EVALUATING FISH IMPINGEMENT AND ENTRAINMENT AT THE COMANCHE PEAK STEAM ELECTRIC STATION

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

George A Bauml, WFSC, BS

Denton, Texas

May 1996

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This study was designed to determine if impingement and entrainment by cooling water intake at the Comanche Peak Steam Electric Station have an adverse impact upon the Squaw Creek Reservoir fish population. The yearly impingement of fish was estimated to be 262,994 of 14 species. The threadfin shad (*Dorosoma petenense*) accounted for 96% of this total. Entrainment of eggs and larvae for a five month period was estimated to be 15,989,987 and 42,448,794 respectively. Two fish population studies were performed on Squaw Creek Reservoir to help assess impact. It was determined that the losses due to impingement and entrainment have no adverse impact upon the fish population of Squaw Creek Reservoir.

TABLE OF CONTENTS

Page

LIST OF TABLES v

LIST OF ILLUSTRATIONS vi

INTRODUCTION 1

Effects of Cooling Water Intakes on Fishes 2

Assessing Impact on Fish Populations 3

Objectives 4

Site Description 5

Chapter

I. IMPINGEMENT STUDY 8

Materials and Methods 8

Results 9

Discussion 18

Summary 21

II. ENTRAINMENT STUDY 22

Materials and Methods 22

Results 26

Discussion 32

Summary 40

III. LAKE SURVEY 41
  Materials and Methods 41
  Results 43
  Discussion 53
IV. IMPACT ASSESSMENT 59
CONCLUSION 62
APPENDIX 65
REFERENCES 78

LIST OF TABLES

Page

Table 1. Results of equivalent adult loss model. 35

Table 2. Numbers of fishes collected in impingement samples. 66

Table 3. Environmental conditions during impingement sampling. 71

Table 4. Ichthyoplankton densities during Unit 1 night sampling. 72

Table 5. Ichthyoplankton densities during Unit 1 day sampling. 73

Table 6. Ichthyoplankton densities during Unit 2 night sampling. 74

Table 7. Ichthyoplankton densities during Unit 2 day sampling. 75

Table 8. Gillnetting results. 76

Table 9. Electrofishing results. 77

LIST OF ILLUSTRATIONS

Page

Figure 1. Diagram of CPSES intake structure. 7

Figure 2. Estimated numbers impinged. 10

Figure 3. Estimated biomass impinged. 12

Figure 4. Size ranges of fishes impinged. 13

Figure 5. Numbers impinged and temperature. 14

Figure 6. Linear regression of temperature and impingement. 16

Figure 7. Diel impingement trends. 17

Figure 8. Estimated entrainment. 27

Figure 9. Seasonal trends of fish egg densities. 29

Figure 10. Seasonal trends of larval fish densities. 31

Figure 11. Seasonal trends of juvenile fish densities. 33

Figure 12. Multiple depth analysis of ichthyoplankton densities. 34

Figure 13. Map of Squaw Creek Reservoir showing sampling sites. 42

Figure 14. Species compositions and numbers collected electrofishing. 44

Figure 15. Size ranges of fishes collected by electrofishing. 45

Figure 16. Electrofishing site comparisons for November. 46

Figure 17. Electrofishing site comparisons for June. 48

Figure 18. Species compositions and numbers collected gillnetting. 49

Figure 19. Size ranges of fishes collected by gillnetting. 50

Figure 20. Gillnetting site comparisons for November. 51

Figure 21. Gillnetting site comparisons for June. 52

INTRODUCTION

The energy intensive activities of our modern society create an enormous demand for electricity, the primary source of which is the steam electric station (SES). The process of steam electric generation can potentially have various ecological implications, one of which is the mortality of fish due to the intake of cooling water. Studies have shown that the magnitude of fish loss at some sites can be sufficient to cause adverse impact to the resident populations of the cooling water source (Jenson and Loftus 1976). At other sites impacts are not observed due to the design, siting, and operation of the cooling water intake, and/or the ability of the natural systems to compensate for losses (NUS Corp 1979).

When awareness of the potential magnitude of intake related problems expanded, intensive efforts were made by regulatory agencies, power utilities, and environmental consultants to document the problem, and arrive at rational decisions regarding the consequences. These efforts lead to the inclusion of Section 316(b) in the amendments to the Federal Water Pollution Control Act (FWPCA) of 1972 (Public Law 92-500). Section 316(b) requires that "the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." Thus, the potential threat of SES cooling water intake to the biological integrity of the water source has become a major focus of study.

