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**L-LAKE ZOOPLANKTON: L-LAKE/STEEL CREEK
BIOLOGICAL MONITORING PROGRAM - 11/85 - DECEMBER
1991 (U)**

by
J. A. Bowers

Savannah River Site
Aiken, South Carolina 29808

Normandeau Associates Inc.

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NAI-SR-142

L-LAKE ZOOPLANKTON:
L-LAKE/STEEL CREEK
BIOLOGICAL MONITORING PROGRAM
JANUARY 1986 - DECEMBER 1991

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March 1992

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PREFACE

The L-Lake Biological Monitoring Program was designed to meet environmental regulatory requirements associated with the restart of L-Reactor and address portions of Section 316(a) of the Clean Water Act, which requires an applicant for a discharge permit to provide scientific evidence that the discharge causes no significant impact on the indigenous ecosystem. The Department of Energy (DOE) must demonstrate that the discharge of L-Reactor effluent into L Lake will not inhibit the eventual establishment of a "Balanced Biological Community" (BBC) in at least 50% of the lake.

L-Lake Description

The Savannah River Site (SRS) encompasses 300 sq mi of the Atlantic Coastal Plain in west-central South Carolina. The Savannah River forms the western boundary of the site (Figure 1). Five major tributaries of the Savannah River--Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek--drain the site. All but Upper Three Runs Creek receive, or in the past received, thermal effluents from nuclear production reactors. At the time of this report, no reactors are operating or discharging thermal effluents. In 1958, Par Pond--a 1000 hectare cooling reservoir--was built on the upper reaches of Lower Three Runs Creek to accommodate the thermal effluent from two nuclear reactors (P and R). In 1985, L Lake--a 400 hectare cooling nuclear reservoir--was built on the upper reaches of Steel Creek to receive effluent from another nuclear reactor (L). Prior to the construction of L Lake, all L-Reactor effluents were discharged directly into Steel Creek. L Lake was formed by constructing a 1200-m long embankment across the Steel Creek valley approximately 8 km upstream of its confluence with the Savannah River. The lake has an

Figure 1. A map of the Savannah River Site showing the major aquatic systems.

average width of approximately 600 m and extends along the Steel Creek valley approximately 7000 m from the dam to the headwaters. Water level is maintained at a normal pool elevation of 58 m above mean sea level by overflow into a vertical intake tower that has multilevel discharge gates. The intake tower is connected to a horizontal conduit that passes through the dam and releases water into Steel Creek.

During construction of L Lake, most of the vegetation in the lake bed was cut and hauled away or burned on site. Vegetation growing on the Steel Creek floodplain in the lower two-thirds of the lake area was not cleared. Two coves in the lower half of the lake and the area above Road B were left with standing timber to enhance fish and wildlife habitat. The shoreline was cleared to 3 to 5 ft above maximum pool elevation and was seeded for erosion control. Artificial reefs (tire, cinder block, and log piles) were constructed to enhance fish habitat in shallow depths.

L-Lake dam was sealed in September 1985 and filled with drainage from Steel Creek, water pumped from the Savannah River, water released from Par Pond into Steel Creek, and rainfall runoff from the Steel Creek watershed. The lake achieved normal pool level in October 1985, and L-Reactor was brought on-line and began discharging heated water in November 1985. L-Reactor was shut down during the summer of 1988 and, as of this report, has not been restarted.

L Lake operates as a once-through cooling reservoir. During peak operation levels, approximately 11 m^3 of water/sec is pumped from the Savannah River to L-Reactor. The water passes through the reactor's heat exchangers and is discharged into Region 2 in the upper portion of L Lake (Figure 2). Water

Figure 2. L Lake and its sampling regions.

temperature in the discharge canal is expected to exceed 70°C at times (DOE 1984). NPDES permit criteria specify that the lake must not exceed a five-day average temperature of 32.2°C at a depth of 2 ft over 50% of its area nor ever exceed an instantaneous temperature of 35°C. Reactor power levels must be adjusted to meet these criteria.

Several factors are characteristic of any cooling reservoir. First, the addition of heated water at one end of the lake creates a thermal gradient along the length of the lake. Second, the lower-density hot water remains on the surface of the lake and contributes to the natural stratification. Third, the warmer temperatures help maintain high productivity levels in a part of the lake irrespective of season. These factors may be of great importance in the development of the reservoir's biological communities.

Biological Monitoring Program

To assess the impact of the thermal discharge on the L-Lake ecosystem, the lake originally was divided into eight zones based on the expected thermal gradient estimated from a mathematical model (Firstenberg and Fisher 1980). Water-quality sampling was initiated in November 1985. Biological sampling in all regions began in January 1986. In April 1986, a reassessment of safety considerations resulted in the elimination of sampling in Regions 2 and 3, nearest the point of discharge. Region 1 also was eliminated at this time as a logical extension of the modified sampling scheme because of its disjunct location and habitat differences between it and the rest of the lake. Data from Regions 4 - 8 (Figure 2) are discussed in this report. The scope-of-work for the monitoring program was extensively revised in 1990.

The objective of the L-Lake study is to evaluate the impact of the discharge of heated water on the L-Lake community. A new reservoir requires several years of natural development before the lake is stabilized (Gunnison 1985). It is recognized that to comply with permit requirements, L Lake will have to be evaluated over a period of years before a stable community structure is established. This study is designed to assess the progress of the L-Lake communities toward the establishment of a balanced biological community that is representative of large reservoirs in this geographic area. Thus, the definition of a "Balanced Biological Community" is of considerable importance and, for purposes of this study, is defined as a community:

- a. whose members are not dominated by pollution (particularly thermally) tolerant organisms;
- b. with diversity and productivity characteristics similar to those of other reservoirs in the area;
- c. that supports representatives of all expected trophic groups; and
- d. whose members are successfully reproducing and maintaining the community.

This report summarizes the results of five years of data from Regions 4 - 8 of L Lake under the L-Lake/Steel Creek Biological Monitoring Program. Steel Creek is discussed separately from L Lake in volumes NAI-SR-144 through NAI-SR-148.

Each major component of the L-Lake portion of the biological monitoring program is presented in a separate volume as follows:

NAI-SR-138 L-Lake Water Quality
NAI-SR-139 L-Lake Fish
NAI-SR-140 L-Lake Macroinvertebrates
NAI-SR-141 L-Lake Habitat Formers
NAI-SR-142 Zooplankton
NAI-SR-143 Primary Producers

EXECUTIVE SUMMARY

1. The objectives of this portion of the L-Lake Biological Monitoring Program are to provide an analysis of the zooplankton community in L Lake that will help determine whether this ecosystem contains, or is developing in a manner that indicates that it will contain, a Balanced Biological Community pursuant to the requirements for a successful 316(a) demonstration. The data presented in this report cover the period January 1986 to December 1991.
2. A total of 90 taxa were collected in L Lake and Par Pond in 1991, slightly higher than the 85 taxa collected in 1990. The number of taxa on a lakewide basis in 1990 and 1991 was slightly lower than the number of taxa collected in 1989, perhaps because of the less intensive sampling effort. The total number of taxa declined lakewide steadily from 1986, when L Lake was first created, through 1990. The microzooplankton (Protozoa and Rotifera) accounted for 76% of the total number of taxa in 1991, consistent with previous years, where microzooplankton composed 70.5-83.8% of the total number of taxa. Macrozooplankton, particularly Cladocera and Copepoda, made up the remaining taxa in 1991, as had been true in previous years.
3. The L-Lake zooplankton community accumulated taxa quite rapidly in the beginning of the study (January through March 1986) then slowed markedly and remained constant through December 1987, then slowed again and remained constant through 1989 (Chimney and Bowen 1990). Relatively few new taxa

were added in subsequent years. Changes in cumulative taxa richness reflected the initial development of the L-Lake zooplankton community (i.e., colonization by new taxa) and subsequent replacement of taxa in later months as a true lake-adapted fauna developed.

4. From 1986-1989, Protozoa numerically dominated the zooplankton community in all regions and generally comprised at least 90% of all organisms collected throughout this study. Most of the dominant taxa from 1986 - 1989 were ciliate protozoans. Rotifera ranked second in relative abundance (generally <10% but occasionally reaching up to ca. 27%). This contrasted with early studies of Par Pond, in which the relative abundance of Rotifera and macrozooplankton was comparatively higher. In 1990 and 1991, Protozoa made up at least 93% of the total zooplankton density in both L Lake and Par Pond, with Rotifera composing most of the remainder.
5. There were no consistent regional differences in taxa richness, or densities of Protozoa, Rotifera, Cladocera or Copepoda in the mixed zone of L Lake during this study. In general, changes in the abundance of zooplankton did not respond to reactor operation, particularly the summer shut downs. Many of the L-Lake zooplankton taxa are ubiquitous in their distribution and tolerate a wide range of physico-chemical conditions, including temperature. The major impacts of L-Reactor operations on the L-Lake zooplankton may have been in stimulating high phytoplankton densities and biovolumes by maintaining elevated nutrient levels and introducing a pelagic vertebrate planktivore into the system (i.e., threadfin shad), rather than the creation of a thermal gradient.

6. The zooplankton community of L Lake was comparable to communities found in other SRS impoundments, southeastern lakes/reservoirs, and cooling impoundments with respect to zooplankton density and taxa richness. Historically, only densities of Protozoa were markedly higher in L Lake than in the other systems and perhaps atypical of southeastern reservoirs. In 1990 and 1991, L Lake and Par Pond were similar in terms of density and relative abundance. The L-Lake zooplankton fauna represented all trophic levels that would be expected to occur in a temperate freshwater system.
7. This study did not specifically address the question of successful reproduction in zooplankton. However, several indirect lines of evidence suggested that it did occur. First, the physico-chemical conditions and amounts of potential food available (i.e., phytoplankton and seston) in L Lake were well within the tolerance limits for zooplankton, and would permit the development of an indigenous community. Second, immature forms of some zooplankton taxa (i.e., copepod nauplius larvae) were always present throughout this study. Third, adult zooplankton carrying eggs or embryos were observed at various times. Fourth, zooplankton generally have relatively short lifespans (days to weeks) and a tremendous reproductive capacity. The persistence of zooplankton in itself suggested that reproduction was occurring within the system, and that the community was not supported by continuous invasion or importation of organisms from the Savannah River or Par Pond.

1.0 INTRODUCTION

The zooplankton community in freshwater ecosystems is composed of the small animals (mainly Protozoa, Rotifera, Cladocera, Copepoda, and occasionally Ostracoda, Hydracarina, and Gastrotricha) that are found floating in the water column and/or associated with vegetation and other structures in the littoral zone (Odum 1971; Hutchinson 1967). Zooplankton are an integral component of the lentic freshwater fauna and are responsible for a major portion of the secondary production that occurs in lakes and reservoirs. As such, they serve as a vital link in the flow of energy between primary producers (i.e., phytoplankton and aquatic macrophytes) and higher trophic levels (e.g., macroinvertebrates and fishes; Cole 1979; Hutchinson 1967; Wetzel 1983). Zooplankton are especially important food items to many larval and adult fishes (Crecco and Blake 1983; Mills and Schiavone 1982; O'Brien 1979). A flourishing zooplankton community is essential for the establishment and persistence of a fish community in L Lake.

Zooplankton monitoring studies conducted on other southeastern reservoirs (e.g., Applied Biology Inc. 1982; Carolina Power & Light Co. 1976; Carr and Associates, Inc. 1982; Dames and Moore 1985; Duke Power Co. 1977, 1985; Weiss et al. 1975) have been somewhat limited in scope, since they focused mainly on the larger taxa, the macrozooplankton (Cladocera, Copepoda), for a variety of reasons, such as ease of collection and identification. However, investigations by other workers (e.g., Beaver and Crisman 1982; Hunt and Chein 1983; Likens and Gilbert 1970; Makarewicz and Likens 1979; Pace 1982; Pace and Orcutt 1981) have indicated that microzooplankton (Protozoa and Rotifera) may dominate the zooplankton community numerically, accounting for up to 98% of all organisms in some

communities, and contribute significantly to total zooplankton productivity (Wetzel 1983). An investigation of Par Pond and Pond B on the Savannah River Site supported these findings: the microzooplankton numerically dominated the zooplankton communities of both reservoirs throughout the year (Chimney et al. 1985).

The zooplankton of L Lake are exposed to a thermal gradient during periods of reactor operation. Although temperatures in the immediate vicinity of the L-Reactor cooling water discharge ($\geq 70^{\circ}\text{C}$ during reactor operation; J. Gladden, pers. comm.) are well above tolerance limits for aquatic biota, most of the reservoir does produce and sustain zooplankton. Temperature has a profound effect on zooplankton community dynamics. Rates for respiration, grazing, growth, and egg development are, within limits, all positively correlated with increases in temperature (Allen 1976; Carlson 1974; Edmondson 1965; Gehrs 1974; Nalco Environmental Sciences 1976; Vernberg and Vernberg 1974). Shorter periods of egg development and reduced generation times can lead to increased population densities (Wetzel 1983). Extreme temperature variation within a lake can promote substantial changes in the overall zooplankton community structure along the thermal gradient (Nursall and Gallup 1971). Natural variation in the temperature related physiological and competitive fitness of each taxon may lead to changes in community composition; thermal loading may select for those species that are best able to take advantage of a warmer-than-normal environment (Carlson 1974; Dale and Swartzman 1984).

The objectives of this portion of the L-Lake Biological Monitoring Program are to provide an analysis of the zooplankton community in L Lake that will help

determine whether this ecosystem contains, or is developing in a manner that indicates that it will contain, a Balanced Biological Community pursuant to the requirements for a successful 316(a) demonstration. In general, these data will be used to:

1. compare characteristics of the L-Lake zooplankton community with data available in the literature for zooplankton in other southeastern reservoirs (including Par Pond and Pond B on the SRS), reservoirs that have been established recently, and reservoirs that receive thermal effluents and have demonstrated regulatory compliance;
2. analyze quantitative data on the species composition, temporal variation, and spatial distribution of the zooplankton community in Regions 4 - 8 to evaluate the biotic response to the thermal effluent; and;
3. document the development of the L-Lake zooplankton community by comparing data collected in 1991 with those collected in 1986, 1987, 1988, 1989, and 1990.

Data presented in this report cover the period January 1986 to December 1991.

2.0 METHODS AND MATERIALS

2.1 FIELD PROCEDURES

A change in the scope of the zooplankton studies was initiated in 1990. Zooplankton collections were eliminated from regions 4, 6, and 8, and the frequency of sampling was reduced from monthly to quarterly. Collections were no longer divided between epilimnion and hypolimnion during periods of thermal stratification but instead collected from the entire water column. A detailed description of the historical methods (1986 through 1989) employed appears in Chimney and Bowen (1990).

From 1986-1989, replicate zooplankton samples were collected monthly at single stations in the pelagic zone (Table 2-1, Figure 2-1). In 1990 and 1991, single zooplankton samples were collected quarterly (Table 2-1) from each of four stations, marked by permanent buoys, in the pelagic zone of Regions 5 and 7 (Figure 2-2). Each "sample" represented an integrated collection of organisms taken from the entire water column (surface to bottom).

Beginning in 1990, replicate microzooplankton (Protozoa, Rotifera, and Gastrotricha) samples were collected from the entire water column, four discrete samples for microzooplankton per region and date, using a water pump system (Figure 2-3). In 1990 only, four discrete samples for each region and date were also collected for nauplius larvae. The end of the hose was first positioned near the bottom, then retrieved upwards through the water column so that approximately 1 L of water was collected for each meter of depth the hose traveled (referred to as a "pump haul"). Water from each pump haul was

Table 2-1. Sampling dates for collection of L-Lake zooplankton.
January 1986-December 1991.

	1986	1987	1988	1989	1990	1991
JANUARY	6	5	4	4	-	-
FEBRUARY	3	2	1	6	6	5
MARCH	3	2	7	6	-	-
APRIL	9	6	4	3	-	-
MAY	5	4	3	2	1	7
JUNE	2	1	6	5	-	-
JULY	7	6	5	3	-	-
AUGUST	4	3	2	8	7	6
SEPTEMBER	8	1	6	5	-	-
OCTOBER	6	5	3	2	-	-
NOVEMBER	4	9	8	7	6	5
DECEMBER	2	1	6	4	-	-

Figure 2-1. Location of L-Lake zooplankton sampling stations in the pelagic zone of Regions 4 - 8. January 1986-December 1989.

Figure 2-2. Location of L-Lake zooplankton sampling stations in the pelagic zone of Regions 5 - 7. January 1990-December 1991.

Figure 2-3. Schematic of water pump system used to collect microzooplankton and nauplius larvae from L-Lake pelagic sampling stations.

composited into a 25-L carboy and thoroughly mixed by agitating the carboy; a 1-L aliquot was withdrawn to produce an "integrated whole-water" sample. Each sample was stored in a 1-L plastic bottle and preserved in the field with Lugol's solution (1% final volume), which is an effective preservative for zooplankton, especially delicate protozoans (Pace and Orcutt 1981; Wetzel and Likens 1979).

Four replicate macrozooplankton (Cladocera, Copepoda, and Ostracoda) samples were collected per region and date by vertically hauling a plankton net (20.3-cm mouth diameter, 153- μ m mesh size) through the water column at a speed of between 0.5 and 1.0 m/sec (Weber 1973). The macrozooplankton collected in each net haul were carefully rinsed into a 125-mL plastic storage bottle and preserved in the field with Lugol's solution (1% final volume).

Beginning in 1991, nauplii larvae were collected in separate net tows. Four replicate tows per region and date were made by hauling a plankton net (20.3-cm mouth diameter, 80- μ m mesh size) through the water column at a speed between 0.5 and 1.0 m/sec (Weber 1973). Nauplii larvae from each tow were carefully rinsed into a 125-mL plastic storage bottle and preserved in the field with a 1% Lugol's solution.

In situ instrument readings of temperature ($^{\circ}$ C), dissolved oxygen (mg/L), pH, and conductivity (μ S/cm) were recorded in conjunction with water quality sampling (see Kretchmer 1992) on the same day as zooplankton sampling from 1986 to 1989. Measurements were made using a Hydrolab water quality analyzer (Model 8002 or Surveyor II) or a similar instrumentation (YSI 58 O₂ meter, Cole-Palmer 1481-50 conductivity meter, Orion 701A pH meter). These data were used to

determine if an oxygen-poor hypolimnion existed and to document physico-chemical conditions on the day of collection. Instrument data were not collected in 1990 or 1991.

