1 OF 3

NAI-SR-139

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

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PREFACE

The L Lake Biological Monitoring Program was designed to meet environmental regulatory requirements associated with the re-start 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, approximately 11 m³/sec of water is pumped from the Savannah River to L-Reactor. The water passes through the heat exchangers and is discharged into Region 2 in the upper portion of L Lake (Figure 2). Water temperature in the

Figure 2. L Lake and its sampling regions.

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 biological community of the reservoir.

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 although the scope-of-work for the monitoring program was extensively revised in 1990, such that most fish sampling programs were restricted to Regions 5 and 7. This reduced scope of work

will remain in effect until three months prior to restarting L-Reactor. At such time, the full scope of work will be reinstated.

The objective of this 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 six years of data 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. Based on results of 1987 studies, it was concluded that several factors contributed to the formation of a balanced biological community in L Lake: 1) the community was similar to that of other cooling reservoirs; 2) successful reproduction of the major species was documented; 3) fish condition and health were within average values; 4) typical reservoir food chains and trophic groups were well represented; and 5) fish kills were scarce or absent in the lower half of the lake.
2. In 1988, trends in condition and incidence of infectious disease changed. Condition no longer appeared to be within average values and for some taxa continued to decline. Incidence of infectious disease increased sharply in 1988, and a major fish kill, caused by redsore disease, occurred in the lower half of L Lake. However, in spite of decreased condition and increased disease incidence, several of the primary criteria for a biologically balanced community were met based on the 1988 results. The fish assemblage of L Lake remained similar to that in other reservoirs. Recruitment of the major taxa was not noticeably impaired and all major trophic groups were well represented.
3. Data collected during 1989 indicated that disease incidence remained relatively high and again resulted in a measurable fish kill. However, the fish assemblage of L Lake generally satisfied the remaining criteria for a balanced biological community. The species composition remained similar to that of other reservoirs: the major taxa were successfully

reproducing; fish condition was generally within average values; and typical trophic groups and food chains were well represented.

4. Data collected during 1990 indicated that overall abundance of bluegill, redbreast sunfish, and threadfin shad was lower than in 1989. No reactor-related fish kills were observed but disease incidence (specifically redsore) remained relatively high and again resulted in a measurable fish kill. Condition of bluegill and largemouth bass improved slightly in 1990 compared with 1989 values.
5. Overall abundance of juvenile and adult fish apparently declined in 1991. Catch per unit effort for bluegill, redbreast sunfish, and threadfin shad was lower in 1991 than in 1990 for most sampling programs and target densities from hydroacoustic surveys were also lower. Yellow perch and coastal shiner formed a sizeable portion of the electrofishing catches, suggesting that the L-Lake fish assemblage was shifting to a more even distribution of species, despite a decline in taxa richness.
6. Condition of large (>300 mm) largemouth bass declined slightly in 1991, coincidental with a major die-off caused by an Aeromonas epizootic. Condition of bluegill, redbreast sunfish and smaller largemouth bass remained similar to 1990 values.
7. Ichthyoplankton densities of many species were lower in 1991 than in 1990. Patterns of early spawning, which were observed in earlier years when L-Reactor was operating, were not evident in 1991.

8. No reactor-related fish kills were observed in L Lake during 1991, but disease incidence remained relatively high and again resulted in a measurable fish kill. However, the remaining criteria for a balanced biological community appear to have been met by the L-Lake fish assemblage. The species composition was similar to that of other reservoirs; the most abundant taxa were successfully reproducing; fish condition was generally within average values for the region; and typical functional groups and energy pathways were well represented.

1.0 INTRODUCTION

Steel Creek is a 21 km long tributary of the Savannah River that drains the central portion of the Savannah River Site (SRS). From 1954 to 1968, Steel Creek received high-temperature (max - 40 °C) nuclear reactor cooling water (maximum flow - 23 m³/s), resulting in the elimination of aquatic vegetation and erosion of sediments from the midreaches and deposition in the lower reaches of the stream. Except for a brief period in the mid-1970s, there was no direct reactor discharge from 1968 through 1985.

During the 17-year hiatus in reactor operation, ecological succession resulted in the development of a secondary growth of shrubs, bushes, and emergent and submerged macrophytes in and along the stream channel, which attracted a variety of aquatic and terrestrial animals. The Steel Creek swamp and marsh (94 ha), formed where Steel Creek enters the Savannah River floodplain, and the channel below it developed into a particularly important habitat supporting a variety of organisms. To protect this habitat from thermal impacts when L-Reactor was restarted in 1985, Steel Creek was impounded approximately 12 km from its confluence with the Savannah River to form L Lake, a 400-ha cooling reservoir operated as a once-through system with water pumped from the Savannah River and discharged into Steel Creek. Environmental regulations mandate that L Lake support a balanced biological community over at least 50% of its area. Assessment of the L-Lake fish assemblage is the subject of this report.

Assessment of the L-Lake fish assemblage necessitates consideration of several interrelated factors including thermal effects, nutrient loading, and natural successional changes. The fact that the L-Lake fish assemblage is

subjected to almost no fishing pressure should also be considered. Thermal influences on fish fall into several broad categories including lethal effects that cause death or eliminate otherwise acceptable habitat; controlling effects that influence processes such as growth, activity, and oxygen consumption by altering metabolic rate; and directive effects that include changes in fish movement and orientation in response to temperature gradients and relatively rapid changes in temperature (Brown 1974). Examples of lethal effects previously observed in SRS waters are the exclusion of fish from Four Mile Creek during periods of reactor operation (Paller and Saul 1986) and mortality in Pond C due to reactor cycling (Aho and Anderson 1986). Examples of controlling effects include changes in condition (Gibbons et al. 1978) and the prevalence of redsore disease in largemouth bass from heated areas in Par Pond (Esch and Hazen 1978). An example of directive effects is the aggregation of largemouth bass near the thermal inflow in Par Pond during the winter (Clugston 1973). Undoubtedly, all three types of effects occur to varying degrees in most thermally impacted systems and can be expected in L Lake.

Successional changes in the fish assemblage of L Lake may complicate an assessment of thermal effects by superimposing natural changes in species composition, richness, and abundance over thermally induced perturbations. The fish assemblages of newly filled southeastern reservoirs typically undergo successional changes as lotic species are replaced by species better adapted to a lentic environment (Turner 1971). Complicating this succession in L Lake, and possibly causing deviations from typical patterns, are the influences of reactor operation and a lack of fishing pressure. Fishing can strongly influence the size, age structure, and abundance of predator fishes, with subsequent effects on forage species (Hickman and Congdon 1974). The thermal influences of reactor

operation and associated nutrient loading (caused by the pumping of relatively nutrient-rich Savannah River water into L Lake) may also influence succession by altering the length of the growing season and the extent of primary productivity, both of which can influence size, abundance, and species composition (Taylor 1971; Carlander 1977).

The specific objectives of this study are:

- 1) to characterize the structural and some functional aspects of the L-Lake fish assemblage, with particular reference to changes in these parameters between the upper and lower ends of the lake;
- 2) to evaluate the magnitude and direction of temporal changes in the L-Lake fish assemblage and distinguish secondary successional and seasonal changes from those caused by reactor operation; and
- 3) to compare data from the L-Lake fish assemblage with data from the fish assemblages of other reservoirs and lakes that have demonstrated compliance with environmental regulations.

2.0 METHODS AND MATERIALS

2.1 INTRODUCTION

Eight sampling regions were established along the longitudinal axis of L Lake, from above Road B on Steel Creek to the dam embankment (Figure 2-1). The division of the lake into sampling regions along its longitudinal axis facilitated the examination of changes in the fish community along physico-chemical gradients associated with proximity to the reactor outfall and ensured that the fish assemblage was systematically sampled throughout the lake. Regular sampling during periods of reactor operation was discontinued in Regions 2 and 3 in April 1986 for safety reasons. Sampling in Region 1 was also eliminated at this time because of its disjunct location and because of habitat differences between it and the rest of the lake. Details of the sampling programs employed from 1986 through 1989 are described in Paller et al. (1987 and 1988), Heuer et al. (1989), and Sayers et al. (1990). In 1990 and 1991 sampling for most programs was restricted to Regions 5 and 7 in L Lake. Additionally, some programs now include sampling in Par Pond to provide comparative data between an old reservoir and a new one. Data from Par Pond are presented in Appendix Tables only.

Adult/juvenile fish sampling methods in L Lake included shoreline electrofishing, artificial-reef electrofishing, hoop netting, midwater trawling, and hydroacoustic surveys. In Par Pond, shoreline electrofishing, hoop netting and midwater trawling sampled the adult/juvenile fish (Appendix Figure 1). From 1986 through 1989, larval fish were sampled with nets and light traps, however larval fish were sampled only with nets in 1990 and 1991. The netting program was comprised of littoral surface tows (nets were drawn horizontally within the 1-m depth stratum), and oblique tows (nets were towed obliquely through the water

Figure 2-1. Locations of electrofishing transects and artificial reefs in L Lake. January 1986-December 1991. Only Regions 5 and 7 were sampled in 1990 and 1991.

column). Ichthyoplankton samples were not collected in Par Pond. Water temperature, dissolved oxygen, and pH were measured in conjunction with all fish sampling programs.

2.2 SAMPLING SCHEDULE

Electrofishing and hoop netting in L Lake and Par Pond were conducted quarterly (February, May, August, November; Table 2-1). Hydroacoustic surveys (Regions 2 through 8) and midwater trawls (Regions 5 and 7) were done monthly in L Lake. Midwater trawls were collected quarterly in Par Pond. Due to the 1991 drawdown of Par Pond, the summer quarterly samples were collected in July. The extremely low water level prevented launching of the midwater trawl boat during November, so fall trawl samples were not collected. During each sampling period, efforts were made to sample within and among lakes in the shortest time possible (maximum of four consecutive days within a lake; seven days between lakes) to reduce temporal bias.

Due to the brief duration of the larval stage, it was necessary to sample larval fish more frequently than adult fish. During the February-August spawning period, all sampling was conducted biweekly in Regions 5 and 7 (Table 2-1). No ichthyoplankton samples were collected in January or from September through December.

Due to various equipment malfunctions, inclement weather, or inability to collect sufficient numbers of fish, certain sampling programs were not always completed as specified in the Standard Operating Procedures. A list of these events is included as Appendix Table 1.

Table 2-1. Sampling dates for fish collections in L Lake. January-December 1991.^a

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
<u>Electrofishing</u>												
transects		13			2			21			6	
reefs		13			2			21			6	
<u>Ichthyoplankton</u>												
oblique tows		7,21	6,20	3,17	1,15,29	12,26	11,25	8,22				
surface tows		7,21	6,20	3,17	1,15,29	12,26	11,25	8,22				
vertical profile		7,21	6,20	3,17	1,15,29	12,26	11,25	8,22				
<u>Sonar</u>												
hydroacoustics	9	12	6	10	8	5	18	7	18	16	20	4
gill nets	9	12	6	10	8	5	18	7	18	16	20	4
midwater trawls	9	12	6	10	8	5	18	7	18	16	20	4
<u>Hoop netting</u>		13			3			21			6	
<u>Lavage</u>	28,29	8	12		28		30,31		9		25	
<u>Fish Kills</u>												
				1,5,9,12	1,6,8,10	4,7,10						
				16,19,24,26	13,15,17,20	18,25						
				22,24,28,31								

^aSee Sayers et al. (1990) for sampling dates from January 1986-December 1989, and Sayers et al. 1991 for sampling dates from January-December 1990.

2.3 ADULT AND JUVENILE FISH SAMPLING PROCEDURES

2.3.1 Electrofishing

Electrofishing was conducted at night when collection efficiency was considered highest for most species (Reynolds 1983). Shoreline collections were made along fixed 100-m transects parallel to the shore at the 1-m depth contour. Two transects were located in both the east and west littoral zones of Regions 5 and 7 (i.e., four transects were sampled per region per quarter; Figure 2-1). Collections were also made around three types of artificial reefs: block piles, wood piles, and tire piles. The distribution of artificial reefs in each region is shown in Table 2-2. Water temperature, dissolved oxygen concentration, and pH were recorded at a depth of 1 m after each site was sampled.

Electrofishing was conducted from an aluminum boat equipped with a 4500-W, 230-V gasoline-powered generator. A four-electrode anode array was mounted on a boom and suspended in the water approximately 2 m in front of the boat; the cathode boom was secured to the bow of the boat. Direct current (DC) discharge was controlled by a Smith-Root Model IV electrofisher set to deliver 440 V at 5.6 amps at a frequency of 60 pulses/sec. Current to the electrodes was pulsed by a foot switch operated by a netter at the bow. Transects were sampled by slowly motoring the boat along the shoreline; reefs were sampled by making a circuit around each reef. Shocking time (i.e., the duration that electricity was discharged to the water) was limited to 150-200 sec at each 100-m transect, but reef shock times varied. Stunned fishes were lifted from the water by wooden-handled dipnet (6.35-mm mesh diameter) and placed in a holding tank until the transect or reef was completely sampled.

Table 2-2. Number and location of artificial reefs in L Lake.
January 1986-December 1991.

Region	Reef Type		
	Block pile	Tire pile	Wood pile
3 E ^a	1	1	
3 W	1	1	
4 E	1	1	
4 W	1	1 ^b	
5 E ^c	1	1	
5 W ^c	1	1	
6 E	1	1 ^d	1
6 W	1 ^d	1	1
7 E ^c	1	1	1
7 W ^c	1	1	2
8 E	1	1	
8 W	1	1	

^aRegion 3 not sampled after 1986.

^bReef lost due to deterioration.

^cOnly Regions 5 and 7 sampled during 1990 and 1991.

^dToo deep to sample at normal lake level.

For field analysis, fishes were identified, measured (to the nearest 1.0 mm total length), weighed (to the nearest gram scale increment), and examined for parasites, disease symptoms, and morphological deformities. Sunfish between 90 mm and 150 mm or fusiform fish (e.g., catfish or largemouth bass) < 200 mm had been marked with a finclip on the left pectoral fin; larger fish had been marked by inserting a numbered plastic anchor tag (Model FD-68B, Floy Tag & Manufacturing, Inc., Seattle) at the base of the dorsal fin. The finclip program, however, was discontinued in January 1991.

Because of their extremely high abundance, it was sometimes necessary to subsample small (< 90 mm) sunfish, threadfin shad, and cyprinids rather than analyze them individually. To subsample small sunfish, 50 individuals (if possible) of each species from each sample were randomly selected, measured for total length, and weighed in aggregate. The remaining fish (of each species) were then counted and weighed in aggregate before being released. The range of total length of the aggregate sample was determined to estimate the size distribution of the unmeasured fish. Threadfin shad analysis differed in that no more than 10 randomly selected individuals > 90 mm TL were measured and weighed; the remainder was then subsampled (as above). Additional threadfin shad > 90 mm (up to a total of 50 individuals) were included in the subsample. For cyprinids, 10 specimens were measured and weighed in aggregate; the remainder were counted and weighed in aggregate.

2.3.2 Hoop Netting

When oxygen concentrations were suitable (> 3.0 mg/L), hoop nets were set in paired replicates at the 4-m depth along the east and west banks of Regions 5 and 7. Nets were deployed parallel to the shoreline and replicates separated

by no less than 100 m. The hoop nets were 4 m long and 1 m in diameter. The square mesh size was 38 mm in the body of the net and 25 mm in the cod end. A concrete block was attached to each end of the net to ensure that it remained anchored. A line with a float was also attached to each end to mark the location of the net and to facilitate retrieval. Each net was baited with one-half cake of Ivory soap. Nets were set for approximately 48 h. Fish captured in the hoop nets were counted, weighed, measured and examined as described above.

2.3.3 Hydroacoustics

The dual-beam hydroacoustic system (Biosonics Corporation, Seattle) included a dual-beam transducer mounted on the boat hull just beneath the water surface, an echo sounder, an oscilloscope (for instantaneous monitoring of the data), and a digital video-cassette recorder (for data storage and subsequent quantitative analysis). In the dual-beam system, pulses are transmitted on a narrow beam, and echoes are received on both narrow and wide beam elements. Data were processed by a dual-beam processor that provides information on target numbers and size.

Hydroacoustic data were collected at night, when fish are most likely to enter the open water (Mullan and Applegate 1967), along a series of fixed transects located between the east-west littoral zones, perpendicular to the longitudinal axis of the lake (Figure 2-2). Transects were established at two locations in Regions 4 through 8 and three locations in Regions 2 and 3, and replicate runs were made at each transect. Prior to data collection, the instrument was calibrated against a known-sized object suspended at a known depth.

Figure 2-2. Location of hydroacoustic transects in L Lake, January 1986-December 1991.

Although the dual-beam hydroacoustic system provided information on fish size, abundance, and density, it did not indicate species composition. Several methods were used to determine the species composition of the fishes recorded by the echo locator. Gill nets were set for 60 min at locations where the oscilloscope and echo traces indicated concentrations of large (>100 mm TL) fish. The 46-m long, 2.5-m deep gill nets were rigged with adjustable anchor lines so that the sample depth could be matched to the fish sightings. The mesh sizes of the panels were 25, 38, and 50 mm. Midwater trawling with a 1-m diameter, 6-mm mesh shad scoop was employed primarily for ground truthing of hydroacoustic surveys. From 1986 through 1989, at least one trawl sample was collected along each hydroacoustic transect at the depth of greatest fish concentrations. In 1990, trawl collections were reduced to 10 tows per month, in each of Region 5 and Region 7. This revised sampling pattern no longer provided ground truthing for the hydroacoustic surveys and was revised again in 1991 to provide better ground truthing of the sonar data. During 1991, a total of 20 tows per month were collected, three tows each in Regions 2, 4, 5, 6, 7, and 8 and two tows in Region 3. In each region, tows were conducted along each of the hydroacoustic survey transects and except in Region 3, also along a third transect parallel and between the hydroacoustic transects.

2.3.4 Fish Kill Investigations

Fish kills were divided into two categories: thermal fish kills associated with reactor operation and epidemic kills resulting from disease (especially redsore, i.e., Aeromonas infection). Thermal kills were restricted to the area around the reactor outfall and lasted for a few days after reactor activation, whereas epidemic kills occurred throughout the lake and lasted several weeks or months.

During 1991, surveys were conducted to assess epidemic kills by motoring slowly along the shoreline of L Lake and enumerating all dead fish. Prior to 1991, fish kill surveys were conducted by walking the entire shoreline and enumerating all dead fish within 2 m of the bank. This survey method was discontinued because of vegetation development along the bank and safety concerns (i.e., possible encounters with alligators or venomous snakes). Dead fish were identified to the lowest possible taxon and, when possible, assigned to 50-mm TL classes. All dead fish were then removed from the area to prevent their being recounted in subsequent surveys. Surveys were conducted 2 or 3 days a week at the height of the epidemic and 1 or 2 days a week thereafter for the duration of the epidemic.

2.3.5 Stomach and Gonadal Analysis

Stomach and gonadal analyses were conducted on redbreast sunfish and bluegill beginning in January 1987. Thirty specimens of each species, evenly divided (when possible) among small (< 90 mm), medium (90-150 mm), and large (> 150 mm) size classes, were collected from the upper (Region 5) and lower (Region 7) ends of L Lake. All fish were collected at night during the quarterly electrofishing program. Fish were placed on ice and brought to the laboratory where each individual's stomach was excised by severing the esophagus immediately anterior to the stomach and the large intestine directly posterior to the pylorus. The stomach contents were removed and wet-weighed to the nearest 0.01 g. Individual food items were identified to the lowest practical taxon, and their relative abundance was estimated.

Threadfin shad were included in the stomach analysis program following a prominent increase in abundance after October 1987. At least 10 fish (when

possible) were removed from each bank of each region (5 and 7) during routine night electrofishing and brought to the laboratory. The esophagus and gizzard of each fish were removed, and the contents were pooled with those of other shad collected from the same bank and region. Gut contents were preserved in 15% ethanol in a vial at a standard volume. The vial was agitated and a 1-mL aliquot transferred to a Sedgewick-Rafter slide where all food items in 10 random fields were counted and identified under 100X magnification. Shad diet data were reported as the estimated percent (by number) occupied by each taxon.

Beginning in June 1987, a gastric lavage technique (Light et al. 1983) was used to obtain diet data for largemouth bass without sacrificing the study subject. The lavage equipment consisted of a pressurized 5-L canister and hose connected to a polished plastic tube that was inserted into the fish's stomach. Water was forced into the stomach, thus flushing contents into an inclined trough with a strainer at the lower end. After draining, the food material was removed, stored on ice, and returned to the laboratory for analysis. Empty stomachs were noted. Gastric lavage was performed every two months on 60 bass (when possible) electroshocked from the upper (Regions 4 and 5; N = 30) and lower (Regions 7 and 8; N = 30) regions of the lake. Because largemouth bass are largely diurnal, visual predators (Becker 1983), all fish were collected during the day when feeding was most likely to occur. Food items were identified to the lowest practical taxon, enumerated, and weighed. Ten percent (usually N = 6 fish) of the bass sample was dissected to evaluate the efficiency of stomach-content removal by the lavage technique.

All fish returned to the laboratory were dissected to assess spawning condition. Gonads were excised and wet-weighed to the nearest 0.01 g. The

developmental state of the gonads (i.e., immature, mature, ripe, or spent) was also determined for each fish.

2.4 ICHTHYOPLANKTON SAMPLING PROCEDURES

2.4.1 Surface Tows

Surface samples were collected at a depth of approximately 0.5 m with paired 0.5-m diameter, 505- μ m mesh plankton nets held side by side in an aluminum frame (i.e., bongo net configuration). Collections were made along designated transects by suspending the nets in front of the boat and pushing them through the water at approximately 0.9 m/s. Transects were located parallel to the shore within the 2-m depth contour along the east and west banks (Figure 2-3). Tow sample depth was monitored by on-board electronic depth sounders. All samples were taken between 1.5 hours after sundown and 1.5 hours before sunrise to maximize catch rates. The order in which the two regions were sampled was randomized on each sample date to avoid systematic bias associated with diel changes in ichthyoplankton distribution.

Paired samples were collected by pushing the nets for approximately 5 min, filtering approximately 50 m³ of water through each net. Sample volumes were determined by a digital flowmeter (General Oceanics, Inc., Miami, FL) mounted in the center of each net. After collecting a sample, the nets were retrieved and rinsed to flush the contents into 1-L collection bottles attached to the cod end of each net. Enough buffered formalin (pH = 7) was added to the bottles to bring the formalin concentration to approximately 5%. The formalin contained rose bengal (0.33g dye/L formalin) to stain the eggs and larvae for easier separation from detritus. Surface water temperature, dissolved oxygen concentration, and pH were recorded at each sample transect.

Figure 2-3. Location of ichthyoplankton transects in L Lake, January 1986-December 1991

2.4.2 Oblique Tows

L-Lake ichthyoplankton were also sampled by making oblique tows through the water column between 1.5 hours after sundown and 1.5 hours before sunrise with paired 0.5-m diameter, 505- μ m mesh bongo nets. To perform oblique tows, a handline (marked at 1-m intervals) was attached to the side of the net frame, and a 5-mm wire cable was attached to the center of the frame between the two nets. The other end of the cable was attached to an electric winch mounted on the deck of a boat. The cable was kept slack and the handline held taut as the nets were lowered to the sampling depth. This ensured that the net frame remained parallel to the direction of boat movement and prevented sampling until the nets were lowered to the appropriate depth. When the sample depth (determined by marked cable) was reached, the handline was slackened and the cable pulled taut so that the net frame was oriented perpendicularly to the direction of boat movement. The nets were then slowly (< 0.25 m/s) retrieved by the winch as the boat moved along the transect. The rate of towing was approximately 0.9 m/s, and the duration of the tow was about 5 min, so that approximately 50 m³ of water was filtered by each net. The exact amount of water filtered was calculated by a digital flowmeter mounted in the center of each net.

During the first 21 months of the L-Lake study, oblique tows were taken from close to the bottom of each region. Consequently, the anoxic hypolimnion, which was presumably devoid of fish larvae, was intensively sampled during much of the year. Methods were changed in October 1987 to restrict oblique tows to the epilimnion. The epilimnion was arbitrarily defined as the upper part of the water column where dissolved oxygen was ≥ 3.0 mg/L. The depth of the epilimnion was determined by vertical profiles of temperature and dissolved oxygen measured

at 1-m intervals to the bottom in the center of each region a few hours before the oblique tows were taken.

During 1991, two oblique sampling transects were located parallel to the shoreline in the old creek channel in each region (5 and 7; Figure 2-3). Two paired samples were collected in each region on each sample date. Oblique samples were taken on the same night as the surface samples; the order of sampling was randomized to prevent systematic bias. Sample preservation and processing were described in Section 2.4.1.

2.4.3 Sorting and Identification

In the laboratory, ichthyoplankton samples were drained through a #35 sieve (500- μ m mesh) and rinsed with tap water. Fish larvae were sorted from associated debris under a dissecting microscope and removed using forceps or an eyedropper. Larvae were identified under a dissecting microscope to the lowest possible taxon and stored in 70% ethanol. Identifications were facilitated with voucher specimens and numerous references (Table 2-3).

2.5 DATA ANALYSIS

Catch per unit effort (CPUE) was calculated for all adult and juvenile fish sampling methods (no. fish/100 m for electrofishing transects, no. fish/min for artificial reefs, no. fish/net/day for hoop netting, no. fish/tow for midwater trawls). Ichthyoplankton catches were expressed as densities (no. larvae/1000 m³). Relative abundance was calculated by dividing the mean CPUE (adult and juvenile fish) or mean density (ichthyoplankton) of each taxon by the sum of the densities of all taxa and multiplying by 100. All means were calculated from individual densities or CPUEs; means were not calculated from other means.

Table 2-3. References pertinent to the identification of larval fishes.

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- Auer, N.D. (ed.). 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Spec. Pub. 82-83. Great Lakes Fishery Commission. Ann Arbor, MI.
- Bulak, J.S. 1985. Distinction of larval blueback herring, gizzard shad, and threadfin shad from the Santee-Cooper drainage, South Carolina. J. Elisha Mitchell Sci. Soc. 101:177-186.
- Buynak, G.L. and H.W. Mohr, Jr. 1978a. Larval development of the redbreast sunfish (Lepomis auritus) from the Susquehanna River. Trans. Am. Fish. Soc. 107:600-604.
- Conner, J.V. 1979. Identification of larval sunfishes (Centrarchidae, Elasmobranchidae) from southern Louisiana. In: Hoyt, R.D. (ed.). Proc. 3rd Sym. on Larval Fish. Western Kentucky University, Bowling Green, KY.
- Fuiman, L.A. 1979. Description and comparisons of catostomid fish larvae: Northern Atlantic Drainage species. Trans. Am. Fish. Soc. 108:560-603.
- Hardy, J.D., Jr. 1978. Development of fishes of the Mid-Atlantic Bight. Vol. 2. Anguillidae through Syngnathidae. Biol. Serv. Prog. FWS/OBS-78/12. US Dept. Int. Washington, DC.
- Hardy, J.D., Jr. 1978. Development of fishes of the Mid-Atlantic Bight. Vol. 3. Aphredoderidae through Rachycentridae. Biol. Serv. Prog. FWS/OBS-78/12. US Dept. Int. Washington, DC.
- Hogue, J.J., Jr., R. Wallus, and L.K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. Tenn. Valley Authority. Norris, TN.
- Hogue, J.J., Jr. and J. P. Buchanan. 1977. Larval development of spotted sucker (Minytrema melanops). Trans. Am. Fish. Soc. 106:347-353.
- Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of fishes of the Mid-Atlantic Bight. Vol. 1 Acipenseridae through Ictaluridae. Biol. Serv. Prog. FWS/OBS-78/12. US Dept. Int. Washington, DC.
- Lippson, A.J. and R.L. Moran. 1974. Manual for identification of early development stages of fishes of the Potomac River estuary. PPSP-MP-13. Md. Dept. Nat. Res. ETS, Martin-Marietta Corp. Baltimore, MD.
- Margulies, D. 1983. A preliminary guide to the identification of families of larval fishes occurring in the Ohio River. Ohio J. Sci. 83:135-138.
- McGowan, E.G. 1984. An identification guide for selected larval fishes from Robinson Impoundment, South Carolina. Carolina Power & Light Co. New Hill, NC.
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Table 2-3 (continued). References pertinent to the identification of larval fishes.

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- McGuire, D.L. 1981. Annotated key to the larval suckers (Catostomidae) of the Missouri River Drainage, Montana. Proc. Montana. Acad. Sci. 40:1-8.
- Meyer, F.A. 1970. Development of some larval centrarchids. Prog. Fish. Cult. 32:30-136.
- Siefert, R.E. 1969. Characteristics for separation of white and black crappie larvae. Trans. Am. Fish. Soc. 98:326-328.
- Taubert, B.D. 1977. Early morphological development of the green sunfish, Lepomis cyanellus, and its separation from other Lepomis species. Trans. Am. Fish. Soc. 106:445-448.
- Wang, C.S.J., and R.J. Kernahan. 1979. Fishes of the Delaware estuaries, a guide to the early life histories. EA Communication, Ecological Analysts, Inc. Towson, MD.
- Wiltz, J.W. 1984. Development stages of the highfin carpsucker (Carpionodes velifer), and its separation from other catostomids of the Altamaha River, Georgia. Georgia J. Sci. 42:97-108.
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Hydroacoustic data were recorded on VCR tapes and were analyzed using the Biosonics Corporation's (Seattle) 221 echo signal processor. The results of the analyses, including information on size frequency and numbers at each depth in each transect, were then converted to fish densities. Densities at each depth stratum within a transect were calculated by dividing the number of fish observed in the stratum by the cone-shaped volumes of water sampled (i.e., subtended by the echo impulse). Because of signal interference near the bottom and boat-avoidance by fish near the surface, the top one meter and bottom one meter of the water column were excluded from analysis.

In addition to community-level analyses, several population parameters were calculated. The coefficient of condition (K) was calculated for dominant species as follows:

$$K = \text{weight (g)} / \text{length}^3 \text{ (mm)} \times 100,000 \text{ (Lagler 1956).}$$

The index of stomach fullness, used to determine feeding intensity (Hyslop 1980), was calculated using the formula of Windell (1971):

$$\text{weight of stomach contents (g)} \times 100 / \text{weight of fish (g)}.$$

Frequency of occurrence (of stomachs with food, the percent of stomachs with a particular food item) was used to qualitatively characterize feeding habits for dominant taxa (Popova 1967; Hyslop 1980). The gonadosomatic index (Kaya and Hasler 1972) was calculated as follows:

$$\text{GSI} = \text{weight of gonads (g)} \times 100 / \text{weight of fish (g)}.$$

The size structures of dominant species were examined using length-frequency distributions based on the number of fish in successive 10-cm length

groups. When necessary, the number of fish in each length group < 90 mm was estimated by multiplying the total number of fish < 90 mm by the proportion of fish in each length group as determined by measurements made on subsamples (see Section 2.3.1).

Proportional stock density (PSD) for largemouth bass was calculated as the number of fish of quality length/number of fish of stock length $\times 100$ (Anderson 1976). Size limits for stock and quality fish were set at 200 mm and 300 mm respectively, as suggested by Gabelhouse (1984). Ninety-five percent confidence intervals for PSD were calculated using Table W of Rohlf and Sokal (1969) or the normal approximation described by Gustafson (1988). Largemouth bass PSD was shown to vary seasonally by Carline et al. (1984), due to differential vulnerability to collection of stock- and quality-sized fish. Carline et al. (1984) suggested that spring would be the most appropriate season to assess PSD based on the results of Houser and Rainwater (1975), so PSD was calculated based on May electrofishing collections at shoreline transects and artificial reefs. Growth rates were estimated from recaptured tagged fish by dividing the change in length by the time elapsed between marking and recovery.

