Appendix C
AmerenCIPS Newton Lake Project
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Volume I

AmerenCIPS Newton Lake Project

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VOLUME II

CHAPTER 1. OVERVIEW OF RESULTS

Introduction:

The AmerenCIPS Newton Lake Project was initiated primarily to determine additional biological impacts, if any, on the biota of Newton Lake from increased thermal loading when Newton Power Station is operated under a new "Variance." The Variance allows increases of maximum thermal discharges to the extent that water temperatures during June-October will not exceed a monthly average of 106EF and a maximum of 111EF for no more than 3% of the hours. During the remaining months, discharge limits are to be similar to those prior to the Variance. Thus, average monthly water temperatures may not exceed 102EF and maximum temperatures will be no more than 111EF.

The thermal discharge on Coffeen Lake was also modified in 1997. The historic variance was as follows:

> "The thermal discharge to Coffeen Lake from Central Illinois Public Service's Coffeen Power Station shall not result in a temperature, measured at the outside edge of the mixing zone in Coffeen Lake, which: 1) exceeds 105 degrees Fahrenheit as a monthly average from June through September and 112 degrees Fahrenheit as a maximum for more than three percent of the hours during that same period; 2) exceeds 89 degrees Fahrenheit as a monthly average from October through May and 94 degrees Fahrenheit as a maximum for more than two percent of the hours during the same period."

This was changed so that the summer time frame of June through September was changed to May through October.

This study was designed to examine effects of the Variance thermal regime in Newton Lake at trophic levels encompassing primary producers to tertiary consumers. Ecological principles dictate that adverse effects on lower trophic levels will be manifested at higher trophic levels. Since fish tend to integrate thermal effects in aquatic systems and they are of particular importance to the public, considerable emphasis is placed on this taxon. In order to monitor changes in the lower trophic levels, phytoplankton, macrophytes, zooplankton, benthos, and phytomacrobenthos were monitored in Newton Lake.

Newton Lake has 1,750 acres to service two electrical generating units with a design capacity of 1,234 GMW. Coffeen Lake (1,100 acres) was chosen as a study lake because it has similar thermal loading from its two electrical generating units that have a total capacity of 1,005 GMW. Thermal loading affects Lake of Egypt much less. This 2,300-acre lake, located in southern Illinois, supports four units with a total design capacity of 272 GMW. All three power plants are coal fired.

A portion of this study compares the health and condition of Newton Lake fish species to those in Lake of Egypt and Coffeen Lake. Growth is an excellent indicator of health and condition of fish because it integrates all of the biotic and abiotic factors acting on them. Age and growth analysis is especially appropriate for this study because average growth rates for age classes within species can be determined via back-calculation for several years prior to plant operation under the new variance. With additional years of study a comparisons of growth rates before and after operation under the new variance would provide key information on how fishery resources is affected in the long term. Age and growth analysis also permits direct comparisons of growth among the three lakes for the various species. Even if fish are growing well, a desirable fishery will not exist unless recruitment is adequate. Ichthyoplankton as well as recruitment to age-1 was also monitored.

Fish health assessments were made not only by growth analysis but also with condition factors and stress indicators. The effects of stress depend upon the fishes' ability to acclimate not only to higher temperature extremes and lower oxygen but also to the wide temperature fluctuations that occur in cooling ponds.

If the fish require refuge from the potentially stressful temperatures, then it is important to determine if suitable habitat is available. Fish movement was monitored to determine habitat utilization. Since movement of largemouth bass (*Micropterus salmoides*) and to a much lesser degree channel catfish (*Ictalurus punctatus*) was monitored in all three lakes, habitat utilization can be compared among lakes as well as seasonally within each lake.

For sampling purposes Newton Lake was divided into four segments (Figure 1.1), and Coffeen Lake and Lake of Egypt into two segments (Figure 1.2; Figure 1.3). The basic sampling regime is outlined in Table 1.1.

This report is separated into sixteen chapters, and primarily includes an analysis of the data collected in August 1997 through August 31, 1999. An effort has been made to address the magnitude, cause, and significance of the fish kill that occurred in Newton Lake and Coffeen Lake in July of 1999.

Plant Operation in Relation to the Variance

Newton power plant discharge temperatures never exceeded the new variance criteria in 1997 or 1998. Thus, 1998 can be considered a pre-variance year. Newton power plant discharge temperatures in the summer of 1999 reached but did not exceed the new variance levels. The highest monthly average of 104°F occurred in July 1999 (Table 1.2) Mean daily temperatures exceeded 105°F in all three years (Figures 1.4, 1.5, 1.6). All of the 100 hours of discharge temperature equal to or above 111°F occurred between July 22, 1999 and July 31, 1999 (Table 1.3). The new variance allowed 110 hours.

July 1999 had the highest mean monthly temperature (103°F) in Coffeen Lake (Table 1.4). Thus mean month temperatures did not exceed the 105°F mean monthly maximum allowed by the variance. Only 83 of the allowable 132 hours above or equal to 112°F were used in 1999. All except 3 hours occurred between July 23, 1999 and July 31, 1999. Three hours associated with start up above 120°F occurred on September 7, 1999 (Table 1.5). Mean daily temperatures were above 105°F and peaked in July 1997, 1998, and 1999 (Figures 1.7, 1.8, 1.9).

Characteristics of the Fish Community

The fish community has undergone many changes since 1976. Fishing started in 1980. Initially crappie were abundant and grew well in Newton Lake. Although they still continue to grow well, recruitment was greatly reduced by 1987. Crappie from a recently built nursery area on the lake probably accounts for their slight increase in the 1999-electrofishing catch (Table 1.6). Historically, except for the first few years, very few bluegill reached 7 inches in total length (Table 1.7). Except for the 1998 spring sample, less than 5% of the bluegill were larger than 6 inches since 1994. During the late 1970's and early 1980's, a significant number of channel catfish exceeded 20 inches in total length. After the mid 1980's fewer than 7 percent of the sampled channel catfish exceeded 20 inches (Table 1.8). Largemouth bass are the most sought after sport-fish in Newton Lake. There has been an 18-inch minimum length limit and a 3 fish per day creel limit on the lake since it opened for fishing in 1980. The highest percentage of bass larger than 18 inches in total length tended to occur in the spring samples rather then in the fall samples (Table 1.9). Since 1990 the percentage of large bass appears to be decreasing, although spring samples in 1997 and 1998 show 14 and 15 percent of the bass sampled were over 18 inches in total length.

The growth rate of white crappie in Newton Lake was faster than in Coffeen Lake but slower than in Lake of Egypt (Table 1.10). Bluegill were growing slowly in all three lakes (Table 1.11). Channel catfish were growing very slowly in Newton Lake. Their weight (0.6 lb) at age-10 was only about half of a 10-year-old channel catfish (1.1 lb) in Coffeen Lake. Ten-year-old channel catfish in Lake of Egypt averaged 2.9 pounds (Table 1.12). Largemouth bass grew fairly fast for the first two or three years in Newton Lake and Coffeen Lake (Table 1.13). Their growth rate then slowed down; however, there are significant numbers of three to five pound bass in Newton Lake and three to four pound bass in Coffeen Lake. Bass larger than six pounds are relatively rare in both lakes. Noteworthy is the fact that growth rate of largemouth bass in the cooler Lake of Egypt is slower than in either Newton Lake or Coffeen Lake.

Mean relative weights of largemouth bass were higher in Newton Lake and Coffeen Lake than in the cooler Lake of Egypt (Table 1.14). Except for their August average of 82 in Lake of Egypt, all mean relative weights were within the desirable range of 100 plus or minus 10. Except for the fall (November) values in Newton Lake (91) and Coffeen Lake (92), the mean relative weight of bluegill tended to be below the desirable range at all other times of the year and in all three lakes. Channel catfish in Lake of Egypt tended to have mean relative weights above 90; whereas, catfish in both Newton Lake and Coffeen Lake had relative weights less than 90.

During the three years of this study, largemouth bass in Newton Lake had a higher percentage of empty stomachs (60.2%) than either Coffeen Lake (40.6%) or Lake of Egypt (40.7%). Channel Catfish from Coffeen Lake had the highest percentage of empty stomachs (55.8%) and channel catfish from Lake of Egypt had the lowest (34.3%). Largemouth bass had a higher percentage of empty stomachs in 1999 than in 1998. Channel catfish also had a higher percentage of empty stomachs in Newton Lake and Coffeen Lake in 1999 than in 1998, but in Lake of Egypt channel catfish had a lower percentage of empty stomachs in 1999 (Table 1.15).

Based on the catch curve method, the mean annual mortality of largemouth bass in 1997-1999 was highest in Newton Lake (51%) and lowest in Lake of Egypt (28%) with Coffeen Lake falling in between (36%) the other two lakes (Table 1.16). Bluegill follow the same trend with a 72% annual mortality rate in Newton Lake, 45% in Lake of Egypt and 63% in Coffeen Lake (Table 1.16). Channel catfish, on the other hand, had the highest annual mortality rate in Lake of Egypt (50%) followed by Newton Lake with 37% and those in Coffeen Lake with 23%. The mortality rate calculations for channel catfish from Lake of Egypt were based on very few specimens. All of the values from all three lakes for all three species were well within the ranges reported in the literature.

Growth rates, mortality rates and recruitment rates determine the structure of a fish population. Larval fish densities were monitored in Newton Lake, Coffeen Lake, and Lake of Egypt. Most fish species in Illinois spawn in the spring when water temperatures reach a certain level. As water temperatures continue to increase, essentially, a temperature is reached where a given species stops spawning. It seems logical to assume that this "spawning window" may be narrowed by rapidly adding heat to a lake; however, the hatching date ranges were not restricted in Newton Lake or Coffeen Lake and were actually extended when compared to the cooler Lake of Egypt (Table 1.17). Except for *Pomoxis* in Lake of Egypt and *Lepomis* in Coffeen Lake, spawning took place over more days in 1999 than in 1998 in all three lakes (Table 1.17).

In Newton Lake and Coffeen Lake, the densities of larval *Lepomis* and *Dorosoma* in ichthyoplankton tows were the same in 1999 as they were in 1998 (Table 1.18). In Lake of Egypt, the density of *Dorosoma* in 1998 was the same as in 1999, but the density of *Lepomis* was greater in 1998 than in 1999 (Table 1.18). There was no difference in catch per hour for *Lepomis*, *Dorosoma* or *Micropterus* in light traps between 1998 and 1999 in any of the three lakes (Table 1.19).

Zooplankton, the initial food supply for larval fish was also relatively abundant. During the spawning of the various species of fish mean total zooplankton ranged from approximately 100 to 800 zooplankters per liter of lake water (see Chapter 8).

It is possible to have large numbers of larval fishes and still have a weak year class of fish. Shoreline seining captures larger, thus older fish, than ichthyoplankton net tows. In all three lakes, there was no difference in the catch per unit effort of all fish (primarily young of the year) collected by shoreline seining in 1998 versus 1999 (Table 1.20). Nor was there any difference in the shoreline seining catch per unit effort for young of the year largemouth bass between 1998 and 1999 in Newton Lake or Coffeen Lake. In Lake of Egypt more largemouth bass were captured in 1999 than in 1998.

Most biologists prefer to measure recruitment after the fish go through the first winter, in other words at age-1. In Newton Lake, our fall electrofishing samples indicated a drop in catch per hour of age-1+ largemouth bass in 1999 over 1998 (Table 1.21). The information in Table 16 is based on a relatively small sample size. In 1998 and 1999, IDNR made a much larger fall electrofishing collection of largemouth bass in Newton Lake. These fish were not aged, but they were measured. If we assume that an age-1+ largemouth bass captured in the fall would have a total length up to 11.8 inches, then in 1998, out of the 705 largemouth bass collected there were 287 age-1+ bass. In 1999, out of the 514 largemouth bass sampled there were 255 age-1+ bass. This is equivalent to 23.9 age-1+ bass per hour in 1998 and 21.2 age-1+ bass per hour in 1999. Since we have not received the 1999 fall sampling data for Coffeen Lake from IDNR, we can not make the same calculations for this lake. Actually, the best estimate can be made only after the spring 2000 electrofishing data are obtained. These data will allow us to compare spring to spring recruitment for age-1+ largemouth bass.

Creel Harvest Data

Creels were not run on either Coffeen Lake or Lake of Egypt in 1997-1999. AmerenCIPS provided historical 12-month creel data for Newton Lake. Evidently, these historic creels were designed to yield harvest but not catch data. AmerenCIPS contracted with the Illinois Natural History Survey to conduct a creel survey on Newton Lake in 1998 and 1999. The 1998 creel survey was for only 9 months. The heavily fished November, December, and January months were evidently not creeled. To date we have not received the 1999 survey data.

Yearly angling effort dropped from a high of 150,814 hours in 1986 (12 months) to a 12 month low level of 70,330 hours in 1991 (Table 1.22). In 1998 fishing pressure was back up to 105,931 hours for the 9 months of the creel. The harvest of largemouth bass has remained remarkably consistent since 1986 ranging from 731 to 1,743 fish (Table 1.23). In 1998 a total of 1,289 largemouth bass was harvested. A size limit of 18 inches total length and a harvest limit of3 fish per day has been in place since Newton Lake was opened to fishing in 1980.

Bluegill harvest has been very low throughout all creel years. The harvest of 947 bluegill in 1998 approaches the 1986 high of 1,009 fish (Table 16.24). Crappie harvest fell from a high of 89,499 in 1986 and 66,971 in 1987 to 69 in 1988. This drastic decrease in harvest reflects the classical significant reduction in recruitment of crappie, which is well documented but not understood, in older and warmer power cooling lakes. Since angler harvest of crappie tends to be dominated by 3 and 4-year-old fish, the reduction in recruitment probably started in 1985.

Channel catfish harvest in Newton Lake in 1998 was approximately one-half that of previous years (Table 1.25). The harvested fish average approximately one pound in weight, which reflects the relatively slow growth rate of the channel catfish in Newton Lake. Since a 10-year-old catfish in Newton Lake only averages approximately 0.6 pounds, the harvested fish are probably the faster growing portion of the population.

Significant changes in the structure and utilization by anglers of the fish community in Newton Lake have taken place, but as far as the data show, these changes occurred before the new variance was placed into effect.

In addition to describing the fish community and its utilization by anglers, other components of the flora and fauna were monitored in Newton Lake. Since the power plant did not operate within the new variance parameters until 1999, the 1997-1998 data can be viewed as base line information.

Primary Productivity/Phytoplankton

Primary productivity and phytoplankton densities were monitored only in Newton Lake. During both 1998 and 1999, net photosynthesis tended to be higher during the summer months (Figure 1.10). The values of net photosynthesis fall well within the range of values found for other lakes (Table 1.26). Since the highest temperatures occurred in Newton Lake in July of 1999, the effects of these temperatures on the flora and fauna were investigated, where possible, by comparing data from July and August 1998 to similar data collected in July and August 1999.

Phytoplankton cell counts peaked in June 1998 and in January 1999 (Figure 1.11). Even though there was a decrease in mean total phytoplankton densities in July and August 1999 over July and August 1998 (Table 1.27) there were no differences in the rate of photosynthesis (Table 1.28) or chlorophyll a levels, probably due to a deeper euphotic zone (Table 1.29). There was a very slightly higher OD664/OD665 ratio in July and August 1998 than in 1999 (Table 1.30). The net photosynthetic rate and not the number of phytoplankters is the factor that ultimately determines the amount of oxygen in the euphotic zone of the lake.

Macrophytes

By producing shade, macrophytes reduce the temperatures in shallow water. Unfortunately, macrophytes cover a very small portion of Newton Lake. The dominant plant in Newton Lake is water willow (*Dianthera americana*). Water willow covered approximately 35 acres in August 1998, 22 acres in August 1999, and 15 acres in 1997 (Table 1.31). The lower coverage in 1999 over 1998 was a function of water level. In August 1998, Newton Lake was at pool level; whereas, in August 1999 it was 5.2 feet below pool. Within the vegetation beds, there was no difference in stem density per unit of surface area between 1998 (4.94 lb/m^2) and 1999 (4.00 lb/m^2) (Table 1.31). Since in all three years, the area of macrophyte coverage was only 0.9-2% of the lake, it would be highly desirable to find a way to increase this coverage.

Zooplankton

As expected, zooplankton fluctuated widely throughout the year (Figure 1.12). Densities ranged from approximately 100 to 800 organisms per liter. Peak densities occurred in the winter and early spring. Zooplankton densities from April through August fell within the middle of the range for 12 other Illinois lakes (Figure 1.13). Mean zooplankton densities were actually higher by 40% in July and August 1999 (239/L) than in July and August 1998 (171/L) (Table 1.32).

Benthos

Diptera comprised 82% of the benthos numerically and 76% by weight. Haplotaxidae (tubificids) made up 14% by numbers, but only 8% by weight; whereas Veneroida (clams) comprised only 1% of the benthos by number, but 12% by weight. The highest mean number and weight of the benthos per meter squared occurred in the winter of 1998 (Figure 1.14). Benthos densities in Newton Lake from May through October tended to fall within the lower third of the densities found in 12 Illinois lakes (Figure 1.15). Both the density (74%) and weight (46%) of the benthos per meter squared were considerably higher in 1999 than in 1998 (Table 1.33).

Phytomacrobenthos

Phytomacrobenthos are the macroinvertebrates that are attached to the aquatic vegetation. In Newton Lake, the phytomacrobenthos are primarily found on water willow. The numbers of phytomacrobenthos peaked in August 1998 and 1999. Their weight peaked in August 1998 and in September 1999 (Figure 1.16). The mean number of phytomacrobenthos in July and August 1999 was 93% higher than their density in 1998 (Table 1.34). Likewise, the mean weight of phytomacrobenthos in July and August 1999 was 140% higher than in July and August 1998 (Table 1.34).

Fish Kill

Temperature related fish kills occurred in Coffeen Lake and Newton Lake in 1999. A fish kill did not occur in Lake of Egypt in 1999 nor did a kill occur in any of the three lakes in 1998. The following discussion concerning the fish kills emphasizes largemouth bass.

In Coffeen Lake, the fish kill probably started on July 27, 1999, peaked on July 28, 1999, with no other fish except for one gizzard shad and one white crappie found after July 28 (Table 1.35). SIUC personnel counted a total of 121 dead largemouth bass. In addition to the fish that died, large numbers of the exotic Asiatic clam (*Corbicula sp.*) were also killed. Unlike the fish, the number of clams that died was not quantified. In both lakes, fish that were not too decayed were measured for total length. The six dead channel catfish that were measured from Coffeen Lake were not among the larger individuals in the population (Figure 1.17) and many large individuals were present in the population in the fall of 1999 (Figure 1.18). The dead largemouth bass tended to be among the larger fish in the population (Figure 1.19). This is not unexpected since large bass are more susceptible to higher temperatures and low dissolved oxygen stress than are small bass; however, there was no discernible difference in their fall 1999 length frequency distribution from that of the fall of 1998 (Figure 1.20).

In Newton Lake, there were two distinct fish kills. The first occurred on June 9, 1999 when 27 largemouth bass were found (Table 1.36). No other species of fish were found at this time or over the next few weeks. Maximum hourly discharge temperatures were approximately 96°F for two hours on June 8, 1999, and temperatures approached 95°F on the afternoon of June 9, 1999, but by this time the fish were already dead. There was a considerable amount of oxygenated deeper cooler water in segment 1 on June 2 and June 8

(Figure 1.21). Since no other species were found, it is possible that these fish died as a result of an informal bass club tournament instead of a thermal kill.

A definite temperature related fish kill probably started on July 27, 1999, in Newton Lake. On this date, 18 largemouth bass and 33 other fish from 5 different taxa were found. Unlike the kill on Coffeen Lake, which lasted only a couple of days, fish died in Newton Lake from July 27, 1999--August 31, 1999. During the first couple of days, primarily dead bass and not morbid bass were found. Later, especially in August both dead and dying fish were observed. Externally, the dying fish were heavily infected with bacteria and fungus. Thus, it appears that the stress in late July made the fish vulnerable to bacteria and fungus infections in August. We collected both dying fish and apparently healthy fish by electrofishing in late July. The fish health assessment index proposed by Goede (1993, see chapter 9 for citation) was not sensitive enough to delineate between these two groups of bass (Table 1.37). Thus, this index is not suitable for monitoring short-term thermal stress events. The larger largemouth bass (Figure 1.22) and channel catfish (Figure 1.23) died in the kill, but no change could be detected in the 1999 versus 1998 fall length frequency distributions for either species (Figures 1.24-1.25).

Significance of Dead Largemouth Bass

A few calculations will show that the number of largemouth bass that died in Coffeen Lake and Newton Lake pose no significant long-term effect on the two bass populations. Assuming that we counted only 50% of the largemouth bass that died, then 242 bass died in Coffeen Lake (0.22 per acre) and 454 in Newton Lake (0.26 per acre). If there are 20 bass per acre in Coffeen Lake (1100 acres), then the death of 242 bass represents only 1% of the population. Although we have no recent creel data for Coffeen Lake, this is probably well below what is removed by anglers each year and, in fact, the approved sampling protocol for this study kills approximately 150 bass per year in each lake. Average total annual mortality for largemouth bass in Coffeen Lake is approximately 36% (Table 1.16).

Assuming 20 largemouth bass per acre in Newton Lake (1750 acres), there were 35,000 bass in the lake. If anything, this is an underestimate considering that from February through October of 1998 the creel results indicated that 56,339 bass were caught. In other words if there were 35,000 bass, each bass on average was caught 1.6 times. Based on a population of 35,000 bass, the death of 454 bass in Newton Lake would equal only 1% of the population. In both lakes, the fish that died were large fish in the population but based on the 1998 nine month creel, which does not include the heavily fished late fall and winter months, anglers removed 1289 bass that were 18 inches or larger (Table 1.23). Also, to place the loss into perspective, average total annual mortality for bass in Newton Lake is 51% (Table 1.16).

Temperature/Depth/Oxygen Profiles

Temperature-depth-oxygen profiles were routinely taken every two weeks in each of the three lakes near the middle of each segment (Figures 1.1-1.3). Unfortunately, no profiles were scheduled for the day of the fish kills. Additional profiles were taken during the fish health and fish movement portions of the study. These profiles are given in Chapter 15.

It is difficult to interpret the full meaning of depth-temperature-oxygen profiles by inspection. Estimated percent habitat tables were constructed as an alternative approach (Table 1.38). Basically, the percent of depth is calculated at each sampling station where temperature is at or *below* a given value (from 87-97°F) and dissolved oxygen is at or *above* 1-4 ppm. This percent of depth is assumed to equal the percent by volume of the lake in that section of the lake where the sample was taken. The percent habitat value could be calculated more accurately if a good map of the lake was available with bottom contours. A current map does not exist for either lake. Modeling of this approach on graph paper with lakes of different basin shapes indicates that the habitat values are conservatively within plus or minus 20% of the true value. Thus a habitat value of 50% should be considered to have a range of 40% to 60%. By far the greatest error would occur if the sampling station is located on top of a sharply elevated underwater island or over a creek that is very deep relative to the average depth of the lake. We do not believe that either condition exists at any of our sampling stations.

Unfortunately, we do not have a depth-temperature-oxygen profile in any of the three lakes on July 27, 1999, when the fish kill probably started. In Lake of Egypt, on July 22, 1999 18% of the habitat (lake volume) in segment one (warm area) and 50% of the habitat in segment two (cool area) was 90°F or less and contained at least 4 ppm dissolved oxygen (Table 1.38).

In Coffeen Lake on July 23, 1999, the habitat available at or below 94°F and 4 ppm or more dissolved oxygen was 10% in segment 1 and 5% in segment 2 (Table 1.39). One of the few nighttime profiles that we have shows that by August 1, 1999, habitat conditions were even more restrictive in these areas (Table 1.40); however, we do not have a sampling station on the large cove or the area of the lake north of the plant's intake that are out of the cooling loop. These areas may have had much better water quality than that part of the lake that is in the cooling loop.

Habitat availability conditions on July 24, 1999, and July 18,1998, in Newton Lake are given in Table 1.41. Since the four sampling segments essentially cover the entire lake and they are approximately equal in size, the total habitat available can be estimated. By August

5, 1999, there was a considerable improvement in the amount of suitable habitat (Table 1.42). Almost all of the depth-temperature-oxygen profiles that were used to construct the percent suitable habitat tables were taken during the day. Since photosynthesis only occurs during daylight hours, available habitat for the fish at night was almost certainly less than shown because of lower dissolved oxygen. Cooler water does exist in both Newton Lake (Table 1.43) and Coffeen Lake (Table 1.44) throughout the year. The problem is that this cooler waster has 0-1 ppm dissolved oxygen during the summer.

Summer Habitat Utilization by Largemouth Bass

The fish movement portion of this study gives considerable insight on how largemouth bass react to high summer temperatures and relatively low dissolved oxygen concentrations. During the summer, largemouth bass in both Newton Lake and Coffeen Lake tended to move 1 to 1.5 miles in 24 hours (Figure 1.26). They also tended to use most of the lake, even in the summer (Figures 1.27-1.29).

Individually identifiable, temperature-sensitive sonic transmitters were placed in largemouth bass. These transmitters not only allowed us to locate individual fish but the internal body temperature of the bass could also be determined. By taking a depth/temperature/oxygen profile each time a bass was located, it was possible to determine the location, depth, temperature and dissolved oxygen concentration where the bass was located. These determinations are not exact because it takes 30-60 minutes for the internal body temperature of a bass to equilibrate to the water temperature after a change of 18°F.

Mean summer internal body temperatures (IBT) of largemouth bass ranged from 79-90°F (Figure 1.30). In Coffeen Lake, the mean IBT ranged from 75-97°F (Figure 1.31) and in

Newton Lake mean IBT range was from 75-92°F (Figure 1.32). In both Newton Lake and Coffeen Lake mean maximum internal temperatures occurred in July 1999.

By assuming internal body temperature equaled the external water temperature, it was possible to calculate the oxygen concentration at the fishes' location. In all three lakes, largemouth bass were found at the lowest mean dissolved oxygen concentrations in July 1999 (Figures 1.33-1.35). In Newton Lake for example, in July 1999 largemouth bass were primarily found at oxygen concentrations between 1.9-3.0 ppm (Figure 1.35).

Conclusions:

Since the fish kill on Coffeen Lake occurred with the plant operating at a level that existed under the old variance and the kill on Newton Lake occurred while operating under the new variance, the two cases need to be separated when considering variances. Clearly the habitat that the fish were able to live in was being reduced in the summer of 1999 over 1998, but except for the fish kill there was no indication that the added heat loading in Newton Lake had any negative effect. The fish appeared to be sacrificing higher oxygen levels for lower temperatures. Unfortunately, we do not know where the fish that died were when they were exposed to the critical levels of heat. In both lakes, the kill took place approximately five or six days after the hourly temperatures in the discharge water of Coffeen Lake were exceeding 112°F and those in Newton Lake were exceeding 111°F. It is possible that the dead fish were trapped in an area where their livable habitat was finally eroded away.

To date, there is scant evidence that the fish kills in Newton and Coffeen Lake resulted in significant damage to the fisheries, due to the relatively low proportions of fish that died relative to the numbers of fish in these lakes; however, future creel and relative abundance data collected subsequent to the kills need to be examined to determine whether this view is correct. Other measures, such as fish health assessments, condition factors, relative weights, etc., did not indicate substantial long-term impacts on fish that survived the kill. It is possible that conditions in Newton and/or Coffeen Lakes during summer 1999 will diminish recruitment from 1999 year classes; spring 2000 sampling for relative abundance of age 1 fish needs to be completed before this question can be resolved.

On the other hand, habitat in which fish can survive, based on vertical temperature and dissolved oxygen profiles and the behavior of largemouth bass in the telemetry studies, appears to have been nearly completely lost towards the end of July in Newton Lake, based on our present knowledge of the tolerance of species such as largemouth bass, bluegill, and channel catfish to low dissolved oxygen and elevated temperature. Had habitat conditions been marginally better, there may not have been any kills at all. Conversely, had lake temperatures continued to rise and dissolved oxygen continued to degrade for a few more days, it is possible that the magnitude of the resulting fish kills would have had substantial impacts on the fisheries, especially in Newton Lake and possibly in Coffeen Lake. An apparent decline in electrical power demand, the concomitant reductions in thermal loading, and reduced air temperatures towards the end of July and not the variances led to improving temperature and dissolved oxygen conditions in both Newton Lake and Coffeen Lake.

If the survival of *all* fish is the only consideration, then clearly the thermal loading in the summer needs to be cut way back, even below the old variances, in Newton Lake and Coffeen Lake. This, however, is not the only consideration. These lakes exist so that electrical power can be produced, and the high quality fisheries for largemouth bass in Newton and Coffeen Lakes are probably attributable to thermal loading. Assuming that at the present time there is a critical need to maximize power generation especially during the summer months, and that the old variances were protecting the fish, whereas the new variances are not, then the key question becomes: Is there an acceptable level of thermal loading between the old and new variances?

Table 1.1 Basic sampling schedule for AmerenCips Newton Lake Project.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
				Newton Lake									
Phytoplankton	0	1	1	2	2	2	2	2	2	1	0	1	24 samples per date: Sampled at 3 stations in each of 4 segments; 2 samples per station.
Zooplankton	0	1	1	2	2	2	2	2	2	1	0	1	Same as phytoplankton.
Primary productivity	1	1	1	1	1	1	1	1	1	1	1	1	Same as phytoplankton.
Chlorophyll a	1	1	1	1	1	1	1	1	1	1	1	1	Same as phytoplankton.
Benthos	1	1	1	2	2	2	2	2	2	1	1	1	24 samples per date: 6 stations per transect. Transects at midway between segment borders.
Phytomacrobenthos	0	0	0	0	1	1	1	1	1	0	0	0	40 samples per date: 5 stations per segment where vegetation present; 2 samples per station. Random in areas sampled that had vegetation.
Aquatic vegetation	0	0	0	0	0	0	0	1	0	0	0	0	80 random stations, 20 per segment
Ichthyoplankton	0	0	1	2	2	2	2	1	1	1	0	0	Tows 48 samples per date: 10-min per tow, 6 stations per segment, 2 samples per station. Light traps: 16 per date; 4 traps per segment, 2-hr sets. 1/2 pelagic - 1/2 littoral for both methods.
Health-stress	0	0	1	0	0	0	0	1	0	0	0	0	
Food habits	1	0	1	1	1	1	1	1	1	1	1	1	Until numbers satisfied. Sampling completed as necessary in each segment to satisfy number requirements.
Age and growth, mortality	0	0	0	0	0	0	0	0	0	1	1	1	October (1998 and 1999); November (1997) for mortality. Extra sampling in following months as necessary for age and growth requirements.
Seine / recruitment	0	0	0	2	2	2	2	2	0	0	0	0	40 samples per date. 10 stations per segment.
DC electrofishing	0	0	0	0	0	0	0	1	0	0	0	0	Six zones per ESE Report (1995).
Fish movement	1	1	1	4	4	4	4	4	4	1	1	1	Entire lakes per date; 24-hr sampling 3 seasons (spring, summer, winter), twice per season.
Temp/DO	2	2	2	2	2	2	2	2	2	2	2	2	4 samples per date: midway between segment borders; 1/2 meter intervals from surface to bottom.

Table 1.1. Continued.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
					Lake of Egypt								
Ichthyoplankton	0	0	1	2	2	2	2	1	1	0	0	0	Tows 24 samples per date. Light traps 8. samples per date.
Age and growth, mortality	0	0	0	0	0	0	0	0	0	1	1	1	Same as Newton.
Seine / recruitment	0	0	0	2	2	2	2	2	0	0	0	0	20 samples per date: Same as Newton - 2 segments.
AC Electrofishing CPUE	0	0	0	0	0	0	0	0	1	1	1	0	Sept - Oct 1997 and 1998.
Fish movement	1	1	1	4	4	4	4	4	4	1	1	1	Same as Newton - 2 segments.
Temp/DO	2	2	2	2	2	2	2	2	2	2	2	2	Same as Newton - 2 segments.
Food habits	0	0	1	0	0	0	0	1	1	1	1	0	Only taken during mortality and age/growth.
					Coffeen Lake								
Ichthyoplankton	0	0	1	2	2	2	2	1	1	0	0	0	Tows 24 samples per date. Light traps 8. samples per date.
Age and growth, mortality	0	0	0	0	0	0	0	0	0	1	1	1	Same as Newton.
Seine / recruitment	0	0	0	2	2	2	2	2	0	0	0	0	20 samples per date: Same as Newton - 2 segments.
Fish movement	1	1	1	4	4	4	4	4	4	1	1	1	Same as Newton - 2 segments.
Temp/DO	2	2	2	2	2	2	2	2	2	2	2	2	Same as Newton - 2 segments.
Food habits	0	0	1	0	0	0	0	1	0	1	1	1	Only taken during mortality and age/growth.

Table 1.2. Mean monthly water surface temperatures of the Newton Lake discharge.

Year	Month	Number	Surface temperature monthly average
1997	June	27	95.9
1997	July	31	101.7
1997	August	31	96.2
1997	September	30	94.9
1997	October	31	86.3
1997	November	21	69.5
1997	December	31	71.3
1998	January	31	62.6
1998	February	28	63.8
1998	March	31	67.0
1998	April	30	79.7
1998	May	31	89.8
1998	June	30	96.3
1998	July	31	101.7
1998	August	31	102.3
1998	September	30	94.6
1998	October	31	87.5
1998	November	30	72.4
1998	December	31	69.8
1999	January	31	54.0
1999	February	28	67.0
1999	March	31	72.3
1999	April	30	77.3
1999	May	31	88.4
1999	June	30	97.0
1999	July	31	104.1
1999	August	31	99.7
1999	September	30	93.1
1999	October	31	85.4
1999	November	16	80.9

Table 1.3. Hourly temperatures that exceeded 111 F, Newton Lake discharge, 1998 – 1999. Within a year total hours above 111 F were not to exceed 110 (3% of total number of hours during the period June – October, 3,672 hours).

Date	Time	Surface temp.	Date	Time	Surface temp.	Date	Time	Surface temp.
07/22/1999	13:34:28	111.22	07/24/1999	20:34:28	111.47	07/28/1999	0:34:28	111.36
07/22/1999	14:34:28	111.39	07/24/1999	21:34:28	111.18	07/29/1999	12:34:28	111.33
07/22/1999	15:34:28	111.48	07/24/1999	22:34:28	111.01	07/29/1999	13:34:28	111.79
07/22/1999	16:34:28	111.65	07/25/1999	13:34:28	111.53	07/29/1999	14:34:28	111.99
07/22/1999	17:34:28	111.84	07/25/1999	14:34:28	111.5	07/29/1999	15:34:28	111.87
07/22/1999	18:34:28	112.03	07/25/1999	15:34:28	111.71	07/29/1999	16:34:28	111.99
07/22/1999	19:34:28	112.09	07/25/1999	16:34:28	111.77	07/29/1999	17:34:28	112.31
07/22/1999	20:34:29	112.06	07/25/1999	17:34:28	112.03	07/29/1999	18:34:28	111.43
07/22/1999	21:34:28	111.93	07/25/1999	18:34:28	112.13	07/29/1999	19:34:28	112.61
07/22/1999	22:34:28	111.85	07/25/1999	19:34:28	112.06	07/29/1999	20:34:28	112.85
07/22/1999	23:34:28	111.74	07/25/1999	20:34:28	112.11	07/29/1999	21:34:28	113
07/23/1999	0:34:28	111.48	07/25/1999	21:34:28	112.44	07/29/1999	22:34:28	112.39
07/23/1999	10:34:28	111.59	07/25/1999	22:34:28	112.53	07/29/1999	23:34:28	112.85
07/23/1999	11:34:29	112.01	07/25/1999	23:34:28	112.32	07/30/1999	0:34:28	112.79
07/23/1999	12:34:28	112.32	07/26/1999	11:34:28	111.15	07/30/1999	11:34:28	111.81
07/23/1999	13:34:28	112.53	07/26/1999	12:18:32	111.28	07/30/1999	12:34:28	111.85
07/23/1999	14:34:28	111.93	07/26/1999	16:34:28	111.35	07/30/1999	14:34:28	112.99
07/23/1999	15:34:28	112.06	07/26/1999	17:34:28	112.57	07/30/1999	15:34:28	113.31
07/23/1999	16:34:28	112.05	07/26/1999	18:34:28	112.46	07/30/1999	16:34:28	113.27
07/23/1999	17:34:28	111.98	07/26/1999	19:34:28	112.47	07/30/1999	17:34:28	113.35
07/23/1999	18:34:28	111.84	07/26/1999	20:34:28	112.34	07/30/1999	18:34:28	113.37
07/23/1999	19:34:28	111.77	07/26/1999	21:34:28	112.31	07/30/1999	19:34:28	113.51
07/23/1999	20:34:28	111.73	07/26/1999	22:34:28	112.33	07/30/1999	20:34:28	113.56
07/23/1999	21:34:28	111.79	07/26/1999	23:34:29	112.29	07/30/1999	21:34:28	113.63
07/23/1999	22:34:28	111.75	07/27/1999	0:34:28	112.23	07/30/1999	22:34:28	113.66
07/23/1999	23:34:28	111.49	07/27/1999	14:34:28	111.37	07/30/1999	23:34:28	113.64
07/24/1999	11:34:28	111.54	07/27/1999	15:34:28	111.54	07/31/1999	0:34:28	113.48
07/24/1999	12:34:28	111.96	07/27/1999	16:34:28	111.71	07/31/1999	1:34:28	111.98
07/24/1999	13:34:28	112.18	07/27/1999	17:34:28	111.82	07/31/1999	2:34:28	112.8
07/24/1999	14:34:28	112.27	07/27/1999	18:34:28	111.78	07/31/1999	3:34:28	112.67
07/24/1999	15:34:28	112.09	07/27/1999	19:34:28	111.57			
07/24/1999	16:34:28	112.05	07/27/1999	20:34:29	111.59	TOTAL HOURS 100		
07/24/1999	17:34:28	111.77	07/27/1999	21:34:28	111.7			
07/24/1999	18:34:28	111.7	07/27/1999	22:34:28	111.71			
07/24/1999	19:34:28	111.75	07/27/1999	23:34:28	111.6			

Table 1.4. Mean monthly surface water temperatures in the Coffeen Lake discharge.

Year	Month	Number	Surface temperature monthly average
1996	September	6	92.4
1996	October	19	83.2
1996	November	30	80.5
1996	December	31	76.6
1997	January	31	71.6
1997	February	28	69.6
1997	March	26	76.1
1997	April	15	70.2
1997	May	31	77.7
1997	June	30	87.9
1997	July	31	100.8
1997	August	31	98.7
1997	September	30	88.7
1997	October	31	81.6
1997	November	30	76.0
1997	December	31	73.3
1998	January	23	68.2
1998	February	0	
1998	March	0	
1998	April	15	82.8
1998	May	31	90.8
1998	June	30	94.9
1998	July	31	102.4
1998	August	31	100.1
1998	September	28	96.1
1998	October	31	79.9
1998	November	30	68.1
1998	December	25	66.4
1999	January	26	67.8
1999	February	24	64.9
1999	March	31	73.1
1999	April	18	85.5
1999	May	31	86.4
1999	June	30	90.5
1999	July	31	103.9
1999	August	31	101.5
1999	September	30	94.8
1999	October	31	83.6
1999	November	30	75.3
1999	December	12	70.8

Table 1.5. Hourly temperatures that exceeded 112 F, Coffeen Lake discharge, 1998 – 1999. Within a year total hours above 112 F were not to exceed 132 (3% of total number of hours during the period May – October, 4,416 hours).

Date	Time	Surface temp.	Date	Time	Surface temp.
07/23/1999	16:00:00	112	07/29/1999	13:00:00	112.89
07/23/1999	17:00:00	112.5	07/29/1999	14:00:00	114.24
07/23/1999	18:00:00	112.21	07/29/1999	15:00:00	114.02
07/23/1999	19:00:00	112.59	07/29/1999	16:00:00	114.14
07/23/1999	20:00:00	112.16	07/29/1999	17:00:00	114.56
07/25/1999	14:00:00	112.09	07/29/1999	18:00:00	114.67
07/25/1999	15:00:00	112.72	07/29/1999	19:00:00	114.19
07/25/1999	16:00:00	112.72	07/29/1999	20:00:00	114.21
07/25/1999	17:00:00	112.43	07/29/1999	21:00:00	113.6
07/25/1999	18:00:00	113.34	07/29/1999	22:00:00	114
07/25/1999	19:00:00	112.95	07/29/1999	23:00:00	113.89
07/25/1999	20:00:00	112.2	07/30/1999	1:00:00	113.24
07/25/1999	23:00:00	112.8	07/30/1999	2:00:00	113.9
07/26/1999	12:00:00	113.01	07/30/1999	3:00:00	113.11
07/26/1999	13:00:00	113.48	07/30/1999	4:00:00	112.34
07/26/1999	14:00:00	113.75	07/30/1999	12:00:00	112.74
07/26/1999	15:00:00	113.87	07/30/1999	13:00:00	114.2
07/26/1999	16:00:00	112.19	07/30/1999	14:00:00	114.3
07/26/1999	18:00:00	112.36	07/30/1999	15:00:00	114.65
07/26/1999	19:00:00	113.4	07/30/1999	16:00:00	114.88
07/26/1999	20:00:00	114.35	07/30/1999	17:00:00	115.05
07/26/1999	21:00:00	112.96	07/30/1999	18:00:00	115.39
07/26/1999	22:00:00	114.17	07/30/1999	19:00:00	114.06
07/26/1999	23:00:00	113.93	07/30/1999	20:00:00	113.44
07/27/1999	0:00:00	112.9	07/30/1999	21:00:00	113.52
07/27/1999	14:00:00	113.62	07/30/1999	22:00:00	112.95
07/27/1999	15:00:00	113.22	07/30/1999	23:00:00	113.64
07/27/1999	16:00:00	113.81	07/31/1999	1:00:00	112.54
07/27/1999	17:00:00	113.31	07/31/1999	2:00:00	112.31
07/27/1999	18:00:00	113.68	07/31/1999	14:00:00	113.02
07/27/1999	19:00:00	113.43	07/31/1999	15:00:00	112.88
07/27/1999	20:00:00	113.81	07/31/1999	18:00:00	113.29
07/27/1999	21:00:00	114	07/31/1999	19:00:00	113.83
07/27/1999	22:00:00	113.29	07/31/1999	20:00:00	114.09
07/27/1999	23:00:00	112.91	07/31/1999	21:00:00	114.2
07/28/1999	15:00:00	112.41	07/31/1999	22:00:00	113.68
07/28/1999	16:00:00	112.95	07/31/1999	23:00:00	112.83
07/28/1999	17:00:00	113.17	09/07/1999	14:00:00	120.27
07/28/1999	18:00:00	113.86	09/07/1999	15:00:00	120.08
07/28/1999	19:00:00	113.91	09/07/1999	16:00:00	122.49
07/28/1999	20:00:00	113.58			
07/28/1999	21:00:00	113.37	TOTAL HOURS 83		
07/28/1999	22:00:00	112.17			

Table 1.6. Size frequency distributions for white crappie in Newton Lake based on IDNR fall and spring electrofishing samples from fall 1976 to fall 1999. The electrofishing effort was not constant over all sampling periods.

Year	Sample size	Total length (inches)		
		6	7	10
1976 Fall	6	33	33	33
1977 Spring	6	17	17	17
1977 Fall	6	100	83	83
1978 Spring	37	70	30	19
1978 Fall	11	100	64	18
1979 Spring	65	100	23	8
1979 Fall	0	33	33	33
1980 Spring	24	100	100	62
1980 Fall	57	100	96	17
1981 Spring	185	100	85	5
1981 Fall	78	100	100	44
1982 Spring	89	100	98	31
1982 Fall	140	100	96	36
1983 Spring	793	100	95	14
1983 Fall	No data	No data	No data	No data
1984 Spring	63	100	63	13
1984 Fall	178	100	97	26
1985 Spring	279	100	85	6
1985 Fall	188	100	95	28
1986 Spring	103	100	80	24
1986 Fall	104	100	100	62
1987 Spring	24	100	100	54
1987 Fall	38	100	100	76
1988 Spring	6	100	100	83
1988 Fall	7	100	100	100
1989 Spring	0	0	0	0
1989 Fall	9	100	100	56
1990 Spring	2	100	100	0
1990 Fall	3	100	100	33
1991 Spring	18	33	22	17
1991 Fall	0	0	0	0
1992 Spring	0	0	0	0
1992 Fall	0	0	0	0
1993 Spring	5	60	40	0
1993 Fall	3	100	0	0
1994 Spring	3	43	0	0
1994 Fall	3	100	100	100
1995 Spring	1	100	100	0

Table 1.6. Continued.

Year	Sample size	Total length (inches)		
		6	7	10
1995 Fall	2	100	100	50
1996 Spring	0	0	0	0
1996 Fall	1	0	0	0
1997 Spring	0	0	0	0
1997 Fall	2	100	100	0
1998 Spring	2	100	100	100
1998 Fall	1	100	100	100
1999 Spring	--	--	--	--
1999 Fall	22	100	100	5

Table 1.7. Size frequency distributions for bluegill in Newton Lake based on IDNR fall and spring electrofishing samples from fall 1976 to fall 1999.

Year	Sample size	Total length (inches) 6	7	8
1976 Fall	103	38	6	0
1977 Spring	200	45	5	0
1977 Fall	73	29	3	0
1978 Spring	548	43	9	0
1978 Fall	259	31	4	0
1979 Spring	466	24	3	0
1979 Fall	361	7	0.8	0
1980 Spring	113	15	0	0
1980 Fall	262	13	0.8	0
1981 Spring	379	15	2	0
1981 Fall	264	20	0	0
1982 Spring	1,026	13	0.2	0
1982 Fall	363	3	0.3	0
1983 Spring	534	25	3	0
1983 Fall	No data	No data	No data	No data
1984 Spring	399	29	1	0
1984 Fall	181	18	2	0
1985 Spring	367	13	0.5	0
1985 Fall	550	6	0	0
1986 Spring	312	10	0	0
1986 Fall	125	16	0	0
1987 Spring	472	6	0	0
1987 Fall	372	5	0	0
1988 Spring	150	5	0.7	0
1988 Fall	376	3	0	0
1989 Spring	120	9	0.8	0
1989 Fall	628	5	0	0
1990 Spring	95	17	4	2
1990 Fall	107	5	2	2
1991 Spring	512	5	0.8	0
1991 Fall	108	4	0	0
1992 Spring	108	14	1	0
1992 Fall	78	15	0	0
1993 Spring	112	21	3	0.9
1993 Fall	620	14	3	0
1994 Spring	106	0	0	0
1994 Fall	289	0	0	0
1995 Spring	133	0	0	0

Table 1.7. Continued.

Year	Sample size	Total length (inches)		
		6	7	8
1995 Fall	1,236	<1	0	0
1996 Spring	434	5	2	0.5
1996 Fall	618	0	0	0
1997 Spring	368	4	2	0
1997 Fall	542	2	1	0
1998 Spring	348	28	8	0
1998 Fall	522	2	1	0
1999 Spring	--	--	--	--
1999 Fall	832	1	0	0

Table 1.8. Size frequency distributions for channel catfish in Newton Lake based on IDNR fall and spring electrofishing samples from fall 1976 to fall 1999.

		Total length (inches)		
Year	Sample size	12	16	20
1976 Fall	0	0	0	0
1977 Spring	0	0	0	0
1977 Fall	0	0	0	0
1978 Spring	4	100	0	0
1978 Fall	0	0	0	0
1979 Spring	19	100	53	26
1979 Fall	22	82	77	27
1980 Spring	6	50	33	17
1980 Fall	51	12	6	2
1981 Spring	52	40	31	27
1981 Fall	87	90	23	7
1982 Spring	148	64	18	9
1982 Fall	80	72	28	8
1983 Spring	87	49	9	2
1983 Fall	No data	No data	No data	No data
1984 Spring	327	45	13	0.3
1984 Fall	115	62	23	6
1985 Spring	267	93	8	1
1985 Fall	381	50	17	4
1986 Spring	336	49	11	1
1986 Fall	105	48	15	5
1987 Spring	148	31	8	3
1987 Fall	85	27	12	5
1988 Spring	238	31	7	2
1988 Fall	227	44	12	4
1989 Spring	191	35	7	1
1989 Fall	221	24	10	1
1990 Spring	82	46	7	1
1990 Fall	114	60	19	4
1991 Spring	396	48	13	3
1991 Fall	186	58	13	3
1992 Spring	44	43	5	2
1992 Fall	139	40	18	7
1993 Spring	73	36	15	1
1993 Fall	193	4	0	0
1994 Spring	72	42	19	0
1994 Fall	137	28	8	1

Table 1.8. Continued.

Year	Sample size	Total length (inches)		
		12	16	20
1995 Spring	186	0.5	0	0
1995 Fall	528	9	2	1
1996 Spring	177	14	0	0
1996 Fall	149	13	2	0
1997 Spring	54	32	2	0
1997 Fall	49	35	10	2
1998 Spring	111	8	1	1
1998 Fall	161	33	4	0
1999 Spring	--	--	--	--
1999 Fall	142	37	1	0

Table 1.9. Size frequency distributions for largemouth bass in Newton Lake based on IDNR fall and spring electrofishing samples from fall 1976 to fall 1999.

Year	Sample size	Total length (inches)			
		12	14	16	18
1976 Fall	79	51	51	1	0
1977 Spring	137	59	51	2	0.5
1977 Fall	211	84	61	22	3
1978 Spring	342	92	73	46	4
1978 Fall	427	82	74	49	10
1979 Spring	364	95	86	71	21
1979 Fall	1,622	79	65	29	10
1980 Spring	273	90	79	57	21
1980 Fall	462	74	65	31	11
1981 Spring	471	84	73	47	18
1981 Fall	522	71	66	31	12
1982 Spring	592	86	71	42	19
1982 Fall	445	72	61	21	8
1983 Spring	1,006	82	64	27	13
1983 Fall	No data	No data	No data	No data	No data
1984 Spring	344	88	74	47	14
1984 Fall	356	70	66	30	13
1985 Spring	266	82	75	51	23
1985 Fall	310	59	56	12	6
1986 Spring	343	85	72	43	27
1986 Fall	363	71	62	25	10
1987 Spring	245	78	70	40	22
1987 Fall	469	70	60	20	8
1988 Spring	586	80	72	43	21
1988 Fall	377	82	69	38	15
1989 Spring	663	89	74	48	21
1989 Fall	623	66	62	24	9
1990 Spring	520	85	74	49	18
1990 Fall	518	69	60	20	7
1991 Spring	721	86	64	28	12
1991 Fall	534	70	66	31	13
1992 Spring	383	80	71	43	18
1992 Fall	642	62	57	14	5
1993 Spring	509	69	60	21	8
1993 Fall	637	69	56	11	6
1994 Spring	809	52	50	0	0
1994 Fall	1,126	79	53	6	2
1995 Spring	548	53	50	0	0
1995 Fall	840	44	32	14	2
1996 Spring	592	85	73	43	9

Table 1.9. Continued.

Year	Sample size	Total length (inches)			
		12	14	16	18
1996 Fall	1,000	58	47	27	7
1997 Spring	718	84	70	46	14
1997 Fall	357	24	19	12	5
1998 Spring	691	63	53	41	15
1998 Fall	705	53	41	31	6
1999 Spring	--	--	--	--	--
1999 Fall	514	50	38	13	4

Table 1.10. The numbers, mean back-calculated length (inches) and mean derived weight (pounds) for white crappie from Newton Lake, Coffeen Lake and Lake of Egypt collected from 1997 through 1999.

	Newton Lake			Coffeen Lake			Lake of Egypt		
Age	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)
1		4.26	0.04	1	4.45	0.03		4.46	0.10
2	21	8.38	0.30	13	6.70	0.10	56	8.80	0.40
3				88	8.02	0.20	82	10.97	0.70
4				30	9.04	0.30	20	11.74	0.80
5				2	11.77	0.90	10	12.04	0.90
6							4	12.83	1.10
7								14.99	1.60
8							1	15.55	1.80

Table 1.11. The numbers, mean back-calculated length (inches) and mean derived weight (pounds) for bluegill sunfish from Newton Lake, Coffeen Lake and Lake of Egypt collected from 1997 through 1999.

	Newton Lake			Coffeen Lake			Lake of Egypt		
Age	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)
1	71	2.45	0.01	95	2.64	0.01	5	2.61	0.01
2	202	3.87	0.03	214	3.76	0.03	78	4.10	0.04
3	76	4.88	0.07	125	4.50	0.05	85	5.38	0.10
4	29	5.70	0.11	17	5.03	0.08	98	6.20	0.14
5	10	6.06	0.14	3	5.47	0.10	34	6.51	0.17
6	1	6.10	0.14				22	6.76	0.20
7							1	7.99	0.33

Table 1.12. The numbers, mean back-calculated length (inches) and mean derived weight (pounds) for channel catfish from Newton Lake, Coffeen Lake and Lake of Egypt collected from 1997 through 1999.

	Newton Lake			Coffeen Lake			Lake of Egypt		
Age	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)
1		3.73	0.1		4.16	0.1		4.93	0.1
2	13	6.09	0.1	5	7.24	0.1	1	9.83	0.3
3	28	7.81	0.1	27	9.34	0.2	1	13.22	0.8
4	42	9.11	0.2	32	10.93	0.4	3	15.74	1.3
5	60	10.12	0.3	43	12.30	0.5	5	17.56	1.8
6	65	10.84	0.3	50	13.52	0.7	15	18.80	2.2
7	65	11.60	0.4	39	14.59	0.9	21	19.80	2.6
8	55	12.36	0.5	54	15.52	1.1	17	20.48	2.9
9	27	13.14	0.6	45	16.01	1.2	19	20.91	3.1
10	18	13.06	0.6	13	15.74	1.1	6	22.39	3.7
11	4	12.07	0.5	4	15.64	1.1	4	25.41	5.4
12	4	11.71	0.4	4	15.33	1.0			

Table 1.13. The numbers, mean back-calculated length (inches) and mean derived weight (pounds) for largemouth bass from Newton Lake, Coffeen Lake and Lake of Egypt collected from 1997 through 1999.

Age	Newton Lake			Coffeen Lake			Lake of Egypt		
	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)	Number	Length(in)	Weight(lb)
1	232	6.80	0.1	135	7.50	0.2	25	6.38	0.1
2	152	13.14	1.2	115	12.50	1.1	56	10.61	0.6
3	59	16.11	2.3	95	15.25	2.0	78	12.93	1.0
4	37	17.31	2.9	57	16.57	2.6	45	14.41	1.4
5	32	18.01	3.3	25	17.60	3.2	43	15.41	1.7
6	11	18.70	3.8	9	18.46	3.7	22	16.11	1.9
7	8	19.13	4.1	11	19.05	4.1	19	16.90	2.2
8	1	19.51	4.3	3	19.11	4.2	12	17.40	2.5
9		20.64	5.2	2	19.07	4.1	8	17.92	2.8
10	1	21.10	5.5	1	18.74	3.9	3	18.97	3.3
11							1	19.52	3.6
12							1	18.58	3.1
13							1	19.41	3.7

Table 1.14. Summary of mean relative weights for largemouth bass, bluegill, and channel catfish captured in each lake during November 1997, and March, August, and November of 1998 and 1999.

	Newton Lake			Lake of Egypt			Coffeen Lake		
Year	March	August	November	March	August	November	March	August	November
				Largemouth Bass					
1997	--	--	105	--	--	89	--	--	99
1998	105	96	106	89	82	95	104	96	105
1999	108	97	105	98	82	--	110	93	105
Mean	107	97	105	93	82	92	107	95	103
				Bluegill					
1997	--	--	85	--	--	81	--	--	82
1998	92	84	85	90	84	93	--	88	97
1999	78	89	98	82	82	--	83	90	96
Mean	81	87	91	86	83	87	83	88	92
				Channel Catfish					
1997	--	--	82	--	--	87	--	--	82
1998	86	90	84	100	87	107	89	83	92
1999	86	82	84	96	94	--	79	95	91
Mean	86	86	83	98	89	103	84	88	89

Table 1.15. Mean percentage of largemouth bass, and channel catfish with empty stomachs from the three Illinois power-cooling reservoirs (Newton Lake, Coffeen Lake, and Lake of Egypt) during 1997, 1998, and 1999.

		Newton Lake		Coffeen Lake		Lake of Egypt	
Species	Year	% Empty	Months[a]	% Empty	Months[a]	% Empty	Months[a]
Largemouth Bass	1997	49.9	4	33.6	2	36.4	1
	1998	51.7	9	29.4	5	30.4	4
	1999	70.0	12	54.6	5	55.4	2
	Mean	60.2		40.6		38.4	
Channel Catfish	1997	30.6	4	46.3	2	25.0	1
	1998	48.6	9	43.1	6	39.4	4
	1999	59.2	10	87.5	3	28.6	2
	Mean	51.0		55.8		34.3	

[a]/ Number of months that samples were taken.

Table 1.16. Summary of Chapman-Robson (1960)(C-R) and catch curve estimates (C-C) of actual annual mortality rate (percent) for largemouth bass, bluegill, and channel catfish calculated from catch data of fish captured in each lake during fall 1997, 1998 and 1999 (-- indicates an undeterminable value).

Year	Newton Lake		Lake of Egypt		Coffeen Lake	
	C-R	C-C	C-R	C-C	C-R	C-C
			Largemouth Bass			
1997	73	63	30	28	40	37
1998	56	34	39	28	50	35
1999	61	55	--[1]	--[1]	40	38
Mean	63	51	35	28	43	36
			Bluegill			
1997	73	72	59	38	69	58
1998	88	78	36	52	70	69
1999	88	67	--[1]	--[1]	56	61
Mean	83	72	48	45	65	63
			Channel Catfish			
1997	54	41	67	50	32	13
1998	44	38	11	--	33	18
1999	40	32	--[1]	--[1]	36	38
Mean	46	37	39	50	34	23

[1/] No sampling scheduled.

Table 1.17. Hatching date ranges for 1998-99 by taxa in three Illinois power cooling reservoirs. In 1998 and 1999, hatching dates were calculated using the 1998 aged larvae and their subsequent length-age linear regression prediction equations. The initial temperature is the lowest temperature at the beginning of the hatching range. The ending temperature is the highest temperature at the end of the hatching range.

Lake	Year	Taxa	Hatching date range	Days	Hatching temp. range (°F)	
					Initial	Ending
Newton Lake	1998	*Lepomis*	4/15-9/19	158	56	94
		Dorosoma	3/27-6/30	96	60	100
		Morone[2]	4/04-5/15[1]	42		
		Micropterus	4/05-5/09[1]	35		
	1999	*Lepomis*	3/31-10/01	185	70	87
		Dorosoma	3/11-7/01	113	52	92
		Morone[2]	3/14-5/03[1]	51		
		Micropterus	3/27-5/11[1]	44		
Coffeen Lake	1998	*Lepomis*	4/23-10/04	165	78	84
		Dorosoma	3/29-6/27	81	62	97
		Morone[2]	4/04-4/28[1]	25		
		Pomoxis	4/08-5/14[1]	37		
	1999	*Lepomis*	5/02-9/10	132	80	103
		Dorosoma	3/21-7/09	111	67	100
Lake of Egypt	1998	*Lepomis*	5/09-9/05	120	67	91
		Dorosoma	4/03-6/29	88	63	92
		Pomoxis	4/01-5/05[1]	35		
		Micropterus[2]	4/26-5/20[1]	25		
	1999	*Lepomis*	5/01-9/08	131	74	87
		Dorosoma	4/08-7/16	100	63	89
		Pomoxis	4/04-5/06[1]	33		
		Micropterus[2]	4/19-5/24[1]	36		

[1]Hatching range temperatures fall within the ranges for those of *Dorosoma* for that year.
[2]Hatching range was calculated from a length-age linear regression equation developed from a small sample size of fish and having relatively low R^2 values.

Table 1.18. Mean densities (n/m^3) for larval fish (all segments combined) in three Illinois power cooling lakes. Superscripts with different letters are significantly different between years, within taxa, at $\alpha = 0.05$. Mean densities were calculated using samples within the time period of capture of each taxa.

Lake	Year	Taxa	Density	Range	Std.dev.
Newton Lake	1998	*Lepomis*	0.0129[a]	0-0.0842	0.0174
	1999	*Lepomis*	0.0146[a]	0-0.0970	0.0244
	1998	**Dorosoma**	0.7992[a]	0-4.6318	1.1534
	1999	*Dorosoma*	0.9326[a]	0-5.5988	1.5106
Coffeen Lake	1998	*Lepomis*	0.0067[a]	0-0.0441	0.0106
	1999	*Lepomis*	0.0015[a]	0-0.0075	0.0024
	1998	*Dorosoma*	0.1123[a]	0-0.6234	0.1931
	1999	*Dorosoma*	0.1038[a]	0-0.8778	0.2312
Lake of Egypt	1998	*Lepomis*	0.0946[a]	0-0.4197	0.1266
	1999	*Lepomis*	0.0245[b]	0-0.1107	0.0326
	1998	*Dorosoma*	0.3407[a]	0-3.9256	1.0363
	1999	*Dorosoma*	0.3691[a]	0-1.833	0.6348

Table 1.19. Mean CPUE (n/hr) for larval fish (all segments combined) collected with light traps in three Illinois power cooling lakes. Superscripts with different letters are significantly different between segments, within taxa, at $\alpha = 0.05$. Mean CPUE was calculated using samples within the time period of capture of each taxa.

Lake	Year	Taxa	CPUE	Range	Std.dev.
Newton Lake	1998	*Lepomis*	5.18[a]	0-30.35	8.01
	1999	*Lepomis*	26.75[a]	0-383.37	68.26
	1998	*Dorosoma*	2.45[a]	0-32.00	6.74
	1999	*Dorosoma*	6.26[a]	0-49.94	12.77
	1998	*Micropterus*	1.27[a]	0-4.53	1.81
	1999	*Micropterus*	2.72[a]	0-40.72	9.29
Coffeen Lake	1998	*Lepomis*	2.4[a]	0-14.94	3.56
	1999	*Lepomis*	17.01[a]	0-152.57	37.38
	1998	*Dorosoma*	0.64[a]	0-2.69	0.98
	1999	*Dorosoma*	1.48[a]	0-9.68	2.76
	1998	*Micropterus*	0.04[a]	0-.12	0.06
	1999	*Micropterus*	0.31[a]	0-1.00	0.47
Lake of Egypt	1998	*Lepomis*	2.84[a]	0-15.47	4.43
	1999	*Lepomis*	5.44[a]	0-46.09	12.35
	1998	*Dorosoma*	6.96[a]	0-56.64	14.96
	1999	*Dorosoma*	3.74[a]	0-36.29	9.36
	1998	*Micropterus*	0.8[a]	0-2.12	0.91
	1999	*Micropterus*	1.35[a]	0-7.75	3.13

Table 1.20. Mean number[1] of all fish collected in seine hauls in August 1997 and April through August 1998 and 1999. Number of largemouth bass are in parenthesis.

Lake	Year 1997	1998	1999
Newton	[a]2.98 (1.58)[a]	[a]16.38 (5.90)[a]	[a]7.89 (3.49)[a]
Coffeen	[a]8.80 (1.50)[a]	[a]11.96 (0.40)[b]	[a]8.83 (0.17)[b]
Lake of Egypt	[a]28.85 (1.25)[b]	[a]12.44 (1.29)[b]	[a]30.56 (2.64)[b]

[1]/ Numbers with same superscript are not significantly different at the $\alpha = 0.05$ level.

Table 1.21. Electrofishing catch per hour for age-1+ largemouth bass collected by Southern Illinois University personnel during fall of each year. Largemouth bass ages were determined by examining their saggittae otoliths.

	1997			1998			1999		
Lake	Effort (hrs)	Sample[a] size	Catch per hour	Effort (hrs)	Sample[a] size	Catch per hour	Effort (hrs)	Sample[a] size	Catch per hour
Newton	9.3	132	1.94	6.3	111	9.84	9	187	3.11
Coffeen	4.8	106	3.33	7.3	109	6.03	5.1	141	7.06
Lake of Egypt	12.6	98	1.83	10.2	105	2.25	---	---	---

[a]/ Total number of all aged largemouth bass examined for age-1+ fish.

Table 1.22. Summary of fishing and harvest effort on Newton Lake (1,750 acres) from 1986-1993 and 1998. Creel data for 1986-1993 were taken from Merle Price's report to Ameren CIPS (Table 50). Creel data for 1998 was taken from INHS April 12, 1999, report to Ameren CIPS.

	Angling	Total No. Fish		Fish/acre		Fish/hr.	Total pounds		Pounds/acre		Pounds/acre	
Year	hours	Caught	Harvested	Caught	Harvested	caught	Caught	Harvested	Caught	Harvested	Caught	Harvested
1986	150,814		125,746		72			76,368		43.6		0.51
1987	119,609		90,018		51			64,448		36.8		0.54
1988	73,395		25,537		15			26,630		15.2		0.36
1989	84,022		24,942		14			29,146		16.6		0.35
1990	82,351		32,102		18			44,356		25.3		0.34
1991	70,330		21,029		12			23,142		16.1		0.33
1992	78,531		24,320		14			30,514		17.4		0.39
1993	51,152		10,495		6			14,991		8.6		0.29
1998	105,931	89,726	12,432	127	7	1	114,902	11,937	66	6.8	0.68	0.08

[a] Lake was closed 5/20/93 – 8/31/93.

[b] Creel was only run from 2/01/98 through 10/31/98 (9 months).

Table 1.23. Summary of largemouth bass catch and harvest on Newton Lake (1,750 acres) from 1986-1993 and 1998. Creel data for 1986-1993 were taken from Merle Price's report to Ameren CIPS (Table 50). Creel data for 1998 was summarized from INHS April 12, 1999 report to Ameren CIPS.

	Total no. fish		Fish/acre		No. fish.hr.		Total pounds		Pounds/acre		Pounds/hr.	
Year	Caught	Harvested	Caught	Harvested	Caught	Harvested	Caught	Harvested	Caught	Harvested	Caught	Harvested
1986		1,743		1.0		0.01		7,033		4.0		0.05
1987		1,278		0.7		0.01		5,409		3.0		0.04
1988		1,231		0.7		0.02		5,322		3.0		0.07
1989		1,141		0.6		0.01		5,160		3.0		0.06
1990		1,216		0.7		0.01		5,248		3.0		0.06
1991		1,143		0.7		0.02		4,883		2.8		0.07
1992		1,441		0.8		0.02		6,351		3.6		0.08
1993		731		0.4		0.01		3,465		2.0		0.07
1998	56,339	12,432	32	0.7	0.35	0.01	103,364	4,752	59	2.7	0.60	0.03

[a] Lake was closed 5/20/93 – 8/31/93.

[b] Creel was only run from 2/01/98 through 10/31/98 (9 months).

Table 1.24. Summary of bluegill and white crappie harvest, on Newton Lake (1,750 acres), from 1986-1993 and 1998. Creel data for 1986-1993 were taken from Merle Price's report to AmerenCIPS (Table 50). Creel data for 1998 was summarized from INHS April 12, 1999 report to AmerenCIPS.