2.2 LABORATORY PROCEDURES

Each 1-L whole-water microzooplankton sample was allowed to settle for 24 hours to concentrate all organisms at the bottom of the collection bottle. The volume of each settled sample was reduced to about 100 mL by carefully siphoning off the excess liquid.

To prepare microzooplankton samples for counting, each concentrated sample (and a rinse from the sample bottle) was poured into a graduated cylinder, and allowed to resettle for a minimum of 16 hours, and the excess liquid was siphoned off. Each resettled sample was then mixed by agitating the cylinder, and a 1- or 2-mL aliquot was transferred with a calibrated pipette to an inverted microscope counting chamber. Large protozoans ($\geq 50, \mu\text{m}$) and all rotifers were enumerated at 100X by scanning the entire chamber. Small protozoans ($< 50 \mu\text{m}$) were counted along a minimum of two transects (52 mm) across the counting chamber at 200X. Magnifications of 400X to 630X were used in identification of the smallest protozoans (8.5 - 15.0 μm). The volume of each sample was adjusted to obtain an optimum counting density of at least 150 organisms. Sketches were made of all taxa to ensure consistency in taxonomic identification throughout the study.

All macrozooplankton in a 1-mL aliquot from each replicate net sample were identified and counted at 100X in a Sedgwick-Rafter counting cell (Lind 1974).

Similarly, all copepod nauplii from a 1-mL aliquot from each replicate sample were enumerated. The contents of each storage bottle were thoroughly mixed before the aliquot was removed with a calibrated pipette. Starting in 1989, and in consultation with SRL, samples were concentrated prior to removing the aliquot. This was done in an attempt to obtain counts of at least 75 organisms per cell. Representative specimens of each macrozooplankton taxon were placed in mounting medium (CMC-10) on glass slides and maintained in a reference collection specific to this project. Beginning in 1987, slides were supplemented with a photomicrographic record of taxa.

Micro- and macrozooplankton were identified to the lowest taxonomic level practicable, usually genus or species. Some forms, such as copepod nauplii, contracted rotifers, and certain protozoa, were lumped into similar groups (i.e., holophyrid ciliates, bdelloid rotifers). Principal taxonomic references used in the identification of zooplankton for this study included Ahlstrom (1940, 1943), Bartos (1959), Berner (1982), Brick (1972), Brooks (1959), DeFlandre (1959), Edmondson (1959), Jahn and Jahn (1949), Kahl (1930-1932), Noland (1959), Pennak (1978), Ruttner-Kolisko (1974), and Wilson and Yeatman (1959).

Starting in 1990, length measurements were made of the dominant cladoceran and copepod taxa. Approximately 100 individuals, when available, were measured from each sample using procedures outlined in Pace (1986). Non-daphnid cladocerans were measured from the top of the carapace to the base of the tail spine. Daphnid cladocerans were measured from the top of the eye to the base of the tail spine. Copepods were measured from the anterior margin of the head to the end of the caudal rami (excluding setae).

2.3 DATA ANALYSIS

Beginning in 1990, raw count data were used to calculate the volumetric density of each microzooplankton taxon, following Lind (1974):

$$VD_1 = [(C \times A) / (L \times W \times S \times V)] \times 1000 \quad 1.$$

Where:

VD₁ - volumetric density of microzooplankton (organisms/m³)
C - raw count of microzooplankton in the sample
A - area of counting chamber (mm²)
L - length of the transect(s) examined in the counting chamber (mm)
W - width of transect(s) examined (mm)
S - number of transects examined
V - volume of sample settled (L)

Densities of microzooplankton collected from 1986-1989 are expressed as numbers per liter.

Areal densities for microzooplankton were calculated from the volumetric density using the following formula:

$$AD_1 = VD_1 \times H \quad 2.$$

Where:

AD₁ - areal density of microzooplankton (organisms/m²)
VD₁ - volumetric density of microzooplankton (organisms/m³)
H - haul distance of pump haul (m)

Beginning in 1990, raw count data were used to calculate the volumetric density of each macrozooplankton taxon, following Lind (1974):

$$VD_2 = (C \times V_s) / (32.4 \times H) \times 1000 \quad 3.$$

Where:

- VD_a = volumetric density of macrozooplankton (organisms/m³)
C = raw count of macrozooplankton in the 1-mL chamber (organisms/mL)
V_s = volume of sample in collection vial (mL)
 - M_f - M_e (difference in bottle weights assumed to be equivalent to mL)
M_f = weight of sample bottle when full (g)
M_e = weight of sample bottle when empty (g)
H = haul distance of net tow (m)
32.4 = Factor required to express volume (L) of water passing through net [cross-sectional area of net mouth (m²) X 1000 L/m³]

Densities of macrozooplankton collected from 1986-1989 are expressed as numbers per liter.

Areal densities of macrozooplankton were calculated using the following formula:

$$AD_a = VD_a \times H \quad 4.$$

Where:

- AD_a = areal density of macrozooplankton (organisms/m²)
VD_a = volumetric density of macrozooplankton (organisms/m³)
H = haul distance of net tow (m)

Raw count data were used to calculate the volumetric density of copepod nauplii in 1990 and 1991 following Lind (1974).

$$VD_n = (C \times V_s/V_e) \times 10^6 \quad 5.$$

Where:

- VD_n = volumetric density of nauplii (organisms/m³)
C = raw count of nauplii in the 1-mL chamber (organisms/mL)
V_s = volume of sample in collection vial (mL)
 - M_f - M_e (difference in bottle weights assumed to be equivalent to mL)
M_f = weight of sample bottle when full (g)
M_e = weight of sample bottle when empty (g)

V_s = volume of sample collected, assumed to be 980 mL

Areal densities of copepod nauplii were calculated using the following formula:

$$AD_n = VD_n \times H \quad 6.$$

Where:

AD_n = areal density of nauplii (organisms/m²)

VD_n = volumetric density of nauplii (organisms/m³)

H = haul distance of pump haul (m)

Beginning in 1991, raw count data were used to calculate the volumetric density of copepod nauplii, following Lind (1974).

$$VD_n = (C \times V_s / 32.4 \times H) \times 1000 \quad 7.$$

Where:

VD_n = volumetric density of nauplii (organisms/m³)

C = raw count of nauplii in the 1-mL chamber (organisms/mL)

V_s = volume of sample in collection vial (mL)

$M_f - M_e$ (difference in bottle weights assumed to be equivalent to mL)

M_f = weight of sample bottle when full (g)

M_e = weight of sample bottle when empty (g)

H = haul distance of net tow (m)

32.4 = factor required to express volume (L) of water passing through net [cross-sectional area of net mouth (m²) x 1000 L/m³]

Areal densities of copepod nauplii were calculated using the following formula:

$$AD_n = VD_n \times H \quad 8.$$

Where:

AD_n = areal density of nauplii (organisms/m²)

VD_n = volumetric density of nauplii (organisms/m³)

H = haul distance of net tow (m)

All statistics were calculated using SAS (SAS 1985a, 1985b, 1985c) with reference made to Green (1979), Roscoe (1975), Sokal and Rohlf (1981), Steel and Torrie (1960), Winer (1971). The data have been summarized by standard

statistical procedures (mean, median [Med], number of observations [N], standard deviation [SD] or standard error [SE], coefficient of variation [CV], maximum value [Max] and minimum value [Min]), plotted and examined for temporal and spatial trends. Descriptive statistics were calculated by pooling data for each region over the entire sampling period for a given year. When mean values are cited, the corresponding standard deviation (± 1 unit) or standard error is also given. All densities shown in plots are means of replicate samples. Relative abundance (percent composition) of major taxonomic groups of zooplankton was calculated from mean densities as:

$$\text{relative abundance} = \frac{\text{taxa density}}{\text{total zooplankton taxa density}} \times 100 \quad 9.$$

Minor discrepancies between mean densities and relative abundance values can be attributed to rounding errors. Zooplankton taxa richness (number of taxa) was calculated as the number of unique taxa identified from four replicate samples combined for all dates at a given region or for all regions on a given date.

Regional differences in total zooplankton density for 1990 and 1991 were evaluated using a repeated measures analysis of variance (Winer 1971). A one-way model using region as the classification variable was utilized. The four quarterly collections of total volumetric density for each region and replicate were used as the repeated measurements. Total volumetric density was transformed using the $\ln(x+1)$ transformation.

The main focus of this report will be an interpretation of zooplankton data from the mixed zone. Hypolimnetic data, collected from 1986-1989, are presented and addressed where appropriate.

3.0 RESULTS AND DISCUSSION

3.1 ZOOPLANKTON TAXA

Zooplankton taxa collected from the mixed zone and hypolimnion of L-Lake Regions 4 - 8 from 1986 to 1989 are listed in Appendix Table 1. Individual taxa collected quarterly from L Lake and Par Pond combined in 1990 and 1991 are listed in Appendix Table 2. Cyclopoid copepodids, calanoid copepodids, and nauplius larvae were enumerated separately during this study and were considered as individual "taxonomic units" for the purposes of calculating taxa richness. A total of 90 taxa were collected in L Lake and Par Pond in 1991; 39 (43%) were Protozoa, 29 were Rotifera (32%), 11 were Cladocera (12%), 10 were Copepoda (11%) and 1 was an Ostracoda (1%) (Appendix Table 2). Total number of taxa in 1991 was slightly higher than the number of taxa in 1990 (85), but proportions of the groups were similar (Bowen and Chimney 1991). The number of taxa collected in 1990 (81) and 1991 (84) on a lakewide basis was slightly lower than in 1989 (88; see Section 3.5). This could be the result of a less-intensive sampling effort beginning in 1990 (Chimney and Bowen 1990).

The total number of taxa collected on an annual basis was highest in 1986 (125) following creation of L Lake and decreased steadily on a lakewide basis through 1990 (Bowen and Chimney 1991). Microzooplankton taxa (Protozoa and Rotifera) have accounted for 70.5 - 83.8% of the taxa collected annually since 1986. Cladocerans and copepods composed the majority of the remaining taxa (Bowen and Chimney 1991).

Seasonal differences occurred in the number of taxa in 1991. Numbers of

taxa were highest in fall and lowest in winter. Historically, taxa richness has been lowest in summer (1986, 1987, 1988, 1990) and winter (1990; Bowen and Chimney 1990). Protozoan taxa comprised over 40% of the total number of taxa in all seasons. Rotifer taxa were ranked second in terms of numbers of taxa, consistently composing at least 30% of the total number of taxa in all seasons. Numbers of rotifer and protozoan taxa were highest in summer and fall, contributing to the high number of taxa overall, and lowest in winter. Cladocera contributed between 6 and 10 taxa to the L-Lake zooplankton community. Copepods (all lifestages combined) contributed from 5-9 additional taxa. Ostracoda were rarely collected, and other groups (e.g., Gastrotricha) were not collected in 1991 (Appendix Table 2). The distribution of taxa among the various groups is similar to that observed in 1990 (Appendix Table 2).

The L-Lake zooplankton community accumulated taxa quite rapidly in the beginning of the study (January through March 1986). In March 1986, this increase slowed markedly, remained relatively constant through the end of 1987, and then slowed again through 1989. It appeared that by the end of 1989 the L-Lake cumulative taxa curve was becoming asymptotic (Chimney and Bowen 1990). The initial high taxa richness levels in L Lake in early 1986, coupled with the absence of any net changes in taxa richness in the succeeding months indicated that the increase in cumulative taxa richness observed during this study reflected faunal replacement rather than net additions of taxa to the system (Chimney and Bowen 1990). The rapid accumulation of taxa during the first part of the study (January to March 1986) was considered normal for a developing zooplankton community in a new impoundment. The slower accumulation of taxa from 1987 through the end of 1989 would be expected as the community began to

stabilize and true lake-adapted species replaced the early colonizers and stream taxa that originated in Steel Creek.

3.2 ZOOPLANKTON DENSITY

3.2.1 Protozoa

Descriptive statistics for volumetric densities (organisms/L) of Protozoa collected from 1986-1989 from the mixed zone and hypolimnion of Regions 5 and 7 in L Lake are presented in Appendix Tables 4 and 5. Means and standard deviations are also listed in Table 3-1. Seasonal patterns from 1986-1989 are shown in Figure 3-1. Volumetric (organisms/m³) and areal (organisms/m²) densities of Protozoa collected quarterly in 1990 and 1991 in Par Pond and L Lake are presented for each replicate sample in Appendix Table 3. Mean volumetric and areal densities and standard errors for L-Lake collections are displayed in Table 3-2 and Figure 3-2. Annual mean densities by region and for the entire lake are shown in Figure 3-3.

Historically, at Region 5, annual mean densities (organisms/L) ranged from $26,855 \pm 15,452$ in 1987 to $40,861 \pm 24,469$ in 1988 (Table 3-1). In 1990, the average annual density (organisms/m³), $11,741,813 \pm 2,121,061$ (Table 3-2), was less than half that observed historically. Protozoan areal densities averaged $149,289,131 \pm 29,476,654$ organisms per m² in Region 5 in 1990. In 1991, the average annual density of protozoans was $17,194,063 \pm 3,893,773$ organisms/m³, an increase from 1990 densities but still lower than previous years. Protozoan areal densities averaged $206,524,938 \pm 46,711,856$ organisms per m² in 1991.

Table 3-1. Means and standard deviations (organisms/L) for densities of Protozoa, Rotifera, Cladocera, and Cyclopoida/Calanoida from the mixed zone and hypolimnion of L-Lake Regions 4-8. January 1986-December 1989.

Taxon	Region	Mixed Zone		Hypolimnion	
<u>1986</u>					
Protozoa	4	29943 ±	18786	22923 ±	16361
	5	28644 ±	14004	23082 ±	16290
	6	25214 ±	10843	9850 ±	7095
	7	26325 ±	17402	10179 ±	8494
	8	26725 ±	17347	9621 ±	7191
Rotifera	4	917 ±	690	82 ±	138
	5	917 ±	896	16 ±	45
	6	835 ±	843	69 ±	78
	7	907 ±	890	16 ±	28
	8	752 ±	766	79 ±	123
Cladocera	4	20 ±	21	3 ±	2
	5	22 ±	33	7 ±	7
	6	21 ±	26	3 ±	3
	7	26 ±	39	2 ±	2
	8	23 ±	27	2 ±	3
Cyclopoida/ Calanoida	4	40 ±	33	13 ±	10
	5	45 ±	43	21 ±	27
	6	53 ±	47	6 ±	5
	7	56 ±	42	7 ±	6
	8	58 ±	47	6 ±	8
<u>1987</u>					
Protozoa	4	27260 ±	16119	16212 ±	8348
	5	26855 ±	15452	7942 ±	4557
	6	32473 ±	15032	12569 ±	10932
	7	30260 ±	20934	7982 ±	4962
	8	27790 ±	15174	5141 ±	1746
Rotifera	4	1017 ±	1199	52 ±	54
	5	1097 ±	1435	25 ±	39
	6	823 ±	1381	37 ±	53
	7	1116 ±	2010	62 ±	84
	8	1236 ±	2640	33 ±	65
Caldocera	4	15 ±	23	0 ±	0
	5	12 ±	18	<1 ±	<1
	6	12 ±	21	<1 ±	<1

Table 3-1. (continued). Means and standard deviations (organisms/L) for densities of Protozoa, Rotifera, Cladocera, and Cyclopoida/Calanoida from the mixed zone and hypolimnion of L-Lake Regions 4-8. January 1986-December 1989.

Taxon	Region	Mixed Zone		Hypolimnion	
<u>1987 (continued).</u>					
Cladocera (cont.)	7	6 ±	7	<1 ±	1
	8	5 ±	6	<1 ±	<1
Cyclopoida/	4	42 ±	54	2 ±	2
Calanoida	5	42 ±	47	2 ±	1
	6	36 ±	37	3 ±	2
	7	31 ±	33	4 ±	4
	8	36 ±	42	1 ±	1
<u>1988</u>					
Protozoa	4	48682 ±	38981	25454 ±	20235
	5	40861 ±	24469	28126 ±	23291
	6	47149 ±	30843	15204 ±	11892
	7	60733 ±	49313	15096 ±	10748
	8	61137 ±	51217	25402 ±	31599
Rotifera	4	1668 ±	1702	60 ±	107
	5	1706 ±	1394	58 ±	124
	6	1742 ±	1643	18 ±	39
	7	1369 ±	1313	156 ±	220
	8	1338 ±	1326	42 ±	75
Cladocera	4	3 ±	4	<1 ±	<1
	5	3 ±	4	<1 ±	1
	6	3 ±	5	1 ±	3
	7	3 ±	6	<1 ±	<1
	8	4 ±	8	<1 ±	1
Cyclopoida/ Calanoida	4	12 ±	8	2 ±	2
	5	12 ±	10	2 ±	2
	6	9 ±	5	2 ±	4
	7	9 ±	5	1 ±	1
	8	10 ±	6	1 ±	<1
<u>1989</u>					
Protozoa	4	28209 ±	21667	20808 ±	6916
	5	29432 ±	22979	10529 ±	4469
	6	32473 ±	19006	10647 ±	12751

Table 3-1. (continued). Means and standard deviations (organisms/L) for densities of Protozoa, Rotifera, Cladocera, and Cyclopoida/Calanoida from the mixed zone and hypolimnion of L-Lake Regions 4-8. January 1986-December 1989.

Taxon	Region	Mixed Zone		Hypolimnion	
<u>1989</u> (continued).					
Protozoa (cont.)	7	28267 ±	19861	7492 ±	3676
	8	28397 ±	17926	12818 ±	10805
Rotifera	4	2887 ±	3083	210 ±	153
	5	2679 ±	2843	72 ±	178
	6	3001 ±	3252	157 ±	169
	7	2800 ±	3298	92 ±	176
	8	3099 ±	3863	495 ±	1125
Caldocera	4	1 ±	1	<1 ±	<1
	5	1 ±	1	<1 ±	<1
	6	1 ±	1	<1 ±	<1
	7	1 ±	1	<1 ±	<1
	8	1 ±	1	<1 ±	<1
Cyclopoida/ Calanoida	4	13 ±	7	3 ±	4
	5	13 ±	9	2 ±	3
	6	11 ±	9	2 ±	4
	7	12 ±	8	3 ±	8
	8	11 ±	8	2 ±	4

Figure 3-1. Mean density of Protozoa (organisms x 1000/L) in the mixed zone of L-Lake Regions 4 - 8. January 1986-December 1989.

