters with occasional increases due to presence of nonviable organic material. During the study, mean AI values at the channel stations were lowest in 1974 ranging from 27.4 to 123.2 in June and May, respectively as shown below.

Mean Autotrophic Indices				
	Channel		Overbank	
Year	Range	Months	Range	Months
1974	27.4- 123.2	Jun/May		
1975	100.8- 327.4	May/Aug		
1976	75.0-1,023.6	Jul/Jun		
1977	57.3- 228.3	May/Jul		
1978	38.4-1,858.7	Apr/May		
1982	84.9- 930.0	Apr/May	131.1-4,286.6	Jun/May
1983	103.3-4,417.9	Jun/Aug	100.9-6,789.8	Apr/Oct

The AI values increased through 1976, declined in 1977 then continued to rise through the rest of the study period. In 1983 the AI values were highest with mean values ranging from 103.3 to 4,417.9 in June and August, respectively. Mean values for the overbank stations ranged from 100.9 to 6,789.8 in April and October 1983. At the channel stations AI values were usually highest early in the year (April, May, June) but usually varied thereafter. This was not true for the overbank stations which exhibited no consistent trends.

The AI values in 1982 and 1983 are skewed by the presence of a few samples in both years with large amounts of ash-free dry material (which could be nonviable organic material) and somewhat lower chlorophyll a values. This happens at both channel and overbank stations. Even with these samples removed, however, the AI values generally increased to highest levels in 1982 and 1983.

Interestingly, the phaeophytin index (PI), a ratio of chlorophyll a to phaeophytin a, its major degradation product decreases steadily from 1975 (the first year it was calculated). In 1975 approximately 94 percent of the samples had PI values greater than or equal to 1.6, usually considered to indicate healthy, rapidly growing algal communities. The mean PI values continually decreased through the years reaching the lowest collective point in 1983 when only 42 percent of the samples had PI greater than or equal to 1.6. This suggest some factor, which was increasing in strength, may have been stressing the periphytic algal phytopigments throughout the study reach. This is particularly apparent for the 1982-1983 period, when corrected chlorophyll a concentrations were low and variable among stations and the amount of phaeophytin a was highest in proportion to the active pigment chlorophyll a.

The slight increase in BOD, TOC, and nitrogen concentrations between 1978 and 1982-1983 were the only discernable changes in the chemical parameters which could affect growth of the community and therefore the PI and AI. However, increases in nitrogen would tend to stimulate the growth of algae, increasing chlorophyll a concentrations and increasing the PI values. In a carbon-limited system, if present here, the increased levels of organic carbon should have a similar response as nitrogen. If the reservoir system is not carbon-limited, this increase in organic materials could be stimulating the heterotrophic portions of the periphyton. This in turn would cause increases in the AI values. The cause of this decline in algal "health" and the apparent increase in heterotrophism in the periphyton community is not discernable.

6.3 Summary and Conclusions

The periphyton community in the vicinity of BLN was sampled using artificial substrates during preoperational monitoring from 1974 through 1983. Between 1974 and 1978, only stations in the Tennessee River channel were sampled, TRM 388.0, 391.2, and 396.8. After the plant diffuser was redesigned, the potential for thermal or chemical plume influence on the left overbank was created. Because of this, the sampling protocol included stations on the left overbank, TRM 386.4, 388.4, 389.9, and 391.1 when it resumed in 1982. Samples were analyzed for genera present and cellular abundance of algal periphyton, as well as periphyton autotrophic indices, a ratio of ash-free dry material to active (excluding phaeophytin a) chlorophyll a.

During the six years of preoperational monitoring a total of 62 periphyton genera were found and included 26 chlorophytes, 26 chrysophytes, 7 cyanophytes, and 3 euglenophytes. Of the 62 genera found, 14 genera (9 chlorophytes, 3 chrysophytes, 1 cyanophyte, and 1 euglenophyte) occurred only in one collection month. Most of these 14 genera were planktonic forms which had become entangled in the filamentous periphytic algae.

The periphyton communities throughout the study period had 10 genera which were the dominant taxa, accounting for 19.8 to 91.9 percent of the total abundance in any sample. Several were dominant in only one or two sample sets, Spirogyra (1), Staurastrum (1), Navicula (1), Oscillatoria (1), and Synedra (2). The chrysophytes Gomphonema, Melosira, and Cocconeis were dominant in 4, 5, and 22 sample sets, respectively. Stigeoclonium, a rheophilic filamentous chlorophyte, was predominant in 46 sample sets and Achnanthes, a rheophilic chrysophyte, was the most numerous genus in 58 sample sets. Of the two latter genera, Achnanthes was predominant in 51 percent of the samples from 1974-1978 and Stigeoclonium in 21 percent. This reversed in 1982 and 1983 when Stigeoclonium was most numerous in 48 percent of the sample sets and Achnanthes in 28 percent.

At the channel stations there was a general increase in numbers of genera from 1974 to 1978 then a decline in 1982 and 1983 to levels similar to 1974-1975. The number of taxa at channel stations ranged from 5 in June and August 1982 at TRM 396.8 and June 1983 at TRM 391.2 to 24 in September 1978 at TRM 396.8. Overbank stations had the minimum number of taxa, 5, at TRMs 386.4 and 389.9 in June 1982 and the maximum number, 17, at TRM 389.9 in August 1983.

When compared using SQS, the community structure at channel stations was similar in a minimum of 68 percent of the sample sets where comparisons were possible in 1976 to a maximum of 100 percent of the sample sets in 1977 and 1983. When both taxa and abundance were considered (PS), the frequency of similarity was lower ranging from 25 percent in 1983 to 88 percent in 1974. In these comparisons the uppermost channel station, TRM 396.8, was frequently dissimilar to the other channel stations according to the PS index but this was not so when only taxa were considered indicating similar genera, but differing cell abundances. As with channel stations, a high percentage of overbank stations had similar genera composition (81 percent in 1982, 95 percent in 1983) but differing total abundances. This also held true when channel and overbank community structure was compared again indicating similar taxa but different abundances.

Diversities at both channel and overbank stations were usually high in April (occasionally May), decreased to a low in June and then increased again through August or September. Over all stations, the diversities were highest during 1976 and lowest in 1974. The diversity index values for channel stations ranged from 0.80 in July 1974 to 2.99 in September 1976 while diversity index values for overbank stations ranged from 0.57 in April 1983 to 3.17 in April 1982.

Channel stations had chrysophytes as the dominant group during 1974-1976, with Cocconeis and Achnanthes the predominant forms. Beginning in 1977 and continuing through 1983, chrysophytes dominated early in the year, in June chlorophytes began to dominate at some stations and both groups were intermittently dominant for the remainder of the year. When chrysophytes were dominant, Achnanthes was usually the most predominant diatom, while Stigeoclonium was the predominant chlorophyte taxa when chlorophytes were dominant. Only once, May 1983 at TRM 391.2, were bluegreens (cyanophytes) numerically abundant enough to predominate. However, the dominant taxa for this sample set was Stigeoclonium. Overbank stations exhibited similar percentage composition changes as channel stations except that chlorophytes were predominant at all overbank stations in April 1983 and cyanophytes were never the predominant group.

Abundance data were pooled, either by combining years or stations analyzed statistically and several facts were elucidated. When years were combined, the total abundance at TRM 388.0 and 396.8 were similar and highest, TRM 391.2 had different densities which were somewhat lower. All channel stations had significantly higher abundances than overbank stations with TRM 388.4 having lowest abundances and being significantly different from other overbank stations. Chrysophytes began the sampling year with high numbers which decreased through the year while the opposite was true for chlorophytes. When stations were combined, total abundances were highest and were similar in 1977 and 1978, whereas abundances for 1982 and 1983 were similar and significantly lower than 1977-1978. The remaining years 1976, 1975, and 1974 had decreasing abundances, respectively, and were significantly different. The abundances were usually highest in June and lowest in September or October.

Abundance data for each month were also statistically analyzed individually. There were no consistent trends for either overbank or channel stations, except that channel stations were similar each July when sufficient replicates were present to run statistical analyses, July 1974, 1976-1978.

Abundance data did not correlate with most of the water chemistry data. There were weak inverse correlations with pH and dissolved oxygen and fairly strong direct correlation with the concentrations of ammonia nitrogen. There were stronger relationships with flow, with highest abundances in years of lowest flow and vice versa. There was also a relationship with solar irradiation where years of highest total abundances (1977-1978) were also years of longer period of high levels of solar irradiation.

Results of one-way ANOVA's on the autotrophic index data showed that the channel stations: (1) were not significantly different in 58 percent of the months, (2) were all significantly different in two months (six percent), and (3) in the remainder two stations were similar but different from the third channel station. When channel and overbank stations were compared, 50 percent of the months were not significantly different. The other half of the sample months had varying results, but usually some overbank and some channel stations were similar.

The corrected chlorophyll a (CCA) was lowest in 1982 samples and highest in 1978 samples for channel stations. Overbank stations had highest and lowest CCA values in 1983. There were no consistent periodic trends for the CCA but this parameter, except for 1974, did exhibit a strong direct relationship with total abundance. The phaeophytin index (PI), the ratio of active chlorophyll a to its degradation product, phaeophytin a, was highest in 1975 indicating healthy algal populations. The PI declined steadily from 1975, the first calculated, to the lowest values for the study in 1983.

Ash-free dry weight data did have more consistent trends. Values were usually lowest early in the year (April-June) then higher the remainder of the year. The AFDW data for the channel stations was lowest in 1974 and 1982 and highest in 1976. The overbank stations had both highest and lowest AFDW data in 1982.

AI values for the channel stations were lowest in 1974, increased through 1976, declined in 1977 then continued to rise steeply for the remainder of the study. There was no logical correlation of this steep rise with any chemical data other than noting a general rise in the levels of TOC, organic nitrogen, and BOD_5 which may have given rise to the increased AI values.

Values for channel station AI's were usually higher early in the year then became inconsistent for the remainder of the year. The AI values for overbank stations were highest and lowest in 1983. Both 1982 and 1983 overbank AI values were generally similar to the channel stations, but exhibited no trends.

Through the monitoring period, periphyton abundance has exhibited a long term cycle with 1974 as the nadir and 1978 as the peak. Any comparison of abundances in the future with these must consider such apparent cycle. During this time, chlorophytes have occupied increasingly larger portions of the periphyton community and cyanophytes have only rarely been significant. Genera composing the periphyton assemblage at anytime were similar; however, there were differences in the abundances of these genera, usually with channel stations having more dense populations. Trends in chlorophyll levels were usually in good agreement with those of total abundances. However, there was a general increase through the years of phaeophytin _a_ levels. Autotrophic indices were very variable for each station through 1977, then began to increase through 1983. Reasons for this increase may be a shift toward more heterotrophic growth because of apparent increases in organic materials (suggested by increases in TOC and BOD_5). This too may be part of a reservoir cycle as was suggested for the total abundance. This possible cyclic nature in the ratio of periphytic autotrophs to heterotrophs should also be considered when future AI values are compared to these.

Overall, the periphyton community is relatively healthy, exhibiting typical densities, taxa, and abundances for this portion of the mainstream Tennessee River system.

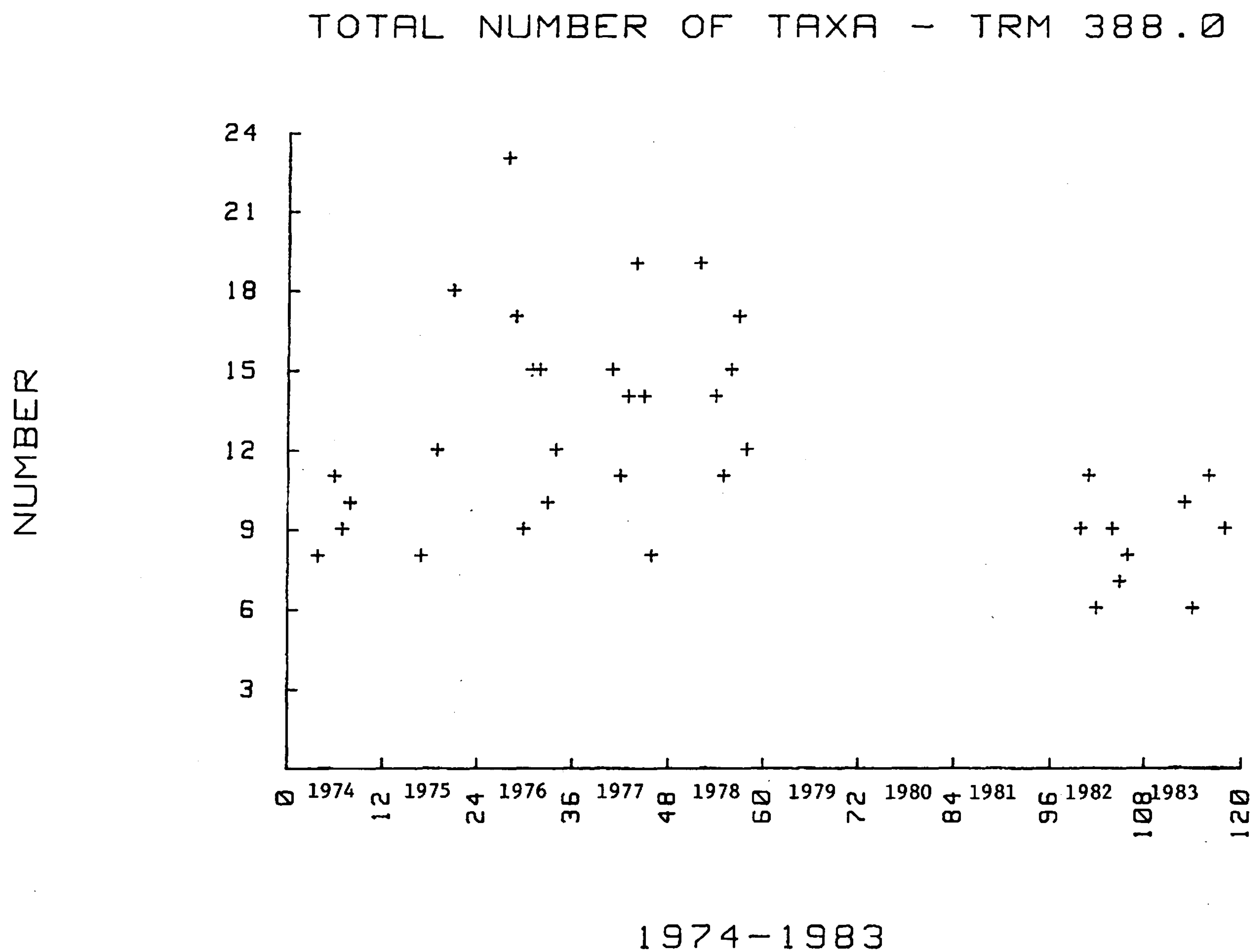


Figure 6-1. Total Number of Periphyton Taxa Collected at TRM 388.0 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

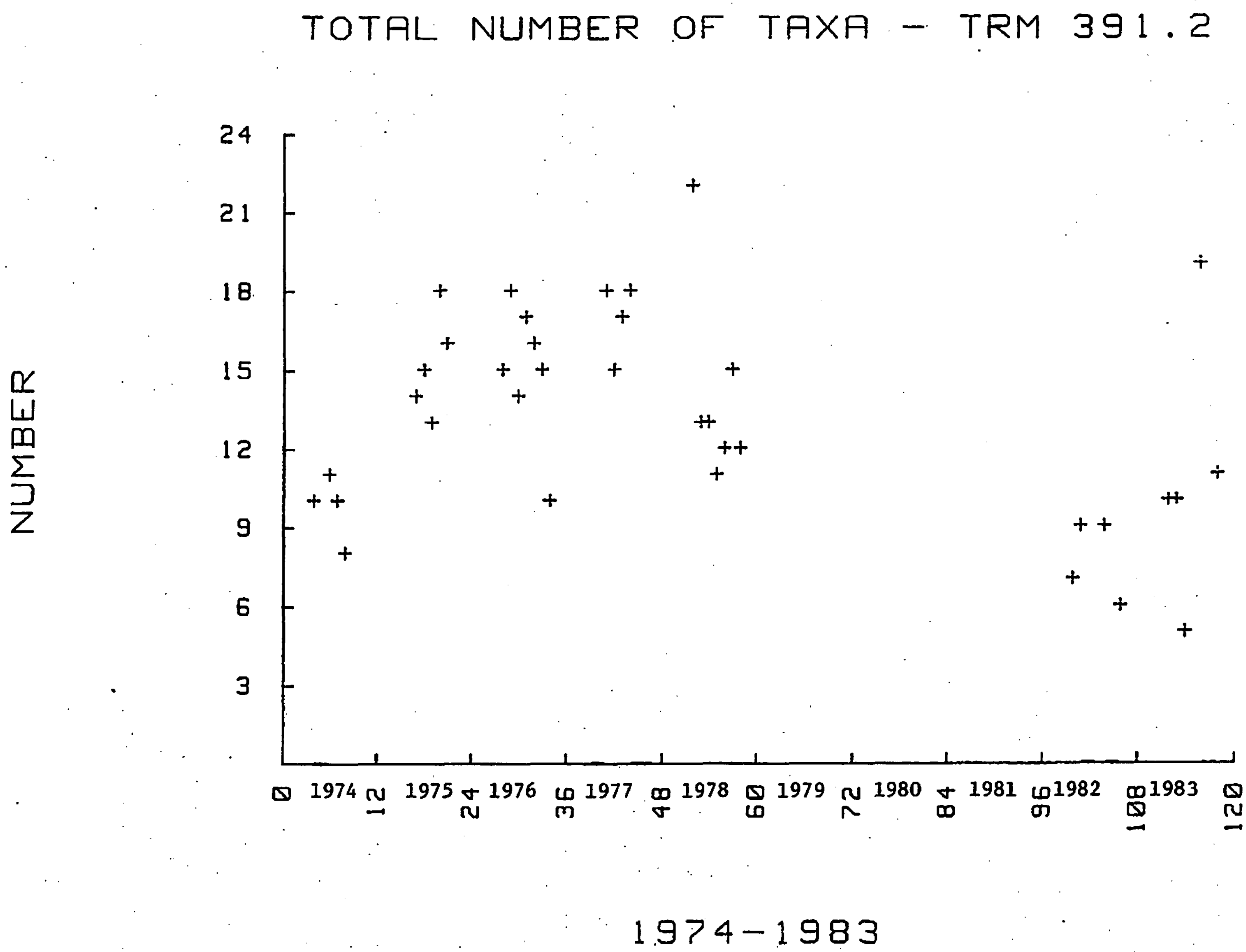


Figure 6-2 . Total Number of Periphyton Taxa Collected at TRM 391.2 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

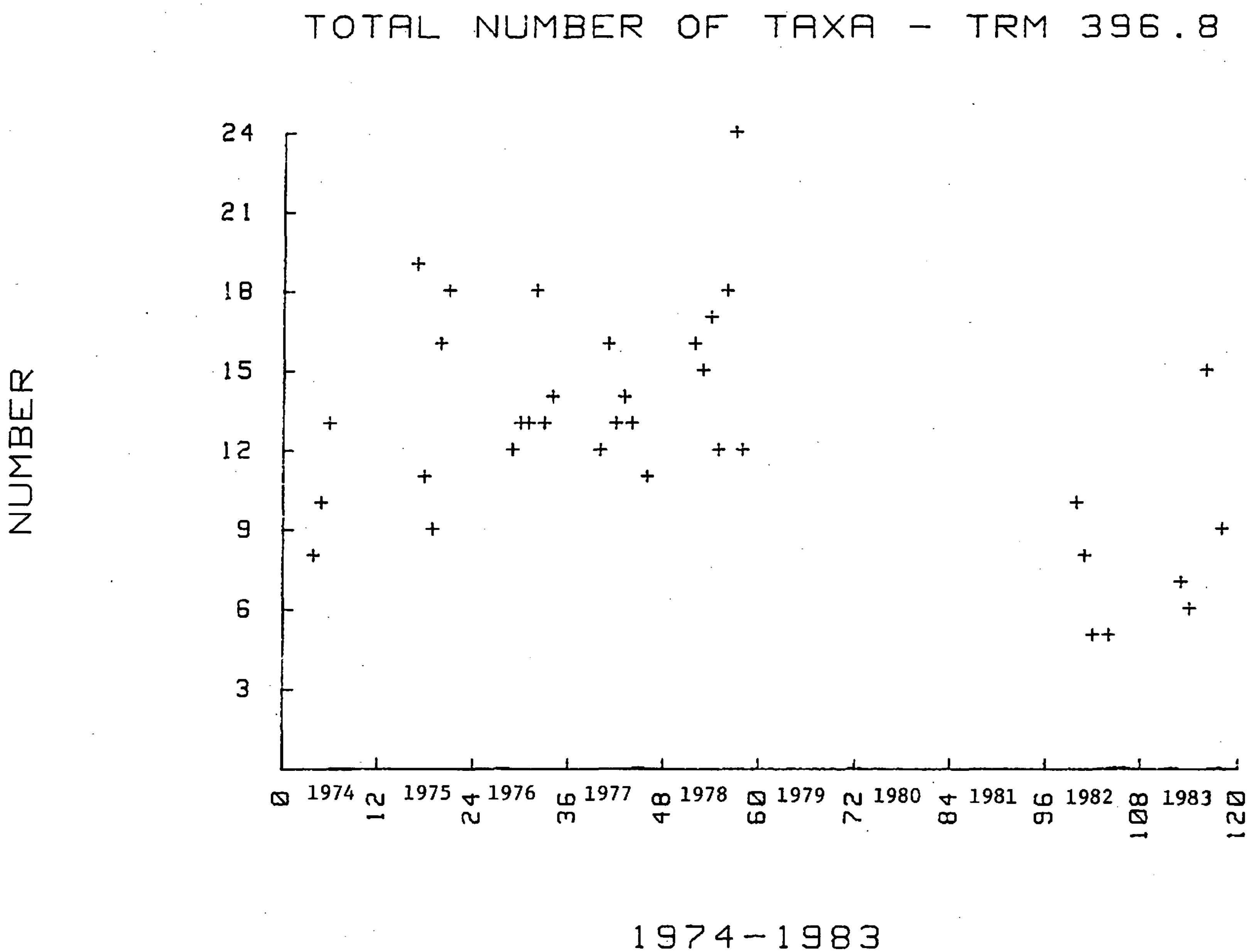


Figure 6-3 . Total Number of Periphyton Taxa Collected at TRM 396.8 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

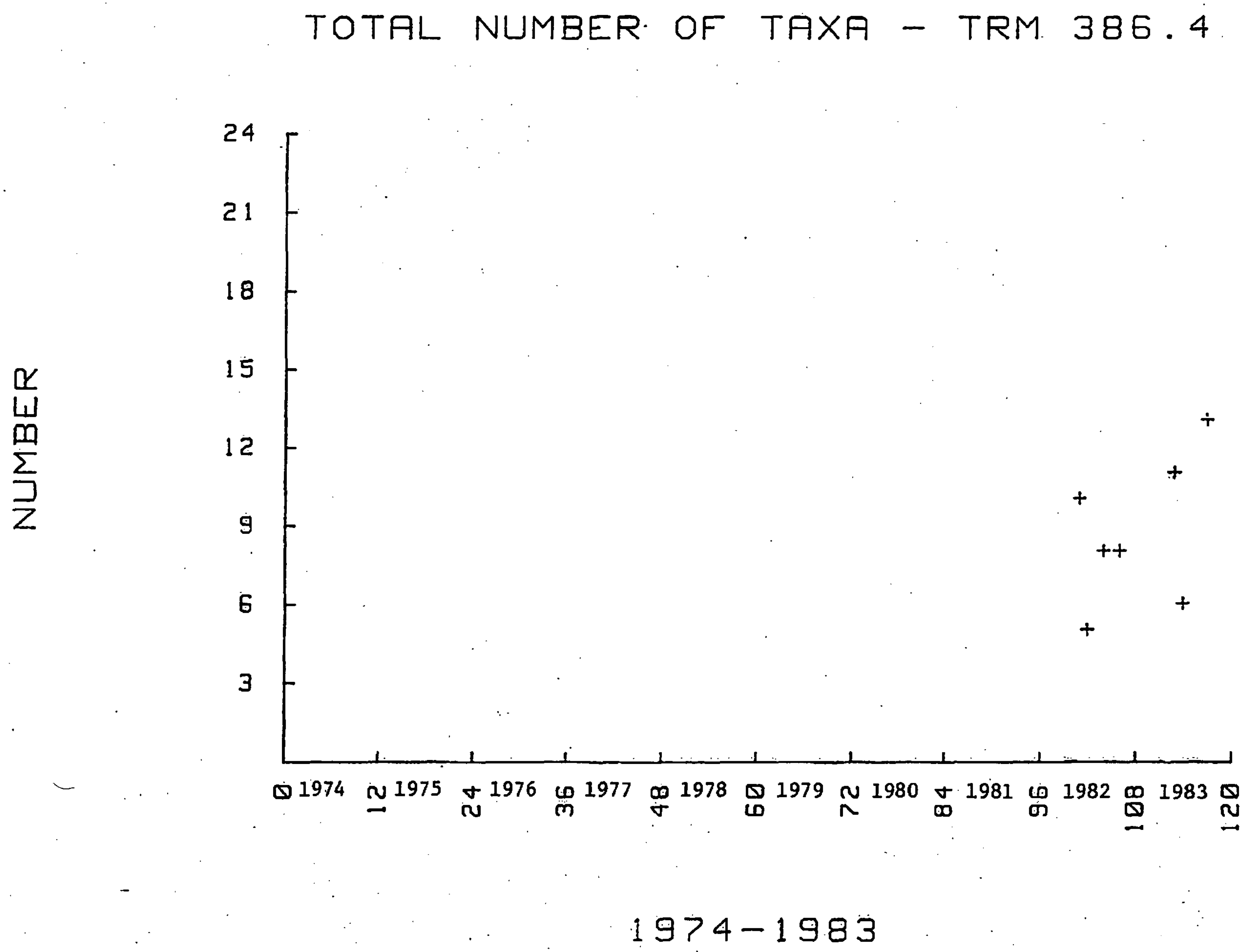


Figure 6-4 . Total Number of Periphyton Taxa Collected at TRM 386.4 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

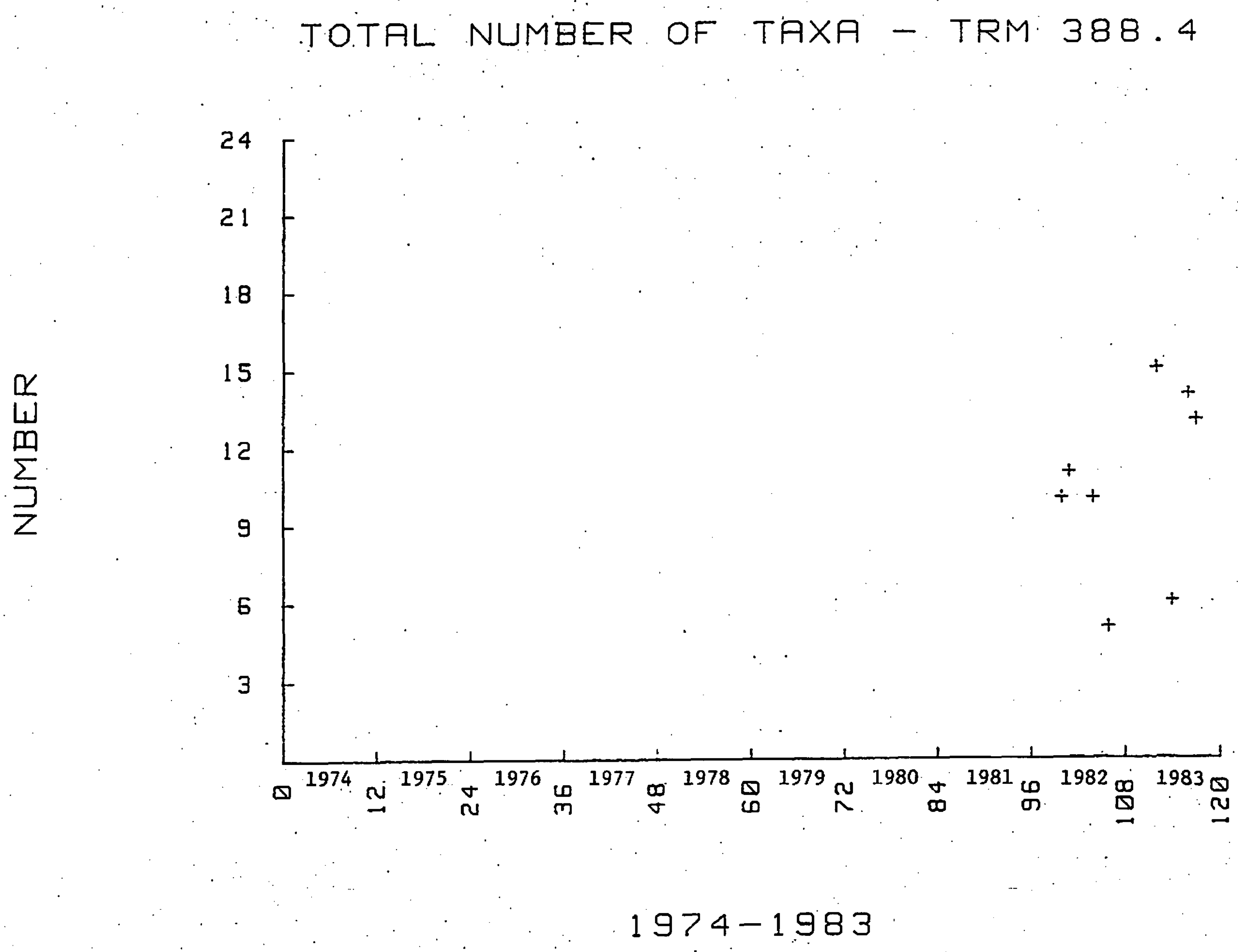


Figure 6-5 . Total Number of Periphyton Taxa Collected at TRM 388.4 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

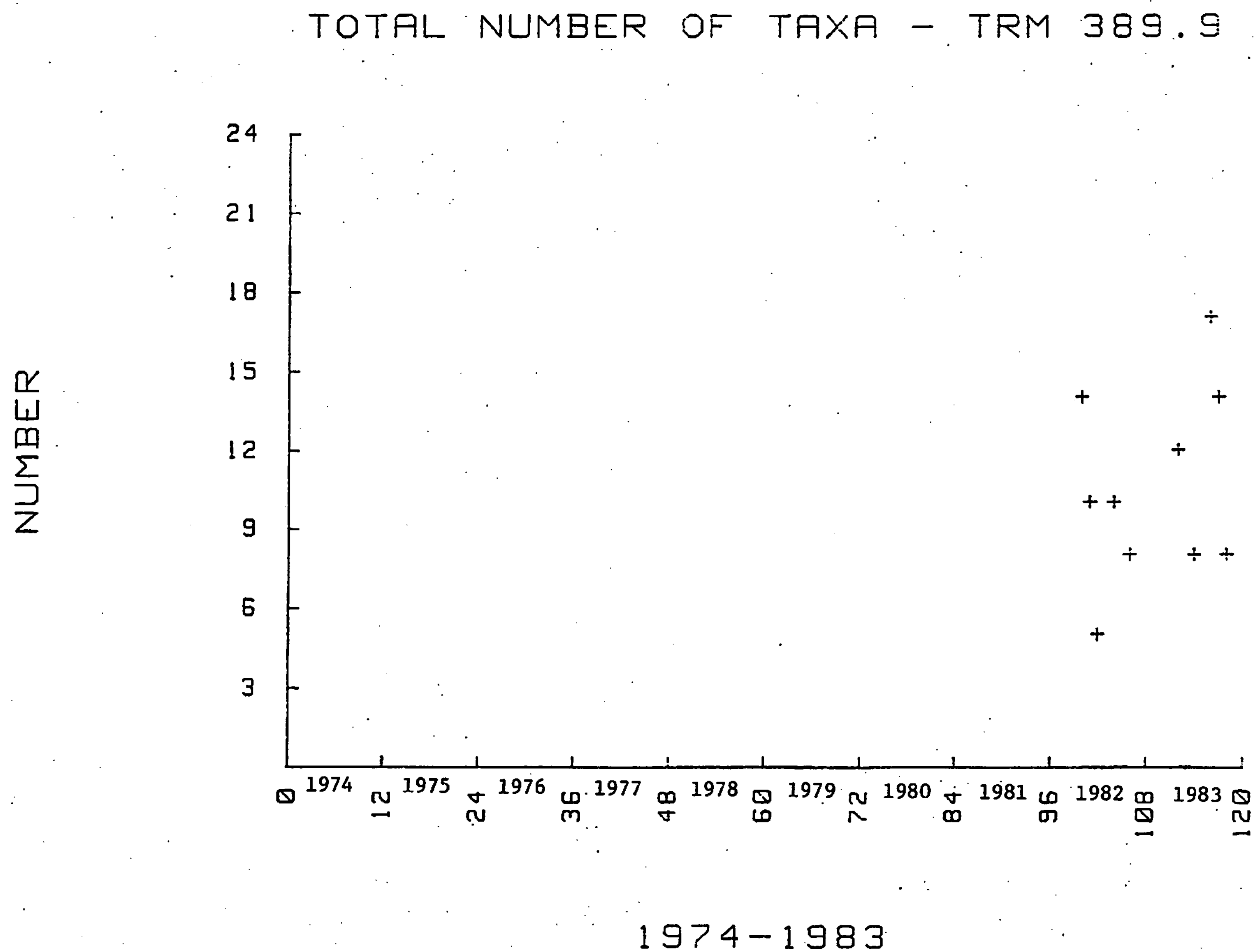


Figure 6-6 . Total Number of Periphyton Taxa Collected at TRM 389.9 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

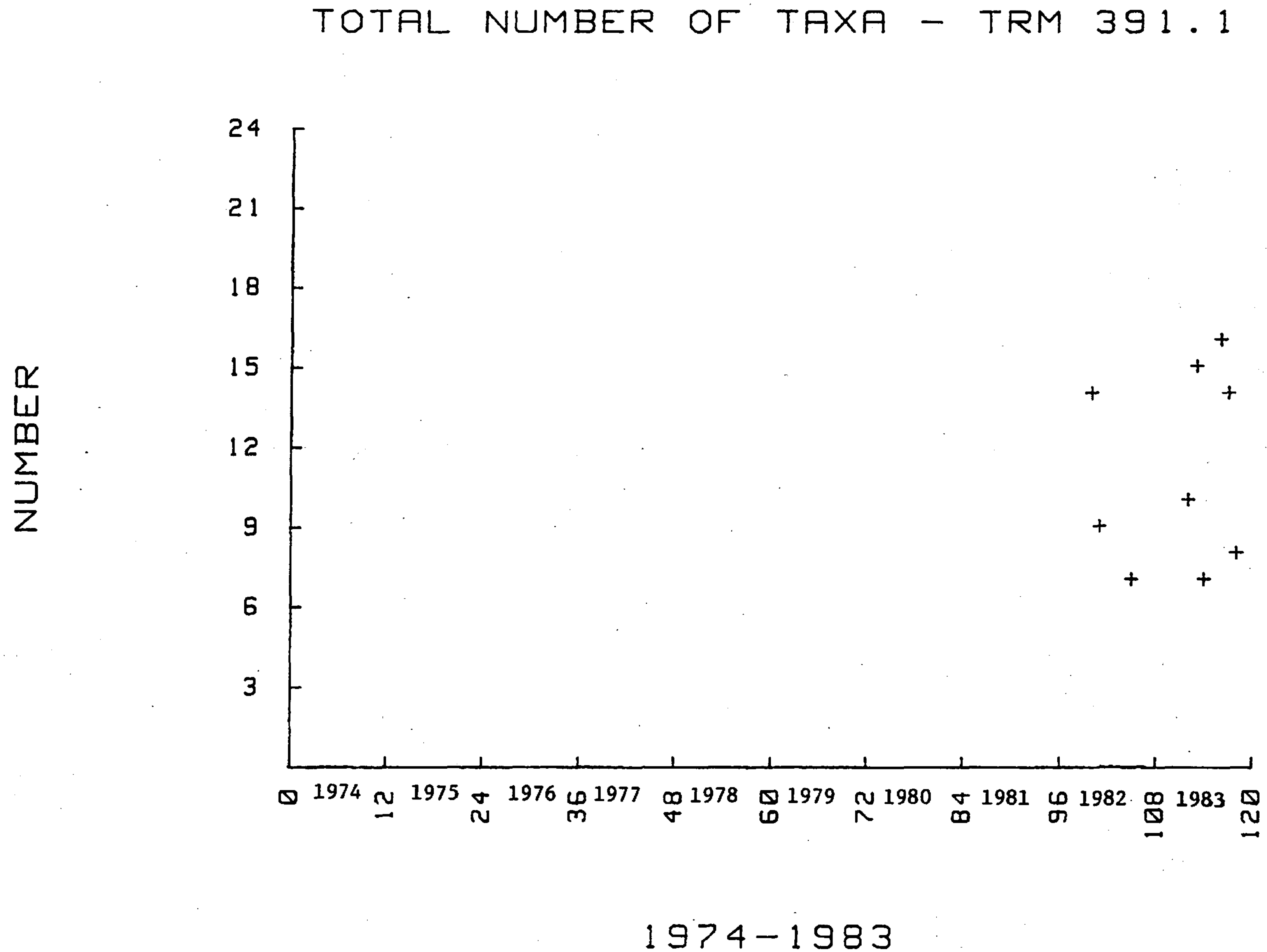


Figure 6-7 . Total Number of Periphyton Taxa Collected at TRM 391.1 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

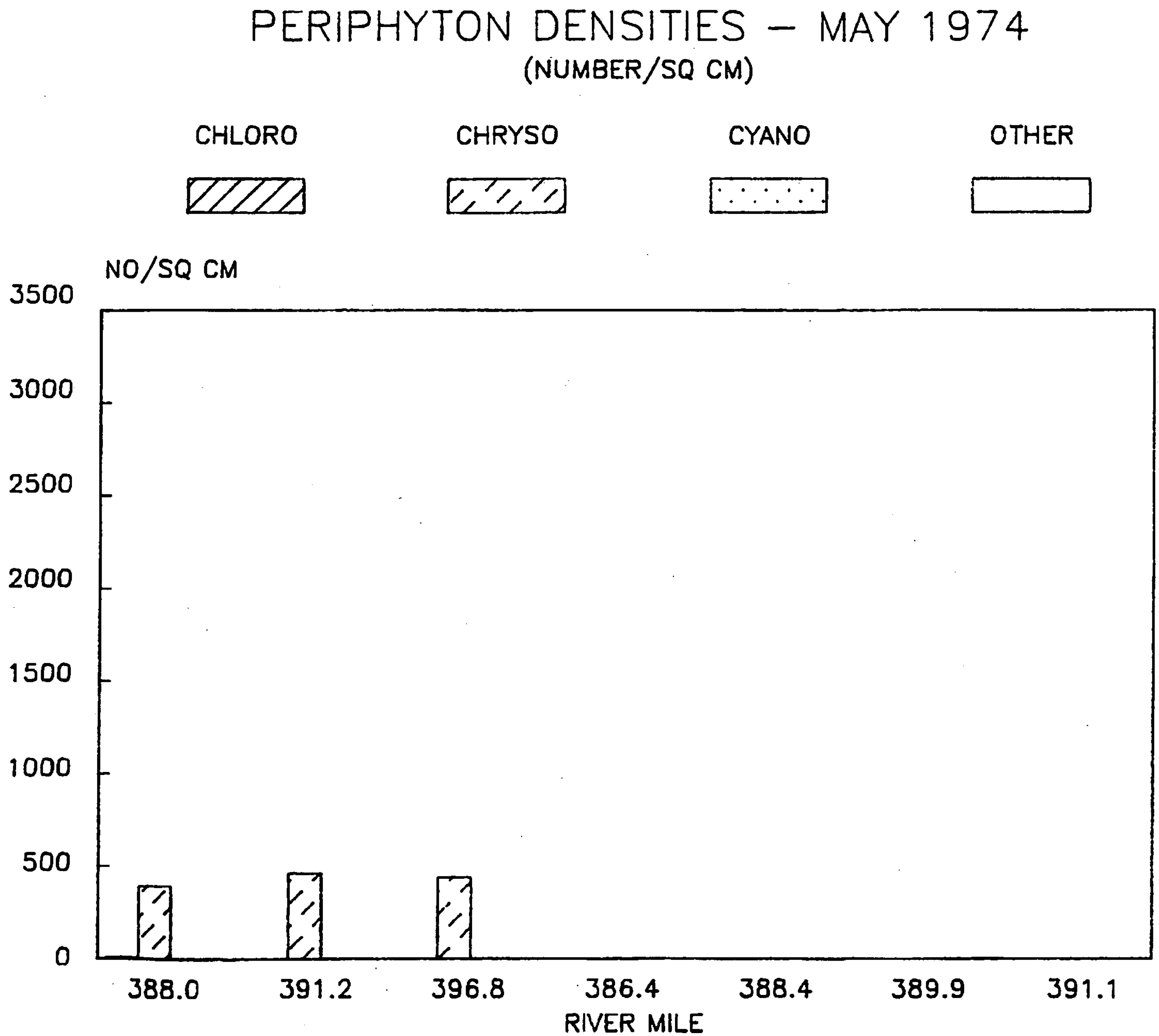


Figure 6-8. Periphyton Densities by Major Group Collected in May 1974 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

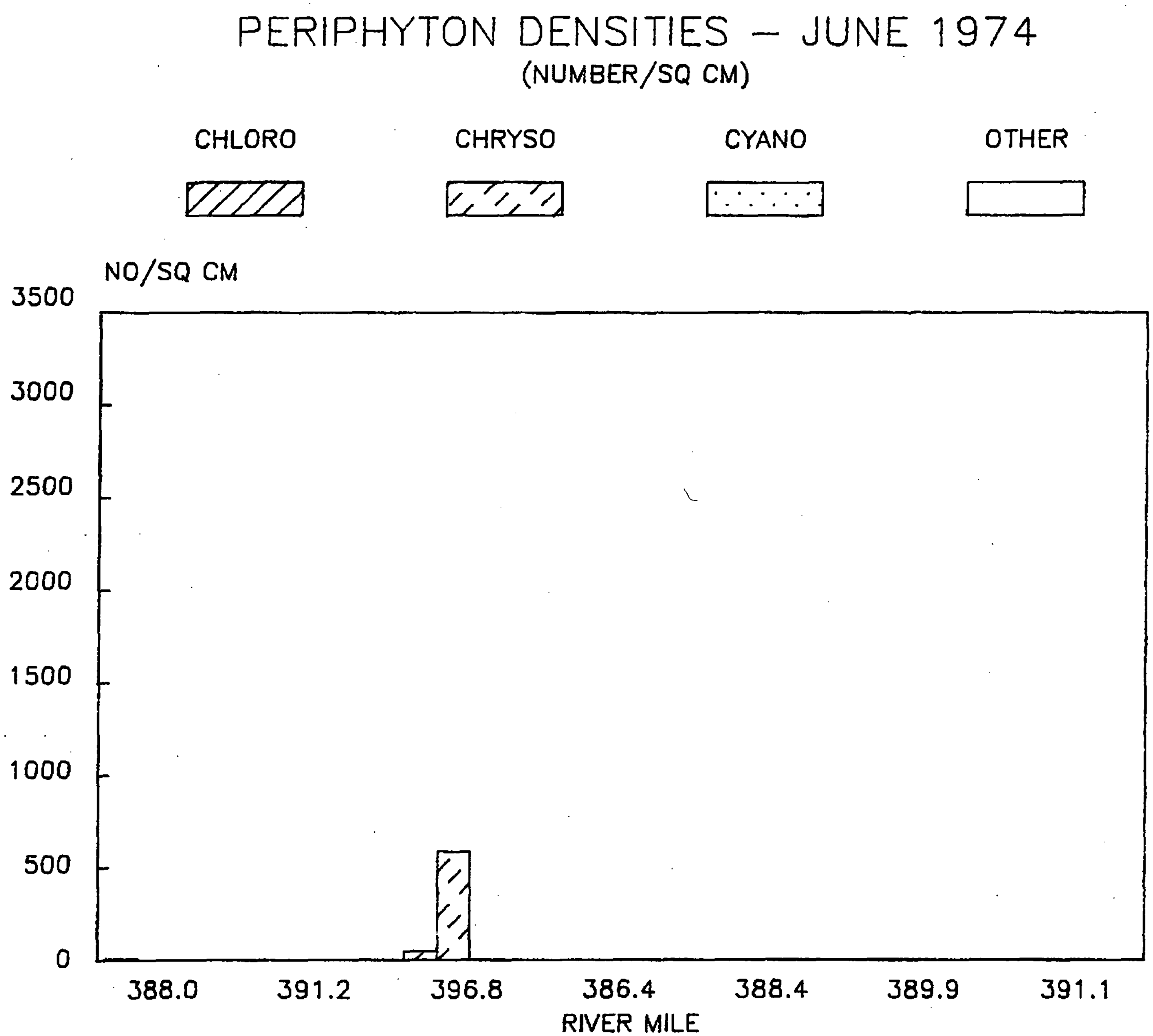


Figure 6-9. Periphyton Densities by Major Group Collected in June 1974 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

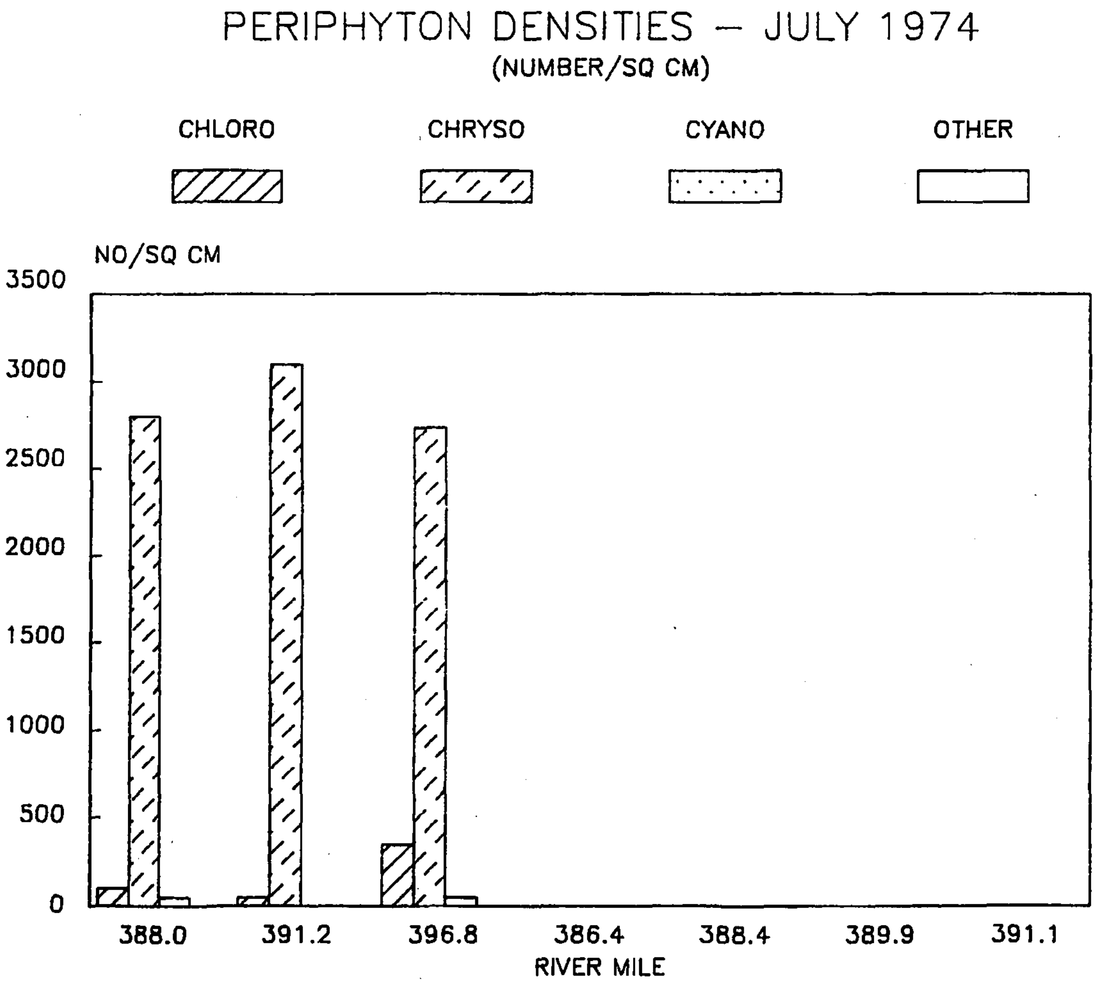


Figure 6-10. Periphyton Densities by Major Group Collected in July 1974 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

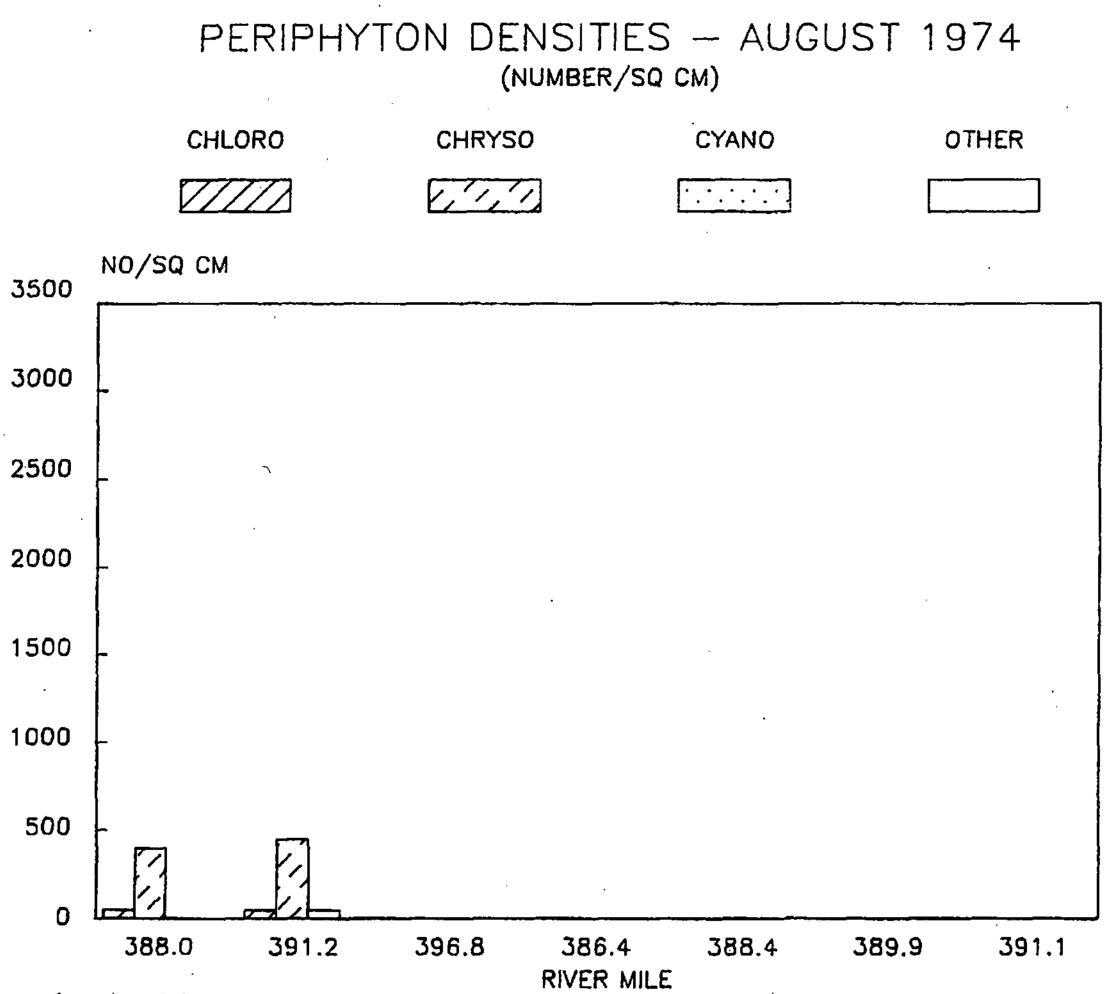


Figure 6-11. Periphyton Densities by Major Group Collected in August 1974 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

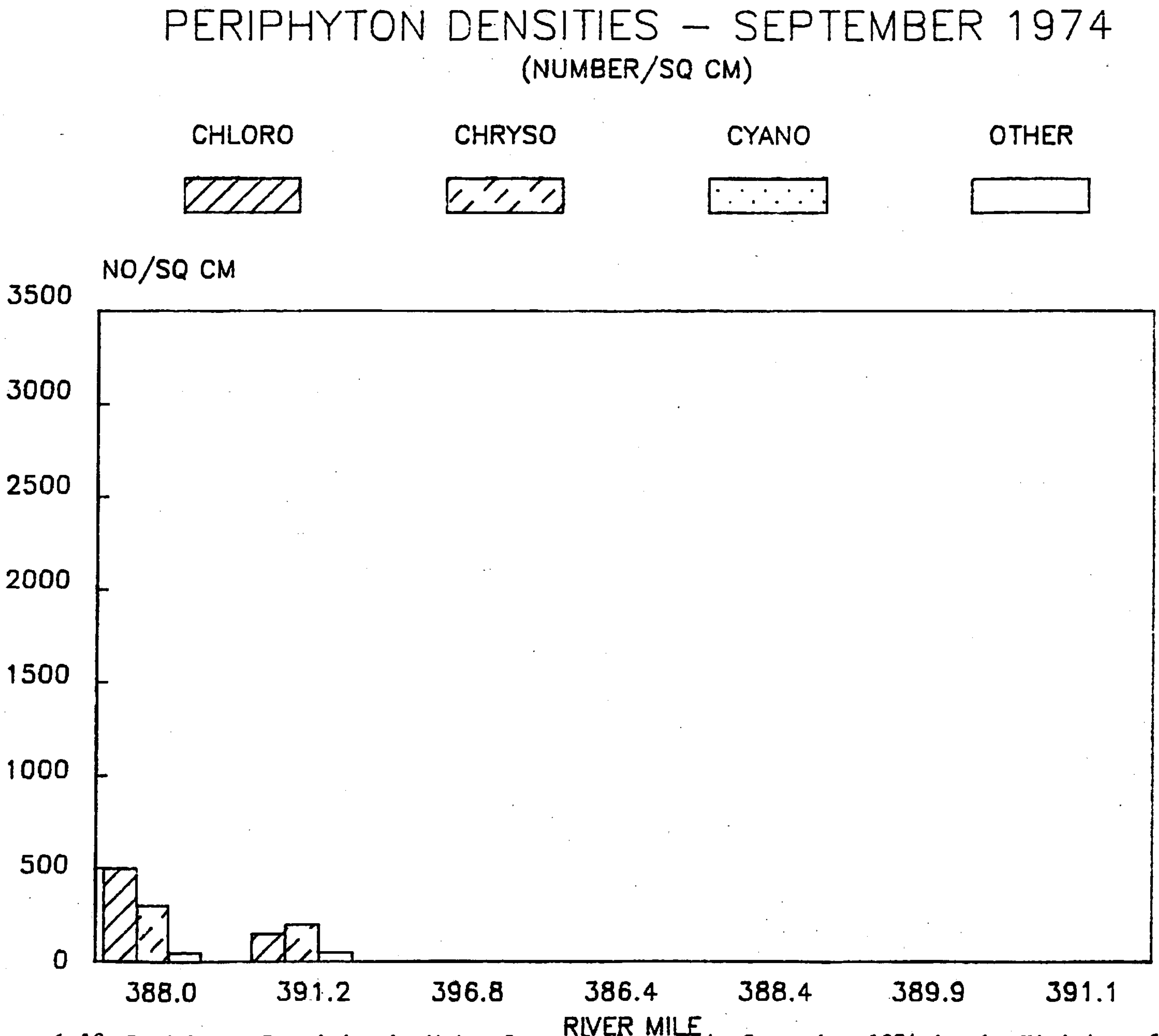


Figure 6-12. Periphyton Densities by Major Group Collected in September 1974 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

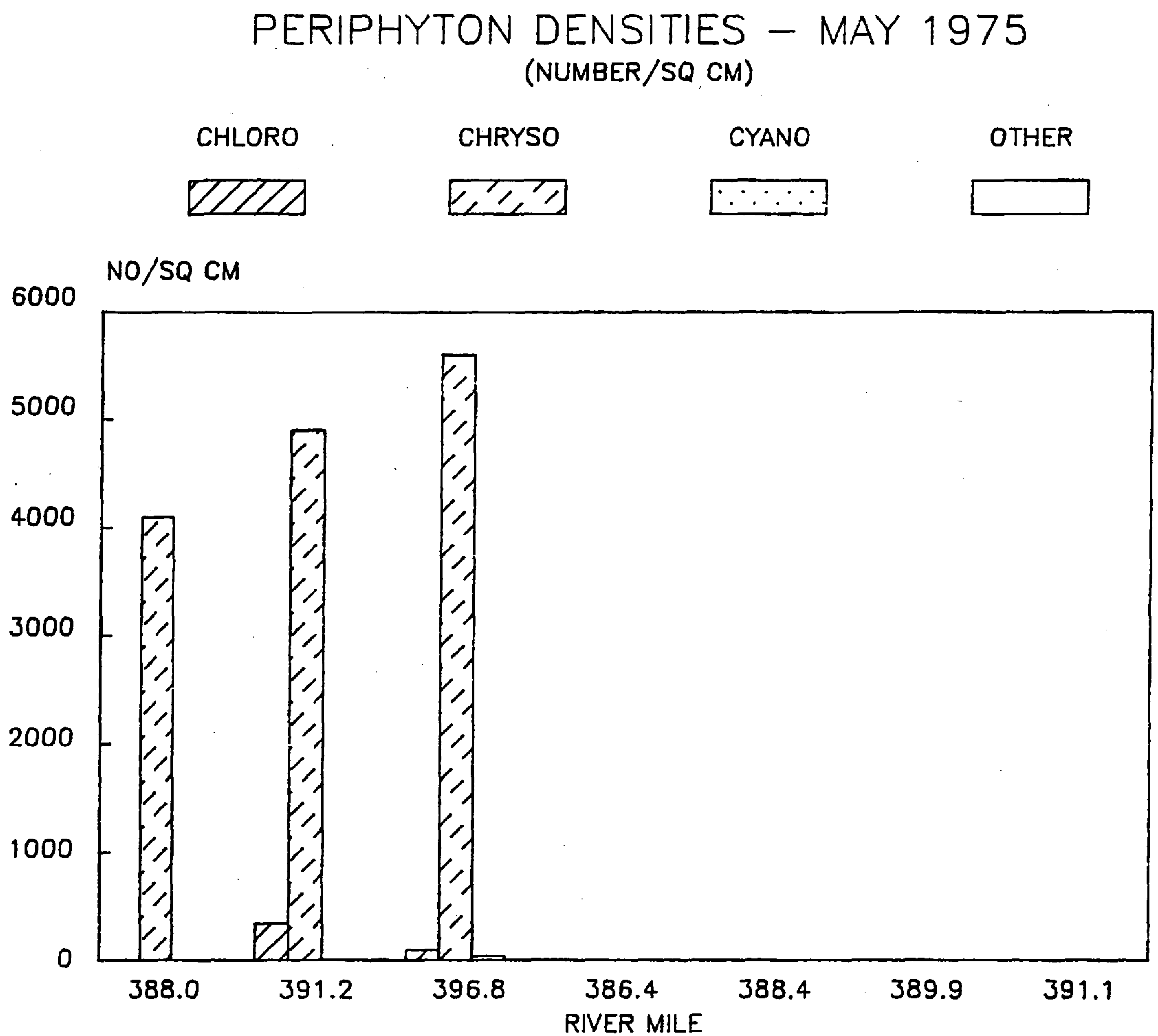


Figure 6-13. Periphyton Densities by Major Group Collected in May 1975 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

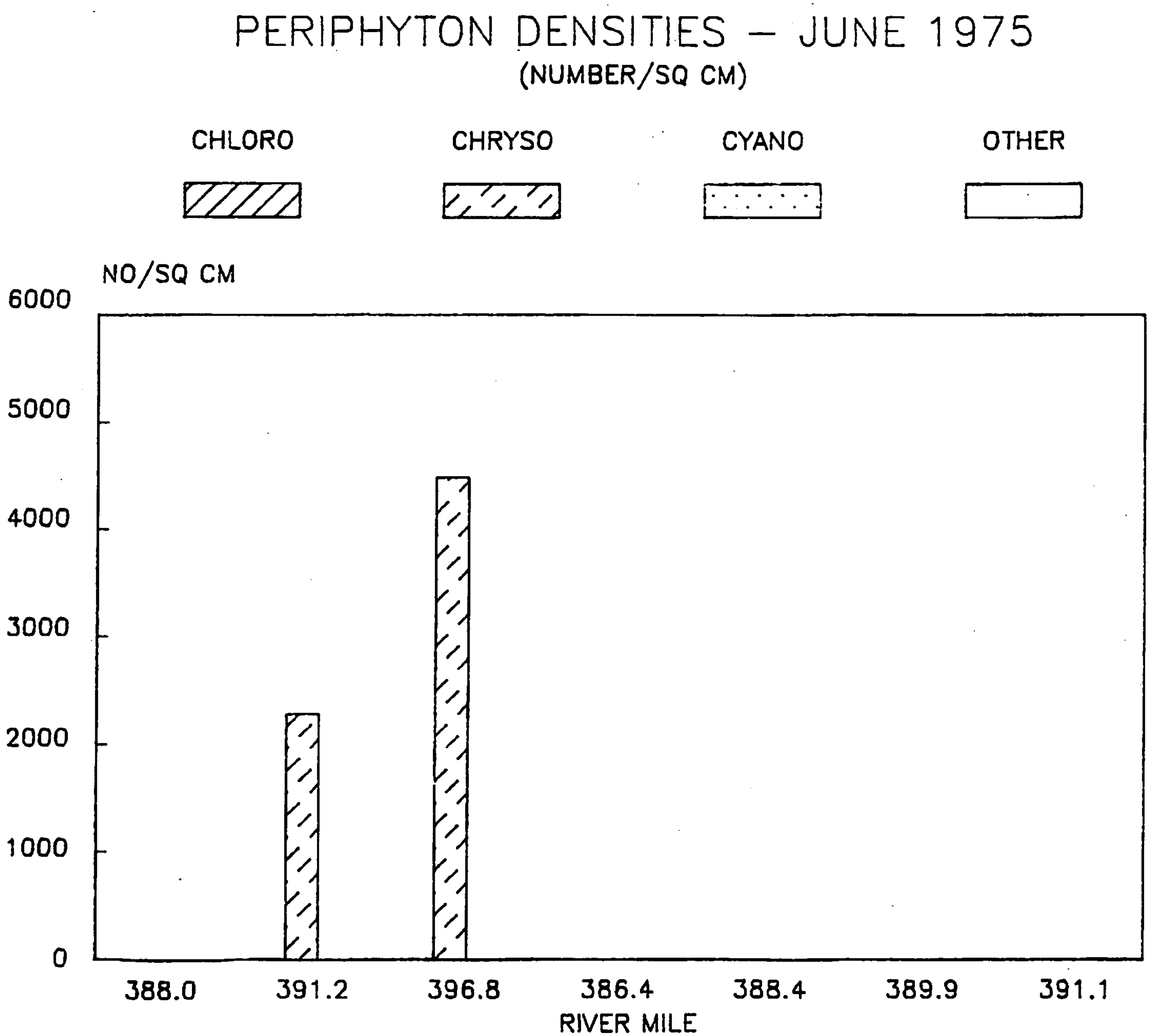


Figure 6-14. Periphyton Densities by Major Group Collected in June 1975 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

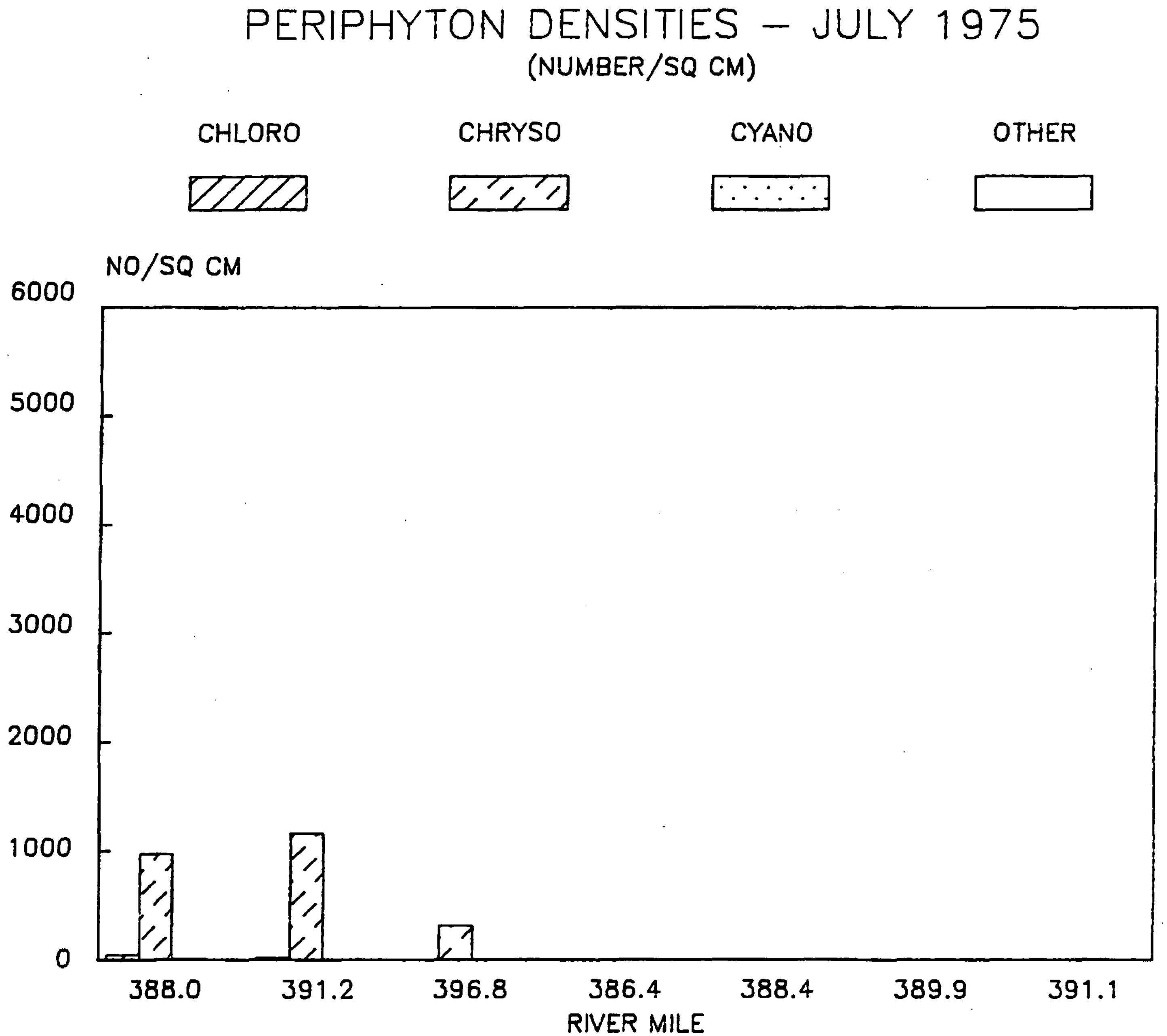


Figure 6-15. Periphyton Densities by Major Group Collected in July 1975 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

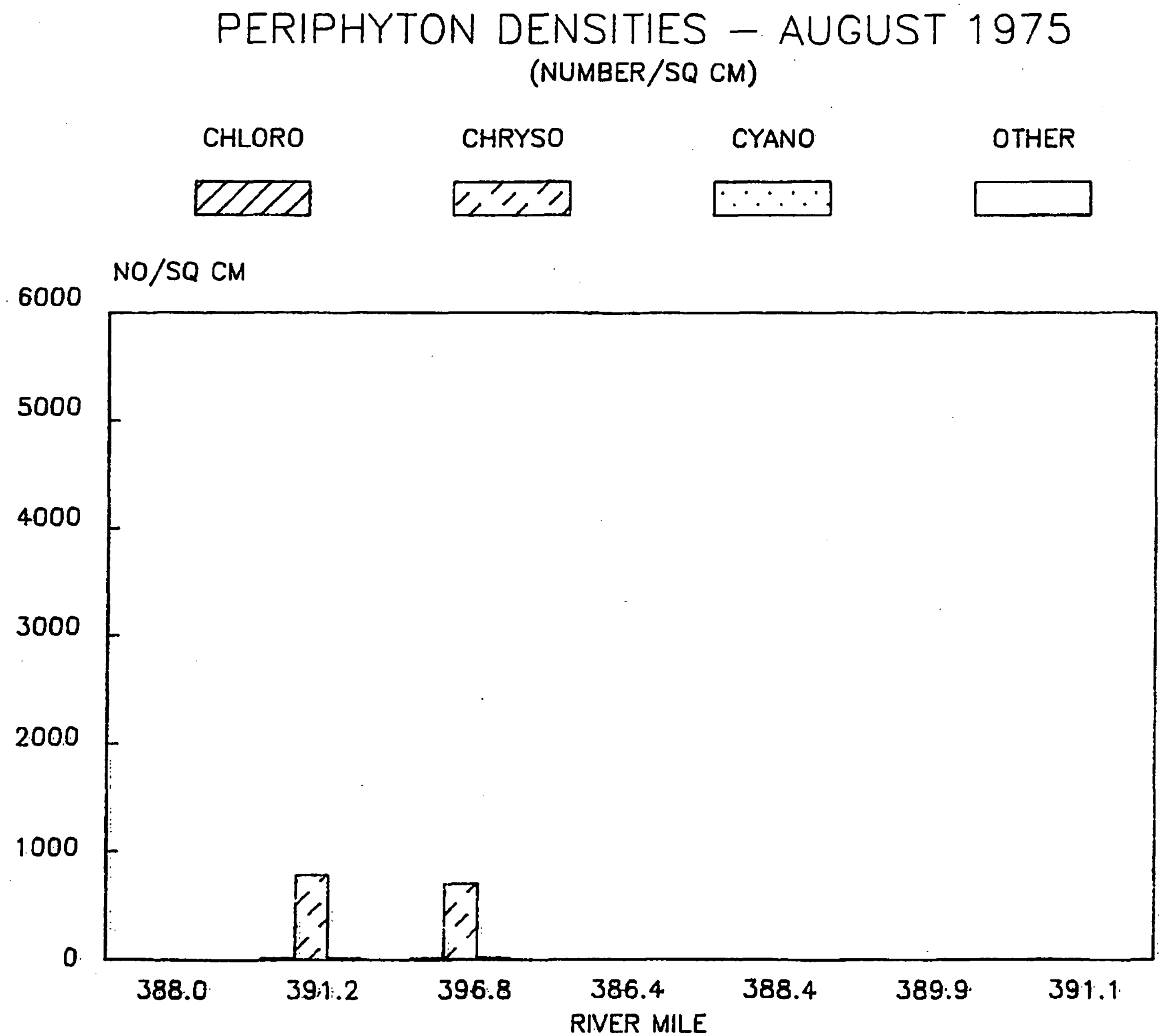


Figure 6-16. Periphyton Densities by Major Group Collected in August 1975 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

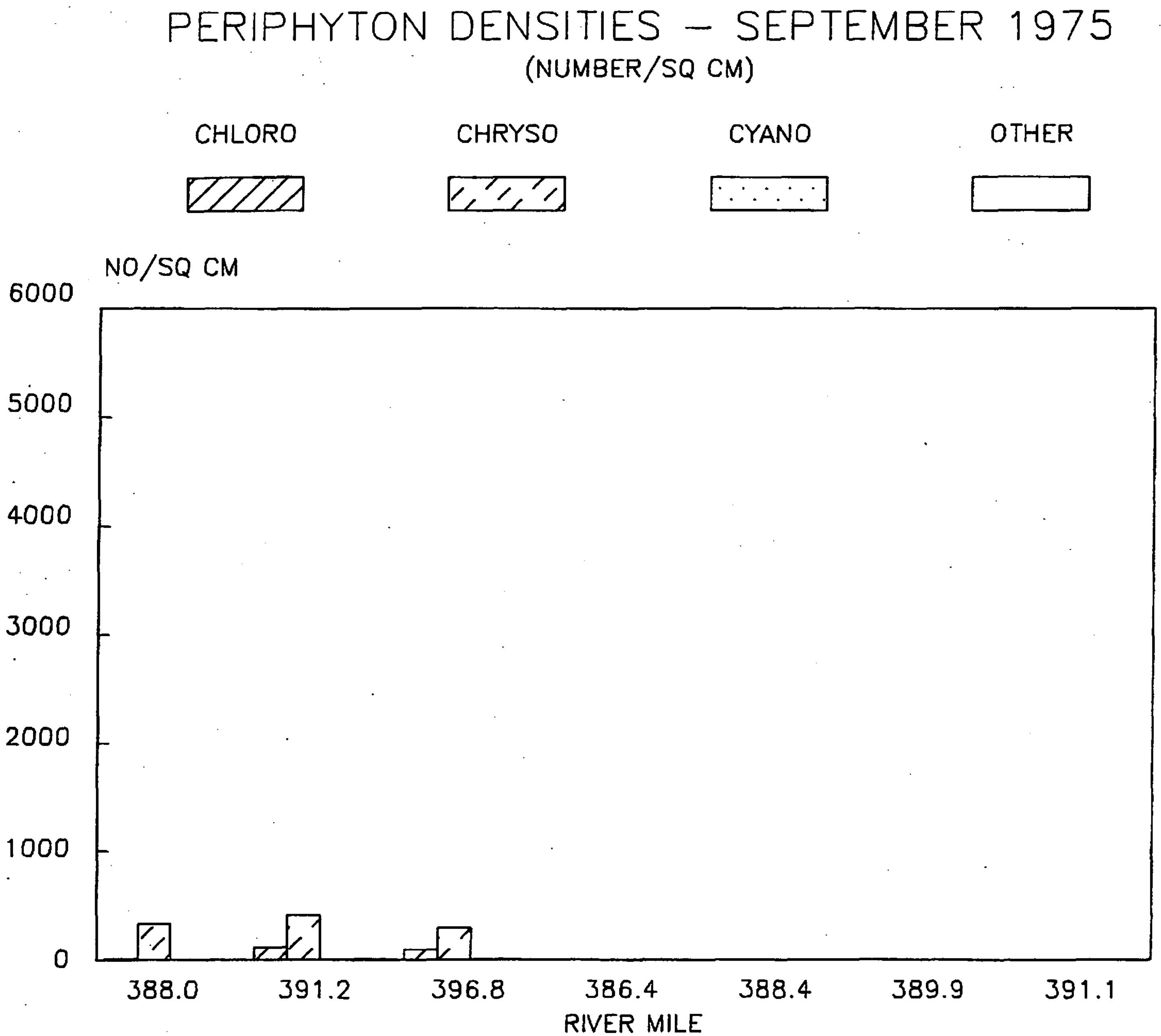


Figure 6-17. Periphyton Densities by Major Group Collected in September 1975 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

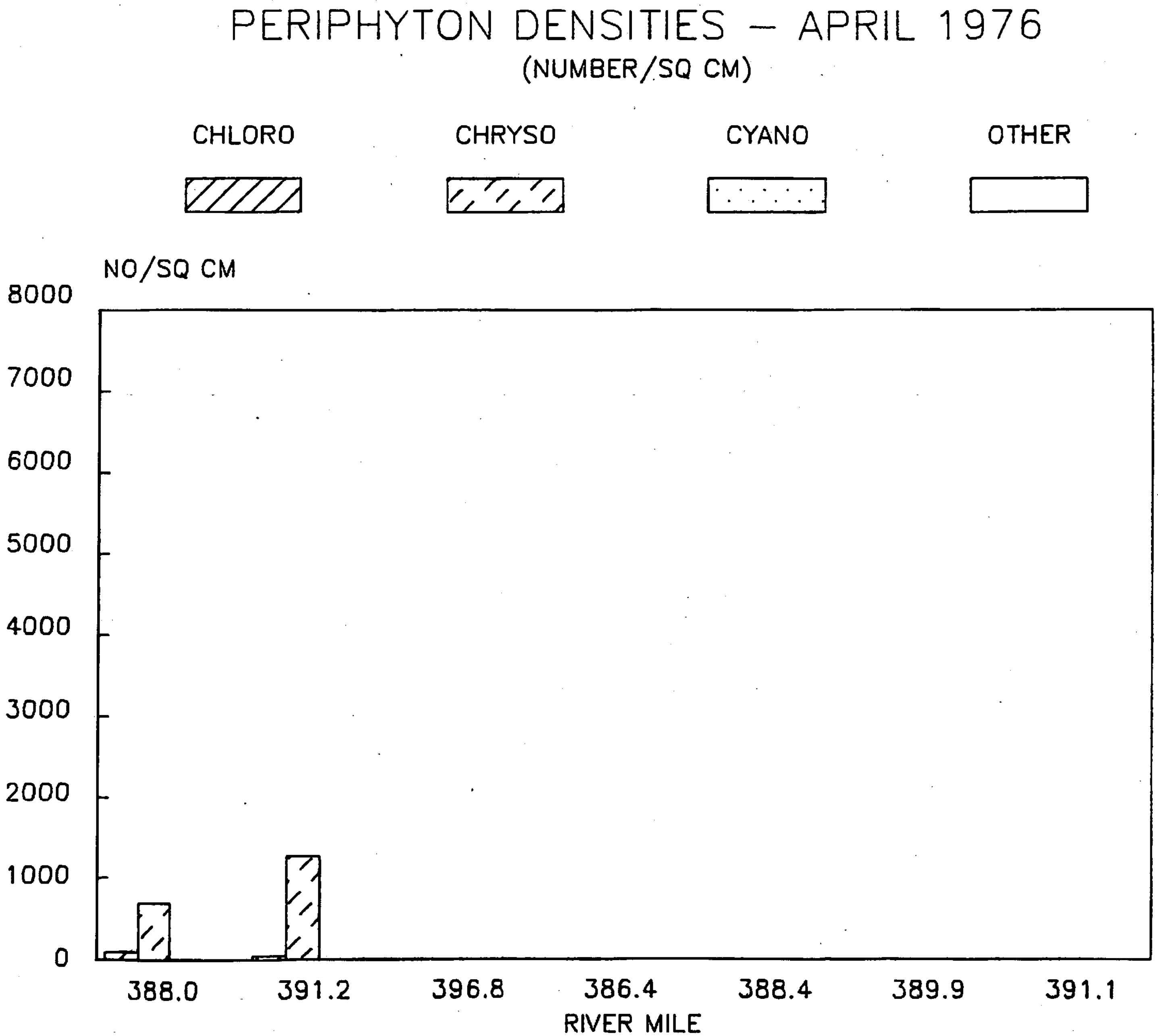


Figure 6-18. Periphyton Densities by Major Group Collected in April 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

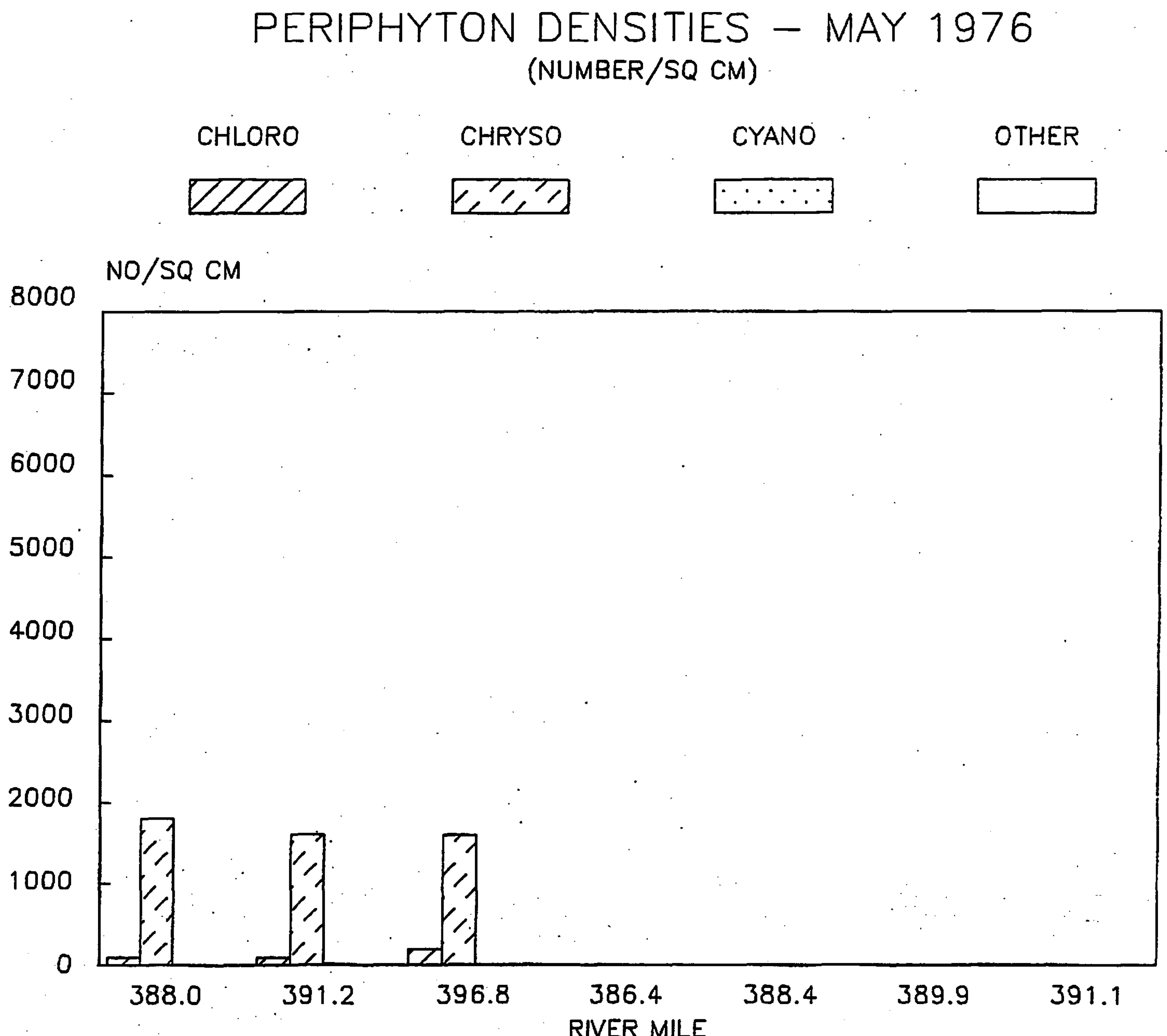


Figure 6-19. Periphyton Densities by Major Group Collected in May 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