A list of the common and scientific names of all fish species collected from L Lake during the course of this study is presented in Appendix Table 2. Discussion in this report focuses on Regions 5 and 7 due to changes in the sampling program.

3.0 RESULTS AND DISCUSSION

3.1 WATER QUALITY

L-Reactor did not operate during 1991 and there were no pronounced longitudinal gradients apparent in L Lake with respect to temperature, dissolved oxygen, or pH (Table 3-1). Historically, there have been differences in temperature of as much as 4 °C between the monthly mean temperatures in Regions 4 and 8 (see Figure 3-1 in Sayers et al. 1990). Quarterly mean temperatures during 1991 in Regions 5 and 7 of L Lake were similar to those reported for Regions 4, 6, and 8 in 1989 (Sayers et al. 1990) and for Regions 5 and 7 in 1990 (Sayers et al. 1991). Winter and spring mean temperatures during 1989, 1990, and 1991 were much lower than during years when L-Reactor was operating (1986-1988).

3.2 ADULT AND JUVENILE FISH

3.2.1 Electrofishing

3.2.1.1 100-m Shoreline Transects

Redbreast sunfish, coastal shiners, bluegills, and yellow perch were the most common fish collected at the shoreline electrofishing transects during 1991, with each species accounting for >10% of the total mean annual catch per unit effort (Table 3-2). Brook silversides and largemouth bass were also relatively common, contributing 6% and 8% of the total catch per unit effort (CPUE), respectively. The most notable changes between 1991 data and previous years are the dramatic decline in threadfin shad CPUE and the increase in the relative abundance of coastal shiners and yellow perch. Another notable change is that for the second consecutive year, annual mean CPUE for redbreast sunfish has exceeded that for bluegill. These two species accounted for a large proportion of the total CPUE in 1991 but not as large a proportion as in previous years.

Table 3-1. Quarterly mean, minimum (MIN), and maximum (MAX) temperature ($^{\circ}\text{C}$), dissolved oxygen (D.O. mg/L), and pH in Regions 5 and 7 of L Lake during 1991.

		<u>WINTER</u>		<u>SPRING</u>		<u>SUMMER</u>		<u>FALL</u>	
		<u>REGION</u>	<u>REGION</u>	<u>REGION</u>	<u>REGION</u>	<u>REGION</u>	<u>REGION</u>	<u>REGION</u>	<u>REGION</u>
		5	7	5	7	5	7	5	7
TEMPERATURE	MEAN	12.1	11.7	23.7	23.9	28.6	28.7	16.9	17.0
	MIN	11.7	9.4	23.0	22.9	28.1	27.8	16.1	16.1
	MAX	12.4	12.6	24.8	24.7	29.3	29.7	17.3	17.6
D. O.	MEAN	10.9	10.2	9.2	9.6	7.8	7.8	7.4	7.4
	MIN	10.1	7.6	8.5	8.9	7.4	7.2	6.6	6.2
	MAX	11.7	11.9	9.7	10.3	8.4	8.9	8.2	8.2
pH	MEAN	7.2	7.3	6.8	7.1	6.2	6.2	5.8	6.1
	MIN	6.5	6.7	6.6	6.3	5.9	5.9	5.3	5.2
	MAX	8.3	8.4	7.0	7.7	6.5	6.8	6.2	6.8

Table 3-2. Annual mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for each species from L Lake in 1991.

	REGION 5			REGION 7			ALL REGIONS		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.31	0.25	1.68	0.81	0.32	3.32	0.56	0.21	2.61
threadfin shad	0.69	0.62	3.69	0.44	0.32	1.79	0.56	0.34	2.61
coastal shiner	3.50	0.82	18.79	7.06	1.91	28.83	5.28	1.07	24.49
yellow bullhead	0.06	0.06	0.34	0.06	0.06	0.26	0.06	0.04	0.29
brook silverside	0.75	0.38	4.03	1.87	0.51	7.65	1.31	0.33	6.09
hybrid sunfish	0.13	0.09	0.67	0.06	0.06	0.26	0.09	0.05	0.43
redbreast sunfish	4.69	1.12	25.17	7.19	2.00	29.34	5.94	1.15	27.54
bluegill	3.94	1.16	21.14	3.62	1.04	14.80	3.78	0.77	17.54
largemouth bass	2.06	0.45	11.07	1.44	0.34	5.87	1.75	0.28	8.12
yellow perch	2.50	0.86	13.42	1.94	0.62	7.91	2.22	0.52	10.29
TOTAL	18.62	2.05	100.0	24.50	4.87	100.0	21.56	2.65	100.0

Mean annual CPUE was roughly one-third larger in Region 7 (24.5 fish/transect) than in Region 5 (18.6 fish/transect; Table 3-2) and a similar pattern was reported in 1990 (Sayers et al. 1991). However, there was no predictable pattern regarding spatial distribution of individual species. Mean CPUE in Region 5 exceeded CPUE in Region 7 for five of the ten taxa that were collected.

Detailed examination of the mean annual CPUE revealed moderately high variability among the various zones and regions. For example, annual total CPUE ranged from 7.5 to 17.8 fish/transect in the eastern zone of Region 7 versus a range of 27.8 to 45 fish/transect in the western zone of Region 7 (Table 3-3). For certain species, such as coastal shiner, variation within sampling region was very high. Variation within zone was also relatively large for several species (e.g., coastal shiners in the western zone of Region 5 or redbreast sunfish in the western zone of Region 7). Results from 1990 (Sayers et al. 1991) also indicated high spatial variation in annual CPUE.

In addition to the spatial variation described above, electrofishing catches also showed temporal variation. Mean quarterly total CPUE showed only limited variation in Region 5 (ranging from 14 fish/transect during spring to 21.5 fish/transect during fall) but variation in Region 7 catches was greater (ranging from 15.5 fish/transect during fall to 35.25 fish/transect during winter; Table 3-4). Quarterly mean total catches in 1991 were generally similar to or smaller than 1990 catches during summer and fall, while winter and spring catches were variable among the two years.

Table 3-3. Annual mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) at each shoreline electrofishing transect during 1991.

	ZONE E						ZONE W					
	REP A			REP B			REP A			REP B		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>REGION 5</u>												
gizzard shad	0.25	0.25	1.64	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	4.44
threadfin shad	0.25	0.25	1.64	0.00	0.00	0.00	0.00	0.00	0.00	2.50	2.50	11.11
coastal shiner	2.50	1.85	16.39	1.50	0.87	13.95	5.75	1.60	22.12	4.25	1.80	18.89
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.96	0.00	0.00	0.00
brook silverside	0.50	0.50	3.28	0.25	0.25	2.33	0.50	0.29	1.92	1.75	1.44	7.78
hybrid sunfish	0.00	0.00	0.00	0.25	0.25	2.33	0.25	0.25	0.96	0.00	0.00	0.00
redbreast sunfish	2.25	0.48	14.75	2.25	0.95	20.93	9.00	3.39	34.62	5.25	1.49	23.33
bluegill	4.25	0.75	27.87	3.00	0.41	27.91	7.25	4.27	27.88	1.25	1.25	5.56
largemouth bass	2.50	1.55	16.39	1.00	0.41	9.30	1.75	0.48	6.73	3.00	0.71	13.33
yellow perch	2.75	2.10	18.03	2.50	0.87	23.26	1.25	0.63	4.81	3.50	2.87	15.56
TOTAL	15.25	0.48	100.0	10.75	2.06	100.0	26.00	4.92	100.0	22.50	2.78	100.0
<u>REGION 7</u>												
gizzard shad	1.75	1.11	23.33	0.75	0.48	4.23	0.75	0.25	2.70	0.00	0.00	0.00
threadfin shad	0.50	0.29	6.67	1.25	1.25	7.04	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	0.25	0.25	3.33	3.50	2.02	19.72	10.00	5.12	36.04	14.50	1.19	32.22
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.56
brook silverside	1.25	0.48	16.67	1.50	1.50	8.45	2.00	0.41	7.21	2.75	1.44	6.11
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.56
redbreast sunfish	0.50	0.50	6.67	4.00	0.71	22.54	8.25	3.54	29.73	16.00	4.71	35.56
bluegill	1.50	0.65	20.00	2.50	0.96	14.08	3.25	0.48	11.71	7.25	3.73	16.11
largemouth bass	0.75	0.48	10.00	1.25	0.48	7.04	2.50	0.96	9.01	1.25	0.63	2.78
yellow perch	1.00	0.71	13.33	3.00	1.15	16.90	1.00	0.41	3.60	2.75	2.10	6.11
TOTAL	7.50	2.63	100.0	17.75	2.84	100.0	27.75	10.59	100.0	45.00	9.57	100.0

Table 3-4. Quarterly mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for shoreline electrofishing in Regions 5 and 7 of L Lake during 1991.

	WINTER						SPRING					
	REGION 5			REGION 7			REGION 5			REGION 7		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.25	0.25	1.30	0.25	0.25	0.71	1.00	1.00	7.14	2.00	1.08	7.08
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	2.75	2.43	19.64	1.50	1.19	5.31
coastal shiner	4.75	2.46	24.68	10.25	5.65	29.08	1.50	0.65	10.71	6.75	4.03	23.89
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	1.79	0.25	0.25	0.88
brook silverside	0.50	0.29	2.60	3.00	1.08	8.51	0.50	0.50	3.57	2.50	1.55	8.85
hybrid sunfish	0.25	0.25	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	4.25	1.38	22.08	9.75	5.07	27.66	2.75	1.11	19.64	9.75	6.25	34.51
bluegill	3.00	1.29	15.58	6.25	4.01	17.73	2.25	0.75	16.07	3.00	1.08	10.62
largemouth bass	1.25	0.48	6.49	1.50	1.19	4.26	3.00	1.35	21.43	1.75	0.48	6.19
yellow perch	5.00	2.42	25.97	4.25	1.80	12.06	0.00	0.00	0.00	0.75	0.25	2.65
TOTAL	19.25	4.50	100.0	35.25	14.59	100.0	14.00	2.94	100.0	28.25	11.09	100.0
	SUMMER						FALL					
	REGION 5			REGION 7			REGION 5			REGION 7		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.00	0.00	0.00	0.75	0.25	3.95	0.00	0.00	0.00	0.25	0.25	1.61
threadfin shad	0.00	0.00	0.00	0.25	0.25	1.32	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	2.75	1.03	13.92	6.00	3.46	31.58	5.00	1.78	23.26	5.25	2.78	33.87
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.25	0.25	1.27	1.00	0.41	5.26	1.75	1.44	8.14	1.00	0.58	6.45
hybrid sunfish	0.25	0.25	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	1.61
redbreast sunfish	8.50	3.86	43.04	5.50	1.32	28.95	3.25	0.48	15.12	3.75	2.06	24.19
bluegill	3.00	1.08	15.19	3.00	0.71	15.79	7.50	4.21	34.88	2.25	0.95	14.52
largemouth bass	1.75	0.48	8.86	1.00	0.41	5.26	2.25	1.11	10.47	1.50	0.65	9.68
yellow perch	3.25	2.02	16.46	1.50	0.50	7.89	1.75	0.48	3.14	1.25	1.25	8.06
TOTAL	19.75	3.42	100.0	19.00	4.04	100.0	21.50	5.74	100.0	15.50	6.44	100.0

Changes in quarterly CPUE and relative abundance were variable depending upon the species being examined. Catches per unit effort for coastal shiners were higher in winter than in spring for both Regions 5 and 7 but then remained largely unchanged for the remainder of 1991 (Table 3-4). Coastal shiners were absent from shoreline electrofishing catches in 1989 (Sayers et al. 1990) and were also relatively rare in winter and spring catches from 1990 (Sayers et al. 1991). The relatively large increase in cyprinid catches that was observed in late 1990 (Figure 3-1) was due largely to increased catches of coastal shiners. The 1991 data suggest that this species is forming a significant portion of the fish assemblage of L Lake.

Catches of redbreast sunfish fluctuated among season and sampling location, with summer providing the largest catches for Region 5 and winter or spring providing the largest catches for Region 7 (Table 3-4). Redbreast sunfish have been forming an increasingly larger proportion of shoreline electrofishing catches in recent years (Figures 3-1 and 3-2) and they now appear to form a larger portion of the total catch than bluegill.

Bluegill catches showed limited seasonal and spatial variation, although fall catches in Region 5 and winter catches in Region 7 were larger than the other sampling periods. During winter, this species accounted for 16 to 18% of the total catch (Table 3-4). Winter and spring catches were sharply lower but summer and fall catches were variable between 1990 and 1991. Catch rates for bluegill in 1991 were lower than those observed in 1990 for virtually all sampling periods in both regions (Figure 3-1). This continues a downward trend in bluegill CPUE that began in 1987 (Figure 3-2; Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990, 1991).

Figure 3-1. Mean quarterly CPUE (catch/transect) for selected species at shoreline electrofishing transects in Regions 5 and 7 of L. Lake during 1990 and 1991.

Figure 3-2. Mean monthly CPUE (catch/transect) for selected species at shoreline electrofishing transects in Regions 4, 6 and 8 of L Lake from 1986 through 1989.

Seasonal variation in CPUE was rather pronounced for yellow perch with catches ranging from 0 to 5.0 fish/transect in Region 5 and from 0.8 to 4.3 fish/transect in Region 7 (Table 3-4). Prior to 1990, yellow perch generally formed a minor portion of shoreline electrofishing catches (Paller et al. 1988; Heuer et al. 1989; Sayers 1990), but they began to form a modest portion of the total catch in late 1990 (Sayers et al. 1991).

Largemouth bass catches showed limited seasonal and spatial variation, with CPUE ranging from 1.25 to 3.0 fish/transect in Region 5 and from 1.0 to 1.75 fish/transect in Region 7 (Table 3-4). These catch rates are generally similar to those observed in 1990 (Figure 3-1), but particularly the spring catches are lower than those observed in earlier years for Regions 4, 6, and 8 (Figure 3-3).

Threadfin shad CPUE was at or near 0 fish/transect during winter, summer, and fall (Table 3-4). These low catch rates are very dissimilar from data collected in 1989 (Figure 3-2) and 1990 (see Table 3-3 in Sayers et al. 1991). Spring CPUE averaged 2.75 fish/transect in Region 5 and 1.5 fish/transect in Region 7, values generally similar to those observed in 1990 (Sayers et al. 1991) but substantially lower than spring catches from Region 4, 6, and 8 in 1989 (Figure 3-2; Sayers et al. 1990).

The extent of variation within sampling locations was dependent largely on the species being examined. Replicate catches within sampling zones were generally similar for some species, such as largemouth bass or brook silverside, but were highly variable for other species such as threadfin shad or coastal shiner (Table 3-5).

Figure 3-3. Mean monthly CPUE (catch/transect) for largemouth bass at shoreline electrofishing transects in Regions 4,6 and 8 of L Lake from 1986 through 1989.

Table 3-5. Quarterly catch per unit effort (CPUE) and relative abundance (%) at each shoreline electrofishing transect during 1991.

	ZONE E				ZONE W			
	REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Winter - Region 5</u>								
gizzard shad	1.00	7.14	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	1.00	7.14	0.00	0.00	9.00	39.13	9.00	30.00
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.00	1.00	4.35	1.00	3.33
hybrid sunfish	0.00	0.00	1.00	10.00	0.00	0.00	0.00	0.00
redbreast sunfish	3.00	21.43	1.00	10.00	7.00	30.43	6.00	20.00
bluegill	6.00	42.86	4.00	40.00	2.00	8.70	0.00	0.00
largemouth bass	2.00	14.29	0.00	0.00	1.00	4.35	2.00	6.67
yellow perch	1.00	7.14	4.00	40.00	3.00	13.04	12.00	40.00
TOTAL	14.00	100.00	10.00	100.00	23.00	100.00	30.00	100.00
<u>Region 7</u>								
gizzard shad	0.00	0.00	0.00	0.00	1.00	1.75	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	1.00	25.00	1.00	5.88	24.00	42.11	15.00	23.81
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	2.00	50.00	6.00	35.29	3.00	5.26	1.00	1.59
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	0.00	0.00	2.00	11.76	18.00	31.58	19.00	30.16
bluegill	0.00	0.00	3.00	17.65	4.00	7.02	18.00	28.57
largemouth bass	0.00	0.00	0.00	0.00	5.00	8.77	1.00	1.59
yellow perch	1.00	25.00	5.00	29.41	2.00	3.51	9.00	14.29
TOTAL	4.00	100.00	17.00	100.00	57.00	100.00	63.00	100.00

Table 3-5 (continued). Quarterly catch per unit effort (CPUE) and relative abundance (%) at each shoreline electrofishing transect during 1991.

	ZONE E				ZONE W			
	REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Spring - Region 5</u>								
gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	4.00	20.00
threadfin shad	1.00	6.25	0.00	0.00	0.00	0.00	10.00	50.00
coastal shiner	1.00	6.25	0.00	0.00	3.00	21.43	2.00	10.00
yellow bullhead	0.00	0.00	0.00	0.00	1.00	7.14	0.00	0.00
brook silverside	2.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	2.00	12.50	1.00	16.67	6.00	42.86	2.00	10.00
bluegill	3.00	18.75	3.00	50.00	3.00	21.43	0.00	0.00
largemouth bass	7.00	43.75	2.00	33.33	1.00	7.14	2.00	10.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	16.00	100.00	6.00	100.00	14.00	100.00	20.00	100.00
<u>Region 7</u>								
gizzard shad	5.00	41.67	2.00	14.29	1.00	3.70	0.00	0.00
threadfin shad	1.00	8.33	5.00	35.71	0.00	0.00	0.00	0.00
coastal shiner	0.00	0.00	0.00	0.00	11.00	40.74	16.00	26.67
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.67
brook silverside	2.00	16.67	0.00	0.00	1.00	3.70	7.00	11.67
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	0.00	0.00	4.00	28.57	7.00	25.93	28.00	46.67
bluegill	2.00	16.67	1.00	7.14	3.00	11.11	6.00	10.00
largemouth bass	2.00	16.67	1.00	7.14	3.00	11.11	1.00	1.67
yellow perch	0.00	0.00	1.00	7.14	1.00	3.70	1.00	1.67
TOTAL	12.00	100.00	14.00	100.00	27.00	100.00	60.00	100.00

Table 3-5 (continued). Quarterly catch per unit effort (CPUE) and relative abundance (%) at each shoreline electrofishing transect during 1991.

	ZONE E				ZONE W			
	REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Summer - Region 5</u>								
gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	0.00	0.00	3.00	18.75	3.00	10.00	5.00	29.41
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	1.00	6.25	0.00	0.00	0.00	0.00
hybrid sunfish	0.00	0.00	0.00	0.00	1.00	3.33	0.00	0.00
redbreast sunfish	1.00	6.25	5.00	31.25	19.00	63.33	9.00	52.94
bluegill	5.00	31.25	3.00	18.75	4.00	13.33	0.00	0.00
largemouth bass	1.00	6.25	1.00	6.25	2.00	6.67	3.00	17.65
yellow perch	9.00	56.25	3.00	18.75	1.00	3.33	0.00	0.00
TOTAL	16.00	100.00	16.00	100.00	30.00	100.00	17.00	100.00
<u>Region 7</u>								
gizzard shad	1.00	8.33	1.00	7.14	1.00	5.00	0.00	0.00
threadfin shad	1.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	0.00	0.00	4.00	28.57	4.00	20.00	16.00	53.33
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	1.00	8.33	0.00	0.00	2.00	10.00	1.00	3.33
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	2.00	16.67	5.00	35.71	7.00	35.00	8.00	26.67
bluegill	3.00	25.00	1.00	7.14	4.00	20.00	4.00	13.33
largemouth bass	1.00	8.33	2.00	14.29	1.00	5.00	0.00	0.00
yellow perch	3.00	25.00	1.00	7.14	1.00	5.00	1.00	3.33
TOTAL	12.00	100.00	14.00	100.00	20.00	100.00	30.00	100.00

Table 3-5 (continued). Quarterly catch per unit effort (CPUE) and relative abundance (%) at each shoreline electrofishing transect during 1991.

	ZONE E				ZONE W			
	REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Fall - Region 5</u>								
gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	8.00	53.33	3.00	27.27	8.00	21.62	1.00	4.35
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.00	1.00	2.70	6.00	26.09
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	3.00	20.00	2.00	18.18	4.00	10.81	4.00	17.39
bluegill	3.00	20.00	2.00	18.18	20.00	54.05	5.00	21.74
largemouth bass	0.00	0.00	1.00	9.09	3.00	8.11	5.00	21.74
yellow perch	1.00	6.67	3.00	27.27	1.00	2.70	2.00	8.70
TOTAL	15.00	100.00	11.00	100.00	37.00	100.00	23.00	100.00
<u>Region 7</u>								
gizzard shad	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	0.00	0.00	9.00	34.62	1.00	14.29	11.00	40.74
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.00	2.00	28.57	2.00	7.41
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3.70
redbreast sunfish	0.00	0.00	5.00	19.23	1.00	14.29	9.00	33.33
bluegill	1.00	50.00	5.00	19.23	2.00	28.57	1.00	3.70
largemouth bass	0.00	0.00	2.00	7.69	1.00	14.29	3.00	11.11
yellow perch	0.00	0.00	5.00	19.23	0.00	0.00	0.00	0.00
TOTAL	2.00	100.00	26.00	100.00	7.00	100.00	27.00	100.00

3.2.1.2 Artificial Reefs

Annual mean CPUE at artificial reefs showed moderate variation among the reef types. Mean total CPUE was greatest at block piles (7.4 fish/min), intermediate at wood piles (4.6 fish/min), and lowest at tire piles (1.3 fish/min; Table 3-6). Redbreast sunfish was the most abundant species at block piles based on CPUE, accounting for 71% of the total catch. Bluegills and largemouth bass were also relatively common at block piles, respectively forming 9% and 8% of the total catch. Gizzard shad, threadfin shad, coastal shiners, flat bullheads, brook silversides, and warmouths all formed relatively minor portions (1-3%) of the total catch. Total CPUE at block piles in 1991 increased slightly from 1990 (5.6 fish/min; Sayers et al. 1991), but was still well below the values observed in 1988 (22.6 fish/min; Heuer et al. 1989) and 1989 (18.4 fish/min; Sayers et al. 1990). Relative abundance of threadfin shad declined from 20% in 1990 to 3% in 1991; however, relative abundance of redbreast sunfish increased from 50% in 1990 to 71% in 1991.

Redbreast sunfish was also the most abundant species at wood piles, forming 51% of the total catch (Table 3-6). Largemouth bass, bluegills, gizzard shad, and brook silversides were also relatively common, each forming at least 5% of the total catch. Total CPUE at wood piles in 1991 (4.6 fish/min) was similar to 1990 (4.9 fish/min; Sayers et al. 1991), but threadfin shad formed a much smaller portion of the catch in 1991 (< 1%) than in 1990 (16%; Sayers et al. 1991) and redbreast sunfish were relatively more abundant in 1991. Wood pile catch rates in 1990 and 1991 were considerably lower than those observed in 1989 (9.7 fish/min; Sayers et al. 1990) or 1988 (11.1 fish/min; Heuer et al. 1989).

Table 3-6. Annual mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for each species at each type of artificial reef in L Lake during 1991.

	BLOCK PILES			TIRE PILES			WOOD PILES		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.12	0.06	1.67	0.04	0.04	2.74	0.27	0.13	5.93
threadfin shad	0.23	0.13	3.16	0.10	0.05	7.25	0.03	0.03	0.64
coastal shiner	0.13	0.11	1.71	0.15	0.09	11.56	0.00	0.00	0.00
snail bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.62
flat bullhead	0.15	0.06	2.04	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.20	0.09	2.74	0.13	0.06	9.91	0.27	0.14	5.80
hybrid sunfish	0.02	0.02	0.22	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	5.27	2.67	71.29	0.28	0.15	20.94	2.34	0.80	51.21
warmouth	0.05	0.04	0.67	0.03	0.03	2.64	0.09	0.06	2.01
bluegill	0.64	0.32	8.67	0.10	0.06	7.81	0.68	0.30	14.90
redear sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.34
largemouth bass	0.58	0.15	7.82	0.36	0.12	27.45	0.85	0.28	18.55
yellow perch	0.00	0.00	0.00	0.13	0.11	9.71	0.00	0.00	0.00
TOTAL	7.40	2.97	100.0	1.32	0.28	100.0	4.58	1.29	100.0

Total annual CPUE at tire piles in 1991 was 1.3 fish/min, with largemouth bass, redbreast sunfish, and coastal shiners forming most of the total (Table 3-6). The low catch rate at tire piles is probably due in part to deterioration of the reefs. Coastal shiners and largemouth bass were proportionally more abundant while threadfin shad were less abundant in 1991 than previous years, but the low overall catch rates preclude drawing any strong conclusions about changes in species distribution at the tire piles. The sharp decline in total CPUE at tire piles from 1988 (16.7 fish/min; Heuer et al. 1989) and 1989 levels (11.2 fish/min; Sayers et al. 1990) could be due in part to lower fish production on the reefs in Regions 5 and 7 compared to the other regions. The relatively large standard deviations reported for annual means in 1988 and 1989 suggest that CPUE was variable among the regions. However, this reduction has been concurrent with a general reduction in CPUE among the other L-Lake fish sampling programs, suggesting that the decline is largely due to reduced fish abundance throughout the lake.

Spatial variation in total CPUE at artificial reefs was generally low during 1991. Catches at artificial reefs in Region 5 and 7 were generally similar for each reef type (Table 3-7). However, total CPUE at block piles during fall did differ dramatically (25.2 fish/min in Region 5 versus 2.9 fish/min in Region 7). Spatial variation at wood piles cannot be addressed under the current scope of sampling because no wood piles are located in Region 5.

Temporal variation in total CPUE at artificial reefs was relatively small for tire piles, ranging from 0.6 to 1.7 fish/min in Region 5 and from 0.9 to 2.2 fish/min in Region 7 (Table 3-7). However, variation in total CPUE was more pronounced at the block and wood piles. Fall catches were substantially larger

Table 3-7. Quarterly mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) at artificial reefs in Regions 5 and 7 of L Lake during 1991.

	BLOCK PILES						TIRE PILES						WOOD PILES		
	REGION 5			REGION 7			REGION 5			REGION 7			REGION 7		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Winter</u>															
gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
snail bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
flat bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.50	0.24	5.25	0.00	0.00	0.00	0.29	0.29	14.88	0.00	0.00	0.00
hybrid sunfish	0.13	0.13	1.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	5.84	5.84	81.38	8.17	8.17	86.08	0.59	0.59	33.77	0.28	0.28	14.05	2.13	0.86	76.65
warmouth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	14.05	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	0.26	0.26	2.69	0.29	0.29	16.56	0.29	0.29	14.88	0.39	0.26	14.03
redear sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	1.20	0.92	16.77	0.57	0.20	5.99	0.87	0.87	49.68	0.00	0.00	0.00	0.26	0.18	9.32
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.83	42.15	0.00	0.00	0.00
TOTAL	7.18	6.89	100.0	9.49	8.38	100.0	1.74	0.57	100.0	1.98	0.80	100.0	2.78	1.00	100.0
<u>Spring</u>															
gizzard shad	0.27	0.27	4.79	0.59	0.29	11.14	0.00	0.00	0.00	0.29	0.29	25.59	0.91	0.31	23.34
threadfin shad	1.31	0.78	23.43	0.29	0.00	5.56	0.58	0.00	49.88	0.00	0.00	0.00	0.12	0.12	2.97
coastal shiner	0.00	0.00	0.00	0.88	0.88	16.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
snail bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.11	2.90
flat bullhead	0.40	0.40	7.18	0.29	0.29	5.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.40	0.40	7.18	0.59	0.59	11.15	0.29	0.29	25.06	0.28	0.28	24.41	0.50	0.34	12.67
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	2.14	2.14	38.29	1.90	1.90	36.07	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.62	23.83
warmouth	0.27	0.27	4.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	0.54	0.54	9.57	0.29	0.29	5.55	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.25	12.73
redear sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	0.27	0.27	4.79	0.44	0.44	8.32	0.29	0.29	25.06	0.56	0.01	50.00	0.84	0.62	21.56
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	5.60	3.51	100.0	5.27	2.92	100.0	1.16	0.59	100.0	1.13	0.03	100.0	3.92	0.91	100.0

Table 3-7 (continued). Quarterly mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) at artificial reefs in Regions 5 and 7 of L Lake during 1991.

	BLOCK PILES						TIRE PILES						WOOD PILES		
	REGION 5			REGION 7			REGION 5			REGION 7			REGION 7		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Summer</u>															
gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.09	6.64
threadfin shad	0.27	0.27	12.81	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	20.00	0.00	0.00	0.00
coastal shiner	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.37	40.00	0.00	0.00	0.00
snail bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
flat bullhead	0.14	0.14	6.76	0.24	0.24	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.13	0.13	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	20.00	0.12	0.12	4.82
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	0.98	0.98	47.34	0.24	0.24	16.67	0.00	0.00	0.00	0.00	0.00	0.00	1.26	1.15	48.79
warmouth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	0.96	0.96	66.67	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	9.65
redeer sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	2.41
largemouth bass	0.55	0.29	26.69	0.00	0.00	0.00	0.44	0.06	69.75	0.18	0.18	20.00	0.72	0.30	27.68
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	30.25	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	2.07	1.01	100.0	1.44	1.44	100.0	0.63	0.13	100.0	0.92	0.92	100.0	2.58	1.44	100.0
<u>Fall</u>															
gizzard shad	0.14	0.14	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
coastal shiner	0.13	0.13	0.52	0.00	0.00	0.00	0.30	0.30	38.46	0.55	0.55	25.00	0.00	0.00	0.00
snail bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
flat bullhead	0.14	0.14	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.44	4.87
hybrid sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	20.57	20.57	81.62	2.34	2.34	80.00	0.24	0.24	30.77	1.10	1.10	50.00	5.05	2.52	55.95
warmouth	0.13	0.13	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.20	4.09
bluegill	2.89	2.08	11.49	0.19	0.19	6.67	0.24	0.24	30.77	0.00	0.00	0.00	1.59	1.09	17.61
redeer sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	1.20	0.42	4.78	0.39	0.39	13.33	0.00	0.00	0.00	0.55	0.55	25.00	1.58	0.88	17.48
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	25.20	22.23	100.0	2.92	2.92	100.0	0.78	0.18	100.0	2.20	2.20	100.0	9.02	4.33	100.0

than the other seasons at block piles (particularly in Region 5) and wood piles, while summer catches were typically lower than winter or spring catches. The reduced summer catches are probably related to high water temperatures, as the artificial reefs are located in shallow water. The 1991 seasonal pattern does not resemble the 1990 distribution of artificial reef catches and probably reflects random variation.

3.2.2 Hoop Netting

Gizzard shad and largemouth bass were the only species of fish collected during 1991 hoop net sampling in L Lake (Table 3-8). The total number of species collected in hoop nets has declined dramatically from 1988 and 1989 levels and is probably related to the reduced scope of sampling employed in 1990 and 1991. Prior to 1990, 480 to 720 hoop net samples were collected per year in L Lake (Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990), versus 32 samples per year in 1990 and 1991.

Catch rates for largemouth bass have typically averaged 0-0.01 fish/net/day prior to 1991, but increased to 0.03 fish/net/day in 1991 (Table 3-8). This increase may be insignificant given the reduced scope of sampling. Hoop net catch rates for gizzard shad in 1991 (0.03-0.06 fish/net/day) were similar to values reported in previous years (Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990, 1991).

Seasonal variation in quarterly CPUE for hoop nets was generally small, but the extent of such variation is greatly affected by the low catch rates and small number of samples collected. No fish were collected during winter or fall samples and spring and summer collections yielded catch rates of 0.19 and 0.13

Table 3-8. Annual mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (Z) for each species in hoop nets in Regions 5 and 7 of L Lake during 1991.