	Number of bluegill		
Year	Harvested	Caught	Number of harvested white crappie
1986	1,009		89,499
1987	619		66,971
1988	90		69
1989	283		141
1990	281		199
1991	112		3
1992	29		0
1993[a]	91		0
1998[b]	947	4,482	?[c]

a Lake was closed 5/20/93 - 8/31/93

b In 1998 creel was only run from 2/01/98 through 10/31/98 (9 months).

c Some of the miscellaneous category that contains 61 fish may be crappie.

Table 1.25. Summary of channel catfish catch and harvest on Newton Lake (1,750 acres) from 1986-1993 and 1998. Creel data for 1986-1993 were taken from Merle Price's report to Ameren CIPS (Table 50). Creel data for 1998 was summarized from INHS April 12, 1999 report to Ameren CIPS.

	Total no. fish		Fish/acre		No. fish.hr.		Total pounds		Pounds/acre		Pounds/hr.	
Year	Caught	Harvested	Caught	Harvested	Caught	Harvested	Caught	Harvested	Caught	Harvested	Caught	Harvested
1986		32,280		18.0		0.21		35,231		20.0		0.23
1987		20,691		12.0		0.17		21,398		12.0		0.18
1988		23,939		14.0		0.33		21,070		12.0		0.29
1989		22,887		13.0		0.27		23,605		13.0		0.28
1990		30,133		17.0		0.37		38,824		22.0		0.47
1991		19,500		11.0		0.28		23,154		13.0		0.33
1992		22,755		13.0		0.29		24,058		14.0		0.31
1993		9,642		6.0		0.19		11,486		7.0		0.22
1998		9,720		5.6		0.19		6,984		4.0		0.05

[a] Lake was closed 5/20/93 – 8/31/93.

[b] Creel was only run from 2/01/98 through 10/31/98 (9 months).

Table 1.26. Primary production values from several studies (after Kimmel et al. 1990)[a].

Reservoir, Location	Year	Production	Units	Comments	Reference
Francis Case, SD	1968	260	mg C m^{-2} d^{-1}	Net O_2 change, summer estimates	Martin and Novotny (1975)
Lewis and Clark, NB	1968	530	mg C m^{-2} d^{-1}	Net O_2 change, summer estimates	Martin and Novotny (1975)
Hebgen, MT	1965	658	mg C m^{-2} d^{-1}	Net O_2 change, summer estimates	Martin and Arneson (1978)
Canyon Ferry, MT	1958	1125	mg C m^{-2} d^{-1}	Net O_2 change, April – September	Wright (1958, 1959, 1960)
Ashtabula, ND	1966 - 68	1828	mg C m^{-2} d^{-1}	Net O_2 change	Peterka and Reid (1966), Knuston (1970), cited in Soltero et al. (1975)
Newton Lake, IL	1997 – 98	944	mg C m^{-2} d^{-1}	Net O_2 change	this study

[a]/ See Chapter 4 for citations.

Table 1.27. Mean total phytoplankton cells per L (Coccoid singles excluded) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.			n	R^2	p value
1998	41,524,675[a]	±	5021267	48	16.4%	0.0001
1999	26,716,306[b]	±	2867931	48		

Table 1.28 Mean net photosynthesis (mg C m^{-2} day^{-1}) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.			n	R^2	p value
1998	1340.7[a]	±	381.1	16	0.0 %	0.8379
1999	1392.5[a]	±	219.6	16		

Table 1.29. Mean chlorophyll *a* (µg / L) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.			n	R^2	p value
1998	14.6[a]	±	0.8	70	0.6 %	0.3623
1999	13.8[a]	±	1.2	72		

Table 1.30. Mean OD 664 / OD 665 ratio (range 1.0 – 1.7) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.			n	R^2	p value
1998	1.37[a]	±	0.01	70	9.6 %	0.0002
1999	1.32[b]	±	0.01	72		

Table 1.31. Density of macrophytes, primarily water willow, in Newton Lake. Superscripts indicate statistical differences between weights ($p = 0.0001$).

Date	Pool elevation (ft)	Macrophyte area in acres (%[a])	Pounds per m^2	Mean maximum depth (ft)
August 1977	-2.1	15.1 (0.9)	1.00[b]	0.96
August 1998	0	34.8 (2.0)	4.94[a]	1.59
August 1999	-5.2	21.9 (1.2)	4.00[a]	1.05

[a]/ Percent of lake based on a lake area of 1,750 acres.

Table 1.32. Mean zooplankton densities in Newton Lake with all four sampling segments combined.

Date	Number per L
August 1997	146[a]
July – August 1998	171[b]
July – August 1999	239[c]

[a] / Means with different superscripts are different at α=0.05.

Table 1.33. Mean July and August benthos densities for all four segments combined. Superscripts indicate statistical differences between years at $\alpha = 0.05$.

Date	Density (n per m^2)	Weight (g per m^2)
1998	966[b]	0.9733[b]
1999	1,683[a]	1.418[a]

Table 1.34. Densities of phytomacrobenthos over time in Newton Lake with all four segments combined.

Date	Mean Number (m^2)	Mean Weight g/m^2
July 1997	1,628[a]	0.369[a]
July – August 1998	4,519[b]	1.337[b]
July – August 1999	8,729[c]	3.220[c]

Means with different superscripts are different at the $\alpha = 0.05$ level.

Table 1.35. Numbers of dead and morbid fishes observed by SIU personnel in Coffeen Lake in 1999.

Date	Largemouth bass	Lepomis	Channel catfish	Morone	White crappie	Carp	Shad
4/9/99	0	0	2	0	0	1	0
6/2/99	0	0	0	0	0	0	0
6/3/99	0	0	0	0	0	0	0
6/8/99	0	0	0	0	0	0	0
6/15/99	0	0	0	0	0	0	0
6/16/99	0	0	0	0	0	0	0
6/29/99	0	0	0	0	0	0	0
6/30/99	0	0	0	0	0	0	0
7/8/99	1	0	0	0	0	0	0
7/9/99	0	0	0	0	0	0	0
7/13/99	0	0	0	0	0	0	0
7/16/99	0	0	0	0	0	0	0
7/21/99	0	0	0	1	1	0	0
7/23/99	0	0	0	0	0	0	0
7/27/99	15	31	0	0	0	0	5
7/28/99	105	0	5	11	0	0	7
8/1/99	0	0	0	0	0	0	0
8/2/99	0	0	0	0	0	0	0
8/6/99	0	0	0	0	0	0	0
8/10/99	0	0	1	0	1	0	0
8/11/99	0	0	0	0	0	0	0
8/19/99	0	0	0	0	0	0	0
8/20/99	0	0	0	0	0	0	0
8/24/99	0	0	0	0	0	0	0
8/25/99	0	0	0	0	0	0	0
8/26/99	0	0	0	0	0	0	0
8/27/99	0	0	0	0	0	0	0
Total	121	31	8	12	2	1	12

Table 1.36. Numbers of dead and morbid fishes observed by SIU personnel in Newton Lake in 1999.

Date	Largemouth bass	Lepomis	Channel catfish	Morone	Carp	Shad
3/23/99	1	0	0	0	0	0
5/20/99	1	0	0	0	0	1
6/1/99	0	0	0	0	0	0
6/2/99	0	0	0	0	0	0
6/3/99	0	0	0	0	0	0
6/4/99	0	0	0	0	0	0
6/8/99	0	0	0	0	0	0
6/9/99	27	0	0	0	0	0
6/14/99	0	0	0	0	0	0
6/15/99	0	0	0	0	0	0
6/19/99	0	0	0	0	0	0
6/22/99	4	0	0	0	0	0
6/23/99	0	0	0	0	0	0
6/24/99	0	0	0	0	0	0
6/29/99	0	0	0	0	0	0
7/6/99	0	0	0	0	0	0
7/7/99	1	0	0	0	0	0
7/8/99	0	0	0	0	0	0
7/14/99	0	0	0	0	0	0
7/15/99	0	0	0	0	0	0
7/16/99	0	0	0	0	0	0
7/20/99	1	0	0	1	0	0
7/21/99	0	0	0	0	0	0
7/23/99	0	0	0	0	0	0
7/24/99	0	0	0	0	0	0
7/27/99	18	1	22	1	1	8
7/29/99	60	4	36	1	0	15
7/30/99	5	0	0	0	0	0
7/31/99	0	0	0	0	0	0
8/5/99	3	0	9	0	0	2
8/9/99	3	0	2	0	0	0
8/10/99	0	0	0	0	0	0
8/11/99	20	0	0	0	0	35
8/18/99	24	0	1	2	0	0
8/19/99	18	0	0	0	0	0
8/24/99	6	0	0	0	0	0
8/25/99	9	0	0	0	0	0
8/26/99	14	0	0	0	0	0
8/27/99	11	0	0	0	0	0
8/31/99	1	0	0	0	0	0
Total	227	5	70	5	1	59

Table 1.37. FHAI scores for largemouth bass, 1998-1999. No differences occurred among the lakes within a season. Asterisks indicate differences between seasons at the $\alpha = 0.05$ level.

Year	Season	Lake	N	FHAI	Std. err.
1998	Spring	Newton*	36	103	5.12
		Coffeen*	30	100	5.79
		Egypt*	31	97	4.79
	Summer	Newton	26	59	5.65
		Coffeen	30	71	4.38
		Egypt	30	53	6.15
1999	Spring	Newton	31	81	5.91
		Coffeen	30	90	6.04
		Egypt	32	91	8.65
	Summer	Newton	17	70	6.52
		Coffeen	31	76	6.50
		Egypt	28	74	7.92
		Newton Moribund	10	102	7.29
		Non-power cooling lakes	23	71	5.66

Table 1.38. Estimated percent habitat available in Lake of Egypt, July 22, 1999 (Segment 1 = 5:26 PM, Segment 2 = 4:20 PM). Habitat is considered available if it contained no less than the minimum oxygen or no more than the maximum temperature indicated.

Minimum oxygen (ppm)	Maximum temperature (°F)	% Habitat available	
		Segment 1	Segment 2
4	87	5	29
4	88	14	43
4	89	18	43
4	90	18	50
4	91	23	61
4	92	23	61
4	93	23	61
4	94	23	61
4	95	23	61
4	96	23	61
4	97	23	61
3	87	14	36
3	88	23	50
3	89	27	50
3	90	27	57
3	91	32	68
3	92	32	68
3	93	32	68
3	94	36	68
3	95	36	68
3	96	36	68
3	97	36	68
2	87	18	36
2	88	27	50
2	89	32	50
2	90	32	57
2	91	36	68
2	92	36	68
2	93	36	68
2	94	41	68
2	95	45	68
2	96	45	68
2	97	45	68
1	87	23	50
1	88	32	64
1	89	36	64
1	90	36	71
1	91	41	82
1	92	41	82
1	93	41	82
1	94	45	82
1	95	50	82
1	96	52	82
1	97	52	82

Table 1.39. Estimated percent habitat available in Coffeen Lake, July 23, 1999 (Segment 1 = 3:10 PM, Segment 2 = 2:50 PM). Habitat is considered available if it contained no less than the minimum oxygen or no more than the maximum temperature indicated.

Minimum oxygen (ppm)	Maximum temperature (°F)	% Habitat available[a] Segment 1	Segment 2
4	87	0	0
4	88	0	0
4	89	0	0
4	90	0	0
4	91	0	0
4	92	0	0
4	93	5	0
4	94	10	5
4	95	14	10
4	96	19	20
4	97	24	25
3	87	0	0
3	88	0	0
3	89	0	0
3	90	0	0
3	91	0	5
3	92	5	5
3	93	10	10
3	94	14	15
3	95	19	20
3	96	24	30
3	97	29	35
2	87	0	0
2	88	0	0
2	89	0	0
2	90	0	10
2	91	5	15
2	92	10	15
2	93	14	20
2	94	19	25
2	95	24	30
2	96	29	40
2	97	33	45
1	87	0	0
1	88	0	5
1	89	5	5
1	90	10	15
1	91	14	20
1	92	19	20
1	93	24	25
1	94	29	30
1	95	33	35
1	96	38	45
1	97	43	50

[a]/ Habitat at the sampling station. Coffeen Lake has a large cove and an area north of the intake that may have had better conditions.

Table 1.40. Estimated percent habitat available in Coffeen Lake, August 1, 1999, at the discharge (upstream from segment 1 midpoint) and dam (border of segments 1 and 2) temperature monitor buoys (Discharge = 1:45 AM, Dam = ca. 2:00 AM). Habitat is considered available if it contains no less than the minimum oxygen or no more than the maximum temperature indicated.

Minimum oxygen (ppm)	Maximum temperature (°F)	% Habitat available	
		Segment 1	Segment 2
4	87	0	0
4	88	0	0
4	89	0	0
4	90	0	0
4	91	0	0
4	92	0	0
4	93	0	0
4	94	0	0
4	95	0	0
4	96	0	14
4	97	0	29
3	87	0	0
3	88	0	0
3	89	0	0
3	90	0	0
3	91	0	0
3	92	0	0
3	93	0	0
3	94	0	0
3	95	0	0
3	96	0	21
3	97	10	36
2	87	0	0
2	88	0	0
2	89	0	0
2	90	0	0
2	91	0	0
2	92	0	0
2	93	0	0
2	94	0	0
2	95	0	14
2	96	0	36
2	97	10	50
1	87	0	0
1	88	0	0
1	89	0	0
1	90	0	0
1	91	0	0
1	92	0	0
1	93	0	0
1	94	0	0
1	95	0	14
1	96	0	36
1	97	10	50

Table 1.41. Estimated percent habitat available in Newton Lake, July 24, 1999 (Segment 1 = 9:20 AM, Segment 2 = 10:33AM, Segment 3 = 12:12 PM, Segment 4 = 1:36 PM). Habitat is considered available if it contains no less than the minimum oxygen or no more than the maximum temperature indicated.

Minimum	Maximum	% Habitat available				Total habitat	
oxygen (ppm)	temperature (°F)	Segment 1	Segment 2	Segment 3	Segment 4	1999	1998[a]
4	87	0	0	0	0	0	2
4	88	0	0	0	0	0	7
4	89	0	0	0	0	0	12
4	90	0	0	0	0	0	16
4	91	0	0	0	0	0	27
4	92	0	0	0	10	3	34
4	93	0	0	6	20	7	37
4	94	0	0	18	50	17	39
4	95	0	0	24	80	26	42
4	96	0	0	38	85	31	44
4	97	0	0	38	85	31	44
3	87	0	0	0	0	0	2
3	88	0	0	0	0	0	7
3	89	0	0	0	0	0	12
3	90	0	0	0	0	0	16
3	91	0	0	0	0	0	27
3	92	0	0	0	10	3	36
3	93	0	0	6	20	7	39
3	94	0	0	18	50	17	41
3	95	0	0	24	80	26	47
3	96	0	6	38	85	32	48
3	97	0	6	38	85	32	48
2	87	0	0	0	0	0	2
2	88	0	0	0	0	0	7
2	89	0	0	0	0	0	12
2	90	0	0	0	0	0	16
2	91	0	0	0	0	0	27
2	92	0	0	0	10	3	36
2	93	0	6	6	20	8	39
2	94	0	6	18	50	19	41
2	95	0	6	24	80	28	47
2	96	0	13	38	85	34	48
2	97	0	13	38	85	34	48
1	87	0	0	0	0	0	6
1	88	0	0	0	0	0	13
1	89	0	0	0	0	0	18
1	90	0	0	0	0	0	22
1	91	13	0	6	0	5	33
1	92	13	0	6	10	7	42
1	93	13	6	12	20	13	44
1	94	25	6	24	50	26	47
1	95	25	6	29	80	35	52
1	96	25	13	44	85	42	54
1	97	25	13	44	85	42	54

[a]/ July 18, 1998.

Table 1.42. Estimated percent habitat available in Newton Lake, August 5, 1999 (Segment 1 = 3:50 PM, Segment 2 = 4:05 PM, Segment 3 = 4:20 PM, Segment 4 = 4:40 PM). Habitat is considered available if it contains no less than the minimum oxygen or no more than the maximum temperature indicated.

Minimum oxygen (ppm)	Maximum temperature (°F)	% Habitat available				
		Segment 1	Segment 2	Segment 3	Segment 4	Total habitat
4	87	0	0	0	5	1
4	88	0	0	0	25	6
4	89	0	0	11	55	17
4	90	0	0	11	65	19
4	91	0	6	33	100	35
4	92	0	6	58	100	41
4	93	0	13	58	100	43
4	94	0	13	58	100	43
4	95	0	13	58	100	43
4	96	0	13	58	100	43
4	97	0	25	58	100	46
3	87	0	0	0	5	1
3	88	0	0	0	25	6
3	89	0	6	11	55	18
3	90	0	6	11	65	21
3	91	0	13	33	100	37
3	92	0	13	58	100	43
3	93	0	19	58	100	44
3	94	0	19	58	100	44
3	95	0	19	58	100	44
3	96	13	19	58	100	48
3	97	13	31	58	100	51
2	87	0	0	0	5	1
2	88	0	0	0	25	6
2	89	0	13	11	55	20
2	90	0	13	11	65	22
2	91	0	19	33	100	38
2	92	0	19	58	100	44
2	93	0	25	58	100	46
2	94	0	25	58	100	46
2	95	0	25	58	100	46
2	96	13	25	58	100	49
2	97	13	38	58	100	52
1	87	0	0	6	5	3
1	88	0	6	6	25	9
1	89	0	19	17	55	23
1	90	0	19	17	65	25
1	91	13	25	39	100	44
1	92	13	25	64	100	51
1	93	13	31	64	100	52
1	94	13	31	64	100	52
1	95	13	31	64	100	52
1	96	25	31	64	100	55
1	97	25	44	64	100	58

Table 1.43. Estimated percent habitat available in Newton Lake based upon temperature only. Habitat is considered available if it contains no more than the maximum temperature indicated.

Date	Maximum temperature	% Habitat available				
		Segment 1	Segment 2	Segment 3	Segment 4	Mean
06/02/99	70	0	31	26	0	14
06/02/99	75	17	47	32	0	24
06/02/99	80	28	69	100	100	74
06/02/99	85	28	75	100	100	76
06/18/99	70	0	10	21	0	8
06/18/99	75	0	17	26	0	11
06/18/99	80	0	30	50	77	39
06/18/99	85	17	57	100	100	68
07/02/99	70	0	9	25	0	8
07/02/99	75	0	21	31	0	13
07/02/99	80	0	38	42	0	20
07/02/99	85	6	62	75	86	57
07/13/99	70	0	15	15	0	7
07/13/99	75	0	21	21	0	10
07/13/99	80	0	32	32	0	16
07/13/99	85	0	38	50	75	41
07/24/99	70	0	9	15	0	6
07/24/99	75	0	16	21	0	9
07/24/99	80	0	28	32	0	15
07/24/99	85	0	41	44	5	22
08/05/99	70	0	9	19	0	7
08/05/99	75	0	16	25	0	10
08/05/99	80	0	22	31	0	13
08/05/99	85	0	28	36	0	16
08/18/99	70	0	9	9	0	4
08/18/99	75	0	15	15	0	7
08/18/99	80	0	21	21	0	10
08/18/99	85	19	50	44	35	37
08/31/99	70	0	0	0	0	0
08/31/99	75	0	9	3	0	3
08/31/99	80	0	16	9	0	6
08/31/99	85	0	53	84	100	59

Table 1.44. Estimated percent habitat available in Coffeen Lake based upon temperature only. Habitat is considered available if it contains no more than the maximum temperature indicated.

Date	Maximum temperature	% Habitat available		
		Segment 1	Segment 2	Mean
06/02/1999	70	3	23	13
06/02/1999	75	18	35	27
06/02/1999	80	39	56	48
06/02/1999	85	71	100	86
06/16/1999	70	0	11	6
06/16/1999	75	3	16	9
06/16/1999	80	13	30	21
06/16/1999	85	61	100	80
07/08/1999	70	0	7	3
07/08/1999	75	0	11	6
07/08/1999	80	8	20	14
07/08/1999	85	34	39	36
07/23/1999	70	7	0	4
07/23/1999	75	12	3	7
07/23/1999	80	17	8	12
07/23/1999	85	21	18	19
08/06/1999	70	0	7	3
08/06/1999	75	0	11	6
08/06/1999	80	0	16	8
08/06/1999	85	0	20	10
08/19/1999	70	0	7	3
08/19/1999	75	0	7	3
08/19/1999	80	0	11	6
08/19/1999	85	0	25	13

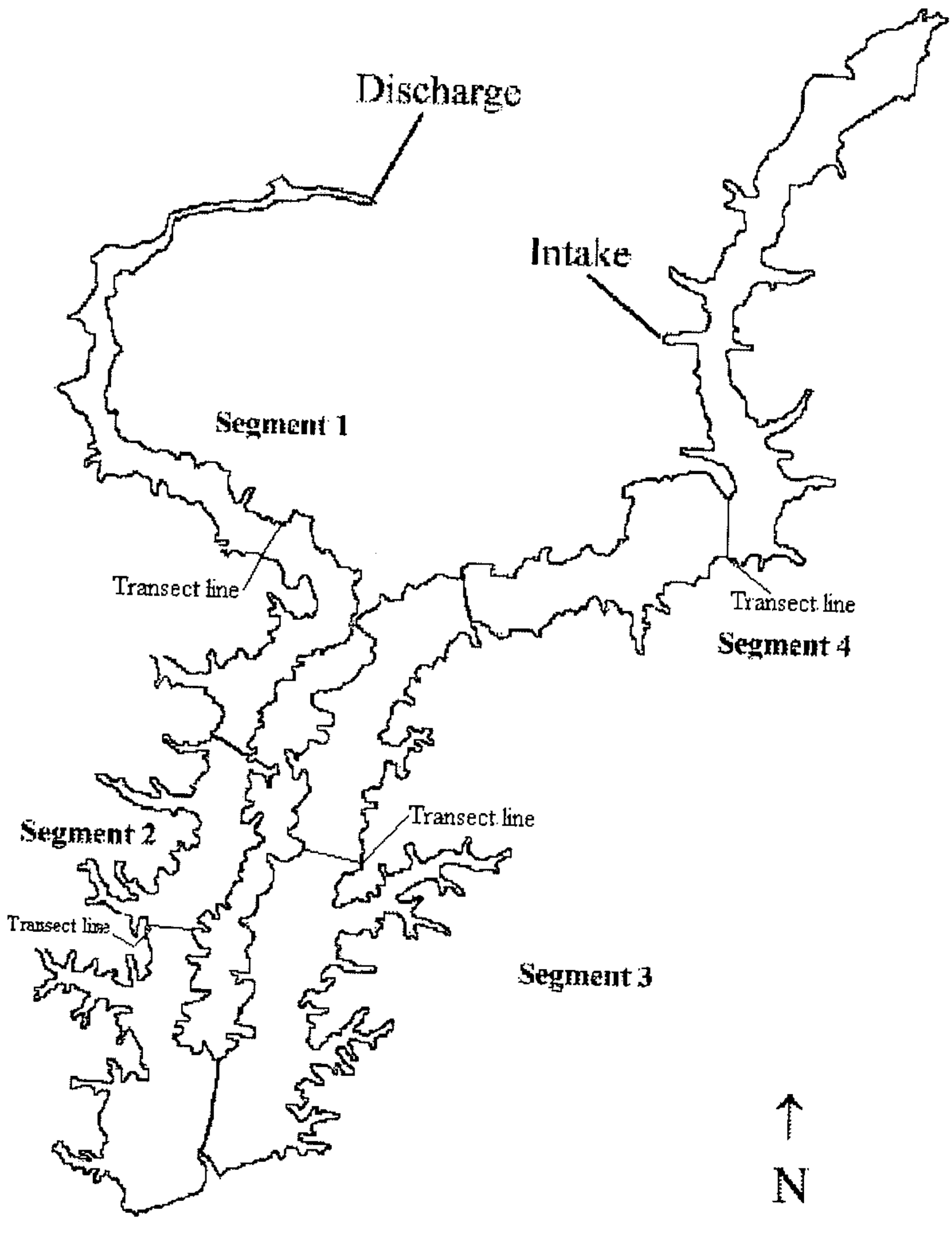


Figure 1.1. Newton Lake with four segments and transect lines where sampling was conducted for water quality, benthos, and zooplankton from August 1997 through 1999.

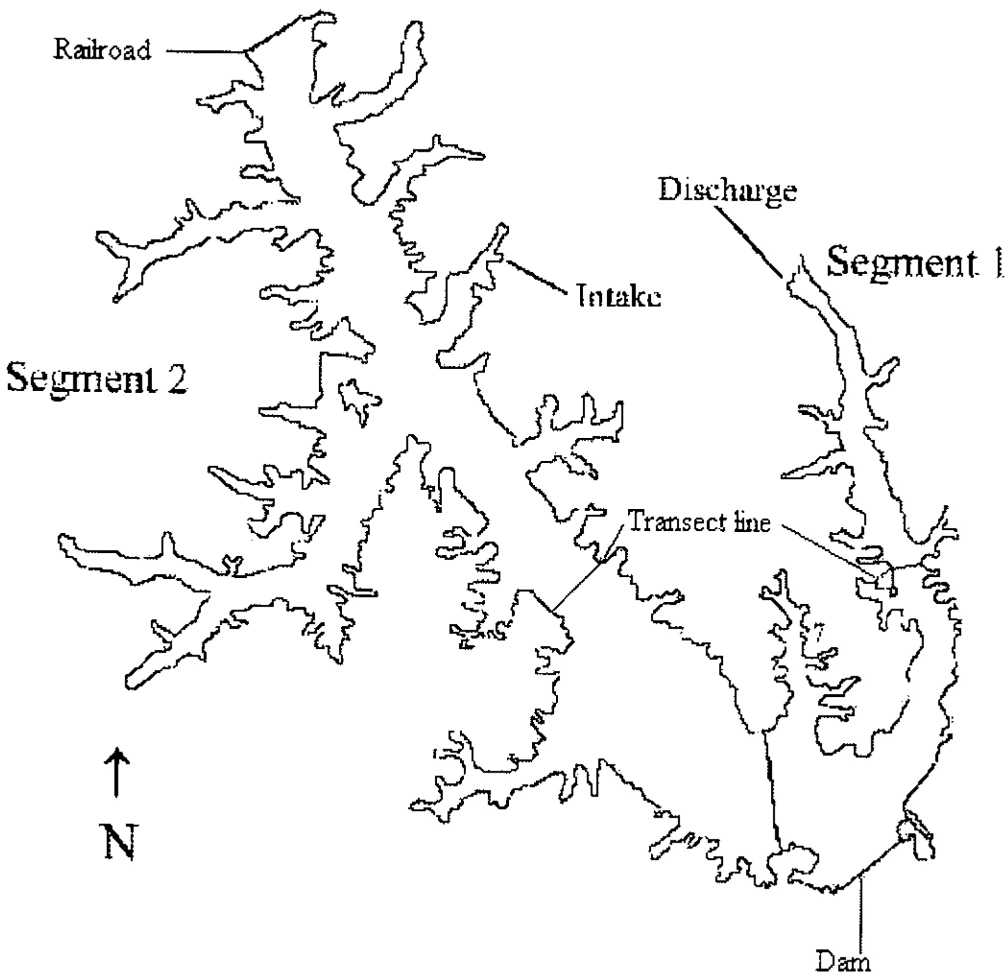


Figure 1.2. Coffeen Lake with two segments and transect lines where sampling was conducted for water temperature and dissolved oxygen from August 1997 through 1999.

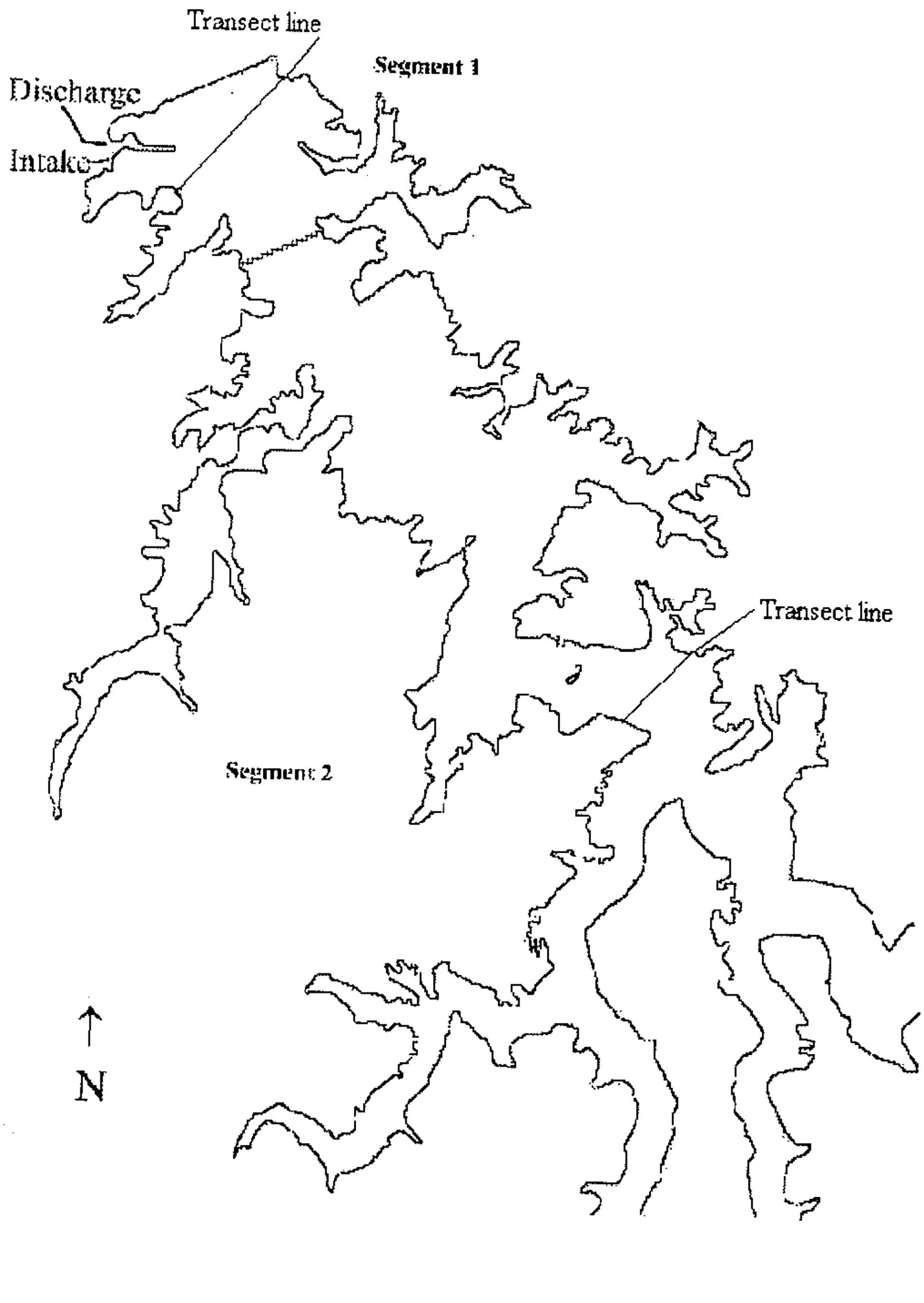


Figure 1.3. Lake of Egypt with two segments and transect lines where sampling was conducted for water temperature and dissolved oxygen from August 1997 through August 1999.

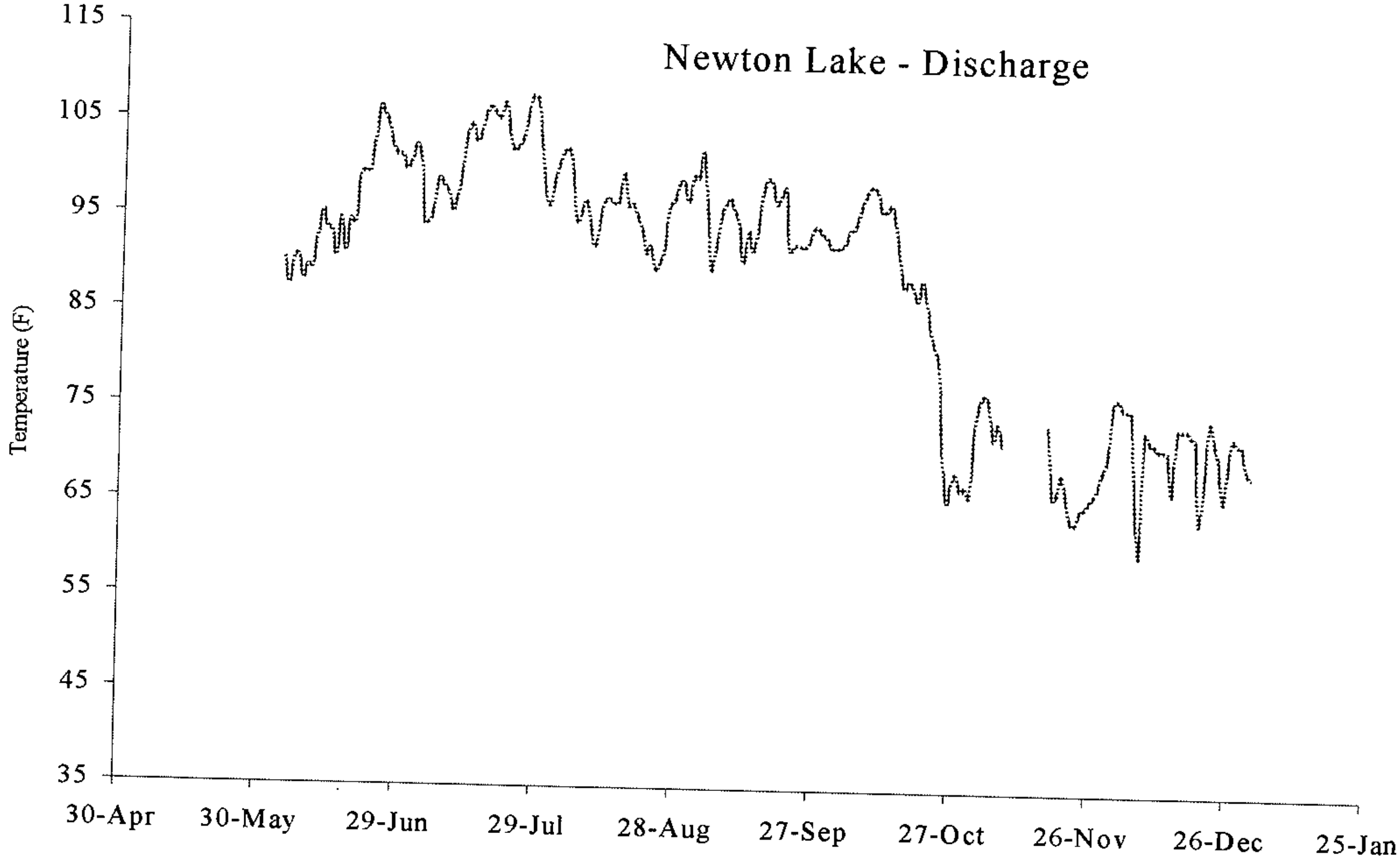


Figure 1.4. Mean daily surface temperatures during 1997 at the Newton Lake discharge.

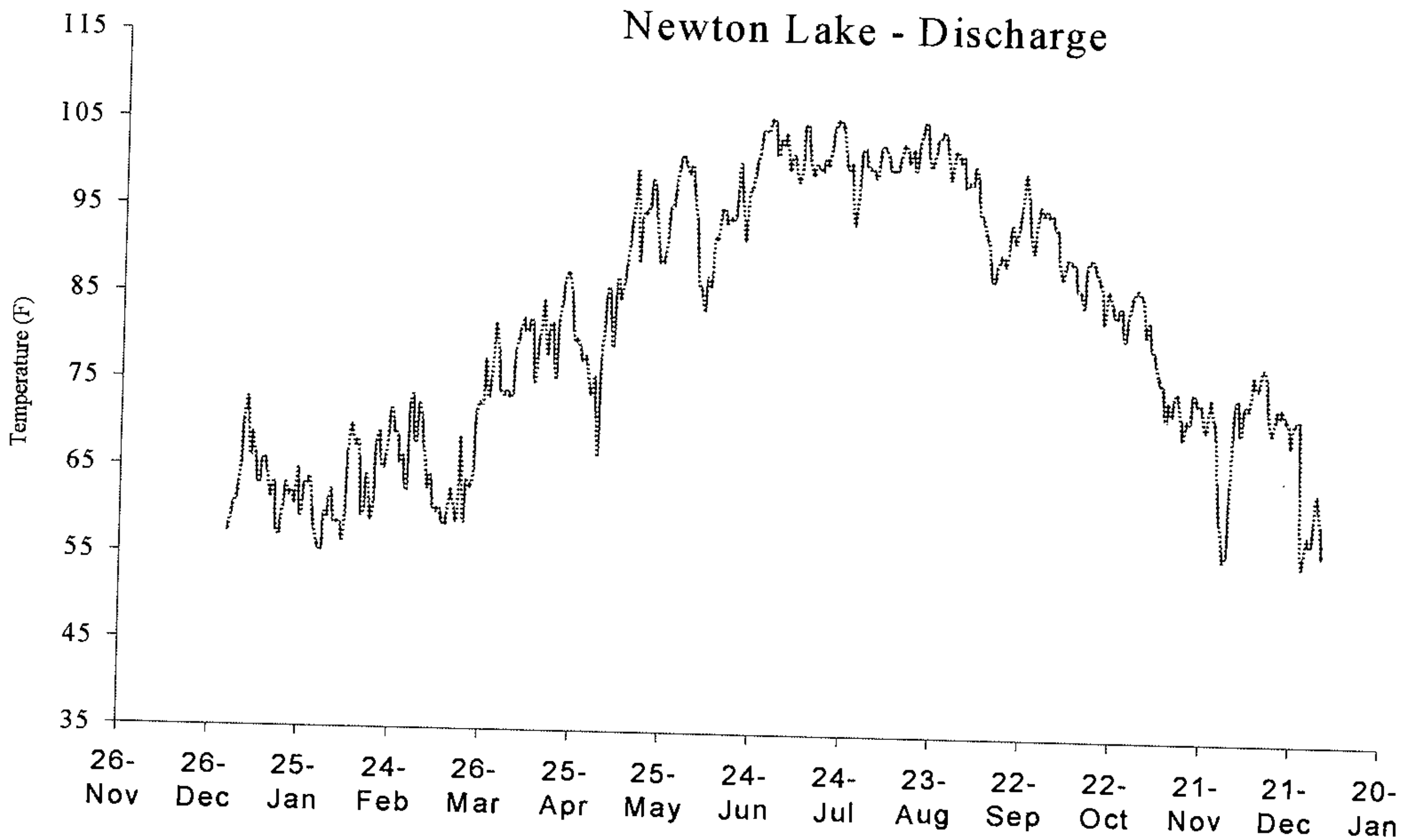


Figure 1.5. Mean daily surface temperatures during 1998 at the Newton Lake discharge.

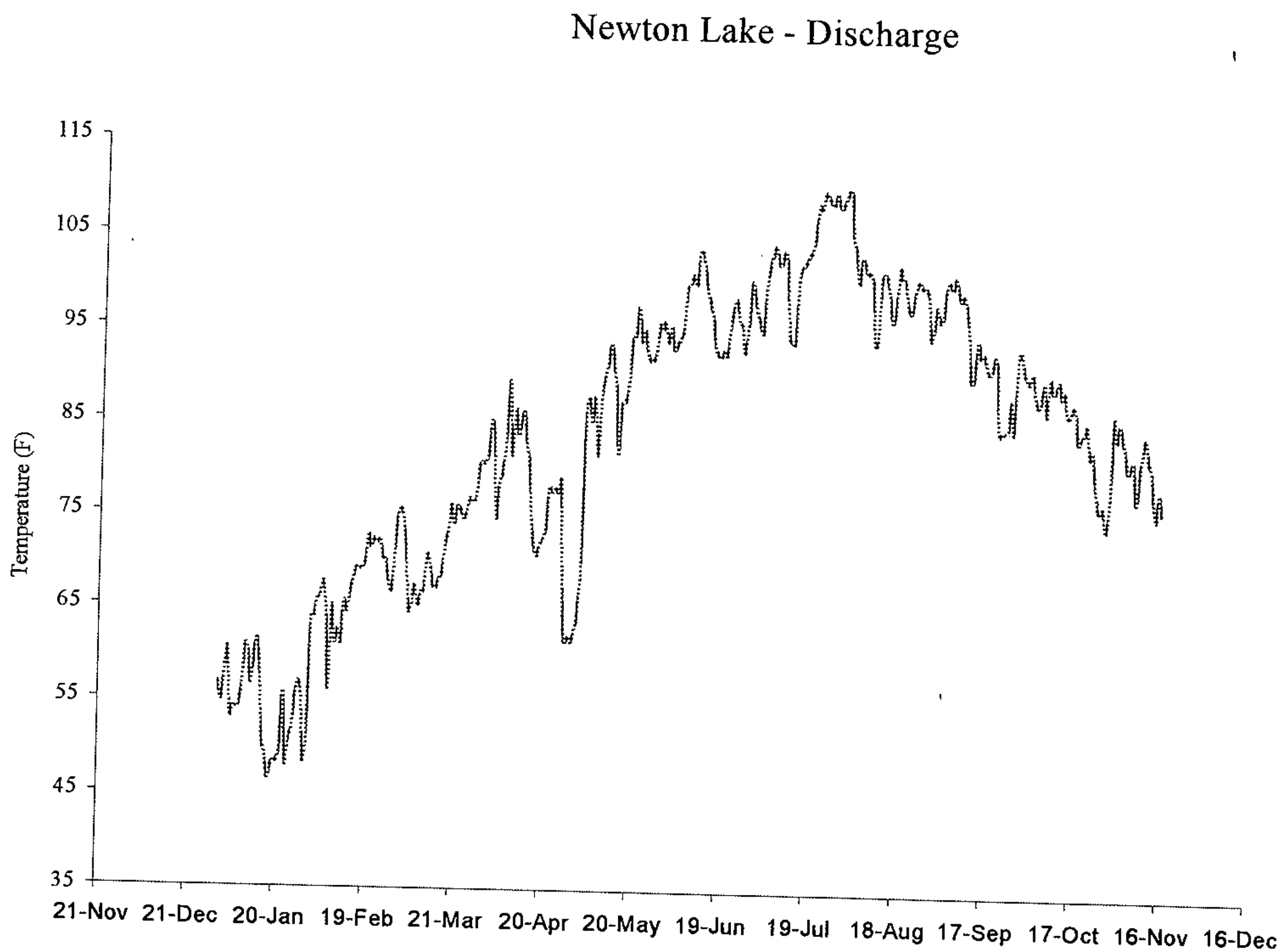


Figure 1.6. Mean daily surface temperatures during 1999 at the Newton Lake discharge.

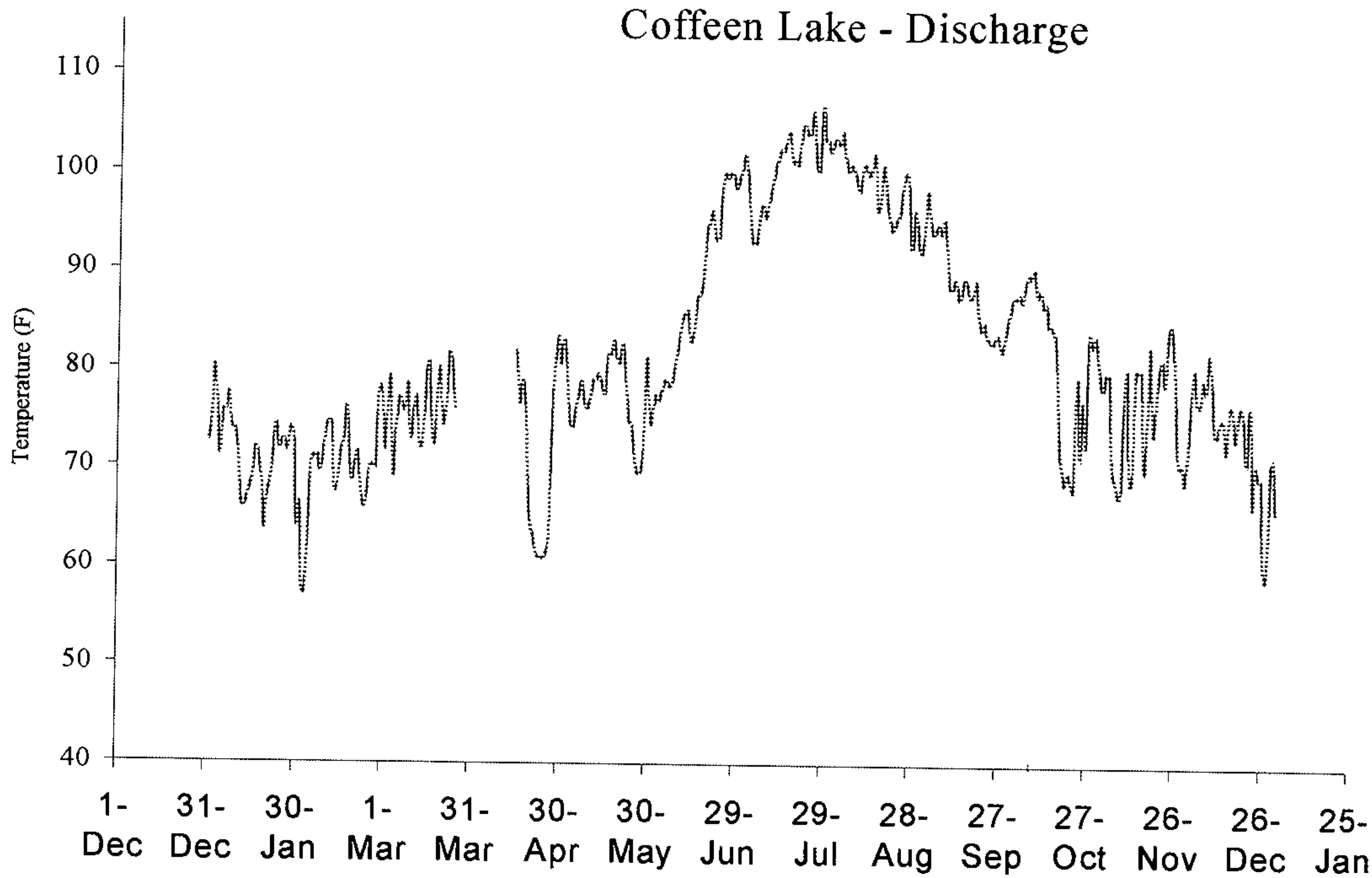


Figure 1.7. Mean daily surface temperatures during 1997 at the Coffeen Lake discharge. Lake bottom is approximately 18.0 feet.

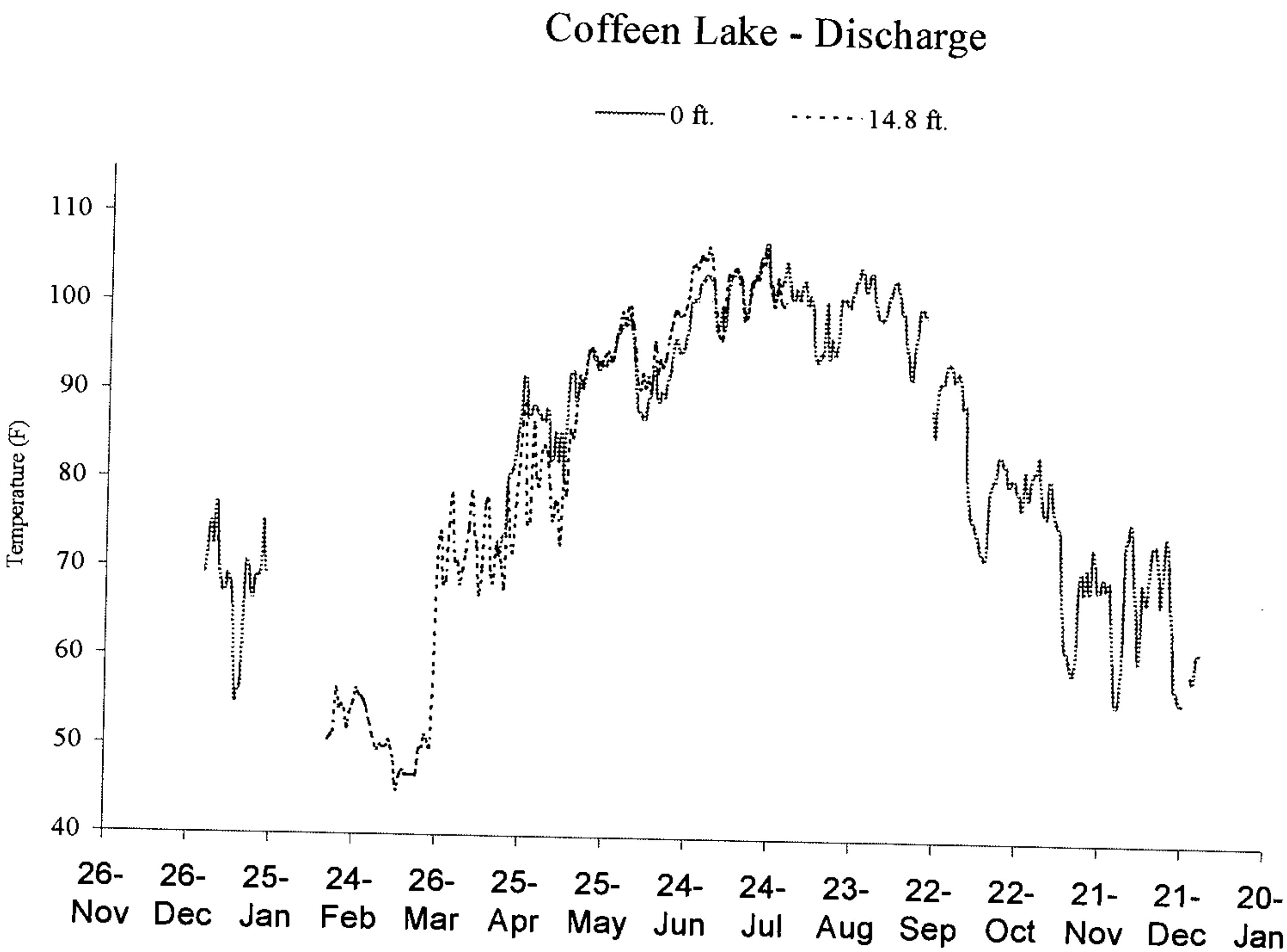


Figure 1.8. Mean daily temperatures during 1998 at the Coffeen Lake discharge. Lake bottom is approximately 18.0 feet.

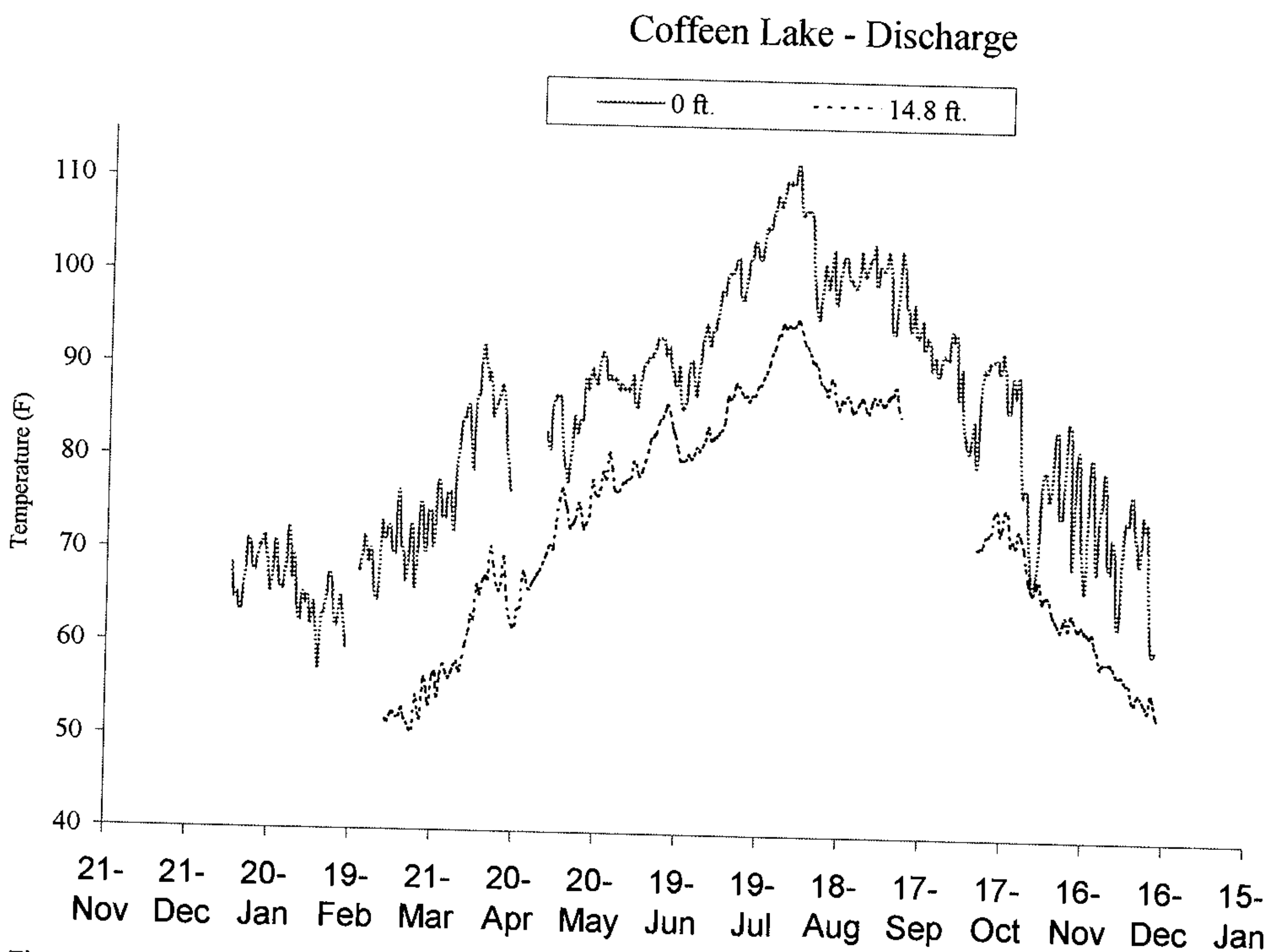


Figure 1.9. Mean daily temperatures during 1999 at the Coffeen Lake discharge. Lake bottom is approximately 18.0 feet.

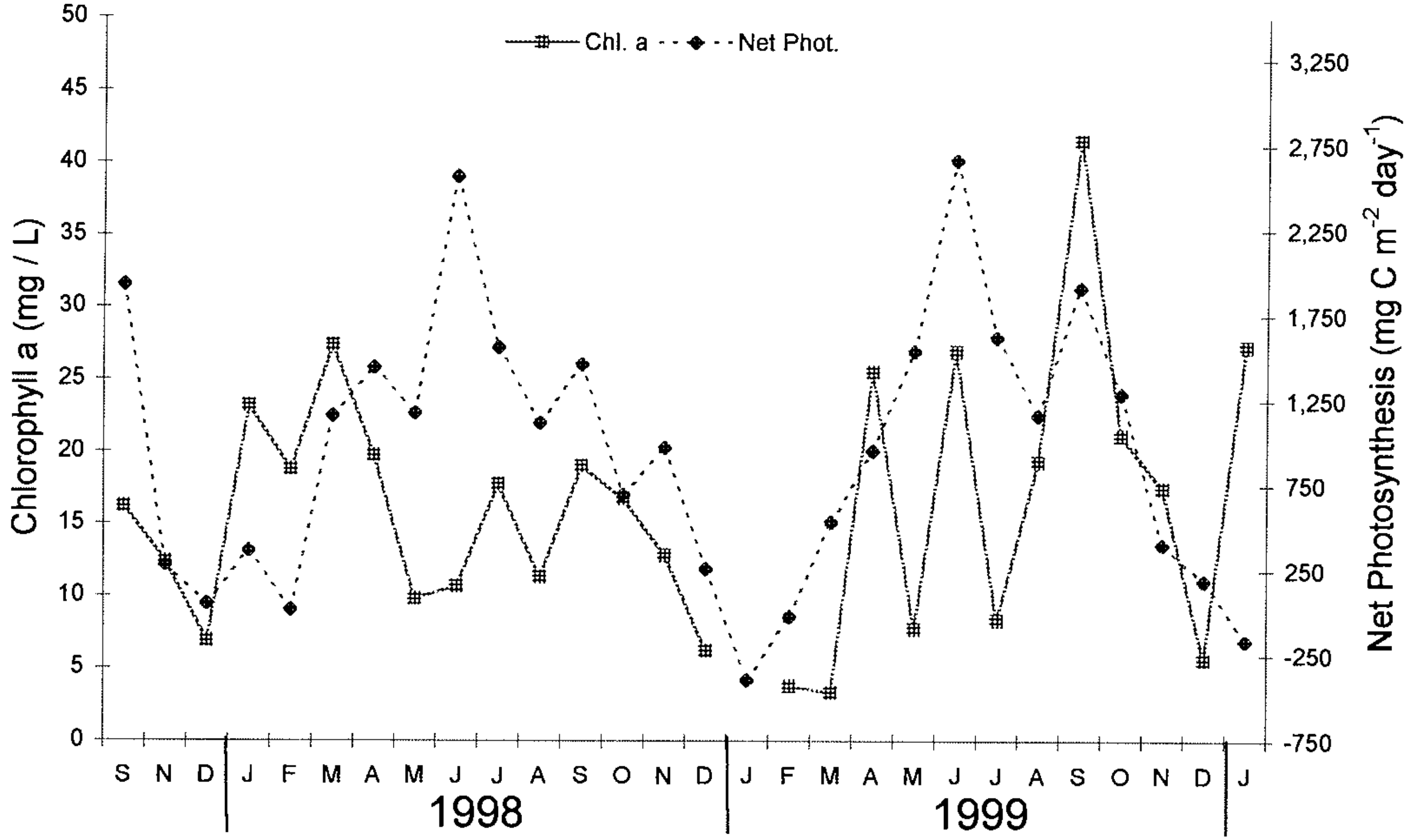


Figure 1.10. Mean chlorophyll *a* (μg / L) and mean net photosynthesis (mg C m^{-2} day^{-1}), Newton Lake, all segments combined. Note that during the winter months some negative photosynthesis occurred and the date axis does not intersect the net photosynthesis axis at 0.

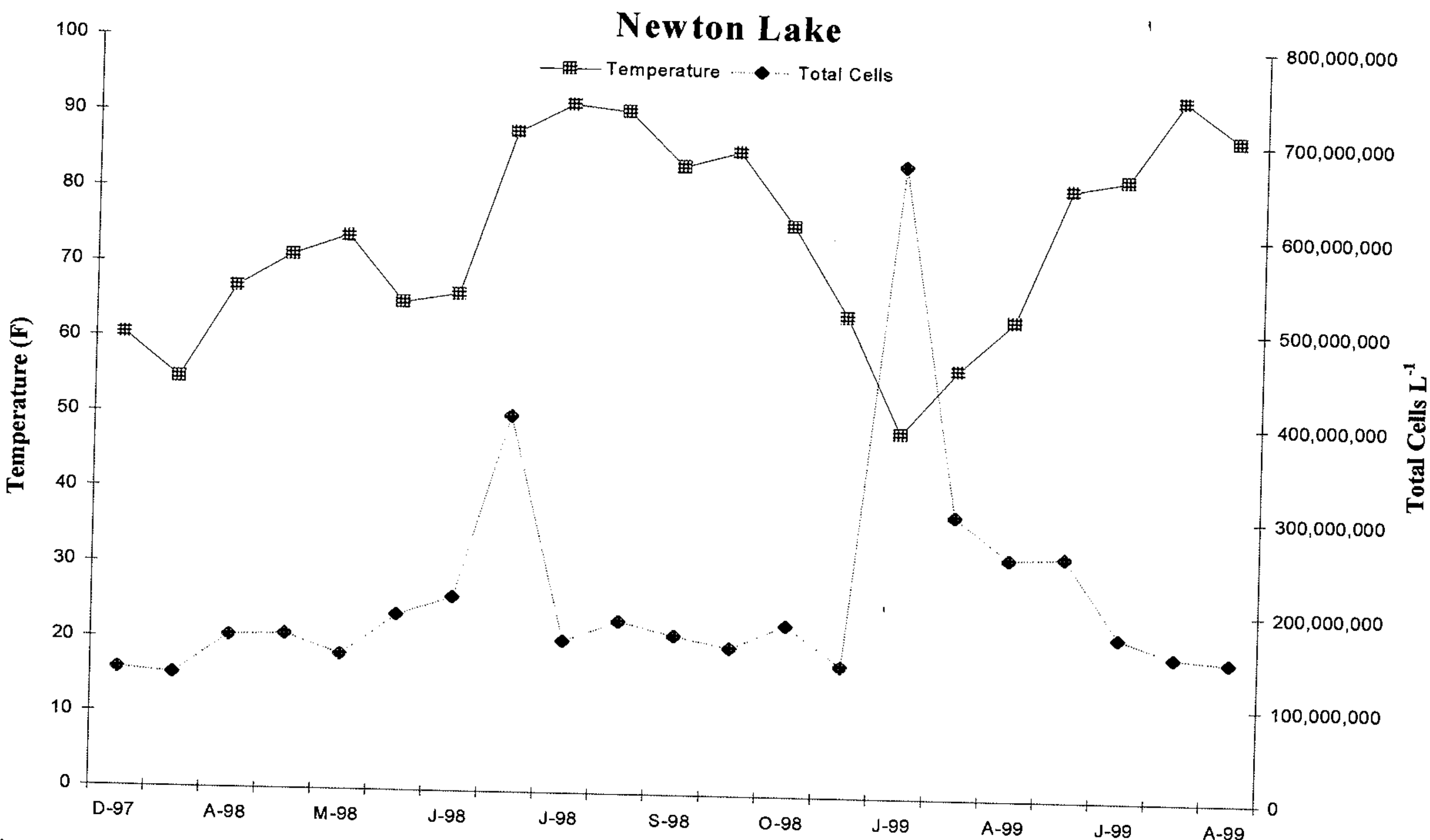


Figure 1.11. Mean total cell count L^{-1} (Coccoid singles included) and mean euphotic temperature (F) for Newton Lake, all segments combined, 1997 – 1999.

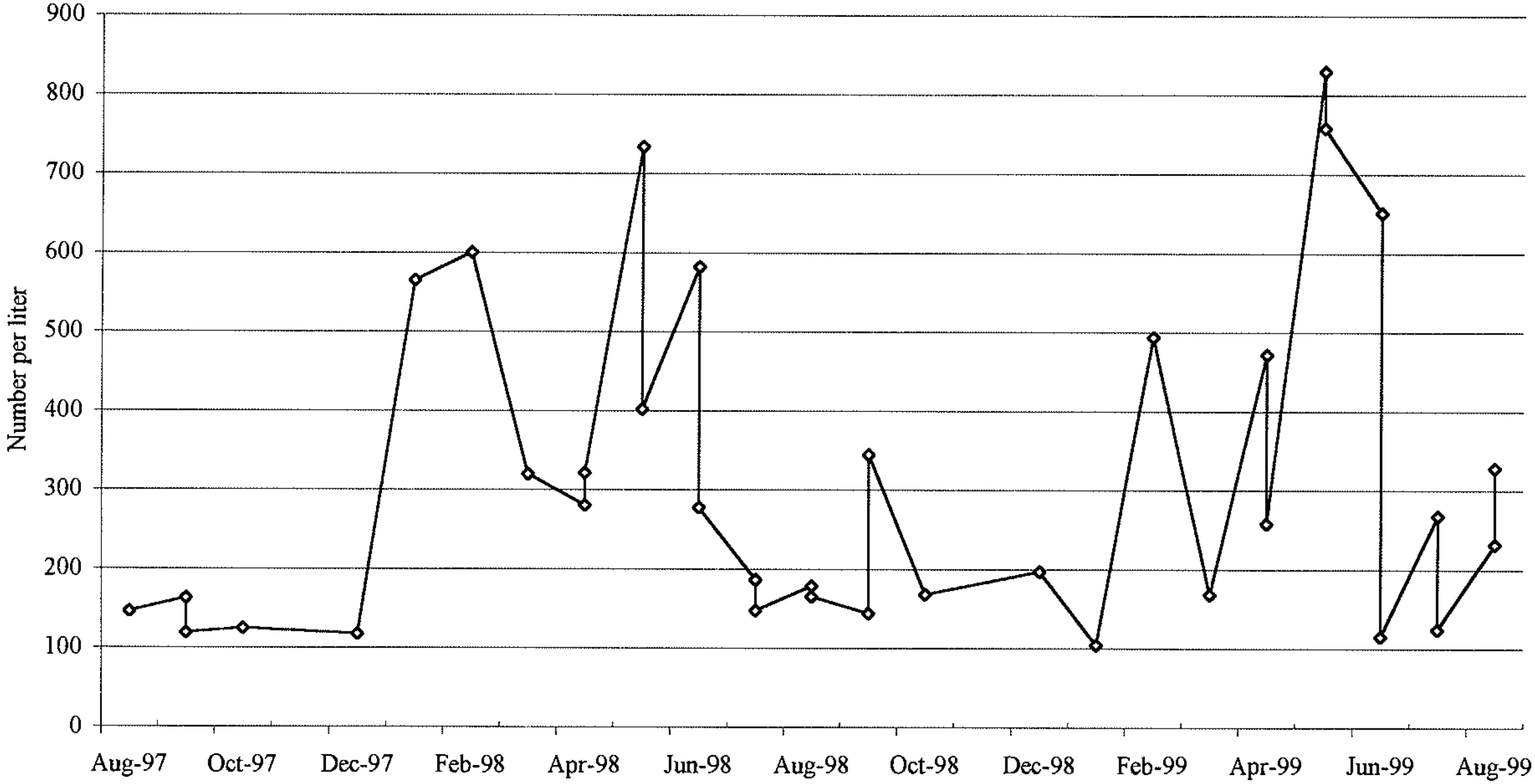


Figure 1.12. Mean densities of zooplankton by date collected in Newton Lake (12 stations, all segments combined) from August 1997 through August 1999.