Table 3-2. Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		VOLUMETRIC		% REL.
1990		MEAN	S. E.	ABUND.
<u>Region 5</u>				
WINTER	PROTOZOA	9918000	1292540	99.26
	ROTIFERA	35000	23629	0.35
	CLADOCERA	4601	1073	0.05
	NAUPLIUS	26173	12187	0.26
	COPEPODID	7790	729	0.08
	COPE. ADULT	533	157	0.01
SPRING	PROTOZOA	21687000	2221748	93.27
	ROTIFERA	1542000	157732	6.63
	CLADOCERA	2461	368	0.01
	NAUPLIUS	11964	5721	0.05
	COPEPODID	7902	670	0.03
	COPE. ADULT	880	219	0.00
SUMMER	PROTOZOA	975250	437133	76.65
	ROTIFERA	290000	39370	22.79
	CLADOCERA	134	71	0.01
	NAUPLIUS	6505	6505	0.51
	COPEPODID	455	155	0.04
	COPE. ADULT	38	13	0.00
FALL	PROTOZOA	14387000	2851387	95.26
	ROTIFERA	689500	119765	4.57
	CLADOCERA	1261	560	0.01
	NAUPLIUS	21327	9710	0.14
	COPEPODID	3210	990	0.02
	COPE. ADULT	359	57	0.00
ALL SEASONS	PROTOZOA	11741813	2121061	94.66
	ROTIFERA	639125	154303	5.15
	CLADOCERA	2114	513	0.02
	NAUPLIUS	16492	4455	0.13
	COPEPODID	4839	875	0.04
	COPE. ADULT	452	100	0.00

Table 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		AREAL		% REL. ABUND.
1990		MEAN	S.E.	
<u>Region 5</u>				
WINTER	PROTOZOA	125003150	19694534	99.29
	ROTIFERA	402000	261669	0.32
	CLADOCERA	56039	11839	0.04
	NAUPLIUS	335939	154743	0.27
	COPEPODID	97282	11419	0.08
	COPE. ADULT	6403	1565	0.01
SPRING	PROTOZOA	288020500	45811428	93.36
	ROTIFERA	20178500	3070057	6.54
	CLADOCERA	32532	5887	0.01
	NAUPLIUS	155000	82047	0.05
	COPEPODID	103431	13079	0.03
	COPE. ADULT	12110	3371	0.00
SUMMER	PROTOZOA	10730000	4979175	77.26
	ROTIFERA	3092500	410434	22.27
	CLADOCERA	1469	789	0.01
	NAUPLIUS	58546	58546	0.42
	COPEPODID	4932	1744	0.04
	COPE. ADULT	400	133	0.00
FALL	PROTOZOA	173402875	40751358	95.51
	ROTIFERA	7856000	925980	4.33
	CLADOCERA	14647	6883	0.01
	NAUPLIUS	245459	115644	0.14
	COPEPODID	39319	13081	0.02
	COPE. ADULT	4332	892	0.00
ALL SEASONS	PROTOZOA	149289131	29476654	94.81
	ROTIFERA	7882250	2088273	5.01
	CLADOCERA	26172	6250	0.02
	NAUPLIUS	198736	55529	0.13
	COPEPODID	61241	11660	0.04
	COPE. ADULT	5811	1387	0.00

Table 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

1990		VOLUMETRIC		% REL. ABUND.
		MEAN	S.E.	
<u>Region 7</u>				
WINTER	PROTOZOA	13358750	700943	98.91
	ROTIFERA	111500	19973	0.83
	CLADOCERA	3550	1180	0.03
	NAUPLIUS	30561	16376	0.23
	COPEPODID	1708	607	0.01
	COPE. ADULT	336	191	0.00
SPRING	PROTOZOA	21084500	2500257	93.63
	ROTIFERA	1413250	231943	6.28
	CLADOCERA	1667	285	0.01
	NAUPLIUS	8929	2980	0.04
	COPEPODID	8719	829	0.04
	COPE. ADULT	1348	499	0.01
SUMMER	PROTOZOA	1895250	631372	75.82
	ROTIFERA	604000	207475	24.16
	CLADOCERA	90	54	0.00
	NAUPLIUS	0	0	0.00
	COPEPODID	197	100	0.01
	COPE. ADULT	14	9	0.00
FALL	PROTOZOA	23400000	4135670	96.12
	ROTIFERA	928500	269734	3.81
	CLADOCERA	1428	513	0.01
	NAUPLIUS	6658	4215	0.03
	COPEPODID	7649	2983	0.03
	COPE. ADULT	477	152	0.00
ALL SEASONS	PROTOZOA	14934625	2431485	95.02
	ROTIFERA	764313	153294	4.86
	CLADOCERA	1684	434	0.01
	NAUPLIUS	11537	4848	0.07
	COPEPODID	4568	1183	0.03
	COPE. ADULT	544	178	0.00

Table 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		AREAL		% REL.
1990		MEAN	S.E.	ABUND.
<u>Region 7</u>				
WINTER	PROTOZOA	171198875	7672120	98.93
	ROTIFERA	1406750	193164	0.81
	CLADOCERA	43894	12513	0.03
	NAUPLIUS	380344	186168	0.22
	COPEPODID	21251	6541	0.01
	COPE. ADULT	4071	2153	0.00
SPRING	PROTOZOA	286483000	26968265	93.78
	ROTIFERA	18731500	1477768	6.13
	CLADOCERA	22476	2799	0.01
	NAUPLIUS	113265	39640	0.04
	COPEPODID	118900	8621	0.04
	COPE. ADULT	18206	6562	0.01
SUMMER	PROTOZOA	25307250	7791421	76.10
	ROTIFERA	7942000	2623348	23.88
	CLADOCERA	1174	702	0.00
	NAUPLIUS	0	0	0.00
	COPEPODID	2626	1273	0.01
	COPE. ADULT	191	122	0.00
FALL	PROTOZOA	310645000	64267237	96.41
	ROTIFERA	11368000	1988000	3.53
	CLADOCERA	17223	4165	0.01
	NAUPLIUS	89962	55548	0.03
	COPEPODID	92539	25861	0.03
	COPE. ADULT	6482	2342	0.00
ALL SEASONS	PROTOZOA	198408531	33163724	95.16
	ROTIFERA	9862063	1804066	4.73
	CLADOCERA	21192	4967	0.01
	NAUPLIUS	145893	57502	0.07
	COPEPODID	58829	13951	0.03
	COPE. ADULT	7238	2381	0.00

Table 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		VOLUMETRIC		% REL.
1990		MEAN	S.E.	ABUND.
<u>All Regions</u>				
WINTER	PROTOZOA	11638375	941326	99.06
	ROTIFERA	73250	20350	0.62
	CLADOCERA	4076	765	0.03
	NAUPLIUS	28367	9486	0.24
	COPEPODID	4749	1230	0.04
	COPE. ADULT	435	120	0.00
SPRING	PROTOZOA	21385750	1552506	93.45
	ROTIFERA	1477625	132104	6.46
	CLADOCERA	2064	262	0.01
	NAUPLIUS	10446	3041	0.05
	COPEPODID	8311	517	0.04
	COPE. ADULT	1114	268	0.00
SUMMER	PROTOZOA	1435250	395722	76.10
	ROTIFERA	447000	114357	23.70
	CLADOCERA	112	42	0.01
	NAUPLIUS	3253	3253	0.17
	COPEPODID	326	98	0.02
	COPE. ADULT	26	9	0.00
FALL	PROTOZOA	18893500	2882454	95.79
	ROTIFERA	809000	143890	4.10
	CLADOCERA	1344	353	0.01
	NAUPLIUS	13992	5630	0.07
	COPEPODID	5429	1679	0.03
	COPE. ADULT	418	78	0.00
ALL SEASONS	PROTOZOA	13338219	1612763	94.86
	ROTIFERA	701719	107573	4.99
	CLADOCERA	1899	333	0.01
	NAUPLIUS	14015	3269	0.10
	COPEPODID	4704	724	0.03
	COPE. ADULT	498	101	0.00

Table 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		AREAL		% REL. ABUND.
1990		MEAN	S. E.	
<u>All Regions</u>				
WINTER	PROTOZOA	148101013	13112782	99.08
	ROTIFERA	904375	242327	0.61
	CLADOCERA	49966	8298	0.03
	NAUPLIUS	358142	112376	0.24
	COPEPODID	59266	15607	0.04
	COPE. ADULT	5237	1309	0.00
SPRING	PROTOZOA	287251750	24609964	93.57
	ROTIFERA	19455000	1600760	6.34
	CLADOCERA	27504	3566	0.01
	NAUPLIUS	134133	42912	0.04
	COPEPODID	111166	7818	0.04
	COPE. ADULT	15158	3604	0.00
SUMMER	PROTOZOA	18018625	5090211	76.45
	ROTIFERA	5517250	1533205	23.41
	CLADOCERA	1321	492	0.01
	NAUPLIUS	29273	29273	0.12
	COPEPODID	3779	1090	0.02
	COPE. ADULT	296	92	0.00
FALL	PROTOZOA	242023938	43744839	96.08
	ROTIFERA	9612000	1212902	3.82
	CLADOCERA	15935	3756	0.01
	NAUPLIUS	167710	66261	0.07
	COPEPODID	65929	16767	0.03
	COPE. ADULT	5407	1229	0.00
ALL SEASONS	PROTOZOA	173848831	22265605	95.01
	ROTIFERA	8872156	1368970	4.85
	CLADOCERA	23682	3952	0.01
	NAUPLIUS	172314	39604	0.09
	COPEPODID	60035	8946	0.03
	COPE. ADULT	6524	1361	0.00

TABLE 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		VOLUMETRIC		% REL. ABUND.
1991		MEAN	S.E.	
<u>Region 5</u>				
WINTER	PROTOZOA	5271000	635445	96.86
	ROTIFERA	145500	13048	2.67
	CLADOCERA	5540	476	0.10
	NAUPLIUS	9888	1535	0.18
	COPEPODID	8786	866	0.16
	COPE. ADULT	1236	553	0.02
SPRING	PROTOZOA	11037750	1089906	93.38
	ROTIFERA	741250	121302	6.27
	CLADOCERA	16937	2086	0.14
	NAUPLIUS	7198	1321	0.06
	COPEPODID	15712	1980	0.13
	COPE. ADULT	1651	280	0.01
SUMMER	PROTOZOA	13490000	865982	93.87
	ROTIFERA	879750	127358	6.12
	CLADOCERA	118	42	0.00
	NAUPLIUS	211	31	0.00
	COPEPODID	666	123	0.00
	COPE. ADULT	86	19	0.00
FALL	PROTOZOA	38977500	8838653	97.83
	ROTIFERA	837500	77500	2.10
	CLADOCERA	10360	1012	0.03
	NAUPLIUS	4441	400	0.01
	COPEPODID	8671	1707	0.02
	COPE. ADULT	3048	589	0.01
ALL SEASONS	PROTOZOA	17194063	3893773	96.22
	ROTIFERA	651000	87761	3.64
	CLADOCERA	8239	1684	0.05
	NAUPLIUS	5435	1033	0.03
	COPEPODID	8459	1507	0.05
	COPE. ADULT	1505	334	0.01

TABLE 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

1991		AREAL		% REL. ABUND.
		MEAN	S.E.	
<u>Region 5</u>				
WINTER	PROTOZOA	66557000	6423685	96.85
	ROTIFERA	1843500	130890	2.68
	CLADOCERA	70203	5074	0.10
	NAUPLIUS	123983	15438	0.18
	COPEPODID	111004	8205	0.16
	COPE. ADULT	15518	6580	0.02
SPRING	PROTOZOA	131334000	18552067	93.52
	ROTIFERA	8613125	1217109	6.13
	CLADOCERA	197269	21306	0.14
	NAUPLIUS	83502	14866	0.06
	COPEPODID	181942	15823	0.13
	COPE. ADULT	19002	2555	0.01
SUMMER	PROTOZOA	168271750	13317590	93.97
	ROTIFERA	10787625	1262389	6.02
	CLADOCERA	1575	589	0.00
	NAUPLIUS	2694	525	0.00
	COPEPODID	8448	1883	0.00
	COPE. ADULT	1055	221	0.00
FALL	PROTOZOA	459937000	112998178	97.91
	ROTIFERA	9520000	449889	2.03
	CLADOCERA	117904	7821	0.03
	NAUPLIUS	50653	3514	0.01
	COPEPODID	97321	14369	0.02
	COPE. ADULT	35291	7521	0.01
ALL SEASONS	PROTOZOA	206524938	46711856	96.28
	ROTIFERA	7691063	982017	3.59
	CLADOCERA	96738	19122	0.05
	NAUPLIUS	65208	12467	0.03
	COPEPODID	99679	16737	0.05
	COPE. ADULT	17716	3899	0.01

TABLE 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

1991		VOLUMETRIC		% REL. ABUND.
		MEAN	S.E.	
	<u>Region 7</u>			
WINTER	PROTOZOA	5483250	702861	95.59
	ROTIFERA	213500	26538	3.76
	CLADOCERA	10370	1038	0.18
	NAUPLIUS	15100	6127	0.26
	COPEPODID	10900	1218	0.19
	COPE. ADULT	823	142	0.01
SPRING	PROTOZOA	13676250	1083125	94.55
	ROTIFERA	742500	182329	5.13
	CLADOCERA	24530	9371	0.17
	NAUPLIUS	7017	616	0.05
	COPEPODID	11994	2145	0.08
	COPE. ADULT	2239	352	0.02
SUMMER	PROTOZOA	12691450	1968053	92.88
	ROTIFERA	972600	91881	7.12
	CLADOCERA	80	35	0.00
	NAUPLIUS	110	51	0.00
	COPEPODID	377	71	0.00
	COPE. ADULT	52	20	0.00
FALL	PROTOZOA	22175250	9746655	97.91
	ROTIFERA	452500	39025	2.00
	CLADOCERA	7540	1438	0.03
	NAUPLIUS	4334	1016	0.02
	COPEPODID	6331	1512	0.03
	COPE. ADULT	2269	611	0.01
ALL SEASONS	PROTOZOA	13506550	2713626	95.60
	ROTIFERA	595775	87598	4.22
	CLADOCERA	10680	3128	0.08
	NAUPLIUS	6640	1986	0.05
	COPEPODID	7401	1347	0.05
	COPE. ADULT	1346	293	0.01

TABLE 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

1991		AREAL		% REL. ABUND.
		MEAN	S.E.	
<u>Region 7</u>				
WINTER	PROTOZOA	78739250	10211536	95.57
	ROTIFERA	3127500	478017	3.80
	CLADOCERA	152721	17823	0.19
	NAUPLIUS	199275	70592	0.24
	COPEPODID	154240	12907	0.19
	COPE. ADULT	11874	1967	0.01
SPRING	PROTOZOA	194801875	26539395	94.90
	ROTIFERA	9856875	1487455	4.80
	CLADOCERA	314420	87664	0.15
	NAUPLIUS	101011	16312	0.05
	COPEPODID	161967	14711	0.08
	COPE. ADULT	31038	4383	0.02
SUMMER	PROTOZOA	177625825	28902837	92.95
	ROTIFERA	13454475	912948	7.04
	CLADOCERA	1052	402	0.00
	NAUPLIUS	1399	533	0.00
	COPEPODID	5262	968	0.00
	COPE. ADULT	725	281	0.00
FALL	PROTOZOA	327613000	147317836	97.98
	ROTIFERA	6460000	371932	1.93
	CLADOCERA	105862	17294	0.03
	NAUPLIUS	60468	10353	0.02
	COPEPODID	87327	14437	0.03
	COPE. ADULT	31127	5963	0.01
ALL SEASONS	PROTOZOA	194694988	41118508	95.78
	ROTIFERA	8224713	1075086	4.05
	CLADOCERA	143514	35570	0.07
	NAUPLIUS	90538	24784	0.04
	COPEPODID	102199	17164	0.05
	COPE. ADULT	18691	3769	0.01

TABLE 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		VOLUMETRIC		% REL. ABUND.
		MEAN	S.E.	
1991				
	<u>All Regions</u>			
WINTER	PROTOZOA	5377125	440449	96.21
	ROTIFERA	180500	19037	3.23
	CLADOCERA	8055	1088	0.14
	NAUPLIUS	12494	3085	0.22
	COPEPODID	9843	799	0.18
	COPE. ADULT	1029	276	0.02
SPRING	PROTOZOA	12357000	868661	94.02
	ROTIFERA	741875	101374	5.64
	CLADOCERA	20733	4670	0.16
	NAUPLIUS	7107	676	0.05
	COPEPODID	13853	1523	0.11
	COPE. ADULT	1945	236	0.01
SUMMER	PROTOZOA	13090725	1006703	93.39
	ROTIFERA	926175	74784	6.61
	CLADOCERA	99	27	0.00
	NAUPLIUS	161	34	0.00
	COPEPODID	521	85	0.00
	COPE. ADULT	69	14	0.00
FALL	PROTOZOA	30576375	6868744	97.86
	ROTIFERA	645000	83109	2.06
	CLADOCERA	8950	973	0.03
	NAUPLIUS	4387	506	0.01
	COPEPODID	7501	1145	0.02
	COPE. ADULT	2658	420	0.01
ALL SEASONS	PROTOZOA	15350306	2357819	95.95
	ROTIFERA	623388	61192	3.90
	CLADOCERA	9459	1761	0.06
	NAUPLIUS	6037	1106	0.04
	COPEPODID	7930	999	0.05
	COPE. ADULT	1426	219	0.01

TABLE 3-2 (continued). Mean, standard error, and relative abundance for areal (m^2) and volumetric density (m^3) for zooplankton groups collected seasonally at Regions 5 and 7 in L Lake in 1990 and 1991.