	REGION 5			REGION 7			ALL REGIONS		
	CPUE	S.E.	Z	CPUE	S.E.	Z	CPUE	S.E.	Z
gizzard shad	0.06	0.06	66.67	0.03	0.03	50.00	0.05	0.03	60.00
largemouth bass	0.03	0.03	33.33	0.03	0.03	50.00	0.03	0.02	40.00
TOTAL	0.09	0.07	100.0	0.06	0.04	100.0	0.08	0.04	100.0

fish/net/day, respectively (Table 3-9). Catch rates for largemouth bass were equal during spring and summer but gizzard shad CPUE was slightly higher during spring. The 1991 pattern of seasonal variation was very different from that observed in 1990, when catch rates were highest during winter (Figure 3-4). Historically, hoop net catches have been highest during spring and summer in Lake (Figure 3-5) with bluegills forming the majority of the catch.

There was relatively little spatial variation in hoop net catch rates during 1991, due largely to the very low rates. Catches were typically zero in at least one of the two regions (Table 3-10), but because of the low CPUEs the net difference between regions was generally small. Historically, spatial variation in hoop net catches was small, with bluegills being the most common species in all regions. The absence of bluegills and other species that were commonly collected in hoop nets suggests a general reduction in abundance of these species. However, this conclusion is weakly supported due to the combined effects of a greatly reduced scope of sampling and the typically low catch rates associated with this gear type. The high proportion of hoop net samples with zero catch (Table 3-11) suggests that this gear type may not be particularly useful under the reduced scope of sampling that was employed in 1990 and 1991.

3.2.3 Midwater Trawling

Mean monthly catch per unit effort (fish/tow) was quite variable and generally low for midwater trawl samples; however, average rates did exceed 20 fish/tow during July 1991 (Figure 3-6). Virtually all fish collected in midwater trawl samples were threadfin shad, although two black crappies and one brook silverside were also collected (see Appendix Table 3 for a complete listing of individual trawl catches). Trawl catches were quite variable from month to month

Table 3-9. Quarterly mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for each species in hoop net collections from L Lake during 1991.

	WINTER			SPRING			SUMMER			FALL		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.00	0.00	.	0.13	0.13	66.67	0.06	0.06	50.00	0.00	0.00	.
largemouth bass	0.00	0.00	.	0.06	0.06	33.33	0.06	0.06	50.00	0.00	0.00	.
TOTAL	0.00	0.00	.	0.19	0.13	100.0	0.13	0.08	100.0	0.00	0.00	.

Figure 3-4. Mean quarterly CPUE (catch/net/day) for selected species in hoop nets in Regions 5 and 7 of L Lake during 1990 and 1991.

Figure 3-5. Mean monthly CPUE (catch/net/day) for selected species in hoop nets in Regions 4, 6 and 8 of L Lake from 1986 through 1989.

Table 3-10. Quarterly mean catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for hoop nets in Regions 5 and 7 of L Lake during 1991.

	WINTER						SPRING					
	REGION 5			REGION 7			REGION 5			REGION 7		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.00	0.00	.	0.00	0.00	.	0.25	0.25	100.0	0.00	0.00	0.00
largemouth bass	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00	0.13	0.13	100.0
TOTAL	0.00	0.00	.	0.00	0.00	.	0.25	0.25	100.0	0.13	0.13	100.0

	SUMMER						FALL					
	REGION 5			REGION 7			REGION 5			REGION 7		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
gizzard shad	0.00	0.00	0.00	0.13	0.13	100.0	0.00	0.00	.	0.00	0.00	.
largemouth bass	0.13	0.13	100.0	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.
TOTAL	0.13	0.13	100.0	0.13	0.13	100.0	0.00	0.00	.	0.00	0.00	.

Table 3-11. Quarterly catch per unit effort (CPUE) and relative abundance (%) for each species in hoop net samples collected from L Lake during 1991.

	ZONE E				ZONE W			
	REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Winter - Region 5</u>								
gizzard shad	0.00	.	0.00	.	0.00	.	0.00	.
largemouth bass	0.00	.	0.00	.	0.00	.	0.00	.
TOTAL	0.00	.	0.00	.	0.00	.	0.00	.
<u>Winter - Region 7</u>								
gizzard shad	0.00	.	0.00	.	0.00	.	0.00	.
largemouth bass	0.00	.	0.00	.	0.00	.	0.00	.
TOTAL	0.00	.	0.00	.	0.00	.	0.00	.
<u>Spring - Region 5</u>								
gizzard shad	0.00	.	0.00	.	1.00	100.00	0.00	.
largemouth bass	0.00	.	0.00	.	0.00	0.00	0.00	.
TOTAL	0.00	.	0.00	.	1.00	100.00	0.00	.
<u>Spring - Region 7</u>								
gizzard shad	0.00	0.00	0.00	.	0.00	.	0.00	.
largemouth bass	0.50	100.00	0.00	.	0.00	.	0.00	.
TOTAL	0.50	100.00	0.00	.	0.00	.	0.00	.
<u>Summer - Region 5</u>								
gizzard shad	0.00	.	0.00	.	0.00	.	0.00	0.00
largemouth bass	0.00	.	0.00	.	0.00	.	0.50	100.00
TOTAL	0.00	.	0.00	.	0.00	.	0.50	100.00

Table 3-11 (continued). Quarterly catch per unit effort (CPUE) and relative abundance (%) for each species in hoop net samples collected from L Lake during 1991.

	ZONE E				ZONE W			
	REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Summer - Region 7</u>								
gizzard shad	0.00	.	0.00	.	0.00	.	0.50	100.00
largemouth bass	0.00	.	0.00	.	0.00	.	0.00	0.00
TOTAL	0.00	.	0.00	.	0.00	.	0.50	100.00
<u>Fall - Region 5</u>								
gizzard shad	0.00	.	0.00	.	0.00	.	0.00	.
largemouth bass	0.00	.	0.00	.	0.00	.	0.00	.
TOTAL	0.00	.	0.00	.	0.00	.	0.00	.
<u>Fall - Region 7</u>								
gizzard shad	0.00	.	0.00	.	0.00	.	0.00	.
largemouth bass	0.00	.	0.00	.	0.00	.	0.00	.
TOTAL	0.00	.	0.00	.	0.00	.	0.00	.

Figure 3-6. Mean monthly CPUE (catch/tow) for bluegill and threadfin shad in midwater trawls from Regions 5 and 7 of L. Lake during 1991.

(Figure 3-6) and also varied among regions, with monthly regional CPUE ranging from 0.0 fish/tow to 44.5 fish/tow during June in Region 3 (Table 3-12). The predominance of threadfin shad in 1991 trawl catches (Figure 3-7) was similar to results from 1989 (Sayers et al. 1990) and 1990 (Sayers et al. 1991). Winter (January through March) and spring (April through June) trawl catches in Regions 5 and 7 were generally higher in 1991 than the quarterly averages reported for 1990 by Sayers et al. (1991). However, summer (July through September) trawl catches were considerably lower in 1991 than in 1990, and fall catch rates were similar both years. These results suggest that threadfin shad abundance declined in 1991, however, this could be an artifact due to comparing two different sampling methods (ten tows per region were collected only in Regions 5 and 7 during 1990 versus two or three tows per region for Regions 2 through 8 in 1991).

3.2.4 Hydroacoustics

False targets produced by uncut trees were eliminated using criteria described by Paller et al. (1988) and Heuer et al. (1989). Prior to 1990, analysis was limited to ten transects located in Regions 4-8. After 1990, sixteen transects located in Regions 2-8 were used in data analysis.

The lakewide monthly average fish target densities observed during 1991 followed seasonal patterns similar to previous years (Figure 3-8). Densities were typically low in winter, increased rapidly over the spring months to a sharp peak in mid-summer, then declined in the fall. Peak density in August 1991 was lower than peak densities recorded in the summers of 1987 to 1990. Overall, there was a reduction in fish densities during 1991 as compared to previous years.

Table 3-12. Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of L Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 2</u>												
threadfin shad	0.00	0.00	.	0.33	0.33	100.0	1.00	1.00	100.0	0.00	0.00	.
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
black crappie	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
TOTAL	0.00	0.00	.	0.33	0.33	100.0	1.00	1.00	100.0	0.00	0.00	.
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
threadfin shad	0.00	0.00	.	30.33	18.56	98.91	8.00	1.53	100.0	29.00	2.65	100.0
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.33	0.33	1.09	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	30.67	18.35	100.0	8.00	1.53	100.0	29.00	2.65	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
threadfin shad	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
brook silverside	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
black crappie	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
TOTAL	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.

Table 3-12 (continued). Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of L Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 3</u>												
threadfin shad	0.50	0.50	100.0	3.00	0.00	100.0	2.00	2.00	100.0	0.50	0.50	100.0
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.50	0.50	100.0	3.00	0.00	100.0	2.00	2.00	100.0	0.50	0.50	100.0
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
threadfin shad	0.00	0.00	.	44.50	0.50	100.0	14.50	5.50	100.0	14.00	5.00	100.0
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	44.50	0.50	100.0	14.50	5.50	100.0	14.00	5.00	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
threadfin shad	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
brook silverside	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
black crappie	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
TOTAL	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.

Table 3-12 (continued). Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 4</u>												
threadfin shad	2.00	1.15	100.0	1.00	0.58	100.0	4.33	1.20	100.0	0.33	0.33	100.0
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	2.00	1.15	100.0	1.00	0.58	100.0	4.33	1.20	100.0	0.33	0.33	100.0
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
threadfin shad	0.00	0.00	.	19.00	7.94	98.28	2.33	1.20	100.0	3.67	1.76	100.0
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.33	0.33	1.72	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	19.33	7.69	100.0	2.33	1.20	100.0	3.67	1.76	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
threadfin shad	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
brook silverside	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
black crappie	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
TOTAL	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.

Table 3-12 (continued). Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of L Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 5</u>												
threadfin shad	3.67	1.86	100.0	2.67	1.67	100.0	3.00	2.52	100.0	0.00	0.00	.
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
black crappie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
TOTAL	3.67	1.86	100.0	2.67	1.67	100.0	3.00	2.52	100.0	0.00	0.00	.
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
threadfin shad	0.00	0.00	.	25.67	14.17	100.0	2.67	0.88	100.0	7.67	0.33	100.0
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	25.67	14.17	100.0	2.67	0.88	100.0	7.67	0.33	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
threadfin shad	0.33	0.33	100.0	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
brook silverside	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
black crappie	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
TOTAL	0.33	0.33	100.0	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.

Table 3-12 (continued). Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of L Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 6</u>												
threadfin shad	2.67	0.67	100.0	0.67	0.67	100.0	0.00	0.00	.	0.00	0.00	.
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.
black crappie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.
TOTAL	2.67	0.67	100.0	0.67	0.67	100.0	0.00	0.00	.	0.00	0.00	.
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
treadfin shad	0.00	0.00	.	19.00	3.21	100.0	11.33	1.45	100.0	3.00	1.53	100.0
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	19.00	3.21	100.0	11.33	1.45	100.0	3.00	1.53	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
threadfin shad	0.00	0.00	.	0.00	0.00	.	0.33	0.33	100.0	0.00	0.00	.
brook silverside	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	.
black crappie	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	.
TOTAL	0.00	0.00	.	0.00	0.00	.	0.33	0.33	100.0	0.00	0.00	.

Table 3-12 (continued). Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of L Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 7</u>												
threadfin shad	4.67	0.88	100.0	0.00	0.00	.	0.33	0.33	100.0	1.00	0.00	100.0
brook silverside	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	4.67	0.88	100.0	0.00	0.00	.	0.33	0.33	100.0	1.00	0.00	100.0
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
threadfin shad	0.00	0.00	.	8.00	2.52	96.0	9.00	3.79	100.0	0.33	0.33	100.0
brook silverside	0.00	0.00	.	0.33	0.33	4.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	8.33	2.67	100.0	9.00	3.79	100.0	0.33	0.33	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
threadfin shad	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.33	0.33	100.0
brook silverside	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00
TOTAL	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.33	0.33	100.0

Table 3-12 (continued). Mean monthly catch per unit effort (CPUE), standard error (S.E.), and relative abundance (%) for midwater trawl samples from Regions 2 through 8 of L Lake collected during 1991.

	<u>JAN</u>			<u>FEB</u>			<u>MAR</u>			<u>APR</u>		
	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%	CPUE	S.E.	%
<u>Region 8</u>												
threadfin shad	1.67	1.20	100.0	0.00	0.00	.	0.00	0.00	.	1.00	0.58	100.0
brook silverside	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00	.	0.00	0.00	.	0.00	0.00	0.00
TOTAL	1.67	1.20	100.0	0.00	0.00	.	0.00	0.00	.	1.00	0.58	100.0
	<u>MAY</u>			<u>JUN</u>			<u>JUL</u>			<u>AUG</u>		
threadfin shad	0.00	0.00	.	5.00	1.53	100.0	0.33	0.33	100.0	0.33	0.33	100.0
brook silverside	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	.	5.00	1.53	100.0	0.33	0.33	100.0	0.33	0.33	100.0
	<u>SEP</u>			<u>OCT</u>			<u>NOV</u>			<u>DEC</u>		
threadfin shad	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
brook silverside	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
black crappie	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.
TOTAL	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.	0.00	0.00	.

Figure 3-7. Mean percent composition of monthly trawl samples collected during 1991 in L. Lake (number above bars indicates the total number of fish collected).

TARGET DENSITIES 1986 - 1991

Figure 3-8. Average target density for L Lake as determined by echolocation.
January 1986-December 1991.

Monthly target density by region (Table 3-13) showed considerable variation among regions and months during 1991. Highest target densities for individual regions did not consistently follow patterns observed in previous years. Monthly peak densities for each region were as follows: Regions 2, 3, and 5 - August; Region 4 - February; Region 6 - June; Region 7 - April; and Region 8 - September. The higher densities observed in Region 4 during February are consistent with previous years, again indicating the use of this area as a staging and spawning area. Due to the reduced abundance of fish in 1991, large schools of fish moving up and down the lake could greatly influence density estimates for any given region during any given month. Densities by transect and month are presented in Appendix Table 4.

Smaller size class groupings were again used in analyzing the 1991 data to more accurately detect growth based on hydroacoustic data. Growth was indicated by shifts in the percentage composition of size classes over time. Slight shifts were observed in 1991 indicating fish growth during the year. Overall, 1.1% of the targets were estimated to represent fish between 10 and 49 mm total length (TL); 84.2% of the targets represented intermediate-sized fish (50 to 149 mm TL); and 14.6% of the targets represented fish greater than 150 mm TL (Table 3-14). The increase in percentage composition of intermediate and adult fish was first documented in 1989 and has continued through 1991. These shifts again indicate that L Lake is maturing to a system not dominated by young-of-the year fish.

Ground truthing was used to determine species identification of targets and was accomplished using gill nets and midwater trawls. A total of 241 fish, representing 6 species (Table 3-15), were collected in 45.42 hours of gill net sets. This represents a reduction in the number of fish and species collected

Table 3-13. Echolocation target densities (no./1000 m³) in Regions 4-8 of L Lake. January 1986-December 1989. Regions 2-8. January 1990-December 1991.

Month	Region					Ave. lake density
	4	5	6	7	8	
<u>1986</u>						
Jan	13.67	10.54	7.60	9.77	9.27	10.17
Feb	2.04	2.23	2.90	1.47	1.41	2.01
Mar	4.13	3.65	2.70	2.60	2.50	3.12
Apr	1.69	3.26	3.17	2.21	1.65	2.40
May	4.10	4.18	3.57	1.85	2.84	3.31
Jun	4.28	4.92	2.55	4.33	2.22	3.66
Jul	10.27	8.47	12.59	6.79	4.31	8.49
Aug	7.89	8.16	6.19	6.17	6.70	7.02
Sep	5.56	6.17	6.12	4.87	5.94	5.73
Oct	2.56	2.92	2.64	1.81	2.21	2.43
Nov	3.29	2.94	3.26	1.75	1.88	2.62
Dec	2.52	2.88	2.56	2.91	1.28	2.43
Mean yearly density	5.17	5.03	4.65	3.88	3.52	4.45
<u>1987</u>						
Jan	1.12	1.02	0.39	0.73	0.57	0.77
Feb	1.04	1.55	2.33	1.54	1.51	1.59
Mar	14.29	10.41	13.18	0.82	0.00	7.74
Apr	16.95	8.06	13.56	8.82	7.21	10.92
May	18.31	12.07	11.16	10.08	8.88	12.10
Jun	19.05	15.92	26.57	14.04	16.71	18.46
Jul	21.26	21.81	23.15	15.28	26.32	21.56
Aug	32.47	36.76	46.31	39.26	54.52	41.86
Sep	19.84	18.43	23.96	27.93	54.75	28.98
Oct	19.64	9.28	8.05	8.52	14.00	11.90
Nov	25.86	10.35	14.17	7.90	7.46	13.15
Dec	24.58	10.84	8.53	13.94	14.50	14.48
Mean yearly density	17.87	13.04	15.95	12.41	17.20	15.29

Table 3-13 (continued). Echolocation target densities (no./1000 m³) in Regions 4-8 of L Lake. January 1986-December 1989. Regions 2-8 January 1990-December 1991.

Month	Region					Ave. lake density
	4	5	6	7	8	
<u>1988</u>						
Jan	16.27	5.77	7.53	9.17	28.96	13.54
Feb	14.45	14.51	59.57	33.77	24.87	29.43
Mar	6.74	4.44	4.77	5.49	15.13	7.31
Apr	100.87	15.23	27.85	13.15	6.37	32.69
May	33.37	50.23	36.99	24.43	108.77	50.76
Jun	35.75	40.01	85.16	40.94	72.92	54.96
Jul	51.60	35.63	101.45	54.24	121.89	72.96
Aug	38.56	28.92	35.72	37.67	58.47	39.87
Sep	36.91	19.36	8.25	21.43	26.56	22.50
Oct	3.88	2.08	3.15	6.32	14.73	6.03
Nov	12.77	6.20	2.85	7.56	6.92	7.26
Dec	31.25	7.36	14.23	20.38	16.20	17.88
Mean yearly density	31.87	19.15	32.29	22.88	41.82	29.60
<u>1989</u>						
Jan	68.83	32.23	14.84	28.21	24.39	33.70
Feb	19.08	15.43	24.55	16.61	15.18	18.17
Mar	5.41	5.55	17.83	64.97	22.28	23.21
Apr	35.56	11.22	61.60	47.37	45.84	40.32
May	60.22	37.57	36.95	24.73	26.38	37.17
Jun	58.90	63.50	76.72	58.94	97.22	71.06
Jul	25.77	30.12	27.51	34.45	29.83	29.54
Aug	33.52	32.76	43.82	40.12	45.42	39.13
Sep	29.59	25.89	44.18	44.40	63.38	41.49
Oct	22.29	14.30	18.92	21.93	14.15	18.32
Nov	14.83	8.16	6.28	15.87	6.81	10.39
Dec	4.61	a	5.85	5.68	3.94	5.02
Mean yearly density	31.55	25.16	31.59	33.61	32.91	30.63 ^b

Table 3-13 (continued). Echolocation target densities (no./1000 m³) in Regions 4-8 of L Lake. January 1986-December 1989. Regions 2-8 January 1990-December 1991.

Month	Region							Ave. lake density
	2	3	4	5	6	7	8	
<u>1990</u>								
Jan	0.24	22.96	51.05	18.20	9.20	19.34	8.51	18.50
Feb	0.90	3.10	13.00	11.06	30.58	16.10	3.37	11.16
Mar	3.45	5.27	21.18	16.87	9.25	13.37	3.72	10.44
Apr	13.57	30.14	69.02	25.22	31.53	31.14	27.59	32.60
May	24.11	12.39	20.49	15.89	16.90	16.42	14.85	17.29
Jun	11.12	20.40	28.80	36.02	45.51	22.26	39.63	29.10
Jul	39.88	68.79	62.16	62.41	63.43	40.34	53.71	55.82
Aug	14.77	19.68	18.31	9.47	13.12	14.06	36.50	17.99
Sep	22.62	16.91	18.52	12.35	22.77	18.74	21.60	19.07
Oct	14.18	20.83	24.00	14.42	10.59	15.57	22.54	17.45
Nov	7.53	11.54	5.57	3.25	5.10	3.23	8.62	6.41
Dec	8.75	5.31	15.76	12.70	9.82	7.10	3.34	8.97
Mean Yearly Density	13.43	19.78	28.99	19.82	22.32	18.14	20.33	20.40
<u>1991</u>								
Jan	1.18	2.31	6.83	15.79	24.35	13.06	13.98	11.07
Feb	1.32	11.53	44.67	19.70	14.49	9.78	2.57	14.87
Mar	2.63	7.25	13.44	16.95	9.23	0.98	0.75	7.32
Apr	4.07	6.39	12.72	13.40	16.00	24.71	20.07	13.91
May	8.52	9.62	14.62	12.19	12.88	13.50	13.24	12.08
Jun	2.40	2.88	4.40	8.56	30.78	22.39	19.13	12.94
Jul	11.90	8.55	11.44	15.93	20.02	23.86	20.83	16.08
Aug	39.11	31.10	25.13	29.83	23.89	18.96	25.14	27.59
Sep	3.11	7.14	15.66	12.55	14.00	13.89	25.23	13.08
Oct	3.55	2.93	2.65	3.90	3.15	2.41	1.75	2.91
Nov	2.10	1.41	1.64	1.71	1.44	2.25	0.79	1.62
Dec	1.74	2.88	1.58	2.01	6.22	8.03	1.18	3.38
Mean Yearly Density	6.80	7.83	12.90	12.71	14.70	12.82	12.06	11.40

*Missing data due to defective VCR tape.

^bDue to a missing sample the mean average lake density presented differs slightly from the average mean yearly density, which is 30.96 targets/1000 m³.

Table 3-14. Length-frequency distribution (%) of fish targets as determined by echolocation sampling on L Lake. January-December 1991.

Length (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
10 - 19	0	0	0	0	0	0	0	0	0	0	0	0	0
20 - 29	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 39	0	0	0	0	0	0	0	0	0	0	0	0	0
40 - 49	0.4	0.2	0.8	0.5	0.7	1.3	2.5	0.8	2.4	5.0	2.1	1.7	1.1
50 - 59	4.5	4.9	4.2	8.0	7.0	12.1	11.2	10.2	9.6	10.2	8.5	9.1	8.2
60 - 79	12.4	10.3	7.1	12.6	13.3	15.2	22.6	21.1	12.9	18.9	9.5	8.1	14.7
80 - 89	17.4	15.5	13.7	17.5	15.1	19.4	21.9	20.1	17.2	14.0	19.1	11.4	17.5
100 - 124	16.8	18.8	16.9	17.6	19.9	20.6	17.5	17.4	14.7	14.8	17.4	9.8	17.5
125 - 149	34.8	35.2	38.1	28.6	27.0	20.3	16.7	20.4	23.8	20.0	18.8	26.9	26.3
150 - 249	10.3	13.7	15.9	12.6	13.2	7.9	6.0	6.8	14.4	11.2	11.0	25.1	11.2
250 - 399	1.5	0.4	1.4	1.7	1.9	1.8	0.9	1.8	2.3	2.8	2.4	5.2	1.7
400 - 599	1.3	0.6	1.6	0.8	1.3	1.1	0.4	1.2	2.0	3.0	8.3	1.2	1.3
600 - 799	0.2	0	0	0	0.6	0.1	0	0.1	0.4	0	1.5	1.3	0.2
800 - 1000	0.3	0	0.3	0	0	0	0.2	0.1	0	0	0.2	0	0.1
> 1000	0	0.4	0	0	0	0	0	0.1	0.2	0	1.3	0.2	0.1
Total	99.9	100	100	99.9	100	99.8	99.9	100.1	99.9	99.9	100.1	100	99.9

3-45

Table 3-15. Fish collected in gill nets set in conjunction with echolocation sampling in Regions 2-8 of L Lake. January-December 1991. Numbers in parentheses indicate average total length (mm).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Number	%
gizzard shad	9 (356)	3 (347)	2 (370)	16 (357)	59 (351)	13 (355)	36 (356)	7 (345)	16 (356)	11 (362)	10 (361)	7 (360)	189	78.4
yellow bullhead	--	--	4 (346)	1 (366)	1 (348)	2 (336)	1 (344)	--	1 (317)	1 (320)	--	--	11	4.6
brown bullhead	--	--	--	--	--	1 (405)	--	--	--	--	--	--	1	0.4
flat bullhead	--	--	2 (306)	2 (331)	1 (300)	3 (310)	5 (326)	3 (326)	3 (339)	--	--	3 (359)	22	9.1
largemouth bass	1 (424)	--	2 (451)	3 (436)	3 (449)	--	3 (313)	--	--	--	3 (433)	--	15	6.2
black crappie	--	--	--	--	--	1 (340)	1 (316)	--	1 (349)	--	--	--	3	1.2
Total (number)	10	3	10	22	64	20	46	10	21	12	13	10	241	99.9
Hours set	4.3	4.17	4.08	4.47	4.85	4.23	4.08	1.83	4.08	3.0	4.03	2.0	45.12	

in 1991. Midwater trawl data (Figure 3-7) shows that catches in 1991 were dominated by threadfin shad. This is the same pattern as noted in previous years.

Gill net data and midwater trawl data were combined for the entire year, grouped by size classes, and compared with length frequency data derived from hydroacoustic data (Figure 3-9). It is apparent that gill nets and midwater trawls exhibited more size selectivity in collections than hydroacoustic collections. Gill nets collected larger fish and midwater trawls collected smaller fish, while hydroacoustics collected over all size ranges. Gear selectivity is apparently still a problem in the ground truthing program for verification of hydroacoustic size estimations.

Hydroacoustic target densities in 1991 showed a large decrease over values observed from 1988 through 1990. This possibly reflects the continued overall reduction of productivity experienced in L Lake during 1991. It is again apparent that hydroacoustic sampling has documented the continued ecological succession of L Lake during 1991.

3.2.5 Taxa Richness

Taxa richness was calculated by counting the number of unique taxa present in electrofishing, gill net, midwater trawl, and hoop net samples. Under the reduced scope of sampling employed in 1990 and 1991, gill nets and trawls were the only gear types fished outside of Regions 5 and 7. Sixteen taxa, including one hybrid group, were collected from L Lake during 1991 (Table 3-16). The number of unique taxa observed in adult fish collections declined dramatically from 1986 to 1987 but then remained steady through 1989 at a level of 21-22

SONAR GROUND TRUTHING

1991 SONAR VS GROUND TRUTHING

Figure 3-9. Length frequencies of fish targets recorded by echolocation (hydroacoustics) and fish collected by shad scoops and gill nets in Regions 2-8 of L Lake. January-December 1991.

Table 3-16. Species collected by electrofishing, gill net, midwater trawl, or hoop net samples from Regions 2-8 of L Lake January-December 1991.

TAXON	QUARTER 1	QUARTER 2	QUARTER 3	QUARTER 4	TOTAL TAXA
gizzard shad	X	X	X	X	
threadfin shad	X	X	X	X	
redfin pickerel					
chain pickerel					
common carp					
rosyface chub					
bluehead chub					
golden shiner					
ironcolor shiner					
dusky shiner					
coastal shiner	X	X	X	X	
creek chubsucker					
lake chubsucker					
northern hogsucker					
spotted sucker					
snail bullhead		X			
snail bullhead					
white catfish					
yellow bullhead	X	X	X	X	
brown bullhead		X			
brown bullhead					
flat bullhead	X	X	X	X	
madtom					
mosquitofish					
brook silverside	X	X	X	X	
mud sunfish					
bluespotted sunfish					
hybrid sunfish	X		X	X	
redbreast sunfish	X	X	X	X	
pumpkinseed					
varmouth	X	X		X	
bluegill	X	X	X	X	
dollar sunfish					
redeer sunfish			X		
redeer sunfish					
spotted sunfish					
largemouth bass	X	X	X	X	
black crappie		X	X		
yellow perch	X	X	X	X	
blackbanded darter					
TOTAL UNIQUE TAXA	12	14	13	12	16

unique taxa (Table 3-17). Many of the species that were extirpated from L Lake were species associated with lotic habitat, so their loss is not unexpected. The decline in total unique taxa from 22 to 19 in 1990 (Table 3-18) and 16 in 1991 is probably due to lower probability of collecting rare species under the reduced scope of sampling. Each of the six species that were collected in 1990 but missing in 1991 (redfin pickerel, chain pickerel, common carp, golden shiner, lake chubsucker, and white catfish) have exhibited sporadic occurrence in catches from recent years, so their absence in 1991 is not particularly noteworthy. A similar point applies to the three species (redeer sunfish, snail bullhead, and brown bullhead) that were collected in 1991 after being absent from 1990 collections.

3.2.6 Food Habits

Stomach contents were examined from 129 bluegills, 207 redbreast sunfish, and 360 largemouth bass during 1991. The percentage of empty stomachs ranged from 9.8 to 12.8% for bluegills, from 8.2 to 12.8% for redbreast sunfish, and from 44.4 to 53.3% for largemouth bass (Table 3-19). The percentage of empty stomachs observed in 1991 did not appear to be related to season or region of collection. The proportion of empty stomachs observed in 1991 was similar to results from 1989 and 1990 (Sayers et al. 1990, 1991).

Crustaceans and insects were typically found in the largest number of bluegill stomachs that contained food during 1991 (Table 3-20). Mollusks, plant material, and fish were also found in a sizable number of bluegill stomachs at certain times of the year. The very large frequencies of occurrence for crustaceans observed in 1991 tend to be higher than those reported in earlier years, while the frequencies of occurrence for insects observed in 1991 are

2 OF 3

Table 3-17. Species collected by electrofishing, gill net, shad scoop, and hoop net samples from Regions 4-8 of L Lake, January 1986-December 1989.

Taxon	1986												1987											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
American eel															X									
threadfin shad																		X	X	X	X	X	X	X
gizzard shad													X	X		X	X	X	X	X	X	X	X	X
redfin pickerel	X	X	X	X				X	X															
chain pickerel	X			X	X		X	X	X	X	X	X	X	X	X	X	X					X	X	X
rosyface chub	X	X																						
common carp																								
bluehead chub		X	X																					
golden shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X
rosyface shiner								X																
ironcolor shiner												X												
dusky shiner											X									X				
coastal shiner								X				X	X	X	X	X	X	X	X	X			X	X
creek chubsucker	X	X	X		X		X				X													
lake chubsucker			X	X	X							X				X								
northern hogsucker	X		X																					
spotted sucker			X																					
white catfish																								
yellow bullhead	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
brown bullhead								X						X										
flat bullhead	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
snail bullhead*																								
madtom, Noturus spp.																	X							
mosquitofish	X	X	X	X	X	X	X	X			X	X												
brook silverside	X	X	X		X	X						X												
mud sunfish											X													
bluespotted sunfish	X				X					X						X								
redbreast sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pumpkinseed			X																					

*Data for snail bullhead collected prior to 1988 are tentative, as this species may have been misidentified as flat bullhead.

Table 3-17 (continued). Species collected by electrofishing, gill net, shad scoop, and hoop net samples from Regions 4-8 of L Lake, January 1986-December 1989.

Taxon	1988												1989											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
American eel																	X					X		
threadfin shad	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
gizzard shad	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
redfin pickerel																								
chain pickerel	X	X									X		X		X				X			X	X	X
rosyface chub																								
common carp													X											
bluehead chub																								
golden shiner	X	X	X	X		X	X	X							X				X	X	X	X	X	X
rosyface shiner																								
ironcolor shiner																								
dusky shiner																								
coastal shiner																			X	X		X	X	X
creek chubsucker		X																						
lake chubsucker																								
northern hogsucker											X													
spotted sucker				X																				
white catfish																				X	X		X	
yellow bullhead	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
brown bullhead																								
flat bullhead	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
snail bullhead*						X			X		X		X	X	X			X		X		X	X	
madtom, Noturus spp.																								
mosquitofish										X														
brook silverside	X		X				X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X
mud sunfish																								
bluespotted sunfish																				X				
redbreast sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pumpkinseed																								

*Data for snail bullhead collected prior to 1988 are tentative, as this species may have been misidentified as flat bullhead.