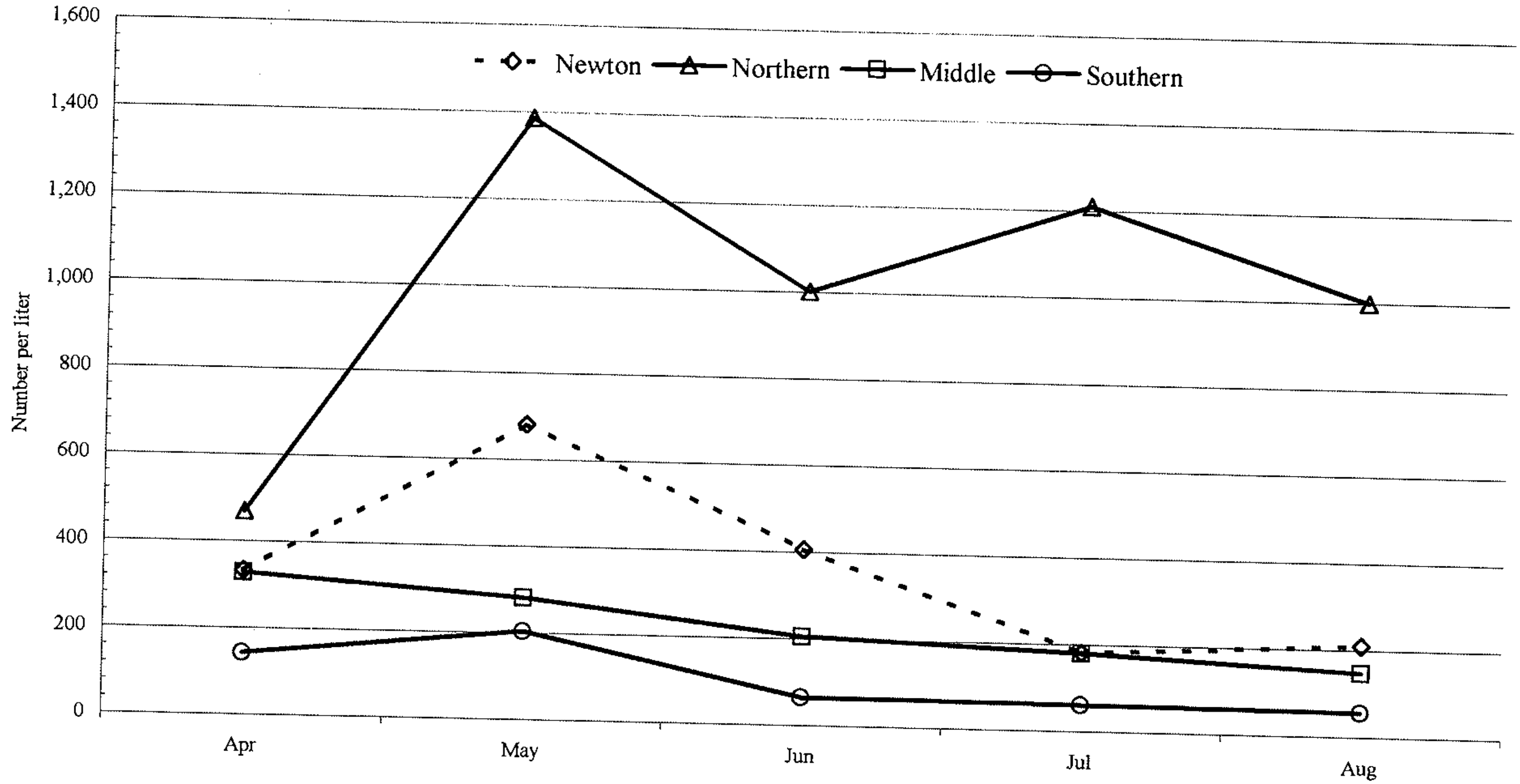


Figure 1.13. Mean monthly densities of zooplankton collected in Newton Lake compared to 12 lakes grouped into three regions of Illinois. Zooplankton was collected from the Illinois lakes during April through August of 1993 through 1997. Five lakes were sampled in the northern zone, six in the middle zone, and four in the southern zone. Four to six samples were taken from the Illinois lakes each month for five years.

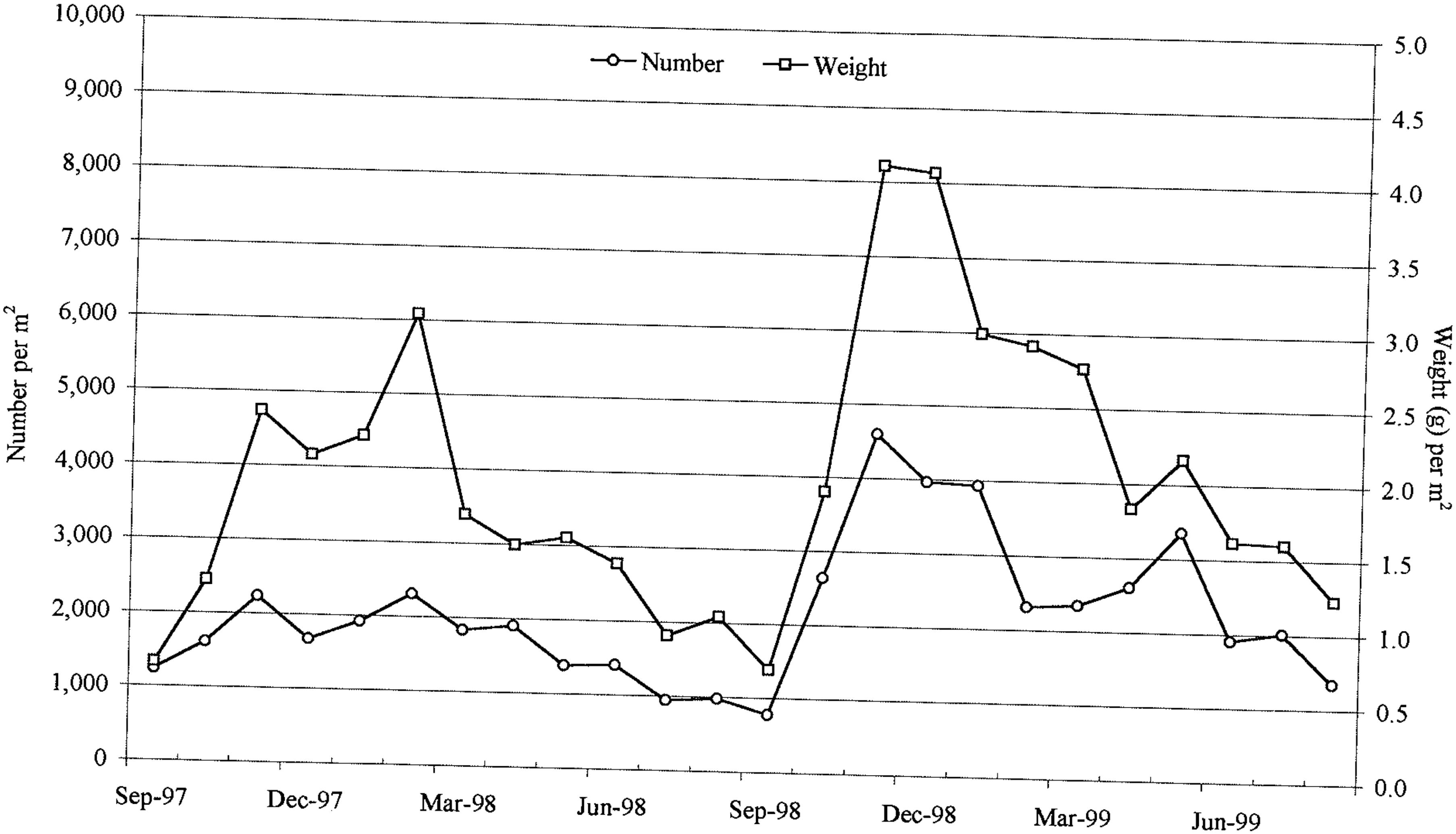


Figure 1.14. Mean monthly densities and weights of benthos collected in Newton Lake (24 stations for all segments combined) from September 1997 through August 1999. Benthos was collected using a ponar dredge.

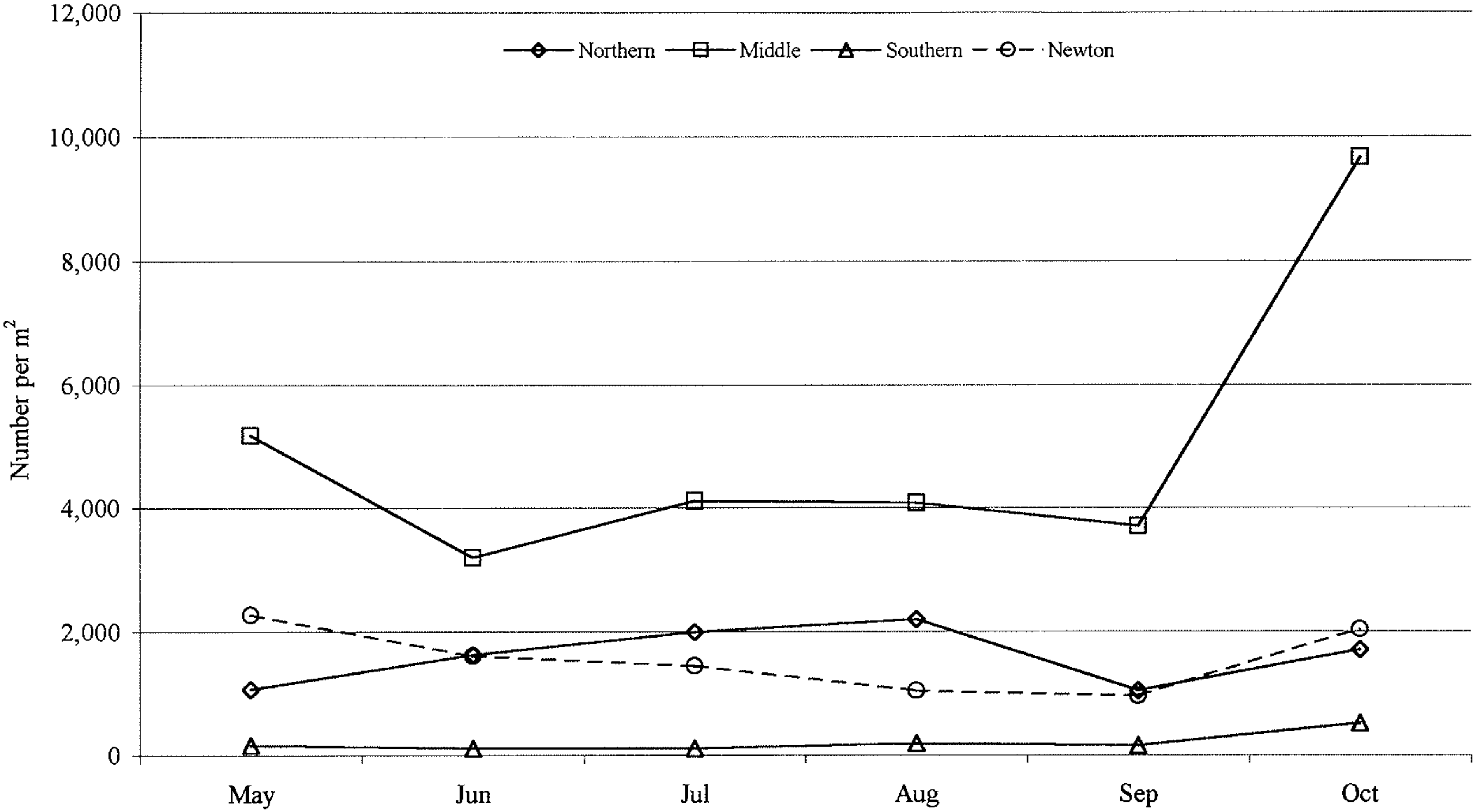


Figure 1.15. Mean benthos densities in 12 lakes located in three regions of Illinois compared to densities in Newton Lake from May through October. Benthos was collected each year during 1993 through 1997 from the 12 Illinois lakes and in 1998 and 1999 in Newton Lake. Four to six samples were taken each month from each of the 12 lakes for five years. Five lakes were sampled in the northern zone, six in the middle zone, and four in the southern zone.

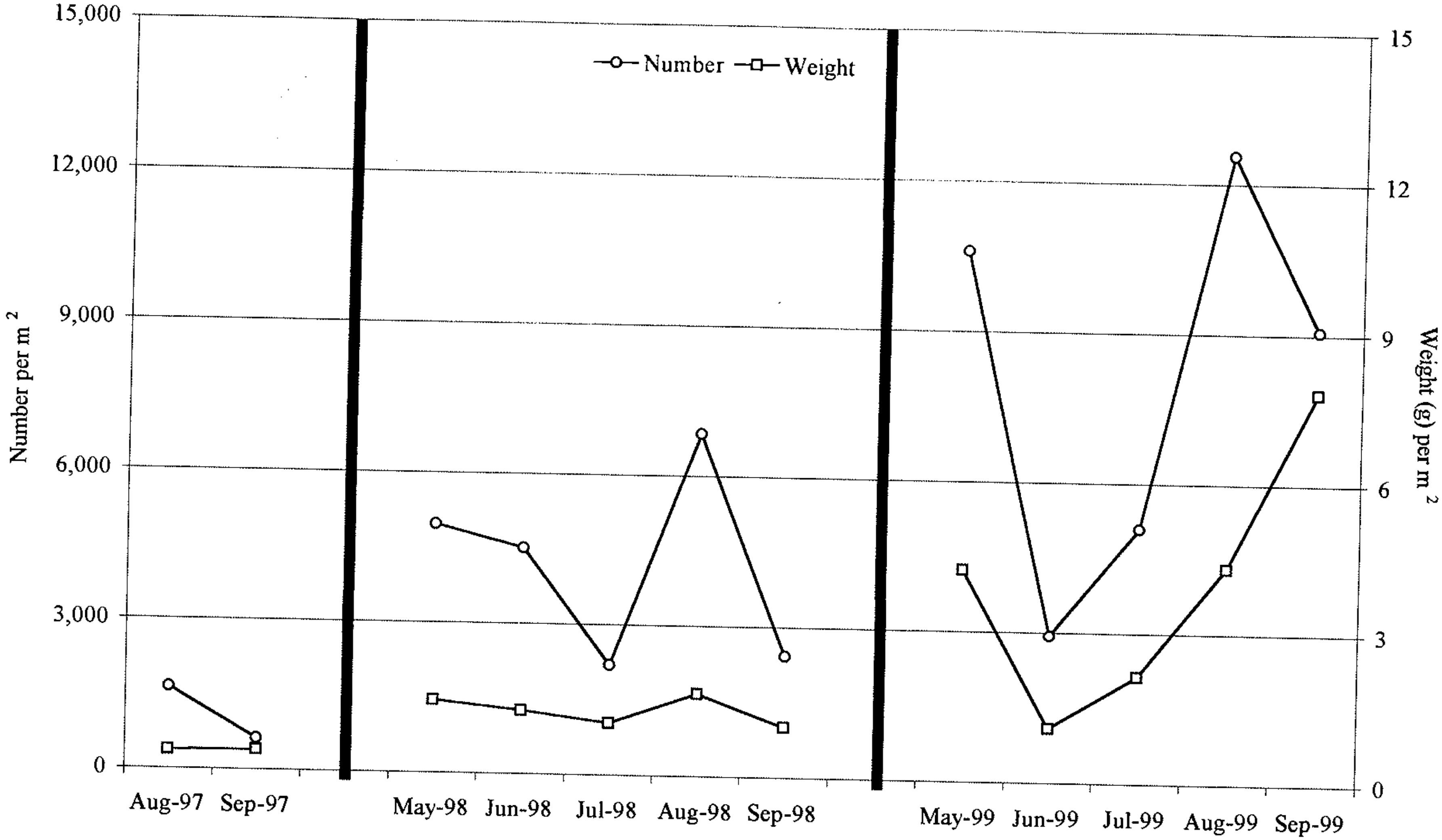


Figure 1.16. Mean monthly densities and weights of phytomacrobenthos collected in Newton Lake during August and September 1997 and May through September 1999. Two samples were collected from each of twenty stations (when possible) located throughout Newton Lake.

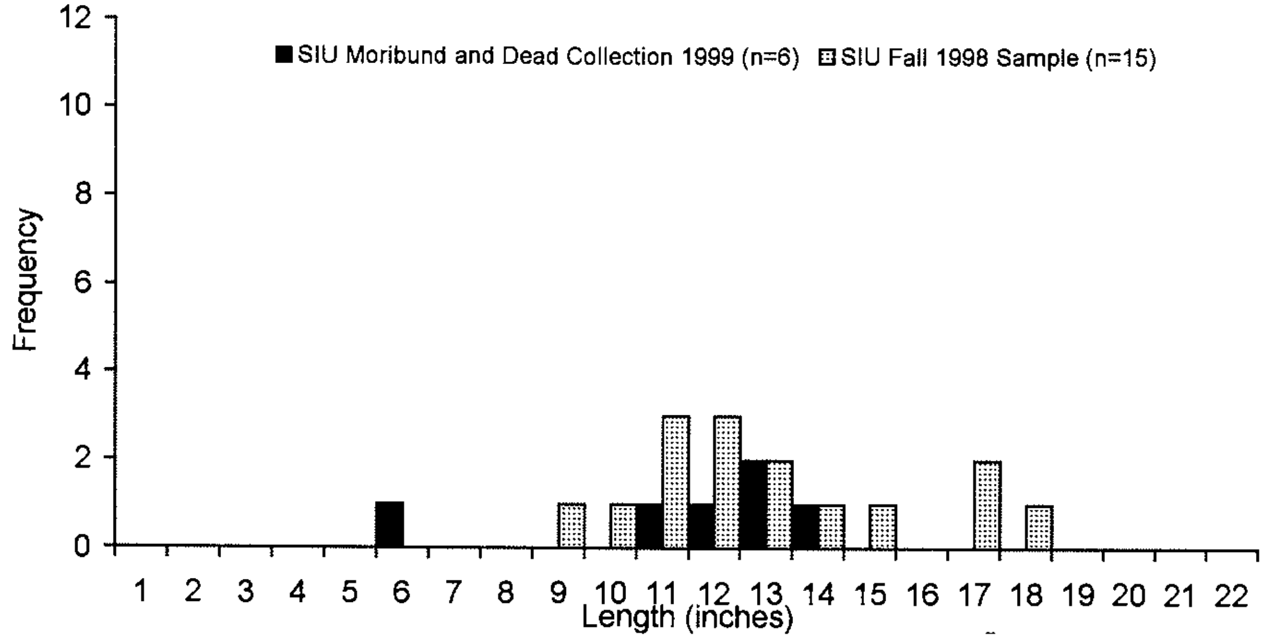


Figure 1.17. Comparison of the length frequency histograms of channel catfish obtained by electrofishing during fall 1998 on Coffeen Lake by Southern Illinois University Fisheries Research Lab (N=15), and dead and moribund fish collected during between 1 June 1999 and 31 August 1999 by SIU during routine sampling trips (N=6).

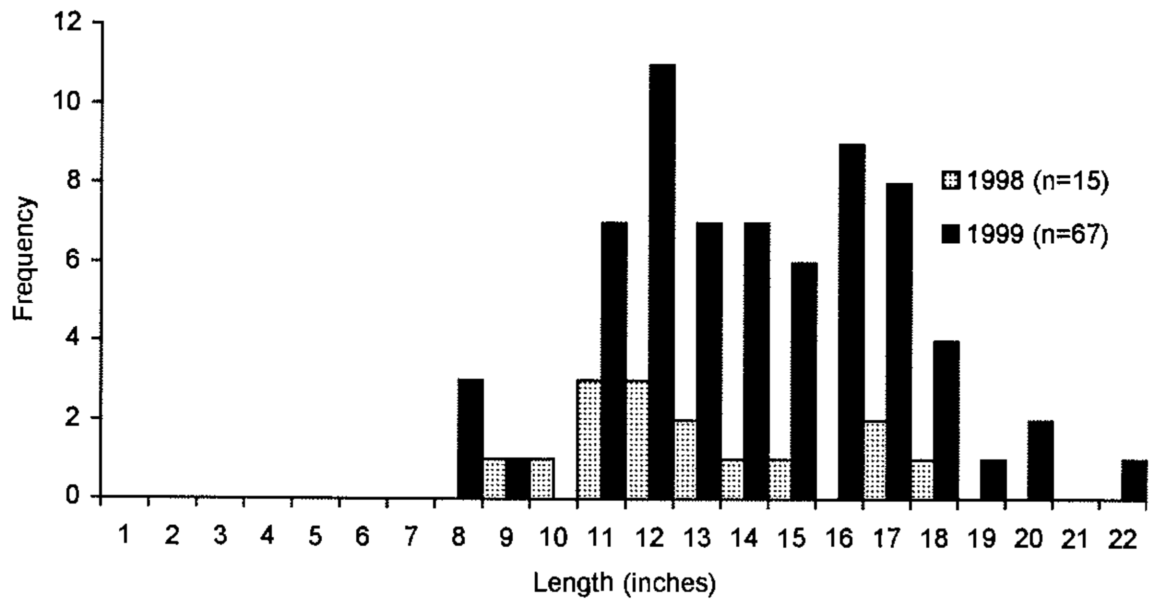


Figure 1.18. Comparison of the length frequency histograms of channel catfish obtained in fall of 1998 (N=15) and 1999 (N=67) by electrofishing on Coffeen Lake by Southern Illinois University Fisheries Research Lab.

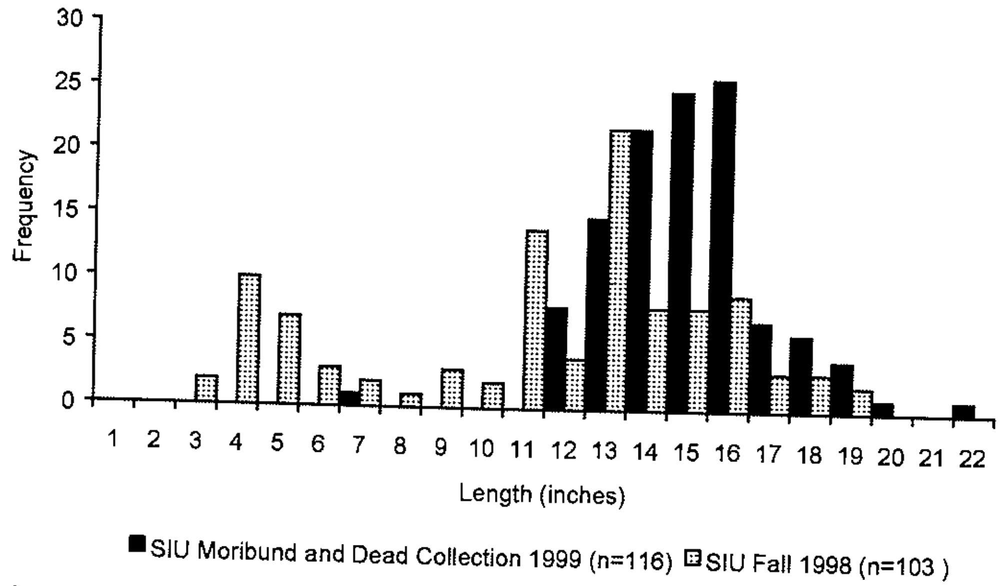


Figure 1.19. Comparison of the length frequency histograms of largemouth bass obtained by electrofishing during fall 1998 on Coffeen Lake by Southern Illinois University Fisheries Research Lab (N=103), and dead and moribund fish collected between 1 June 1999 and 31 August 1999 by SIU during routine sampling trips (N=116).

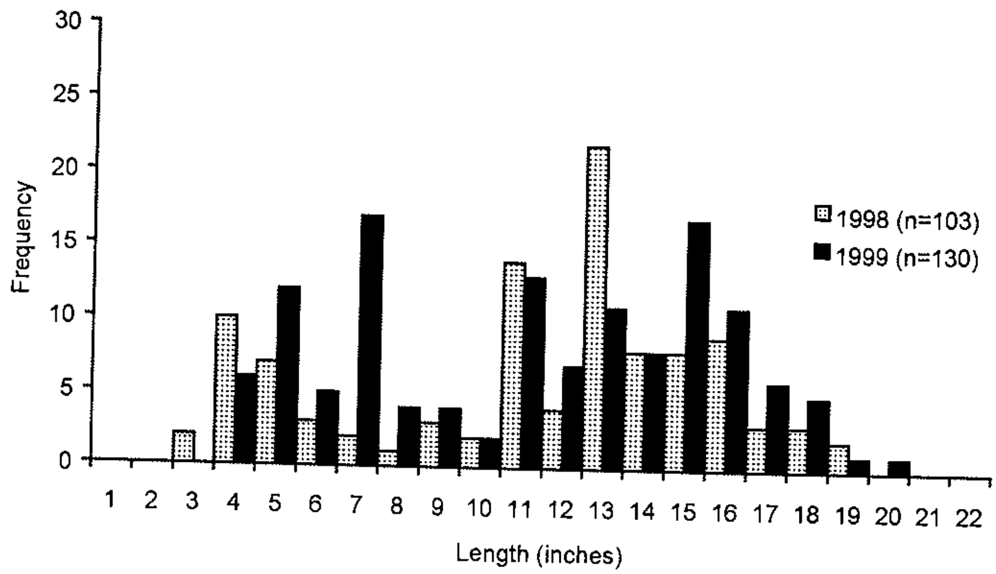
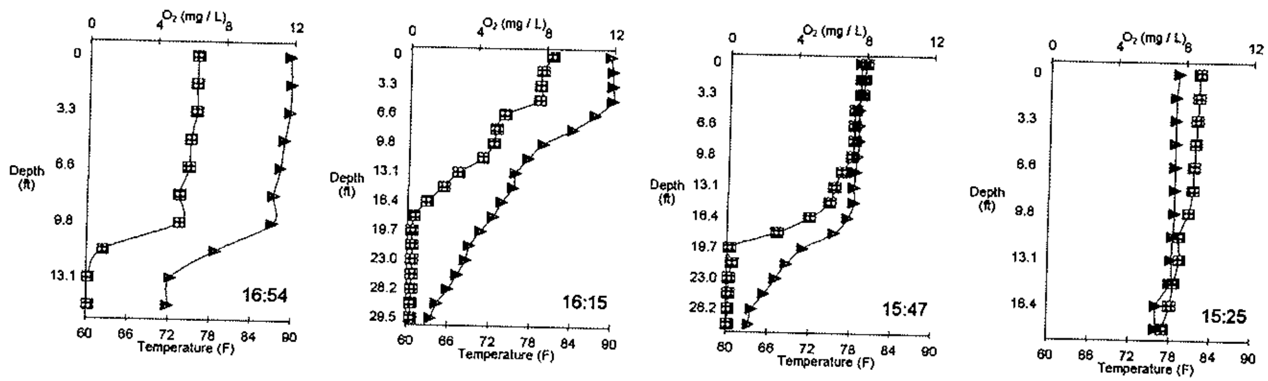


Figure 1.20. Comparison of the length frequency histograms of largemouth bass obtained in fall of 1998 (N=103) and 1999 (N=130) by electrofishing on Coffeen Lake by Southern Illinois University Fisheries Research Lab.

Newton Lake – June 2, 1999



Newton Lake – June 18, 1999

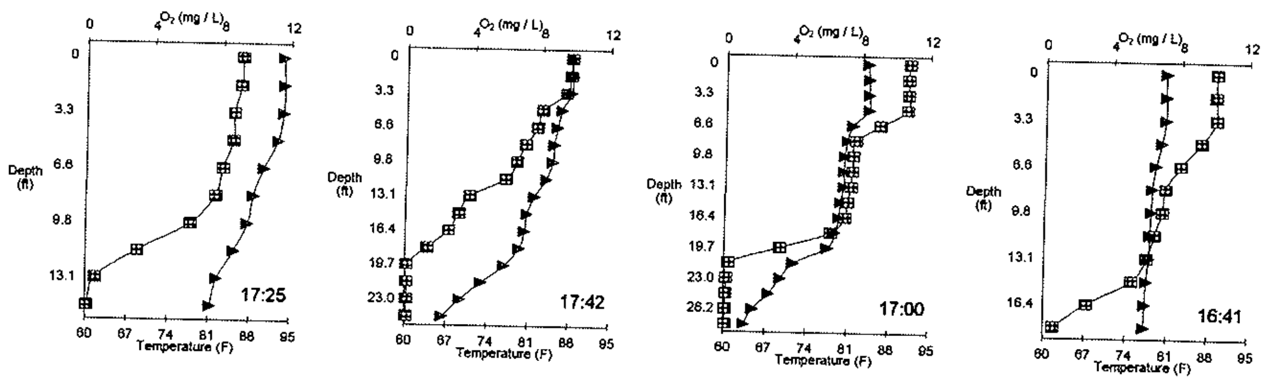


Figure 1.21. Temperature and dissolved oxygen by date within 4 segments of Newton Lake, IL. Triangles represent temperature (F) and squares represent oxygen (mg / L). Time of measurement is indicated on each graph.

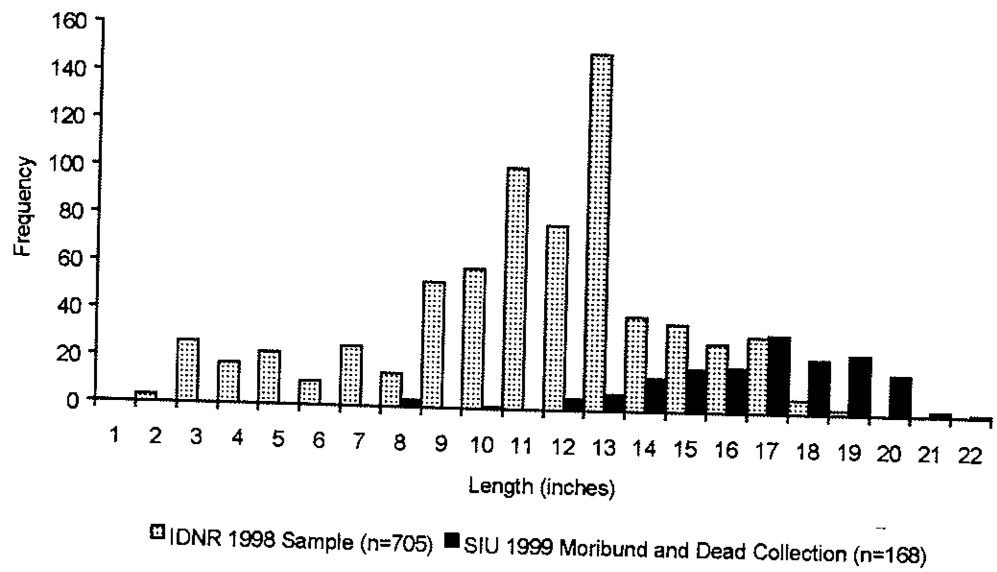


Figure 1.22. Comparison of the length frequency histograms of largemouth bass obtained by 12 hours of electrofishing during fall 1998 on Newton Lake by the Illinois Department of Natural Resources (IDNR)(N=705), and dead and moribund fish collected between 1 June 1999 and 31 August 1999 by Southern Illinois University Fisheries Research Lab (SIU) during routine sampling trips (N=168).

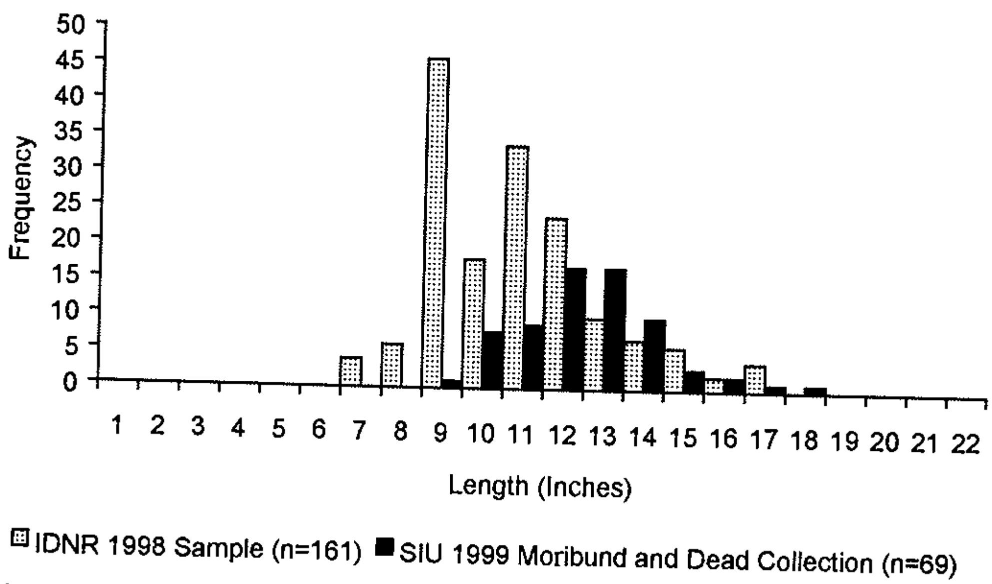


Figure 1.23. Comparison of the length frequency histograms of channel catfish obtained by 12 hours of electrofishing during fall 1998 from Newton Lake by the Illinois Department of Natural Resources (IDNR)(N=161), and dead and moribund fish collected between 1 June 1999 and 31 August 1999 by Southern Illinois University Fisheries Research Lab (SIU) during routine sampling trips (N=69).

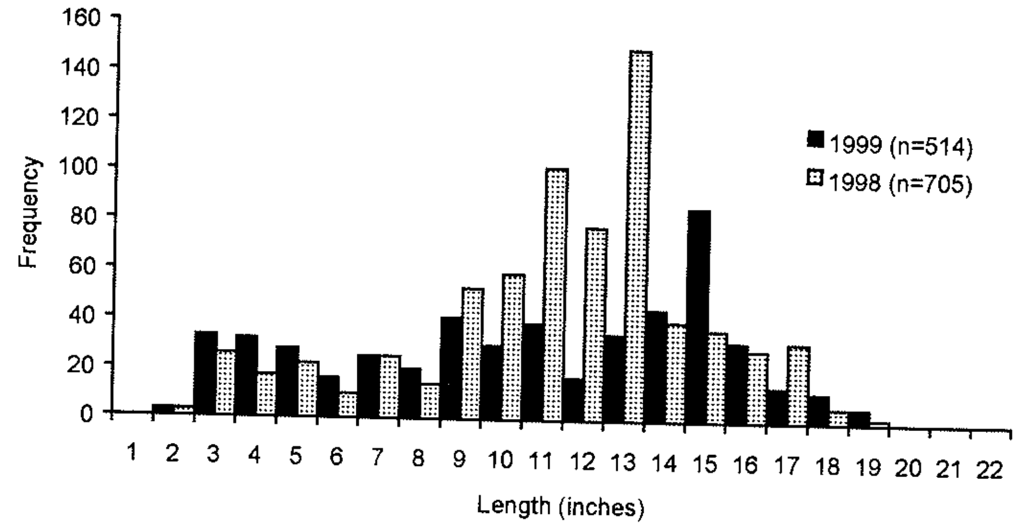


Figure 1.24. Comparison of the length frequency histograms of largemouth bass obtained in fall of 1998 (N=705) and 1999 (N=514) from 12 hours of electrofishing on Newton Lake, data provided by the Illinois Department of Natural Resources.

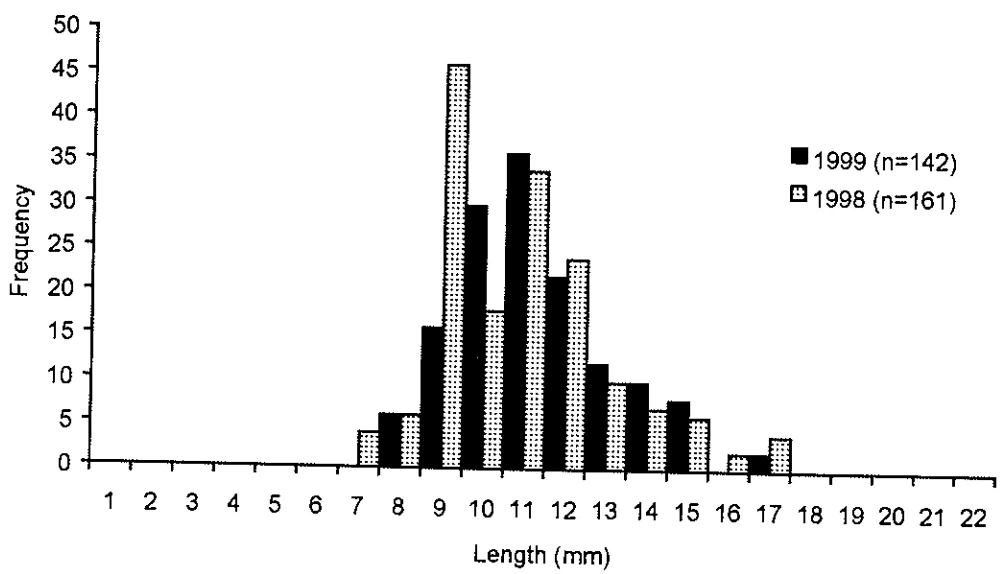


Figure 1.25. Comparison of the length frequency histograms of channel catfish obtained in 1998 (N=161) and 1999 (N=142) from 12 hours of electrofishing during fall on Newton Lake, data provided by the Illinois Department of Natural Resources.

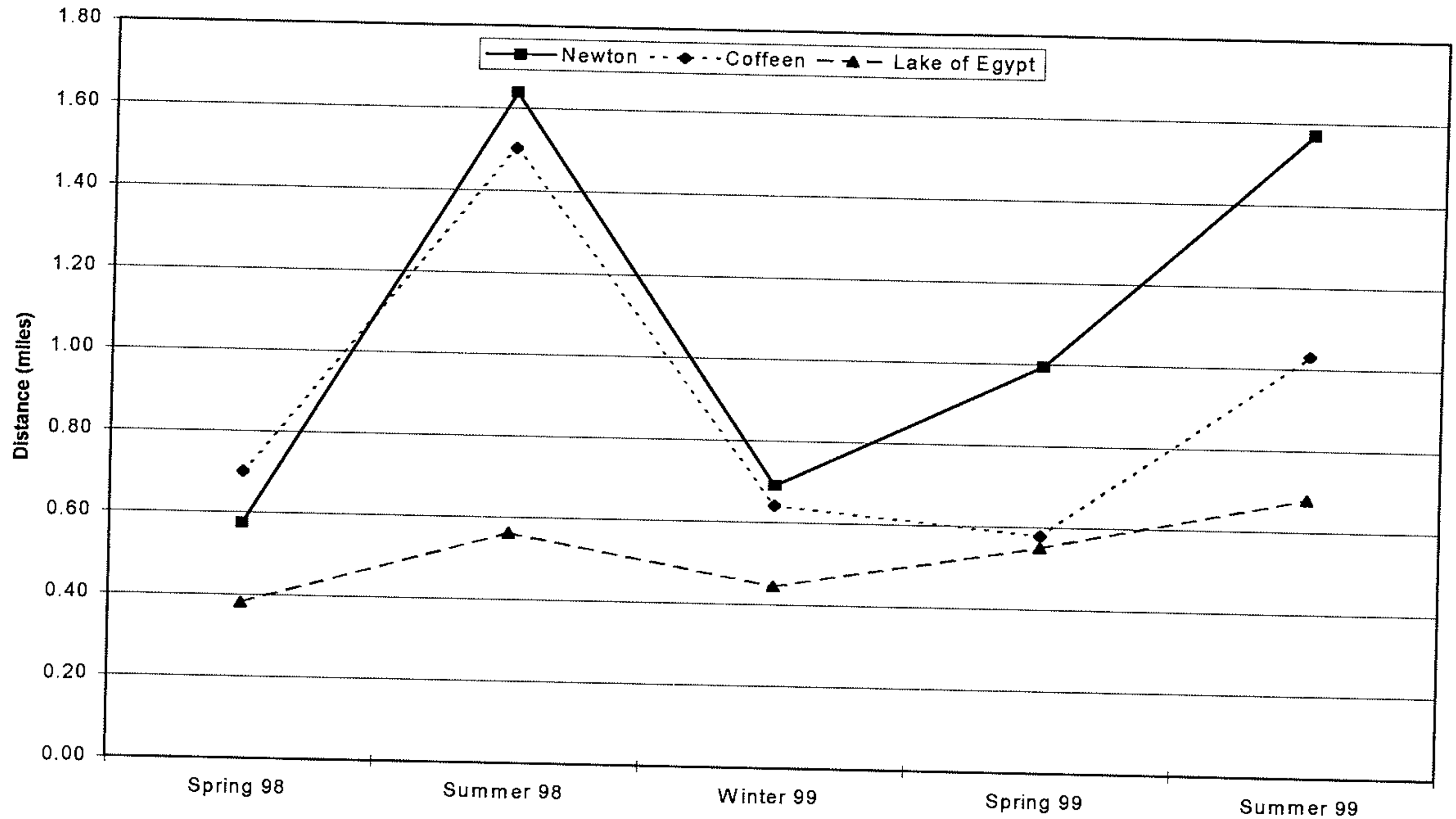


Figure 1.26. Comparison among sampling seasons for largemouth bass mean observed diel movements in three Illinois power cooling reservoirs.

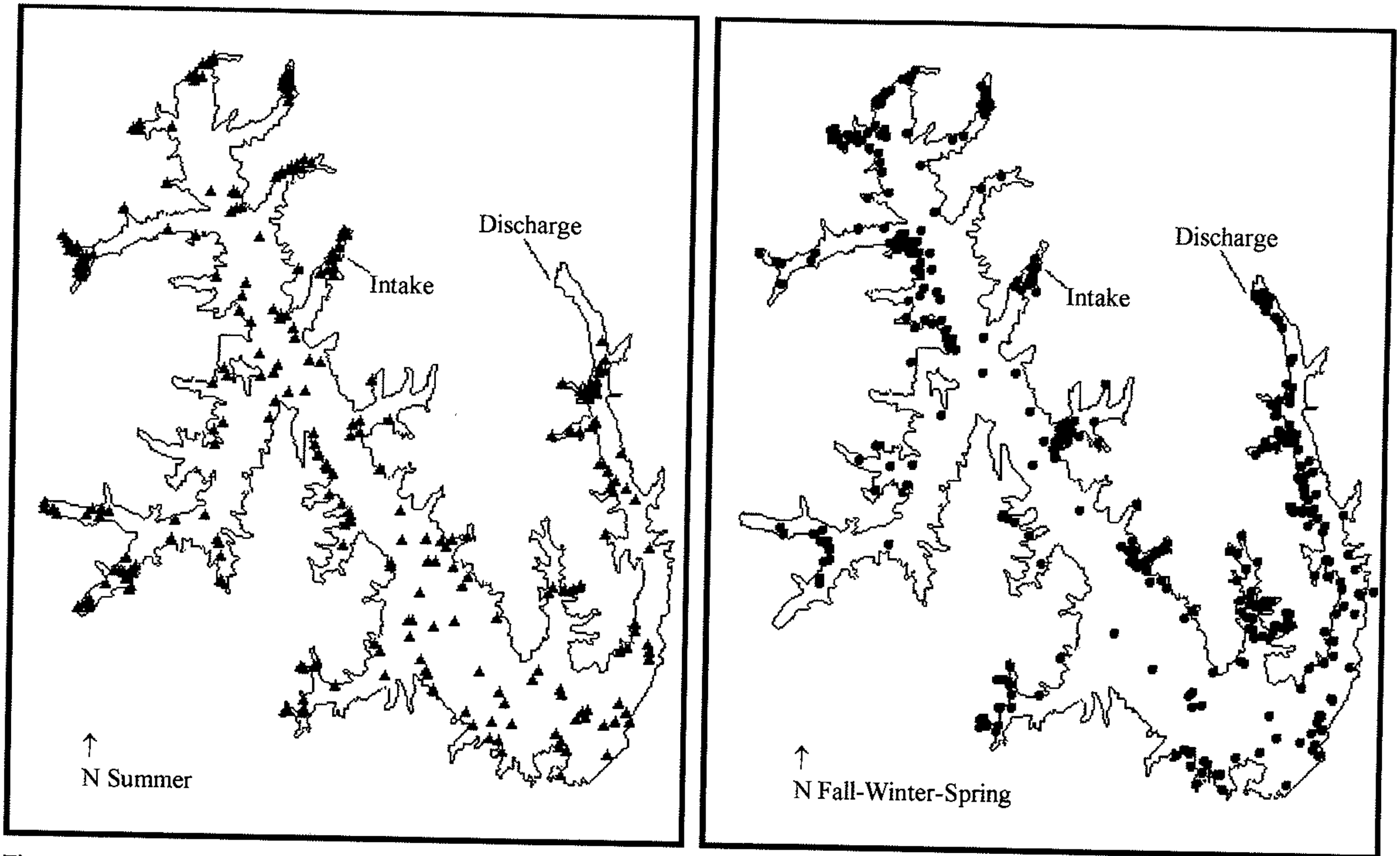


Figure 1.27. Seasonal largemouth bass locations in Coffeen Lake, Montgomery Co. Illinois, as determined by ultrasonic telemetry. June, July, and August represent summer months.

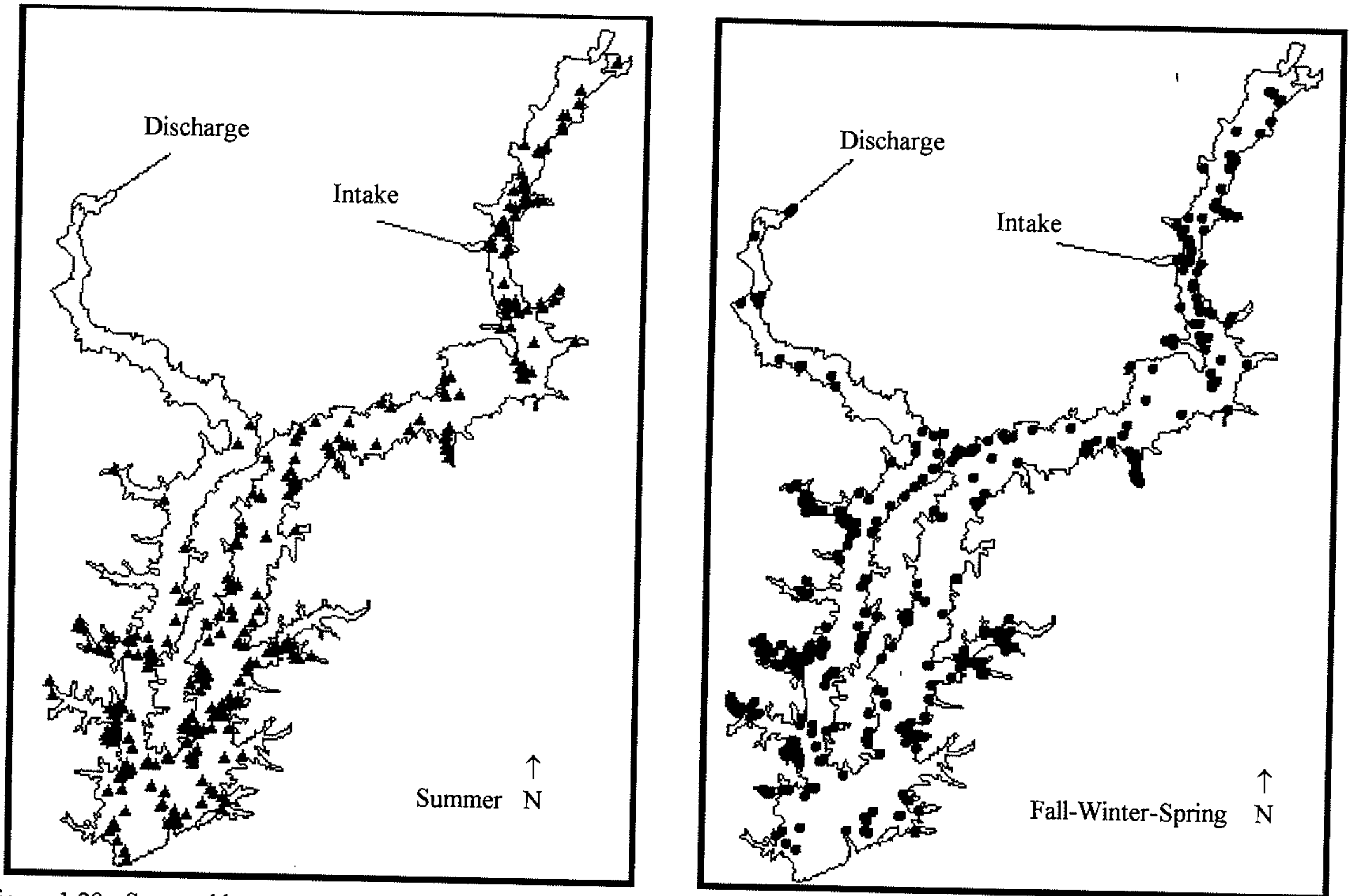


Figure 1.28. Seasonal largemouth bass locations in Newton Lake, Jasper Co. Illinois, as determined by ultrasonic telemetry. June, July, and August represent summer months.

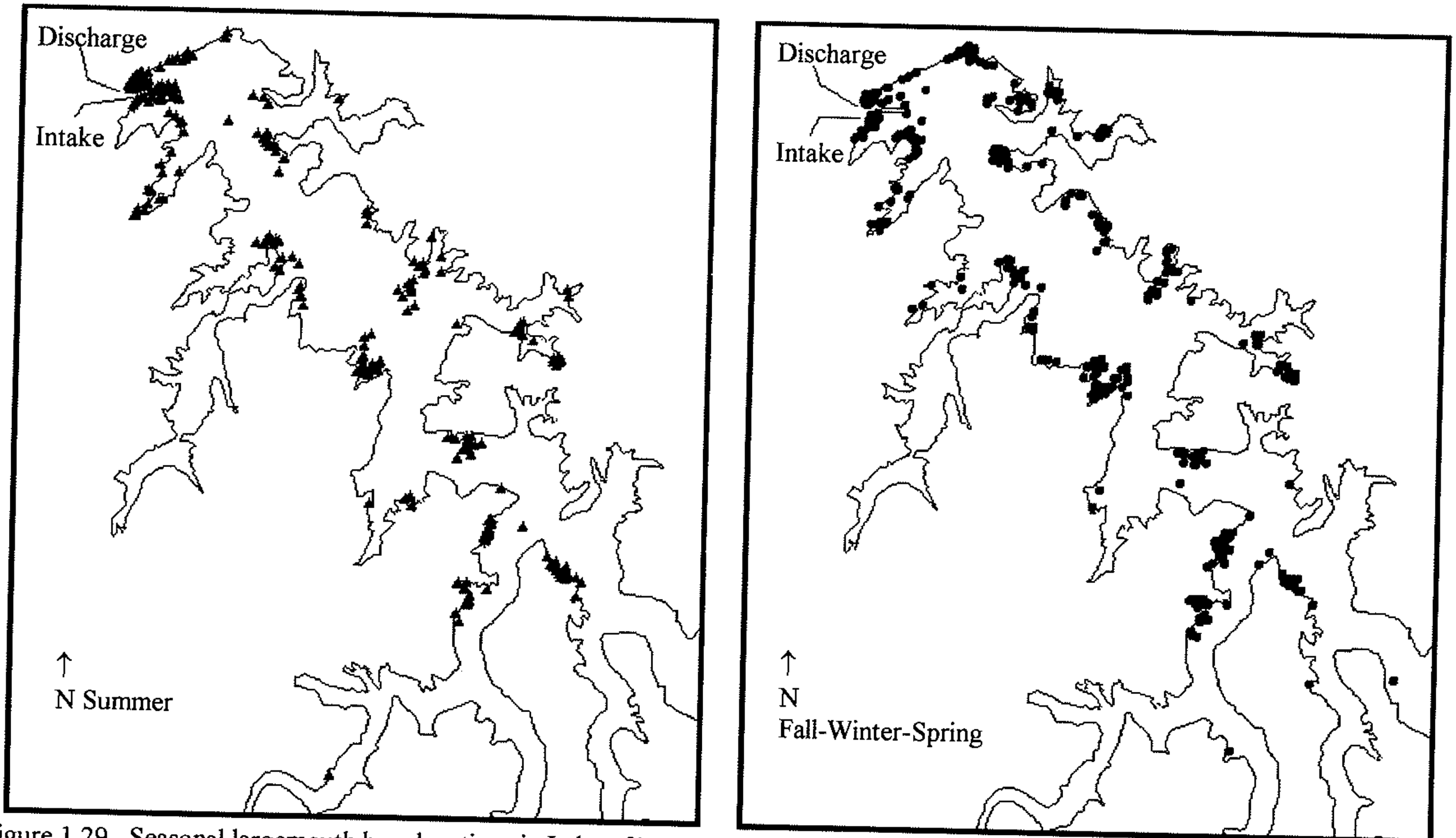


Figure 1.29. Seasonal largemouth bass locations in Lake of Egypt, Williamson / Johnson Co. Illinois, as determined by ultrasonic telemetry. June, July, and August represent summer months.

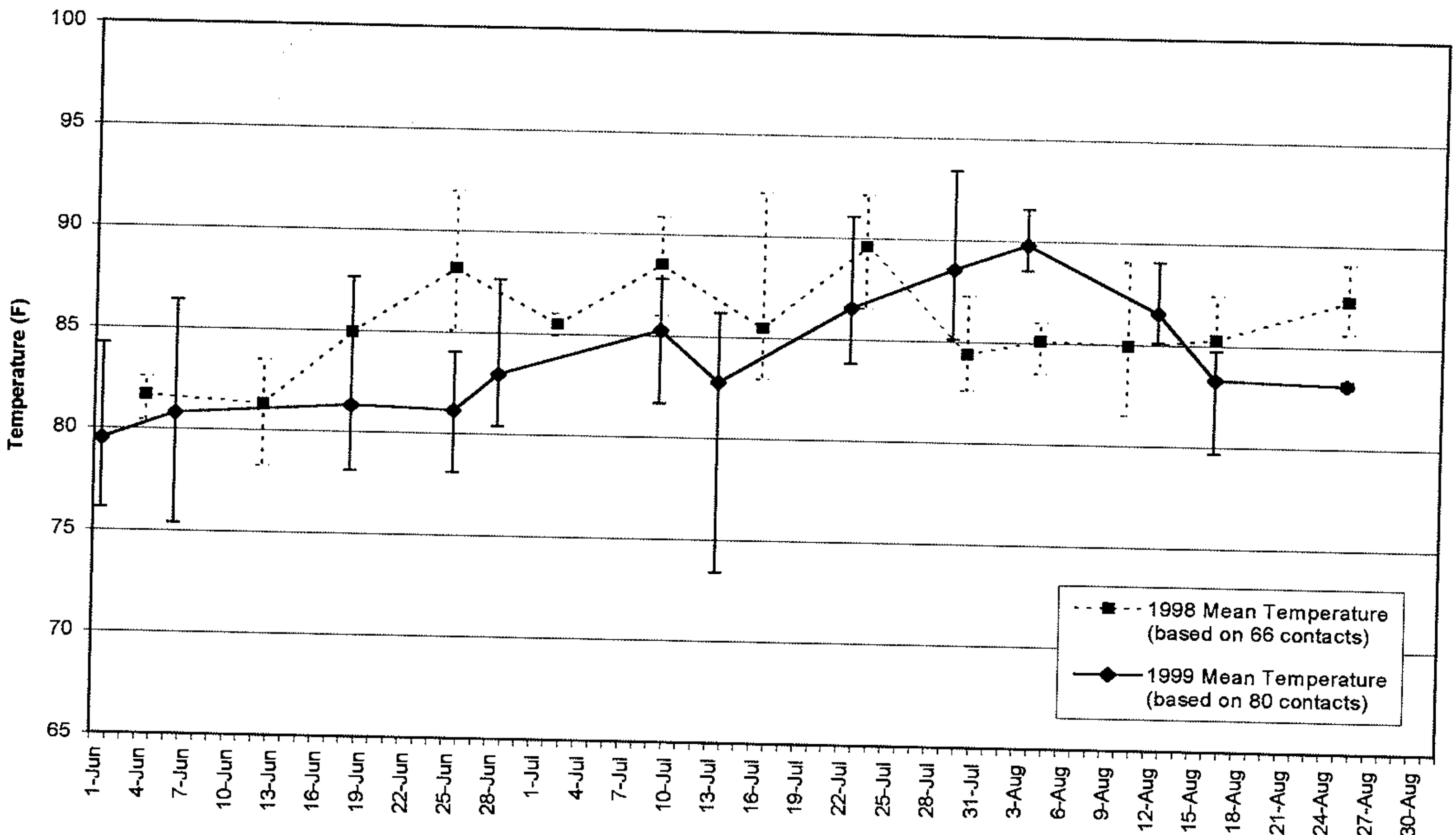


Figure 1.30. Internal body temperatures of largemouth bass in Lake of Egypt, Williamson / Johnson Co. Illinois. Only contacts with largemouth bass were used when their internal body temperatures, determined by the temperature sensitive ultrasonic transmitters, corresponded with a water temperature on the temperature-depth-oxygen profile that was taken at the location of each fish. The bars represent ranges.

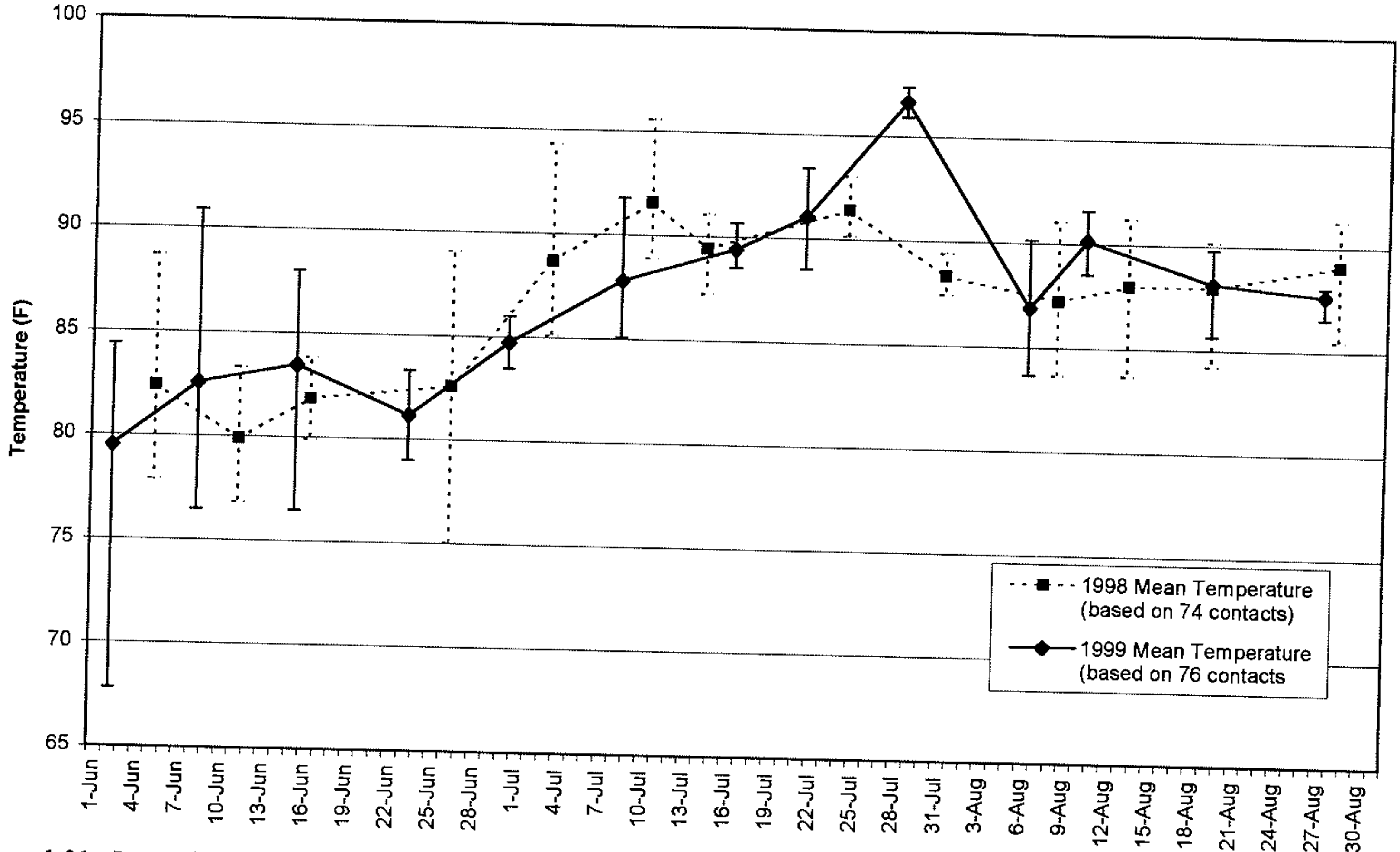


Figure 1.31. Internal body temperatures of largemouth bass in Coffeen Lake, Montgomery Co. Illinois. Only contacts with largemouth bass were used when their internal body temperatures, determined by the temperature sensitive ultrasonic transmitters, corresponded with a water temperature on the temperature-depth-oxygen profile that was taken at the location of each fish. The bars represent ranges.

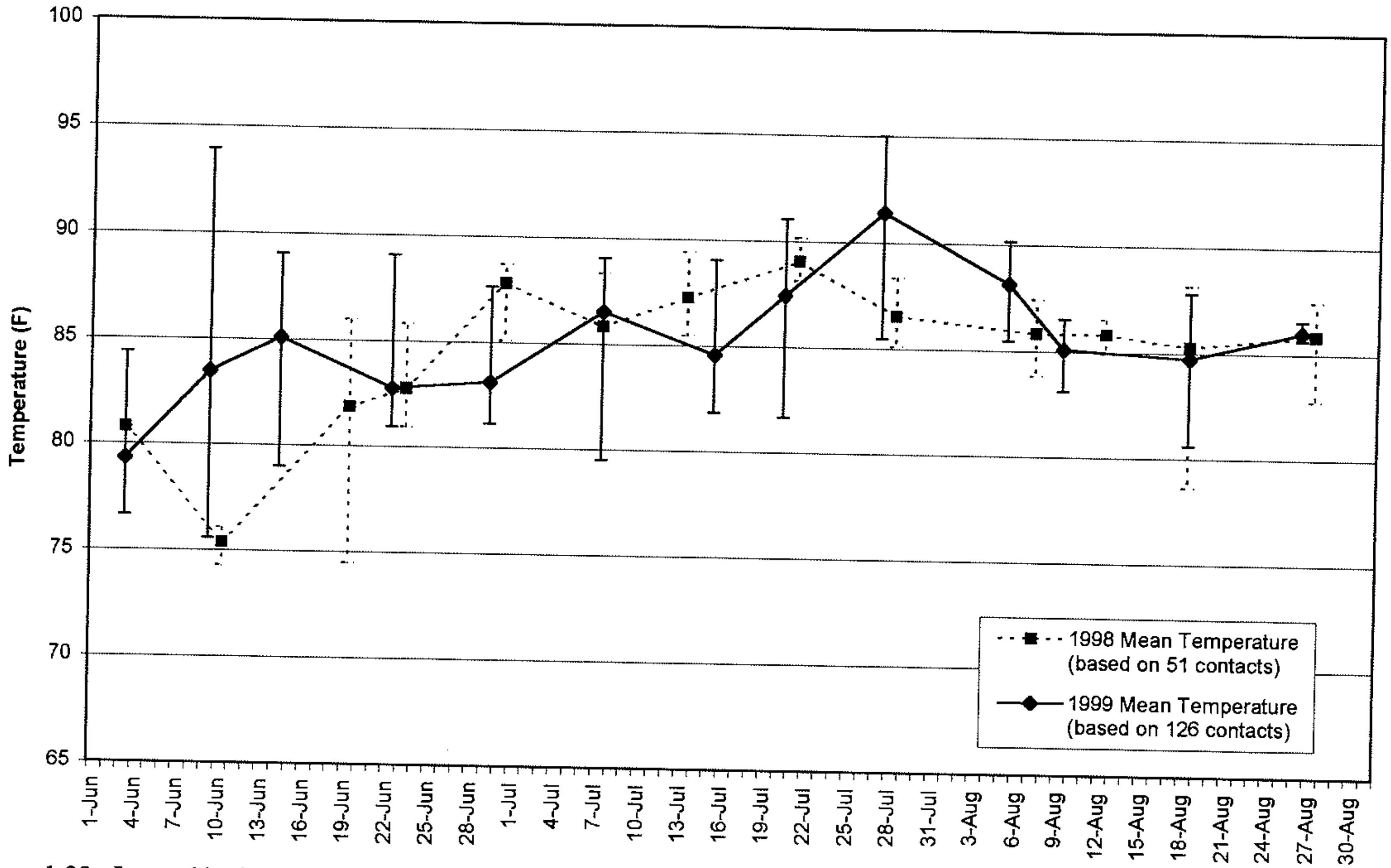


Figure 1.32. Internal body temperatures of largemouth bass in Newton Lake, Jasper Co. Illinois. Only contacts with largemouth bass were used when their internal body temperatures, determined by the temperature sensitive ultrasonic transmitters, corresponded with a water temperature on the temperature-depth-oxygen profile that was taken at the location of each fish. The bars represent ranges.

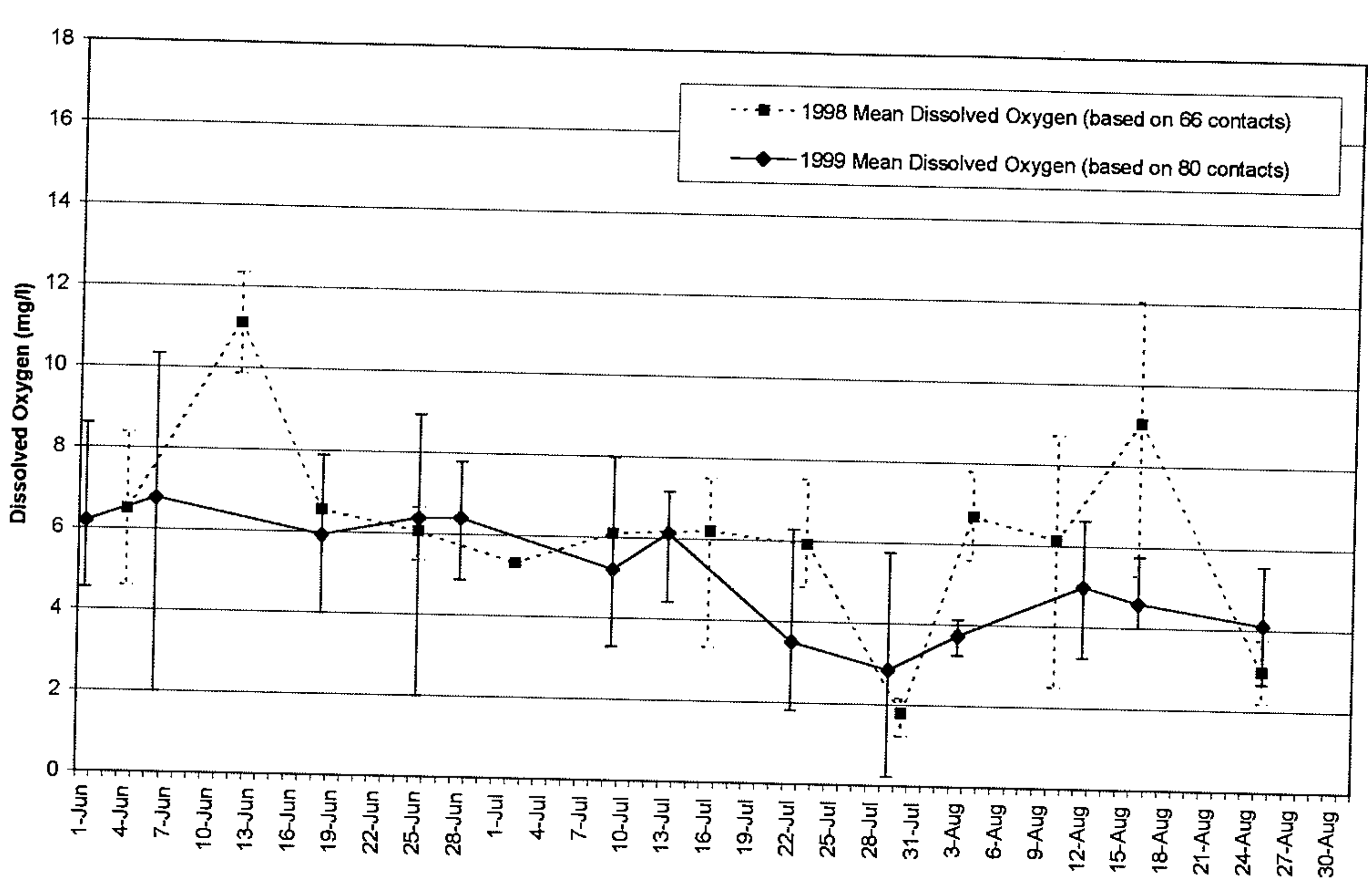


Figure 1.33. Dissolved oxygen levels at the depth where largemouth bass where located in Lake of Egypt, Williamson / Johnson Co. Illinois. Only contacts with largemouth bass were used when their internal body temperatures, determined by the temperature sensitive ultrasonic transmitters, corresponded with a water temperature on the temperature-depth-oxygen profile that was taken at the location of each fish. The bars represent ranges.