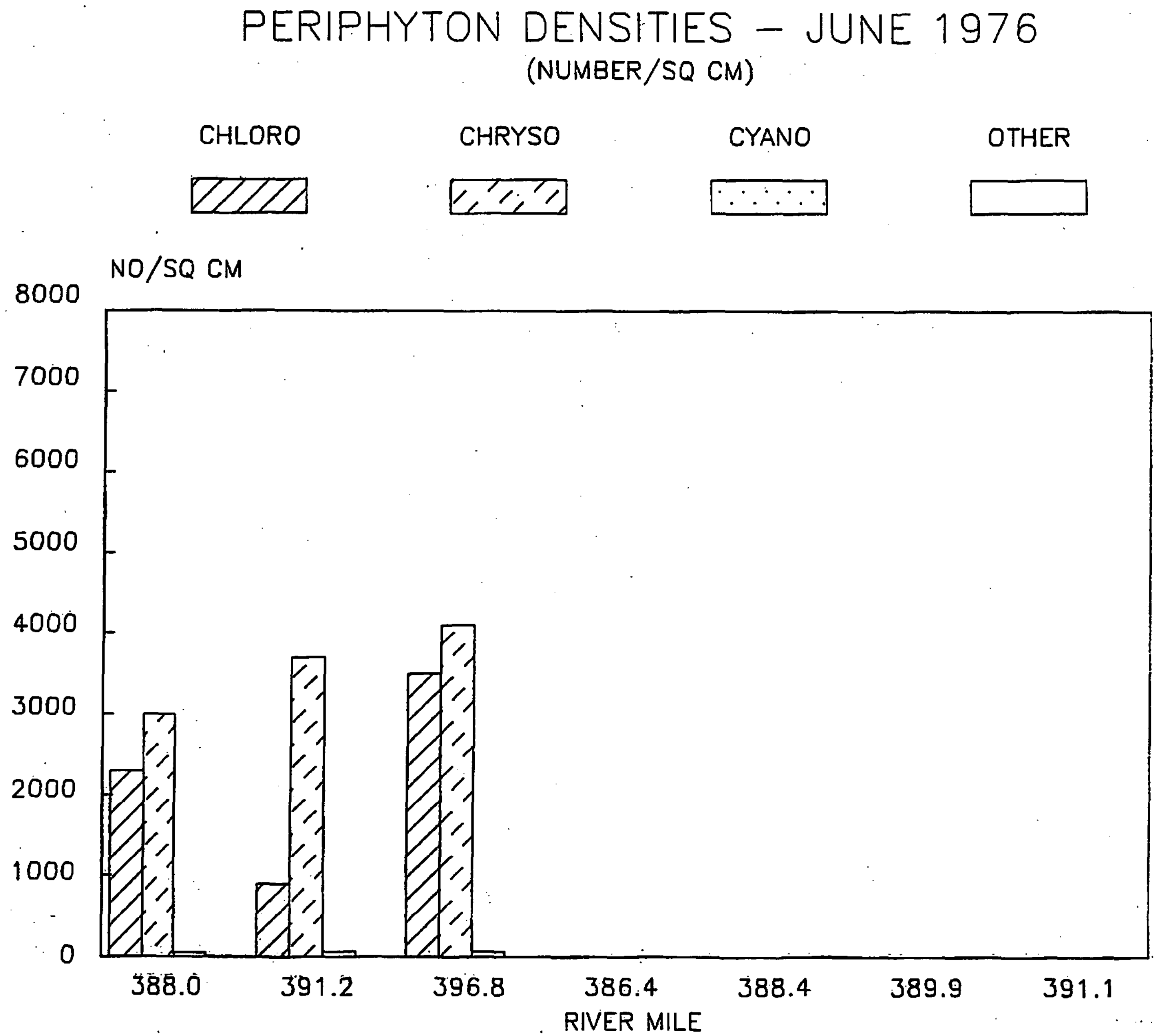


Figure 6-20. Periphyton Densities by Major Group Collected in June 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

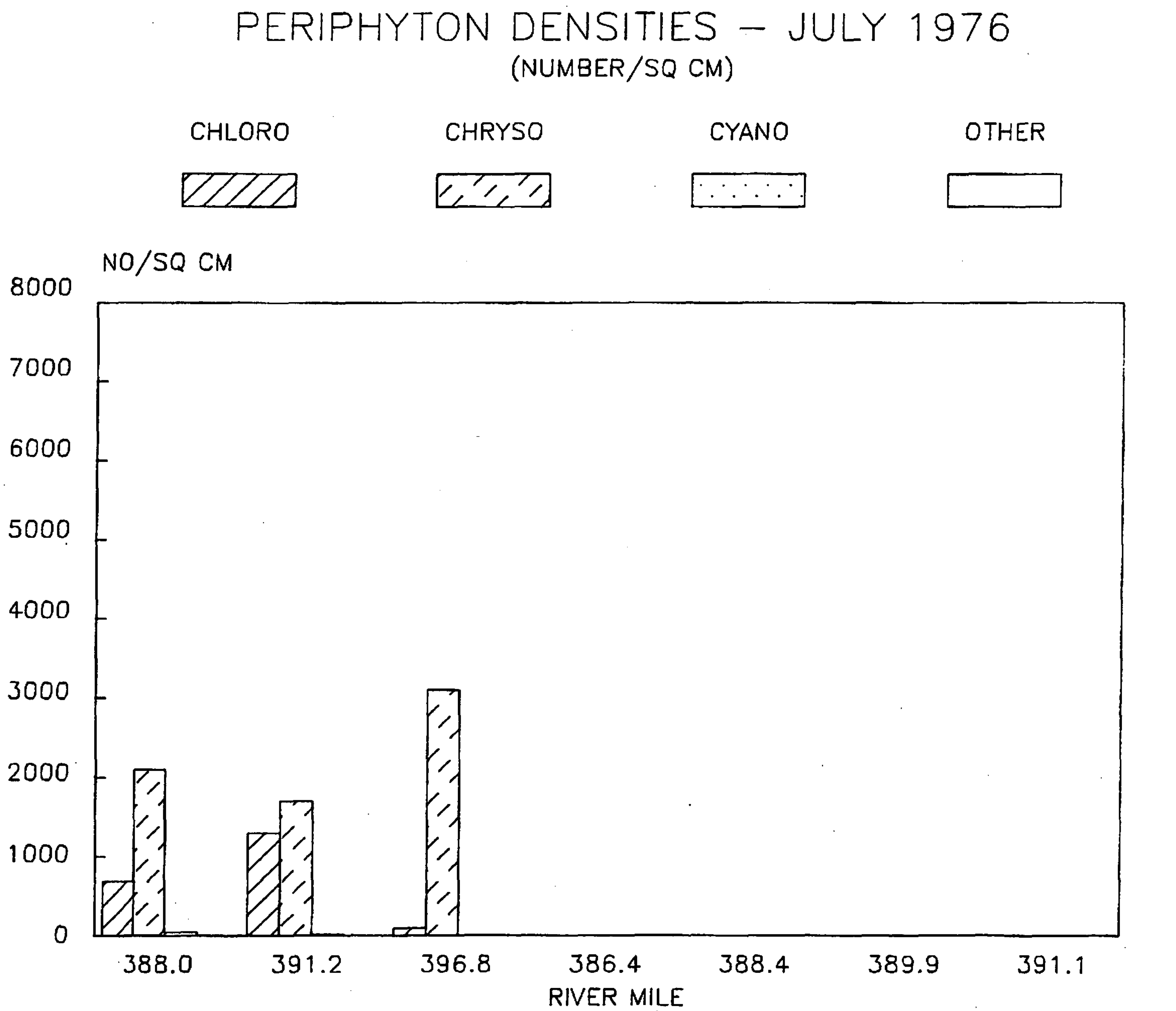


Figure 6-21. Periphyton Densities by Major Group Collected in July 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

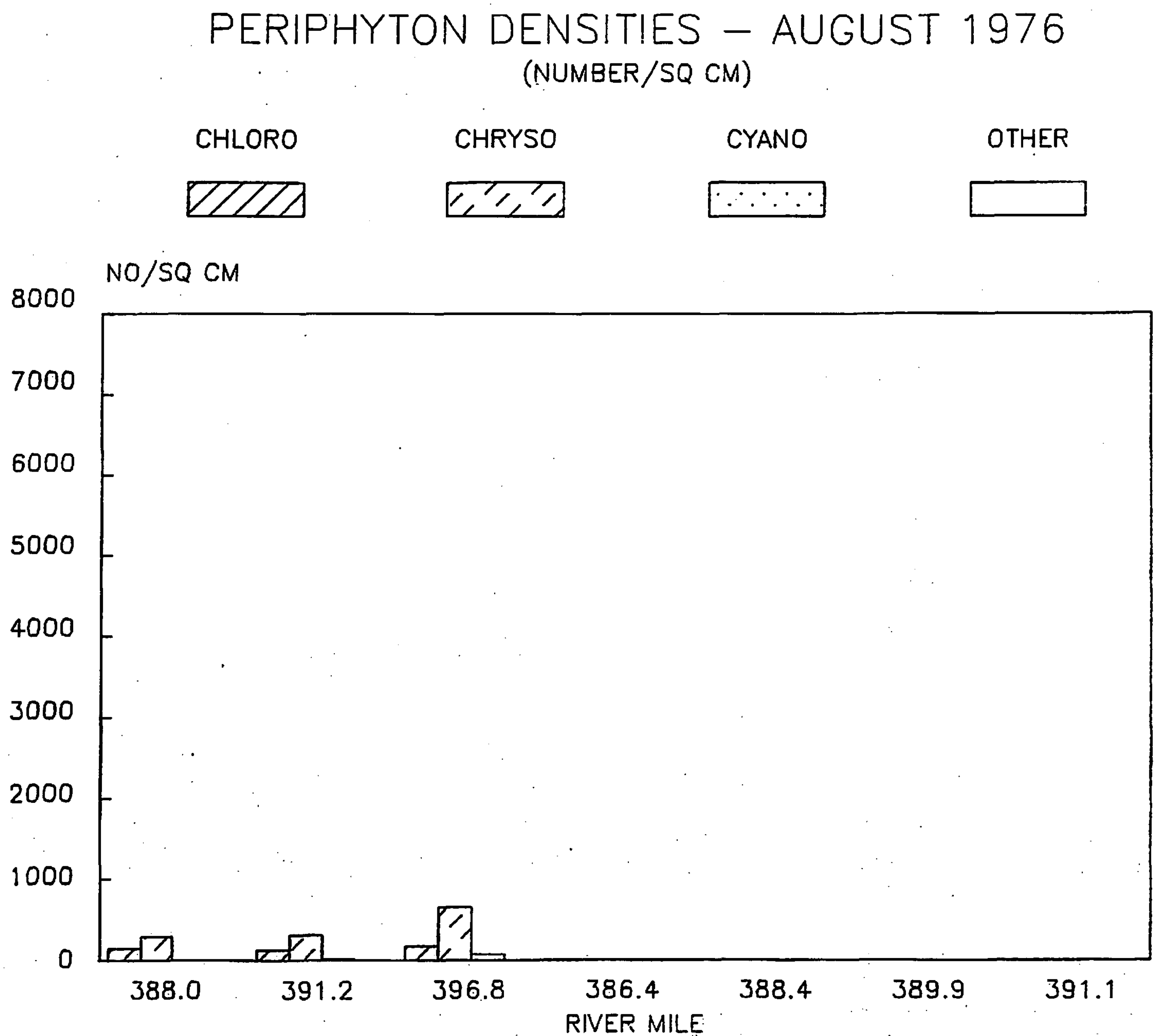


Figure 6-22. Periphyton Densities by Major Group Collected in August 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

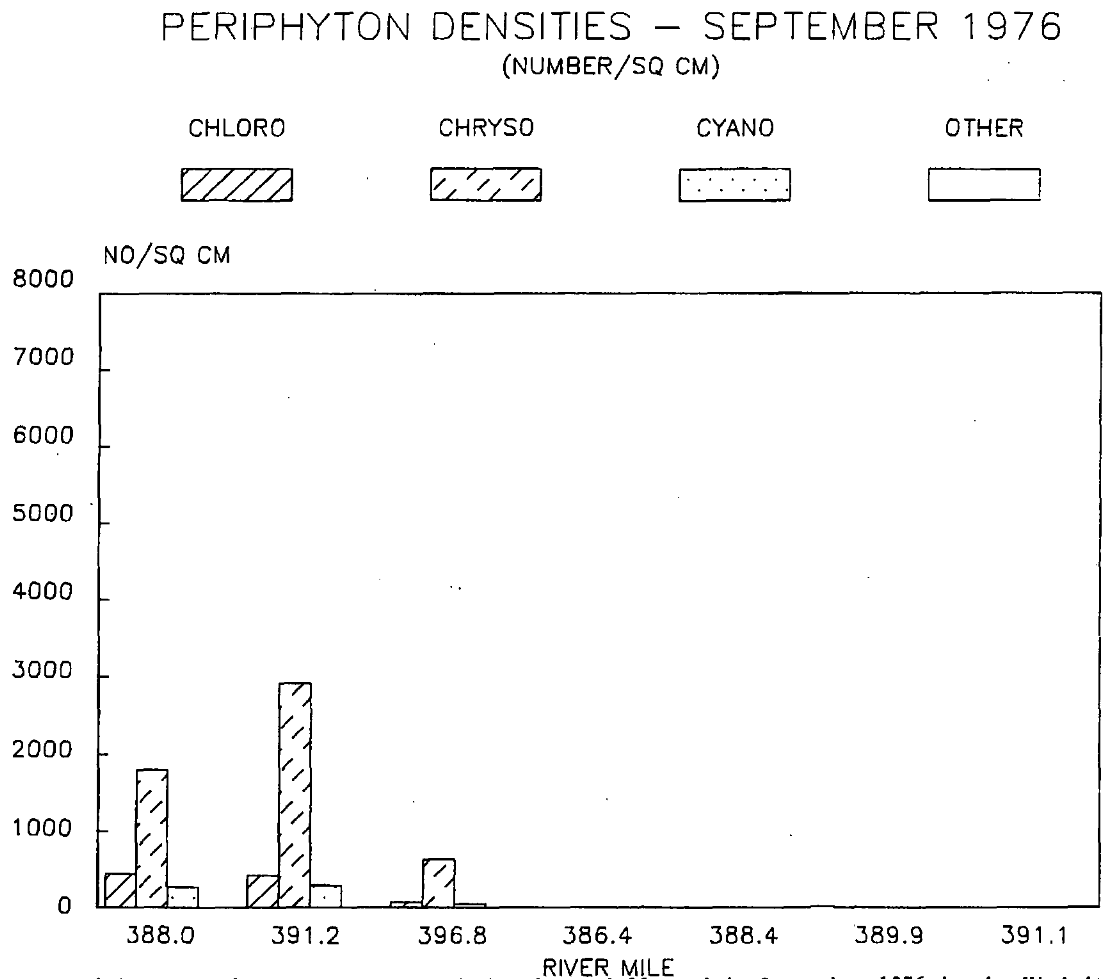


Figure 6-23. Periphyton Densities by Major Group Collected in September 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

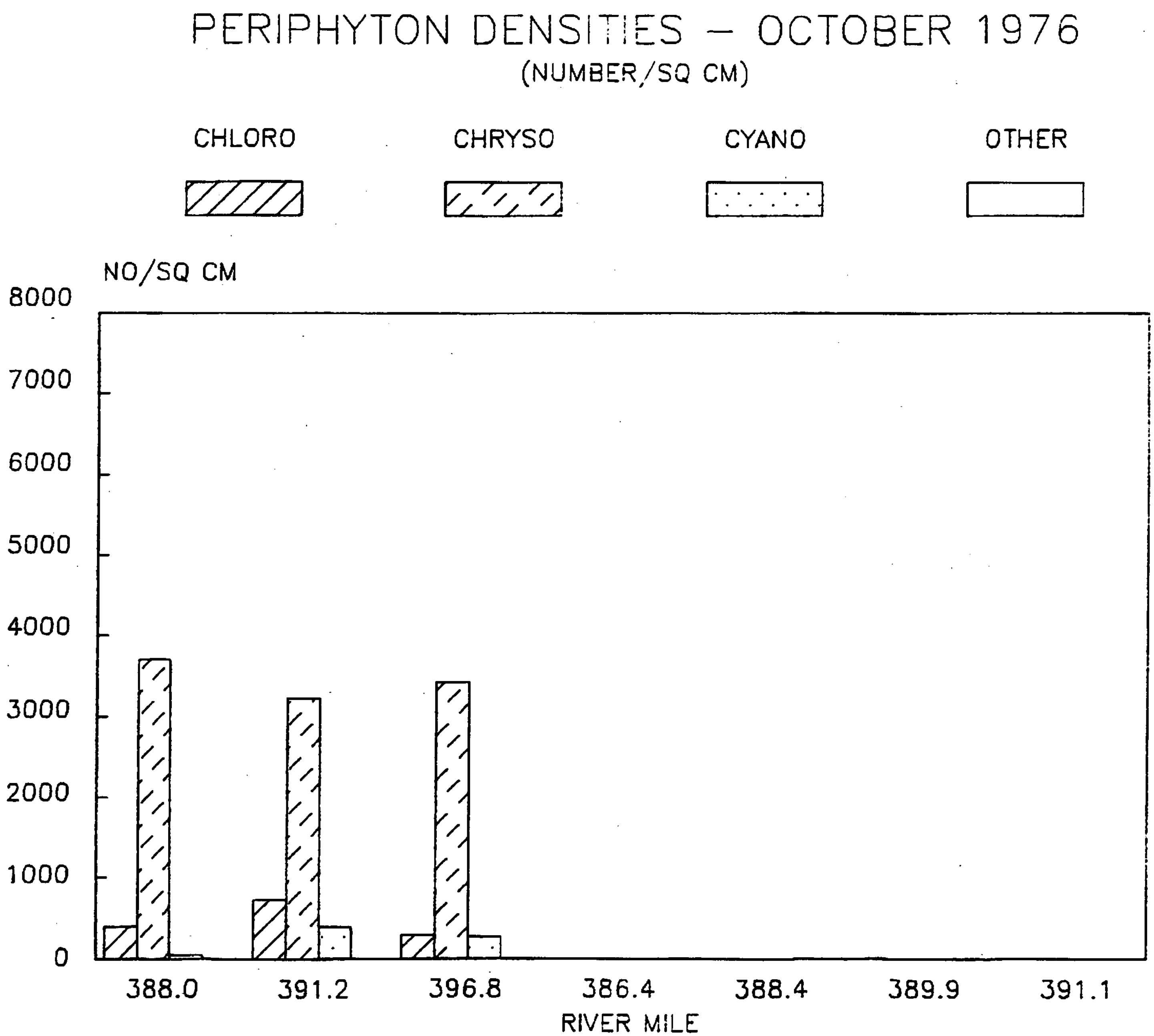


Figure 6-24. Periphyton Densities by Major Group Collected in October 1976 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

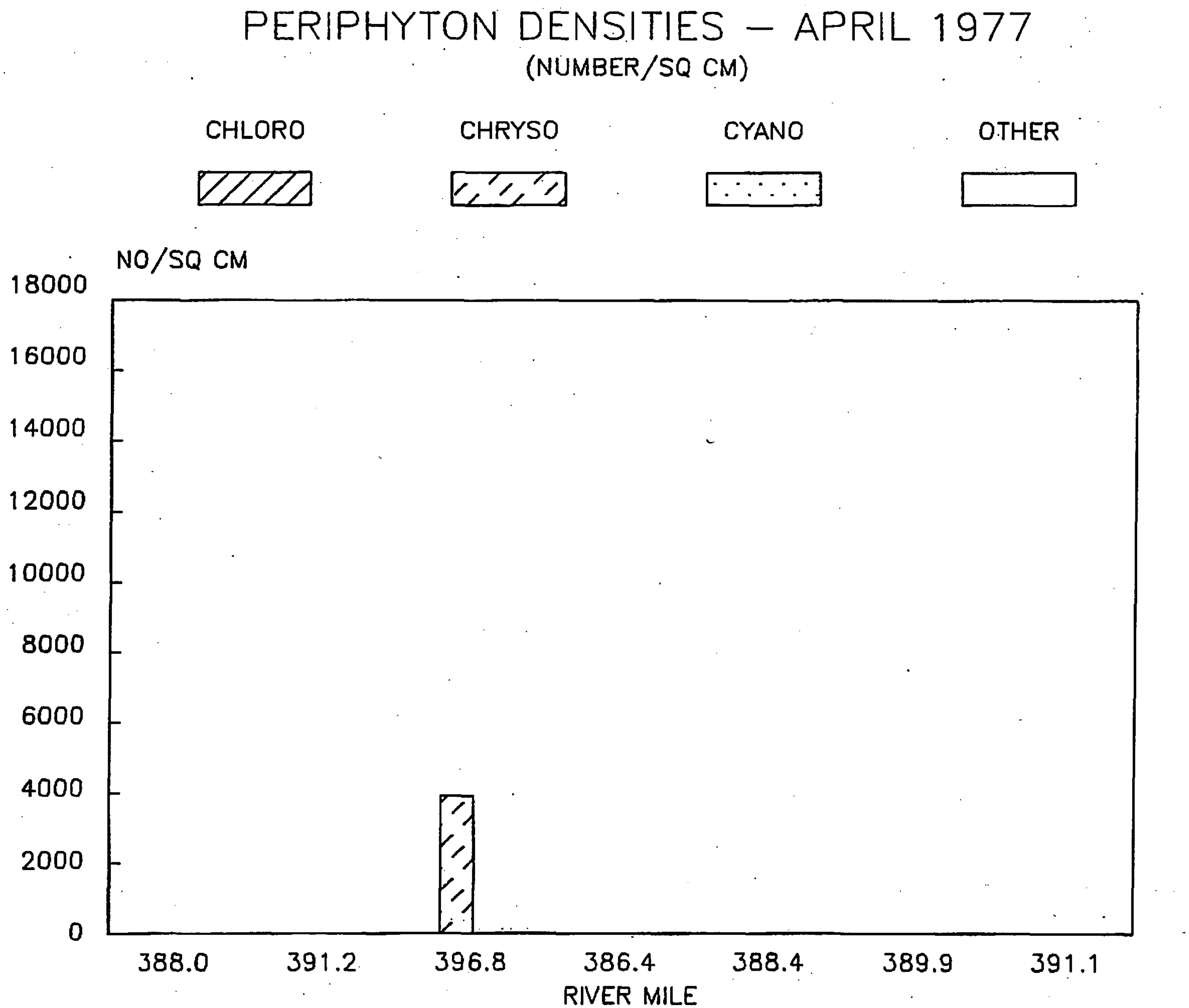


Figure 6-25. Periphyton Densities by Major Group Collected in April 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

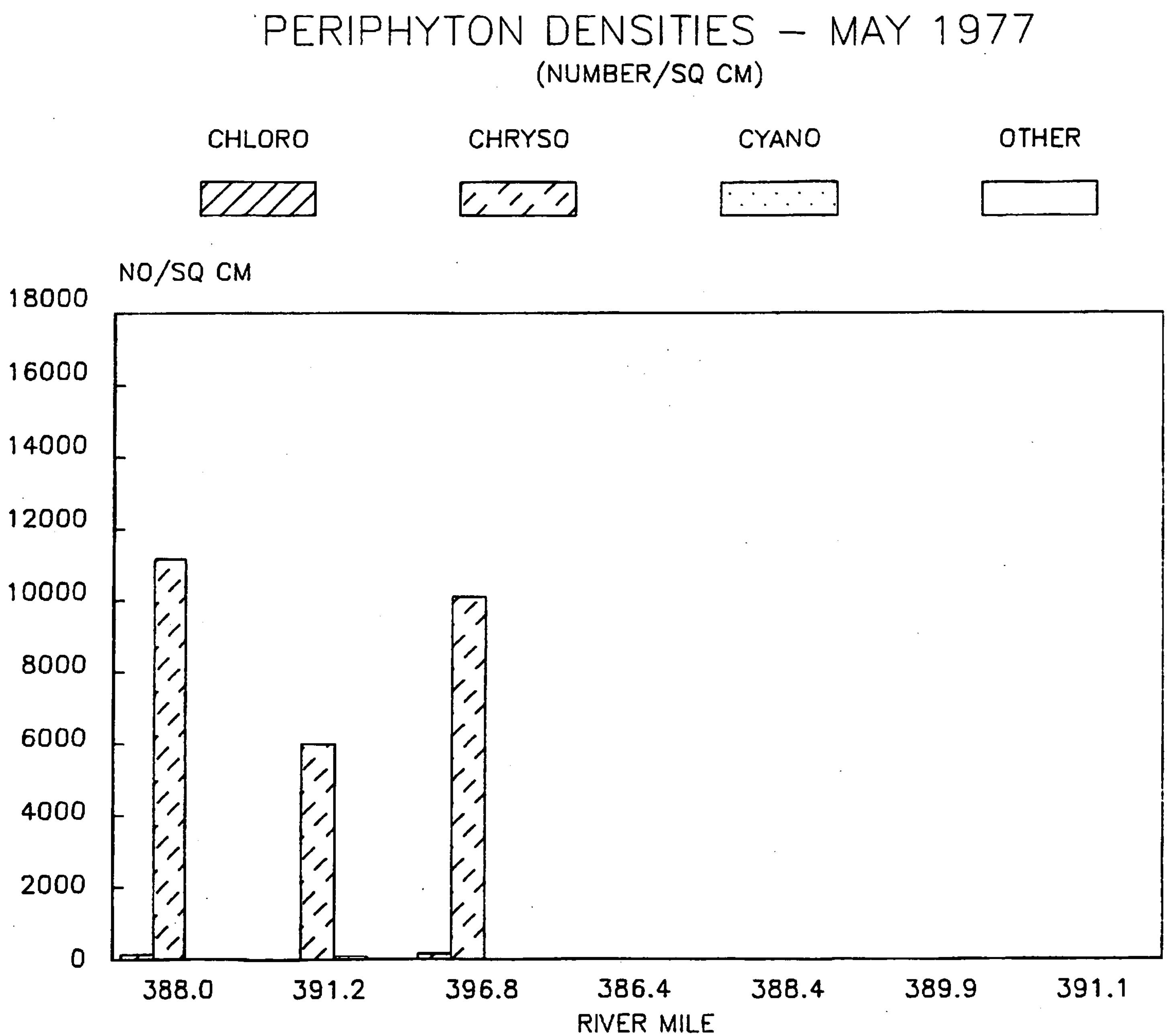


Figure 6-26. Periphyton Densities by Major Group Collected in May 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

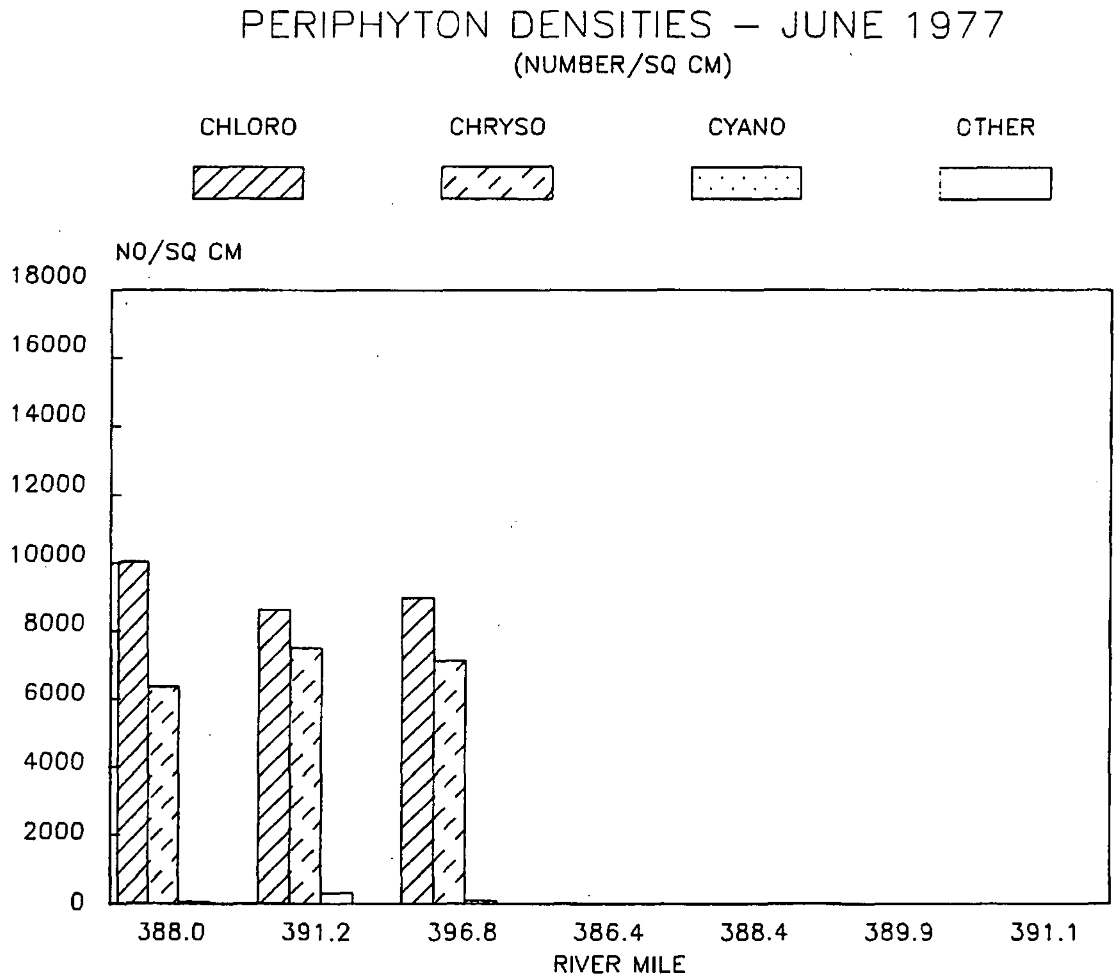


Figure 6-27. Periphyton Densities by Major Group Collected in June 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

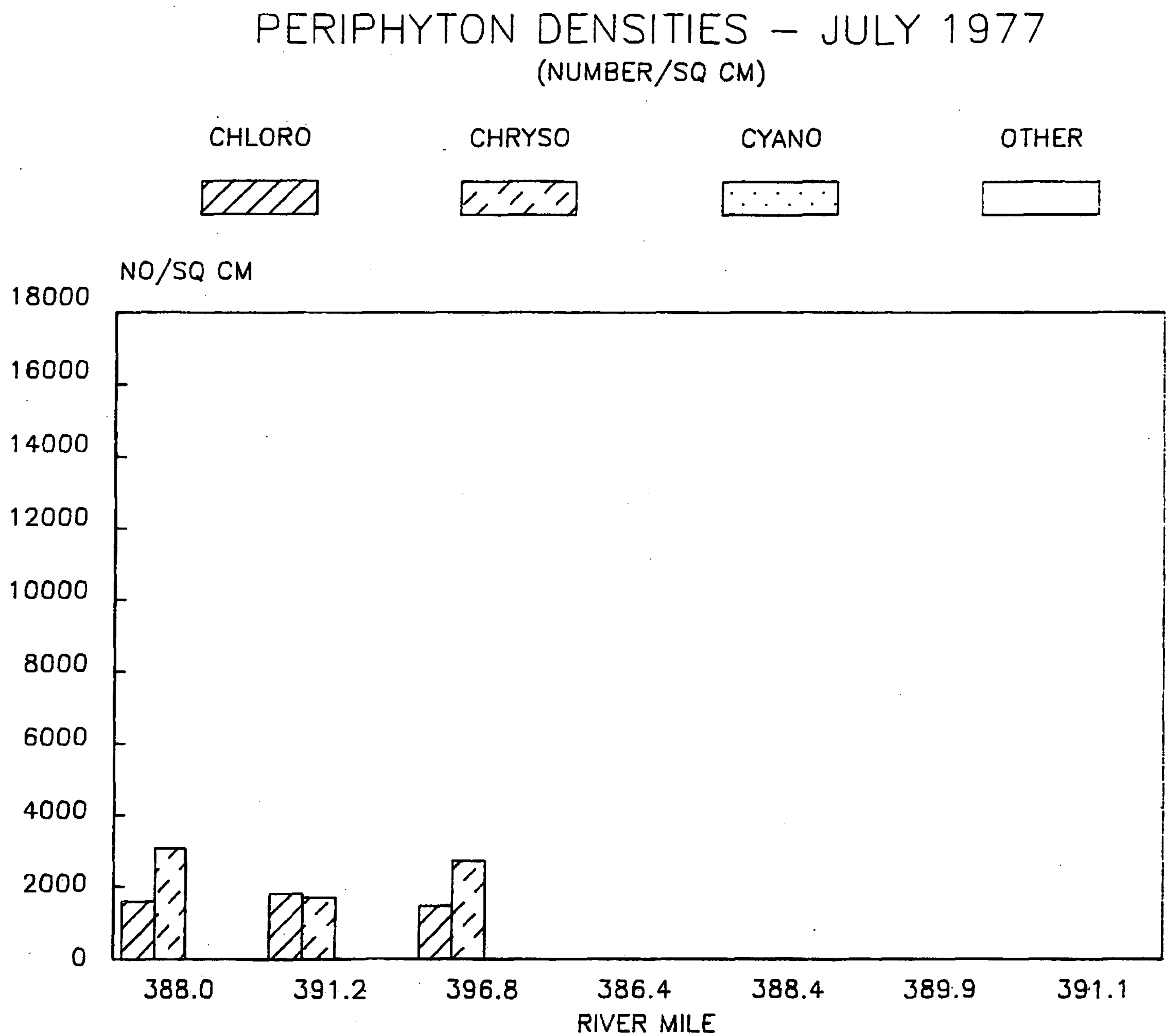


Figure 6-28. Periphyton Densities by Major Group Collected in July 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

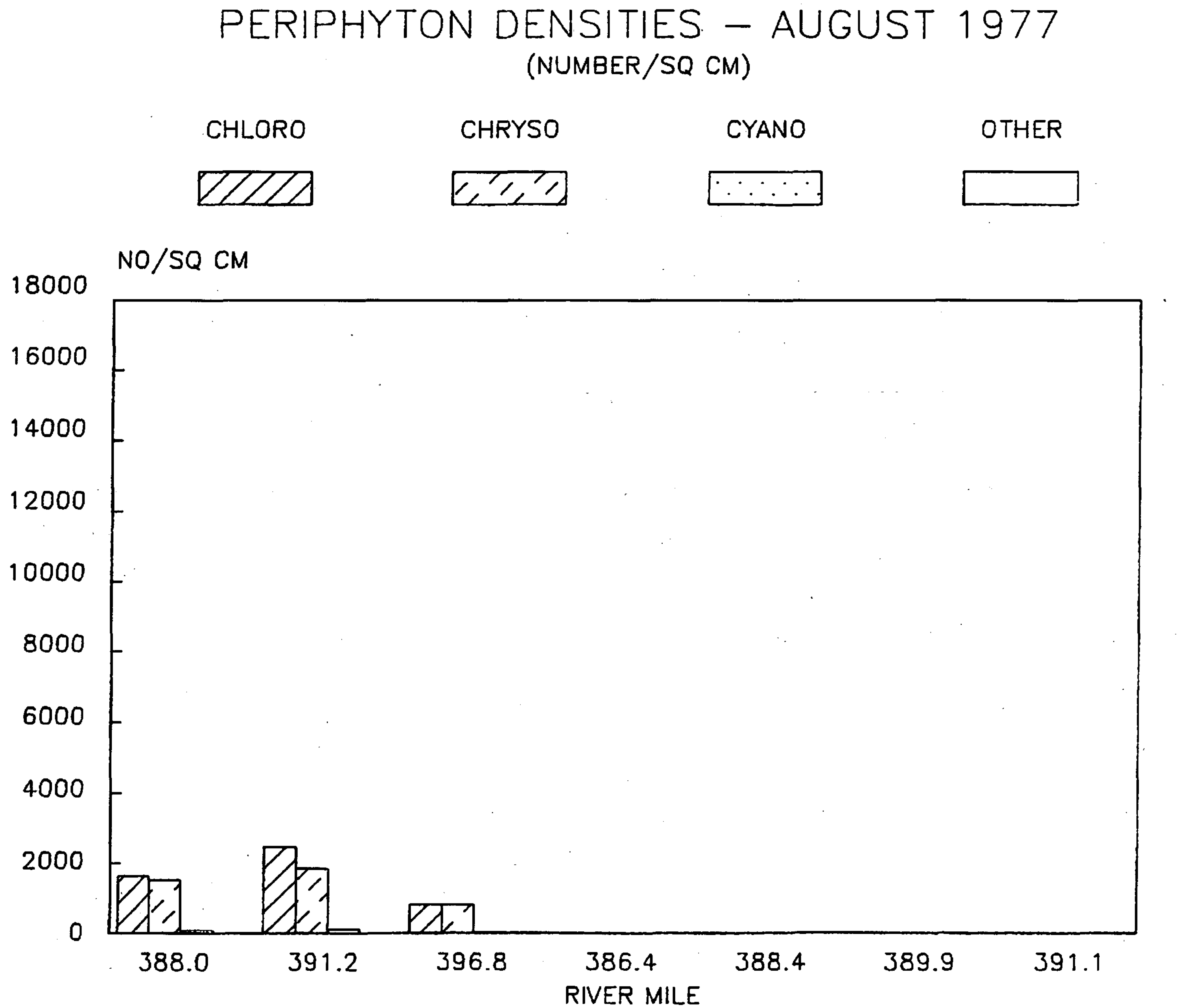


Figure 6-29. Periphyton Densities by Major Group Collected in August 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

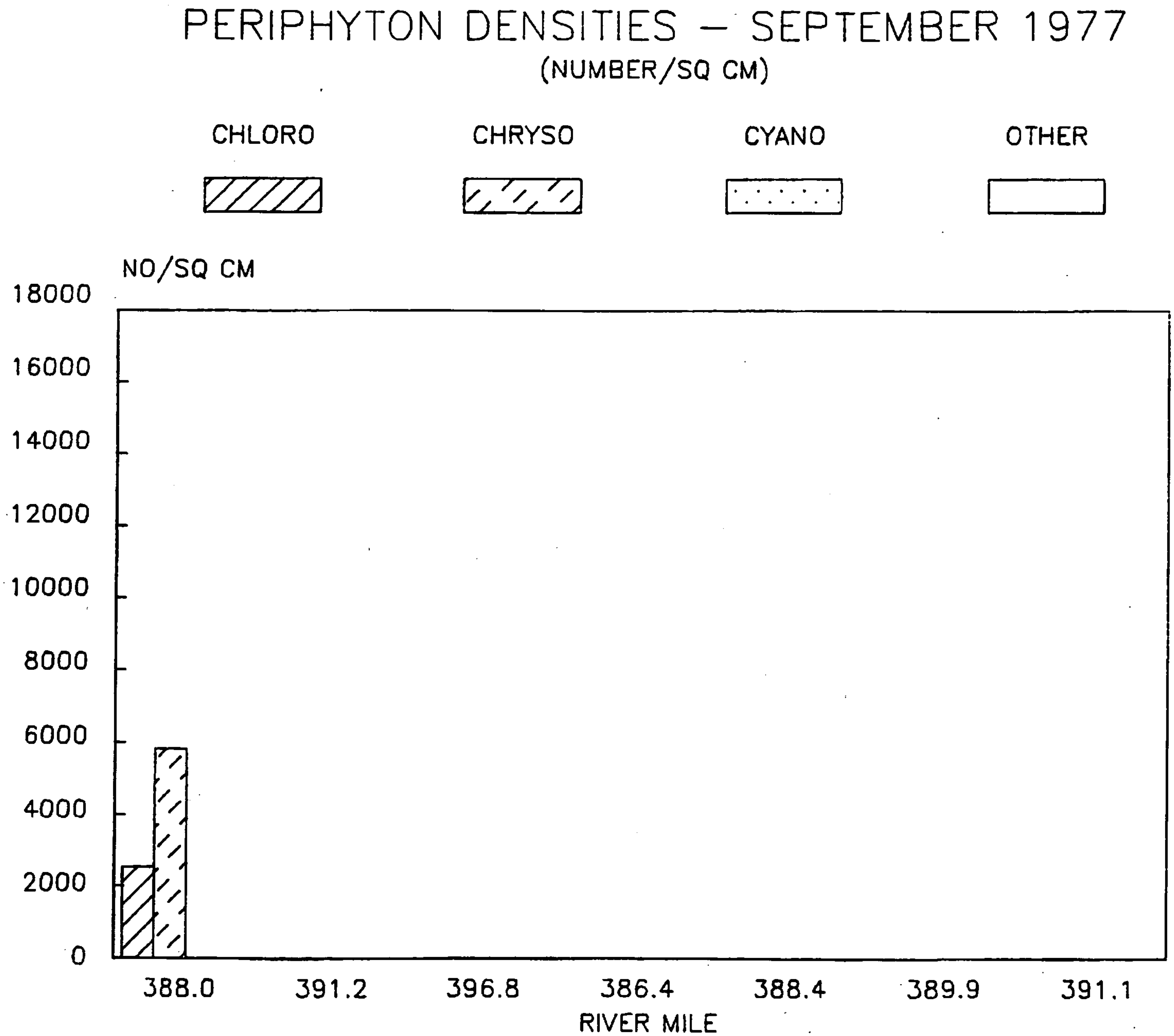


Figure 6-30. Periphyton Densities by Major Group Collected in September 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

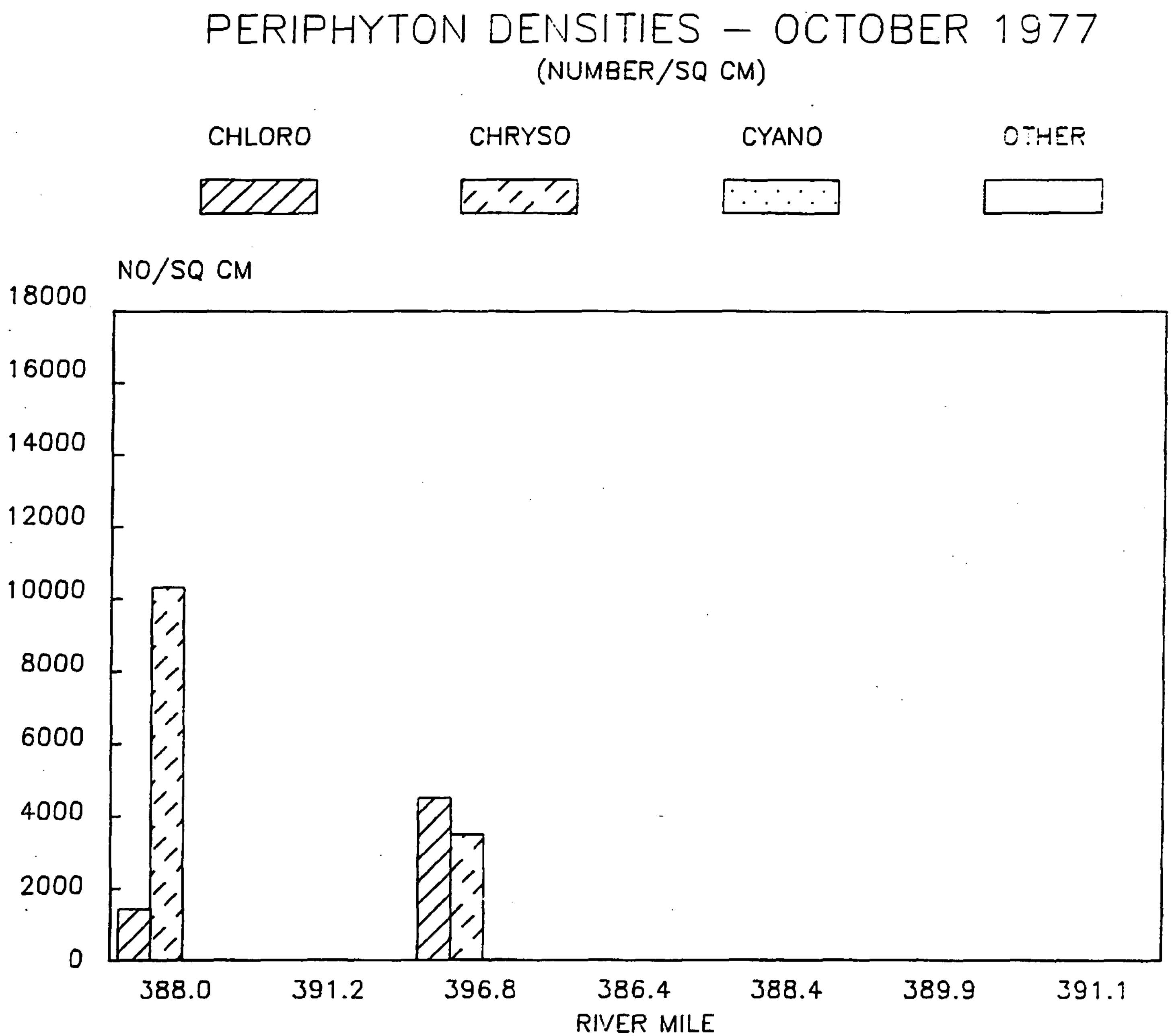


Figure 6-31. Periphyton Densities by Major Group Collected in October 1977 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

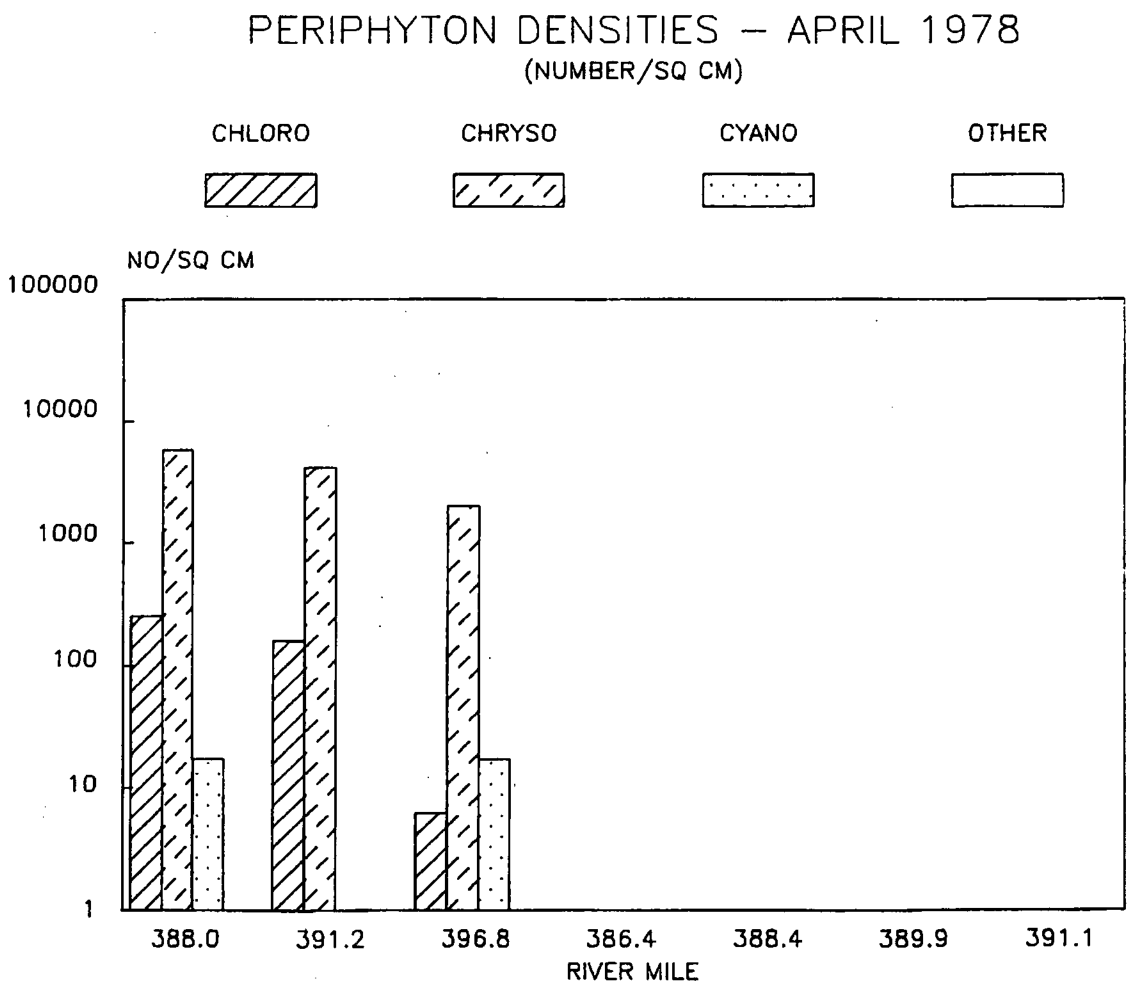


Figure 6-32. Periphyton Densities by Major Group Collected in April 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

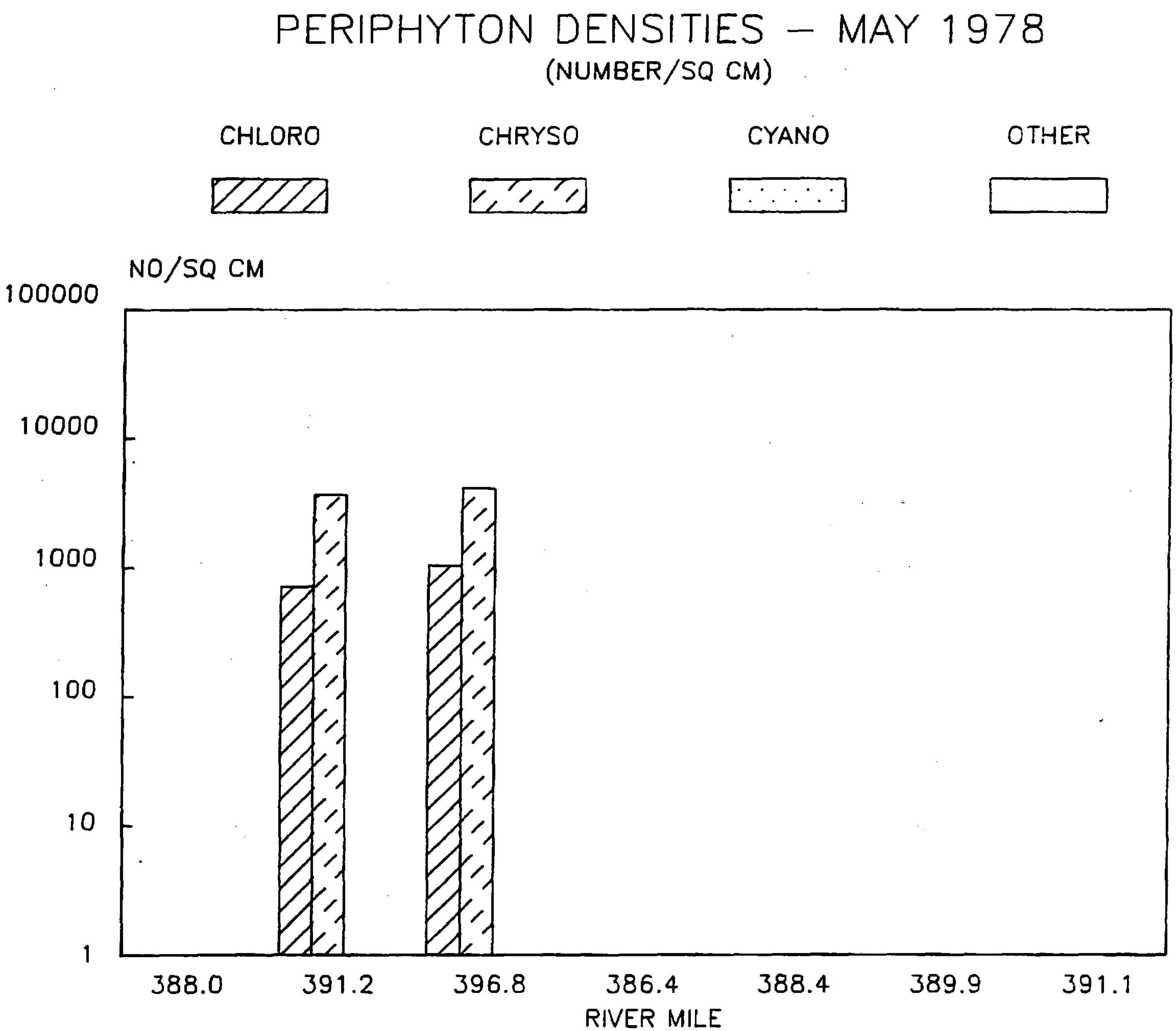


Figure 6-33. Periphyton Densities by Major Group Collected in May 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

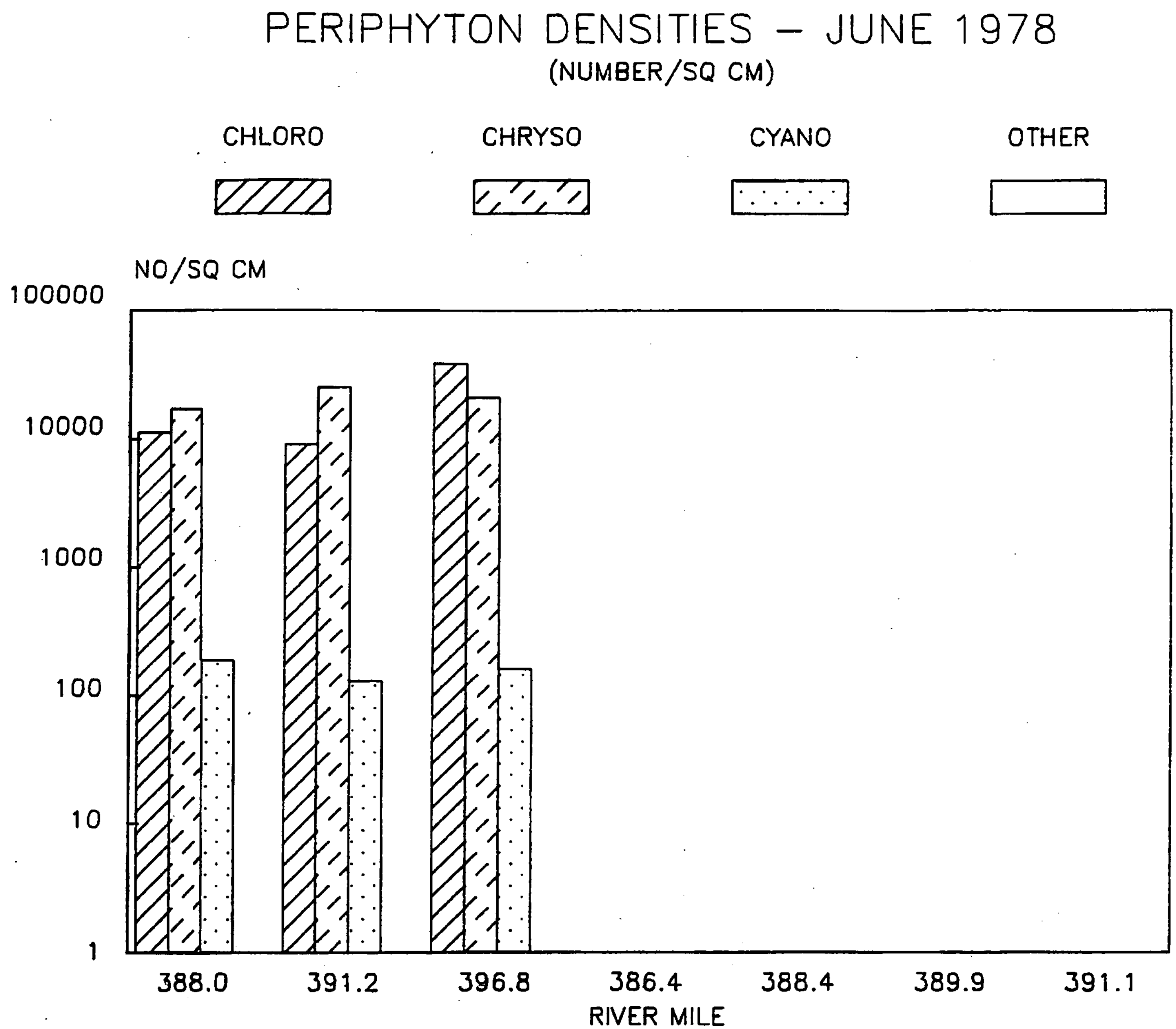


Figure 6-34. Periphyton Densities by Major Group Collected in June 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

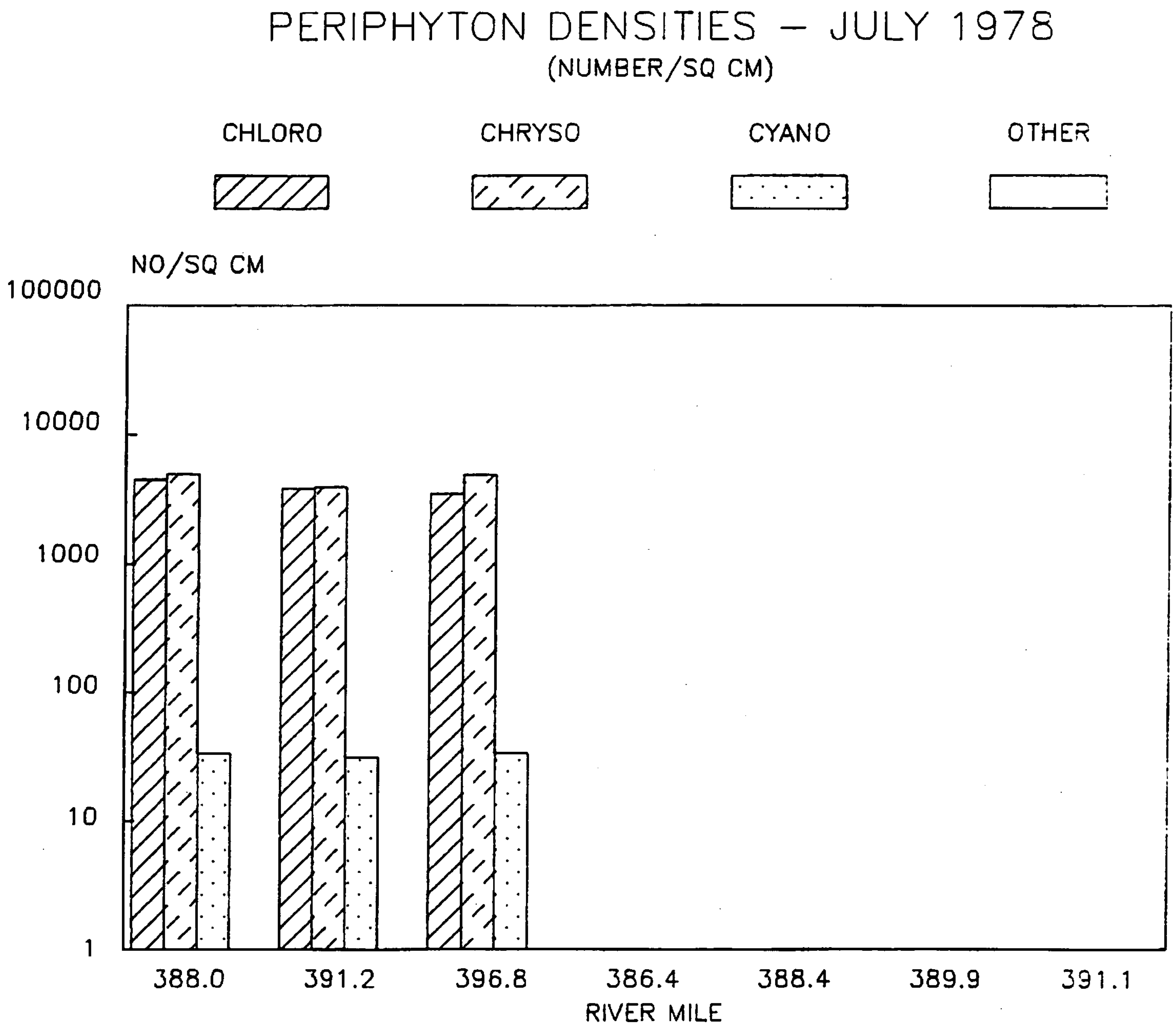


Figure 6-35. Periphyton Densities by Major Group Collected in July 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

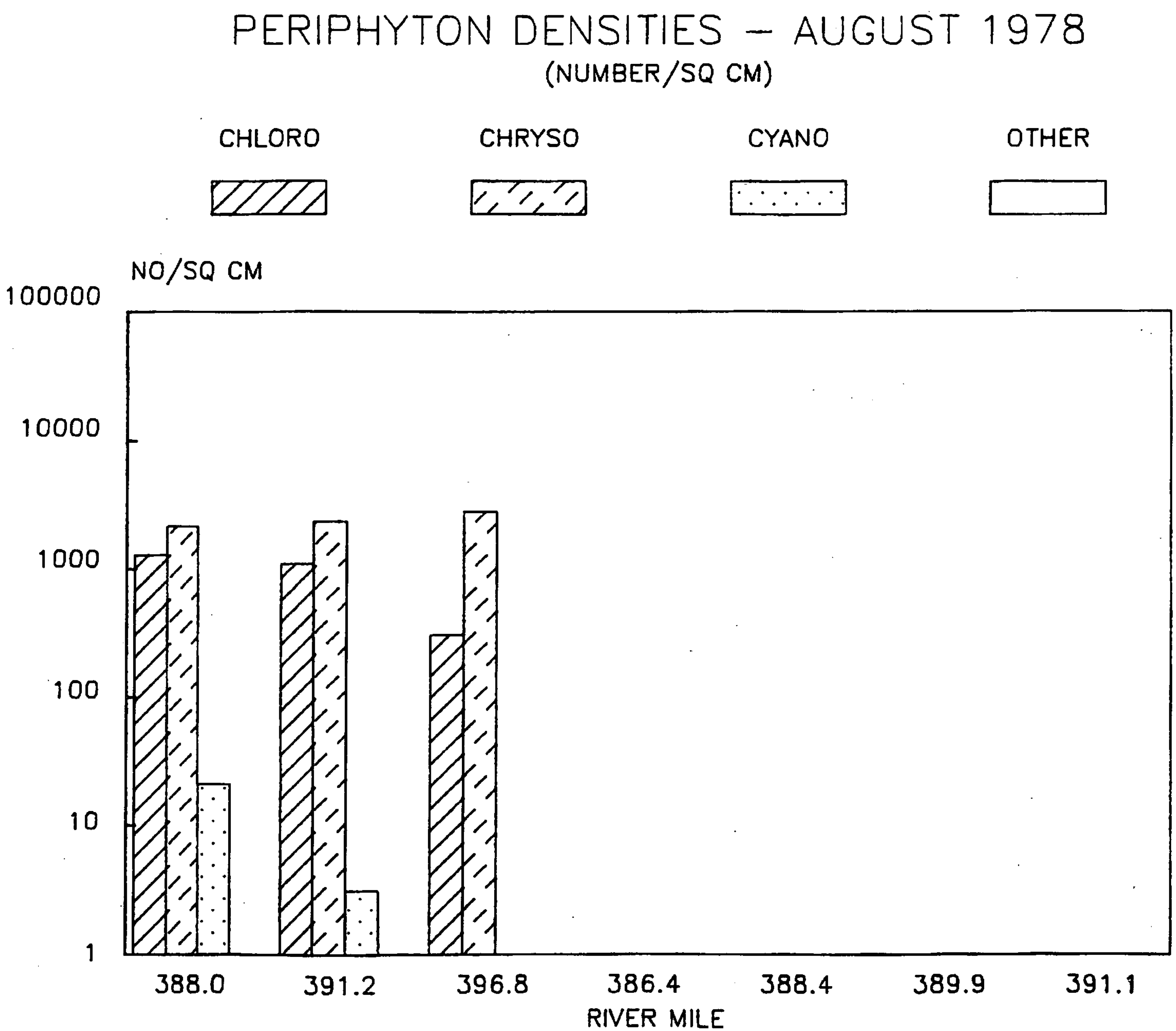


Figure 6-36. Periphyton Densities by Major Group Collected in August 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

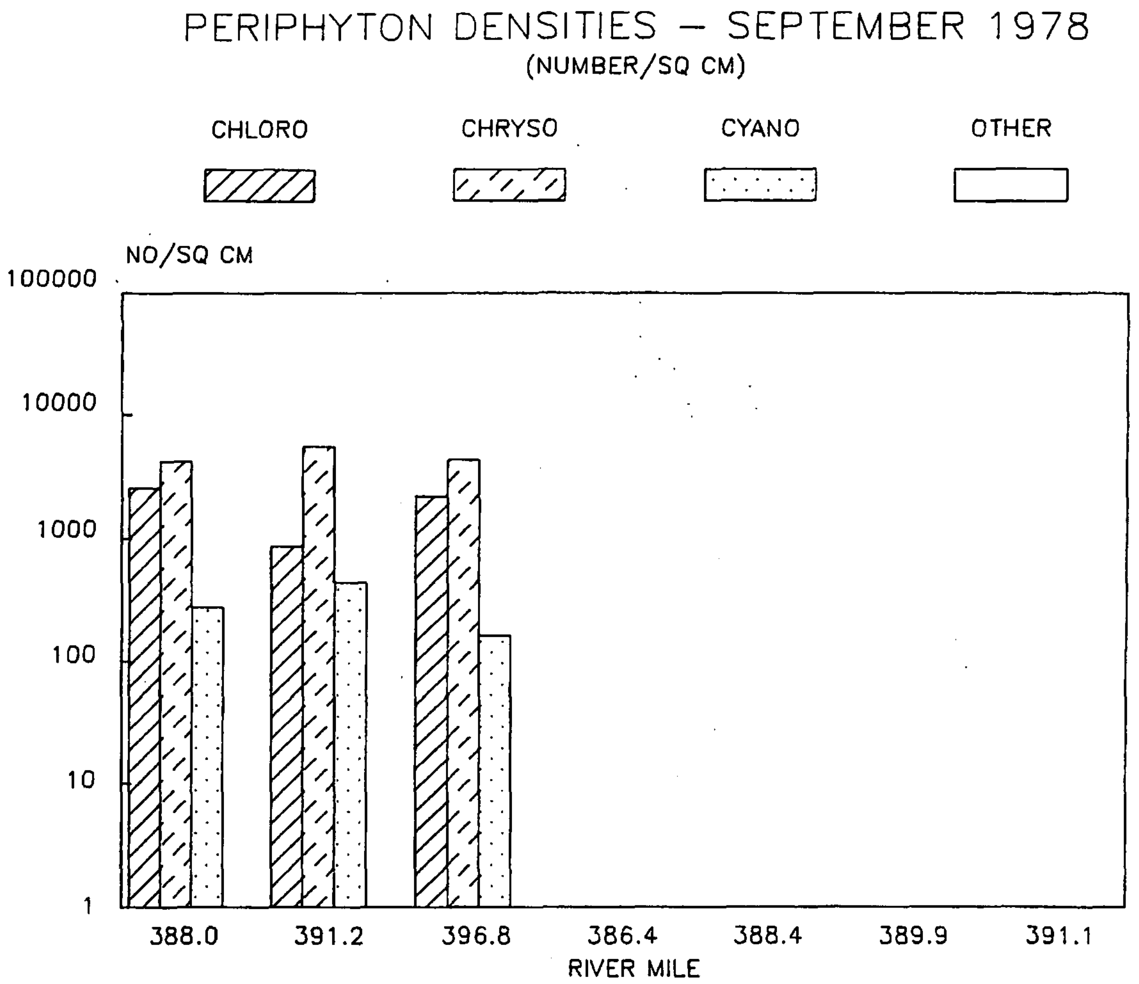


Figure 6-37. Periphyton Densities by Major Group Collected in September 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

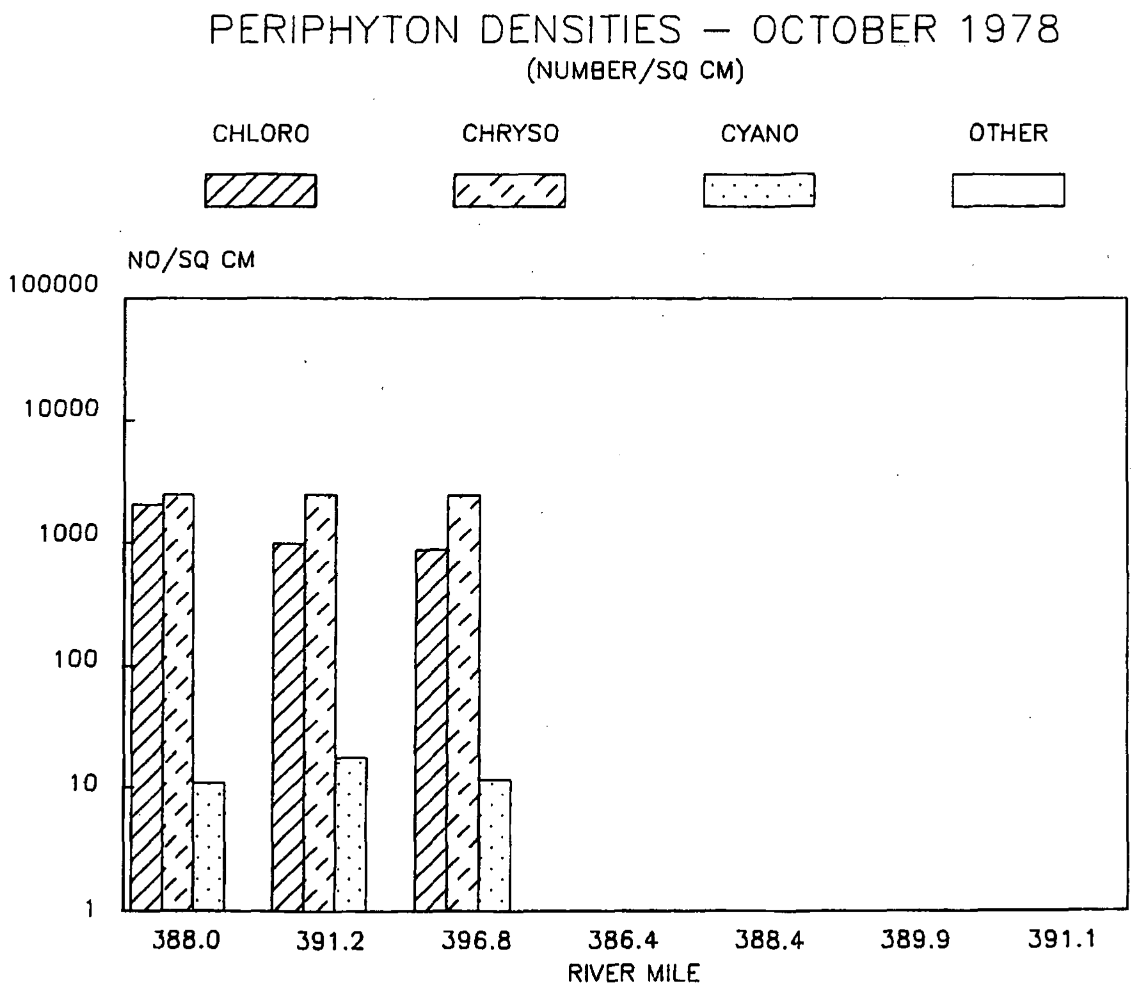


Figure 6-38. Periphyton Densities by Major Group Collected in October 1978 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

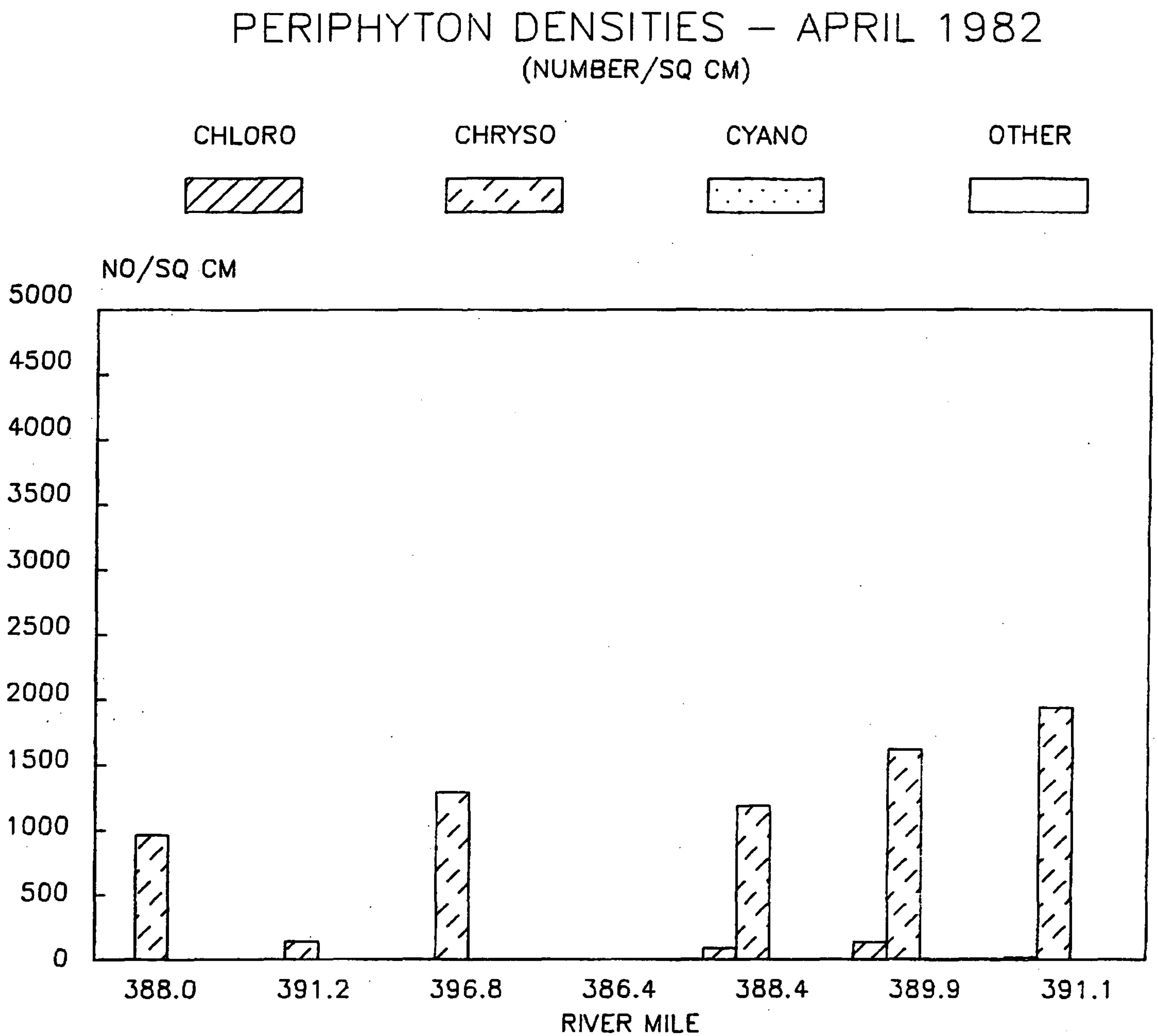


Figure 6-39. Periphyton Densities by Major Group Collected in April 1982 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

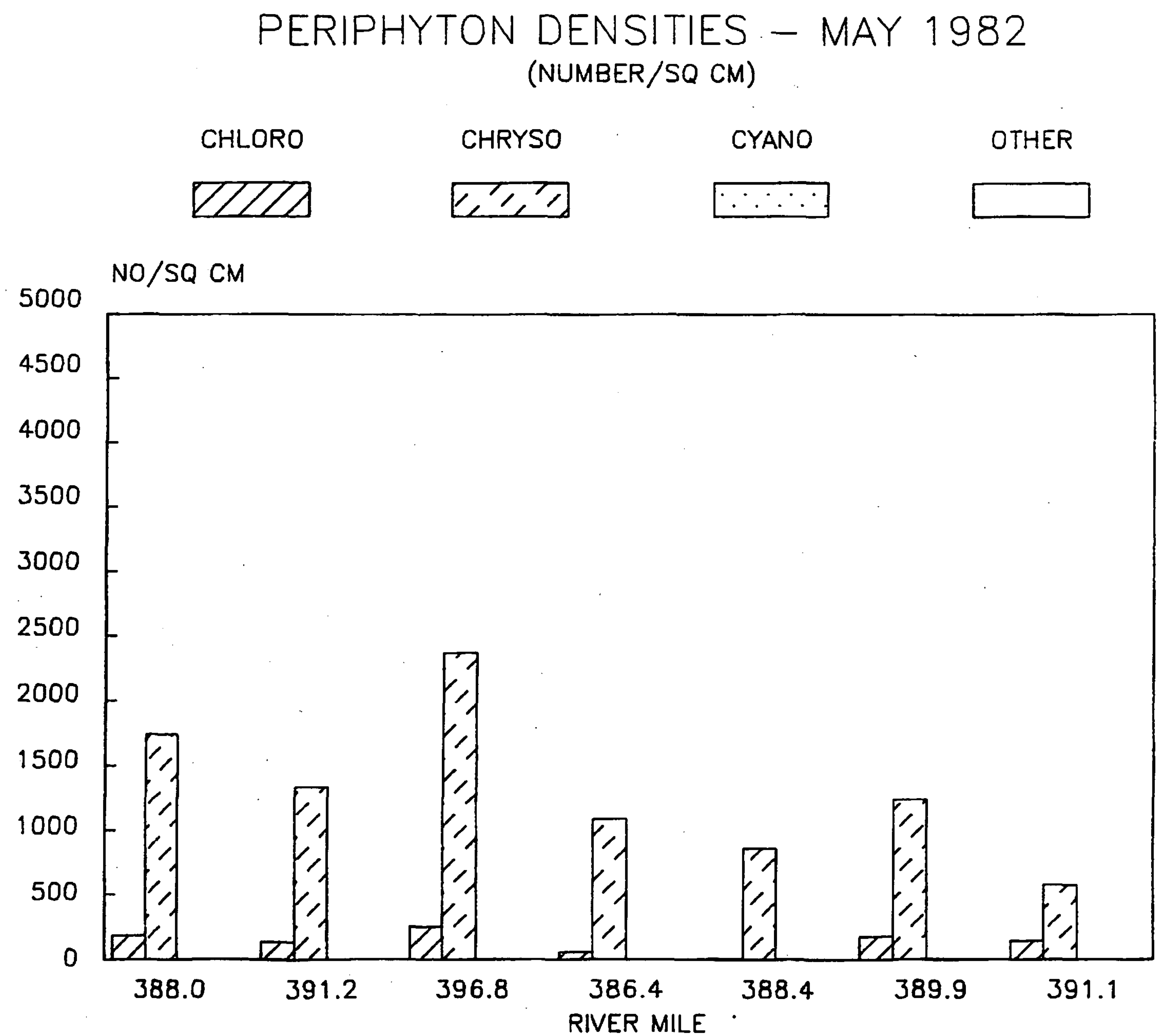


Figure 6-40. Periphyton Densities by Major Group Collected in May 1982 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

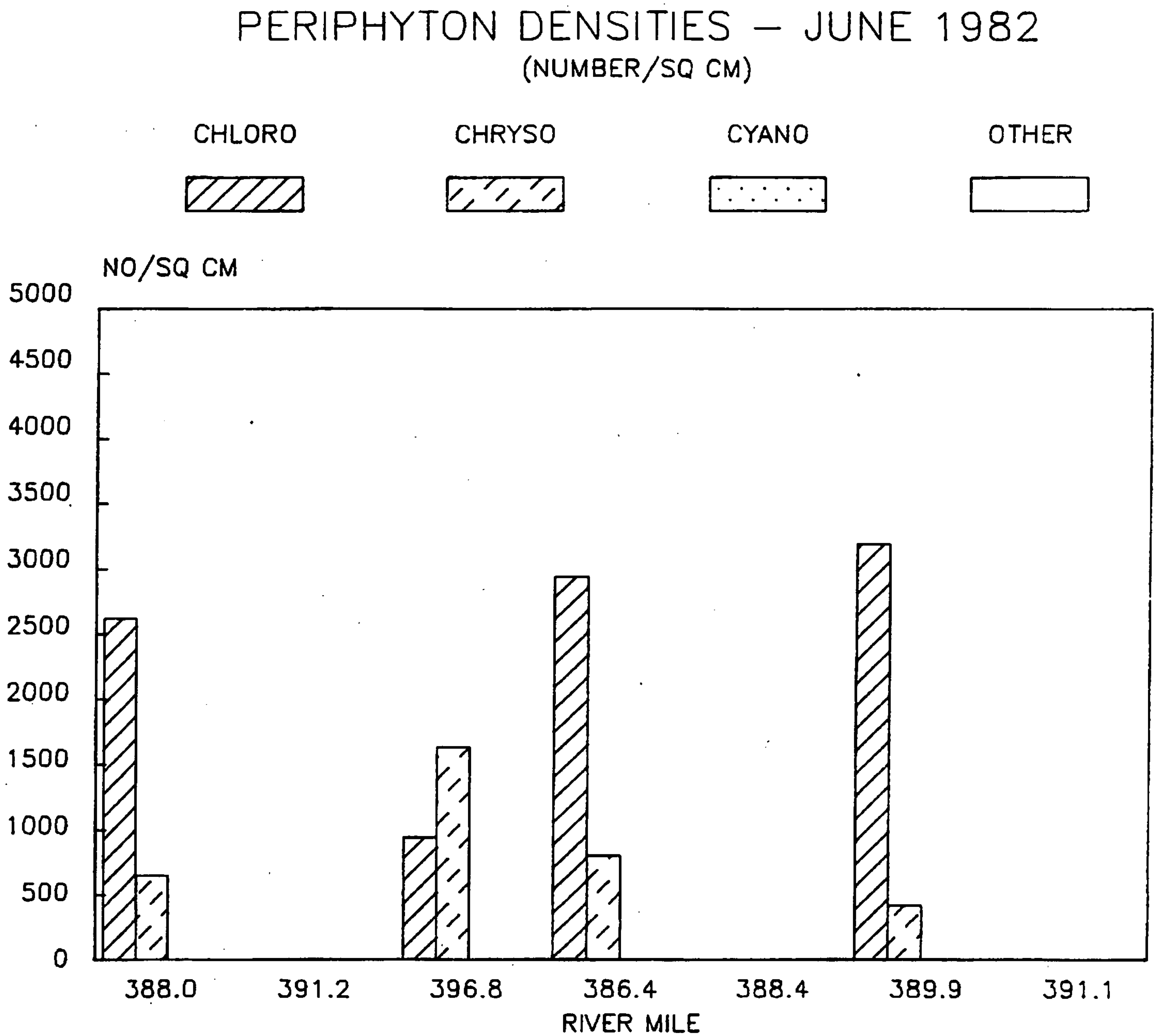


Figure 6-41. Periphyton Densities by Major Group Collected in June 1982 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

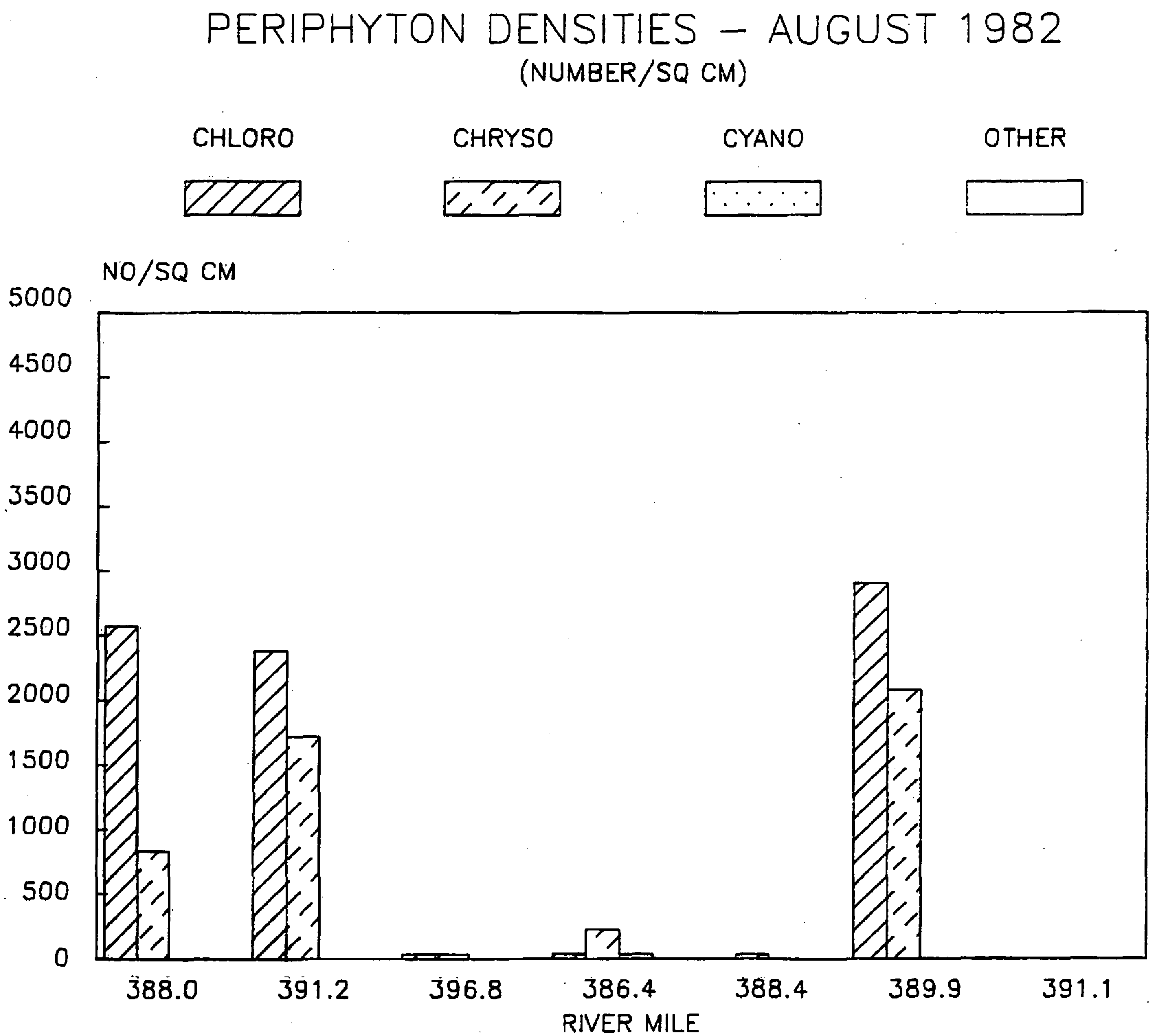


Figure 6-42. Periphyton Densities by Major Group Collected in August 1982 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