Table 3-17 (continued). Species collected by electrofishing, gill net, shad scoop, and hoop net samples from Regions 4-8 of L Lake, January 1986-December 1989.

Taxon	1986												1987											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
warmouth		X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X
bluegill	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
dollar sunfish	X	X	X	X	X	X	X	X	X		X		X	X	X	X		X	X	X	X			
redeer sunfish				X		X		X																
spotted sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
largemouth bass	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
black crappie			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
yellow perch			X			X		X												X				
blackbanded darter																								
MONTHLY TOTAL	14	16	18	15	16	14	13	18	11	10	14	14	13	14	13	14	14	14	12	15	13	12	13	13
YEARLY TOTAL	30												21											

Table 3-17 (continued). Species collected by electrofishing, gill net, shad scoop, and hoop net samples from Regions 4-8 of L Lake, January 1986-December 1989.

Taxon	1986												1987											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
warmouth	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
bluegill	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
dollar sunfish		X	X		X																			
redear sunfish								X														X		X
spotted sunfish	X	X	X	X	X		X	X	X	X	X	X			X			X	X					X
largemouth bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
black crappie	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
yellow perch						X	X										X		X	X	X	X	X	X
blackbanded darter																				X	X	X		
MONTHLY TOTAL	13	14	13	12	11	12	12	13	12	10	12	13	12	10	14	10	12	12	15	17	14	18	17	15
YEARLY TOTAL	21												22											

Table 3-18. Species collected by electrofishing, gill net, shad scoop, or hoop net from samples from Regions 2-8 of L Lake during 1990.

TAXON	QUARTER 1	QUARTER 2	QUARTER 3	QUARTER 4	TOTAL TAXA
gizzard shad	X	X	X	X	
threadfin shad	X	X	X	X	
redfin pickerel			X		
chain pickerel	X				
common carp				X	
rosyface chub					
bluehead chub					
golden shiner			X	X	
ironcolor shiner					
dusky shiner					
coastal shiner	X	X	X	X	
creek chubsucker					
lake chubsucker	X				
northern hogsucker					
spotted sucker					
snail bullhead					
white catfish	X	X			
yellow bullhead	X	X	X	X	
brown bullhead					
flat bullhead	X	X	X	X	
madtom					
mosquitofish					
brook silverside	X	X	X	X	
mud sunfish					
bluespotted sunfish					
hybrid sunfish	X	X		X	
redbreast sunfish	X	X	X	X	
pumpkinseed					
warmouth	X	X	X	X	
bluegill	X	X	X	X	
dollar sunfish					
redeer sunfish					
spotted sunfish					
largemouth bass	X	X	X	X	
black crappie	X		X	X	
yellow perch	X	X	X	X	
blackbanded darter					
TOTAL UNIQUE TAXA	16	13	14	15	19

Table 3-19. Number of stomachs examined and percent empty stomachs during food habits study in Regions 5 and 7 of L Lake, January-November 1991

MONTH	BLUEGILL				LARGEMOUTH BASS				REDBREAST SUNFISH			
	REGION 5		REGION 7		REGION 5		REGION 7		REGION 5		REGION 7	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
JAN					30	66.67	30	73.33				
FEB	3	0.00	28	7.14					21	9.52	27	7.41
MAR					30	56.67	30	53.33				
MAY	12	8.33	20	5.00	30	33.33	30	36.67	25	0.00	23	0.00
JUL					30	30.00	30	30.00				
AUG	7	0.00	13	23.08					27	14.81	28	25.00
SEP					30	23.33	30	60.00				
NOV	25	20.00	21	9.52	30	56.67	30	66.67	25	8.00	31	16.13
TOTAL	47	12.77	82	9.76	180	44.44	180	53.33	98	8.16	109	12.84

Table 3-20. Frequency of occurrence of major food items in stomachs of bluegill, redbreast sunfish, and largemouth bass collected in Regions 5 and 7 during 1991 in L Lake. Values are the percent of stomachs containing the food item and are based only on non-empty stomachs.

Species and Monthly	Food Items											
	<u>Annelid</u>		<u>Crustacean</u>		<u>Fish</u>		<u>Insect</u>		<u>Mollusk</u>		<u>Plant</u>	
	5	7	5	7	5	7	5	7	5	7	5	7
Bluegill												
Feb	0.0	0.0	66.7	92.3	0.0	0.0	66.7	50.0	0.0	34.6	0.0	15.4
May	0.0	0.0	81.8	47.4	0.0	0.0	45.5	78.9	27.3	10.5	9.1	42.1
Aug	0.0	0.0	100.0	70.0	28.6	0.0	42.9	90.0	0.0	0.0	14.3	10.0
Nov	0.0	0.0	47.4	42.1	0.0	0.0	57.9	52.6	10.5	0.0	10.5	5.3
Redbreast Sunfish												
Feb	0.0	4.0	68.4	80.0	0.0	4.0	68.4	24.0	21.1	32.0	10.5	16.0
May	4.0	0.0	40.0	56.5	0.0	0.0	68.0	73.9	8.0	8.7	4.0	4.3
Aug	4.3	4.8	34.8	33.3	0.0	0.0	47.8	90.5	0.0	4.8	13.0	9.5
Nov	0.0	0.0	39.1	11.5	0.0	0.0	39.1	57.7	13.0	11.5	0.0	11.5
Largemouth Bass												
Jan	0.0	0.0	20.0	0.0	50.0	75.0	50.0	25.0	0.0	0.0	0.0	0.0
Mar	0.0	0.0	30.8	7.1	38.5	85.7	61.5	28.6	0.0	0.0	7.7	28.6
May	0.0	0.0	0.0	0.0	100.0	89.5	15.0	10.5	0.0	5.3	0.0	0.0
Jul	0.0	0.0	0.0	0.0	100.0	100.0	0.0	4.8	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0	100.0	100.0	17.4	8.3	0.0	0.0	0.0	0.0
Nov	7.7	0.0	0.0	0.0	53.8	100.0	38.5	10.0	0.0	0.0	0.0	0.0

generally lower than values reported from 1987 through 1990 (Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990, 1991). All size classes of bluegill appeared to be feeding primarily on crustaceans and insects, although no insects were found in stomachs from large bluegills in Region 5 (Table 3-21). Amphipods were the most common crustacean in bluegill stomachs, comprising 26% of the average stomach volume (Table 3-22). This is the highest percentage volume for this food type during the five years that food data have been analyzed. As in previous years, dipterans were the most common insects in bluegill stomachs, but they formed a substantially smaller portion of the total volume in 1991 compared to previous years. As in 1990, a substantial portion of the stomach contents (29.5% in 1991) could not be identified. This large proportion of unidentifiable material may be the result of smaller fish being examined. Stomachs in smaller fish would be more susceptible to digestion during freezing and thawing associated with sample storage and processing.

Fullness indices for bluegills were variable among season and region, ranging from 0.99 during fall in Region 7 to 1.40 during spring in Region 5 (Figure 3-10). The fullness values observed in 1991 are similar to those observed in 1990 (Sayers et al. 1991) but were lower than 1989 values (Sayers et al. 1990).

Insects were generally found in the greatest percentage of redbreast sunfish stomachs, although crustaceans were also found in a large proportion of the sample (Table 3-20). The proportion of stomachs containing insects showed no distinct seasonal pattern, but crustaceans were found in proportionally more stomachs during February and May. Mollusks were also found in many of the redbreast sunfish stomachs, particularly during February and November. The

Table 3-21. Frequency of occurrence of major food items in stomachs of three length classes of bluegill and redbreast sunfish collected from Regions 5 and 7 during 1991 in L Lake. Values are the percent of stomachs containing the food item and are based only on non-empty stomachs.

Species and Length (mm)	Food Items													
	<u>Annelid</u>		<u>Crustacean</u>		<u>Fish</u>		<u>Insect</u>		<u>Mollusk</u>		<u>Plant</u>			
	5	7	5	7	5	7	5	7	5	7	5	7		
<hr/>														
Bluegill														
<90			0.0	0.0	52.6	69.6	0.0	0.0	52.6	47.8	5.3	0.0	10.5	4.3
90-150			0.0	0.0	78.9	57.9	5.3	0.0	57.9	71.1	21.1	10.5	10.5	15.8
>150			0.0	0.0	100.0	76.9	50.0	0.0	0.0	69.2	0.0	53.8	0.0	53.8
Redbreast Sunfish														
<90			2.7	0.0	43.2	30.2	0.0	0.0	56.8	72.1	8.1	2.3	5.4	4.7
90-150			2.4	2.7	42.9	54.1	0.0	0.0	64.3	48.6	14.3	13.5	9.5	10.8
>150			0.0	6.7	54.5	66.7	0.0	6.7	18.2	53.3	0.0	53.3	0.0	26.7

Table 3-22. Mean percent composition of dominant food items in the stomachs of bluegill from L Lake collected from 1987 through 1991.

Food Item	Year				
	1987	1988	1989	1990	1991
Annelida	0.85	0.00	0.30	1.05	0.00
Bryozoan	0.27	0.29	0.00	0.00	0.00
Crustacea					
Cladocera	9.40	11.51	9.91	3.84	6.89
Copepoda	5.13	4.74	4.25	0.65	0.00
Ostracoda	9.89	6.09	0.10	0.00	0.71
Amphipoda	0.61	3.77	15.57	8.02	26.44
Isopoda	0.00	0.00	0.10	0.56	0.00
unknown	2.20	0.19	0.10	0.00	0.00
Insect					
Ephemeroptera	0.37	0.39	0.10	0.00	0.66
Odonata	0.12	0.00	0.20	5.89	4.65
Neuroptera	0.00	0.10	0.20	0.45	0.00
Tricoptera	0.12	0.19	0.00	0.00	0.18
Lepidoptera	0.12	0.00	0.00	0.00	0.00
Coleoptera	0.98	1.26	0.61	1.03	0.09
Diptera	56.04	54.55	56.02	46.46	14.36
Orthoptera	0.00	0.00	0.00	0.00	0.44
Hymenoptera	2.93	1.06	0.10	0.00	0.00
Hemiptera	0.00	0.00	0.00	0.03	0.00
Megaloptera	0.00	0.00	0.00	0.53	0.00
unknown	3.91	0.48	0.30	0.00	1.54
Molluscs					
Gastropoda	2.08	1.35	1.62	0.58	0.56
Pelecypoda	0.00	0.87	1.42	0.09	1.61
unknown	0.00	0.10	0.00	0.01	0.00
Fish					
Clupeidae	0.00	0.48	0.20	0.00	0.00
Esocidae	0.00	0.00	0.00	0.00	0.00
Cyprinidae	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.24	0.19	0.00	0.25	0.00
eggs	0.12	1.06	1.82	0.14	0.00
unknown	0.98	0.48	0.20	0.43	0.88
Plants					
algal	2.08	9.28	4.45	5.77	10.78
vascular	0.13	0.68	1.92	1.42	0.70
seeds	0.37	0.77	0.40	0.11	0.00
Arachnida					
spiders	0.12	0.10	0.10	0.00	0.00
Unidentifiable					
Remains	0.00	0.00	0.00	22.68	29.52

Figure 3-10. Mean quarterly fullness indices for bluegill, redbreast sunfish, and largemouth bass from Regions 5 and 7 of L Lake during 1991.

variations in foods of small (< 90 mm), medium (91-150 mm), and large (>150 mm) redbreast sunfish were generally not consistent between Regions 5 and 7. For example, mollusks were most common in large fish in Region 7 but medium fish in Region 5 (Table 3-21).

Amphipods were the most common crustacean taxa in redbreast sunfish stomachs, forming on average 12% of the total volume. Dipterans formed the largest proportion of the identifiable material in redbreast sunfish stomachs (19.7%) but roughly 44% of the stomach contents could not be identified (Table 3-23). The percentage of dipterans observed in 1991 was considerably lower than values observed in previous years and could represent a shift in feeding habits away from insects. However, the large proportion of unidentifiable material observed in 1990 and 1991 obscures the significance of changes in the diet of redbreast sunfish.

Fullness indices for redbreast sunfish were also variable among season and region, and were generally greatest during spring and summer (Figure 3-10). The values observed in 1991 (ranging from 0.72 to 1.21) were similar to those observed in 1989 (Sayers et al. 1990) and 1990 (Sayers et al. 1991).

Roughly one-half of the largemouth bass stomachs that were examined in 1991 were empty, with a slightly larger proportion of empty stomachs in Region 7 (53%) versus Region 5 (44%; Table 3-19). A similar proportion of empty largemouth bass stomachs was observed in L Lake during 1989 (Sayers et al. 1990) and 1990 (Sayers et al. 1991). Fish were found in more largemouth bass stomachs than any other prey type during all sampling periods and frequently were found in all the stomachs containing food (Table 3-20). Insects were seasonally common in

Table 3-23. Mean percent composition of dominant food items in the stomachs of redbreast sunfish from L Lake collected from 1987 through 1991.

Food Item	Year				
	1987	1988	1989	1990	1991
Crustacea					
Cladocera	3.61	7.41	7.93	0.80	3.04
Copepoda	2.99	1.35	2.68	0.00	0.00
Ostracoda	6.09	6.40	0.43	0.00	0.76
Amphipoda	0.87	3.37	11.36	5.69	11.96
Isopoda	0.00	0.00	0.00	0.83	0.00
Decapoda	0.12	0.00	0.00	0.00	0.00
unknown	1.74	0.34	0.00	0.00	0.00
Annelida	0.50	0.11	0.21	0.81	0.62
Insect					
Ephemeroptera	0.75	0.56	0.32	0.00	0.32
Odonata	0.12	0.17	0.43	10.24	2.62
Neuroptera	0.00	0.00	0.21	0.01	0.01
Tricoptera	0.00	0.34	0.00	0.00	0.16
Lepidoptera	0.00	0.00	0.00	0.00	0.00
Coleoptera	0.37	0.22	0.32	0.36	2.97
Diptera	68.28	64.76	62.81	33.45	19.74
Orthoptera	0.25	0.11	0.00	0.00	0.00
Hymenoptera	1.37	0.67	0.32	0.00	0.00
Hemiptera	0.00	0.00	0.11	0.00	0.54
unknown	2.74	0.67	0.00	0.00	3.15
Molluscs					
Gastropoda	1.62	1.01	2.89	0.22	0.85
Pelecypoda	0.12	4.04	4.50	0.13	2.24
unknown	0.00	0.00	0.11	0.00	0.00
Fish					
Ictaluridae	0.00	0.00	0.00	0.00	0.00
Clupeidae	0.00	0.45	0.00	0.00	0.00
Esocidae	0.00	0.00	0.00	0.00	0.00
Cyprinidae	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.62	0.00	0.32	0.00	0.00
Lepisoteidae	0.00	0.00	0.00	0.00	0.00
Atherinidae	0.00	0.00	0.00	0.00	0.00
eggs	0.00	0.90	1.07	0.00	0.00
unknown	0.62	0.56	0.00	0.00	0.43
Plants					
algal	5.10	5.72	3.32	3.16	5.61
vascular	1.62	0.90	0.32	0.28	0.00
seeds	0.25	0.00	0.32	0.03	0.64
Unidentifiable					
Remains	0.00	0.00	0.00	43.99	44.34

largemouth bass stomachs, with the highest frequencies of occurrence in January and March. Insects were generally found in proportionally more stomachs from Region 5 than from Region 7, while fish were found in proportionally more stomachs from Region 7. The cause of these spatial differences is unclear. Centrarchid and clupeid fishes were the most common fish taxa consumed by largemouth bass, forming 33.9 and 20.9% of the total stomach volume (Table 3-24). Unidentifiable fish also formed roughly 15% of the stomach volume. Cyprinid, atherinid, ictalurid, and percid fishes were all observed in largemouth bass stomachs during 1991. This coincides with a decline in the relative abundance of centrarchid and clupeid fishes in the diet of largemouth bass compared with earlier years (Table 3-24) and probably reflects changes in the structure of the L-Lake fish assemblage. Electrofishing and hydroacoustic surveys conducted in 1991 suggest that threadfin shad and bluegill abundance was lower in 1991 than previous years but that coastal shiners (Cyprinidae), brook silversides (Atherinidae), and yellow perch (Percidae) were more abundant in 1991 than in previous years.

Fullness values for largemouth bass were highest during September, ranging from 0.52 to 1.82 in Region 5 and 0.89 to 1.46 in Region 7 (Figure 3-10). Observations in 1989 (Sayers et al. 1990) and 1990 (Sayers et al. 1991) also revealed rather large differences in largemouth bass fullness between regions or sampling periods.

No threadfin shad were collected during winter or fall electrofishing surveys, so diet analyses for these seasons could not be conducted in 1991. For the spring and summer samples, miscellaneous fragments formed 82 and 71% respectively of all items observed (Figure 3-11). Diatoms, rotifers, and

Table 3-24. Mean percent composition of dominant food items in the stomachs of largemouth bass from L Lake collected from 1987 through 1991.

Food Item	Year				
	1987	1988	1989	1990	1991
Crustacea					
Cladocera	0.00	0.00	0.00	0.00	0.00
Copepoda	0.00	0.00	0.00	0.00	0.00
Ostracoda	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.48	0.00	1.01
Isopoda	0.00	0.00	0.00	0.00	0.00
Decapoda	0.00	0.00	0.00	0.00	0.55
unknown	0.00	0.00	0.00	0.00	0.00
Annelida	0.00	0.00	0.00	0.75	0.54
Insect					
Ephemeroptera	0.00	0.00	0.00	0.00	0.05
Odonata	0.00	0.47	0.00	0.54	9.55
Neuroptera	0.00	0.00	0.00	0.00	0.01
Tricoptera	0.00	0.00	0.00	0.00	0.00
Lepidoptera	0.00	0.47	0.00	0.00	0.00
Coleoptera	0.00	0.00	0.00	0.00	0.71
Diptera	8.65	1.88	7.66	4.76	1.64
Orthoptera	0.00	0.00	0.00	0.27	0.50
Hymenoptera	0.00	0.00	0.48	0.00	0.00
Hemiptera	0.00	0.00	0.48	0.00	0.00
unknown	0.48	0.00	0.48	0.00	0.00
Molluscs					
Gastropoda	0.00	0.00	0.00	0.00	0.00
Pelecypoda	0.00	0.00	0.00	0.00	0.11
unknown	0.00	0.00	0.00	0.00	0.00
Fish					
Ictaluridae	0.00	1.41	0.48	0.55	2.71
Clupeidae	0.00	18.31	36.36	44.97	20.92
Esocidae	0.00	0.47	0.00	0.00	0.00
Cyprinidae	0.48	0.00	0.48	0.00	4.89
Centrarchidae	52.88	45.54	42.16	41.02	33.91
Lepisosteidae	0.00	0.00	0.48	0.00	0.00
Atherinidae	0.00	0.00	0.48	1.64	4.34
eggs	0.00	0.47	0.00	0.00	0.90
Percidae	0.00	0.00	0.00	0.00	0.54
unknown	16.35	24.40	4.31	1.56	14.86
Plants					
algal	0.48	1.41	4.78	0.99	0.46
vascular	18.27	4.69	0.96	0.00	0.00
seeds	0.00	0.00	0.00	0.00	0.00

Table 3-24 (continued). Mean percent composition of dominant food items in the stomachs of largemouth bass from L Lake collected from 1987 through 1991.

Food Item	Year				
	1987	1988	1989	1990	1991
Arachnida spiders	2.40	0.00	0.00	0.00	0.00
Unidentifiable Remains	0.00	0.00	0.00	2.95	1.77

Figure 3-11. Quarterly relative importance (based on numerical abundance) of various food types found in gizzards of threadfin shad collected in L. Lake during 1991. F = filamentous fragments, M = microcrustaceans, O = other, G = green algae, D = diatoms, I = insects, R = rotifers.

microcrustaceans were also relatively common, with each taxon accounting for roughly 5% of all items observed. The continued predominance of filamentous fragments suggests that benthic feeding by threadfin shad is common. The inclusion of microcrustaceans and rotifers indicates that pelagic feeding is also relatively common. The lack of winter and fall samples precludes seasonal comparisons, but the 1991 data were similar to those of earlier spring and summer samples (Figures 3-12 and 3-13; Heuer et al. 1989; Sayers et al. 1990, 1991).

3.2.7 Mark and Recapture Studies

Earlier mark and recapture data from L Lake indicated that only flat bullhead, redbreast sunfish, bluegill, and largemouth bass produced sufficient numbers of recaptured fish to allow meaningful interpretation of the results (Paller et al. 1988). Due largely to the reduced scope of sampling in 1990 and 1991, the numbers of fish tagged or recaptured in these years were considerably lower than in previous years. No bluegills, redbreast sunfish, or flat bullheads were recaptured and very few specimens of these species were tagged during 1991 (Tables 3-25, 3-26 and 3-27). Thirteen largemouth bass were recaptured during 1991 and these fish exhibited an estimated yearly growth increment of 36 mm (Table 3-28). Both the average and maximum days-at-large for largemouth bass increased over 1990 values.

3.2.8 Growth

Calculation of growth for recaptured bluegill, redbreast sunfish, and flat bullhead was not possible in 1991. The average daily growth rate for largemouth bass (0.10 mm/day) was slightly higher than in 1990, but was still lower than values observed in 1988 and 1989 (Table 3-28). The slower growth of largemouth bass in recent years is probably due to older fish forming a larger proportion

Figure 3-12. Average quarterly percent numerical abundance of selected food types in the gizzards of threadfin shad collected in L Lake during 1990. mcrust = microcrustaceans, misfrag = filamentous fragments, green = green algae, bluegrn = blue green algae.

Figure 3-13. Average monthly percent numerical abundance of selected food types in the gizzards of threadfin shad collected in L Lake 1987 through 1989. mcrust = microcrustaceans, misfrag = filamentous fragments, green = green algae, bluegrn = blue green algae.

Table 3-25. Summary table of mark-recapture data for bluegill in L Lake, 1986-1991 (DAL = Days at large).

Year	No. Tagged	Avg Total Length (mm)	No. Recap.	Cum. Recap %	Avg. DAL	Max. DAL	Avg. Growth (mm/day)	Yearly Growth Est. (mm)
1986 ^a	462	169.1	5	2.8	36.0	87	0.05	19
1987 ^b	2,662	170.2	75	3.2	77.0	215	0.08	28
1988 ^c	1,769	177.0	38	4.2	99.4	300	0.06	21
1989 ^d	1,216	184.2	15	2.6	156.5	385	0.11	39
1990 ^e	67	207.6	1	2.6	196.0	196	0.01	2
1991	0	--	0	2.6	--	--	--	--

^aPaller et al. 1987.

^bPaller et al. 1988.

^cHeuer et al. 1989.

^dSayers et al. 1990.

^eSayers et al. 1991.

Table 3-26. Summary table of mark-recapture data for redbreast sunfish in L Lake, 1986-1991 (DAL = Days at large).

Year	No. Tagged	Avg Total Length (mm)	No. Recap.	Cum. Recap %	Avg. DAL	Max. DAL	Avg. Growth (mm/day)	Yearly Growth Est. (mm)
1986 ^a	1,683	180.3	16	2.2	34.9	87	0.01	5
1987 ^b	1,444	193.4	37	1.9	101.7	573	0.15	55
1988 ^c	1,608	199.4	52	2.5	171.5	1,000	0.03	12
1989 ^d	825	199.3	30	2.8	212.0	845	0.06	22
1990 ^e	10	186.7	2	2.8	88.5	100	0.03	11
1991	2	209.5	0	2.8	--	--	--	--

^aPaller et al. 1987.

^bPaller et al. 1988.

^cHeuer et al. 1989.

^dSayers et al. 1990.

^eSayers et al. 1991.

Table 3-27. Summary table of mark-recapture data for flat bullhead in L Lake, 1986-1991 (DAL = Days at large).

Year	No. Tagged	Avg Total Length (mm)	No. Recap.	Cum. Recap %	Avg. DAL	Max. DAL	Avg. Growth (mm/day)	Yearly Growth Est. (mm)
1986 ^a	271	301.0	10	7.0	95.9	194	0.10	35
1987 ^b	290	287.2	36	10.3	174.6	502	0.06	23
1988 ^c	419	288.5	19	10.2	289.0	882	0.04	15
1989 ^d	349	300.6	15	7.4	259.1	1,084	0.04	15
1990 ^e	48	305.4	2	7.3	323.5	369	0.02	8
1991	24	326.3	0	7.2	--	--	--	--

^aPaller et al. 1987.

^bPaller et al. 1988.

^cHeuer et al. 1989.

^dSayers et al. 1990.

^eSayers et al. 1991.

Table 3-28. Summary table of mark-recapture data for largemouth bass in L Lake, 1986-1991
(DAL = Days at large).

Year	No. Tagged	Avg Total Length (mm)	No. Recap.	Cum. Recap %	Avg. DAL	Max. DAL	Avg. Growth (mm/day)	Yearly Growth Est. (mm)
1986 ^a	462	262.3	11	3.7	32.9	82	-0.13	-48
1987 ^b	1,098	323.1	123	10.8	136.6	511	0.30	108
1988 ^c	933	348.8	102	13.2	169.6	727	0.25	91
1989 ^d	721	370.2	78	15.1	264.8	1,037	0.16	57
1990 ^e	89	393.1	25	16.2	430.6	1,375	0.07	24
1991	94	367.7	13	16.7	686.9	1,680	0.10	36

^aPaller et al. 1987.

^bPaller et al. 1988.

^cHeuer et al. 1989.

^dSayers et al. 1990.

^eSayers et al. 1991.

of the tagged population since relatively few fish have been tagged in recent years. Evidence for this is provided by increases in both the average and maximum days-at-large and by the annual growth increment, which is typical for age-5 to age-7 largemouth bass (Carlander 1977).

Estimates of growth based on recaptures of tagged fish apply only in larger (>150 mm), slower-growing fish, whereas younger fish usually grow faster. In previous years, length-frequency distributions have been used to provide growth estimates for younger, smaller fish (Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990). However, due to the relatively small sample sizes used to form the length-frequency distributions in 1990 and 1991, this procedure provided little insight into growth rates for bluegill and largemouth bass (Table 3-29, 3-30). Sufficient numbers of redbreast sunfish (Table 3-31) were collected to suggest that young-of-the year reach lengths of 51 to 80 mm, similar to results reported for 1990 data (Sayers et al. 1991). The bimodal length-frequency distribution for redbreast sunfish also suggests that yearlings achieve lengths of 91-120 mm. These growth intervals appear to be slightly larger than those of other southern populations (Carlander 1977).

3.2.9 Condition Factors

Mean condition factors for the three species studied (bluegill, redbreast sunfish, and largemouth bass) were similar between Regions 5 and 7 for all size classes (Table 3-32). Condition factors for young fish were typically smaller than for adults, similar to results reported by Paller et al. (1988), Heuer et al. (1989), and Sayers et al. (1990, 1991).

Table 3-29. Length frequency distribution by quarter of bluegill in L Lake. January-December 1991.

LENGTH CLASS (mm)	WINTER	SPRING	SUMMER	FALL
21 - 30				6
31 - 40			2	6
41 - 50	1		10	3
51 - 60	4		3	2
61 - 70	6	5		5
71 - 80	1	5	3	11
81 - 90	5	3	3	13
91 -100	2	3	3	8
101-110	1	2	3	6
111-120	4	2		8
121-130	4	3	3	4
131-140	7	4	3	3
141-150	1	2	1	3
151-160	3	1		1
161-170	1		1	
171-180	3			
181-190	4			
191-200		1		
211-220		1		
221-230			1	
241-250		1		
261-270		1		

Table 3-30. Length frequency distribution by quarter of largemouth bass in L Lake. January-December 1991.

LENGTH CLASS (mm)	WINTER	SPRING	SUMMER	FALL
41 - 60			6	1
61 - 80	1		3	4
81 -100				6
101-120		1	1	2
121-140	2	2	7	1
141-160	2		5	7
161-180	7	1	7	7
181-200	11	2	9	14
201-220	17	3	4	9
221-240	8	7	4	2
241-260	3	9	7	3
261-280	4	4	3	2
281-300	5	1	10	
301-320	5	6	6	3
321-340	4	3	2	2
341-360	5	5	6	3
361-380	9	4	8	10
381-400	14	12	8	5
401-420	18	9	6	4
421-440	11	5	9	5
441-460	8	7	9	8
461-480	6	1	9	1
481-500	5	6	7	4
501-520	2	4	12	
521-540	3	3	2	1
541-560	1	2		2

Table 3-31. Length frequency distribution by quarter of redbreast sunfish in L Lake. January-December 1991.

LENGTH CLASS (mm)	WINTER	SPRING	SUMMER	FALL
31 - 40	1	1		4
41 - 50		2	7	7
51 - 60	21	13	8	28
61 - 70	40	9	6	29
71 - 80	23	19	11	26
81 - 90	18	8	20	17
91 -100	29	7	7	20
101-110	16	8	5	27
111-120	18	9	5	13
121-130	8	8	3	5
131-140	8	2	3	5
141-150	4	2	1	1
151-160	3		1	
161-170	1	2	3	1
171-180	2	2		
181-190			3	1
191-200		1		
201-210			1	
211-220	2			
221-230	1		1	1
231-240	1	1		
251-260	1			

Table 3-32. Average condition of three species of fish from Regions 5 and 7 of L Lake collected in 1991.

Species	Size Class	Region					
		5			7		
		Mean	S.D.	N	Mean	S.D.	N
Redbreast	Young	1.50	0.33	34	1.59	0.40	36
Sunfish	Adult	1.64	0.29	79	1.65	0.22	101
Bluegill	Young	1.49	0.14	8	1.70	0.31	12
	Adult	1.71	0.31	40	1.84	0.23	43
Largemouth	Young	1.12	0.14	9	1.18	0.16	15
Bass	Adult	1.20	0.13	86	1.22	0.15	84
	Large	1.43	0.20	142	1.38	0.16	148

Variable relative abundance of the respective size classes in a sample may affect overall average condition factors, thus obscuring long-term changes. In order to minimize this phenomenon, yearly average condition factors were examined separately for young and adult of each species. Condition factors measured in 1986 were the highest observed during the study period (1986-1991) for all size classes of each species (Figures 3-14 and 3-15). Condition of young and adult bluegill or redbreast sunfish has remained relatively stable since 1987 (Figure 3-14). Bluegill condition in L Lake is similar to or slightly greater than the values reported for U.S. populations by Carlander (1977). Condition factors for redbreast sunfish in L Lake have also remained stable since 1987 but are slightly lower than the limited data reported for this species by Carlander (1977).

Mean condition of large (> 300 mm) largemouth bass apparently declined slightly in 1991, following a relatively stable period from 1988 through 1990 (Figure 3-15). Mean condition of adult (151-300 mm) and young (≤ 150 mm) largemouth bass remained basically unchanged from that of earlier years. Mean condition factors for large largemouth bass are similar to those of other U.S. populations, but it appears that adult and young largemouth bass condition in L Lake is slightly lower than in other parts of the country (Carlander 1977). The decline in condition of large adults observed in 1991 may reflect decreased abundance of prey species and the large number of older bass that were killed during a redsore epizootic (see section 3.2.11).