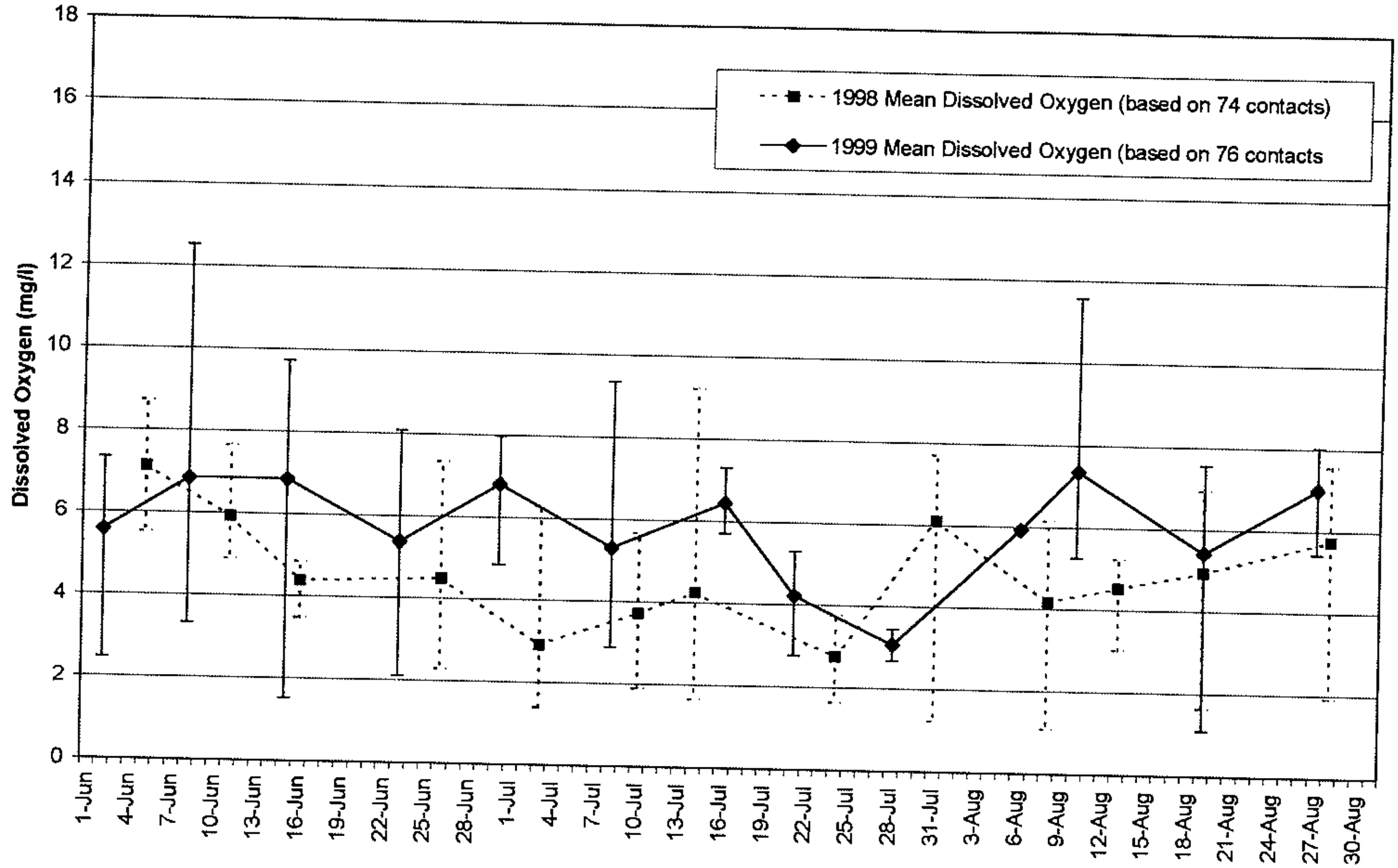


Figure 1.34. Dissolved oxygen levels at the depth where largemouth bass where located in Coffeen Lake, Montgomery Co. Illinois. Only contacts with largemouth bass were used when their internal body temperatures, determined by the temperature sensitive ultrasonic transmitters, corresponded with a water temperature on the temperature-depth-oxygen profile that was taken at the location of each fish. The bars represent ranges.

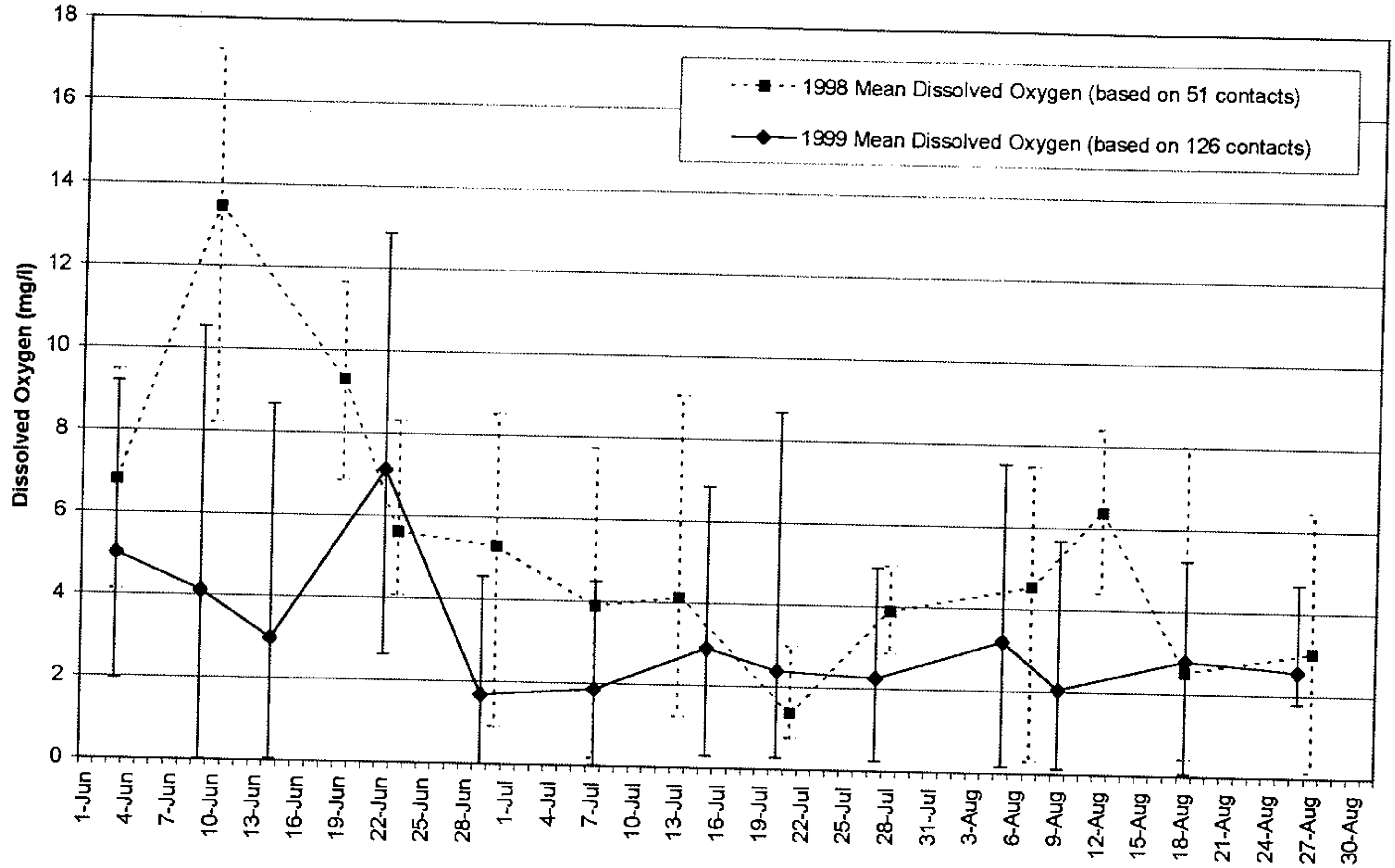


Figure 1.35. Dissolved oxygen levels at the depth where largemouth bass where located in Newton Lake, Jasper Co. Illinois. Only contacts with largemouth bass were used when their internal body temperatures, determined by the temperature sensitive ultrasonic transmitters, corresponded with a water temperature on the temperature-depth-oxygen profile that was taken at the location of each fish. The bars represent ranges.

Chapter 2. Phytoplankton (See Chapter 4)

Chapter 3. Zooplankton

Introduction:

Zooplankton are an integral part of the food web since they are forage for fish and other invertebrates at one time or another in the fishes' life cycles. Larval and early fingerling stages of most sport fish species feed on zooplankton. The spawning season for a given fish species tends to correlate with water temperature and day length. In order to survive and grow, young fish an abundant supply of zooplankton. Since water temperatures in a power cooling lake are influenced by sources other than ambient temperatures and daylight length, the question arises – do the pulses of zooplankton abundance correspond with the pulses of larval fish production.

Sampling was conducted for zooplankton at various times throughout the year in an attempt to determine effects of water temperature and season on zooplankton abundance in Newton Lake's four segments.

Methods:

Zooplankton was sampled with the same frequency from the same segments, transects, and sampling stations previously described in Chapter 2 (Phytoplankton). To obtain species composition as well as abundance, two vertical tows were taken at each sampling station. A conical net (0.5-m diameter, 64Φ mesh, 5:1 length to diameter) was lowered to the bottom of the euphotic zone (see Chapter 2) and then raised at a timed speed of 0.5 m/sec. Samples were preserved in 4% Lugol's solution (50 ml 8% Lugol's + 50 ml sample). Samples were appropriately labeled and taken to Southern Illinois University's Cooperative Fisheries Laboratory where subsamples of the invertebrates were identified as members of the Phylum Rotatoria (rotifers), or the subclasses Cladocera and Copepoda. Enumeration of each were further subdivided by grouping Cladocera and Copepoda that were known to be particularly important to diets of larval fish. These groups included the Families Daphnidae and Bosminidae, Orders Cyclopoida and Calanoida, other Cladocera, and the juvenile stage of copepods (nauplii). The Genera *Leptidora* and *Diaphanosoma* were also enumerated separately. Reference literature included Merritt and Cummins (1996) and Pennak (1989). Individuals from each subsample were quantified by groups and as total zooplankton. Dilution methods described by Wetzel and Likens (1991) were used. Samples collected were enumerated by placing the entire samples in a specific volume of water and then stirred with a magnetic stirrer. A Hansen-Stemple volumetric pipette was used to collect and place a subsample in a Wards zooplankton counting wheel, and the number of each taxa present in the subsamples was extrapolated according to the dilutions and initial volume of water sampled. Exact laboratory protocol depended upon the density of organisms in the samples collected.

Zooplankton sampled during August 1997 through August 1999 were included in this report (Appendix 3.1), and sampling was completed as scheduled throughout the study period. For general comparison of abundance, nauplii and rotifers, and the adult taxa remaining are often analyzed separately.

Results and Discussion:

Zooplankton total densities were dependent upon year, month, and segment in which they were collected ($p = 0.0001$, $R^2 = 0.4391$). Zooplankton were collected at significantly ($p = 0.0261$) higher densities in segments 1 and 2 (336 - 339 per L) than in the remaining segments (294 – 298 per L, Table 3.1). During the two-year study, mean zooplankton densities were significantly higher in May than all other months (p = 0.0001) and were lowest in October and December (Table 3.2, Figure 3.1, Appendix 3.2). Zooplankton densities among segments fluctuated widely throughout the study period, and there were no specific trends of abundance due to season and segments over time (Figure 3.2). Total seasonal zooplankton numbers in Newton Lake are well within the range of average densities during April through August in twelve other non-power cooling, Illinois lakes (Figure 3.3). Zooplankton totals in Newton Lake during July and August were significantly (p=0.0001) higher in 1999 (239 per L) than in 1998 (171 per L) and in August of 1997 (146 per L). Expectations of lower densities possibly due to peaking lake temperatures during the two summer months were not entirely met since zooplankton numbers increased in late August of 1999. Low zooplankton abundance also apparent during fall of 1997 and 1998.

Total zooplankton numbers were primarily due to representatives of the Phylum Rotatoria (Table 3.1). High rotifer densities are important since they are forage for most larger zooplankton. Mean rotifer numbers for each date sampled ranged from 62 to 736 per L (Appendix 3.3) and averaged 278 per L. Densities of rotifers were significantly higher in segments 1 and 2 than in segments 3 and 4 (p = 0.0005, Table 3.1). Although density differences among segments were significant, large fluctuations are evident by large standard deviations and apparent by inconsistent density patterns for each segment over time (Figure 3.4). There was more consistency of rotifer densities by month in both years. Densities were consistently higher in May and June of both years (Figure 3.5), and

May densities were significantly higher than all other months sampled ($p = 0.0001$, Table 3.2).

Adequate rotifer densities are essential for the survival and reproduction of larger zooplankton. Most sportfish larvae rely on adult Cladocera and copepods for forage until they are large enough to switch diets that include macroinvertebrates or other larval fish. Thus, low numbers of the larger zooplankton may limit survival of the larval sportfish and, ultimately, recruitment. Adult zooplankton (Orders Cyclopoida and Calanoida) densities in Newton Lake were lower during April through July than in the twelve, non-power cooling, Illinois lakes (Figure 3.6). Mean densities of samples examined each date for adult zooplankton ranged from <1 to 31 per L from August 1997 through August 1999 (Appendix 3.2). Densities were dependent on year, month, and segment sampled ($p=0.0001$; $R^2=0.4243$). Mean densities were significantly ($p=0.0001$) higher in October, January, April, and May than all other months (Table 3.2). Adult zooplankton densities collected during July, August, and September ranged from 1 to 4 per L and were significantly lower than all other months. Lowest densities were sampled during the three month period in 1999 (1 per L). The densities were significantly ($p = 0.0001$) lower than for the same period in 1998 (2 per L) and during August and September 1997 (3 per L). Although adult zooplankton were collected at significantly higher densities in segments 3 and 4 ($p = 0.0001$) than in segments 1 and 2 (Table 3.1), the mean densities for all segments only ranged from 8 to 15 per L. As was evident with rotifers, each segment contained the highest densities of adult zooplankton at one time or another (Figure 3.7). There were no trends of abundance among the segments based on season or water temperatures.

Nauplii are also potentially important forage for larvae of smaller fish including bluegill. Nauplii were twice as abundant as the adult zooplankton. Their numbers were dependent on month and segment that they were collected ($p = 0.0001$). Their mean densities were significantly highest in segment 3 (34 per L) and lowest in segment 1 (17 per L, Table 3.1). They had highest mean densities in April, May, and October (Table 3.2), and the peak densities in those months were evident during both years of the study (Figure 3.5). There were no evident trends of abundance among segments due to season (Figure 3.8).

Abundance of each of the adult zooplankton taxon fluctuated throughout the annual period (Table 3.2, Appendix 3.3). Densities of the individual taxa ranged from 0 to 81 per L. Calanoid copepods had a significantly (p=0.001) higher mean density (7 per L) than all other individual taxa collected. However, percent contribution of each taxa to the samples collected fluctuated by time of year (Figure 3.9). For instance, *Diaphanosoma* spp. contributed 20-80% during May through September of each year, but very few (<2%) were present in our samples during October through April. In contrast, Calanoid copepods contributed to over 50% of the total zooplankton collected between October and June and were by far the most dominant taxon present during that time. *Bosminus* spp. contributed most (10-25%) from December 1997 through May 1998, but were much less prevalent in 1999. Endemic *Daphnia* sp. were most prevalent from December through April in both years of the study. *Daphnia lumholtzi* is an exotic species that has only been recently described in North America. Although its presence in Newton Lake was observed throughout most the year, it contributed most to the total zooplankton in July and September 1998 and June 1999. Although there was some fluctuation in contribution, Cyclopoid copepods were present throughout the study.

The most important aspect of zooplankton numbers to larval fish is their abundance during periods between first feeding (beyond yolk sac stages) and when they convert to larger prey. For piscivorous fish species, the life stage at which zooplankton are used exclusively for forage is usually spans a very short period. For instance, largemouth bass may require zooplankton for only a few weeks. This is especially true if smaller larval fish such as gizzard shad and bluegill spawn shortly after the bass and become available prey. Since densities of adult zooplankton were among their highest during April and May, larval largemouth bass were probably not adversely affected by the low densities during the summer months. Fish species that are not piscivorous and spawn later than bass require higher numbers of zooplankton to persist throughout the summer months. In Newton Lake, very low zooplankton numbers during July and August would most likely negatively affect survival of larval *Lepomis* species that hatch during the entire summer and require zooplankton well into the fall..

Literature Cited:

Merritt, R.W. and K.W. Cummins (eds.). 1996. An introduction to the aquatic insects of North American (3rd edition). Kendall/Hunt Publishing Company.

Pennak, R.W. 1989. Fresh-water invertebrates of the United States. *Protozoa to Mollusca* (3rd edition). John Wiley & Sons, Inc., New York.

Wetzel, R.G., and G.E. Likens. 1991. Limnological Analyses, 2nd edition. Springer Verlag, New York.

Table 3.1. Mean densities of zooplankton collected from four segments in Newton Lake during August 1997 through August 1999. The zooplankton was collected from three stations per segment, and two vertical tows were taken at each station (n = 834). Superscripts with the same letter are not statistically different (p=0.0001).

Taxa	Segment	Mean density (n per L)	Range		Standard deviation	Number of samples
Nauplii	1^{c}	17	0	120	18.65	210
	$2^{a,b}$	29	<1	511	45.39	208
	3^{a}	34	<1	198	41.15	207
	4^{b}	27	<1	149	30.47	209
Total		**27**	**0**	**511**	**35.91**	834
Rotifers	1^{a}	311	0	1,426	299.06	210
	2^{a}	299	4	1,511	276.84	208
	3^{b}	247	10	697	174.66	207
	4^{b}	257	0	1,031	198.06	209
		278	**0**	**1,511**	**244.08**	834
Zooplankton	1^{c}	8	0	81	10.98	210
	2^{b}	11	<1	62	12.31	208
	3^{a}	14	0	76	15.21	207
	4^{a}	15	<1	66	16.18	209
Total		**12**	**0**	**81**	**13.99**	834
Total Zooplankton	1^{a}	336	0	1,459	311.40	210
	2^{a}	339	13	1,527	290.96	208
	3^{b}	294	21	863	196.95	207
	4^{b}	298	9	1,099	211.89	209
Total		**317**	**0**	**1,527**	**258.00**	834

Table 3-2. Mean densities of zooplankton collected from four segments in Newton Lake during August 1997 through August 1999. The zooplankton was collected from three stations per segment, and two vertical tow were taken at each station. Superscripts with the same letter are not statistically different (p=0.0001).

Taxa	Date	Mean density (n per L)	Range		Standard deviation	Number of samples
Total Zooplankton	January[d]	335	23	747	255.24	48
	February[b]	547	155	1,203	238.33	48
	March[e]	242	36	993	191.05	47
	April[d]	333	75	936	161.09	96
	May[a]	681	180	1,527	330.34	96
	June[c]	407	9	1,302	277.52	93
	July[e,f]	181	33	689	98.52	94
	August[e,f]	210	0	645	122.10	120
	September[e,f]	193	21	534	121.53	96
	October[f]	146	13	346	74.78	48
	December[f]	157	28	305	70.39	48
Rotifers	January[d]	295	10	653	230.37	48
	February[b]	518	150	1,181	229.55	48
	March[e,f]	198	0	889	163.66	47
	April[d,e]	252	0	849	143.54	96
	May[a]	614	141	1,511	326.65	96
	June[c]	368	7	1,216	261.34	93
	July[f]	176	29	681	99.64	94
	August[e,f]	203	0	635	119.80	120
	September[f]	180	10	514	119.30	96
	October[g]	67	4	202	44.68	48
	December[c]	109	16	275	54.11	48

Table 3-2. Continued.

Taxa	Date	Mean density (n per L)	Range		Standard deviation	Number of samples
Adult zooplankton	January[b,c]	19	0	62	16.71	48
	February[e]	10	0	25	7.91	48
	March[c]	17	2	51	12.55	47
	April[a,b]	23	4	76	16.32	96
	May[b,c]	19	1	48	12.58	96
	June[d,e]	13	0	81	15.78	93
	July[f]	1	0	8	1.52	94
	August[f]	2	0	17	2.74	120
	September[f]	4	0	14	3.37	96
	October[a]	24	3	65	16.47	48
	December[c,d]	16	1	37	11.80	48
Nauplii	January[d]	20	1	49	15.60	48
	February[d]	19	2	49	12.44	48
	March[c,d]	28	3	120	23.27	47
	April[a]	61	5	511	57.33	96
	May[b]	48	4	198	40.49	96
	June[c,d]	27	1	173	31.49	93
	July[e]	4	0	27	5.06	94
	August[e]	5	0	40	6.27	120
	September[e]	8	0	36	6.46	96
	October[a,b]	56	3	143	40.54	48
	December[c]	33	2	98	30.12	48

Table 3-3. Mean densities of zooplankton collected from Newton Lake during August 1997 through August 1999. Zooplankton samples (834) were collected from four segments, three stations per segment and two vertical tows per station. Tows were conducted with 0.5 m diameter, 63-*u*mesh plankton nets. Superscripts indicate statistical significance among taxa (p=0.0001).

Taxa	Number (n per L)	Range		Standard deviation
Bosminidae	1[b,c]	0	29	3.25
Calanoid Copepod	7[a]	0	69	9.37
Cyclopoid Copepod	1[b]	0	20	2.09
Daphnia spp.	1c	0	20	2.03
Diaphanosoma spp.	1[c]	0	13	1.84
Leptodora kindti	<1[d]	0	1	0.03
Daphnia lumholtzi	<1[d]	0	11	1.15
Other Cladocera	<1[d]	0	1	0.12
Others	<1[d]	0	3	0.19
Total Zooplankton	**12**	**0**	**81**	**13.99**
Nauplii	27	0	511	35.91
Rotifera	278	0.00	1510.62	244.08

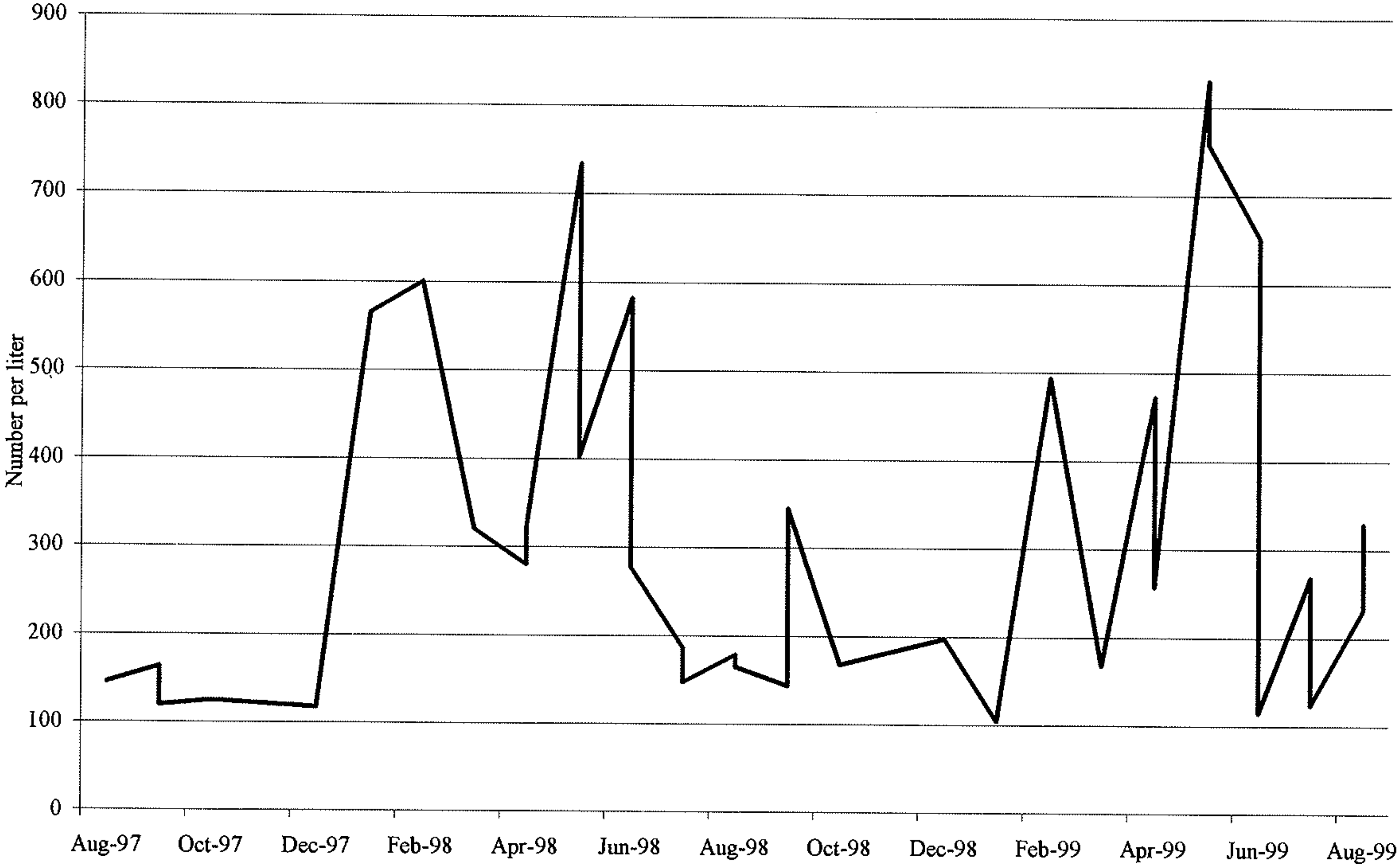


Figure 3.1. Mean densities of all zooplankton by date collected in Newton Lake (12 stations) from August 1997 through August 1999. Two vertical tows were taken per station using a 0.5-m, 63-u mesh plankton net.

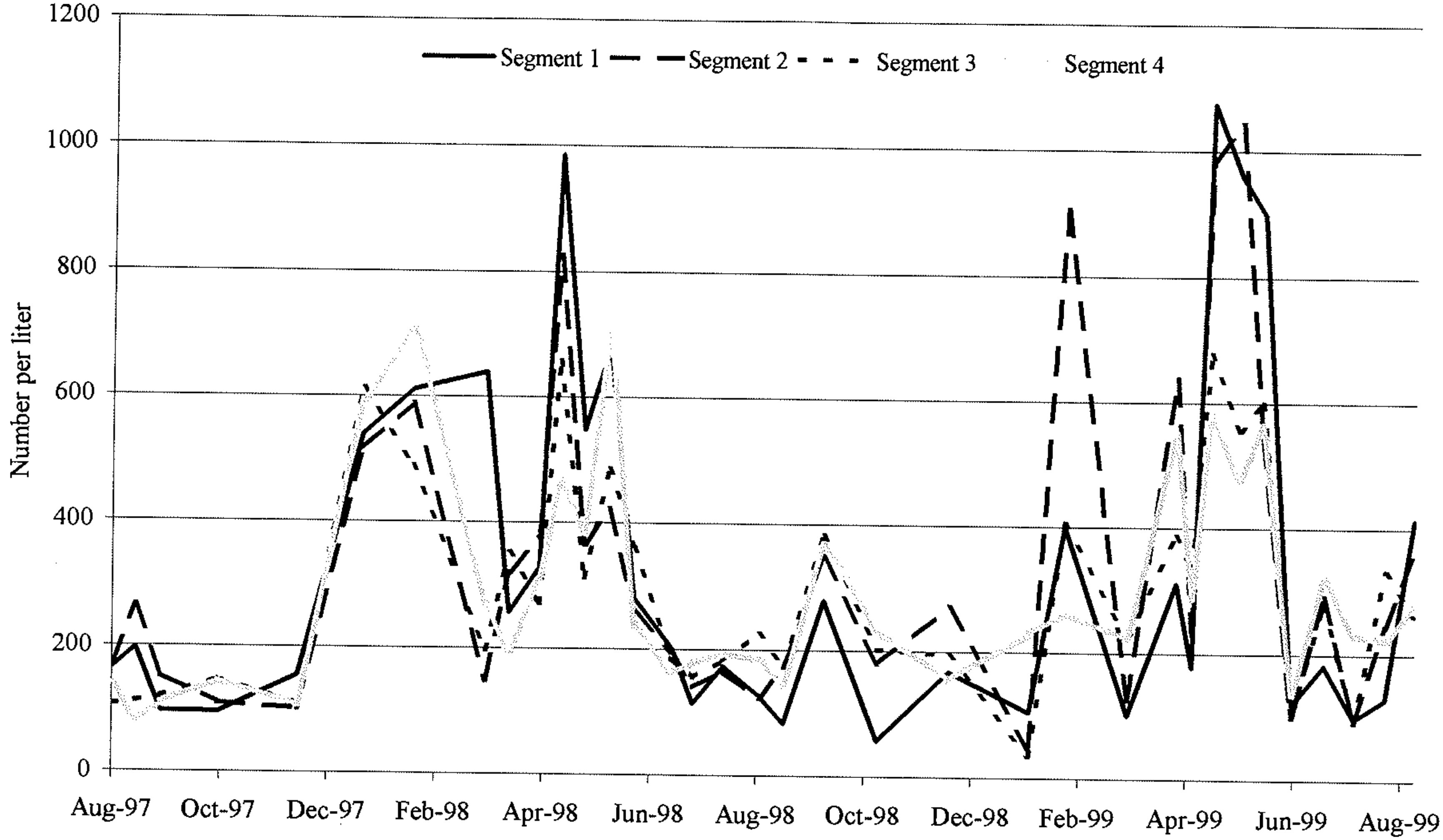


Figure 3.2. Mean densities by date of all zooplankton collected in Newton Lake in four segments and three stations per segment during August 1997 through August 1999. Two vertical tows were taken per station using a 0.5-m, 63-*u* mesh plankton net.

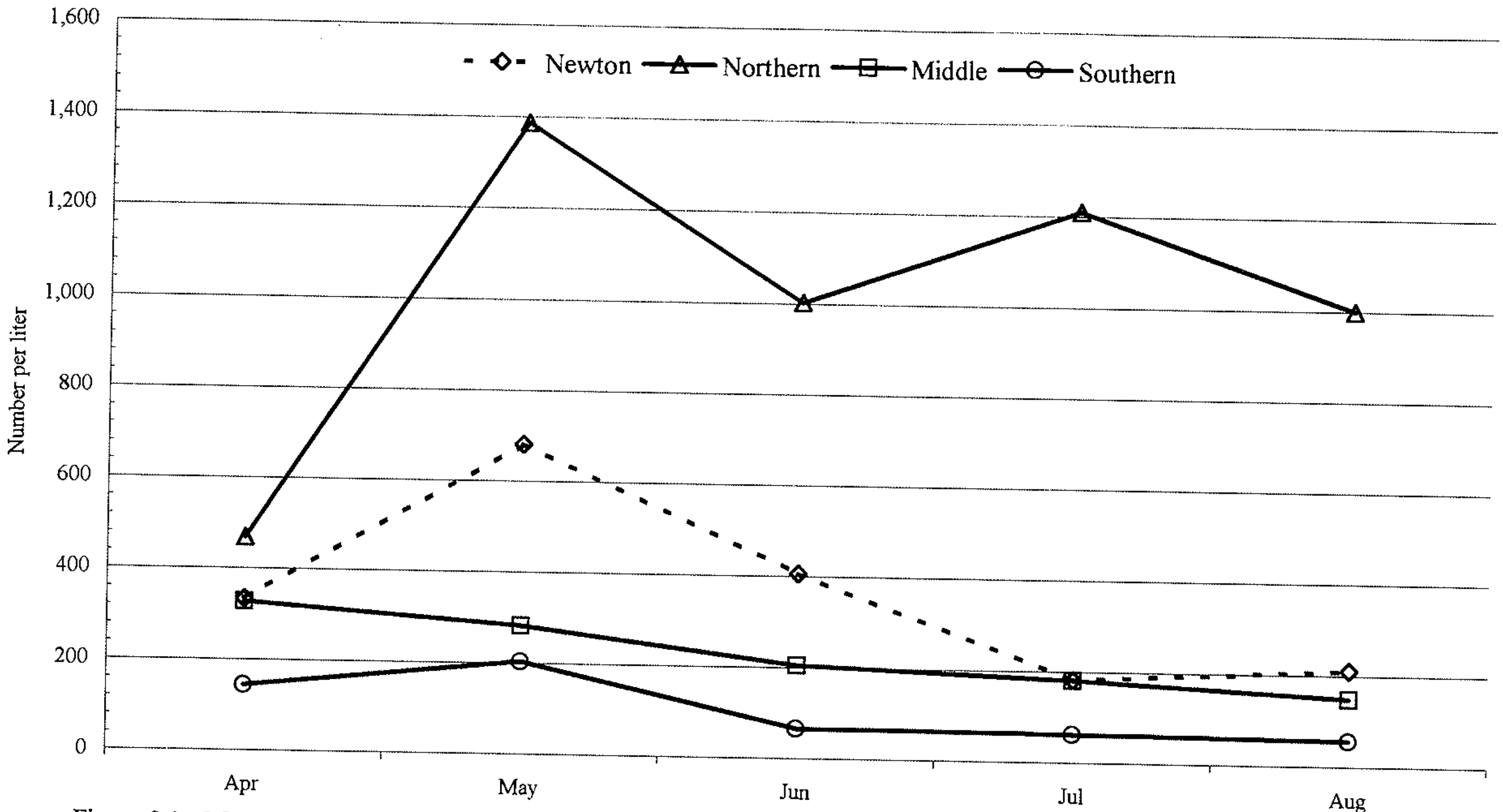


Figure 3.3. Mean monthly densities of zooplankton collected in Newton Lake compared to 12 lakes grouped into three regions of Illinois. Zooplankton was collected from the Illinois lakes during April through August of 1993 through 1997. Five lakes were sampled in the northern zone, six in the middle zone, and four in the southern zone. Four to six samples were taken from the Illinois lakes each month for five years.

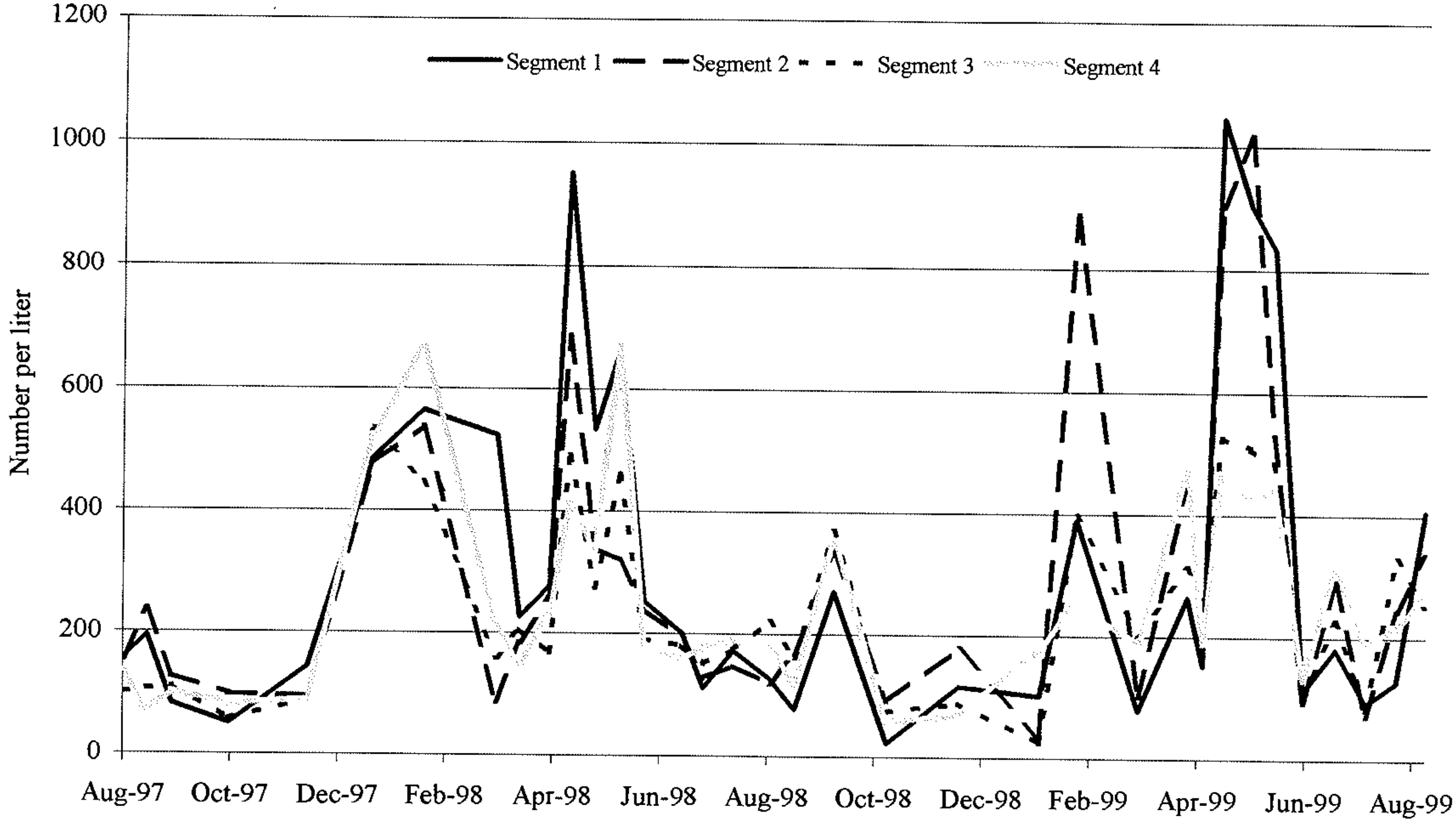


Figure 3.4. Mean densities by date of rotifers collected in Newton Lake in four segments and three stations per segment during August 1997 through August 1999. Two vertical tows were taken per station using a 0.5-m, 63-*u* mesh plankton net.

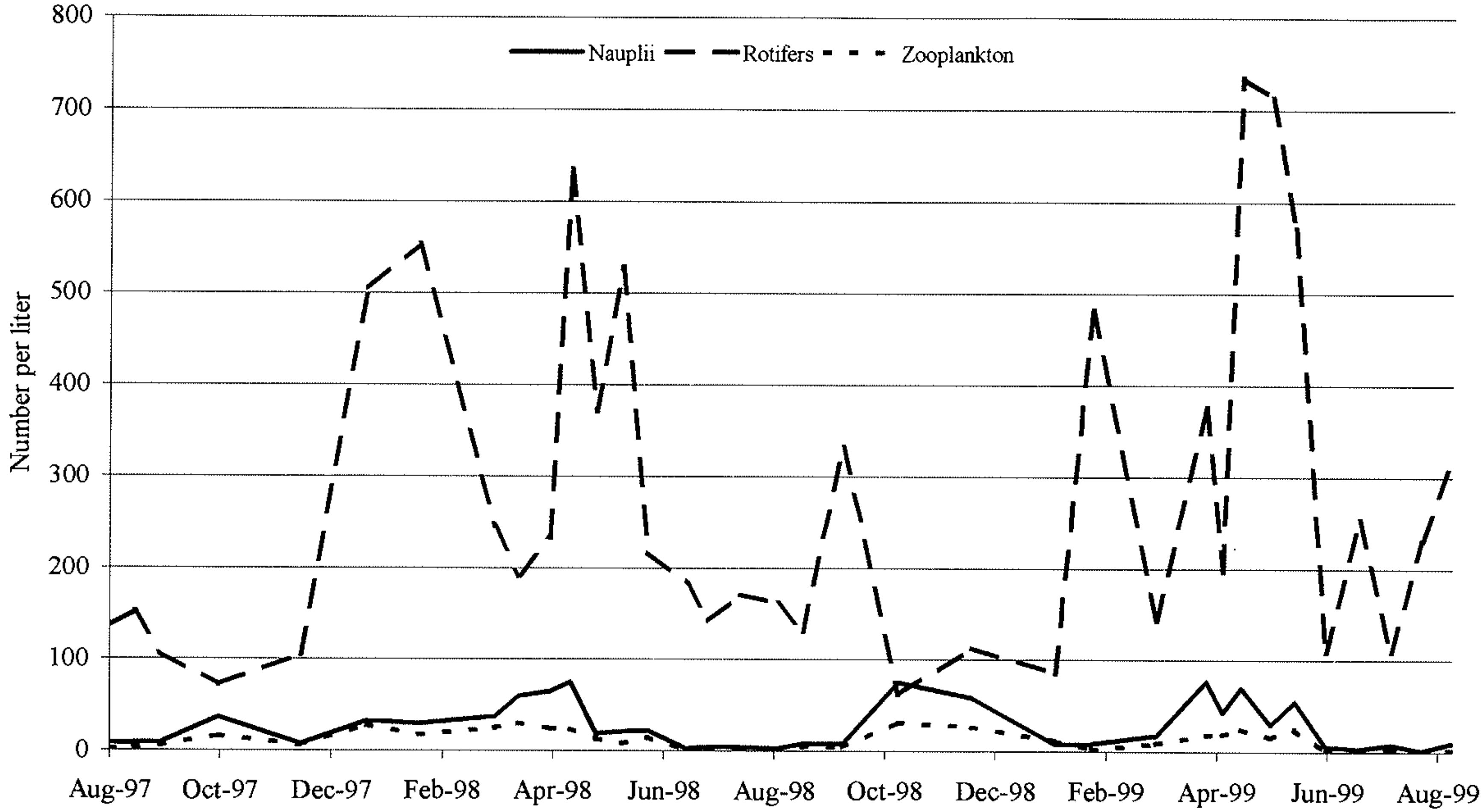


Figure 3.5. Mean densities by date of rotifers, nauplii, and remaining adult zooplankton collected in Newton Lake in four segments and three stations per segment during August 1997 through August 1999. Two vertical tows were taken per station using a 0.5-m, 63-*u* mesh plankton net.

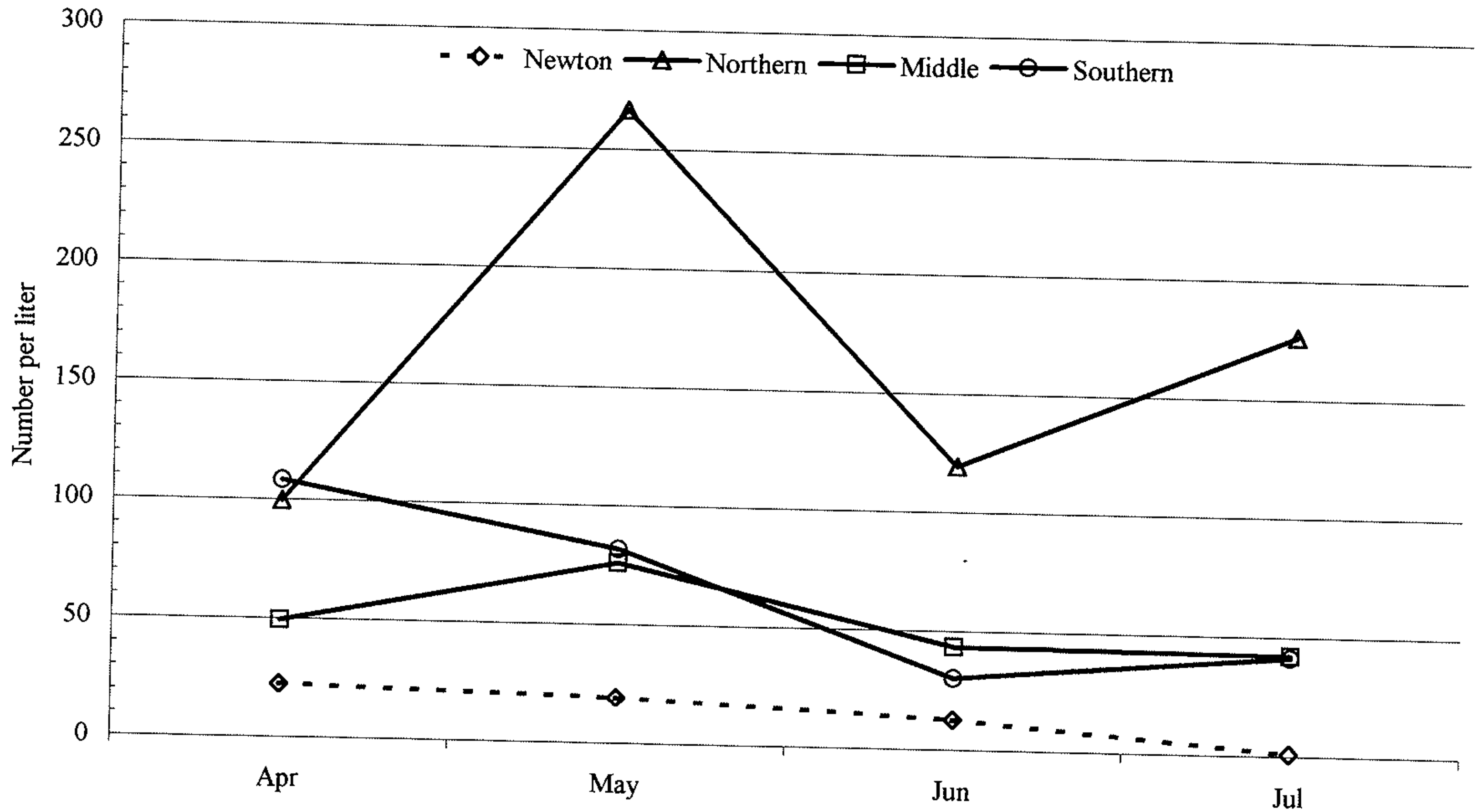


Figure 3.6. Mean monthly densities of adult cladocera and copepod zooplankton collected in Newton Lake compared to 12 lakes grouped into three regions of Illinois. Zooplankton was collected from the Illinois lakes during April through August of 1993 through 1997. Five lakes were sampled in the northern zone, six in the middle zone, and four in the southern zone.

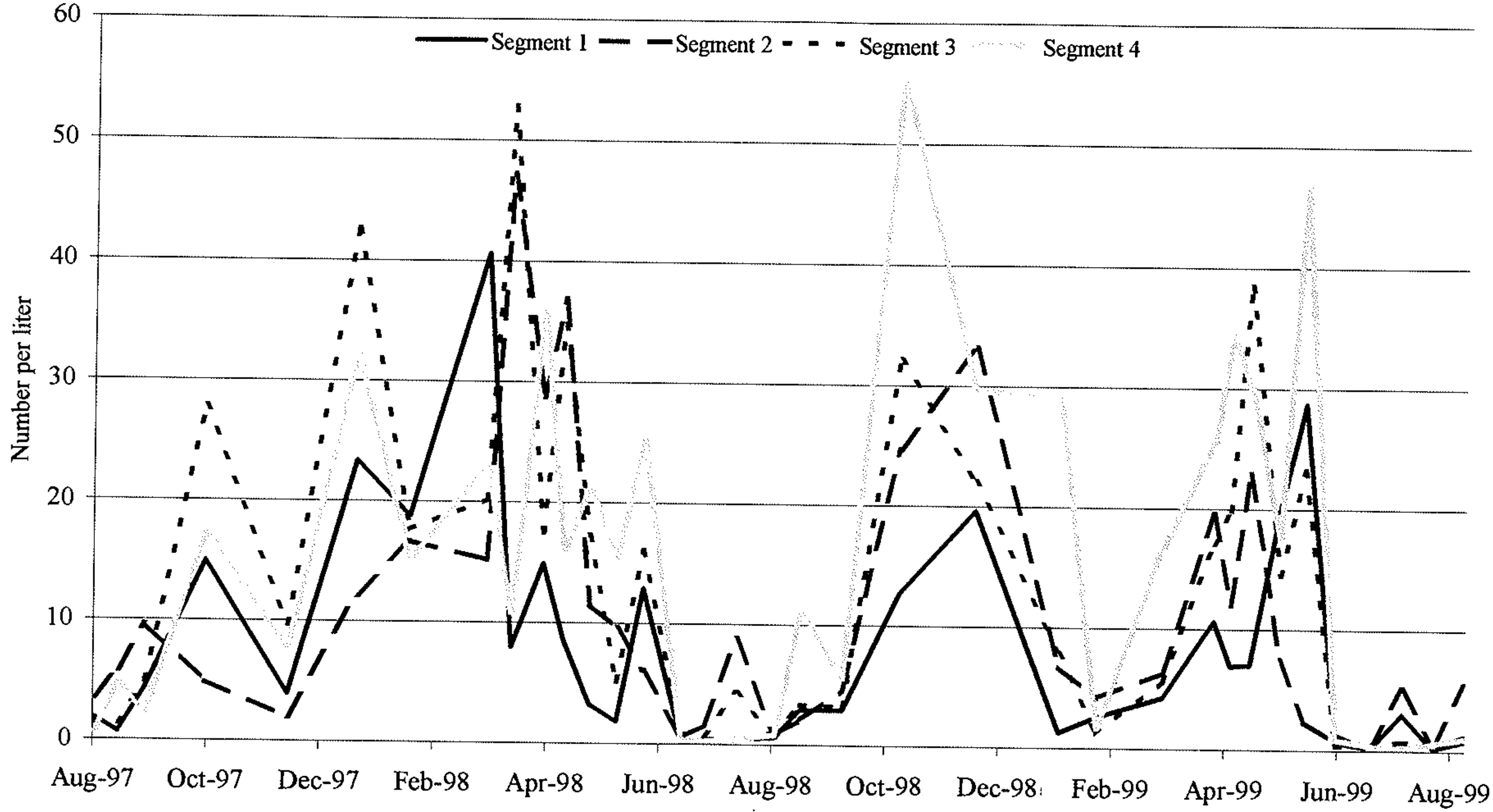


Figure 3.7. Mean densities by date of zooplankton (excluding nauplii and rotifers) collected in Newton Lake in four segments and three stations per segment during August 1997 through August 1999. Two vertical tows were taken per station using a 0.5-m, 63-*u* mesh plankton net.

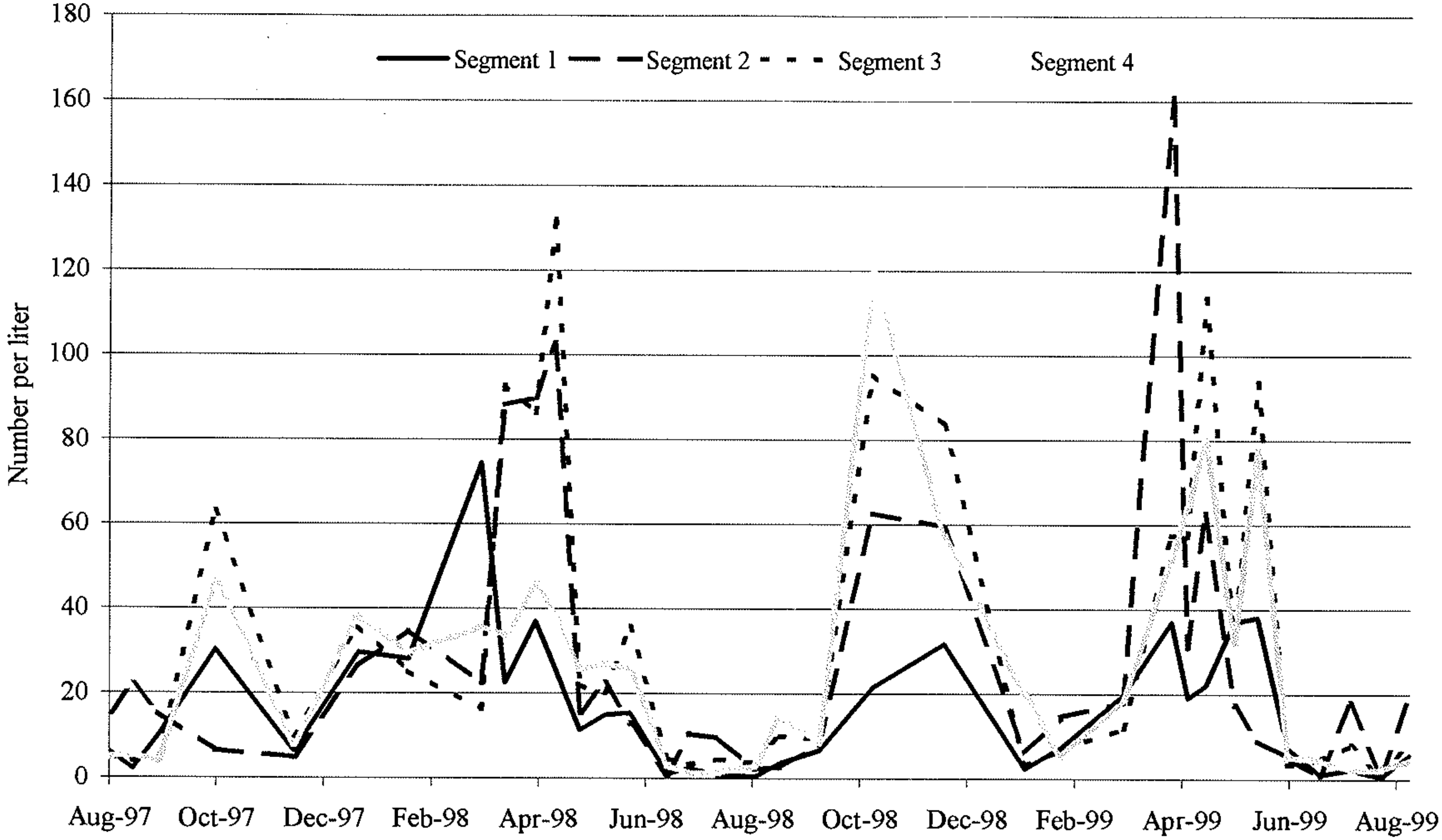


Figure 3.8. Mean densities by date of nauplii collected in Newton Lake in four segments and three stations per segment during August 1997 through August 1999. Two vertical tows were taken per station using a 0.5-m, 63-*u* mesh plankton net.

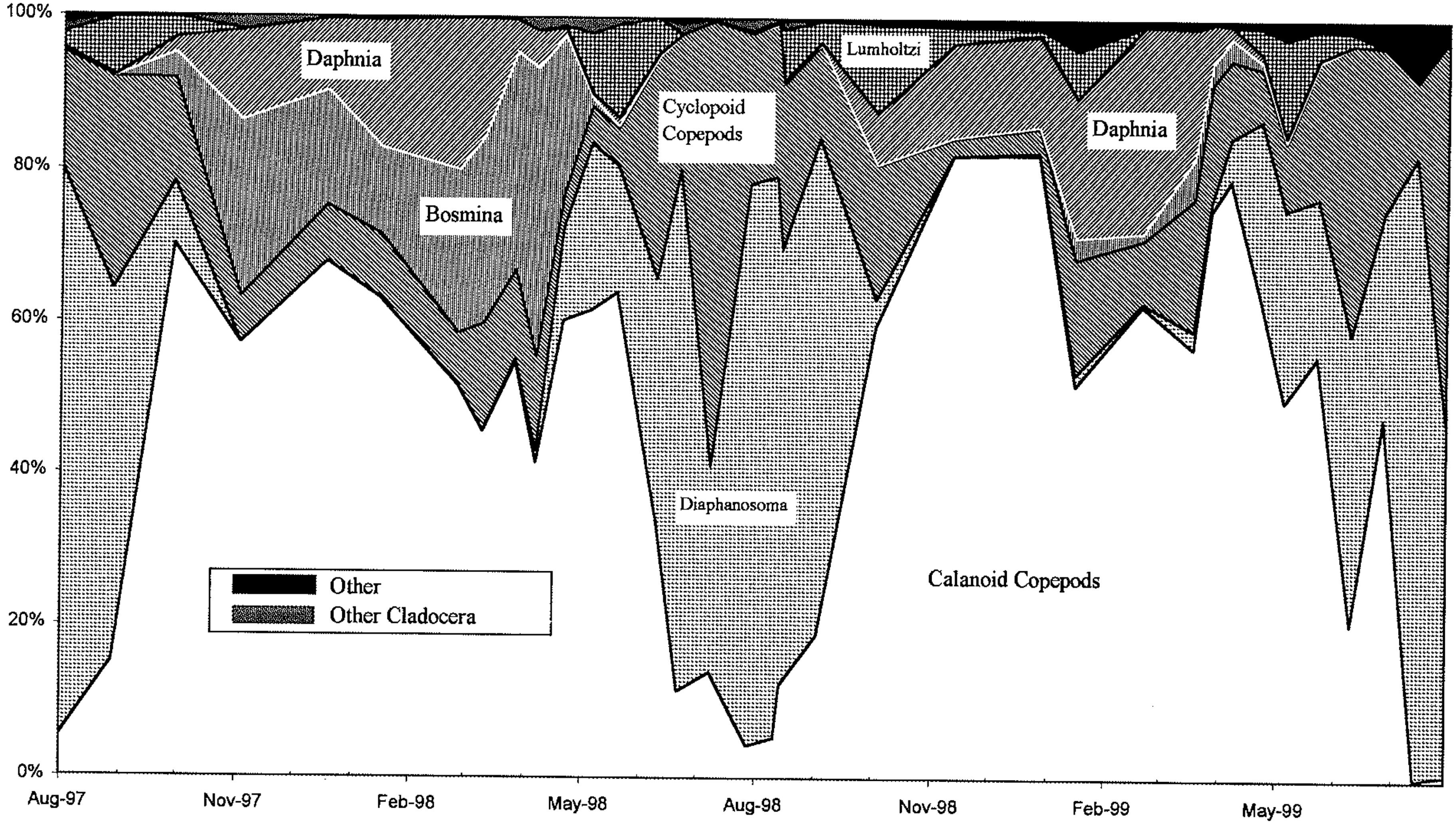


Figure 3-9. Percent contribution of zooplankton taxa collected in Newton Lake from August 1997 through August 1999.

Chapter 3. Appendix: Supplemental Data Tables

Appendix 3.1. Zooplankton samples were collected from Newton Lake on dates, segments, and stations listed. Two samples were taken per station with vertical tows using a 63-*u* mesh plankton net.

Date	Segments	Stations
08/29/97	1-4	1-3
09/11/97	1-3	1-3
09/25/97	1-4	1-3
10/27/97	1-4	1-3
12/10/97	1-4	1-3
01/15/98	1-4	1-3
02/12/98	1-4	1-3
03/25/98	1-4	1-3
04/07/98	1-4	1-3
04/24/98	1-4	1-3
05/05/98	1-4	1-3
05/19/98	1-4	1-3
06/02/98	1-4	1-3
06/16/98	1-4	1-3
07/07/98	1-4	1-3
07/19/98	1-4	1-3
08/05/98	1-4	1-3
08/25/98	1-4	1-3
09/08/98	1-4	1-3
09/30/98	1-4	1-3
10/30/98	1-4	1-3
12/09/98	1-4	1-3
01/23/99	1-4	1-3
02/12/99	1-4	1-3
03/19/99	1-4	1-3
04/15/99	1-4	1-3
04/24/99	1-4	1-3
05/04/99	1-4	1-3
05/20/99	1-4	1-3
06/02/99	1-4	1-3
06/19/99	1-4	1-3
07/07/99	1-4	1-3
07/24/99	1-4	1-3
08/10/99	1-4	1-3
08/26/99	1-4	1-3

Appendix 3.2. Mean densities of zooplankton collected from Newton Lake during August 1997 through August 1999. Zooplankton samples (834) were collected from four segments, three stations per segment and two vertical tows per station. Tows were conducted with 0.5 m diameter, 63-*u* mesh plankton nets. Superscripts indicate statistical significance among months (p=0.0001).

Taxa	Date	Number per L	Range		Standard deviation	Number of samples
All Zooplankton	August-97	146	25	479	104.37	24
	September-97	141	21	372	89.67	48
	October-97	124	13	217	50.86	24
	December-97	117	28	294	56.29	24
	January-98	565	337	747	110.99	24
	February-98	600	382	1,099	168.54	24
	March-98	320	103	993	235.94	23
	April-98	301	111	519	95.79	48
	May-98	568	191	1,459	278.25	48
	June-98	433	20	1,059	224.30	45
	July-98	167	56	276	62.89	48
	August-98	172	0	645	101.79	48
	September-98	244	44	534	127.97	48
	October-98	168	43	346	88.65	24
	December-98	197	69	305	60.39	24
	January-99	104	23	403	99.68	24
	February-99	493	155	1,203	285.88	24
	March-99	168	36	361	88.88	24
	April-99	365	75	936	202.99	48
	May-99	794	180	1,527	342.24	48
	June-99	383	9	1,302	319.97	48
	July-99	196	33	689	124.45	46
	August-99	280	51	564	115.86	48

Appendix 3.2. Continued.

Taxa	Date	Number per L	Range		Standard deviation	Number of samples
Rotifers	August-97	136	21	463	100.82	24
	September-97	129	10	371	84.70	48
	October-97	72	4	192	44.05	24
	December-97	104	24	275	54.18	24
	January-98	505	315	653	97.81	24
	February-98	554	344	1,031	162.04	24
	March-98	256	65	889	204.40	23
	April-98	212	88	420	75.24	48
	May-98	503	148	1,426	261.68	48
	June-98	398	16	1,022	223.62	45
	July-98	163	54	275	62.50	48
	August-98	166	0	635	99.66	48
	September-98	232	41	514	127.07	48
	October-98	62	14	202	45.71	24
	December-98	113	16	202	54.85	24
	January-99	85	10	345	82.89	24
	February-99	483	150	1,181	280.67	24
	March-99	143	0	334	84.07	24
	April-99	287	0	849	182.03	48
	May-99	725	141	1,511	349.39	48
	June-99	340	7	1,216	291.96	48
	July-99	189	29	681	126.79	46
	August-99	273	51	557	112.70	48

Appendix 3.2. Continued.

Taxa	Date	Number per L	Range	Standard deviation	Number of samples
Zooplankton	August-97	2	<1 4	1.20	24
	September-97	4	<1 14	3.64	48
	October-97	16	3 37	11.90	24
	December-97	6	1 14	3.77	24
	January-98	28	10 62	14.62	24
	February-98	17	10 25	3.62	24
	March-98	26	11 51	11.03	23
	April-98	27	6 76	18.85	48
	May-98	19	2 46	13.20	48
	June-98	12	1 44	10.33	45
	July-98	1	<1 4	0.61	48
	August-98	2	0 17	3.77	48
	September-98	5	1 14	3.12	48
	October-98	31	5 65	17.17	24
	December-98	26	10 37	7.42	24
	January-99	11	<1 60	14.73	24
	February-99	2	0 7	1.61	24
	March-99	8	2 25	6.40	24
	April-99	18	4 63	11.98	48
	May-99	20	1 48	12.04	48
	June-99	12	<1 81	18.61	48
	July-99	1	0 8	2.04	46
	August-99	1	<1 11	1.93	48

Appendix 3.2. Continued.

Taxa	Date	Number per L	Range	Standard deviation	Number of samples
Nauplii	August-97	8	2 40	7.55	24
	September-97	8	<1 36	7.98	48
	October-97	37	3 87	25.51	24
	December-97	7	2 17	3.72	24
	January-98	32	9 49	9.08	24
	February-98	29	20 49	8.09	24
	March-98	39	9 120	28.63	23
	April-98	62	13 170	36.46	48
	May-98	47	4 198	45.90	48
	June-98	23	1 109	17.25	45
	July-98	3	<1 19	3.66	48
	August-98	3	0 24	3.98	48
	September-98	8	1 24	4.53	48
	October-98	75	10 143	44.12	24
	December-98	58	9 98	22.24	24
	January-99	8	1 39	9.89	24
	February-99	8	2 20	4.99	24
	March-99	17	3 38	7.66	24
	April-99	60	5 511	72.87	48
	May-99	50	4 129	34.69	48
	June-99	30	1 173	40.51	48
	July-99	5	0 27	6.07	46
	August-99	5	<1 34	6.94	48

Appendix 3.3. Mean densities (n per L) of zooplankton taxa collected with vertical tows from 12 stations in Newton Lake using 0.5-m diameter, 63-µ mesh plankton nets. Samples (834) were collected during August 1997 through August 1999

Taxa	08/29/97	09/11/97	09/25/97	10/27/97	12/10/97	01/15/98	02/12/98	03/25/98	04/07/98	04/24/98	05/05/98
Bosminidae	0.01	0.01	0.00	0.54	1.35	4.14	1.95	5.31	7.27	6.93	9.11
Calanoid Copepod	0.10	0.39	0.81	11.38	3.36	18.76	10.80	12.82	13.57	13.30	10.00
Cyclopoid Copepod	0.28	0.67	1.47	2.19	0.36	2.05	1.43	1.69	4.18	2.83	3.00
Daphnia spp.	0.00	0.00	0.00	0.33	0.68	2.57	2.84	4.91	4.64	1.02	1.18
Diaphanosoma spp.	1.39	1.79	2.61	1.33	0.00	0.00	0.01	0.01	0.03	0.10	0.37
Leptodora kindti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daphnia lumholtzi	0.04	0.21	0.41	0.43	0.01	0.01	0.00	0.00	0.01	0.01	0.00
Other Cladocera	0.02	0.03	0.01	0.00	0.10	0.07	0.03	0.03	0.03	0.07	0.42
Others	0.02	0.01	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Total Zooplankton	**1.86**	**3.12**	**5.31**	**16.22**	**5.86**	**27.59**	**17.10**	**24.77**	**29.73**	**24.26**	**24.08**
Nauplii	7.76	8.31	8.34	36.58	7.24	32.50	29.26	37.19	59.34	64.64	75.02

Appendix 3.3. Continued.