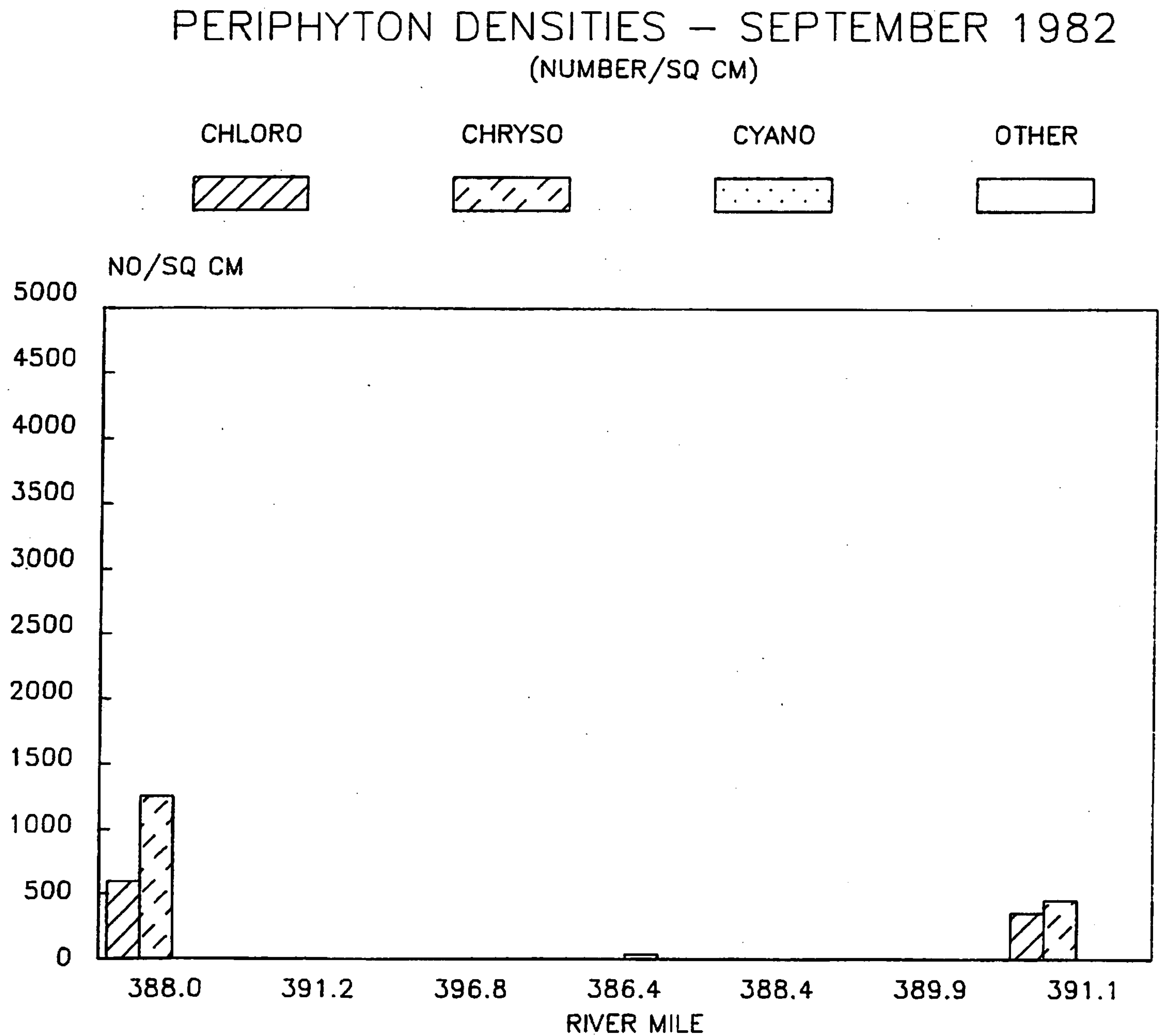


Figure 6-43. Periphyton Densities by Major Group Collected in September 1982 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

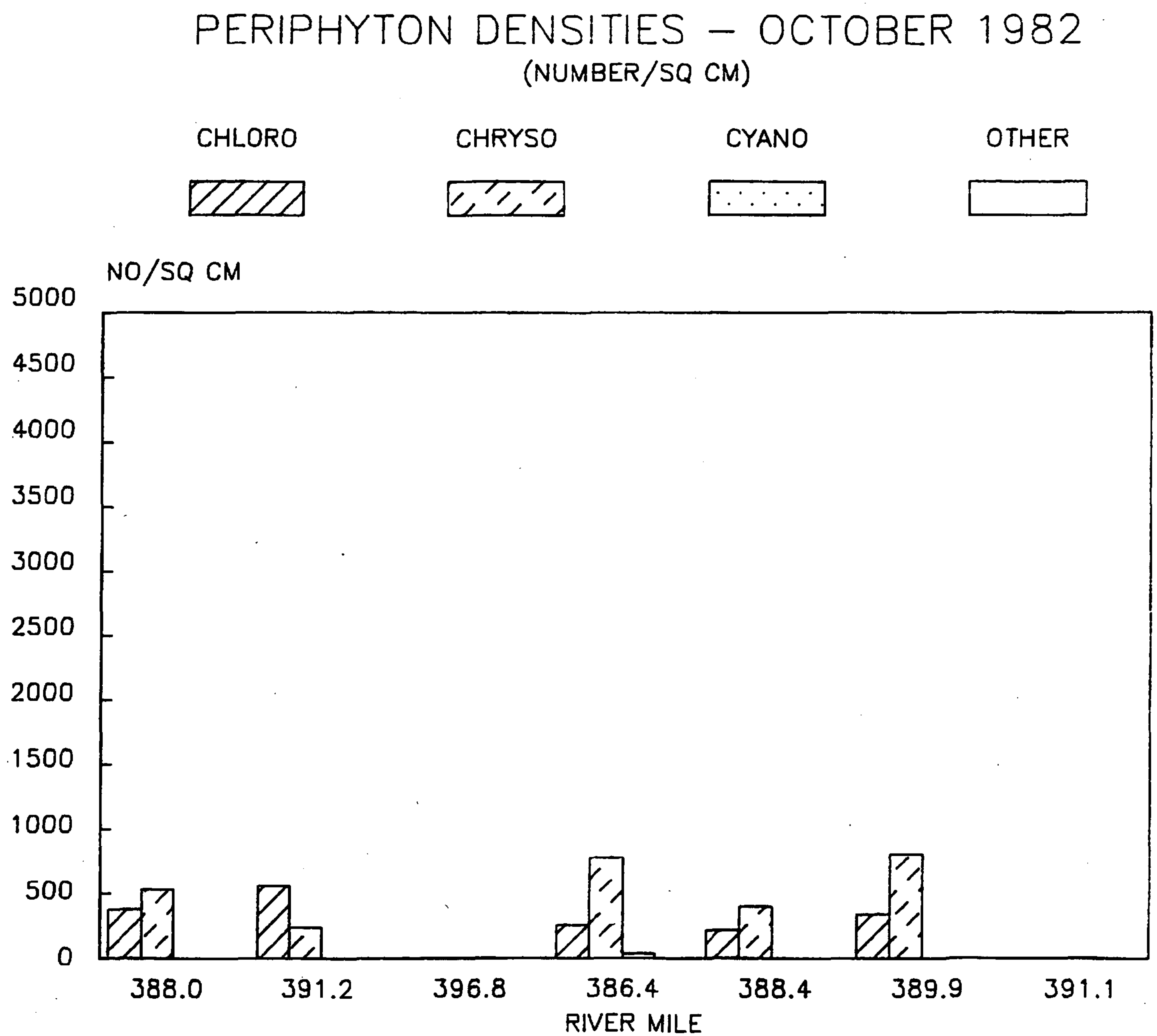


Figure 6-44. Periphyton Densities by Major Group Collected in October 1982 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

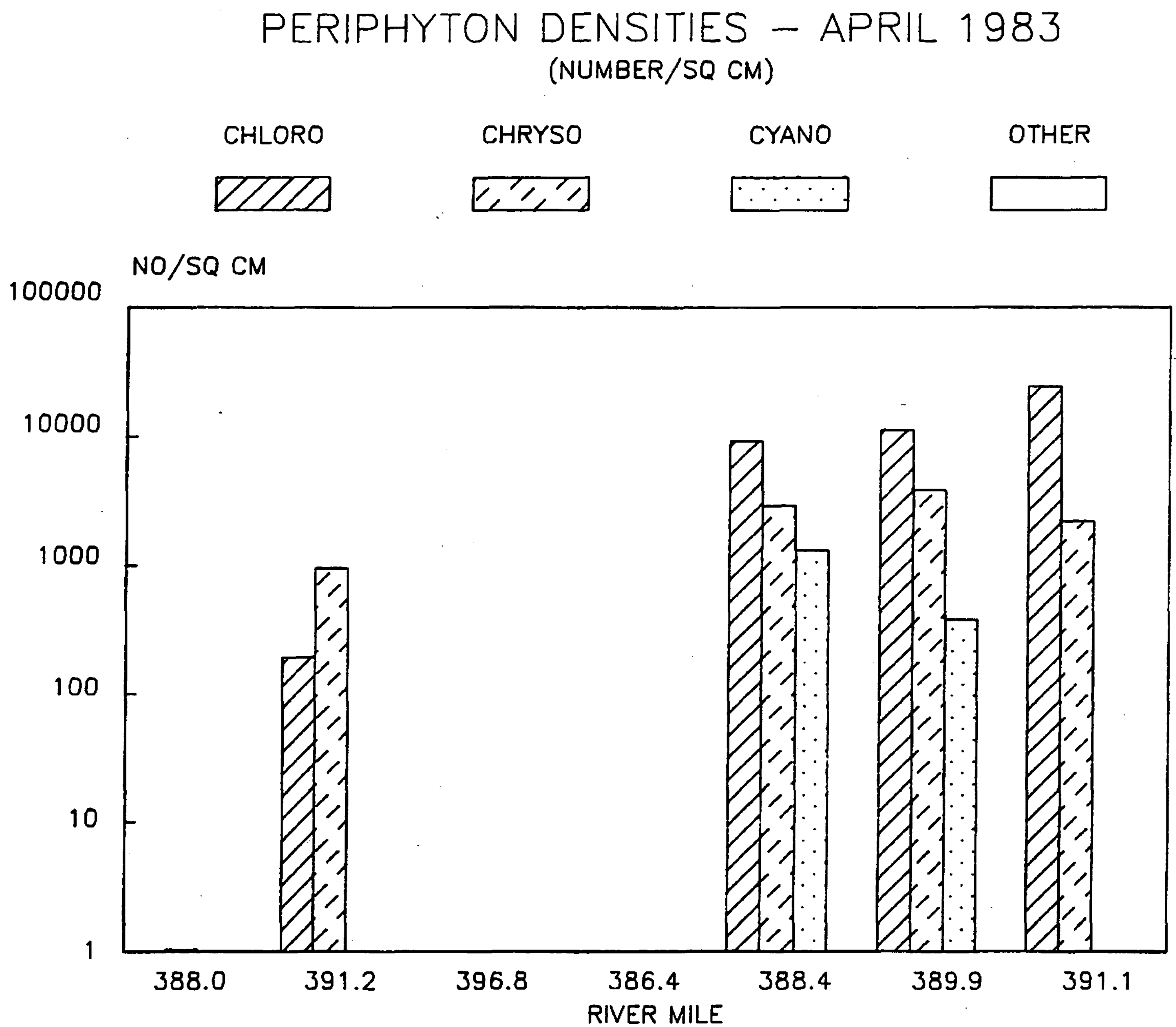


Figure 6-45. Periphyton Densities by Major Group Collected in April 1983 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

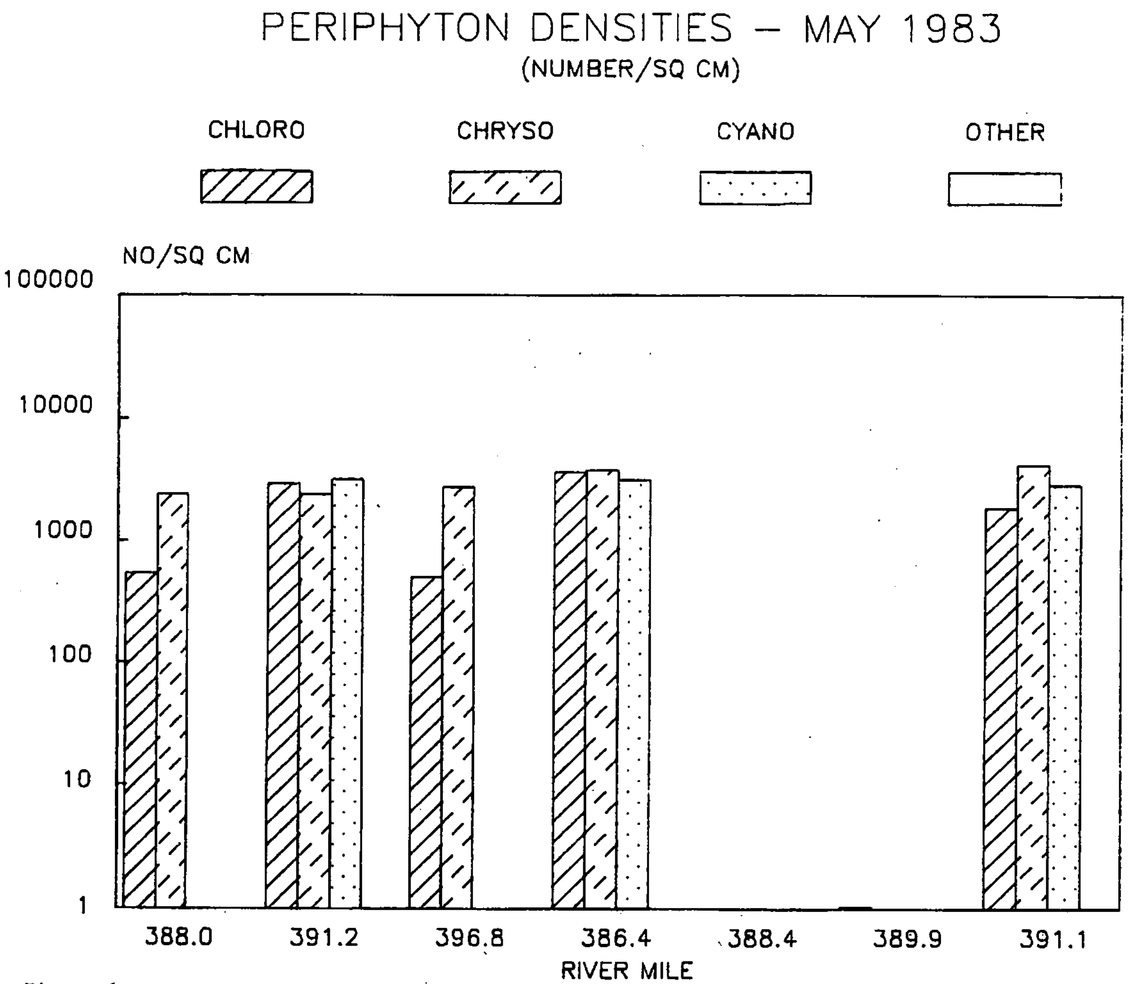


Figure 6-46. Periphyton Densities by Major Group Collected in May 1983 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

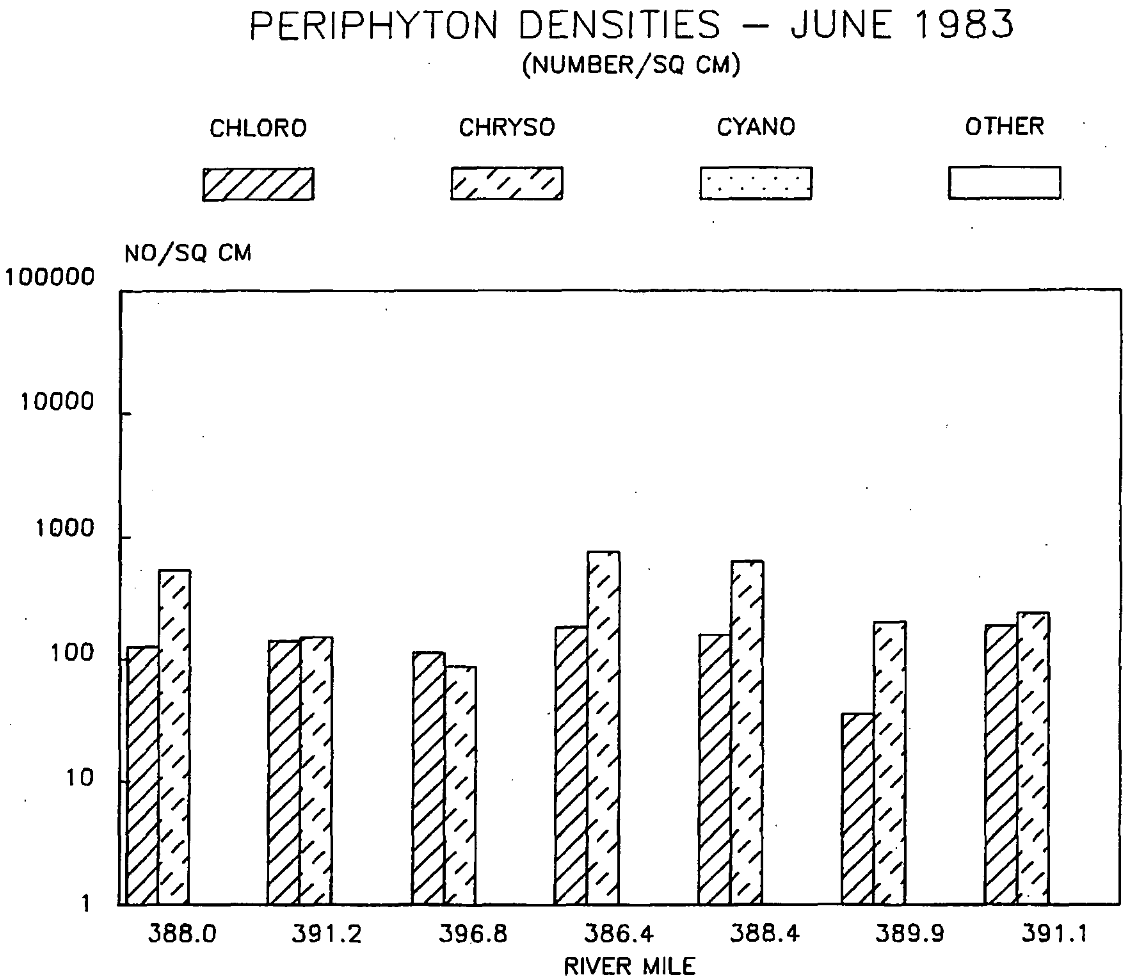


Figure 6-47. Periphyton Densities by Major Group Collected in June 1983 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

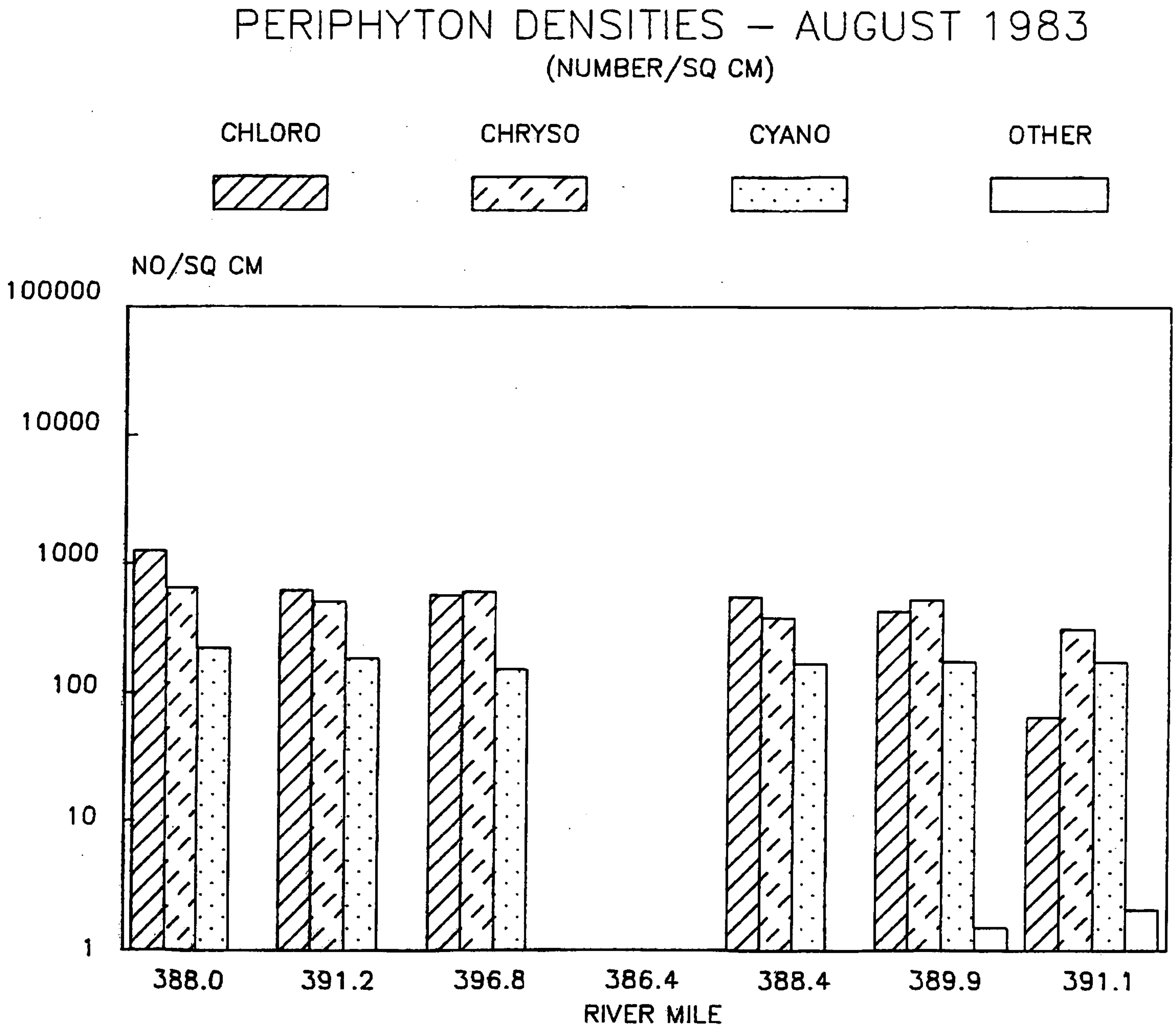


Figure 6-48. Periphyton Densities by Major Group Collected in August 1983 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

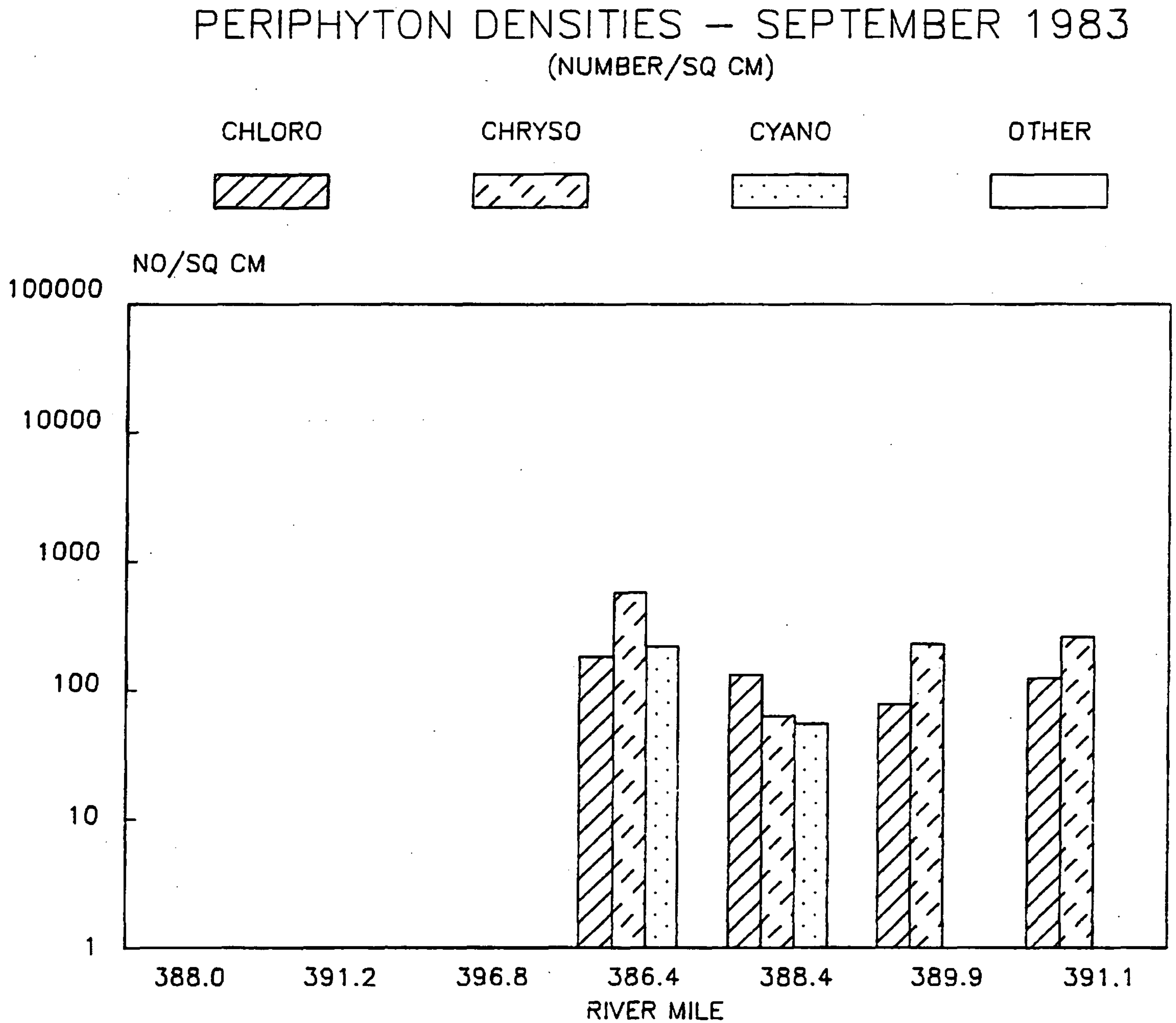


Figure 6-49. Periphyton Densities by Major Group Collected in September 1983 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

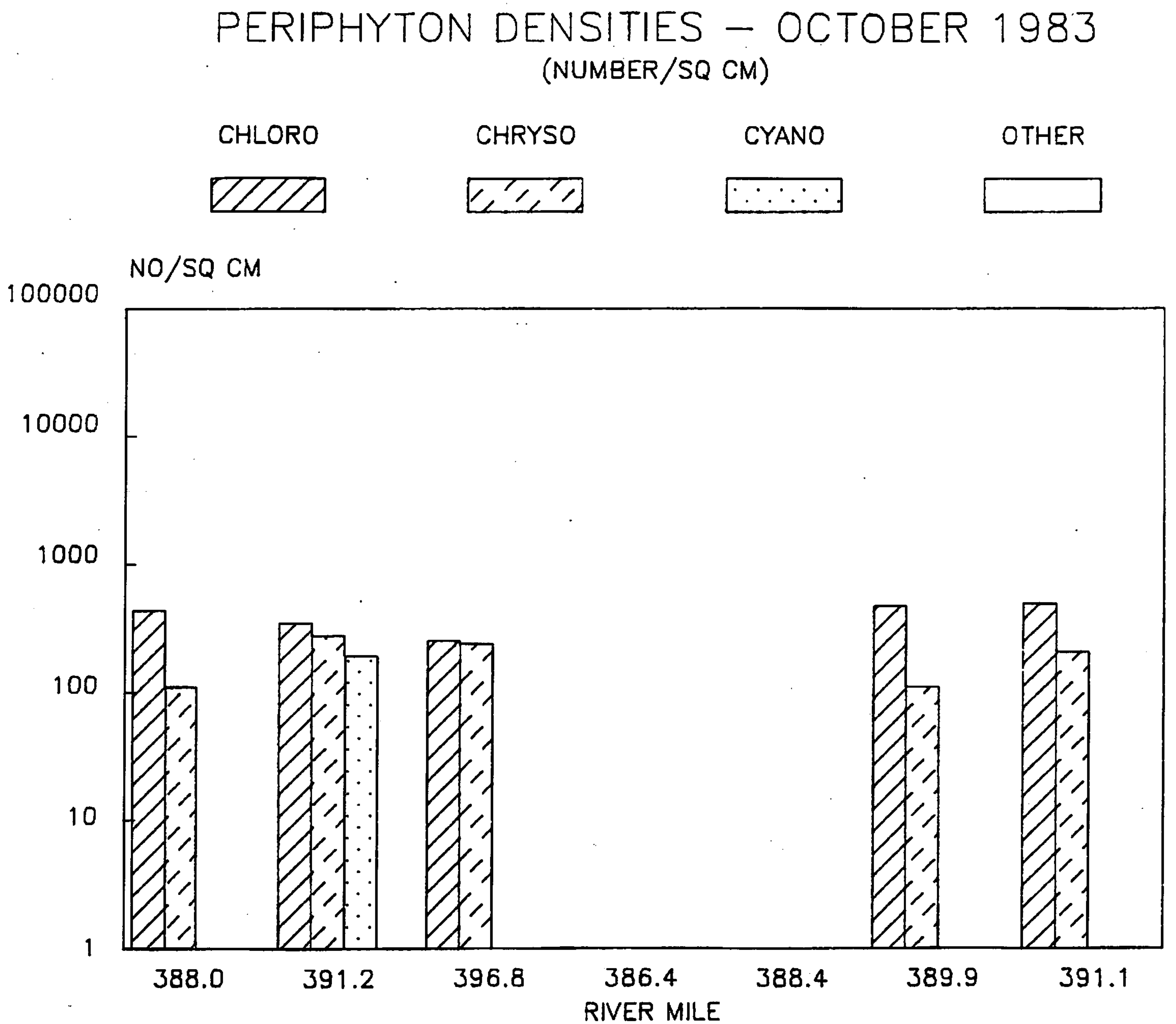


Figure 6-50. Periphyton Densities by Major Group Collected in October 1983 in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring.

PERIPHYTON TOTAL DENSITIES – APRIL
(ALL YEARS)

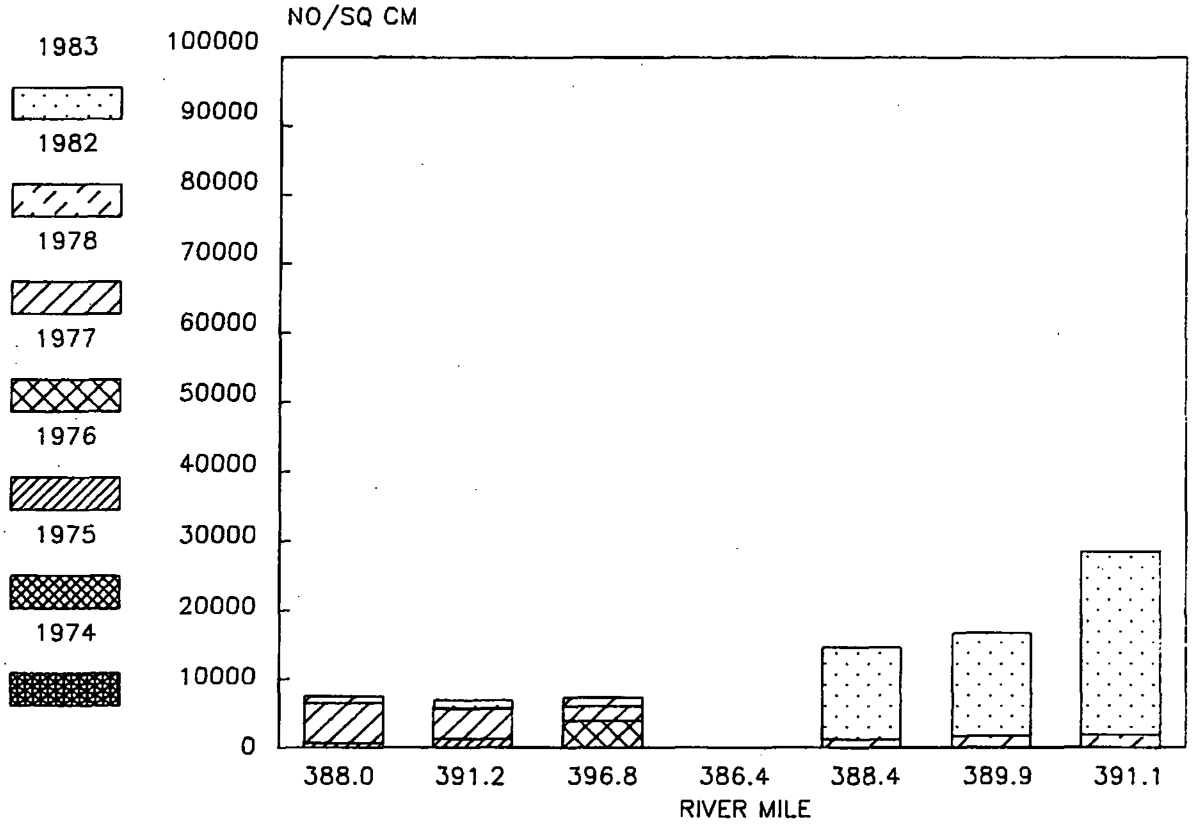


Figure 6-51. Mean Total Periphyton Densities for the Month of April Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

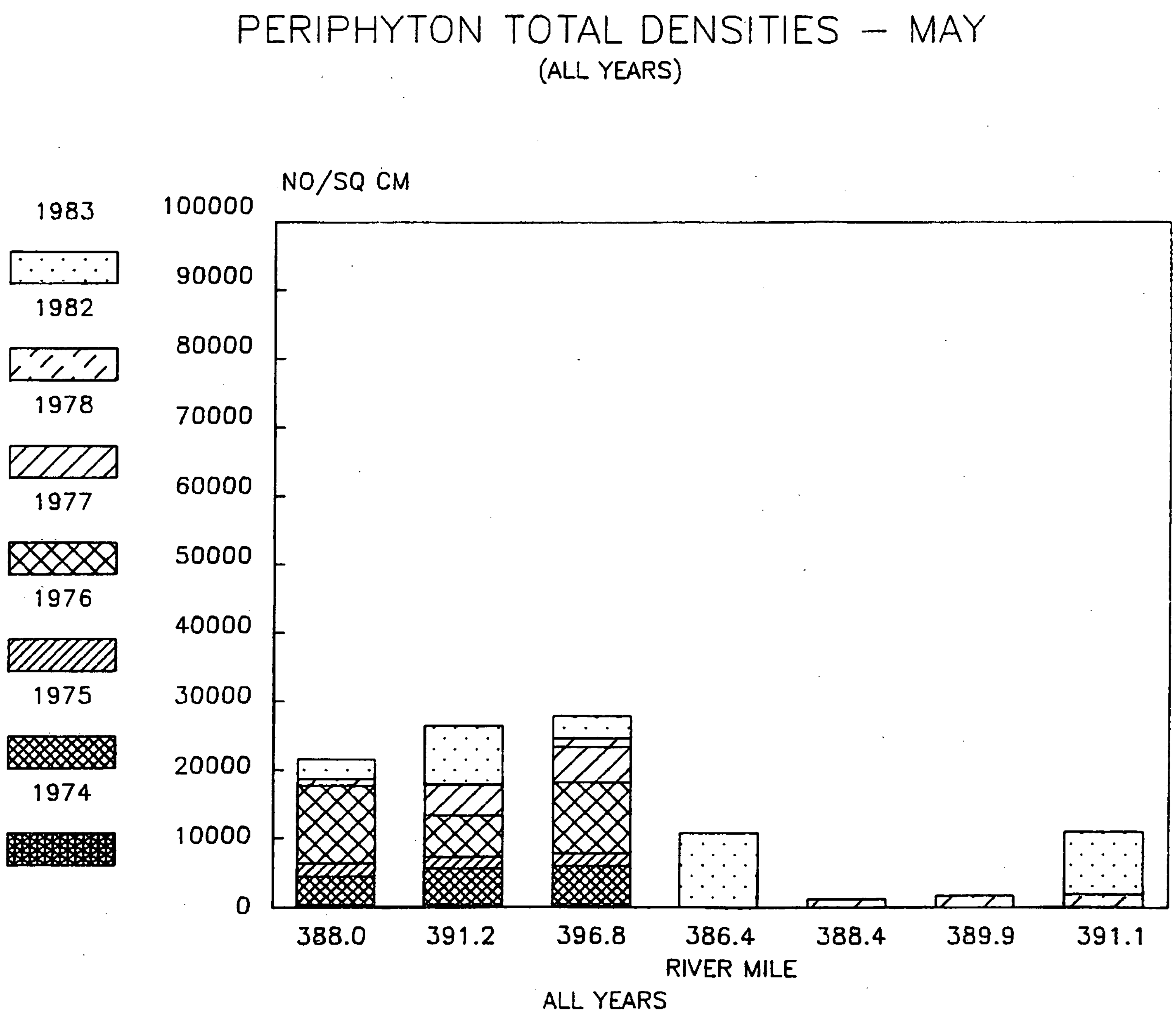


Figure 6-52. Mean Total Periphyton Densities for the Month of May Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

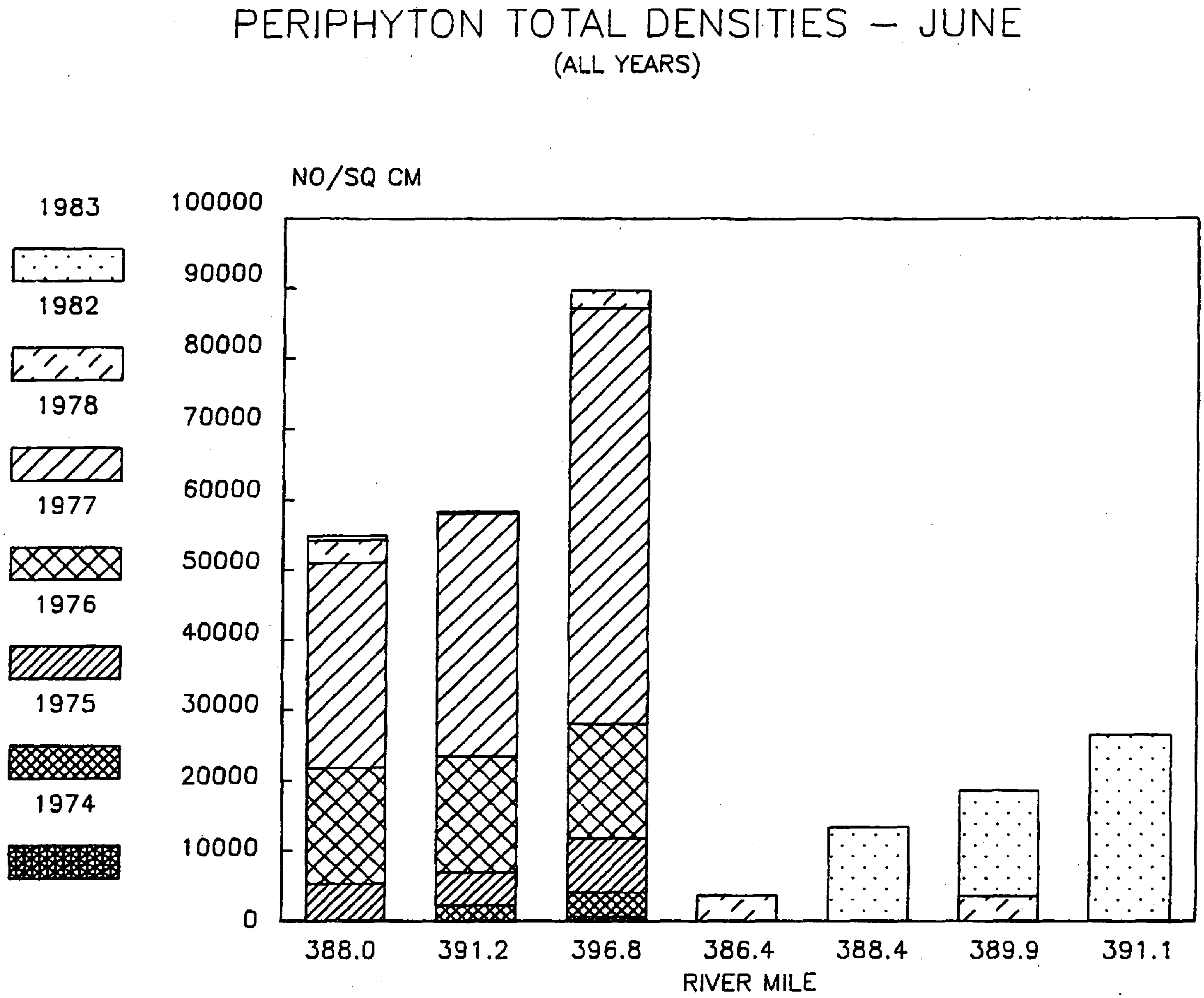


Figure 6-53. Mean Total Periphyton Densities for the Month of June Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

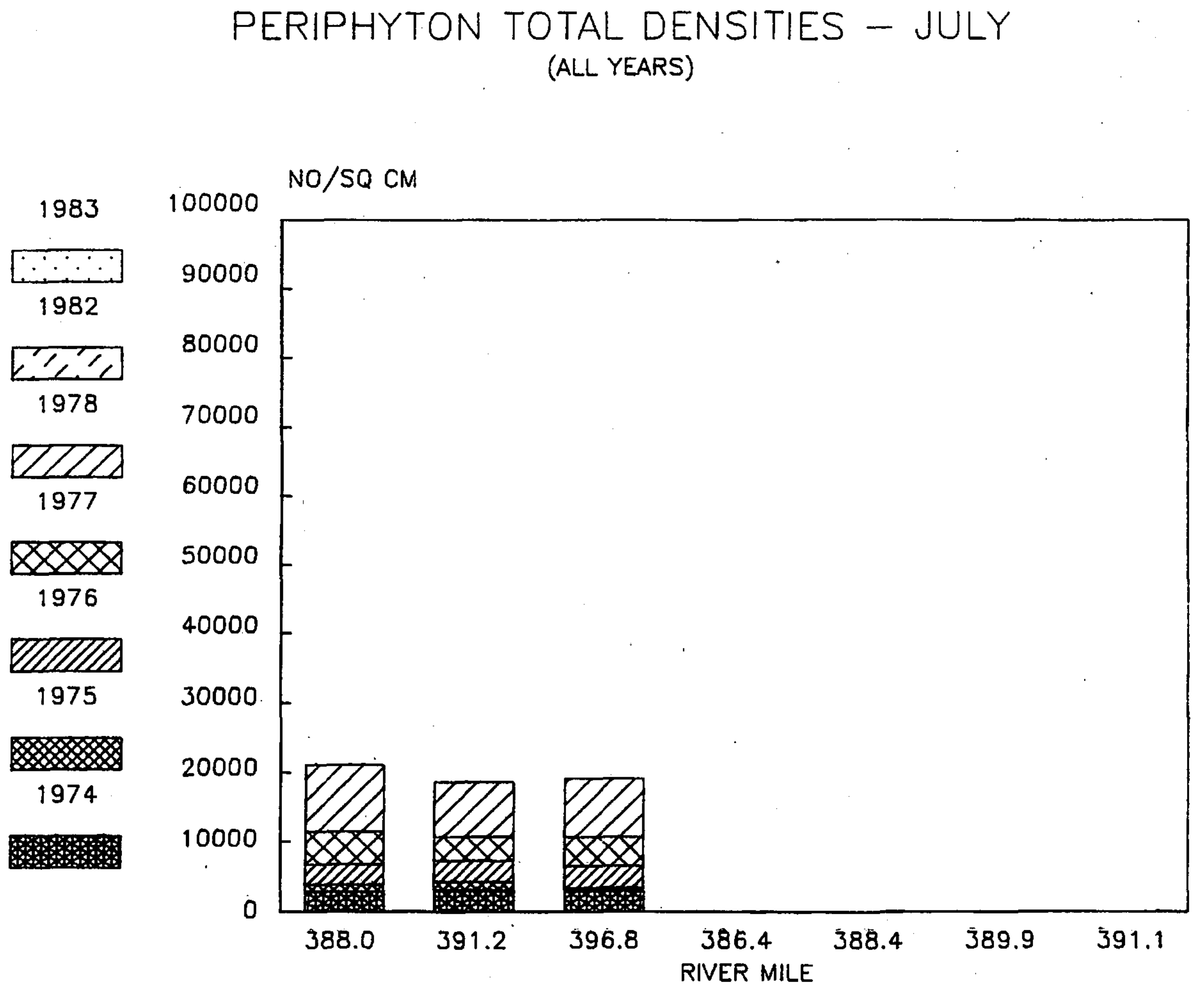


Figure 6-54. Mean Total Periphyton Densities for the Month of July Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

PERIPHYTON TOTAL DENSITIES – AUGUST
(ALL YEARS)

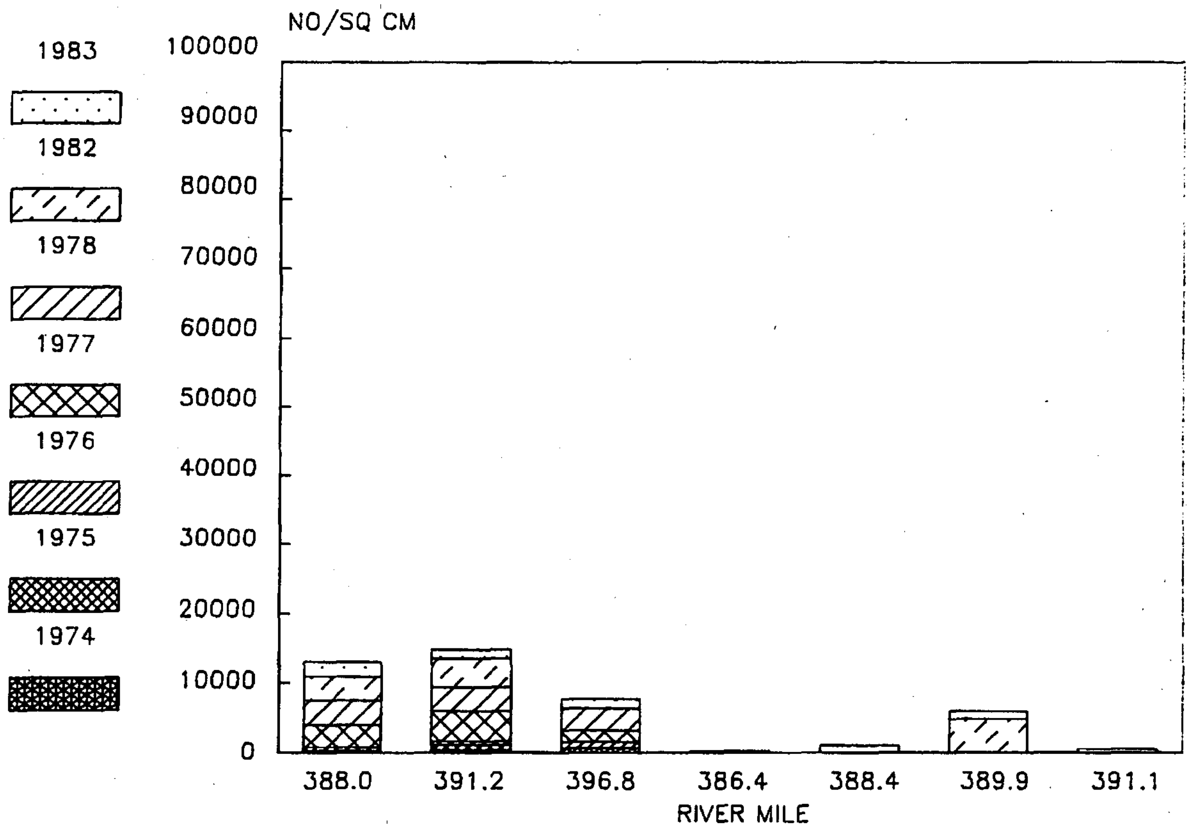


Figure 6-55. Mean Total Periphyton Densities for the Month of August Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

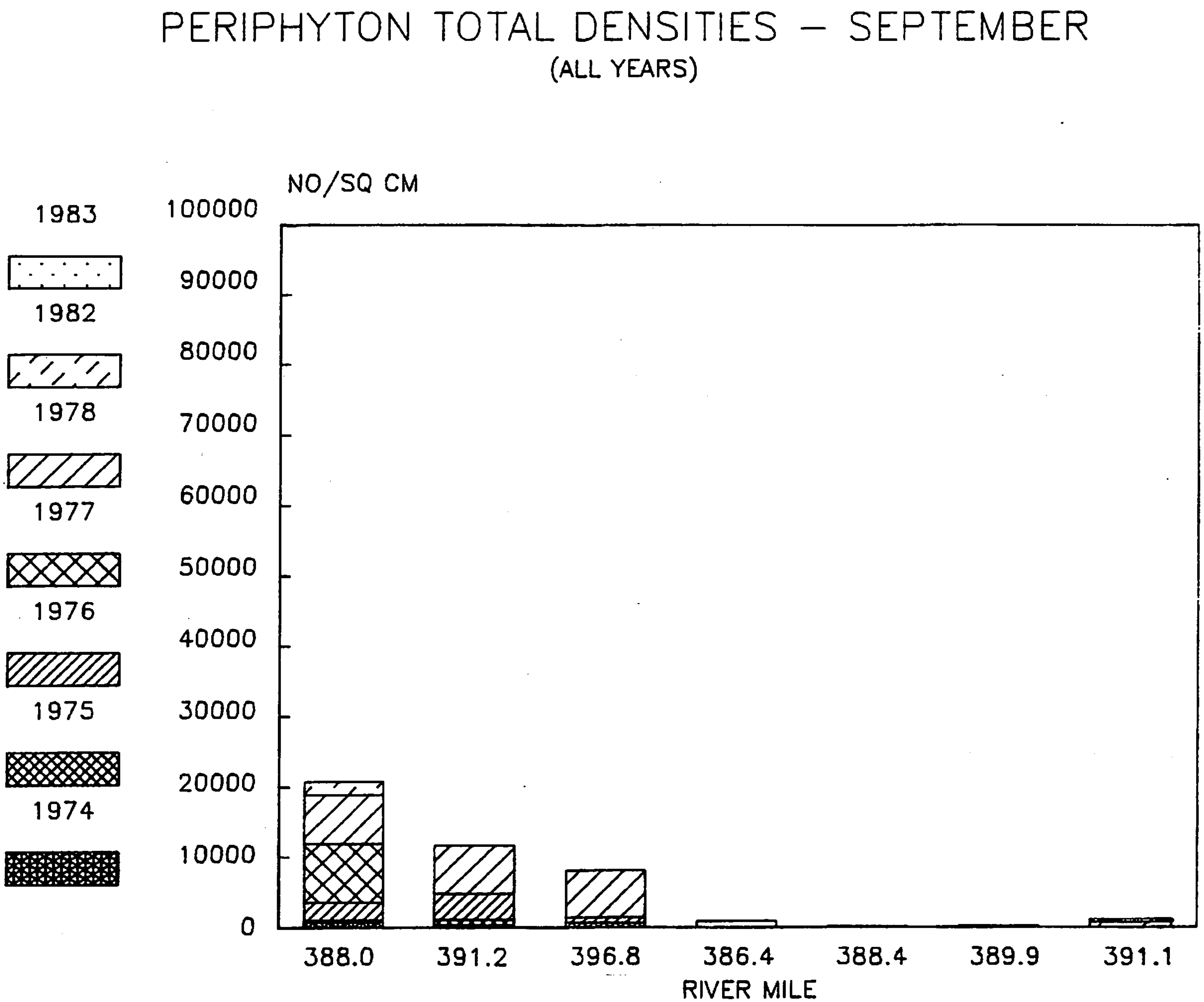


Figure 6-56. Mean Total Periphyton Densities for the Month of September Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

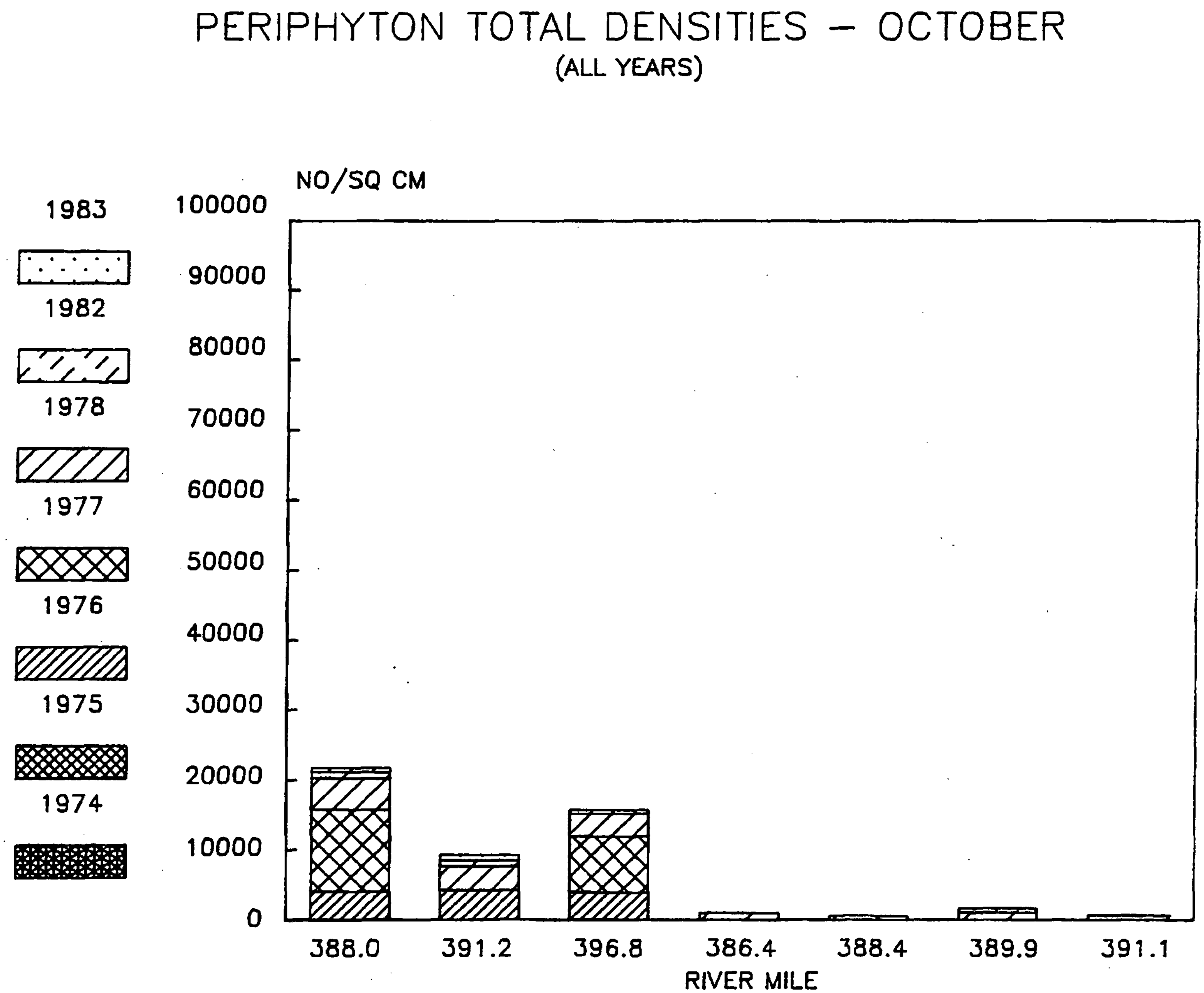


Figure 6-57. Mean Total Periphyton Densities for the Month of October Collected in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974-1983.

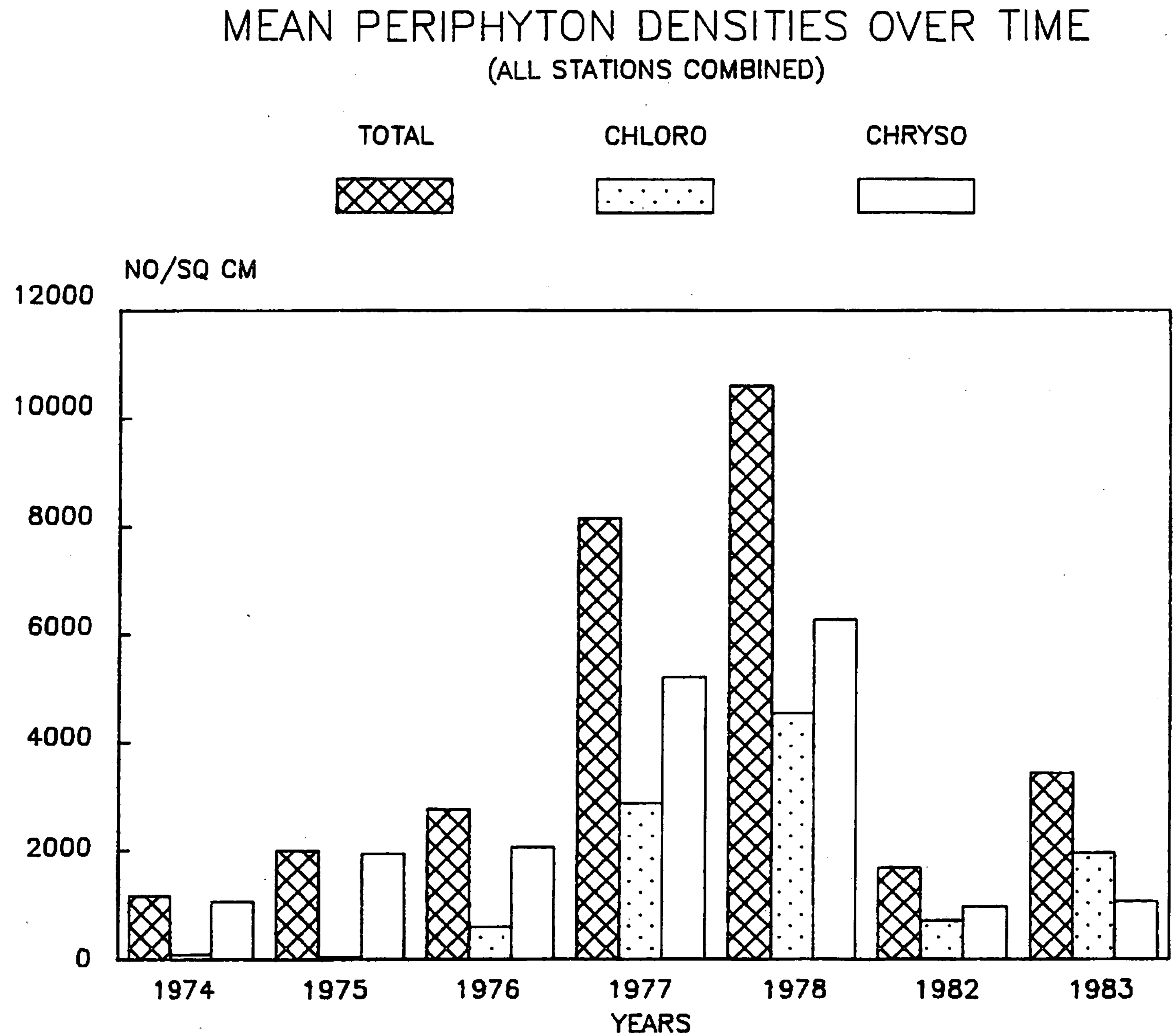


Figure 6-58. Mean Periphyton Densities by Major Group for Each Year (All Stations Combined) in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir, During Preoperational Monitoring, 1974–1983.

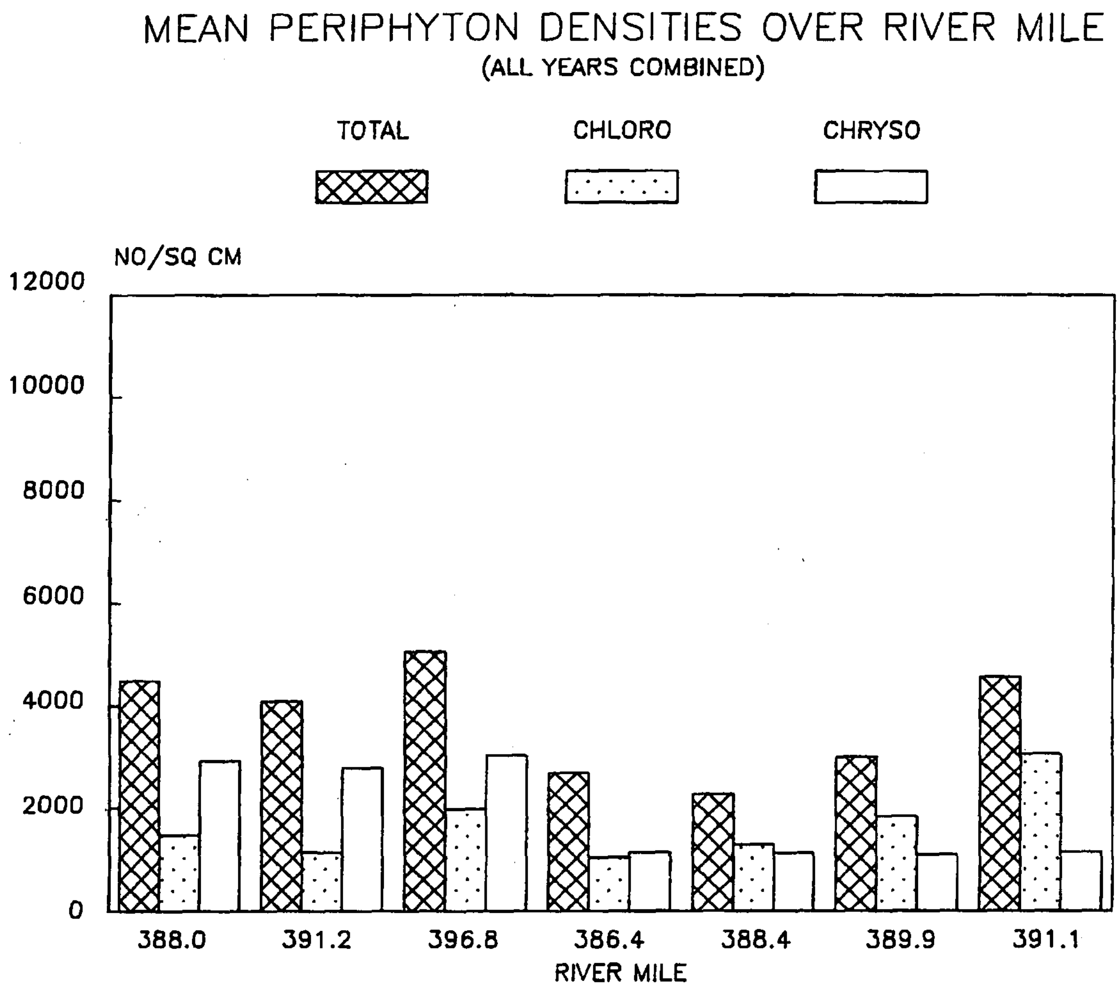


Figure 6-59. Mean Periphyton Densities by Major Group at Each River Mile Sampled (All Years Combined) in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir During Preoperational Monitoring, 1974-1983.

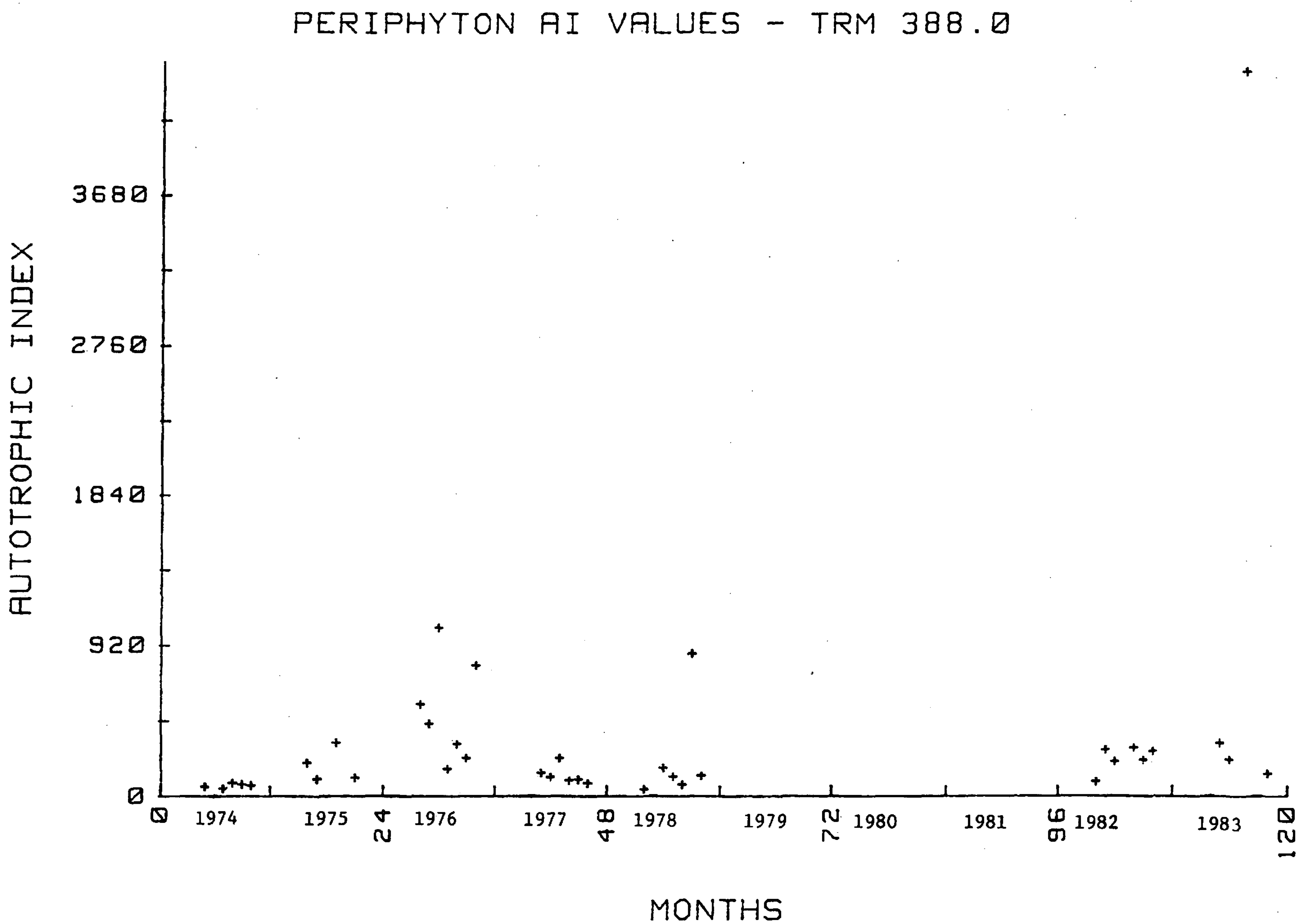


Figure 6-60. Mean Autotrophic Index Values by Collection Dates Collected at TRM 388.0 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

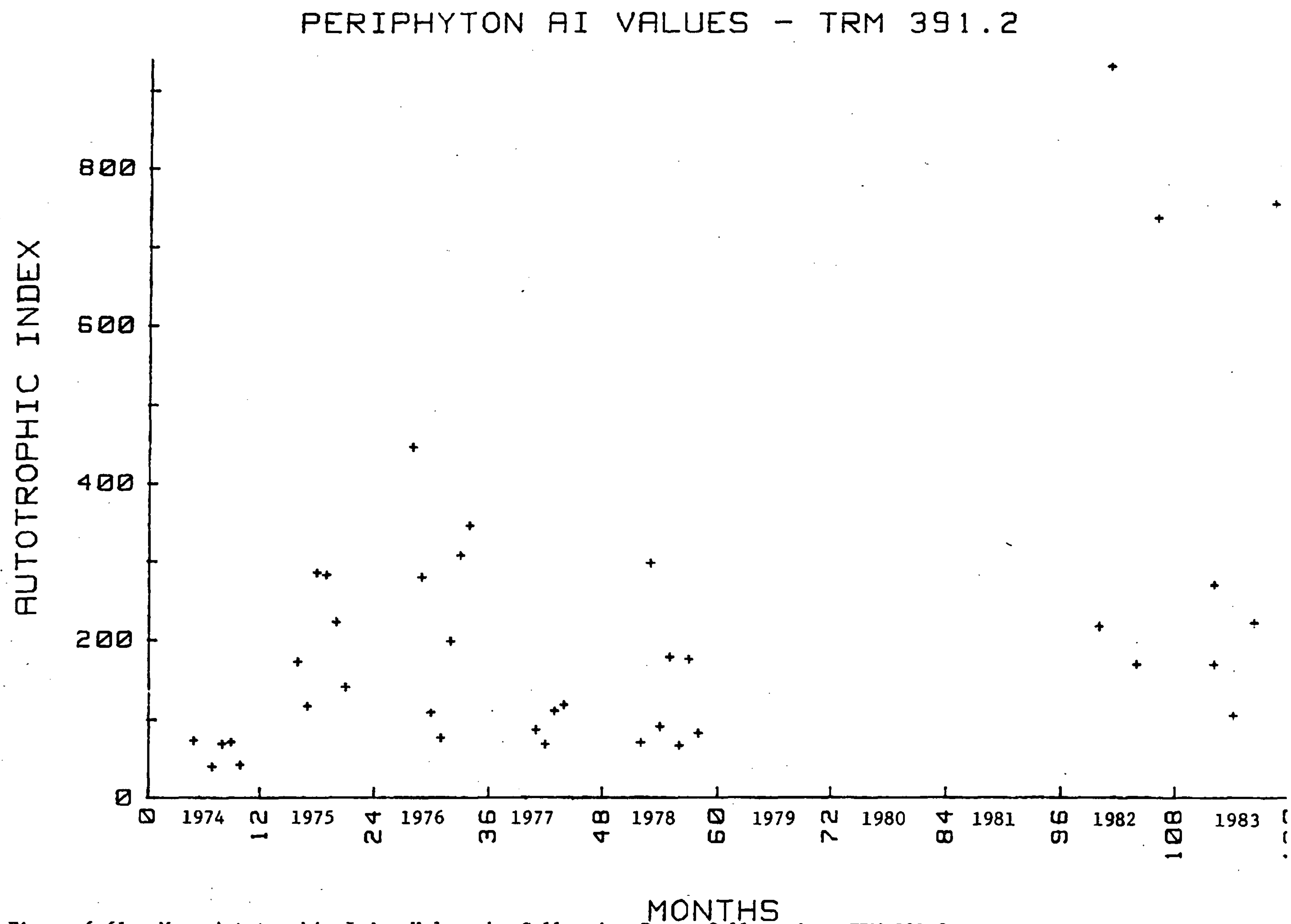


Figure 6-61. Mean Autotrophic Index Values by Collection Dates Collected at TRM 391.2 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

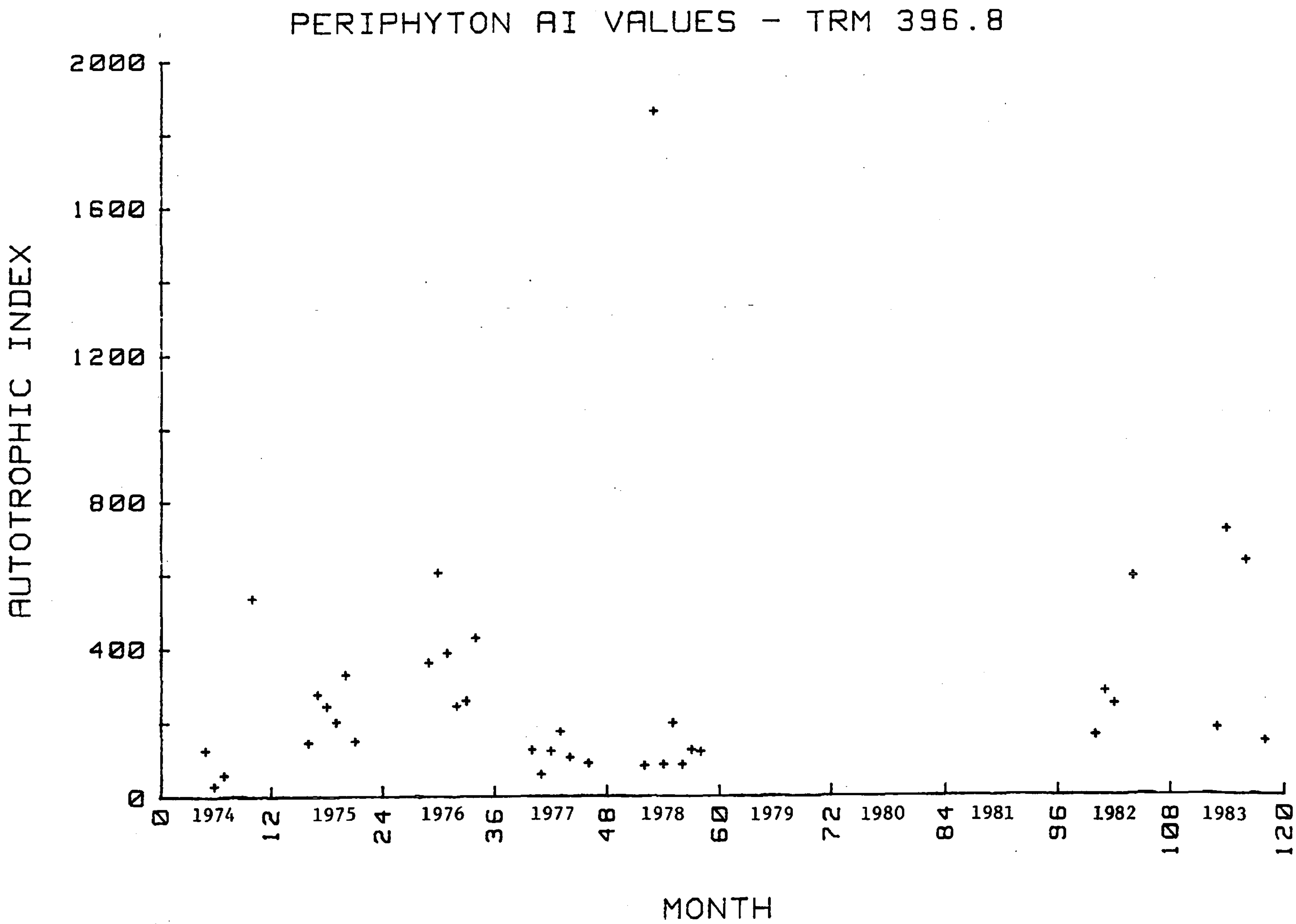


Figure 6-62. Mean Autotrophic Index Values by Collection Dates Collected at TRM 396.8 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

3.0

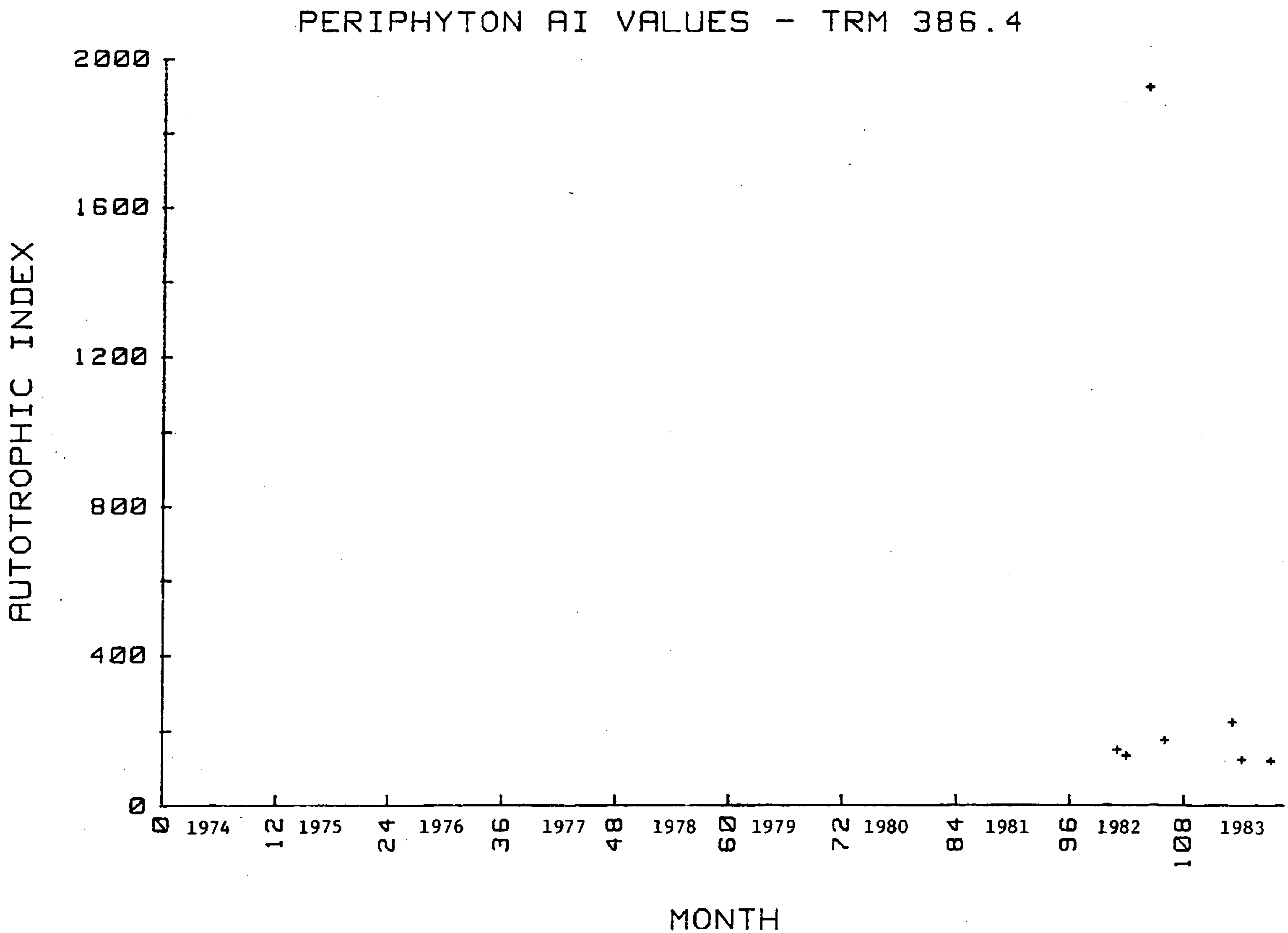


Figure 6-63. Mean Autotrophic Index Values by Collection Dates Collected at TRM 386.4 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

3.1

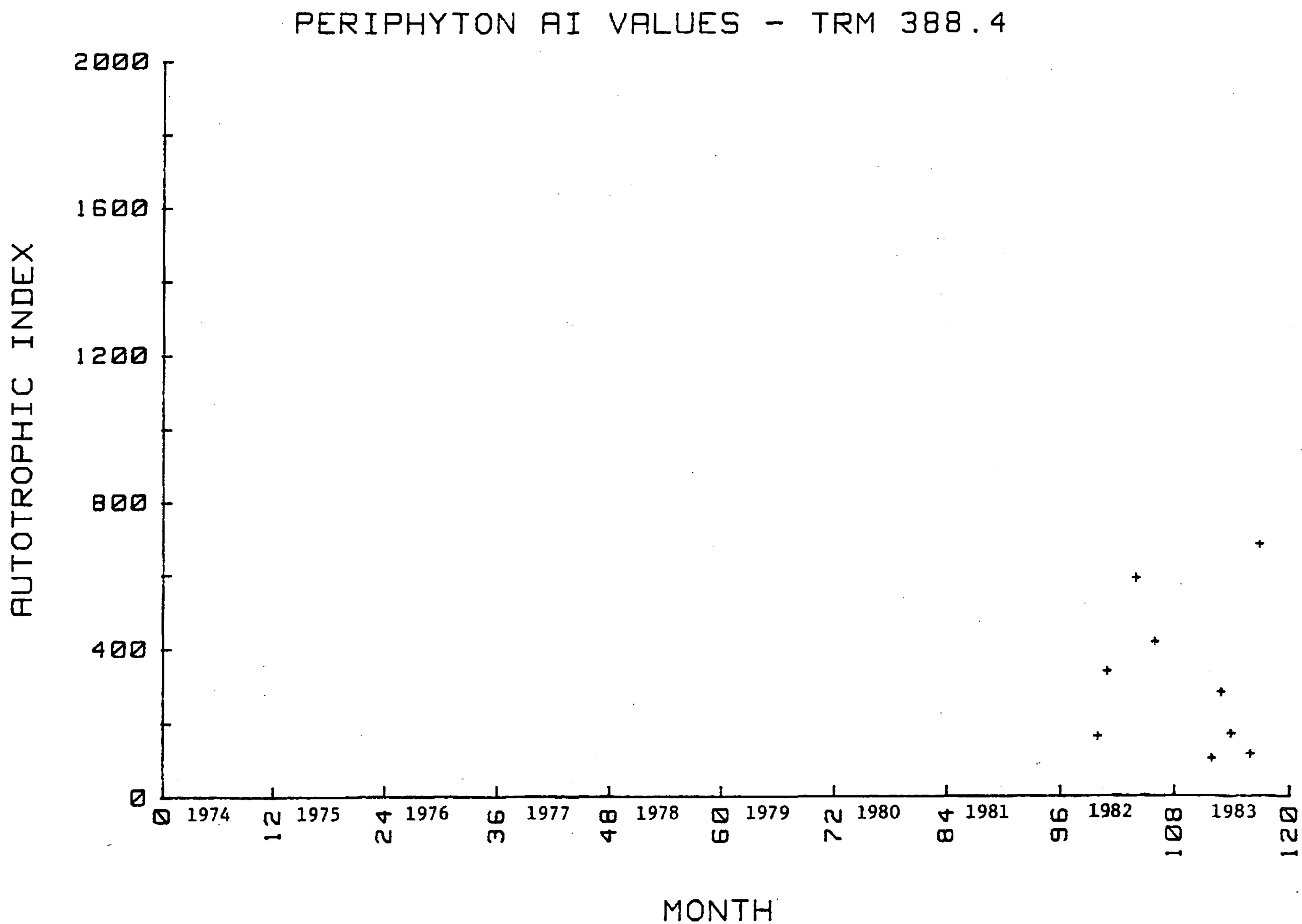


Figure 6-64. Mean Autotrophic Index Values by Collection Dates Collected at TRM 388.4 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

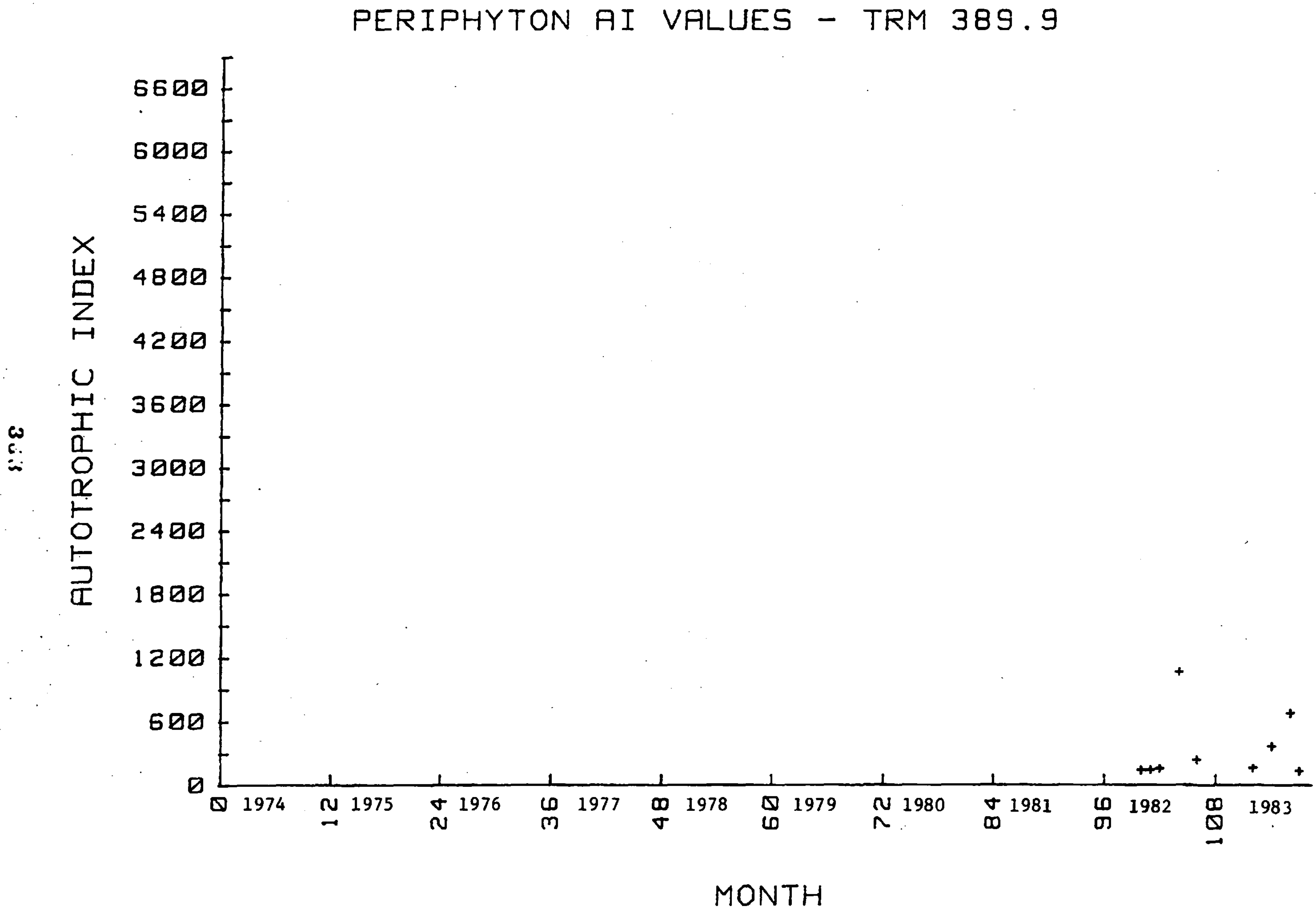


Figure 6-65. Mean Autotrophic Index Values by Collection Dates Collected at TRM 389.9 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

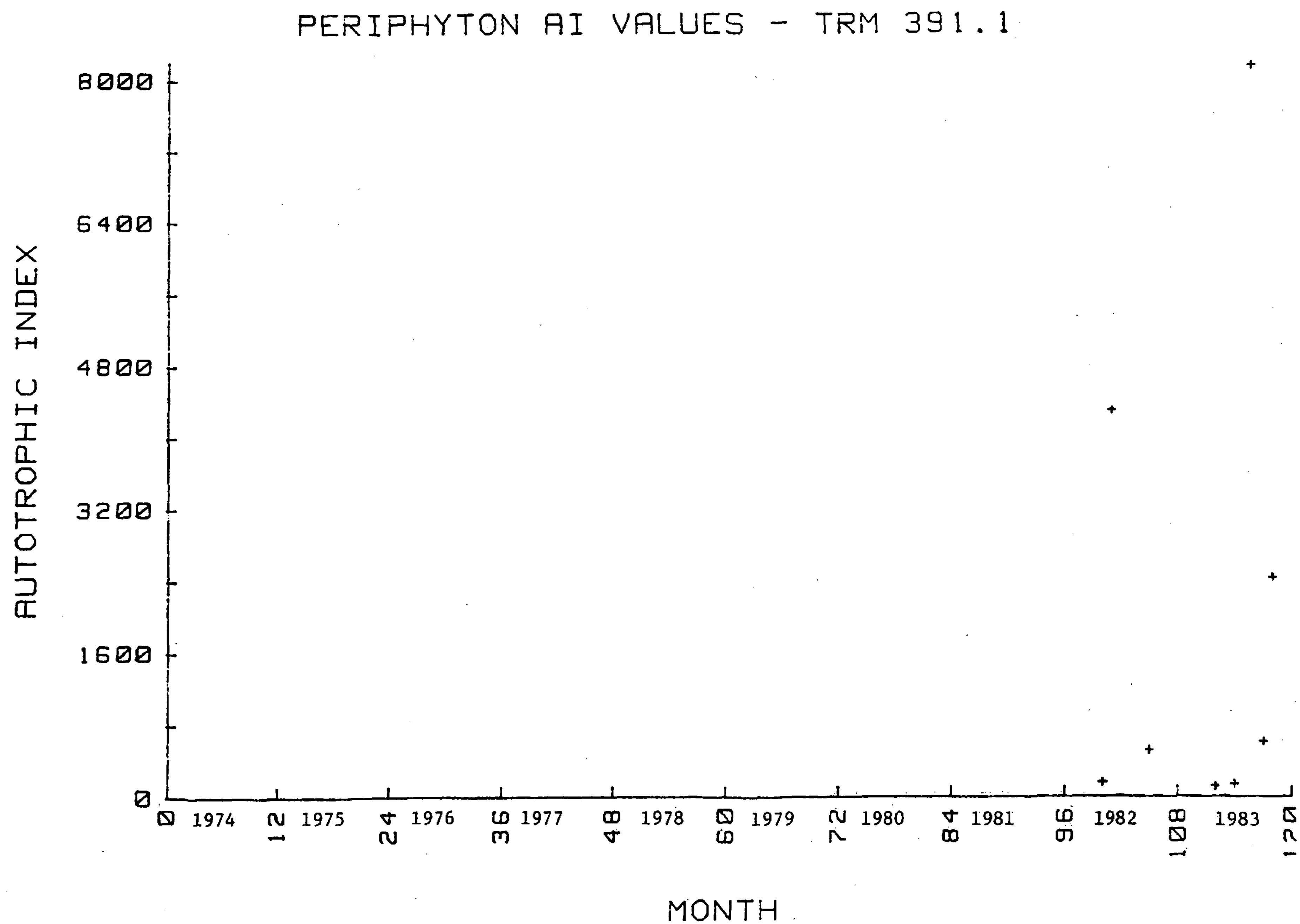


Figure 6-66. Mean Autotrophic Index Values by Collection Dates Collected at TRM 391.1 During Preoperational Monitoring, Bellefonte Nuclear Plant, Guntersville Reservoir, 1974-1983.