3.2.10 Gonadal Development

The relatively small sample sizes of gonadal data preclude using these data to draw any firm conclusions. Minimum length at maturity for female bluegills was 69 mm in Region 5 and 73 mm in Region 7, while average length of mature fish

Figure 3-14. Comparison of mean condition of adult and young bluegill and redbreast sunfish from Regions 4 through 8 (1986-1989) or Regions 5 and 7 (1990 and 1991) of L Lake. Vertical bars extend $\pm$ one standard deviation from the mean and the sample size is indicated above each point.

Figure 3-15. Comparison of mean condition of three size classes of largemouth bass from Regions 4 through 8 (1986-1989) or Regions 5 and 7 (1990 and 1991) of L. Lake. Vertical bars extend $\pm$ one standard deviation from the mean and the sample size is indicated above each point.

ranged from 96.75 to 100.2 mm (Table 3-33). Minimum length at maturity for male bluegills was 103 mm, but was based on only three individuals from Region 7 and one from Region 5 (Table 3-33).

Average gonadosomatic index (GSI) for female bluegills was highest during spring, but male GSI peaked in summer (Figure 3-16). The proportion of females that were ripe was highest in spring but a similar proportion of males were ripe in spring and summer. Review of data from previous L-Lake reports also showed a highly variable temporal pattern for GSI data (Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990, 1991).

Interregional differences between average lengths of redbreast sunfish males or females were generally small, although spent males in Region 7 averaged 38 mm longer than those of Region 5 (Table 3-34). The minimum lengths at maturity (59 mm for females and 71 mm for males) were slightly larger than in 1990 (46 mm for females and 51 mm for males; Sayers et al. 1991) but probably do not differ significantly. GSI values for female redbreast sunfish were highest during spring and summer, and these periods coincided with periods of peak ripeness (Figure 3-17). GSI values for males peaked during summer, although the proportion of ripe males was high during both spring and summer.

3.2.11 Disease

During 1991, a total of 95 fish were observed with obvious external lesions, parasites, or morphological abnormalities in collections from L Lake (Table 3-35). This total is substantially lower than the 1,839 observations reported for 1989 (Sayers et al. 1990) and less than half the 226 observations reported for 1990 (Sayers et al. 1991). The lower number of abnormalities

Table 3-33. Characteristics, classed by maturity stage, of bluegill collected from Regions 5 and 7 of L Lake during 1991.

Sex and Maturity Stage	Region 5				Region 7			
	N	Avg. Length	Min. Length	Avg. Cond.	N	Avg. Length	Min. Length	Avg. Cond.
<u>Female</u>								
Immature	6	67.8	64.0	1.39	11	79.6	53.0	1.42
Mature	12	96.8	69.0	1.49	5	100.2	73.0	1.70
Ripe	160.0	160.0	1.54	2	181.0	102.0	2.10	
Spent	132.0	132.0	1.61	9	130.7	97.0	1.70	
<u>Male</u>								
Immature	9	85.0	58.0	1.49	14	84.9	64.0	1.38
Mature	1	132.0	132.0	1.74	3	138.7	103.0	1.73
Ripe	2	139.0	123.0	2.00	5	130.4	48.0	1.67
Spent	8	124.3	112.0	1.60	15	144.6	104.0	1.76

Figure 3-16. Mean quarterly gonadosomatic index (GSI) and percent frequency of ripe specimens (% ripe) of female and male bluegills from Regions 5 (clear boxes) and 7 (striped boxes) of L. Lake during 1991.

Table 3-34. Characteristics, classed by maturity stage, of redbreast sunfish collected from Regions 5 and 7 of L Lake during 1991.

Sex and Maturity Stage	Region 5				Region 7			
	N	Avg. Length	Min. Length	Avg. Cond.	N	Avg. Length	Min. Length	Avg. Cond.
<u>Female</u>								
Immature	14	65.0	48.0	1.62	27	73.1	48.0	1.53
Mature	15	93.5	59.0	1.63	8	97.1	82.0	1.55
Ripe	21	114.9	66.0	1.66	18	112.3	75.0	1.69
Spent	15	97.8	72.0	1.44	7	104.6	83.0	1.57
<u>Male</u>								
Immature	7	71.6	58.0	1.51	14	85.0	60.0	1.47
Mature	4	100.0	71.0	1.64	3	122.0	106.0	1.37
Ripe	10	185.5	89.0	1.96	5	180.0	128.0	1.85
Spent	9	117.1	83.0	1.61	20	155.2	95.0	1.66

Figure 3-17. Mean quarterly gonadosomatic index (GSI) and percent frequency of ripe specimens (% ripe) of female & male redbreast sunfish from Regions 5 (clear boxes) and 7 (striped boxes) of L. Lake during 1991.

Table 3-35. Occurrences of external aberrances for fish collected in L Lake during 1991.

Common Name	Redsore	Finrot	Laceration	Dead	Other	Anchorworm	Leech	Blackspot	Trematode
gizzard shad	2								
threadfin shad									
coastal shiner									
snail bullhead									
yellow bullhead									1
brown bullhead									
flat bullhead									
brook silverside									
hybrid sunfish									
redbreast sunfish	3								32
warmouth									
bluegill								2	1
redeer sunfish									
largemouth bass	23	1	1	1	1	1	3	8	15
black crappie									
yellow perch									
Total	28	1	1	1	1	1	3	10	49

observed in 1990 and 1991 undoubtedly reflects the reduced sampling effort employed during those years. The decline in incidence of abnormalities from 1990 to 1991 probably reflects a general decline in the occurrences of abnormalities and may be related to lower fish abundance.

Trematode infestation and redsore were the most commonly observed abnormalities, affecting primarily redbreast sunfish and largemouth bass (Table 3-35). Blackspot was the only other abnormality observed on more than 10 fish. The total incidences of trematode and blackspot in 1991 were much lower than in 1990 and accounted for most of the decline in abnormality incidence from 1990 to 1991. Total incidence of redsore was similar in 1990 (22 fish; Sayers et al. 1991) and 1991 (Table 3-35), but largemouth bass composed a larger proportion and redbreast sunfish a smaller proportion of the 1991 total. The same predominant abnormalities (trematode, blackspot disease, and redsore) were reported as the most common abnormalities in previous years (Paller et al. 1987; Paller et al. 1988; Heuer et al. 1989; Sayers et al. 1990, 1991).

Roughly 12% of the redbreast sunfish and largemouth bass collected from Regions 5 and 7 during 1991 were infested with trematodes (Table 3-36). The percentages of infestation between regions were very similar for redbreast sunfish while the percentage of infested largemouth bass was slightly higher in Region 5 than in Region 7. The peak incidence of trematode infestation occurred during the winter quarterly samples and its magnitude (14%) was similar to that of previous years (Figure 3-18). The percent incidence of trematode infestation during the spring, summer, and fall samples was generally low compared to typical infestation rates from 1987 through 1990.

Table 3-36. Incidences of trematode infestation among different fish species collected from Regions 5 and 7 of L Lake. Data are presented as number of fish examined (NO.) and percent incidence of infestation (%). January-December 1991.

SPECIES	REGION 5		REGION 7		LAKEWIDE		
	NO.	%	NO.	%	NO. INFECTED	NO. EXAMINED	% INFECTED
gizzard shad	66	0.00	56	0.00	0	122	0.00
threadfin shad	2	0.00	1	0.00	0	3	0.00
snail bullhead			1	0.00	0	1	0.00
yellow bullhead	1	0.00			0	1	0.00
flat bullhead	10	0.00	6	0.00	0	16	0.00
brook silverside			1	0.00	0	1	0.00
hybrid sunfish	3	0.00	1	0.00	0	4	0.00
redbreast sunfish	114	13.16	141	12.06	32	255	12.55
warmouth	2	0.00	5	0.00	0	7	0.00
bluegill	48	0.00	55	1.82	1	103	0.97
redeer sunfish			1	0.00	0	1	0.00
largemouth bass	58	15.52	67	8.96	15	125	12.00
black crappie			2	0.00	0	2	0.00
yellow perch	33	0.00	31	0.00	0	64	0.00

Figure 3-18. Monthly incidence (percent of infected fish) of trematodes in L Lake from 1986 through 1991.

The incidence of redsore lesions reached an all-time high in April of 1991 (13.6%) eclipsing the previous high of 6.5% set in June of 1990 (Figure 3-19). The vast majority of the fish exhibiting redsore lesions were largemouth bass, with redbreast sunfish and gizzard shad showing lower rates of infestation (Table 3-37).

The high incidences of redsore observed in 1988, 1989, 1990, and 1991 were associated with extensive epizootics of Aeromonas, that resulted in mortalities during April and May in 1988; April, May, and June in 1989; March, April, May, and June in 1990; and April, May, and June in 1991. Shoreline surveys and estimates based on open water transects (following AFS 1982) indicated that roughly 2,000 fish died during the epizootic in 1991 (Table 3-38). This estimate is probably lower than the actual mortality since avian and mammalian scavengers were very active during the kill and some fish probably sank before they could be counted.

The total number of fish killed during the 1991 redsore epizootic (2,072) was substantially lower than in 1990. Whereas the 1990 fish kill was composed largely of black crappie (Sayers et al. 1991), largemouth bass formed roughly 84% of all dead fish during the 1991 fish kill (Table 3-38). Approximately 60% of the dead largemouth bass were >400 mm long and roughly 97% exceeded 300 mm (Figure 3-20). The total number of dead largemouth bass observed in 1991 was substantially higher than the 1990 (282 fish) or 1989 (348 fish) totals, but smaller than the 2,079 observed in 1988.

The number of dead black crappies found during the 1991 redsore epizootic (177; Table 3-38) was lower substantially than in 1990 (4,575; Figure 3-21). As

Figure 3-19. Monthly incidence (percent of infected fish) of redsore lesions in L Lake from 1986 through 1991.

Table 3-37. Number of fish examined for redsore (No.) and percent incidence of the disease (%) in Regions 5 and 7 of L Lake. January-December 1991.

SPECIES	REGION 5		REGION 7		LAKEWIDE		
	NO.	%	NO.	%	NO. INFECTED	NO. EXAMINED	% INFECTED
gizzard shad	66	1.52	56	1.79	2	122	1.64
threadfin shad	2	0.00	1	0.00	0	3	0.00
snail bullhead			1	0.00	0	1	0.00
yellow bullhead	1	0.00			0	1	0.00
flat bullhead	10	0.00	6	0.00	0	16	0.00
brook silverside			1	0.00	0	1	0.00
hybrid sunfish	3	0.00	1	0.00	0	4	0.00
redbreast sunfish	114	1.75	141	0.71	3	255	1.18
warmouth	2	0.00	5	0.00	0	7	0.00
bluegill	48	0.00	55	0.00	0	103	0.00
redeer sunfish			1	0.00	0	1	0.00
largemouth bass	58	10.34	67	16.42	17	125	13.60
black crappie			2	0.00	0	2	0.00
yellow perch	33	0.00	31	0.00	0	64	0.00

Table 3-38. Number of moribund fish observed during a fish kill associated ith the redsore epizootic in L Lake. During spring of 1991.

Month	Taxa ^a								
	LMB	BGS	RBS	BCR	OTHER SUNFISHES	CATFISHES	GIZZARD SHAD	OTHER TAXA	ALL TAXA
April	38	1	1	148	0	1	4	1	194
May	1678	54	4	29	6	45	24	6	1846
June	27	0	1	0	0	3	0	1	32
All Months	1743	55	6	177	6	49	28	8	2072
(% of Total)	(84%)	(3%)	(<1%)	(9%)	(<1%)	(2%)	(1%)	(1%)	

^aLMB - largemouth bass, BGS - bluegill, RBS - redbreast sunfish, BCR - black crappie, other taxa includes unidentifiable specimens.

Figure 3-20. Length frequency distribution of dead or moribund largemouth bass found during the redsore epizootics from 1988 through 1991.

Figure 3-21. Length frequency distribution of dead or moribund black crapple found during the redsore epizootics from 1990 through 1991.

in 1990, virtually all of these fish were adults, ranging from 200 to 400 mm. Because black crappies are poorly represented in other fisheries collections it is difficult to speculate on the causes of fluctuations in the number of fish killed during the redsore epizootic.

The number of dead bluegills and redbreast sunfish observed during the 1990 and 1991 redsore epizootics was down substantially from 1988 and 1989 levels (Figures 3-22 and 3-23) suggesting that these species are not as susceptible to redsore mortality in the absence of thermal effluents. Gizzard shad and catfishes (mostly flat bullheads) were also subjected to redsore-induced mortality during 1991, accounting for 1 and 2% respectively of the total fish killed (Table 3-38).

Esch and Hazen (1978, 1980) proposed that stress, induced by elevated temperatures played a significant role in increasing susceptibility of largemouth bass to redsore. They also observed an inverse correlation between body condition of largemouth bass and the probability of largemouth bass contracting redsore disease. The large number of largemouth bass killed by redsore during 1991 cannot be related to discharge of thermal effluents, but may still be related to stress.

Condition factors of largemouth bass in L Lake have generally ranged from 1.1 to 1.6 (Figure 3-15), values that are similar to other U.S. populations (Carlander 1977). The generally stable condition values provide no direct evidence of stress. However, the size structure of the largemouth bass population in L Lake has changed rather dramatically from 1987 to 1991. The proportional stock density of largemouth bass in electrofishing collections at

Figure 3-22. Length frequency distribution of dead or moribund bluegill found during the redsore epizootics from 1988 through 1991.

Figure 3-23. Length frequency distribution of dead or moribund redbreast sunfish found during the redsore epizootics from 1988 through 1991.

shoreline transects and artificial reefs increased from 59% in 1987 to 100% in 1990, but then dropped to 85% in 1991 (Table 3-39). This drop coincided with a rather extensive die off of adult largemouth bass during the Aeromonas epizootic and suggests that the largemouth bass population was still subject to stress, perhaps due to high density and intraspecific competition.

Reynolds and Babb (1978) suggested that largemouth bass populations are likely to be in balance with their forage base when PSD ranges between 40 and 60%. Given the rather large PSD values observed in L Lake during recent years, it is possible that adult largemouth bass are suffering high susceptibility to redsore due to overcrowding or insufficient forage.

3.3 ICHTHYOPLANKTON

3.3.1 Taxonomic Notes

The ability to identify fish larvae improved throughout the study as taxonomic information was accumulated from recent publications and fishery research agencies. There were some notable differences in the techniques employed throughout the study from 1986 through 1991:

1. Sunfish larvae that had been previously reported as Lepomis sp. (Paller et al. 1987, Paller et al. 1988) were assumed to be bluegills in the reports summarizing 1988 (Heuer et al. 1989), 1989 (Sayers et al. 1990 and 1991), and 1990 results. After the first positive identification of this species in June 1987, it was determined that bluegills were the only abundant species of Lepomis larvae collected in 1988, 1989, and 1990 (see Sections 3.3.2.1-3.3.2.2 below as well as Heuer et al. 1989 and Sayers et al. 1990). It was more accurate to describe the 1986-1989 assemblage of larval fishes as being dominated by a single sunfish species than as one

Table 3-39. Largemouth bass proportional stock density (PSD), number of stock-sized fish (N), and 95% Confidence Interval (C.I.) for PSD as calculated using May electrofishing data collected from 1987-1991 in L Lake.

	1987 ^a	1988 ^a	1989	1990	1991
PSD	59%	72%	87%	100%	85%
N	92	79	136	20	34
C.I. ^b	48-70	61-83	81-93	83-100	69-95

^aDenotes year when L-Reactor was operational from January through June.

^b95% confidence intervals were constructed according to formulas provided by Rohlf and Sokal (1969) and Gustafson (1988).

composed of several species. It is doubtful that much information was lost as other species of Lepomis (i.e., warmouth, redbreast sunfish, and spotted sunfish) were easily identified and segregated after 1987; however, these species were not distinguished in 1986 and were included in the data reported for bluegill in that year (sunfish identifications were confirmed by C.F. Bryan, Louisiana Cooperative Fish and Wildlife Research Unit, Louisiana State University, Baton Rouge).

2. Due to time constraints, crappie larvae were identified only to the generic level. It is probable that all were black crappie because this is the only species of Pomoxis that has been reported from L Lake and close examination of randomly chosen Pomoxis larvae revealed all to be black crappie.
3. Criteria used in 1986 to distinguish golden shiner larvae were judged to be inadequate and this taxon was pooled with the unidentified cyprinids in subsequent reports. Individual species in the genus Notropis could be distinguished (Fuiman et al. 1983); however, data for separate species were pooled and reported at the family level to facilitate comparison with data collected earlier.
4. L-Lake fish larvae samples were often dominated by high densities of threadfin and gizzard shad. During periods of peak shad densities (mid-April through late-May) there were typically 1,000 to 2,000 shad collected per sample. It was estimated that > 90% of these were collected during the larval stage of development (early life history stages are defined in Table 3-40). It is possible to separate the two species of shad during this stage by counting preanal myomeres (Hardy 1978). However, this is a laborious procedure and was not practical for the sample sizes encountered in this study. Additionally, shad larvae are particularly fragile because

of their filiform body shape, and the majority of specimens that were collected in net tows were too damaged to identify to species (preliminary results indicated > 75% of each sample collected in mid-April 1988 was unidentifiable to species). Given the time constraints and high proportion of damaged fish, free-feeding shad larvae were identified only to genus, Dorosoma sp. This was not expected to compromise the results or hinder comparisons with other studies, as investigators do not routinely distinguish shad larvae (Moen and Dewey 1978; Tarplee and Partin 1981; Shelton et al. 1982; Gilliland 1983; Matthews 1984; Dewey and Moen 1987; Petering and Van Den Avyle 1988; Van Den Avyle and Petering 1988). It was possible to separate the yolk-sac larvae (Table 3-40) of each shad species based on descriptions by Shelton and Stephens (1980) and Shelton et al. (1982). Therefore, ichthyoplankton data reported for individual shad species are for the yolk-sac larva forms. Hence, the period of peak spawning of each species of shad could be inferred from density of yolk-sac larvae.

3.3.2 Results

Comparison of the 1990 and 1991 ichthyoplankton data to that of previous years was made difficult by the reduced scope of sampling begun in 1990. Prior to 1990, littoral and oblique tows were collected on a weekly basis from February through August in all regions and on a biweekly basis for the remainder of the year in Regions 4, 6, and 8. Ichthyoplankton collections in 1990 and 1991 were restricted to Regions 5 and 7 and were collected only on a biweekly schedule from February through August. Thus the 1989 annual means presented for Regions 5 and 7 (Table 3-33 in Sayers et al. 1990) are based on twice as many samples and may not be directly comparable to those calculated using 1990 and 1991 data. A

Table 3-40. Definition of terms used to describe the early life history stages of gizzard shad and threadfin shad (modified from Auer 1982).

YOLK-SAC LARVA:	This phase occurs from the moment of hatching (emergence) to complete yolk absorption. Shad yolk-sac larvae are typically small (total length, TL, range - 3.3-6.0 mm), unpigmented, and poorly developed compared to yolk-sac larvae of other temperate freshwater fishes. All fins, swimming musculature, and the digestive tract remain incompletely formed during this phase.
LARVA:	This phase begins with the onset of exogenous feeding and ends with the absorption of the finfold and development of the full complement of adult fin rays. Shad larvae are filiform and lightly pigmented. This period is characterized by rapid behavioral and morphological development and growth (TL range: 6.0-25.0 mm).
JUVENILE:	This phase follows fin ray development and acquisition of the adult morphology and persists until sexual maturity (TL range: 25.0-50.0 mm).

similar problem exists in comparing the oblique tow data. A listing of all 1991 ichthyoplankton catches is provided in Appendix Table 5.

3.3.2.1 Littoral Surface Tows

Larvae of ten distinct species, as well as unidentified cyprinids (minnows) and centrarchids (sunfishes) were collected in littoral surface tows during 1991 (Table 3-41). Shad, bluegill, and brook silverside larvae were the most abundant taxa in Regions 5 and 7 and black crappie were also relatively abundant in Region 7. These same four taxa were also the most abundant in 1989 (Sayers et al. 1990) and 1990 collections (Sayers et al. 1991). Black crappie and brook silverside larvae have formed an increasingly larger portion of the surface catch in recent years (Sayers et al. 1991), but annual mean densities of brook silverside larvae in 1991 were similar to 1990 values while densities of black crappie larvae declined roughly 50% from 1990 to 1991. Densities of larval bluegill have been declining in recent years and this trend apparently continued in 1991 with annual means in Regions 5 and 7 of 408 and 316 larvae/1000 m³ compared with 591 and 678 larvae/1000 m³ in 1990 (Sayers et al. 1991). Eastern mudminnow, warmouth, largemouth bass, yellow perch, and bannerfin shiner were collected in sufficient densities to warrant inclusion in the 1991 results. Densities of shad larvae were much greater in 1991 (503-1207 larvae/1000 m³) than in 1990 (280-452 larvae/1000 m³), suggesting a relatively strong 1991 year class.

Black crappie were among the first larvae to appear in 1991 surface samples, with peak abundance occurring in early-April in Region 5 and mid-April in Region 7 (Figure 3-24). Larvae of redbreast sunfish were found in littoral surface samples beginning in mid-April and were found sporadically through late August (Figure 3-24). Densities of redbreast sunfish larvae were generally low

Table 3-41. Annual mean density (no./1000 m³), standard deviation (S.D.), and relative abundance (%) of ichthyoplankton in pelagic oblique and littoral surface samples from Regions 5 and 7 of L Lake during 1991.

SPECIES	OBLIQUE						SURFACE					
	REGION 5			REGION 7			REGION 5			REGION 7		
	MEAN	S.D.	%	MEAN	S.D.	%	MEAN	S.D.	%	MEAN	S.D.	%
shad	515.56	1388.3	91.68	468.13	1378.6	79.14	1206.8	3028.2	57.67	503.00	1169.0	35.89
gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	19.99	0.26
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.38	227.56	2.10
eastern mudminnow	0.00	0.00	0.00	0.00	0.00	0.00	0.31	2.41	0.01	0.00	0.00	0.00
minnow	0.75	3.92	0.13	0.00	0.00	0.00	80.34	292.47	3.84	26.02	76.22	1.86
bannerfin shiner	0.00	0.00	0.00	4.94	26.52	0.84	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	4.83	11.30	0.86	3.37	9.76	0.57	249.28	349.32	11.91	218.79	307.48	15.61
sunfishes (Centrarchidae)	0.00	0.00	0.00	0.73	3.81	0.12	0.00	0.00	0.00	0.92	4.04	0.07
sunfish (<i>Lepomis</i> sp.)	0.00	0.00	0.00	0.00	0.00	0.00	0.39	3.04	0.02	1.16	8.97	0.08
redbreast sunfish	0.40	3.00	0.07	0.70	3.68	0.12	8.64	20.81	0.41	11.32	28.85	0.81
warmouth	0.35	2.65	0.06	0.00	0.00	0.00	0.64	3.45	0.03	2.32	8.38	0.17
bluegill	27.79	43.96	4.94	65.23	87.43	11.03	408.13	1008.0	19.50	316.17	717.60	22.56
largemouth bass	0.37	2.74	0.07	0.32	2.42	0.05	6.72	20.54	0.32	4.89	21.11	0.35
black crappie	6.79	16.17	1.21	8.07	25.00	1.37	110.90	285.83	5.30	267.14	1045.6	19.06
yellow perch	2.85	10.42	0.51	6.50	18.70	1.10	6.17	26.12	0.29	7.71	30.52	0.55
unknown	2.69	14.38	0.48	33.49	135.74	5.66	14.31	41.40	0.68	9.02	37.20	0.64
TOTAL	562.38	1434.2	100.0	591.49	1559.5	100.0	2092.6	3559.1	100.0	1401.5	2268.6	100.0

Figure 3-24. Biweekly densities (larvae/1000 m³) of larval black crappie, bluegill, and redbreast sunfish from littoral surface tows in Regions 5 and 7 of L. Lake during 1991.

(<50 larvae/1000 m³) and they were consistently more abundant in samples from late-July and August. Bluegill larvae were found in littoral surface samples from early-May with peak densities in mid-May and early-August samples (Figure 3-24), suggesting that bluegill spawning occurs throughout the summer.

Shad larvae (Dorosoma sp.) were found in littoral surface samples from early-April through late-June, with peak abundance occurring in mid-May (Figure 3-25). Yolk-sac larvae of gizzard shad were found in littoral surface tows only in early-April and only in Region 7, suggesting that spawning in the lower portion of L Lake occurs in late-March. Yolk-sac larvae of threadfin shad were also found only in samples from Region 7, but not until early-May. Threadfin shad yolk-sac larvae were collected in Regions 5 and 7 in 1990 and the period of occurrence for threadfin shad larvae was slightly later in 1991 than the mid-April to late-May period reported in 1990 (Sayers et al. 1991). Larval densities in Region 5 during the period of greatest abundance were typically double those in Region 7, suggesting that spawning activity was greater in the upstream end of L Lake, a point also supported by the hydroacoustic surveys.

Larvae of brook silverside were first found in early-February littoral samples, but they were not collected again until mid-April (Figure 3-26). Densities of larval brook silversides fluctuated between about 150 and 550 larvae/1000 m³ from mid-April until mid-June, and then declined until a sharp increase in late-July that continued through August. This bimodal pattern was evident in Regions 5 and 7, so it probably indicates multiple spawning in 1991.

Cyprinid (minnow) larvae were collected in littoral surface tows from early-April through late-May and from late-July through August (Figure 3-26).

Figure 3-25. Biweekly densities (larvae/1000 m³) of larval shad (*Dorosoma* sp.), threadfin shad, and gizzard shad from littoral surface tows in Regions 5 and 7 of L Lake during 1991.

Figure 3-26. Biweekly densities (larvae/1000 m³) of larval cyprinids and brook silverside from littoral surface tows in Regions 5 and 7 of L. Lake during 1991.

This longer period of occurrence (compared with 1989 and 1990 results) and the increased numbers of coastal shiners collected in the juvenile/adult fisheries surveys suggest that cyprinids are becoming an important component of the L-Lake fish assemblage.

3.3.2.2 Pelagic Oblique Tows

Larvae of eight distinct species as well as unspecified shad, sunfish, and minnows were collected in pelagic oblique ichthyoplankton tows during 1991 (Table 3-41). Shad larvae were the most abundant taxa based on annual mean densities, forming 79% of the total catch in Region 7 and 92% in Region 5. Bluegill was the only other taxa that composed at least 5% of the total catch. In previous years, black crappie larvae also formed about 5% of the pelagic ichthyoplankton catch (Sayers et al. 1990, 1991), but in 1991 this taxa accounted for about 1% of the total. Bannerfin shiner was the only taxa collected in pelagic oblique samples that was not collected in littoral surface samples. This species has not been previously identified from ichthyoplankton or adult fish samples from L Lake and the collection of larval forms may indicate that a breeding population has become established in L Lake. However, it is also possible that larval bannerfin shiners were entrained from the Savannah River.

Black crappie were the first abundant species to appear in pelagic oblique ichthyoplankton samples. They occurred from mid-March through late-April in Region 5 and through mid-May in Region 7 (Figure 3-27). Bluegill larvae were found in oblique samples from early-May through late-August in Regions 5 and 7, but densities in Region 7 were typically higher than in Region 5. Very few redbreast sunfish larvae were collected in oblique tows.

Figure 3-27. Biweekly densities (larvae/1000 m³) of larval black crappie, bluegill, and redbreast sunfish from pelagic oblique tows in Regions 5 and 7 of L. Lake during 1991.

All of the shad collected in oblique samples had developed beyond the yolk-sac stage and, therefore, were identifiable only to genus (Dorosoma). Shad larvae were found in pelagic oblique samples from mid-April through mid-June with peak abundance in mid-May (Figure 3-28). This period of occurrence was very similar to that observed in littoral surface samples.

Cyprinid larvae appeared later in oblique tows (mid-May) than in surface tows, and densities in Region 7 were much higher than in Region 5 (Figure 3-29). Brook silverside larvae were found in oblique samples from mid-May through early-August in Region 5 and through mid-July in Region 7. Densities of brook silverside larvae were lower in oblique tows than in surface samples, a pattern that was also observed in 1990 (Sayers et al. 1991).

3.3.3 Discussion

Results of this study indicate that patterns of fish reproduction typical of a mature reservoir have developed within five years after impoundment of Lake. Successful reproduction of reservoir-type species such as gizzard shad, threadfin shad, brook silverside, bluegill, redbreast sunfish, and black crappie was indicated by collection of larval forms of these species. Additionally, larvae of largemouth bass were collected in both surface and oblique ichthyoplankton samples, documenting successful reproduction of this species. Heuer et al. (1989) had attributed the scarcity of largemouth bass and redbreast sunfish larvae to secretive behavior; however, the increased number of redbreast sunfish larvae in 1989 suggests that secretive behavior was not responsible for low catches in previous years and a similar argument may also apply to largemouth bass based on results from 1990 to 1991.

Figure 3-28. Biweekly densities (larvae/1000 m³) of larval shad (*Dorosoma* sp.), threadfin shad, and gizzard shad in pelagic oblique tows in Regions 5 and 7 of L Lake during 1991.

Region 5

▨ Brook silverside ■ Cyprinids

Region 7

Figure 3-29. Biweekly densities (larvae/1000 m³) of larval cyprinids and brook silverside in pelagic oblique tows in Regions 5 and 7 of L. Lake during 1991.

Gizzard shad and threadfin shad are typically the dominant taxa of the ichthyoplankton of southern U.S. reservoirs (Kilch 1976; Krause 1979; Cada et al. 1980; Lewis and Siler 1980; Dewey and Moen 1982; Downey and Toetz 1983; Matthews 1984; Petering and Van Den Avyle 1988). The continued presence of these taxa in the ichthyoplankton of L Lake suggests that the fish assemblage in L Lake is similar to that of a typical southeastern reservoir. Densities of shad larvae were slightly larger in 1991 than in 1990 and formed roughly 50% of the ichthyoplankton in surface samples and 80-90% of the ichthyoplankton in oblique samples. Shad larvae are generally most abundant in shoreline habitats (Miller 1960; Mayhew 1974; Van Den Avyle and Fox 1980) and this pattern was observed in L Lake, with littoral densities exceeding pelagic densities in Regions 5 and 7 (Table 3-41). However, the relative abundance and seasonal mean and maximum densities of shad in the littoral zone of L Lake (~20%, mean of 503 to 1207, max = 9700; Table 3-41 and Figure 3-25) were far less than values recorded from the littoral zones of other Southern U.S. reservoirs including Lake Oconee, Georgia (Petering and Van Den Avyle 1988), Lake Carl Blackwell, Oklahoma (Downey and Toetz 1983), and impounded sections of the Cape Fear River, North Carolina (Sager 1981).

Although shad larvae were not identified to species, most were probably threadfin shad. The primary support for this conclusion was the prevalence of adult and juvenile threadfin shad in electrofishing and midwater trawl samples and the scarcity of adult and juvenile gizzard shad.

Heuer et al. (1989) suggested that hot water effluents from L-Reactor influenced shad reproduction in L Lake by attracting adults to the warmer, upstream regions of the lake. Because L-Reactor was on stand-by during 1990 and

1991, water temperatures were similar among all regions of L Lake. The longitudinal gradient in density of larval shad, cited by Heuer et al. (1989) as evidence of thermal influence was missing in 1990 (Sayers et al. 1991), but was again evident in 1991 (Table 3-41). The onset of shad spawning was later in 1990 and 1991 than in years when L-Reactor was operating, presumably due to cooler water temperatures.

The introduction of shad into systems previously dominated by centrarchids frequently results in a decline in recruitment, growth, and condition of resident sunfishes (Jahn 1983; Moss and Reeves 1983; Neuswanger 1983; Putnam 1983; Russell 1983; Kirk and Davies 1985; Kirk et al. 1986). Heuer et al. (1989) suggested that decreased abundance of larval bluegills in the limnetic zone of L Lake in 1988 was conclusive evidence of negative effects by shad on the sunfishes of L Lake. Densities of bluegill larvae in limnetic samples rebounded in 1989 to levels similar to 1987 (Sayers et al. 1990) but declined again in 1990 (Sayers et al. 1991). Further, density of bluegill larvae almost doubled in the littoral zone of L Lake during 1989 and there is no direct evidence to suggest that growth or condition of bluegill has declined as a result of shad introduction.