		<u>AREAL</u>		% REL. ABUND.
1991		MEAN	S. E.	
<u>All Regions</u>				
WINTER	PROTOZOA	72648125	6040466	96.16
	ROTIFERA	2485500	333940	3.29
	CLADOCERA	111462	17798	0.15
	NAUPLIUS	161629	36351	0.21
	COPEPODID	132622	10811	0.18
	COPE. ADULT	13696	3253	0.02
SPRING	PROTOZOA	163067938	19197547	94.34
	ROTIFERA	9235000	920213	5.34
	CLADOCERA	255845	47268	0.15
	NAUPLIUS	92257	10739	0.05
	COPEPODID	171954	10690	0.10
	COPE. ADULT	25020	3269	0.01
SUMMER	PROTOZOA	172948788	14837082	93.44
	ROTIFERA	12121050	879827	6.55
	CLADOCERA	1314	344	0.00
	NAUPLIUS	2046	424	0.00
	COPEPODID	6855	1150	0.00
	COPE. ADULT	890	177	0.00
FALL	PROTOZOA	393775000	89509864	97.94
	ROTIFERA	7990000	638301	1.99
	CLADOCERA	111883	9076	0.03
	NAUPLIUS	55561	5390	0.01
	COPEPODID	92324	9616	0.02
	COPE. ADULT	33209	4512	0.01
ALL SEASONS	PROTOZOA	200609963	30628079	96.04
	ROTIFERA	7957888	717803	3.81
	CLADOCERA	120126	20303	0.06
	NAUPLIUS	77873	13834	0.04
	COPEPODID	100939	11794	0.05
	COPE. ADULT	18204	2669	0.01

Figure 3-2. Mean density $\times 10^6$ (areal, per m^2 and volumetric, per m^3) and standard error of Protozoa in the mixed zone of L-Lake Regions 5, 7, and both regions combined in 1990 and 1991.

Areal

Volumetric

Figure 3-3. Annual mean density $\times 10^6$ (areal, per m^2 and volumetric, per m^3) of zooplankton groups collected from Regions 5, 7, and both regions combined in 1990 and 1991.

Densities at Region 7 were similar to those observed at Region 5. Historically, annual mean densities (organisms/L) ranged from $26,325 \pm 17,402$ in 1986 to $60,733 \pm 49,313$ in 1988 (Table 3-1). In 1990, the average annual density of $14,934,625 \pm 2,431,485$ organisms per m^3 (Table 3-2) was less than half that observed historically. The average areal density of protozoans was $198,408,531 \pm 33,163,724$ organisms/ m^2 in 1990 at Region 7. The annual average protozoan volumetric density in 1991, $13,506,550 \pm 2,713,626$ organisms/ m^3 , was similar to the 1990 value. Areal densities averaged $194,694,988 \pm 41,118,508$ organisms per m^2 .

Lower densities in 1990 and 1991 in comparison to previous years at both regions may, in part, have been due to changes in sampling methodology. In previous years, hypolimnetic waters, which historically had lower zooplankton densities than epilimnetic waters, were sampled and analyzed separately during periods of thermal stratification. In 1990 and 1991, hypolimnion waters were included in the sampling regime regardless of stratification.

Annually averaged volumetric and areal densities of Protozoa were slightly lower in 1990 at Region 5 in comparison to Region 7 (Figure 3-3). This can be attributed to the absence of protozoans from one of the replicate samples. In 1991, areal densities were similar between the two regions, but volumetric densities were slightly higher at Region 5 in comparison to Region 7. Regional differences in 1991 were most pronounced in the fall (Figure 3-2).

The Protozoa have numerically dominated the zooplankton community of L Lake throughout this study (Appendix Tables 3, 4, 5; Tables 3-1 and 3-2; Figures 3-1

and 3-3). Historically, Protozoa composed at least 90% of the total density (see Section 3.3). This trend continued in 1991. Protozoa made up at least 93% of the total density in all four seasons (Table 3-2). Temporal variation of monthly mean protozoan densities (all taxa combined) in the mixed zone of L Lake from 1986-1989 has shown no indication of a consistent seasonal or regional trend (Figure 3-1). Reactor operation (including the summer shut down) did not seem to have any effect on densities. In previous years, orders of magnitude changes were typical but showed no consistent pattern. Summer peaks occurred in 1988 and 1989. Densities in 1990 were an order of magnitude lower in summer in comparison to other seasons (Figure 3-2). This is primarily due to the exceptionally low densities of Protozoa in Region 5 ($975,250 \pm 437,133$ organisms/m³), the lowest density recorded at this site during the study (Appendix Tables 3 and 4). In 1991, protozoan densities varied by less than an order of magnitude among seasons. Densities were lowest in winter, showed a moderate increase in spring, remained stable through summer, and peaked in fall collections (Table 3-2). In general, Protozoa densities in L Lake (Figures 3-1, and 3-3) have historically been at least an order of magnitude greater than corresponding population levels observed in Par Pond (Chimney et al. 1985). In 1990, Par Pond Protozoa densities were similar to those observed in L Lake. In 1991, Par Pond protozoan densities were lower than those in L Lake in winter, spring, and summer. However, fall densities in 1991 were similar in both reservoirs (Appendix Table 3).

From 1986-1989, density peaks associated with individual taxa were observed in almost every month. Two species, Ciliate sp. 4 and Uronema sp. 1 were associated with these peaks regardless of the season. Strombidium delicatissimum densities tended to peak in winter, Vorticella sp. 3 in winter and summer, and

Urotricha farcta in spring and fall (Chimney and Bowen 1990). In 1990, spring and fall peaks could be attributed to increases in the abundance of Uronema sp. 1. Increases in the density of Ciliate sp. 4 contributed to the spring peak. The fall peak in 1991 was largely the result of increased densities of Uronema sp.

3.2.2 Rotifera

Descriptive statistics for volumetric densities (organisms/L) of Rotifera collected from 1986-1989 from the mixed zone and the hypolimnion of L Lake are presented in Appendix Tables 4 and 5. Means and standard deviations are also presented in Table 3-1. Seasonal patterns from 1986-1989 are depicted in Figure 3-4. Volumetric (organisms/m³) and areal (organisms/m²) densities of Rotifera collected quarterly in 1990 and 1991 in L Lake and Par Pond are presented for each replicate sample in Appendix Table 3. Mean volumetric and areal densities and standard errors for quarterly L-Lake collections are displayed in Table 3-2 and Figure 3-5. Annual mean densities by region and lakewide are shown in Figure 3-3.

Historically, annual mean densities (organisms/L) at Region 5 steadily increased from 917 ± 896 in 1986 to 2679 ± 2843 in 1989 (Table 3-1). In 1990, the average annual density (organisms/m³) decreased to $639,125 \pm 154,303$ (Table 3-2), approximately one-quarter of the previous year's value. 1991 volumetric densities averaged $651,000 \pm 87,761$ organisms/m³, similar to 1990 levels. The annual average areal density in 1990 at Region 5 was $7,882,250 \pm 2,088,273$. Areal densities in 1991 were similar to those in 1990, averaging $7,691,063 \pm 982,017$ per m² for the four seasons (Table 3-2).

Figure 3-4. Mean density of Rotifera (organisms x 1000/L.) in the mixed zone of L-Lake Regions 4 - 8. January 1986-December 1989.

Figure 3-5. Mean density $\times 10^6$ (areal, per m^2 and volumetric, per m^3) and standard error of Rotifera in the mixed zone of L-Lake Regions 5, 7, and both regions combined in 1990 and 1991.

Densities at Region 7 were similar to those at Region 5 (Table 3-2; Figures 3-3, 3-4, 3-5). As at Region 5, Rotifera densities increased from the first collections in 1986 (907 ± 890 organisms/L) to 2800 ± 3298 in 1989 (Table 3-1), then sharply declined in 1990 to $764,313 \pm 153,294$ organisms/m³. This corresponded to an areal density of $9,862,063 \pm 1,804,066$ organisms/m². Densities in 1991 were similar to those in 1990, averaging $595,775 \pm 87,598$ organisms/m³. Areal densities averaged $8,224,713 \pm 1,075,086$ in 1991 (Table 3-2).

Decreases in Rotifera densities in 1990 and 1991 may, in part, have been due to modifications in sampling methodology. Historically, means and the range of individual values in the hypolimnion have been markedly lower when compared to those from the mixed zone. In previous years, hypolimnetic waters, which usually have low densities of Rotifera, were sampled separately during periods of thermal stratification; these collections were not used in the computation of the annual average for these years. In 1990 and 1991, the entire water column was sampled regardless of stratification. Inclusion of hypolimnetic waters in the annual average in 1990 and 1991 may have led to reduced densities in comparison to previous years.

Mean rotifer densities (all taxa combined) in the mixed zone of L Lake did not vary seasonally or regionally on a consistent basis during this study (Figure 3-4, 3-5). Reactor operation (including the summer shut down) did not seem to have any direct effect on rotifer densities. Rotifera densities peaked in the summer months in 1987, 1988, and 1989. Historically, except for peak densities in 1987, 1988, and 1989, mixed zone rotifer densities in L Lake were comparable to rotifer populations observed by Chimney et al. (1985) in Par Pond. In 1990

and 1991, annual densities of Rotifera were generally similar to those observed in Par Pond, but differed in their seasonal patterns (Appendix Table 3). In 1990, L-Lake densities peaked in spring. Par Pond densities peaked in the winter, when L-Lake Rotifera densities were lowest, and declined to their lowest point in fall. In 1991, L-Lake rotifer densities were lowest in winter, increased in spring, peaked in summer, and decreased in fall. However, Par Pond densities remained relatively low from winter through summer, then increased dramatically in fall (Appendix Table 3).

Although consistent seasonal cycles in Rotifera densities did not occur from 1986-1989 (Figure 3-4), peak abundances of several taxa occurred irregularly. Anuraeopsis fissa and Trichocerca pusilla contributed to the high Rotifera densities in the summer months from 1987-1989. Keratella cochlearis was observed in relatively high numbers in the late winter - early spring collections in 1986 and 1988 (Chimney and Bowen 1990).

Rotifera densities in 1990 varied by as much as two orders of magnitude in L Lake. Densities were highest in spring, and can be attributed to high numbers of Polvarthra remata and Conochiloides dossuarius. Densities were lowest in winter at both regions (Figure 3-5). At Region 5, winter densities were the lowest observed in that region since the beginning of the study (Table 3-2; Appendix Tables 4 and 5).

In 1991, rotifer densities showed less seasonal variability than in previous years. Densities were lowest in winter, and steadily increased in spring and summer. The peak summer densities could be attributed to high numbers

of Keratella cochlearia, along with Polvarthra remata. Fall densities remained high at Region 5 but decreased at Region 7 (Table 3-2, Figure 3-5).

3.2.3 Cladocera

Descriptive statistics for volumetric (organisms/L) densities of Cladocera collected from 1986-1989 from the mixed zone and the hypolimnion of Regions 5 and 7 of L Lake are presented in Appendix Tables 4 and 5. Means and standard deviations are also presented in Table 3-1. Seasonal patterns from 1986-1989 are shown in Figure 3-6. Volumetric (organisms/m³) and areal (organisms/m²) densities of Cladocera collected quarterly in 1990 and 1991 in Par Pond and L Lake are presented for each replicate sample in Appendix Table 3. Mean volumetric and areal densities and standard errors for L-Lake collections are displayed in Table 3-2 and Figure 3-7. Mean densities in 1990 and 1991, by region and for the entire lake, are shown in Figure 3-3.

Annual mean densities of Cladocera decreased steadily from 1986-1989. At Region 5, densities averaged 22 ± 33 organisms/L in 1986, decreasing to 1 ± 1 organisms/L by 1989 (Table 3-1). In 1990, densities from quarterly collections averaged 2114 ± 513 organisms/m³, which corresponds to an areal average of $26,172 \pm 6,250$ per m² (Table 3-2). A similar trend occurred at Region 7. Densities in 1986 averaged 26 ± 39 , decreasing in every year to a low of 1 ± 1 per L in 1989 (Table 3-1). In 1990, densities per m³ averaged $1,684 \pm 434$ /m³ at Region 7, corresponding to an areal density of $21,192 \pm 4,967$ per m². In 1991, Cladoceran densities increased from 1990 levels. Densities averaged 8239 ± 1684

Figure 3-6. Mean density of Cladocera (organisms/L) in the mixed zone of L-Lake Regions 4 - 8. January 1986-December 1989.

Figure 3-7. Mean density $\times 10^3$ (areal, per m^2 and volumetric, per m^3) and standard error of Cladocera in the mixed zone of L-Lake Regions 5, 7, and both regions combined in 1990 and 1991.

organisms/m³ at Region 5 and $10,680 \pm 3128$ per m³ at Region 7. Areal densities in 1991 averaged $96,738 \pm 19,122$ organisms/m² at Region 5 and $143,514 \pm 35570$ per m² at Region 7 (Table 3-2).

Mean cladoceran densities (all taxa combined) in the mixed zone of L Lake varied seasonally and exhibited several distinct population pulses from 1986 through 1988, generally in the spring or summer (Figure 3-6). A population peak did not occur in 1989; densities were near 0 organisms/L throughout most of this year. In 1990, cladoceran densities were an order of magnitude lower in summer (Figure 3-7), a trend made more apparent by the use of densities expressed on a volumetric basis. Highest densities occurred in winter. In 1991, cladoceran densities were lowest in summer at both stations. Densities were highest lakewide in spring. Fall densities showed a moderate increase from the low summer values.

Historically, there have been no consistent regional differences, although densities at Regions 4 - 6 were markedly higher than in Regions 7 and 8 during the 1987 population pulse (Figures 3-6 and 3-7). Reactor operation (including the summer shut down) did not appear to have any direct impact on temporal variation in population levels. Mixed zone densities of Cladocera in L Lake in 1986 and 1987 were comparable to population levels observed by Chimney et al. (1985) in Par Pond. In 1990, annual mean densities in Par Pond were similar to those in L Lake, averaging 1,469 per m³ (Appendix Table 3). Par Pond densities in 1991 averaged 7152 organisms/m³, higher than Par Pond densities in 1990 but lower than densities in L Lake; cladoceran densities in Par Pond were highest in winter and lowest in summer (Appendix Table 3).

Mean cladoceran densities in 1986 were highest during the period from May to June. Community dominants included Daphnia parvula, Diaphanosoma brachyurum, and Bosmina longirostris (Chimney and Bowen 1990). Peak densities of total Cladocera declined steadily from initial levels in 1986 through 1988; no seasonal peaks were evident in 1989. In 1990, seasonal variations in cladoceran abundance were due mainly to fluctuations of the dominant species, Bosmina longirostris, which had its highest density in winter and lowest density in summer. High cladoceran densities in winter and spring, 1991 were also primarily due to high abundances of B. longirostris. The resurgence of cladoceran densities in fall following low summer densities was caused by moderate densities of B. longirostris, Ceriodaphnia spp., and Holopedium amazonicum.

The steady decline in the cladoceran abundance peak during the spring and summer and shift from numerical dominance by large-bodied cladocerans (Daphnia and Diaphanosoma) to smaller taxa (Bosmina) coincided with the introduction and establishment of a pelagic vertebrate planktivore in L Lake (i.e., threadfin shad; see Sayers and Mealing 1990). It has been well documented that planktivorous fish, through size-selective predation, can dramatically alter both the species composition and abundance of the open-water zooplankton community (Wetzel 1983 and references contained therein). Increased cladoceran densities in 1991 coincided with a decline in the threadfin shad catches (Sayers and Mealing 1992).

3.2.4 Copepoda

Descriptive statistics for volumetric (organisms/L) densities of Copepoda collected from 1986-1989 from the mixed zone and the hypolimnion of L Lake are presented in Appendix Tables 4 and 5 for the suborders Cyclopoida and Calanoida

(combined) and Harpacticoida. Means and standard deviations for Cyclopoida/Calanoida are presented in Table 3-1. Seasonal patterns from 1986-1989 are shown in Figure 3-8. Harpacticoida at all regions in L Lake were found only in 1986 and 1989; mean densities were always less than 1 organism/L, and individual densities never exceeded 2 organisms/L. Volumetric (organisms/m³) and areal (organisms/m²) densities of Copepoda lifestages (nauplii, copepodids, and adults) collected quarterly in 1990 and 1991 are presented for each replicate sample in Appendix Table 3. Mean volumetric and areal densities and standard errors for L-Lake collections are displayed in Table 3-2 and Figures 3-9 (nauplii), 3-10 (copepodids), and 3-11 (adults). Mean densities for each lifestage in 1990 and 1991 by region and for the entire lake are shown in Figure 3-3.

In Region 5, annual Cyclopoida/Calanoida copepod densities were highest in the first year of the study, averaging 45 ± 43 organisms/L. Decreases in copepod density occurred in 1988 and 1989, averaging 12 ± 10 and 13 ± 9 organisms per L (Table 3-1). In 1990, densities of all lifestages of copepods averaged 21,783/m³ at Region 5 (Table 3-2), higher than observed in 1988/1989 but lower than 1986/1987. This corresponded to an areal density of 265,788 organisms/m². Nauplii were the predominant component, averaging $16,492 \pm 4,455$ or 76% of the total copepods. Copepodids averaged $4,839 \pm 875$ and composed most of the remaining proportion (22%). Adults averaged 452 ± 100 , and represented only a small portion (2%) of the total copepods. In 1991, copepod densities (all lifestages combined) averaged 15,399 organisms per m³, equivalent to an areal density of 182,603 per m², slightly lower than densities in 1990. Copepodids predominated, averaging 8459 ± 1507 per m³, 55% of the total copepods. Nauplii

Figure 3-8. Mean density of Copepoda (organisms/L) in the mixed zone of L-Lake Regions 4 - 8. January 1986-December 1989.

- Region 5
- Region 7
- Both Regions

Figure 3-9. Mean density $\times 10^3$ (areal, per m^2 and volumetric, per m^3) and standard error of Copepoda nauplius larvae in the mixed zone of L-Lake Regions 5, 7, and both regions combined in 1990 and 1991.

Figure 3-10. Mean density $\times 10^3$ (areal, per m^2 and volumetric, per m^3) and standard error of Copepoda copepodids in the mixed zone of L-Lake Regions 5, 7, and both regions combined in 1990 and 1991.

Figure 3-11. Mean density $\times 10^2$ (areal, per m^2 and volumetric, per m^3) and standard error of Copepoda adults in the mixed zone of L-Lake Regions 5, 7, and both regions combined in 1990 and 1991.

ranked second in abundance, averaging 5435 ± 1033 per m^3 , 35% of the total copepod population. Adult copepods averaged 1505 ± 334 per m^3 , or 10% of the total copepods.