Studies of the environmental impact of intake structures can include any aquatic organism, but most studies assess impact on fish populations. Fish are selected over other aquatic organisms because they are easier to quantify, they are top end predators which makes them good indicators of ecosystem health, and they have commercial and recreational value. Understanding fish population responses to removal by natural predation and commercial and recreational harvest is core to fisheries management.

Effects of Cooling Water Intakes on Fishes

The operation of cooling water intake structures can cause direct loss to fish populations by impingement and entrainment. Impingement is the physical blocking, or straining, of larger fish from waters being drawn into the SES. It can occur when intake velocities are too fast for organisms to escape, and they become trapped against screening structures. Here they may die due to exhaustion or asphyxiation. Fish that survive are subjected to screen wash sprays which can cause scale loss and result in a weakened fish prone to infection. Fish may also experience prolonged removal from the water resulting in asphyxiation and desiccation.

Entrainment occurs when small organisms, such as fish eggs and larvae, pass through the straining devices of the intake structure and into the SES. Entrainment of fishes is the result of pumping water which contains suspended or passively moving ichthyoplankton (fish eggs and larvae). Ichthyoplankton can pass through screening devices and be drawn into the plant where they may be subjected to mechanical, thermal, and/or chemical stressors (Schubal and Marcy 1978). Survival of ichthyoplankton after passage through condenser cooling water systems has been intensely studied, but results have been conflicting (USEPA 1976). Although it has been shown that one hundred percent mortality does not always occur (Lawler and Englert 1977), most studies of entrainment impact make this assumption as a worst case scenario.

The potential for SES's to impinge and entrain fish depends upon: 1) structural factors, such as location and design of the intake, 2) environmental factors, such as water temperature, and 3) biological factors, such as spawning and feeding strategies. The potential for impingement and entrainment to adversely impact the fish population of the water source depends upon the capacity for each species to compensate for losses sustained (Goodyear 1977). The capacity for a species to compensate is dependant upon the number and life stages of individuals lost, and the robustness of that species' population in the cooling water source.

Assessing Impact on Fish Populations

Assessing the impact of the loss of organisms due to impingement and/or entrainment at SES cooling water intakes has proven to be a complex problem. With the passage of section 316(b) many studies were conducted which approached this problem from numerous angles. The focus of these studies include estimating total numbers of fish impinged and entrained by direct enumeration and extrapolation (Kelso and Milburn 1979), development of models for estimating fish impingement (Murarka et al. 1977) and entrainment (Patterson 1987), and determining the impact of fish removal by SES intakes upon the fish populations of the cooling water source (Goodyear 1977, Rago 1984, Christensen et al. 1977). Evaluation of impact is best assessed with a combination of several approaches. Most studies involve direct enumeration of impingement and entrainment by sampling and extrapolation. This is essential information, but is of little value without an analysis of the source waters fish population. This information along with qualitative data, such as life histories, and physical attributes of the source water body, provide a measure of the potential degree to which a species may be adversely affected, which may, in many cases, be the only measure necessary to determine potential impact of the intake (Cannon and Lauer 1976). In cases where potential risk is believed to be serious, population dynamics techniques and statistical modeling can be used to measure potential population response to impacts.

Objectives

This project was designed to determine if the intake of cooling water by the Comanche Peak Steam Electric Station (CPSES) has an adverse impact upon the fish population of it's cooling water source, Squaw Creek Reservoir (SCR). The project consisted of three studies: 1) analysis of impingement; 2) analysis of entrainment; and 3) analysis of the SCR fish population. The objective of the first study was to determine the impingement fish population at CPSES (estimate the numbers and sizes of each fish species impinged during a year) and assess temporal trends. The objective of the second study was to identify and estimate the number of fish eggs and larvae entrained and assess temporal trends (100% mortality of entrained ichthyoplankton and maximum intake operation was assumed as worst case conditions for the assessment of impact). The objective of the third study was to evaluate SCR species composition, abundance, conditions, and size ranges, and assess spatial trends. The data collected from each of these activities were used in conjunction with life history information, a pre-operational SCR lake survey, and the results of other impingement and entrainment studies to assess the impact of CPSES cooling water intake upon SCR.

Statistical analysis' were used to test the following null hypotheses:

1) Impingement is not correlated with water temperature.

2) There is no significant difference in ichthyoplankton densities between top, middle, and bottom depths.