Bluegill and black crappie (the two most common centrarchid larvae in L Lake) typically spawn in the littoral zone of lakes and the larvae then migrate to the limnetic zone where zooplankton densities are greater (Fabar 1967; Werner 1967; Storck et al. 1978; Werner and Hall 1988). Such behavior, coupled with biweekly sampling plans could easily explain year-to-year differences in limnetic densities, as it would be possible to miss the shift to open water.

3.4 THERMAL INFLUENCES

Previous investigations on L Lake (Paller et al. 1987, 1988; Heuer et al. 1989) examined: 1) successional changes in taxonomic composition and abundance for evidence of domination by thermally tolerant species or the elimination of thermally sensitive species; 2) changes in condition of important species; and 3) the prevalence of diseases that might represent indirect effects of thermal discharge. Neither study described any appreciable negative effects due to thermal discharge into L Lake relating to these criteria.

3.4.1 Successional Changes

Paller et al. (1988) described the successional changes in the fish assemblage of L Lake from its initial filling in late 1985 through the end of 1987. They reported a general reduction in populations of lotic species such as dollar sunfish, spotted sunfish, spotted sucker, redbfin pickerel, and shiners. They also reported an increase in lentic species such as bluegill (stocked when the reservoir was filled), largemouth bass (resident and stocked), black crappie (probably entrained as eggs or larvae from Par Pond), and redbreast sunfish (resident), as well as the appearance of threadfin and gizzard shad. Beckman and Elrod (1971) and Turner (1971) described similar declines in the abundance of lotic species following the formation of a new impoundment.

Unlike Steel Creek, with its wide diversity of habitat types (Firth et al. 1986), L Lake provided largely homogeneous fish habitat, particularly during the period immediately following impoundment. Given that species diversity is related to habitat diversity, it is unrealistic to expect that L Lake would sustain levels of diversity similar to those of Steel Creek. The decline in

species richness observed shortly after impoundment was similar to a decrease in species richness described for a main stem Missouri River impoundment (Walburg et al. 1971).

Thermally sensitive species can be eliminated from highly thermal systems; however, elimination of thermally sensitive species from L Lake has not been documented. Species richness declined precipitously when temperatures exceeded 35 °C in Four Mile Creek (Paller and Saul 1986). It is unlikely that the initial decline in species richness in L Lake (from 1986 through 1987) was related to thermal stress, since most of the lake never experienced water temperatures greater than 35 °C and was otherwise little affected by heated discharges (Heuer et al. 1989). Limited habitat diversity in the newly impounded reservoir is a more probable cause for the initial decline in species richness.

Taxa richness in L Lake was basically unchanged from 1987 to 1988 and this trend continued through 1989 (Heuer et al. 1989). The same dominant taxa were found during 1989, despite a general decline in abundance from 1988 levels. Taxa richness declined to 19 distinct taxa (including hybrid sunfish) in 1990 and 16 taxa in 1991, undoubtedly due in large part to the reduced scope of sampling begun in 1990. Species such as American eel, lake chubsucker, or bluespotted sunfish are collected rarely and a reduced sampling effort would be less likely to collect such taxa.

The dominant species in L Lake (bluegill, redbreast sunfish, largemouth bass, and threadfin shad) are all well adapted to the climate of the southern United States (Clugston 1973; Beitinger 1974). Continued domination of the L Lake fish assemblage by these species would not be unusual or indicative of

thermal influences relating to operation of L-Reactor. Some impoundments become overpopulated by bluegill (Carlander 1977), and the increased abundance of larval bluegills in 1988 and 1989 suggests this may be occurring in L Lake. However, the decline in larval bluegill densities in 1990 coupled with decreased abundance of juvenile and adult bluegills in 1990 and 1991 suggests the problem is not acute. Yellow perch and coastal shiner were relatively abundant in the 1991 electrofishing catches, suggesting that these two species now constitute a major portion of the L-Lake fish assemblage. Despite the decline in taxa richness, it appears that fish production in L Lake is actually becoming more evenly distributed among a variety of species rather than being concentrated almost entirely in bluegill, redbreast sunfish, and threadfin shad. Thus, trends observed during 1991 indicate that successional changes in L Lake are typical of the development of a warm-water reservoir fish assemblage.

3.4.2 Changes in Growth and Condition

Paller et al. (1988) described decreases in condition of largemouth bass, redbreast sunfish, and bluegill from 1986 to 1987 in L Lake. They attributed these decreases to either diminished food supplies or increased competition for food rather than to effects of thermal effluents. Heuer et al. (1989) reported that condition of these three species continued to decline during 1988 in L Lake. They ruled out thermal effects since maximum littoral temperatures in 1988 were lower than in previous years. Condition of bluegill, redbreast sunfish, and largemouth bass in 1989 was similar to 1988 levels but generally lower than the 1986-1988 average (Sayers et al. 1990).

Condition of redbreast sunfish in 1990 was largely unchanged from 1989 levels and remained near the values reported each year since 1987, as did

condition of young bluegills. Condition of adult bluegills increased in 1990 as did condition of adult largemouth bass. Condition of redbreast sunfish and bluegill in 1991 remained basically unchanged from 1990 values. Mean condition of large (>300 mm) largemouth bass declined slightly in 1991 but remained unchanged from earlier years for adult (151-300 mm) and young (≤ 150 mm) fish. Despite the decline, condition factors of large adult bass in L Lake are similar to those of other U.S. populations (Carlander 1977). The fact that condition of smaller bass in L Lake is slightly lower than other U.S. populations may reflect density-dependent regulation of growth. It is possible that condition of younger fish will improve in 1992 because the population of large bass was reduced by the 1991 redsore epizootic.

The limited results regarding growth rates of marked fish in 1990 and 1991 make it difficult to determine the direction of growth trends in L Lake. The decline in growth rates for largemouth bass during 1990 contradicts a slight increase in condition for adults, but probably indicates that older fish form a major portion of the tagged population. The slight rebound in growth rates for tagged largemouth bass may reflect reduced intraspecific competition for food following the major die-off of largemouth bass in the spring of 1991. Because of the small number of recaptures, virtually no useful information was obtained regarding growth of bluegill, redbreast sunfish, and flat bullhead.

3.4.3 Prevalence of Disease

Esch and Hazen (1978) implicated elevated temperatures in the causal sequence of redsore disease (pathogen: Aeromonas hydrophila) of largemouth bass in Par Pond. Paller et al. (1988) noted the presence of redsore disease in L Lake but concluded, based on low incidence in 1987, that it was not serious.

Heuer et al. (1989) reported a major outbreak of redsore disease in L Lake in 1988, but suggested the cause was high fish densities rather than thermal effluents. The relatively high incidence of redsore disease in L Lake during 1989, 1990, and 1991, coupled with the fact that L-Reactor did not operate during those years, supports the claim of Heuer et al. (1989) that high fish density, rather than thermal effluents, was the cause of the outbreak.

3.5 SIMILARITY TO OTHER RESERVOIRS

Despite seasonal and temporal differences in abundance of fish and ichthyoplankton, no consistent patterns were observed indicating differences in abundance of taxa richness among Regions 5 and 7. Therefore, data from Regions 5 and 7 were combined to allow comparison with fish assemblages from selected reservoirs based on yearly averages of relative abundance.

The fish assemblage of L Lake was again dominated by bluegill, redbreast sunfish, and largemouth bass in 1991, much as in previous years. However, unlike previous years, clupeids formed a relatively small portion of the total catch (5%) while minnows (mostly coastal shiners) and other fishes (mostly brook silversides and yellow perch) formed 24 and 17% of the total electrofishing catch. This shift to an assemblage with more minnows and other types of fishes has left the L-Lake fish assemblage more similar to other reservoirs in the region than in the past (Figure 3-30).

The visual comparisons of the fish assemblages suggest that the 1991 L Lake data are most similar to that observed in Monticello or Russell reservoirs. The greatest difference between L Lake and the other reservoirs is in the scarcity of other sunfishes, suckers, and other fishes such as catfishes. Pond B and Par

Figure 3-30. Relative abundance (% composition) of major fisheries groups in L Lake from 1986-1991 (B = January-June; L = July-December) and in the South Carolina reservoirs (Shedrow in prep.). BG-RBS-LMB = bluegill, redbreast sunfish, largemouth bass.

Pond are also thermal discharge reservoirs located on the Savannah River Site, although they do not share the same drainage as L Lake (also see Appendix Tables 6, 7, and 8 for 1991 fish collection data from Par Pond). The fish assemblages of these reservoirs did not appear to be strongly similar to that of L Lake, but each of these reservoirs is considerably older than L Lake. Given a sufficient length of time, the fish assemblage of L Lake can probably be expected to resemble those of Pond B and Par Pond.

The 1991 data suggested that the fish assemblage of L Lake was more typical of southeastern reservoirs than in the past. The predominance of bluegill, redbreast sunfish and largemouth bass was probably due largely to the brief life of the reservoir. Heavy dominance by either clupeids or centrachids is common among reservoirs of the region as evidenced by Greenwood, Monticello, Russell, and Robinson reservoirs (Figure 3-30).

3.6 TROPHIC RELATIONSHIPS

Many researchers have reported on feeding habits of fishes and their role in ecosystem function (Bartell and Kitchell 1978; Wallace 1979; Drenner et al. 1984; Ziebell et al. 1986). All typical reservoir trophic groups of fishes were present in L Lake by 1987. Threadfin and gizzard shad represented the lowest trophic level, functioning as primary consumers. Beginning in 1988, threadfin shad exhibited two feeding patterns. Some fed on benthos or detritus, others filter-fed on plankton (Heuer et al. 1989). The filter-feeding pattern was again evident in 1990 and 1991, indicating that energy pathways in the limnetic zone are becoming more important. The continued use of threadfin shad as prey by largemouth bass completes the grazing-based food chain that was described as incomplete by Paller et al. (1988).

Previous studies on L Lake indicated that the zooplankton/small fish portion of the grazing-based food chain was particularly well developed (Paller et al. 1988; Heuer et al. 1989). Microcrustaceans continued to form a major part of the diet of small bluegills and redbreast sunfish during 1991. These results are similar to those of Siefert (1972), Barger and Kilambi (1980), and Keast (1980). The addition of threadfin shad feeding on algae and the inclusion of threadfin shad in the diet of largemouth bass provide another pathway for energy to flow through the grazing-based food chain in L Lake.

The detritus-based food chain continued to play an important role in energy transfer in L Lake. The relative importance of mollusks declined from that reported in previous years (Heuer et al. 1989; Sayers et al. 1990). However, insect larvae and amphipods remained the primary food of bluegills and redbreast sunfish. The increased abundance of coastal shiners, which also feed primarily on insects and crustaceans (Lee et al. 1980) also provides a potential pathway for energy transfer from detritus to fish. The detritus-based food chain was completed by largemouth bass preying on either bluegills, redbreast sunfish, threadfin shad (that occasionally feed directly on detritus), or minnows.

Detritus- and grazing-based food chains are typical of lakes and reservoirs (Odum 1971; Wetzel 1983). The presence of these two energy pathways, as well as the presence of all trophic groups, supports the designation of L Lake as a balanced biological community.

3.7 REPRODUCTION OF FISHES

Due to high mortality of early life stages, documentation of successful reproduction of a fish species requires collection of juveniles or adults, as

well as eggs and larvae (Nikolsky 1963; Summerfelt 1975; Paller et al. 1988). From 1987 through 1991, similar patterns of occurrence of adults and larvae were noted for the dominant taxa, reflecting continued successful reproduction of these taxa.

Paller et al. (1988) listed clubsuckers and brook silversides as species precluded from successful reproduction in L Lake by lack of suitable spawning habitat. Heuer et al. (1989) reported successful reproduction of lake chubsuckers and brook silversides, suggesting that suitable spawning habitat was available. Brook silversides are apparently rebounding in L Lake as evidenced by increasing densities of larval brook silversides in 1989 and 1990. However, neither larval nor adult lake chubsuckers were collected during 1991.

Larval fish densities in both the pelagic and littoral portions of L Lake during 1991 were similar to those observed in 1990. Patterns of accelerated spawning reported by Paller et al. (1988) and Heuer et al. (1989) were generally not observed in 1989 (Sayers et al. 1990), 1990 (Sayers et al. 1991), or 1991. The cooler water temperatures that existed are the probable cause for the later spawning periods.

4.0 SUMMARY AND CONCLUSIONS

Condition of large (> 300 mm) largemouth bass declined slightly in 1991, coincidental with a major die-off caused by an Aeromonas epizootic. Condition of bluegill, redbreast sunfish, and smaller largemouth bass remained similar to 1990 values. The year-to-year fluctuations in condition observed over the course of this study probably reflect natural changes associated with the processes of ecological succession as a fish assemblage typical of southeastern reservoirs develops in L Lake.

Juvenile and adult bluegill abundance apparently declined from 1989 and 1990 levels, despite high larval bluegill production in 1988 and also 1989 (Heuer et al. 1989; Sayers et al. 1990). Production of larval bluegill also declined in 1991. Abundance of juvenile and adult redbreast sunfish declined slightly in 1991 and larval redbreast sunfish were scarce in 1991. Overall abundance of threadfin shad declined sharply from 1990 levels but larval shad densities were higher in 1991. Relative abundance of yellow perch, brook silversides, and coastal shiner was higher in 1991 due to increased catches per unit of effort for these species and smaller catches for the more common sunfishes and shad. These changes indicated that the L-Lake fish assemblage has shifted to a more even distribution of individuals among species.

No reactor-related fish kills occurred in L Lake in 1991 but species richness declined from 1990 levels. This decline was probably the result of reduced collections of rare species, due largely to the reduced scope of sampling employed in 1990 and 1991.

Based on results of 1987 studies, it was concluded that several factors contributed to the formation of a balanced biological community in L Lake: 1) the community was similar to that of other cooling reservoirs; 2) successful reproduction of the major species was documented; 3) fish condition and health were within average values; 4) typical reservoir food chains and trophic groups were well represented; and 5) fish kills were scarce or absent in the lower half of the lake.

In 1988, trends in condition and incidence of infectious disease changed. Condition continued to decline for some taxa. Incidence of infectious disease increased sharply in 1988, and a major fish kill, caused by redsore disease, occurred in the lower half of L Lake. However, in spite of decreased condition and increased disease incidence, several of the primary criteria for a biologically balanced community were met based on the 1988 results. The fish assemblage of L Lake remained similar to that in other reservoirs. Recruitment of the major taxa was not noticeably impaired and all major trophic groups were well represented.

Data collected during 1989 indicated that disease incidence remained relatively high in 1989 and again resulted in a measurable fish kill. However, the fish assemblage of L Lake generally satisfies the remaining criteria for a balanced biological community. The species composition remained similar to that of other reservoirs; the major taxa were successfully reproducing; fish condition was generally within average values; and typical trophic groups and food chains were well represented.

Disease incidence remained relatively high and again resulted in a measurable fish kill during 1990. However, the remaining criteria for a balanced biological community appeared to be met by the L-Lake fish assemblage. The species composition was similar to that of other reservoirs; the most abundant taxa were successfully reproducing; fish condition was generally within average values for the region; and typical groups and food chains were well represented.

Abundance of juvenile and adult fish was again lower in 1991, as evidenced by catches per unit of effort for many taxa in most sampling programs. Disease incidence was again high in 1991, causing high mortality of adult largemouth bass. Examination of proportional stock density suggested that the L-Lake bass population contained too many large fish to be in proper balance with its forage base, even despite the large die-off caused by redsore. However, the remaining criteria for a balanced biological community appeared to be satisfied. The species composition was similar to that of other reservoirs; the most abundant fish taxa were successfully reproducing; fish condition was generally within average ranges for the region; and all typical functional groups and energy pathways were well represented.

5.0 LITERATURE CITED

- Aho, J.M. and C.S. Anderson. 1986. Dynamics of the fish kills in Pond C: life in a capricious environment. In: Aho, J.M., C.S. Anderson, K.B. Floyd, and M.T. Negus (eds.). Patterns in Fish Assemblage Structure and Dynamics of the Savannah River Plant: Comprehensive Cooling Water Report. SREL 27. DE-AC09-76SR00-819. Savannah River Ecology Laboratory. Aiken, SC.
- American Fisheries Society (AFS). 1982. Monetary values of freshwater fish and fish-kill counting guidelines. Spec. Publ. No. B. ISSN0097-0638. Bethesda, MD.
- Anderson, R.O. 1976. Management of small warm water impoundments. Fisheries 1(6): 5-7, 26-28.
- Auer, N.D. (ed.). 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Spec. Pub. 82-82. Great Lakes Fisheries Commission. Ann Arbor, MI.
- Barger, L.E. and R.V. Kilambi. 1980. Feeding ecology of larval shad, Dorosoma, in Beaver Reservoir, Arkansas. Proc. Fourth Larval Fish Conf. Oxford, MS.
- Bartell, S.M. and J.F. Kitchell. 1978. Seasonal impact of planktivory on phosphorus release by Lake Wingra zooplankton. Vehr. Internat. Verein. Limnol. 20:466-474.
- Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press. Madison, WI.
- Beckman, L.G. and J.H. Elrod. 1971. Apparent abundance and distribution of young-of-year fish in Lake Oahe, 1965-69. In: Hall, G.E. (ed.). Reservoir Fisheries and Limnology. Spec. Publ. No. 8. Am. Fish. Soc. Washington, DC.
- Beitinger, T.L. 1974. Thermoregulatory behavior and diel activity patterns of bluegill, Lepomis macrochirus, following thermal shock. U.S. Fish and Wild. Serv. Bull. 72:1087-1093.
- Brown, H.W. 1974. Handbook on the effects of temperature on some North American fishes. Am. Elec. Power Ser. Corp. Canton, OH.
- Cada, G.F., J.M. Loar, and K. D. Kumar. 1980. Diel patterns of ichthyoplankton length-density relationships in Upper Watts Bar Reservoir, Tennessee. pp. 79-89 In Fuiman, L.A. (ed). Proc. Fourth Ann. Larval Fish Conf., U.S. Fish Wildl. Serv. FWS/OBS-80/43.
- Carlander, K.D. 1977. Handbook of Freshwater Fisheries Biology, Vol. II. The Iowa State Univ. Press. Ames, IA.

- Carline, R.F., B.L. Johnson, and T.J. Hall. 1984. Estimation and interpretation of proportional stock density for fish populations in Ohio impoundments. *N. Am. J. Fish. Mgmt.* 4:139-154.
- Clugston, J.P. 1973. The effects of heated effluents from a nuclear reactor on species diversity, abundance, reproduction and movement of fish. Ph.D. Dissertation. Univ. Georgia. Athens, GA.
- Dewey, M. R. and T.E. Moen. 1982. Temporal and spatial distribution of some young-of-the-year fishes in DeGray Lake, Arkansas, 1975-1978. pp. 37-41. In: Bryan, C.F., J.V. Conner, and F.M. Truesdale (eds.). Fifth Ann. Larval Fish Conf., Louisiana State Univ., Baton Rouge, LA.
- Dewey, M.R. and T.E. Moen. 1987. Entrainment of larval fish from DeGray Lake, Arkansas, during epilimnial and hypolimnial discharges. pp. 437-460. In: Kennedy, R.H. and J. Nix (eds.). Proceedings of the DeGray Lake Symposium, Technical Report E-87-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- DOE. 1984. Final Environmental Impact Statement. L-Reactor Operation. Savannah River Plant. DOE/EIS-0108. U.S. Dept. of Energy. Washington, DC.
- Downey, P. and D. Toetz. 1983. Distribution of larval gizzard shad (Dorosoma cepedianum) in Lake Carl Blackwell, Oklahoma. *Amer. Midl. Nat.* 109:23-33.
- Drenner, R.W., J.R. Mummert, F. deNoyelles, Jr., and D. Kettle. 1984. Selective particle ingestion by a filter-feeding fish and its impact on phytoplankton community structure. *Limnol. Oceanogr.* 29:941-948.
- Esch, G.W. and T.C. Hazen. 1978. Thermal ecology and stress - a case history for red-sore disease in large-mouth bass (Micropterus salmoides). In: Thorp, J.H. and J.W. Gibbons (eds.). Energy and Environmental Stress in Aquatic Systems. U.S. DOE. Symp. Ser. CONF-771114.
- Esch, G.W. and T.C. Hazen. 1980. Stress and body condition in a population of largemouth bass: implications for red-sore disease. *Trans. Am. Fish. Soc.* 109:532-536.
- Faber, D.J. 1967. Limnetic larval fish in northern Wisconsin lakes. *J. Fish. Res. Bd. Canada* 24:927-937.
- Firstenberg, H. and G. Fisher. 1980. An Investigation of Cooling Lakes for the Closed Cycle Operation of Electric Generating Stations. NUS Corporation. Rockville, MD.
- Firth, P., J.R. O'Hop, B. Coler, and R.A. Green. 1986. Lotic aquatic ecosystems of the Savannah River Plant: impact evaluation, habitat analyses and the lower food chain communities. ECS-SR-26. Prepared by Environmental & Chemical Sciences, Inc. for E.I. du Pont de Nemours & Company. Aiken, SC.

- Fuiman, L.A., J.V. Conner, B.F. Lathrop, G.L. Buynak, D.E. Snyder, and J.J. Loos. 1983. State of the art of identification for cyprinid fish larvae from eastern North America. *Trans. Am. Fish. Soc.* 112:319-332.
- Gabelhouse, Jr., D.W. 1984. A length-categorization system to assess fish stocks. *N. Amer. J. Fish. Manage.* 4:273-285.
- Gibbons, J.W., D.H. Bennett, G.W. Esch, and T.C. Hazen. 1978. Effects of thermal effluent on body condition of largemouth bass. *Nature* 274:470-471.
- Gilliland, E.R. 1983. Density and distribution of larval fish in an Oklahoma power plant cooling water reservoir. *Proc. Oklahoma Acad. Sci.* 63:33-36.
- Gunnison, D.G. (ed.) 1985. Microbial Processes in Reservoirs. Dr. W. Junk. Boston, MA.
- Gustafson, K.A. 1988. Approximating confidence intervals for indices of fish population size structure. *N. Am. J. Fish. Mgmt.* 8:139-141.
- Hardy, J.D. Jr., 1978. Development of fishes of the mid-Atlantic Bight. *Aphredoderidae through Rachycentridae*. FWS/OBS-78/12.
- Heuer, J.H., L.A. Kissick, H.G. Mealing, D.W. Hughes, and B.P. Lindsey. 1989. L-Lake Fish: L-Lake/Steel Creek Biological Monitoring Program. January 1986-December 1988. NAI-SR-80. Prepared by Normandeau Associates, Inc. for E.I. du Pont de Nemours & Co. Aiken, SC.
- Hickman, G.O. and J.C. Congdon. 1974. Effects of length limits on the fish population of five North Missouri lakes. In: Funk, J.L. (ed.). *Symposium on overharvest and management of largemouth bass in small impoundments*. N. Central Division, Spec. Publ. No. 3. Am. Fish. Soc.
- Houser, A. and W.C. Rainwater. 1975. Production of largemouth bass in Beaver and Bull Shoals lakes. pp. 310-316. In: Stroud, R.H. and H. Clepper, (eds.). *Black Bass Biology and Management*. Sport Fishery Institute, Washington, DC.
- Hyslop, E.J. 1980. Stomach contents analysis - a review of methods and their application. *J. Fish Biol.* 17:411-429.
- Jahn, L. 1983. Effects of gizzard shad in a 250 acre Illinois lake. pp. 30-37. In: *Proceedings of small lakes workshop: pros and cons of shad*. Iowa Conservation Commission. Des Moines, IA.
- Kaya, C.M. and A.O. Hasler. 1972. Photoperiod and temperature effects on the gonads of green sunfish, Lepomis cyanellus (Rafinesque), during the quiescent, winter phase of its annual sexual cycle. *Trans. Am. Fish Soc.* 101:270-275.

- Keast, A. 1980. Food and feeding relationships of young fish in the first weeks after the beginning of exogenous feeding in Lake Opinicon, Ontario. *Env. Biol. Fish.* 5:305-314.
- Kilch, B. L. 1976. Horizontal distribution and relative abundance of larval fishes in Center Hill Reservoir, Tennessee. *Tenn. Wildl. Res. Agency Tech. Rep. No. 53.*
- Kirk, J. P. and W. D. Davies. 1985. Competitive influences of gizzard shad on largemouth bass and bluegill in small impoundments. *Proc. Ann. Conf. Southeast. Assoc. Fish. Wildl. Agencies* 39:116-124.
- Kirk, J.P., W.D. Davies, and K. Park. 1986. Response of some members of the fish community to gizzard shad removal from Chambers County Public Fishing Lake, Alabama. *N. Am. J. Fish. Mgmt.* 6:252-255.
- Krause, R.A. 1979. Temporal and spatial variations in abundance of limnetic larval fishes in Center Hill Reservoir, Tennessee. Unpubl. M. Sc. Thesis. Tennessee Tech. Univ.
- Lagler, K.F. 1956. Freshwater Fishery Biology. Wm. C. Brown Company. Dubuque, IA.
- Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. Pub. #1980-12. North Carolina Biological Survey. NC State Museum of Natural History.
- Lewis, R.E. and J.R. Siler. 1980. Determination of the vertical distribution of ichthyoplankton in Lake Norman, North Carolina, using a discrete-depth sampling design. pp. 91-100. In: Fuiman, L.A. (ed.). *Proc. Fourth Ann. Larval Fish Conf., U.S. Fish Wildl. Serv.* FWS/OBS-80/43.
- Light, R.W., P.H. Adler, and D.E. Arnold. 1983. Evaluation of gastric lavage for stomach analysis. *N. Am. J. Fish. Mgmt.* 3:81-85.
- Matthews, W.J. 1984. Influence of turbid inflows on vertical distribution of larval and freshwater drum. *Trans. Am. Fish. Soc.* 113:192-198.
- Mayhew, J. 1974. Abundance, distribution, mortality and production of 0-age fish. Iowa Fed. Aid Proj. F-88-R-1 (performance report for jobs 1 and 3). Iowa Conservation Commission.
- Miller, R.R. 1960. Systematics and biology of the gizzard shad (Dorosoma cepedianum) and related fishes. *U.S. Fish Wildl. Serv. Fish. Bull.* 173 (60):371-392.
- Moen, T.E. and M.R. Dewey. 1978. Loss of larval fish by epilimnial discharge from DeGray Lake, Arkansas. *Arkansas Acad. Sci. Proc.* 32:65-67.

- Moss, J. L. and W. C. Reeves. 1983. Bluegill responses to threadfin shad elimination in a 130 acre impoundment. pp. 150-167. In: Proceedings of small lakes workshop: pros and cons of shad. Iowa Conservation Commission. Des Moines, IA.
- Mullan, J.W., and R.L. Applegate. 1967. Food habits of five centrarchids during filling of Beaver reservoir, 1965-1966. Technical Paper 50: Bureau of Sport Fisheries and Wildlife.
- Neuswanger, D.J. 1983. Effects of gizzard shad introduction on the fishery of Lake Paho, Missouri. pp. 87-99. In: Proceedings of small lakes workshop: pros and cons of shad. Iowa Conservation Commission. Des Moines, IA.
- Nikolsky, G.V. 1963. The Ecology of Fishes. Academic Press. New York, NY.
- Odum, E.P. 1971. Fundamentals of Ecology. 3rd. ed. W.B. Saunders Co. Philadelphia, PA.
- Paller, M.H. and B.M. Saul. 1986. Effects of thermal discharges on the distribution and abundance of adult fishes in the Savannah River and selected tributaries. Annual Report. November 1984-August 1985. ECS-SR-28. Prepared by Environmental & Chemical Sciences, Inc. for E.I. du Pont de Nemours & Company. DPST-8. Aiken, SC.
- Paller, M.H., J.H. Heuer, H.G. Mealing, and D.W. Hughes. 1987. L-Lake Fish: L-Lake/Steel Creek Biological Monitoring Program. January-December 1986. ECS-SR-50. Prepared by Environmental & Chemical Sciences, Inc. for E.I. du Pont de Nemours & Co. Aiken, SC.
- Paller, M.H., J.K. Heuer, L.A. Kissick, H.G. Mealing, and D.W. Hughes. 1988. L-Lake Fish: L-Lake/Steel Creek Biological Monitoring Program. January 1986-December 1987. ECS-SR-65. Prepared by Environmental & Chemical Sciences, Inc. for E.I. du Pont de Nemours & Co., Aiken, SC.
- Petering, R.W. and M.J. Van Den Avyle. 1988. Relative efficiency of a pump for sampling larval gizzard and threadfin shad. Trans. Am. Fish. Soc. 117: 78-83.
- Popova, O.A. 1967. The "predator-prey" relationship among fishes (a survey of Soviet papers). Pages 359 - 376. In: S.D. Gerking (ed.). The Biological Basis of Freshwater Fish Production. Blackwell Scientific Publication. Oxford, England.
- Putnam, T. 1983. Factors leading to renovation of two small Iowa public fishing lakes. pp. 134-140. In: Proceedings of small lakes workshop: pros and cons of shad. Iowa Conservation Commission. Des Moines, IA.
- Reynolds, J.B. and L.R. Babb. 1978. Structural dynamics of largemouth bass populations. pp 50-61. In: Novinger, G.D. and J.G. Dillard (eds.). New Approaches to the Management of Small Impoundments. N. Central Div., Am. Fish. Soc. Spec. Pub 5.

- Reynolds, J.B. 1983. Electrofishing. In: Nielsen, L.A., and D.L. Johnson (eds.). Fisheries Techniques. Am. Fish. Soc. Bethesda, MD.
- Robins et al. 1991
- Rohlf, F.J. and R.R. Sokal. 1969. Statistical Tables. W.H. Freeman Co., San Francisco.
- Russell, K. 1983. The effects of gizzard shad on the bluegill fishery of Argyle Lake. pp.175-177. In: Proceedings of small lakes workshop: pros and cons of shad. Iowa Conservation Commission. Des Moines, IA.
- Sager, D.R. 1981. Abundance and distribution of larval fishes in the Cape Fear River above Buckhorn Dam, North Carolina. pp. 370-374. In: Krumholz, L.A. (ed.). The Warmwater Streams Symposium. American Fisheries Society, Southern Division, Bethesda, MD.
- Sayers, R.E., H.G. Mealing, and K.K. Patterson. 1990. L Lake Fish: L Lake/Steel Creek Biological Monitoring Program. January 1986-December 1989. NAI-SR-113. Prepared by Normandeau Associates Inc. for Westinghouse Savannah River Co. Aiken, SC.
- Sayers, R.E., H.G. Mealing, and K.K. Patterson. 1991. L-Lake Fish: L-Lake/Steel Creek Biological Monitoring Program. January 1986-December 1990. NAI-SR-130. Prepared by Normandeau Associates Inc. for Westinghouse Savannah River Co. Aiken, SC.
- Shedrow, B. (in prep). A comparative review of selected water quality and biological data from L Lake and nine other South Carolina reservoirs. Draft report.
- Shelton, W.L, C.D. Riggs, and L. G. Hill. 1982. Comparative reproductive biology of the threadfin and gizzard shad in Lake Texoma, Oklahoma-Texas. pp. 47-51. In: Bryan, C.F., J.V. Conner, and F.M. Truesdale (eds.). 1982. Proceedings of the Fifth Annual Larval Fish Conference, Baton Rouge, LA.
- Shelton, W.L. and R.R. Stephens. 1980. Comparative embryogeny and early development of threadfin and gizzard shad. Prog. Fish Cult. 42:34-41.
- Siefert, R.E. 1972. First food of larval yellow perch, white sucker, bluegill, emerald shiner and rainbow smelt. Trans. Am. Fish. Soc. 101:219-225.
- Storck, T.W., D. Dufford, and K.T. Clement. 1978. The distribution of limnetic fish larvae in a flood control reservoir in central Illinois. Trans. Am. Fish. Soc. 107:419-424.
- Summerfelt, R.C. 1975. Relationship between weather and year- class strength of largemouth bass. In: Clepper, H. (ed.). Black Bass Biology and Management. Sport Fishing Institute, Washington, DC.