Annual densities at Region 7 showed a similar decline from 1986 to 1988/1989. In 1986, the annual average density was 56 ± 42 (Table 3-1). In 1988 and 1989, densities averaged 9 ± 5 and 12 ± 8 organisms/L, respectively. Historically, means and the range of individual densities in the hypolimnion were lower than values from the mixed zone. In 1990, total copepod density averaged $16,649/m^3$, an increase from densities in 1988 and 1989, but less than peak levels observed in 1986. This corresponded to an areal average of $211,960/m^2$. Most of these were nauplius larvae, averaging $11,537 \pm 4,848 /m^3$, 69% of the total copepod density (Table 3-2). Copepod copepodids were the next most abundant, averaging $4,568 \pm 1,183/m^3$ or 27% of the total copepod density. Adults were relatively rare, averaging $544 \pm 178/m^3$ or 3% of the total copepods. In 1991, total copepod densities averaged 15,387 organisms per m^3 , similar to levels in 1990. Areal densities averaged $211,428$ per m^2 . Copepodids were the most abundant lifestage, averaging 7401 ± 1347 per m^3 or 48% of all copepods combined. Nauplii composed 43% of the total copepod population, averaging 6640 ± 1986 organisms/ m^3 . Adult copepods had an average density of $1346 \pm 293/m^3$ or 9% of the total copepod population.

Regional differences were apparent in 1990 but not in 1991. Total copepod densities at Region 5 in 1990 were approximately 30% higher than at Region 7.

Nauplii in particular were more abundant at Region 5. There were no consistent regional differences evident for any copepod lifestages in 1991 (Figures 3-9, 3-10, 3-11).

Historically, copepod densities in the mixed zone of L Lake were similar to corresponding population levels of Copepoda in Par Pond (Chimney et al. 1985). In 1990, total copepod densities averaged over the year were approximately half those in Par Pond (Appendix Table 3). Differences were most pronounced in summer, when total copepod densities were extremely low in L Lake, in contrast to Par Pond. Observed differences were mainly due to variations in densities of the predominant constituent, nauplii, which were more abundant in winter, spring, and summer in Par Pond when compared to L Lake (Appendix Table 3). In 1991, densities of total copepods were approximately 50% of those in L Lake. When averaged on an annual basis, densities of all copepod lifestages were lower in Par Pond than in L Lake. However, differences in seasonal patterns between L Lake and Par Pond were observed for all three lifestages (Appendix Table 3).

Mean copepod densities (Cyclopoida and Calanoida taxa combined) varied seasonally; historically, a population peak occurred in the summer of each year, although these peaks were most dramatic in 1986 and 1987 (Figure 3-8). There were no consistent regional differences in mean densities. Reactor operation (including the summer shut down) did not appear to have any direct impact on copepod densities. In 1990, copepod densities in L Lake were highest in winter, and lowest in summer (Table 3-2), mainly due to the seasonal fluctuations of nauplii (Figure 3-9). Copepodids and adult copepod densities were an order of magnitude lower in summer in comparison to the other seasons (Figures 3-10, 3-

11). In 1991, highest copepod densities occurred in winter and spring, due to elevated densities of juvenile copepods (nauplii and copepodids). Densities of all lifestages were lowest in summer, and increased in the fall (Figures 3-9, 3-10, 3-11).

Copepods exhibited three periods of relatively high mean densities in the mixed zone of L Lake during this study: April to August 1986, October 1986, and June to August 1987 (Figure 3-8). There was a seasonal shift in the dominant Copepoda taxa in 1986 and 1987. Cyclopoids, such as Mesocyclops edax, which were numerically important early in the year, were replaced by calanoids such as Diaptomus sp. in late summer (Chimney and Bowen 1990). Mean copepod densities in all regions during 1988 and 1989 were greatly reduced compared to the previous years (Figure 3-8). The community was numerically dominated by nauplius larvae throughout most of 1988 and 1989, although it did appear that there was a seasonal transition from a M. edax dominated community to one dominated by Diaptomus sp. as noted in 1986 and 1987. In 1990, nauplius larvae predominated in the copepod population. Densities of copepod larvae far exceeded adult densities. Winter collections had relatively similar numbers of cyclopoid and calanoid copepodids, but cyclopoids predominated for the remainder of the year. In 1991, copepodids composed nearly half of the copepods that were collected. Three-quarters of the copepodids collected in the winter and spring were cyclopoids, and the remainder were calanoids. In fall, cyclopoids composed two-thirds of the copepodids. Fall peaks of adult copepods in 1991 were largely due to increased numbers of Tropocyclops prasinus.

The reduction in total densities and near elimination of adult individuals from the mixed zone copepod community coincided with the increase in the abundance of threadfin shad in L Lake (see Sayers and Mealing 1990). These events were consistent with similar trends observed in the Cladocera (Section 3.2.3) and suggest that size-selective predation by the fish was responsible. Threadfin shad became less abundant in 1991 (Sayers and Mealing 1992), which coincided with an increase in densities of copepods and adults, the lifestages most likely to be consumed (Figures 3-10 and 3-11).

3.2.5 Statistical Analysis of 1990 and 1991 Regional Differences

Regional differences in zooplankton density were investigated by comparing the total volumetric densities, obtained by summing the individual group densities (Protozoa, Rotifera, Cladocera, Copepoda). Total zooplankton densities were not significantly different among regions in 1990 ($F=3.94$, $P=0.09$), or in 1991 ($F=1.13$, $P=0.33$; Table 3-3).

3.3 ZOOPLANKTON RELATIVE ABUNDANCE

Annual mean relative abundance (% composition) of the major taxonomic groups of zooplankton in the mixed zone and hypolimnion of Regions 5 and 7 of L Lake from 1986 to 1989 is listed in Appendix Tables 4 and 5 and monthly relative abundances are displayed in Figure 3-12. Relative abundances based on both areal and volumetric density for quarterly samples collected in 1990 and 1991 appear in Table 3-2 and Figure 3-13.

On an annual basis, Protozoa represented (by density) from 91.0 - 97.8% of all zooplankton in the mixed zone throughout L Lake from 1986-1989 (Appendix

Table 3-3. Analysis of variance results comparing seasonal total zooplankton density ($\ln [x+1]$ transformed) between Regions 5 and 7 in 1990 and 1991.

Geometric Regional Mean and Standard Deviation									
		Winter		Spring		Summer		Fall	
Year	Region	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1990	5	9,712,472	0.3	22,894,706	0.2	902,974	2.1	14,420,479	0.4
	7	13,449,583	0.3	22,020,708	0.3	2,087,352	1.1	22,999,800	0.5
1991	5	5,327,036	0.3	11,682,211	0.2	14,277,938	0.1	36,143,716	0.7
	7	5,606,149	0.3	14,361,739	0.2	13,290,131	0.3	17,287,738	1.3

ANOVA RESULTS

Year	Source of Variation	Degrees of Freedom	Mean Square	F Value	P > F
1990	Region	1	1.27	3.94	0.09
	Error	6	0.32		
1991	Region	1	0.15	1.13	0.33
	Error	6	0.13

Figure 3-12. Relative abundance (% composition) of zooplankton collected from the mixed zone of L-Lake Regions 4 - 8. Pro = Protozoa; Rot = Rotifera; Cla = Cladocera; Cyc/Cal = Cyclopoida/Calanoida; Har = Harpacticoida; Ost = Ostracoda; Gas = Gastrottricha. January 1986- December 1989.

Figure 3-12 (continued). Relative abundance (% composition) of zooplankton collected from the mixed zone of L-Lake Regions 4 - 8. Pro = Protozoa; Rot=Rotifera; Cla = Cladocera; Cyc/Cal = Cyclopoida/Calanoida; Har = Harpacticoida; Ost = Ostracoda; Gas = Gastrotricha. January 1986- December 1989.

Figure 3-12 (continued). Relative abundance (% composition) of zooplankton collected from the mixed zone of L-Lake Regions 4 - 8. Pro = Protozoa; Rot=Rotifera; Cla = Cladocera; Cyc/Cal = Cyclopoida/Calanoida; Har = Harpacticoida; Ost = Ostracoda; Gas = Gastrotricha. January 1986- December 1989.

Figure 3-13. Relative abundance (percent composition, based on areal and volumetric density) of zooplankton groups collected quarterly in L-Lake Regions 5 and 7 in 1990 and 1991.

Tables 4, 5; Figure 3-12). Rotifera was the next most abundant group in the mixed zone, with mean relative abundances of 2.2 - 9.0% from 1986-1989. In 1989, relative abundances of Protozoa decreased, with a corresponding increase in Rotifera. Historically, the macrozooplankton (Cladocera, Copepoda, and Ostracoda combined) never accounted for more than 0.50% of total mixed zone densities in any year. Protozoa comprised at least 96% of the zooplankton community in the hypolimnion from 1986-1989.

In 1990, Protozoa composed approximately 95% of the total annual density (volumetric and areal) for L Lake as a whole (Table 3-2). Rotifera was the next most abundant group, averaging 5% for the year. Together, the microzooplankton composed at least 99% (based on either areal or volumetric densities) of the total abundance in all regions in all seasons in 1990 (Table 3-2; Figure 3-13).

Relative abundances in 1991 were similar to those observed in 1990. Protozoans were numerically the most abundant group, composing 95.95% of the total volumetric density and 96.04% of the areal density (Table 3-2, Figure 3-13). Rotifera were ranked second in terms of overall abundance, making up 3.90% of the total volumetric density and 3.81% of the total areal density. Together, these two microzooplankton groups accounted for over 99% of the total density (areal or volumetric) at both regions in all four seasons.

From 1986-1989, the Protozoa numerically dominated the mixed zone zooplankton community of L Lake, comprising at least 70% of all organisms collected in each month of this study; protozoan relative abundance was greater than 90% on most dates (Figure 3-12). In 1990, protozoan relative abundance

exceeded 93% in winter, spring, and fall, but decreased to 75 - 77% in summer (Figure 3-13). Relative abundances in 1991 showed little seasonal variability, averaging at least 93% throughout the year at both regions.

From 1986 through 1988, the maximum relative abundance of Rotifera in each region (ca. 10 to 26%) occurred in September 1987 and was associated with high densities of Anuraeopsis fissa. High relative rotifer abundances in the summer of 1989 exceeded the 1987 values at Regions 4, 5, and 6. Relative abundances of Rotifera in 1990 increased from winter to spring, peaking in summer, reaching 23 - 24% before decreasing in fall (Figure 3-13). In 1991, proportions of rotifers showed less seasonal variability in comparison to the previous year. Relative abundances were higher in spring and summer in comparison to winter levels, and decreased to their lowest level by fall sampling (Figure 3-13).

The zooplankton community in Par Pond historically has also been numerically dominated by microzooplankton. However, in Par Pond, the Rotifera historically have accounted for 40.3 to 61.8% of total zooplankton densities on an overall basis, while the Protozoa comprised only 34.2 to 57.1% (Chimney et al. 1985). In 1990, Protozoa in Par Pond composed 95% of the total volumetric density, and rotifers contributed less than 5% of the total density (Appendix Table 3). Relative abundances of protozoans in 1991 averaged 94%. Proportions of rotifers ranged from 3% in spring to 10% in winter. These results represent a dramatic departure from the previous study. The observed differences may, in part, be due to changes in sampling methodology. Historically, samples were collected at five discrete depths, whereas collection methods beginning in 1990 integrated collections over all depths. Historically, the macrozooplankton of

Par Pond represented over 10% of all organisms collected on any given date and over 55% at the Hot Arm in August 1984 (Chimney et al. 1985). In 1990 and 1991, L Lake and Par Pond had similar proportions of macrozooplankton.

3.4 SIZE-FREQUENCY DISTRIBUTION OF ZOOPLANKTON

The size structure of zooplankton is an important indication of trophic resources, particularly where visual predators predominate. Furthermore, size structure has been hypothesized to vary with lake trophic state (Brooks 1969; Bays and Crisman 1983). Other studies have failed to confirm this relationship (Pace 1986). The size frequency distribution of cladocerans and various lifestages of copepods was examined by season in 1990 and 1991 for L Lake as a whole (Figure 3-14, Table 3-4).

The majority of cladocerans collected in this study were small (0.3 - 0.4 mm), although larger individuals were occasionally collected. In 1990, Cladocera measured from 0.2 - 0.9 mm in length (Table 3-4). Throughout the year, the majority of individuals measured were 0.3 mm in length. This was particularly evident in winter, spring, and fall samples, when 0.3-mm cladocerans predominated. Cladocerans were relatively rare in summer. Only a few, measuring 0.2 - 0.4 mm, were collected. The largest cladoceran, measuring 0.9 mm, was collected in the fall. In 1991, Cladocera ranged in length from 0.2 - 1.1 mm. The majority of cladocerans in winter and spring measured 0.3 - 0.4 mm. Moderate numbers of larger cladocerans (>0.7 mm) appeared in spring. Few cladocerans were collected in summer. In fall, cladocerans ranged from 0.2 - 0.9 mm in length, with the majority measuring 0.3 - 0.4 mm (Table 3-4).

Cladocera 1990

Figure 3-14. Quarterly size frequency distribution (in mm) of zooplankton groups collected in L Lake in 1990 and 1991.

**Copepoda nauplius
1990**

Figure 3-14 (continued). Quarterly size frequency distribution (in mm) of zooplankton groups collected in L Lake in 1990 and 1991.

Copepoda copepodid 1990

3-53

1991

Figure 3-14 (continued). Quarterly size frequency distribution (in mm) of zooplankton groups collected in L Lake in 1990 and 1991.

Copepoda adult
1990

Figure 3-14 (continued). Quarterly size frequency distribution (in mm) of zooplankton groups collected in L Lake in 1990 and 1991.

Table 3-4. Monthly size frequency distribution (mm) of zooplankton groups in L Lake in 1990 and 1991.

1990					
Taxa	Length	WINTER	SPRING	SUMMER	FALL
		Number			
CLADOCERA	0.2	6	2	3	8
	0.3	26	24	4	21
	0.4	9	1	1	4
	0.5	2			2
	0.9				1
COPEPODA	0.1	1	1		
NAUPLIUS	0.2	20	3	13	29
	0.3	24	5	18	24
	0.4	1			
	0.5	1			
COPEPODA	0.3	1	3		2
COPEPODID	0.4	26	19	1	24
	0.5	30	38	7	41
	0.6	23	17	13	27
	0.7	12	10	4	19
	0.8	2	10	1	12
	0.9	1	2		5
	1.0		3		1
	1.1		1		
COPEPODA ADULT	0.6			1	
	0.8		1		3
	0.9	3	1		4
	1.0	1			2
	1.1	1			

Table 3-4 (continued). Monthly size frequency distribution (mm) of zooplankton groups in L Lake in 1990 and 1991.

1991					
Taxa	Length	WINTER	SPRING	SUMMER	FALL
		Number			
CLADOCERA	0.2	4	7		1
	0.3	43	81	2	9
	0.4	32	22		9
	0.5	6	4		6
	0.6	1	5	1	5
	0.7		1		3
	0.8		5		
	0.9		3		2
	1.0		2		
	1.1		1		
COPEPODA	0.2	36	9		5
NAUPLIUS	0.3	74	13		4
	0.4	2	1		
COPEPODA COPEPODID	0.3		2		
	0.4	17	18	2	3
	0.5	26	35	3	6
	0.6	34	21	4	4
	0.7	9	14	4	
	0.8	6	10	1	2
	0.9	6	10		
	1.0	6	3		
	1.1	1	3		
	1.2	1	1		
	1.3		1		
COPEPODA ADULT	0.4	1			2
	0.5				23
	0.8		1		
	0.9	2	3		1
	1.0		1		
	1.1				1

In the two years of study, most copepod nauplii measured 0.2 - 0.3 mm in length (Table 3-4, Figure 3-14). In 1990, nauplii as small as 0.1 mm and as large as 0.5 mm were collected. As nauplii abundances were lowest in the spring of 1990 (Table 3-2), few individuals were measured from these collections. Nauplii sizes in 1991 ranged from 0.2 - 0.4 mm in winter, spring, and fall (Table 3-4). Almost all were 0.2 - 0.3 mm in length. No nauplii were measured in summer.

Copepod copepodids collected in 1990 ranged from 0.3 - 1.1 mm in length (Table 3-4; Figure 3-14). In winter, copepodids measuring 0.4 - 0.6 mm predominated. By spring sampling, numbers of copepodids in larger size classes (0.8 - 1.1 mm) had increased. This may, in part, be an indication of growth of copepodids collected in winter or a shift to larger species. In summer, copepodid densities decreased (Table 3-2), and those that were collected measured 0.4 - 0.8 mm. The size class distribution in fall was similar to that observed in spring. Copepodids ranged from 0.3 - 1.0 mm in length, with those measuring 0.4 - 0.7 mm most numerous.

In 1991, copepod copepodids ranged from 0.3 - 1.3 mm in length, similar to the previous year (Figure 3-14; Table 3-4). The majority of copepodids collected in winter measured 0.4 - 0.6 mm. Increased numbers of larger copepodids measuring 0.7 - 0.9 mm occurred in spring samples. Fewer copepodids were measured from summer and fall samples; most measured between 0.4 - 0.7 mm.

Adult copepods were relatively rare in L Lake in 1990 and 1991 (Table 3-2). In 1990, lengths ranged from 0.6 - 1.1 mm (Table 3-4, Figure 3-14). Most that

were collected measured 0.8 - 0.9 mm. Measurements of adult copepod lengths in 1991 ranged from 0.4 - 1.1 mm. Fall collections had a preponderance of 0.5-mm adults. Few copepods were measured in winter and spring, and none were measured in summer.

3.5 COMPARISON OF L LAKE WITH OTHER LENTIC SYSTEMS

Zooplankton data from this study (maximum and minimum total densities and taxa richness) have been compared to data available in the literature for other lentic ecosystems (Par Pond, Pond B, and other southeastern lakes, reservoirs, and cooling impoundments; Table 3-5). Any conclusions drawn from these data must be made with caution, however. These studies varied considerably with respect to field and laboratory methodology, which has a direct effect on the data generated. For example, except for the study of Par Pond and Pond B by Chimney et al. (1985), zooplankton in the other systems were collected using tow nets with mesh openings that ranged from 35 to 80 μ m in size. Such sampling equipment would have missed virtually all of the protozoan taxa and potentially underestimated both the abundance and taxonomic diversity of Rotifera. This would account, in part, for the higher densities and total taxa richness values observed in L Lake, Par Pond, and Pond B compared to the other systems. Nevertheless, these data were useful in assessing the present ecological status of L Lake in relation to comparable aquatic ecosystems.