Site Description

The Comanche Peak Steam Electric Station is a nuclear powered facility located in Hood and Somervall counties, Texas. It is a two unit power plant with a net rating of 2,300 MW. Both units are served by one cooling water intake which is a standard, recessed cove structure with eight cooling water pumps, four for each unit (Figure 1). The pumps operate at 275 rpm, and each is capable of pumping 1041 m^3 (275,000 gallons) per minute. The pumps are located behind a total of twelve FMC Link-Belt vertical traveling screens (EBASCO 1993). A common debris trough and sump serves all screens during washes. The operating site is located on a peninsula, and the intake is in a recessed cove which opens to the main body of the reservoir. Water depth in front of the intake is about 15 m. After use, the cooling water is discharged to SCR through a sluice on the opposite side of the peninsula. The CPSES began operating in April 1990 with the

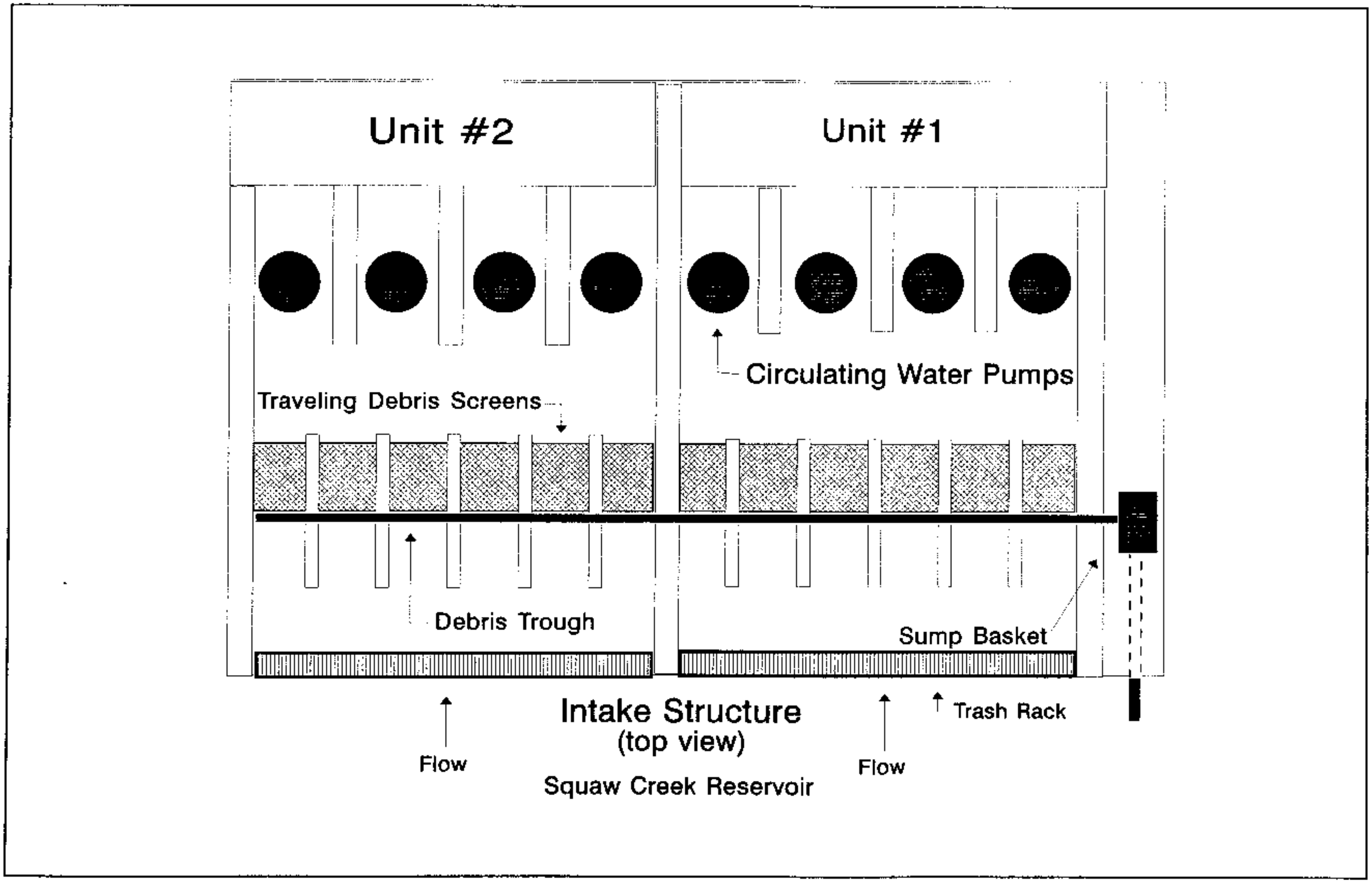


Figure 1. Diagram of the CPSES intake structure (top view). There are four circulatory water pump and six traveling debris screens for each unit. One debris trough and sump serve screen washes for both units.

completion of the first unit. Full capacity operation began upon completion of the second unit in August 1993.