- Tarplee, W.H. and W. E. Partin. 1981. Spatial and temporal distributions of ichthyoplankton in the Neuse River, North Carolina, near a low dam and power plant intake. pp. 142-153. In: Krumholz, L.A. (ed.). The Warmwater Streams Symposium. American Fisheries Society, Bethesda, MD. 422 pp.
- Taylor, M.P. 1971. Phytoplankton productivity response to nutrients correlated with certain environmental factors in six TVA reservoirs. In: Hall, G.E. (ed.). Reservoir Fisheries and Limnology. Spec. Publ. No. 8. Am. Fish. Soc. Washington, DC.
- Turner, W.R. 1971. Sport fish harvest from the Rough River, Kentucky, before and after impoundment. In: Hall, G.E. (ed.). Reservoir Fisheries and Limnology. Spec. Publ. No. 8. Am. Fish. Soc. Washington, DC.
- Van Den Avyle, M.J. and D.D. Fox. 1980. Diel, vertical and horizontal variations in abundance of larval Dorosoma spp. in Center Hill Reservoir, Tennessee. pp. 116-122. In: Fuiman, L.A. (ed.) Proc. Fourth Ann. Larval Fish Conf., U.S. Fish Wildl. Serv. S/OBS-80/43.
- Van Den Avyle, M.J. and R. W. Petering. 1988. Inundated amber as nursery habitat for larval gizzard and threadfin shad in a new pumped storage reservoir. Trans. Am. Fish. Soc. 117:84-89.
- Walburg, C.H., G.L. Kaiser, and P.L. Hudson. 1971. Lewis and Clark Lake Tailwater Biota and Some Relations of the Tailwater and Reservoir Fish Populations. pp 449-467. In: Hall, G.E.(ed.) Reservoir Fisheries and Limnology. Am. Fish. Soc. Spec. Publ. No. 8 Washington, DC.
- Wallace, R.A. 1979. Animal Behavior: Its Development, Ecology, and Evolution. Goodyear Publishing Company, Santa Monica, CA.
- Werner, R.G. 1967. Intralacustrine movements of bluegill fry in Crane Lake, Indiana. Trans. Am. Fish. Soc. 96: 416-420.
- Werner, E.E. and D.J. Hall. 1988. Ontogenetic habitat shifts in bluegill: the foraging rate-predation risk trade-off. Ecology 69: 1352-1366.
- Wetzel, R.G. 1983. Limnology. 2nd. ed. W.B. Saunders Co. New York, NY.
- Windell, J.T. 1971. Food analysis and rate of digestion. In: Ricker, E.W. (ed). Methods for Assessment of Fish Production in Freshwater. IBP Handbook No. 3. Blackwell Scientific. Oxford, England.
- Ziebell, C.D., J.C. Tash, and R.L. Banefield. 1986. Impact of threadfin shad on macrocrustacean zooplankton in two Arizona lakes. J. Freshwat. Ecol. 3:399-406.

Appendix Figure 1. Location of electrofishing and midwater trawl stations in Par Pond. January 1990-December 1991.

Appendix Table 1.

List of deviations from standard operating procedures for
the L-Lake Fish sampling program, 1991.

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1. 43 of the 60 largemouth bass lavage samples targeted for January collection were finally collected on 8 February 1991. Original sampling efforts in January failed to collect sufficient numbers of fish.
 2. Region 5, east bank, Replicate B hoop net sample for February was lost due to loss of the net.
 3. August Par Pond adult fish sampling was conducted in July. Dam repairs were scheduled for August and drawdown of the lake would preclude sampling in August.
 4. Two August gill net collects were missed due to risk of lightning around L Lake.
 5. One October gill net sample was not collected due to equipment failure.
 6. Due to low catch rates, targeted numbers of redbreast sunfish, bluegill, and threadfin shad were not collected during any of the quarterly sampling trips for diet analyses.
 7. Par Pond midwater trawl samples were not collected in November because the low water level prevented launching of the sampling boat.
 8. One of the Par Pond November hoop net samples was pulled after fishing for 3 days rather than 2 days. The net could not be found until the third day, but no fish were caught.

Appendix Table 2.

List of scientific and common names of fish collected from L Lake.
January 1986-December 1991^a.

Scientific name	Common name
<u>Anguilla rostrata</u>	American eel
<u>Dorosoma petenense</u>	threadfin shad
<u>D. cepedianum</u>	gizzard shad
<u>Esox americanus</u>	redfin pickerel
<u>E. niger</u>	chain pickerel
<u>Cyprinus carpio</u>	common carp
<u>Cyprinella leedsi</u>	bannerfin shiner
<u>Nocomis leptcephalus</u>	bluehead chub
<u>Notemigonus chrysoleucas</u>	golden shiner
<u>Notropis rubellus</u>	rosyface shiner
<u>N. chalybaeus</u>	ironcolor shiner
<u>N. cummingsae</u>	dusky shiner
<u>N. petersoni</u>	coastal shiner
<u>N. rubescens</u>	rosyface chub
<u>Erimyzon oblongus</u>	creek chubsucker
<u>E. sucetta</u>	lake chubsucker
<u>Hypentelium nigricans</u>	northern hog sucker
<u>Minytrema melanops</u>	spotted sucker
<u>Ameiurus natalis</u>	yellow bullhead
<u>A. nebulosis</u>	brown bullhead
<u>A. platycephalus</u>	flat bullhead
<u>A. brunneus</u>	snail bullhead
<u>Ictalurus catus</u>	white catfish
<u>Noturus insignis</u>	marginated madtom
<u>Gambusia affinis</u>	mosquitofish
<u>Labidesthes sicculus</u>	brook silverside
<u>Acantharcus pomotis</u>	mud sunfish
<u>Centrarchus macropterus</u>	flier
<u>Enneacanthus gloriosus</u>	bluespotted sunfish
<u>Lepomis auritus</u>	redbreast sunfish
<u>L. gibbosus</u>	pumpkinseed
<u>L. gulosus</u>	warmouth
<u>L. macrochirus</u>	bluegill
<u>L. marginatus</u>	dollar sunfish
<u>L. microlophus</u>	redear sunfish
<u>L. punctatus</u>	spotted sunfish
<u>Micropterus salmoides</u>	largemouth bass
<u>Pomoxis nigromaculatus</u>	black crappie
<u>Perca flavescens</u>	yellow perch
<u>Percina nigrofasciata</u>	blackbanded darter

^afrom Robins et al. 1991.

Appendix Table 3.

Catch per tow for each species collected in midwater trawl
samples in L Lake during 1991.

OBS	REGION	MONTH	TRANSECT	COMMON NAME	COUNT
1	2	JAN	1		.
2	2	JAN	2		.
3	2	JAN	3		.
4	2	FEB	1	threadfin shad	1
5	2	FEB	2		.
6	2	FEB	3		.
7	2	MAR	1	threadfin shad	3
8	2	MAR	2		.
9	2	MAR	3		.
10	2	APR	1		.
11	2	APR	2		.
12	2	APR	3		.
13	2	MAY	1		.
14	2	MAY	2		.
15	2	MAY	3		.
16	2	JUN	1	threadfin shad	67
17	2	JUN	2	black crappie	1
18	2	JUN	2	threadfin shad	7
19	2	JUN	3	threadfin shad	17
20	2	JUL	1	threadfin shad	5
21	2	JUL	2	threadfin shad	10
22	2	JUL	3	threadfin shad	9
23	2	AUG	1	threadfin shad	28
24	2	AUG	2	threadfin shad	34
25	2	AUG	3	threadfin shad	25
26	2	SEP	1		.
27	2	SEP	2		.
28	2	SEP	3		.
29	2	OCT	1		.
30	2	OCT	2		.
31	2	OCT	3		.
32	2	NOV	1		.
33	2	NOV	2		.
34	2	NOV	3		.
35	2	DEC	1		.
36	2	DEC	2		.
37	2	DEC	3		.
38	3	JAN	1	threadfin shad	1
39	3	JAN	2		.
40	3	FEB	1	threadfin shad	3
41	3	FEB	2	threadfin shad	3
42	3	MAR	1	threadfin shad	4
43	3	MAR	2		.
44	3	APR	1		.

Appendix Table 3 (continued).

Catch per tow for each species collected in midwater trawl
samples in L Lake during 1991.

OBS	REGION	MONTH	TRANSECT	COMMON NAME	COUNT
45	3	APR	2	threadfin shad	1
46	3	MAY	1		.
47	3	MAY	2		.
48	3	JUN	1	threadfin shad	45
49	3	JUN	2	threadfin shad	44
50	3	JUL	1	threadfin shad	9
51	3	JUL	2	threadfin shad	20
52	3	AUG	1	threadfin shad	9
53	3	AUG	2	threadfin shad	19
54	3	SEP	1		.
55	3	SEP	2		.
56	3	OCT	1		.
57	3	OCT	2		.
58	3	NOV	1		.
59	3	NOV	2		.
60	3	DEC	1		.
61	3	DEC	2		.
62	4	JAN	1		.
63	4	JAN	2	threadfin shad	2
64	4	JAN	3	threadfin shad	4
65	4	FEB	1	threadfin shad	1
66	4	FEB	2		.
67	4	FEB	3	threadfin shad	2
68	4	MAR	1	threadfin shad	6
69	4	MAR	2	threadfin shad	5
70	4	MAR	3	threadfin shad	2
71	4	APR	1		.
72	4	APR	2	threadfin shad	1
73	4	APR	3		.
74	4	MAY	1		.
75	4	MAY	2		.
76	4	MAY	3		.
77	4	JUN	1	black crappie	1
78	4	JUN	1	threadfin shad	7
79	4	JUN	2	threadfin shad	34
80	4	JUN	3	threadfin shad	16
81	4	JUL	1	threadfin shad	4
82	4	JUL	2	threadfin shad	3
83	4	JUL	3		.
84	4	AUG	1	threadfin shad	7
85	4	AUG	2	threadfin shad	3
86	4	AUG	3	threadfin shad	1
87	4	SEP	1		.
88	4	SEP	2		.

Appendix Table 3 (continued).

Catch per tow for each species collected in midwater trawl
samples in L Lake during 1991.

OBS	REGION	MONTH	TRANSECT	COMMON NAME	COUNT
89	4	SEP	3		.
90	4	OCT	1		.
91	4	OCT	2		.
92	4	OCT	3		.
93	4	NOV	1		.
94	4	NOV	2		.
95	4	NOV	3		.
96	4	DEC	1		.
97	4	DEC	2		.
98	4	DEC	3		.
99	5	JAN	1	threadfin shad	5
100	5	JAN	2		.
101	5	JAN	3	threadfin shad	6
102	5	FEB	1	threadfin shad	6
103	5	FEB	2	threadfin shad	1
104	5	FEB	3	threadfin shad	1
105	5	MAR	1		.
106	5	MAR	2	threadfin shad	1
107	5	MAR	3	threadfin shad	8
108	5	APR	1		.
109	5	APR	2		.
110	5	APR	3		.
111	5	MAY	1		.
112	5	MAY	2		.
113	5	MAY	3		.
114	5	JUN	1	threadfin shad	12
115	5	JUN	2	threadfin shad	54
116	5	JUN	3	threadfin shad	11
117	5	JUL	1	threadfin shad	1
118	5	JUL	2	threadfin shad	3
119	5	JUL	3	threadfin shad	4
120	5	AUG	1	threadfin shad	8
121	5	AUG	2	threadfin shad	8
122	5	AUG	3	threadfin shad	7
123	5	SEP	1	threadfin shad	1
124	5	SEP	2		.
125	5	SEP	3		.
126	5	OCT	1		.
127	5	OCT	2		.
128	5	OCT	3		.
129	5	NOV	1		.
130	5	NOV	2		.
131	5	NOV	3		.
132	5	DEC	1		.

Appendix Table 3 (continued).

Catch per tow for each species collected in midwater trawl
samples in L Lake during 1991.

OBS	REGION	MONTH	TRANSECT	COMMON NAME	COUNT
133	5	DEC	2		.
134	5	DEC	3		.
135	6	JAN	1	threadfin shad	2
136	6	JAN	2	threadfin shad	2
137	6	JAN	3	threadfin shad	4
138	6	FEB	1	threadfin shad	2
139	6	FEB	2		.
140	6	FEB	3		.
141	6	MAR	1		.
142	6	MAR	2		.
143	6	MAR	3		.
144	6	APR	1		.
145	6	APR	2		.
146	6	APR	3		.
147	6	MAY	1		.
148	6	MAY	2		.
149	6	MAY	3		.
150	6	JUN	1	threadfin shad	14
151	6	JUN	2	threadfin shad	25
152	6	JUN	3	threadfin shad	18
153	6	JUL	1	threadfin shad	11
154	6	JUL	2	threadfin shad	9
155	6	JUL	3	threadfin shad	14
156	6	AUG	1	threadfin shad	4
157	6	AUG	2	threadfin shad	5
158	6	AUG	3		.
159	6	SEP	1		.
160	6	SEP	2		.
161	6	SEP	3		.
162	6	OCT	1		.
163	6	OCT	2		.
164	6	OCT	3		.
165	6	NOV	1		.
166	6	NOV	2	threadfin shad	1
167	6	NOV	3		.
168	6	DEC	1		.
169	6	DEC	2		.
170	6	DEC	3		.
171	7	JAN	1	threadfin shad	6
172	7	JAN	2	threadfin shad	5
173	7	JAN	3	threadfin shad	3
174	7	FEB	1		.
175	7	FEB	2		.
176	7	FEB	3		.

Appendix Table 3 (continued).

Catch per tow for each species collected in midwater trawl
samples in L Lake during 1991.

OBS	REGION	MONTH	TRANSECT	COMMON NAME	COUNT
177	7	MAR	1	threadfin shad	1
178	7	MAR	2		.
179	7	MAR	3		.
180	7	APR	1	threadfin shad	1
181	7	APR	2	threadfin shad	1
182	7	APR	3	threadfin shad	1
183	7	MAY	1		.
184	7	MAY	2		.
185	7	MAY	3		.
186	7	JUN	1	threadfin shad	11
187	7	JUN	2	brook silverside	1
188	7	JUN	2	threadfin shad	10
189	7	JUN	3	threadfin shad	3
190	7	JUL	1	threadfin shad	16
191	7	JUL	2	threadfin shad	8
192	7	JUL	3	threadfin shad	3
193	7	AUG	1		.
194	7	AUG	2	threadfin shad	1
195	7	AUG	3		.
196	7	SEP	1		.
197	7	SEP	2		.
198	7	SEP	3		.
199	7	OCT	1		.
200	7	OCT	2		.
201	7	OCT	3		.
202	7	NOV	1		.
203	7	NOV	2		.
204	7	NOV	3		.
205	7	DEC	1	threadfin shad	1
206	7	DEC	2		.
207	7	DEC	3		.
208	8	JAN	1	threadfin shad	4
209	8	JAN	2		.
210	8	JAN	3	threadfin shad	1
211	8	FEB	1		.
212	8	FEB	2		.
213	8	FEB	3		.
214	8	MAR	1		.
215	8	MAR	2		.
216	8	MAR	3		.
217	8	APR	1		.
218	8	APR	2	threadfin shad	1
219	8	APR	3	threadfin shad	2
220	8	MAY	1		.

Appendix Table 3 (continued).

Catch per tow for each species collected in midwater trawl
samples in L Lake during 1991.

OBS	REGION	MONTH	TRANSECT	COMMON NAME	COUNT
221	8	MAY	2		.
222	8	MAY	3		.
223	8	JUN	1	threadfin shad	8
224	8	JUN	2	threadfin shad	4
225	8	JUN	3	threadfin shad	3
226	8	JUL	1	threadfin shad	1
227	8	JUL	2		.
228	8	JUL	3		.
229	8	AUG	1		.
230	8	AUG	2	threadfin shad	1
231	8	AUG	3		.
232	8	SEP	1		.
233	8	SEP	2		.
234	8	SEP	3		.
235	8	OCT	1		.
236	8	OCT	2		.
237	8	OCT	3		.
238	8	NOV	1		.
239	8	NOV	2		.
240	8	NOV	3		.
241	8	DEC	1		.
242	8	DEC	2		.
243	8	DEC	3		.

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Appendix Table 4.

Fish density (no./1000 m³) and standard deviation at each transect in Regions 2-8 of
L Lake as indicated by echolocation. January-December 1991.

Transect	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
<u>Region 2</u>												
A	1.97 (2.58)	0.32 (0.78)	2.23 (5.45)	4.06 (6.29)	(9.45) (13.46)	2.11 (2.76)	24.71 (25.70)	52.12 (66.28)	2.26 (5.53)	7.21 (11.47)	2.12 (5.18)	0.00 (0.00)
B	1.48 (3.47)	0.51 (1.21)	4.91 (8.61)	5.38 (6.39)	14.22 (16.90)	4.43 (5.13)	8.60 (6.39)	40.13 (54.16)	6.08 (3.43)	3.48 (1.57)	3.67 (5.72)	3.58 (6.44)
C	0.00 (0.00)	3.41 (8.35)	0.00 (0.00)	2.32 (3.21)	0.00 (0.00)	0.00 (0.00)	2.37 (3.32)	24.74 (35.90)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.03 (1.75)
<u>Region 3</u>												
A	4.04 (6.89)	10.95 (19.20)	9.19 (20.80)	8.93 (15.25)	13.42 (15.42)	2.02 (2.86)	10.29 (6.74)	35.90 (32.51)	8.91 (6.78)	4.95 (3.85)	2.12 (1.97)	2.68 (8.48)
B	2.32 (1.36)	19.71 (36.95)	10.76 (21.62)	4.51 (6.82)	5.97 (6.62)	1.41 (2.19)	8.42 (4.16)	21.70 (23.22)	8.13 (4.55)	2.35 (2.53)	1.01 (1.14)	1.30 (1.38)
C	0.57 (1.01)	3.93 (7.80)	1.80 (4.99)	5.72 (8.16)	9.48 (11.33)	5.21 (6.45)	6.94 (1.59)	35.71 (46.35)	4.37 (2.69)	1.50 (1.95)	1.11 (1.37)	4.66 (12.01)

Appendix Table 4 (continued).

Fish density (no./1000 m³) and standard deviation at each transect in Regions 2-8 of L Lake as indicated by echolocation. January-December 1991.

Transect	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
<u>Region 4</u>												
A	2.91 (3.30)	85.67 (100.19)	14.55 (20.19)	13.33 (17.54)	9.03 (5.89)	3.58 (3.22)	6.77 (3.86)	30.19 (28.95)	11.72 (4.56)	1.37 (0.90)	1.37 (0.97)	1.42 (2.10)
B	9.76 (11.95)	13.92 (11.22)	12.60 (22.38)	12.27 (11.07)	18.82 (20.46)	5.02 (4.15)	16.11 (10.19)	21.33 (16.38)	18.61 (13.60)	3.61 (3.13)	1.84 (1.43)	1.70 (3.60)
<u>Region 5</u>												
A	8.09 (9.80)	12.90 (10.45)	14.20 (25.66)	12.99 (14.77)	9.19 (8.65)	5.75 (4.43)	15.85 (7.63)	32.08 (31.80)	14.00 (12.29)	4.18 (1.56)	1.59 (1.85)	1.59 (2.53)
B	23.50 (41.73)	26.50 (23.23)	19.70 (38.15)	13.80 (14.00)	15.19 (14.70)	11.37 (8.29)	16.02 (4.65)	27.57 (25.97)	11.10 (7.60)	3.62 (3.07)	1.84 (2.12)	2.43 (4.64)
<u>Region 6</u>												
A	18.82 (19.79)	13.72 (9.43)	8.52 (16.33)	13.83 (16.82)	11.90 (8.93)	26.82 (27.87)	16.57 (2.50)	22.91 (20.41)	13.14 (10.75)	3.21 (2.26)	1.89 (2.00)	5.67 (9.61)
B	29.88 (32.56)	15.26 (9.52)	9.94 (22.43)	18.16 (24.25)	13.85 (10.84)	34.74 (40.64)	23.48 (8.72)	24.86 (20.77)	14.86 (9.58)	3.10 (1.42)	1.00 (1.05)	6.77 (15.15)

Appendix Table 4 (continued).

Fish density (no./1000 m³) and standard deviation at each transect in Regions 2-8 of
L Lake as indicated by echolocation. January-December 1991.

Transect	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
<u>Region 7</u>												
A	12.80 (13.40)	11.81 (5.12)	1.39 (1.16)	28.69 (28.93)	13.26 (9.72)	25.11 (28.04)	19.69 (6.11)	18.18 (12.08)	13.92 (7.15)	1.90 (1.19)	0.46 (0.50)	6.83 (10.29)
B	13.28 (10.04)	8.15 (5.77)	0.65 (0.63)	21.52 (22.25)	13.69 (11.21)	19.68 (16.19)	28.02 (14.90)	19.74 (14.53)	13.85 (9.79)	2.82 (1.73)	3.68 (5.95)	9.00 (16.17)
<u>Region 8</u>												
A	15.77 (3.91)	4.58 (4.46)	1.11 (0.87)	25.21 (27.70)	16.35 (16.90)	19.71 (16.76)	17.92 (6.07)	21.89 (21.12)	23.28 (21.24)	2.12 (1.42)	1.01 (0.97)	1.94 (1.66)
B	12.86 (17.66)	1.31 (1.42)	0.53 (0.81)	16.40 (23.25)	10.14 (10.46)	18.55 (13.46)	23.75 (9.68)	28.38 (29.47)	27.19 (27.16)	1.39 (1.71)	0.60 (0.55)	0.71 (1.60)

Appendix Table 5.

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
07FEB91	5	SURFACE	E	A	brook silverside	20.11
07FEB91	7	SURFACE	E	A	brook silverside	17.09
06MAR91	5	SURFACE	W	A	black crappie	20.32
20MAR91	5	OBLIQUE	C	A	yellow perch	19.41
20MAR91	5	OBLIQUE	C	B	black crappie	39.44
20MAR91	5	OBLIQUE	C	C	yellow perch	19.91
20MAR91	5	OBLIQUE	C	D	black crappie	40.38
20MAR91	5	OBLIQUE	C	D	yellow perch	60.57
20MAR91	5	SURFACE	E	A	black crappie	33.43
20MAR91	5	SURFACE	E	A	yellow perch	66.87
20MAR91	5	SURFACE	E	B	black crappie	49.97
20MAR91	5	SURFACE	E	B	yellow perch	116.59
20MAR91	5	SURFACE	W	A	black crappie	239.85
20MAR91	5	SURFACE	W	A	yellow perch	34.26
20MAR91	5	SURFACE	W	B	black crappie	133.58
20MAR91	5	SURFACE	W	B	unknown	38.17
20MAR91	5	SURFACE	W	B	yellow perch	152.67
20MAR91	7	OBLIQUE	C	A	yellow perch	34.06
20MAR91	7	OBLIQUE	C	B	black crappie	17.00
20MAR91	7	OBLIQUE	C	B	yellow perch	50.99
20MAR91	7	OBLIQUE	C	C	yellow perch	16.12
20MAR91	7	SURFACE	E	A	black crappie	94.80
20MAR91	7	SURFACE	E	A	yellow perch	189.61
20MAR91	7	SURFACE	E	B	black crappie	155.10
20MAR91	7	SURFACE	E	B	yellow perch	135.71
20MAR91	7	SURFACE	W	A	black crappie	54.01
20MAR91	7	SURFACE	W	B	black crappie	90.61
20MAR91	7	SURFACE	W	B	yellow perch	36.24
03APR91	5	OBLIQUE	C	A	black crappie	38.90
03APR91	5	OBLIQUE	C	B	black crappie	59.92
03APR91	5	OBLIQUE	C	B	yellow perch	19.97
03APR91	5	OBLIQUE	C	C	black crappie	39.77
03APR91	5	OBLIQUE	C	C	yellow perch	39.77
03APR91	5	OBLIQUE	C	D	black crappie	39.80
03APR91	5	SURFACE	E	A	black crappie	1068.18
03APR91	5	SURFACE	E	A	shad	19.42
03APR91	5	SURFACE	E	B	black crappie	754.33
03APR91	5	SURFACE	E	B	shad	19.34
03APR91	5	SURFACE	W	A	black crappie	1065.03
03APR91	5	SURFACE	W	A	minnow	149.48
03APR91	5	SURFACE	W	B	black crappie	1306.13
03APR91	5	SURFACE	W	B	eastern mudminnow	18.66
03APR91	5	SURFACE	W	B	minnow	18.66
03APR91	7	OBLIQUE	C	A	black crappie	49.77

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
02MAY91	5	SURFACE	W	B	black crappie	82.96
02MAY91	5	SURFACE	W	B	bluegill	41.48
02MAY91	5	SURFACE	W	B	brook silverside	82.96
02MAY91	5	SURFACE	W	B	largemouth bass	20.74
02MAY91	5	SURFACE	W	B	minnow	41.48
02MAY91	5	SURFACE	W	B	shad	4480.02
02MAY91	7	SURFACE	E	A	black crappie	426.00
02MAY91	7	SURFACE	E	A	brook silverside	463.04
02MAY91	7	SURFACE	E	A	largemouth bass	18.52
02MAY91	7	SURFACE	E	A	minnow	18.52
02MAY91	7	SURFACE	E	A	shad	4019.18
02MAY91	7	SURFACE	E	B	black crappie	656.31
02MAY91	7	SURFACE	E	B	brook silverside	562.55
02MAY91	7	SURFACE	E	B	largemouth bass	18.75
02MAY91	7	SURFACE	E	B	shad	3356.55
02MAY91	7	SURFACE	E	B	threadfin shad	1762.66
02MAY91	7	SURFACE	W	A	black crappie	89.23
02MAY91	7	SURFACE	W	A	bluegill	17.85
02MAY91	7	SURFACE	W	A	brook silverside	410.44
02MAY91	7	SURFACE	W	A	shad	1891.61
02MAY91	7	SURFACE	W	B	black crappie	36.33
02MAY91	7	SURFACE	W	B	bluegill	18.17
02MAY91	7	SURFACE	W	B	brook silverside	345.17
02MAY91	7	SURFACE	W	B	minnow	36.33
02MAY91	7	SURFACE	W	B	shad	2107.34
15MAY91	5	OBLIQUE	C	A	bluegill	118.78
15MAY91	5	OBLIQUE	C	A	minnow	19.80
15MAY91	5	OBLIQUE	C	A	shad	5800.34
15MAY91	5	OBLIQUE	C	A	warmouth	19.80
15MAY91	5	OBLIQUE	C	B	bluegill	102.49
15MAY91	5	OBLIQUE	C	B	largemouth bass	20.50
15MAY91	5	OBLIQUE	C	B	shad	4816.91
15MAY91	5	OBLIQUE	C	B	unknown	61.49
15MAY91	5	OBLIQUE	C	C	bluegill	176.34
15MAY91	5	OBLIQUE	C	C	minnow	22.04
15MAY91	5	OBLIQUE	C	C	shad	3614.88
15MAY91	5	OBLIQUE	C	D	bluegill	178.78
15MAY91	5	OBLIQUE	C	D	brook silverside	22.35
15MAY91	5	OBLIQUE	C	D	shad	6570.14
15MAY91	5	OBLIQUE	C	D	unknown	89.39
15MAY91	5	SURFACE	E	A	bluegill	316.01
15MAY91	5	SURFACE	E	A	brook silverside	256.76
15MAY91	5	SURFACE	E	A	largemouth bass	59.25
15MAY91	5	SURFACE	E	A	minnow	19.75

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
03APR91	7	OBLIQUE	C	A	yellow perch	16.59
03APR91	7	OBLIQUE	C	B	black crappie	66.10
03APR91	7	OBLIQUE	C	B	yellow perch	16.52
03APR91	7	OBLIQUE	C	C	black crappie	18.42
03APR91	7	OBLIQUE	C	C	yellow perch	18.42
03APR91	7	OBLIQUE	C	D	black crappie	18.27
03APR91	7	SURFACE	E	A	black crappie	941.39
03APR91	7	SURFACE	E	A	gizzard shad	120.18
03APR91	7	SURFACE	E	A	minnow	20.03
03APR91	7	SURFACE	E	A	shad	80.12
03APR91	7	SURFACE	E	A	yellow perch	40.06
03APR91	7	SURFACE	E	B	black crappie	1016.98
03APR91	7	SURFACE	E	B	gizzard shad	99.70
03APR91	7	SURFACE	E	B	yellow perch	19.94
03APR91	7	SURFACE	W	A	black crappie	183.84
03APR91	7	SURFACE	W	A	minnow	20.43
03APR91	7	SURFACE	W	A	yellow perch	20.43
03APR91	7	SURFACE	W	B	black crappie	1081.55
03APR91	7	SURFACE	W	B	shad	102.03
03APR91	7	SURFACE	W	B	yellow perch	20.41
17APR91	5	OBLIQUE	C	A	black crappie	45.83
17APR91	5	OBLIQUE	C	A	shad	550.02
17APR91	5	OBLIQUE	C	B	black crappie	22.16
17APR91	5	OBLIQUE	C	B	shad	642.67
17APR91	5	OBLIQUE	C	C	shad	854.09
17APR91	5	OBLIQUE	C	D	black crappie	53.90
17APR91	5	OBLIQUE	C	D	shad	1060.10
17APR91	5	SURFACE	E	A	black crappie	257.45
17APR91	5	SURFACE	E	A	brook silverside	703.71
17APR91	5	SURFACE	E	A	largemouth bass	34.33
17APR91	5	SURFACE	E	A	minnow	51.49
17APR91	5	SURFACE	E	A	shad	5715.47
17APR91	5	SURFACE	E	B	black crappie	719.06
17APR91	5	SURFACE	E	B	brook silverside	200.67
17APR91	5	SURFACE	E	B	largemouth bass	66.89
17APR91	5	SURFACE	E	B	shad	6237.47
17APR91	5	SURFACE	W	A	black crappie	328.30
17APR91	5	SURFACE	W	A	brook silverside	766.02
17APR91	5	SURFACE	W	A	largemouth bass	72.95
17APR91	5	SURFACE	W	A	minnow	656.59
17APR91	5	SURFACE	W	A	shad	3137.05
17APR91	5	SURFACE	W	B	black crappie	472.15
17APR91	5	SURFACE	W	B	brook silverside	127.12
17APR91	5	SURFACE	W	B	largemouth bass	108.96