7.0 BENTHIC MACROINVERTEBRATES

7.1 Materials and Methods

Field--Preoperational benthic studies were conducted from 1974 through 1978 and during 1982 and 1983 on a monthly basis from February through October each year. Beginning in March 1978 benthic monitoring was expanded beyond the mainstream channel to include the left overbank habitat because it was determined that this area could be exposed to the BLN thermal/chemical plume under low and reverse flow conditions. Left overbank stations were located at TRMs 386.4, 388.4, 389.9, and 391.1; channel stations were located at TRMs 388.0, 391.2, and 396.8 (figure 7-1).

Ten Ponar grab samples were collected at each station. Samples were washed over a standard number 35 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. Sediment samples were collected concurrently with macroinvertebrate samples to characterize benthic substrates and better assess effects of substrate differences upon the macroinvertebrate data.

From 1974 through 1979 artificial substrates (wire barbeque baskets--volume 7675 cm^3, filled with washed river rocks) were also used to collect macroinvertebrates at each channel station. These samplers were allowed to colonize on the bottom for approximately one month. After retrieval, the baskets were opened and the rocks were placed on a standard number 35 mesh wash screen and rinsed with water. After removal of the organisms by washing and handpicking, the rocks were discarded and the organisms and debris were placed in plastic bags, labeled, preserved with 10 percent formalin and returned to the laboratory for processing. Although preoperational monitoring was suspended after the October 1979 survey, artificial substrate sampling was continued the first several months (February through May) in 1980 as part of the construction effects monitoring program. Artificial substrate sampling was terminated in May 1980 following approval of TVA's recommendation which followed evaluation of 1974-1979 construction effects data. The 1980 artificial data are included in this report.

Laboratory--Macroinvertebrate samples were rewashed with water over a standard number 30-mesh screen, placed in white enamel trays, separated from remaining detrital material, transferred into vials, and preserved with a solution of 70 percent ethyl alcohol and 5 percent glycerine. Macroinvertebrates were classified to the lowest taxon practicable and enumerated. References used in identification include numerous taxonomic keys which are on file at the Benthic Laboratory in the E&D Building in Muscle Shoals, Alabama.

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).

Spatial comparisons utilized Sorensen's Quotient of Similarity (SQS) as described by McCain (1975) to evaluate differences among stations based on community structure. A criterion of 70 was chosen as an estimate of similarity. Values less than 70 would indicate different communities based upon taxonomic structure (SQS). Diversity indices (Patten, 1962) were calculated to determine community diversity at each station. Graphical comparisons of stations were made over time for total and dominant group densities.

Sediment samples which were collected from channel stations during 1974-1979, primarily were intended to support the construction effects monitoring program and are discussed in detail in TVA's construction assessment (TVA 1980). Although additional sediment samples were collected through 1983, they are not discussed as part of this preoperational assessment, but are available for future use.

7.2 Results and Discussion

A total of 138 of aquatic macroinvertebrate taxa was collected and identified at the seven localilties monitored from 1974 to 1983. One hundred-ten taxa were recorded from the three channel stations (tables 7-1 and 7-2), while 113 were recorded from the four overbank stations (table 7-1). These two major habitat types had 86 taxa in common (62.3 percent of the total number). Twenty-one taxa were found in the channel that were not found in the overbank (table 7-3) the majority of these being rheophilic species. The majority were caddisflies (5), stoneflies (2), mayflies (2), and crayfish (2). Twenty-five taxa were found in the overbank that were not found in the channel (table 7-3), most of which are limnophilic. The majority were dragonflies (5), mussels (3), chironomids (3), and snails (2). The spatial and seasonal trends in numbers of taxa and populations and the dynamics of dominant taxa are discussed separately for channel and overbank. The fauna at BLN was very similar to that in the vicinity of the Murphy Hill site (TRM 368.5 to 371.5), as 87 percent of the taxa reported from that site for 1981-1982 (TVA, 1983) were found near BLN.

The Channel Fauna--Based on Ponar grab sampling, the average density (no./m^2) of benthic macroinvertebrates increased markedly in the channel with time (figure 7-2), although there were differences among stations. At TRM 388.0, mean number per m^2 in 1977 more than doubled over the previous three years; the mean numbers increased further in 1978, thereafter leveling off. Mean numbers per m^2 at TRM 391.2 and TRM 396.8 were lower than at TRM 388.0 and did not increase markedly until 1982, when values more than tripled. Seasonal trends in benthic macroinvertebrate density were not evident at any station (figure 7-3). Mean density at TRM 388.0 was consistently higher than at the other two stations each month sampled.

The number of taxa found per year (based on Ponar samples) increased at each station from 10 or less in 1974 to 40 or more in 1983 (figure 7-4). The mean number of taxa collected per month increased concomitantly (figure 7-4) with a sharp rise at all three stations from 1979 to 1982. The station at TRM 388.0 generally had a few more taxa than the other two stations (table 7-4). No significant seasonal trend in number of taxa was found over the eight-year monitoring period (figure 7-5).

The general trend of an increase in macroinvertebrate abundance and in the number of taxa from 1974 to 1983 at all three channel stations is substantiated by the diversity index values (table 7-5). A gradual increase in diversity values occurred at TRM 388.0 and 396.8 in 1977. From 1978 on, diversity values increased at all three stations. The increases in the overall values of diversity indices for each year are shown in figure 7-6.

The seasonal trend in diversity varied with station locality. At TRM 388.0, diversity values were usually highest in spring and fall months, with lower summer values. At TRM 391.2, diversity was usually highest in summer months. At TRM 396.8, the high values were more variable but occurred more often in spring months. Combining all stations and years, diversity was lowest in March (average diversity index = 1.22) and highest in July (average diversity index = 1.66).

Results of the SQS analysis were variable depending on samplng date. When the data were combined on a yearly basis, the station at TRM 388.0 appeared to be similar to the station at TRM 391.2 (table 7-6). The station at TRM 396.8 was similar to TRM 388.0 only in 1976 and 1977, and similar to TRM 391.2 only in 1976 and 1983. The SQS values for 1983 showed that all three stations were similar to each other (> 70 percent).

The dominant taxon (based on frequency of occurrence in Ponar samples and numerical abundance) at all three stations from 1974 to 1979 was Corbicula manilensis (table 7-7). Two oligochaete worms, an unidentified Tubificidae and Branchiura sowerbyi, were usually next in ranking; the tubificids were usually more abundant, whereas Branchiura occurred in more samples. These three taxa were the only ones found at every station every year sampling was conducted. Hexagenia ranked as high as third only at TRM 388.0 in 1975, 1978, and 1979. However, in 1982 and 1983, Hexagenia became the dominant taxon at all three stations (table 7-7) as Corbicula population estimates declined. Examination of the population trends of these two taxa throughout the study period shows an increase in Corbicula at TRM 388.0 from 1977 through 1979, followed by sharp decreases in 1982 and 1983 (figure 7-7). In contrast, populations of Hexagenia have increased steadily at TRM 388.0 on an average yearly basis (figure 7-10), although seasonal fluctuations are great due to the life cycle of these insects. Typically the population is large in spring until mid-June when emergence to the adult stage begins. The population of nymphs then declines through the summer months as emergence continues. By late summer and early fall (September and October) the population again increases as eggs hatch. In fall and winter, the population decreases somewhat due to predation pressure on the young nymphs. This annual pattern is evident in figures 7-10, 7-11, and 7-12. The Corbicula populations at TRM 391.2 and 396.8 were more stable on the average throughout the monitoring period (figures 7-8 and 7-9). Another taxon which increased markedly at TRM 388.0 and 396.8 was Gammarus, ranking second in 1983.

Considering data from only the Ponar sampling, taxa that were not found at any of the channel stations from 1974-1979 but that were picked up in the 1982 and 1983 surveys include Amnicola, Baetidae, Berosus, Clinotanypus, Elmidae, Erpobdellidae, Ferrissia, Gammarus, Glossiphoniidae, Goniobasis, Gyraulus, Hydroptila, Macromia, Molonna, Naididae, Nemata, Nigronia, Oecetis, Paratendipes, Pectinatella, Phylocentropus, Proptera, Psidium, Somatogyrus, Stenochironomus, Taphromysis, Triaenodes, Tribetos, Viviparus, and Xenochironomus. Some of these taxa were rarely collected and their scarcity could account for sampling error prior to 1982. However, the appearance of approximately 30 recent colonizers compared to only 12 taxa which were not collected since 1979 (see table 7-1) indicates an appreciable change in the channel macroinvertebrate community, and largely accounts for the increase in diversity.

The dominant taxa in the artificial substrate samples from the three channel stations are ranked in table 7-8. Shifts in the order of dominance from year to year were common. At TRM 388.0, the caddisfly Cyrnellus fraternus and the amphipod Hyalella azteca were usually the most abundant taxa until 1980 when the midge Cricotopus became dominant. TRM 396.8 showed a similar pattern. At TRM 391.2 the dominant taxon changed each year until 1979 and 1980 when Cricotopus became abundant. Taxa other than Cricotopus which became relatively prevalent after 1976 were Agraylea, Cloeon, Glyptotendipes, Neureclipsis, Pleurocera, Polypedilum, Rheotanytarsus, and Tricorythodes.

The Overbank Fauna--Macroinvertebrate density (no/m^2) at all four overbank stations was greater in 1982 and 1983 than in 1978 and 1979, (figure 7-13) reflecting a trend similar to that in the channel habitats. The station at TRM 389.9 had the lowest mean density whereas the station at TRM 386.4 had the highest mean density three of the four years sampling was conducted. Total macroinvertebrate density showed a definite seasonal pattern. Numbers decreased steadily through the spring months, reaching a low in mid to late summer, followed by increasing numbers in October (figure 7-14).

The number of taxa at each of the four stations increased from 1979 to 1982, but then showed a slight decrease in 1983; the mean number of taxa per month reflected this trend. The mean number of taxa per month (when the data were combined over all four sampling years and stations) indicate that a greater number of benthic species were present in spring (February-April) than during the remainder of the year (figure 7-16). The lowest mean number of taxa occurred in October, although it was not appreciably different from the means for May through September.

Diversity increased each year at each station (table 7-9). The greatest increase occurred at station TRM 389.9, where the mean value rose from 4.66 in 1978 to 6.40 in 1983. No seasonal trends in diversity were evident.

Results of station comparisons using SQS values (table 7-10) were variable. Community structure at the overbank sations, based on presence/absence of macroinvertebrate taxa, appeared to remain quite similar among stations, the lowest similarity occurring in 1979.

The two dominant taxa at stations TRM 386.4 and 389.9 were Hexagenia and Tubificidae in 1978 but changed often thereafter (table 7-11). The dominant taxa at stations TRM 388.4 and 391.1 was Coelotanypus 1978 and 1979, but changed to Chironomus at TRM 388.4 in 1982 and 1983. Corbicula populations increased in 1982 and 1983 at each station (figures 7-17 to 7-20), although densities were low at TRM 388.4 and 391.1. Populations of *Hexagenia* appeared to follow an opposite trend, as densities were lower in 1983 at TRM 386.4, 389.9, and 391.1 than in previous years (figures 7-21, 7-23, and 7-24). TRM 388.4 was an exception (figure 7-22). At TRM 386.4, *Hexagenia* was clearly dominant in 1978 and 1979, except in July and August when most had emerged (figure 7-21), at which time tubificid worms were most numerous. In the fall of 1979, *Hexagenia* numbers did not increase as in 1978. In the spring of 1982, *Hexagenia* appeared in high numbers sporadically, and decreased thereafter. Various genera of Chironomidae, including *Chironomus*, *Procladius*, and *Dicrotendipes*, increased in 1982 and 1983. At TRM 388.4, *Coelotanypus* was the dominant taxon in 1978 and 1979, but was replaced by *Chironomus* in 1982 and 1983 (table 7-11). *Dicrotendipes* decreased over the study period; *Corbicula* density was low but increased slightly in 1982 and 1983 (figure 7-18). At TRM 389.9, the dominant taxa *Hexagenia*, *Corbicula*, and Tubificidae were somewhat more stable, although some shifting in ranking occurred (table 7-11). At TRM 391.1, *Coelotanypus* remained the dominant taxon, whereas *Hexagenia* and *Corbicula* occurred in low numbers.

Taxa that occurred at all four overbank stations each sampling year were *Ablabesmyia*, *Branchiura*, *Caenis*, *Chaoborus*, *Coelotanypus*, *Corbicula*, *Cryptochironomus*, *Dicrotendipes*, *Hexagenia*, *Polypedilum*, *Procladius*, and Tubificidae. Taxa that were last collected in 1979 were Culicidae, *Micropsectra*, *Paragordius*, *Rheotanytarsus*, *Stenacron*, and *Tanytarsus*; all were rarely collected, except *Rheotanytarsus* which was relatively common at TRMs 388.4 and 391.1 in 1979.

The environmental factors responsible for the observed changes in the channel and overbank communities were not investigated in a causative manner in this study. However, water quality parameters that were monitored were examined and are discussed here. Physical conditions such as flow and water temperature (chapter 2 of this report) did not appear to change appreciably from 1974 to 1983 to account for the faunal changes. Water quality parameters and measurements are given in chapter 4. Total organic carbon, total nitrogen, and BOD showed increased values in 1982 and 1983, reflecting increased productivity. Yearly changes in other parameters were not obvious and would not be expected to affect the macrobenthos. Aquatic macrophyte and mosquito control programs probably did not appreciably affect nontarget macroinvertebrates (see chapter 3 of this report).

A sand and gravel dredging operation may have impacted macroinvertebrates. Most of the dredging was done at TRM 389.4 from 1975 to 1979. TRM 388.0 was dredged in the fall and winter of 1977, and TRM 389.0 was dredged the first half of 1976 and in November and December of 1979. Turbidity from dredging operations usually extends several miles downstream. The type and extent of any effects of the increased turbidity on different macroinvertebrate taxa were not determined in this study.

7.3 Summary and Conclusions

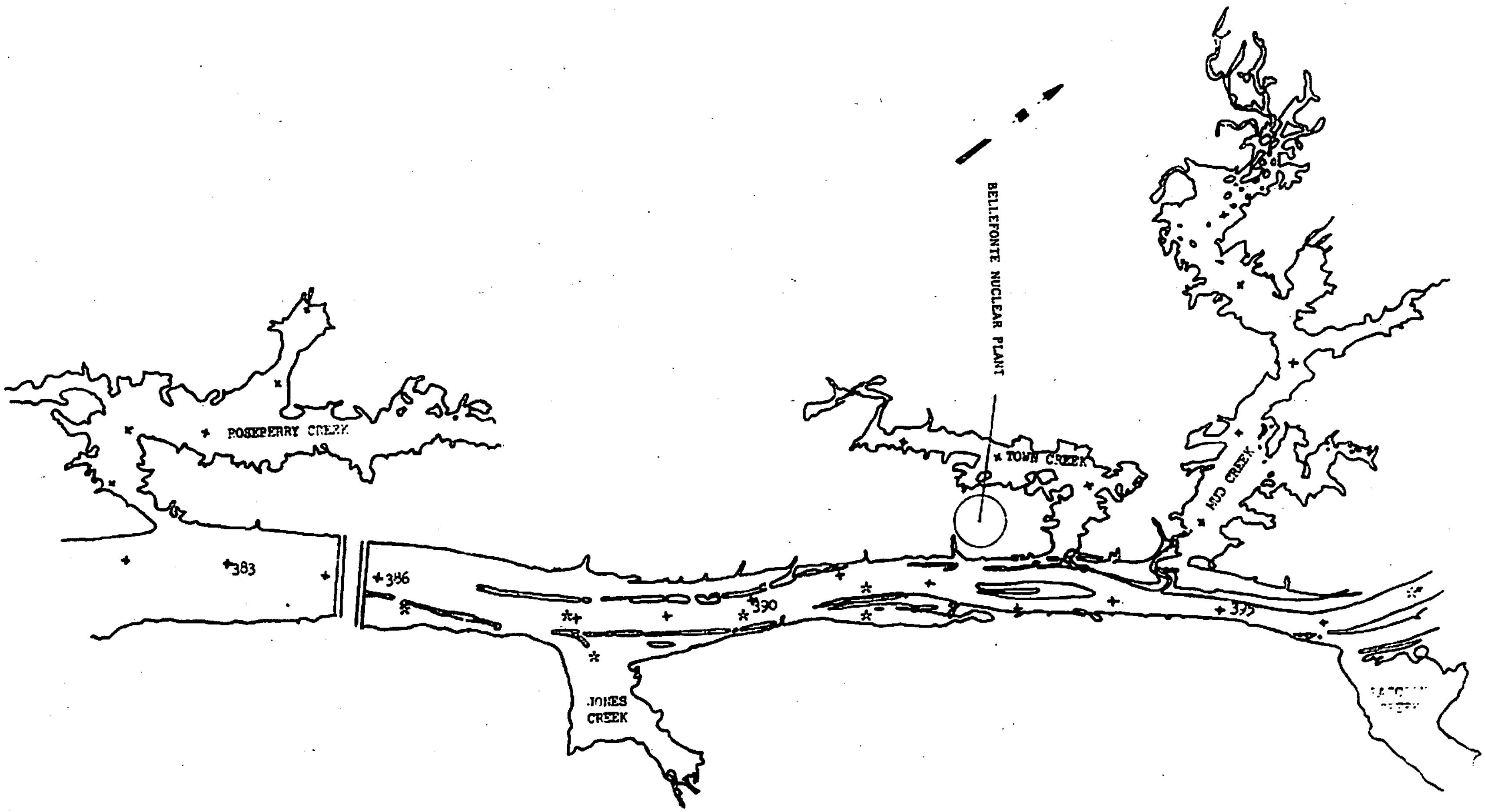
A total of 138 macroinvertebrate taxa were found at the seven stations monitored in the vicinity of BLN from 1974-1979 and 1982-1983.

A general increase in number of taxa and in number of organisms was observed throughout the study period. Higher diversity values reflected these increases.

The macroinvertebrate community in the channel was dominated by the asiatic clam Corbicula manilensis and oligochaetes through 1979 (based on Ponar sampling). However, when sampling was resumed in 1982, a major shift in dominance was evident. The burrowing mayfly, Hexagenia sp., became the most numerous taxon at all three stations (TRMs 388.0, 391.2, and 396.8). Artificial substrate samples, taken from 1974 through May 1979, showed many changes in dominant rheophilic taxa, although the caddisflies Cyrnellus fraternus and Neureclipsis were usually common. In 1980, the chironmid Cricotopus was dominant at all three stations.

The overbank community exhibited two seasonal trends. The mean number of taxa was highest in spring, decreasing in summer to a low in October. The mean number of organisms decreased steadily throughout spring to a low in late summer, followed by an increase in October. The burrowing mayfly, Hexagenia sp., and the chironomids Coelotanypus and Chironomus were usually the dominant taxa. In general, Corbicula manilensis increased in numbers throughout the four sampling years (1978-1979, 1982-1983), whereas Hexagenia decreased.

The observed spatial and temporal changes in the macroinvertebrate fauna in the vicinity of BLN were not investigated in a causative manner in this study. No physical conditions or water quality changes within the reservoir could be definitely attributed to increasing or decreasing trends in numbers of taxa or individuals.



* - Benthic Stations

Figure 7-1. Location of Benthic Stations for the Preoperational Monitoring Program in the Vicinity of Bellefonte Nuclear Plant.

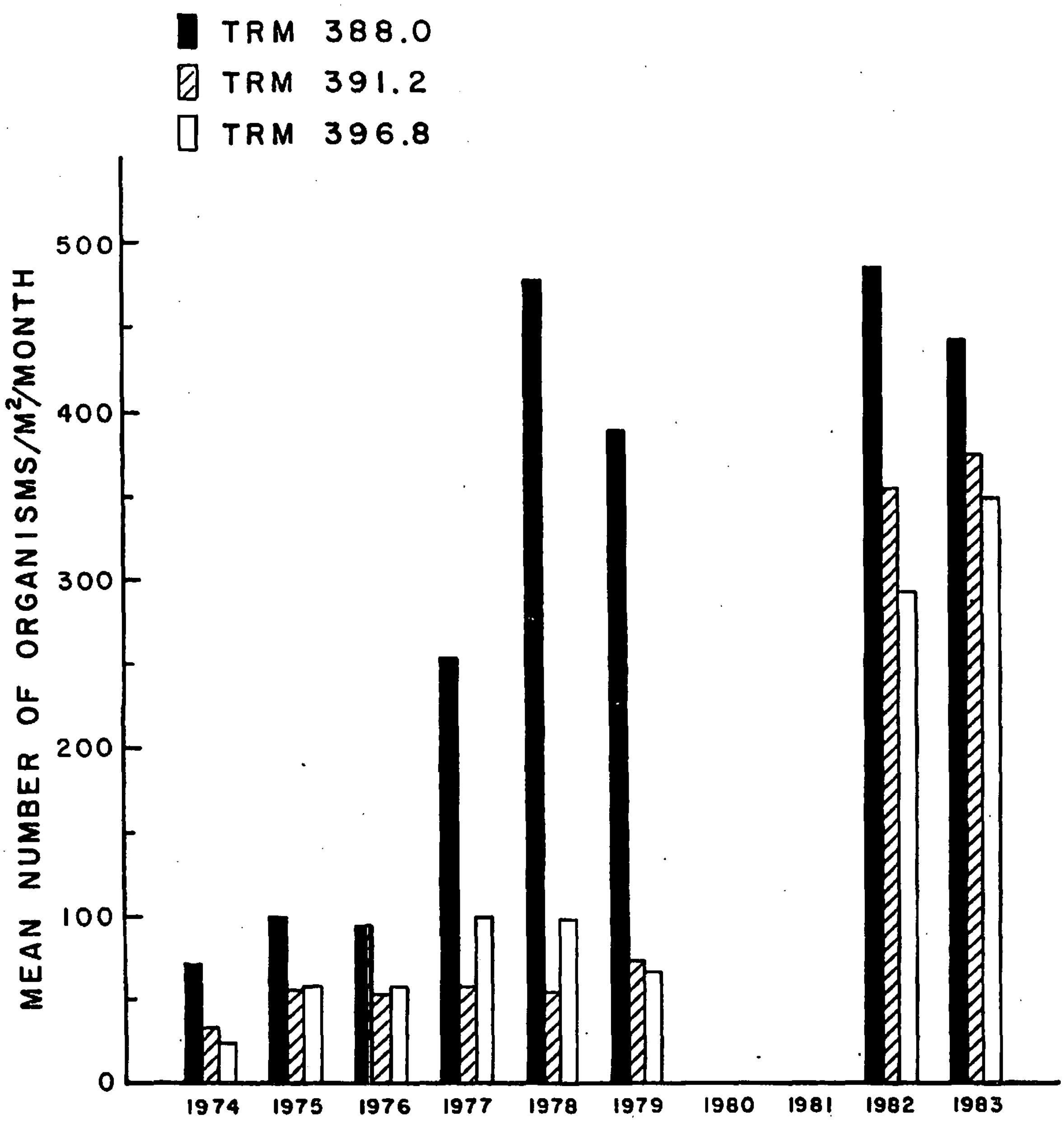


Figure 7-2. Yearly Mean Densities of Total Macroinvertebrates at Three Channel Stations in the Vicinity of Bellefonte Nuclear Plant, 1974-1983. Based on Ponar Grab Samples.

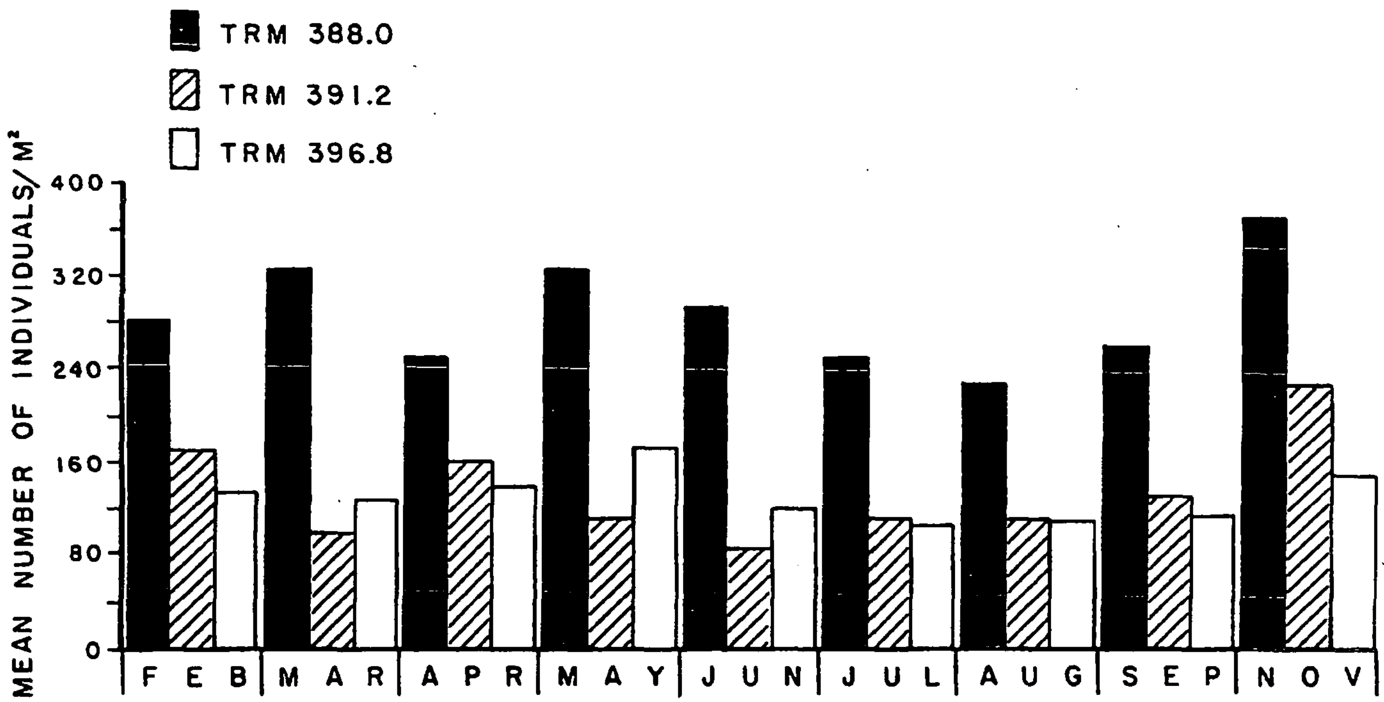


Figure 7-3. Monthly Variation in Mean Number of Macroinvertebrates/m², Years 1974-1983 combined, at Three Channel Stations in the Vicinity of Bellefonte Nuclear Plant. Based on Ponar Grab Samples.

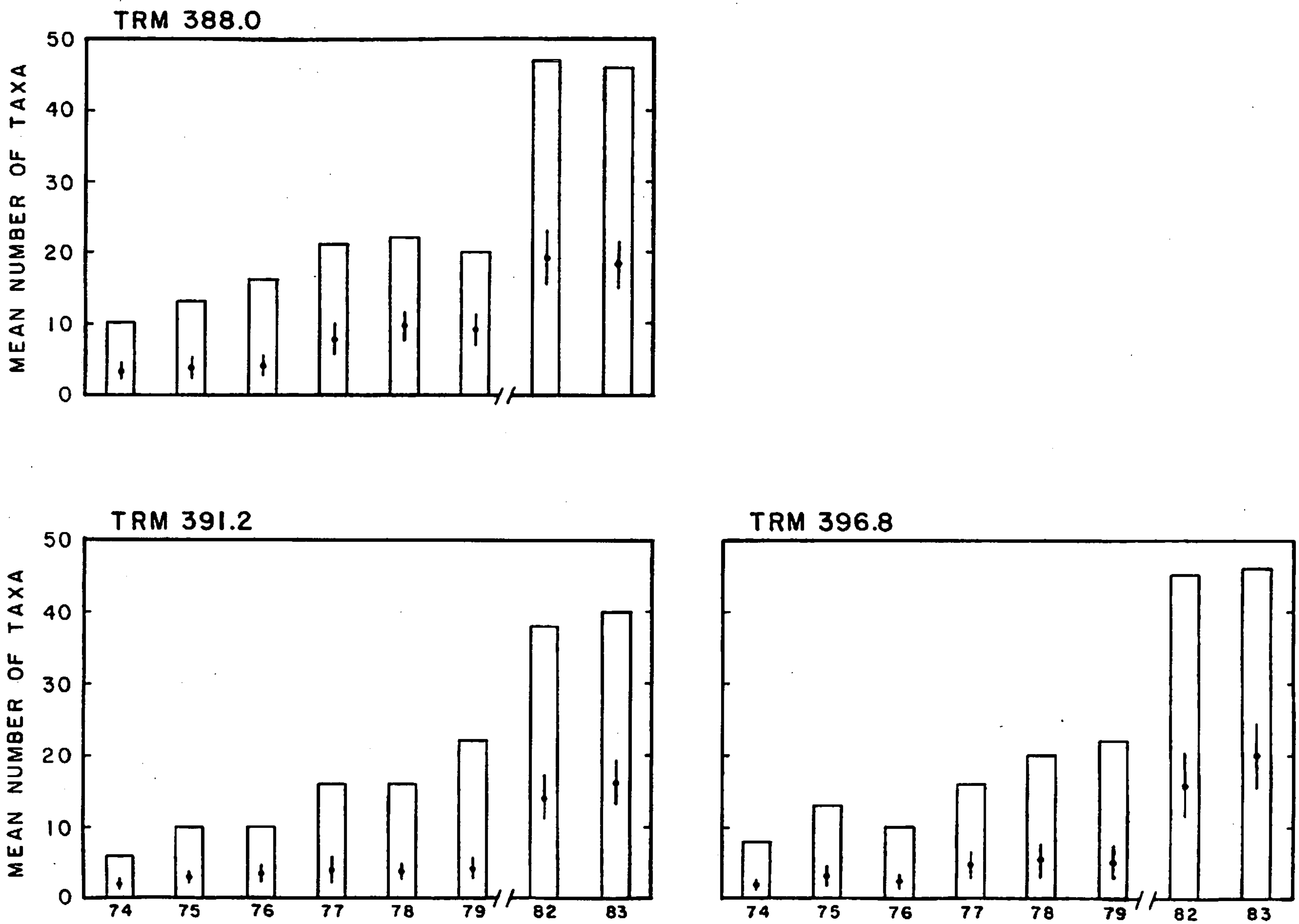


Figure 7-4. Number of Different Taxa (bars) Collected per Year at the Three Channel Stations. Points indicate Mean Number of Taxa Collected per Month with 95% Confidence Limits. Based on Ponar Grab Samples.

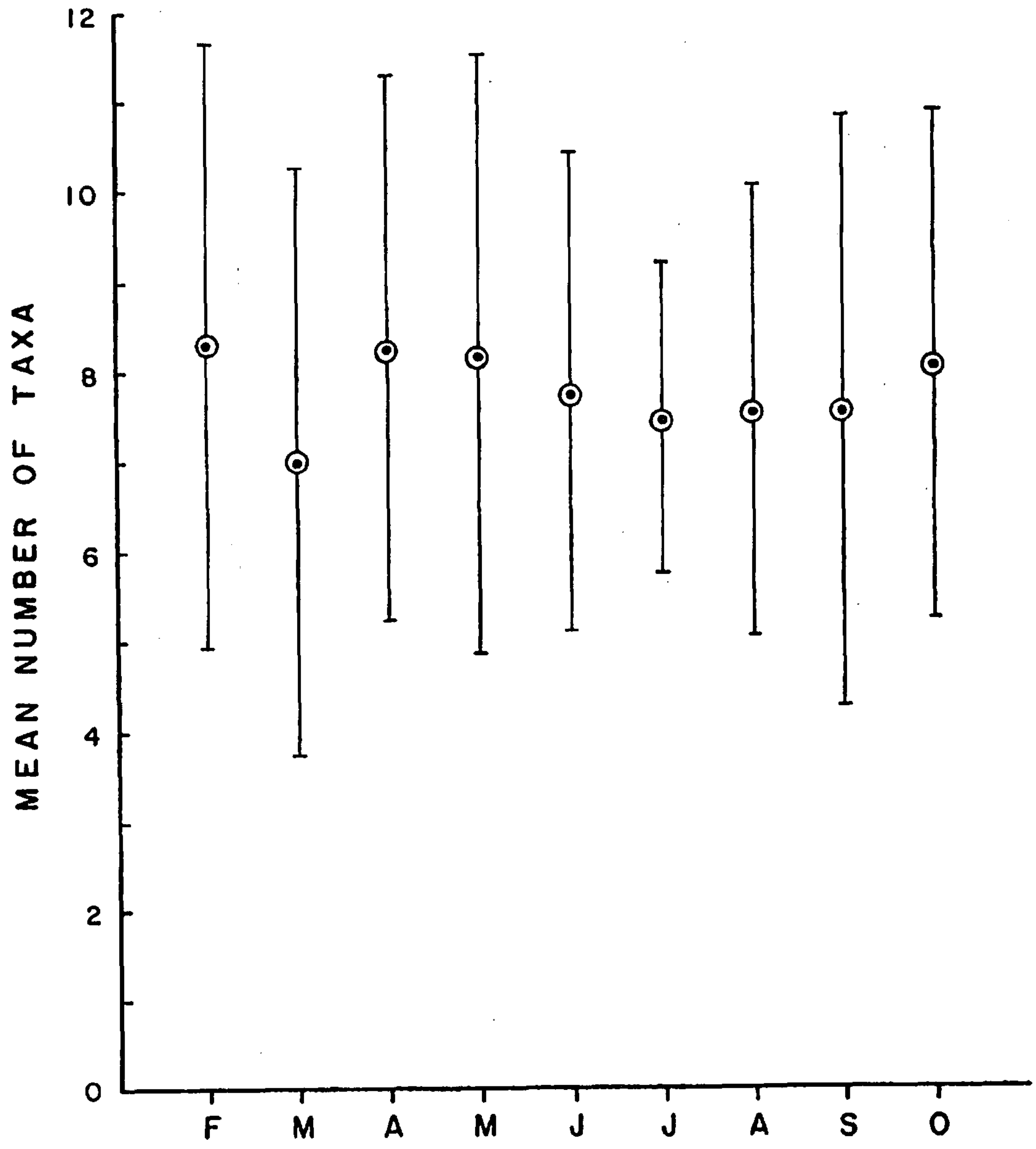


Figure 7-5. Mean Number of Taxa Collected per Month (±95% Confidence Limits), Combined over all Three Channel Stations and Eight Years of Sampling (1974-79, 1982-83). Based on Ponar Grab Samples.

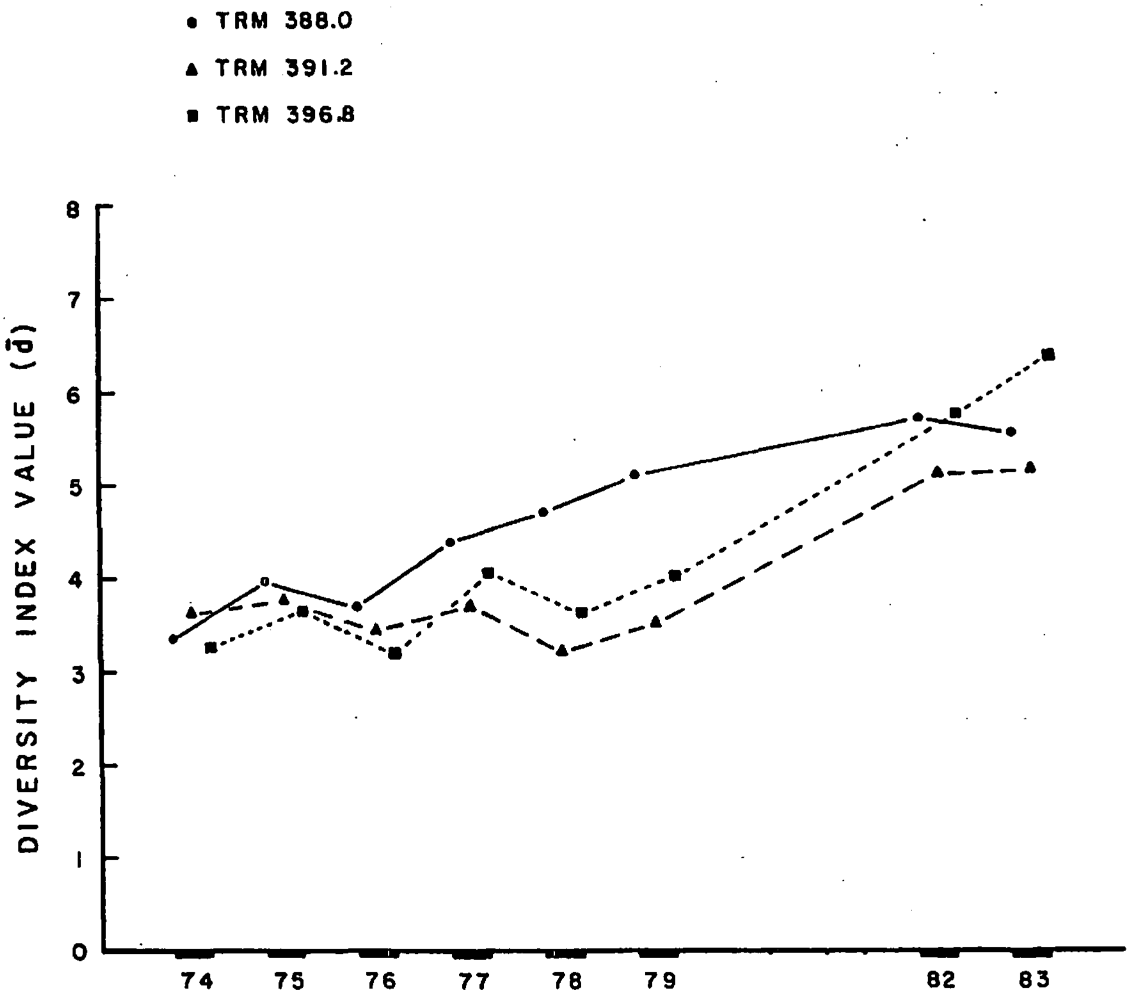


Figure 7-6. Yearly Diversity Index Values (d̄) at Three Channel Stations. Based on Ponar Grab Samples.

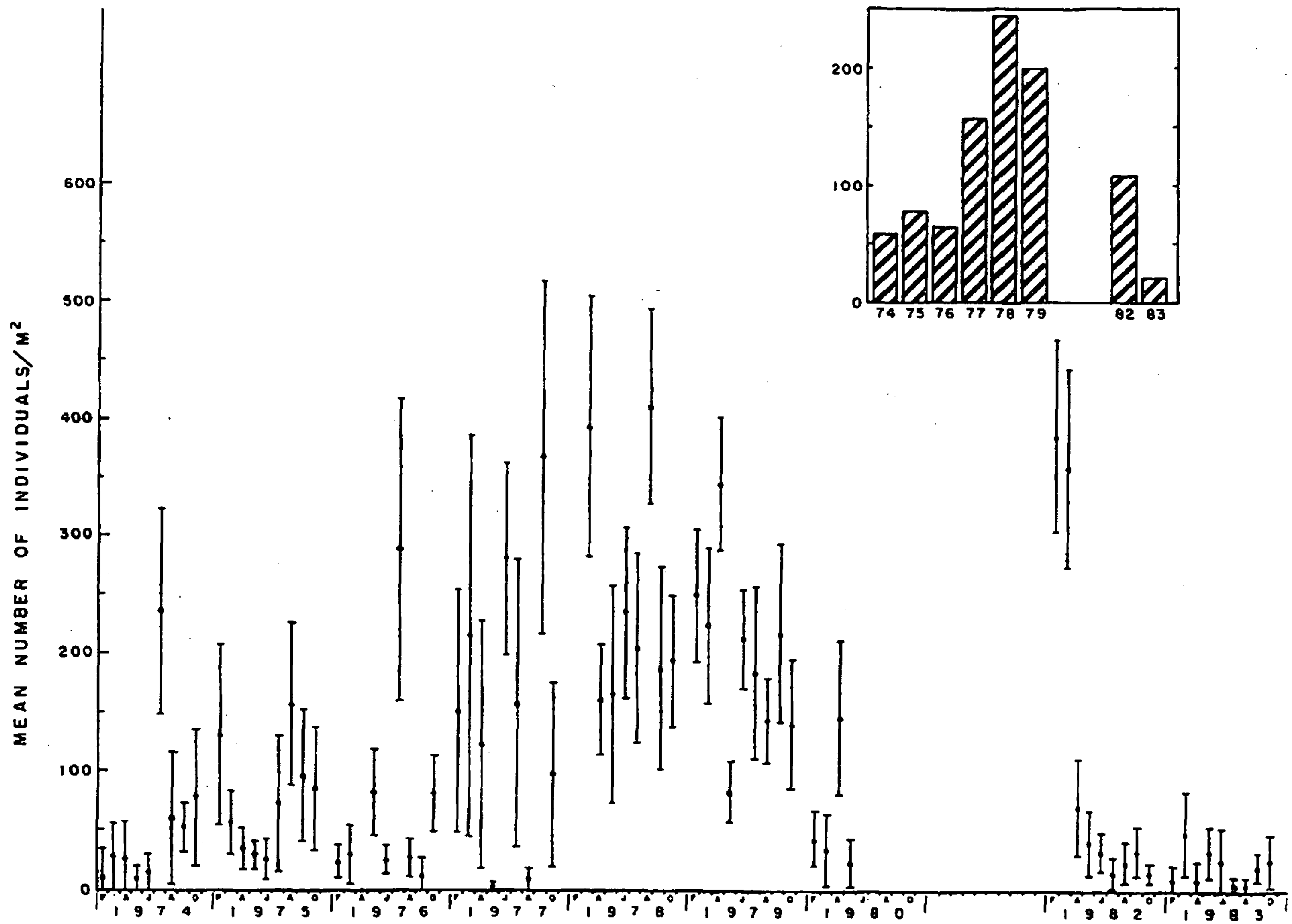


Figure 7-7. Mean Density of Corbicula manilensis at TRM 388.0 (Channel), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

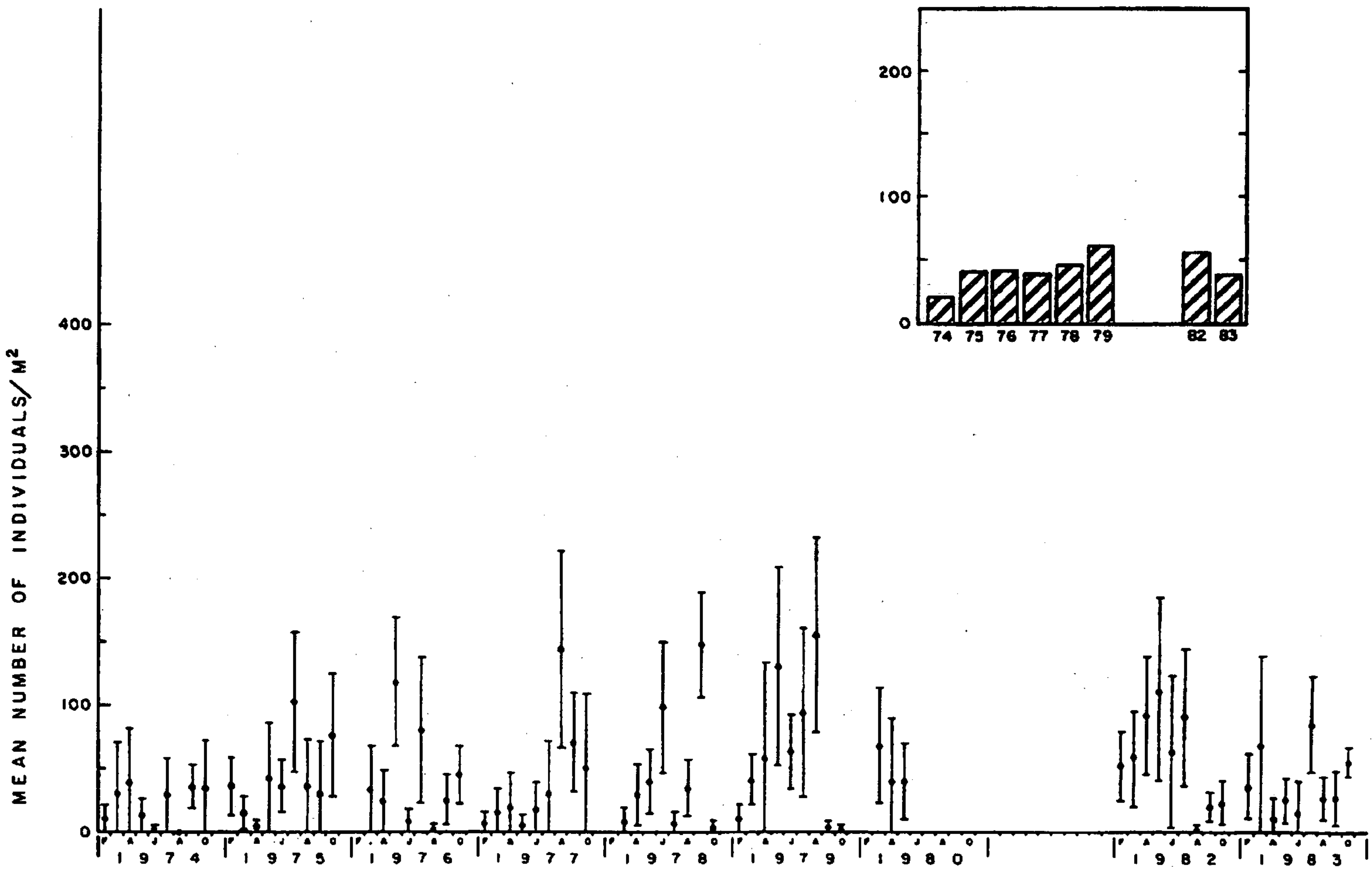


Figure 7-8. Mean Density of Corbicula manilensis at TRM 391.2 (Channel), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

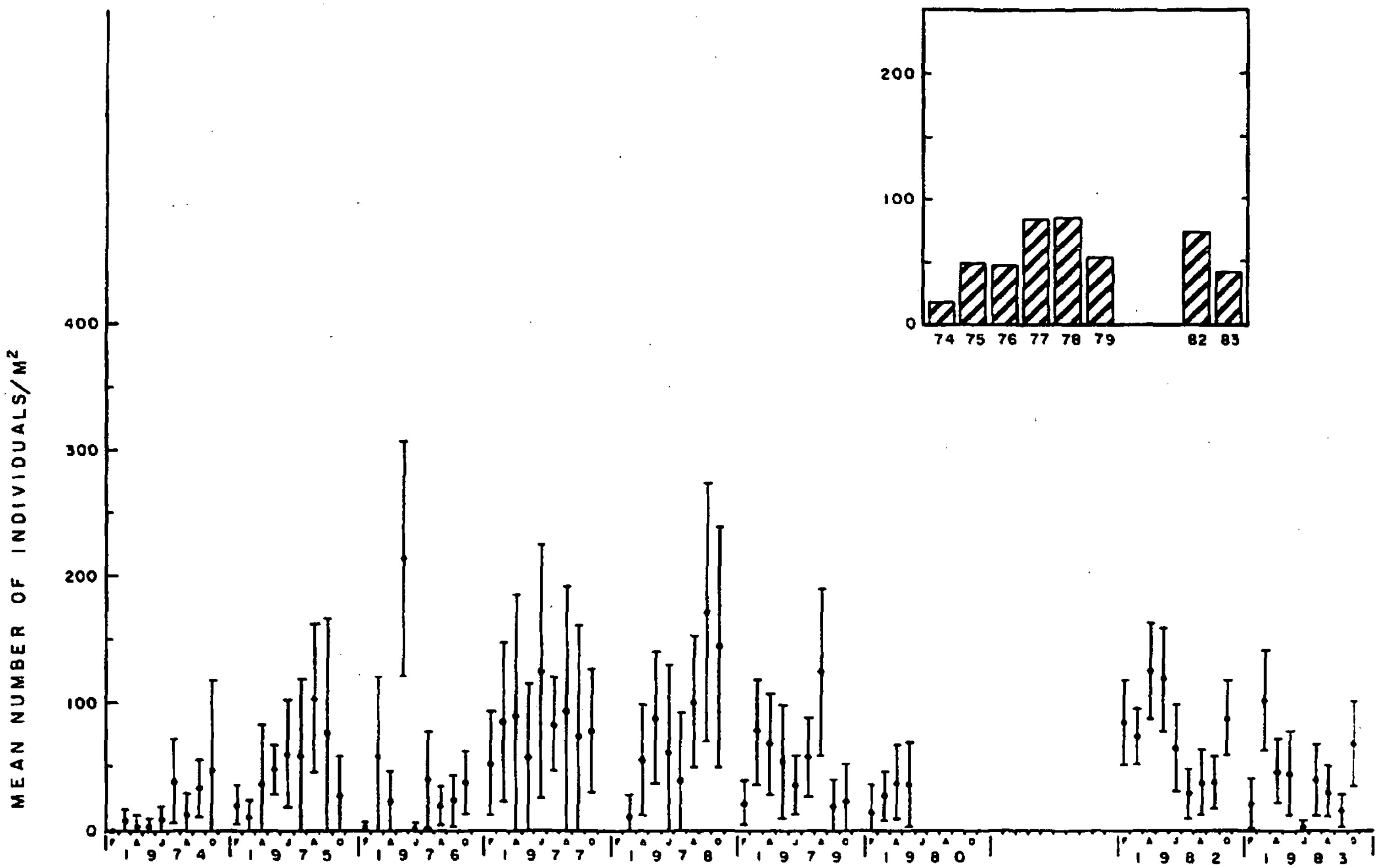


Figure 7-9. Mean Density of Corbicula manilensis at TRM 396.8 (Channel), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

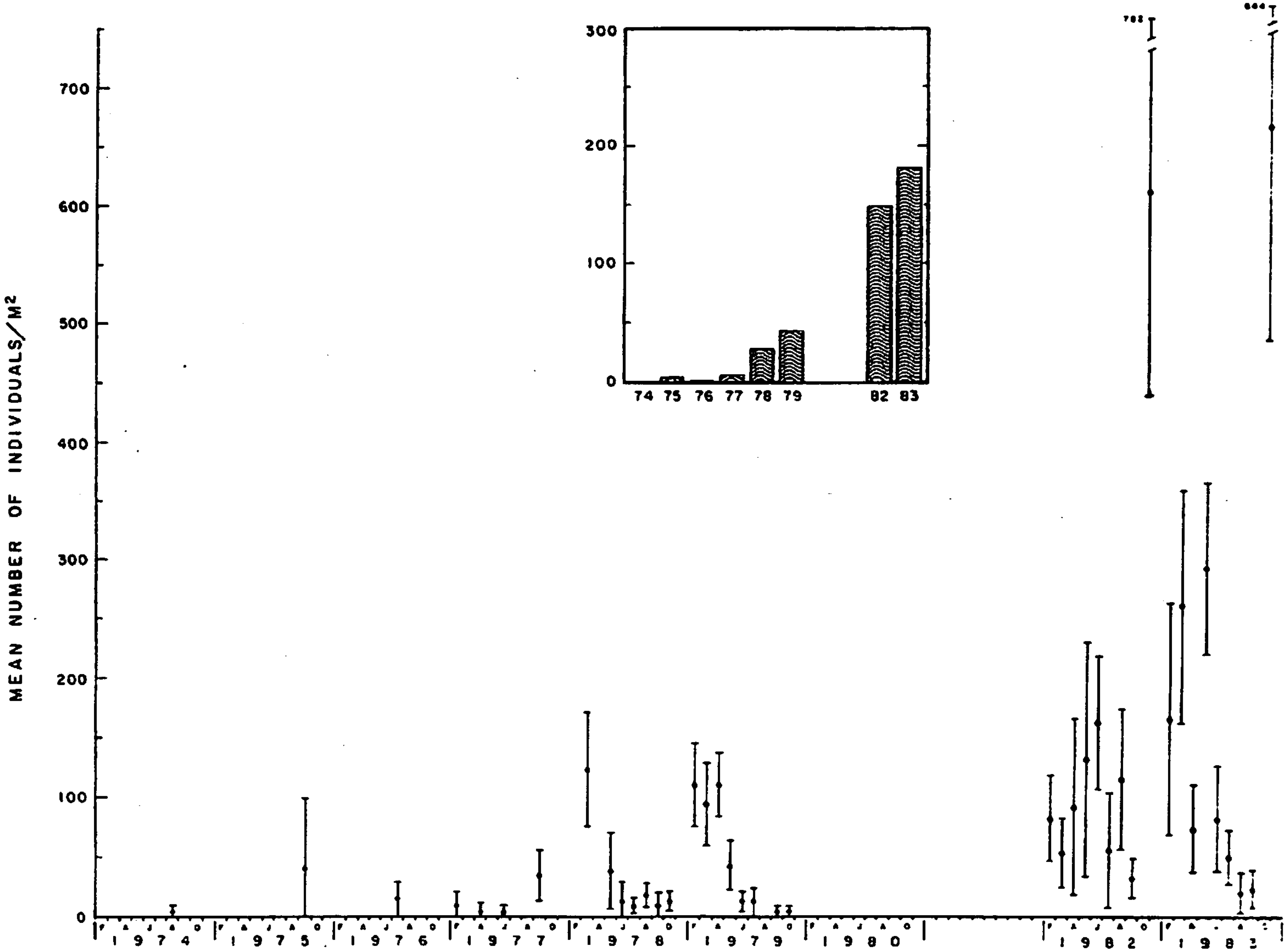


Figure 7-10. Mean Density of Hexagenia sp. at TRM 388.0 (Channel), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

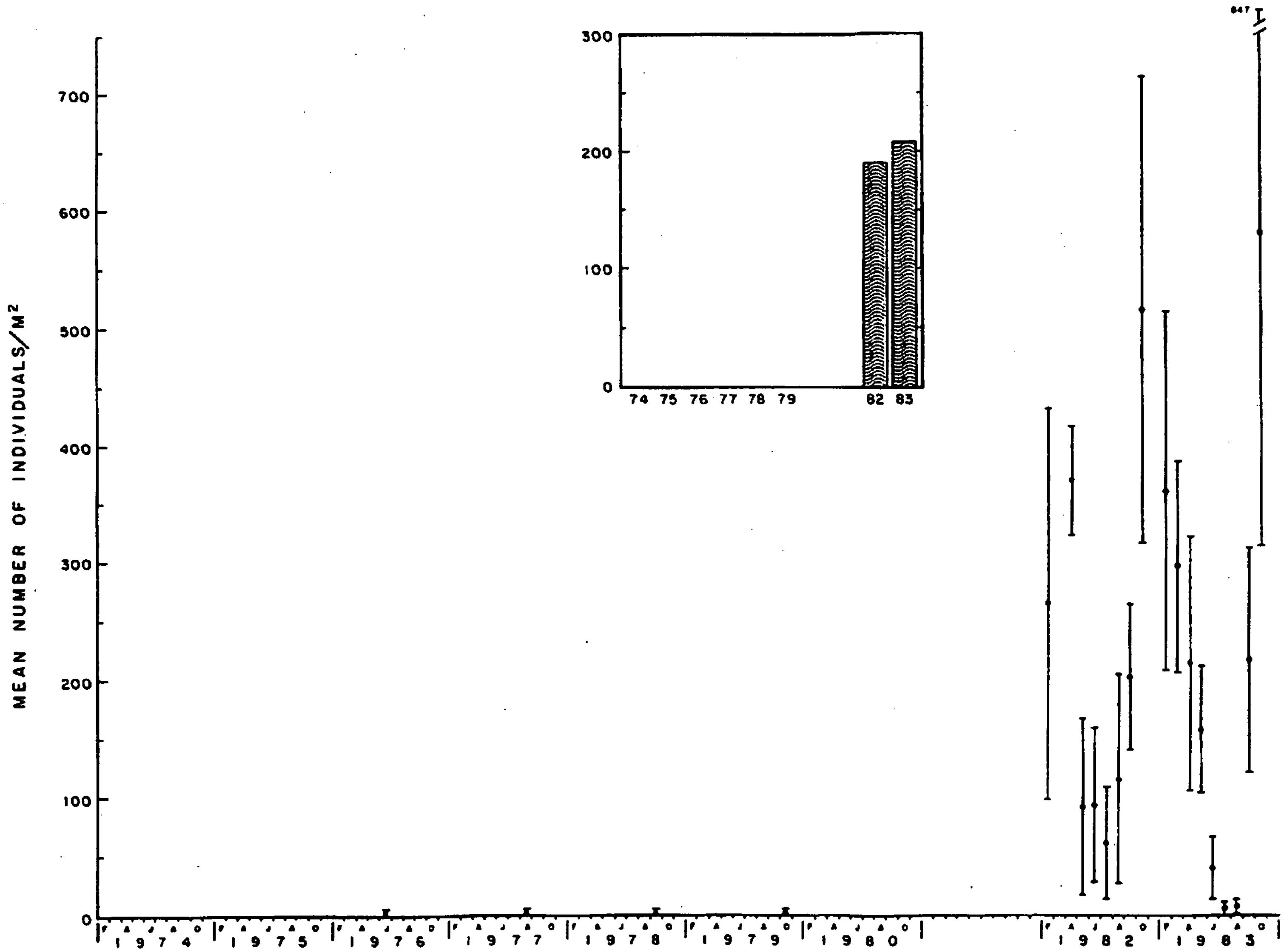


Figure 7-11. Mean Density of <u>Hexagenia</u> sp. at TRM 391.2 (Channel), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

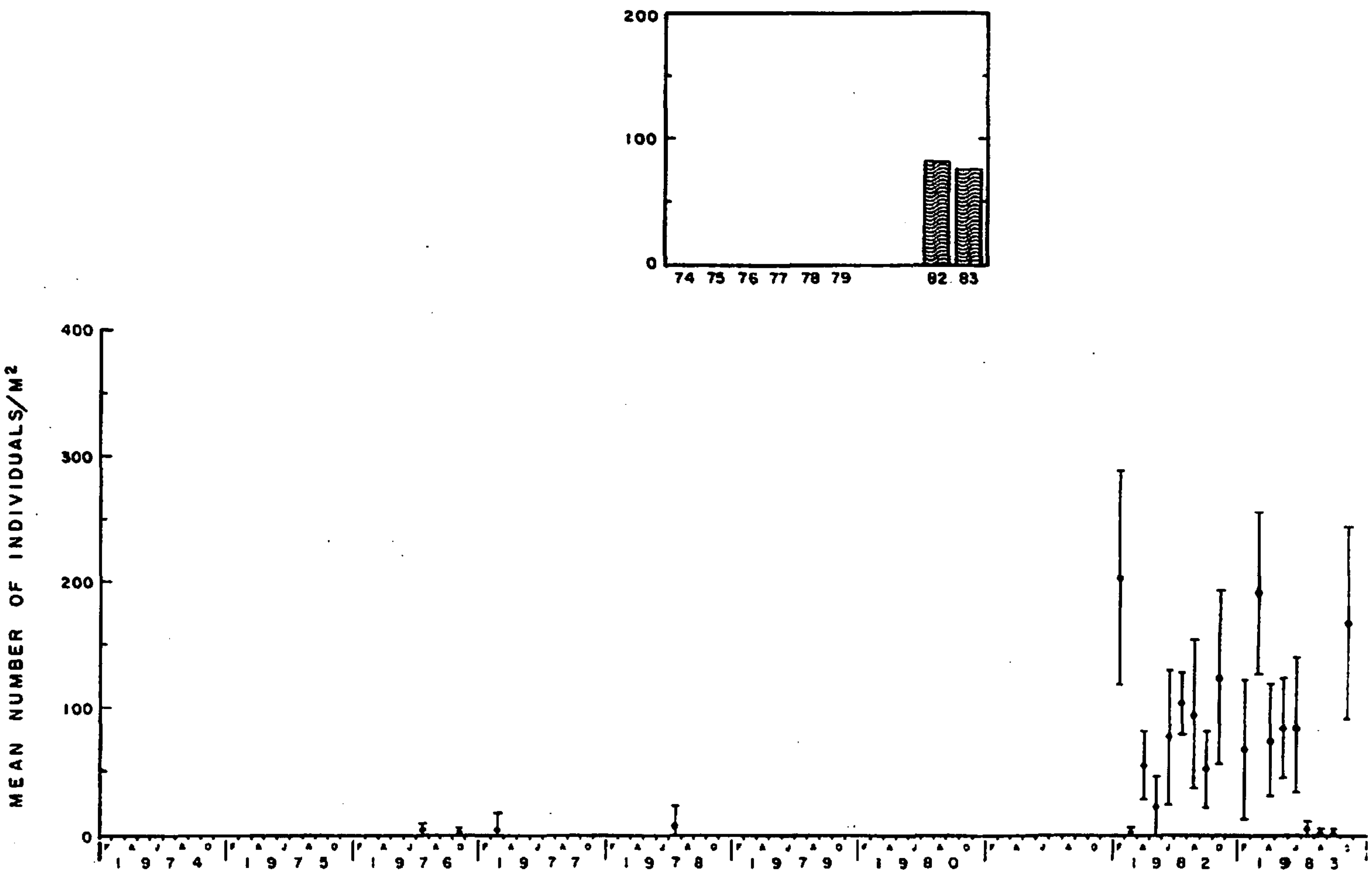


Figure 7-12. Mean Density of <u>Hexagenia</u> sp. at TRM 396.8 (Channel), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

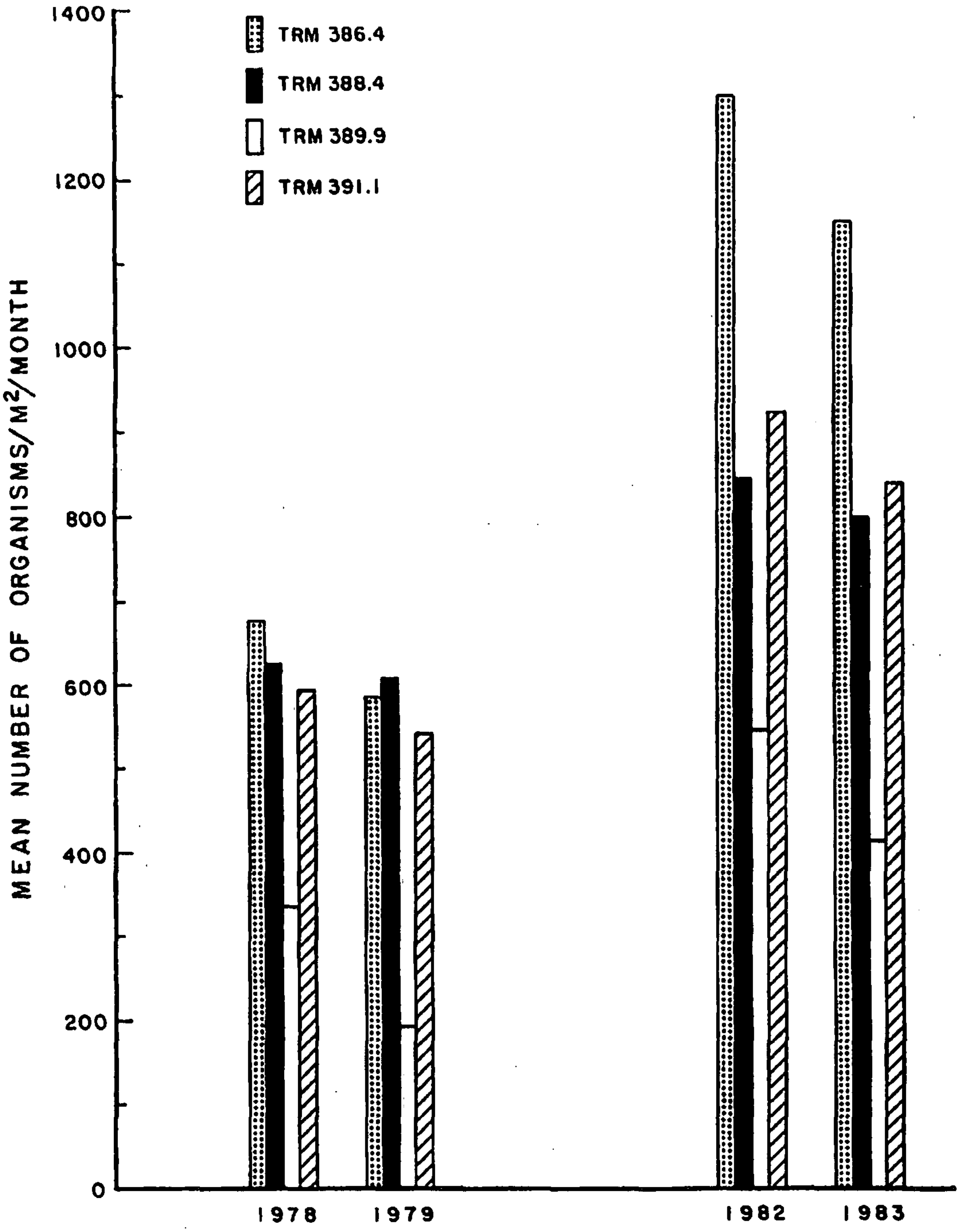


Figure 7-13. Yearly Mean Densities of Total Macroinvertebrates at Four Overbank Stations in the Vicinity of Bellefonte Nuclear Plant. Based on Ponar Grab Samples.

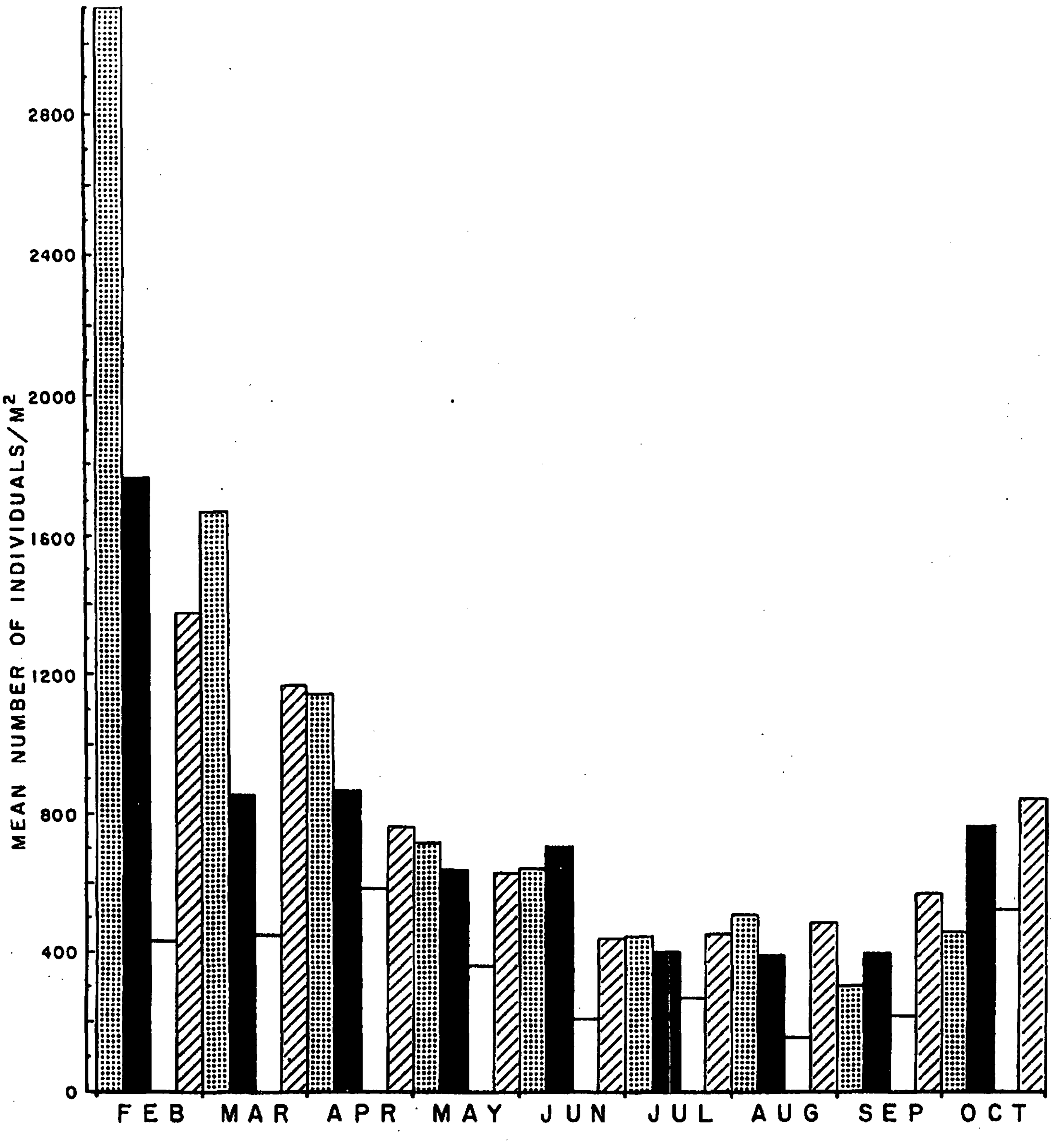


Figure 7-14. Mean Number of Macroinvertebrates/m² per Month, Years 1978-79 and 1982-83 Combined, at Four Overbank Stations. Based on Ponar Grab Samples. Legend as in Figure 7-13.

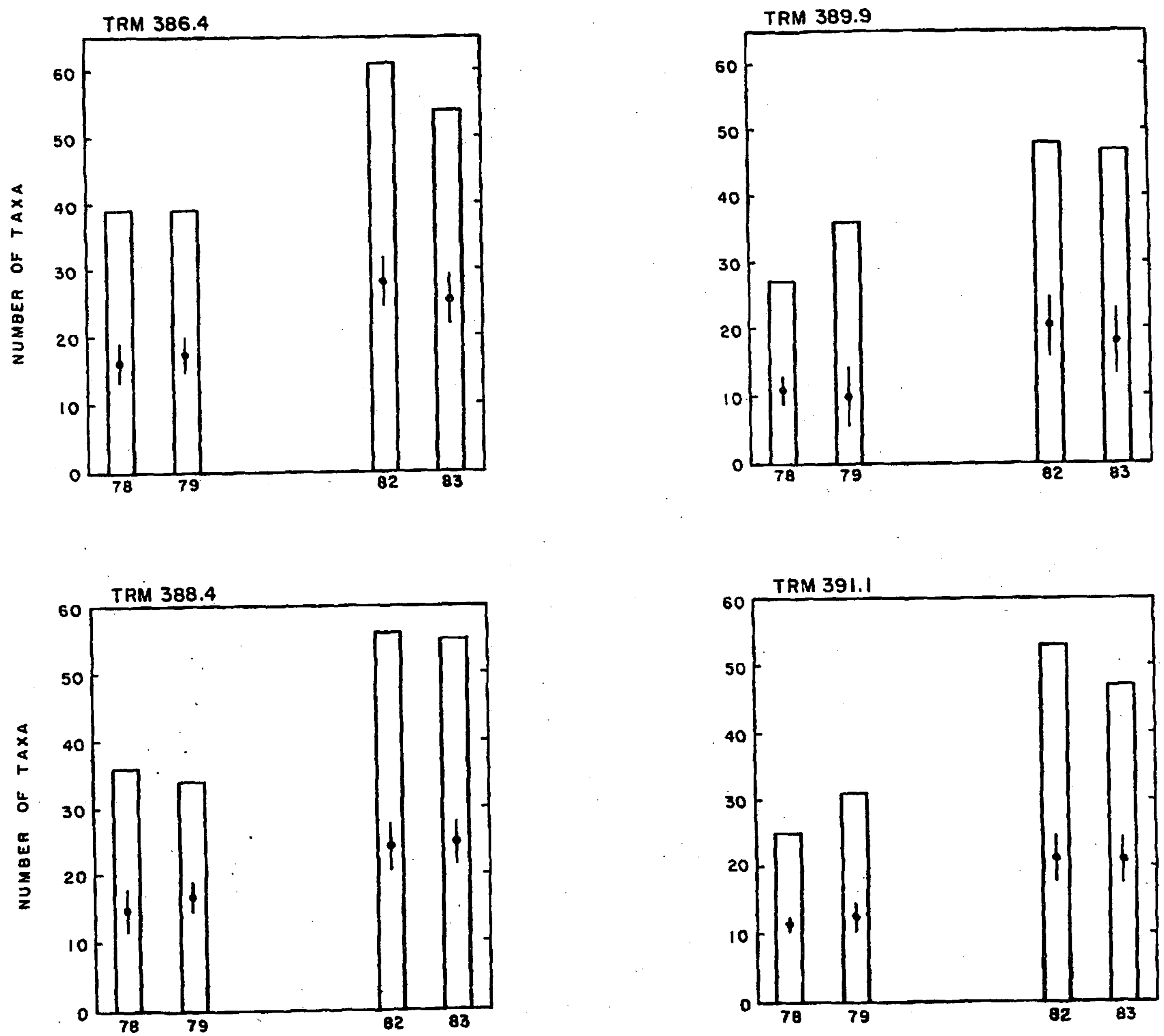


Figure 7-15. Number of Different Taxa (bars) and Mean Number of Taxa per Month (Points, ±95% Confidence Limits) Collected at Four Overbank Stations. Based on Ponar Grab Samples.

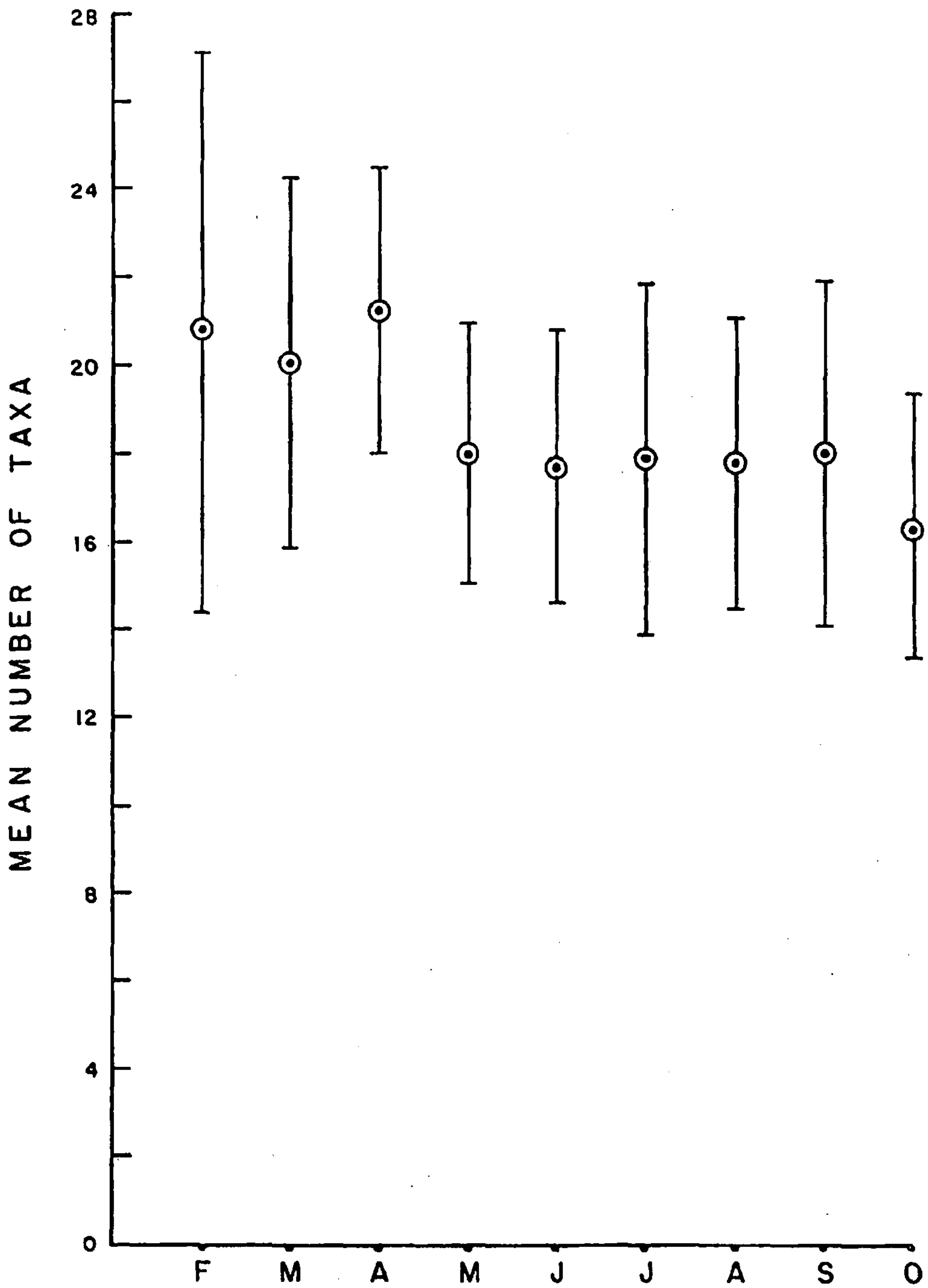


Figure 7-16. Mean Number of Taxa Collected per Month, Combined Over all Four Overbank Stations and Four Years (1978-79 and 1982-83). Based on Ponar Grab Samples.