Taxa	05/19/98	06/02/98	06/16/98	07/07/98	07/19/98	08/05/98	08/25/98	09/08/98	09/30/98	10/30/98	12/09/98
Bosminidae	2.77	0.09	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
Calanoid Copepod	8.05	4.94	9.71	0.18	0.09	0.49	0.03	0.26	0.78	18.62	21.50
Cyclopoid Copepod	0.58	0.38	0.74	0.15	0.13	2.05	0.15	0.98	0.51	5.51	0.60
Daphnia spp.	0.12	0.05	0.16	0.00	0.00	0.00	0.00	0.01	0.01	2.14	3.21
Diaphanosoma spp.	1.64	1.75	2.54	0.17	0.51	0.95	0.55	3.63	2.69	1.13	0.01
Leptodora kindti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daphnia lumholtzi	0.04	0.63	1.86	0.02	0.00	0.00	0.00	0.01	0.11	3.64	0.56
Other Cladocera	0.15	0.16	0.13	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.27
Total Zooplankton	**13.35**	**8.01**	**15.17**	**0.53**	**0.75**	**3.51**	**0.74**	**4.92**	**4.11**	**31.24**	**26.19**
Nauplii	18.54	21.14	22.43	2.41	4.32	4.01	2.23	7.79	8.02	74.79	58.03
Rotifera	370.5298	528.8198	217.0196	183.6111	141.8928	171.0278	161.9282	130.9985	332.8115	61.8512	112.8595

Appendix 3.3. Continued.

Taxa	01/23/99	02/12/99	03/19/99	04/15/99	04/24/99	05/04/99	05/20/99	06/02/99	06/19/99	07/07/99	07/24/99
Bosminidae	0.02	0.07	0.08	0.98	0.50	0.73	0.14	0.05	0.00	0.00	0.00
Calanoid Copepod	9.22	1.27	5.18	10.34	13.73	19.50	9.50	12.02	0.46	0.06	1.09
Cyclopoid Copepod	0.36	0.37	0.69	3.16	2.83	2.51	1.01	2.14	0.15	0.10	0.49
Daphnia spp.	1.32	0.45	2.24	3.08	0.93	0.39	0.16	0.13	0.00	0.00	0.00
Diaphanosoma spp.	0.04	0.04	0.02	0.44	0.22	1.38	3.46	6.09	0.17	0.10	0.62
Leptodora kindti	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daphnia lumholtzi	0.08	0.15	0.01	0.02	0.00	0.01	0.50	3.09	0.03	0.00	0.00
Other Cladocera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	0.13	0.10	0.06	0.17	0.07	0.17	0.14	0.58	0.01	0.00	0.08
Total Zooplankton	**11.20**	**2.44**	**8.28**	**18.19**	**18.28**	**24.67**	**14.92**	**24.10**	**0.82**	**0.27**	**2.29**
Nauplii	7.85	8.45	17.13	76.78	42.71	69.79	29.45	54.59	5.23	2.73	7.62
Rotifera	85.23	482.53	142.53	376.85	196.50	735.43	713.75	571.74	108.57	253.83	108.60

Appendix 3.3. Continued.

Taxa	08/10/99	08/26/99
Bosminidae	0.00	0.00
Calanoid Copepod	0.00	0.02
Cyclopoid Copepod	0.04	1.10
Daphnia spp.	0.00	0.00
Diaphanosoma spp.	0.36	0.98
Leptodora kindti	0.00	0.00
Daphnia lumholtzi	0.00	0.00
Other Cladocera	0.00	0.00
Others	0.03	0.05
Total Zooplankton	**0.44**	**2.15**
Nauplii	1.02	9.53
Rotifera	230.11	316.84

Chapter 4. Chlorophyll, Primary Productivity, and Phytoplankton (Primary Responsibility – Timothy Spier)

Introduction:

The primary producers are important to any ecosystem, as they are responsible for capturing sunlight, fixing carbon, and making this energy and biomass available to the other organisms in the ecosystem. In most aquatic ecosystems, the algae bear most of this responsibility. Algae are important in aquatic ecosystems not only because they capture sunlight and fix carbon, but also because they produce oxygen during photosynthesis. Thus, any stress which reduces the productivity of the phytoplankton can adversely affect the entire ecosystem. Conversely, stimulation of phytoplankton productivity can increase productivity of all trophic levels.

Operation of the Newton Lake generating station might influence the primary productivity of Newton Lake. An increase in discharge temperature as per the Newton Lake variance might reduce primary productivity by subjecting the phytoplankton to intolerable temperatures. Or, since phytoplankton are poikilothermic, an increase in discharge temperature might stimulate primary productivity by keeping the algae at their physiological optimum temperature for longer periods of time. Phytoplankton might be especially sensitive to increases in thermal loading as they have limited locomotion and thus limited ability to escape intolerable temperatures. Horizontal thermal clines may lead to horizontally stratified primary productivity.

Other than increasing temperature, the generating station might influence productivity in other ways. For example, entrainment of phytoplankton within the plant might affect primary productivity as phytoplankton might be subjected to mechanical, thermal, or chemical stress while traveling through the generating station.

High currents near the discharge might also influence productivity. An increase in current might increase turbidity in some segments, lowering productivity by limiting light or stimulating productivity by increasing the amount of available nutrients in the water column.

This study analyzed the effect that the Newton Lake generating station had on the primary productivity in Newton Lake. Data was collected on chlorophyll *a*, net rate of photosynthesis, and phytoplankton cell counts as well as factors which can influence these values, such as temperature, nutrients, light, and zooplankton.

Materials and Methods:

Sampling Sites

Newton Lake was divided into 4 segments (segment 1 = discharge, segment 4 = intake). Transects were established at the midpoint of each segment with 3 stations spaced equidistant from each other along the transect (Figure 4.1). All segments were sampled on the same day.

Euphotic Zone

The euphotic zone is defined as the upper portion of the water column in which oxygen evolution from photosynthesis exceeds oxygen consumption from phytoplankton respiration. In aquatic ecosystems, although much light hits the surface of the water, light is quickly attenuated with depth. At least 1% of the light incident to the surface of the water must be present to drive photosynthesis so that the plants produce more oxygen than they use up in respiration. Thus, the depth at which 1% of the incident light is present (the compensation point) is taken as the bottom of the euphotic zone. Below the compensation point more oxygen is used up by the plants than they produce.

A LiCor model LI-250 photometer with a spherical quantum sensor was used to measure the amount of light at the surface of the lake. Then, the sensor was lowered until a reading was obtained which was 1% of the incident light value. This depth was measured, and the process was repeated two more times. The average of these three measurements was considered the bottom of the euphotic zone. Euphotic zone depth was calculated once at each segment.

Nutrients

A composite water sample was obtained by combining samples taken at equal intervals from the surface to the compensation point. A 1 L water sample was obtained from one of the composite samples at each station of each segment, totaling 3 samples per segment per month. Samples were collected in acid washed bottles and kept on ice or at 4 C until being analyzed for nitrate, total ammonia, and total phosphorus. All analyses were performed within 48 hours of sampling except total phosphorus, which was performed within 20 days of sampling after samples were fixed with 2.0 ml of concentrated sulfuric acid.

All colormetric analyses were read using a Hach model DR / 3000 spectrophotometer. Methods were adapted from the Hach DR / 3000 procedures manual and from *Standard Methods for the Analysis of Water and Wastewater, 19th edition* (APHA 1995). Nitrate was determined using cadmium reduction. Ammonia was determined by Nesslerization. Total phosphorus concentrations were found using persulfate oxidation. For all chemical tests, samples of known concentration were run with each analysis for quality control.

Chlorophyll a

One - 300 ml water sample was obtained from each composite sample and immediately filtered through a Whatman GF – F filter. Under conditions of extremely high turbidity only 150 mLs was filtered. One ml of saturated $MgCO_3$ solution was added prior to filtration. The filter was immediately wrapped in foil, placed in a waterproof bag, and placed on ice. Upon return to the laboratory, the filters were ground with a Teflon - glass tissue grinder for 1 minute in 90%

acetone. The ground filter and acetone slurry was placed in a capped test tube and stored at 4 C in the dark for approximately 20 hours. Samples were then centrifuged, and the acetone supernatant placed in a 10 cm cell. Optical density was read at 664 nm with a spectrophotometer before acidifying the sample with 1 ml of 0.1 N HCl. Ninety seconds after acidification, the sample was again read at 665 nm. Application of the optical density before and after acidification allows us to determine the amount of chlorophyll *a* and pheophytin as well as the ratio of the optical density at 664 nm (OD 664) to the optical density at 665 nm (OD 665) . A specific absorption coefficient of 90 was used as reported in *Standard Methods for the Analysis of Water and Wastewater* (APHA 1995). Three composite water samples were obtained at each station, and there were 3 stations per segment, for a total of 9 chlorophyll *a* samples per segment per month.

Primary Production

Primary production was measured once per month in the middle station of each segment using dissolved oxygen changes and the light bottle – dark bottle (LB – DB) method. At least 3 water samples were obtained from within the euphotic zone using a 3.2 L acrylic water sampler. One sample was taken from the surface, one from the bottom of the euphotic zone, and the remaining samples were dispersed throughout the euphotic zone. Samples were transferred to one clear (LB), one opaque (DB), and one initial (IB) 300 ml BOD bottles. The LB and DB were resuspended at their initial depth from a floating platform, while the IB was used to determine initial dissolved oxygen concentration using a YSI model 50 – B oxygen meter with BOD probe. All bottles were kept in darkness until initiation of the experiment. Two series of LB's and DB's were sampled each month at each segment.

Once resuspended, each series of bottles remained in the water for several hours. Peak light occurs during the interval 10:00 – 14:00 hours, thus all samples were obtained as near to this period as possible. Incident light data was collected from sunup to sundown to create a profile of diurnal light.

At the termination of the sample period, final oxygen concentration was determined for each bottle.Net photosynthesis was calculated at each sampling depth by subtracting the initial oxygen concentration from the final oxygen concentration. These values (in mg O_2 L^{-1}, equal to g O_2 m^{-3}) were plotted against depth (in m), a quadratic function was fitted to the data, and this curve was integrated from the surface to the compensation point to estimate the total production in the euphotic zone under 1 m^2 of surface water. Daily light data (in μE m^{-2} s^{-1}) was also plotted against time (in s) and integrated from sunup to sundown to obtain total incident light per m^2 of surface area. Integrating this curve for the sample period for each segment gave the total light per m^2 of surface during the sample period. By comparing the total light hitting the surface during the sample period to the total light hitting the surface during the entire day, a scaling factor was calculated which was used to adjust each segment's productivity to reflect the entire day's production. In this way, differences in light during each segment's incubation period do not influence productivity estimations. This procedure does not properly adjust negative net photosynthesis values. More appropriate adjustments were investigated but did not appear to impact the negative net photosynthesis values. Daily production values were converted from g O_2 m^{-2} day^{-1} to mg C m^{-2} day^{-1} by multiplying by 1000 (to convert to mg O_2 m^{-2} day^{-1}), then multiplying by 0.375 (12 g mol^{-1} C / 32 g mol^{-1} O_2) and dividing by 1.2 (the photosynthetic quotient) (Cole 1994).

Phytoplankton Cell Counts

A 1 L water sample for phytoplankton cell counts was obtained from two of the composite samples at each station of each segment, totaling 6 samples per segment per sampling trip. Samples were collected bi – monthly from April – September and every six weeks from October – March.

Samples were preserved in 1.0 ml buffered Lugol's solution per 100 ml sample solution. Samples were appropriately labeled, stored in amber bottles, and returned to the laboratory. Phytoplankton were allowed to settle in graduated cylinders for 2 days, after which the top 900 mls of sample were poured off, leaving approximately 100 mls of concentrated sample. This sample contained all the phytoplankton originally present in the 1 L water sample. A 2 ml subsample was drawn from this concentrated sample and allowed to settle in a sedimentation chamber equipped with a Whipple ocular micrometer. Phytoplankton were enumerated using an inverted compound Wild microscope. In addition, samples of live phytoplankton were frequently brought back to the laboratory to aid in the identification of the preserved specimens.

Phytoplankton were enumerated to the lowest taxon possible. Cell counts are reported in numbers L^{-1}. A total of 5 fields were counted per subsample, and 2 subsamples were enumerated from each concentrated sample. Mean number of phytoplankters per field was determined for each subsample. The field area was compared to the sedimentation chamber area to determine the number of cells per sedimentation chamber, and thus the number of cells in a 2 ml subsample. This number was multiplied by the volume of the concentrated sample to obtain the number of cells per concentrated sample, which, due to our settling procedure, is equal to the number of cells per liter of lake water. Averaging this value over 2 subsamples for each taxon gave the mean number of cells per liter for a sample. Summing the mean number of cells per liter for all taxa gave the mean total cell count per sample.

Reference literature included Tiffany and Britton (1992), Prescott (1962), and Smith (1950).

Statistical Analyses

Values of chlorophyll *a*, OD 664 / OD 665 ratio (hereafter referred to as OD ratio), daily net photosynthesis, and phytoplankton cell count were compared between segments after partitioning out the date and segment * date interaction using SAS general linear model procedures (SAS Institute 1995). Univaritate plots were created to check for outliers and to obtain an understanding of the general relationship between variables. Assumptions of normality and homogeneity of variance were investigated by comparing within – group sample sizes and variances; all comparisons had large, nearly equal sample sizes, and group variances were similar for all comparisons. Under these conditions, analysis of variance is robust in relation to normality and homogeneity assumptions. Frequency distributions of the standardized residuals were plotted to visually check for normality of the residuals. Standardized residuals were also plotted against predicted values to visually check for homoscedasticity. Transformations of the data were performed when necessary. Significant segment effects were investigated using Scheffe's post hoc test. All tests were performed at $\alpha = 0.05$.

Several linear regressions were also performed using data from this experiment. Similar methids were used to check assumptions of linearity, homoscedasticity, and normality.

Results:

Nutrients

Mean values with 95% confidence intervals of nitrate, ammonia, and total phosphorus by segment for each sampling date are given in Tables 4.1 – 4.3. Mean values with 95% confidence intervals of nitrate, ammonia, and total phosphorus for each segment are given in Tables 4.4 – 4.6. Tables 4.4 – 4.6 also contain results from the statistical comparison of segments.

On March 29, 1998, extremely high turbidity levels in segment 1 led to high total phosphorus levels. Since the phosphorus in these samples was likely unavailable to phytoplankton, these values were considered outliers and were excluded from statistical analyses.

Ammonia values are reported in mg L^{-1} NH_3. However, no measurement was made of temperature or pH of the lake water at the time of sampling, so we were unable to determine what percentage of the ammonia was in the un – ionized form. At 30 C and pH = 7 only 0.8% of the total ammonia nitrogen (TAN) is expected to be in the toxic NH_3 form, but as temperature remains at 30 C and pH increases to 8, 8% of the TAN becomes toxic, and at pH = 9 44% of the TAN is in the un – ionized form. Ameren – CIPS periodically measured pH in Newton Lake as part of the routine water quality sampling; several times during 1999 pH was measured greater than 8 with a high of 8.62.

Segments had significanlty different levels of nitrate after controlling for the date and the date * segment interaction (omnibus R^2 = 94.9%, segment effect p value = 0.0209). However, post hoc tests did not produce a clear pattern of differences among segments. Segment 1 had the highest nitrate values and was significantly different from segment 4, which had the lowest nitrate values. Segments 2 and 3 had values in between segments 1 and 4 and were not significantly different from either of these segments.

Segments had significantly different levels of ammonia after controlling for the date and the date * segment interaction (omnibus R^2 = 96.1%, segment effect p value = 0.0001). All segments were significantly different from each other. Ammonia levels were highest in segment 1 and decreased as water travelled around the lake to segment 4.

Segments had significantly different levels of total phosphorus after controlling for the date and the date * segment interaction (omnibus R^2 = 87.9%, segment effect p value = 0.0001). Total phosphorus levels were highest in segment 1 and decreased as water travelled around the lake to segment 4. Segment 4 was significantly lower than all other segments, and segment 1 was significantly higher than all segments other than segment 2. Segments 2 and 3 were not different from each other.

Chlorophyll a

Mean values with 95% confidence intervals of chlorophyll *a*, OD ratio, and pheophytin *a* are given in Tables 4.7 – 4.9. Mean values with 95% confidence intervals of chlorophyll *a* and OD 664 / OD 665 ratio for each segment are given in Tables 4.10 and 4.11. Tables 4.10 and 4.11 also contain results from the statistical comparison of segments. Values of chlorophyll *a* and OD ratio for each segment are also represented graphically in Figures 4.2 and 4.3.

Segments had significantly different chlorophyll *a* values after controlling for the date and the date * segment interaction (omnibus R^2 = 94.6%, segment effect p value = 0.0001). Chlorophyll *a* levels were lowest in segment 1, peaked in segments 2 and 3, and were lower in segment 4.

Similar effects were found for the OD ratio. Segments were significantly different after controlling for the date and the date * segment interaction (omnibus R^2 = 92.8%, segment effect p value = 0.0001). The OD 664 / OD 665 distribution in Newton Lake mimiced the chlorophyll *a* pattern. Comparing Figures 4.2 and 4.3 suggests that chlorophyll *a* levels and OD ratios are tightly linked. In fact, the Pearson correlation coefficient between chlorophyll *a* and OD ratio was $r = 0.88494$ ($p = 0.0001$), suggesting that chlorophyll *a* levels are driving the OD ratio.

Primary Productivity

Mean values with 95% confidence intervals of net photosynthesis are given in Table 4.12. Mean values with 95% confidence intervals of net photosynthesis for each segment are given in Table 4.13. Table 4.13 also contains results from the statistical comparison of segments. Values of net photosynthesis for each segment are also represented graphically in Figure 4.4.

Segments had significantly different net photosynthesis levels after controlling for the date and the date * segment interaction (omnibus $R^2 = 98.7\%$, segment p value = 0.0001). The pattern for net photosynthesis was similar to the chlorophyll *a* pattern: segment 1 was significantly lowest, segments 2 and 3 were significantly highest, and segment 4 had intermediate levels of net photosynthesis.

Phytoplankton Cell Counts

Initial calculations of total phytoplankton counts indicated that densities were much higher than normally found in the literature. Further investigation showed that the total cell counts were dominated by the extremely small Coccoid single phytoplankters (Division Cyanophyta, Order Chroococcales) which on average made up approximately 75% of the total cell counts. Consequently, this group was analyzed seperately from all other phytoplankton taxa. Removal of the Coccoid singles reduced the total cell counts to levels more similar to other studies (Moran 1981). It is unknown if other studies include the Coccoid singles in their numbers. Since the Coccoid singles are so small, conversion of phytoplankton numbers to biomass or biovolume might demphasize this taxon.

Mean values with 95% confidence intervals of total phytoplankton counts for Coccoid singles and other taxa are given in Tables 4.14 and 4.15. Mean values with 95% confidence intervals of total phytoplankton counts for Coccoid singles and other taxa for each segment are given in Tables 4.16 and 4.17. Tables 4.16 and 4.17 also contain results from the statistical comparison of segments. Values of total phytoplankton counts for Coccoid singles and other taxa for each segment are also represented graphically in Figures 4.5 and 4.6.

Segments had significanlty different mean total numbers of Coccoid single phytoplankton cells after controlling for the date and the date * segment interaction (omnibus R^2 = 83.6%, segement effect p value = 0.0001). Segment 1 had significanlty higher Coccoid single numbers than the other segments, while segment 3 had significanly lower Coccoid single numbers than the other segments. Segments 2 and 4 has similar Coccoid single numbers. Further analysis of the standardized residuals from this procedure suggested that the data needed to be transformed. Log base 10 transformation of the Coccoid single numbers improved the distribution of the standardized residuals without changing the pattern of the results (omnibus R^2 = 72.9%, segment effect p value = 0.0001).

Segments did not differ in mean total numbers of phytoplankton cells (Coccoid singeles excluded) after controlling for the date and the date * segment interaction (omnibus R^2 = 72.4%, segement effect p value = 0.4576). Further analysis of the standardized residuals from this procedure suggested that the data needed to be transformed. Log base 10 transformation of the total phytoplankton numbers improved the distribution of the standardized residuals. Segments had significantly different log of total phytoplankton numbers after controlling for the date and the date * segment interaction (omnibus R^2 = 73.8%, segment effect p value = 0.0286). Log of total phytoplankton count was no different for segments 1, 2, and 4, while segment 3 was significantly lower than the other 3.

Discussion:

Nutrients

Water samples were obtained from the composite samples used in chlorophyll analysis. These samples were analyzed for ammonia, nitrate, and total phosphorus. Ammonia and nitrate can be important sources of nitrogen for phytoplankton, while phosphorus is often the limiting nutrient in freshwater ecosystems and thus total phosphorus levels can influence primary production.

Ammonia, nitrate, and total phosphorus concentrations were typical for midwestern reservoirs. Hoyer and Jones (1983) reported total phosphorus levels in 96 reservoirs in Missouri and Iowa ranged from 0.0052 - 0.2653 mg L^{-1} with a mean of 0.0384 mg L^{-1} ; total nitrogen ranged from 0.3 – 3.4 mg L^{-1} with a mean of 0.7 mg L^{-1} . Mean surface total phosphorus ranged from 0.008 – 0.145mg L^{-1} and nitrate ranged from 0.02 – 0.11 mg L^{-1} across 7 cooling reservoirs in the southeast U.S. (Mallin et al. 1994). Newton Lake total phosphorus mean value was 0.201 mg L^{-1} PO_4. Mean total inorganic nitrogen in Newton Lake was 1.514 mg L^{-1} NO_3 + NH_3, which does not include organic forms of nitrogen. Mean nitrate for Newton Lake was 1.195 mg L^{-1} NO_3 while mean ammonia was 0.319 mg L^{-1} NH_3.

While some overlap exists between segments for nutrient levels, a general pattern is evident. Nutrients are generally highest in segments 1 and 2 and decrease in the cooler segments 3 and 4. No information is available concerning the watershed for different segments of the lake; however, considering that segments 1 and 2 comprise the west arm of Newton Lake and segments 3 and 4 comprise the east arm of the lake, it is not surprising that nutrient levels were similar for segments 1 and 2 and segments 3 and 4. Anectdotal evidence suggests that segment 1 receives a great deal of agricultural runoff which carries a high sediment load. High sediment levels in this segment likely influenced the high total phosphorus levels in segment 1.

Chlorophyll a

Missouri and Iowa reservoirs had a mean chlorophyll *a* concentration of 0.0170 mg L^{-1} and the range was 0.0007 – 0.1422 mg L^{-1} (Hoyer and Jones 1983). For 7 southeastern U.S. cooling reservoirs, chlorophyll *a* ranged from 0.0032 – 0.0766 mg L^{-1} (Mallin et al. 1994). In this study, Newton Lake mean chlorophyll *a* was 0.0156 mg L^{-1} .

Results from this study indicate that chlorophyll *a* levels were depressed in the warm water near the discharge, increased to a maximum in the slightly cooler water near the boat ramp (segments 2 and 3), then decreased in the cool water arm (segment 4). These results suggest that algal productivity was lowest in the discharge water and stimulated in the next segment before falling to intermediate levels in the coolest arm. Several factors could influence chlorophyll *a* levels and lead to the differences seen between segments. Such factors include nutrient concentrations, light availability, herbivore densities, water temperature, and stress as algae travel through the power plant,.

As noted above, nutrient levels were highest in segment 1, but chlorophyll *a* was lowest in this segment, suggesting that chlorophyll *a* is influenced less by nutrients and more by other factors discussed below.

Available light can also affect photosynthesis and thus chlorophyll *a*. Total incident light was considered equal for all segments; however, differences in turbidity can affect the amount of light available in the water column. Although turbidity was not measured directly, depth of the euphotic zone can be used to investigate the extent of turbidity in the water. Segment 1, with the lowest chlorophyll *a* levels, also had significantly lower mean euphotic zone depth than the other segments (Table 4.18). Along with the already mentioned high turbidity during precipitation events, the high current due to the proximity of the discharge might also increase abiogenic turbidity in segment 1. Note that this measure of turbidity is affected by both biogenic and abiogenic factors. For example, an algae bloom can decrease light penetration, as can an increase in suspended solids.

Herbivore (zooplankton) density has been shown to control plankton productivity in a "top down" manner (Carpenter and Kitchell 1993). Since herbivores were expected to have a more direct influence on phytoplankton numbers than chlorophyll *a* values, the effect of zooplankton on primary productivity will be discussed with the total cell numbers.

Central to this study is the effect increased temperature will have on productivity. The significanly different chlorophyll *a* levels found in the segments, which also differ in temperature, implies that temperature is influencing primary productivity to some extent. To further investigate the effect of temperature, data from the temperature loggers (see Job 15) were compared to chlorophyll *a* levels for each segment. Since sampling sites were located several hundred meters upstream from the nearest loggers for each segment, a regression equation was developed which adjusted the temperature logger data to reflect the cooling of the water as it passed from the sampling site to the logger buoy. To create the equation, data from the temperature profiles (which were obtained at the sampling site) were matched with the appropriate logger data. Temperature data from different depths of the profile was paired with surface logger data taken within ½ hour of the profile data, allowing the regression to predict the temperature at any depth at the sampling site given the temperature taken from the nearest surface logger. A similar equation was developed using data from the logger located at 1.5

meters. Note that adjusting temperature in this manner will not influence statistical analyses in any way. The temperature was adjusted in order to create a more intuitively understandable relationship between chlorophyll *a* and temperature. Also, the temperature loggers often malfunctioned, and by creating two seperate equations using the surface and 1.5 meter loggers allowed for more complete sample day coverage.

For chlorophyll *a* analysis, mean daily temperature for the midpoint of the euphotic zone on the sample date was compared to mean chlorophyll *a* levels for each segment. Figure 4.7 graphically compares chlorophyll *a* and mean daily euphotic temperature. Linear regression analysis shows that there was no relationship between chlorophyll *a* and mean euphotic temperature (R^2 = 0.2 %, p value = .6391). Since it was expected that chlorophyll *a* levels would increase with increasing temperature but then decrease once temperature levels became too high, a second regression was developed which compared chlorophyll *a* to the square of temperature; however, this regression was also not significant. Phytoplankton likely require some time to synthesize chlorophyll *a*, so comparisons were made between chlorophyll *a* and mean euphotic temperature for several days prior to the sampling date. No relationship was found with temperatures up to 1 week in advance of sampling.

Previous studies have suggested that phytoplankton are subjected to several stresses as they travel through a power plant. Mechanical, chemical, and thermal stress all can affect the algae (Morgan and Stross 1969). Segment 4, at the intake, had significantly higher chlorophyll *a* levels than segment 1, which lies below the discharge. Destruction of the plankton as they travel through the plant could lead to the lower chlorophyll *a* levels in segment 1 and also might lead to the increased nutrient levels in this segment due to leaching from damaged cells. However, it is not known how many phytoplankters are actually entrained in the plant. The sampling station in segment 1 is several hundred meters from the discharge, and while high currents in this segment might carry phytoplankton a long distance, it is not known if the samples taken there contained phytoplankton that actually traveled through the plant.

OD Ratio

The OD ratio is used as an indicator of the physiological condition of the phytoplankton. This ratio ranges from 1.0 to 1.7 (using 90% acetone), with larger values indicating better physiological condition. The OD ratio was lowest in segment 1, highest in segments 2 and 3, and in between in segment 4 (Table 4.11). Thus, the algae in the coolest portion of the lake did not have the highest OD ratio. The OD ratio pattern mirrored that of chlorophyll *a*. Theoretically, chlorophyll *a* levels could be high while the OD ratio was low, for example if a large number of phytoplankton were present which were in poor physiological condition. However, the previously mentioned strong correlation between chlorophyll *a* and OD ratio suggests that the OD ratio might not provide any information beyond that given by chlorophyll *a* levels.

Net Photosynthesis

Both chlorophyll *a* and net photosynthesis rates are important to understanding primary productivity in lake ecosystems. Most of the above discussion concerning chlorophyll *a* can also be applied to net photosynthesis

Data obtained from the light bottle – dark bottle (LB – DB) experiments can give rates of respiration, net photosynthesis, and gross photosynthesis. Respiration might be a useful number, as poikilothermic organisms can be expected to increase their metabolism as temperature increases. However, respiration as measured in the LB – DB experiment includes not only algal but also zooplankton and bacterial respiration.

Of net and gross photosynthesis, net photosynthesis is an indicator of the biomass and energy made available for higher trophic levels. Thus, when discussing primary productivity this report only discusses the net photosynthesis rates in Newton Lake.

Mean daily productivity for Newton Lake was 944 mg C m^{-2} day^{-1}, which is considered nearly eutrophic by Kimmel et al. (1990). Mean production values calculated with the oxygen evolution method for several North American lakes are compared to Newton Lake in Table 4.19. Newton Lake productivity fell nearly in the middle of the range of productivities given in Table 4.19.

Photosynthesis values followed the same pattern as chlorophyll *a*: lowest at the warm segment, highest in the next two segments, and intermediate values in segment 4. Again, possible influences on productivity include nutrients, light, herbivores, temperature, and entrainment stress. However, not all of these factors were expected to influence the net photosynthesis rates. Herbivore density and entrainment stress did not likely affect the photosynthesis measurements due to the relatively short time scale of this experiment.

Light levels as measured by euphotic zone depths were expected to affect photosynthesis values as the euphotic depth is used to create these values. Indeed, mean euphotic zone depths varied in an expected manner with net photosynthesis values. Segments with deeper euphotic zones tended to have higher net photosynthesis values. This effect is most likely due to the fact that photosynthetic rates are integrated over a greater depth in segments with more clear water.

Mean euphotic temperature was determined for productivity samples in the same way it was determined for chlorophyll *a* samples. Since net photosynthesis values were extrapolated for an entire day, mean daily temperature was once again used. Mean euphotic zone temperature and net photosynthesis are compared graphically in Figure 4.8. Linear regression analysis showed that temperaature had a significant, positive relationship with net photosynthesis (R^2 = 36.3 %, p value = 0.0001). Analysis of residuals and univariate plots suggested that a transformation was appropriate, but several different transformations did not improve the regression.

Phytoplankton Cell Count

In the following discussion of phytoplankton cell counts, all references to "cell counts" or phytoplankton relate to all phytoplankton enumerated except the Coccoid singles group which was excluded from analyses because of its undue influence on total cell numbers.

Mean phytoplankton numbers per liter were determined by Division in order to compare the green (Division Chlorophyta) and blue – green (Division Cyanophyta) algae. These two Divisions made up the majority of the total phytoplankton cell counts. Mean values for each Division are represented graphically in Figure 4.9. Comparison of Figure 4.9 to Figure 4.6 shows that the summer bloom of algae, which occured in June of 1998 and May of 1999, is comprised mostly of blue – green algae, while the winter bloom that was observed in January of 1999 was made up of green algae.

There existed no difference among segment mean total cell counts although segments differed in both chlorophyll *a* and net photosynthesis values. Linear regression analysis found no relationship between total phytoplankton cells and chlorophyll *a* levels (R^2 = 2.1%, p value = 0.3480) or net photosynthesis (R^2 = 1.9%, p value = 0.3478). Since each segment had the same number of phytoplankters but segments 1 and 4 had lower productivity, factors such as temperature and light availabilty are very likely influencing rates of primary production. Herbivorous zooplankton were expected to influence cell counts more directly than they would influence chlorophyll *a* or net photosynthesis, so mean zooplankton density was compared to phytoplankton cell counts. Rotifers and nauplii were excluded from this analysis since larger

Cladocerans and Copepods have a greater effect on phytoplankton (Carpenter et al. 1993). A linear regression comparing mean phytoplankton cell count and mean zooplankton density was not significant (R^2 = 0.3%, p value = 0.6394).

To estimate the relative photosynthetic efficiency of the phytoplankton, mean net photosynthesis and mean chlorophyll *a* per phytoplankton cell per liter were calculated. Values for mean net photosynthesis were in mg C m^{-2} day^{-1}, while values for phytoplankton counts were in cells L^{-1}, so mean net photosynthesis per cell per liter has the units mg C L m^{-2} day^{-1} $cell^{-1}$. Values for chlorophyll *a* were in μg chlorophyll *a* L^{-1}, so values for chlorophyll *a* per cell per liter has the units μg chlorophyll *a* $cell^{-1}$. These values are represented graphically in Figures 4.10 and 4.11.

Summer Comparisons

The fish kill in July of 1999 stimulated an interest in comparing productivity between summer of 1998 and summer of 1999. Specifically, July and August values for chlorophyll *a*, OD ratio, net photosynthesis, and total cell counts were combined for all segments and compared between years. Comparisons were also made between years within each month.

Tables 4.20 and 4.21 give mean values of chlorophyll *a* and OD ratio for summer 1998 and summer 1999. These tables also give results from the statistical comparison between years. Chorophyll *a* values did not differ between summer 1998 and summer 1999 (R^2 = 0.6%, p value = 0.3623) while OD ratio was significanlty higher during summer 1998 (R^2 = 9.6%, p value = 0.0002) although this model did not account for much of the OD ratio variability. Within month comparisons showed that both chlorophyll *a* and OD ratio were significantly higher in July 1998 than in July 1999 (R^2 = 79.9%, p value = 0.0001 for chlorophyll *a*, R^2 = 68.9%, p value = 0.0001 for OD ratio) and each was significantly lower in August 1998 than in August 1999 (R^2 =

68.1%, p value = 0.0001 for chlorophyll *a*, R^2 = 16.5%, p value = 0.0005 for OD ratio) (Tables 4.22 and 4.23).

Table 4.24 gives mean values of net photosynthesis for summer 1998 and summer 1999. This table also give results from the statistical comparison between years. Net photosynthesis values did not differ between summer 1998 and summer 1999 (R^2 = 0.0%, p value = 0.8379). Within month comparisons also showed that net photosynthesis was not different between 1998 and 1999 for July (R^2 = 0.0%, p value = 0.9008) or August (R^2 = 0.0%, p value = 0.7578) (Table 4.25). Low sample size and high variability of the dependent variable likely limited the power of this test.

Table 4.26 gives mean values of total phytoplankton cell counts for summer 1998 and summer 1999. This table also give results from the statistical comparison between years. Total phytoplankton cell counts were significanlty higher in summer 1998 than in summer 1999 (R^2 = 16.4%, p value = 0.0001). Within month comparisons also showed that phytoplankton cell counts were significantly higher in 1998 than in 1999 for July (R^2 = 16.9%, p value = 0.0037) and August (R^2 = 23.2%, p value = 0.0005) (Table 4.27). Note that although cell counts were lower during summer 1999, net photosynthesis remained the same, most likely due to the deeper euphotic zone in 1999 (Figure 4.12).

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Table 4.1 Mean euphotic zone nitrate concentration with confidence intervals (C. I.) from Newton Lake. Values are in mg / L NO_3. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.	n	Segment 2 95 % C. I.	n	Segment 3 95 % C. I.	n	Segment 4 95 % C. I.	n
09/25/97	0.98 ± 2.17	2	0.94 ± 1.53	2	0.88 ± 0.90	2	0.91 ± 0.54	2
10/29/97	.		.		.		.	
11/19/97	0.57 ± 0.45	3	0.69 ± 0.63	3	0.92 ± 0.18	3	0.88 ± 0.34	3
12/18/97	0.54 ± 0.59	3	0.28 ± 0.30	3	0.59 ± 0.12	3	0.63 ± 0.46	3
01/31/98	1.16 ± 0.49	3	1.12 ± 0.20	3	1.18 ± 0.04	3	1.16 ± 0.15	3
02/21/98	1.18 ± 0.35	3	1.49 ± 0.55	3	1.24 ± 0.22	3	1.03 ± 0.26	3
03/29/98	.		0.70 ± 0.06	3	0.87 ± 0.11	3	0.53 ± 0.18	3
04/24/98	0.77 ± 0.23	3	0.87 ± 0.39	3	0.92 ± 0.15	3	1.02 ± 0.61	3
05/20/98	1.06 ± 0.06	3	0.94 ± 0.28	3	1.08 ± 0.20	3	1.07 ± 0.34	3
06/26/98	1.03 ± 0.04	3	0.99 ± 0.09	3	1.01 ± 0.22	3	1.02 ± 0.41	3
07/19/98	0.67 ± 0.45	3	0.87 ± 0.57	3	0.71 ± 0.57	3	0.67 ± 0.14	3
08/25/98	0.98 ± 0.17	3	0.96 ± 0.75	3	1.09 ± 0.41	3	0.92 ± 0.10	3
09/30/98	1.05 ± 1.23	3	0.77 ± 0.19	3	1.45 ± 0.57	3	0.93 ± 0.25	3
10/30/98	1.07 ± 0.54	3	0.86 ± 0.29	3	0.91 ± 0.54	3	0.98 ± 0.52	3
11/24/98	1.76 ± 0.41	3	1.75 ± 0.53	3	1.84 ± 0.17	3	1.74 ± 0.23	3
12/18/98	2.04 ± 0.34	3	2.06 ± 0.37	2	1.86 ± 1.86	2	1.46 ± 0.97	3
02/20/99	3.28 ± 0.73	3	3.10 ± 0.49	3	3.20 ± 0.28	3	3.37 ± 0.80	3
03/19/99	3.48 ± 1.22	3	3.73 ± 1.04	3	3.22 ± 0.25	3	3.12 ± 0.34	3
04/24/99	1.66 ± 0.16	3	1.62 ± 0.21	3	1.61 ± 0.12	3	1.78 ± 0.24	3
05/20/99	0.96 ± 0.32	3	0.80 ± 0.39	3	0.79 ± 0.13	3	0.62 ± 0.11	3
06/19/99	1.05 ± 0.05	3	0.95 ± 0.08	3	0.87 ± 0.10	3	0.96 ± 0.22	3
07/24/99	0.67 ± 0.78	3	0.61 ± 0.35	3	0.70 ± 0.64	3	0.87 ± 0.14	3
08/26/99	1.19 ± 0.70	3	1.10 ± 0.19	3	1.05 ± 0.46	3	0.87 ± 0.76	3
09/28/99	1.05 ± 0.94	3	1.20 ± 0.27	3	0.64 ± 0.95	3	0.69 ± 1.08	3
10/29/99	0.97 ± 0.53	3	0.89 ± 1.24	3	0.84 ± 0.55	3	0.61 ± 0.22	3
11/23/99	0.74 ± 0.52	3	0.69 ± 0.53	3	0.91 ± 0.40	3	0.55 ± 0.89	3
12/21/99	1.42 ± 0.45	3	1.26 ± 0.55	3	1.20 ± 0.29	3	1.16 ± 0.43	3
01/20/00	1.17 ± 0.24	3	0.85 ± 0.79	3	1.00 ± 0.23	3	1.12 ± 0.17	3

Table 4.2. Mean euphotic zone total ammonia nitrogen concentration with confidence intervals (C. I.) from Newton Lake. Values are reported in mg / L NH_3. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.	n	Segment 2 95 % C. I.	n	Segment 3 95 % C. I.	n	Segment 4 95 % C. I.	n
09/25/97	0.21 ± 0.01	2	0.16 ± 0.47	2	0.18 ± 0.51	2	0.19 ± 0.55	2
10/29/97	0.42 ± 0.08	3	0.44 ± 0.17	3	0.59 0.17	3	0.53 0.11	3
11/19/97	0.28 ± 0.01	3	0.28 ± 0.05	3	0.28 ± 0.05	3	0.30 ± 0.10	3
12/18/97	0.23 ± 0.04	3	0.23 ± 0.05	3	0.19 ± 0.02	3	0.18 ± 0.04	3
01/31/98	0.27 ± 0.02	3	0.24 ± 0.01	3	0.26 ± 0.05	3	0.26 ± 0.01	3
02/21/98	0.53 ± 0.07	3	0.51 ± 0.11	3	0.47 ± 0.05	3	0.24 ± 0.01	3
03/29/98	0.63 ± 0.05	3	0.49 ± 0.11	3	0.47 ± 0.08	3	0.42 ± 0.06	3
04/24/98	0.40 ± 0.04	3	0.31 ± 0.03	3	0.29 ± 0.05	3	0.28 ± 0.04	3
05/20/98	0.51 ± 0.51	2	0.40 ± 0.05	3	0.31 ± 0.01	3	0.31 ± 0.04	2
06/26/98	0.42 ± 0.16	3	0.42 ± 0.09	3	0.35 ± 0.04	3	0.32 ± 0.05	3
07/19/98	0.40 ± 0.04	3	0.35 ± 0.03	3	0.30 ± 0.01	3	0.29 ± 0.03	3
08/25/98	0.32 ± 0.04	3	0.28 ± 0.05	3	0.22 ± 0.05	3	0.25 ± 0.03	3
09/30/98	0.34 ± 0.07	3	0.29 ± 0.07	3	0.23 ± 0.02	3	0.23 ± 0.02	3
10/30/98	0.37 ± 0.04	3	0.26 ± 0.01	3	0.25 ± 0.02	3	0.24 ± 0.03	3
11/24/98	0.28 ± 0.03	3	0.25 ± 0.02	3	0.26 ± 0.04	3	0.23 ± 0.00	3
12/18/98	0.29 ± 0.02	3	0.33 ± 0.32	2	0.27 ± 0.04	2	0.24 ± 0.02	3
02/20/99	0.46 ± 0.17	3	0.40 ± 0.03	3	0.37 ± 0.01	3	0.42 ± 0.04	3
03/19/99	0.54 ± 0.04	3	0.53 ± 0.01	3	0.54 ± 0.02	3	0.51 ± 0.01	3
04/24/99	0.40 ± 0.02	3	0.36 ± 0.11	2	0.31 ± 0.02	3	0.37 ± 0.03	3
05/20/99	0.47 ± 0.05	3	0.35 ± 0.03	3	0.30 ± 0.01	3	0.28 ± 0.02	3
06/19/99	0.36 ± 0.03	3	0.30 ± 0.03	3	0.27 ± 0.03	3	0.27 ± 0.06	3
07/24/99	0.29 ± 0.01	3	0.30 ± 0.10	3	0.23 ± 0.03	3	0.23 ± 0.03	3
08/26/99	0.32 ± 0.02	3	0.27 ± 0.01	3	0.23 ± 0.03	3	0.24 ± 0.01	3
09/28/99	0.29 ± 0.03	3	0.28 ± 0.01	3	0.28 ± 0.00	3	0.28 ± 0.01	3
10/29/99	0.32 ± 0.02	3	0.31 ± 0.04	3	0.27 ± 0.03	3	0.26 ± 0.06	3
11/23/99	0.31 ± 0.07	3	0.23 ± 0.05	3	0.24 ± 0.07	3	0.21 ± 0.01	3
12/21/99	0.34 ± 0.07	3	0.31 ± 0.04	3	0.28 ± 0.04	3	0.25 ± 0.03	3
01/20/00	0.32 ± 0.07	3	0.28 ± 0.03	3	0.23 ± 0.00	3	0.23 ± 0.01	3

Table 4.3. Mean euphotic zone total phosphorus concentration with confidence intervals (C. I.) from Newton Lake. Values are in mg / L PO_4. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.	n	Segment 2 95 % C. I.	n	Segment 3 95 % C. I.	n	Segment 4 95 % C. I.	n
09/25/97	0.23 ± 0.10	2	0.18 ± 0.03	2	0.17 ± 0.09	2	0.17	1
10/29/97	0.19 ± 0.01	3	0.19 ± 0.02	3	0.17 ± 0.01	3	0.17 ± 0.03	3
11/19/97	0.13 ± 0.01	3	0.15 ± 0.04	3	0.13 ± 0.01	3	0.10 ± 0.04	3
12/18/97	0.13 ± 0.00	3	0.10 ± 0.00	3	0.11 ± 0.01	3	0.10 ± 0.01	3
01/31/98	0.16	1	0.15 ± 0.06	3	0.16 ± 0.09	3	0.14 ± 0.10	3
02/21/98	0.42 ± 0.13	3	0.40 ± 0.05	3	0.40 ± 0.04	3	0.14 ± 0.02	3
03/29/98	1.44 ± 0.03	3	0.40 ± 0.01	3	0.38 ± 0.01	3	0.32 ± 0.02	3
04/24/98	0.25 ± 0.09	3	0.27 ± 0.01	3	0.23 ± 0.06	3	0.21 ± 0.05	3
05/20/98	0.38 ± 0.03	3	0.32 ± 0.02	3	0.26 ± 0.03	3	0.26 ± 0.01	3
06/26/98	0.20 ± 0.13	3	0.16 ± 0.11	3	0.13 ± 0.17	2	0.06 ± 0.35	2
07/19/98	0.25 ± 0.03	3	0.23 ± 0.03	3	0.18 ± 0.01	3	0.17 ± 0.03	3
08/25/98	0.21	1	0.17 ± 0.11	2	0.17 ± 0.02	3	0.12 ± 0.10	3
09/30/98	0.20 ± 0.02	3	0.11 ± 0.64	2	0.16 ± 0.28	3	0.12 ± 0.01	3
10/30/98	0.30 ± 0.06	3	0.26 ± 0.01	3	0.22 ± 0.10	3	0.24 ± 0.02	3
11/24/98	0.16 ± 0.01	3	0.13 ± 0.03	3	0.14 ± 0.04	3	0.13 ± 0.03	3
12/18/98	0.12 ± 0.06	3	0.14 ± 0.07	2	0.12 ± 0.09	2	0.10 ± 0.01	3
02/20/99	0.34 ± 0.50	3	0.33 ± 0.14	3	0.32 ± 0.41	3	0.37 ± 0.33	3
03/19/99	0.46 ± 0.03	3	0.45 ± 0.04	3	0.44 ± 0.01	3	0.44 ± 0.05	3
04/24/99	0.24 ± 0.05	3	0.20 ± 0.02	3	0.21 ± 0.04	3	0.21 ± 0.13	3
05/20/99	0.22 ± 0.11	3	0.18 ± 0.08	3	0.13 ± 0.12	3	0.09 ± 0.16	3
06/19/99	0.19 ± 0.22	3	0.20 ± 0.03	3	0.10 ± 0.20	3	0.12 ± 0.06	3
07/24/99	0.15 ± 0.11	3	0.12 ± 0.06	3	0.12 ± 0.07	3	0.12 ± 0.10	3
08/26/99	0.26 ± 0.06	3	0.21 ± 0.04	3	0.19 ± 0.03	3	0.18 ± 0.03	3
09/28/99	0.22 ± 0.09	3	0.20 ± 0.13	3	0.20 ± 0.07	3	0.20 ± 0.10	3
10/29/99	0.16 ± 0.11	3	0.15 ± 0.12	3	0.13 ± 0.17	2	0.12 ± 0.08	3
11/23/99	0.14 ± 0.21	2	0.08 ± 0.22	2	0.11 ± 0.50	2		
12/21/99	0.12 ± 0.14	3	0.08 ± 0.12	3	0.10 ± 0.07	3	0.08 ± 0.15	2
01/20/00	0.24 ± 0.09	3	0.19 ± 0.17	3	0.16 ± 0.04	3	0.16 ± 0.02	3

Table 4.4. Mean nitrate (mg / L NO_3) and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the $\alpha = 0.05$ level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.			n	omnibus R^2	p value
1	1.253^{a}	±	0.139	77	94.9%	0.0209
2	1.180^{ac}	±	0.142	79		
3	1.203^{ac}	±	0.125	79		
4	1.148^{bc}	±	0.140	80		

Table 4.5. Mean ammonia (mg / L NH_3) and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the $\alpha = 0.05$ level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.			n	omnibus R^2	p value
1	0.358^{a}	±	0.015	79	96.1%	0.0001
2	0.329^{b}	±	0.016	81		
3	0.304^{c}	±	0.019	82		
4	0.288^{d}	±	0.016	82		

Table 4.6. Mean total phosphorus (mg / L PO_4) and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the $\alpha = 0.05$ level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.			n	omnibus R^2	p value
1	0.228^{a}	±	0.019	75	87.9%	0.0001
2	0.210^{ac}	±	0.019	79		
3	0.194^{bc}	±	0.019	79		
4	0.174^{d}	±	0.018	77		

Table 4.7. Mean euphotic zone chlorophyll *a* concentration with confidence intervals (C. I.) from Newton Lake. Values are in μg / L chlorophyll *a*. Segment 1 = discharge, segment 4 = intake.

	Segment 1		Segment 2		Segment 3		Segment 4	
Date	95 % C. I.	n	95 % C. I.	n	95 % C. I.	n	95 % C. I.	n
09/25/97	10.5 ± 2.0	9	13.8 ± 1.2	9	18.2 ± 4.2	9	14.0 ± 4.2	9
10/29/97	7.6 ± 0.5	9	15.7 ± 3.6	9	4.7 ± 1.2	9	5.3 ± 1.0	8
11/19/97	7.9 ± 1.7	9	20.1 ± 2.7	9	13.0 ± 1.3	9	8.7 ± 1.7	9
12/18/97	4.9 ± 0.9	9	8.1 ± 1.3	9	7.9 ± 1.1	9	6.7 ± 1.3	9
01/31/98	25.5 ± 2.2	9	23.7 ± 1.4	9	21.2 ± 0.8	8	22.0 ± 1.0	9
02/21/98	20.5 ± 6.2	9	18.1 ± 1.8	9	16.3 ± 2.5	9	20.2 ± 1.1	9
03/29/98	12.8 ± 3.0	8	32.5 ± 5.2	9	24.0 ± 1.8	9	38.5 ± 3.1	9
04/24/98	17.7 ± 1.9	9	26.2 ± 1.9	9	20.5 ± 1.1	9	14.6 ± 1.0	9
05/20/98	3.3 ± 0.3	9	10.9 ± 1.5	9	14.3 ± 1.8	9	10.8 ± 0.6	8
06/26/98	5.6 ± 0.5	9	9.1 ± 1.4	9	17.4 ± 1.7	9	10.5 ± 2.1	9
07/19/98	16.1 ± 0.9	9	19.4 ± 1.2	9	18.8 ± 0.8	9	16.6 ± 1.0	9
08/25/98	9.4 ± 1.2	9	10.5 ± 0.8	8	12.5 ± 1.3	9	12.7 ± 0.5	8
09/30/98	19.0 ± 1.4	7	23.0 ± 0.8	9	17.2 ± 0.7	9	16.5 ± 1.1	8
10/30/98	10.1 ± 1.6	9	19.7 ± 1.1	9	19.1 ± 1.0	9	18.1 ± 0.7	9
11/24/98	7.1 ± 0.7	9	11.4 ± 1.9	9	20.4 ± 3.7	9	12.3 ± 1.8	9
12/18/98	6.5 ± 0.9	9	5.2 ± 0.5	9	6.9 ± 0.8	4	6.6 ± 0.6	9
02/20/99	1.0 ± 0.5	9	2.4 ± 0.5	9	9.5 ± 0.7	9	2.3 ± 0.8	9
03/19/99	2.6 ± 0.8	8	3.9 ± 1.2	9	2.2 ± 1.8	9	4.6 ± 1.0	9
04/24/99	21.5 ± 2.0	9	26.5 ± 2.7	9	29.1 ± 3.8	9	25.0 ± 1.7	8
05/20/99	0.7 ± 1.1	9	8.6 ± 0.7	9	12.9 ± 1.3	9	8.7 ± 0.6	9
06/19/99	33.1 ± 2.3	9	28.0 ± 2.0	9	23.3 ± 0.7	9	23.4 ± 2.0	9
07/24/99	6.6 ± 1.5	9	5.1 ± 0.6	9	10.4 ± 1.2	9	11.0 ± 0.6	9
08/26/99	14.8 ± 1.6	9	20.5 ± 1.5	9	22.4 ± 1.9	9	19.4 ± 0.5	9
09/28/99	43.3 ± 1.9	9	47.0 ± 2.1	9	38.4 ± 1.9	9	37.4 ± 1.1	9
10/29/99	13.8 ± 1.3	8	24.2 ± 1.5	8	20.8 ± 2.9	6	25.5 ± 1.0	8
11/23/99	13.7 ± 0.4	9	17.7 ± 2.1	8	15.8 ± 0.9	9	22.6 ± 2.2	9
12/21/99	3.5 ± 0.5	9	4.2 ± 0.6	11	6.7 ± 0.6	9	8.7 ± 0.8	8
01/20/00	28.6 ± 2.5	6	23.5 ± 4.8	6	29.9 ± 2.9	6	27.0 ± 2.9	5

Table 4.8. Mean euphotic zone OD 664 / OD 665 ratio with confidence intervals (C. I.) from Newton Lake. Values range from 1.0 (no chlorophyll *a* present) to 1.7 (no pheophytin *a* present). Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.	n	Segment 2 95 % C. I.	n	Segment 3 95 % C. I.	n	Segment 4 95 % C. I.	n
09/25/97	1.27 ± 0.03	9	1.34 ± 0.01	9	1.37 ± 0.04	9	1.31 ± 0.08	9
10/29/97	1.23 ± 0.01	9	1.35 ± 0.04	9	1.16 ± 0.03	9	1.18 ± 0.03	8
11/19/97	1.25 ± 0.03	9	1.40 ± 0.02	9	1.32 ± 0.01	9	1.27 ± 0.03	9
12/18/97	1.18 ± 0.03	9	1.26 ± 0.03	9	1.26 ± 0.02	9	1.23 ± 0.03	9
01/31/98	1.42 ± 0.02	9	1.41 ± 0.01	9	1.39 ± 0.01	8	1.40 ± 0.01	9
02/21/98	1.35 ± 0.05	9	1.34 ± 0.03	9	1.32 ± 0.04	9	1.34 ± 0.02	9
03/29/98	1.23 ± 0.05	8	1.44 ± 0.02	9	1.38 ± 0.03	9	1.48 ± 0.01	9
04/24/98	1.36 ± 0.05	9	1.41 ± 0.01	9	1.37 ± 0.01	9	1.32 ± 0.01	9
05/20/98	1.13 ± 0.01	9	1.28 ± 0.02	9	1.33 ± 0.03	9	1.28 ± 0.01	8
06/26/98	1.17 ± 0.01	9	1.26 ± 0.03	9	1.36 ± 0.02	9	1.28 ± 0.04	9
07/19/98	1.39 ± 0.01	9	1.43 ± 0.01	9	1.41 ± 0.01	9	1.40 ± 0.01	9
08/25/98	1.29 ± 0.04	9	1.32 ± 0.01	8	1.35 ± 0.02	9	1.33 ± 0.01	8
09/30/98	1.37 ± 0.01	7	1.41 ± 0.01	9	1.36 ± 0.01	9	1.35 ± 0.01	8
10/30/98	1.24 ± 0.03	9	1.38 ± 0.02	9	1.35 ± 0.02	9	1.35 ± 0.01	9
11/24/98	1.23 ± 0.01	9	1.32 ± 0.03	9	1.41 ± 0.04	9	1.32 ± 0.03	9
12/18/98	1.20 ± 0.02	9	1.17 ± 0.01	9	1.20 ± 0.02	4	1.21 ± 0.01	9
02/20/99	1.04 ± 0.02	9	1.09 ± 0.02	9	1.28 ± 0.01	9	1.09 ± 0.03	9
03/19/99	1.07 ± 0.02	8	1.10 ± 0.03	9	1.07 ± 0.06	9	1.12 ± 0.03	9
04/24/99	1.38 ± 0.02	9	1.43 ± 0.02	9	1.44 ± 0.02	9	1.40 ± 0.01	8
05/20/99	1.00 ± 0.05	9	1.24 ± 0.01	9	1.30 ± 0.02	9	1.25 ± 0.01	9
06/19/99	1.48 ± 0.01	9	1.45 ± 0.01	9	1.42 ± 0.00	9	1.41 ± 0.01	9
07/24/99	1.26 ± 0.04	9	1.21 ± 0.02	9	1.31 ± 0.02	9	1.34 ± 0.01	9
08/26/99	1.27 ± 0.04	9	1.40 ± 0.02	9	1.41 ± 0.02	9	1.39 ± 0.01	9
09/28/99	1.47 ± 0.01	9	1.49 ± 0.01	9	1.45 ± 0.01	9	1.43 ± 0.01	9
10/29/99	1.31 ± 0.02	8	1.41 ± 0.01	8	1.38 ± 0.03	6	1.40 ± 0.01	8
11/23/99	1.30 ± 0.01	9	1.37 ± 0.02	8	1.34 ± 0.01	9	1.40 ± 0.02	9
12/21/99	1.12 ± 0.02	9	1.16 ± 0.02	11	1.22 ± 0.01	9	1.27 ± 0.01	8
01/20/00	1.41 ± 0.02	6	1.41 ± 0.03	6	1.45 ± 0.02	6	1.43 ± 0.02	5

Table 4.9. Mean euphotic zone pheophytin *a* concentration with confidence intervals (C. I.) from Newton Lake. Values are in µg / L pheophytin *a*. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.	n	Segment 2 95 % C. I.	n	Segment 3 95 % C. I.	n	Segment 4 95 % C. I.	n
09/25/97	16.4 ± 0.6	9	14.2 ± 0.5	9	15.8 ± 0.8	9	17.2 ± 4.1	9
10/29/97	15.8 ± 0.5	9	15.2 ± 0.5	9	15.3 ± 0.6	9	15.6 ± 0.5	8
11/19/97	13.5 ± 0.7	9	14.6 ± 0.9	9	15.3 ± 0.5	9	13.9 ± 1.0	9
12/18/97	14.0 ± 1.2	9	13.4 ± 0.4	9	13.6 ± 0.4	9	13.7 ± 0.4	9
01/31/98	16.7 ± 0.8	9	16.9 ± 0.5	9	16.8 ± 0.5	8	16.8 ± 0.7	9
02/21/98	18.8 ± 1.1	9	18.6 ± 1.4	9	19.1 ± 3.3	9	21.7 ± 1.2	9
03/29/98	26.1 ± 2.4	8	19.1 ± 1.2	9	20.8 ± 4.0	9	17.0 ± 1.3	9
04/24/98	16.5 ± 2.3	9	18.6 ± 0.4	9	18.0 ± 0.8	9	17.1 ± 0.4	9
05/20/98	14.4 ± 0.4	9	15.8 ± 0.7	9	16.1 ± 0.8	9	16.3 ± 0.7	8
06/26/98	16.9 ± 0.4	9	15.0 ± 0.9	9	16.0 ± 0.4	9	15.4 ± 0.5	9
07/19/98	12.6 ± 0.6	9	11.9 ± 0.4	9	13.1 ± 0.3	9	12.5 ± 0.5	9
08/25/98	13.3 ± 1.6	9	12.4 ± 0.3	8	12.6 ± 0.4	9	14.4 ± 0.7	8
09/30/98	16.5 ± 0.2	7	15.9 ± 0.3	9	16.6 ± 0.5	9	16.8 ± 0.4	8
10/30/98	19.0 ± 0.9	9	16.5 ± 1.4	9	19.1 ± 1.9	9	18.1 ± 0.7	9
11/24/98	14.2 ± 0.3	9	13.5 ± 0.3	9	13.5 ± 0.3	9	14.0 ± 0.3	9
12/18/98	15.7 ± 0.3	9	16.4 ± 0.5	9	17.4 ± 0.6	4	15.8 ± 0.4	9
02/20/99	15.3 ± 0.8	9	15.1 ± 0.5	9	14.4 ± 0.4	9	14.5 ± 1.1	9
03/19/99	23.4 ± 0.4	8	23.8 ± 0.6	9	21.4 ± 3.3	9	22.4 ± 2.1	9
04/24/99	17.8 ± 0.4	9	16.7 ± 0.5	9	17.4 ± 0.7	9	19.0 ± 0.8	8
05/20/99	25.8 ± 2.8	9	16.3 ± 0.6	9	17.0 ± 0.6	9	15.7 ± 0.4	9
06/19/99	15.5 ± 0.5	9	15.1 ± 0.5	9	15.3 ± 0.3	9	16.1 ± 0.3	9
07/24/99	11.1 ± 0.4	9	11.6 ± 0.5	9	12.7 ± 0.3	9	11.8 ± 0.3	9
08/26/99	23.7 ± 2.9	9	15.0 ± 0.5	9	15.5 ± 0.5	9	15.7 ± 0.6	9
09/28/99	20.8 ± 0.9	9	20.7 ± 1.0	9	20.8 ± 0.5	9	24.1 ± 0.9	9
10/29/99	17.1 ± 1.2	8	17.2 ± 0.8	8	17.4 ± 0.8	6	18.8 ± 1.5	8
11/23/99	18.4 ± 0.6	9	16.0 ± 0.6	8	16.7 ± 0.4	9	16.4 ± 0.5	9
12/21/99	16.0 ± 0.8	9	13.8 ± 0.2	11	14.7 ± 0.5	9	13.8 ± 0.8	8
01/20/00	19.7 ± 0.7	6	16.5 ± 1.6	6	16.6 ± 0.5	6	16.5 ± 1.0	5

Table 4.10. Mean chlorophyll *a* (μg / L) and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the α = 0.05 level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.	n	omnibus R^2	p value
1	12.9^{a} ± 1.1	244	94.6%	0.0001
2	16.9^{b} ± 1.1	248		
3	16.9^{b} ± 0.9	240		
4	15.9^{c} ± 1.0	241		

Table 4.11. Mean OD 664 / OD 665 ratio and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the α = 0.05 level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.	n	omnibus R^2	p value
1	1.265^{a} ± 0.013	244	92.8%	0.0001
2	1.329^{b} ± 0.012	248		
3	1.337^{b} ± 0.010	240		
4	1.319^{c} ± 0.010	241		

Table 4.12. Mean net photosynthesis values with confidence intervals (C. I.) from Newton Lake. Values are in mg C m^{-2} day^{-1}. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.	n	Segment 2 95 % C. I.	n	Segment 3 95 % C. I.	n	Segment 4 95 % C. I.	n
09/25/97	1695.8 ±	1	2262.2 ±	1	2383.3 ±	1	1383.2 ±	1
11/18/97	15.3 ± 874.8	2	557.8 ± 250.2	2	378.7 ± 473.3	2	184.4 ± 34.0	2
12/17/97	397.4 ± 1377.0	2	323.8 ± 418.4	2	-306.5 ± 35.7	2	-189.6 ± 301.1	2
01/30/98	434.5 ±	1	416.1 ± 416.1	2	262.6 ±	1	291.3 ±	1
02/20/98	-232.9 ± 986.6	2	-214.6 ± 1151.1	2	44.9 ± 325.7	2	466.7 ± 1126.0	2
03/28/98	1198.7 ± 1570.9	2	499.6 ± 241.1	2	865.6 ± 2174.8	2	2073.9 ± 888.2	2
04/23/98	1073.7 ± 2139.1	2	1983.6 ± 2556.9	2	1557.1 ± 899.3	2	1160.4 ± 824.9	2
05/19/98	545.9 ± 880.8	2	1548.8 ± 1631.4	2	1225.9 ± 350.6	2	1381.3 ± 4247.2	2
06/25/98	1847.6 ± 1093.1	2	2452.9 ± 2975.8	2	3359.1 ± 267.1	2	2612.0 ± 1187.2	2
07/18/98	1851.4 ± 1191.1	2	3013.1 ± 171.7	2	1455.9 ± 1121.1	2	-68.9 ± 984.9	2
08/24/98	1192.9 ± 3090.2	2	1324.9 ± 47.4	2	1286.7 ± 3364.7	2	669.4 ± 860.1	2
09/29/98	825.0 ± 391.5	2	996.6 ±	1	1970.5 ± 781.0	2	1823.7 ± 1439.0	2
10/29/98	239.2 ± 239.2	2	1077.6 ± 114.4	2	743.1 ± 781.0	2	728.4 ± 1013.4	2
11/23/98	772.8 ±	1	725.2 ± 41.3	2	996.1 ± 423.9	2	1302.1 ± 905.4	2
12/17/98	364.7 ± 188.4	2	261.5 ± 648.3	2	27.8 ± 353.9	2	385.4 ± 573.5	2
01/22/99	-77.9 ± 261.7	2	-723.5 ± 1293.8	2	-669.1 ± 65.9	2	-94.6 ± -94.6	2
02/19/99	60.2 ± 95.7	2	51.9 ± 109.9	2	119.2 ± 43.3	2	-311.3 ± 157.1	2
03/18/99	492.1 ± 284.9	2	776.0 ± 648.2	2	330.7 ± 477.5	2	549.7 ± 66.3	2
04/23/99	645.4 ± 343.8	2	709.5 ± 976.1	2	1091.0 ± 430.3	2	1369.6 ± 1111.6	2
05/19/99	791.3 ± 1358.8	2	2124.8 ± 419.0	2	1673.5 ± 398.7	2	1577.6 ± 171.7	2
06/18/99	1944.0 ± 244.2	2	2802.6 ± 490.3	2	3259.6 ± 2094.8	2	2648.1 ± 2468.9	2
07/23/99	1055.2 ± 4324.1	2	1207.3 ± 3098.7	2	2321.5 ± 2297.3	2	1906.6 ± 2937.3	2
08/25/99	1030.5 ± 327.1	2	1425.1 ± 899.6	2	1203.1 ± 1335.4	2	990.9 ± 46.2	2
09/27/99	1716.5 ± 328.9	2	1985.2 ± 212.9	2	2373.7 ± 1785.7	2	1575.4 ± 293.3	2
10/28/99	795.3 ± 1502.1	2	1354.4 ± 399.5	2	1449.8 ± 1567.5	2	1554.6 ± 663.2	2
11/22/99	114.0 ± 68.6	2	361.8 ± 112.7	2	452.1 ± 216.2	2	685.6 ± 389.2	2
12/20/99	240.6 ± 1542.7	2	561.9 ± 1567.1	2	-68.0 ± 1212.2	2	19.3 ± 73.4	2
01/19/00	-97.6 ± 45.6	2	-269.9 ± 1033.7	2	61.0 ± 479.3	2	-347.6 ± 632.3	2

Table 4.13. Mean net photosynthesis (mg C m^{-2} day^{-1}) and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the $\alpha = 0.05$ level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.	n	omnibus R^2	p value
1	735[a] ± 149	53	98.7%	0.0001
2	1036[b] ± 217	54		
3	1057[b] ± 236	54		
4	944[c] ± 197	54		

Table 4.14. Mean euphotic zone total phytoplankton cells (Coccoid singles, Division Cyanophyta, Order Croococcales) with confidence intervals (C. I.) from Newton Lake. Values are in cells L^{-1}. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.		n	Segment 2 95 % C. I.		n	Segment 3 95 % C. I.		n	Segment 4 95 % C. I.		n
12/18/97	88528190	± 7066438	6	91724154	± 10243481	6	84053841	± 11327849	6	81305313	± 4402892	5
01/31/98	81816667	± 18664335	3	83414648	± 11468386	4	104028613	± 26610291	4	91775289	± 11291716	5
04/08/98	190319629	± 33028269	6	95399512	± 13034482	6	96518099	± 13803296	6	94920117	± 12075684	6
04/25/98	87569401	± 11128386	6	156762012	± 37976745	6	141517266	± 29744113	5	121286816	± 2839215	4
05/07/98	124067305	± 47072194	5	137298594	± 32067873	5	116013477	± 39655540	5	98180000	± 20820638	5
05/20/98	181019375	± 9195690	5	144137956	± 10856737	6	105236688	± 15072631	5	100263768	± 15978605	6
06/03/98	140558477	± 39357318	5	110580339	± 13520977	6	98333406	± 17400790	5	107863770	± 15128568	6
06/16/98	321833529	± 6942092	6	202112734	± 128335385	2						
07/08/98	137426432	± 21314427	6	130555111	± 23925784	6	96997493	± 16860684	6	103549219	± 17671962	6
08/04/98	166113401	± 24007114	6	146541320	± 26042337	6	135828451	± 10059635	6	134709863	± 22474197	6
09/09/98	121127018	± 17471339	6	142987409	± 23803001	6	119049642	± 12049037	6	156602214	± 21226685	6
09/30/98	166330727	± 53275309	5	125745186	± 43711049	4	116524831	± 31023581	6	102973945	± 20978164	5
10/30/98	166829297	± 31133149	5	137373166	± 28773957	6	119273359	± 14533914	5	142859570	± 35597153	5
12/09/98	149698932	± 28872849	6	120487826	± 9152990	6	100481094	± 16723297	5	116013477	± 12540691	6
01/22/99	1208074219	± 280347368	6	421227995	± 83535788	6	138640898	± 70021548	5	687611556	± 112691261	6
03/19/99	346418159	± 169220520	6	319367268	± 214440963	5	224883335	± 59425135	6	206239363	± 56779293	6
04/15/99	266952443	± 71986349	6	217352367	± 95216718	6	136394775	± 22467795	6	247109344	± 125745359	6
05/20/99	149089142	± 37810144	6	135460276	± 38858003	6	133463438	± 23608832	6	143433991	± 70131994	6
06/19/99	196618234	± 124773748	6	163036327	± 110482440	6	80484078	± 20666018	6	81972118	± 24256249	6
07/24/99	146605240	± 46039040	6	140961168	± 89577125	6	121267641	± 44496875	6	106811658	± 26122951	6
08/26/99	140047122	± 12743025	6	115753964	± 11034848	6	95660302	± 16372657	6	135786264	± 36790788	6

Table 4.15. Mean euphotic zone total phytoplankton cells (excluding Coccoid singles) with confidence intervals (C. I.) from Newton Lake. Values are in cells L^{-1}. Segment 1 = discharge, segment 4 = intake.