In many respects, the zooplankton community of L Lake from 1986 to 1991 was representative of communities found in other comparable lentic habitats. L Lake zooplankton taxa (Appendix Tables 1 and 2) were similar to assemblages collected from the impoundments listed in Table 3-5 and represented all trophic levels

Table 3-5. Comparison of zooplankton density and taxa richness data from the mixed zone of L-Lake Regions 4 - 8 with values from other Savannah River Site impoundments, southeastern lakes/reservoirs, and cooling impoundments.

	Max. total density (no./L)	Min. total density (no./L)	No. Protozoa taxa	No. Rotifers taxa	No. Cladocera taxa	No. Copepoda taxa	No. total taxa
<u>This Study 1986:</u>							
L-Lake Region 4	70662	6564	42	31	9	8	91
L-Lake Region 5	58651	5985	47	28	10	9	95
L-Lake Region 6	8764	95	46	27	9	8	91
L-Lake Region 7	4006	7000	43	30	8	7	89
L-Lake Region 8	3343	4455	43	28	11	8	91
All L-Lake regions	83343	95	59	44	12	9	125
<u>This Study 1987:</u>							
L-Lake Region 4	59695	788	44	27	9	7	88
L-Lake Region 5	64123	6126	40	26	8	7	82
L-Lake Region 6	65506	7953	39	24	8	6	78
L-Lake Region 7	80794	4843	42	27	7	7	84
L-Lake Region 8	60741	7998	40	21	8	6	76
All L-Lake regions	80794	4843	53	35	9	7	105
<u>This Study 1988:</u>							
L-Lake Region 4	164900	12911	40	27	8	7	84
L-Lake Region 5	112879	10599	41	23	7	7	80
L-Lake Region 6	128763	9737	38	25	7	7	79
L-Lake Region 7	178907	8933	37	21	7	8	75
L-Lake Region 8	186753	10014	39	22	6	8	77
All L-Lake regions	186753	8933	50	30	11	9	102
<u>This Study 1989:</u>							
L-Lake Region 4	95491	10232	30	21	6	7	65
L-Lake Region 5	88474	3804	28	23	5	7	64
L-Lake Region 6	76163	4744	33	22	8	7	71
L-Lake Region 7	96368	7775	32	23	8	6	70
L-Lake Region 8	70439	7020	33	21	9	9	73
All L-Lake regions	96368	4744	37	25	14	11	88
<u>This Study 1990:</u>							
L-Lake Region 5	25920	181	31	22	12	10	76
L-Lake Region 7	31676	759	30	23	8	10	71
All L-Lake Regions	31676	181	33	25	12	10	81
Par Pond	14190	3633	19	11	7	9	46
<u>This Study 1991:</u>							
L Lake Region 5	55990	3995	30	25	9	9	74
L Lake Region 7	50497	4638	33	25	8	9	76
All L Lake Regions	55990	3995	37	27	10	9	84
Par Pond	38258	3186	27	23	8	8	66
<u>SRS Impoundments:</u>							
Par Pond	4054	205	79	68	11	6	164
Pond B ^a	3102	169	58	44	4	9	115
<u>Southeastern Lakes/Reservoirs:</u>							
Warrior Lake, AL ^a	600	10	11	38	15	4	68
Seminole Lake, FL ^a	1275	<1	6	25	15	8	54
Lake Norman, NC ^a	190	<1	-	-	-	-	-
Lake Norman, NC ^a	267	15	-	45	28	11	84
Lake Robinson, SC ^a	409	-	4	33	13	8	58
Clark Hill Lake, SC ^a	311	6	2	31	19	7	59
Hartwell Lake, SC ^a	545	10	-	13	10	6	29
Lake Keowee, SC ^a	95	-	-	53	22	10	85
Lake Mylie, SC ^a	186	<1	-	33	34	12	79
Fishing Creek Res., SC ^a	49	<1	-	-	-	-	-
Waterloo Lake, SC ^a	420	<1	-	-	-	-	-
Parr Reservoir, SC ^a	231	-	-	-	-	-	-
Monticello Reservoir, SC ^a	384	-	-	-	-	-	-
Lake Anna, VA ^a	-	-	-	42	17	12	71
<u>Other Cooling Impoundments:</u>							
Sunderland Reservoir, NE ^a	1416	-	-	28	20	12	60
Dresden Cooling Lake, IL ^a	520	-	-	29	14	12	55
Lake Sangchris, IL ^a	-	-	-	29	28	10	67

^adatum not available; ^bChimney et al. 1985; ^cHarmon Engineering and Testing Co., Inc. 1983; ^dWater and Air Research, Inc. 1983; ^eWeiss et al. 1975; ^fDuke Power Co. 1985; ^gCaroline Power and Light 1976; ^hMallin 1984; ⁱApplied Biology 1982; ^jCarr and Assoc. 1982; ^kDuke Power Co. 1977; ^lDames and Moore 1985; ^mSaunders 1975; ⁿNalco Environmental Sci. 1976; ^oEcological Analysts 1982; ^pLewis 1984; ^qWaite 1981.

expected to occur among zooplankton in a freshwater lentic system. Taxa richness of Rotifera, Cladocera, and Copepoda in L Lake was within the range of values reported from these other systems. In 1990 and 1991, densities of Protozoa, Rotifera, Cladocera, and Copepoda (Table 3-2) were comparable to population levels observed in Par Pond (Appendix Table 3). Based on a previous study of all the zooplankton groups, only densities of Protozoa were consistently higher (one to two orders of magnitude) in L Lake than in Par Pond (see Chimney et al. 1985) or the other systems, and were perhaps atypical of southeastern impoundments.

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4.0 SUMMARY AND CONCLUSIONS

A total of 90 taxa were collected in L Lake and Par Pond in 1991, slightly higher than the 85 taxa collected in 1990. The number of taxa lakewide was slightly lower than the number collected in 1989, perhaps because of the less intensive sampling effort in 1990 and 1991. The total number of taxa steadily declined from 1986, when L Lake was first created, through 1990. Microzooplankton (Protozoa and Rotifera) accounted for 76% of the total number of taxa in 1991, consistent with previous years, where microzooplankton composed 70.5 - 83.8% of the total number of taxa. Macrozooplankton, particularly Cladocera and Copepoda, made up the remaining taxa in 1991, as had been true in previous years.

The L-Lake zooplankton community accumulated taxa (cumulative taxa richness) quite rapidly in the beginning of the study (January through March 1986), then slowed markedly and remained constant through December 1987, then slowed again and remained constant through 1989 (Chimney and Bowen 1990). Relatively few new taxa were added in subsequent years. Changes in cumulative taxa richness reflected the initial development of the L-Lake zooplankton community (i.e., colonization by new taxa) and subsequent replacement of taxa in later months as a true lake-adapted fauna developed.

Protozoa numerically dominated the zooplankton community in all regions and generally comprised at least 90% of all organisms collected throughout this study. Most of the dominant taxa from 1986-1989 were ciliate protozoans. Rotifera ranked second in relative abundance (generally <10% but occasionally

reaching up to ca. 27%). This contrasted with early studies of Par Pond, in which the relative abundance of Rotifera and macrozooplankton was comparatively higher. However, in 1990 and 1991, Par Pond and L Lake were similar in terms of the relative abundance of the major groups.

There were no consistent regional differences in taxa richness or densities of Protozoa, Rotifera, Cladocera or Copepoda in the mixed zone of L Lake during this study. In general, changes in the abundance of zooplankton did not respond to reactor operation, particularly the summer shut downs. Many of the L Lake zooplankton taxa are ubiquitous in their distribution and tolerate a wide range of physico-chemical conditions, including temperature. The major impacts of L-Reactor operations on the L-Lake zooplankton may have been in stimulating high phytoplankton densities and biovolumes (see Carson 1992) by maintaining elevated nutrient levels in L Lake (see Kretchmer 1992) and introducing a pelagic vertebrate planktivore into the system (i.e., threadfin shad), rather than the creation of a thermal gradient.

The zooplankton community of L Lake was comparable to communities found in other SRS impoundments, southeastern lakes/reservoirs, and cooling impoundments with respect to zooplankton density and taxa richness. Historically, only densities of Protozoa were markedly higher in L Lake than in the other systems and were perhaps atypical of southeastern reservoirs. In 1990 and 1991, L Lake and Par Pond were similar in terms of zooplankton density and relative abundance. The L-Lake zooplankton fauna represented all orders/classes of zooplankton that would be expected to commonly occur in a temperate freshwater system.

This study did not specifically address the question of successful reproduction in zooplankton. However, several indirect lines of evidence suggested that it did occur. First, the physico-chemical conditions (see Kretchmer 1992) and amounts of potential food available (i.e., phytoplankton and seston; see Carson 1992) in L Lake were well within the tolerance limits for zooplankton, and would permit the development of an indigenous community. Second, immature forms of some zooplankton taxa (i.e, copepod nauplius larvae) were always present throughout this study. Third, adult zooplankton carrying eggs or embryos were observed at various times. Fourth, zooplankton generally have relatively short lifespans (days to weeks) and a tremendous reproductive capacity (see Hutchinson 1967; Wetzel 1983). The persistence of zooplankton in itself suggested that reproduction was occurring within the system, and that the community was not supported by continuous invasion or importation of organisms from the Savannah River or Par Pond.

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APPENDIX

Appendix Table 1.

Zooplankton taxa collected from L-Lake mixed zone and hypolimnion.
January 1986-December 1989.

Taxon	Region				
	4	5	6	7	8
Phylum Protozoa					
<u>Acanthocystis</u> spp.				X	
<u>Acineta</u> spp.		X			
<u>Actinophrys</u> spp.	X	X	X	X	
<u>Amphileptidae</u>	X	X	X	X	X
<u>Askenasia</u> sp. 1	X	X	X	X	X
<u>Askenasia</u> sp. 2	X	X	X	X	X
<u>Askenasia</u> spp.	X	X	X	X	X
<u>Astramoeba</u> spp.		X			X
<u>Bursaridium</u> spp.	X	X		X	X
<u>Campanella umbellaria</u>	X	X	X	X	X
<u>Centropyxis aculeata</u>	X	X	X	X	X
ciliate - unidentified spp.	X	X	X		X
ciliate - unidentified spp. < 50 μ	X	X	X	X	X
ciliate - unidentified spp. 50 - 99 μ	X	X	X	X	X
ciliate - unidentified spp. 100 - 200 μ	X	X	X	X	X
ciliate - unidentified spp. > 200 μ	X	X		X	
ciliate sp. 01	X	X	X	X	X
ciliate sp. 02					X
ciliate sp. 04	X	X	X	X	X
ciliate sp. 05	X	X	X	X	X
ciliate sp. 08		X	X	X	
ciliate sp. 12	X	X	X	X	X
ciliate sp. 15	X	X	X	X	X
ciliate sp. 21	X		X		
ciliate sp. 26	X	X	X		
ciliate sp. 27	X	X	X	X	X
ciliate sp. 29				X	X
<u>Codonella cratera</u>	X	X	X	X	X
<u>Coleps hirtus</u>		X	X	X	X
<u>Coleps</u> sp. 1	X	X	X	X	X
<u>Coleps</u> spp.	X	X	X	X	X
<u>Coleps striatus</u>	X	X	X	X	X
<u>Colpoda</u> spp.	X				
<u>Cyclidium</u> sp.1	X	X	X	X	X
<u>Cyclotrichium</u> sp. 1	X		X	X	X
<u>Cyrtolophosis</u> spp.	X	X	X	X	X
<u>Didinium balbianii nanum</u>	X	X	X	X	X
<u>Didinium nasutum</u>	X	X	X	X	X
<u>Diffugia elegans</u>				X	
<u>Diffugia limnetica</u>	X	X	X	X	X
<u>Diffugia</u> sp. 1	X	X	X	X	X

Appendix Table 1 (continued).

Zooplankton taxa collected from L-Lake mixed zone and hypolimnion.
January 1986-December 1989.

Taxon	Region				
	4	5	6	7	8
Phylum Protozoa (continued).					
<u>Dileptus bivacuolatus</u>		X	X	X	X
<u>Epistylis</u> spp.	X	X	X	X	X
<u>Euglypha ciliata</u>	X	X	X	X	X
<u>Euglypha</u> sp. 1	X	X	X	X	
<u>Euglypha</u> sp. 2	X	X			
<u>Euglypha</u> spp.				X	
<u>Halteria</u> sp. 1			X	X	X
<u>Halteria</u> sp. 2	X	X	X	X	X
<u>Hemiohyrs</u> sp. 1	X	X	X	X	X
holophryid ciliate < 50 μ	X	X	X	X	X
holophryid ciliate 50 - 99 μ	X	X	X	X	X
holophryid ciliate > 100 μ			X		X
<u>Keronidae</u>	X			X	
<u>Mesodinium acarus</u>	X	X	X	X	X
<u>Metacystis</u> spp.				X	
<u>Microthorax elegans</u>		X			
<u>Nuclearia simplex</u>	X	X	X	X	X
oxytrich ciliate		X			
<u>Paraeuglypha reticulata</u>	X	X	X	X	X
<u>Paramecium</u> spp.					X
<u>Podophrya</u> sp.	X	X	X		
<u>Rhabdostyla</u> spp.		X			
<u>Spathidioides sulcata</u>	X	X	X	X	X
<u>Spirostomatidae</u>		X	X	X	X
<u>Stauroprya elegans</u>	X	X	X	X	X
<u>Stentor</u> sp. 1	X	X	X	X	X
<u>Strobilidium gyrans</u>	X	X	X	X	X
<u>Strobilidium</u> sp.	X			X	
<u>Strombidium delicatissium</u>	X	X	X	X	X
<u>Strombidium</u> spp.	X	X	X	X	X
suctorian ciliate	X	X	X	X	X
<u>Tintinnopsis cylindrata</u>	X	X	X	X	X
<u>Tintinnopsis</u> sp. 1	X	X	X	X	X
<u>Trachelius</u> spp.	X	X	X	X	X
<u>Trinema</u> sp. 1	X				X
<u>Urocentrum turbo</u>		X			X
<u>Uronema</u> sp. 1	X	X	X	X	X
<u>Uronema</u> spp.	X				
<u>Urotricha armata</u>	X	X	X	X	X
<u>Urotricha farcta</u>	X	X	X	X	X
<u>Urotricha</u> sp. 3	X	X	X	X	X

Appendix Table 1 (continued).

Zooplankton taxa collected from L-Lake mixed zone and hypolimnion.
January 1986-December 1989.

Taxon	Region				
	4	5	6	7	8
Phylum Protozoa (continued).					
<u>Vampyrella lateritia</u>			X		
<u>Vorticella</u> sp. 1	X	X	X	X	X
<u>Vorticella</u> sp. 2	X	X	X	X	X
<u>Vorticella</u> sp. 3	X	X	X	X	X
Phylum Rotifera					
<u>Anuraeopsis fissa</u>	X	X	X	X	X
<u>Ascomorpha saltans</u>	X				
<u>Asplanchna priodonta</u>	X	X	X		X
<u>Asplanchna</u> sp.	X	X	X	X	X
<u>Brachionus angularis</u>	X	X	X	X	X
<u>Brachionus bidentata</u>	X	X			
<u>Brachionus caudatus</u>	X	X	X	X	X
<u>Brachionus havanaensis</u>	X	X	X	X	X
<u>Cephalodella</u> sp. 1	X	X	X	X	X
<u>Cephalodella</u> sp. 2	X	X	X	X	X
<u>Cephalodella</u> spp.					X
<u>Collotheca mutabilis</u>	X	X	X	X	X
<u>Collotheca pelagica</u>	X				
<u>Colurella obtusa</u>		X			
<u>Colurella uncinata</u>					X
<u>Conochiloides dossuarius</u>	X	X	X	X	X
<u>Conochilus unicornis</u>	X	X	X	X	X
<u>Filinia longiseta</u>	X	X	X	X	X
<u>Floscularia</u> sp. 1	X				X
<u>Hexarthra mira</u>	X	X	X	X	X
<u>Kellicottia bostoniensis</u>	X	X	X	X	X
<u>Kellicottia longispina</u>	X				
<u>Keratella cochlearis</u>	X	X	X	X	X
<u>Keratella cochlearis tecta</u>	X	X	X	X	X
<u>Keratella cochlearis hispida</u>		X			
<u>Keratella crassa</u>	X	X	X	X	X
<u>Lecane</u> sp. 1	X				
<u>Lecane</u> sp. 2	X		X		
<u>Lecane</u> spp.				X	X
<u>Lecane stichaea</u>				X	X
<u>Lepadella patella</u>	X			X	
<u>Lepadella</u> spp.	X			X	
<u>Lepadella triptera</u>		X			
<u>Monommata actices</u>	X	X			

Appendix Table 1 (continued).

Zooplankton taxa collected from L-Lake mixed zone and hypolimnion.
January 1986-December 1989.

Taxon	Region				
	4	5	6	7	8
Phylum Rotifera (continued).					
<u>Monostyla bulla</u>	X			X	
<u>Monostyla closteroerca</u>	X	X			X
<u>Monostyla lunaris</u>	X			X	
<u>Notommata</u> sp.	X	X	X	X	X
<u>Ploesoma</u> sp. 1	X	X	X	X	X
<u>Polyarthra euryptera</u>			X	X	X
<u>Polyarthra remata</u>	X	X	X	X	X
<u>Polyarthra</u> sp.	X	X	X	X	X
<u>Polyarthra vulgaris</u>	X	X	X	X	X
rotifer - unidentified spp. < 50 μ	X	X	X	X	
rotifer - unidentified spp. 50 - 99 μ	X	X	X	X	X
rotifer - unidentified spp. 100 - 200 μ	X	X	X	X	X
rotifera unidentified sp. 1	X			X	
<u>Synchaeta oblonga</u>	X	X	X	X	X
<u>Synchaeta</u> spp.	X	X	X	X	X
<u>Synchaeta stylata</u>				X	X
<u>Trichocerca cylindrica</u>	X	X	X	X	X
<u>Trichocerca multicornis</u>		X	X		
<u>Trichocerca pusilla</u>	X	X	X	X	X
<u>Trichocerca rousseleti</u>	X	X	X	X	X
<u>Trichocerca similis</u>	X	X	X	X	X
<u>Trichocerca</u> sp. 1		X	X	X	X
<u>Trichocerca</u> spp.	X	X			
Phylum Gastrotricha					
<u>Stylochaeta</u> spp.	X	X	X	X	X
Phylum Arthropoda					
Class Crustacea					
Subclass Brachiopoda					
Order Cladocera					
<u>Alona affinis</u>			X		
<u>Alona rectangula</u>	X			X	X
<u>Alona</u> sp.	X	X	X	X	X
<u>Bosmina longirostris</u>	X	X	X	X	X
<u>Bosminopsis dietersi</u>			X	X	X
<u>Ceriodaphnia</u> spp.	X	X	X	X	X
<u>Chydorus brevilabris</u>	X	X	X	X	X
<u>Daphnia ambigua</u>	X	X	X		X
<u>Daphnia parvula</u>	X	X	X	X	X
<u>Daphnia retrocurva</u>	X	X	X	X	X

Appendix Table 1 (continued).