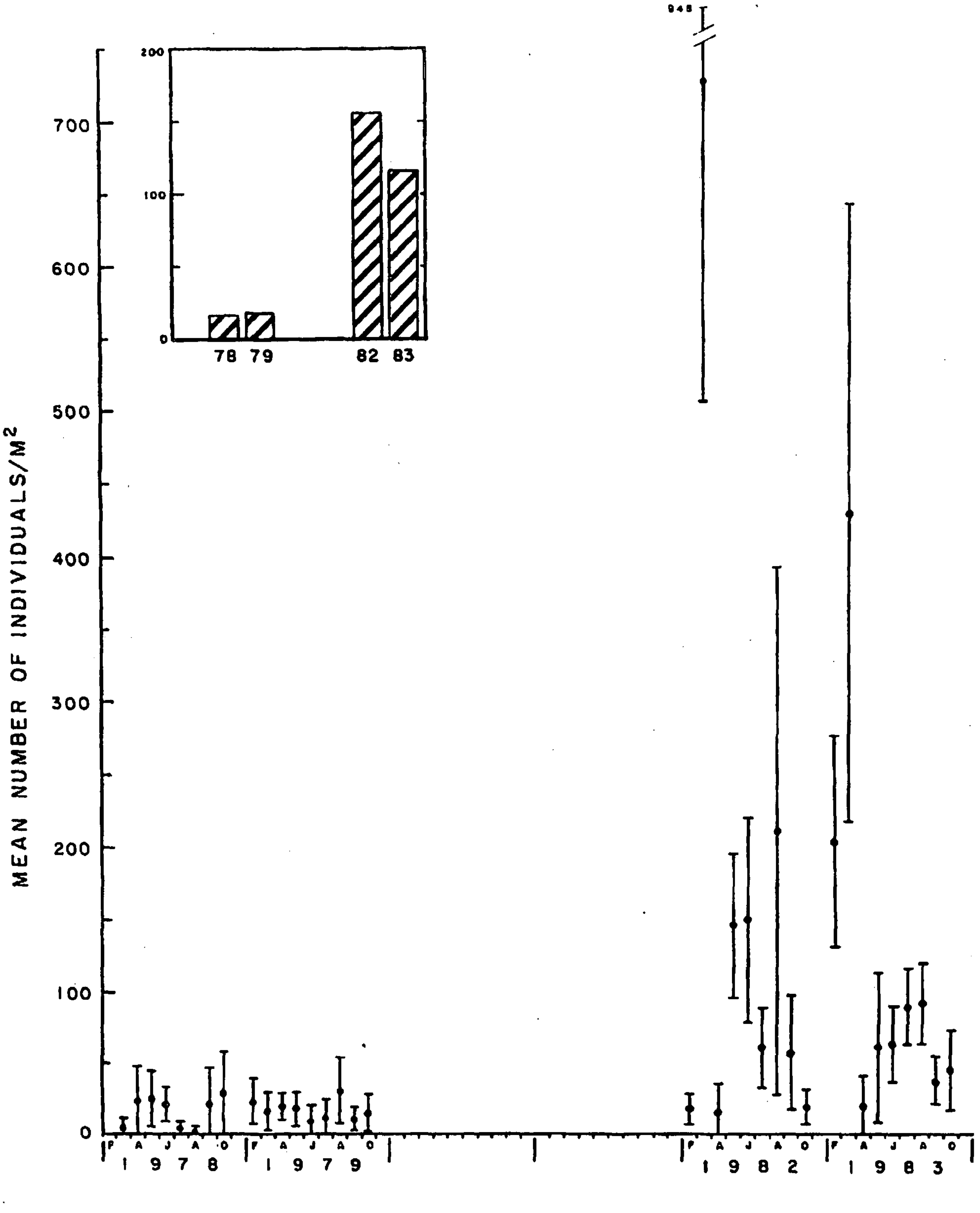


Figure 7-17. Mean Density of Corbicula manilensis at TRM 386.4 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

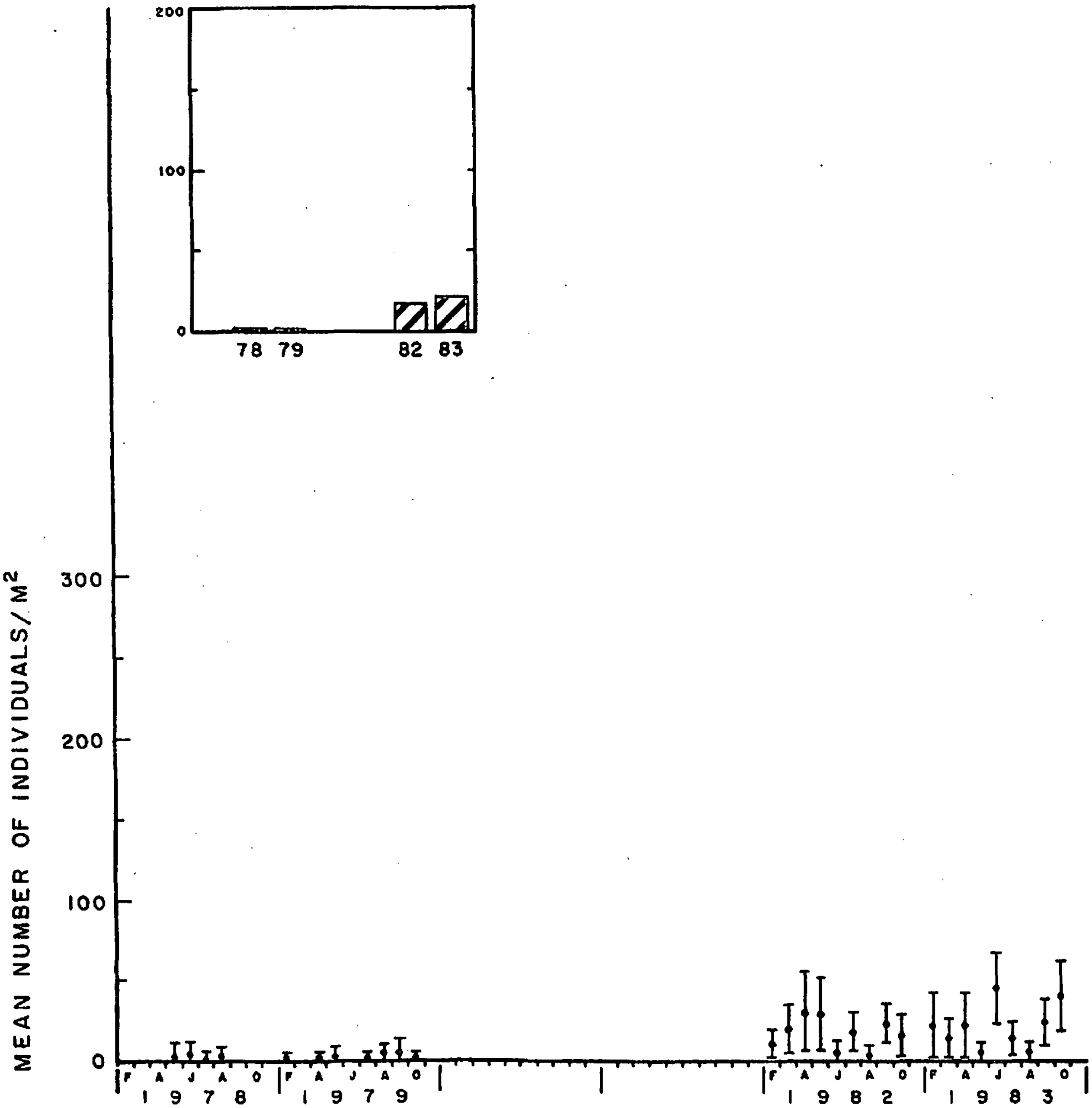


Figure 7-18. Mean Density of Corbicula manilensis at TRM 388.4 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

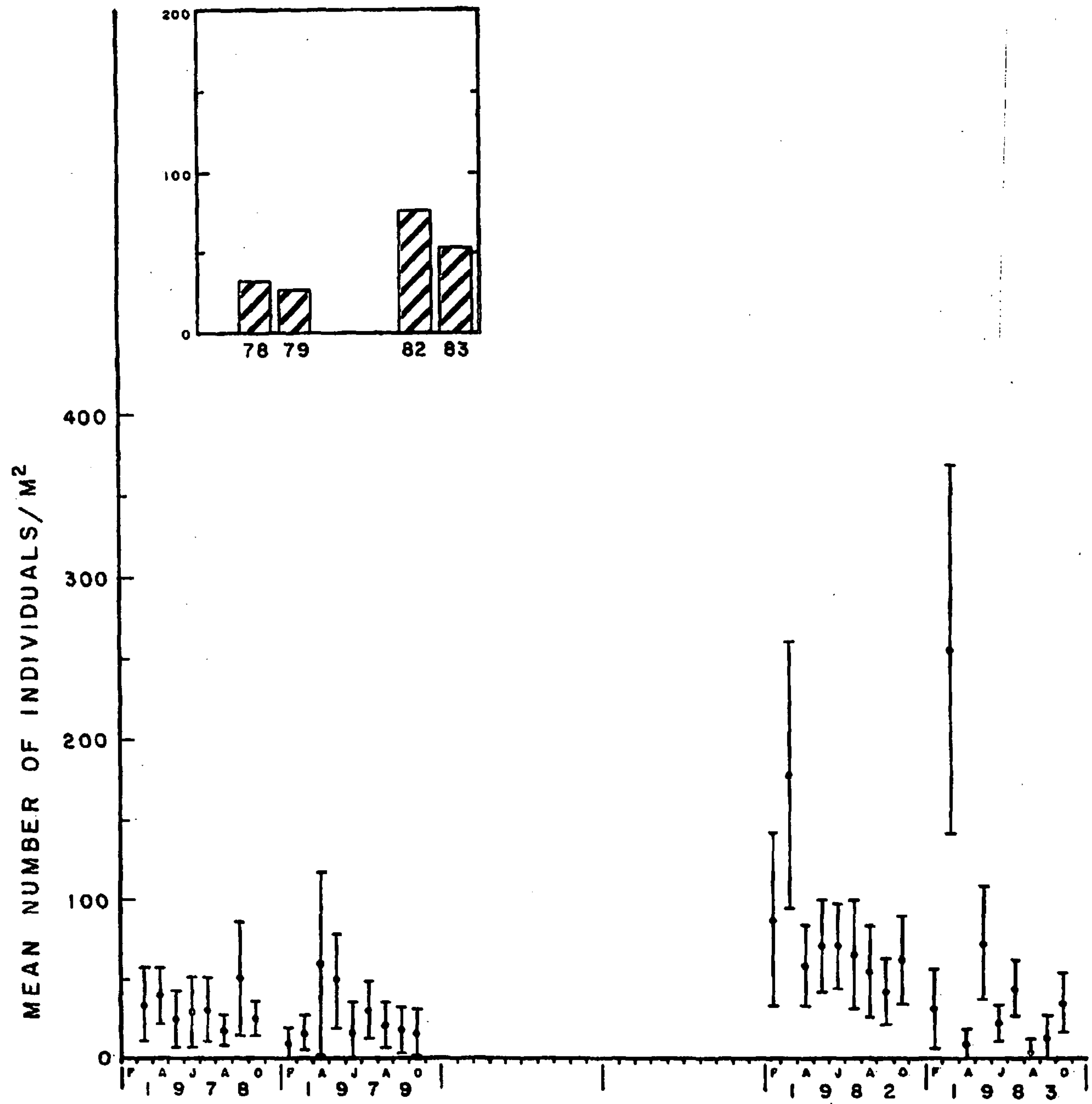


Figure 7-19. Mean Density of Corbicula manilensis at TRM 389.9 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

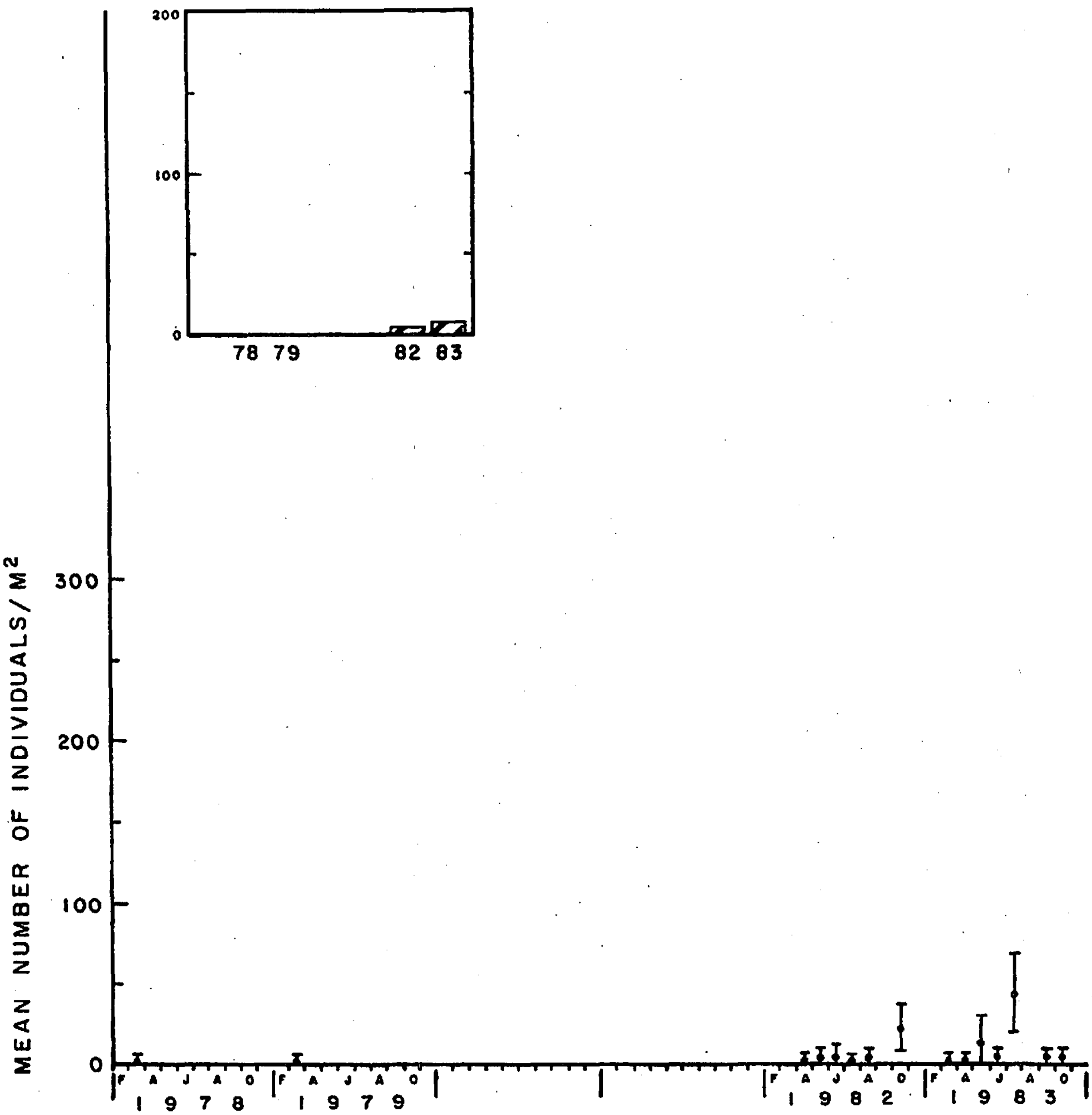


Figure 7-20. Mean Density of <u>Corbicula</u> <u>manilensis</u> at TRM 391.1 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

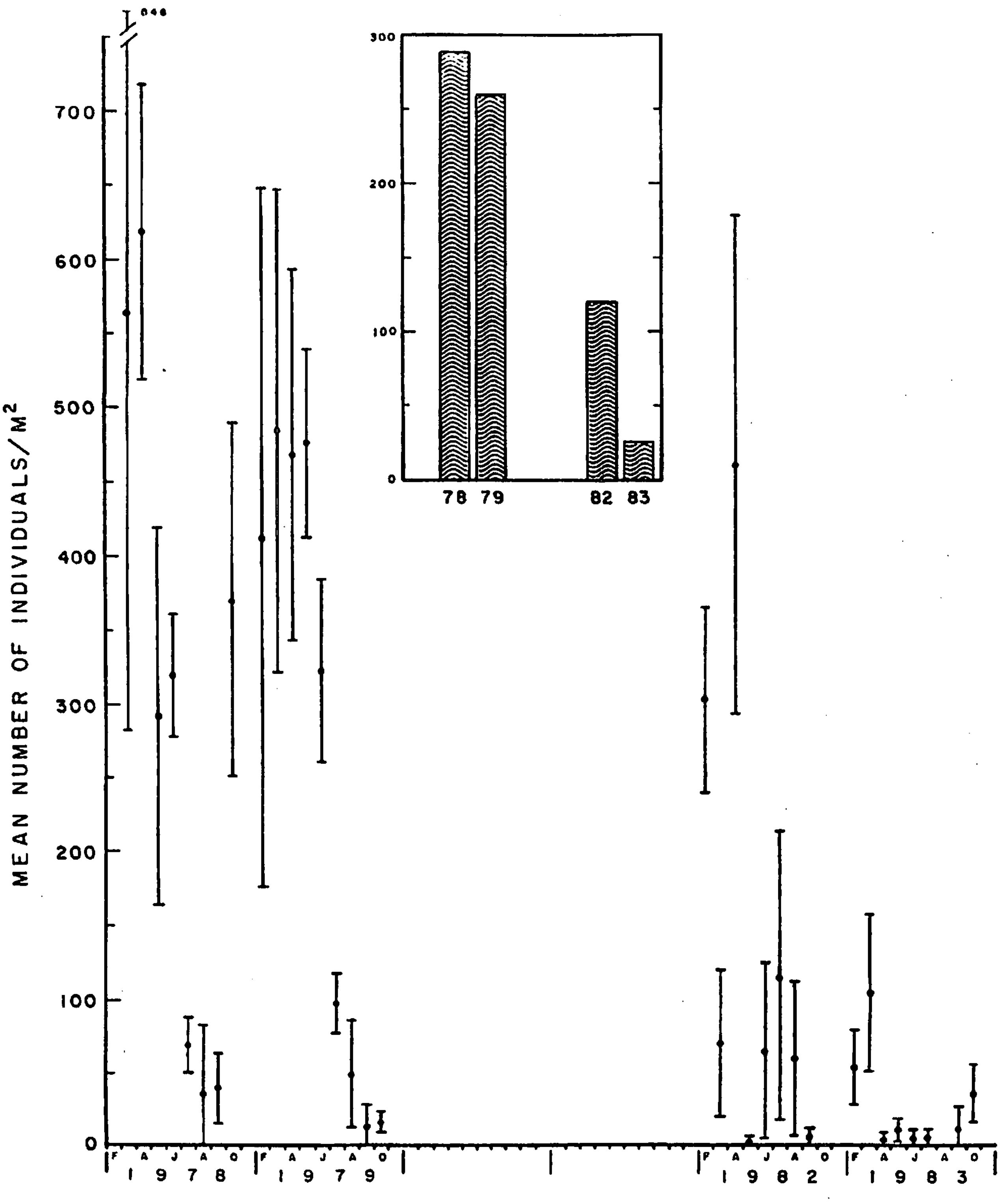


Figure 7-21. Mean Density of Hexagenia sp. at TRM 386.4 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

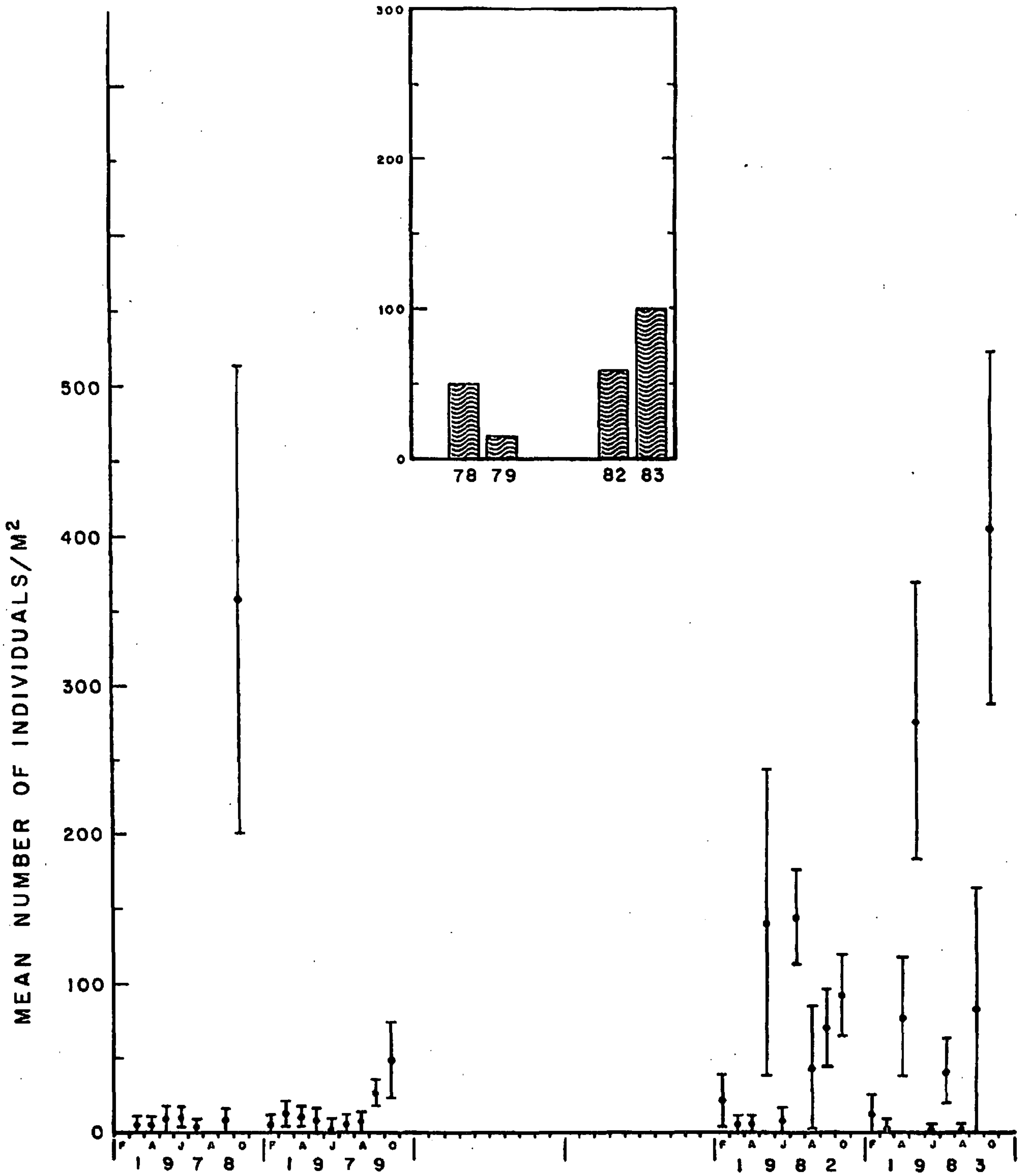


Figure 7-22. Mean Density of Hexagenia sp. at TRM 388.4 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

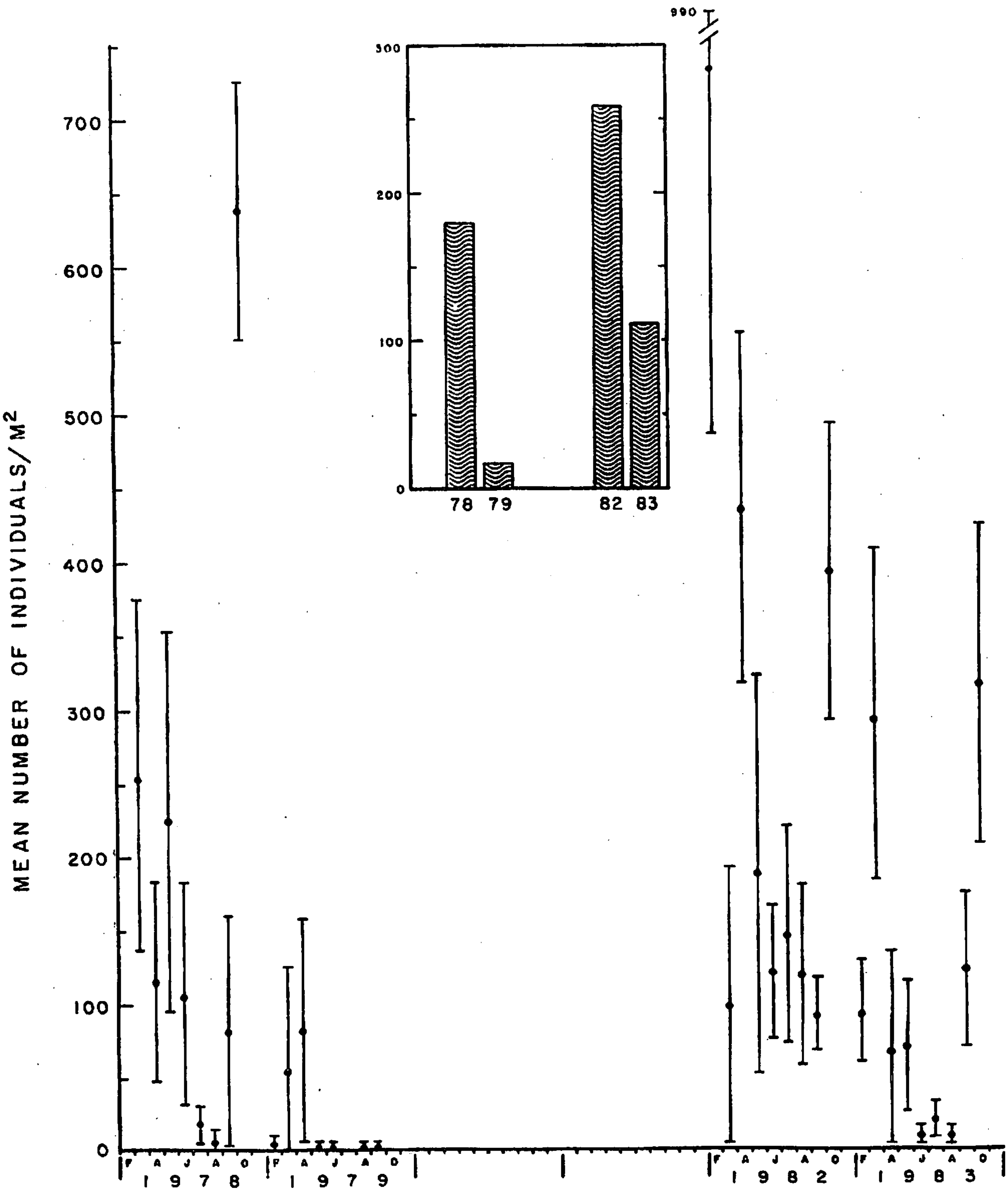


Figure 7-23. Mean Density of Hexagenia sp. at TRM 389.9 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

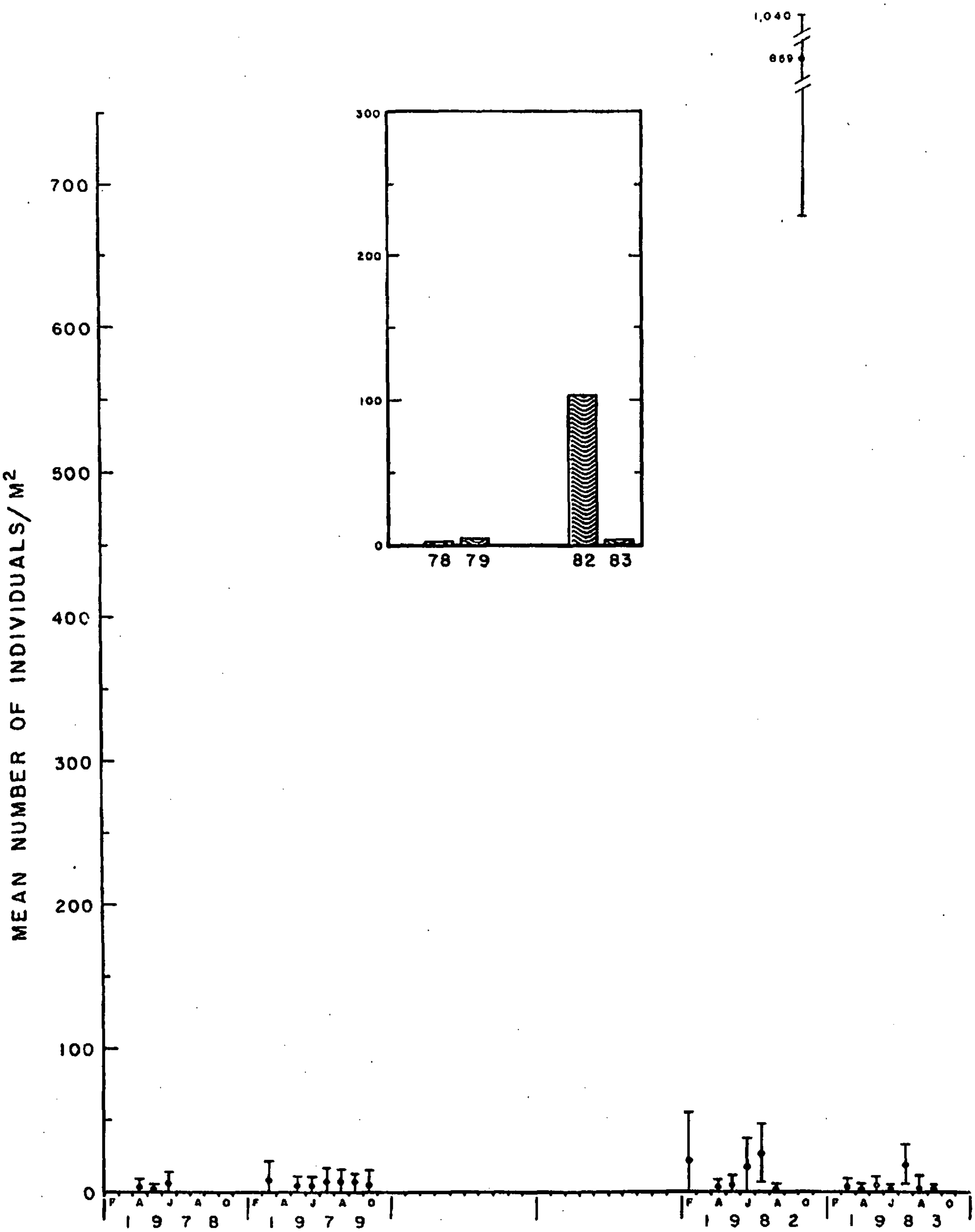


Figure 7-24. Mean Density of <u>Hexagenia</u> sp. at TRM 391.1 (Overbank), ±95% Confidence Limits. INSET: Yearly Mean Density. Based on Ponar Grab Samples.

8.0 Aquatic Macrophytes

8.1 Materials and Methods

Aerial Photography--Large scale color aerial photography (1" = 600') was used to determine acreages of aquatic macrophytes from 1978 to 1983 in an area upstream (TRM 395.0 to 397.0 including Raccoon Creek) and an area downstream (TRM 391.5 to TRM 385.8 including Jones Creek) of BLN. Overflights were conducted during the latter portion of the growing season in August, September, or early October. Interpretation of the imagery was aided by ground truthing done at the approximate time of the overflights. Submersed and floating-leaved communities and one emergent macrophyte community (American lotus) were delineated on aerial photographs and acreages determined using an electronic planimeter. Acreages of aquatic macrophytes for Guntersville Reservoir were obtained from seasonal workplans of the aquatic plant management program (Goldsby *et al*. 1979; Burns *et al*. 1984).

Standing Crop--Standing crop (above ground biomass) of aquatic macrophytes was monitored at eight sampling stations (figure 8-1, table 8-1). Stations 1, 2, 5, and 6 were sampled from 1974-1979 and from 1982-1983. Stations 7 and 8 were added in March 1978 and sampled during 1978-1979 and 1982-1983, while stations 3 and 4 were sampled only during 1982-1983. Addition of the latter four stations was due to modification in BLN design and the onset of preoperational monitoring activities. The sampling stations represented two primary littoral habitats--shallow overbank and steep shoreline main channel habitats. The mainstream or channel littoral habitats were represented by stations 1, 3, 5, and 7, while the shallow overbank habitat included stations 2, 4, 6, and 8 (table 8-1).

The sampling frequency at all stations from 1974 to 1979 was at approximate two month intervals. During 1982 and 1983 sampling was conducted during January, and in 1982 monthly from May to September. High flows during the late spring of 1983 delayed sampling, resulting in a monthly sampling period from early June to October.

Samples were collected by removing standing crop of all macrophytes rooted in 0.1 m^2 quadrats. Five 0.1 m^2 quadrats were sampled at each 1.5-foot contour interval along a belt transect oriented perpendicular to reservoir bottom contours. In a few instances, samples collected during the early portion of 1974 were at 1.0-foot contour intervals. Sampling contours began at the shallow edge of the macrophyte colony near the shoreline and extended to the deepwater edge, where macrophyte growth was limited by light penetration or flow. When required, sampling at the deeper water depths was aided by divers using scuba.

Samples were separated by species in the laboratory and washed to remove foreign debris. Samples were then oven dried and ashed in a muffle furnace to determine ash-free dry weight.

Data Analysis--Mean standing crop, expressed in g/m^2 ash-free dry weight was calculated for each station by total and by species, and plotted graphically for each station over time.

A two-way Analysis of Variance (ANOVA) was used (SAS 1982) to examine standing crop differences for months and stations in 1982 and

1983. Data collected from 1974 to 1979 was not utilized because of the different sampling frequency. When interaction was significant, a one-way ANOVA was run separately for stations and months. Stations and months were then ranked ($\alpha = 0.05$) using Duncan's New Multiple Range Test (SAS 1982).

Long range trends at stations 1, 2, 5, 6, 7, and 8 were examined using regression analysis (Snedecor and Cochran 1967). Stations 3 and 4 were not included due to the short term (1982-1983) duration of data acquisition. Standing crop data from stations 1 and 2 were pooled to determine trends for macrophytes upstream of BNP and stations 3 through 8 pooled to determine downstream trends.

8.2 Results and Discussion

Acreages of aquatic macrophytes on Guntersville Reservoir exceed those of any other reservoir within the TVA system (Burns et al. 1984). Reservoir morphometry characterized by broad shallow overbanks and a limited amplitude of water level fluctuation are conducive to submersed macrophyte growth. From an aquatic plant management perspective, aquatic macrophyte growth on Guntersville Reservoir can be described as excessive. In addition to causing reservoir use conflicts in some areas, macrophytes likely have significant impacts on other biological communities as well as overall water quality of the reservoir.

Aerial Photography--Aquatic macrophyte communities on Guntersville Reservoir extend approximately to the 587 foot contour if substrate and flow do not inhibit establishment and growth. The major submersed and floating-leaved aquatic macrophyte communities in 1983 upstream and downstream of BNP are shown in figures 8-2 and 8-3. Also included is American lotus (Nelumbo lutea (Willd.) Pers.), an emergent species, readily identifiable on aerial photography.

Aquatic macrophyte acreages in the area upstream of the BLN site (TRM 395.0 to 397.0 including Raccoon Creek) and the area downstream of BLN (TRM 358.8 to 391.5 including Jones Creek) showed increases from the late 1970's until 1981 or 1982 and declines in 1983 (table 8-2). This trend paralleled that for all of Guntersville Reservoir (table 8-2) during the same time period when aquatic macrophyte acreages doubled on the reservoir. The decline in 1983 is thought to be partially related to high flows during mid-May 1983.

A summary of acreages by species (table 8-3) from 1978 to 1983 showed Eurasian watermilfoil (Myriophyllum spicatum L.) to be the dominant submersed aquatic macrophyte. This has been the case since the late 1960's when Eurasian watermilfoil inhabited approximately 22,000 acres within the TVA system. In addition to Eurasian watermilfoil, several other submersed and floating-leaved aquatic macrophytes such as spinyleaf naiad (Najas minor All.), southern naiad (N. quadalupensis (Spreng.) Magnus), American pondweed (Potamogeton nodosus Poir.), Brazilian elodea (Egeria densa Planch.), coontail (Ceratophyllum demersum L.), and muskgrass (Chara sp.) occurred as mixtures with milfoil or less frequently in seperate colonies. Hydrilla (Hydrilla verticillata (L.f) Royle), a particularly noxious weed, was discovered in Guntersville Reservoir in 1982 and several colonies occurred just downstream of BLN. This species is expected to spread and will likely be one of the dominant submersed macrophyte species in the Tennessee Valley within the next decade.

Substantial increases of American lotus occurred in the downstream area from 1978 to 1983. In several shallow overbank areas this emergent species replaced submersed macrophytes such as watermilfoil. No attempts have been made to control lotus with herbicides, and the species is expected to increase in acreage unless naturalistic controls limit its expansion.

Standing Crop--Annual growth curves for submersed aquatic macrophytes at the eight sampling stations (figures 8-4 through 8-11) showed Eurasian watermilfoil comprised the highest percentage of the total standing crop at all sampling stations. Several other species such as C. demersum, E. densa, H. verticillata, Potamogeton crispus L., P. nodosus, N. minor, N. quadalupensis, Vallisneria americana Michx., and unidentified species occurred at several sampling stations, but generally comprised a small percentage of total standing crop.

Peak standing crop generally occurred during the summer or early fall months and declined during winter months. Maximum standing crop occassionally exceeded 150 g/m^2 ash-free dry weight with a maximum of 253 g/m^2 at Station 4 in June 1982.

A two-way Analysis of Variance comparing standing crop by date and station showed highly significant interaction for 1982 and 1983 (table 8-4). Since interaction was highly significant during both years, a one-way analysis was run by month (table 8-5) and by sampling station (table 8-6) for each year and ranked (α = 0.05) using Duncan's New Multiple Range Test.

Differences in standing crop by month, with one exception in each 1982 (station 8) and 1983 (station 4), were highly significant; differences at Station 8 in 1982 and Station 4 in 1983 were significant (table 8-5). Significant differences between months were expected as standing crop increased from a "normal" low during the winter months to maximum standing crop during the summer or early fall months. In 1982, July generally had the highest standing crop and January the lowest for most stations (table 8-5). In 1983, the highest standing crop occurred most commonly in October and the lowest generally during the early June sampling date. The observed differences in 1982 and 1983 were attributed to high flows in mid-May of 1983 that reduced the standing crop of macrophyte communities. Instead of the July peak that was observed in 1982, the 1983 peak in standing crop was delayed until October due to the lag time required for regrowth from rootcrowns.

Differences in standing crop by station in 1982 were significant in August and highly significant in May, June and July. In 1983 significant differences occurred in early June (6th), late June (29th), July, and October, with January being highly significant (table 8-6). While some stations (e.g. 1, 4, 7) consistently ranked high and others low (e.g. 3, 6, 8), there were no readily discernable trends relating to overbank (stations 2, 4, 6, 8) versus channel stations (1, 3, 5, 7). The low rank of station 6 during the later portion of 1982 and during 1983, may have been the result of herbicide treatments for hydrilla control.

An examination of long range trends determined from regression analysis (figures 8-12 through 8-17) showed significant changes at stations 5 and 7 and a highly significant change at station 1 (table 8-7). Although significant at $\alpha = 0.05$, changes at stations 5 and 7 likely were not meaningful because of the low R-squared values (< 0.20). All three stations showing significant or highly significant changes were channel stations, but the trends were not parallel. Stations 1 and 7 had significant increases in standing crop, while station 5 had a significant decrease (figures 8-12, 8-14, and 8-16). Although not significant (table 8-7), the changes in overbank stations (2, 6, and 8) also were variable with a decrease at stations 2 and 6 and an increase at station 8 (figures 8-13, 8-15, and 8-17). Significant changes in the channel stations 1 and 7 may be related to colonization of unoccupied habitat.

Pooled data from the two stations (1 and 2) upstream of BLN compared with pooled data from downstream stations (3, 4, 5, 6, 7, and 8), showed a significant increase for upstream stations, while downstream stations did not show a significant trend (table 8-7; figure 8-18, 8-19). Increase upstream of BLN resulted from the colonization by macrophytes at station 1. A major difference in upstream and downstream areas occurred in 1983, when standing crop downstream, for some unknown reason, was depressed (figure 8-19).

8.3 Summary and Conclusions

Acreages of submersed and floating-leaved aquatic macrophytes in the vicinity of BLN increased from the late 1970's until 1981 or 1982, then declined in 1983. This trend parallels that for Guntersville Reservoir. While several species of submersed macrophytes occurred in the vicinity of BLN, Eurasian watermilfoil was the dominant submersed macrophyte species.

Eurasian watermilfoil comprised the largest percentage of submersed macrophyte standing crop for most sampling dates. Regression analysis indicated significant or highly significant trends at three sampling stations. Although all three of the stations represent channel habitat, the trends were not consistent as two increased and the other decreased. Pooled data from the two stations upstream of BLN showed a significant increase in standing crop, while pooled data from downstream stations was not significant.

Analysis of variance showed significant or highly significant differences in standing crop for all months during 1982 and 1983. The month with the highest and lowest standing crop differed in 1982 and 1983 and is attributed to the effect of high flows in mid-May 1983. Differences in standing crop by station for 1982 and 1983 were generally significant or highly significant. While some stations consistently ranked high and others low, there was no readily discernable trend relating to overbank versus channel stations.

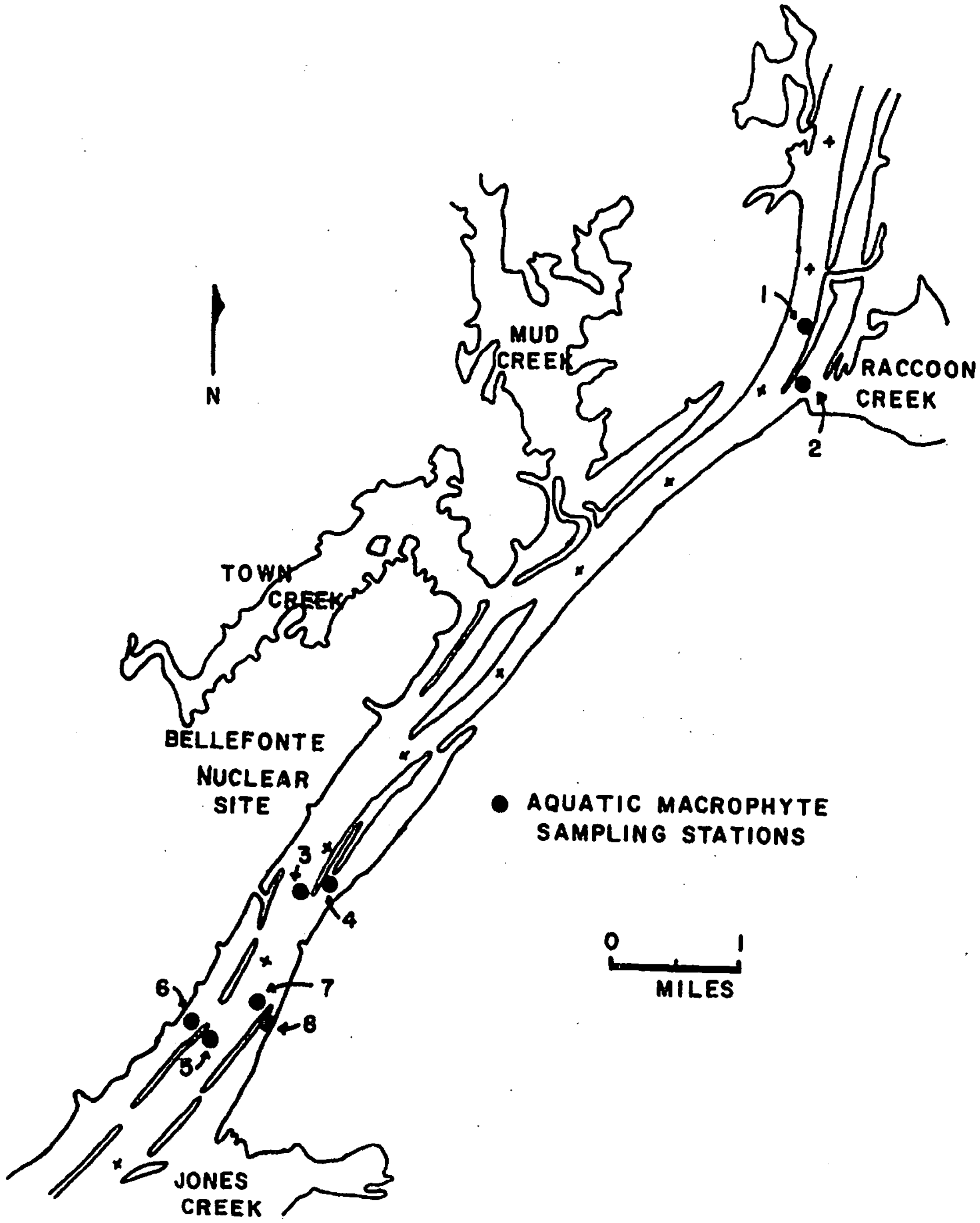


Figure 8-1. Sampling Stations for Aquatic Macrophytes in the Vicinity of Bellefonte Nuclear Plant, Guntersville Reservoir.

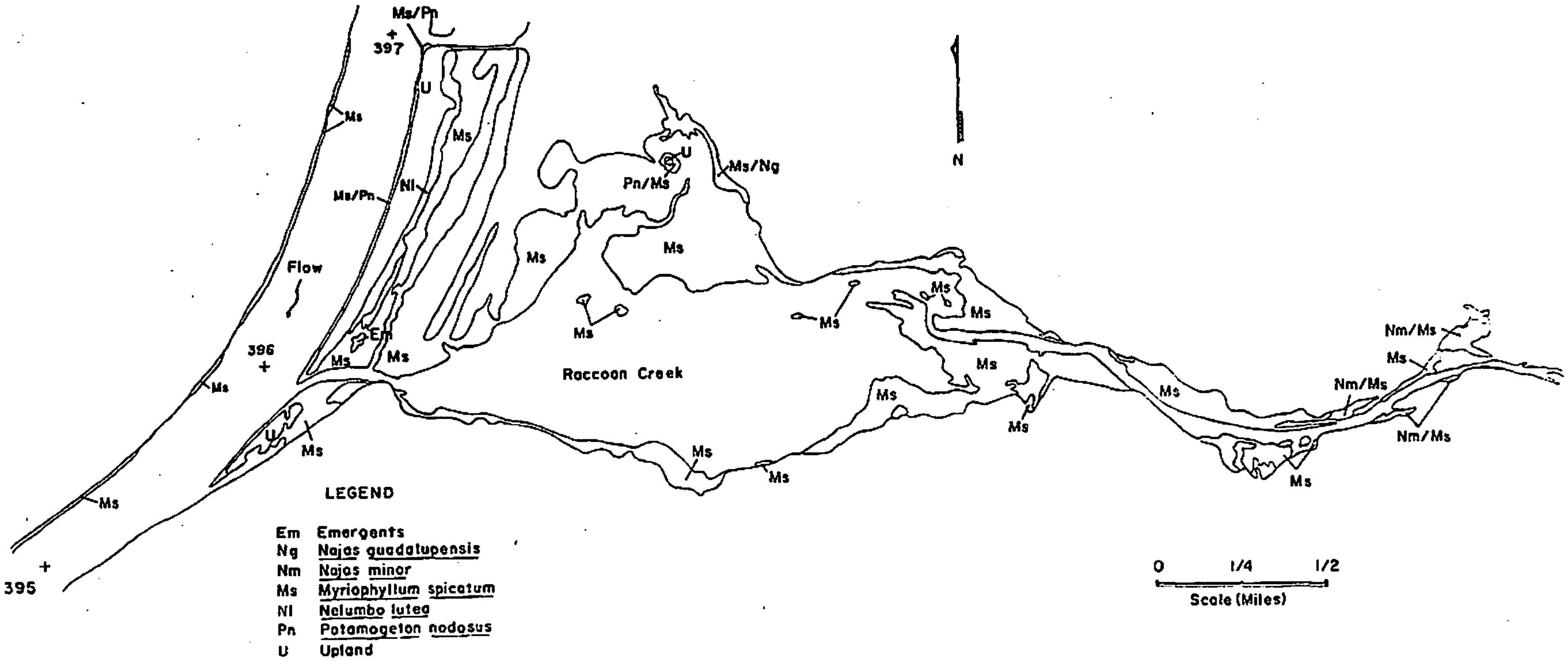


Figure 8-2. Aquatic Macrophyte Communities Upstream of Bellefonte Nuclear Plant on Guntersville Reservoir in 1983.

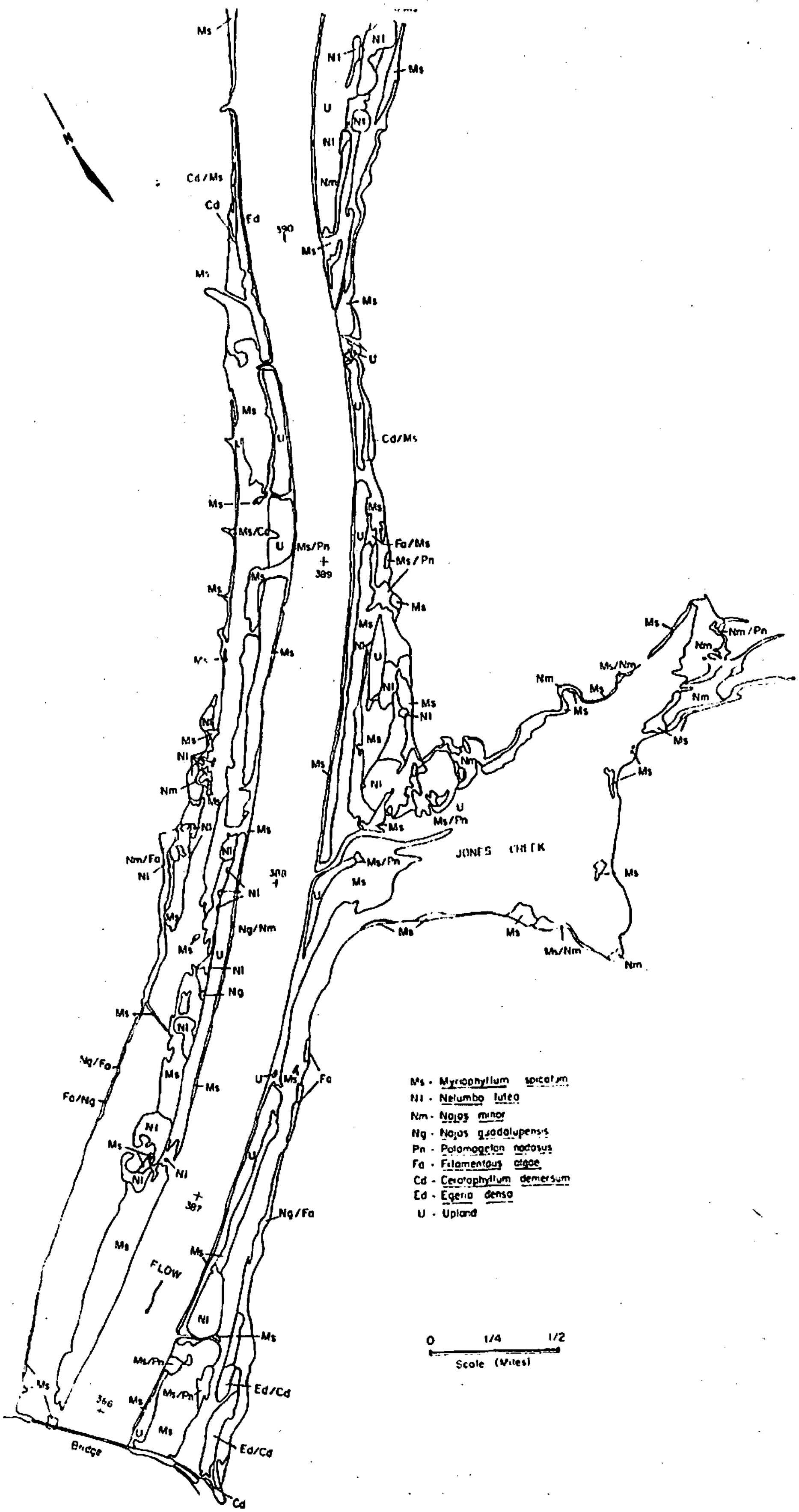


Figure 8-3. Aquatic Macrophyte Communities Downstream of Bellefonte Nuclear Plant on Guntersville Reservoir in 1983.

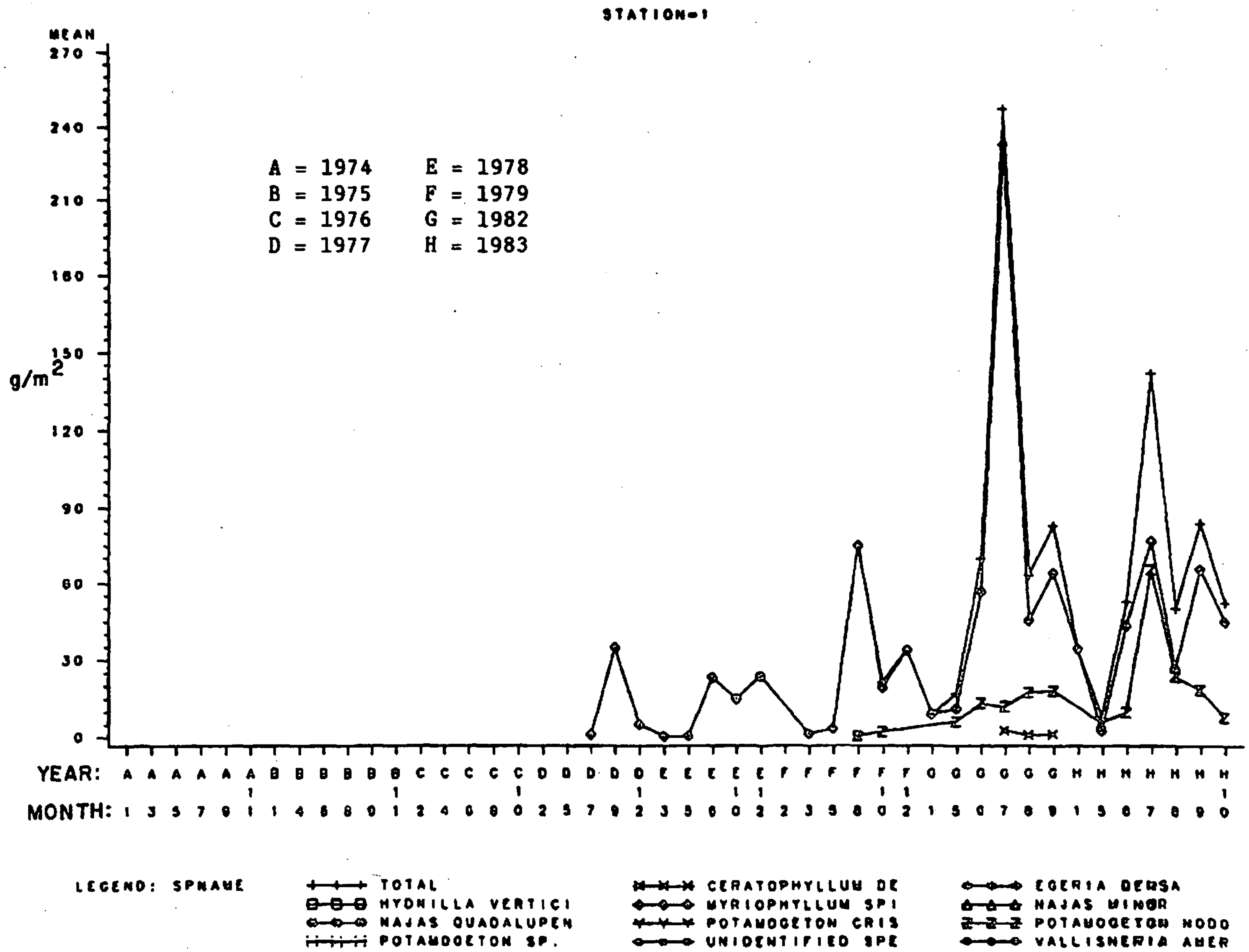


Figure 8-4. Standing Crop of Aquatic Macrophytes at Station 1 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974-1979 and 1982-1983.

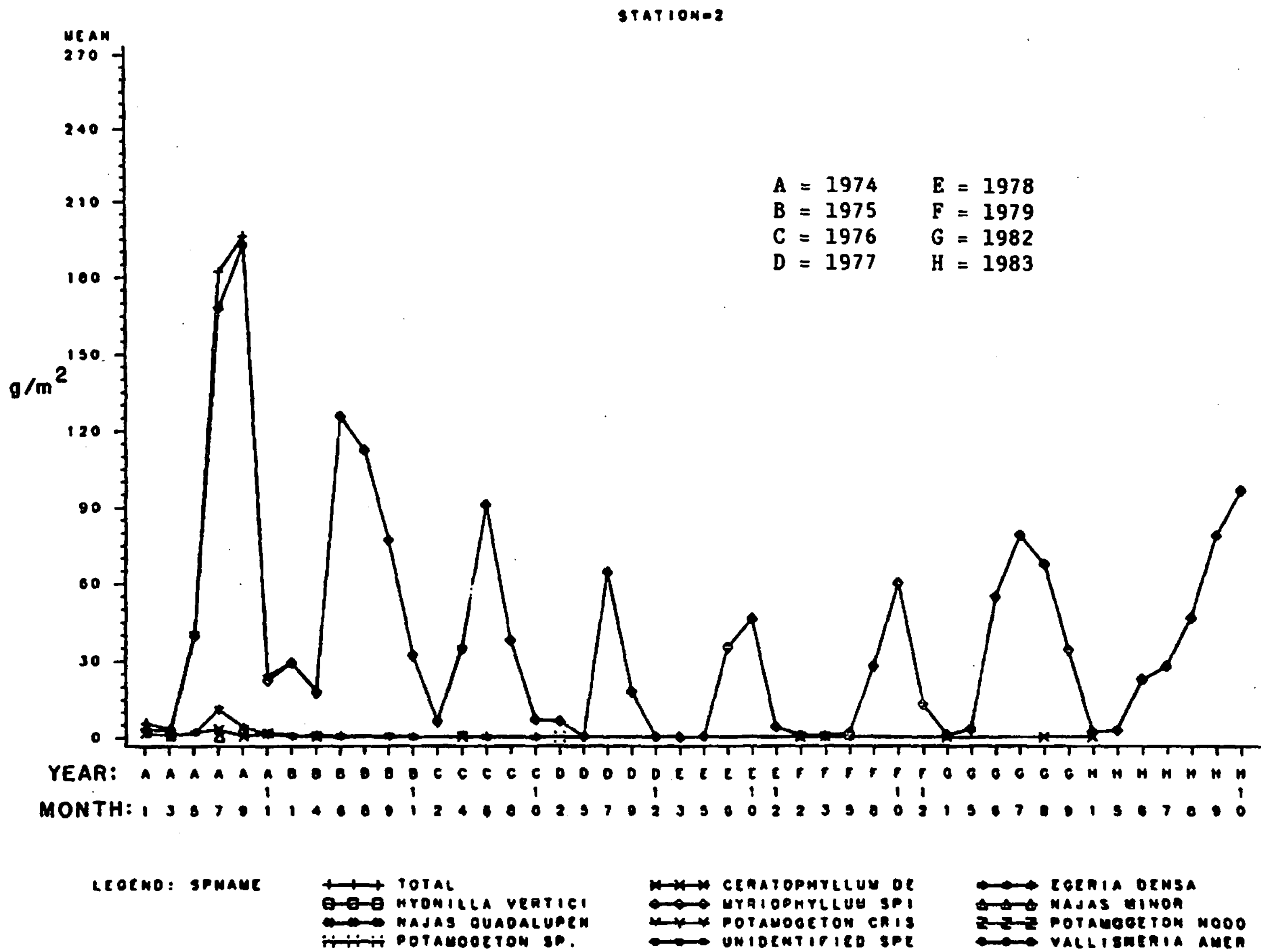


Figure 8-5. Standing Crop of Aquatic Macrophytes at Station 2 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974-1979 and 1982-1983.

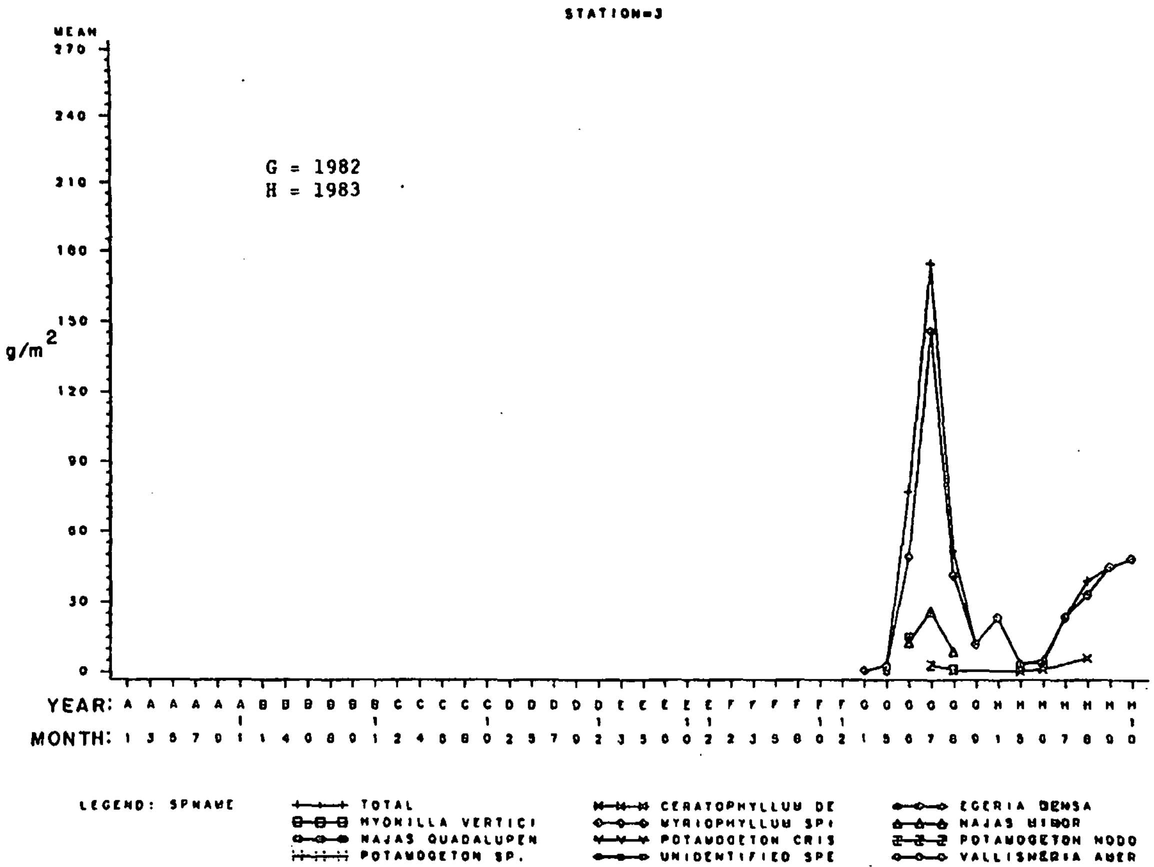


Figure 8-6. Standing Crop of Aquatic Macrophytes at Station 3 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1982-1983.

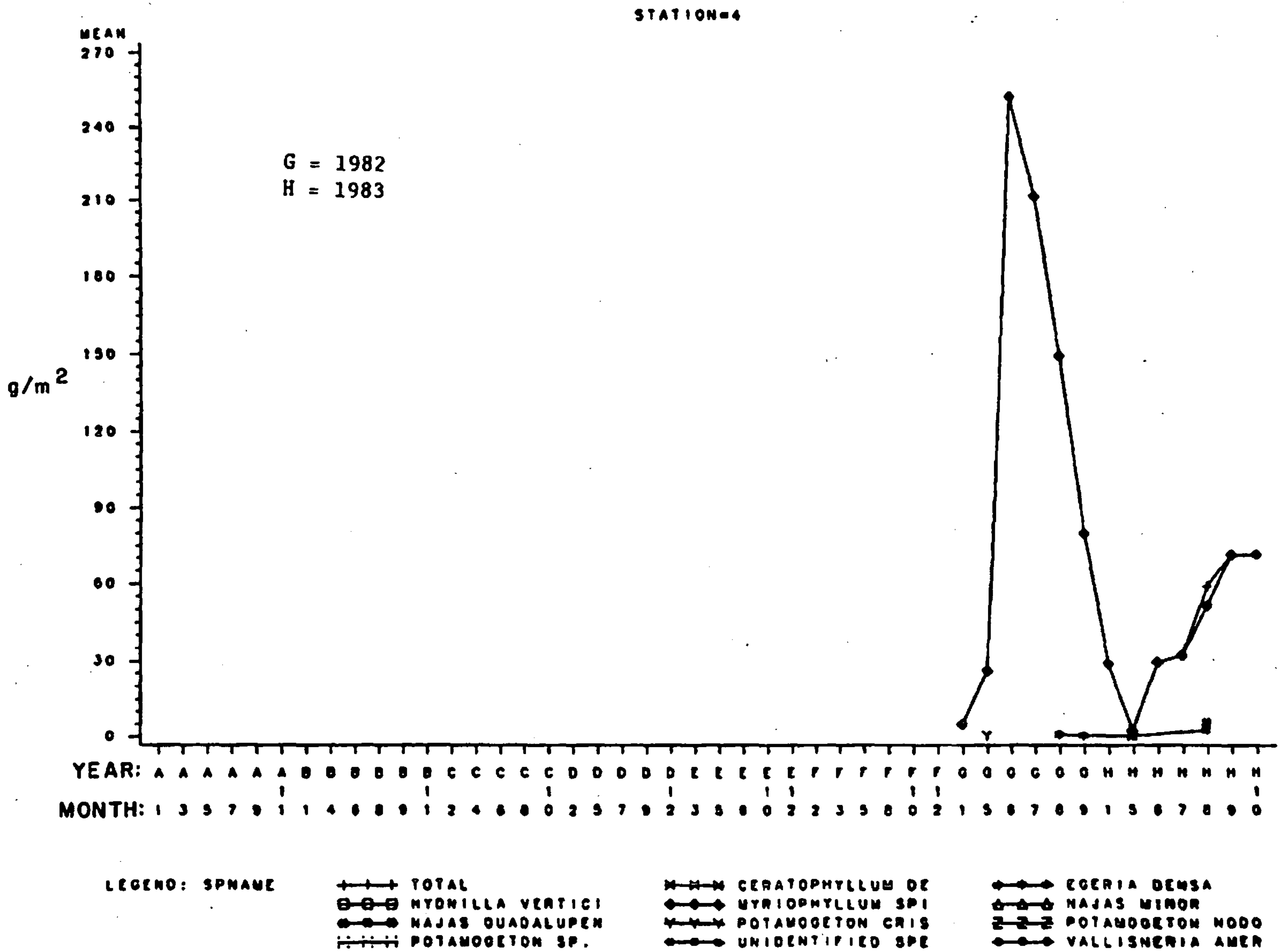


Figure 8-7. Standing Crop of Aquatic Macrophytes at Station 4 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1982-1983.

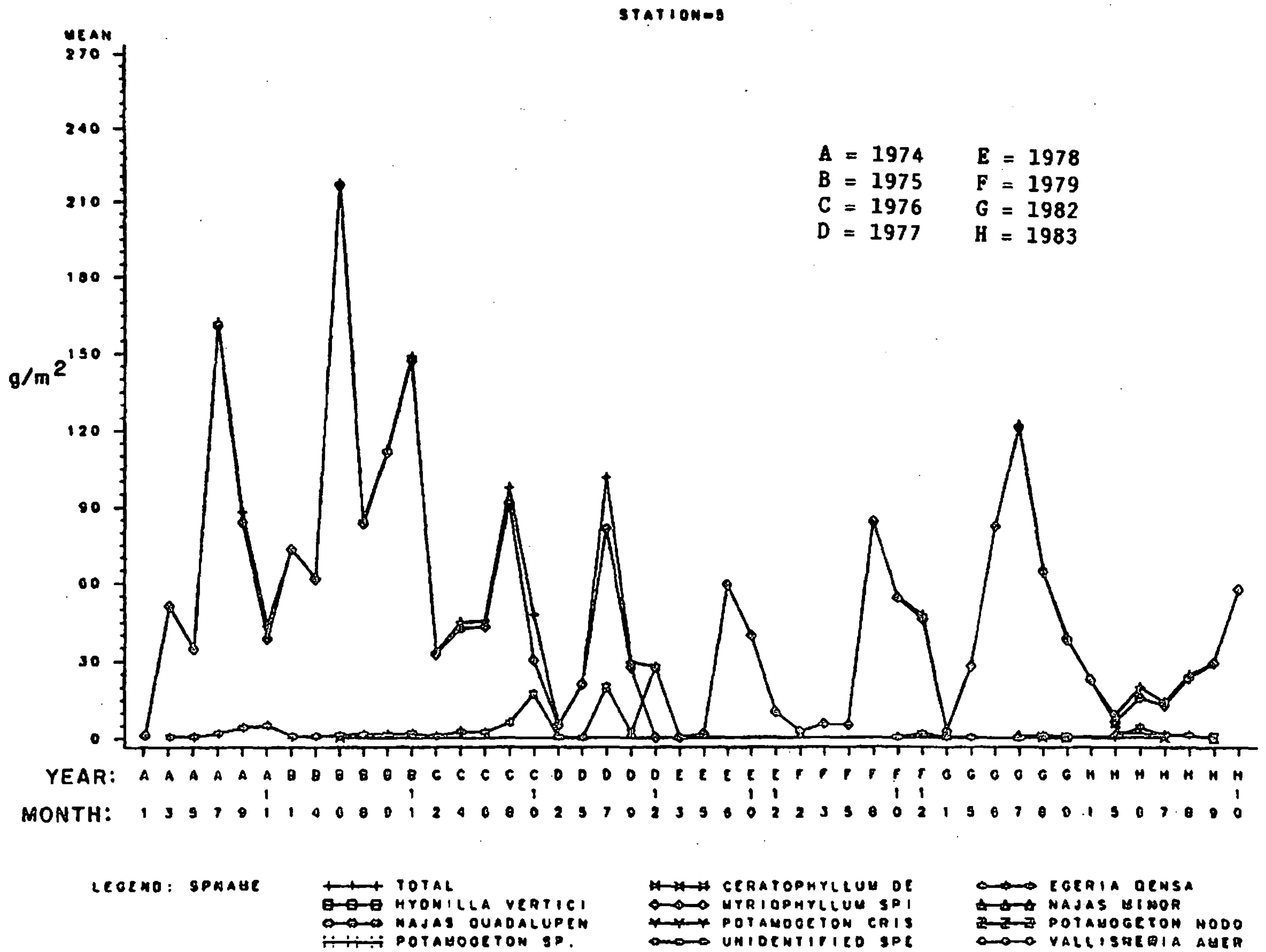


Figure 8-8. Standing Crop of Aquatic Macrophytes at Station 5 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974-1979 and 1982-1983.

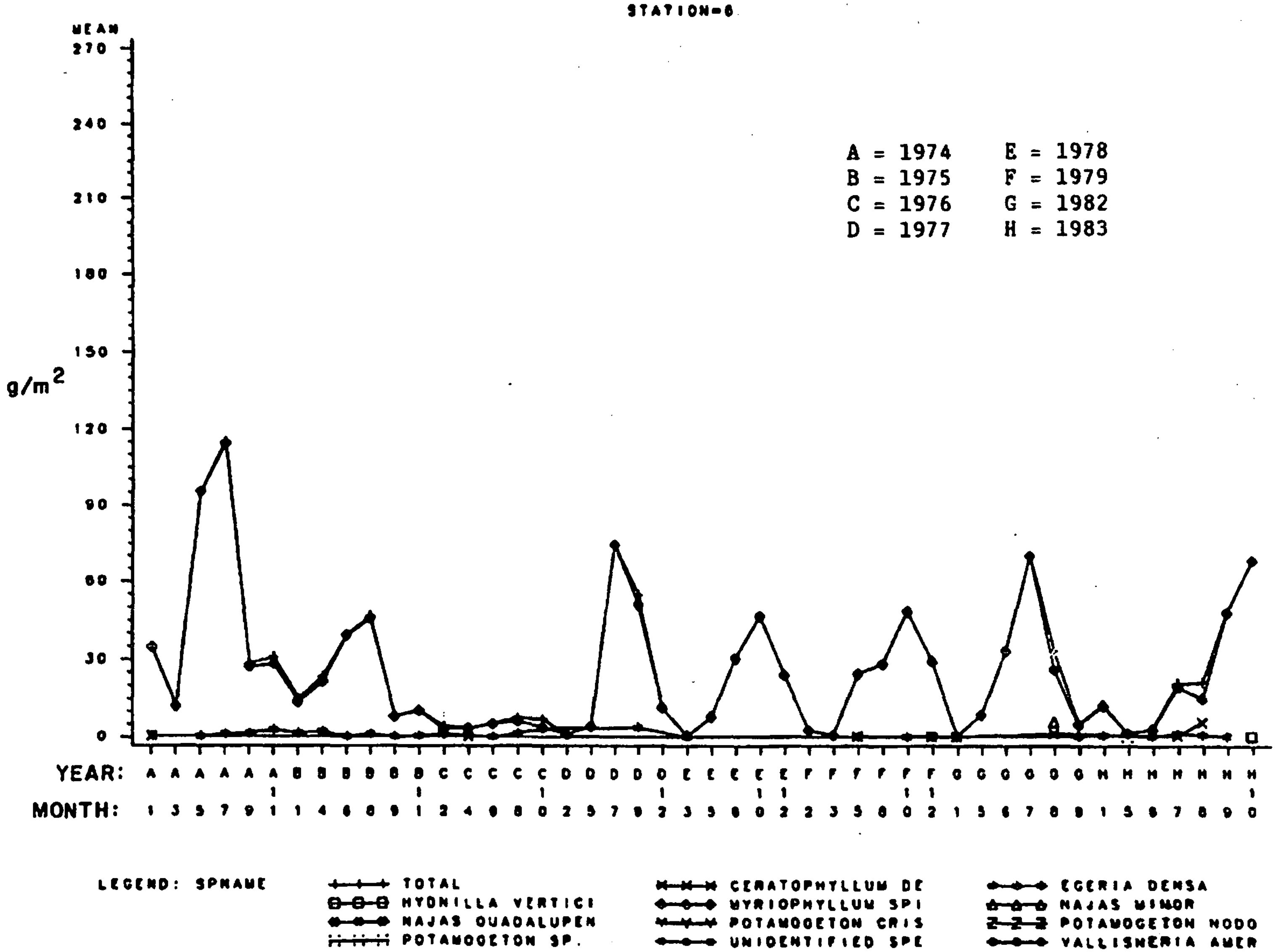


Figure 8-9. **Standing Crop of Aquatic Macrophytes at Station 6 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974-1979 and 1982-1983.**

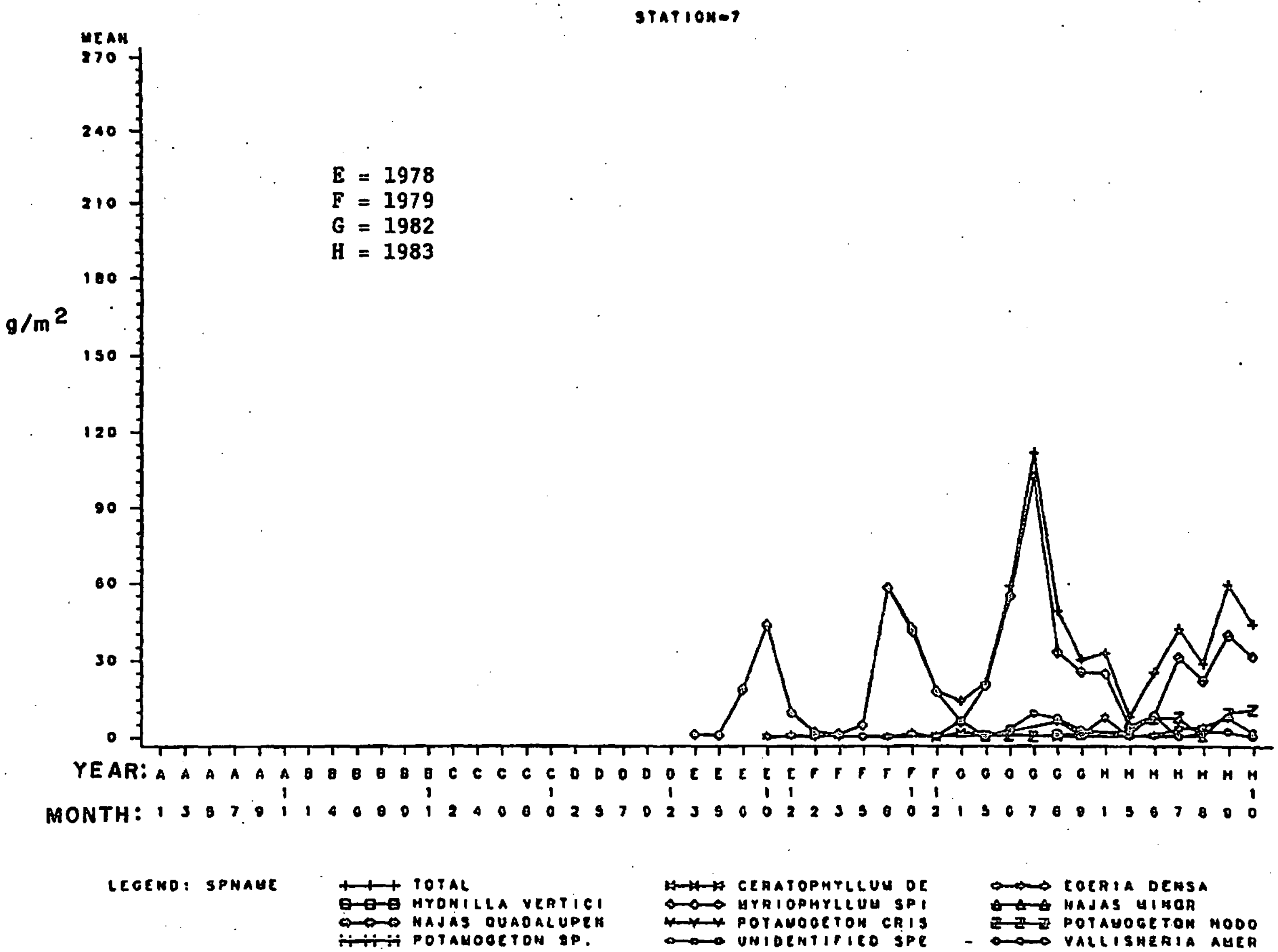


Figure 8-10. Standing Crop of Aquatic Macrophytes at Station 7 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974-1979 and 1982-1983.

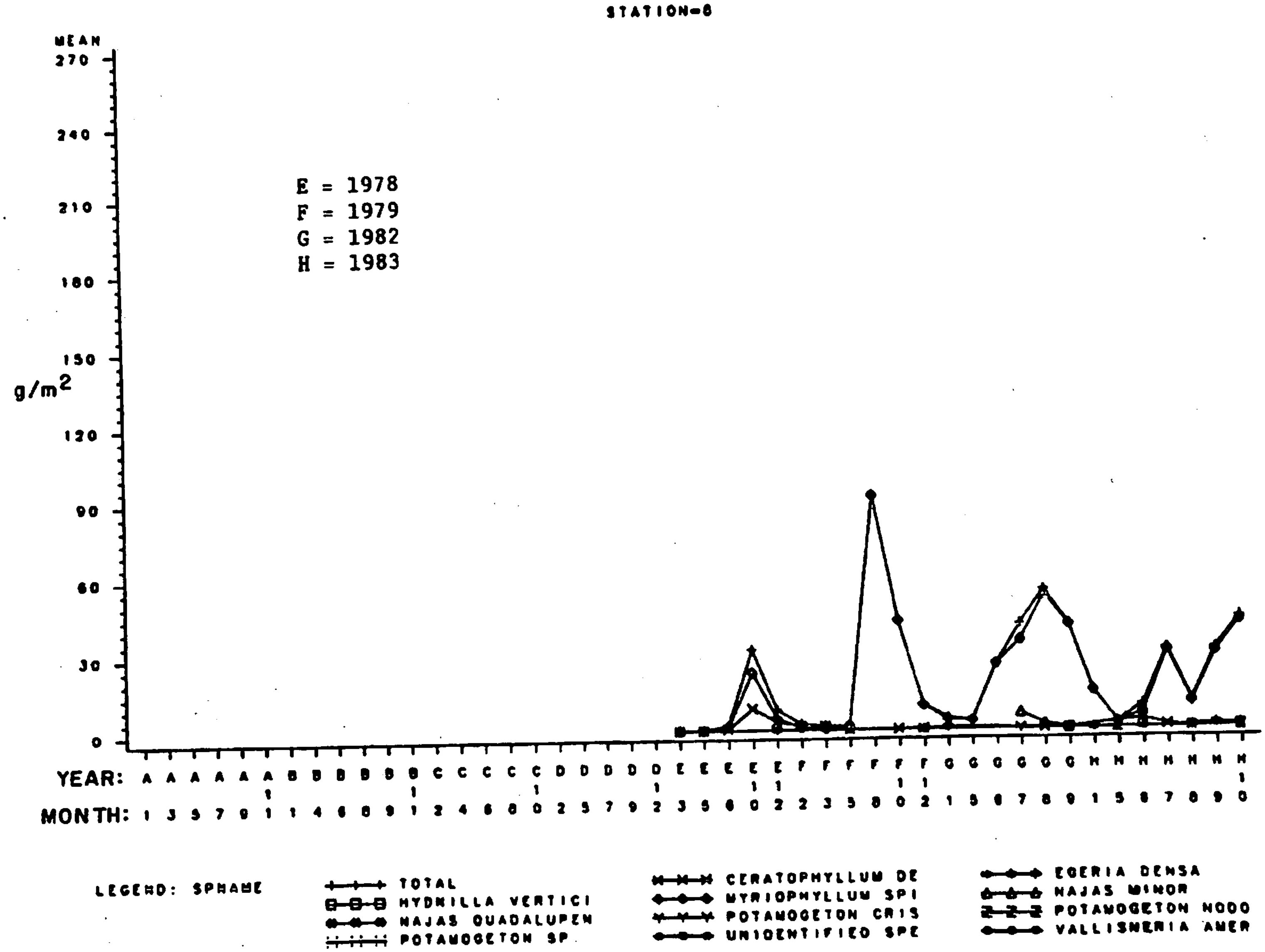


Figure 8-11. Standing Crop of Aquatic Macrophytes at Station 8 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974-1979 and 1982-1983.