The cooling water source for CPSES is Squaw Creek Reservoir, which was constructed by Texas Utilities. It is located in a fairly nutrient-poor watershed (EBASCO 1993). The reservoir was filled in May 1977, and has a surface area of 1324 ha (3,272 acres) with approximately 112 km (70 miles) of shoreline, and a shoreline development index of 5.0 (Hellier et al. 1987). Maximum depth is 41.2 m (135 ft) with a mean depth of 14.05 m (46.1 ft) (Hellier et al. 1987). A constant water level is maintained by surface runoff from a 165.8 sq. km (64 sq. mile) drainage basin, and supplemental inflow through a pipeline from Lake Granbury (Sellers 1984 in Hellier et al. 1987).

CHAPTER I

IMPINGEMENT STUDY

Materials and Methods

A total of 80 impingement samples were collected from October 19, 1993 through October 12, 1994. Collections were made weekly from October through March, biweekly April through August, and weekly again September through October. For each sampling date, collection baskets were placed in the debris/fish sump at 8:00 pm, retrieved at 8:00 am for the night sample, replaced, and retrieved again at 8:00 pm for the day sample. For each sample collection, water temperature, conductivity, and dissolved oxygen were measured from a water sample retrieved at the intake.

Sample processing began by grouping the fish collected by species. If the species had ≤25 individuals, total length and weight were recorded for each individual. If the species had >25 individuals, the number, lengths, and weights were estimated by sub-sampling.

If sub-sampling was required, the species was checked for obvious size groups, as between young of the year (y-o-y) fish and mature adults. If the species could not be separated into size groups, the total weight of the species was recorded, and a representative sub-sample of 30 individuals was processed. The lengths and weights of the sub-sample were recorded and the total number in the group was estimated. If the species was separated by size group and a group had ≤25 individuals, length and weight were recorded for each individual. If the species was separated by size group and a group had >25 individuals, the total weight of the size group was recorded and a representative sub-sample of 30 individuals was processed.

The total numbers of each species collected was estimated for the 12 month sampling period to assess impact and for comparison with other 316(b) demonstrations. The following formula from NUS Corp (1977) was used to estimate the number of fish impinged:

$$N_i = \sum_{j=1}^{40} X_{ij} * T_j$$

where: N_i = estimated number of taxon I impinged during the 12- month study

X_{ij} = the number of taxon I impinged during 24 hours on date j

T_j = the number of days the plant operated during the period represented by j

40 = The number of dates sampled

Percent composition of impingement samples for each species by number and biomass were determined, as well as size ranges. The relationship between temperature and impingement rates was analyzed with regression analysis, and day and night impingement rates were compared.

Results

A total of 262,994 fish representing 13 species was estimated to have been impinged from October 19, 1993 through October 18, 1994 (Figure 2). The predominant species impinged was threadfin shad(*Dorosoma petenense*), comprising 96% of the total. Bluegill sunfish (*Lepomis macrochirus*) was second in abundance at 2% of the total,