Date	Segment 1 95 % C. I.			n	Segment 2 95 % C. I.			n	Segment 3 95 % C. I.			n	Segment 4 95 % C. I.			n
12/18/97	38121453	±	4956912	6	41470823	±	5006212	6	43331641	±	12224523	6	38942177	±	7064791	5
01/31/98	29837516	±	14787243	3	24746346	±	8494491	4	31361990	±	12082420	4	40951798	±	7061659	5
04/08/98	71672678	±	15603882	6	32445422	±	7597531	6	39131378	±	8853513	6	33410603	±	6887933	6
04/25/98	30131544	±	5257166	6	48265441	±	11281254	6	40161756	±	6713727	5	34688988	±	5798441	4
05/07/98	22834520	±	4315996	5	26991830	±	11224395	5	23939045	±	9974356	5	28395497	±	12368552	5
05/20/98	49941405	±	3904775	5	55609766	±	5441576	6	55609766	±	8855895	5	58798570	±	4381111	6
06/03/98	78950527	±	28902895	5	92721294	±	10070118	6	106134114	±	25979194	5	93590596	±	21789118	6
06/16/98	125831477	±	14136246	6	152179000	±	136568221	2								
07/08/98	51656998	±	33493085	6	57207747	±	21603046	6	32982344	±	16825729	6	37916911	±	17615894	6
08/04/98	39703583	±	6299193	6	42118197	±	6113927	6	35897063	±	2031653	6	34714556	±	7214914	6
09/09/98	33186885	±	3320334	6	37693194	±	6307647	6	31927676	±	3687262	6	35967374	±	4024435	6
09/30/98	32483773	±	4224372	5	30508668	±	12887040	4	29185539	±	5516930	6	26301502	±	8008207	5
10/30/98	43298914	±	14061092	5	39048283	±	5172369	6	37201016	±	7468376	5	46520445	±	6507370	5
12/09/98	20971913	±	3830556	6	16606227	±	3887537	6	15892888	±	3639324	5	18696387	±	3326269	6
01/22/99	109838875	±	14253351	6	44014810	±	5707367	6	18646530	±	6698726	5	64513720	±	9847061	6
03/19/99	23365459	±	5531348	6	22953011	±	8794951	5	30918774	±	16164830	6	31253149	±	16420313	6
04/15/99	36988292	±	15980537	6	47645782	±	32440260	6	23626148	±	3071589	6	52305446	±	20856266	6
05/20/99	62852927	±	24316250	6	124993452	±	43720619	6	144461592	±	72180620	6	143280176	±	43890377	6
06/19/99	41735500	±	13036227	6	42866308	±	13144174	6	51132093	±	18452126	6	40341906	±	8073232	6
07/24/99	29461057	±	10199005	6	24500921	±	16756623	6	25933940	±	6015029	6	22665467	±	5736174	6
08/26/99	24332941	±	3594912	6	24035384	±	3028789	6	24686543	±	4639773	6	38114192	±	15852360	6

Table 4.16 Mean total phytoplankton cells L^{-1} (Coccoid singles only) and confidence interval (C. I.) from Newton Lake by segment, December 1997 – August 1999. Means with different superscripts are significantly different at the $\alpha = 0.05$ level after controlling for the date and date X segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.			n	R^2	p value
1	224050868[a]	±	39144643	118	83.6%	0.0001
2	158157237[b]	±	15887764	116		
3	118561720[c]	±	6932111	111		
4	155822462[b]	±	22337513	113		

Table 4.17. Mean total phytoplankton cells L^{-1} (Coccoid singles excluded) and confidence interval (C. I.) from Newton Lake by segment, December 1997 – August 1999. Means with different superscripts are significantly different at the $\alpha = 0.05$ level after controlling for the date and date * segment interaction. Reported p value is for the segment effect.

Segment	95% C. I.			n	omnibusR^2	p value
1	48018371[a]	±	4896994	118	72.4%	0.4576
2	46573798[a]	±	5163255	116		
3	42276233[a]	±	5893780	111		
4	46705552[a]	±	5140237	113		

Table 4.18. Mean euphotic zone depth (m) and confidence interval (C. I.) from Newton Lake by segment, September 1997 – January 2000. Means with different superscripts are significantly different at the α = 0.05 level.

Segment	95% C. I.			n	omnibus R^2	p value
1	1.95[a]	±	0.11	69	13.2%	0.0001
2	2.27[b]	±	0.13	70		
3	2.61[cd]	±	0.12	70		
4	2.40[bd]	±	0.14	70		

Table 4.19. Primary production values from several studies (after Kimmel et al. 1990).

Reservoir, Location	Year	Production	Units	Comments	Reference
Francis Case, SD	1968	260	mg C m^{-2} d^{-1}	Net O_2 change, summer estimates	Martin and Novotny (1975)
Lewis and Clark, NB	1968	530	mg C m^{-2} d^{-1}	Net O_2 change, summer estimates	Martin and Novotny (1975)
Hebgen, MT	1965	658	mg C m^{-2} d^{-1}	Net O_2 change, summer estimates	Martin and Arneson (1978)
Canyon Ferry, MT	1958	1125	mg C m^{-2} d^{-1}	Net O_2 change, April – September	Wright (1958, 1959, 1960)
Ashtabula, ND	1966 - 68	1828	mg C m^{-2} d^{-1}	Net O_2 change	Peterka and Reid (1966), Knuston (1970), cited in Soltero et al. (1975)
Newton Lake, IL	1997 – 98	944	mg C m^{-2} d^{-1}	Net O_2 change	this study

Table 4.20. Mean chlorophyll *a* (µg / L) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.	n	R^2	p value
1998	$14.6^a \pm 0.8$	70	0.6 %	0.3623
1999	$13.8^a \pm 1.2$	72		

Table 4.21 Mean OD 664 / OD 665 ratio (range 1.0 – 1.7) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.	n	R^2	p value
1998	$1.37^a \pm 0.01$	70	9.6 %	0.0002
1999	$1.32^b \pm 0.01$	72		

Table 4.22. Mean chlorophyll *a* (µg / L) and confidence interval (C. I.) from Newton Lake for July and August, all segments combined. July 1998 mean was compared to July 1999 mean, and August 1998 mean was compared to August 1999 mean. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	Month	95 % C. I.	n	R^2	p value
1998	July	17.7^a ± 0.5	36	79.9 %	0.0001
1999	July	8.3^b ± 0.8	36		
1998	August	11.3^a ± 0.6	34	68.1 %	0.0001
1999	August	19.3^b ± 1.0	36		

Table 4.23. Mean OD 664 / OD 665 ratio (range 1.0 – 1.7) and confidence interval (C. I.) from Newton Lake for July and August, all segments combined. July 1998 mean was compared to July 1999 mean, and August 1998 mean was compared to August 1999 mean. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	Month	95 % C. I.	n	R^2	p value
1998	July	1.41^a ± 0.01	36	68.9 %	0.0001
1999	July	1.28^b ± 0.02	36		
1998	August	1.32^a ± 0.01	34	16.5 %	0.0005
1999	August	1.37^b ± 0.02	36		

Table 4.24. Mean net photosynthesis (mg C m^{-2} day^{-1}) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.			n	R^2	p value
1998	1340.7[a]	±	381.1	16	0.0 %	0.8379
1999	1392.5[a]	±	219.6	16		

Table 4.25. Mean net photosynthesis (mg C m^{-2} day^{-1}) and confidence interval (C. I.) from Newton Lake for July and August, all segments combined. July 1998 mean was compared to July 1999 mean, and August 1998 mean was compared to August 1999 mean. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	Month	95 % C. I.			n	R^2	p value
1998	July	1562.9[a]	±	791.2	8	0.0 %	0.9008
1999	July	1622.6[a]	±	412.1	8		
1998	August	1118.5[a]	±	229.8	8	0.0 %	0.7578
1999	August	1162.4[a]	±	131.2	8		

Table 4.26. Mean total phytoplankton cells L^{-1} (Coccoid singles excluded) and confidence interval (C. I.) from Newton Lake for July and August combined, and with all segments combined. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	95% C. I.			n	R^2	p value
1998	41524675[a]	±	5021267	48	16.4%	0.0001
1999	26716306[b]	±	2867931	48		

Table 4.27. Mean total phytoplankton cells L^{-1} (Coccoid singles excluded) and confidence interval (C. I.) from Newton Lake for July and August, all segments combined. July 1998 mean was compared to July 1999 mean, and August 1998 mean was compared to August 1999 mean. Means with different superscripts are significantly different at the $\alpha = 0.05$ level.

Year	Month	95 % C. I.			n	R^2	p value
1998	July	44941000[a]	±	9908026	24	16.9 %	0.0037
1999	July	25640346[b]	±	4317158	24		
1998	August	38108350[a]	±	2521312	24	23.2 %	0.0005
1999	August	27792265[b]	±	4017142	24		

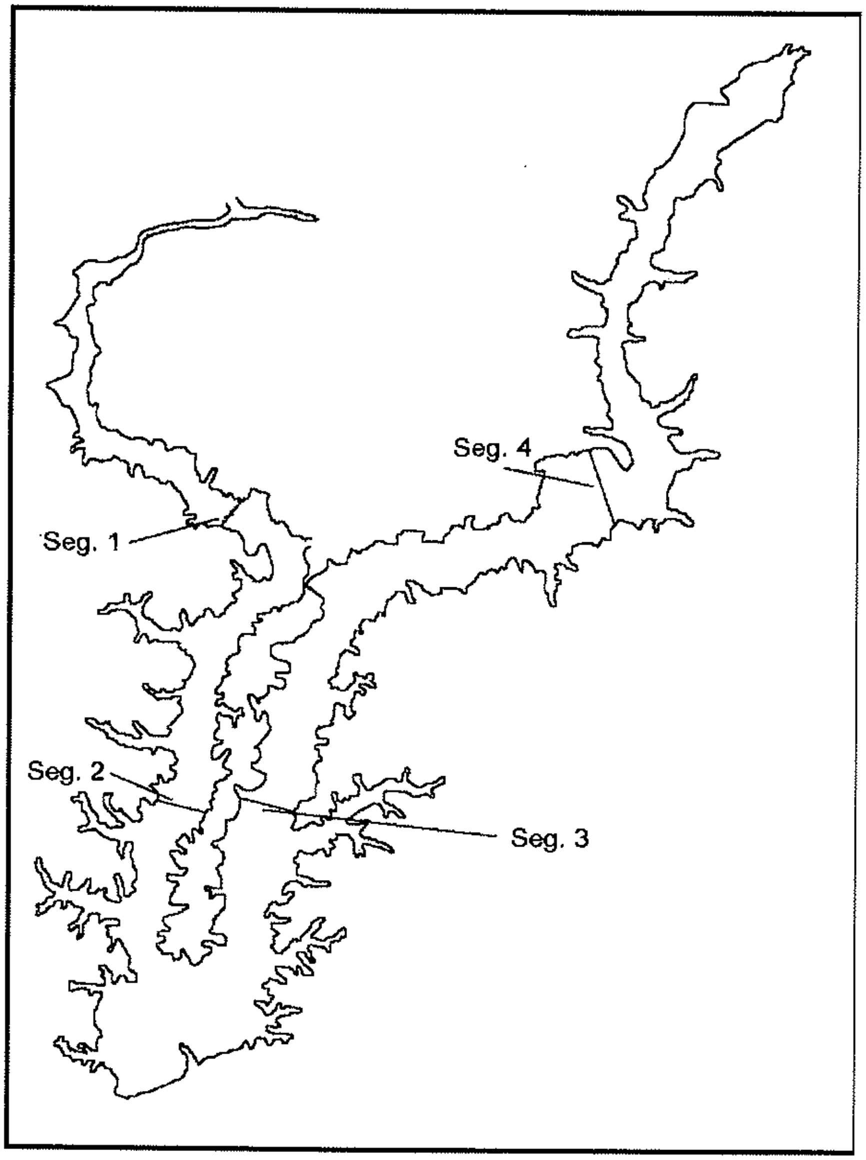


Figure 4.1. Sampling stations on Newton Lake.

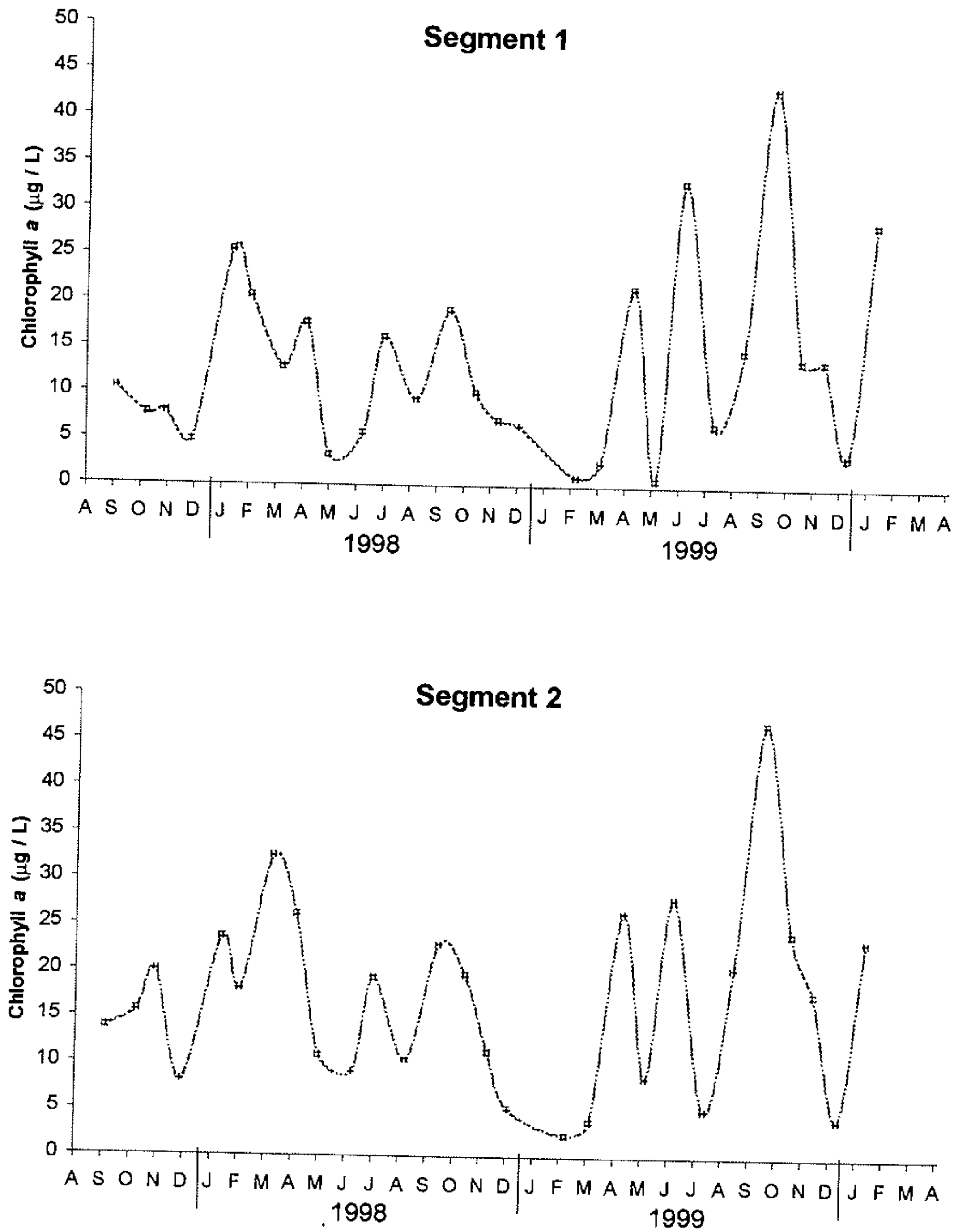
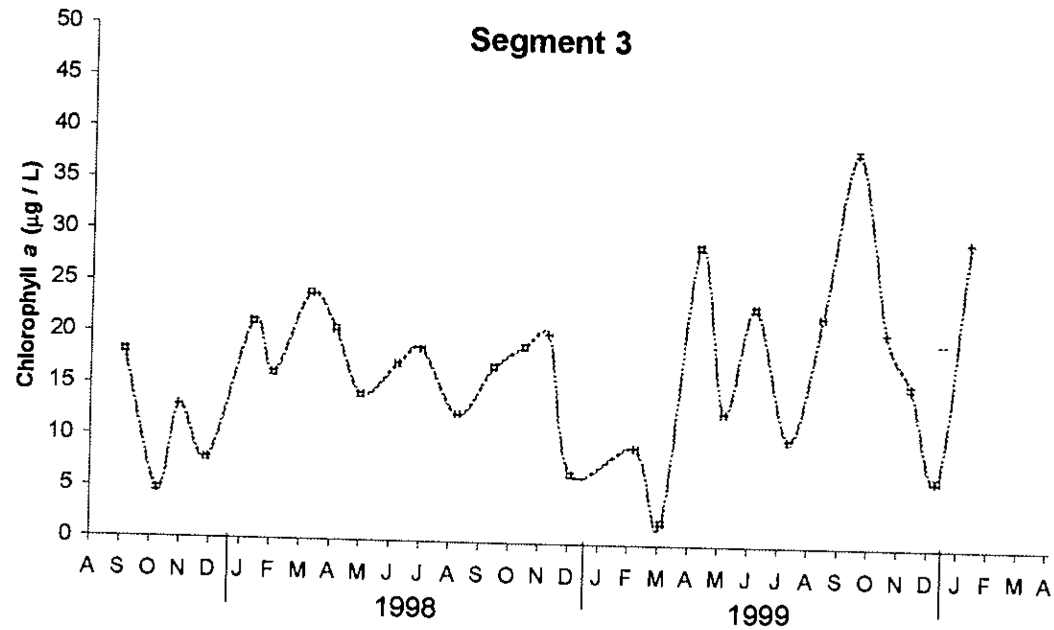


Figure 4.2. Mean chlorophyll *a* concentration (μg / L) from Newton Lake.



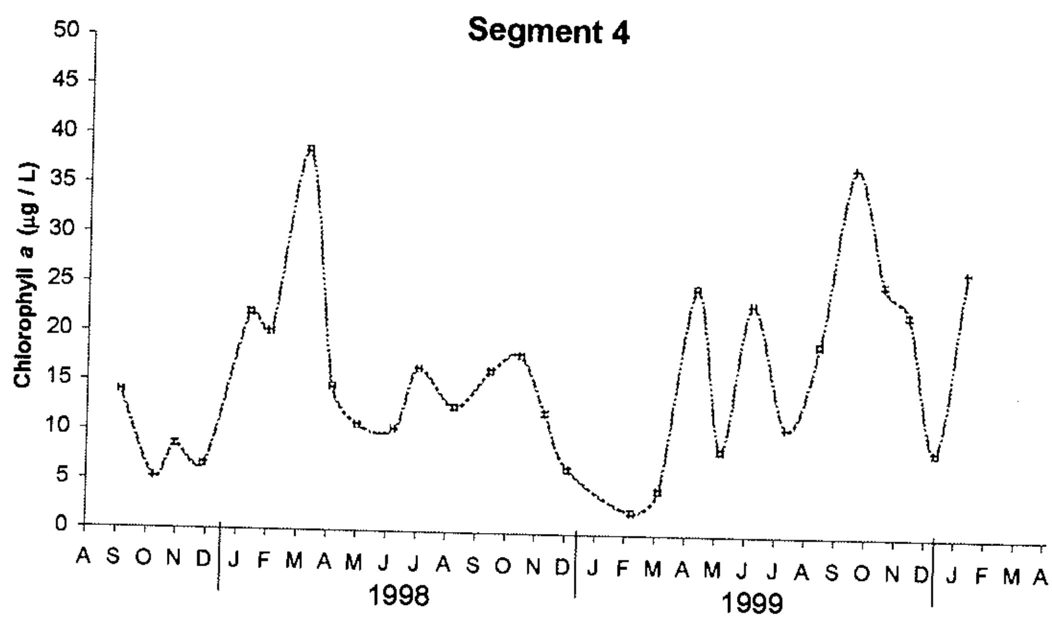
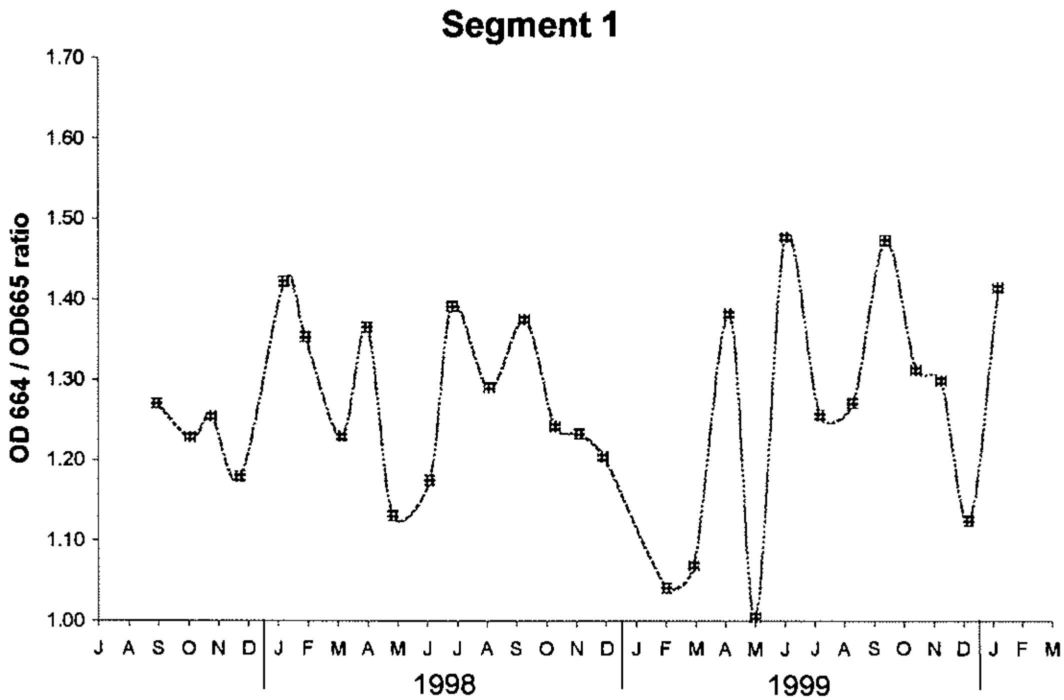


Figure 4.2 (continued). Mean chlorophyll *a* concentration (µg / L) from Newton Lake.



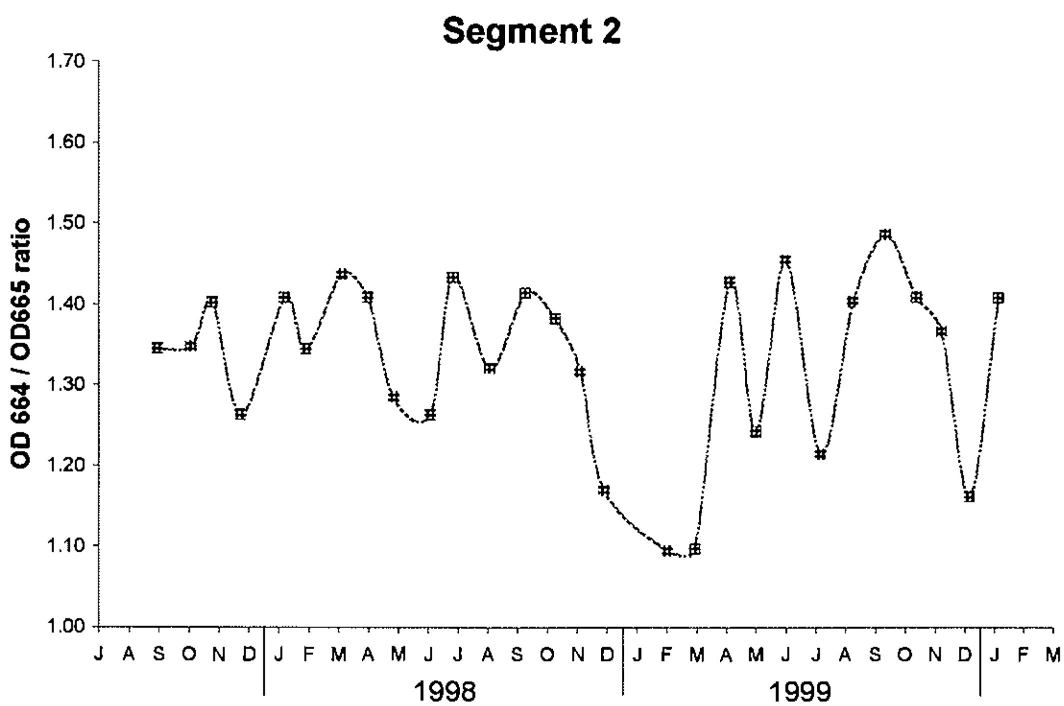
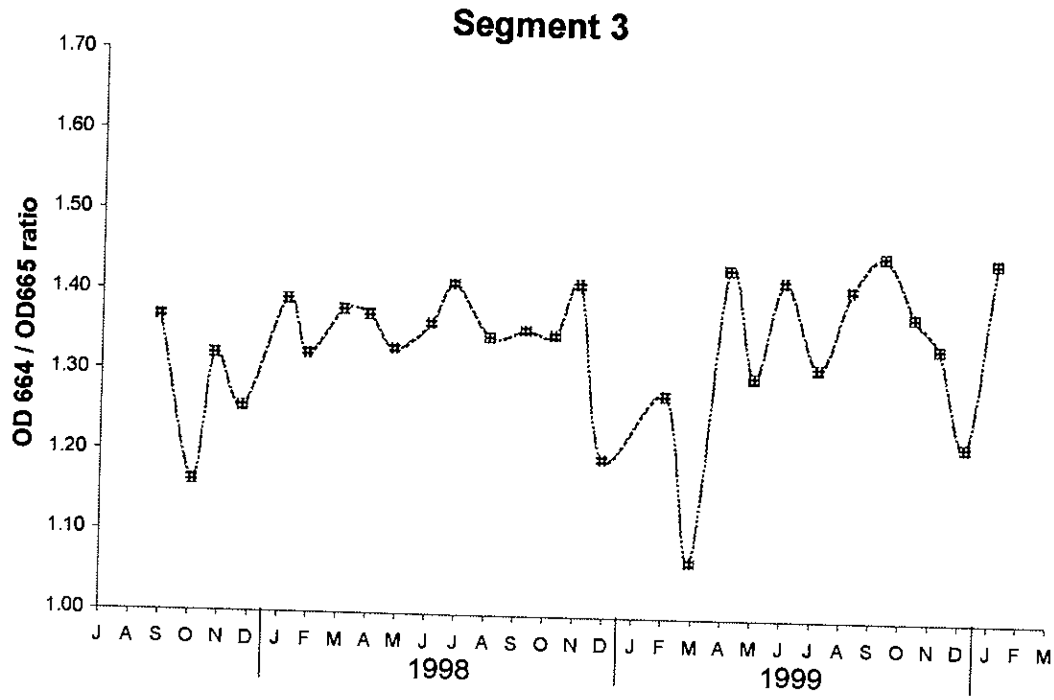


Figure 4.3. Mean OD 664 / OD 665 ratio from Newton Lake.



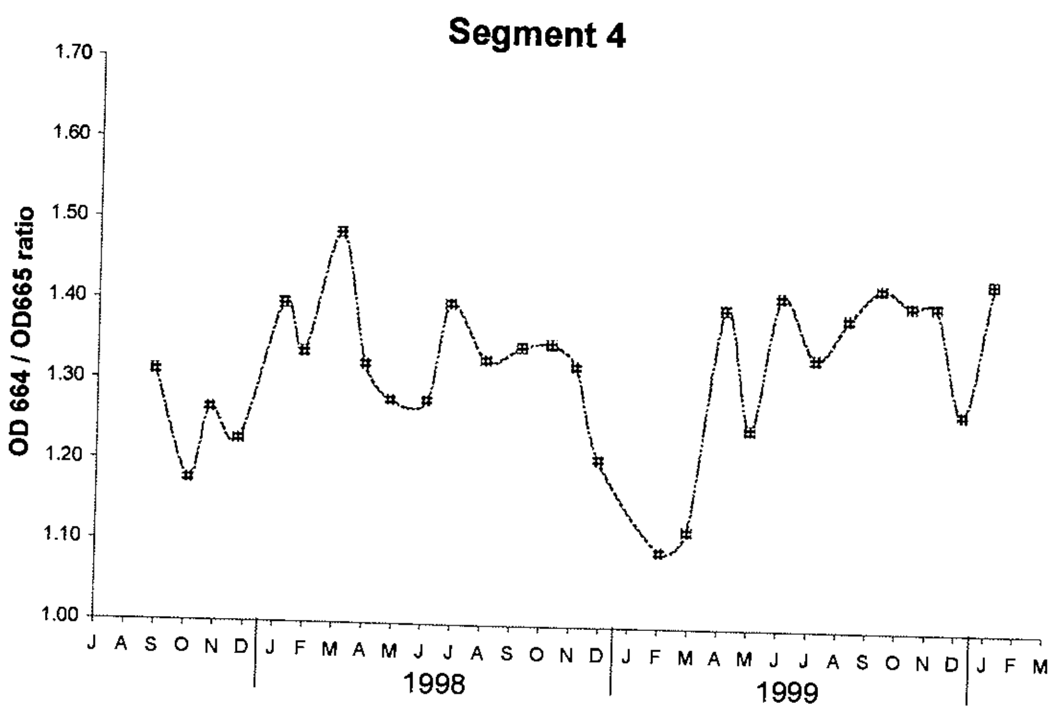


Figure 4.3 (continued). Mean OD 664 / OD 665 ratio from Newton Lake.

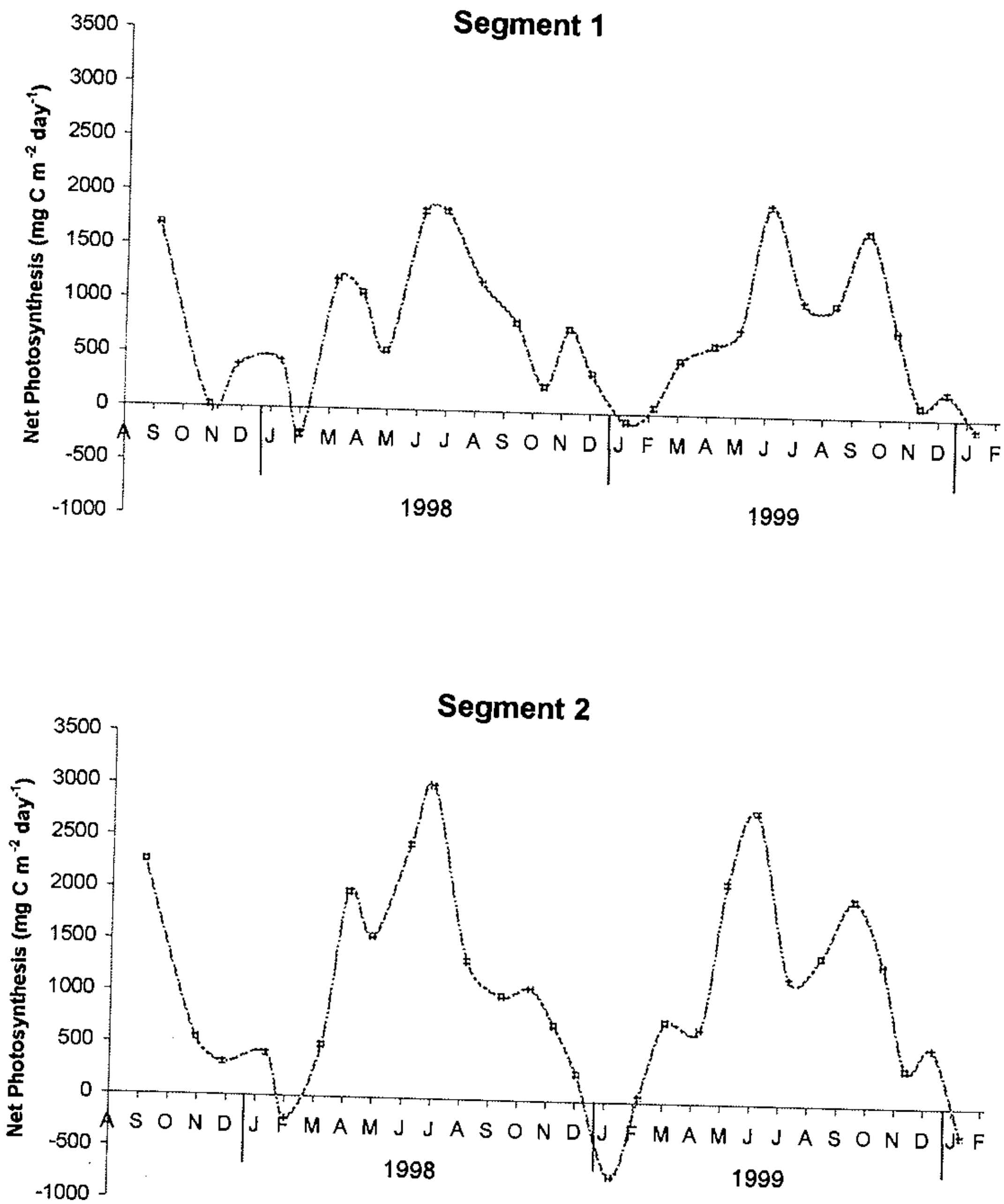
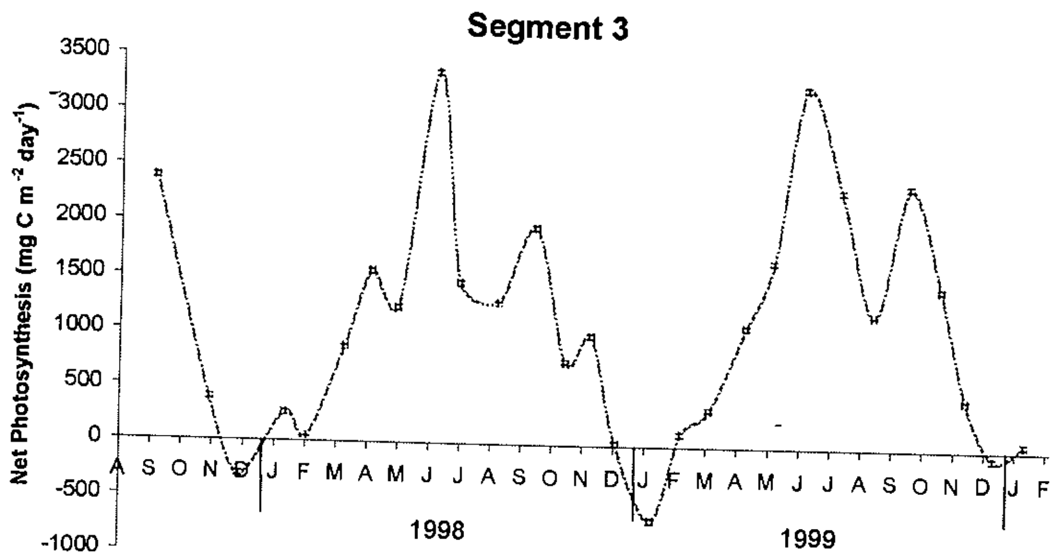


Figure 4.4. Mean net photosynthesis values (mg C m^{-2} day^{-1}) from Newton Lake.



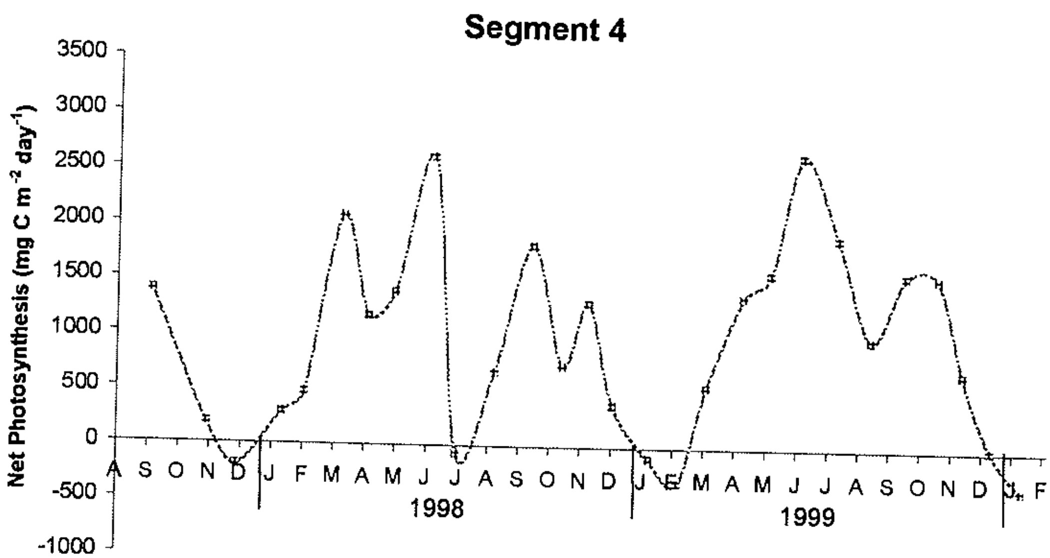


Figure 4.4 (continued). Mean net photosynthesis values (mg C m^{-2} day^{-1}) from Newton Lake.

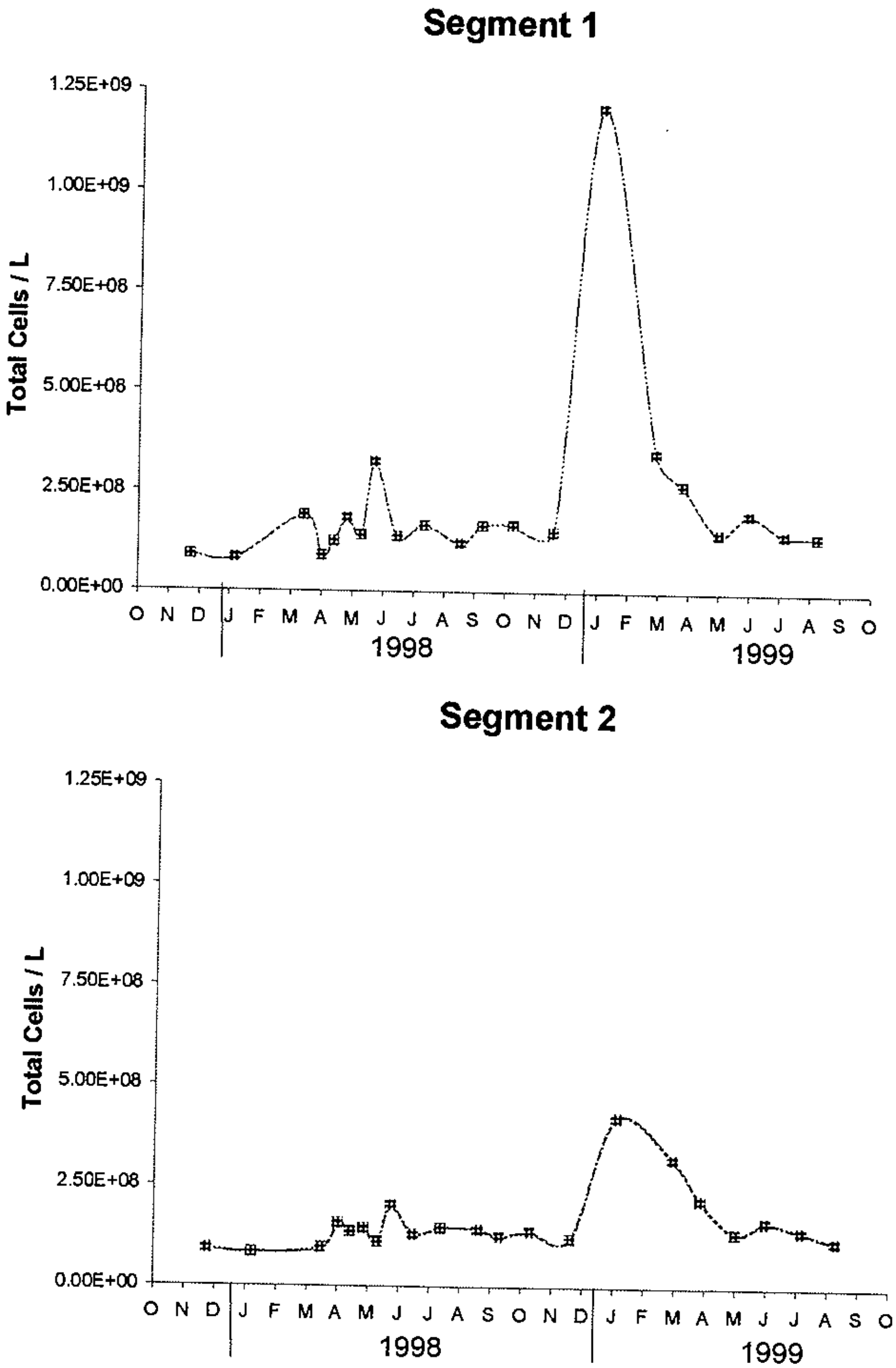


Figure 4.5. Mean total phytoplankton cells L^{-1} (Coccoid singles, Division Cyanophyta, Order Croococcales) from Newton Lake.

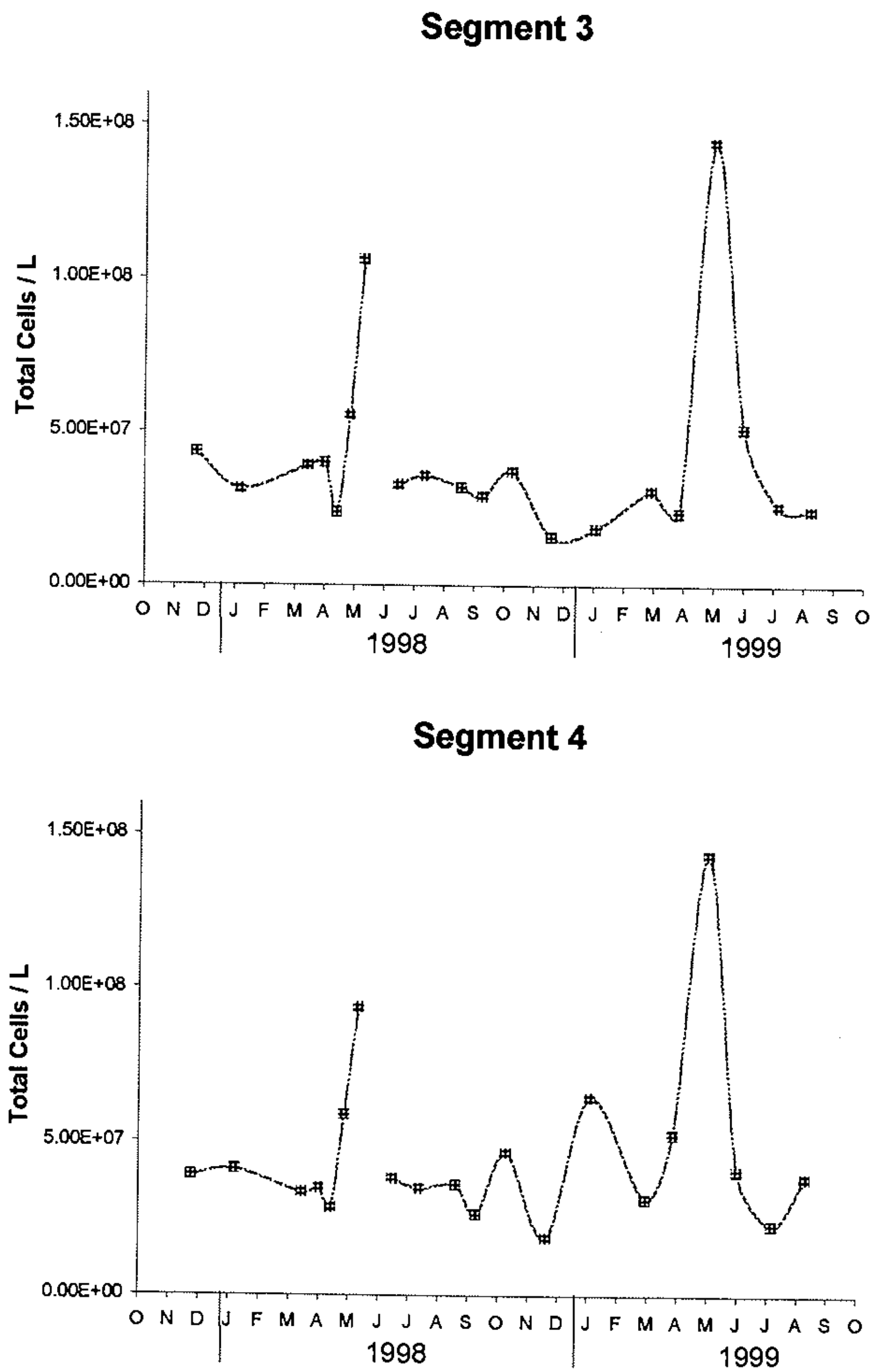


Figure 4.6 (continued). Mean total phytoplankton cells L^{-1} (Coccoid singles excluded) from Newton Lake.

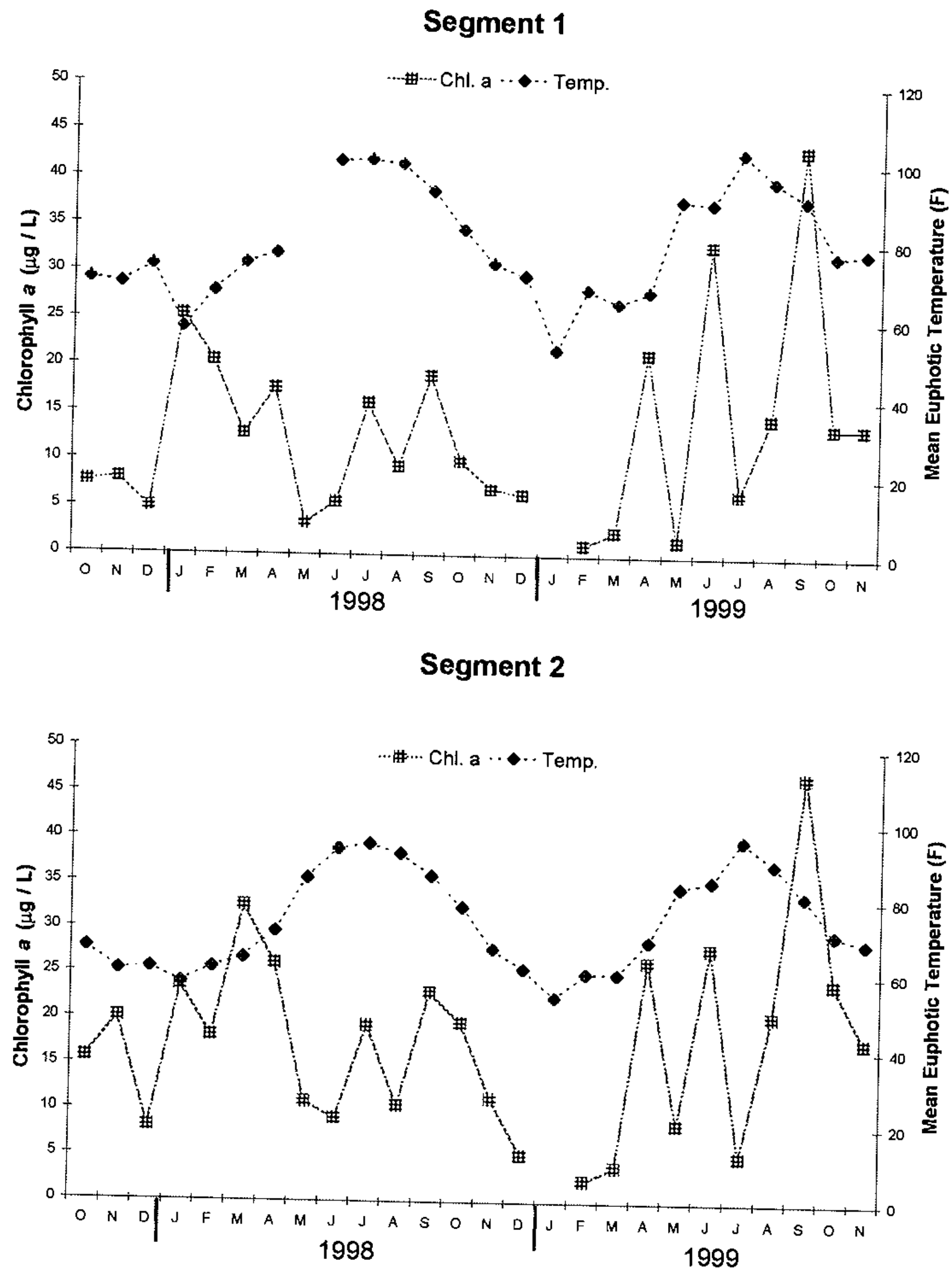


Figure 4.7. Mean chlorophyll a (µg / L) and mean daily euphotic temperature (F), Newton Lake. Euphotic temperature is the mean temperature recorded by temperature loggers and adjusted for sampling site on the day of chlorophyll sampling.

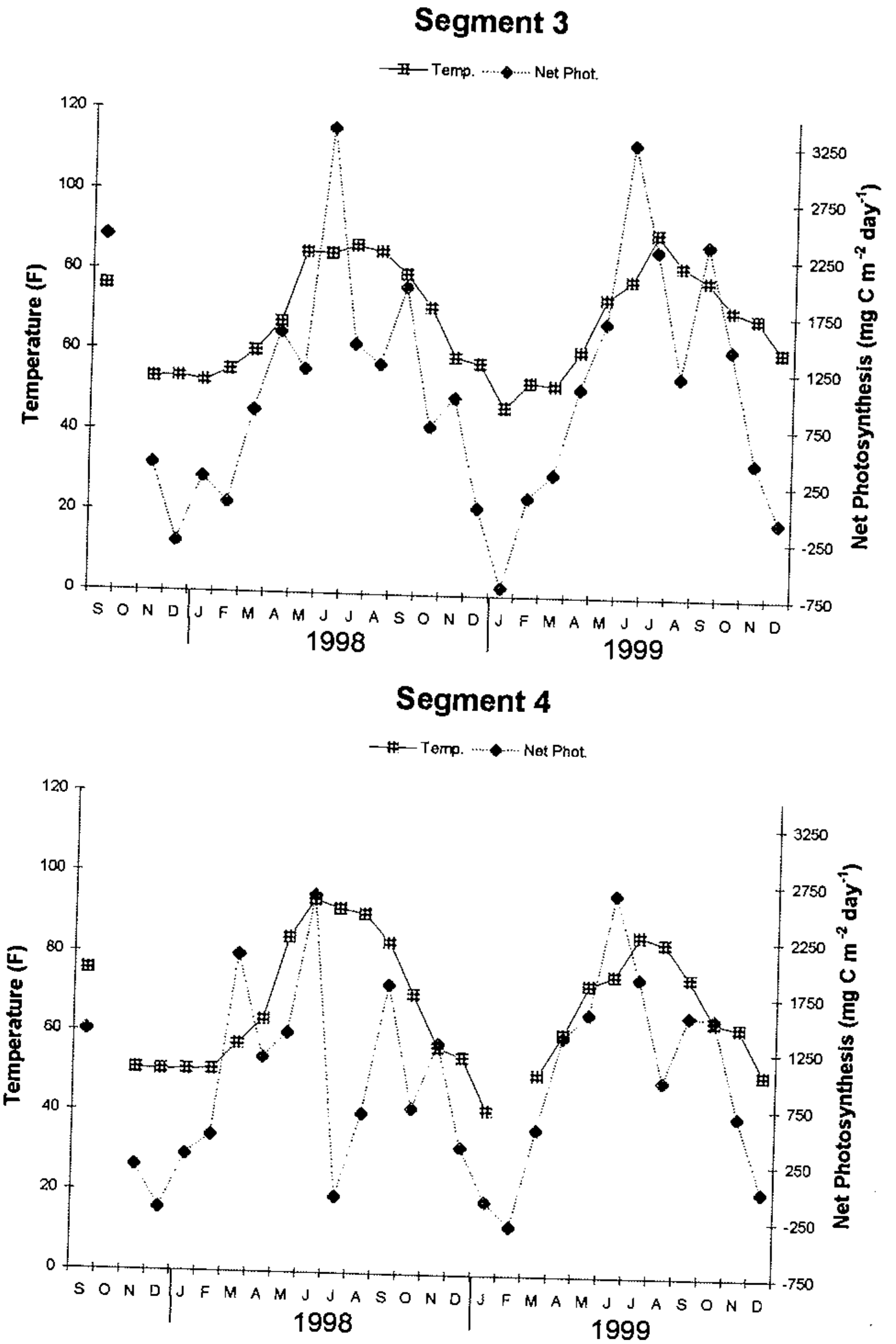
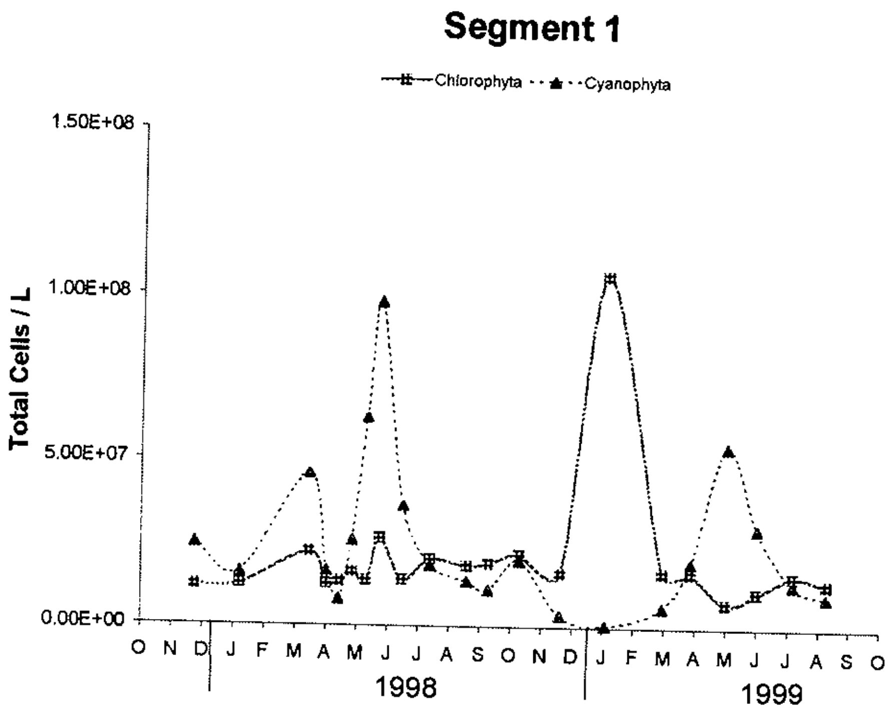


Figure 4.8 (continued). Mean net photosynthesis (mg C m^{-2} day^{-1}) and mean euphotic temperature (F), Newton Lake. Euphotic temperature is the mean temperature recorded by temperature loggers and adjusted for sampling site on the day of chlorophyll sampling.



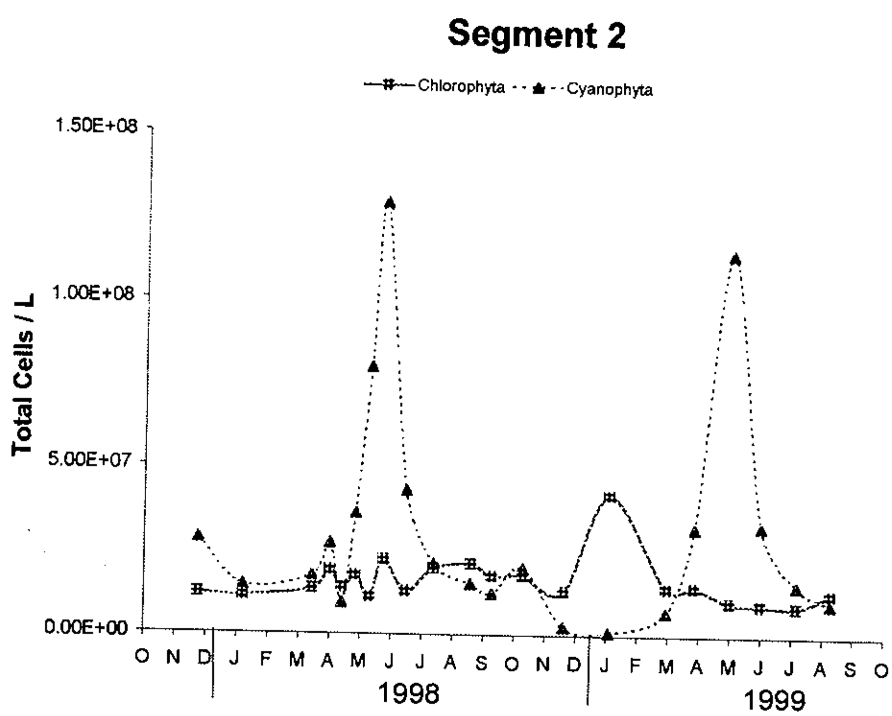
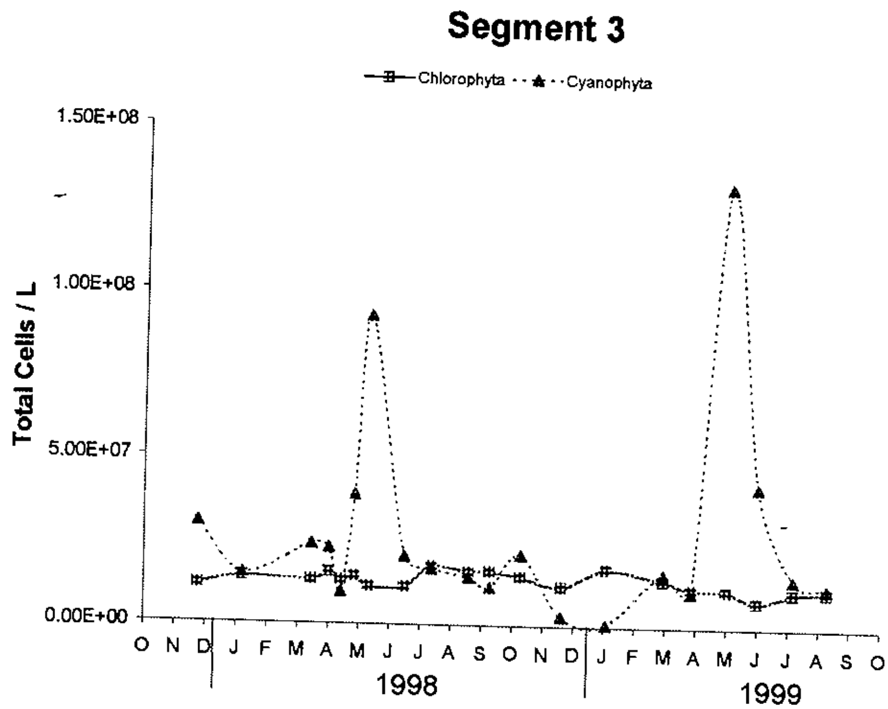


Figure 4.9. Mean total phytoplankton cells L^{-1} Divisions Chlorophyta and Cyanophyta (excluding Coccoid singles, division Cyanophyta) from Newton Lake.



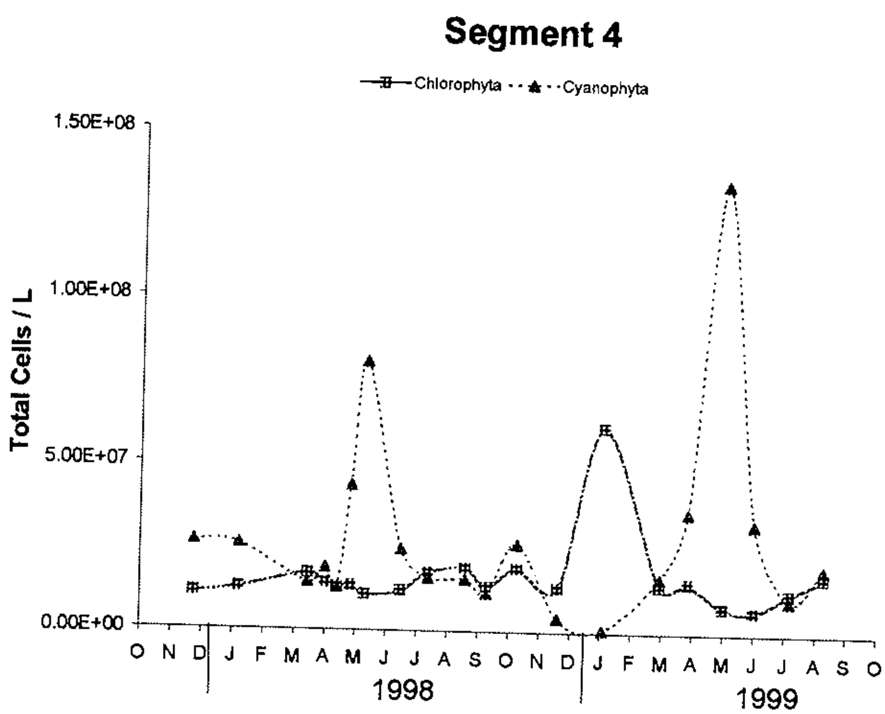
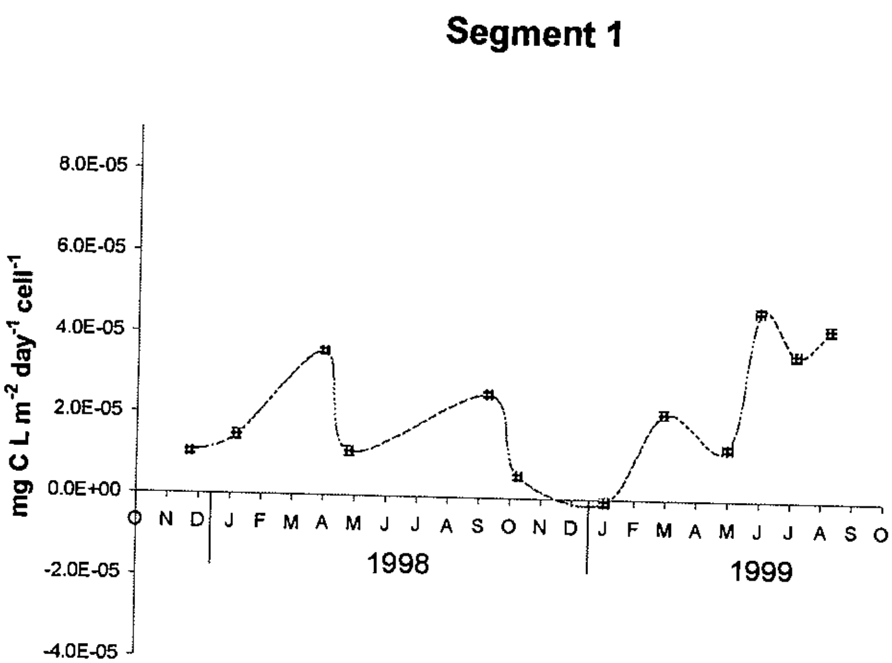


Figure 4.9 (continued). Mean total phytoplankton cells L^{-1} Divisions Chlorophyta and Cyanophyta (excluding Coccoid singles, division Cyanophyta) from Newton Lake.



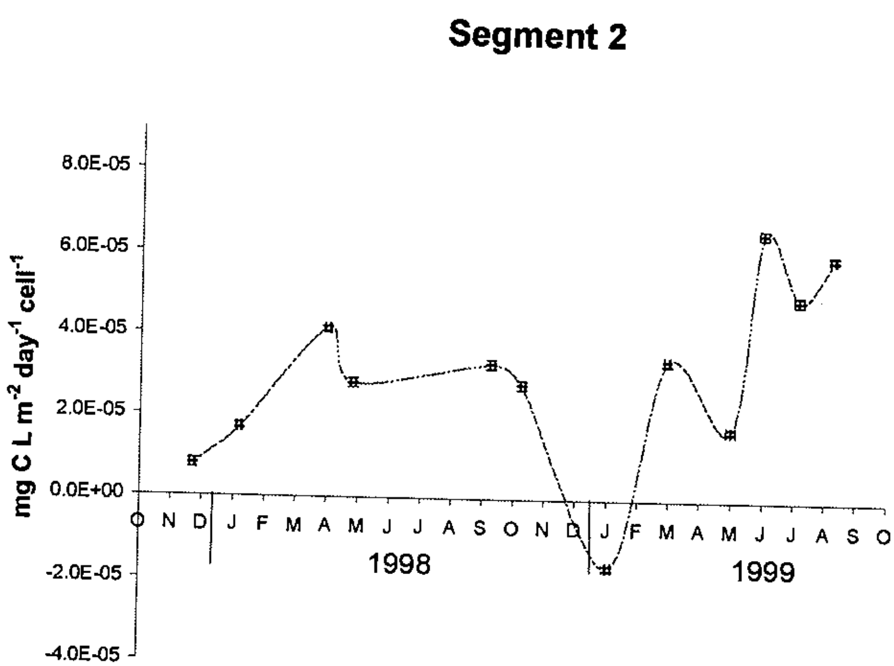
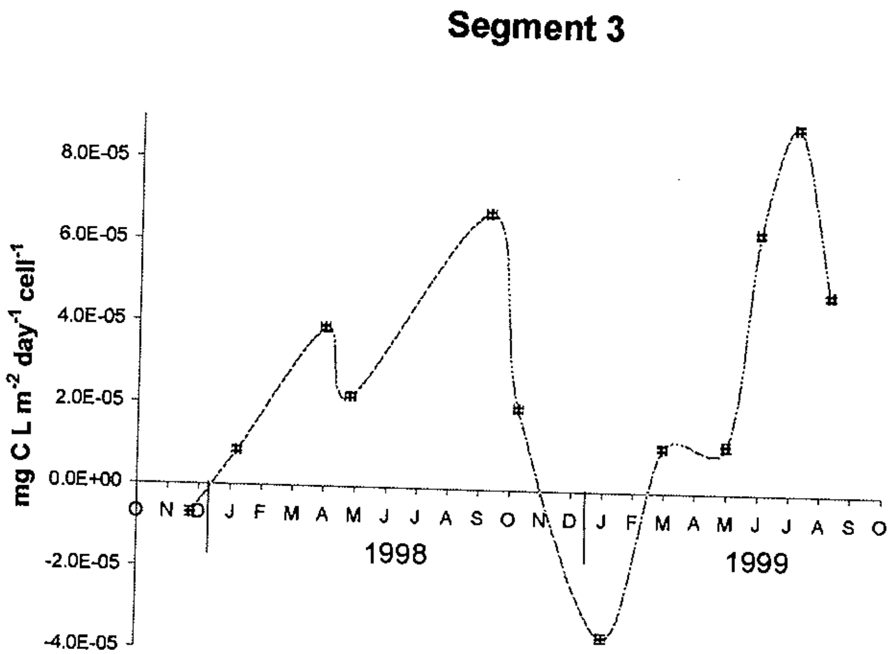


Figure 4.10. Mean net photosynthesis per total phytoplankton cells L^{-1} (Coccoid singles excluded) from Newton Lake.