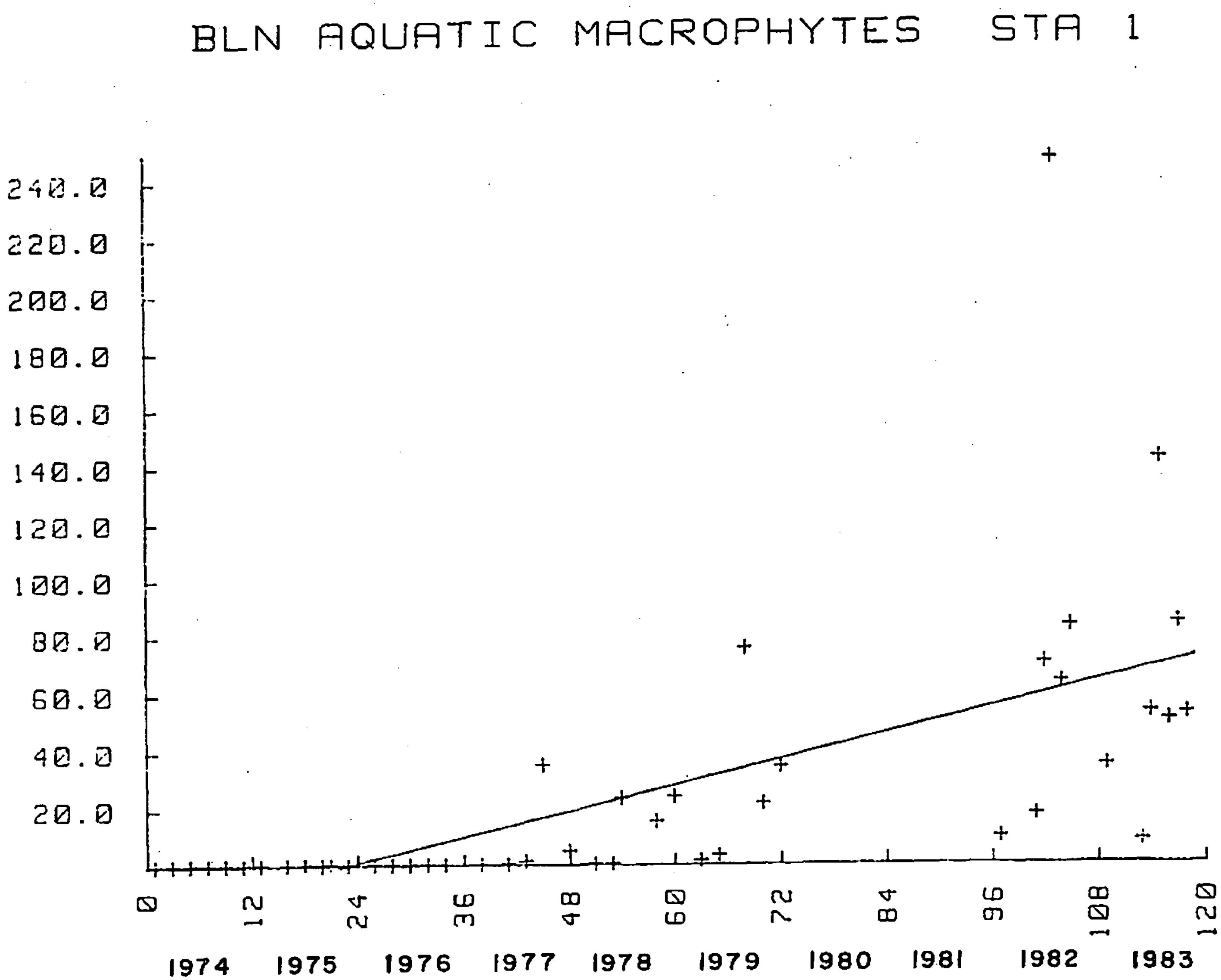


Figure 8-12. Regression Analysis of Aquatic Macrophyte Standing Crop at Station 1 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974 to 1983.

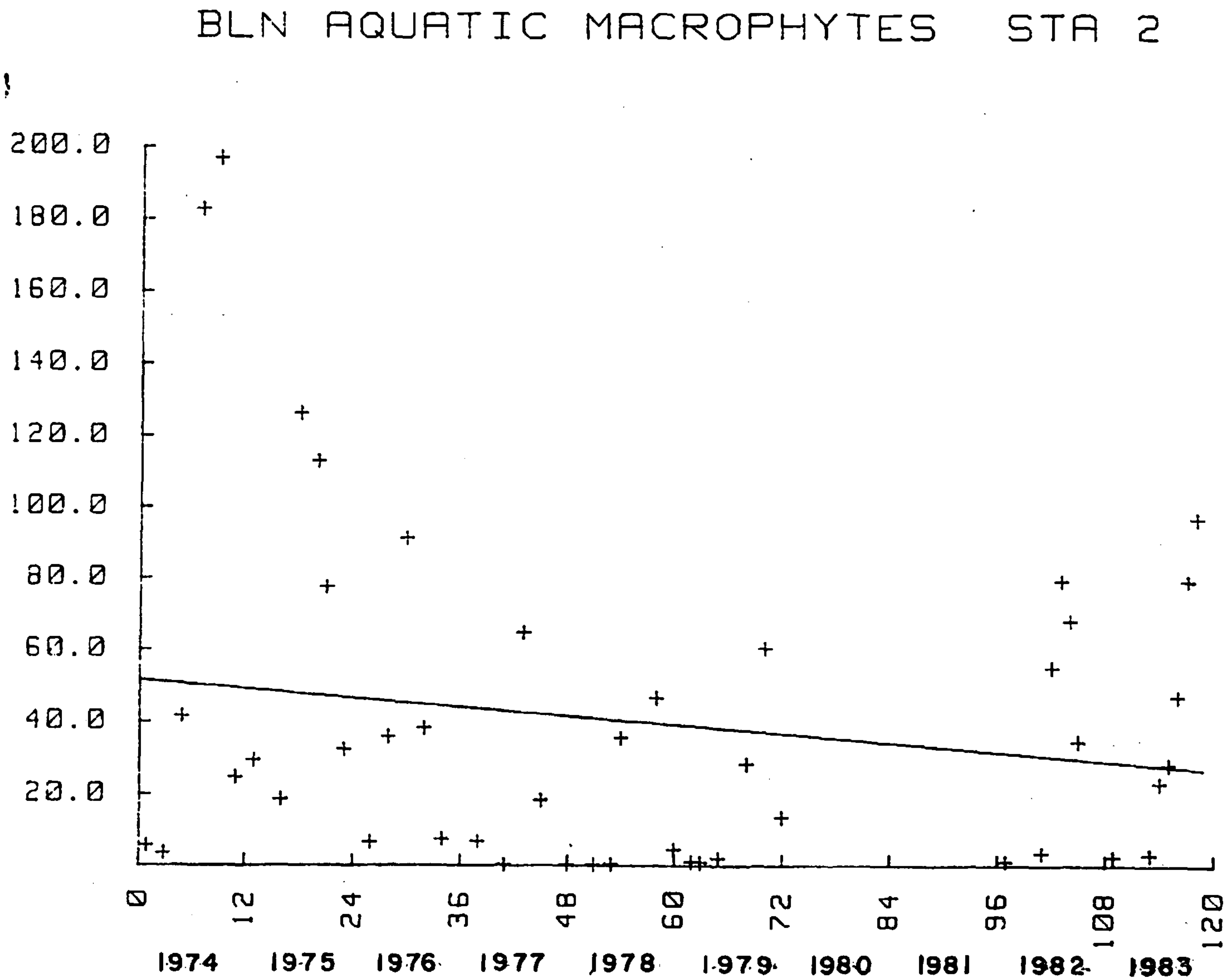


Figure 8-13. Regression Analysis of Aquatic Macrophyte Standing Crop at Station 2 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974 to 1983.

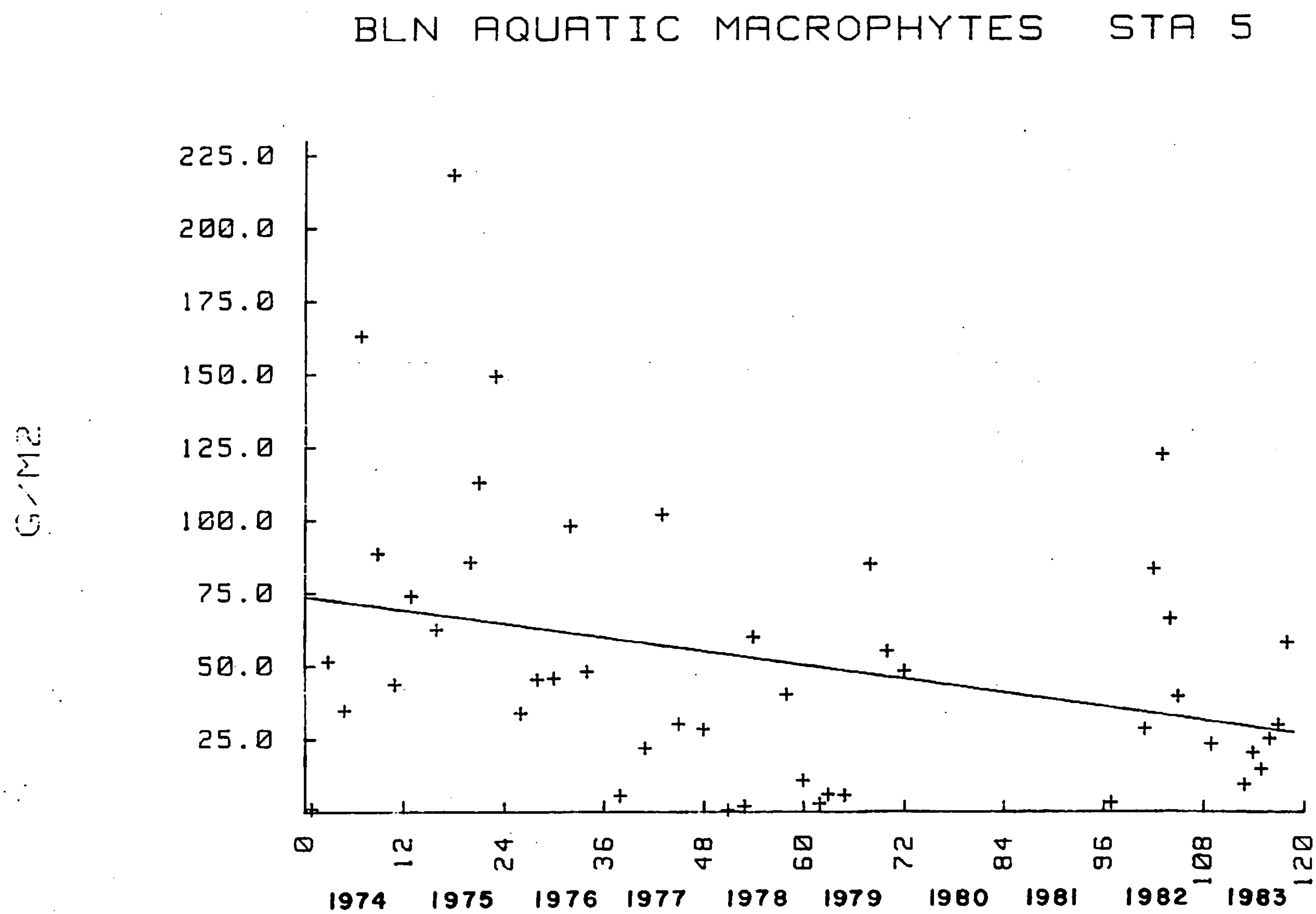


Figure 8-14. Regression Analysis of Aquatic Macrophyte Standing Crop at Station 5 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974 to 1983.

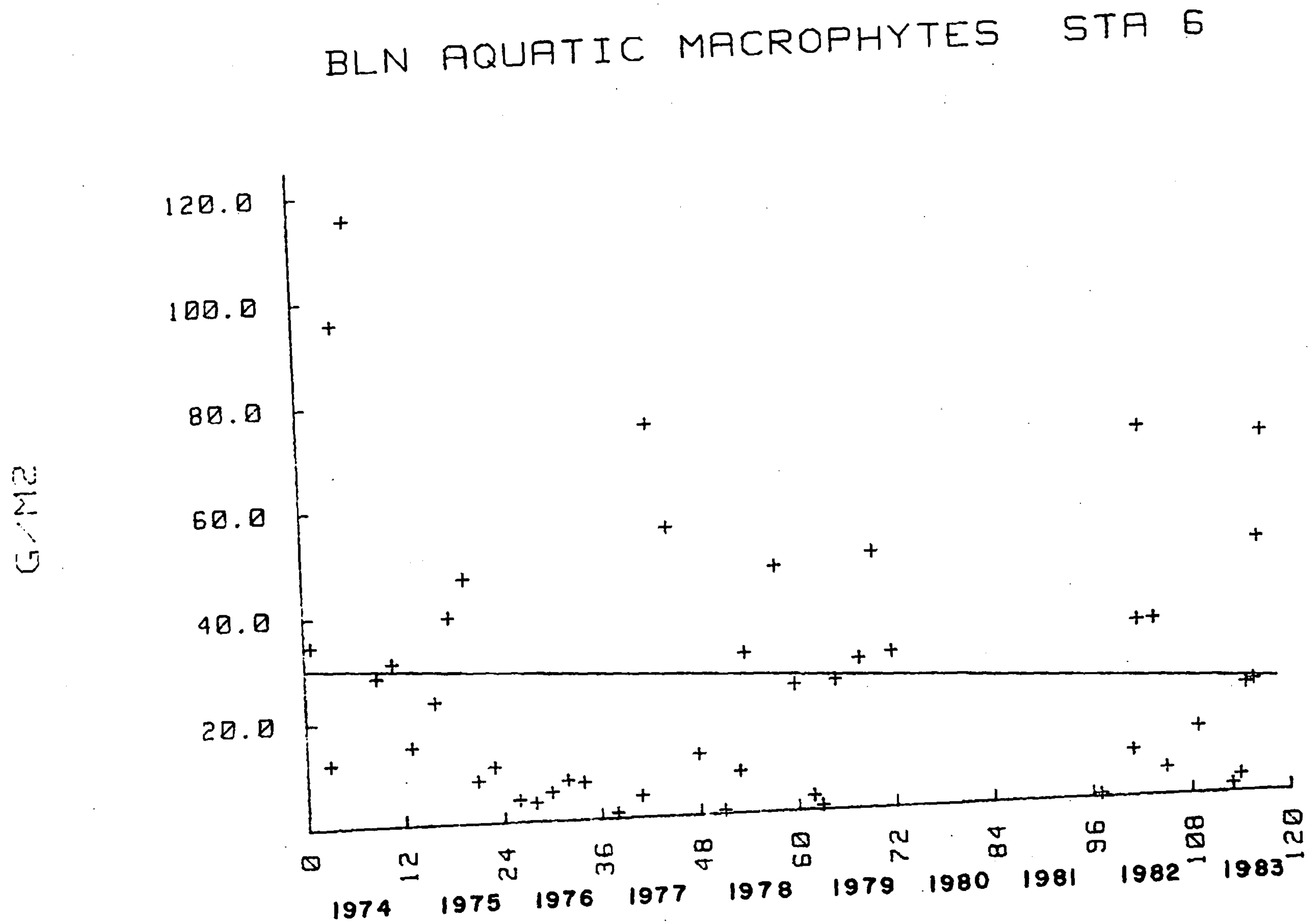


Figure 8-15. **Regression Analysis of Aquatic Macrophyte Standing Crop at Station 6 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1974 to 1983.**

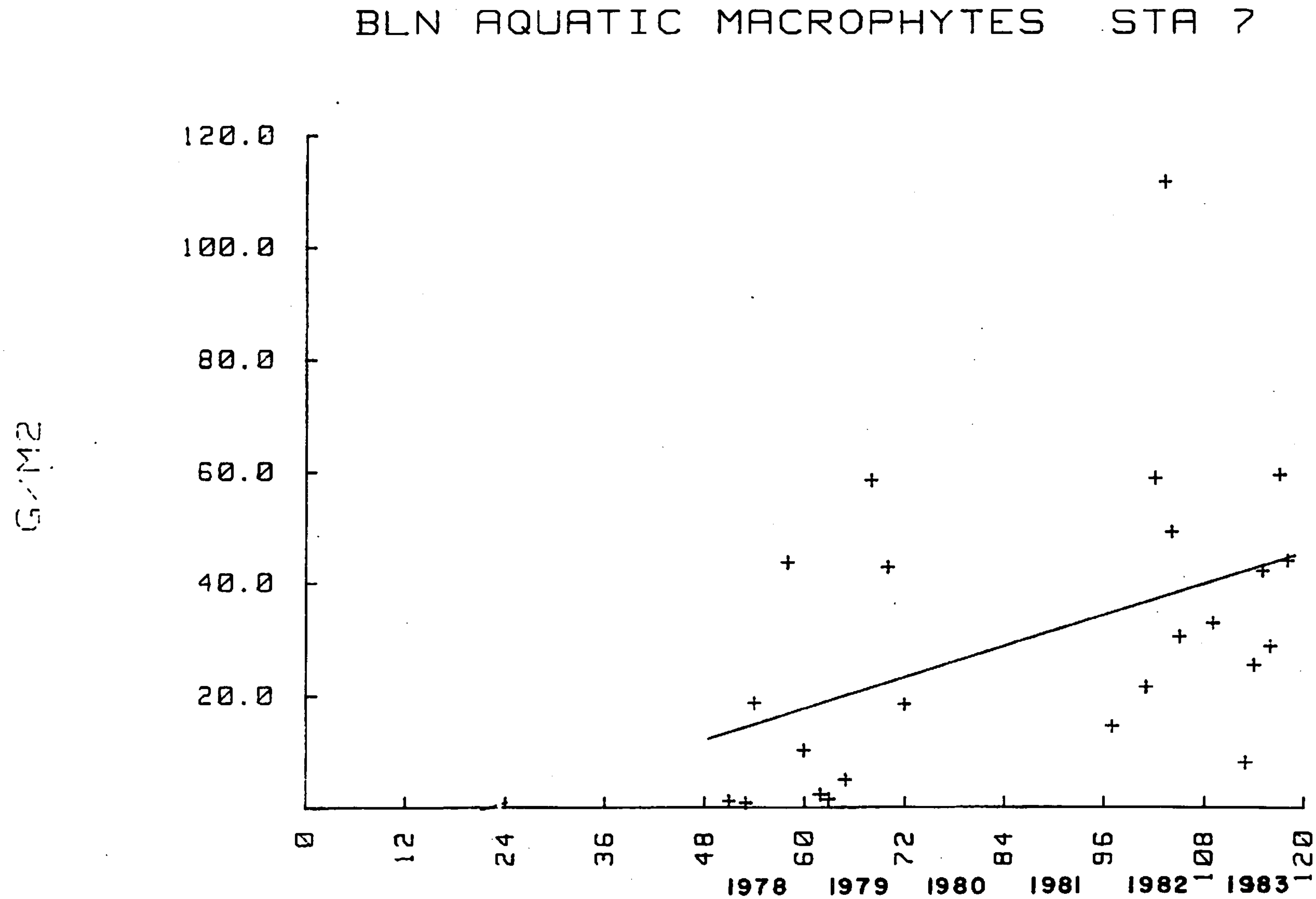


Figure 8-16. Regression Analysis of Aquatic Macrophyte Standing Crop at Station 7 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1978 to 1983.

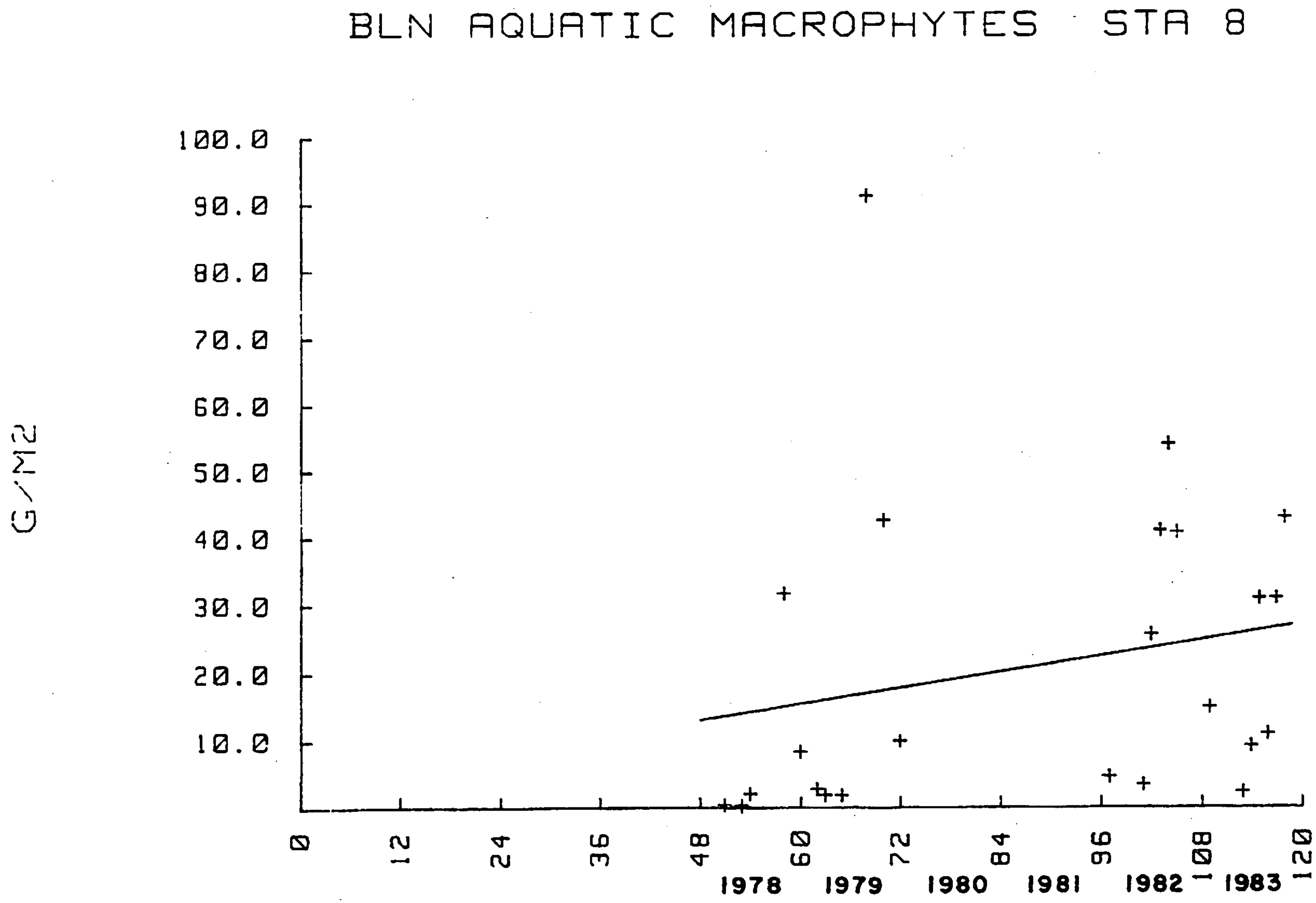


Figure 8-17. Regression Analysis of Aquatic Macrophyte Standing Crop at Station 8 on Guntersville Reservoir in the Vicinity of Bellefonte Nuclear Plant from 1978 to 1983.

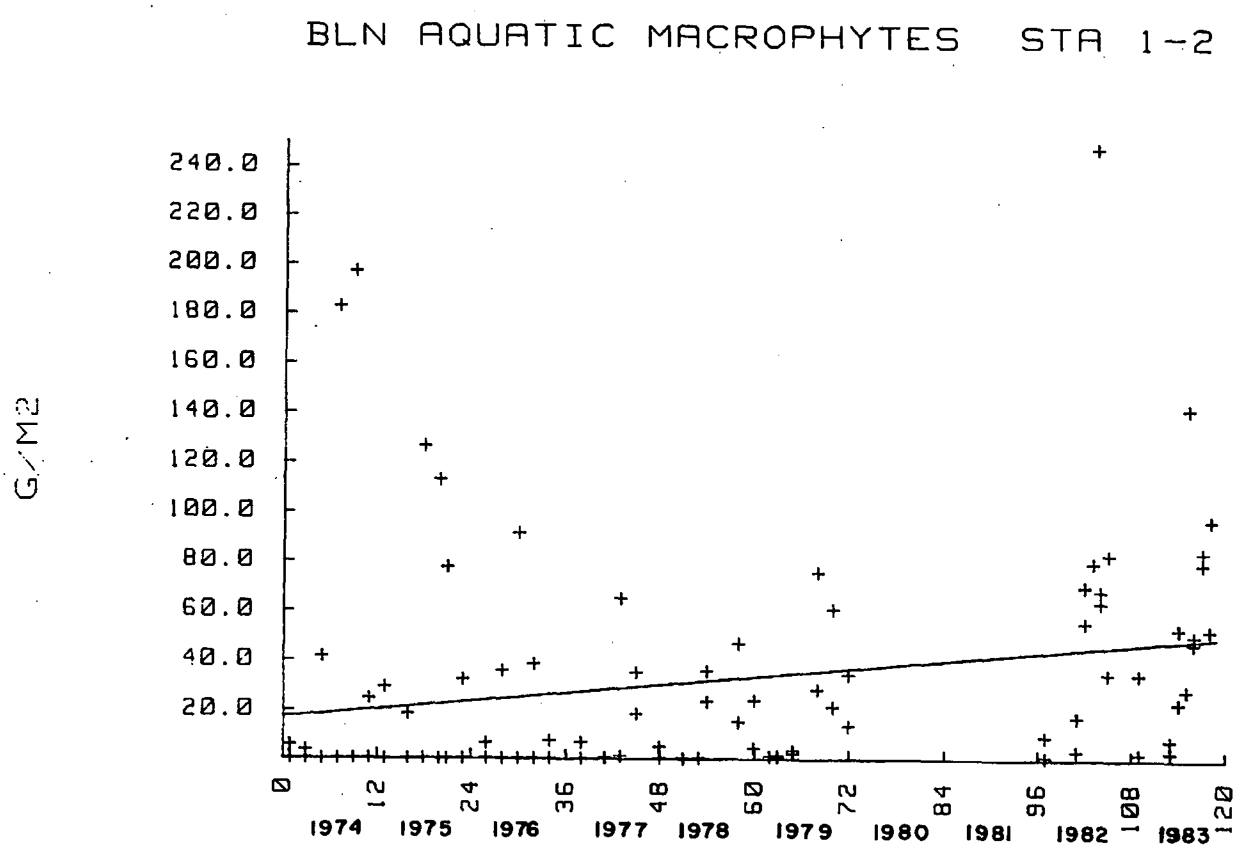


Figure 8-18. Regression Analysis of Pooled Standing Crop Data at Stations Upstream of Bellefonte Nuclear Plant on Guntersville Reservoir from 1974 to 1983.

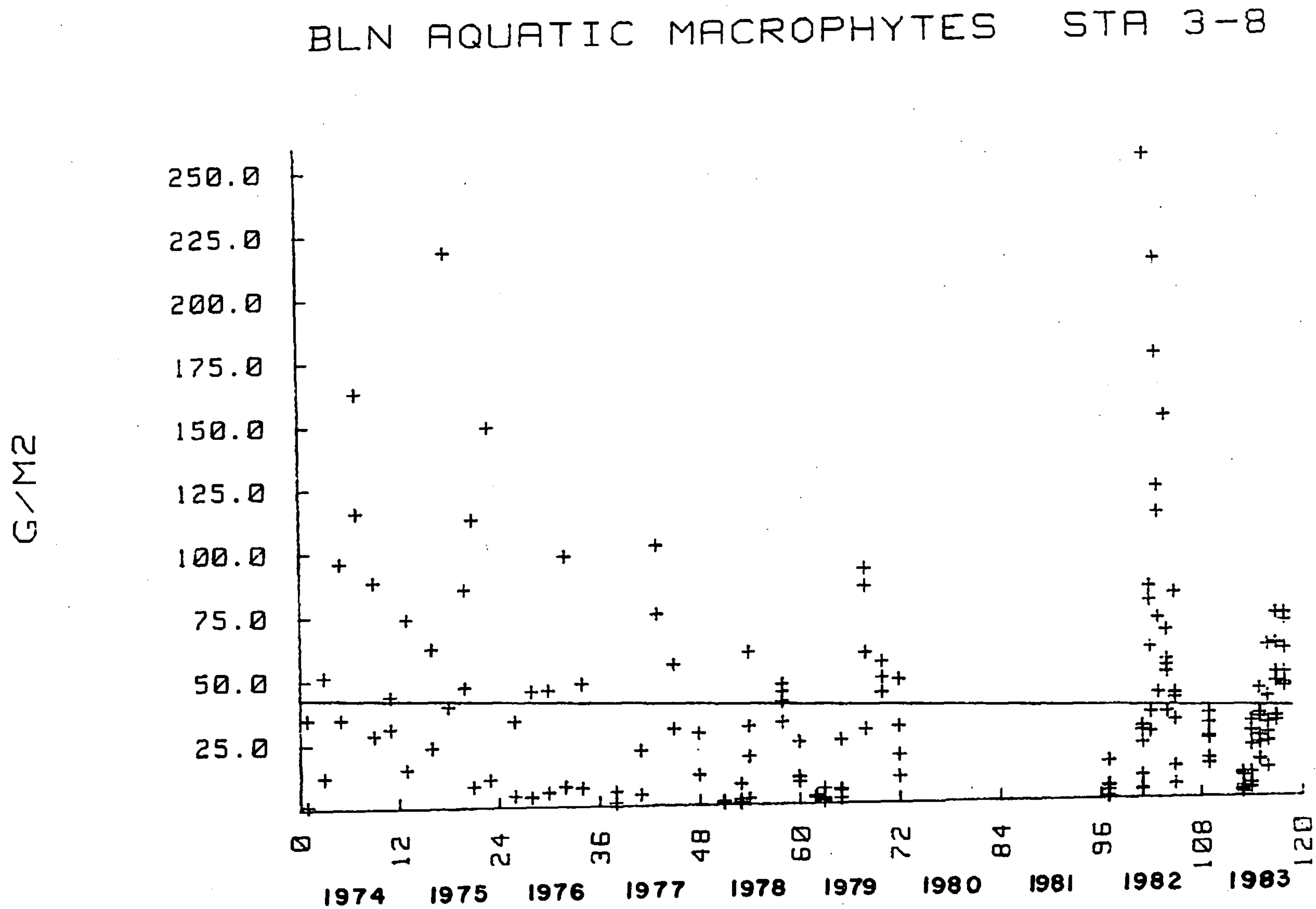


Figure 8-19. Regression Analysis of Pooled Standing Crop Data at Stations Downstream of Bellefonte Nuclear Plant on Guntersville Reservoir from 1974 to 1983.

9.0 FISH

9.1 Materials and Methods

9.1.1 Fish Eggs and Larvae

Monitoring to provide data on the species composition, seasonal abundance and distribution of fish eggs and larvae in the vicinity of the Bellefonte Nuclear Plant (BLN) site on Guntersville Reservoir began in 1974 and continued through 1983. Results of experimental sampling the first year were summarized in a progress report (TVA 1974b) while data collected in 1975 and 1976 were presented in a preliminary entrainment report (TVA 1977).

Collections in 1974 and 1975 were made using several gear types and sampling strategies. Collection procedures were stablized in 1976 with two changes in gear that were utilized during the remaining years of sampling: (1) Mesh size of all nets was reduced from 0.79 mm to 505 micron (0.50 mm) and (2) the netting gear used in 1974 and 1975 were replaced with a 0.5-meter net towed on an oblique path through the water being sampled.

Although the remainder of the fisheries preoperational monitoring program at BLN was not initiated until 1981, ichthyoplankton data collected during the period 1977-1983 are presented in this report. These preoperational data will be compared to subsequent investigations to determine and assess any operational impacts caused by BLN.

Field--Ichthyoplankton samples were collected all years (1977-1983) along a transect perpendicular to river flow near the proposed BLN intake channel at TRM 392.2 (figure 9-1). In 1977, collections were also made along a transect at TRM 369.5 (Murphy Hill) to provide comparable data from another area of Guntersville Reservoir.

Samples were taken with a beam net 0.5 m square, 1.8 m long, with 505 micron "nitex" mesh netting. Oblique tows upstream at 1.0 m/s (boat speed) for 10 minutes resulted in approximately 150 m^3 of water filtered per sample. A large-vaned General Oceanics flowmeter was suspended in the net mouth to measure volume filtered. A tow was made by first lowering the net to the lower limit of the stratum to be sampled, then, with the boat in motion, raising it obliquely at one minute intervals through the stratum.

In 1977, full stratum samples were collected from each shoreline of the plant transect (TRM 392.2) and stratified samples (0-3 meters and 3 meters to bottom) were collected from two stations in each of the channels on either side of Bellefonte Island (figure 9-1). At the Murphy Hill transect (TRM 369.5) full stratum samples were collected on the right shoreline and at two overbank stations left of channel. Stratified (three strata) midchannel samples were also collected from one station along this transect. Sampling at this transect was discontinued after 1977.

Progressive choking of overbank areas with water milfoil throughout the sampling season in previous years had impeded larval sampling at all transects on Guntersville Reservoir. For this reason shallow sampling from the right and left shorelines of the plant transect was discontinued in 1978. For the remaining years of this study, sampling at the plant transect consisted of two stratified (0-3 meters and 3 meters to bottom) samples along the transect from each of the two channels formed by Bellefonte Island. A horizontal sample 0.5-1.0 meter from the bottom was added in the middle of the north channel. This sample was designed to more effectively collect larvae that might be hatched on the bottom and transported downstream before rising sufficiently in the water column to be sampled by obliquely towed nets.

To assess temporal concentrations of larval fishes during the period 1977-1983, collections were made biweekly both day and night. Sampling began in March and continued through August. All samples were immediately fixed in a 10 percent formalin solution and subsequently shipped to TVA's Fisheries Laboratory in Norris, Tennessee, for processing.

Laboratory--Ichthyoplankters were removed from the samples, identified to the lowest possible taxon, counted and measured (larvae only) to the nearest mm total length (TL) following procedures outlined in NROPS-FO-BR-24.1 (TVA 1983c). Taxonomic decisions were based on TVA's "Preliminary Guide to the Identification of Larval Fishes in Tennessee River," (Hogue et al. 1976) and other pertinent literature.

The term "unidentifiable larvae" applies to specimens too damaged or mutilated to be identified, while "unspecifiable" before a taxon implies a level of taxonomic resolution (i.e., "unspecifiable catostomids" designates larvae within the family Catostomidae that currently cannot be identified to a lower taxon). The category "unidentifiable eggs" applies to specimens that cannot be identified due to damage or lack of taxonomic knowledge.

Taxonomic refinement is a function of specimen size and developmental stage. Throughout this report, the designation "unspecifiable clupeids" refers to clupeids less than 20 mm TL and could include *Dorosoma cepedianum* (gizzard shad), *D. petenense* (threadfin shad), and/or *Alosa chrysochloris* (skipjack herring). Any clupeid specimen identified to species is 20 mm or longer.

Developmental stage of percichthyids also determines level of taxonomic resolution. *Morone saxatilis* (striped bass) hatch at a much larger size than either *M. chrysops* (white bass) or *M. mississippiensis* (yellow bass). Although it was impossible to distinguish between larvae of the latter two species, *M. saxatilis* was eliminated as a possibility based on developmental characteristics of specimens 6 mm or less in total length (hence, the taxonomic designation *Morone*, (not *saxatilis*)). Specimens identified as *Morone* spp. in most instances were greater than 6 mm TL.

Data Analyses--Densities of fish eggs and larvae were expressed as numbers per 1000 m^3 for comparisons between stations and among years. Data collected at the Murphy Hill site (TRM 369.5) in 1977 were included for occurrence and relative abundance and comparisons. Density analyses for evaluating temporal and spatial abundance and distribution were in most cases conducted only on data from the BLN plant transect.

9.1.2 Juvenile and Adult Fish

Field--Several methods were utilized to sample juvenile and adult fish. These included cove rotenone, gill netting, and electrofishing. Materials and methods are described below for each sampling regime.

Cove Rotenone--Fish sampling with rotenone was initiated in Guntersville Reservoir in 1949 to determine standing stock (numbers/ha and kg/ha) of game, prey, and commercial fish species. Samples were taken at various locations annually through 1961. Annual sampling started again in 1971 and has continued through 1983 (with the exception of 1973 and 1978). In addition to standing stock information, these data provide species occurrence and composition information and characterize the overall fish community of the reservoir.

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 Guntersville Reservoir from 1949 through 1960 included: (1) use of varying techniques for determining area and volume of the sample site, (2) some sampling conducted without the use of block nets, and (3) undescribed subsampling techniques. Current fish sampling procedures are conducted in accordance with the Field Operations Biological Resources Procedures Manual, 1983.

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. Description of sample sites (1971-1983) are in table 9-1. Since the beginning of the BLN preoperational period in 1974, cove rotenone population estimates were usually based on samples from at least three sites. However, additional sites were included in 1975 (8) and 1976 (5), and only two sites were sampled in 1979. Since 1980, the same three sites have been sampled (TRM 382.4, Roseberry Creek; TRM 393.4, Town Creek; and TRM 394.3, Mud Creek) (figure 9-1).

Standardized field techniques for rotenone sampling included: (1) sampling when water temperature is greater than or equal to 20°C; (2) accurate surveying of surface area within one day prior to sample collection; (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) pickup of all visible fish on two consecutive days; and (8) specified sorting, counting, weighing, subsampling, and data recording procedures.

In addition to the standardized procedures, some sample sites were treated with herbicides to remove or reduce dense stands of submersed aquatic macrophytes to facilitate fish recovery. Herbicide treatment, applied according to recommended methods (see section 3.3), was done three to four weeks prior to rotenone sampling. With the exception of 1980, two of the three primary sample sites (Mud Creek and Town Creek) have been treated since 1977. In 1980, these sites were sampled with dense stands of aquatic macrophyte present to evaluate fish standing stock estimates under these conditions. Roseberry Creek, the third primary sample site, never required herbicide treatment due to sparse stands of aquatic macrophytes.

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 volume of the cove to achieve a rotenone 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 10 percent buffered formalin and returned to the laboratory for identification. Each remaining species was then sorted into groups by 25-mm length increments. Fish were grouped into game, commercial, and prey species and classified as young, intermediate, and adults, based on total length (table 9-2).

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. The remainder of the size class was then weighed collectively and numbers estimated by the relationship:

$$\frac{\text{No. in subsample}}{\text{Weight of subsample}} = \frac{\text{No. in remainder}}{\text{Weight of remainder}}$$

Fish collected the second day were processed in the same way, except that number of fish only was recorded for each size class of each species. Weights of second-day fish were calculated from length-weight relationships derived from first-day fish.

Gill Netting--Sinking experimental gill nets, 37.9 m x 2.4 m with five equal panels of 1.3, 2.5, 3.8, 5.1, and 6.4 cm bar mesh were used. Two nets, spaced approximately 100 m apart, were fished perpendicular to each shoreline at each of three stations (TRMs 396.6, 391.0, and 388.1) and two on the right shoreline only at TRM 392.5 (figure 9-2). Mesh progression on each set of nets was set in opposite direction. The nets were fished two consecutive nights monthly from March 1981 through February 1984. All fish were identified to species and enumerated by capture mesh size. Gill net stations were the same as electrofishing with the exception of the stations in Mud and Town Creeks. No nets were set at these two locations. Sample areas are described as follows.

Station 1 (TRM 396.6) was located approximately 6.8 km (4.2 miles) upstream of the intake structure. Water velocity was usually higher at this station than at other stations. Shoreline at this station consisted of steep eroded banks dropping down to a beach of sand and mud at the river's edge. Shoreline vegetation consisted of sparse trees and cane. Aquatic vegetation was heavy during the summer months and extended approximately 4 to 5 m from shore, where water depth increased sharply. Water depth at this station ranged from 0.3 to 7.0 m.

Station 2 (TRM 392.5), located 0.5 km (0.3 mile) above the intake structure, was sampled only along the right shoreline. Shoreline vegetation here consisted of dense trees and vines. The river's channel dropped off steeply from the shore to a depth of approximately 9.0 m.

aquatic vegetation covered the water surface for about 3 m from the shore during the summer months. Nets were set at depths of 0.3 to 9.0 m.

Station 3 (TRM 391.0) was located approximately 1.9 km (1.2 miles) below the intake. Nets on the right side of this station were fished in shallow overbank except during late summer months when due to heavy growth of milfoil (Myriophyllum spicatum) the nets had to be fished in the channel at the outer edge of the milfoil. Shoreline vegetation consisted of hardwood forest and scattered shrub. Currents in the overbank were slow to moderate. The left shoreline at this station consisted of scattered trees and vines with gradually sloping sandy banks and numerous submerged stumps. Nets were set in depths from 0.6 to 7.0 m. Milfoil growth on this side was sparse and water velocity was moderate.

Station 4 (TRM 388.1) was located approximately 6.8 km (4.2 miles) downstream of the intake. The right shoreline had scattered trees with thick brush and vines. Shallow water (0.3 m) extended about 7.0 m from the bank and then depth increased to approximately 7.0 m. The shallow area was heavily infested with milfoil during the summer. Nets were set in 0.3 to 7.0 m of water. The left shoreline was similar to the right. The banks were sloping and stumpy. Water depths at net sites were 0.3 to 6.0 m. Milfoil growth and water velocities were both moderate on this side of the river.

Electrofishing--Preoperational electrofishing sampling was conducted at six stations monthly from March 1981 through February 1984. Electrofishing equipment consisted of a boat-mounted 230-volt, 3.5-kilowatt direct current generator delivering a current of approximately four amperes continuously to the water by boom-dropped electrodes. Fish affected by the electrofishing unit were captured with a long-handled dip net, identified to species, and enumerated. A count of the numbers of those fish not netted was included in the sample data, provided a positive species identification was possible. Each electrofishing run consisted of continually shocking for two minutes a section of shoreline while moving in a downstream direction. All stations were sampled within a 24-hour period. Five, 2-minute runs, separated by a buffer zone of approximately 20 meters, were sampled along each shoreline at three transects (TRMs 396.6, 391.0, and 388.1) and the right shoreline at TRM 392.5 (figure 9-3). In addition, five 2-minute timed runs were made along the shoreline in both Town Creek and Mud Creek.

Shoreline along Mud Creek consisted of scattered trees and a heavy growth of vines and shrubs. Habitat varied from steep banks and deep water (3 m) at one end of the station to flat banks and shallow water at the other. Water velocities varied from slow to moderate, depending on river levels. There were numerous tree tops and stumps throughout the station.

In Town Creek Station numerous trees, thick vines, and shrubs made up the shoreline vegetation. Banks were flat with water depths ranging from 1 to 3 m. Aquatic vegetation was sparse in the deeper water but got very dense in the shallow end of the station during the summer months. Water velocities were normally low.

Data Analysis--Methods utilized to evaluate juvenile and adult fish data are described below by collection method.

Cove Rotenone--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 1974 through 1983. Important species were determined by the following criteria: (1) must occur in at least 50 percent of samples since 1974, and (2) must comprise one percent of either the total number or total biomass collected.

Gill Netting--The basic unit used in these analyses was catch-per-unit effort (c/f) expressed as number of each fish species caught per gill-net-night (fish from all mesh sizes were combined). The analyses were designed to detect significant spatial and temporal differences in c/f of important fish species combined and individually. Important species were defined as those occurring in 50 percent or more of all samples and comprising at least one percent of total number of fish captured. All statistical analyses were performed on log transformed data, $\log_{10}$ (c/f + 1); however, antilogs of transformed data were used in the text and tables to facilitate comparison.

Gill nets were set on both left and right banks at stations 1, 3, and 4. To determine if catch data from left and right banks could be pooled within each station, t-tests were used to compare c/f of all species combined and important species combined by station and quarter, with years combined.

A three-way Multivariate Analyses of Variance (MANOVA) was employed to test effects of station, year, quarter (main effects), and interactions among these main effects on combined important species. This procedure identified relative influence of main effects and interactions on the whole fish assemblage sampled by experimental gill nets.

A univariate three-way Analysis of Variance (ANOVA) was then employed in testing influence of the main effects and interactions on c/f of each important species. This procedure identified individual species contributing to assemblage responses observed with the MANOVA.

Two-way ANOVA (year and station) with interaction was run by quarter for each species showing effects in the three-way ANOVA. This procedure reduced the overriding seasonal influence included in quarter effects and facilitated analysis of spatial and long term differences in individual species c/f. If a significant effect ($\alpha = 0.05$) was found with ANOVA, Duncan's New Multiple Range Test was used to identify which values were significantly different.

Catch data were analyzed by quarter because changes in c/f of fish occur by season, not by month. Grouping monthly catch data by quarter allowed these seasonal changes to be more readily identified.

Quarters were: winter, December-February; spring, March-May; summer, June-August; fall, September-November. Because winter quarter was split by consecutive years, year designation was based on December; i.e., December 1981-February 1982 was winter quarter, 1981.

Electrofishing--Electrofishing data were characterized by listing all species identified in the samples, total number of each species taken, number of samples in which each species occurred, number of months each species was collected, and percentage of overall catch by species. Spatial and temporal differences and trends were determined using only those species regularly occurring in samples. These were termed important species and were defined as those occurring in 50 percent or more of the months sampled and comprising at least one percent of the total catch.

The unit used in these analyses was catch-per-electrofishing-run (c/f). All statistical analyses were performed on $\log_{10}$ (c/f +1) transformed data; however, untransformed c/f data are used in the text and tables, except where noted, to facilitate comparison.

Electrofishing runs were made on the left and right banks of the reservoir at stations 1, 3, and 4. T-tests were used to compare c/f at left and right banks of these stations to determine if data could be pooled for subsequent analyses. Both c/f of all species combined and c/f of combined important species were tested. Monthly catch data were grouped and analyzed by quarters in the same manner and for the same reasons as gill netting data.

Effects of year, station, quarter, and interactions of these variables on c/f of combined important species were tested with three-way Multivariate Analyses of Variance (MANOVA). The relative influences of these three main variables and their interactions on the whole fish assemblage sampled effectively by electrofishing were identified with MANOVA.

Three-way univariate Analysis of Variance (ANOVA) tested effects of year, station, quarter, and their interactions on c/f of each important species. Relative contributions of each species to the whole assemblage effects observed with MANOVA were identified with this procedure. Duncan's New Multiple Range Test was used to identify significantly different c/f values by year, station, and quarter.

9.2 Results and Discussion

9.2.1 Fish Eggs and Larvae

Table 9-3 lists dates, number of samples, and mean temperatures (all depths) by sample period for each year of preoperational monitoring. Table 9-4 lists scientific and common names for each taxon discussed in this section.

Fish Eggs--Fish eggs were numerous in ichthyoplankton collections from the BLN site during all years of preoperational study (table 9-5). Seasonal densities ranged from 592/1,000 m^3 in 1982 to 2,134/1,000 m^3 in 1980 (table 9-6). Freshwater drum eggs comprised more than 95 percent of total eggs collected each year. They were the only eggs collected from the Murphy Hill transect (TRM 369.5) in 1977.

Freshwater drum eggs first occurred in samples at BLN in late April or early May when water temperatures ranged between 16.9 and 23.5°C. They were present until the end of the sampling season, mid to late August, all years. Peak densities were observed from late May to mid-June (figure 9-4) at water temperatures ranging from 21.5 to 27.8°C.

Seasonal (average) densities of freshwater drum eggs among years were variable and no apparent trend in diel distribution was noted (table 9-7). Horizontal distribution was similar most years in the channels on either side of Bellefonte Island (table 9-8). However, within either channel, seasonal densities were sometimes quite different between stations, but no trend in horizontal distribution was obvious through the years. For example, in 1979 seasonal densities of freshwater drum eggs were much greater from the station on the right side of the south channel than from the left. In 1980 the left station had much greater densities. Vertical distribution of freshwater drum eggs within stations was uniform most years (table 9-9). The mid-channel epibenthic samples from the north side of Bellefonte Island generally contained seasonal densities of freshwater drum eggs as high as or higher than the other channel strata.

The planktonicity of freshwater drum eggs makes them vulnerable to capture by larval fish sampling gear. The abundance and generally uniform distribution of freshwater drum eggs in collections from the BLN site indicated that the Tennessee River upstream of this area is an important spawning area. Ichthyoplankton data collected in 1975 (TVA 1976) from three transects on the Tennessee River near the Widows Creek Steam Electric Plant (WCF) support this hypothesis (table 9-10). The lowest seasonal density from these samples was observed at the WCF upstream transect approximately 13 miles downstream of Nickajack Dam (TRM 424.7). Densities of freshwater drum eggs were higher at the WCF plant transect (TRM 408) and highest at the downstream transect (TRM 401.1). Seasonal densities of drum eggs from the BLN transects were lower than the WCF downstream transect. These data suggest that in 1975 an important freshwater drum spawning area existed between TRM 408 (WCF plant transect) and TRM 401.1.

Seasonal occurrence of freshwater drum eggs at BLN is consistent with results of other TVA studies. Spawning by freshwater drum occurs earlier and lasts longer in the Tennessee Valley than in Lewis and Clark Lake on the Missouri River as reported by Swedburg and Walburg (1970).

They reported spawning in pelagic areas over a period of 6-7 weeks in June and July after water temperatures reached 18°C.

Fish Larvae--Composition of ichthyoplankton samples collected near BLN was fairly stable five of the seven years with a range of 20-24 taxa taken at the plant transect (table 9-5). Extremes occurred in 1980 (30 taxa) and 1982 (17 taxa). Lowest seasonal density for total larvae during the study period was observed in 1982 (table 9-6). Twenty-five taxa were collected from the Murphy Hill (TRM 369.5) transect in 1977 compared to 22 from the BLN plant transect. The total number of larvae collected at Murphy Hill was also greater (table 9-5) which is attributable to more overbank samples from this transect.

Eleven taxa: unspecifiable clupeids, unspecifiable cyprinids, *Cyprinus carpio*, catostomids (Ictiobinae), *Ictalurus punctatus*, *Morone* spp., *Morone* (not *saxatilis*), *Lepomis* spp., *Pomoxis* spp., unspecifiable percids (including darters) and *Aplodinotus grunniens* were collected all seven years (table 9-5). Ictiobinae, a subfamily of Catostomidae, is included in this group though not identified as such in 1978 and 1979 collections. Because ictiobines amounted to more than 98% of the total catostomid larvae collected during the other five years of this study, the unspecifiable catostomids in the 1978 and 1979 collections will also be considered members of the subfamily Ictiobinae. *Hiodon tergisus*, *Ictalurus furcatus*, and *Stizostedion canadense* larvae were present in collections six of the seven years of study. Identifications of *Stizostedion* spp. from 1977 and 1978 are now deemed sauger larvae (Scott, MS).

Composition and relative abundance of larvae in collections from the BLN site on Guntersville Reservoir were similar to those reported for collections from the adjacent Wheeler and Nickajack Reservoirs (TVA 1978 and 1979). At BLN unspecifiable clupeids was the most abundant taxon in samples all years comprising 59 to 94 percent of total larvae collected (table 9-5). Freshwater drum larvae were second in abundance and the only other taxon to exceed one percent relative abundance each year. Percichthyid larvae exceeded one percent of total catch five of the seven years, ranging from 2.9 to 6.4 percent relative abundance during the period 1979-1983. Numbers of catostomid larvae exceeded one percent relative abundance for three years with a peak of 9.5 percent composition in 1979. Although Lepomis spp. larvae were present in samples all years, numbers were relatively low from the plant transect. There, collections exceeded one percent relative abundance only in 1982 and 1983. The higher percent composition of lepomids at the Murphy Hill transect (TRM 369.5) in 1977 (table 9-5) is the result of more samples from shallow overbank areas. Unspecifiable cyprinids was the only other taxon to exceed one percent relative abundance in a year (1979). Several of lepomids at the Murphy Hill transect (TRM 369.5) in 1977 (table 9-5) is the result of more samples from shallow overbank areas. Unspecifiable cyprinids was the only other taxon to exceed one percent relative abundance in a year (1979). Several of lepomids at the Murphy Hill transect (TRM 369.5) in 1977 (table 9-5) is the result of more samples from shallow overbank areas. Unspecifiable cyprinids was the only other taxon to exceed one percent relative abundance in a year (1979). Several morphologically distinct species-groups of cyprinds are included in this category, which makes further analysis of spatio-temporal distribution impractical due to the different seasonal abundance patterns of the various taxa represented.

Seasonal density of total larvae collected at BLN was highest in 1977 and lowest in 1982 (table 9-6). Each year seasonal peak densities occurred during a two week period in mid-May, usually paralleling peak densities of clupeids. Water temperatures associated with seasonal peak densities were variable, ranging from 16.3 to 23.6°C (table 9-6). Annual peak abundance of larvae at the BLN site was between the early May peaks reported for Nickajack Reservoir and early to mid-June peaks reported for Wheeler Reservoir (TVA 1978 and 1979).

Abundance and distribution of the four most abundant larval taxa (unspecifiable clupeids, freshwater drum, ictiobines and percichthyids) and other selected taxa collected from the BLN transect are discussed below.

Polyodon spathula--Larval paddlefish collected during this study were included as part of a summary of all of TVA's early life history data for paddlefish (Wallus 1983). Paddlefish larvae were not collected every year of this study, and when present were found in low numbers (table 9-5). However, the commercial importance of this species makes it appropriate to summarize all the data previously reported which included collections from BLN during the period 1974-82.

Based on lengths and calculated age estimates of paddlefish larvae collected from the BLN site and transport computations, the

Tennessee River from Nickajack Dam downstream to the BLN site was identified as a paddlefish spawning area. Larval paddlefish were present in BLN samples 6 of the 10 years, 1974-1983. They were collected only in April when water temperatures were 12-21°C, and most were collected at night. Horizontal distribution was widespread. Paddlefish larvae were present in samples from all stations across the reservoir at the Bellefonte site. No apparent trends in vertical distribution were observed at the BLN site; however, data from other locations (Cumberland and Gallatin Steam Plants) documented greater numbers of paddlefish larvae near the surface. Also, large numbers of paddlefish larvae in individual samples suggest they are swept downstream as a contagious group. Annual fluctuations in abundance of paddlefish larvae from the BLN site are related to discharges from Nickajack Dam. Greater numbers of paddlefish larvae were collected during years of highest flows (Wallus 1983).

Unspecifiable clupeids--Unspecified clupeids first appeared in samples during mid to late April in water temperatures ranging between 13.6 and 18.5°C. Peak densities usually occurred by mid-May (figure 9-5), but clupeids were typically abundant in samples from their first occurrence in April through the month of June. This pattern of occurrence is similar to those reported from Nickajack and Wheeler Reservoirs (TVA 1978 and 1979). Annual seasonal densities at BLN varied with greatest densities observed in 1977 (table 9-7). The 1977 collections included samples from shoreline areas at the plant transect which would account for the higher seasonal density of shad larvae compared to other years. Samples during 1978-1983 were all from channel stations at the plant transect, and annual seasonal densities, though variable, were not greatly different. As expected, horizontal distribution data from the plant transect showed greatest densities of unspecified clupeids from shoreline stations (table 9-8). With a few exceptions, annual horizontal (table 9-8) and vertical (table 9-9) distributions were relatively uniform from the main channel stations. Only in 1980 was there an obvious difference in densities between the channels north and south of Bellefonte Island. Densities of unspecified clupeids were higher in daytime collections in 1977 and 1978 (table 9-7), but diel densities were relatively uniform for the remaining five years of the study.

Ictiobinae (Buffalos and carpsuckers)--Ictiobine larvae usually first appeared in collections from late March to mid-April (figure 9-6) at water temperatures ranging from 12.8 to 18.5°C. Annual abundance was variable with peaks occurring in 1978, 1979, and 1983 (table 9-5). This variability in abundance is probably related to water flow. Osburn and Self (1964) stated that spring rains and flooding were an apparent stimulus for spawning of _Ictiobus_ _bubalus_ and _I_. _cyprinellus_ in Oklahoma. They indicated that if proper water conditions were lacking, spawning might not occur or the spawn might be light. Seasonal densities of ictiobine larvae from BLN collections compared to corresponding discharge rates from Nickajack Dam support this hypothesis (table 9-11). Highest seasonal densities occurred in years of higher mean discharges.

Peak densities of ictiobine larvae were typically greatest in mid to late April at temperatures ranging from 13.9 to 21.0°C (figure 9-6). A second peak in abundance was seen in June of some years (most obvious in 1979 and 1981) at water temperatures ranging from 24.5 to 25.8°C.

Wrenn and Grinstead (1968) reported that, in 1967, smallmouth buffalo (I. bubalus) spawned as early as March 28 and continued until May 25 in Wheeler Reservoir. Water temperatures in Wheeler during that period were almost identical to those recorded during the first annual peak in ictiobine densities in this study. They also reported a peak spawning period in Guntersville Reservoir in 1966 (April 14-26) for smallmouth buffalo identical to the times of peak abundances of ictiobines in this study. Temperatures (15.0-16.7°C) in 1966 were also compatible with those of this study. Walburg and Nelson (1966) reported that smallmouth buffalo spawned between May 25 and June 20, 1964 in Lewis and Clark Lake on the Missouri River. However, spawning temperatures (16.7-21.1°C) were similar to those during peak abundances in this study. Also, heaviest spawning of bigmouth buffalo (I. cyprinellus) in the Qu'appelle River in Saskatchewan was reported by Johnson (1963) in waters 15.5-18.3°C. Guidice (1964) reported optimum spawning temperatures for buffalo between 18 and 23°C.

Secondary peaks in ictiobine larval densities occurred in four of the seven years of this study. Although secondary peaks in 1977 and 1980 (figure 9-6) were results of collections of only three and two ictiobine specimens, respectively, in 1979 the secondary peak was composed of approximately 9 percent (298) of the total ictiobine catch and in 1981 it constituted approximately 61 percent (67) of the total catch. In both 1979 and 1981, the secondary peaks were preceded by at least one sample period from which no ictiobines were collected. This disjunct occurrence coupled with higher temperatures at times of the second peak suggest that these secondary annual peaks may be the result of carpsucker spawns. Although Gale and Mohr (1976) document quillback (Carpiodes cyprinus) spawning in the Susquehanna River from late April to mid-June at water temperatures ranging from 10-20°C, other literature indicates higher water temperature requirements for carpsucker spawning. Jester (1972) reported spawning temperatures of 19.4-23.3°C in New Mexico, 21.1-24.4°C in South Dakota and 23.9°C in Oklahoma for the river carpsucker (C. carpio). Fuiman (1978) found river carpsucker eggs in Virginia on 20 May at water temperatures of 22°C.

Day and night densities of ictiobine larvae in collections were variable (table 9-7). Spatial distribution was basically uniform at the BLN site with no trend observed horizontally (table 9-8) or vertically (table 9-9). This differs from data reported from Nickajack Reservoir where catostomid larvae were more abundant in deeper water both day and night (TVA 1979).

Ictalurus punctatus and Ictalurus furcatus-- Although larvae of these catfish species were collected each year at BLN, they were never abundant (table 9-5). They are discussed at this point to document two important patterns of temporal/diel distribution. With the exception of 1982, channel catfish first occurred in larval fish collections every year between June 6 and June 20 at water temperatures between 24.5 and 25.8°C. Channel and blue catfish larvae were collected, almost exclusively, at night (table 9-12). Walker (1975) and TVA (1979) reported similar findings from Nickajack Reservoir.

Percichthyidae (Morone spp. and Morone (not saxatilis))-- Temperate bass larvae were typically collected at the BLN plant transect from late March through June (figure 9-7). Seasonal densities among years were variable and low with relatively uniform diel distribution (table 9-7). Densities of percichthyid larvae were higher from shoreline stations in 1977 than from channel stations. Densities from channel stations were relatively uniform horizontally, but were generally higher in the south channel the last five years of the study (table 9-8). Vertical distribution patterns varied and showed no trend in the total densities of percichthyid larvae collected (table 9-9). However, smaller larvae were more abundant in the deeper waters. All larvae collected from the mid-channel epibenthic station were 6 mm or less in TL and 91 percent were newly hatched (3-4 mm TL). This is not surprising because percichthyid eggs are demersal and adhesive and hatching occurs on bottom.

Perca flavescens--The yellow perch was introduced into Chatuge Reservoir on the Hiwassee River in 1953 (Timmons 1975). Its gradual spread in distribution in the Tennessee River system makes documentation of spawning success worthwhile. Yellow perch larvae were first collected in Guntersville Reservoir at the BLN site in 1980 and were present in low numbers the following two years (table 9-5). Larvae were found in samples collected on 4/17/80, 4/14/81, and 4/26/82. Water temperatures ranged from 15.3 to 18.5°C for these collection dates.

Stizostedion canadense--Sauger larvae were never abundant in BLN larval fish samples (table 9-5), yet their presence most years is considered important. In the Tennessee Valley, sauger spawn in the riverine headwaters of reservoirs, and regular occurrence of newly hatched larvae at the BLN site documents the headwater of Guntersville Reservoir below Nickajack Dam as an important spawning area (Scott, MS).

The riverine nature of Guntersville Reservoir from Nickajack Dam downstream to BLN provides very few overbank refuge areas. Therefore, sauger larvae hatched upstream of BLN are subject to transport down river, past the sample stations. Nelson (1968) collected sauger larvae ranging from 4.5 to 6.2 mm TL in plankton nets set below spawning areas in the Missouri River.

Scott (MS) considered spans of sauger larvae occurrence at BLN indicative of durations of spawning seasons during the period 1976-1980 because early prolarvae were consistently captured (table 9-13). He reported newly hatched larvae first appearing in 1976 on March 22 at a water temperature of 13.4°C. They were present in samples for the next three weeks until April 12, when water temperatures reached 17.1°C, indicating a 4-week spawning season. During this study, sauger larvae first occurred in samples from late March to mid-April (figure 9-8) at water temperatures ranging from 12.8 to 18.5°C. Spawning duration similar to that of 1976 was implied by the biweekly data of 1977, 1979, and 1980, when 5- and 6-mm larvae were collected during two or three consecutive sampling periods.

Scott reported that analysis of variance detected significant differences in the abundance of sauger larvae transported past the Bellefonte site in 1976 between day versus night samples, and shallow versus deep samples. Most larvae were collected at night, and were more abundant in samples from deep strata. During this study, most sauger larvae were collected at night (table 9-14). In 1979 and 1980, the two years of greatest sauger abundance, 84 and 71 percent, respectively, of the sauger larvae collected were from night samples. During most years of this study, numbers of sauger larvae in collections were too low to identify trends in vertical distribution.

Aplodinotus grunniens--Percent composition of freshwater drum larvae at the BLN plant transect varied, from 2.3 in 1977 to 31.1 in 1983 (table 9-5). They first appeared in samples in late April most years and were present all years through August when sampling ended (figure 9-9). Greatest densities were observed in June each year. Seasonal diel densities were variable with no discernable trend (table 9-7). Seasonal densities of freshwater drum larvae across the Bellefonte plant transect were relatively uniform, though higher in the south channel most years (table 9-8). With few exceptions, greater densities of freshwater drum larvae were recorded from deep-channel strata (table 9-9). Likewise, densities of freshwater drum larvae from the mid-channel epibenthic station in the channel north of Bellefonte Island were comparable to those from the deep strata of other channel stations.

Seasonal densities of freshwater drum larvae at BLN were always less than densities of freshwater drum eggs. This is not unexpected in that most of the semibuoyant eggs spawned in the river reach between Widows Creek Steam Plant and the BLN site would drift past the BLN sample area prior to hatching.

9.2.2 Juvenile and Adult Fish

Cove Rotenone--Since 1971, 62 fish species have been collected in cove rotenone samples in Guntersville Reservoir. This contrasts somewhat with the number of species (55) that occurred in rotenone samples during the preoperational monitoring period, 1974-1983 (table 9-15). However, as indicated in appendices A and B, numbers and biomass of fish collected in cove rotenone samples were usually dominated by few species with several species occurring incidentally. For any given year since 1974, the total number of species has been comparable. For example, 34 species were collected in 1974 and 31 species in 1983. Numerically, the 1983 samples were dominated by 4 species: Redear sunfish (43 percent), bluegill (24 percent), gizzard shad (14 percent), and threadfin shad (11 percent). Whereas biomass was dominated by gizzard shad (54 percent) and redear sunfish (17 percent) (table 9-16).

Standing stock estimates of fish in Guntersville Reservoir by size class and use category are presented in tables 9-17 and 9-18. Total number of fish in all size classes ranged from about 10,000/ha in 1974 to 58,000/ha in 1980, and total biomass ranged from 238 kg/ha in 1983 to 463 kg/ha in 1981. The extreme range in abundance occurred in the young-of-year size class which was usually dominated by lepomids (redear sunfish and bluegill primarily), particularly in 1980 when dense stands of aquatic macrophytes were not treated prior to rotenone sampling. Also, the large number of young-of-year lepomids in 1980 was reflected in the highest estimated game fish biomass, 121 kg/ha. Prey species comprised 64 percent (297 kg/ha) of the highest total biomass estimate in 1981. Standing stock estimates from cove rotenone in Guntersville Reservoir (1974-1983) were similar to those observed in Chickamauga Reservoir, another Tennessee River mainstream reservoir with abundant aquatic macrophytes (TVA 1985).

Although removal of macrophytes in coves prior to rotenone application may alter the composition of the fish population to some degree, this procedure to date has provided relatively consistent population estimates. As indicated from cove rotenone samples in 1980, numbers of young-of-year lepomids are probably underestimated with weed removal. On the other hand, dense aquatic weed stands in coves appear to alter distribution of adults of some species. The overriding purpose of weed removal has been to facilitate fish recovery following application of the rotenone. Also, due to the relative nature of fish standing stock estimates in reservoirs, the importance of collecting comparable samples (power plant preoperation vs. operation) under similar environmental conditions has been emphasized (Barwick 1984).

Temporal Trends--Because cove rotenone samples are generally dominated by few species, emphasis for evaluating population trends has been focused on these important (dominant) species. Eleven species were ranked important in the preoperational monitoring period (1974-1983) for BLN (table 9-19). Four species (bluegill, redear sunfish, largemouth bass, and gizzard shad) occurred in every sample. Numerically, cove rotenone samples were dominated by bluegill and redear sunfish, 38 percent and 31 percent, respectfully. Gizzard shad comprised only 11 percent of the population by number, but dominated biomass at 44 percent. Biomass composition by bluegill and redear sunfish was 13 percent and 9 percent, respectfully. Largemouth bass constituted about 4 percent of estimated total biomass during the preoperational period. Results of linear regression analyses (table 9-20) and numerical abundance and biomass estimates of young, intermediate, and adult size classes of the eleven species through time are discussed below.

1. Spotted gar

Biomass of spotted gar, highest in 1974 (11 kg/ha), was dominated by the adult size class (table 9-21). However, biomass of this size class had a significant decreasing trend. The young and intermediate size classes showed neither an increasing nor decreasing trend.

2. Gizzard shad

Total numbers and biomass of this species were highest in 1981, when peak numbers of both young and adult size classes occurred (table 9-22). Generally, standing stock estimates for young-of-year gizzard shad varied more than those for adults. Standing biomass of young shad ranged from 0.08 kg/ha in 1975 to 22 kg/ha in 1981, and biomass of adult shad ranged from 75 kg/ha in 1974 to 294 kg/ha in 1981. Significant increasing or decreasing trends did not occur in either size class.

3. Threadfin shad

Neither increasing nor decreasing trends were found for young or adult threadfin shad. Highest biomass (15 kg/ha) was recorded in 1975, the only year that adults were collected in rotenone samples (table 9-23).

4. Bullhead minnow

Highest numbers (1,167/ha) of bullhead minnow occurred in 1977 (table 9-24), but it was absent in 1974 and 1982 samples. Number of fish of this species showed a significant decreasing trend. Biomass was consistently low, but no trends were noted.

5. Channel catfish

Number of fish or biomass of all size classes of channel catfish showed a significant decreasing trend in the preoperational period 1974 to 1983. Number of fish and biomass for all three size classes was highest in 1975 with a total biomass of 18 kg/ha (table 9-25).

6. Warmouth

Total number (2,200/ha) of warmouth was highest in 1979 and total biomass (6 kg/ha) peaked in 1980 (table 26). Numerically, young-of-year comprised 94 percent of the 1979 sample and 90 percent in 1980. Significant increasing or decreasing trends were not established for any size class of this species.

7. Bluegill

Total biomass estimates for bluegill ranged from 52 kg/ha in 1977 to 12 kg/ha in 1981 (table 9-27). The greatest variability in standing stocks for this species occurred in young-of-year and intermediate size classes. For example, from 1974 through 1979, mean percent composition of total biomass by intermediate size bluegill was 37 percent, and in the last four years (1980-1983) it was 22 percent. Number and biomass of adults were generally more stable, but on the basis of regression analyses, number of young, intermediate, and adults and biomass of intermediates and adults had a significant decreasing trend.

8. Longear sunfish

Total biomass estimates for longear sunfish did not exceed 2 kg/ha, except in 1976 when it was 3.9 kg/ha (table 9-28). This species was not collected in cove rotenone samples in 1983. Both number and biomass of all three size classes had a significant decreasing trend.

9. Redear sunfish

Total biomass estimates of all three size classes of redear sunfish ranged from 60 kg/ha in 1980 to 10 kg/ha in 1982 (table 9-29). With exception of 1980, number and biomass of the adult size class were relatively uniform compared to those for young-of-year. Numbers of young ranged from 25/ha in 1974 to about 41,000/ha in 1980. However, linear regression analysis showed that only number and biomass of adults had significant decreasing trends. Number and biomass of young-of-year redear showed an increasing trend, but not statistically significant.

10. Largemouth bass

Total estimated biomass for the three size classes of largemouth bass ranged from about 8 to 16 kg/ha (table 9-30). Number and biomass of the intermediate and adult size classes were relatively uniform throughout the preoperational period 1974 through 1983, showing no significant increasing or decreasing trends. However, significant decreasing trends were noted for number and biomass of young bass. Number of fish in this size class ranged from 407/ha in 1976 to 24/ha in 1981.

11. Freshwater drum

Except for biomass of young-of-year drum, numbers and biomass of all size classes of this species had significant decreasing trends. The highest biomass (94 kg/ha) occurred in 1981, but no young-of-year drum were present in rotenone samples that year (table 9-31).

<u>Gill Netting</u>--A total of 37 fish species, and one stocked hybrid (white bass x striped bass), in 11 families was captured by gill netting

during the 35 month sampling period (915 net nights). Total catch was 8,853 fish. Three species accounted for 56 percent of total catch (table 9-32): gizzard shad (24 percent), yellow bass (16 percent), and skipjack herring (16 percent). Fifteen fish species qualified as important. These are listed by overall c/f in table 9-33.

No significant differences ($\alpha = 0.05$) were found in c/f of all fish species combined when comparing left and right banks within stations (t-tests). A similar set of comparisons using combined important species revealed a significant difference ($\alpha = 0.05$) in c/f between left and right banks only at station 1 during fall quarter. Because 11 of 12 comparisons of important species c/f showed no significant difference between left and right banks, all catch data within stations were pooled for subsequent analysis.

MANOVA revealed significant effects for quarter, year, station, and year x quarter interaction on c/f of the important species assemblage (table 9-34). The greatest effect was from quarter, a predictable result because catchability of fish in nets is greatly influenced not only by seasonal changes in distribution and abundance (e.g., spawning migration and recruitment) but by seasonally varying environmental factors (e.g., water temperature and velocity) that affect actions of fish. The next greatest effect was among years followed by year x quarter interaction and by station effect (table 9-34).

Effects of quarter, year, station, and year x quarter interaction on individual important species were examined in three-way ANOVA. Quarter had a highly significant effect ($\alpha = 0.01$) on c/f of all but two important species, golden shiner and largemouth bass (table 9-35).

These quarterly differences are apparent in table 9-36, a listing of mean quarterly c/f for all important species. Generally, c/f was greatest during spring or summer with sauger and white crappie being exceptions. Sauger c/f was highest during winter, white crappie during fall. As noted previously, these quarter effects reflect seasonal trends in distribution, daily movement patterns, etc., that could be partially explained by examining the biology of each species. Such detail would serve no purpose in this report. Operational monitoring data should be examined for significant deviations from these seasonal relative abundance trends. If differences were found, it would be necessary then to examine in detail the biology of any affected species to identify potential causative factors.

Year had a highly significant effect on c/f of 8 important species: spotted gar, skipjack herring, mooneye, channel catfish, white bass, white crappie, sauger, and freshwater drum (table 9-35). Station, however, influenced c/f of only two species, spotted gar and longnose gar. Year x quarter interaction had a highly significant effect (α = 0.01) on five species, spotted gar, mooneye, bluegill, redear sunfish, and sauger, and a significant effect (α = 0.05) on freshwater drum.

Three-way ANOVA revealed individual important species c/f varied more temporally (both seasonally and yearly) than spatially (by station), hence the greater values for temporal effects in MANOVA. Except for longnose gar and spotted gar, distribution of important species was fairly uniform in Guntersville Reservoir near BLN at any given time (i.e., year and quarter effects excluded). This finding suggests operational impacts of BLN might be most evident in altered distribution of important species captured by gill netting. If station becomes a significant effect for several additional species during operational gill netting, potential impacts of BLN would be indicated.

Two-way ANOVA (year and station) for each quarter and each species removed seasonal effects and clarified spatial and temporal patterns identified in three-way ANOVA. Significant effects of station on spotted gar c/f during summer and fall quarters and on longnose gar during summer were found with this analysis (table 9-37). Examination of catch data by station and Duncan's New Multiple Range Test revealed relative abundance of these two species changed uniformly from upstream to downstream (table 9-37). Spotted gar abundance increased progressing from upstream to downstream stations while longnose gar abundance increased from downstream to upstream. Explanation for the inverse relationship between upstream/downstream c/f for longnose and spotted gar is lacking. Although both species generally spawn in the same type habitat, other habitat preferences are not well documented. Based on frequent occurrence of spotted gar in cove rotenone samples, this species may be more abundant in overbank areas with less current velocity. Downstream gill net stations contain more overbank area than upstream stations where longnose gar dominated. Significant changes in these distribution patterns during BLN operation might indicate plant impacts.

The eight species (identified previously) showing significant year effects in three-way ANOVA were tested for significant year effects by quarter with two-way ANOVA. Only two of these eight species, white bass and sauger, demonstrated a year effect during all four quarters (table 9-38). Catches of both species were significantly greater in 1981 than during subsequent years. Abundance of white bass apparently declined throughout the sampling period. Decline of sauger was not as consistent among quarters as white bass (table 9-35) and year x quarter interaction was highly significant in three-way ANOVA (table 9-35). White bass and sauger move upstream in winter and spring, concentrate in tailwater areas prior to spawning, and then disperse throughout the reservoir during summer. Gill net stations in the vicinity of BLN are in the path of these movement patterns, as indicated by higher c/f in winter for sauger and in spring for white bass.

Significant year effects for mooneye resulted from unusually high c/f for this species during winter and particularly spring of 1981 (table 9-38). Catch of mooneye remained relatively low throughout the rest of the sampling period, and no trends in abundance were evident from summer and fall c/f values. The significant year x quarter interaction for mooneye (table 9-35) reflects this temporal inconsistency. Therefore, it seems more likely year effects for mooneye resulted from unusually high catchability, e.g., high recruitment or unusual movement patterns for winter-spring, 1981, than long term trends in abundance.

Year effects for freshwater drum also resulted from relatively high c/f during winter and spring, 1981T (table 9-38). Inconsistencies among quarters, however, were greater than for mooneye, and year x quarter interaction was significant in three-way ANOVA (table 9-35). As with mooneye, no long-term trends were indicated for freshwater drum.

Year effects for channel catfish were driven by significant differences in c/f among years only during spring, and for white crappie by significant differences only during winter. Year x quarter interaction values were not significant for either of these species in three-way ANOVA (table 9-35). This was reflected in fairly consistent declines in c/f during all quarters over the sample period (table 9-36). It cannot be concluded that abundance of these two species was declining, however, because significant differences were limited to one quarter for each species.

Differences in c/f among years (table 9-38) were highly significant during two quarters for spotted gar (spring and fall), and skipjack herring (winter and spring). Spotted gar c/f was greatest in 1983 during spring quarter (1.16 per net night) but highest in 1982 during fall (0.80 per net night). This inconsistency in quarterly catch among years was reflected in a highly significant year x quarter interaction in three-way ANOVA (table 9-35).

Catches of skipjack herring during winter and spring were significantly greater in 1981 than in 1982 and 1983. These differences were responsible for the highly significant year effect found for this species in three-way ANOVA (table 9-35). However, skipjack herring c/f was highest in 1983 during summer, higher in 1983 than 1982 during spring, and practically equal in 1982 and 1983 during fall. Therefore, no long term trend in abundance was indicated. Fairly uniform changes in c/f among quarters resulted in no significant year x quarter interaction in three-way ANOVA (table 9-35).

Electrofishing--During the 33 month sampling period, 1,625 electrofishing runs yielded 9,086 fish of 26 species representing 10 families. Three species dominated the samples; gizzard shad comprised

62 percent of the total catch, emerald shiner 13 percent, and bluegill 12 percent (table 9-39). Along with these species, redear sunfish and largemouth bass exceeded 1 percent of total catch and qualified as important species (table 9-40).

No significant differences ($\alpha = 0.05$) in c/f of combined important species between left and right banks were found for any of the stations. Only 1 of 12 comparisons between left and right banks showed significant differences in c/f of all species combined, that was at station 3 during fall ($t = 2.288$; probability of exceeding $|T| = 0.040$). In subsequent analyses, catch data from left and right banks at each station were combined.

MANOVA revealed that c/f of the fish assemblage important in electrofishing was significantly influenced by year, quarter, and year x quarter interaction (table 9-41). Quarter exerted the greatest influence, as in the analysis of gill netting catch data. This quarter effect simply reflects combined responses of the five important species to the same seasonally variable physical and biotic factors discussed under gill netting. (Emerald shiner was the only species important in electrofishing not also important in gill netting.) The next greatest effect was from year x quarter interaction followed by year effect (table 9-41).

Quarter effects were highly significant for all important species in three-way ANOVA testing (table 9-42). It is unlikely, however, that these quarterly patterns (table 9-43) could be used to detect BLN operational impacts because of highly significant year x quarter interactions for all important species (table 9-42). Interaction between short term (quarter) and long term (year) temporal effects is evident by inspection of quarterly catch data for each year (table 9-44). Quarterly changes in c/f were not consistent throughout the three years of sampling. For example, highest c/f for emerald shiner in 1981 occurred during spring quarter, in 1982 during winter quarter, and in 1983 during fall quarter. Similar inconsistencies account for year x quarter interactions for all other important species.

Year effect was highly significant for emerald shiner and largemouth bass and significant for bluegill and redear sunfish in three-way ANOVA testing (table 9-42). Catch per effort for bluegill and largemouth bass was highest in 1983, lowest in 1982, and intermediate in 1981 (table 9-45). Emerald shiner and redear sunfish c/f was also lowest in 1982, and practically equal in 1981 and 1983. However, comparison of yearly c/f for each quarter (table 9-44) reveals no consistent time trend for any of these species. As noted previously, significant year x quarter interactions were due to inconsistent yearly trends among quarters.

Station effect was highly significant for emerald shiner and significant for gizzard shad (table 9-42). Duncan's New Multiple Range Test revealed c/f of emerald shiner was significantly greater at station 2 than all other stations except number 3 (table 9-46). Inspection of quarterly c/f data for each station reveals that exceptionally high c/f during fall quarter (table 9-46) was primarily responsible for station differences. Number and c/f of emerald shiner occurring in monthly samples at each station were examined, and four samples with unusually high c/f were found (table 9-47). These four samples accounted for 58 percent of all emerald shiner taken in electrofishing indicating a very patchy distribution of this species. Occurrence of emerald shiner in only 7 percent of all electrofishing runs and significant quarter x station and year x quarter x station interactions further supports this conclusion. Thus, the apparent station effect for thus species does not appear likely to provide a test of BLN impacts.

Duncan's New Multiple Range Test demonstrated gizzard shad c/f was greater at station 2 than in Mud Creek and at station 1 (table 9-46). Gizzard shad displayed a more consistent spatial distribution pattern than emerald shiner. Inspection of quarterly catch data for each station reveals c/f was highest at station 2 during 3 quarters (spring, summer, and winter). There was no significant interaction between station, year, and quarter for gizzard shad in three-way ANOVA testing (table 9-42).

Lack of station effects or significant station interaction terms for all species except emerald shiner suggests potential changes in distribution of these species due to BLN operation could be tested by electrofishing. However, it appears doubtful electrofishing could detect changes in distribution because it provided little information about the Guntersville Reservoir fish assemblage in the vicinity of BLN. Of the 26 species captured by electrofishing, 5 were classified important but only after the criteria were changed from that usually employed. Ordinarily, important species are defined as those occurring in 50 percent or more of all electrofishing runs. With this criterion, only gizzard shad (50.5 percent) would have qualified; therefore, the criteria were modified to make greater use of the data. Even with the modified criteria, information about temporal changes in abundance of all important species was limited by strong year x quarter interactions. Information about distribution of emerald shiner was limited by significant interaction along station, year, and quarter.

Problems encountered with electrofishing data may have been due to ineffectiveness of this gear in sampling littoral habitat near BLN. Approximately 38 percent of all electrofishing runs yielded no fish. Capture frequency (number of fish per electrofishing run) should follow a Poisson distribution. Comparison of observed with expected frequency distributions (table 9-48) demonstrated electrofishing near BLN resulted in an exceptionally high number of runs yielding zero or one fish. From inspection of the data in table 9-48 it is apparent the chi-square test was not needed to determine the distributions were different.

9.3 Summary and Concludions

9.3.1 Fish Eggs and Larvae

Composition and relative abundance of ichthyoplankton in the vicinity of BLN on Guntersville Reservoir was typical of other mainstream Tennessee River reservoirs. Freshwater drum eggs dominated egg collections. Larvae were dominated by clupeids (59-94 percent) with freshwater drum second in abundance (2-31 percent). No other taxon exceeded 10 percent composition in a year. Temperate bass exceeded 1 percent of the total catch five of the seven years of this study and ictiobine larvae exceeded one percent three years. Lepomids and cyprinids were the only other taxa to exceed 1 percent of the total larval catch at BLN in a given year. Lower abundances of the latter two taxa at BLN compared to previous data from Guntersville and to other reservoirs are due to the elimination of overbank sampling at the BLN transect after 1977.

Ichthyoplankton data collected at BLN has aided in documenting the Tennessee River upstream of BLN as an important spawning area for Polyodon spathula (Wallus 1983) and Stizostedion canadense (Scott, MS), two important migratory species. Paddlefish spawns above BLN, as well as ictiobine spawns, appeared related to annual discharge rates from Nickajack Dam. Freshwater drum also spawned in the vicinity of BLN and upstream as evidenced by high densities of freshwater drum eggs from BLN samples.

During the period 1975-1976, ichthyoplankton of Guntersville Reservoir near BLN, while varied, was dominated by clupeids (approximately 70-90 percent of all larvae captured). Cyprinids, catostomids, percichthyids, sciaenids and in certain restricted habitats, centrarchids, were important constituents but neither exceeded 10 percent of the larvae captured (TVA 1977). Data collected during this study period, 1977-1983, indicated no major changes in the relative abundance or distribution of ichthoplankton in the vicinity of BLN.

9.3.2 Juvenile and Adult Fish

Estimates of fish standing stocks by cove rotenone sampling indicated fish populations in Guntersville Reservoir coves were dominated by 11 species although more than 50 species occurred in samples during the BLN preoperational period, 1974-1983. These 11 species were further dominated by 5 species: bluegill, freshwater drum, gizzard shad, large-mouth bass, and redear sunfish. Numerically, these species ranked as follows: bluegill (38 percent), redear sunfish (31 percent), gizzard shad (11 percent), freshwater drum (1.3 percent), and largemouth bass (1.3 percent). Accordingly, biomass composition was: gizzard shad (44 percent), bluegill (13 percent), freshwater drum (11 percent), redear sunfish (9 percent), and largemouth bass (4 percent).

Number or biomass of fish of one or more size classes for 8 of the 11 dominant ("important") species showed significant decreasing trends over the period 1974-1983. Causes for these declining trends were not apparent. However, they did not appear to be associated with any drastic changes in water quality. Presence or absence of aquatic macrophytes in coves may have influenced the standing stock estimates, but this was not clearly defined. For example, number of young-of-year redear sunfish (41,000/ha) was highest with dense growths of macrophytes present, while the highest estimate for number of young-of-year bluegill (22,000/ha) occurred under sparse macrophyte conditions.