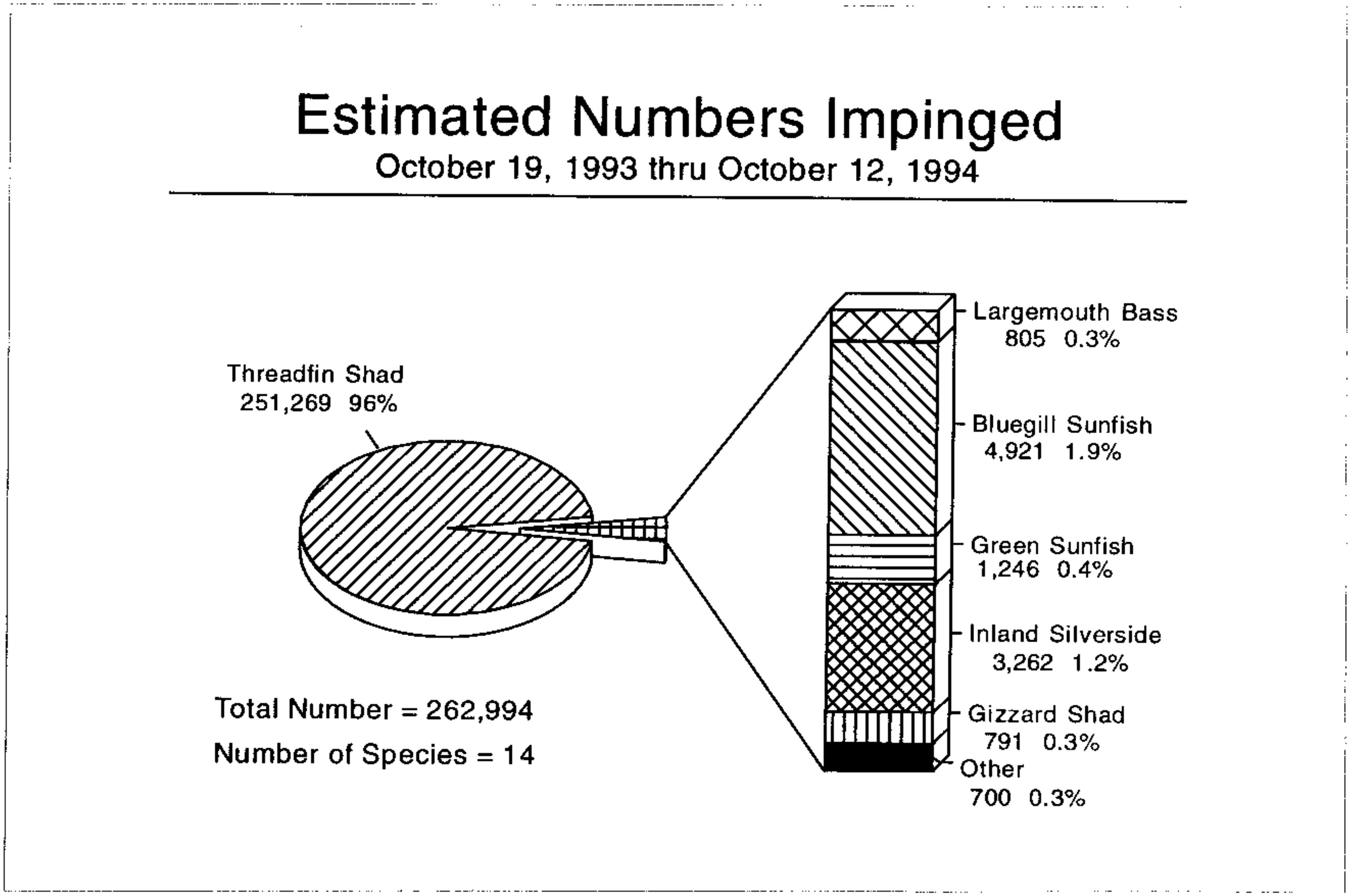


Figure 2. The estimated number of fishes impinged over the sampling period and percent species composition .

followed by inland silversides (*Menidia beryllina*) at 1.2%. The most common top-end predator species was largemouth bass (*Micropterus salmoides*) at 0.35%. Of the remaining 10 species, each accounted for less than 0.5%, and combined represented 2% of the total fish impinged. Total biomass of these fish was estimated to be 614,047 kg (Figure 3). Due to their high numbers, threadfin shad and bluegill sunfish were again highest at 57% and 17% of the total biomass. Large individuals of gizzard shad (*Dorosoma cepedianum*), white bass (*Morone crysops*) and freshwater drum (*Aplodinotus grunniens*) were impinged, and, despite low numbers, they comprised 9%, 5% and 3% of the total biomass. The remaining 9 species comprised 9% of the total biomass.

Size ranges were used to determine approximate age class composition of fishes impinged (Figure 4). Approximately 75% of the threadfin shad were less than 61 mm, and probably belonged to the first year age class. Impingement of bluegill sunfish was also primarily juvenile fish with about 60% less than 90 mm. Inland silversides, and green sunfish (*Lepomis cyanellus*) were more evenly distributed across size classes with the approximate first year classes comprising 35% and 45% of impingements. All largemouth bass impinged were juveniles with none over 136 mm. Impinged channel catfish (*Ictalurus puntatus*) averaged about 120 mm in length, which indicates most were juveniles. The few white bass impinged were all adult size, ranging between 250 and 380 mm in length.