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
17APR91	5	SURFACE	W	B	minnow	2142.84
17APR91	5	SURFACE	W	B	shad	2778.43
17APR91	7	OBLIQUE	C	A	shad	376.88
17APR91	7	OBLIQUE	C	B	black crappie	161.02
17APR91	7	OBLIQUE	C	B	shad	402.56
17APR91	7	OBLIQUE	C	B	unknown	60.38
17APR91	7	OBLIQUE	C	C	black crappie	43.22
17APR91	7	OBLIQUE	C	C	shad	151.27
17APR91	7	OBLIQUE	C	D	shad	353.95
17APR91	7	SURFACE	E	A	black crappie	169.78
17APR91	7	SURFACE	E	A	brook silverside	226.37
17APR91	7	SURFACE	E	A	largemouth bass	18.86
17APR91	7	SURFACE	E	A	redbreast sunfish	37.73
17APR91	7	SURFACE	E	A	shad	509.33
17APR91	7	SURFACE	E	B	black crappie	634.28
17APR91	7	SURFACE	E	B	brook silverside	74.62
17APR91	7	SURFACE	E	B	largemouth bass	74.62
17APR91	7	SURFACE	E	B	minnow	18.66
17APR91	7	SURFACE	E	B	redbreast sunfish	111.93
17APR91	7	SURFACE	E	B	shad	970.07
17APR91	7	SURFACE	W	A	black crappie	2907.69
17APR91	7	SURFACE	W	A	brook silverside	983.48
17APR91	7	SURFACE	W	A	minnow	21.38
17APR91	7	SURFACE	W	A	shad	2330.43
17APR91	7	SURFACE	W	A	unknown	42.76
17APR91	7	SURFACE	W	A	warmouth	21.38
17APR91	7	SURFACE	W	B	black crappie	7490.37
17APR91	7	SURFACE	W	B	brook silverside	144.05
17APR91	7	SURFACE	W	B	largemouth bass	144.05
17APR91	7	SURFACE	W	B	minnow	555.60
17APR91	7	SURFACE	W	B	redbreast sunfish	20.58
17APR91	7	SURFACE	W	B	shad	2140.11
02MAY91	5	SURFACE	E	A	black crappie	20.62
02MAY91	5	SURFACE	E	A	brook silverside	412.32
02MAY91	5	SURFACE	E	A	shad	3958.31
02MAY91	5	SURFACE	E	B	black crappie	20.90
02MAY91	5	SURFACE	E	B	brook silverside	292.62
02MAY91	5	SURFACE	E	B	minnow	41.80
02MAY91	5	SURFACE	E	B	shad	4305.74
02MAY91	5	SURFACE	W	A	black crappie	81.97
02MAY91	5	SURFACE	W	A	brook silverside	307.40
02MAY91	5	SURFACE	W	A	largemouth bass	20.49
02MAY91	5	SURFACE	W	A	minnow	122.96
02MAY91	5	SURFACE	W	A	shad	4938.82

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
15MAY91	5	SURFACE	E	A	redbreast sunfish	39.50
15MAY91	5	SURFACE	E	A	shad	4819.19
15MAY91	5	SURFACE	E	A	unknown	19.75
15MAY91	5	SURFACE	E	B	bluegill	3224.28
15MAY91	5	SURFACE	E	B	brook silverside	530.83
15MAY91	5	SURFACE	E	B	largemouth bass	19.66
15MAY91	5	SURFACE	E	B	minnow	78.64
15MAY91	5	SURFACE	E	B	shad	19443.97
15MAY91	5	SURFACE	E	B	unknown	196.60
15MAY91	5	SURFACE	E	B	warmouth	19.66
15MAY91	5	SURFACE	W	A	bluegill	756.93
15MAY91	5	SURFACE	W	A	brook silverside	221.54
15MAY91	5	SURFACE	W	A	minnow	203.08
15MAY91	5	SURFACE	W	A	shad	5612.38
15MAY91	5	SURFACE	W	A	unknown	55.39
15MAY91	5	SURFACE	W	A	warmouth	18.46
15MAY91	5	SURFACE	W	B	bluegill	416.72
15MAY91	5	SURFACE	W	B	brook silverside	208.36
15MAY91	5	SURFACE	W	B	minnow	170.48
15MAY91	5	SURFACE	W	B	redbreast sunfish	18.94
15MAY91	5	SURFACE	W	B	shad	5057.46
15MAY91	5	SURFACE	W	B	unknown	75.77
15MAY91	7	OBLIQUE	C	A	bluegill	121.17
15MAY91	7	OBLIQUE	C	A	brook silverside	20.19
15MAY91	7	OBLIQUE	C	A	shad	3513.88
15MAY91	7	OBLIQUE	C	A	unknown	242.34
15MAY91	7	OBLIQUE	C	B	bannerfin shiner	167.98
15MAY91	7	OBLIQUE	C	B	black crappie	41.99
15MAY91	7	OBLIQUE	C	B	shad	5879.17
15MAY91	7	OBLIQUE	C	B	sunfishes	21.00
15MAY91	7	OBLIQUE	C	B	unknown	860.88
15MAY91	7	OBLIQUE	C	B	yellow perch	83.99
15MAY91	7	OBLIQUE	C	C	bannerfin shiner	108.75
15MAY91	7	OBLIQUE	C	C	black crappie	18.12
15MAY91	7	OBLIQUE	C	C	largemouth bass	18.12
15MAY91	7	OBLIQUE	C	C	shad	4368.08
15MAY91	7	OBLIQUE	C	C	unknown	217.50
15MAY91	7	OBLIQUE	C	C	yellow perch	36.25
15MAY91	7	OBLIQUE	C	D	black crappie	18.24
15MAY91	7	OBLIQUE	C	D	bluegill	291.90
15MAY91	7	OBLIQUE	C	D	brook silverside	18.24
15MAY91	7	OBLIQUE	C	D	shad	6877.98
15MAY91	7	OBLIQUE	C	D	unknown	474.34
15MAY91	7	OBLIQUE	C	D	yellow perch	91.22

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
15MAY91	7	SURFACE	E	A	bluegill	229.28
15MAY91	7	SURFACE	E	A	brook silverside	706.95
15MAY91	7	SURFACE	E	A	minnow	38.21
15MAY91	7	SURFACE	E	A	shad	1031.76
15MAY91	7	SURFACE	E	A	unknown	133.75
15MAY91	7	SURFACE	E	B	bluegill	1615.53
15MAY91	7	SURFACE	E	B	brook silverside	37.57
15MAY91	7	SURFACE	E	B	largemouth bass	18.79
15MAY91	7	SURFACE	E	B	redbreast sunfish	56.36
15MAY91	7	SURFACE	E	B	shad	2780.22
15MAY91	7	SURFACE	E	B	sunfishes	18.79
15MAY91	7	SURFACE	E	B	unknown	37.57
15MAY91	7	SURFACE	E	B	warmouth	18.79
15MAY91	7	SURFACE	W	A	bluegill	1031.44
15MAY91	7	SURFACE	W	A	brook silverside	626.23
15MAY91	7	SURFACE	W	A	minnow	36.84
15MAY91	7	SURFACE	W	A	shad	3444.26
15MAY91	7	SURFACE	W	A	sunfishes	18.42
15MAY91	7	SURFACE	W	A	unknown	36.84
15MAY91	7	SURFACE	W	A	warmouth	18.42
15MAY91	7	SURFACE	W	B	bluegill	4168.91
15MAY91	7	SURFACE	W	B	brook silverside	143.76
15MAY91	7	SURFACE	W	B	minnow	107.82
15MAY91	7	SURFACE	W	B	shad	5336.93
15MAY91	7	SURFACE	W	B	sunfishes	17.97
15MAY91	7	SURFACE	W	B	unknown	251.57
15MAY91	7	SURFACE	W	B	warmouth	35.94
29MAY91	5	OBLIQUE	C	A	bluegill	20.87
29MAY91	5	OBLIQUE	C	A	shad	1356.65
29MAY91	5	OBLIQUE	C	B	bluegill	43.20
29MAY91	5	OBLIQUE	C	B	shad	1252.68
29MAY91	5	OBLIQUE	C	C	bluegill	20.49
29MAY91	5	OBLIQUE	C	C	brook silverside	40.97
29MAY91	5	OBLIQUE	C	C	shad	512.16
29MAY91	5	OBLIQUE	C	D	bluegill	81.12
29MAY91	5	OBLIQUE	C	D	brook silverside	40.56
29MAY91	5	OBLIQUE	C	D	shad	1196.48
29MAY91	5	SURFACE	E	A	bluegill	357.61
29MAY91	5	SURFACE	E	A	brook silverside	1464.48
29MAY91	5	SURFACE	E	A	shad	17.03
29MAY91	5	SURFACE	E	B	bluegill	1242.56
29MAY91	5	SURFACE	E	B	brook silverside	155.32
29MAY91	5	SURFACE	E	B	minnow	51.77
29MAY91	5	SURFACE	E	B	shad	155.32

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
29MAY91	5	SURFACE	W	A	bluegill	396.76
29MAY91	5	SURFACE	W	A	brook silverside	551.05
29MAY91	5	SURFACE	W	A	shad	198.38
29MAY91	5	SURFACE	W	B	bluegill	1004.21
29MAY91	5	SURFACE	W	B	brook silverside	89.26
29MAY91	5	SURFACE	W	B	minnow	22.32
29MAY91	5	SURFACE	W	B	shad	1472.84
30MAY91	7	OBLIQUE	C	A	bluegill	91.05
30MAY91	7	OBLIQUE	C	A	shad	637.35
30MAY91	7	OBLIQUE	C	B	bluegill	94.34
30MAY91	7	OBLIQUE	C	B	shad	636.79
30MAY91	7	OBLIQUE	C	C	bluegill	62.21
30MAY91	7	OBLIQUE	C	C	brook silverside	41.47
30MAY91	7	OBLIQUE	C	C	shad	1078.29
30MAY91	7	OBLIQUE	C	D	bluegill	85.76
30MAY91	7	OBLIQUE	C	D	shad	857.63
30MAY91	7	SURFACE	E	A	bluegill	80.72
30MAY91	7	SURFACE	E	A	brook silverside	383.41
30MAY91	7	SURFACE	E	B	bluegill	365.54
30MAY91	7	SURFACE	E	B	brook silverside	31.23
30MAY91	7	SURFACE	E	B	shad	60.92
30MAY91	7	SURFACE	W	A	brook silverside	207.63
30MAY91	7	SURFACE	W	B	bluegill	114.62
30MAY91	7	SURFACE	W	B	brook silverside	57.31
30MAY91	7	SURFACE	W	B	shad	19.10
12JUN91	5	OBLIQUE	C	A	bluegill	40.56
12JUN91	5	OBLIQUE	C	A	brook silverside	20.28
12JUN91	5	OBLIQUE	C	A	shad	81.12
12JUN91	5	OBLIQUE	C	B	bluegill	21.51
12JUN91	5	OBLIQUE	C	B	brook silverside	21.51
12JUN91	5	OBLIQUE	C	B	shad	301.10
12JUN91	5	OBLIQUE	C	C	shad	59.41
12JUN91	5	OBLIQUE	C	D	bluegill	20.28
12JUN91	5	OBLIQUE	C	D	shad	202.82
12JUN91	7	OBLIQUE	C	A	bluegill	57.04
12JUN91	7	OBLIQUE	C	A	shad	171.13
12JUN91	7	OBLIQUE	C	B	bluegill	20.10
12JUN91	7	OBLIQUE	C	B	shad	422.06
12JUN91	7	OBLIQUE	C	B	unknown	20.10
12JUN91	7	OBLIQUE	C	C	bluegill	190.91
12JUN91	7	OBLIQUE	C	C	shad	127.27
12JUN91	7	OBLIQUE	C	D	bluegill	204.59
12JUN91	7	OBLIQUE	C	D	brook silverside	45.46
12JUN91	7	OBLIQUE	C	D	shad	340.99

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
12JUN91	7	SURFACE	E	A	bluegill	331.56
12JUN91	7	SURFACE	E	A	brook silverside	82.89
12JUN91	7	SURFACE	E	A	unknown	20.72
12JUN91	7	SURFACE	E	B	bluegill	427.18
12JUN91	7	SURFACE	E	B	brook silverside	719.46
12JUN91	7	SURFACE	E	B	warmouth	44.97
13JUN91	5	SURFACE	E	A	bluegill	399.20
13JUN91	5	SURFACE	E	A	brook silverside	70.45
13JUN91	5	SURFACE	E	B	bluegill	182.30
13JUN91	5	SURFACE	E	B	brook silverside	40.51
13JUN91	5	SURFACE	W	A	bluegill	62.18
13JUN91	5	SURFACE	W	A	brook silverside	373.09
13JUN91	5	SURFACE	W	B	bluegill	262.90
13JUN91	7	SURFACE	W	A	bluegill	408.77
13JUN91	7	SURFACE	W	B	bluegill	240.64
13JUN91	7	SURFACE	W	B	brook silverside	18.51
26JUN91	5	OBLIQUE	C	A	bluegill	134.71
26JUN91	5	OBLIQUE	C	A	brook silverside	44.90
26JUN91	5	OBLIQUE	C	A	redbreast sunfish	22.45
26JUN91	5	OBLIQUE	C	B	bluegill	23.02
26JUN91	5	OBLIQUE	C	B	brook silverside	23.02
26JUN91	5	OBLIQUE	C	C	bluegill	64.44
26JUN91	5	OBLIQUE	C	C	brook silverside	21.48
26JUN91	5	OBLIQUE	C	D	bluegill	87.32
26JUN91	5	SURFACE	E	A	bluegill	21.07
26JUN91	5	SURFACE	E	A	brook silverside	105.35
26JUN91	5	SURFACE	E	B	bluegill	62.20
26JUN91	5	SURFACE	E	B	brook silverside	103.67
26JUN91	5	SURFACE	E	B	unknown	20.73
26JUN91	5	SURFACE	W	A	bluegill	160.05
26JUN91	5	SURFACE	W	A	brook silverside	420.13
26JUN91	5	SURFACE	W	A	shad	20.01
26JUN91	5	SURFACE	W	B	bluegill	220.40
26JUN91	5	SURFACE	W	B	brook silverside	200.36
26JUN91	5	SURFACE	W	B	shad	20.04
26JUN91	7	OBLIQUE	C	A	bluegill	65.58
26JUN91	7	OBLIQUE	C	B	bluegill	108.44
26JUN91	7	OBLIQUE	C	C	bluegill	218.20
26JUN91	7	OBLIQUE	C	C	brook silverside	19.84
26JUN91	7	OBLIQUE	C	C	shad	19.84
26JUN91	7	OBLIQUE	C	D	bluegill	155.95
26JUN91	7	SURFACE	E	A	bluegill	37.08
26JUN91	7	SURFACE	E	A	brook silverside	18.54
26JUN91	7	SURFACE	E	B	bluegill	110.00

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
26JUN91	7	SURFACE	E	B	brook silverside	36.67
26JUN91	7	SURFACE	E	B	redbreast sunfish	18.33
26JUN91	7	SURFACE	W	A	bluegill	958.26
26JUN91	7	SURFACE	W	A	brook silverside	78.23
26JUN91	7	SURFACE	W	A	minnow	19.56
26JUN91	7	SURFACE	W	B	bluegill	2287.26
26JUN91	7	SURFACE	W	B	brook silverside	96.92
26JUN91	7	SURFACE	W	B	redbreast sunfish	116.30
11JUL91	5	OBLIQUE	C	A	bluegill	21.98
11JUL91	5	OBLIQUE	C	C	bluegill	71.17
11JUL91	7	OBLIQUE	C	A	bluegill	131.70
11JUL91	7	OBLIQUE	C	A	brook silverside	21.95
11JUL91	7	OBLIQUE	C	B	bluegill	174.40
11JUL91	7	OBLIQUE	C	B	brook silverside	21.80
11JUL91	7	OBLIQUE	C	C	bluegill	357.03
11JUL91	7	OBLIQUE	C	D	bluegill	329.89
11JUL91	7	SURFACE	E	A	bluegill	58.09
11JUL91	7	SURFACE	E	B	bluegill	78.15
11JUL91	7	SURFACE	E	B	brook silverside	39.08
11JUL91	7	SURFACE	W	A	bluegill	250.87
11JUL91	7	SURFACE	W	A	brook silverside	68.42
11JUL91	7	SURFACE	W	B	bluegill	532.80
11JUL91	7	SURFACE	W	B	brook silverside	23.17
11JUL91	7	SURFACE	W	B	minnow	23.17
11JUL91	7	SURFACE	W	B	sunfish	69.50
12JUL91	5	SURFACE	E	A	bluegill	2077.77
12JUL91	5	SURFACE	E	A	redbreast sunfish	22.10
12JUL91	5	SURFACE	E	B	bluegill	1657.47
12JUL91	5	SURFACE	E	B	brook silverside	45.41
12JUL91	5	SURFACE	W	A	bluegill	95.70
12JUL91	5	SURFACE	W	A	brook silverside	143.56
12JUL91	5	SURFACE	W	B	bluegill	64.05
12JUL91	5	SURFACE	W	B	brook silverside	48.03
25JUL91	5	OBLIQUE	C	A	bluegill	41.51
25JUL91	5	OBLIQUE	C	B	bluegill	63.22
25JUL91	5	OBLIQUE	C	C	bluegill	18.73
25JUL91	5	OBLIQUE	C	C	brook silverside	18.73
25JUL91	5	SURFACE	E	A	bluegill	387.71
25JUL91	5	SURFACE	E	A	brook silverside	659.11
25JUL91	5	SURFACE	E	A	redbreast sunfish	38.77
25JUL91	5	SURFACE	E	B	bluegill	1574.54
25JUL91	5	SURFACE	E	B	brook silverside	588.08
25JUL91	5	SURFACE	E	B	minnow	56.91
25JUL91	5	SURFACE	E	B	redbreast sunfish	56.91

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
25JUL91	5	SURFACE	E	B	unknown	18.97
25JUL91	5	SURFACE	W	A	brook silverside	1041.90
25JUL91	5	SURFACE	W	A	redbreast sunfish	37.89
25JUL91	5	SURFACE	W	B	bluegill	359.14
25JUL91	5	SURFACE	W	B	brook silverside	737.18
25JUL91	5	SURFACE	W	B	minnow	37.80
25JUL91	7	OBLIQUE	C	A	bluegill	92.56
25JUL91	7	OBLIQUE	C	B	bluegill	74.81
25JUL91	7	OBLIQUE	C	C	bluegill	96.66
25JUL91	7	OBLIQUE	C	D	bluegill	77.33
25JUL91	7	OBLIQUE	C	D	redbreast sunfish	19.33
25JUL91	7	SURFACE	E	A	bluegill	35.76
25JUL91	7	SURFACE	E	A	brook silverside	518.45
25JUL91	7	SURFACE	E	A	redbreast sunfish	35.76
25JUL91	7	SURFACE	E	B	bluegill	197.51
25JUL91	7	SURFACE	E	B	brook silverside	430.94
25JUL91	7	SURFACE	E	B	minnow	17.96
25JUL91	7	SURFACE	E	B	redbreast sunfish	17.96
25JUL91	7	SURFACE	E	B	unknown	17.96
25JUL91	7	SURFACE	W	A	bluegill	226.90
25JUL91	7	SURFACE	W	A	brook silverside	610.89
25JUL91	7	SURFACE	W	A	redbreast sunfish	17.45
25JUL91	7	SURFACE	W	B	bluegill	1449.75
25JUL91	7	SURFACE	W	B	brook silverside	1467.43
25JUL91	7	SURFACE	W	B	minnow	17.68
25JUL91	7	SURFACE	W	B	redbreast sunfish	17.68
08AUG91	5	OBLIQUE	C	A	bluegill	19.90
08AUG91	5	OBLIQUE	C	B	bluegill	62.06
08AUG91	5	OBLIQUE	C	C	bluegill	16.64
08AUG91	5	OBLIQUE	C	C	brook silverside	16.64
08AUG91	5	OBLIQUE	C	D	bluegill	16.69
08AUG91	5	SURFACE	E	A	bluegill	6608.21
08AUG91	5	SURFACE	E	A	brook silverside	78.90
08AUG91	5	SURFACE	E	A	minnow	19.73
08AUG91	5	SURFACE	E	A	redbreast sunfish	118.36
08AUG91	5	SURFACE	E	A	unknown	98.63
08AUG91	5	SURFACE	E	B	bluegill	1317.77
08AUG91	5	SURFACE	E	B	brook silverside	756.10
08AUG91	5	SURFACE	E	B	minnow	108.01
08AUG91	5	SURFACE	E	B	redbreast sunfish	21.60
08AUG91	5	SURFACE	W	A	bluegill	264.46
08AUG91	5	SURFACE	W	A	brook silverside	82.65
08AUG91	5	SURFACE	W	A	minnow	462.81
08AUG91	5	SURFACE	W	A	redbreast sunfish	66.12

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
08AUG91	5	SURFACE	W	A	unknown	198.35
08AUG91	5	SURFACE	W	B	bluegill	144.28
08AUG91	5	SURFACE	W	B	brook silverside	468.90
08AUG91	5	SURFACE	W	B	minnow	216.42
08AUG91	5	SURFACE	W	B	redbreast sunfish	36.07
08AUG91	5	SURFACE	W	B	unknown	18.03
08AUG91	7	OBLIQUE	C	A	bluegill	93.49
08AUG91	7	OBLIQUE	C	B	bluegill	38.21
08AUG91	7	OBLIQUE	C	C	bluegill	39.40
08AUG91	7	OBLIQUE	C	C	sunfishes	19.70
08AUG91	7	OBLIQUE	C	D	bluegill	79.94
08AUG91	7	OBLIQUE	C	D	redbreast sunfish	19.99
08AUG91	7	SURFACE	E	A	bluegill	230.75
08AUG91	7	SURFACE	E	A	brook silverside	88.75
08AUG91	7	SURFACE	E	A	minnow	88.75
08AUG91	7	SURFACE	E	A	redbreast sunfish	142.00
08AUG91	7	SURFACE	E	B	bluegill	116.74
08AUG91	7	SURFACE	E	B	brook silverside	447.52
08AUG91	7	SURFACE	E	B	minnow	38.91
08AUG91	7	SURFACE	W	A	bluegill	2354.48
08AUG91	7	SURFACE	W	A	brook silverside	53.51
08AUG91	7	SURFACE	W	A	minnow	142.70
08AUG91	7	SURFACE	W	A	redbreast sunfish	17.84
08AUG91	7	SURFACE	W	B	bluegill	409.96
08AUG91	7	SURFACE	W	B	brook silverside	312.35
08AUG91	7	SURFACE	W	B	minnow	97.61
22AUG91	5	OBLIQUE	C	A	bluegill	22.46
22AUG91	5	OBLIQUE	C	B	bluegill	46.88
22AUG91	5	OBLIQUE	C	C	bluegill	20.95
22AUG91	5	SURFACE	E	A	bluegill	123.09
22AUG91	5	SURFACE	E	A	brook silverside	184.64
22AUG91	5	SURFACE	E	A	minnow	20.52
22AUG91	5	SURFACE	E	A	redbreast sunfish	20.52
22AUG91	5	SURFACE	E	B	bluegill	261.47
22AUG91	5	SURFACE	E	B	brook silverside	60.34
22AUG91	5	SURFACE	E	B	minnow	40.23
22AUG91	5	SURFACE	E	B	redbreast sunfish	20.11
22AUG91	5	SURFACE	W	A	bluegill	260.43
22AUG91	5	SURFACE	W	A	brook silverside	1367.24
22AUG91	5	SURFACE	W	A	minnow	86.81
22AUG91	5	SURFACE	W	A	redbreast sunfish	21.70
22AUG91	5	SURFACE	W	B	bluegill	165.07
22AUG91	5	SURFACE	W	B	brook silverside	990.44
22AUG91	5	SURFACE	W	B	sunfish	23.58

Appendix Table 5 (continued).

Catches for each ichthyoplankton sample collected from
Regions 5 and 7 of L Lake during 1991.

DATE	REGION	STRATUM	ZONE	REPLICATE	TAXON	DENSITY
22AUG91	5	SURFACE	W	B	unknown	117.91
22AUG91	7	OBLIQUE	C	A	bluegill	131.87
22AUG91	7	OBLIQUE	C	B	bluegill	22.89
22AUG91	7	OBLIQUE	C	C	bluegill	60.83
22AUG91	7	OBLIQUE	C	D	bluegill	84.41
22AUG91	7	SURFACE	E	A	bluegill	198.28
22AUG91	7	SURFACE	E	A	brook silverside	654.31
22AUG91	7	SURFACE	E	A	minnow	59.48
22AUG91	7	SURFACE	E	B	bluegill	21.91
22AUG91	7	SURFACE	E	B	brook silverside	701.17
22AUG91	7	SURFACE	E	B	minnow	43.82
22AUG91	7	SURFACE	W	A	bluegill	225.96
22AUG91	7	SURFACE	W	A	brook silverside	655.29
22AUG91	7	SURFACE	W	A	minnow	45.19
22AUG91	7	SURFACE	W	A	redbreast sunfish	22.60
22AUG91	7	SURFACE	W	B	bluegill	139.25
22AUG91	7	SURFACE	W	B	brook silverside	533.78
22AUG91	7	SURFACE	W	B	minnow	92.83
22AUG91	7	SURFACE	W	B	redbreast sunfish	46.42

Appendix Table 6.

Par Pond electrofishing CPUE and relative abundance for each species collected quarterly in each zone during 1991.

SPECIES	ZONE C		ZONE E		ZONE W	
	CPUE	%	CPUE	%	CPUE	%
<u>Winter</u>						
bowfin	0.00	0.00	0.00	.	0.00	0.00
threadfin shad	0.00	0.00	0.00	.	0.00	0.00
chain pickerel	0.00	0.00	0.00	.	1.00	16.67
golden shiner	0.00	0.00	0.00	.	2.00	33.33
creek chubsucker	0.00	0.00	0.00	.	0.00	0.00
lake chubsucker	0.00	0.00	0.00	.	0.00	0.00
flat bullhead	0.00	0.00	0.00	.	0.00	0.00
brook silverside	0.00	0.00	0.00	.	0.00	0.00
redbreast sunfish	1.00	4.76	0.00	.	0.00	0.00
warmouth	2.00	9.52	0.00	.	0.00	0.00
bluegill	17.00	80.95	0.00	.	3.00	50.00
spotted sunfish	0.00	0.00	0.00	.	0.00	0.00
largemouth bass	1.00	4.76	0.00	.	0.00	0.00
black crappie	0.00	0.00	0.00	.	0.00	0.00
TOTAL	21.00	100.0	0.00	.	6.00	100.0
<u>Spring</u>						
bowfin	0.00	0.00	0.00	0.00	1.00	12.50
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00
chain pickerel	0.00	0.00	1.00	6.25	0.00	0.00
golden shiner	0.00	0.00	1.00	6.25	0.00	0.00
creek chubsucker	0.00	0.00	1.00	6.25	0.00	0.00
lake chubsucker	0.00	0.00	0.00	0.00	1.00	12.50
flat bullhead	2.00	20.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	4.00	25.00	0.00	0.00
redbreast sunfish	0.00	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	1.00	6.25	0.00	0.00
bluegill	3.00	30.00	5.00	31.25	2.00	25.00
spotted sunfish	0.00	0.00	0.00	0.00	1.00	12.50
largemouth bass	5.00	50.00	3.00	18.75	3.00	37.50
black crappie	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	10.00	100.0	16.00	100.0	8.00	100.0

Appendix Table 6 (continued).

Par Pond electrofishing CPUE and relative abundance for each species collected quarterly in each zone during 1991.

SPECIES	ZONE C		ZONE E		ZONE W	
	CPUE	%	CPUE	%	CPUE	%
<u>Summer</u>						
bowfin	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	0.00	0.00	0.00	0.00	0.00	0.00
chain pickerel	0.00	0.00	0.00	0.00	2.00	66.67
golden shiner	0.00	0.00	0.00	0.00	1.00	33.33
creek chubsucker	0.00	0.00	0.00	0.00	0.00	0.00
lake chubsucker	0.00	0.00	0.00	0.00	0.00	0.00
flat bullhead	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	0.00	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	1.00	20.00	1.00	100.0	0.00	0.00
spotted sunfish	0.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	4.00	80.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	5.00	100.0	1.00	100.0	3.00	100.0
<u>Fall</u>						
bowfin	0.00	0.00	0.00	0.00	0.00	0.00
threadfin shad	1.00	9.09	16.00	51.61	0.00	0.00
chain pickerel	0.00	0.00	1.00	3.23	1.00	12.50
golden shiner	0.00	0.00	0.00	0.00	0.00	0.00
creek chubsucker	0.00	0.00	0.00	0.00	0.00	0.00
lake chubsucker	0.00	0.00	1.00	3.23	0.00	0.00
flat bullhead	0.00	0.00	0.00	0.00	0.00	0.00
brook silverside	0.00	0.00	0.00	0.00	0.00	0.00
redbreast sunfish	1.00	9.09	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	8.00	72.73	11.00	35.48	5.00	62.50
spotted sunfish	0.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	1.00	9.09	1.00	3.23	2.00	25.00
black crappie	0.00	0.00	1.00	3.23	0.00	0.00
TOTAL	11.00	100.0	31.00	100.0	8.00	100.0

Appendix Table 7.

Catch per unit effort (CPUE) and relative abundance (%) for each species
in quarterly hoop net samples collected from Par Pond during 1991.

	ZONE E				ZONE C				ZONE W			
	REP A		REP B		REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Winter</u>												
creek chubsucker	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
lake chubsucker	0.00	.	0.00	.	1.50	100.00	0.00	0.00	0.00	0.50	100.00	.
flat bullhead	0.00	.	0.00	.	0.00	0.00	3.00	100.00	0.00	0.00	0.00	.
warmouth	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
bluegill	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
black crappie	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
TOTAL	0.00	.	0.00	.	1.50	100.00	3.00	100.00	0.00	0.50	100.00	.
<u>Spring</u>												
creek chubsucker	0.00	0.00	0.00	.	0.00	.	0.00	0.00	0.50	100.00	0.50	100.00
lake chubsucker	0.00	0.00	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00
flat bullhead	0.00	0.00	0.00	.	0.00	.	1.00	100.00	0.00	0.00	0.00	0.00
warmouth	0.50	50.00	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.50	50.00	0.00	.	0.00	.	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1.00	100.00	0.00	.	0.00	.	1.00	100.00	0.50	100.00	0.50	100.00

Appendix Table 7 (continued).

Catch per unit effort (CPUE) and relative abundance (%) for each species
in quarterly hoop net samples collected from Par Pond during 1991.

	ZONE E				ZONE C				ZONE W			
	REP A		REP B		REP A		REP B		REP A		REP B	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
<u>Summer</u>												
creek chubsucker	0.00	0.00	0.50	100.00	0.50	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lake chubsucker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
flat bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	0.00	2.00	66.67	4.00	100.00	0.00	0.00	0.00	0.00
black crappie	1.00	100.00	0.00	0.00	0.50	16.67	0.00	0.00	4.50	100.00	1.00	100.00
TOTAL	1.00	100.00	0.50	100.00	3.00	100.00	4.00	100.00	4.50	100.00	1.00	100.00
<u>Fall</u>												
creek chubsucker	0.00	.	0.00	0.00	0.00	0.00	0.00	.	0.00		0.00	.
lake chubsucker	0.00	.	0.00	0.00	0.00	0.00	0.00	.	0.00		0.00	.
flat bullhead	0.00	.	0.50	100.00	0.00	0.00	0.00	.	0.00		0.00	.
warmouth	0.00	.	0.00	0.00	0.00	0.00	0.00	.	0.00		0.00	.
bluegill	0.00	.	0.00	0.00	0.00	0.00	0.00	.	0.00		0.00	.
black crappie	0.00	.	0.00	0.00	1.00	100.00	0.00	.	0.00		0.00	.
TOTAL	0.00	.	0.50	100.00	1.00	100.00	0.00	.	0.00		0.00	.

Appendix Table 8.

Par Pond midwater trawl catches January-December 1991.

TAXA	ZONE E		ZONE C		ZONE W	
	CPUE	%	CPUE	%	CPUE	%
<u>WINTER</u>						
TOTAL	0		0		0	
<u>SPRING</u>						
TOTAL	0		0		0	
<u>SUMMER</u>						
TOTAL	0		0		0	
<u>FALL^a</u>						

^aSamples not collected due to drawdown of Par Pond.

DATE

FILMED

5/20/94

END