Although standing stock estimates of fish in Guntersville Reservoir were comparable to other TVA mainstream reservoirs, considerable year to year variation in these estimates were apparent. In addition to changes in the actual fish population, various factors or conditions can influence standing stock estimates via cove rotenone sampling; however, it is difficult to delineate specific factors for a single given year. Annual estimates for several succeeding years, as presently conducted, is considered the best approach in monitoring potential adverse changes relative to operation of BLN.

Relative abundance of fish species important (dominant) in gill net catches varied more temporally (both seasonally and yearly) than spatially (by station). Consistent trends in relative abundance through the 33-month sampling period were not apparent, except for a decline in white bass. Catch per unit effort of sauger, white crappie, and channel catfish also tended to decline through the sampling period, but these trends were either inconsistent (year x quarter interactions) or not statistically significant. Lack of station effects, except for longnose and spotted gar, suggests BLN operational impacts might be most evident in altered distribution of species dominant in gill netting.

Electrofishing samples provided little additional information about adult and juvenile fish distribution and relative abundance not available from cove rotenone and gill netting. An unusually high number of electrofishing runs yielded no fish. Causes of the low capture rate can only be speculated on at present and may have been due to unsuitability of the sampling method for littoral habitat near BLN.

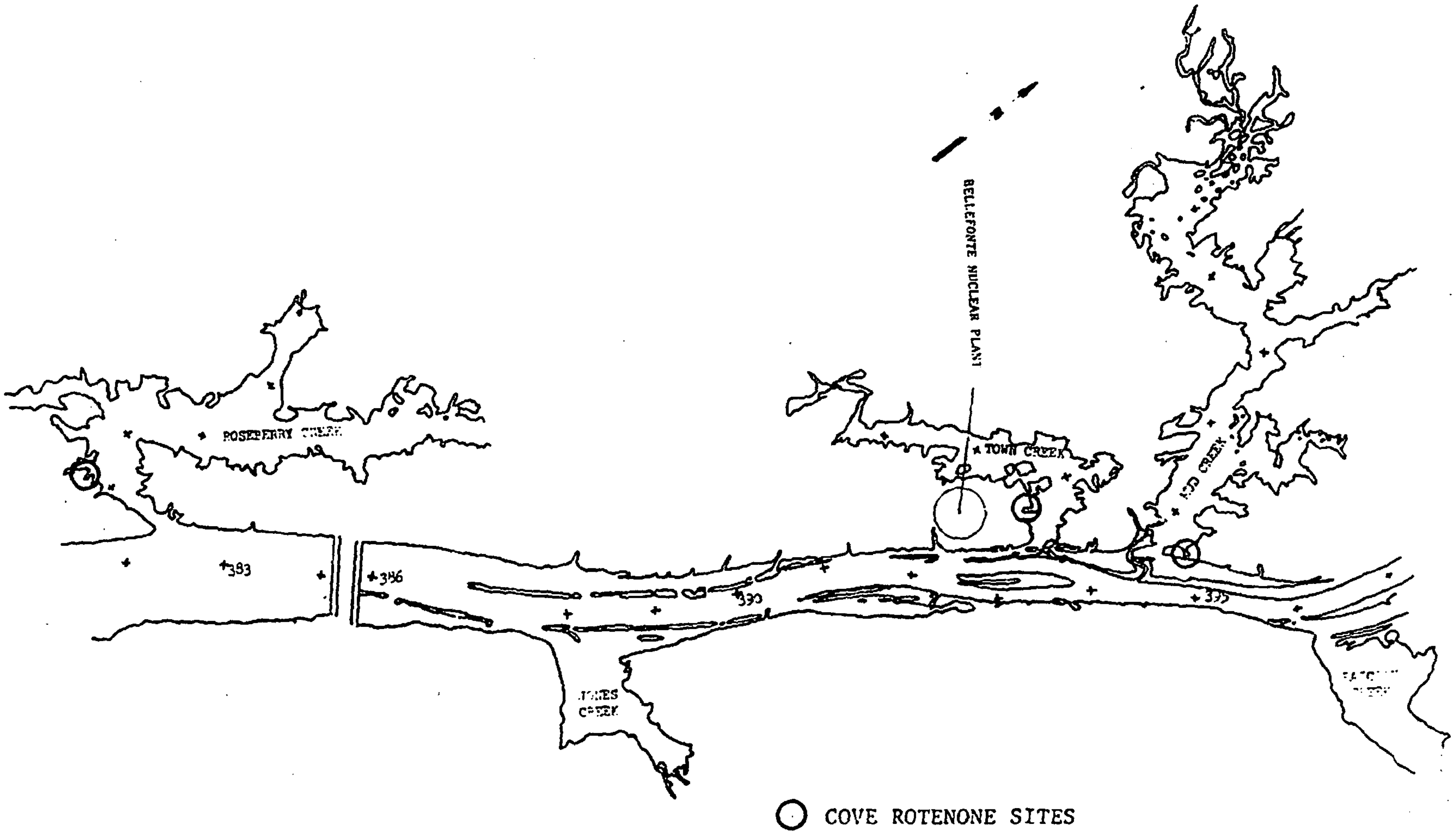


Figure 9-1. Location of Cove Rotenone Sample Sites in Guntersville Reservoir, 1980 Through 1983.

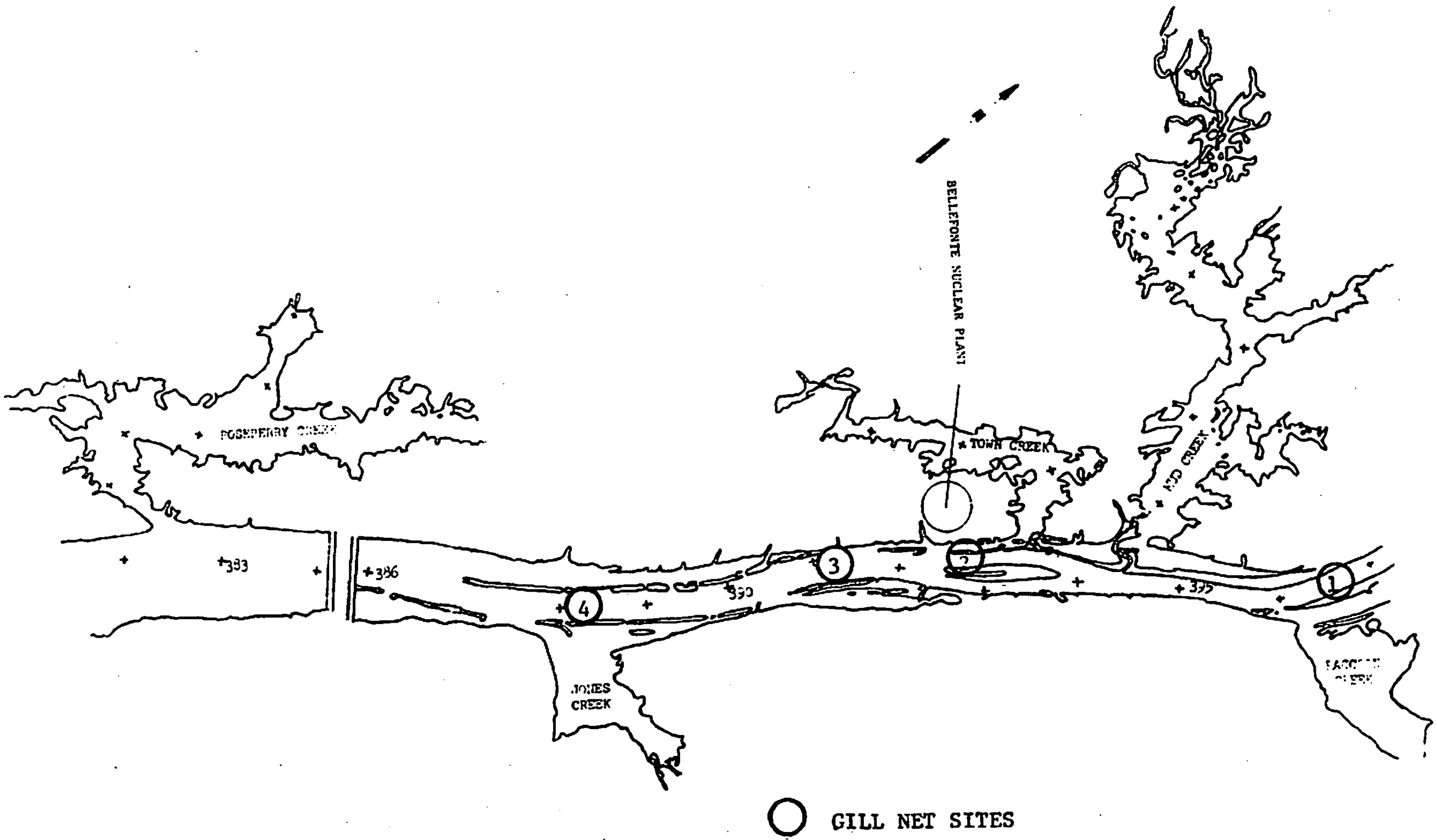


Figure 9-2. Location of Gill Net Sampling Stations in Guntersville Reservoir, 1980 Through 1983.

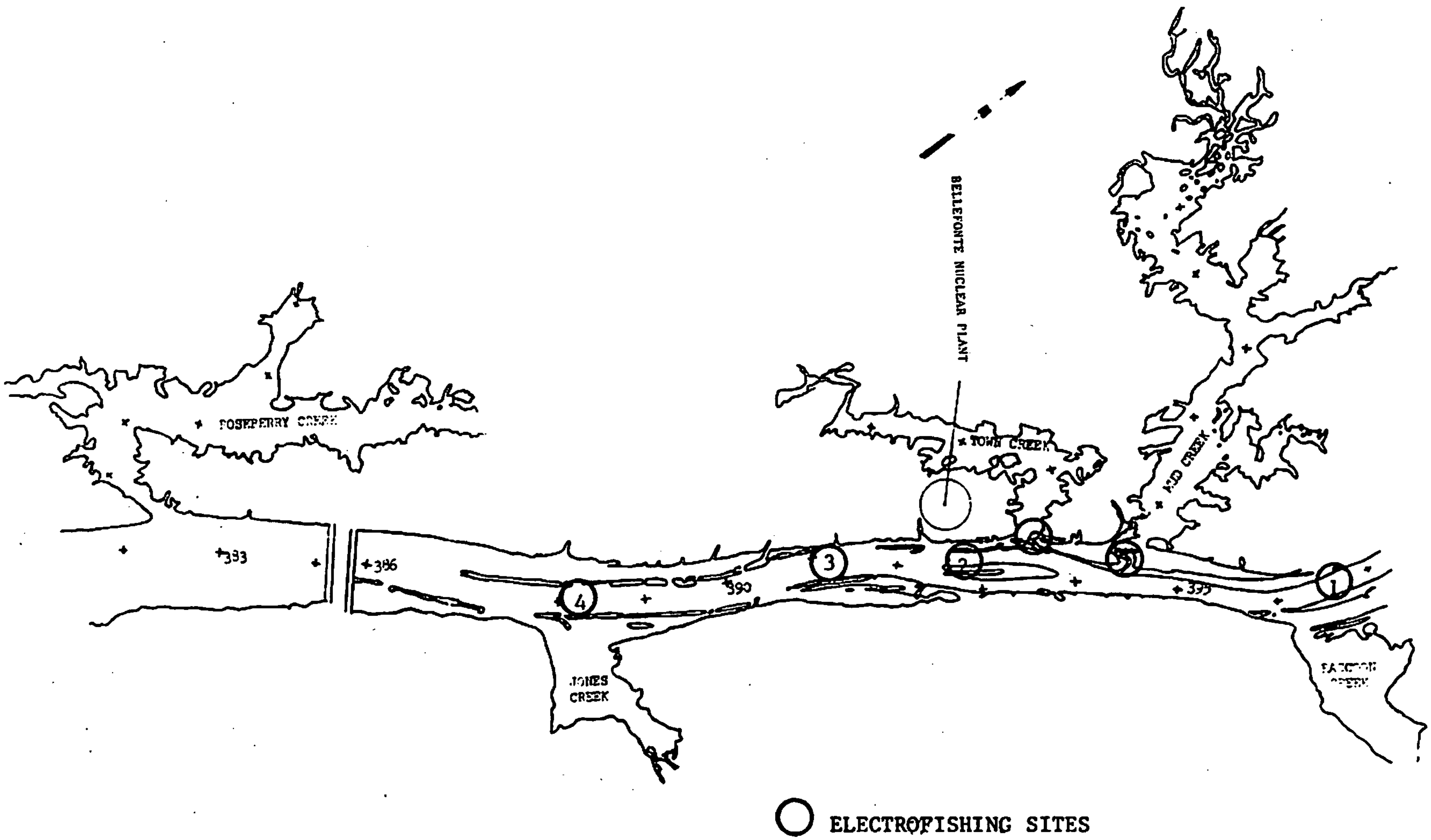


Figure 9-3. Location of Electrofishing Sampling Stations in Guntersville Reservoir, 1980 Through 1983.

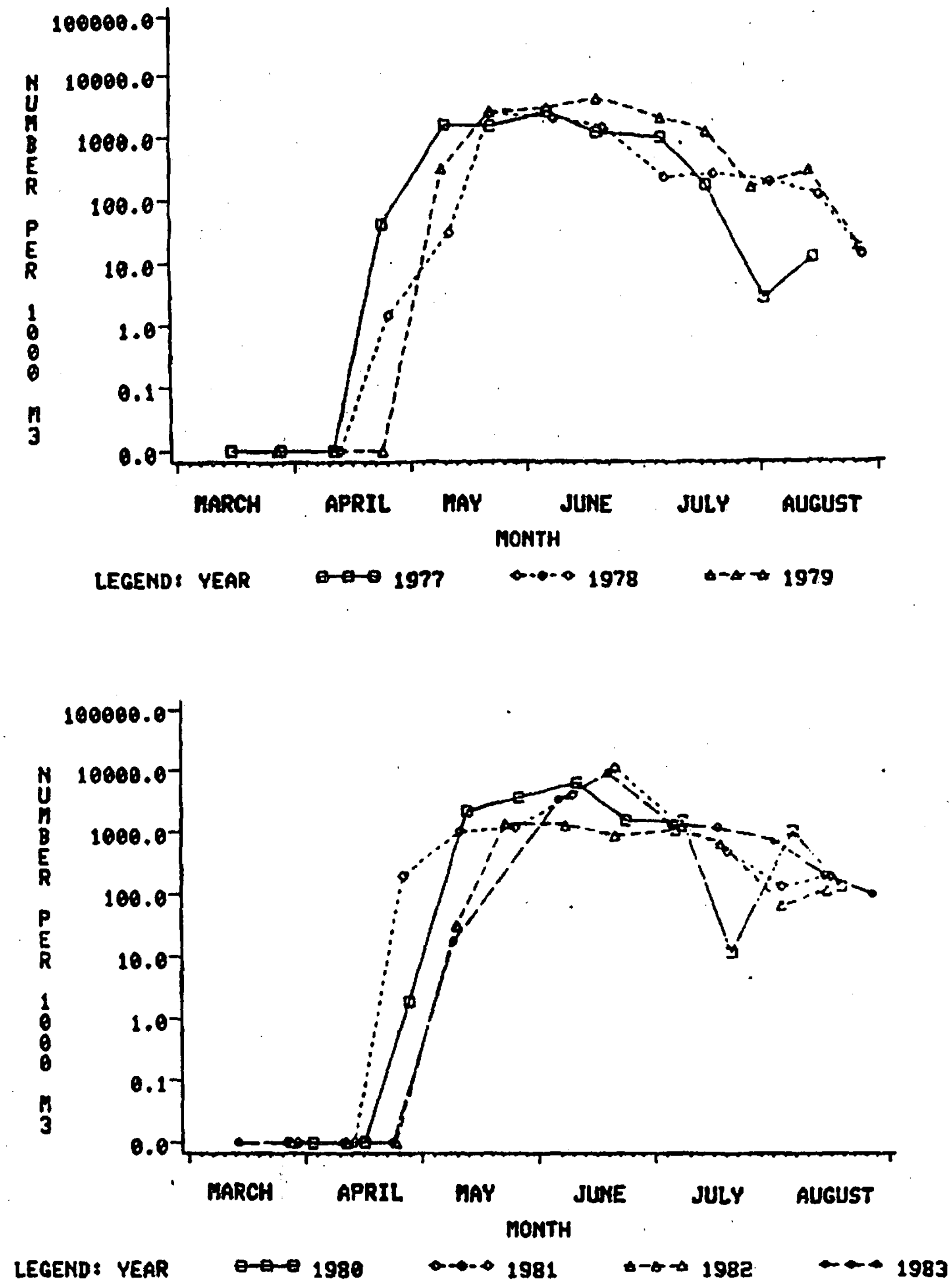


Figure 9-4. Densities (no./1,000 m^3) of drum eggs estimated from collections near the Bellefonte Nuclear Plant site, 1977-1983.

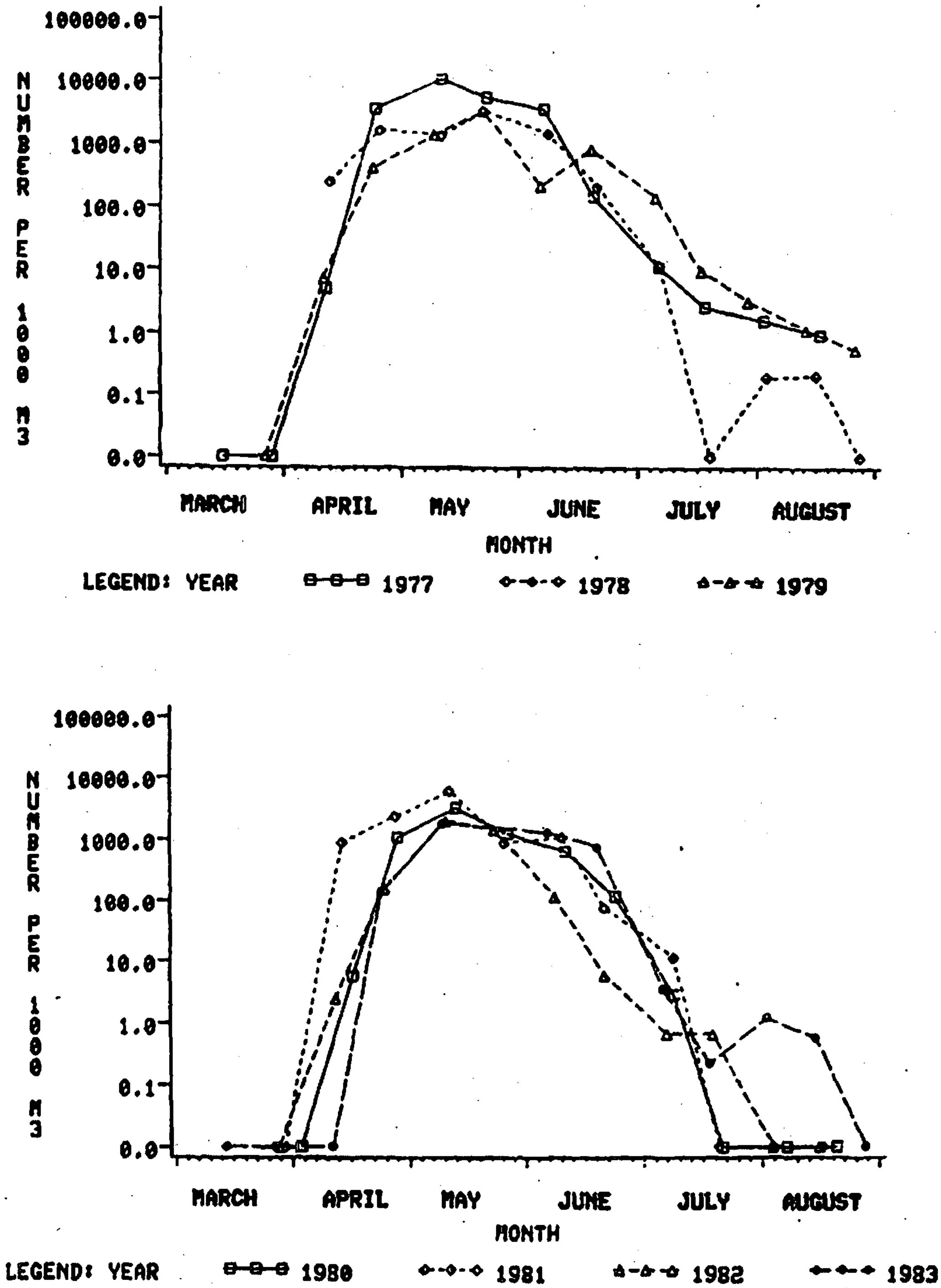


Figure 9-5. Densities (no./1,000 m^3) of unspecified clupeid larvae estimated from collections near the Bellefonte Nuclear Plant site, 1977-1983.

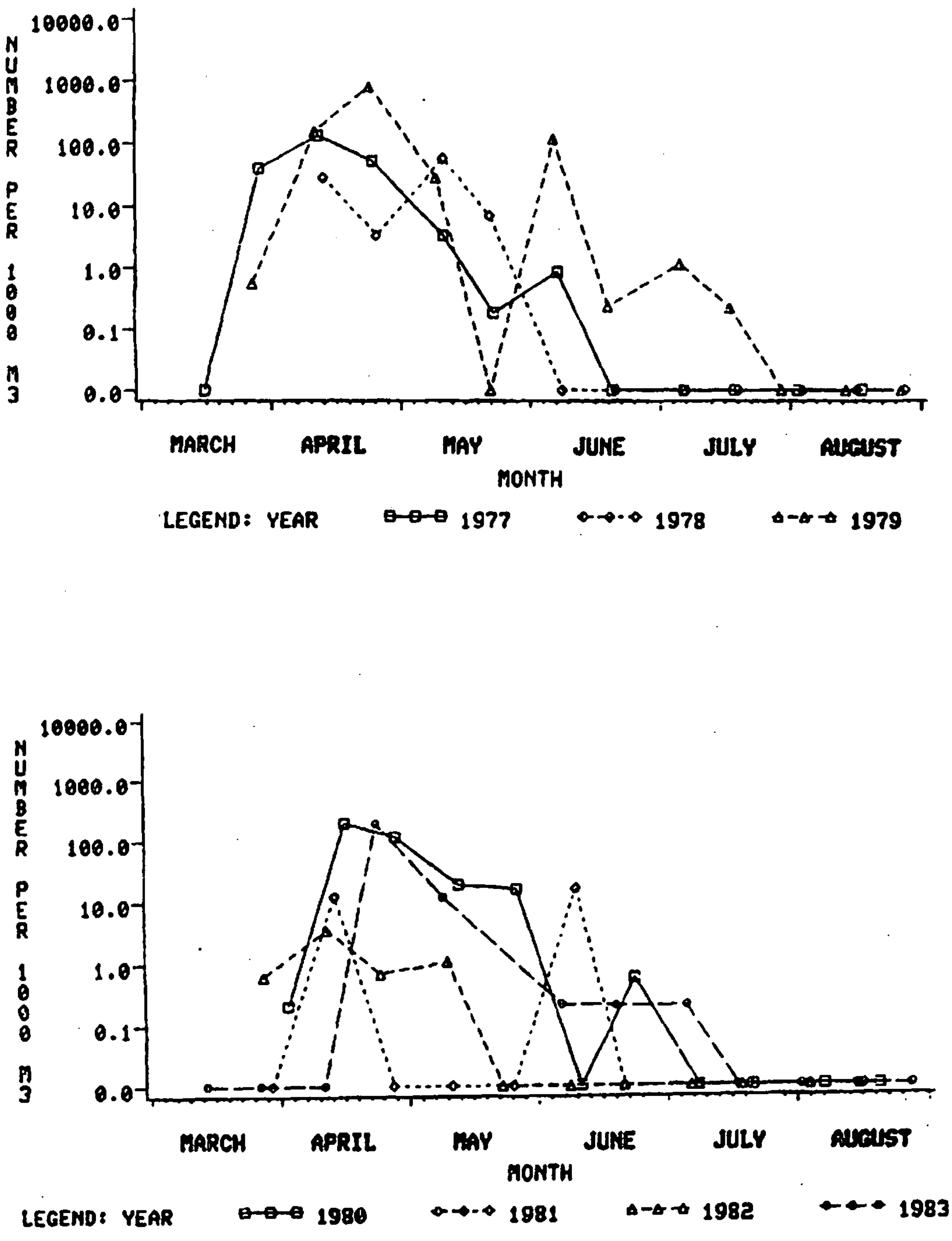


Figure 9-6. Densities (no./1,000 m^3) of Ictiobinae larvae estimated from collections near the Bellefonte Nuclear Plant site, 1977-1983.

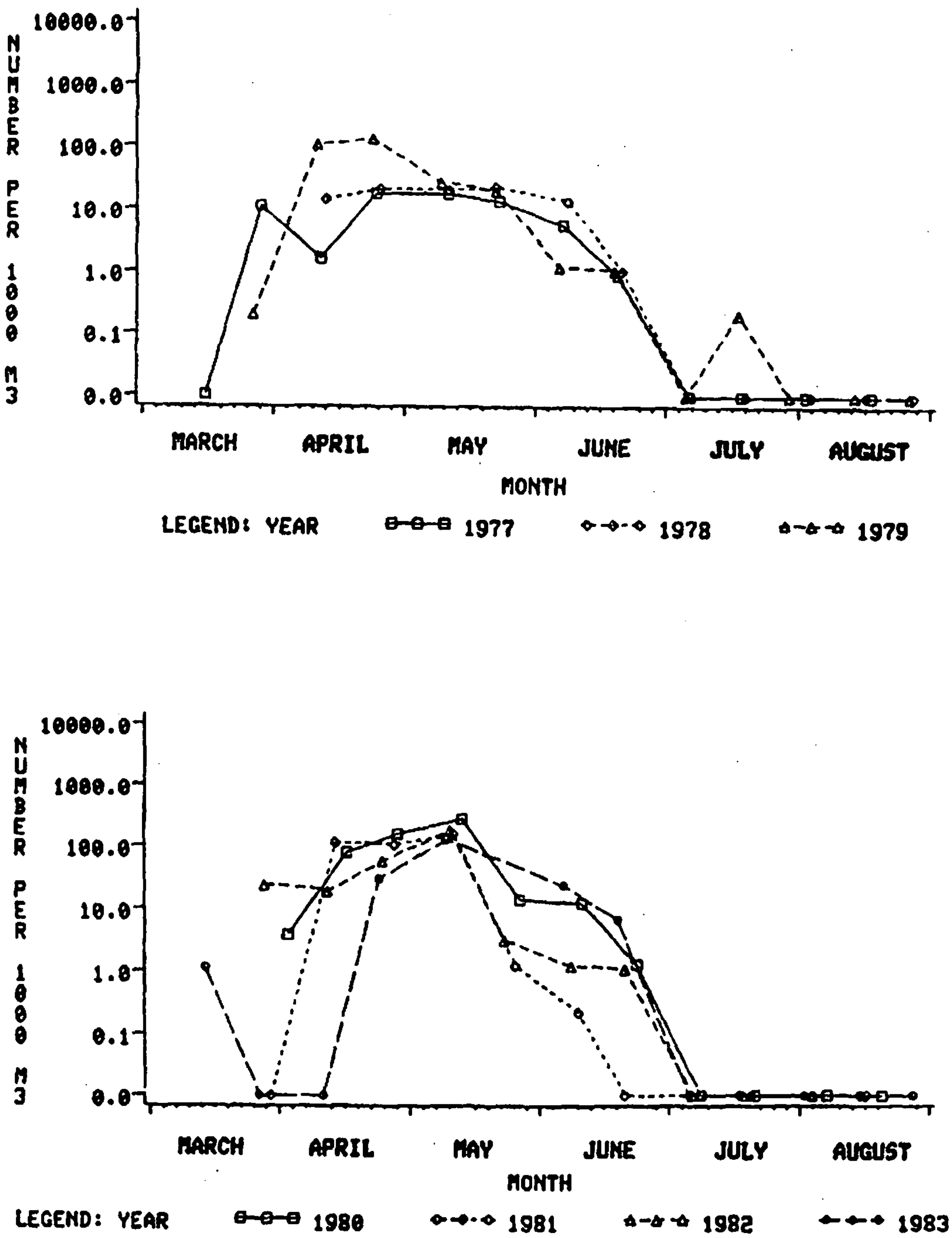


Figure 9-7. Densities (nó./1,000 m^3) of percichthyid larvae (includes <u>Morone</u> (not <u>saxatilis</u>) and <u>Morone</u> spp.) estimated from collections near the Bellefonte Nuclear Plant site, 1977-1983.

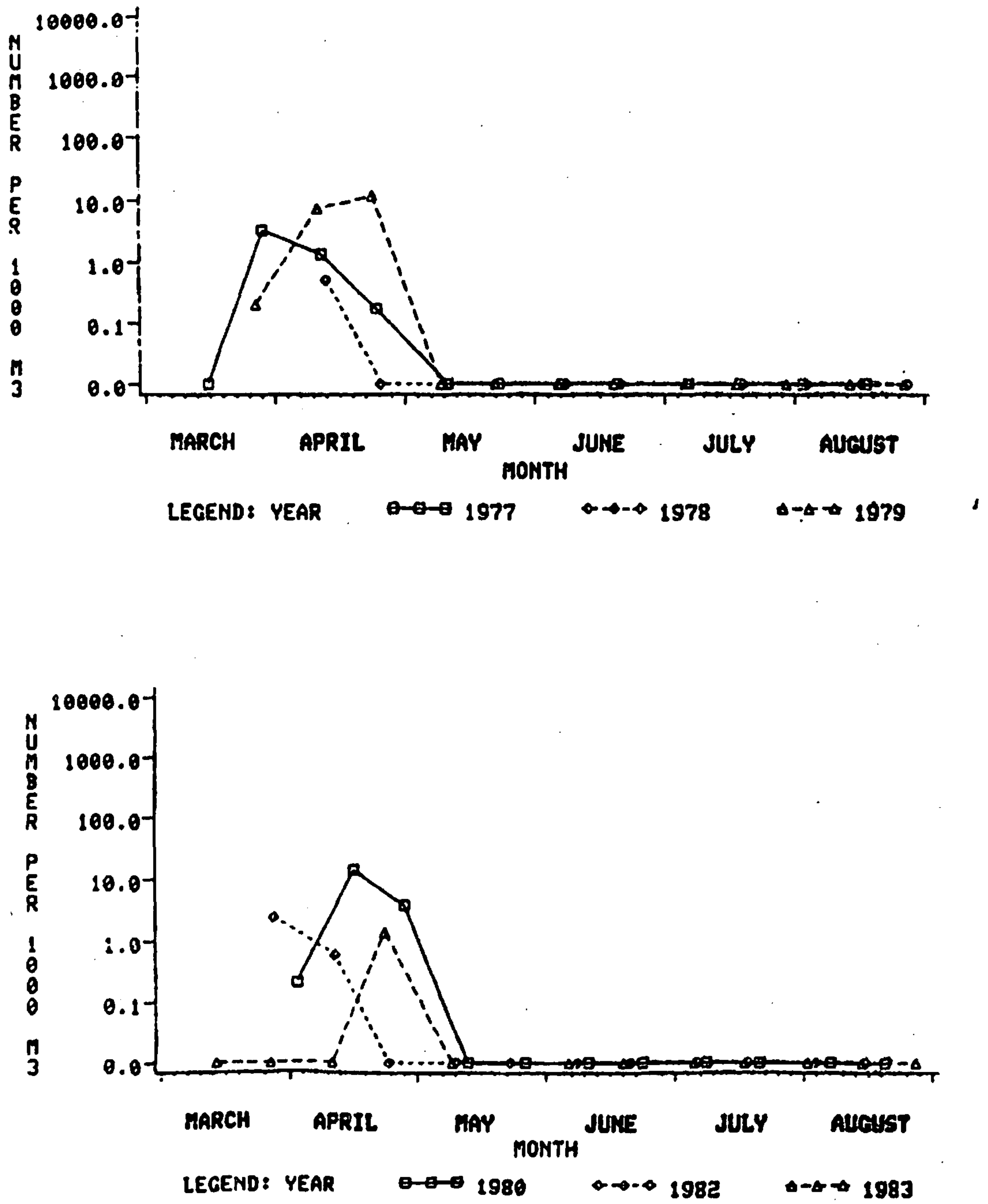


Figure 9-8. Densities (no./1,000 m^3) of sauger larvae estimated from collections near the Bellefonte Nuclear Plant site, 1977-1983.

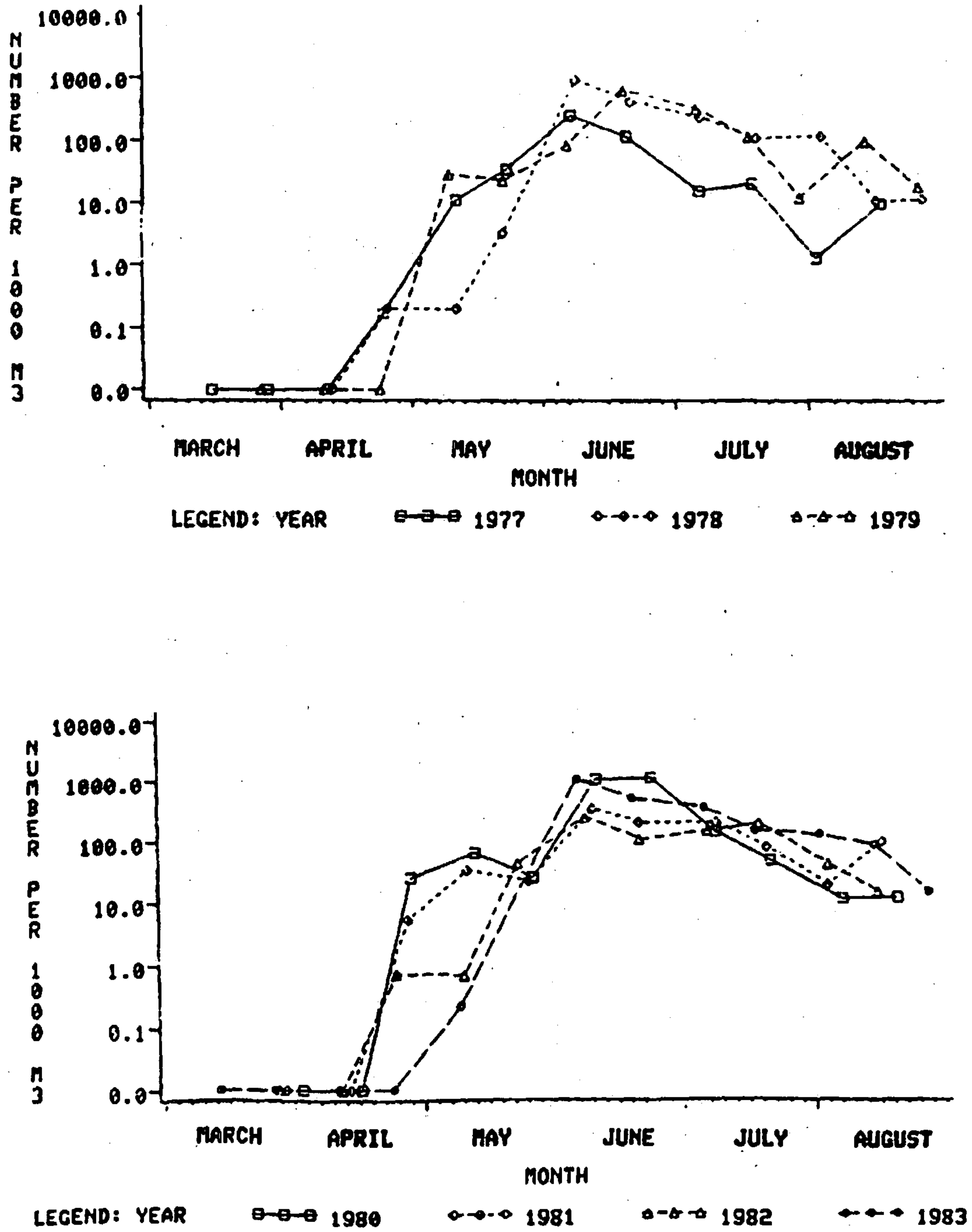


Figure 9-9. Densities (no./1,000 m^3) of drum larvae estimated from collections near the Bellefonte Nuclear Plant site, 1977-1983.

10.0 SUMMARY AND CONCLUSIONS

This preoperational assessment of water quality and biological resources of Guntersville Reservoir near BLN was written to satisfy monitoring requirements of NPDES Permit No. AL0024635 and provide a baseline description of habitat diversity, spatial-temporal trends, preexisting reservoir conditions, and cause/effect relationships between biological communities and environmental factors. When operational studies are completed, this assessment and results of a subsequent baseline study to precede fuel loading of unit one, will allow evaluation of project impacts and provide protection from liability for existing aquatic conditions.

Several events which have occurred within Guntersville Reservoir (other then BLN) will continue to have potential for affecting aquatic conditions. These include operation of Widows Creek Steam Plant (24.9 km upstream of BLN), herbicide treatments of aquatic habitats to reduce growth of aquatic macrophytes, and operation of a commercial sand and gravel dredge in the immediate vicinity of the BLN site. Discovery of the pervasive aquatic macrophyte species Hydrilla verticillata on Guntersville Reservoir in 1982 will likely intensify efforts to reduce aquatic macrophyte growth. Bypass of the sewage treatment facility at Chattanooga, Tennessee (Nickajack Reservoir), during 1982 and 1983 had no measurable impact on water quality in Guntersville Reservoir (biological related parameters).

Water Quality

Evaluation of Nickajack tailrace data (water entering Guntersville Reservoir) identified a significant ($\alpha = 0.05$) increase over time in total-P and a highly significant (α = 0.01) decrease in NO_2 + N_3-N and summer (June-September) DO concentrations. Evaluation of water quality in the vicinity of BLN indicated the study area was relatively stable, as only a few parameters changed significantly over the entire period of study. Changes which did occur were observed between data collected during 1974-1979 and data collected during 1982-1983. Of particular interest was an increase in BOD, TOC, and organic nitrogen in 1982-1983. The increase in BOD, TOC, and organic nitrogen appeared to coincide with bypass at Moccasin Bend sewage treatment plant into Nickajack Reservoir upstream of Guntersville Reservoir and BLN. However, analysis of water quality data in Nickajack Dam tailrace indicated changes observed near BLN were unrelated to the Moccasin Bend bypass. Increases in these organic-related parameters near BLN may be related to increased colonization of Guntersville Reservoir by aquatic macrophytes which showed substantial gains in 1980 and 1981 and remained high (> 12,000 acres) during 1982 and 1983. The increase in aquatic plants represented an approximate doubling of acres colonized within Guntersville Reservoir between 1979 and 1982.

Copper and lead concentrations frequently exceeded the average water quality criteria, and lead also exceeded the maximum criteria at all mid-channel stations.

Phytoplankton

Phytoplankton assemblages of the mainstream channel and left overbank habitats were diverse. Twenty-two of the 137 phytoplankton genera identified during the study were important with regard to abundance, representing at least 10 percent of total abundance during one or more collection periods.

Comparisons of community structures from the mainstream channel and left overbank habitats indicated a low degree of similarity among overbank stations (a result of flow isolation which allowed development of distinct and separate communities) compared to channel stations which were contiguous with regard to flow.

Patterns of algal succession changed during the preoperational study period. Chrysophyta and Chlorophyta dominated the phytoplankton assemblage every collection period in 1974 and Chrysophyta was again dominant every collection period (except March) in 1983. During 1975-1982 Cyanophyta became the most abundant phytoplankton group, comprising especially large segments of the total assemblage in August 1975 (77 percent), August 1976 (81 percent), and July (83 percent), September (76 percent), and October (73 percent) in 1977. Dominant Cyanophyta genera were Anacystis and Merismopedia during 1975-1982, but changed to Oscillatoria in 1983. Cyanophyta dominance was usually greater on the overbank habitat than in the river channel. October 1982 and several months in 1983 were unique in that Cyanophyta was not represented in the phytoplankton community. The dominant genus occurring most often during the study was a chrysophyte, Melosira.

Phytoplankton abundance was greater for the overbank habitat than the mainstream channel. The most productive stations with regard to cell numbers were TRM 388.0 in the channel and TRM 386.4 on the left overbank, indicating a downstream increase in phytoplankton abundance. Greatest phytoplankton abundance measured during the monitoring period exceeded 56 million cells/L at TRM 386.4 in August 1982.

Temporal evaluation of phytoplankton indicated a cyclic abundance pattern for the channel habitat, beginning low in 1974, increasing through 1977, and declining during 1982 and 1983 to abundance levels at or below those measured in 1974.

Average chlorophyll a concentrations normally were below the 10-30 mg/m³ range indicating potentially eutrophic conditions; however, maximum single-sample concentrations occasionally fell within that range. Maximum chlorophyll concentrations on the left overbank were much greater than corresponding channel concentrations.

Primary productivity data were extremely variable from month-to-month, ranging from a few (<10) to several thousand mg $C/m^2/day$. Reduced and/or fluctuating solar radiation several days before sampling appeared to reduce productivity.

Phytoplankton data were quite variable with regard to stations, months, and years such that spatial trends were seldom obvious. However, there was a trend indicated for greatest total phytoplankton abundance and Cyanophyta dominance on the left overbank and at downstream sampling locations.

Zooplankton

The most consistent component of the zooplankton assemblage was larval copepods (nauplii), but adult copepods were only rarely (twice) present as a major component of the community. The second most prevalent form was the cladoceran, Bosmina longirostris which generally dominated channel zooplankton from May to the end of the sampling year.

Several conclusions can be made from zooplankton data collected during the period 1974-1979 and 1982-1983. These include:

1. Short-term fluctuations (≤one year) in the zooplankton assemblage (both in terms of occurrence and relative abundance) occur frequently near BLN.

2. Based on the occurrence of taxa, the three sample stations in the channel group were more similar than different.

3. Overbank stations showed a greater degree of variability with respect to total density and similarity indices (SQS and PS) than channel stations. This was probably due to a more "patchy" distribution of zooplankton in overbank areas, and less mixing enabling communities to develop in separate overbank areas. Overbank stations were much more productive than channel sites.

4. Number of taxa present, species diversity, and total zooplankton densities were usually lower at the beginning (February) and end (October) of the sample year than in the summer season.

5. The most productive channel station (station 2) and overbank station (station 6) are nearest the BLN diffuser, whereas the least productive station (station 3) represents the upstream "control".

Periphyton

The periphyton community in the vicinity of BLN was sampled using artificial (plexiglass) substrates. Forty-eight of the 62 periphyton genera identified during the study were regular components of the community. Ten of these genera were considered dominant, accounting for 19.8 to 91.9 percent of the total abundance in any sample.

At the channel stations there was a general increase in numbers of genera from 1974 to 1978 then a decline in 1982 and 1983 to levels similar to 1974-1975. The number of taxa at channel and overbank stations ranged from 5-24 and 5-17, respectively.

Comparison of community structure among stations were usually similar based upon taxa. A high percentage of comparisons based upon taxa and abundance were low. This trend held for comparisons involving both channel and overbank habitats.

Channel stations had chrysophytes as the dominant group during 1974-1976, with Cocconeis and Achnanthes the predominant forms. Beginning in 1977 and continuing through 1983, chrysophytes dominated early in the year, in June chlorophytes began to dominate at some stations and both groups were intermittently dominant for the remainder of the year. When chrysophytes were dominant, Achnanthes was usually the most predominant diatom, while Stigeoclonium was the predominant chlorophyte taxa when chlorophytes were dominant. Overbank stations exhibited similar percentage composition changes as channel stations except that chlorophytes were predominant at all overbank stations in April 1983 and cyanophytes were never the predominant group.

Periphyton data pooled over years indicated the total abundances at TRMs 388.0 and 396.8 were similar and both significantly greater than densities at TRM 391.2. All channel stations had significantly higher abundances than overbank stations, with TRM 388.4 (overbank) having the lowest abundance which was significantly lower than other overbank stations.

Data pooled over stations indicated total abundances were similar during 1977 and 1978 and higher than other years. Abundance during 1982 and 1983 were also similar, but lower than other years. Abundances were usually highest in June and lowest in September or October.

The corrected chlorophyll a (CCA) was lowest in 1982 samples and highest in 1978 samples for channel stations. Overbank stations had the greatest range of CCA values in 1983. There were no consistent periodic trends for the CCA but this parameter, except for 1974, did exhibit a strong direct relationship with total abundance. The pheophytin index (PI), the ratio of active chlorophyll a to its degradation product, pheophytin a, was highest in 1975 indicating healthy algal populations.

The PI declined steadily from 1975, the first calculated, to the lowest values for the study in 1983.

AI values for the channel stations were lowest in 1974, increased through 1976, declined in 1977 then continued to rise steeply for the remainder of the study. There was no logical correlation of this steep rise with any chemical data other than noting a general rise in the levels of TOC, organic nitrogen, and BOD_5 which may have given rise to the increased AI values.

Values for channel station AI's were usually high early in the year then became inconsistent for the remainder of the year. Both 1982 and 1983 overbank AI values were generally similar to the channel stations.

Through the monitoring period, periphyton abundance has exhibited a long term cycle with 1974 as the nadir and 1978 as the peak. Any comparison of abundances in the future with these must consider such apparent cycle. During this time, chlorophytes have occupied increasingly larger portions of the periphyton community and cyanophytes have only rarely been significant. Genera composing the periphyton assemblage at anytime were similar; however, there were differences in the abundances of these genera, usually with channel stations having more dense populations. Trends in chlorophyll levels were usually in good agreement with those of total abundances. However, there was a general increase through the years of pheophytin a levels. Autotrophic indices were very variable for each station through 1977, then began to increase through 1983. Reasons for this increase may be a shift toward more heterotrophic growth because of apparent increases in organic materials (suggested by increases in TOC, organic-N, and BOD_5). This too may be part of a reservoir cycle as was suggested for the total abundance. This possible cyclic nature in the ratio of periphytic autotrophs to heterotrophs should also be considered when future AI values are compared to these.

Overall, the periphyton community was relatively healthy, exhibiting typical densities, taxa, and abundances for this portion of the mainstream Tennessee River system.

Macroinvertebrates

A total of 138 macroinvertebrate taxa were found at the seven stations monitored in the vicinity of BLN from 1974-1979 and 1982-1983. A general increase in number of taxa and in number of organisms was observed throughout the study period. Higher diversity values reflected these increases.

The macroinvertebrate community in the channel was dominated by the asiatic clam *Corbicula manilensis* and oligochaetes through 1979 (based on Ponar sampling). However, when sampling was resumed in 1982, a major shift in dominance was evident. The burrowing mayfly, *Hexagenia* sp., became the most numerous taxon at all three stations (TRMs 388.0, 391.2, and 396.8). Artificial substrate samples, taken from 1974 through May 1979, showed many changes in dominant rheophilic taxa, although the caddisflies *Cyrnellus fraternus* and *Neureclipsis* were usually common. In 1980, the chironmid *Cricotopus* was dominant at all three stations.

The overbank community exhibited two seasonal trends. The mean number of taxa was highest in spring, decreasing in summer to a low in October. The mean number of organisms decreased steadily throughout spring to a low in late summer, followed by an increase in October. The burrowing mayfly, *Hexagenia* sp., and the chironomids *Coelotanypus* and *Chironomus* were usually the dominant taxa. In general, *Corbicula manilensis* increased in numbers throughout the four sampling years (1978-1979, 1982-1983), whereas *Hexagenia* decreased.

The observed spatial and temporal changes in the macroinvertebrate fauna in the vicinity of BLN were not investigated in a causative manner in this study. No physical conditions or water quality changes within the reservoir could be definitely attributed to increasing or decreasing trends in numbers of taxa or individuals.

Aquatic Macrophytes

Acreages of submersed and floating-leaved aquatic macrophytes in the vicinity of BLN increased from the late 1970's until 1981 or 1982, then declined in 1983. This trend paralleled that for Guntersville Reservoir. While several species of submersed macrophytes occurred in the vicinity of BLN, Eurasian watermilfoil was the dominant submersed macrophyte species.

Eurasian watermilfoil comprised the largest percentage of submersed macrophyte standing crop for most sampling dates. Regression analysis indicated significant or highly significant trends at three sampling stations. Although all three of the stations represent channel habitat, the trends were not consistent as two increased and the other decreased. Pooled data from the two stations upstream of BLN showed a significant increase in standing crop, while pooled data from downstream stations was not significant.

Analysis of variance showed significant or highly significant differences in standing crop for all months during 1982 and 1983. The month with the highest and lowest standing crop differed in 1982 and 1983 and was attributed to the effect of high flows in mid-May 1983. Differences in standing crop by station for 1982 and 1983 were generally significant or highly significant. While some stations consistently ranked high and others low, there was no readily discernable trend relating to overbank versus channel stations.

Eggs and Larval Fish

Composition and relative abundance of ichthyoplankton in the vicinity of BLN on Guntersville Reservoir was typical of other mainstream Tennessee River Reservoirs. Freshwater drum eggs dominated egg collections. Larvae were dominated by clupeids (59-94 percent) with freshwater drum second in abundance (2-31 percent). No other taxon exceeded 10 percent composition in a year. Temperate bass exceeded 1 percent of the total catch five of the seven years of this study and ictiobine larvae exceeded one percent in three years. Lepomids and cyprinids were the only other taxa to exceed 1 percent of the total larval catch at BLN in a given year. Lower abundances of the latter two taxa at BLN compared to previous data from Guntersville and to other reservoirs are due to the elimination of overbank sampling at the BLN transect after 1977.

Ichthyoplankton data collected at BLN has aided in documenting the Tennessee River upstream of BLN as an important spawning area for Polyodon spathula and Stizostedion canadense two important migratory species. Paddlefish spawns above BLN, as well as ictiobine spawns, appeared related to annual discharge rates from Nickajack Dam. Freshwater drum also spawned in the vicinity of BLN and upstream as evidenced by high densities of freshwater drum eggs from BLN samples. Data collected during this study period indicated no major changes in the relative abundance or distribution of ichthoplankton in the vicinity of BLN.

Juvenile and Adult Fish

Estimates of juvenile and adult fish standing stocks by cove rotenone sampling indicated fish populations in Guntersville Reservoir coves were dominated by 11 species, although more than 50 species occurred in samples during the BLN preoperational period, 1974-1983. These 11 species were further dominated by 5 species: bluegill, freshwater drum, gizzard shad, largemouth bass, and redear sunfish. Numerically, these species ranked as follows: bluegill (38 percent), redear sunfish (31 percent), gizzard shad (11 percent), freshwater drum (1.3 percent), and largemouth bass (1.3 percent). Accordingly, biomass composition was: gizzard shad (44 percent), bluegill (13 percent), freshwater drum (11 percent), redear sunfish (9 percent), and largemouth bass (4 percent).

Number or biomass of fish of one or more size classes for 8 of the 11 dominant ("important") species showed significant decreasing trends over the period 1974-1983. Causes for these declining trends were not apparent. However, they did not appear to be associated with any drastic changes in water quality. Presence or absence of aquatic macrophytes in coves may have influenced the standing stock estimates, but this was not clearly defined. For example, number of young-of-year redear sunfish (41,000/ha) was highest with dense growths of macrophytes present, while the highest estimate for number of young-of-year bluegill (22,000/ha) occurred under sparse macrophyte conditions.

Although standing stock estimates of fish in Guntersville Reservoir were comparable to other TVA mainstream reservoirs, considerable year to year variation in these estimates were apparent. In addition to changes in the actual fish population, various factors or conditions can influence standing stock estimates via cove rotenone sampling; however, it is difficult to delineate specific factors for a single given year. Annual estimates for several succeeding years, as presently conducted, is considered the best approach in monitoring potential adverse changes relative to operation of BLN.

Relative abundance of fish species important (dominant) in gill net catches varied more temporally (both seasonally and yearly) than spatially (by station). Consistent trends in relative abundance through the 33-month sampling period were not apparent, except for a decline in white bass. Catch per unit effort of sauger, white crappie, and channel catfish also tended to decline through the sampling period, but these trends were either inconsistent or not statistically significant. Lack of station effects, except for longnose gar and spotted gar, suggests BLN operational impacts might be most evident in altered distribution of species dominant in gill netting.

Electrofishing samples provided little additional information about adult and juvenile fish distribution and relative abundance not available from cove rotenone and gill netting. An unusually high number of electrofishing runs yielded no fish. Causes of the low capture rate can only be speculated at present but may indicate unsuitability of the sampling method for littoral habitat near BLN.

Comparisons Over Time

Comparison of 1982 and/or 1983 monitoring data with earlier years (1974-1979) indicated that aquatic conditions in the vicinity of BLN are changing. Observations included:

1. Higher concentrations of BOD, TOC, and organic nitrogen in 1982 and 1983 than other years.
2. An approximate doubling in aquatic macrophytes within the reservoir between 1979 and 1982 and subsequent decline in 1983.
3. Transition from a Cyanophyta dominated phytoplankton assemblage in 1975-1982 to a Chrysophyta dominated assemblage in 1983. Lowest relative Cyanophyta abundance occurred in 1983 compared to other years.
4. Change in dominant Cyanophyta genera (phytoplankton community) from *Anacystis* and *Merismopedia* in 1975-1982 to *Oscillatoria* in 1983.
5. Complete absence of Cyanophyta in the phytoplankton assemblage during October 1982 and several months in 1983 (present in every sample, 1974-1979).
6. Significantly lower total phytoplankton abundance in 1983 compared to other years (channel and overbank habitats).
7. An overall increase in zooplankton abundance and average number of taxa per sample during the period 1974-1978, then a decline in 1979-1982.
8. Increase in number of periphyton genera from 1974 to 1978, then a decline in 1982 and 1983.
9. Chlorophytes began to appear as a dominant part of the periphyton community in the latter part of the study, 1977-1983. Chrysophyta had previously dominated the community, 1974-1976.
10. Significantly lower periphyton abundances in 1982 and 1983 compared to other years.
11. Lowest periphyton phaeophytin index values of the study measured in 1983.
12. Sharp increase in periphyton Autotrophic Index Values during 1982 and 1983 (suggesting a sharp increase in organics within the aquatic ecosytem).
13. A major shift in macroinvertebrate dominance, from *Corbicula manilensis* and Oligochaeta in 1974-1979, to *Hexagenia* sp. in 1982-1983.

14. Significant decreasing trends over the period 1974-1983 in the number or biomass of one or more size classes for 8 of the 11 dominant fish species (rotenone).

15. A decline in white bass populations (gill netting).

Resumption of baseline monitoring before operation of BLN should resolve the fate of these changes, provide information on the apparent decline in white bass populations (gill netting), and describe long-term variability within these data. Conclusion of this assessment, however, is that degree of indicated change was not beyond that expected for this reach of Guntersville Reservoir, although the fate of linear trends within these data is uncertain. Pattern of change for algal and planktonic communities appeared more cyclic than linear, indicating that this study may have observed close to the full range of conditions expected for this reservoir area under normal flow and climatic conditons.

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18 CFR 1304.208

Shoreline Stabilization on TVA-Owned Residential Access Shoreland

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CHAPTER XIII--TENNESSEE VALLEY AUTHORITY

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§ 1304.208 Shoreline stabilization on TVA-owned residential access shoreland
TVA may issue permits allowing adjacent residential landowners to stabilize eroding shorelines on TVA-owned residential access shoreland. TVA will determine if shoreline erosion is sufficient to approve the proposed stabilization treatment.

(a) Biostabilization of eroded shorelines.
(1) Moderate contouring of the bank may be allowed to provide conditions suitable for planting of vegetation.
(2) Tightly bound bundles of coconut fiber, logs, or other natural materials may be placed at the base of the eroded site to deflect waves.
(3) Willow stakes and bundles and live cuttings of suitable native plant materials may be planted along the surface of the eroded area.
(4) Native vegetation may be planted within the shoreline management zone to help minimize further erosion.
(5) Riprap may be allowed along the base of the eroded area to prevent further undercutting of the bank.

(b) Use of gabions and riprap to stabilize eroded shorelines.
(1) The riprap material must be quarry-run stone, natural stone, or other material approved by TVA.
(2) Rubber tires, concrete rubble, or other debris salvaged from construction sites shall not be used to stabilize shorelines.
(3) Gabions (rock wrapped with wire mesh) that are commercially manufactured for erosion control may be used.
(4) Riprap material must be placed so as to follow the existing contour of the bank.
(5) Site preparation must be limited to the work necessary to obtain adequate slope and stability of the riprap material.

(c) Use of retaining walls for shoreline stabilization.
(1) Retaining walls shall be allowed only where the erosion process is severe and TVA determines that a retaining wall is the most effective erosion control option or where the proposed wall would connect to an existing TVA-approved wall on the lot or to an adjacent owner's TVA-approved wall.
(2) The retaining wall must be constructed of stone, concrete blocks, poured concrete, gabions, or other materials acceptable to TVA. Railroad ties, rubber tires, broken concrete (unless determined by TVA to be of adequate size and integrity), brick, creosote timbers, and asphalt are not allowed.
(3) Reclamation of land that has been lost to erosion is not allowed.
(4) The base of the retaining wall shall not be located more than an average of two horizontal feet lakeward of the existing full summer pool water. Riprap shall be placed at least two feet in depth along the footer of the retaining wall to deflect wave action and reduce undercutting that could eventually damage the retaining wall.

Tennessee Valley Authority

Form TVA 17416[5-2005]

General and Standard Conditions, Section 26a and Land Use

May 2005

RLR No. ___________

GENERAL AND STANDARD CONDITIONS
Section 26a and Land Use

General Conditions

1. You agree to make every reasonable effort to construct and operate the facility authorized herein in a manner so as to minimize any adverse impact on water quality, aquatic life, wildlife, vegetation, and natural environmental values.
2. This permit may be revoked by TVA by written notice if:
   a) the structure is not completed in accordance with approved plans;
   b) if in TVA's judgment the structure is not maintained as provided herein;
   c) the structure is abandoned;
   d) the structure or work must be altered to meet the requirements of future reservoir management operations of the United States or TVA, or:
   e) TVA finds that the structure has an adverse effect upon navigation, flood control, or public lands or reservations.
3. If this permit for this structure is revoked, you agree to remove the structure, at your expense, upon written notice from TVA. In the event you do not remove the structure within 30 days of written notice to do so, TVA shall have the right to remove or cause to have removed, the structure or any part thereof. You agree to reimburse TVA for all costs incurred in connection with removal.
4. In issuing this Approval of Plans, TVA makes no representations that the structures or work authorized or property used temporarily or permanently in connection therewith will not be subject to damage due to future operations undertaken by the United States and/or TVA for the conservation or improvement of navigation, for the control of floods, or for other purposes, or due to fluctuations in elevations of the water surface of the river or reservoir, and no claim or right to compensation shall accrue from any such damage. By the acceptance of this approval, applicant covenants and agrees to make no claim against TVA or the United States by reason of any such damage, and to indemnify and save harmless TVA and the United States from any and all claims by other persons arising out of any such damage.
5. In issuing this Approval of Plans, TVA assumes no liability and undertakes no obligation or duty (in tort, contract, strict liability or otherwise) to the applicant or to any third party for any damages to property (real or personal) or personal injuries (including death) arising out of or in any way connected with applicant's construction, operation, or maintenance of the facility which is the subject of this Approval of Plans.
6. This approval shall not be construed to be a substitute for the requirements of any federal, state, or local statute, regulation, ordinance, or code, including, but not limited to, applicable electrical building codes, now in effect or hereafter enacted.
7. The facility will not be altered, or modified, unless TVA's written approval has been obtained prior to commencing work.
8. You agree to notify TVA of any transfer of ownership of the approved structure to a third party. Third party is required to make application to TVA for permitting of the structure in their name.
9. You agree to stabilize all disturbed areas within 30 days of completion of the work authorized. All land-disturbing activities shall be conducted in accordance with Best Management Practices as defined by Section 208 of the Clean Water Act to control erosion and sedimentation to prevent adverse water quality and related aquatic impacts. Such practices shall be consistent with sound engineering and construction principles; applicable federal, state, and local statutes, regulations, or ordinances; and proven techniques for controlling erosion and sedimentation, including any *required* conditions.
10. You agree not to use or permit the use of the premises, facilities, or structures for any purposes that will result in draining or dumping into the reservoir of any refuse, sewage, or other material in violation of applicable standards or requirements relating to pollution control of any kind now in effect or hereinafter established.
11. The facility will be maintained in a good state of repair and in good, safe, and substantial condition. If the facility is damaged, destroyed, or removed from the reservoir or stream for any reason, or deteriorates beyond safe and serviceable use, it cannot be repaired or replaced without the prior written approval of TVA.
12. You agree that if any historical or prehistoric archaeological material (such as arrowheads, broken pottery, bone or similar items) is encountered during construction of this facility you will immediately contact this office and temporarily suspend work at that location until authorized by this office to proceed.
13. The Native American Graves Protection and Repatriation Act and the Archaeological Resources Protection Act apply to archaeological resources located on the premises. If LESSEE {or licensee or grantee (for easement) or applicant (for 26a permit on federal land)} discovers human remains, funerary objects, sacred objects, objects of cultural patrimony, or any other archaeological resources on or under the premises, LESSEE {or licensee, grantee, or applicant} shall immediately stop activity in the area of the discovery, make a reasonable effort to protect the items, and notify TVA by telephone (phone _____). Work may not be resumed in the area of the discovery until approved by TVA.

14. On TVA land, unless otherwise stated on this permit, vegetation removal is prohibited.

15. You agree to securely anchor all floating facilities to prevent them from floating free during major floods.

16. You are responsible for accurately locating your facility, and this authorization is valid and effective only if your facility is located as shown on your application or as otherwise approved by TVA in this permit. The facility must be located on land owned or leased by you, or on TVA land at a location approved by TVA.

17. It is understood that you own adequate property rights at this location. If at any time it is determined that you do not own sufficient property rights, or that you have only partial ownership rights in the land at this location, this permit may be revoked if TVA receives an objection to your water use facility from any owner or partial owner of the property rights at this location.

Standard Conditions: (Items that pertain to your request have been checked.)

1. Structures and Facilities

a) ☐ TVA number _____ has been assigned to your facility. When construction is complete, this number shall be placed on a readily visible part of the outside of the facility in the numbers not less than three inches high.

b) ☐ The 100-year flood elevation at this site is estimated to be _____-feet mean sea level. As a minimum, your fixed facility should be designed to prevent damage to stored boats by forcing them against roof during a 100-year flood event.

c) ☐ You agree that the float will be temporarily connected (i.e., by slip pin/ropes) and not permanently attached to nonnavigable houseboat.

d) ☐ You agree that this _____ shall have no side enclosures except wire mesh or similar screening.

e) ☐ Buildings or other enclosed structures containing sleeping or living accommodations, including toilets and related facilities, or that have enclosed floor area in excess of 32 square feet, are prohibited.

f) ☐ Ski jumps will not be left unattended for extended periods of time. All facilities will be tied to the shoreline or to a boathouse or pier fronting your property at the completion of each day's activities.

g) ☐ For all electrical services permitted, a disconnect must be located at or above the _____-foot contour that is accessible during flooding.

h) ☐ You should contact your local government official(s) to ensure that this facility complies with all applicable local floodplain regulations.

i) ☐ The entire closed-loop coil heating and air conditioning system and its support apparatus must be either placed below elevation _____ (to provide a five-foot clearance for water craft at minimum pool elevations of _____) or located underneath a TVA approved water-use facility or other TVA approved structure. The supply and return lines must be buried as they cross the reservoir drawdown zone in areas of water depth less than five feet (minimum pool). The liquid contents of the closed-loop heating and air conditioning system must be propylene glycol or water, and the applicant or authorized agent must provide TVA with written verification of this fact.

j) ☐ You agree that only those facilities which have been approved by TVA prior to construction will be placed within the harbor limits and that permanent mooring buoys, boat slips, or other harbor facilities will not be placed outside the harbor limits.

k) ☐ You agree that all storage, piping, and dispensing of liquid fuel shall comply with applicable requirements of the "Flammable and Combustible Liquids" section of the National Fire Codes and any additional requirements of federal, state, and local laws and regulations.

l) ☐ You agree that the _____ facility hereby approved will be used for _____ and for no other purpose unless approved in writing from TVA.

m) ☐ You agree that if the construction project covered by this permit is not initiated within (18) months after the date of issuance, this permit will then automatically expire and you must submit a new 26a permit application for TVA approval with the applicable fee.

2. Ownership Rights

a) ☐ No fill will be placed higher than elevation _____ maximum shoreline contour (msc), and every precaution will be taken not to disturb or alter the existing location of the _____-foot contour elevation through either excavation or placement of fill.

b) ☐ You are advised that TVA retains the right to flood this area and that TVA will not be liable for damages resulting from flooding.

c) ☐ You shall notify TVA of any sale or transfer of land, which would affect the landward limits of harbor area, as far in advance of such sale or transfer as possible.

d) ☐ This approval of plans is only a determination that these harbor limits will not have any unacceptable effect on TVA programs or other interests for which TVA has responsibility. Such approval does not profess or intend to give the applicant exclusive control over the use of navigable waters involved.

e) ☐ You recognize and understand that this authorization conveys no property rights, grants no exclusive license, and in no way restricts the general public's privilege of using shoreland owned by or subject to public access rights owned by TVA. It is also subject to any existing rights of third parties. Nothing contained in this approval shall be construed to detract or deviate from the rights of the United States and TVA held over this land under the Grant of Flowage Easement. This Approval of Plans does not give any property rights in real estate or material and does not authorize any injury to private property or invasion of private or public rights. It merely constitutes a finding that the facility, if constructed at the location specified in the plans submitted and in accordance with said plans, would not at this time constitute an obstruction unduly affecting navigation, flood control, or public lands or reservations.

3. Shoreline Modification and Stabilization

a) ☐ For purposes of shoreline bank stabilization, all portions will be constructed or placed, on average, no more than two feet from the existing shoreline at normal summer pool elevation.

b) ☐ You agree that spoil material will be disposed of and contained on land lying and being above the _____-foot contour. Every precaution will be made to prevent the reentry of the spoil material into the reservoir.

c) ☐ Bank, shoreline, and floodplain stabilization will be permanently maintained in order to prevent erosion, protect water quality, and preserve aquatic habitat.

d) ☐ You agree to reimburse TVA $_____, which is the current value of the _____ acre feet of power storage volume displaced by fill into the reservoir.

4. Water Intake

a) ☐ If the reservoir falls below the elevation of the intake, the applicant will be responsible for finding another source of raw water.

b) ☐ You must install and maintain a standard regulatory hazard buoy at the end of the intake to warn boaters of the underwater obstruction. The word "intake" should be added to the buoy and be attached using a five-foot cable.

c) ☐ The screen openings on the intake strainer must be 1/8-inch (maximum), to minimize the entrapment of small fish.

d) ☐ This approval does not constitute approval of the adequacy or safety of applicant's water system. TVA does not warrant that the water withdrawn and used by applicant is safe for drinking or any other purpose, and applicant is solely responsible for ensuring that all water is properly treated before using.

5. Bridges and Culverts

a) ☐ You agree to design/construct any instream piers in such a manner as to discourage river scouring or sediment deposition.

b) ☐ Applicant agrees to construct culvert in phases, employing adequate streambank protection measures, such that the diverted streamflow is handled without creating streambank or streambed erosion/sedimentation and without preventing fish passage.

c) ☐ Concrete box culverts and pipe culverts (and their extensions) must create/maintain velocities and flow patterns which offer refuge for fish and other aquatic life, and allow passage of indigenous fish species, under all flow conditions. Culvert floor slabs and pipe bottoms must be buried below streambed elevation, and filled with naturally occurring streambed materials. If geologic conditions do not allow burying the floor, it must be otherwise designed to allow passage of indigenous fish species under all flow conditions.

d) ☐ All natural stream values (including equivalent energy dissipation, elevations, and velocities; riparian vegetation; riffle/pool sequencing; habitat suitable for fish and other aquatic life) must be provided at all stream modification sites. This must be accomplished using a combination of rock and bioengineering, and is not accomplished using solid, homogeneous riprap from bank to bank.

e) ☐ You agree to remove demolition and construction by-products from the site--for recycling if practicable, or proper disposal--outside of the 100-year floodplain. Appropriate BMPs will be used during the removal of any abandoned roadway or structures.

6. Best Management Practices

a) ☐ You agree that removal of vegetation will be minimized, particularly any woody vegetation providing shoreline/streambank stabilization.

b) ☐ You agree to installation of cofferdams and/or silt control structures between construction areas and surface waters prior to any soil-disturbing construction activity, and clarification of all water that accumulates behind these devices to meet *state* water quality criteria *at the stream mile where activity occurs* before it is returned to the *unaffected portion of the stream*. Cofferdams must be used wherever construction activity is at or below water elevation.

c) ☐ A floating silt screen extending from the surface to the bottom is to be in place during excavation or dredging to prevent sedimentation in surrounding areas. It is to be left in place until disturbed sediments are visibly settled.

d) ☐ You agree to keep equipment out of the reservoir or stream and off reservoir or stream banks, to the extent practicable (i.e., performing work "in the dry").

e) ☐ You agree to avoid contact of wet concrete with the stream or reservoir, and avoid disposing of concrete washings, or other substances or materials, in those waters.

f) ☐ You agree to use erosion control structures around any material stockpile areas.

g) ☐ You agree to apply clean/shaken riprap or shot rock (where needed at water/bank interface) over a water permeable/soil impermeable fabric or geotextile and in such a manner as to avoid stream sedimentation or disturbance, or that any rock used for cover and stabilization shall be large enough to prevent washout and provide good aquatic habitat.

h) ☐ You agree to remove, redistribute, and stabilize (with vegetation) all sediment which accumulates behind cofferdams or silt control structures.

i) ☐ You agree to use vegetation (versus riprap) wherever practicable and sustainable to stabilize streambanks, shorelines, and adjacent areas. These areas will be stabilized as soon as practicable, using either an appropriate seed mixture that includes an annual (quick cover) as well as one or two perennial legumes and one or two perennial grasses, or sod. In winter or summer, this will require initial planting of a quick cover annual only, to be followed by subsequent establishment of the perennials. Seed and soil will be protected as appropriate with erosion control netting and/or mulch and provided adequate moisture. Streambank and shoreline areas will also be permanently stabilized with native woody plants, to include trees wherever practicable and sustainable (this vegetative prescription may be altered if dictated by geologic conditions or landowner requirements). You also agree to install or perform additional erosion control structures/techniques deemed necessary by TVA.

<u>Additional Conditions</u>

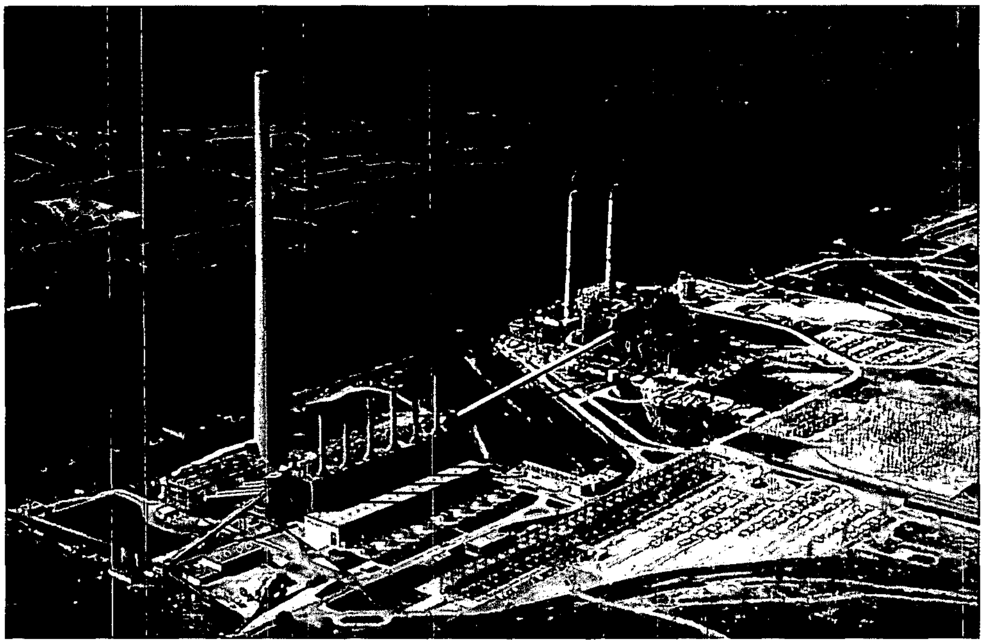
Tennessee Valley Authority
Environmental Stewardship and Policy

Widows Creek Plant A & B
NPDES Permit No. AL0003875
316(b) Monitoring Program
Fish Impingement at Widows Creek Fossil Plants A & B during 2005 through 2007

TENNESSEE VALLEY AUTHORITY

WIDOWS CREEK PLANT A & B
NPDES PERMIT NO. AL0003875
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT WIDOWS CREEK FOSSIL PLANTS A & B DURING 2005 THROUGH 2007



ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

AM&M	Aquatic Monitoring and Management
BIP	Balanced Indigenous Population
CCW	Condenser Cooling Water
CWA	Clean Water Act
EA	Equivalent Adult
EPRI	Formerly known as the Electric Power Research Institute
KW	Kilowatt
PF	Production Foregone
TRK	Tennessee River Kilometer
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
WCF	Widows Creek Fossil Plant

Introduction

Widows Creek Fossil Plant (WCF), placed into operation in 1954, withdraws condenser cooling water (CCW) from the Tennessee River and is subject to compliance with the Alabama Water Pollution Control Act and the federal Clean Water Act (CWA). Section 316(b) of the CWA requires the location, design, and capacity of cooling water intake structures to reflect the best technology availability for minimizing adverse environmental impact. Impingement is a component of Section 316(b) and is defined as an impact in which fish and/or shellfish are trapped or impinged against an intake screen and often killed in the process. Tennessee Valley Authority (TVA) conducted impingement monitoring at WCF from June 2005 through June 2007 to assess the effects of impingement on the aquatic community of Guntersville Reservoir. This report presents impingement data collected from the CCW intake screens during 2005-2007 with comparisons to historical data collected during 1974-1975.

WCF Plants A and B are located on the right bank of the Tennessee River, (Guntersville Reservoir), at Tennessee River Kilometer (TRK) 655.8 (Tennessee River Mile [TRM] 407.5) in northeast Alabama (Figure 1). The plant consists of two sets of units (A and B). Units 1-6 (old plant - A) were completed in 1954 with a capacity of 125,000 kilowatts (KW) per unit. Units 7-8 (new plant – B) were both in operation by 1965 with a capacity of 500,000 KW per unit for a total plant capacity of 1,700 megawatts.

TVA performs Reservoir Fish Assemblage Index (RFAI) (Hickman and Brown 2002) sampling to demonstrate that WCF operation is not adversely affecting the balanced indigenous population (BIP) of Guntersville Reservoir. The primary reason for gathering these data is to support the continuation of the Section 316(a) thermal variance for WCF. However, the RFAI monitoring also gives an indication of the overall impact of plant operations on the reservoir fish assemblage and benthic community, including impacts from the plant's cooling water intake.

Plant Description – Plant A and B

Intake Pumping Structure - Plant A

An intake channel 335.5 meters (1101 ft) long and 36.6 m (120 ft) wide extends from Guntersville Reservoir to the intake structure for Plant A (Figure 1). A trash boom at the channel inlet prevents most of the floating trash from entering the channel. Twelve condenser circulating water pumps are protected by trashracks and traveling screens. Design flow of CCW is 7.1 m^3/s (112,000 gpm) for each of Units 1-4 and 6.1 m^3/s (96,000 gpm) for each of Units 5 and 6. The trashracks are periodically cleaned by a rake operated by the intake gantry crane. Velocities measured at the trashracks for Units 1-6 ranged from 8.5 cm/sec (0.28 fps) to 47.2 cm/sec (1.55 fps).

Intake Pumping Structure - Plant B

The intake structure for Units 7 and 8 is located on the shoreline and draws water directly from the river rather than from an intake channel. Water flows into the intake from the reservoir and is discharged back to the reservoir downstream below the intake channel for Units 1-6 (Figure 1). Six intake pumps provide a combined CCW flow of 60.2 m^3/s (954,000 gpm). Trashracks consisting of 1.59 cm (5/8 in) thick vertical steel bars with 9.21 cm (3 5/8 in) openings and traveling screens with 9.5 mm (3/8 in) square mesh prevent debris and fish from entering the condensers. Water velocities measured in front of the trashracks for Units 7-8 ranged from 25 cm/sec (0.83 fps) to 68 cm/sec (2.22 fps). Highest velocities occurred at the upstream end of the structure and decreased linearly with each successive downstream opening.

Methods

Weekly impingement monitoring began on June 21, 2005 at Plant A and June 15, 2005 at Plant B. Sampling at both plants A and B continued through June 12, and June 6, 2007, respectively. To simplify comparisons in this report, data from June 15, 2005 through June 6, 2006 will be referred to as Year-One, and from June 6, 2006 through June 12, 2007 as Year-Two.

To collect each sample, intake screens were rotated and washed on a prearranged schedule by the plant assistant unit operator to remove all fish and debris. After 24 hours, screens were again rotated and washed with an Aquatic Monitoring and Management (AM&M) crew on site. Fish and debris were collected in a catch basket constructed of 9.5 mm (3/8 in) mesh at the end of the sluice pipe where the monitoring crew removed and processed the sample. Fish were sorted from debris, identified, separated into 25 mm (1 in) length classes, enumerated, and weighed. Data were recorded by one member of the crew and checked and verified (signed) by the other for quality control. Quality Assurance/Quality Control procedures for impingement sampling (TVA 2004) were followed to ensure samples were comparable with historical impingement mortality data. Historical impingement sampling was conducted by TVA from August 1974 through April 1975 (TVA 1976).

Moribund/Dead Fish

The majority of fish collected from a 24-hour screen wash were dead when processed. Incidental numbers of fish which appeared to have been dead for more than 24 hours (i.e., exhibiting pale gills, cloudy eyes, fungus, or partial decomposition) were not included in the sample. Also, during winter, threadfin shad occasionally suffer die-offs and are impinged after death or in a moribund state (Griffith and Tomljanovich 1975, Griffith 1978). If these incidents were observed, they were documented to specify that either all, or a portion of impinged threadfin shad during the sample period were due to cold-shock and would not have been impinged otherwise. Any fish collected alive were returned to the reservoir after processing.

Data Analysis

Impingement mortality data from weekly 24-hour samples were extrapolated to provide annual estimates of total fish impinged for each year of the study. In rare situations when less than a 24-hour sample was possible, data were normalized to 24 hours.

To facilitate the implementation of and compliance with the Environmental Protection Agency's (EPA) regulations for Section 316(b) of the CWA (Federal Register Vol. 69, No. 131; July 9, 2004), prior to its suspension by EPA, impingement losses of fish will be evaluated by extrapolating the losses to equivalent reductions of adult fish, or of biomass production available to predators. EPRI (Formerly known as the Electric Power Research Institute) has identified two models (Barnthouse 2004) for extrapolating losses of fish eggs, larvae and juveniles at intake structures to numbers or production of older fish. The Equivalent Adult (EA) model quantifies entrainment and impingement losses in terms of the number of fish that would have survived to a given future age. The Production Foregone (PF) model applies to forage fish species to quantify the loss from entrainment and impingement in terms of potential available forage for consumption by predators. Data requirements of the models are site-specific on the distribution and abundance of fish populations vulnerable to entrainment and impingement. TVA will use these models to determine the "biological liability" of the WCF CCW intake structure based on the EPA guidance developed under the suspended rule.

Weekly historical data collected during 1974 and 1975 were extrapolated to annual totals of fish impinged. The EA and PF models were also applied to estimate resulting losses from impingement mortality.

Results and Discussion

Plant A

During Year-One and Year-Two of recent impingement monitoring, 1,235 and 41,774 fish were collected from Plant A screen-wash samples, respectively (Table 1). The total number of species collected each year was 16 and 26 in Year-One and Year-Two, respectively (Table 1). Total number of fish estimated impinged by species and year are presented in Table 2. During Year-One, threadfin shad comprised 72% followed by bluegill and freshwater drum (6%), unidentifiable sunfish (5%), channel catfish (4%), yellow bass (3%), and gizzard shad and largemouth bass at 2% each (Table 3). During Year-Two, threadfin shad comprised 93% followed by yellow bass (4%), bluegill, freshwater drum, and unidentifiable sunfish (1%) each (Table 3). Numbers of fish impinged and percent of the annual total by month for both years are presented in Table 4. The estimated annual impingement extrapolated from weekly samples was 8,645 during Year-One and 292,425 during Year-Two (Table 2). Peak impingement occurred during August and September and late March through April at WCF (Table 4 and Figure 2).

Results of total numbers of fish estimated impinged from EA and PF models for Year-One and Year-Two for Plant A were 903 and 14,687, respectively (Table 5).

Plant B

During Year-One and Year-Two at Plant B, 16,218 and 4,902 fish were collected from Plant B screen-wash samples, respectively (Table 6). Total number of fish estimated impinged by species and year are presented in Table 7. The total number of species collected each year was 27 and 23 in Year-One and Year-Two, respectively (Table 6). During Year-One, threadfin shad comprised 90% followed by bluegill (5%), and unidentifiable sunfish (3%) (Table 8). During Year-Two, threadfin shad comprised 58% followed by bluegill (28%), unidentifiable sunfish (8%) freshwater drum (2%) and channel catfish, largemouth bass, and yellow bass at 1% each (Table 8). Numbers of fish impinged and percent of the annual total by month for both years are presented in Table 9. The estimated annual impingement extrapolated from weekly samples was 113,526 during Year-One and 34,314 during Year-Two (Table 7). Peak impingement occurred during July through September for both years sampled and an additional peak occurred in November during Year-Two at Plant B (Table 9 and Figure 3).

Results of total numbers of fish estimated impinged from EA and PF models for Year-One and Year-Two for Plant B were 4,179 and 2,501, respectively (Table 10).

Figure 4 presents historical average WCF intake temperatures from 1986 through 2006 for comparison. Winter temperatures, during both Year-One and Year-Two, dropped 4°F-6°F below the average on several occasions during January through February. This deviation from the seasonal average did not appear coincidental to specific peaks in impingement.

Threadfin and/or gizzard shad typically comprise over 90% of fish impinged on cooling water intake screens of thermal power stations in the Southeastern U. S. (EPRI 2005). They also comprise an average of 35%-56% of total fish biomass where they occur (Jenkins 1967). A recent study by Fost (2006) indicated that cold-stressed threadfin and gizzard shad can be classified as either impaired or moribund. Impaired shad could recover if environmental conditions improved and would, therefore, not die if not impinged. Moribund fish on the other hand, are assumed to not be able to recover and die regardless of impingement. No die-offs of threadfin shad were observed at WCF during the two years of monitoring by AMM crews or were reported by power plant personnel.

Widows Creek Fossil Plant's RFAI average scores since 2000 were 33 and 37 for upstream and downstream sample sites, respectively (TVA 2007 and Scott 2006). These scores indicated similar fish communities for both upstream and downstream of WCF and met the adjusted 70% criteria for designation as BIP. These data indicate that the plant discharge is not adversely impacting the fish community of upper Guntersville Reservoir.

No state or federal protected fish species were collected or are known to occur in the vicinity of WCF.

Comparison with Historical Data

During historical sampling from 1974-1975, the extrapolated totals for number of fish impinged and percent composition by species are presented in Tables 3 and 8. The total estimated numbers of fish impinged during 1974-1975 for Plant A and Plant B were 87,213 and 26,894, respectively. Threadfin shad dominance was consistent for all years monitored. Historical peak impingement occurred March through April of 1975 when over 8,000 threadfin shad were impinged (TVA 1976 and Figures 2 and 3). The exact nature of the high mortality was not determined but it was suspected that natural mortality was associated with spawning stress (TVA 1976).

Summary and Conclusions

Biological liabilities for Plant A and Plant B during 2005-2007 were lower compared to the historical biological liabilities even though total numbers of fish estimated impinged during current impingement monitoring were higher. Favorable RFAI scores for stations upstream and downstream of WCF and relatively low impingement mortality at both Plants A and B indicate WCF is not adversely impacting the resident Guntersville Reservoir fish community in the vicinity of the plant.