Seasonal differences in numbers of fish impinged were distinct (Figure 5). The sampling data show that 92% of the total impingement occurred over a month and a half period from July 27 to September 7. This trend was evident for most of the species

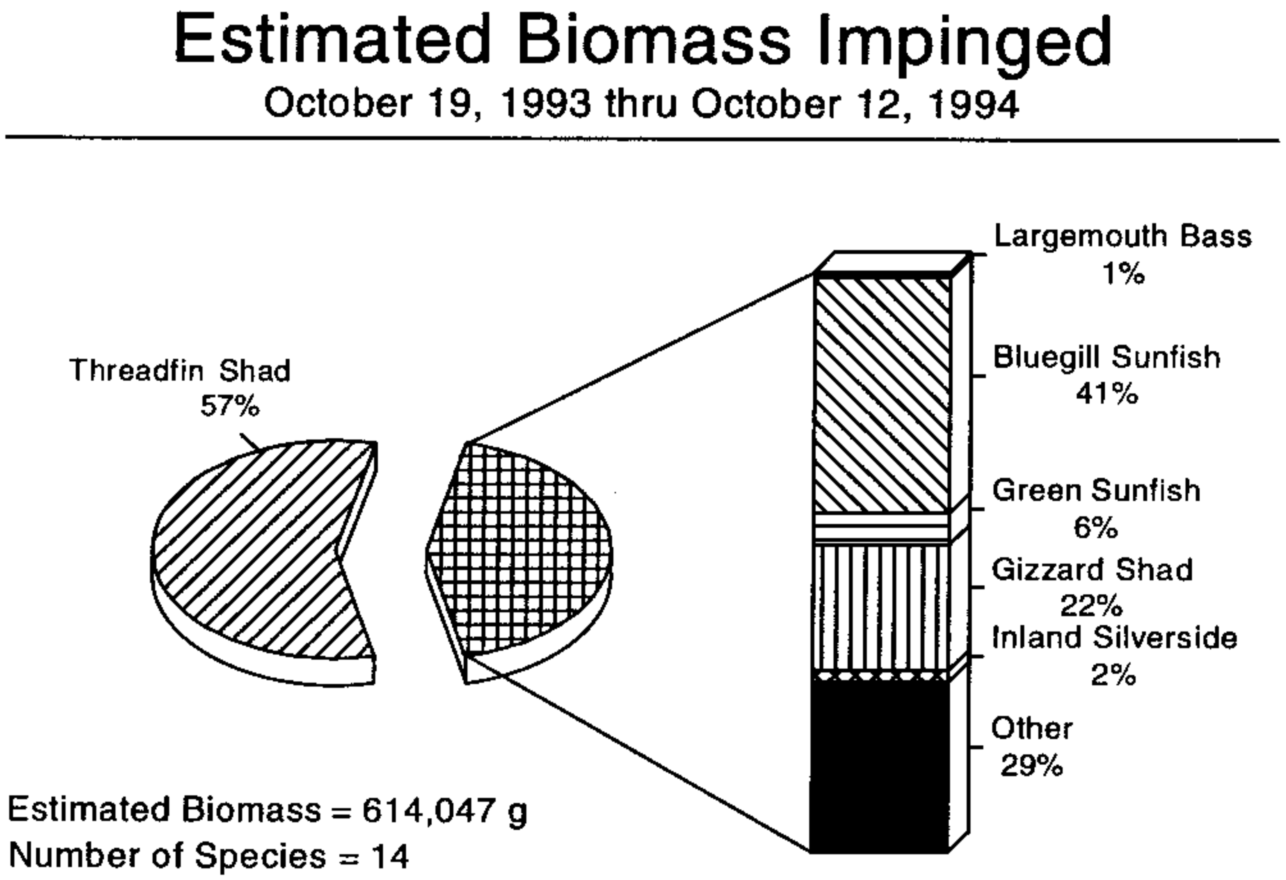


Figure 3. The estimated biomass of fishes impinged over the sampling period and percent species composition .