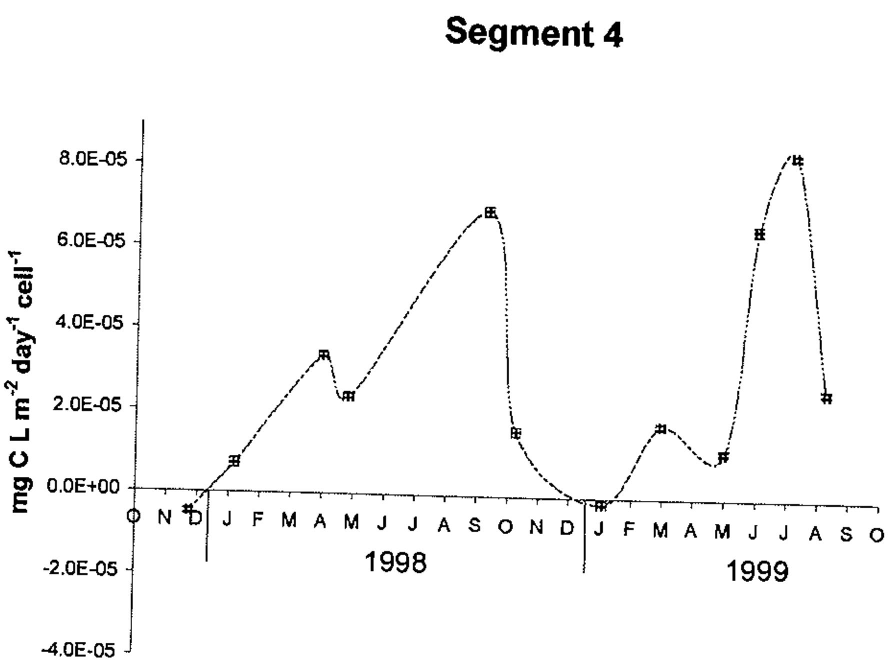


Figure 4.10 (continued). Mean net photosynthesis per total phytoplankton cells L^{-1} (Coccoid singles excluded) from Newton Lake.

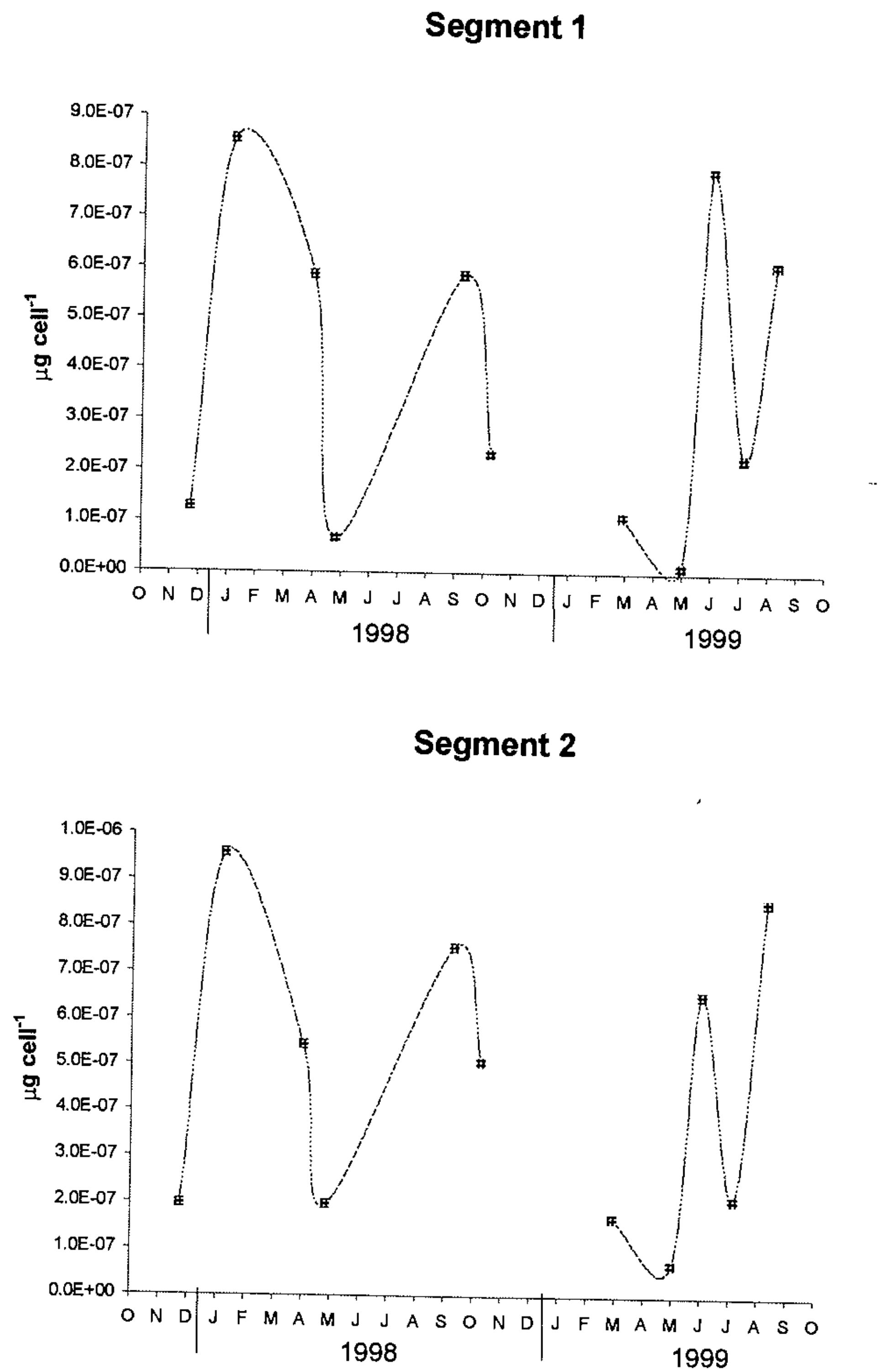
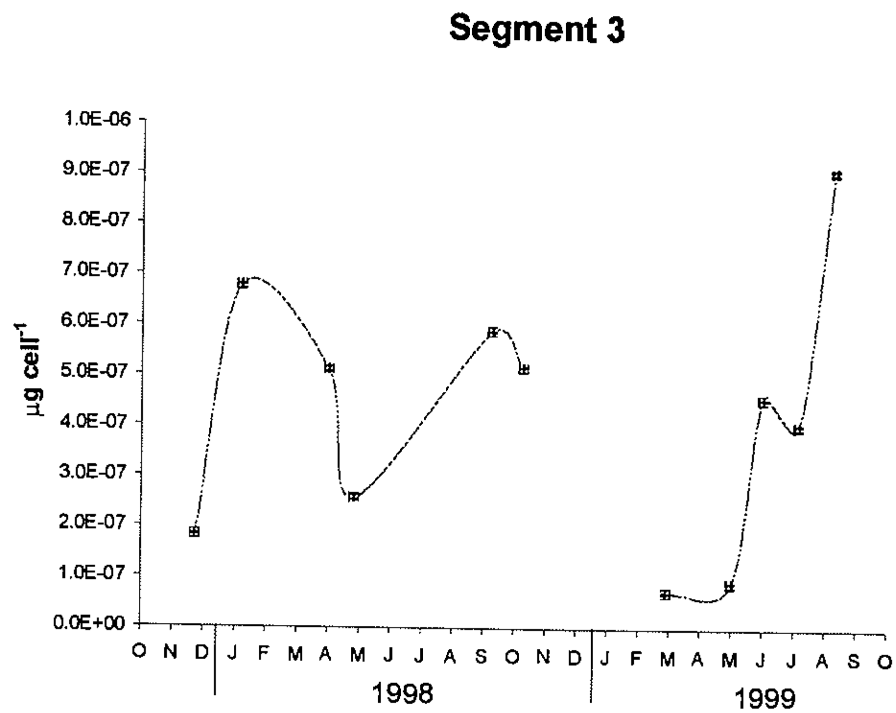


Figure 4.11. Mean chlorophyll *a* per total phytoplankton cells L^{-1} (Coccoid singles excluded) from Newton Lake.



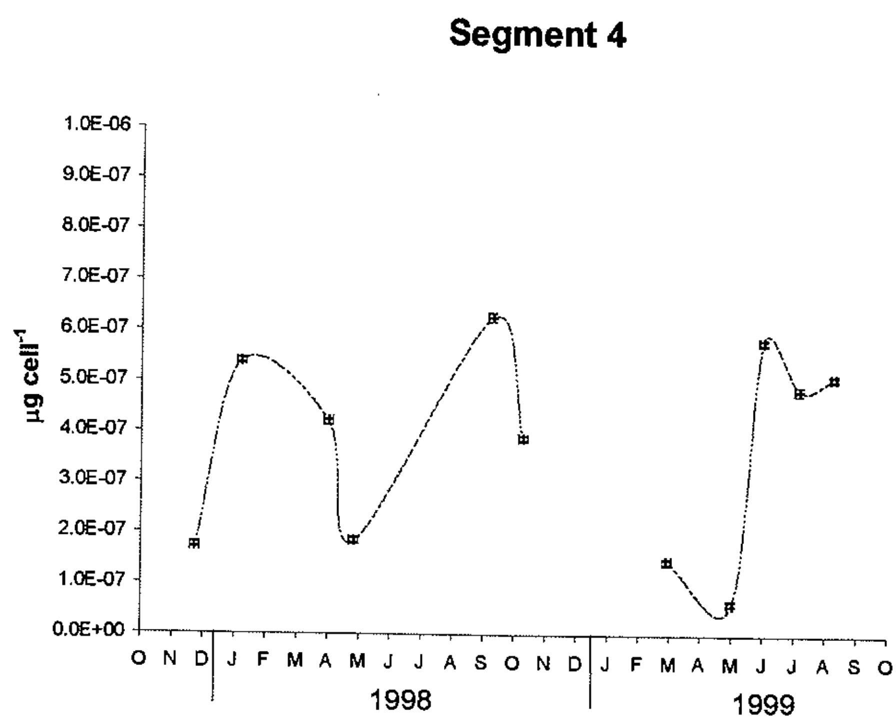


Figure 4.11 (continued). Mean chlorophyll *a* per total phytoplankton cells L^{-1} (Coccoid singles excluded) from Newton Lake.

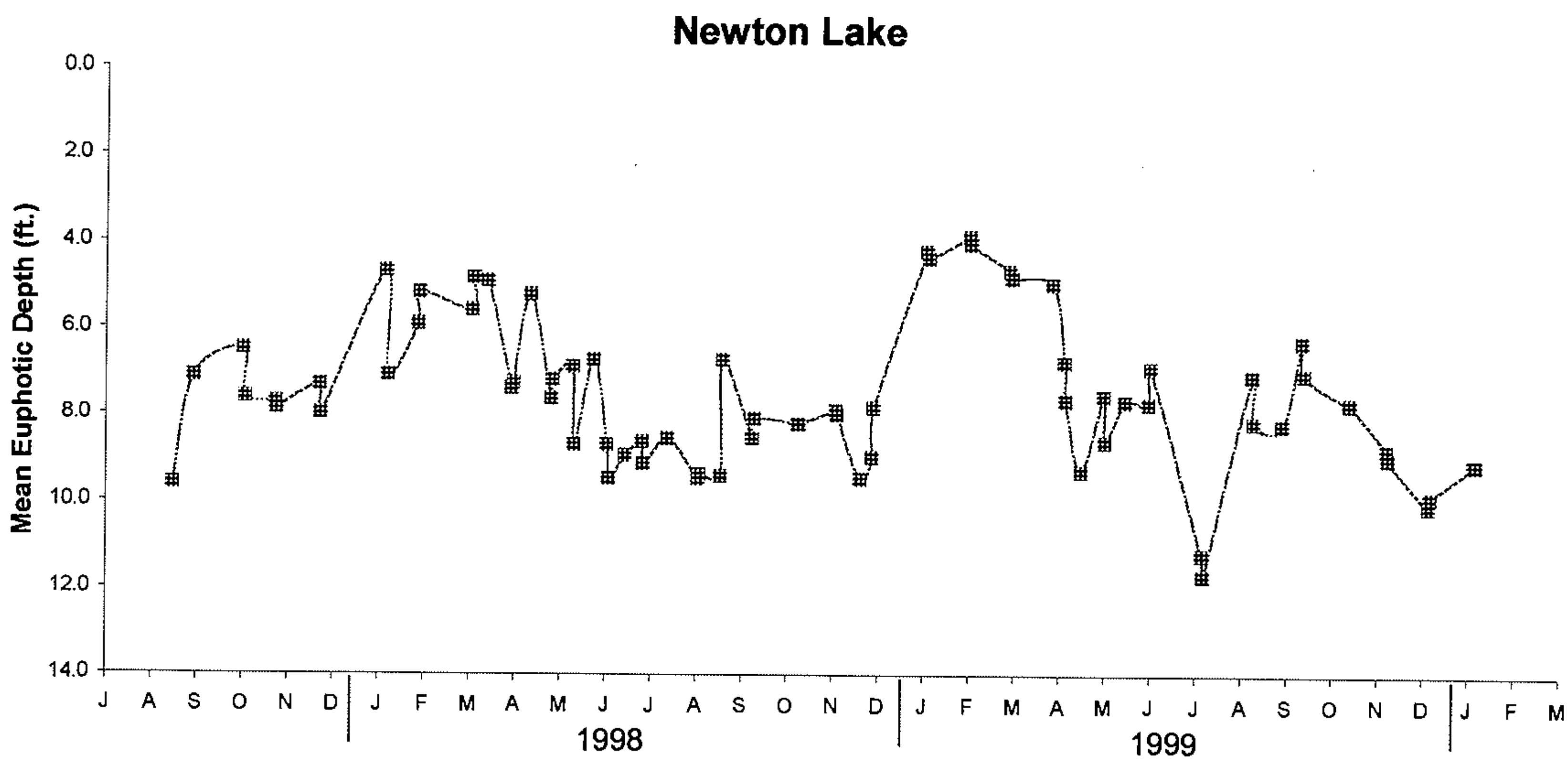


Figure 4.12. Mean euphotic depth (ft.), all segments combined, Newton Lake 1997 – 2000. Note reversal of depth axis to mimic lake cross section

Chapter 5. Benthos

Introduction:

Benthic macroinvertebrates (benthos) are an important part of the aquatic food web since most species of sport fishes feed on them at some stage in their life cycles. Their numbers are not only dependent on substrate types but also cyclic temperature regimes normally associated with seasonal light and ambient temperature changes. The effects of thermal loading in power cooling ponds are poorly understood. The goal of Chapter 5 is to determine seasonal and bathymetric distributions and monitor changes that may occur in the various benthic macroinvertebrate populations in Newton Lake.

Methods:

Sampling for benthos was only done in Newton Lake. Benthos was sampled once a month during October through March and twice a month from April through September, using a standard Ponar dredge (23 cm x 23 cm). Each of the four segments were bisected perpendicularly to the shore with one transect. Six Ponar dredge samples were taken at approximately equal distances from the shore and each other along each of the four transects. The number of samples given in the research protocol were increased from four to six so that benthos in water less than 1-m deep would be sampled. The type of substrate sampled was recorded in the field after the contents of the dredge were placed in a bucket. Invertebrates were initially separated from inorganic material in the field or in the laboratory using a #30 sieve and placed in either 10% buffered formalin or 70% ethanol. Rose Bengal (200 mg/L) was added to the sample to facilitate sorting. At the laboratory, all remaining material was placed in a shallow, white, porcelain-lined pan. A 2x-power, illuminated magnifying lens was used for final removal of invertebrates from the samples. Macroinvertebrates were identified at least to Order. After identification, all macroinvertebrates were stored in 70% ethanol for future reference. The data is reported as mean numbers of invertebrates per square meter and mean number of taxon per square meter. Wet weights were estimated as described in Peterka (1972) and used to estimate total biomass of the benthic macroinvertebrates per square meter. A few clams were collected. Their numbers were included in the density data but their biomass is not included in the weight data.

Analysis for benthic macroinvertebrates that were sampled from September 1997 through August 1999 is summarized in this report. Sampling days and locations are given in Appendix 5.1.

Results and Discussion:

Total benthos densities (n per m^2) were dependent upon year, month, segment, substrate type and depth (p=0.0001; R^2=0.3188).

Mean monthly benthos densities fluctuated in Newton Lake from a low of 780 organisms per m^2 in September of 1998 to a high of 4,597 organisms per m^2 in November 1998 (Table 5.1, Figure 5.1). Densities were generally highest during October through February and lowest in the summer months (June – September). These lower densities are, at least in part, the result of emerging insects. Segment 2 had the highest mean monthly density (3,050) and segment 4 (intake end of the lake) had the lowest mean monthly density (1,285) of benthos (Table 5.2, Figure 5.2). Segment 1 (intake end of the lake) and Segment 3 had intermediate densities. There was no significant difference between densities in Segment 1 and Segment 3.

Average monthly density of benthos found in the warmest months of July and August of 1999 (1,683 per m^2) was 74% higher (p=0.0004) than that found in July and

August 1998 (966 per m^2). The wide ranges and large standard deviations of the samples evidence the variability in the number of benthos collected within each segment.

The mean monthly numbers of benthos that were found in Newton Lake were compared to mean monthly benthos samples found in 12 other Illinois lakes (Hoxmeier et al. 1999). Benthos numbers in Newton Lake are very similar to those in northern Illinois lakes during May through October (Figure 5.3). Lakes located at latitudes similar to Newton Lake had densities that were at least twice those of Newton Lake, but lakes in southern Illinois had densities that were ten times less than the densities in Newton Lake.

Benthos densities' differences among stations and segments were a result of a combination of factors including substrate type and sampling depths (Table 5.3). Highest densities were associated with organic detritus (3,218 per m^2) in the deepest (28 – 31 ft) water sampled (Table 5.4). Substrates with clay and detritus, sand and clay, sand-gravel and clay or sand-gravel-clay and detritus had intermediate densities of benthos. Segment 4 (intake arm of the lake) had the lowest mean densities of all the segments but had no stations deeper than 16 ft and no substrates consisting exclusively of organic detritus. All stations, except Station 1, in Segment 4 had substrates consisting of various amounts of clay, which is a poor substrate for most benthic organisms. Conversely, densities were highest in Segment 2 where four of the six stations consisted of organic detritus in deep-water areas. Water depths at stations sampled in Segment 1 were similar to Segment 4. However, four of the six stations in Segment 1 had substrate containing organic detritus. Thus, except in the summer months, higher densities of benthos were usually present in Segment 1 than in Segment 4 (Figure 5.2). The fact that mean densities and fluctuations of benthos densities were less in

Segment 4 reinforces the hypothesis that substrate quality was a major factor influencing benthos density in that area of Newton Lake.

Biomass was dependent on segment and sampling period (p=0.0001). The mean monthly weight of the benthic macroinvertebrates ranged from a high of 4.1093 g per m^2 in November 1998 to a low of 0.6660 g per m^2 in September 1997 (Figure 5.4, Table 5.5). Both the seasonal changes in weight and weight differences among the four segments almost exactly mirrors that of density. As was the case with densities, the highest mean monthly weight of benthos was in Segment 2 and the lowest was in Segment 4. Segments 1 and 3 had intermediate densities and were not significantly different from each other (Table 5.6, Figure 5.5, Appendix 3).

To a large extent, the number of macroinvertebrate taxa depends upon how far down the specimens are identified. The invertebrates collected from Newton Lake were separated into 19 major taxa (Table 5.7). Eighty-two percent of the organisms collected were in the Order Diptera and 14 percent were in the order Haplotaxida (tubificids). *Chaoborus* spp. and Chironiminae were the dominant subtaxa collected within the orders (Table 5.8). Benthos in the Family Tubificidae represented over 82 percent of the invertebrates included in Haplotaxida. Mean densities of other taxa collected were under 30 individuals per m^2 for the two-year period.

The highest densities of Diptera were collected at stations where substrate consisted of organic detritus (2,599 per m^2) and a mixture of sand, clay, and detritus (1,570 per m^2, Table 5.9). As with invertebrates in the Order Diptera, Haplotaxida were collected from a variety of substrate types. However, the highest densities were collected in substrates that consisted of a mixture of sand and detritus (854 per m^2).

Densities of the individual taxa fluctuated throughout the two-year period (Appendix 5.4). The mean densities of benthos from the Orders Haplotaxida and Diptera were higher than all other taxa collected each sampling date. Thus, trends of abundance for individual taxa were similar to their combined densities as discussed earlier. The two orders were collected at densities that were usually lowest during late July and August of both years sampled and highest in the fall and winter months.

As was the case with density, benthic macroinvertebrates in the Order Diptera contributed most to the total biomass (Table 5.10). Diptera contributed a mean of 1.49 g per m^2 of the total mean of 1.96 g per m^2. Venerioda (clams) and Haplotaxida (tubificids) were the next highest contributors to benthic biomass at 0.24 g per m^2 and 0.16 g per m^2, respectively. *Chaoborus* spp. was the subtaxa that contributed most (1.26 g per m^2) to the mean biomass in the substrate (Table 5.11). Tubificidae and Chironominae contributed approximately 0.32 g per m^2 to the mean benthic, macroinvertebrate biomass in Newton Lake.

Literature Cited:

Hoxmeier, J. H., D. F. Clapp, D. H. Wahl, R. C. Brooks, and R. C. Heidinger. 1999. Final report, Evaluation of walleye stocking program. Division of Fisheries, Illinois Department of Natural Resources, Federal Aid Project F-118-R. 76 p.

Peterka, J.J. 1972. Benthic invertebrates in Lake Astabula Reservoir, North Dakota. American Midland Naturalist 88(2):408-418.

Table 5.1. Mean monthly densities (n per m^2) of benthic macroinvertebrates collected with a ponar dredge from four segments (24 stations) in Newton Lake during September 1997 through August 1999.

Date	Mean density	Range		Standard deviation	Number of samples
September-97	1,237	40	4,772	1,038	46
October-97	1,607	142	7,604	1,738	24
November-97	2,236	61	7,321	1,901	24
December-97	1,671	344	5,440	1,750	22
January-98	1,922	485	7,745	1,633	23
February-98	2,307	182	5,925	1,518	24
March-98	1,830	324	5,116	1,171	23
April-98	1,900	142	5,238	1,372	48
May-98	1,388	20	2,791	703	48
June-98	1,429	121	4,206	1,133	45
July-98	949	0	5,056	1,064	47
August-98	983	20	3,215	832	47
September-98	780	40	3,741	872	47
October-98	2,636	81	7,907	2,073	24
November-98	4,597	162	21,941	5,048	24
December-98	3,964	344	12,315	3,653	23
January-99	3,929	526	15,470	3,505	24
February-99	2,310	61	6,370	1,932	24
March-99	2,342	61	6,491	1,761	24
April-99	2,600	404	7,118	1,571	48
May-99	3,354	506	17,007	2,651	48
June-99	1,904	182	4,449	1,040	48
July-99	2,015	0	7,826	2,002	48
August-99	1,351	0	5,905	1,284	47

Table 5.2. Mean benthic macroinvertebrate densities (n per m^2) in four segments of Newton Lake. Six stations were sampled in each segment during September, 1997 through August, 1999. Superscripts indicate statistical significance among segments (p=0.0001).

Segment	Mean density	Range		Standard deviation	Number of samples
1	1,778[b]	0	9,141	1,614	212
2	3,050[a]	40	21,941	2,944	210
3	1,838[b]	40	17,007	1,786	213
4	1,285[c]	20	5,359	968	215

Table 5.3. Substrate types and depths for each of the stations sampled in Newton Lake during 1997, 1998, and 1999. Segment 1 was located nearest to the power cooling discharge, and Segment 4 was nearest to the intake.

Segment	Station	Depth (ft)	Description
1	1	1.15	sand and gravel
1	2	14.44	organic detritus
1	3	13.94	organic detritus
1	4	13.62	organic detritus
1	5	13.12	organic detritus
1	6	2.46	sand and gravel
2	1	2.46	sand and gravel
2	2	28.71	organic detritus
2	3	30.00	organic detritus
2	4	30.51	organic detritus
2	5	27.89	organic detritus
2	6	1.97	sand and gravel
3	1	2.95	sand and gravel
3	2	18.05	sand and clay
3	3	28.22	organic detritus
3	4	28.22	organic detritus
3	5	29.53	sand, clay and detritus
3	6	1.97	sand and detritus
4	1	0.82	sand and detritus
4	2	14.76	clay and detritus
4	3	16.24	clay and detritus
4	4	14.11	sand and clay
4	5	14.93	sand, gravel, clay and detritus
4	6	2.46	sand, gravel, and clay

Table 5.4. Mean densities (n per m^2) of benthic invertebrates collected from Newton Lake during September 1997 through August 1999. The densities are given according to substrate types and depths. A Ponar dredge was used to collect samples from four segments, each consisting of six stations.

Substrate description	Depth (ft)	Mean density	Range		Standard deviation	Number of samples
Clay and detritus	13 - 18	1,286	100	5,055	936	72
Organic detritus	13 - 18	1,958	40	9,141	1,592	143
Organic detritus	28 – 31	3,218	40	21,941	2,665	210
Sand and clay	13 - 18	996	40	3,721	861	72
Sand and detritus	1 – 3	1,950	101	17,007	2,298	72
Sand and gravel	1 – 3	1,629	0	15,471	1,916	174
Sand, clay, and detritus	28 – 31	1,746	60	5,885	1,498	36
Sand, gravel, and clay	1 – 3	1,198	262	4,206	769	36
Sand, gravel, clay, and detritus	13-18	1,002	20	3,094	787	35

Table 5.5. Mean monthly weights (g per m^2) of benthic macroinvertebrates collected with a ponar dredge from four segments (24 stations) in Newton Lake during September 1997 through August 1999.

Date	Mean weight	Range		Standard deviation	Number of samples
September-97	0.6660	0.0141	4.9888	0.9604	46
October-97	1.2213	0.0262	4.4611	1.3750	24
November-97	2.3703	0.0263	8.9606	2.2219	24
December-97	2.0767	0.0525	10.2386	2.7880	22
January-98	2.2137	0.1476	9.9494	2.3646	23
February-98	3.0412	0.0384	12.8837	3.2416	24
March-98	1.6958	0.0910	6.7745	1.8233	23
April-98	1.4964	0.0080	5.7047	1.5733	48
May-98	1.5517	0.0162	5.7776	1.3551	48
June-98	1.3850	0.0283	5.6036	1.4682	46
July-98	0.9078	0.0000	5.0698	1.2367	47
August-98	1.0388	0.0020	5.3144	1.1327	47
September-98	0.6913	0.0020	4.8433	0.9812	47
October-98	1.9035	0.0101	7.4621	1.9259	24
November-98	4.1093	0.1112	18.0121	4.6180	24
December-98	4.0672	0.3498	16.9828	4.8270	23
January-99	2.9939	0.3053	12.8271	3.2010	24
February-99	2.9158	0.0081	12.0566	3.1908	24
March-99	2.7687	0.0061	12.7422	3.0467	24
April-99	1.8326	0.2204	7.8504	1.9272	48
May-99	2.1673	0.1759	6.5380	1.7308	48
June-99	1.6145	0.0647	4.6412	1.2040	48
July-99	1.6014	0.0000	7.0455	1.7784	48
August-99	1.2267	0.0000	6.4429	1.4152	46

Table 5.6. Mean weights (g per m^2) of benthic macroinvertebrates collected and analyzed by segments. The benthos was collected from Newton Lake during September 1997 through August 1999 using a ponar dredge. Benthic samples were collected from six stations along each transect that bisected each of the four segments. Superscripts indicate statistical significance among segments ($p=0.0001$).

Segment	Mean weight	Range		Standard deviation	Number of samples
1	1.5446[b]	0.0000	9.9090	1.6376	211
2	3.0190[a]	0.0061	18.0121	3.3269	210
3	1.5314[b]	0.0081	10.2386	1.5595	213
4	1.0334[c]	0.0000	12.8837	1.3980	215

Table 5.7. Mean densities (n per m^2) of macroinvertebrate taxa collected in Newton Lake during September 1997 through August 1999. Samples (851) were collected from 24 stations located at four transects (6 stations per transect) within the lake.

Taxon	Mean density	Contribution (%)	Range		Standard deviation
Ephemeroptera	15	1	0	910	64
Hydracarina	1	<1	0	162	8
Diptera	1,619	82	0	21,941	1,950
Odonata	<1	<1	0	81	4
Coleoptera	<1	<1	0	20	2
Bryozoa	1	<1	0	303	12
Trichoptera	9	<1	0	789	40
Pelecypoda	18	1	0	2,063	134
Hemiptera	<1	<1	0	20	1
Gastropoda	<1	<1	0	40	2
Nematoda	6	<1	0	2,427	87
Nematomorpha	1	<1	0	81	5
Veneroida	29	1	0	1,719	123
Haplotaxida	275	14	0	12,659	675
Podocopa	<1	<1	0	40	2
Lumbriculida	<1	<1	0	81	3
Isopoda	<1	<1	0	20	1
Basomatophora	<1	<1	0	81	3
Amphipoda	<1	<1	0	162	6
Total	**1,980**		**0**	**21,941**	**2,057**

Table 5.8. Mean densities (n per m^2) of primary macroinvertebrate subtaxa collected in Newton Lake during September 1997 through August 1999. Samples (841) were collected from 24 stations located at four transects (6 stations per transect) within the lake.

Taxon	Mean density	Range		Standard deviation
Ceratopogonidae	25	0	2,508	136
Chaoborus spp.	1,210	0	21,941	1,973
Tubificidae	227	0	12,659	642
Nematoda	6	0	2,427	88
Chironominae	379	0	11,325	795

Table 5.9. Macroinvertebrate mean densities (n per m^2) from various substrates of twenty-four stations sampled with a ponar dredge in Newton Lake during September 1997 through August 1999.

Taxon	Sand and gravel	Sand, gravel and clay	Sand, gravel, clay and detritus	Sand and clay	Sand, clay and detritus	Sand and detritus	Clay and detritus	Organic detritus
Ephemeroptera	40	8		2	2	71	2	1
Hydracarina	2	2				8		
Diptera	1,009	509	455	698	1,571	795	1,029	2,599
Odonata	2					<1		
Coleoptera	<1	1				1		<1
Bryozoa	2			1	1	1	2	1
Trichoptera	24	6		1		37	1	1
Pelecypoda	25	60	6	<1	39	92	9	1
Hemiptera								<1
Gastropoda	<1	1						<1
Nematoda	4	7	91	6	2	1	4	1
Nematomorpha	1	2		1		1	2	<1
Veneroida	48	138	15	29	28	85	11	2
Haplotaxida	457	466	432	251	103	854	226	64
Podocopa	<1				1	1		
Lumbriculida			2		1			
Isopoda	<1							
Basomatophora			1			1		
Amphipoda	<1							<1

Table 5.10 Mean weight (g per m^2) of benthic macroinvertebrate taxa collected from Newton Lake during September 1997 through August 1999 using a ponar dredge. Benthic samples (857) were collected from six stations along each transect that bisected each of the four segments.

Taxa	Mean weight	Contributi (%)	Range		Standa deviatio
Ephemeroptera	0.0076	<1	0.0	0.5	0.0
Hydracarina	0.0001	<1	0.0	0.0	0.0
Diptera	1.4896	76	0.0	18.0	2.2
Odonata	0.0013	<1	0.0	0.3	0.0
Coleoptera	0.0003	<1	0.0	0.1	0.0
Bryozoa	0.0006	<1	0.0	0.2	0.0
Trichoptera	0.0113	1	0.0	0.7	0.0
Pelecypoda	0.0380	2	0.0	3.4	0.2
Hemiptera	0.0002	<1	0.0	0.1	0.0
Gastropoda	0.0034	<1	0.0	2.0	0.0
Nematoda	0.0011	<1	0.0	0.3	0.0
Nematomorpha	0.0001	<1	0.0	0.0	0.0
Veneroida	0.2383	12	0.0	155.3	5.3
Haplotaxida	0.1591	8	0.0	12.4	0.6
Podocopa	0.0000	<1	0.0	0.0	0.0
Lumbriculida	0.0004	<1	0.0	0.2	0.0
Isopoda	0.0015	<1	0.0	1.2	0.0
Basomatophora	0.0006	<1	0.0	0.2	0.0
Amphipoda	0.0004	<1	0.0	0.2	0.0
Total Mean Weight	**1.9549**		**0.0**	**155.4**	**5.7**

Table 5.11. Mean weights (g per m^2) of benthic macroinvertebrate subtaxa collected in Newton Lake during September 1997 through August 1999. Samples (846) were collected from 24 stations located at four transects (6 stations per transect) within the lake.

Taxon	Mean weight	Range		Standard deviation
Ceratopogonidae	0.0183	0.0000	3.4803	0.1980
Chaoborus sp.	1.2721	0.0000	18.0121	2.2277
Tubificidae	0.1224	0.0000	12.3195	0.5591
Nematoda	0.0011	0.0000	0.3741	0.0180
Chironominae	0.1966	0.0000	3.6097	0.3601

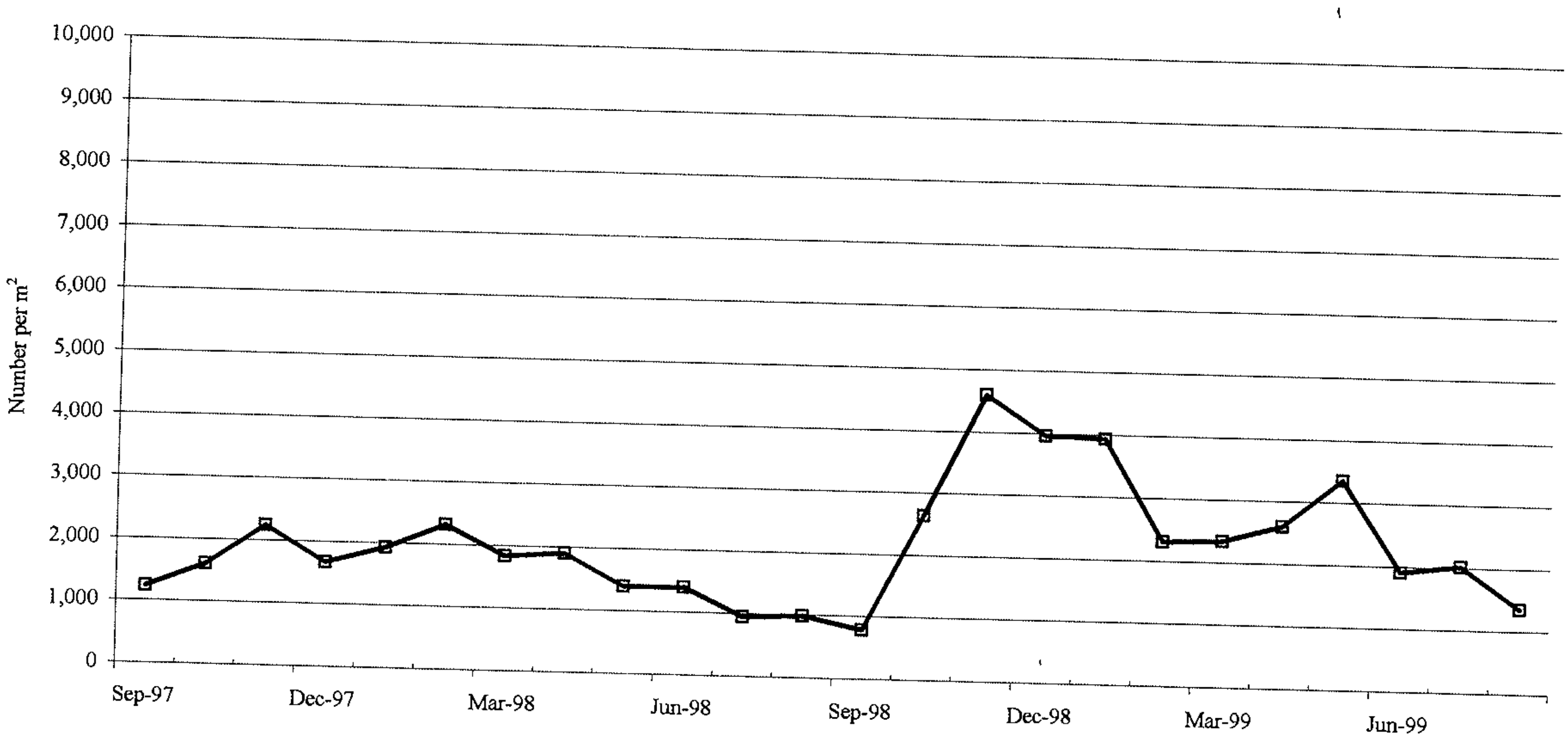


Figure 5.1. Mean monthly macroinvertebrate densities collected in Newton Lake (24 stations) from September 1997 through August 1999. Benthos was collected using a ponar dredge.

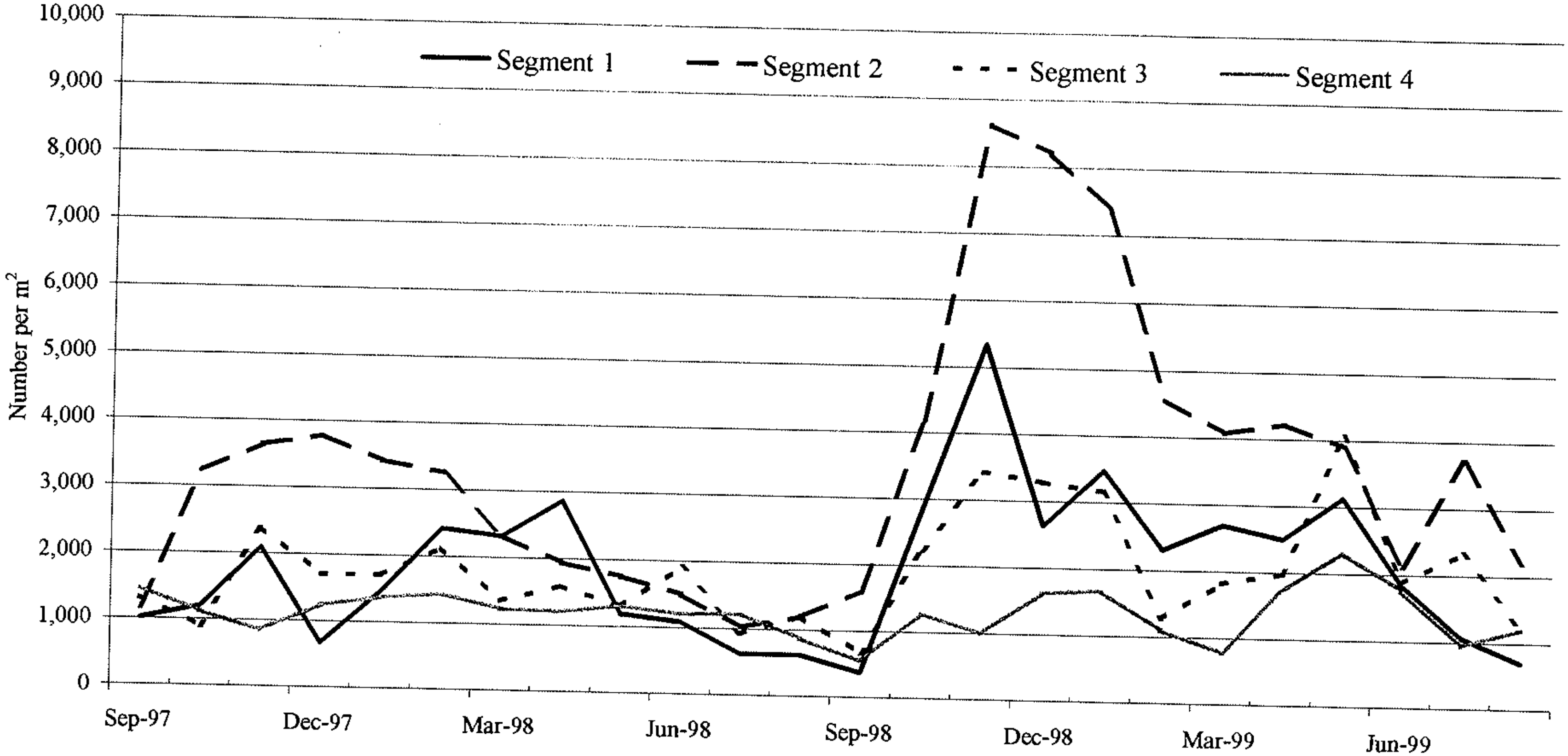


Figure 5.2. Mean monthly macroinvertebrate densities collected in Newton Lake (24 stations) from September 1997 through August 1999. Benthos was collected using a ponar dredge. Segment 1 is at the discharge end of the lake and Segment 4 is at the intake end of the lake.

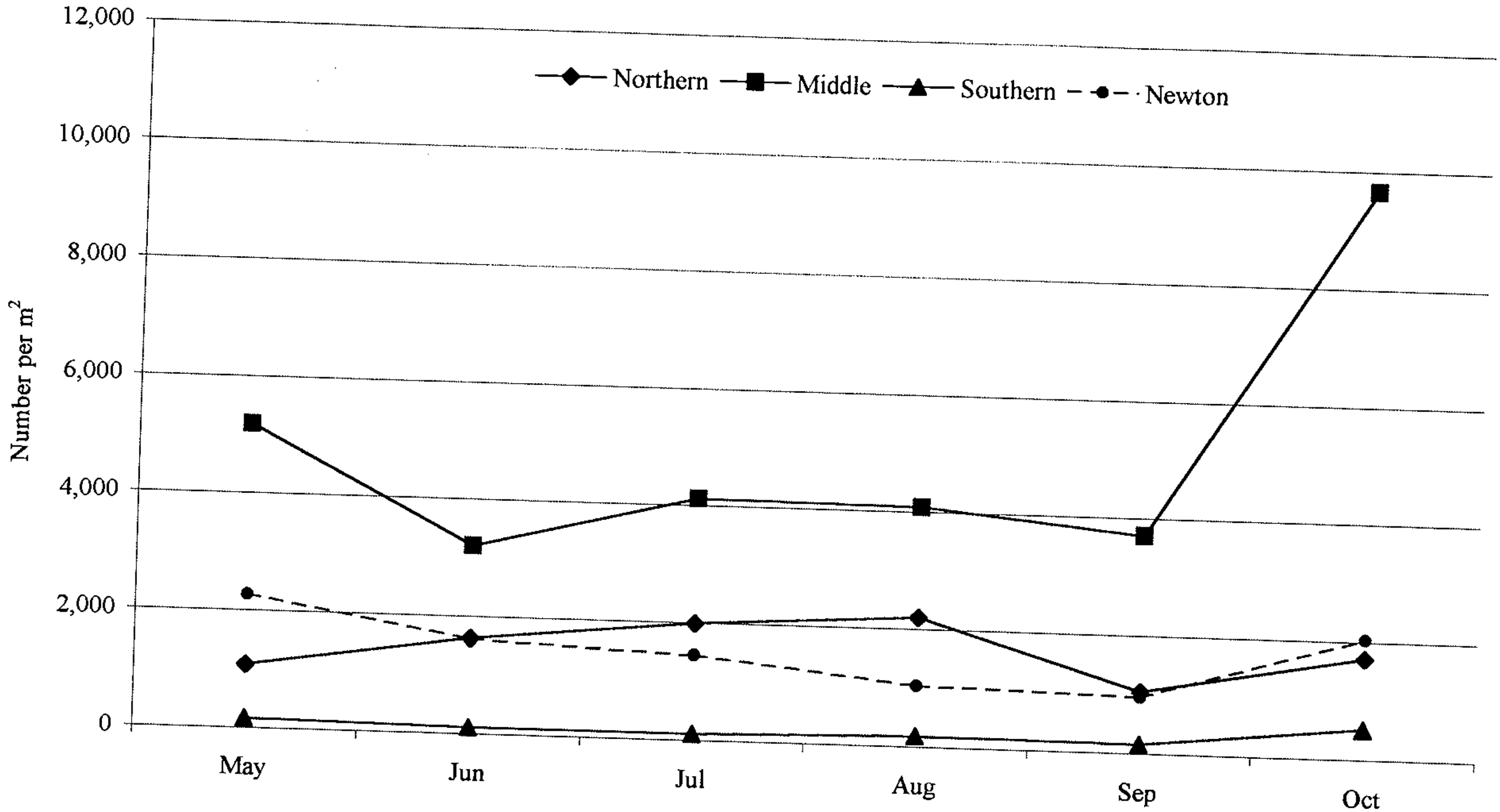


Figure 5.3. Mean benthos densities in 12 lakes located from three regions of Illinois compared to densities in Newton Lake from May through October. Benthos was collected each year during 1993 through 1997 from the 12 Illinois lakes and in 1998 and 1999 in Newton Lake. Four to six samples were taken each month from each of the 12 lakes for five years. Five lakes were sampled in the northern zone, six in the middle zone, and four in the southern zone.

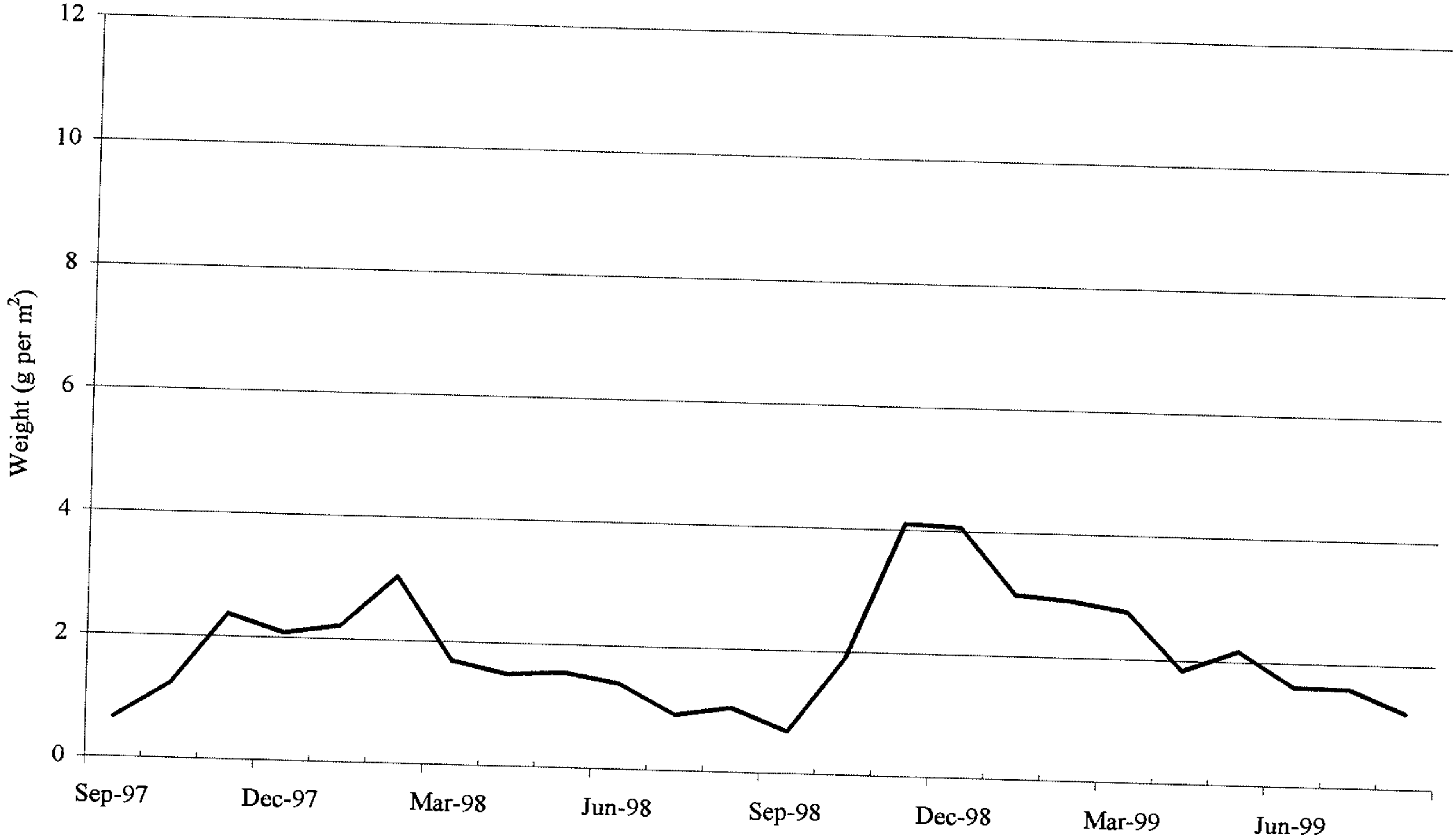


Figure 5.4. Mean monthly weights of macroinvertebrates collected in Newton Lake (24 stations) during 1997 through 1999. Benthos was collected using a ponar dredge.

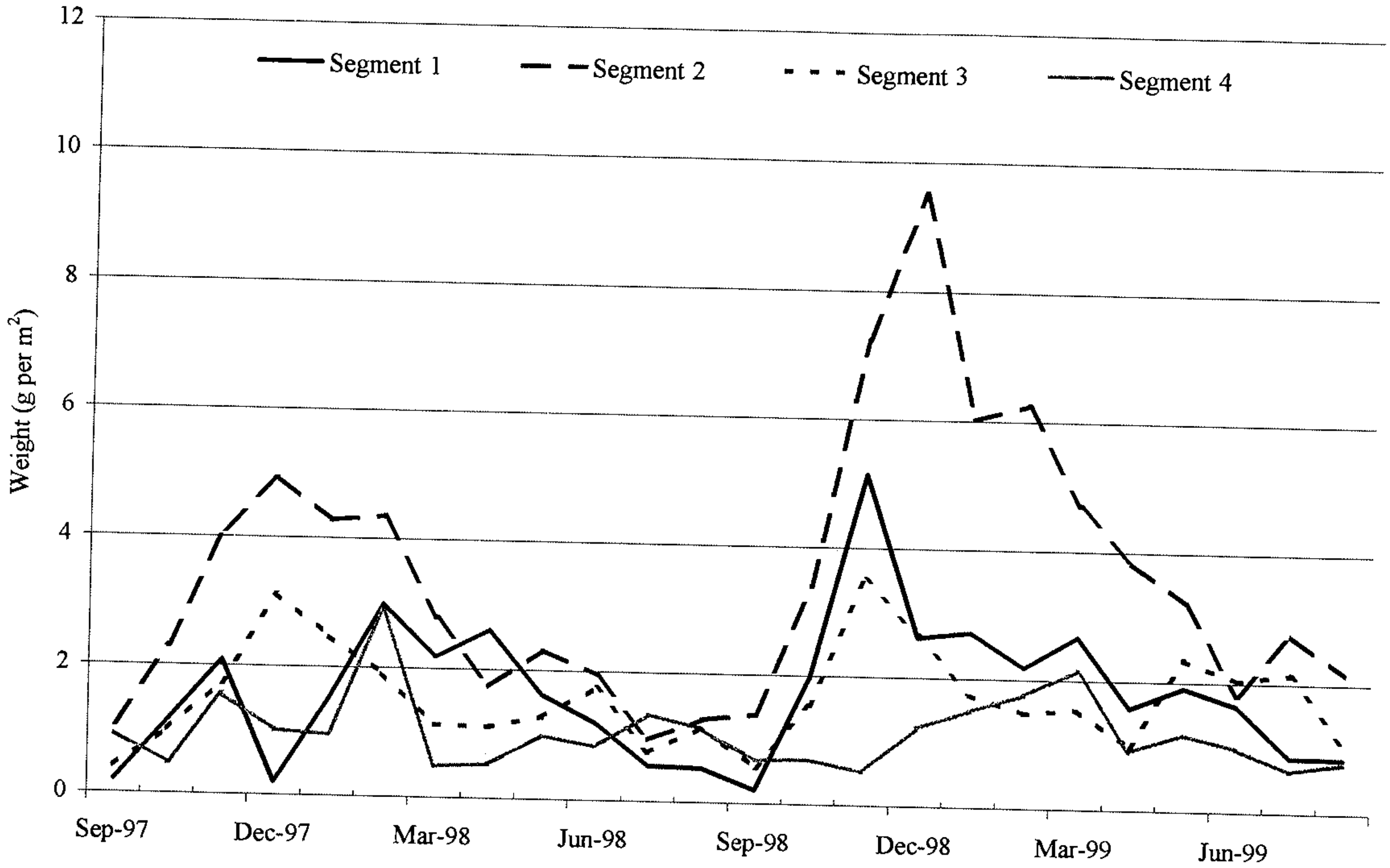


Figure 5.5. Mean monthly weights of macroinvertebrates collected in Newton Lake (24 stations) from September 1997 through August 1999. Benthos was collected using a ponar dredge. Segment 1 is at the discharge end of the lake and Segment 4 is at the intake end of the lake.

Chapter 5. Appendix: Supplemental Data Tables

Appendix 5.1. Collection dates and stations sampled in Newton Lake for benthos during 1997 through 1999. A ponar dredge was used for benthos collection.

Date	Segments	Stations	Date	Segments	Stations
09/11/97	1	1-5	12/10/98	1,2,4	1-6
09/11/97	2	1-6	12/10/98	3	1,2,4,5,6
09/11/97	3	1,5,6	01/28/99	1-4	1-6
09/11/97	4	1,3-6	02/10/99	1-4	1-6
09/12/97	2-3	4	03/22/99	1-4	1-6
09/12/97	4	1	04/15/99	1-4	1-6
09/19/97	3	2,3	04/28/99	1-4	1-6
09/19/97	4	2	05/13/99	1-4	1-6
09/20/97	1	6	05/27/99	1-4	1-6
09/23/97	1-4	1-6	06/09/99	1-4	1-6
10/08/97	1-4	1-6	06/24/99	1-4	1-6
11/24/97	1-4	1-6	07/13/99	1-4	1-6
12/10/97	1-4	1-6	07/30/99	1-4	1-6
01/15/98	1-4	1-6	08/12/99	1-4	1-6
02/12/98	1-4	1-6	08/24/99	1-4	1-6
03/25/98	1-4	1-6			
04/08/98	1-4	1-6			
04/22/98	1-4	1-6			
05/06/98	1-4	1-6			
05/19/98	1-4	1-6			
06/02/98	1-4	1-6			
06/16/98	1	1-5			
06/16/98	2	1,3,4,5			
01/06/00	3-4	1-6			
07/08/98	1	1-5			
07/08/98	2-4	1-6			
07/21/98	1	2-6			
07/21/98	2-6	1-6			
08/05/98	1	2-6			
08/05/98	2-4	1-6			
08/26/98	1-4	1-6			
09/08/98	1-4	1-6			
09/21/98	1-4	1-6			
10/08/98	1-4	1-6			
11/03/98	1-4	1-6			

Appendix 5.2. Mean density (n per m^2) of benthic macroinvertebrates collected from Newton Lake during September 1997 through August 1999. Benthos were collected using a ponar dredge in four segments (24 stations). Segment 1 is at the discharge of the lake and Segment 4 is at the intake end of the lake.

Segment	9/11/97	9/23/97	10/8/97	11/24/97	12/10/97	1/15/98	2/12/98	3/25/98	4/8/98	4/22/98	5/6/98	5/19/98
1	1,638	485	1,193	2,093	674	1,459	2,413	2,312	2,194	3,525	1,591	775
2	735	1,594	3,222	3,630	3,777	3,414	3,256	2,322	2,093	1,786	1,817	1,692
3	1,328	1,294	893	2,380	1,695	1,695	2,127	1,352	967	2,214	1,227	1,389
4	1,419	1,476	1,119	843	1,240	1,368	1,432	1,234	1,105	1,311	1,443	1,170

Segment	6/16/98	7/8/98	7/21/98	8/5/98	8/26/98	09/08/98	09/21/98	10/08/98	11/03/98	12/10/98	01/28/99	02/10/99
1	1,298	897	354	352	856	165	580	2,848	5,349	2,629	3,475	2,302
2	1,567	1,726	330	870	1,523	1,281	1,974	4,176	8,615	8,214	7,408	4,550
3	1,507	1,205	684	762	1,648	425	920	2,241	3,424	3,276	3,158	1,284
4	846	1,753	688	637	1,112	489	603	1,277	1,001	1,621	1,675	1,102

Segment	04/15/99	04/28/99	05/13/99	05/27/99	06/09/99	06/24/99	07/13/99	07/30/99	08/12/99	08/24/99
1	3,340	1,641	4,183	2,073	2,157	1,523	859	1,271	400	944
2	4,149	4,287	3,819	3,977	2,181	2,066	3,707	3,718	2,396	2,016
3	1,665	2,278	4,911	3,219	2,103	1,658	2,653	2,016	1,011	1,473
4	1,736	1,705	2,366	2,282	1,827	1,716	1,065	829	1,170	1,240

Appendix 5.3. Mean weight (g per m^2) of benthic macroinvertebrates collected from Newton Lake during September 1997 through August 1999. Benthos were collected using a ponar dredge in four segments (24 stations).

Segment	9/11/97	9/23/97	10/8/97	11/24/97	12/10/97	1/15/98	2/12/98	3/25/98	4/8/98	4/22/98	5/6/98	5/19/98	6/2/98
1	0.2851	0.1422	1.1392	2.0893	0.2036	1.5106	2.9852	2.1786	2.1196	3.1011	2.0368	1.1975	1.0229
2	0.9404	1.1975	2.2787	4.1075	4.9338	4.2790	4.3539	2.7937	1.7486	1.7233	2.8386	1.7968	1.5797
3	0.4035	0.4169	0.9933	1.7280	3.1112	2.4631	1.9168	1.1220	0.6589	1.5578	1.0414	1.5156	2.2619
4	0.5821	1.2555	0.4742	1.5564	1.0108	0.9464	2.9090	0.4873	0.4273	0.6343	0.6359	1.3512	1.1982

Segment	6/16/98	7/8/98	7/21/98	8/5/98	8/26/98	09/08/98	09/21/98	10/08/98	11/03/98	12/10/98	01/28/99	02/10/99	03/22/99
1	1.4168	0.9066	0.1982	0.2087	0.7971	0.0806	0.3350	1.9886	5.1547	2.6181	2.7142	2.1824	2.6653
2	2.5005	1.7128	0.2025	0.7550	1.8197	1.1759	1.6254	3.3910	7.2444	9.5336	6.0199	6.2555	4.7199
3	1.2255	0.9359	0.6070	0.7654	1.5487	0.2454	0.8756	1.5356	3.5136	2.6621	1.7442	1.4678	1.5430
4	0.4682	2.2174	0.4870	0.5773	1.7000	0.5059	0.8426	0.6990	0.5244	1.2208	1.4975	1.7577	2.1466

Segment	04/15/99	04/28/99	05/13/99	05/27/99	06/09/99	06/24/99	07/13/99	07/30/99	08/12/99	08/24/99
1	2.1115	1.0499	2.5376	1.2700	1.3910	1.8763	0.6400	1.0768	0.3094	1.3767
2	4.0061	3.6832	2.6697	3.7938	2.4550	1.1729	3.4456	2.0681	2.3937	1.9120
3	1.0606	0.9265	1.7617	2.9222	2.0246	2.0411	2.3428	1.9430	0.9175	1.2336
4	0.8750	0.9477	1.0701	1.3131	0.8901	1.0654	0.7489	0.5457	0.7535	0.7897

Appendix 5.4. Mean densities (n per m^2) of macroinvertebrate taxa collected from Newton Lake during September 1997 through August 1999. Twenty-four stations were sampled using a ponar dredge on each date.

Taxa	09/11/97	09/23/97	10/08/97	11/24/97	12/10/97	01/15/98	02/12/98	03/25/98	04/08/98	04/22/98	05/06/98	05/19/98	06/02/98
Ephemeroptera	<1	8	2	43	13	<1	7	8	<1	15	2		7
Hydracarina	<1					<1	2						
Diptera	518	851	1,316	1,797	1,333	1,560	1,982	1,592	1,271	1,624	1,314	1,128	1373
Odonata			<1	3									
Coleoptera			2								<1		
Bryozoa										<1	2	3	13
Trichoptera	<1	3	5	2	3		2						8
Pelecypoda	5	28	93	142	24	16	3	2		45	<1		
Gastropoda			<1										
Hemiptera													
Nematoda		122					<1	4				8	4
Nematomorpha				5	4					2		114	
Veneroida				3	27	<1	19	69	19	48	18		
Haplotaxida	642	194	188	241	268	343	291	152	297	474	181	<1	151
Podocopa									<1			<1	
Lumbriculida										<1			3
Basomatophora													
Amphipoda													

Appendix 5.4. Continued.

Taxa	06/16/98	07/08/98	07/21/98	08/05/98	08/26/98	09/08/98	09/21/98	10/08/98	11/03/98	12/10/98	01/28/99	02/10/99	03/22/99
Ephemeroptera	24	25	14	9	11	<1	13	13	56	7	56	16	17
Hydracarina		<1		<1	2			2	7	4	<1	<1	
Diptera	1,057	1,309	433	504	1,195	548	858	2,400	4,291	3,218	276	1,896	1,998
Odonata						2		2	2		2		
Coleoptera	<1		2										
Bryozoa			<1		4							2	<1
Trichoptera	18	16	3	7	<1	3	4	13	31	18	43	4	8
Pelecypoda						<1	10		2	98	159	30	
Gastropoda											<1		
Hemiptera		<1											
Nematoda				<1		<1		3		<1	33	<1	3
Nematomorpha		<1	<1	3	<1				<1	2		2	
Veneroida	3	3		5	3			2	8	155	2	43	75
Haplotaxida	191	108	82	137	69	28	92	197	197	47	871	316	236
Podocopa									2				
Lumbriculida													
Basomatophora								4					
Amphipoda						7			<1				

Appendix 5.4. Continued.

Taxa	04/15/99	04/28/99	05/13/99	05/27/99	06/09/99	06/24/99	07/13/99	07/30/99	08/12/99	08/24/99
Ephemeroptera	6	5	14	19	3	13	22	9	10	2
Hydracarina	2		2	4	5	<1	2	2	4	2
Diptera	2,283	1,842	2,347	2,463	1,699	1,470	1,696	228	1,132	135
Odonata				<1				1		
Coleoptera			<1							
Bryozoa	5			<1		3		1	3	5
Trichoptera	6	6	1	23	41	8	22	2	4	
Pelecypoda		3								
Gastropoda			2							
Hemiptera										
Nematoda	3	3	9	8	3	5	8	1	5	<1
Nematomorpha								1		
Veneroida	8	35	55	83	75	83	74	6	4	16
Haplotaxida	318	581	137	282	215	158	246	83	92	20
Podocopa										3
Lumbriculida										
Basomatophora										
Amphipoda										

Chapters 6 and 7. Phytomacrobenthos and Aquatic Vegetation

Introduction:

Due to the interaction between the presence of aquatic vegetation and phytomacrobenthos densities and weights, Chapter 6 (Phytomacrobenthos) and Chapter 7 (Aquatic Vegetation) have been combined for this report.

The presence and coverage of aquatic macrophytes plays an important role in the basic ecological functions of a power cooling reservoir such as Newton Lake. Spawning and recruitment of fish are both related to aquatic vegetation in some manner. Some fish use vegetation for spawning, while others require spawning areas devoid of vegetation. The abundance or presence of small fish, whether they are juvenile stages of species that can become very large or species that will not grow more than a few inches, is largely dependent on structure that aquatic macrophytes can provide.

The availability of insects as fish forage is also related to aquatic vegetation coverage. Aquatic invertebrates living on macrophytes - phytomacrobenthos - are an important food item of both juvenile and adult fish.

Chapters 6 and 7 assess the presence and coverage of aquatic macrophytes and the identification, density, and weights of the phytomacrobenthos associated with them. Changes in macrophyte diversity and coverage are being monitored over time and by segments within Newton Lake. Relationships of macrophytes to water levels and invertebrates to water temperature are assessed. Changes in phytomacrobenthos taxa, densities, and weights are also analyzed.

Methods:

Changes in total macrophyte coverage were determined in August 1997, 1998, and 1999 by measuring the extent of the macrophyte beds. Twenty sampling stations, 10 on each side of the lake in each of the four segments, were randomly selected on a map of Newton Lake (Figure 6.1). A numbered metal stake was driven into the shore at each station at pool elevation (505.0). From each stake, a measuring tape was extended out perpendicularly to the shoreline to the outer edge of the vegetation and the distance recorded. The depth of water was recorded at one-meter intervals from the stake to the outer edge of the vegetation. A one-meter long rod was run perpendicularly to the transect line from the shore to the outer edge of the vegetation bed, and the occurrence by plant species was visually noted.

Invertebrates on aquatic vegetation were collected in August and September 1997, and from May through September in 1998 and 1999 from five sampling stations where macrophytes were abundant in each lake segment (Appendix 6.1). Two samples were collected at each station (Figure 6.2). A 1.0-m diameter sampler consisting of a 400-*u* mesh, 3-m long bag with a collapsible opening (Peterka 1972) was used to collect the aquatic vegetation and associated invertebrates in 1997. During the remaining sampling period a 0.5-m (1998) or a 0.291- m (1999) diameter sampler consisting of a 400 *u* mesh, 3-m long bag with a collapsible opening was used. Aquatic macrophytes were cut at the sediment, the bag was closed around the aquatic vegetation, and the contents were immersed in 70% formalin to dislodge the invertebrates from the vegetation. Invertebrates were then stored in a 70% ethanol – rose bengal solution until they were separated and identified as described for Chapter 5 (Benthos). Density of the phytomacrobenthos was estimated as invertebrates per m^2 of water surface area (Downing and Rigler 1984). Wet weights were estimated as described in Peterka (1972) and used to estimate total biomass of the invertebrates per-gram wet weight of the aquatic vegetation. Total biomass and number of phytomacrobenthos at each sampling date was extrapolated from estimated total aquatic macrophytes in the littoral zone.