Zooplankton taxa collected from L-Lake mixed zone and hypolimnion.
January 1986-December 1989.

Taxon	Region				
	4	5	6	7	8
Phylum Arthropoda (continued).					
<u>Daphnia</u> sp.	X		X	X	
<u>Diaphanosoma brachyurum</u>	X	X	X	X	X
<u>Eubosmina</u> sp.		X	X	X	X
<u>Eurycercus (Bullatifrons)</u> sp.		X			
<u>Holopedium gibberum</u>	X				
holophryid ciliate 50 - 99 μ		X			
<u>Ilyocryptus spinifer</u>	X				
<u>Latona setifera</u>			X		
<u>Leptodora kindtii</u>	X	X	X		X
<u>Leydigia acanthocercoides</u>				X	
<u>Leydigia quadrangularis</u>		X		X	X
<u>Moina micrura</u>	X	X	X	X	X
<u>Monospilus dispar</u>					X
<u>Pleuroxus hamulatus</u>			X		
<u>Sida crystallina</u>	X	X	X	X	X
<u>Simocephalus</u> sp.				X	X
unidentified cladocera	X				
<u>Acanthocyclops</u> spp.					X
<u>Acanthocyclops vernalis</u>			X		X
<u>Cyclops</u> sp.	X	X	X	X	X
<u>Diaptomus mississippiensis</u>	X				
<u>Diaptomus</u> sp.	X	X	X	X	X
<u>Ergasilus</u> spp.				X	X
<u>Eurytemora affinis</u>	X	X	X	X	X
<u>Macrocyclus</u> sp.	X	X	X	X	X
<u>Mesocyclops edax</u>	X	X	X	X	X
<u>Microcyclops varicans rubellus</u>				X	
<u>Paracyclops fimbriatus poppei</u>	X	X	X	X	X
<u>Tropocyclops prasinus</u>	X	X	X	X	X
calanoid copepodid	X	X	X	X	X
cyclopoid copepodid	X	X	X	X	X
nauplius larvae	X	X	X	X	X
unidentified copepoda	X	X	X	X	X
<u>Harpacticoida</u>		X	X		X
<u>Nitocra</u> sp.	X	X			
<u>Elaphoidella</u> sp.			X		
Subclass Ostracoda					
Order Podocopa					
unidentified spp.	X	X	X	X	X

Appendix Table 2.

Zooplankton taxa collected in L Lake and Par Pond
(all regions combined) by quarter in 1990 and 1991.

TAXON	1990			
	WINTER	SPRING	SUMMER	FALL
<u>Protozoa</u>				
<u>Askenasia</u> sp. 2	X	X		X
<u>Campanella</u> <u>umbellaria</u>	X	X		X
<u>Centropyxis</u> <u>aculeata</u>				X
ciliate - unidentified spp. 50 - 99 μ	X	X	X	X
ciliate - unidentified spp. < 50 μ	X	X	X	X
ciliate sp. 04	X	X	X	X
ciliate sp. 05		X		X
ciliate sp. 12	X	X		
<u>Codonella</u> <u>cratera</u>	X	X	X	X
<u>Coleps</u> spp.	X	X		X
<u>Coleps</u> <u>striatus</u>	X			
<u>Didinium</u> <u>balbianii</u> var. <u>nanum</u>	X	X		X
<u>Didinium</u> <u>nasutum</u>	X	X		X
<u>Diffugia</u> <u>limnetica</u>				X
<u>Epistylis</u> spp.	X			
<u>Euglypha</u> <u>ciliata</u>				X
<u>Halteria</u> sp. 2	X	X		X
holophryid ciliate 50 - 99 μ	X	X	X	X
holophryid ciliate < 50 μ	X	X		X
<u>Lesquereusia</u> sp.				X
<u>Mesodinium</u> <u>acarus</u>	X	X	X	X
<u>Nuclearia</u> <u>simplex</u>	X	X		
<u>Spathidioides</u> <u>sulcata</u>	X			X
<u>Staurophrya</u> <u>elegans</u>	X	X		
<u>Strobilidium</u> <u>gyrans</u>	X	X	X	X
<u>Strombidium</u> spp.	X	X	X	X
<u>Tintinnopsis</u> <u>cylindrata</u>	X	X	X	X
<u>Tintinnopsis</u> sp. 1	X	X	X	X
<u>Trachelius</u> spp.	X			
<u>Uronema</u> sp. 1	X	X	X	X
<u>Urotricha</u> <u>farcta</u>	X	X	X	X
<u>Vorticella</u> sp. 1	X	X	X	X
<u>Vorticella</u> sp. 2	X			
<u>Vorticella</u> sp. 3	X	X		
<u>Rotifera</u>				
<u>Anuraeopsis</u> <u>fissa</u>			X	X
<u>Asplanchna</u> <u>priodonta</u>				X
<u>Brachionus</u> <u>havanaensis</u>			X	
<u>Cephalodella</u> sp. 2	X			
<u>Collotheca</u> <u>mutabilis</u>		X		X
<u>Conochiloides</u> <u>dossuarius</u>		X	X	X
<u>Conochilus</u> <u>unicornis</u>		X	X	X
<u>Filinia</u> <u>longiseta</u>			X	
<u>Hexarthra</u> <u>mira</u>		X	X	X

Appendix Table 2 (continued).

Zooplankton taxa collected in L Lake and Par Pond
(all regions combined) by quarter in 1990 and 1991.

TAXON	1990			
	WINTER	SPRING	SUMMER	FALL
<u>Kellicottia bostoniensis</u>			X	X
<u>Keratella cochlearis</u>	X	X	X	X
<u>Keratella cochlearis</u> f. <u>tecta</u>			X	X
<u>Keratella crassa</u>	X	X	X	X
<u>Ploesoma</u> sp. 1			X	
<u>Polvarthra remata</u>	X	X	X	X
<u>Polvarthra</u> sp.			X	X
<u>Polvarthra vulgaris</u>		X		X
rotifer - unidentified spp. 100 - 200 μ	X	X	X	
rotifer - unidentified spp. 50 - 99 μ		X		X
<u>Synchaeta oblonga</u>	X	X	X	X
<u>Synchaeta</u> spp.				X
<u>Trichocerca cylindrica</u>			X	X
<u>Trichocerca multicrinis</u>				X
<u>Trichocerca pusilla</u>	X	X	X	X
<u>Trichocerca rousseleti</u>		X	X	X
<u>Trichocerca similis</u>		X	X	X
<u>Cladocera</u>				
<u>Alona rectangula</u>	X	X		
<u>Bosmina longirostris</u>	X	X	X	X
<u>Bosminopsis dietersi</u>		X	X	X
<u>Ceriodaphnia lacustris</u>		X		X
<u>Ceriodaphnia</u> spp.		X		X
<u>Chydorus brevilabris</u>	X	X	X	
<u>Daphnia ambigua</u>		X		
<u>Daphnia parvula</u>		X		
<u>Daphnia retrocurva</u>	X	X		
<u>Diaphanosoma brachyurum</u>		X	X	X
<u>Eurycerus (bullatifrons)</u> sp.		X		
<u>Holopedium gibberum</u>				X
<u>Leydigia quadrangularis</u>	X			
<u>Copepoda</u>				
<u>Acanthocyclops vernalis</u>		X		X
calanoid copepodid	X	X	X	X
cyclopoid copepodid	X	X	X	X
<u>Diaptomus mississippiensis</u>				X
<u>Diaptomus</u> sp.	X	X		
<u>Epischura nordenskioldi</u>		X		X
<u>Ergasilus</u> spp.		X	X	
<u>Eurytemora affinis</u>	X	X		
<u>Mesocyclops edax</u>	X	X	X	X
nauplius larvae - unidentified spp.	X	X	X	X
<u>Tropocyclops prasinus</u>		X		X
Ostracoda - unidentified spp.			X	

Appendix Table 2 (continued).

Zooplankton taxa collected in L Lake and Par Pond
(all regions combined) by quarter in 1990 and 1991.

TAXON	1991			
	WINTER	SPRING	SUMMER	FALL
<u>Protozoa</u>				
<u>Askenasia</u> sp. 2		X		X
<u>Askenasia</u> spp.			X	
<u>Astramoeba</u> spp.				X
<u>Campanella umbellaria</u>	X		X	
<u>Centropyxis aculeata</u>			X	
Ciliate - unidentified spp. 50 - 99 μ	X	X	X	X
Ciliate - unidentified spp. < 50 μ	X	X	X	X
Ciliate sp. 04		X	X	X
Ciliate sp. 05		X	X	X
Ciliate sp. 12	X	X	X	X
Ciliate sp. 15				X
<u>Codonella cratera</u>	X	X	X	X
<u>Coleps hirtus</u>				X
<u>Coleps</u> spp.	X	X	X	
<u>Cyclidium</u> sp. 1			X	
<u>Didinium balbianii</u> var. <u>nanum</u>	X	X		X
<u>Didinium nasutum</u>			X	X
<u>Diffugia limnetica</u>	X	X	X	
<u>Dileptus bivacuolatus</u>			X	X
<u>Epistylis</u> spp.	X	X		
<u>Halteria</u> sp. 2	X	X	X	X
Holophryid ciliate 50 - 99 μ	X	X	X	X
Holophryid ciliate < 50 μ	X	X	X	X
Keronidae		X		
<u>Mesodinium acarus</u>	X	X	X	X
<u>Nuclearia simplex</u>				X
<u>Spathidioides sulcata</u>	X		X	X
<u>Spathidium</u> sp.			X	
<u>Stentor</u> sp.			X	X
<u>Strobilidium gyrans</u>	X	X	X	
<u>Strobilidium</u> sp.	X	X		
<u>Strombidium</u> spp.	X	X	X	X
<u>Tintinnopsis cylindrata</u>	X	X	X	X
<u>Tintinnopsis</u> sp. 1	X	X	X	X
<u>Uronema</u> sp. 1	X	X	X	
<u>Urotricha armata</u>			X	
<u>Urotricha farcta</u>	X	X	X	X
<u>Vorticella</u> sp. 1	X	X	X	X
<u>Vorticella</u> sp. 3				X
<u>Rotifera</u>				
<u>Anuraeopsis fissa</u>		X	X	X
<u>Ascomorpha</u> sp.			X	
<u>Asplanchna priodonta</u>	X			
<u>Cephalodella</u> sp. 2		X		X
<u>Cephalodella</u> spp.				X
<u>Collotheca mutabilis</u>	X	X	X	X
<u>Conochiloides dossuarius</u>		X	X	X
<u>Conochilus unicornis</u>	X	X	X	X
<u>Filinia longiseta</u>		X	X	X

Appendix Table 2 (continued).

Zooplankton taxa collected in L Lake and Par Pond
(all regions combined) by quarter in 1990 and 1991.

TAXON	1991			
	WINTER	SPRING	SUMMER	FALL
<u>Hexarthra mira</u>			X	X
<u>Kellicottia bostoniensis</u>	X	X	X	X
<u>Keratella cochlearis</u>	X	X	X	X
<u>Keratella cochlearis f. tecta</u>				X
<u>Keratella crassa</u>	X	X	X	X
<u>Monostyla closterocerca</u>	X			
<u>Ploesoma sp. 1</u>			X	
<u>Polyarthra euryptera</u>				X
<u>Polyarthra remata</u>	X	X	X	X
<u>Polyarthra sp.</u>		X	X	X
<u>Polyarthra vulgaris</u>	X	X		X
Rotifer - unidentified spp. 100 - 200 μ	X	X	X	X
Rotifer - unidentified spp. 50 - 99 μ	X		X	X
<u>Synchaeta oblonga</u>	X	X	X	X
<u>Synchaeta spp.</u>	X			X
<u>Trichocerca cylindrica</u>	X	X	X	X
<u>Trichocerca multicornis</u>		X	X	X
<u>Trichocerca pusilla</u>	X	X	X	X
<u>Trichocerca rousseleti</u>	X	X	X	X
<u>Trichocerca similis</u>			X	
<u>Cladocera</u>				
<u>Alona rectangula</u>	X			
<u>Bosmina longirostris</u>	X		X	X
<u>Ceriodaphnia lacustris</u>		X		
<u>Ceriodaphnia spp.</u>	X	X	X	X
<u>Daphnia ambigua</u>		X	X	X
<u>Daphnia parvula</u>	X	X	X	
<u>Daphnia retrocurva</u>	X	X		X
<u>Daphnia sp.</u>		X		
<u>Disparalona rostrata</u>		X		
<u>Holopedium amazonicum</u>	X	X	X	X
<u>Diaphanosoma brachyurum</u>	X	X	X	X
<u>Copepoda</u>				
<u>Acanthocyclops vernalis</u>	X			X
Calanoid copepodid	X	X	X	X
Cyclopoid copepodid	X	X	X	X
<u>Diaptomus mississippiensis</u>	X		X	X
<u>Epischura nordenskioldi</u>	X	X		X
<u>Ergasilus spp.</u>				X
<u>Eurytemora affinis</u>		X		
<u>Mesocyclops edax</u>	X	X	X	X
Nauplius larvae - unidentified spp.	X	X	X	X
<u>Tropocyclops prasinus</u>	X	X		X
<u>Ostracoda</u> - unidentified spp.			X	

Appendix Table 3.

Volumetric (organisms/m³) and areal (organisms/m²) density for zooplankton groups in L Lake and Par Pond by season in 1990 and 1991.

VOLUMETRIC		L LAKE								PAR POND
		Region 5				Region 7				
		A	B	C	D	A	B	C	D	A
1990										
WINTER	PROTOZOA	10198000.00	6332000.00	10664000.00	12478000.00	15433000.00	12356000.00	12740000.00	12906000.00	12686000.00
	ROTIFERA	40000.00	100000.00	0	0	170000.00	96000.00	80000.00	100000.00	840000.00
	CLADOCERA	6292.35	6616.16	2606.84	2890.08	7033.82	2826.39	1828.48	2512.35	1229.63
	NAUPLIUS	57551.02	0.00	30612.24	16530.61	76020.41	0.00	30408.16	15816.33	75510.20
	COPEPODID	6108.63	7057.24	8776.35	9217.00	3516.91	916.67	1197.97	1199.07	2920.37
SPRING	COPE. ADULT	321.51	52.42	347.58	468.66	901.77	152.78	63.05	228.40	0
	PROTOZOA	15128000.00	24677000.00	22799000.00	24144000.00	16842000.00	25367000.00	25462000.00	16667000.00	13628000.00
	ROTIFERA	1580000.00	1085000.00	1767000.00	1736000.00	1189000.00	1953000.00	1612000.00	899000.00	527000.00
	CLADOCERA	1665.74	3443.49	2419.75	2314.81	1481.48	2466.05	1120.59	1600.82	2156.25
	NAUPLIUS	9897.96	10408.16	0.00	27551.02	12346.94	11734.69	11632.65	0.00	27551.02
SUMMER	COPEPODID	6583.64	9531.10	7061.73	8432.54	7513.23	11169.75	8188.93	8004.12	4593.75
	COPE. ADULT	237.96	983.86	1086.42	1212.52	952.38	2466.05	172.40	1800.93	281.25
	PROTOZOA	616000.00	0	1241000.00	2044000.00	1560000.00	1689000.00	3663000.00	669000.00	3096000.00
	ROTIFERA	360000.00	180000.00	330000.00	290000.00	1020000.00	460000.00	846000.00	90000.00	490000.00
	CLADOCERA	57.61	345.68	89.51	43.77	245.01	78.35	37.75	0	631.81
FALL	NAUPLIUS	26020.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46326.53
	COPEPODID	288.07	345.68	268.52	919.19	81.67	156.70	490.74	60.28	816.09
	COPE. ADULT	57.61	49.38	44.75	0	0	39.17	0	15.07	105.30
	PROTOZOA	9029000.00	22264000.00	14476000.00	11779000.00	11795000.00	26853000.00	31041000.00	23911000.00	12439000.00
	ROTIFERA	980000.00	440000.00	558000.00	780000.00	795000.00	1725000.00	620000.00	574000.00	182000.00
1991	CLADOCERA	1557.50	2700.00	618.23	167.18	1015.67	2960.19	804.60	930.31	1856.67
	NAUPLIUS	34897.96	10000.00	40408.16	0.00	17551.02	0.00	9081.63	0.00	9693.88
	COPEPODID	1191.03	5900.00	3208.93	2541.15	3505.70	16474.07	4683.91	5930.70	2555.94
	COPE. ADULT	229.04	433.33	471.04	300.93	425.93	300.31	919.54	261.25	1494.98
	WINTER	PROTOZOA	6712000.00	3820000.00	5852000.00	4700000.00	4448000.00	7396000.00	4407000.00	
SPRING	ROTIFERA	132000.00	150000.00	180000.00	120000.00	156000.00	276000.00	190000.00		
	CLADOCERA	6221.71	6324.79	5338.73	4276.01	12120.37	8631.94	12592.59		
	NAUPLIUS	11102.37	8693.26	13438.79	6316.14	10849.00	31837.96	14953.50		
	COPEPODID	8647.12	9135.80	10782.15	6578.48	11950.85	11683.64	12666.67		
	COPE. ADULT	527.26	439.22	2826.39	1151.23	1186.61	523.15	888.89		
SUMMER	PROTOZOA	8805000.00	9866000.00	11715000.00	13765000.00	16645000.00	11695000.00	12530000.00		
	ROTIFERA	630000.00	1105000.00	615000.00	615000.00	735000.00	1260000.00	510000.00		
	CLADOCERA	21715.46	13898.99	13012.35	19121.23	16493.17	52393.10	17461.64		
	NAUPLIUS	8549.38	8655.44	8348.53	3240.00	6776.90	5378.79	8124.56		
	COPEPODID	21479.42	14092.03	12511.87	14765.43	9186.07	17985.69	12182.54		
FALL	COPE. ADULT	2360.38	1544.33	1000.95	1698.02	2087.74	3127.95	1421.30		
	PROTOZOA	12694000.00	15962000.00	12000000.00	13304000.00	12683800.00	10472000.00	18225000.00		
	ROTIFERA	1020000.00	1134000.00	555000.00	810000.00	887400.00	1248000.00	870000.00		
	CLADOCERA	0	114.20	170.32	187.83	111.99	161.62	0		
	NAUPLIUS	170.49	154.19	290.81	229.28	22.18	252.53	115.74		
	COPEPODID	589.07	456.79	1021.95	594.80	419.97	363.64	531.93		
	COPE. ADULT	98.18	114.20	102.19	31.31	111.99	40.40	31.29		
	PROTOZOA	15586000.00	55178000.00	35432000.00	49714000.00	21141000.00	6818000.00	49976000.00		
	ROTIFERA	1060000.00	790000.00	700000.00	800000.00	460000.00	510000.00	500000.00		
	CLADOCERA	12841.05	8416.92	11141.98	9041.67	6878.31	9849.02	9690.53		

Appendix Table 3 (continued).