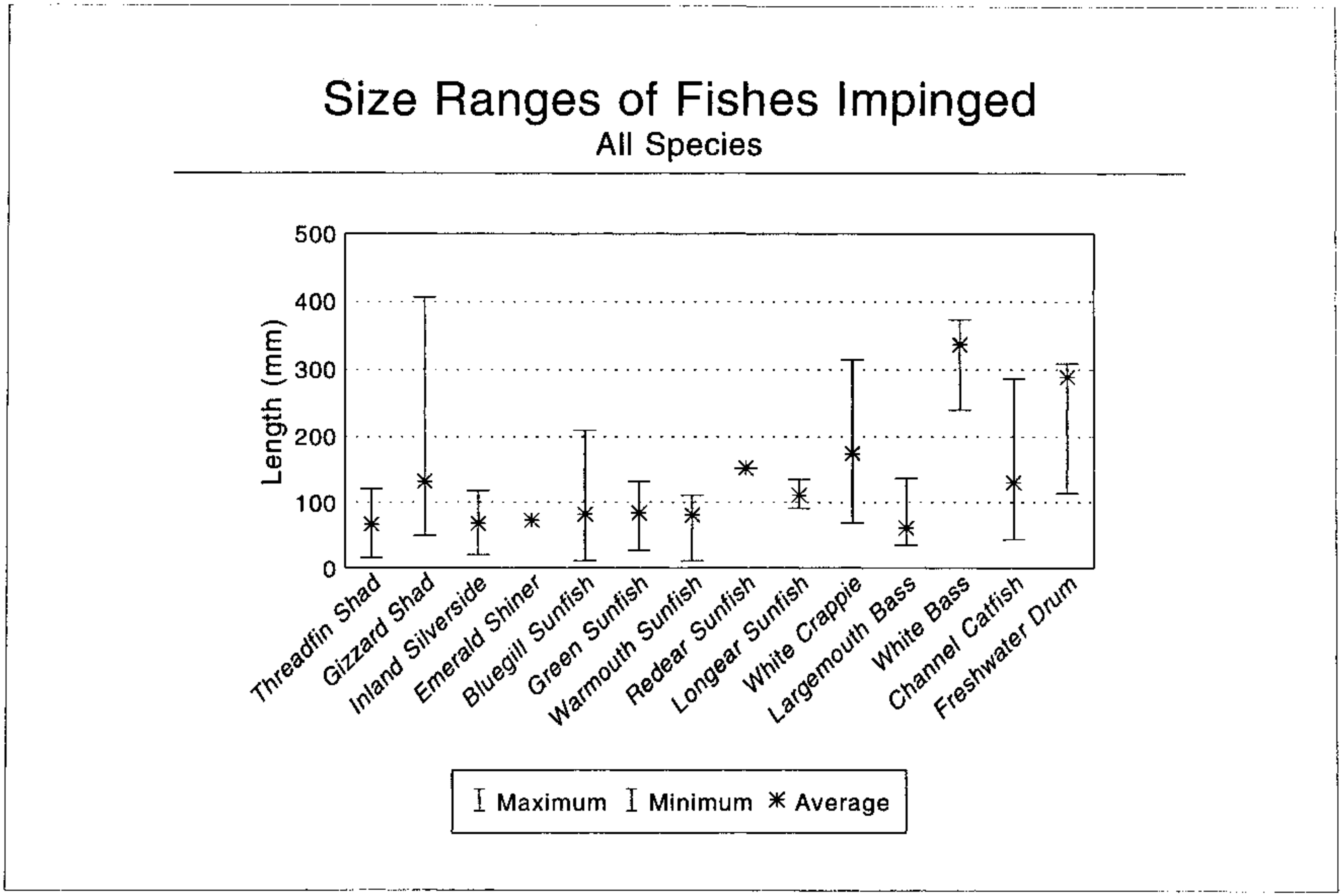


Figure 4. The maximum, minimum, and average lengths of all species of fish collected in impingement samples.