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Table 1. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Widows Creek Fossil Plant A.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Lepisosteidae	*Lepisosteus osseus*	Longnose gar	0	1
Clupeidae	*Dorosoma cepedianum*	Gizzard shad	30	47
	Alosa chrysochloris	Skipjack herring	6	3
	Dorosoma petenense	Threadfin shad	889	38,687
Cyprinidae	*Notemigonus crysoleucas*	Golden shiner	0	2
	Notropis volucellus	Mimic shiner	0	5
	Cyprinella spiloptera	Spotfin shiner	1	0
Catostomidae	*Minytrema melanops*	Spotted sucker	1	1
	Ictiobus niger	Black buffalo	0	1
Ictaluridae	*Ictalurus furcatus*	Blue catfish	0	24
	Ictalurus punctatus	Channel catfish	45	41
	Pylodictis olivaris	Flathead catfish	0	4
Moronidae	*Morone saxatilis*	Striped bass	2	2
	Morone chrysops	White bass	1	91
	Morone mississippiensis	Yellow bass	34	1,653
Centrarchidae	*Pomoxis nigromaculatus*	Black crappie	0	19
	Lepomis Macrochirus	Bluegill	70	406
	Micropterus salmoides	Largemouth bass	22	14
	Lepomis megalotis	Longear sunfish	0	5
	Lepomis auritus	Redbreast sunfish	8	1
	Lepomis microlophus	Redear sunfish	49	365
	Ambloplites rupestris	Rock bass	0	7
	Micropterus punctulatus	Spotted bass	5	39
	Lepomis cyanellus	Green sunfish	1	0
Percidae	*Percina caprodes*	Logperch	0	2
	Sander canadense	Sauger	0	4
	Perca flavescens	Yellow perch	0	2
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	71	349
		Total number of fish	**1,235**	**41,774**
		Total number of species	**16**	**26**

Table 2. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Widows Creek Fossil Plant A During 2005-2007.

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Threadfin shad	6,223	270,809	138,516	11,879	1,167,292	589,586	92
Yellow bass	238	11,571	5,905	10,563	774,004	392,284	4
Bluegill	490	2,842	1,666	20,587	130,375	75,481	1
Freshwater drum	497	2,443	1,470	68,663	310,751	189,707	1
Redear sunfish	343	2,555	1,449	14,539	105,511	60,025	1
White bass	7	637	322	1,288	211,568	106,428	T
Channel catfish	315	287	301	76,678	56,112	66,395	T
Gizzard shad	210	329	270	50,393	65,429	57,911	T
Spotted bass	35	273	154	189	123,795	61,992	T
Largemouth bass	154	98	126	5,530	33,509	19,520	T
Blue catfish	0	168	84	0	49,518	24,759	T
Black crappie	0	133	67	0	26,215	13,108	T
Redbreast sunfish	56	7	32	7,700	2,520	5,110	T
Skipjack herring	42	21	32	4,095	19,635	11,865	T
Rock bass	0	49	25	0	1,519	760	T
Longear sunfish	0	35	18	0	1,589	795	T
Mimic shiner	0	35	18	0	35	18	T
Flathead catfish	0	28	14	0	420	210	T
Sauger	0	28	14	0	9,471	4,736	T
Striped bass	14	14	14	42	798	420	T
Golden shiner	0	14	7	0	441	221	T
Logperch	0	14	7	0	420	210	T
Spotted sucker	7	7	7	4,529	11,025	7,777	T
Yellow perch	0	14	7	0	2,198	1,099	T
Black buffalo	0	7	4	0	9,968	4,984	T
Green sunfish	7	0	4	140	0	70	T
Longnose gar	0	7	4	0	14,126	7,063	T
Spotfin shiner	7	0	4	49	0	25	T
Totals	**8,645**	**292,425**		**276,864**	**3,128,244**		

Table 3. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Widows Creek Fossil Plant A During 1974-1975 and 2005-2007.

	1974-1975		June 2005-2006		June 2006-2007	
Species Composition	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**
Threadfin shad	86	58	72	29	93	56
Bluegill	1	4	6	15	1	4
Unidentified sunfish	-	4	5	16	1	4
Gizzard shad	2	1	2	1	-	-
Channel catfish	1	3	4	11	-	-
Freshwater drum	7	13	6	8	1	2
Largemouth bass	-	1	2	7	-	1
Yellow bass	-	-	3	10	4	27
Spotted bass	-	-	-	1	-	1
Skipjack herring	1	1	-	-	-	-
White crappie	-	2	-	-	-	-
Longnose gar	-	2	-	-	-	-
Sauger	-	2	-	-	-	-
White sucker	1	-	-	-	-	-
Paddlefish	-	2	-	-	-	-
White bass	1	5	0	1	-	3
Total	**100**	**98**	**100**	**99**	**100**	**98**

Dash denotes not a major species that year.

Table 4. Numbers of Fish Impinged at Widows Creek Fossil Plant A by Month and Percent of Annual Total During Year-One, Year-Two, and for Both Years Combined.

Month	Total Number of Fish Impinged Year-One	Percent of Annual Total	Total Number of Fish Impinged Year-Two	Percent of Annual Total	Years One and Two Combined	Percent of Two-year Total
Jan	21	2	4	0	25	0
Feb	5	0	3	0	8	0
Mar	11	1	1,830	4	1,841	4
Apr	5	0	4,504	11	4,509	10
May	12	1	1,593	4	1,605	4
Jun	60	5	738	2	798	2
Jul	373	30	261	1	634	1
Aug	512	41	7,612	18	8,124	19
Sep	146	12	25,002	60	25,148	58
Oct	66	5	63	0	129	0
Nov	24	2	154	0	178	0
Dec	0	0	11	0	11	0
Total	**1,235**		**41,775**		**43,010**	

Table 5. Total Numbers of Fish Estimated Impinged by Year at Widows Creek Fossil Plant A and Numbers Following Application of Equivalent Adult and Production Foregone Models.

	1974-1975	2005-2006	2006-2007
Extrapolated Annual Number Impinged	87,213	8,645	292,425
Number after EA and PF Reduction	12,238	903	14,687

Table 6. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Widows Creek Fossil Plant B.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Lepisosteidae	*Lepisosteus osseus*	Longnose gar	8	0
Clupeidae	*Dorosoma cepedianum*	Gizzard shad	13	5
	Alosa chrysochloris	Skipjack herring	38	2
	Dorosoma petenense	Threadfin shad	14,614	2,824
Cyprinidae	*Notemigonus crysoleucas*	Golden shiner	0	3
	Notropis volucellus	Mimic shiner	0	16
	Notropis atherinoides	Emerald shiner	1	0
Catostomidae	*Moxostoma duquesnii*	Black redhorse	1	0
Ictaluridae	*Ictalurus furcatus*	Blue catfish	1	17
	Ictalurus punctatus	Channel catfish	65	68
	Pylodictis olivaris	Flathead catfish	12	10
	Ameiurus natalis	Yellow bullhead	2	0
Poeciliidae	*Gambusia affinis*	Western mosquitofish	14	0
Atherinoides	*Menidia beryllina*	Inland silverside	0	18
Moronidae	*Morone chrysops*	White bass	0	3
	Morone mississippiensis	Yellow bass	76	41
Centrarchidae	*Pomoxis nigromaculatus*	Black crappie	0	9
	Pomoxis annularis	White crappie	3	0
	Lepomis Macrochirus	Bluegill	731	1,367
	Micropterus salmoides	Largemouth bass	62	28
	Lepomis megalotis	Longear sunfish	17	25
	Lepomis auritus	Redbreast sunfish	1	38
	Lepomis microlophus	Redear sunfish	445	276
	Micropterus dolomieu	Smallmouth bass	0	3
	Micropterus punctulatus	Spotted bass	20	13
	Lepomis humilis	Orangespotted sunfish	12	0
	Lepomis cyanellus	Green sunfish	0	12
	Lepomis spp.	Hybrid sunfish	2	0
	Ambloplites rupestris	Rock bass	3	8

Table 6. (continued)

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Percidae	*Percina caprodes*	Logperch	6	12
	Percina sciera	Dusky darter	1	0
	Percina shumardi	River darter	1	0
	Perca flavescens	Yellow perch	12	0
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	57	104
		Total number of fish	**16,218**	**4,902**
		Total number of species	**27**	**23**

Table 7. **Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Widows Creek Fossil Plant B During 2005-2007.**

Species	Estimated Number			Estimated Biomass (g)			Percent Composition by Number
	Year-One	Year-Two	Average	Year-One	Year-Two	Average	
Threadfin shad	102,298	19,768	61,033	33,873	49,133	41,503	82
Bluegill	5,117	9,569	7,343	93,961	181,846	137,904	10
Redear sunfish	3,115	1,932	2,524	55,993	39,046	47,520	4
Freshwater drum	399	728	564	23,128	34,629	28,879	1
Channel catfish	455	476	466	42,273	113,050	77,662	1
Yellow bass	532	287	410	5,068	11,137	8,103	1
Largemouth bass	434	196	315	700	1,484	1,092	T
Longear sunfish	119	175	147	987	5,201	3,094	T
Skipjack herring	266	14	140	22,631	1,694	12,163	T
Redbreast sunfish	7	266	137	665	7,420	4,043	T
Spotted bass	140	91	116	5,180	6,118	5,649	T
Flathead catfish	84	70	77	840	266	553	T
Gizzard shad	91	35	63	2,905	13,874	8,390	T
Inland silverside	0	126	63	0	462	231	T
Logperch	42	84	63	434	1,372	903	T
Blue catfish	7	119	63	1,092	1,659	1,376	T
Mimic shiner	0	112	56	0	168	84	T
Western mosquitofish	98	0	49	497	0	249	T
Green sunfish	0	84	42	0	924	462	T
Orangespotted sunfish	84	0	42	420	0	210	T
Yellow perch	84	0	42	371	0	186	T
Rock bass	21	56	39	105	5,208	2,657	T
Black crappie	0	63	32	0	1,029	515	T
Longnose gar	56	0	28	21	0	11	T
Golden shiner	0	21	11	0	1,939	970	T
Smallmouth bass	0	21	11	0	63	32	T
White bass	0	21	11	0	938	469	T
White crappie	21	0	11	1,036	0	518	T
Hybrid sunfish	14	0	7	728	0	364	T
Yellow bullhead	14	0	7	49	0	25	T
Emerald shiner	7	0	4	70	0	35	T
River darter	7	0	4	35	0	18	T
Black redhorse	7	0	4	14	0	7	T
Dusky darter	7	0	4	84	0	42	T
Totals	**113,526**	**34,314**		**293,160**	**478,660**		

Table 8. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Widows Creek Fossil Plant B During 1974-1975 and 2005-2007.

	1974-1975		June 2005-2006		June 2006-2007	
Species Composition	**% by Number**	**% after PF and EA**	**% by Number**	**% after PF and EA**	**% by Number**	**% after PF and EA**
Threadfin shad	91	72	90	70	58	25
Bluegill	1	3	5	14	28	44
Unidentified sunfish	-	1	3	8	8	13
Gizzard shad	1	1	-	-	-	-
Channel catfish	-	1	-	1	1	6
Freshwater drum	4	9	-	1	2	2
Largemouth bass	-	-	-	1	1	2
Yellow bass	-	-	-	2	1	3
Spotted bass	-	-	-	1	-	1
Black crappie	-	-	-	-	-	T
Logperch	-	-	-	-	-	1
Sauger	1	7	-	-	-	-
White sucker	1	-	-	-	-	-
Spotted sucker	1	1	-	-	-	-
White bass	-	3	-	-	-	-
Rock bass	-	-	-	-	-	2
Total	**100**	**98**	**98**	**98**	**99**	**97**

Dash denotes not a major species that year.

Table 9. Numbers of Fish Impinged at Widows Creek Fossil Plant B by Month and Percent of Annual Total During Year-One, Year-Two, and for Both Years Combined.

Month	Total Number of Fish Impinged Year-One	Percent of Annual Total	Total Number of Fish Impinged Year-Two	Percent of Annual Total	Year-One and Two Combined	Percent of Two-year Total
Jan	292	2	30	1	322	2
Feb	48	0	28	1	76	0
Mar	40	0	52	1	92	0
Apr	206	1	30	1	236	1
May	69	0	140	3	209	1
Jun	101	1	63	1	164	1
Jul	13,309	82	328	7	13,637	65
Aug	1,135	7	500	10	1,635	8
Sep	583	4	2,052	42	2,635	12
Oct	108	1	65	1	173	1
Nov	300	2	1,596	33	1,896	9
Dec	27	0	18	0	45	0
Total	**16,218**		**4,902**		**21,120**	

Table 10. Total Numbers of Fish Estimated Impinged by Year at Widows Creek Fossil Plant B and Numbers Following Application of Equivalent Adult and Production Foregone Models.

	1974-1975	2005-2006	2006-2007
Extrapolated Annual Number Impinged	26,894	113,526	34,314
Number after EA and PF Reduction	4,287	4,179	2,501

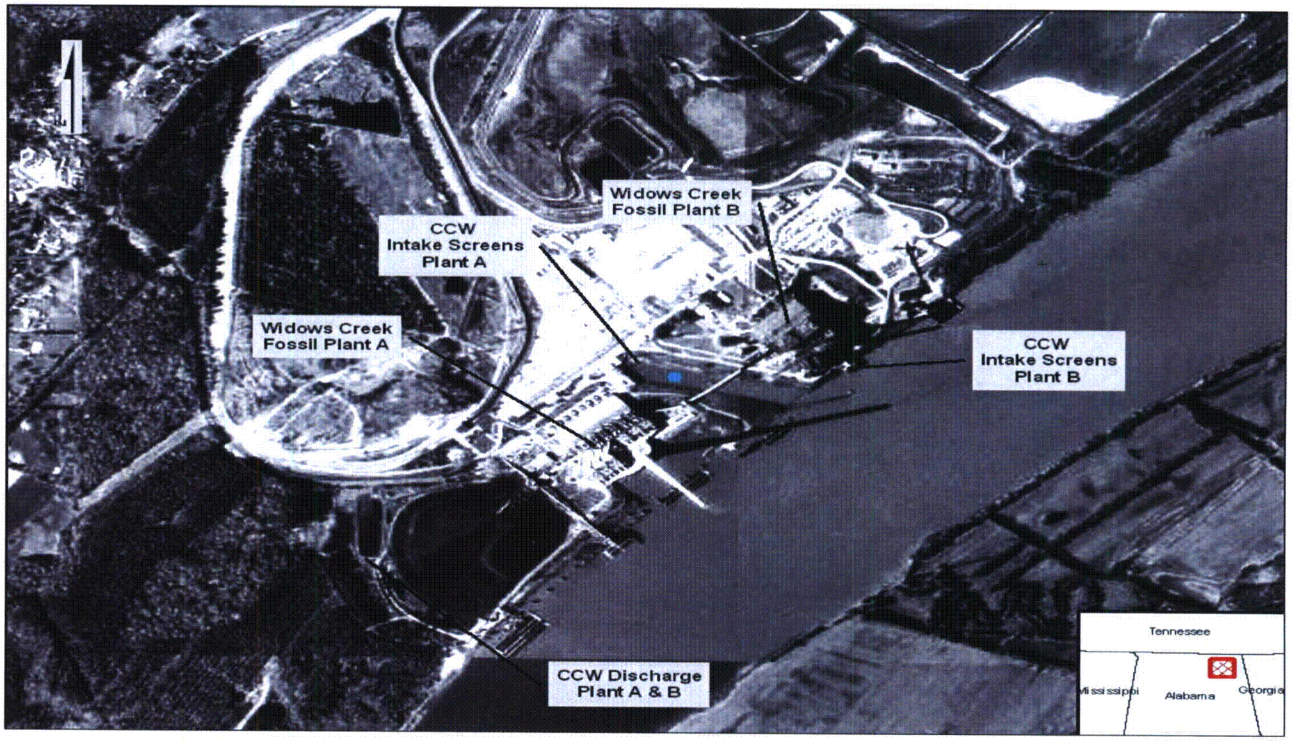

Figure 1. Aerial photograph of Widows Creek Fossil Plant's A and B CCW intake structures including skimmer boom, intake basin, and discharge channel.

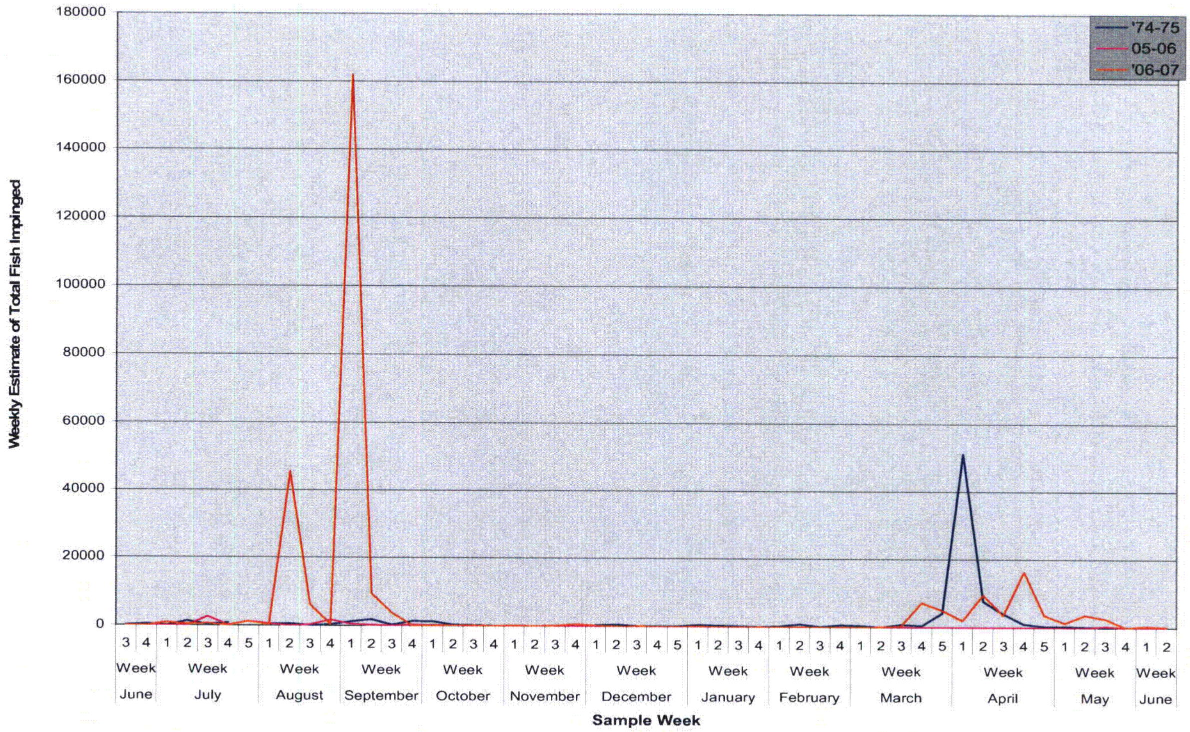

Figure 2. Comparison of estimated weekly fish impingement at TVA's Widows Creek Fossil Plant A during historical and recent monitoring periods.

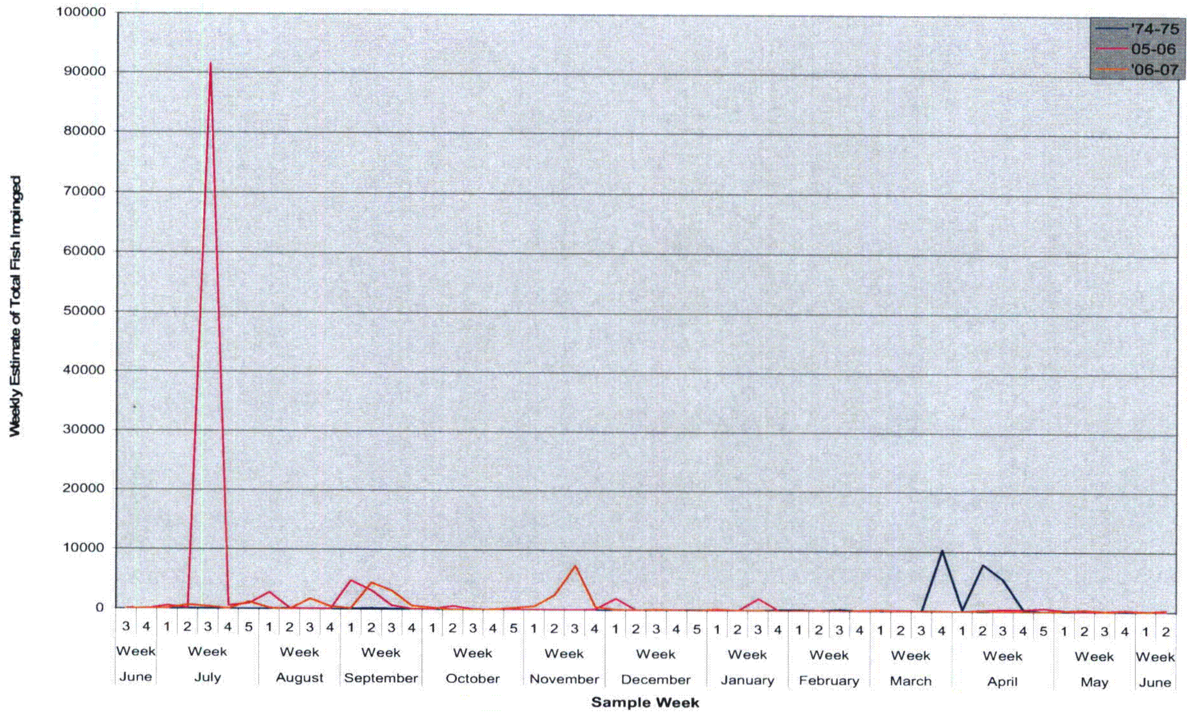

Figure 3. Comparison of estimated weekly fish impingement at TVA's Widows Creek Fossil Plant B during historical and recent monitoring periods.

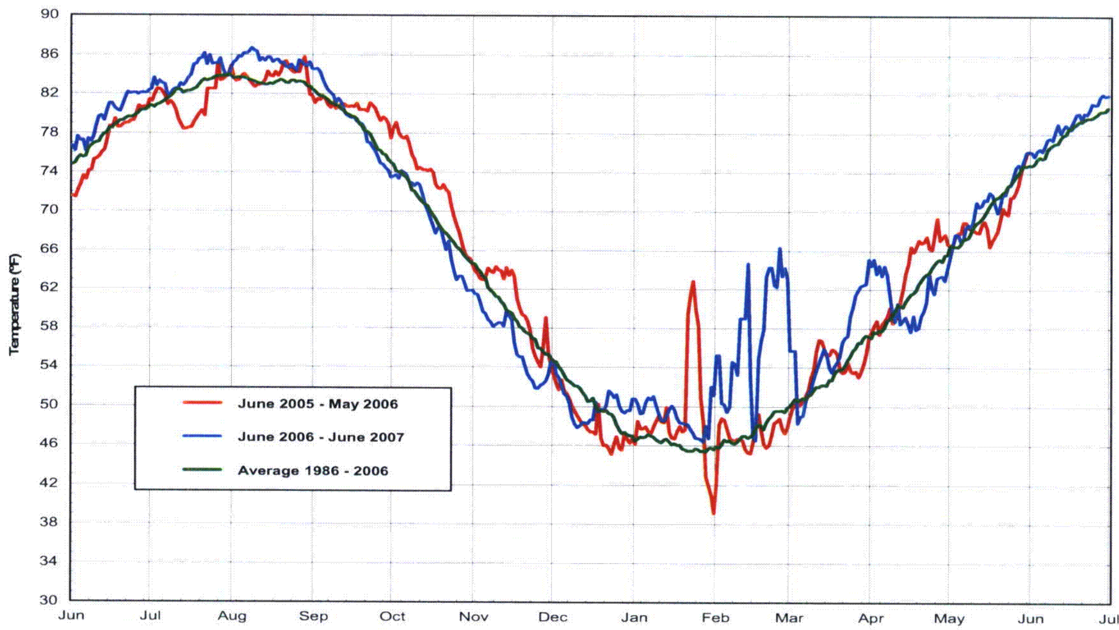

Figure 4. Ambient daily (24-hr avg.) water temperature at Widows Creek Fossil Plant intake during (1986-2007).

Tennessee Valley Authority

TVA's Reservoir Ecological Health Monitoring Function

TVA's Reservoir Ecological Health Monitoring Function

TVA began to systematically monitor conditions in the reservoirs on the Tennessee River system in 1990. The basic purpose of this monitoring program is to provide information on the "health" or integrity of Tennessee Valley reservoirs. The ecological health evaluation is based on five key ecological indicators: dissolved oxygen, chlorophyll, fish (Reservoir Fish Assemblage Index), bottom life (Reservoir Benthic Index), and sediment quality. The ecological health evaluation system examines each indicator separately based on expectations under reference conditions and assigns an ecological classification of poor, fair, or good, and then results are combined into a single, composite score for each reservoir.

TVA monitors ecological conditions at 69 sites on 31 reservoirs. Samples are taken at up to four locations, depending on the reservoir's size. Physical and chemical monitoring is conducted on an annual basis while biological indicators and sediment contaminants are monitored every other year. Each year, biological and sediment sampling is conducted on roughly half the reservoirs, on an alternating basis. If substantial biological changes are detected, biological indicators on that reservoir are monitored the next year to determine if the change was temporary.

<u>Monitoring Design</u>

The monitoring design carefully considered the selection of important ecological indicators, representative sampling locations, and frequency of sampling, all in light of available resources. Following are some of the basic design decisions made in developing this program.

Ecological Indicators – Five key ecological indicators (dissolved oxygen [DO], chlorophyll, sediments, benthos, and fish) were selected.

- *<u>Oxygen</u>* is vital for life. Probably more can be learned about a reservoir from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, and temperature).

- *Chlorophyll* a is a simple, long standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir. Algae are the base of the aquatic food chain; consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Conversely, elevated phytoplankton concentrations are a concern because adverse ecological and use impacts could occur: undesirable shifts in fish composition, reduction in water clarity, more frequent algal blooms, greater potential for the presence of toxic algae, higher oxygen demands, increased periods of anoxic conditions (no oxygen) and resultant anoxic byproducts (i.e. ammonia, sulfide, and dissolved manganese), and more frequent water treatment problems and higher water treatment cost.
- *Sediments* at the bottoms of reservoirs serve as a repository for a variety of materials, especially chemicals which have a low solubility in water. If contaminated, bottom sediments can have adverse impacts on bottom fauna and can often be long-term sources of toxic substances to the aquatic environment. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. Thus, examination of reservoir sediments is useful to determine if toxic chemicals are present and if chemical composition is changing through time.
- *Benthic macroinvertebrates* are usually included in aquatic monitoring programs because they are important to the aquatic food web and because they have limited capability of movement, thereby preventing them from avoiding undesirable conditions.
- *Fish* are usually included in aquatic monitoring programs because they are important to the aquatic food web and because they have a long life cycle which allows them to integrate conditions over time. In streams, fish community monitoring often has found environmental degradation when physical and chemical monitoring have failed

failed to do so. Fish are also important to the public for aesthetic, recreational, and commercial reasons.

Sampling Locations – Four areas were selected for monitoring due to the spatial variation that exists within a reservoir:

- Inflow area, generally riverine in nature. Water velocity is usually sufficient to prevent thermal stratification, and algae productivity is suppressed due to light limitation resulting from greater amounts of suspended material in the water column and reduced time in the photic zone. Likewise, because of the greater velocity, the substrate on the reservoir bottom is generally composed of larger material such as boulder, cobble, and/or sand.
- Transition zone or mid-reservoir area is where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, water clarity increases, and silt becomes a more prominent substrate. Algal productivity increases because of the increased water clarity and reduced mixing, which allows the algae to remain in the photic zone.
- Forebay, the lacustrine area near the dam. Water velocity often is slowest within this reach, creating greater potential for thermal stratification and associated reduction in oxygen concentrations as organic material settles in the water column and decays. Phytoplankton dynamics often shift from light limitation to nutrient limitation.

- Embayments, another important type of reservoir area, also were considered. Previous studies have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with little influence from the main body of the reservoir. Although these are important areas, monitoring of hundreds of embayments was beyond the scope of this program. As a result, only four, large embayments (all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres) are included in this monitoring effort.

The forebay and transition (mid-reservoir) zones are monitored on most reservoirs. In addition, inflow areas are sampled on run-of-the river reservoirs. Only the forebay is sampled on very small reservoirs or reservoirs where zones were indistinguishable and up to four sites (forebay, transition zone, inflow, and embayment) are sampled in selected run-of-the-river reservoirs.

Sampling Frequency – Sampling frequencies (indexing periods) was based on expected temporal variation for each indicator. Temporal variations are introduced not only by seasonal changes, but also because reservoirs are controlled systems with planned annual drawdowns in elevations. Indicators which can vary significantly in the short term (dissolved oxygen and chlorophyll) are monitored monthly from spring to autumn. Other indicators better integrate long-term variations and are sampled once each year. Sediments are monitored once in mid-summer. Fish and benthic assemblages are sampled once in autumn (September-November).

Sample Collection Methods

The number of indicators varies from three to five at different sites. Chlorophyll and sediment quality are excluded at the inflows on run-of-the-river reservoirs because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there.

- *Dissolved Oxygen and Chlorophyll* is sampled at forebay and transition zones. Physical and chemical water quality monitoring is conducted monthly April through September on mainstem reservoirs and April through October on tributary reservoirs. All samples and measurements are taken over the original river channel. Water column profiles are taken for temperature, DO, pH, and conductivity. Composite samples of water within the photic zone (defined as twice the Secchi depth or 4 meters, whichever is greater) are collected for laboratory analysis of chlorophyll, total suspended solids, total organic carbon, alkalinity, and various nutrients (total phosphorus, total ammonia as nitrogen, nitrate-nitrite nitrogen, and organic nitrogen). Sample analysis is conducted by TVA's Central Laboratories.

- *Sediment* - Once a year (i.e., June or July), a composite sediment sample is collected at forebay and transition monitoring locations. Each sediment sample is a composite of at least three subsamples. Each subsample is collected independently and at least 50 feet apart from either of the other two subsamples. All subsamples are collected from the bottom of the original river channel. Only the top 3 centimeters of sediment from each subsample is composited and used for laboratory analysis. Sample analysis is conducted by TVA's Central Laboratories.
- *Benthic macroinvertebrate* samples are collected in the fall/early winter (October-December) at all locations (forebay, transition, and inflow). At each sample location, a line-of-sight transect is established across the width of the reservoir, and one Ponar grab sample is collected at 10 equally-spaced locations along this transect. When rocky substrates are encountered, a Peterson dredge is used. Care is taken to collect samples only from the permanently wetted bottom portion of the reservoir (i.e., below the elevation of the minimum winter pool level). Bottom sediments are washed on a 533μ screen and organisms are counted and identified in the field to either Family or Order level as appropriate (i.e., the lowest practical in the field). Samples are then transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution.
- *Fish Community*- Shoreline electrofishing samples are collected during daylight hours during autumn (September through November) as each sampling location (forebay, transition, and inflow). A total of 15 electrofishing runs, each covering 300 meters of shoreline, are conducted in each of the sampled zones. All habitat types are sampled in proportion to their occurrence in the zone. Twelve experimental gill nets with five 6.1-meter panels (mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7 centimeters) are set for one overnight period in forebay and transition zones. Excessive current prevented use of gill nets in mainstream inflow areas, limiting sampling to only electrofishing in these locations. Nets are set in all habitat types, alternating mesh sizes toward the shoreline between sets.

Total length (mm) and weight (g) are recorded for sport species. Remaining species captured are enumerated prior to release. During electrofishing, fish observed but not captured are included if positive identification can be made and counts are estimated when high densities of identifiable fish are encountered. Young-of-year fish are counted separately and, as in stream IBI calculations (Karr 1981), are excluded from proportional and abundance metrics due to sampling inefficiencies. Only fish examined closely as a result of obtaining length and weight measurements are inspected externally for signs of disease, parasites, and anomalies. Natural hybrids (i.e., those known not to be part of a fisheries management program) are recorded as anomalies. Field data loggers are used to record all results.

Data Evaluation Considerations

Two key elements in developing this program were (1) development of reference conditions for each indicator (i.e., benchmarks representative of good, fair, and poor conditions) and (2) separation of reservoirs into appropriate classes according to ecoregion and reservoir type.

Reference Condition

Like most evaluations, results for ecological integrity studies must be compared to some reference or yard stick to determine if monitoring results are indicative of good, fair, or poor conditions. In streams, this is usually accomplished by studying a site that has had little or preferably no alterations due to human activities. Observations at that site provide the reference conditions or expectations of what represents a site with good/excellent ecological health. Given that reservoirs are not natural systems, this approach is inappropriate. Following is a brief description of the approach taken for each indicator.

- *DO and Sediment* - Evaluation criteria for DO and sediment quality are based on the concept that "ideal conditions" should exist in all types of reservoirs regardless of reservoir/dam operation and ecoregion. In application, this means hypolimnetic anoxia is considered a poor ecological condition even if it is expected given dam and reservoir characteristics. Ideal condition for sediments means concentrations of selected metals should not exceed background levels and there should be no detectable pesticides or PCBs present. In this situation, there is no need for reservoir classification because the same conditions are desired for all reservoirs.

- *Chlorophyll* a - Criteria for chlorophyll are based on natural nutrient composition of soils in the drainage area. Two classes of reservoirs within the Tennessee Valley are considered: reservoirs in watersheds draining nutrient poor soils, primarily those in the Blue Ridge Ecoregion where oligotrophic conditions are expected; and reservoirs in watersheds draining soils which are not nutrient poor and greater productivity (mesotrophic conditions) is expected.
- *Benthic Macroinvertebrates and Fish Assemblage* - Evaluation criteria for benthos and fish present a greater challenge. TVA's experience has found use of best-observed conditions adjusted using professional judgment as the preferred approach. Use of best-observed conditions means the data set for the class of reservoirs under consideration forms the basis to describe the range of conditions which might exist for each community characteristic or metric. In practicality, this assumption of "full range of conditions" is rarely met, so metrics must be adjusted using professional judgment. This requires significant experience with the group of reservoirs and biological communities under consideration.

Reservoir Classification

TVA's monitoring program includes 31 reservoirs which are divided into four classes to evaluate the benthos and fish. One class includes the reservoirs on the Tennessee River, plus the two navigable reservoirs on tributaries to the Tennessee River (loosely termed run-of-the-river reservoirs). This group of reservoirs has relatively short retention times and little winter drawdown. The remaining tributary reservoirs are separated into three classes by ecoregion: Blue Ridge Ecoregion, Ridge and Valley Ecoregion, and the Interior Plateau Ecoregion. The run-of-the-river reservoirs were not subdivided by ecoregion because most of the water flowing through them comes from upstream and does not originate within the ecoregion where the reservoir is physically located. Benthic macroinvertebrate and fish assemblage expectations for each metric have been developed for each of these four reservoir categories.

Ecological Health Rating Methods

- ***Dissolved oxygen*** – The rating criteria represent a multidimensional approach that includes dissolved oxygen levels both throughout the water column and near the bottom of the reservoir. The DO rating (ranging from 1 "poor" to 5 "good") at each sampling location is based on monthly measurements during April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs. This is the six-month period when maximum thermal stratification and maximum hypolimnetic anoxia are expected. The Water Column DO Rating is the six-month average of the proportion of the reservoir cross-sectional area at the sample location that has a DO concentration less than 2.0 mg/L. The Bottom DO Rating is the six-month average of the proportion of the reservoir cross-sectional bottom length that has a DO concentration less than 2.0 mg/L. The final DO rating is a combination of the Water Column DO Rating and Bottom DO Rating.
- ***Chlorophyll*** – Scoring criteria were developed separately for each of the two classes of reservoirs. Reservoirs expected to be oligotrophic receive highest ratings at low chlorophyll concentrations. Reservoirs expected to be mesotrophic receive highest ratings for an intermediate range of concentrations. For reservoirs expected to be mesotrophic, the rating is reduced at high chlorophyll concentrations and at low chlorophyll concentrations if an environmental factor (e.g., turbidity, toxicity,

retention time) inhibits primary production. A sliding scale is used to evaluate the seasonal average chlorophyll concentration for each reservoir class.

- ***Sediment quality*** – The sediment quality rating compares results for metals analyses to sediment guidelines we adapted from EPA Region 5 (EPA 1977). Presence of any of the organic analyses is deemed undesirable so results are compared to laboratory detection limits. If none of the metals exceed these guidelines and no PCBs or pesticides are detected, the site would receive the highest sediment quality rating. An occurrence of analytes above these standards lowers the rating.
- ***Benthic Macroinvertebrates*** – Seven metrics or characteristics encompassing taxa richness, composition and tolerance classification, and organism abundance are used to evaluate the benthic macroinvertebrates in all reservoirs. Scoring criteria for each metric were developed from the data base on TVA reservoirs. The benthic macroinvertebrate score is the total of these seven metrics. Some specific metrics vary between run-of-river reservoirs and tributary reservoirs due to differences in thermal stratification and dissolved oxygen concentrations.
- ***Fish Assemblage*** – Twelve metrics or characteristics encompassing species richness, composition, tolerance classification, and trophic structure, fish abundance, and fish condition are used to derive the Reservoir Fish Assemblage Index (RFAI). The same 12 metrics are used for all classes of reservoirs, although specific scoring ranges for each metric vary by reservoir class.

Final Reservoir Ecological Health Rating

The ecological health scoring process is designed such that four of the indicators (DO, chlorophyll-a, benthos, and fish) are given equal weights with each indicator assigned a rating ranging from 1 (poor) to 5 (excellent). The fifth indicator, sediment quality, is given half the weight of the other indicators and assigned a rating ranging from 0.5 (poor) to 2.5 (excellent). Ratings for the five indicators are summed for each site. Thus, the maximum total rating for a sample site would be 22.5 (all indicators excellent) and the minimum 4.5 (all indicators poor).

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum possible rating for that reservoir, and expressed as a percentage. It is necessary to use a percentage basis because the number of sites monitored varies according to reservoir size and configuration. Only one site, the forebay, is sampled in small tributary reservoirs, and up to four sites (forebay, transition zone, inflow, and embayment) are sampled in selected run-of-the-river reservoirs. Also, the number of indicators varies from three to five at different sites. Chlorophyll and sediment quality are excluded at the inflows on run-of-the-river reservoirs, because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. As a result, the number of scoring possibilities may be as few as 5 indicator ratings for a small reservoir sampled only at the forebay. Or, as many as 18 indicator ratings for a large reservoir sampled at the forebay, transition zone, inflow, and embayment. The total score for the small reservoir would be 22.5 if all indicators rated excellent, whereas, the total score for the large reservoir would be 82.5 if all indicators rated excellent. Hence, using a percentage basis allows easier comparison among reservoirs.

This approach provides a potential range of scores from 22 to 100 percent and applies to all reservoirs regardless of the number of indicators or sample sites. To complete the ecological health scoring process, the 22-100 percent scoring range must be divided into categories representing good, fair, and poor ecological health conditions. The approach used was to first obtain a five-year average ecological health score for each reservoir. The average scores were then plotted and examined for natural breaks which coincided with known reservoir condition. The trisection of these average ecological health scores is summarized below.

Scoring Ranges for All Reservoirs

Poor	Fair	Good
<59	59-72	>72

As the nation's largest public power provider and steward of the nation's fifth largest river system, TVA operates our system of dams and reservoirs in an integrated fashion that balances natural resource stewardship and power production with the other demands on the river system.

A critical aspect, integral to our operations, is timely, accurate assessments of water resource conditions upon which we can base sound management decisions.

TVA has conducted water quality monitoring to some degree since its inception. Initially, monitoring activities focused on specific assessments to meet specific needs as they arose. However, in the late-1980s, the need for a more systematic, Valley-wide approach to monitoring reservoir conditions lead to the creation of TVA's reservoir monitoring effort, termed Reservoir Ecological Health.

The current program integrates stewardship and compliance monitoring needs to support a variety of functions and issues related to environmental compliance, pollution prevention and control, economic development, and partnerships with our stakeholders. Additionally, several components are an integral part of the monitoring strategies, supporting the new reservoir operations policy adopted in 2004.

In absence of universally accepted guidelines to evaluate reservoir ecological health, TVA had to develop evaluation methodologies. The outcome was a weight-of-evidence approach utilizing the five key environmental indicators: dissolved oxygen, chlorophyll, fish, bottom life, and sediment quality. Additionally, the development of communication products appropriate to a wide range of customers including the general public also was a key issue addressed early in this program. The goal was to report a single, composite ecological health score for each reservoir in an easily understandable format.

TVA's methodology has proven successful and was used as a case study in the United States EPA "Lake and Reservoir Bioassessment and Biocriteria - Technical Guidance Document" (EPA 841-B-98-007).

Benefits Provided

Reservoir Ecological Health monitoring program provides TVA a sound foundation of resource information that supports our integrated river management program. The core components of this program have continued systematically since inception, providing both current data for day-to-

to-day operations and a consistent long-term database for assessing changes over time.

TVA's River Operations use these data as important input variables as they make decisions about how to best manage available water to meet the numerous competing demands for water in the Tennessee Valley. The ongoing monitoring program also has eliminated the need for many costly site studies which would otherwise be required for compliance with the National Environmental Policy Act and the Clean Water Act for each project/action. This program fills vital data needs for various environmental assessments for TVA fossil, nuclear, and hydro-generation facilities as well as TVA Section 26(a) assessments. The ready availability of data often prevents delays of 12 to 18 months on projects which might otherwise be necessary to collect appropriate background data for the preparation of EAs and EISs.

In addition, TVA Watershed Teams use this information in their watershed evaluation process to identify areas in need of improvement and/or protective actions and to generate interest by the public and local governments. In fact, TVA conducts a variety of water quality monitoring and assessment activities in partnership with state, federal, and local agencies. By sharing information, TVA and state environmental agencies are able to generate more information than either could reasonably expect to collect and analyze alone.

Tennessee Valley Authority

Environmental Assessment and Finding of No Significant Impact – Hartsville Nuclear Plant Site, Trousdale and Smith Counties, Tennessee Transfer of TVA Property for Industrial Park

Table 3.

Fish Collected in Monthly Netting and Electrofishing Samples at the Hartsville Site September 1992 through January 1993

Environmental Assessment and Finding of No Significant Impact

Hartsville Nuclear Plant Site
Trousdale and Smith Counties, Tennessee
Transfer of TVA Property For Industrial Park

Tennessee Valley Authority

March 2002

Table 3. Fish Collected in Monthly Netting and Electrofishing Samples at the Hartsville Site, September 1992 Through January 1993

Species	Netting		Electrofishing		Total	Relative
	Number	CPUE*	Number	CPUE*	Number	Abundance
Longnose gar	36	0.9	4	0.5	40	4.4
Skipjack herring	17	0.4	-	-	17	1.9
Gizzard shad	80	2.0	218	26.0	298	33.0
Threadfin shad	-	-	166	19.8	166	18.4
Mooneye	69	1.7	-	-	69	7.7
Carp	-	-	28	3.3	28	3.1
Silver chub	-	-	1	0.1	1	0.1
Emerald shiner	-	-	18	2.1	18	2.0
Spotfin shiner	-	-	1	0.1	1	0.1
River carpsucker	21	0.5	4	0.5	25	2.8
Quillback	2	0.1	-	-	2	0.2
Smallmouth buffalo	27	0.7	11	1.3	38	4.2
Bigmouth buffalo	1	t**	3	0.4	4	0.4
Black buffalo	-	-	2	0.2	2	0.2
Spotted sucker	8	0.2	14	1.7	22	2.4
Black redhorse	4	0.1	4	0.5	8	0.9
Golden redhorse	5	0.1	13	1.5	18	2.0
Yellow bullhead	1	t**	-	-	1	0.1
Channel catfish	9	0.2	-	-	9	1.0
White bass	1	t**	-	-	1	0.1
Yellow bass	1	t**	2	0.2	3	0.3
Striped bass	2	0.1	-	-	2	0.2
Warmouth	-	-	1	0.1	1	0.1
Redbreast sunfish	-	-	2	0.2	2	0.2
Green sunfish	-	-	3	0.4	3	0.3
Bluegill	-	-	52	6.2	52	5.8
Longear sunfish	-	-	1	0.1	1	0.1
Redear sunfish	1	t**	3	0.4	4	0.4
Hybrid sunfish	1	t**	-	-	1	0.1
Spotted bass	-	-	2	0.2	2	0.2
Largemouth bass	-	-	31	3.7	31	3.4
White crappie	-	-	1	0.1	1	0.1
Sauger	11	0.3	-	-	11	1.2
Walleye	2	0.1	-	-	2	0.2
Freshwater drum	6	0.2	12	1.4	18	2.0
Total (35 species)	305		597		902	

* Catch per unit effort; gill net effort units are net nights (total 40 net nights); electrofishing effort units are hours (total 8.4 hours)

** Trace, less than 0.1

Tennessee Valley Authority
Aquatic Monitoring and Management

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Introduction

Section 316(a) of the Clean Water Act (CWA) allows point-source discharges of heated water to exceed State water quality thermal criteria based on demonstrating maintenance of Balanced Indigenous Populations (BIP) of aquatic life. The term balanced indigenous population defined by the CWA requires: (1) a biotic community typically characterized by diversity; (2) the capacity for the community to sustain itself through cyclic seasonal change; (3) the presence of necessary food chain species; and (4) a lack of domination by pollution tolerant species. Prior to 2001, the Tennessee Valley Authority's (TVA) Gallatin Fossil Plant (GAF) was operating under a 316(a) alternate thermal limit that had been administratively continued with each permit renewal based on studies conducted in the mid-1970s. The Environmental Protection Agency Region IV guidance to the States for conducting 316(a) studies requires that future alternate thermal limit requests require new data which demonstrates that aquatic communities in the vicinity of the permitee's plant meet the BIP standard. In the Tennessee River system, TVA has used a reservoir Vital Signs (VS) monitoring program since 1990 to evaluate ecological conditions in major reservoirs. A component of this monitoring program is a multi-metric approach to data evaluation for fish communities known as the Reservoir Fish Assemblage Index (RFAI). The Tennessee Department of Environment and Conservation (TDEC) approved the use of RFAI to demonstrate maintenance of BIP downstream from GAF on September 17, 2001, in response to a letter from TVA Fossil Power Group requesting assessment of adequacy and scope of proposed RFAI studies for continuance of alternate thermal limits. Based on that agreement, RFAI samples are required to be taken once every two years to demonstrate that GAF operation is not impacting BIP. To determine BIP for reservoirs in the Cumberland River system, which had not been previously sampled using RFAI techniques, TDEC requested that annual RFAI samples be collected for a three-year period during 2001-2003, followed by repeated samples at two-year intervals. This report presents the results of autumn 2007 RFAI data collected upstream and downstream of GAF with comparisons to RFAI data collected at these sites during autumn 2001, 2002, 2003, and 2005.

Methods

The GAF discharge enters the Cumberland River at Cumberland River Mile (CuRM) 242.5. Fish community sampling sites were selected upstream (CuRM 249.5) and downstream (CuRM 240.0) of the plant discharge.

Fish samples consisted of fifteen 300-meter electrofishing runs (approximately 10 minutes duration each) and ten overnight experimental gill net sets (five 6.1-meter panels with mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7 cm) per site. Attained values for each of the 12 metrics were compared to reference conditions for transition zones of Barkley and Old Hickory reservoirs and were assigned scores based upon three categories hypothesized to represent relative degrees of degradation: least degraded (5); intermediate (3); and most degraded (1). These categories are based on "expected" fish community characteristics in the absence of human-induced impacts other than impoundment. Individual metric scores for a site are summed to obtain the RFAI score. Comparison of the attained RFAI score from the potential impact zone to a predetermined criterion has been developed and utilized to identify presence of normal community structure and hence existence of BIP. For multi-metric indices, two criteria have been suggested to ensure a conservative screening of BIP. First, if an RFAI score reaches 70% of the highest attainable score (adjusted upward to include sample variability), and second, if fewer than half of RFAI metrics potentially influenced by thermal discharge receive a low (1) or moderate (3) score, then normal community structure and function would be present indicating a BIP. The heated discharge would meet screening criteria and no further evaluation would be needed. The range of RFAI scores possible is from 12 to 60. Ecological health ratings (12-21 ["Very Poor"], 22-31 ["Poor"], 32-40 ["Fair"], 41-50 ["Good"], or 51-60 ["Excellent"]) are then applied to scores. As discussed in detail below, the average variance for RFAI scores in TVA reservoirs is 6 ($\pm$ 3). Therefore, any location that attains an RFAI score of 45 (42 + our upward sample variance of 3) or higher would be considered to have BIP. It must be stressed that scores below this endpoint do not necessarily reflect an adversely impacted fish community. The endpoint is used to serve as a conservative screening level, i.e., any fish community that meets these criteria is obviously not adversely impacted. RFAI scores below this level would require a more in-depth look to determine if a BIP exists. An inspection of individual RFAI metric results would be an initial step to help identify if GAF operation is a contributing factor to low scores. This approach is appropriate if a validated multi-metric index is being used and scoring criteria applicable to the zone of study are available.

Upstream/downstream score comparisons can help to determine if GAF operation is adversely impacting the downstream fish community. A similar or higher RFAI score at the downstream site compared to the upstream (control) site is used as one basis for determining absence of GAF operational impacts on the resident fish community. Definition of "similar" is integral to accepting the validity of these interpretations. The Quality Assurance (QA) component of VS monitoring deals with how well the RFAI scores can be repeated and is accomplished by collecting a second set of samples at 15%-20% of sites each year. Experience to date with the QA component of the VS monitoring program shows that comparison of RFAI index scores from 54 paired sample sets collected over seven years range from 0 to 18 points, the 75th percentile is 6, the 90th percentile is 12. The mean difference between these 54 paired scores is 4.6 points with 95% confidence limits of 3.4 and 5.8. Based on these results, a difference of 6 points or less is the value selected for defining "similar" scores between upstream and downstream fish communities. That is, if the downstream RFAI score is within 6 points of the upstream score and if there are no major differences in overall fish community composition, then they will be considered similar. It is important to bear in mind that differences greater than 6 points can be expected simply due to method variation (25% of the QA paired sample sets exceeded that value). When such occurs, a metric by metric examination will be conducted to determine what caused the difference in scores and the potential for the difference to be thermally related.

TVA's VS monitoring program is focused on the Tennessee River system; therefore RFAI samples had not been collected on Old Hickory Reservoir prior to 2001, with the exception of three embayments which were sampled during 1998-1999. Initially, RFAI samples above and below GAF were scored using RFAI criteria for lower mainstem Tennessee River reservoirs due to lack of data from the Cumberland River system. Because these scoring criteria were based on fish communities in Tennessee River reservoirs, they may not have accurately described the condition of the fish communities in Cumberland River reservoirs. Modifications to the scoring criteria used for RFAI metrics were made following the third year of samples from Barkley and Old Hickory Reservoirs in 2003. These new scoring criteria were developed for Barkley and Old Hickory reservoirs from limited Cumberland River data and were supplemented with data collected from the Tennessee River system. These criteria were applied to RFAI sites sampled during 2001-2005 to make the index even more reflective of reservoir conditions (TVA 2005).

Although the initial scoring criteria revisions in 2003 were a worthy attempt at making the RFAI more reflective of lower Cumberland River fish communities, these criteria still lacked adequate Cumberland River reservoir data to accurately score these sites. Revisions to scoring criteria for RFAI metrics for Cumberland River sampling sites were revised again in 2007 and applied to all data presented in this report (TVA 2007). Since the original criteria were established, additional data sets from the Cumberland River have been collected. The new scoring criteria are based exclusively on Cumberland River data, which more accurately reflect the condition of resident fish communities in Barkley and Old Hickory reservoirs. Thirty-two data sets were used for updating Cumberland River scoring criteria. These included data from 1998-2007 from Barkley Reservoir and data collected during 2001-2007 from Old Hickory Reservoir. Most recent scoring criteria are compared to old scoring criteria in Table 1.

Results

In 2007, fish community RFAI scores of 40 ("Fair") and 46 ("Good") were observed at the downstream and upstream stations, respectively (Table 2). Although the downstream site scored lower, it was still within the 6 point range of accepted variability. Of the observed values for metrics that received a lower score at the downstream site, the observed value for the metric "number of species" was the most different between the two sites (Table 2). Twenty-seven species were collected at the downstream site, compared to 34 at the upstream site. Ten species were collected at the upstream site that were not encountered at the downstream site, while four species were collected at the downstream site that were not encountered at the upstream site (Table 3). Although more species were collected upstream resulting in a 2 point score difference for this metric, both sites scored the same for the metrics "number of benthic invertivores" and "number of intolerant species". As water quality conditions deteriorate, these two metrics are good indicators of impacts to the more sensitive species in the fish community. The metric "number of top carnivore species" scored two points lower at the downstream site due to one less top carnivore species; this was not a significant ecological difference between the two sites but was significant to the metric score. Percentages of omnivorous species in the electro-fishing sample were similar (31.3% downstream, 28.1% upstream), but the upstream site scored one point higher. Overall catch rates for the electro-fishing portion of samples were higher at the downstream site, while gill netting catch rates were higher at the upstream site (Table 3). A majority of the species that were collected at the upstream site that were not encountered at the downstream site are commonly caught in gill nets. Variability in gill net catch rates may have significantly affected the score difference between the two sites.

Although the BIP criteria (i.e., RFAI score of 45 {42 + our upward sample variance of 3} or higher) has only been met 2 of the 5 sample years at the upstream site and during 1 of the 5 sample years at the downstream site, all upstream and downstream samples have been within the 6 point range of accepted variability each year, indicating the sites were similar annually (Table 4). During 2007, the upstream site scored 8 points higher than the previous sample in 2005, while the downstream score dropped 3 points from the 2005 score. Over the five sample years, both sites have averaged a score of 40 ("Fair"). Individual metric scores and overall RFAI scores for the upstream and downstream sampling sites for sample years 2001-2003 and 2005 are listed in Appendix 1 (A-D). Species collected and catch per effort during electrofishing and gill netting at the upstream and downstream sampling sites for sample years 2001-2003 and 2005 are listed in Appendix 2 (A-D).

Scores and overall fish community composition were better than expected during 2007 at both sites; the low flow situation in the Cumberland River resulting from the most severe drought in 118 years of record, further exacerbated by Wolf Creek Dam repair, impacted overall water quality in the Cumberland River system. Even under these conditions, the overall composition of the fish community was similar between the two sites and it does not appear that the GAF heated effluent was negatively affecting the fish community below the plant discharge.

Literature Cited

TVA. 2005. Results of fish community monitoring in the vicinity of Gallatin Fossil Plant during autumn 2001-2003 and 2005 in support of a continued 316(a) thermal variance. Tennessee Valley Authority, Knoxville, Tennessee.

TVA. 2007. Revised Cumberland River RFAI Scoring Criteria. Tennessee Valley Authority, Aquatic Monitoring and Management, Chattanooga, Tennessee.

Table 1. Comparison of Old Scoring Criteria to Newly Revised 2007 Scoring Criteria for Transition Areas in Barkley and Old Hickory Reservoirs. Old Scoring Criteria Represent Criteria that were Modified in 2003 Using Limited Cumberland River Data and were Supplemented with Data from the Tennessee River System. New Scoring Criteria were Developed from 32 Datasets from Sampling Conducted During 1998-2007 in Barkley and Old Hickory Reservoirs.

		Old Scoring Criteria Score			New Scoring Criteria Score		
Metric	**Gear**	**1**	**3**	**5**	**1**	**3**	**5**
1. Total species	Combined	<13	13-25	>25	<17	17-33	>33
2. Total Centrarchid species	Combined	<2	2-5	>5	<3	3-5	>5
3. Total benthic invertivores	Combined	<2	2-3	>3	<3	3-6	>6
4. Total intolerant species	Combined	<2	2-4	>4	<4	4-7	>7
5. Percent tolerant individuals	Electrofishing	>59%	30-59%	<30%	>71%	53-71%	<53%
	Gill Netting	>53%	27-53%	<27%	>40%	23-40%	<23%
6. Percent dominance by 1 species	Electrofishing	>43%	22-43%	<22%	>51%	37-51%	<37%
	Gill Netting	>46%	23-46%	<23%	>37%	25-37%	<25%
7. Percent non-native species	Electrofishing	>3%	1-3%	<1%	>7%	4-7%	<4%
	Gill Netting	>8%	4-8%	<4%	>8%	5-8%	<5%
8. Total top carnivore species	Combined	<3	3-7	>7	<5	5-10	>10
9. Percent top carnivores	Electrofishing	<7%	7-15%	>15%	<8%	8-15%	>15%
	Gill Netting	<19%	19-38%	>38%	<32%	32-52%	>52%
10. Percent omnivores	Electrofishing	>44%	22-44%	<22%	>46%	31-46%	<31%
	Gill Netting	>54%	27-54%	<27%	>47%	19-47%	<19%
11. Average number per run	Electrofishing	<174	174-348	>348	<81	81-143	>143
	Gill Netting	<22	22-44	>44	<13	13-23	>23
12. Percent anomalies	Electrofishing	>5%	2-5%	<2%	>5%	2-5%	<2%

	Gill Netting	>5%	2-5%	<2%	>5%	2-5%	<2%

Table 2. Individual Metric Scores and Overall RFAI Scores for Sites Downstream and Upstream of the Gallatin Fossil Plant Discharge, Autumn 2007.

Autumn 2007		Downstream CuRm 240.0		Upstream CuRm 249.5	
Metric		Obs	Score	Obs	Score
A. Species richness and composition					
1. Number of species		27	3	34	5
2. Number of centrarchid species		7	5	7	5
3. Number of benthic invertivores		3	3	5	3
4. Number of intolerant species		5	3	6	3
5. Percent tolerant individuals	Electrofishing	67.5	1.5	65.6	1.5
	Gill Netting	6	2.5	17.3	2.5
6. Percent dominance by one species	Electrofishing	27.4	2.5	26.8	2.5
	Gill Netting	23.3	2.5	12.3	2.5
7. Number non-native species	Electrofishing	15.9	0.5	9.5	0.5
	Gill Netting	6	1.5	5.9	1.5
8. Number of top carnivore species		10	3	11	5
B. Trophic composition					
9. Percent top carnivores	Electrofishing	13.9	1.5	17.5	2.5
	Gill Netting	60.9	2.5	54.1	2.5
10. Percent omnivores	Electrofishing	31.3	1.5	28.1	2.5
	Gill Netting	26.3	1.5	36.8	1.5
C. Fish abundance and health					
11. Average number per run	Electrofishing	75.1	0.5	61.5	0.5
	Gill Netting	13.3	1.5	22	1.5
12. Percent anomalies	Electrofishing	1.1	2.5	1.8	2.5
	Gill Netting	12	0.5	5.9	0.5
RFAI			40		46
			Fair		Good

Table 3. Species Collected and Catch Per Effort During Electrofishing and Gill Netting Downstream and Upstream of Gallatin Fossil Plant, Autumn 2007. (Electrofishing Effort = 300 Meters of Shoreline and Gill Netting Effort = Net-Nights).

Autumn 2007	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Paddlefish	.	.	.	.	.	0.10
Skipjack herring	.	.	3.10	.	.	2.70
Gizzard shad	20.53	85.32	0.40	16.47	64.83	2.00
Threadfin shad	0.20	0.83	.	2.53	9.97	.
Hybrid shad	.	.	1.60	.	.	1.30
Common carp	0.60	2.49	0.20	0.33	1.31	0.40
Golden shiner	0.67	2.77	.	0.27	1.05	.
Spotfin shiner	0.33	1.39	.	1.00	3.94	.
Bullhead minnow	.	.	.	0.07	0.26	.
River carpsucker	.	.	.	.	.	1.30
Quillback	.	.	.	.	.	0.10
Northern hog sucker	.	.	.	0.07	0.26	.
Smallmouth buffalo	0.07	0.28	0.30	0.07	0.26	1.20
Black buffalo	.	.	0.10	.	.	0.40
Spotted sucker	1.07	4.43	.	0.87	3.41	0.30
Black redhorse	.	.	.	0.07	0.26	0.10
Golden redhorse	.	.	.	.	.	0.10
Yellow bullhead	.	.	.	0.13	0.52	.
Channel catfish	1.67	6.93	0.90	.	.	1.40
Flathead catfish	0.53	2.22	0.60	.	.	0.10
Blackspotted topminnow	0.07	0.28	.	.	.	.
Western mosquitofish	.	.	.	0.07	0.26	.
White bass	0.07	0.28	0.70	0.27	1.05	0.40
Yellow bass	0.20	0.83	1.70	1.87	7.35	2.70
Striped bass	0.87	3.60	0.60	0.33	1.31	0.90
Warmouth	0.13	0.55	.	1.80	7.09	0.10
Green sunfish	1.07	4.43	.	0.07	0.26	.
Bluegill	20.13	83.66	0.10	14.73	58.01	0.10
Longear sunfish	4.93	20.50	.	2.73	10.76	.
Redear sunfish	2.00	8.31	0.70	4.00	15.75	0.10
Smallmouth bass	0.07	0.28	.	0.13	0.52	.

Table 3. (continued)

Autumn 2007	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Spotted bass	1.13	4.71	.	0.47	1.84	0.10
Largemouth bass	7.33	30.47	.	7.20	28.35	.
Hybrid bass	0.07	0.28	.	.	.	.
White crappie	.	.	0.10	0.07	0.26	.
Black crappie	0.13	0.55	.	0.33	1.31	0.10
Logperch	0.07	0.28	.	.	.	.
Sauger	0.07	0.28	1.30	0.07	0.26	2.70
Walleye	.	.	.	.	.	2.20
Freshwater drum	0.53	2.22	0.90	0.27	1.05	1.10
Brook silverside	0.07	0.28	.	.	.	.
Inland silverside	10.47	43.49	.	5.20	20.47	.
Total	75.08	311.94	13.30	61.49	241.97	22.00
Number Samples	15		10	15		10
Number Collected	1126		133	922		220
Species Collected	28		16	28		25

Table 4. Comparison of RFAI Scores Collected at Stations Upstream and Downstream of Gallatin Fossil Plant During 2001-2007. Scores were calculated with new scoring criteria that were revised in 2007. RFAI Scores: 12-21 ("Very Poor"), 22-31 ("Poor"), 32-40 ("Fair"), 41-50 ("Good"), or 51-60 ("Excellent").

Reservoir	Site	2001	2002	2003	2005	2007	Average
Old Hickory	Downstream CuRM 240.0	39-Fair	37-Fair	41-Good	43-Good	40-Fair	**40-Fair**
Old Hickory	Upstream CuRm 249.5	37-Fair	33-Fair	44-Good	38-Fair	46-Good	**40-Fair**

Appendix 1-A. Individual Metric Scores and Overall RFAI Scores for Sites Upstream (CuRM 249.5) and Downstream (CuRm 240.0) of the Gallatin Fossil Plant Discharge, Autumn 2001. Observed Values and Scores are Presented for Old Scoring Criteria that were Modified in 2003 and for New Scoring Criteria that were Developed in 2007.

Autumn 2001		**CuRM 240.0**				**CuRM 249.5**			
		Old Criteria		**New Criteria**		**Old Criteria**		**New Criteria**	
Metric		**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**
A. Species richness and									
1. Number of species		29	5	28	3	31	5	30	3
2. Number of centrarchid		5	3	5	3	5	3	5	3
3. Number of benthic		3	3	3	3	3	3	3	3
4. Number of intolerant species		4	3	4	3	6	5	6	3
5. Percent tolerant individuals	Electrofishing	83.1	0.5	83.1	0.5	81.43	0.5	81.4	0.5
	Gill Netting	35.56	1.5	39.5	1.5	41.55	1.5	41.6	0.5
6. Percent dominance by one	Electrofishing	42.59	1.5	42.6	1.5	34.31	1.5	34.3	2.5
	Gill Netting	20.83	2.5	23.5	2.5	34.46	1.5	34.5	1.5
7. Number non-native species	Electrofishing	2.03	1.5	4.8	1.5	2.69	1.5	2.8	2.5
	Gill Netting	5.00	1.5	5.1	1.5	6.42	1.5	6.4	1.5
8. Number of top carnivore		7	3	7	3	9	5	9	3
B. Trophic composition									
9. Percent top carnivores	Electrofishing	16.48	2.5	16.5	2.5	8.19	1.5	8.2	1.5
	Gill Netting	49.44	2.5	44.7	1.5	34.12	1.5	34.1	1.5
10. Percent omnivores	Electrofishing	45.50	0.5	45.5	1.5	38.28	1.5	38.4	1.5
	Gill Netting	30.56	1.5	34.4	1.5	53.72	1.5	53.7	0.5
C. Fish abundance and health									
11. Average number per run	Electrofishing	52.60	0.5	52.6	0.5	52.07	0.5	52.1	0.5
	Gill Netting	32.73	1.5	31.1	2.5	29.60	1.5	29.6	2.5
12. Percent anomalies	Electrofishing	0.38	2.5	0.4	2.5	0.51	2.5	0.5	2.5
	Gill Netting	0.28	2.5	0.3	2.5	0.00	2.5	0	2.5
Overall RFAI Score			**40**		**39**		**42**		**37**
			Fair		**Fair**		**Good**		**Fair**

Appendix 1-B. Individual Metric Scores and Overall RFAI Scores for Sites Upstream (CuRM 249.5) and Downstream (CuRm 240.0) of the Gallatin Fossil Plant Discharge, Autumn 2002. Observed Values and Scores are Presented for Old Scoring Criteria that were Modified in 2003 and for New Scoring Criteria that were developed in 2007

Autumn 2002		CuRM 240.0				CuRM 249.5			
		Old Criteria		New Criteria		Old Criteria		New Criteria	
Metric		Obs	Score	Obs	Score	Obs	Score	Obs	Score
A. Species richness and									
1. Number of species		26	5	25	3	21	3	20	3
2. Number of centrarchid		5	3	5	3	4	3	4	3
3. Number of benthic		3	3	3	3	4	5	4	3
4. Number of intolerant		3	3	3	1	4	3	4	3
5. Percent tolerant individuals	Electrofishing	58.42	1.5	58.4	1.5	91.34	0.5	91.3	0.5
	Gill Netting	35.50	1.5	35.5	1.5	27.03	1.5	27	1.5
6. Percent dominance by one	Electrofishing	28.95	1.5	28.9	2.5	64.62	0.5	64.6	0.5
	Gill Netting	31.36	1.5	31.4	1.5	22.30	2.5	22.3	2.5
7. Number non-native species	Electrofishing	2.46	1.5	16.7	0.5	0.36	2.5	1.8	2.5
	Gill Netting	2.96	2.5	3	2.5	8.78	0.5	8.8	0.5
8. Number of top carnivore		8	5	8	3	5	3	5	3
B. Trophic composition									
9. Percent top carnivores	Electrofishing	12.28	1.5	12.3	1.5	5.05	0.5	5.1	0.5
	Gill Netting	39.64	2.5	39.6	1.5	43.24	2.5	43.2	1.5
10. Percent omnivores	Electrofishing	19.47	2.5	19.5	2.5	66.43	0.5	66.4	0.5
	Gill Netting	40.83	1.5	40.8	1.5	41.22	1.5	41.2	1.5
C. Fish abundance and									
11. Average number per run	Electrofishing	38.00	0.5	38	0.5	18.47	0.5	18.5	0.5
	Gill Netting	16.90	0.5	16.9	1.5	14.80	0.5	14.8	1.5
12. Percent anomalies	Electrofishing	1.93	2.5	1.9	2.5	0.36	2.5	0.4	2.5
	Gill Netting	0.00	2.5	0	2.5	3.38	1.5	3.4	1.5
Overall RFAI Score			**43**		**37**		**35**		**33**
			Good		**Fair**		**Fair**		**Fair**

Appendix 1-C. Individual Metric Scores and Overall RFAI Scores for Sites Upstream (CuRM 249.5) and Downstream (CuRm 240.0) of the Gallatin Fossil Plant Discharge, Autumn 2003. Observed Values and Scores are Presented for Old Scoring Criteria that were Modified in 2003 and for New Scoring Criteria that were Developed in 2007.

Autumn 2003		**CuRM 240.0**				**CuRM 249.5**			
		Old Criteria		**New Criteria**		**Old Criteria**		**New Criteria**	
Metric		**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**	**Obs**	**Score**
A. Species richness and									
1. Number of species		22	3	21	3	29	5	28	3
2. Number of centrarchid		5	3	5	3	7	5	7	5
3. Number of benthic		3	3	3	3	4	5	4	3
4. Number of intolerant		4	3	4	3	5	5	5	3
5. Percent tolerant individuals	Electrofishing	71.99	0.5	72	0.5	65.01	0.5	64	1.5
	Gill Netting	6.67	2.5	6.7	2.5	21.90	2.5	21.9	2.5
6. Percent dominance by one	Electrofishing	28.47	1.5	28.5	2.5	32.48	1.5	32.5	2.5
	Gill Netting	36.67	1.5	36.7	1.5	25.71	1.5	25.7	1.5
7. Number non-native species	Electrofishing	2.08	1.5	2.8	2.5	2.23	1.5	2.9	2.5
	Gill Netting	5.00	1.5	5	1.5	3.81	2.5	3.8	2.5
8. Number of top carnivore		7	3	7	3	10	5	10	3
B. Trophic composition									
9. Percent top carnivores	Electrofishing	18.06	2.5	18.1	2.5	18.47	2.5	18.5	2.5
	Gill Netting	61.67	2.5	61.7	2.5	45.71	2.5	45.7	1.5
10. Percent omnivores	Electrofishing	26.62	1.5	26.6	2.5	19.43	2.5	19.4	2.5
	Gill Netting	21.67	2.5	21.7	1.5	37.14	1.5	37.1	1.5
C. Fish abundance and									
11. Average number per run	Electrofishing	28.80	0.5	28.8	0.5	20.93	0.5	20.9	0.5
	Gill Netting	6.00	0.5	6	0.5	10.50	0.5	10.5	0.5
12. Percent anomalies	Electrofishing	1.16	2.5	1.2	2.5	0.96	2.5	1	2.5
	Gill Netting	0.00	2.5	0	2.5	0.00	2.5	0	2.5
Overall RFAI Score			**39**		**41**		**50**		**44**
			Fair		**Good**		**Good**		**Good**

Appendix 1-D. Individual Metric Scores and Overall RFAI Scores for Sites Upstream (CuRM 249.5) and Downstream (CuRm 240.0) of the Gallatin Fossil Plant Discharge, Autumn 2005. Observed Values and Scores are Presented for Old Scoring Criteria that were Modified in 2003 and for New Scoring Criteria that were Developed in 2007

Autumn 2005		CuRM 240.0				CuRM 249.5			
		Old Criteria		New Criteria		Old Criteria		New Criteria	
Metric		Obs	Score	Obs	Score	Obs	Score	Obs	Score
A. Species richness and									
1. Number of species		30	5	29	3	30	5	30	3
2. Number of centrarchid		6	5	6	5	5	5	5	3
3. Number of benthic		4	3	4	3	5	3	5	3
4. Number of intolerant		5	5	5	3	5	5	5	3
5. Percent tolerant individuals	Electrofishing	63.1	0.5	63.1	1.5	79.8	0.5	79.8	0.5
	Gill Netting	7.1	2.5	7.1	2.5	9.5	2.5	9.5	2.5
6. Percent dominance by one	Electrofishing	36.9	1.5	36.9	2.5	52.6	0.5	52.6	0.5
	Gill Netting	36.7	0.5	36.7	1.5	24.4	1.5	24.4	2.5
7. Number non-native species	Electrofishing	0.7	2.5	14.3	0.5	0.5	2.5	0.5	2.5
	Gill Netting	6.6	1.5	6.6	1.5	2	2.5	2	2.5
8. Number of top carnivore		9	5	9	3	8	5	8	3
B. Trophic composition									
9. Percent top carnivores	Electrofishing	18.1	2.5	18.1	2.5	7.6	1.5	7.6	0.5
	Gill Netting	78.1	2.5	78.1	2.5	65.2	2.5	65.2	2.5
10. Percent omnivores	Electrofishing	39.5	1.5	39.5	1.5	53	0.5	53	0.5
	Gill Netting	15.3	2.5	15.3	2.5	24.4	1.5	24.4	1.5
C. Fish abundance and									
11. Average number per run	Electrofishing	81.5	0.5	81.5	1.5	71.8	0.5	71.8	0.5
	Gill Netting	19.6	1.5	19.6	1.5	20.1	1.5	20.1	1.5
12. Percent anomalies	Electrofishing	2.5	1.5	2.5	1.5	1	2.5	1	2.5
	Gill Netting	0	2.5	0	2.5	1	2.5	1	2.5
Overall RFAI Score			**47**		**43**		**46**		**38**
			Good		**Good**		**Good**		**Fair**

Appendix 2-A. Species Collected and Catch Per Unit Effort During Fall Electrofishing and Gill Netting at the Upstream and Downstream Stations of Gallatin Fossil Plant, autumn 2001.

Autumn 2001	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Skipjack herring	-	-	3.9	-	-	2.0
Gizzard shad	22.4	122.63	7.5	7.73	40.99	1.6
Threadfin shad	0.13	0.73		8.33	44.17	1.2
Common carp	1.07	5.84	0.3	1.27	6.71	0.2
Golden shiner	-	-	1.8	-	-	-
Emerald shiner	-	-	-	0.93	4.95	-
Spotfin shiner	0.13	0.73	-	0.47	2.47	-
Bullhead minnow	-	-	-	0.07	0.35	-
Quillback	-	-	0.1	-	-	-
Smallmouth buffalo	0.4	2.19	0.2	-	-	-
Bigmouth buffalo	0.2	1.09	-	0.2	1.06	0.1
Black buffalo	0.07	0.36	-	0.2	1.06	-
Spotted sucker	0.2	1.09	0.1	1.67	8.83	0.3
Golden redhorse	-	-	0.1	0.2	1.06	0.3
Blue catfish	-	-	0.1	0.33	1.77	1.4
Yellow bullhead	-	-	0.1	-	-	-
Channel catfish	-	-	0.9	0.13	0.71	1.6
Flathead catfish	0.07	0.36	0.8	-	-	0.2
Blackspotted topminnow	0.07	0.36	-	-	-	-
White bass	-	-	0.8	0.07	0.35	0.5
Yellow bass	-	-	6.7	0.07	0.35	0.5
Striped bass	-	-	0.5	0.07	0.35	0.3
Hybrid striped x white bass	-	-	1.0	-	-	1.1
Warmouth	0.13	0.73	0.3	-	-	-
Green sunfish	0.2	1.09	-	-	-	-
Bluegill	12.13	66.42	2.5	1.53	8.13	0.5
Longear sunfish	3.27	17.88	0.3	3.2	16.96	0.1
Redear sunfish	1.2	6.57	1.1	0.8	4.24	0.2
Spotted bass	0.8	4.38	0.3	0.27	1.41	0.4
Largemouth bass	7.8	42.7	0.6	7.33	38.87	0.3
White crappie	-	-	-	0.13	0.71	0.1

Appendix 2-A. (continued)

Autumn 2001	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Black crappie	-	-	-	0.07	0.35	0.1
Logperch	-	-	-	0.13	0.71	-
Sauger	-	-	3.2	0.07	0.35	1.6
Freshwater drum	0.6	3.28	2.8	0.13	0.71	0.3
Brook silverside	0.27	1.46	-	-	-	-
Inland silverside	1.47	8.03	-	1.07	5.65	-
Totals	**52.61**	**287.92**	**36.0**	**36.47**	**193.27**	**14.9**
Number Samples	**15**		**10**	**15**		**10**
Number Fish	**789**		**360**	**547**		**149**
Number Species	**20**		**24**	**26**		**23**

Appendix 2-B. Species Collected and Catch Per Unit Effort During Fall Electrofishing and Gill Netting at the Upstream and Downstream Stations of Gallatin Fossil Plant, Autumn 2002.

Autumn 2002	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Skipjack herring	0.07	0.42	2.30	-	-	2.00
Gizzard shad	5.73	36.13	5.30	11.93	101.70	3.30
Threadfin shad	0.40	2.52	0.60	-	-	0.40
Common carp	0.93	5.88	0.10	0.07	0.57	0.20
Golden shiner	0.27	1.68	-	0.07	0.57	-
Spotfin shiner	0.20	1.26	-	0.80	6.82	-
Bullhead minnow	0.07	0.42	-	-	-	-
River carpsucker	-	-	0.10	-	-	0.50
Quillback	-	-	0.30	-	-	-
Smallmouth buffalo	0.33	2.10	0.40	0.20	1.70	0.10
Spotted sucker	-	-	0.10	0.33	2.84	-
Black redhorse	-	-	-	-	-	0.30
Golden redhorse	-	-	0.10	0.07	0.57	0.40
Brown bullhead	0.07	0.42	-	-	-	-
Channel catfish	0.07	0.42	0.70	-	-	2.00
Flathead catfish	0.07	0.42	0.50	-	-	-
White bass	-	-	0.10	-	-	0.20
Yellow bass	0.27	1.68	0.70	0.07	0.57	1.50
Striped bass	-	-	0.40	-	-	1.10
Warmouth	0.33	2.10	-	0.33	2.84	-
Bluegill	11.00	69.33	0.30	3.13	26.70	-
Longear sunfish	0.80	5.04	0.10	0.27	2.27	0.10
Redear sunfish	0.73	4.62	0.30	0.07	0.57	0.30
Hybrid sunfish	0.13	0.84	-	-	-	-
Spotted bass	0.20	1.26	0.10	-	-	-
Largemouth bass	4.00	25.21	0.20	0.87	7.39	-
Black crappie	-	-	0.20	-	-	-

Appendix 2-B. (continued)

Autumn 2002	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Sauger	0.07	0.42	2.20	-	-	1.60
Freshwater drum	0.20	1.26	1.80	-	-	0.80
Inland silverside	5.40	34.03	-	0.27	2.27	-
Totals	**31.34**	**197.46**	**16.9**	**18.48**	**157.38**	**14.8**
Number Samples	**15**		**10**	**15**		**10**
Number Fish	**470**		**169**	**277**		**148**
Number Species	**22**		**22**	**14**		**16**

Appendix 2-C. Species Collected and Catch Per Unit Effort During Fall Electrofishing and Gill Netting at the Upstream and Downstream Stations of Gallatin Fossil Plant, Autumn 2003.

Autumn 2003	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Skipjack herring	-	-	0.2	-	-	0.7
Gizzard shad	6.53	34.39	0.3	3.47	19.77	1.2
Goldeye	-	-	-	-	-	0.1
Common carp	0.6	3.16	-	0.27	1.52	0.3
Spotfin shiner	0.67	3.51	-	0.07	0.38	-
Bluntnose minnow	-	-	-	0.13	0.76	-
Bullhead minnow	-	-	-	0.20	1.14	-
River carpsucker	-	-	-	-	-	0.7
Quillback	-	-	0.3	-	-	-
Smallmouth buffalo	0.53	2.81	0.4	0.13	0.76	0.6
Black buffalo	-	-	-	0.07	0.38	-
Spotted sucker	0.27	1.40	-	0.27	1.52	-
Golden redhorse	-	-	0.1	0.13	0.76	0.8
Channel catfish	-	-	0.3	-	-	1.1
Flathead catfish	-	-	0.1	-	-	-
White bass	0.07	0.35	-	-	-	0.1
Yellow bass	0.2	1.05	2.2	0.27	1.52	2.7
Striped bass	-	-	0.3	0.2	1.14	0.1
Rock bass	-	-	-	0.07	0.38	-
Warmouth	0.13	0.70	-	1.13	6.46	-
Green sunfish	0.47	2.46	-	0.07	0.38	-
Bluegill	8.2	43.16	0.1	6.8	38.78	0.1
Longear sunfish	3.27	17.19	-	1.4	7.98	0.1
Redear sunfish	1.13	5.96	0.2	2.4	13.69	0.1
Smallmouth bass	-	-	-	0.13	0.76	-
Spotted bass	0.67	3.51	0.1	0.27	1.52	-
Largemouth bass	4.27	22.46	-	2.53	14.45	-
White crappie	-	-	-	0.07	0.38	-
Black crappie	-	-	-	0.2	1.14	-

Appendix 2-C. (continued)

Autumn 2003	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Logperch	-	-	-	0.07	0.38	-
Sauger	-	-	0.8	0.13	0.76	1.2
Freshwater drum	0.53	2.81	0.6	0.33	1.90	0.6
Brook silverside	1.07	5.61	-	-	-	-
Inland silverside	0.2	1.05	-	0.13	0.76	-
Totals	**28.81**	**151.58**	**6**	**20.94**	**119.37**	**10.5**
Number Samples	**15**		**10**	**15**		**10**
Number Fish	**432**		**60**	**314**		**105**
Number Species	**17**		**14**	**26**		**16**

Appendix 2-D. Species Collected and Catch Per Unit Effort During Fall Electrofishing and Gill Netting at the Upstream and Downstream Stations of Gallatin Fossil Plant, Autumn 2005.

Autumn 2005	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Skipjack herring	0.07	0.34	7.20	-	-	2.30
Gizzard shad	30.07	154.45	1.00	37.73	213.58	1.30
Threadfin shad	4.20	21.58	0.30	5.67	32.08	0.40
Largescale stoneroller	0.40	2.05	-	0.13	0.75	-
Common carp	0.60	3.08	0.10	0.33	1.89	0.20
Golden shiner	0.73	3.77	-	-	-	-
Emerald shiner	0.07	0.34	-	0.13	0.75	-
Spotfin shiner	0.60	3.08	-	0.80	4.53	-
Striped shiner	0.07	0.34	-	-	-	-
Bullhead minnow	4.80	24.66	-	1.07	6.04	-
River carpsucker	-	-	-	-	-	0.30
Quillback	-	-	-	-	-	0.10
Northern hog sucker	0.07	0.34	0.10	-	-	-
Smallmouth buffalo	0.33	1.71	0.60	-	-	0.90
Bigmouth buffalo	-	-	-	0.07	0.38	-
Black buffalo	0.20	1.03	-	-	-	0.20
Spotted sucker	0.93	4.79	-	1.40	7.92	0.10
Black redhorse	-	-	0.10	-	-	0.20
Golden redhorse	-	-	-	0.47	2.64	0.20
Channel catfish	0.20	1.03	1.30	-	-	1.90
Flathead catfish	-	-	0.50	-	-	-
White bass	-	-	0.80	-	-	1.40
Yellow bass	0.27	1.37	1.60	0.07	0.38	2.80
Striped bass	-	-	1.20	-	-	0.20
Warmouth	0.27	1.37	-	0.73	4.15	-
Green sunfish	0.73	3.77	-	-	-	-
Bluegill	5.53	28.42	0.20	13.27	75.09	0.10
Longear sunfish	3.20	16.44	-	1.47	8.30	0.10
Redear sunfish	2.33	11.99	0.10	2.40	13.58	0.10
Hybrid sunfish	0.07	0.34	-	-	-	-

Appendix 2-D. (continued)

Autumn 2005	Downstream CuRM 240.0			Upstream CuRM 249.5		
	Electrofishing		Gill Netting	Electrofishing		Gill Netting
Common Name	Catch Per Run	Catch Per Hour	Catch Per Net Night	Catch Per Run	Catch Per Hour	Catch Per Net Night
Spotted bass	1.20	6.16	-	0.20	1.13	-
Largemouth bass	13.07	67.12	-	5.13	29.06	-
White crappie	-	-	0.10	-	-	-
Black crappie	-	-	-	0.07	0.38	-
Logperch	-	-	-	0.07	0.38	-
Sauger	0.13	0.68	3.10	-	-	4.90
Walleye	-	-	0.80	-	-	1.50
Freshwater drum	0.27	1.37	0.50	0.20	1.13	0.90
Brook silverside	-	-	-	0.40	2.26	-
Inland silverside	11.07	56.85	-	-	-	-
Total	**81.48**	**418.47**	**19.60**	**71.81**	**406.40**	**20.10**
Number Samples	**15**		**10**	**15**		**10**
Number Fish	**1222**		**196.0**	**1077**		**201**
Number Species	**27**		**18**	**21**		**21**