Volumetric (organisms/m³) and areal (organisms/m²) density for zooplankton groups in L Lake and Par Pond by season in 1990 and 1991.

AREAL		L LAKE								PAR POND
		Region 5				Region 7				A
		A	B	C	D	A	B	C	D	
1990										
WINTER	PROTOZOA	129514600.00	69652000.00	138632000.00	162214000.00	177479500.00	148272000.00	178360000.00	180684000.00	190290000.00
	ROTIFERA	508000.00	1100000.00	0	0	1955000.00	1152000.00	1120000.00	1400000.00	12600000.00
	CLADOCERA	79916.67	72777.78	33888.89	37570.99	80888.89	33916.67	25598.77	35172.84	18444.44
	NAUPLIUS	730897.96	0.00	397959.18	214897.96	874234.69	0.00	425714.29	221428.57	1132653.06
	COPEPODID	77583.33	77629.63	114092.59	119820.99	40444.44	11000.00	16771.60	16787.04	43805.56
	COPE. ADULT	4083.33	10916.67	4518.52	6092.59	10370.37	1833.33	882.72	3197.53	0
SPRING	PROTOZOA	151280000.00	320801000.00	341985000.00	338016000.00	235788000.00	253670000.00	356468000.00	300006000.00	218048000.00
	ROTIFERA	15800000.00	14105000.00	26505000.00	24304000.00	16646000.00	19530000.00	22568000.00	16182000.00	8432000.00
	CLADOCERA	16657.41	44765.43	36296.30	32407.41	20740.74	24660.49	15688.27	28814.81	34500.00
	NAUPLIUS	98979.59	135306.12	0.00	385714.29	172857.14	117346.94	162857.14	0.00	440816.33
	COPEPODID	65836.42	123904.32	105925.93	118055.56	105185.19	111697.53	114645.06	144074.07	73500.00
	COPE. ADULT	2379.63	12790.12	16296.30	16975.31	13333.33	24660.49	2413.58	32416.67	4500.00
SUMMER	PROTOZOA	5544000.00	0	14892000.00	22484000.00	20280000.00	21957000.00	47619000.00	11373000.00	52632000.00
	ROTIFERA	3240000.00	1980000.00	3960000.00	3190000.00	13260000.00	5980000.00	10998000.00	1530000.00	8330000.00
	CLADOCERA	518.52	3802.47	1074.07	481.48	3185.19	1018.52	490.74	0	10740.74
	NAUPLIUS	234183.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	787551.02
	COPEPODID	2592.59	3802.47	3222.22	10111.11	1061.73	2037.04	6379.63	1024.69	13873.46
	COPE. ADULT	518.52	543.21	537.04	0	0	509.26	0	256.17	1790.12
FALL	PROTOZOA	85775500.00	278300000.00	188188000.00	141348000.00	153335000.00	268530000.00	450094500.00	370620500.00	199024000.00
	ROTIFERA	9310000.00	5500000.00	7254000.00	9360000.00	10335000.00	17250000.00	8990000.00	8897000.00	2912000.00
	CLADOCERA	14796.30	33750.00	8037.04	2006.17	13203.70	29601.85	11666.67	14419.75	29706.79
	NAUPLIUS	331530.61	125000.00	525306.12	0.00	228163.27	0.00	131683.67	0.00	155102.04
	COPEPODID	11314.81	73750.00	41716.05	30493.83	45574.07	164740.74	67916.67	91925.93	40895.06
	COPE. ADULT	2175.93	5416.67	6123.46	3611.11	5537.04	3003.09	13333.33	4055.56	23919.75
1991										
WINTER	PROTOZOA	80544000.00	49660000.00	70224000.00	65800000.00	57824000.00	88752000.00	66105000.00		
	ROTIFERA	1584000.00	1950000.00	2160000.00	1680000.00	2028000.00	3312000.00	2850000.00		
	CLADOCERA	74660.49	82222.22	64064.81	59864.20	157564.81	103583.33	188888.89		
	NAUPLIUS	133228.40	113012.35	161265.43	88425.93	141037.04	382055.56	224302.47		
	COPEPODID	103765.43	118765.43	129385.80	92098.77	155361.11	140203.70	190000.00		
	COPE. ADULT	6327.16	5709.88	33916.67	16117.28	15425.93	6277.78	13333.33		
SPRING	PROTOZOA	92452500.00	108526000.00	152295000.00	172062500.00	233030000.00	128645000.00	175420000.00		
	ROTIFERA	6615000.00	12155000.00	7995000.00	7687500.00	10290000.00	13860000.00	7140000.00		
	CLADOCERA	228012.35	152888.89	169160.49	239015.43	230904.32	576324.07	244462.96		
	NAUPLIUS	89768.52	95209.88	108530.86	40500.00	94876.54	59166.67	113743.83		
	COPEPODID	225533.95	155012.35	162654.32	184567.90	128604.94	197842.59	170555.56		
	COPE. ADULT	24783.95	16987.65	13012.35	21225.31	29228.40	34407.41	19898.15		
SUMMER	PROTOZOA	133287000.00	191544000.00	162000000.00	186256000.00	171231300.00	115192000.00	255150000.00		
	ROTIFERA	10710000.00	13608000.00	7492500.00	11340000.00	11979900.00	13728000.00	12180000.00		
	CLADOCERA	0	1370.37	2299.38	2629.63	1567.90	1777.78	0		
	NAUPLIUS	1790.12	1850.31	3925.93	3209.88	299.38	2777.78	1620.37		
	COPEPODID	6185.19	5481.48	13796.30	8327.16	5879.63	4000.00	7712.96		
	COPE. ADULT	1030.86	1370.37	1379.63	438.27	1567.90	444.44	453.70		
FALL	PROTOZOA	155860000.00	662136000.00	425184000.00	596568000.00	295974000.00	81816000.00	749640000.00		
	ROTIFERA	10600000.00	9480000.00	8400000.00	9600000.00	6440000.00	6120000.00	7500000.00		
	CLADOCERA	128410.49	101003.09	133703.70	108500.00	96296.30	118188.27	145358.02		

Appendix Table 4.

Yearly descriptive statistics and percent composition for density (organisms/L) of major taxonomic groups of L-Lake zooplankton collected from the mixed zone and hypolimnion of Region 5. January 1986-December 1989.

Taxon	Mean	Med	%Comp	N	SD	CV	Min	Max
<u>Mixed Zone - 1986</u>								
Protozoa	28644	26826	96.68	24	14004	48.9	5718	54794
Rotifera	917	685	3.09	24	896	97.7	144	3848
Cladocera	22	8	0.07	24	33	151.3	<1	145
Cyclopoida/Calanoida	45	26	0.15	24	43	97.1	3	200
Harpacticoida	<1	0	0.00	24	<1	290.0	0	1
Ostracoda	<1	0	0.00	24	<1	287.6	0	2
Gastrotricha	0	0	0.00	24	0	.	0	0
<u>Total</u>	<u>29628</u>		<u>100.00</u>					
<u>Hypolimnion - 1986</u>								
Protozoa	23082	20299	99.81	12	16290	70.6	1970	50842
Rotifera	16	0	0.07	12	45	278.3	0	156
Cladocera	7	6	0.03	12	7	98.0	0	25
Cyclopoida/Calanoida	21	7	0.09	12	27	127.9	1	83
Harpacticoida	0	0	0.00	12	0	.	0	0
Ostracoda	0	0	0.00	12	0	.	0	0
Gastrotricha	0	0	0.00	12	0	.	0	0
<u>Total</u>	<u>23126</u>		<u>100.00</u>					
<u>Mixed Zone - 1987</u>								
Protozoa	26855	22744	95.88	24	15452	57.5	5938	61008
Rotifera	1097	414	3.92	24	1435	130.9	54	5180
Cladocera	12	3	0.04	24	18	154.6	0	68
Cyclopoida/Calanoida	42	20	0.15	24	47	112.8	4	164
Harpacticoida	0	0	0.00	24	0	.	0	0
Ostracoda	2	<1	0.01	24	4	150.4	0	11
Gastrotricha	0	0	0.00	24	0	.	0	0
<u>Total</u>	<u>28008</u>		<u>100.00</u>					

Appendix Table 4 (continued).

Yearly descriptive statistics and percent composition for density (organisms/L) of major taxonomic groups of L-Lake zooplankton collected from the mixed zone and hypolimnion of Region 5. January 1986-December 1989.

Taxon	Mean	Med	%Comp	N	SD	CV	Min	Max
<u>Hypolimnion - 1987</u>								
Protozoa	7942	7583	99.65	8	4557	57.4	2328	17804
Rotifera	25	4	0.31	8	39	156.9	0	102
Cladocera	<1	0	0.00	8	<1	282.8	0	1
Cyclopoida/Calanoida	2	2	0.02	8	1	55.7	0	3
Harpacticoida	0	0	0.00	8	0	.	0	0
Ostracoda	1	1	0.01	8	1	102.4	<1	3
Gastrotricha	0	0	0.00	8	0	.	0	0
<u>Total</u>	<u>7970</u>		<u>100.00</u>					
<u>Mixed Zone - 1988</u>								
Protozoa	40861	40867	95.77	24	24469	59.9	10382	109824
Rotifera	1706	1426	4.00	24	1394	81.7	120	5268
Cladocera	3	1	0.01	24	4	140.1	0	13
Cyclopoida/Calanoida	12	8	0.03	24	10	78.3	2	39
Harpacticoida	0	0	0.00	24	0	.	0	0
Ostracoda	<1	0	0.00	24	<1	339.9	0	1
Gastrotricha	83	0	0.19	24	298	360.0	0	1333
<u>Total</u>	<u>42665</u>		<u>100.00</u>					
<u>Hypolimnion - 1988</u>								
Protozoa	28126	18502	99.79	12	23291	82.8	5344	66644
Rotifera	58	0	0.21	12	124	213.3	0	408
Cladocera	<1	0	0.00	12	1	220.4	0	3
Cyclopoida/Calanoida	2	1	0.01	12	2	86.0	<1	5
Harpacticoida	0	0	0.00	12	0	.	0	0
Ostracoda	0	0	0.00	12	0	.	0	0
Gastrotricha	0	0	0.00	12	0	.	0	0
<u>Total</u>	<u>28186</u>		<u>100.00</u>					

Appendix Table 4 (continued).

Yearly descriptive statistics and percent composition for density (organisms/L) of major taxonomic groups of L-Lake zooplankton collected from the mixed zone and hypolimnion of Region 5. January 1986-December 1989.

Taxon	Mean	Med	%Comp	N	SD	CV	Min	Max
<u>Mixed Zone - 1989</u>								
Protozoa	29432	17345	93.62	24	22979	78.1	3304	83494
Rotifera	2679	1162	8.34	24	2843	106.1	40	8554
Cladocera	1	<1	0.00	24	1	121.9	0	2
Cyclopoida/Calanoida	13	10	0.04	24	9	72.0	3	41
Harpacticoida	0	0	0.00	24	0	.	0	0
Ostracoda	<1	0	0.00	24	<1	294.9	0	<1
Gastrotricha	0	0	0.00	24	0	.	0	0
<u>Total</u>	<u>32125</u>		<u>100.00</u>					
<u>Hypolimnion - 1989</u>								
Protozoa	10529	8801	99.31	8	4469	42.4	4242	18320
Rotifera	72	0	0.67	8	178	248.7	0	510
Cladocera	<1	0	0.00	8	<1	155.3	0	<1
Cyclopoida/Calanoida	2	<1	0.02	8	3	152.5	<1	8
Harpacticoida	0	0	0.00	8	0	.	0	0
Ostracoda	<1	0	0.00	8	<1	198.4	0	<1
Gastrotricha	0	0	0.00	8	0	.	0	0
<u>Total</u>	<u>10603</u>		<u>100.00</u>					

Appendix Table 5.

Yearly descriptive statistics and percent composition for density (organisms/L) of major taxonomic groups of L-Lake zooplankton collected from the mixed zone and hypolimnion of Region 8. January 1986-December 1989.

Taxon	Mean	Med	%Comp	N	SD	CV	Min	Max
<u>Mixed Zone - 1986</u>								
Protozoa	26725	20924	96.98	24	17347	64.9	4024	80480
Rotifera	752	409	2.73	24	766	101.8	0	2860
Cladocera	23	13	0.08	24	27	116.9	<1	81
Cyclopoida/Calanoida	58	50	0.21	24	47	82.4	2	127
Harpacticoida	<1	0	0.00	24	<1	382.2	0	1
Ostracoda	<1	0	0.00	24	<1	373.5	0	1
Gastrotricha	0	0	0.00	24	0	.	0	0
<u>Total</u>	<u>27558</u>		<u>100.00</u>					
<u>Hypolimnion - 1986</u>								
Protozoa	9621	7722	99.11	12	7191	74.7	1540	25970
Rotifera	79	24	0.81	12	123	156.6	0	360
Cladocera	2	1	0.02	12	3	152.9	0	10
Cyclopoida/Calanoida	6	3	0.06	12	8	132.2	0	27
Harpacticoida	0	0	0.00	12	0	.	0	0
Ostracoda	<1	0	0.00	12	<1	185.8	0	<1
Gastrotricha	0	0	0.00	12	0	.	0	0
<u>Total</u>	<u>9708</u>		<u>100.00</u>					
<u>Mixed Zone - 1987</u>								
Protozoa	27790	19464	95.60	24	15174	54.6	7884	60514
Rotifera	1236	242	4.25	24	2640	213.6	32	10956
Cladocera	5	3	0.02	24	6	116.3	0	26
Cyclopoida/Calanoida	36	17	0.12	24	42	115.6	3	132
Harpacticoida	0	0	0.00	24	0	.	0	0
Ostracoda	1	<1	0.00	24	3	197.1	0	10
Gastrotricha	0	0	0.00	24	0	.	0	0
<u>Total</u>	<u>29068</u>		<u>100.00</u>					

Appendix Table 5 (continued).

Yearly descriptive statistics and percent composition for density (organisms/L)
of major taxonomic groups of L-Lake zooplankton collected from the mixed
zone and hypolimnion of Region 8. January 1986-December 1989.

Taxon	Mean	Med	%Comp	N	SD	CV	Min	Max
<u>Hypolimnion - 1987</u>								
Protozoa	5141	5437	99.33	8	1746	34.0	1766	7092
Rotifera	33	10	0.64	8	65	198.3	0	192
Cladocera	<1	0	0.00	8	<1	190.0	0	<1
Cyclopoida/Calanoida	1	1	0.02	8	1	86.1	<1	4
Harpacticoida	0	0	0.00	8	0	.	0	0
Ostracoda	<1	<1	0.01	8	1	134.0	0	2
Gastrotricha	0	0	0.00	8	0	.	0	0
<u>Total</u>	<u>5175</u>		<u>100.00</u>					
<u>Mixed Zone - 1988</u>								
Protozoa	61137	44025	97.83	24	51217	83.8	9560	184326
Rotifera	1338	617	2.14	24	1326	99.1	0	4526
Cladocera	4	1	0.01	24	8	227.2	0	38
Cyclopoida/Calanoida	10	9	0.02	24	6	64.7	1	22
Harpacticoida	0	0	0.00	24	0	.	0	0
Ostracoda	<1	0	0.00	24	<1	226.3	0	1
Gastrotricha	3	0	0.00	24	9	338.8	0	31
<u>Total</u>	<u>62492</u>		<u>100.00</u>					
<u>Hypolimnion - 1988</u>								
Protozoa	25402	12577	99.83	14	31599	124.4	5936	102486
Rotifera	42	0	0.17	14	75	177.0	0	256
Cladocera	<1	0	0.00	14	1	223.4	0	2
Cyclopoida/Calanoida	1	<1	0.00	14	<1	75.4	0	1
Harpacticoida	0	0	0.00	14	0	.	0	0
Ostracoda	<1	0	0.00	14	<1	374.2	0	<1
Gastrotricha	0	0	0.00	14	0	.	0	0
<u>Total</u>	<u>25445</u>		<u>100.00</u>					

Appendix Table 5 (continued).

Yearly descriptive statistics and percent composition for density (organisms/L) of major taxonomic groups of L-Lake zooplankton collected from the mixed zone and hypolimnion of Region 8. January 1986-December 1989.

Taxon	Mean	Med	%Comp	N	SD	CV	Min	Max
<u>Mixed Zone - 1989</u>								
Protozoa	28397	21179	90.13	24	17926	63.1	6814	61098
Rotifera	3099	560	9.83	24	3863	124.7	96	10736
Cladocera	1	1	0.00	24	1	89.2	0	2
Cyclopoida/Calanoida	11	9	0.03	24	8	71.3	0	29
Harpacticoida	0	0	0.00	24	0	.	0	0
Ostracoda	<1	0	0.00	24	<1	228.4	0	<1
Gastrotricha	0	0	0.00	24	0	.	0	0
<u>Total</u>	<u>31508</u>		<u>100.00</u>					
<u>Hypolimnion - 1989</u>								
Protozoa	12818	8658	96.27	10	10805	84.3	1990	36844
Rotifera	495	158	3.72	10	1125	227.4	0	3672
Cladocera	<1	<1	0.00	10	<1	142.1	0	1
Cyclopoida/Calanoida	2	<1	0.02	10	4	178.9	0	11
Harpacticoida	0	0	0.00	10	0	.	0	0
Ostracoda	<1	0	0.00	10	<1	316.2	0	<1
Gastrotricha	0	0	0.00	10	0	.	0	0
<u>Total</u>	<u>13315</u>		<u>100.00</u>					

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