Results:

The amount and diversity of macrophytes present in Newton Lake during the three-year study was generally due to differences to water levels and not water temperatures. The effect of the low water levels in August 1997 (2.13 ft below pool) and 1999 (5.20 ft below pool) is best described by comparing the total amount of macrophyte coverage for the entire lake. There are approximately 40.887 miles of shoreline in Newton Lake. The average feet (rounded) that macrophytes extended from the water's edge in August of each year for all 80 sites was 3.04 (1997), 7.03 (1998), and 4.43 (1999). Thus, there were 656,642 ft^2 of macrophytes present in 1997 and 955,603 ft^2 of macrophytes in 1999. The water in Newton Lake in August 1998 was at pool level, and there were 1,517,164 ft^2 of macrophytes. Particularly noteworthy is the fact that there were more macrophytes present in 1999 than in 1997 despite the lower water levels and extremely high water temperatures in 1999. In fact, macrophyte mean densities (lbs per m^2) were highest during May 1998 and August 1999 (Figure 6.3). Several factors could affect macrophyte presence and density in Newton Lake including (but not limited to) water clarity, changes in nutrient loading, and the amount of macrophytes present in the previous years.

The percent of stations with some type of macrophyte was highest during the 1998 sampling when 32.3% of the 80 stations did not have macrophytes. In August 1997 and 1999, macrophytes were not present in 52.5% and 39.5% of the stations in the respective years. The same was basically true when the lakes were divides by segments (Table 6.1). Except for Segment 2 in 1999, percent occurrence and the highest macrophyte diversity was in 1998 when the water level was at pool. Water willow (*Dianthera americana*) was the only macrophyte present in 1997 and was most the prevalent plant in all years. *Phragmites australia and* spike rush (*Eleocharis* spp) were present in the latter two years, but they were most abundant in the water during 1998. The percent occurrence of macrophytes usually decreased from Segment 1 (discharge segment) to Segment 4 (intake segment) of all years.

Distances from the shoreline to the outer edge of macrophytes for the sites containing macrophytes ranged from 0.19 ft to 24.71 ft. The mean was highest in 1998 (Table 6.2). Although water levels were lowest in 1999, the distances that macrophytes were found from shore were not always less than in 1997.

Mean depths at which macrophytes occurred in all years ranged from 0.02 ft to 2.82 ft (Table 6.2). Maximum depths of which macrophytes were sampled were not always due to August water levels. Based on the lack of correlation between water levels and depths of which macrophytes occurred in each year, the plant depths were likely dependent on water clarity and lake contour. Even plant diversity was not water level dependent. This was surprising since many plant species that were identified in 1997 existed in areas that were marginally aquatic. Higher water levels in 1998 did result in more inundated macrophyte species. However, lowest water levels were recorded in August 1999, but macrophytes diversity was higher than in the previous years.

Macrophytes were collected and weighed during May through September when phytomacrobenthos samples were collected (Appendix 6.1). Approximate sample locations for the four lake segments are shown in Figure 6.2. Macrophyte densities (weight per m^2) were generally higher in each month during 1998 than in the other years. Sample weights were variable among the months and years (Figure 6.3). Mean densities during July and August were higher in 1998 and 1999 than in August 1997. As with the 80 sites sampled each August, water willow was the primary species sampled at stations where phytomacrobenthos were collected (Table 6.3), and their percent contribution (by wet weight) was higher than all other macrophyte taxon (Table 6.4).

Plant diversity in the twenty stations sampled May - September increased slightly each year (Table 6.4). Macrophyte taxa collected included water willow, phragmites, cattails (*Typha* spp.), spike rush (*Eleocharis* spp.), primrose (*Jussiaea repens var. glabrescens*, pond weed (*Potomogeton* spp), and other rushes (*Scirpus* spp.). Taxa diversity increased from Segment 1 to Segment 4 each year).

The phytomacrobenthos (invertebrates) mean density for all samples combining the entire sampling period was 5,326 organisms per m^2 with a standard deviation of 7,972 per m^2 (Table 6.5). Such a high standard deviation resulted from individual samples ranging from 31 to 99,844. The highest densities were collected in May (10,605 per m^2) and August (12,566 per m^2) 1999. August densities were significantly (p=0.0006) higher in 1999 than 1997 (1,628 per m^2) and 1998 (6,849 per m^2). The differences were not significant between 1997 and 1998. Examination of abundance trends over time indicate that there was a slight decrease in the aquatic invertebrates during June and July 1998 and 1999, but numbers increased during the following months in each year (Figure 6.4). Trends of abundance by month and year within segments were similar to the combined segments except in Segment 4 where abundance patterns over time were less evident (Figure 6.5). There were no significant differences among the segments (Table 6.6).

Mean densities of the different invertebrate taxon collected ranged from 0.04 per m^2 of Order Decapoda to 3,863.54 per m^2 of Order Diptera (Table 6.7). Diptera were present in all samples and occurred at higher densities than all other organisms (Appendix 6.2). Haplotaxida (mostly Tubificidae) and Trichoptera were present in the second highest densities. Invertebrates of the Family Chironomidae represented 98.8 percent of all the Diptera collected (Table 6.8).

In order to detect the effects of plant densities on phytomacrobenthos densities, plant biomass is included in the analysis. The highest number of invertebrates per pound of macrophytes were collected during May, August, and September 1999 (p=0.0001, Table 6.9). Segment 4 had the highest mean densities per pound when all sampling dates were included in the analysis (p=0.0001, Table 6.10). The higher densities in Segment 4 were mostly evident in months other than in May (Figure 6.6).

The mean weight of phytomacrobenthos per m^2 for the entire sampling period was 2.1283 g per m^2 with a standard deviation of 3.6457 g per m^2 (Table 6.11). Such a large standard deviation is a result of individual samples ranging from 0.0000 to 39.7136 g per m^2. Mean weights were also significantly (p = 0.0001) different across collection dates. September 1999 had significantly higher mean weights than all other months sampled. May and August 1999 were higher than all months except September 1999. As was true for the phytomacrobenthos numbers, mean August weights were significantly higher (p=0.0001) in 1999 (4.313 g per m^2) than in 1998 (1.646 g per m^2) or 1997 (0.369 g per m^2). Biomass trends among dates and segments for phytomacrobenthos were similar to those described for the invertebrate numbers (Figure 6.7). Phytomacrobenthos mean weights in our samples were significantly (p =0.0001) greater in Segments 1 and 2 than in the remaining segments (Table 6.12). Diptera comprised over 72% of the weight of all the organisms collected (Table 6.13) and usually contributed most to biomass on each sampling date (Appendix 6.3).

In order to determine if invertebrate mass was a function of macrophyte densities, we compared the mass per sample means by per pound of macrophytes. This analysis compensates for changes in plant biomass (lbs per m^2) over time. The highest (p = 0.0001) mean weight per pound of macrophytes was collected in September 1999 followed by May and August 1999 (Table 6.14). There were no significant differences in the weight of organisms per pound of macrophytes across segments (Table 6.15). High standard deviations were seen for both collection dates and segments. No trends were apparent for weight of organisms per pound of macrophytes over time for all segments (Figure 6.8). Lower weights during July of both the respective years may have been due to emergence of invertebrates as adults rather than temperature related.

Discussion:

Macrophyte taxa diversity increased in Newton Lake from August 1997 through September 1999. Diversity increased somewhat from Segment 1 to Segment 4 (warm water to cold water). This increase in diversity included a change to such macrophytes as phragmites, bulrush, spike rush, and cattails. Submergent macrophytes other than algae were not found at any sample location. Macrophyte coverage increased from 1997 to 1998, and the increase was related to water levels. However, the lowest water levels were during 1999, and macrophyte coverage and diversity was higher than in 1997.

Considerable variability existed in plant weights sampled for phytomacrobenthos assessment. Due to seasonal plant growth in the lake, it is hard to collect samples over time without confounding variables. We would expect to see seasonal changes in phytomacrobenthos densities and weights per meter squared. This was the case in some instances, but not all.

There does not appear to be a correlation between phytomacrobenthos densities/weights and plant biomass. Macrophyte weights collected in 1998 were significantly higher than in 1997 or 1999. In 1997 and 1998, as plant weights decreased significantly in the samples, invertebrate densities did not. However, there appeared to be a positive correlation between macrophyte and invertebrate densities in 1999 (Figures 6.3 and 6.4). Most of the phytomacrobenthos sampled from all segments were of the Family Chironomidae. One reason for this may be an association of chironomids with water willow, which also comprised the vast majority of macrophytes in Newton Lake. It does not appear that water temperature had an adverse effect on macrophyte or phytomacrobenthos densities.

Macrophyte density was more related to water levels than temperature, and phytomacrobenthos numbers were apparently unaffected by the high water temperatures in 1999.

Literature Cited:

Downing, J.A., and F.H. Rigler. 1984. A manual on methods for the assessment of secondary productivity in fresh water. Blackwell Scientific Publications, Boston, Massachusetts.

Peterka, J.J. 1972. Benthic invertebrates in Lake Astabula Reservoir, North Dakota. American Midland Naturalist 88(2):408-418.

Table 6.1. Percent of stations with no vegetation or occurrence of macrophyte taxa in Newton Lake during August of 1997, 1998, and 1999. Twenty stations were selected in each of four segments. Numbers in parenthesis represent feet below pool in August of each year..

Taxa	1997 (-2.13)	1998 (0.00)	1999 (-5.20)
		Segment 1	
None	20.00	5.00	30.00
Dianthera americana	80.00	95.00	70.00
		Segment 2	
None	35.00	20.83	15.00
Dianthera americana	65.00	62.50	80.00
Phragmites australia		12.50	5.00
Eleocharis spp.		4.17	
		Segment 3	
None	65.00	29.63	33.33
Dianthera americana	35.00	44.44	61.90
Phragmites australia		14.81	4.76
Eleocharis spp.		3.70	
Scirpus spp.		3.70	
Najas spp.		3.70	
		Segment 4	
None	90.00	72.73	80.00
Dianthera americana		13.64	15.00
Eleocharis spp.	10.00	9.09	
Scirpus spp.		4.55	5.00

Table 6.2. Mean distances (ft) from shore to outer edge of macrophytes, and mean depths (ft) macrophytes were found in 20 stations in each of four segments in Newton Lake in August of 1997, 1998, and 1999. Stations without macrophytes were not included in the computations.

Year	Segment	Stations with macrophytes	Mean	Range		Standard deviation	Mean	Range		Standard deviation
			Distance				Depth			
1997	1	16	4.43	0.98	11.21	3.02	0.76	0.24	1.24	0.32
	2	13	8.46	4.92	12.80	2.14	1.12	0.56	1.78	0.40
	3	7	7.63	1.97	12.04	3.18	1.40	0.26	2.59	0.88
	4	2	4.59	3.94	5.25	0.93	0.58	0.53	0.62	0.06
Weighted mean		38	6.40	0.98	12.80	3.24	0.99	0.24	2.59	0.53
1998	1	19	8.30	0.66	24.61	5.40	1.62	0.92	2.36	0.43
	2	16	14.45	7.78	23.95	4.42	2.05	0.91	2.82	0.45
	3	13	10.55	2.30	22.64	5.38	1.14	0.21	2.36	0.70
	4	4	9.05	6.59	10.99	1.95	1.10	0.69	1.49	0.44
Weighted mean		52	10.81	0.66	24.61	5.48	1.59	0.21	2.82	0.62
1999	1	14	6.17	0.19	24.71	6.85	0.88	0.02	1.97	0.71
	2	17	9.85	1.78	17.68	4.22	1.36	0.26	2.26	0.55
	3	13	6.48	0.33	15.72	4.53	0.83	0.03	2.28	0.69
	4	4	4.01	2.00	7.87	2.75	1.00	0.08	2.69	1.16
Weighted mean		48	7.38	0.19	24.71	5.35	1.05	0.02	2.69	0.71

Table 6.3. Percent occurrence of macrophytes in samples collected from Newton Lake during August and September 1997 and May through September 1998 and 1999. When possible, two samples were collected from each of five stations within four segments of the lake.

Macrophyt taxa	Common name	Number of samples	Percent occurrence
	1997		
Dianthera americana	Water willow	66	98.51
Pithophora spp.	Algae	1	1.49
	1998		
Dianthera americana	Water willow	166	83.00
Phragmites australia	Phragmites	11	5.50
Typha spp.	Cattails	2	1.00
Eleocharis spp.	Spike rush	5	2.50
Scirpus spp.	Bulrush	16	8.00
	1999		
Dianthera americana	Water willow	158	68.10
Phragmites australia	Phragmites	14	6.03
Eleocharis spp.	Spike rush	15	6.47
Jussiaea repens var. glabrescens	Primrose	2	0.86
Scirpus spp.	Bulrush	10	4.31
Potomogeton nodosus	Pondweed	1	0.43
Pithophora spp.	Algae	32	13.79

Table 6.4. Percent occurrence by weight (g) of macrophytes in samples collected during 1997, 1998, and 1999 in Newton Lake. Samples were collected at five stations located in four segments.

Year	Segment	Macrophyt taxa	Number of samples	Pounds per m^2	Range		Standard deviation	Percent by weight
1997	1	*Dianthera americana*	10	0.704	0.269	2.291	0.604	100
1997	2	*Dianthera americana*	10	1.394	0.435	3.340	0.886	100
1997	3	*Dianthera americana*	10	0.844	0.137	2.748	0.752	100
1997	3	*Pithophora* spp.	1	0.034	0.034	0.034	0.000	<1
1997	4	*Dianthera americana*	4	1.094	0.135	2.201	0.982	100
		Mean of plants combined by sample	34	0.995	0.135	3.340	0.798	
1998	1	*Dianthera americana*	49	6.426	0.426	17.567	4.663	100
1998	2	*Dianthera americana*	50	7.477	0.673	27.494	5.686	100
1998	3	*Dianthera americana*	46	3.277	0.684	17.948	2.881	92
1998	3	*Phragmites australia*	2	3.449	2.636	4.263	1.150	4
1998	3	*Scirpus* spp.	2	3.051	2.569	3.534	0.682	4
1998	4	*Dianthera americana*	20	1.749	0.370	4.498	1.259	38
1998	4	*Phragmites australia*	1	1.795	1.795	1.795	0.000	2
1998	4	*Typha* spp.	2	3.612	3.006	4.218	0.857	8
1998	4	*Eleocharis* spp.	5	4.063	2.973	5.160	1.075	22
1998	4	*Scirpus* spp.	14	1.925	0.437	5.485	1.396	30
		Mean of plants combined by sample	191	4.941	0.370	27.494	4.577	
1999	1	*Dianthera americana*	42	4.022	1.391	12.386	2.715	96
1999	1	*Jussiaea repens var. glabrescens*	2	0.563	0.397	0.729	0.234	1
1999	1	*Pithophora* spp.	4	1.316	0.033	4.405	2.083	3
1999	2	*Dianthera americana*	49	6.461	0.232	34.442	7.230	99
1999	2	*Phragmites australia*	3	0.243	0.132	0.364	0.116	<1
1999	2	*Pithophora* spp.	3	0.342	0.232	0.497	0.138	<1
1999	3	*Dianthera americana*	46	2.121	0.166	6.624	1.291	84
1999	3	*Phragmites australia*	6	0.684	0.132	1.954	0.662	4
1999	3	*Eleocharis* spp.	3	0.464	0.099	0.795	0.349	1
1999	3	*Scirpus* spp.	2	0.513	0.099	0.927	0.585	1
1999	3	*Pithophora* spp.	16	0.762	0.066	2.649	0.768	10
1999	4	*Dianthera americana*	20	2.671	0.331	9.107	2.274	61
1999	4	*Phragmites australia*	5	1.351	0.232	2.285	0.775	8
1999	4	*Eleocharis* spp.	12	0.803	0.199	1.855	0.501	11
1999	4	*Scirpus* spp.	8	0.861	0.066	2.285	0.966	8
1999	4	*Potomogeton nodosus*	1	0.431	0.431	0.431	0.000	21
1999	4	*Pithophora* spp.	9	1.163	0.099	2.550	0.957	12
		Mean of plants combined by sample	180	4.004	0.068	35.585	4.631	

Table 6.5. Mean number of phytomacrobenthos per m^2 in Newton Lake during August and September 1997 and May - July 1998 and 1999. Superscripts indicate numbers that were significantly different at the $\alpha = 0.05$ level.

Month collected	Number of samples	Number	Range		Standard deviation
Aug-97[d,e]	30	1,628	94	8,399	1,977
Sep-97[e]	30	615	31	4,604	912
May-98[c,d]	39	4,968	331	13,771	3,261
Jun-98[c,d]	38	4,508	509	12,742	3,345
Jul-98[d,e]	40	2,188	209	11,398	2,333
Aug-98[b,c]	40	6,849	311	99,844	15,621
Sep-98[d,e]	40	2,414	173	21,329	4,292
May-99[a]	40	10,605	1,087	48,933	9,889
Jun-99[d,e]	40	2,936	140	17,756	3,419
Jul-99[c,d]	40	5,084	249	27,185	6,161
Aug-99[a]	38	12,566	1,895	33,554	9,869
Sep-99[a,b]	26	9,065	948	28,692	7,933
Weighted mean	**441**	**5,326**	**31**	**99,844**	**7,972**

Table 6.6. Mean density (n per m^2) of phytomacrobenthos collected in four segments of Newton Lake during August and September 1997, and May - September in 1998 and 1999. Five stations were sampled in each segment when possible, and two samples were taken per station. Superscripts with the same letter indicate the means were not statistically significant at the $\alpha = 0.05$ level.

Segment	Number of samples	Mean density	Range		Standard deviation
1[a]	106	5,353	31	31,007	6,392
2[a]	117	6,671	140	48,933	8,662
3[a]	115	3,850	65	21,173	4,390
4[a]	103	5,417	94	99,844	10,986

Table 6.7. Mean densities (n per m^2) of phytomacrobenthic invertebrates collected in Newton Lake during August and September 1997 and May - August 1998 and 1999. Collections were made from 20 stations (441 samples) were sampled throughout the lake when vegetation was present.

Taxa	Mean density	Range		Standard deviation
Ephemeroptera	86.79	0.00	1,894.52	190.98
Hydracarina	5.56	0.00	683.51	39.80
Diptera	3,863.79	1.27	93,228.51	6,415.42
Odonata	113.70	0.00	6,369.09	438.72
Coleoptera	16.23	0.00	1,115.32	76.55
Bryozoa	0.30	0.00	31.07	2.34
Trichoptera	226.72	0.00	3,572.90	467.22
Pelecypoda	0.19	0.00	56.02	2.78
Hemiptera	3.26	0.00	728.27	36.44
Gastropoda	4.10	0.00	453.26	29.89
Nematoda	6.22	0.00	295.15	27.07
Nematomorpha	0.18	0.00	20.37	1.57
Veneroida	0.27	0.00	76.39	3.77
Haplotaxida	739.83	0.00	20,163.60	2,164.96
Podocopa	21.25	0.00	4,225.35	211.50
Lumbriculida	4.86	0.00	1,102.94	54.67
Isopoda	0.17	0.00	56.02	2.78
Ostracoda	1.75	0.00	728.27	34.71
Oligochaeta	118.05	0.00	18,940.06	1,021.52
Acarina	0.72	0.00	56.02	4.89
Amphipoda	4.21	0.00	699.05	37.57
Hirudinea	0.63	0.00	53.47	4.48
Basomatophora	39.64	0.00	1,211.68	137.15
Decapoda	0.04	0.00	15.53	0.74
Tricladida	23.57	0.00	2,050.54	150.49
Other	43.68	0.00	6,741.91	346.97

Table 6.8. Number and percent of invertebrates of the Order Diptera grouped by family that were collected from Newton Lake in association with macrophytes. The phytomacroinvertebrates were collected during August and September 1997 and May - August 1998 and 1999.

Family	Number collected	Percent
Chironomidae	217,858	98.80
Ceratopogonidae	2,483	1.13
Chaoboridae	138	0.06
Tabinidae	18	0.01
Stratiomyidae	6	0.00
Tipulidae	7	0.00

Table 6.9. Mean number of phytomacrobenthos per pound of macrophytes in Newton Lake during August and September 1997 and May - July 1998 and 1999. Superscripts indicate numbers per kilogram that were significantly different at the $\alpha = 0.05$ level.

Month collected	Number of samples	Number per pound	Range		Standard deviation
Aug-97[c,d]	2	1,075.55	521.32	1,629.77	783.80
Sep-97[d]	30	1,005.58	60.53	9,713.99	2,093.32
May-98[d]	39	866.43	78.50	2,651.44	534.58
Jun-98[b,c,d]	38	1,505.66	193.26	4,139.53	1,038.69
Jul-98[d]	40	473.38	31.70	2,259.95	511.82
Aug-98[b,c,d]	39	2,066.42	26.84	22,705.79	3,641.71
Sep-98[d]	40	842.87	28.41	9,274.89	1,617.56
May-99[a]	40	3,941.90	954.56	18,160.00	3,419.60
Jun-99[b,c,d]	40	1,359.85	21.39	4,797.08	1,215.23
Jul-99[b,c,d]	39	1,841.78	132.42	10,669.00	2,092.45
Aug-99[a,b,c]	38	2,768.39	304.12	9,031.36	2,426.01
Sep-99[a,b]	23	3,036.76	1,064.55	6,088.64	1,540.95

Table 6.10. Mean number of phytomacrobenthos per pound of macrophytes collected in four segments of Newton Lake during August and September 1997 and May - August 1998 and 1999. Five stations were sampled in each segment when possible, and two samples were taken per station. Numbers with different superscripts are significantly different at the $\alpha = 0.05$ level.

Segment	Number of samples	Number per pound	Range		Standard deviation
1[b]	98	1,351.47	26.84	9,713.99	1,614.24
2[b]	109	1,426.34	21.39	10,940.29	1,845.92
3[b]	105	1,731.69	92.22	9,461.36	1,943.64
4[a]	96	2,560.07	110.11	22,705.79	3,355.12
Weighted mean	**408**	**1,753.70**	**21.39**	**22,705.79**	**2,310.67**

Table 6.11. Mean weights (g) of phytomacrobenthos per m^2 in Newton Lake during August and September 1997 and May - September 1998 and 1999. Superscripts indicate numbers that were significantly different at the α = 0.05 level.

Month collected	Number of samples	Weight (g per m^2)	Range		Standard deviation
Aug-97[d]	30	0.3691	0.0000	1.9255	0.4371
Sep-97[d]	30	0.3930	0.0194	2.8518	0.6050
May-98[c,d]	39	1.4415	0.0530	4.2331	0.9883
Jun-98[c,d]	38	1.2560	0.1090	3.6744	0.8671
Jul-98[c,d]	40	1.0279	0.0738	4.9339	1.0944
Aug-98[c,d]	40	1.6455	0.1329	9.7746	1.9942
Sep-98[c,d]	40	0.9976	0.0499	9.3251	1.6490
May-99[b]	40	4.2294	0.1988	17.8366	4.1618
Jun-99[c,d]	40	1.0878	0.0435	4.0172	0.9425
Jul-99[c]	40	2.1275	0.0482	10.7218	2.8286
Aug-99[b]	38	4.3130	0.5049	28.2679	5.0490
Sep-99[a]	26	7.8171	0.5561	39.7136	8.7448
Weighted mean	**441**	**2.1283**	**0.0000**	**39.7136**	**3.6457**

Table 6.12. Mean weights (g per m^2) of phytomacrobenthos collected in four segments of Newton Lake during August and September 1997 and May - August 1998 and 1999. Five stations were sampled in each segment when possible, and two samples were taken per station. Segments with different superscripts have significantly different mean weights at the α = 0.05 level.

Segment	Number of samples	Mean Weight	Range		Standard deviation
1[a]	106	2.6769	0.0000	23.8670	3.9940
2[a]	117	2.7115	0.0102	39.7136	4.7131
3[b]	115	1.5800	0.0214	28.2679	3.0962
4[b]	103	1.5134	0.0274	9.7746	1.8746

Table 6.13. Mean weights (g per m^2) of phytomacrobenthic invertebrates collected in Newton Lake during August and September 1997 and May - August 1998 and 1999. Twenty stations (two samples per station) were sampled (441 samples) throughout the lake when vegetation was present.

Taxa	Mean weight	Range		Standard deviation
Ephemeroptera	0.0550	0.0000	1.3409	0.1369
Hydracarina	0.0012	0.0000	0.1693	0.0098
Diptera	1.5411	0.0000	32.8458	2.8118
Odonata	0.2028	0.0000	14.2807	0.8755
Coleoptera	0.0371	0.0000	6.9035	0.3434
Bryozoa	0.0021	0.0000	0.8062	0.0387
Trichoptera	0.0910	0.0000	1.7088	0.2126
Pelecypoda	0.0001	0.0000	0.0295	0.0016
Hemiptera	0.0150	0.0000	2.3348	0.1574
Gastropoda	0.0103	0.0000	0.9525	0.0725
Nematoda	0.0002	0.0000	0.0171	0.0013
Nematomorpha	0.0000	0.0000	0.0051	0.0003
Veneroida	0.0009	0.0000	0.2237	0.0120
Haplotaxida	0.0541	0.0000	2.7651	0.2134
Podocopa	0.0033	0.0000	0.7410	0.0368
Lumbriculida	0.0003	0.0000	0.0575	0.0030
Isopoda	0.0001	0.0000	0.0367	0.0019
Ostracoda	0.0002	0.0000	0.0922	0.0044
Oligochaeta	0.0075	0.0000	1.1540	0.0656
Acarina	0.0003	0.0000	0.0811	0.0039
Amphipoda	0.0025	0.0000	0.3961	0.0227
Hirudinea	0.0050	0.0000	1.7026	0.0823
Basomatophora	0.0607	0.0000	2.8148	0.2527
Decapoda	0.0149	0.0000	6.5571	0.3122
Tricladida	0.0069	0.0000	0.5437	0.0406
Other	0.0157	0.0000	0.6198	0.0652

Table 6.14. Mean weight (g) of phytomacrobenthos per pound of macrophytes in Newton Lake during August and September 1997 and May - July 1998 and 1999. Numbers with different superscripts are significantly different at the $\alpha = 0.05$ level.

Month collected	Number of samples	Weight per pound	Range		Standard deviation
Aug-97[c,d]	2	0.4934	0.1121	0.8746	0.5392
Sep-97[c,d]	30	0.5263	0.0399	6.0172	1.1111
May-98[d]	39	0.2316	0.0149	0.4604	0.1194
Jun-98[c,d]	38	0.3993	0.0463	1.1218	0.2689
Jul-98[d]	40	0.1919	0.0192	0.7714	0.1536
Aug-98[c,d]	39	0.5459	0.0179	3.1118	0.6289
Sep-98[d]	40	0.2853	0.0287	1.5485	0.3209
May-99[b]	40	1.3756	0.2936	3.8668	0.8853
Jun-99[c,d]	40	0.5179	0.0067	2.0598	0.4796
Jul-99[c,d]	39	0.6010	0.0166	2.3116	0.5850
Aug-99[b,c]	38	1.0008	0.1032	7.9437	1.3466
Sep-99[a]	23	2.5487	0.4031	7.6207	2.0173

Table 6.15. Mean weight (g) of phytomacrobenthos per pound of macrophytes collected in four segments of Newton Lake during August and September 1997 and May - August 1998 and 1999. Five stations were sampled in each segment when possible, and two samples were taken per station. Numbers with different superscripts are significantly different at the $\alpha = 0.05$ level.

Segment	Number of samples	Weight per pound	Range		Standard deviation
1[a]	98	0.6838	0.0149	7.6207	1.0947
2[a]	109	0.5318	0.0067	3.8668	0.7074
3[a]	105	0.7605	0.0166	7.9437	1.3042
4[a]	96	0.7537	0.0176	3.2104	0.7298
Total	**408**	**0.6794**	**0.0067**	**7.9437**	**0.9931**

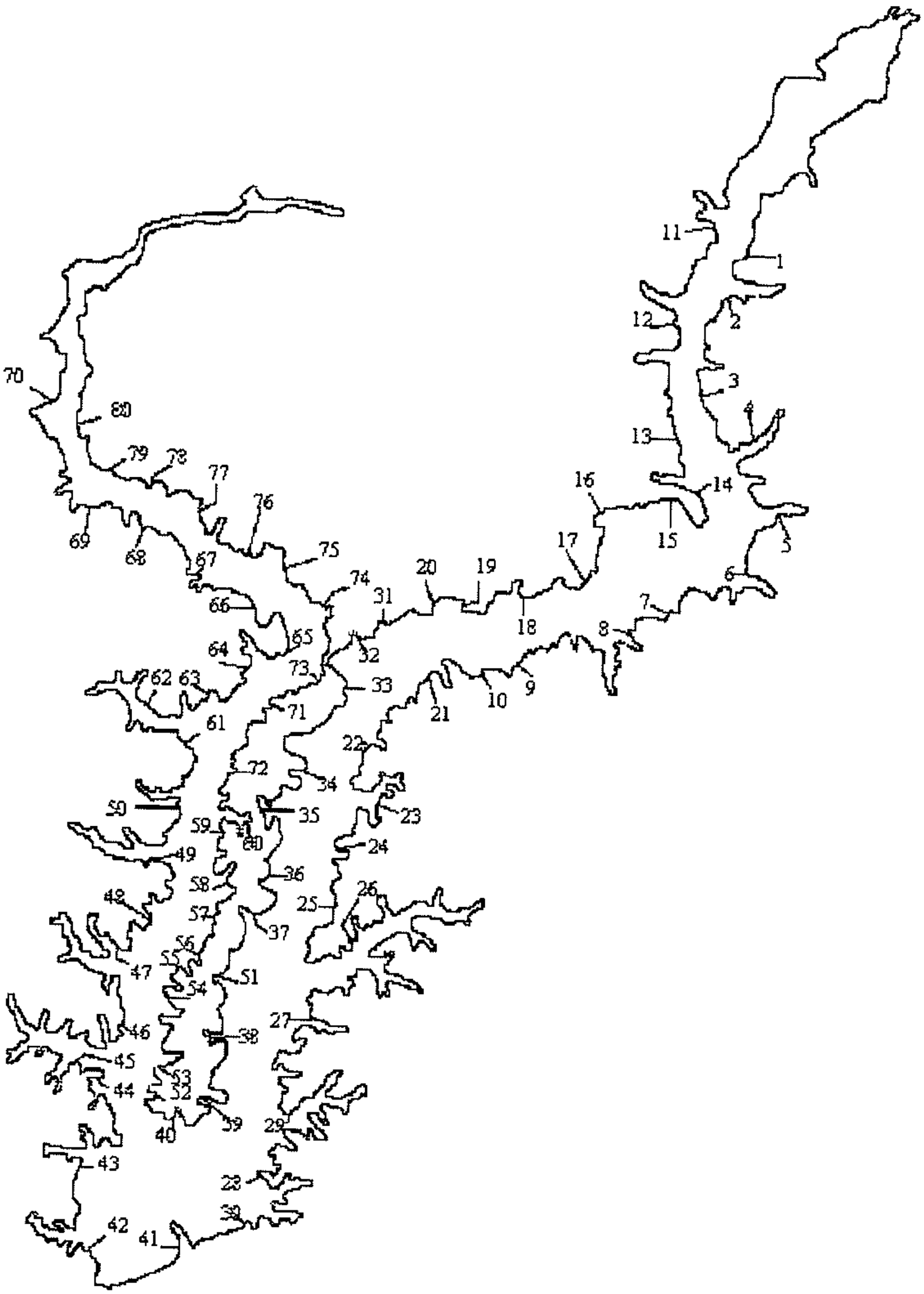


Figure 6.1. Locations where vegetation was identified in August of 1997, 1998, and 1999.

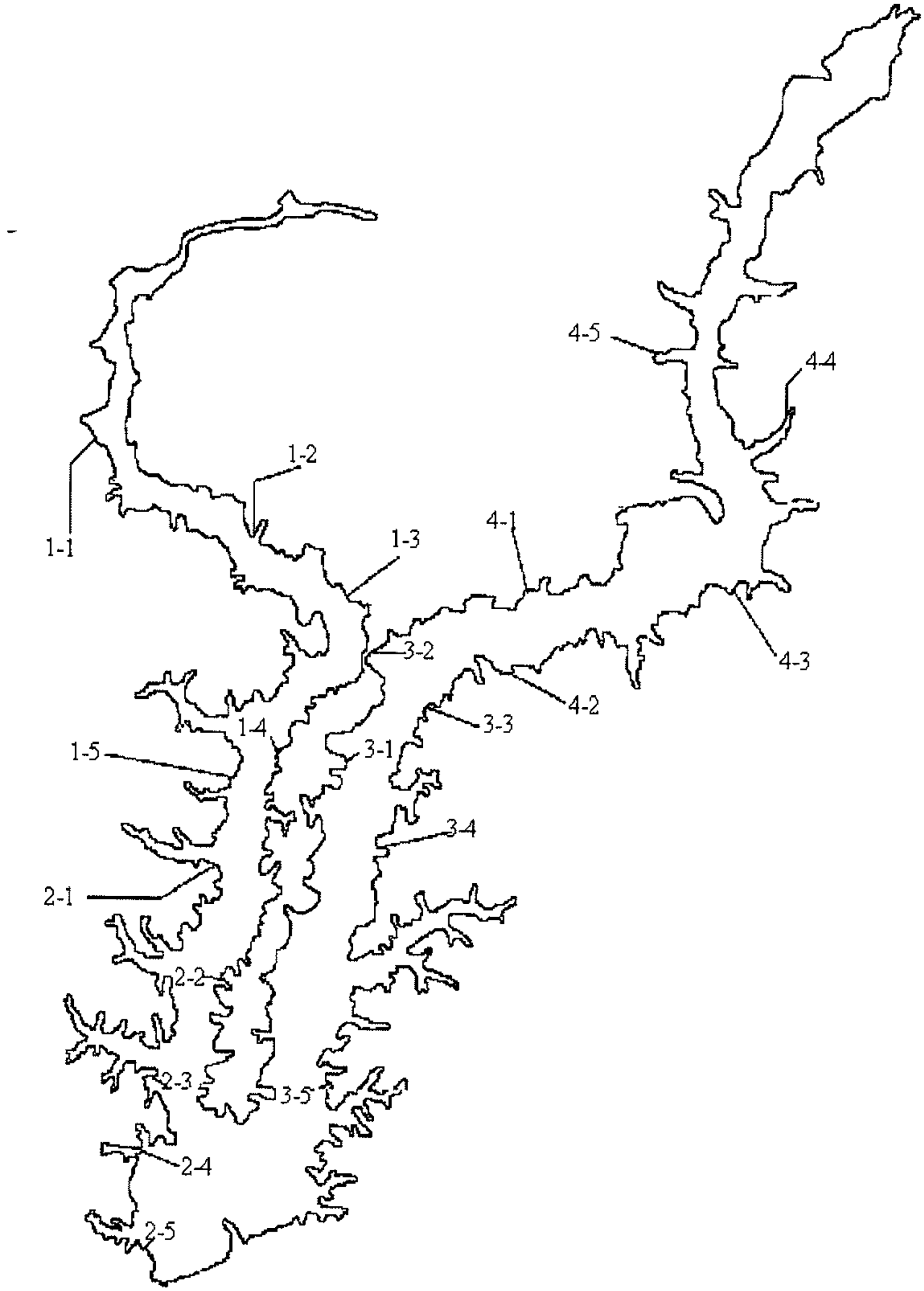


Figure 6.2. Approximate locations of stations in four segments of Newton Lake where phytomacrobenthos was collected during August and September 1997 and May - September 1998 and 1999. Numbers indicate segment - station

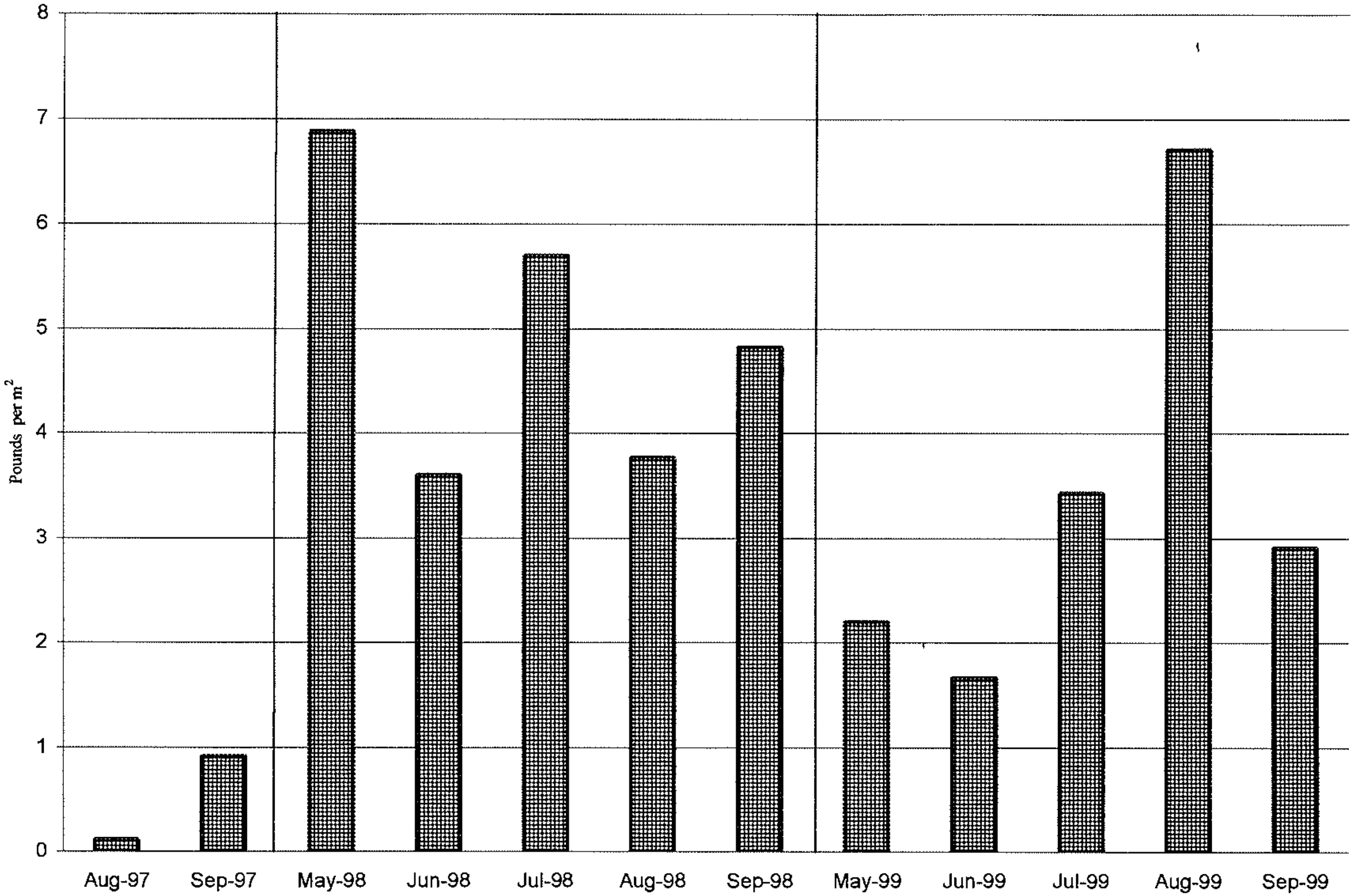


Figure 6.3. Mean weights (lbs per m^2) of macrophytes collected from four segments in Newton Lake. The macrophytes were collected with a 1.0-m (1997), 0.5-m (1998), or a 0.29-m (1999) diameter, 400-*u* mesh net at 5 stations per segment, and two samples per station. The macrophytes were collected at random areas within each station.

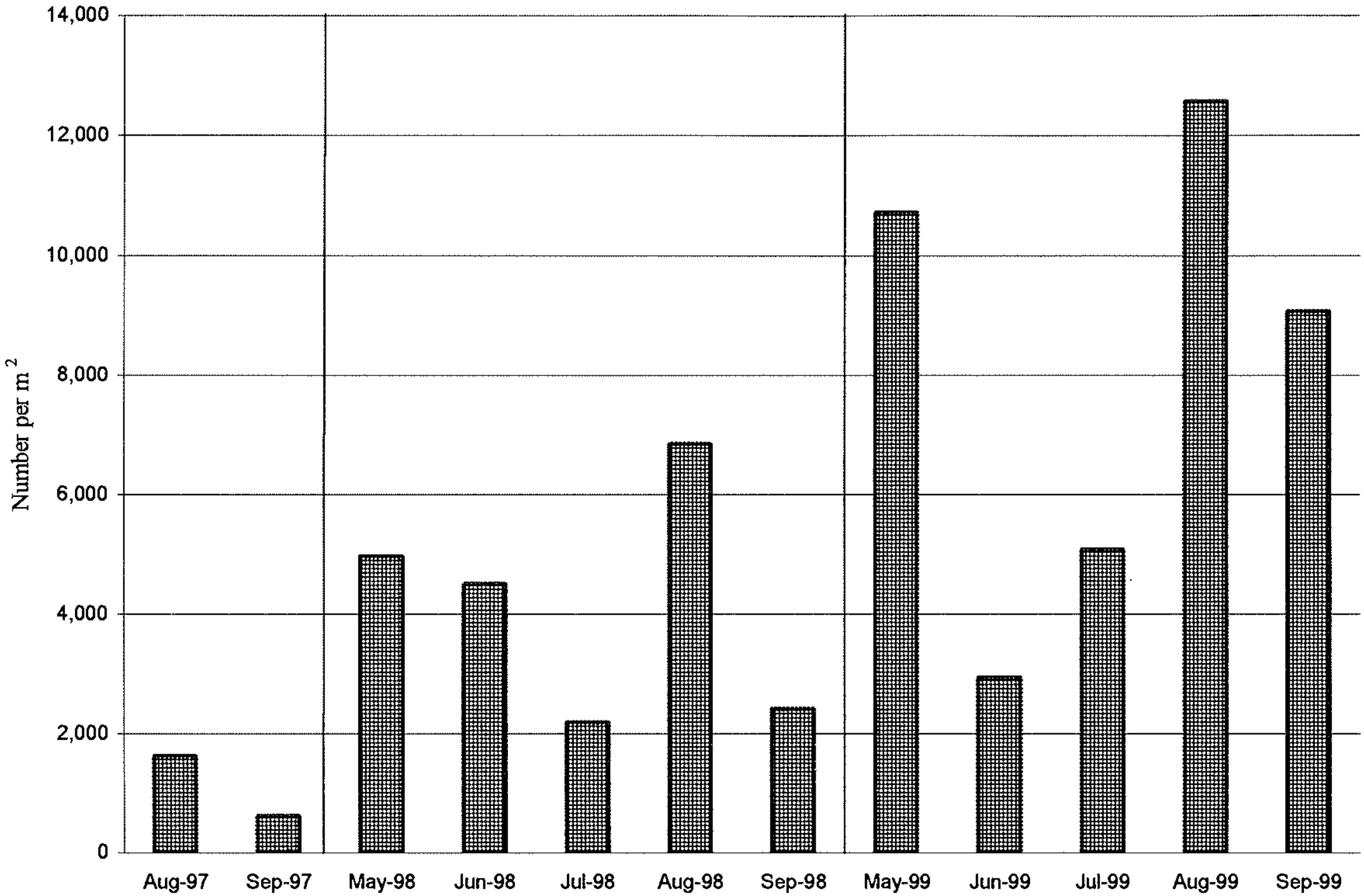


Figure 6.4. Mean number of phytomacrobenthos per m^2 collected from Newton Lake. The invertebrates were collected with1.0-m (1997), 0.5-m (1998), or a 0.29-m (1999) diameter, 400-*u* mesh plankton net at 5 stations in each of four segments. Two samples were taken per station.

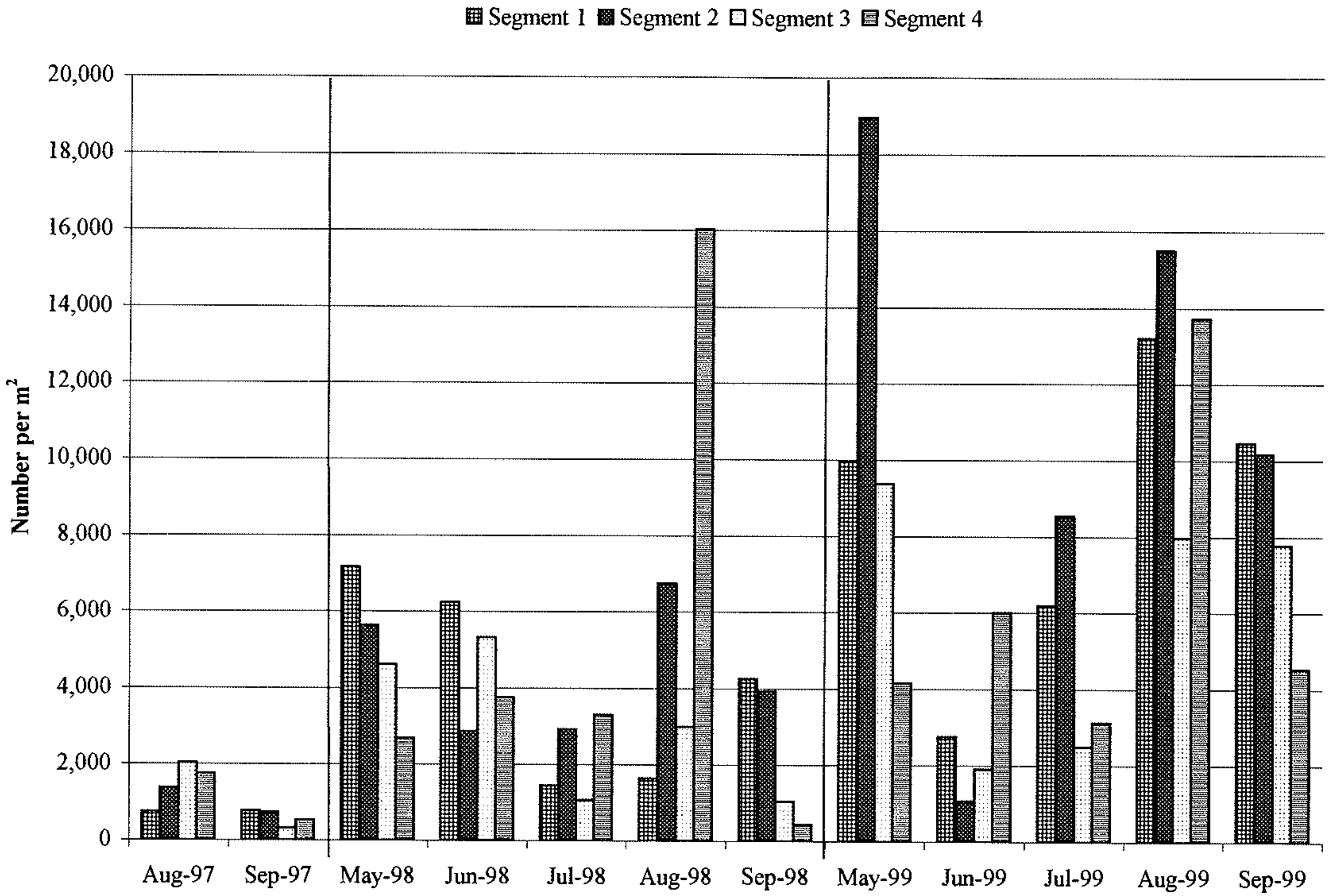


Figure 6.5. Mean number of phytomacrobenthos collected from four segments in Newton Lake. The invertebrates were collected with a 1.0-m (1997), 0.5-m (1998), or a 0.29-m (1999) diameter, 400-*u* mesh plankton net at 5 stations per segment. Two samples were taken per station.

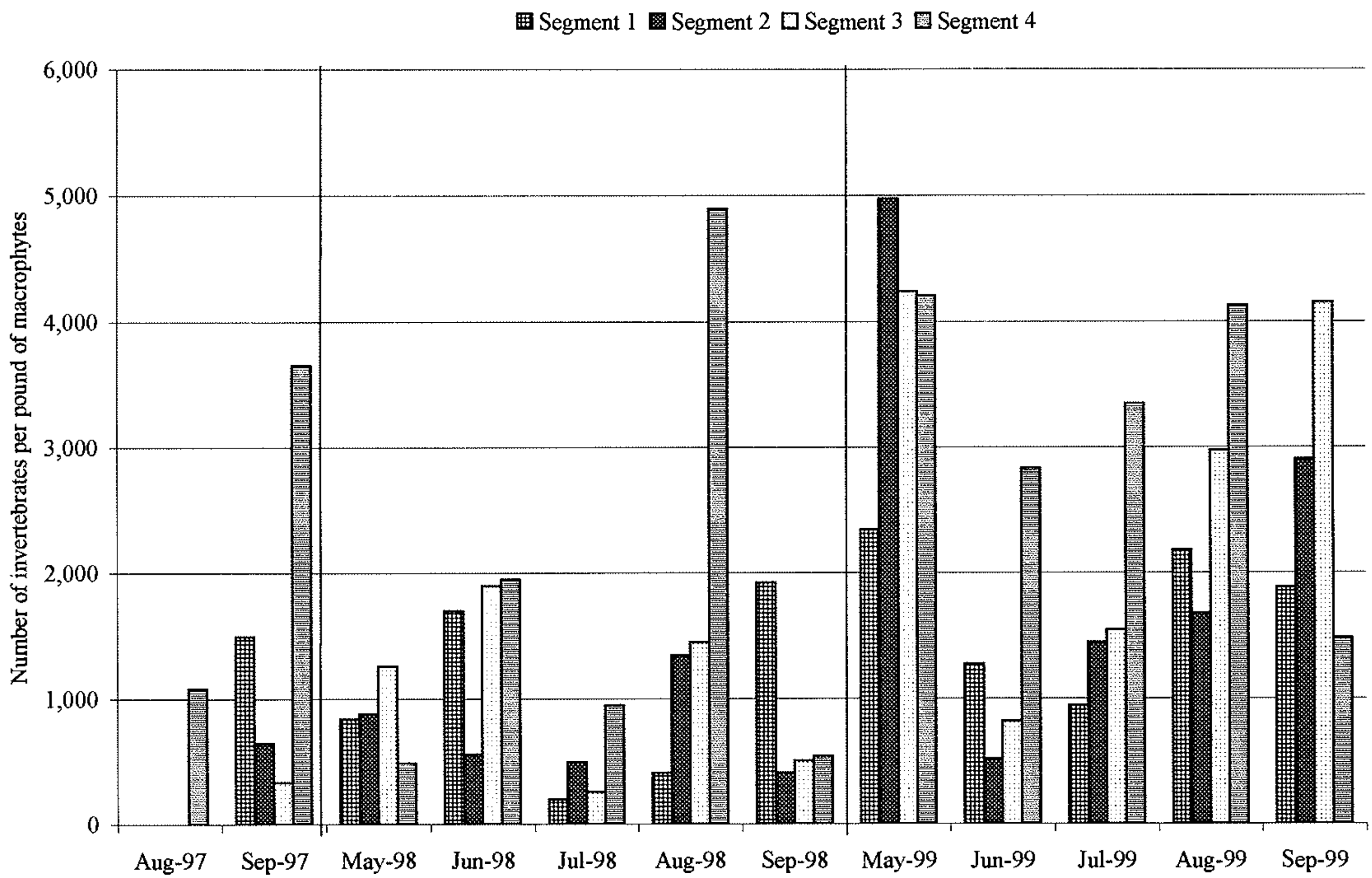


Figure 6.6. Mean number of phytomacrobenthos per pound of macrophytes collected from four segments in Newton Lake. The invertebrates were collected with a 1.0-m (1997), 0.5-m (1998), or a 0.29-m (1999) diameter, 400-*u* mesh plankton net at 5 stations per segment. Two samples were taken per station.

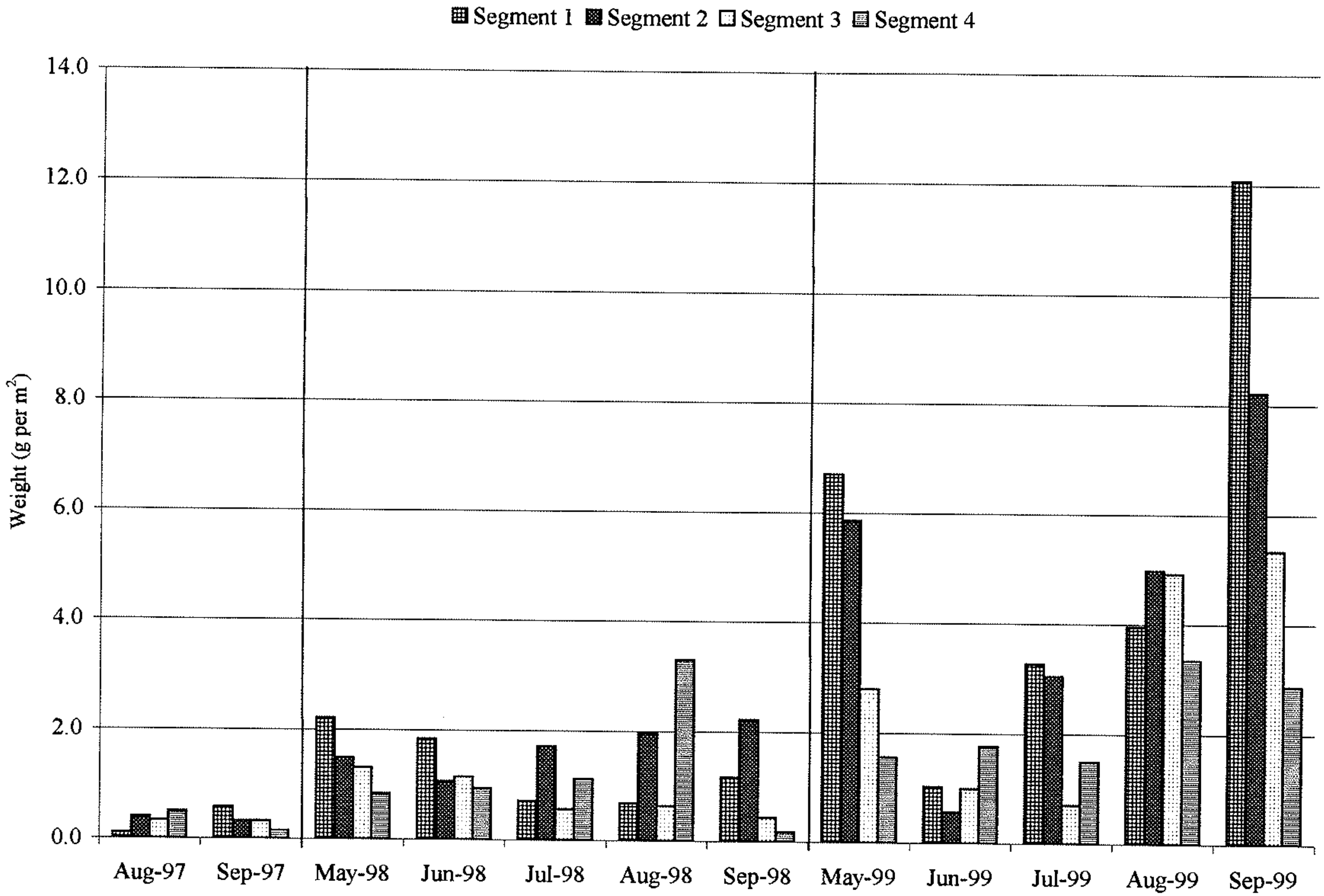


Figure 6.7. Mean weight (g) of phytomacrobenthos per m^2 collected from four segments in Newton Lake. The invertebrates were collected with a 1.0-m (1997), 0.5-m (1998), or a 0.29-m (1999) diameter, 400-*u* mesh plankton net at 5 stations per segment. Two samples were taken per station.

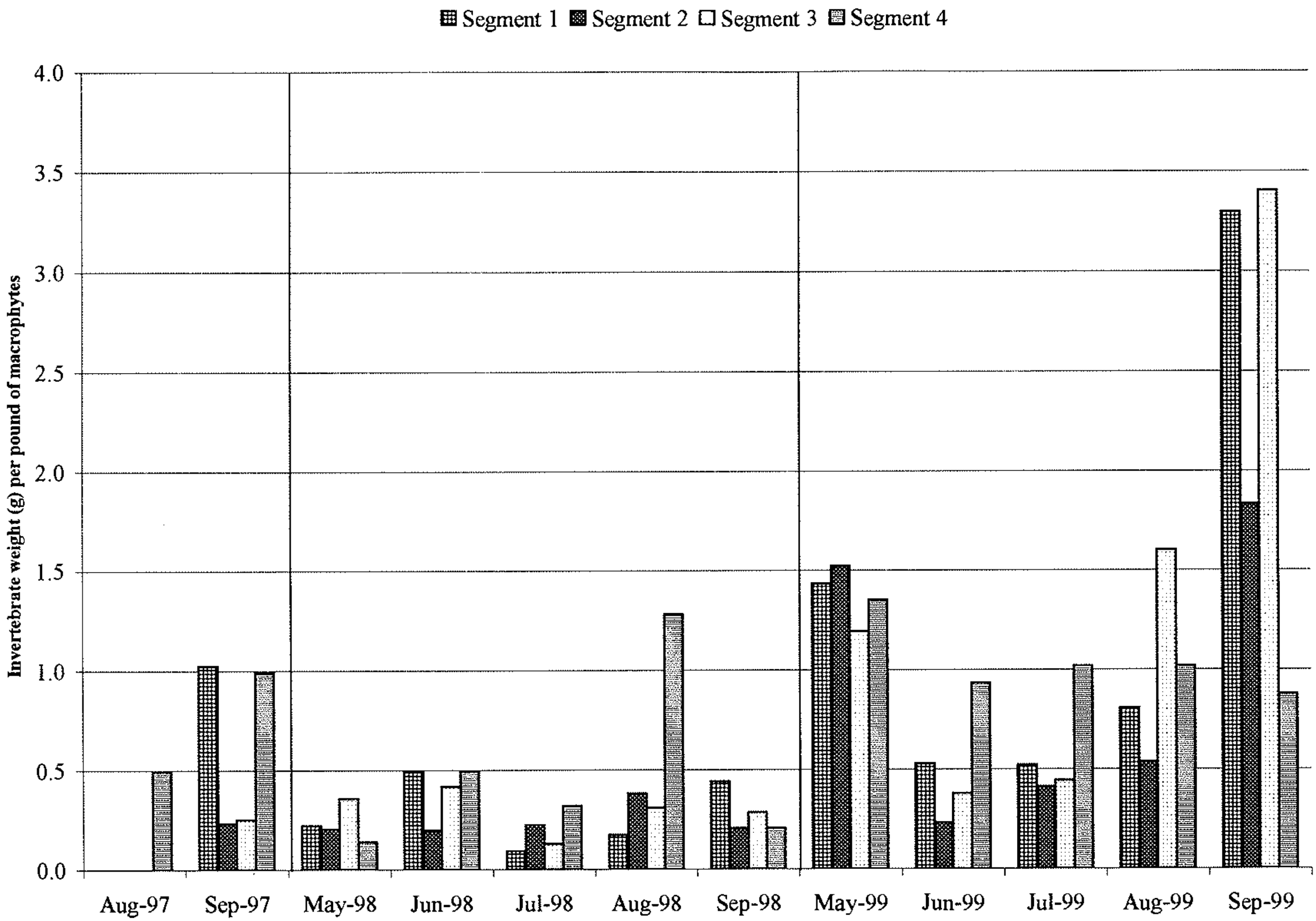


Figure 6.8. Mean weight of phytomacrobenthos per kilogram of macrophytes collected from four segments in Newton Lake. The invertebrates were collected with1.0-m (1997), 0.5-m (1998), or a 0.29-m (1999) diameter, 400-*u* mesh plankton net at 5 stations per segment. Two samples were taken per station.

Chapter 6,7. Appendix: Supplemental Data Tables.

Appendix 6.1. Dates when phytomacrobenthos samples were collected from Newton Lake. The number of samples taken in a given month was dependent upon available macrophytes within a segment. Two samples were collected at each station.

Dates sampled	Segments	Stations
	1997	
8/29/97	1	1,2
8/29/97	2-4	1-5
9/18/97	1,2	1-5
9/18/97	3	5
9/19/97	3	1-4
9/19/97	4	1
	1998	
5/5/98	1-4	1-5
6/4/98	1-4	1-5
7/11/98	1-4	1-5
8/18/98	1-4	1-5
9/2/98	1-4	1-5
	1999	
5/5/99	1-4	1-5
6/3/99	1-4	1-5
7/16/99	1-4	1-5
8/18/99	1	2-5
8/18/99	2-4	1-5
9/23/99	1	1,2,3,5
9/23/99	2-4	1-5

Appendix 6.2. Phytomacrobenthos mean densities (n per m^2) collected from four segments in Newton Lake. Numbers in parenthesis represent total number of samples collected. Number of samples through September 1999 were dependent upon available sites with macrophytes.

Taxa	Aug-97 (30)	Sep-97 (30)	May-98 (39)	Jun-98 (38)	Jul-98 (40)	Aug-98 (40)	Sep-98 (40)	May-99 (40)	Jun-99 (40)	Jul-99 (40)	Aug-99 (38)	Sep-99 (26)
Ephemeroptera	62	13	13	129	207	175	110	23	38	80	102	57
Hydracarina	0	0	<1	5	3	<1	<1	<1	40	5	7	2
Diptera	1,117	455	3,953	3,617	1,556	5,605	1,315	7,756	1,673	3,512	8,127	7,681
Odonata	56	41	1	16	25	61	75	3	57	58	363	831
Coleoptera	11	3	3	5	14	67	3	10	30	2	32	5
Bryozoa	<1	0	0	0	0	0	<1	3	0	0	0	0
Trichoptera	249	37	1	172	209	333	246	4	86	644	498	191
Pelecypoda	<1	0	0	0	0	1	0	0	0	0	0	<1
Hemiptera	<1	<1	<1	<1	3	19	<1	3	0	5	4	1
Gastropoda	9	23	2	1	<1	1	<1	6	10	0	0	<1
Nematoda	<1	1	8	9	<1	2	<1	31	7	5	4	<1
Nematomorpha	<1	<1	<1	<1	0	<1	0	<1	0	0	0	0
Veneroida	<1	<1	0	0	0	2	<1	0	0	0	0	0
Haplotaxida	57	12	945	496	138	285	111	1,812	628	643	3,217	61
Podocopa	30	17	0	<1	1	34	8	<1	0	19	139	6
Lumbriculida	24	0	0	0	0	2	<1	<1	0	28	0	7
Isopoda	0	0	2	0	0	0	0	<1	0	0	0	0
Ostracoda	1	0	0	0	0	18	0	0	0	0	0	0

Appendix 6.2. Continued.

Taxa	Aug-97	Sep-97	May-98	Jun-98	Jul-98	Aug-98	Sep-98	May-99	Jun-99	Jul-99	Aug-99	Sep-99
Oligochaeta	4	<1	22	0	3	214	539	521	0	0	0	0
Acarina	2	<1	<1	6	0	0	0	0	0	0	0	0
Amphipoda	0	2	0	0	<1	<1	<1	9	<1	0	5	46
Hirudinea	0	4	<1	<1	<1	0	0	<1	2	0	<1	0
Basomatophora	2	4	2	44	18	11	2	37	177	51	13	122
Decapoda	0	0	0	0	0	0	0	0	0	0	<1	0
Tricladida	0	0	0	0	0	0	0	23	167	6	39	41
Other	2	2	13	7	7	18	3	362	24	24	15	12
Total	**1,628**	**615**	**4,968**	**4,508**	**2,188**	**6,849**	**2,414**	**10,605**	**2,936**	**5,084**	**12,566**	**9,065**

Appendix 6.3. Phytomacrobenthos mean weights (g per m^2) collected from four segments in Newton Lake. Numbers in parenthesis represent total number of samples collected . Number of samples were dependent upon available sites with macrophytes.

Taxa	Aug-97	Sep-97	May-98	Jun-98	Jul-98	Aug-98	Sep-98	May-99	Jun-99	Jul-99	Aug-99	Sep-99
Ephemeroptera	0.0259	0.0065	0.0238	0.0764	0.1531	0.0998	0.0726	0.0390	0.0066	0.0241	0.0631	0.0481
Hydracarina	0.0000	0.0000	0.0000	0.0008	0.0004	0.0002	0.0000	0.0001	0.0088	0.0015	0.0009	0.0006
Diptera	0.1515	0.1096	1.2577	1.0478	0.6644	1.1389	0.6560	3.4633	0.6623	1.6885	3.0988	5.1622
Odonata	0.0571	0.1548	0.0203	0.0168	0.0420	0.0943	0.1002	0.0573	0.0540	0.0952	0.4181	1.8472
Coleoptera	0.0139	0.0125	0.0058	0.0028	0.0119	0.0645	0.0039	0.2023	0.0231	0.0014	0.0749	0.0045
Bryozoa	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0233	0.0000	0.0000	0.0000	0.0000
Trichoptera	0.0869	0.0160	0.0029	0.0628	0.0941	0.1265	0.0883	0.0038	0.0465	0.2197	0.1865	0.1656
Pelecypoda	0.0002	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
Hemiptera	0.0000	0.0048	0.0006	0.0007	0.0006	0.0697	0.0068	0.0006	0.0000	0.0003	0.0256	0.0898
Gastropoda	0.0169	0.0794	0.0129	0.0003	0.0008	0.0033	0.0022	0.0118	0.0099	0.0000	0.0000	0.0003
Nematoda	0.0000	0.0001	0.0005	0.0002	0.0000	0.0001	0.0000	0.0009	0.0000	0.0003	0.0003	0.0000
Nematomorpha	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Veneroida	0.0075	0.0000	0.0000	0.0000	0.0000	0.0003	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000
Haplotaxida	0.0034	0.0014	0.0807	0.0183	0.0124	0.0092	0.0033	0.2428	0.0555	0.0309	0.1471	0.0050
Podocopa	0.0024	0.0012	0.0000	0.0000	0.0002	0.0052	0.0010	0.0000	0.0000	0.0038	0.0238	0.0013
Lumbriculida	0.0010	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0000	0.0014	0.0000	0.0008
Isopoda	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
Ostracoda	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 6.3. Continued.

Taxa	Aug-97	Sep-97	May-98	Jun-98	Jul-98	Aug-98	Sep-98	May-99	Jun-99	Jul-99	Aug-99	Sep-99
Amphipoda	0.0000	0.0005	0.0002	0.0000	0.0000	0.0000	0.0001	0.0054	0.0002	0.0000	0.0028	0.0292
Hirudinea	0.0000	0.0010	0.0009	0.0009	0.0018	0.0000	0.0000	0.0000	0.0079	0.0000	0.0448	0.0000
Basomatophora	0.0015	0.0001	0.0055	0.0197	0.0193	0.0104	0.0088	0.0814	0.1668	0.0424	0.0309	0.4389
Decapoda	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1726	0.0000
Tricladida	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0088	0.0436	0.0015	0.0126	0.0161
Other	0.0005	0.0022	0.0273	0.0078	0.0269	0.0073	0.0159	0.0531	0.0027	0.0166	0.0101	0.0068
Total	**0.3691**	**0.3930**	**1.4415**	**1.2560**	**1.0279**	**1.6455**	**0.9976**	**4.2294**	**1.0878**	**2.1275**	**4.3130**	**7.8171**