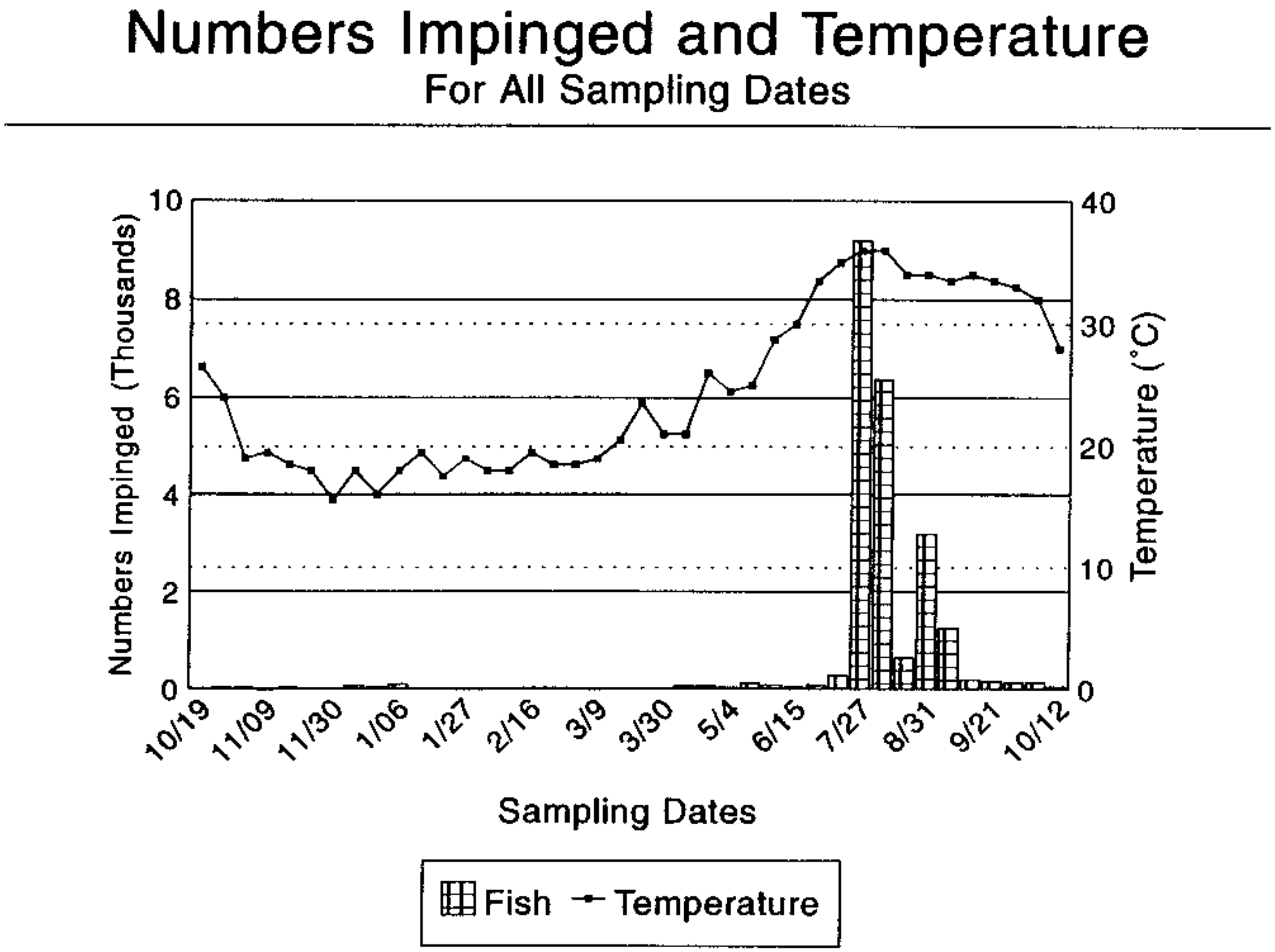


Figure 5. The total number of fishes impinged (all species) and the SCR surface temperature for each sampling period.

collected. Threadfin shad impingements were the most variable, with a moderate increase during the late fall/early winter, and a substantial increase during late summer. Impingement of bluegill sunfish was fairly consistent from October 1993 through March 1994, with a daily average of about 5 for each month, but after March the daily average per month increased and was variable, ranging from 5 to 30 per day. Impingement of largemouth bass was almost exclusively limited to the period from May to August. It was hypothesized that the numbers impinged was influenced by water temperature. A linear regression analysis was performed on the temperature versus the log transformation of the number impinged (Figure 6). The resulting r-squared value was 0.63. The plot of temperature versus log impinged shows two extra high values above the best fit line at the highest temperature reading.

Impingement numbers were greater at night for 36 of the 40 sampling days (Figure 7). For 27 of these days, night impingement comprised at least 70% of the 24-hr total. This was a trend exhibited by most of the species collected. Overall, 57% of the impingements occurred at night, and 43% occurred during the day. This percent comparison is skewed by the large number of threadfin shad collected during the day on the dates of July 28 and September 7. Fifty-three percent of the threadfins were impinged at night while all other species (with more than 50 collected) had at least 70% of their impingement at night.

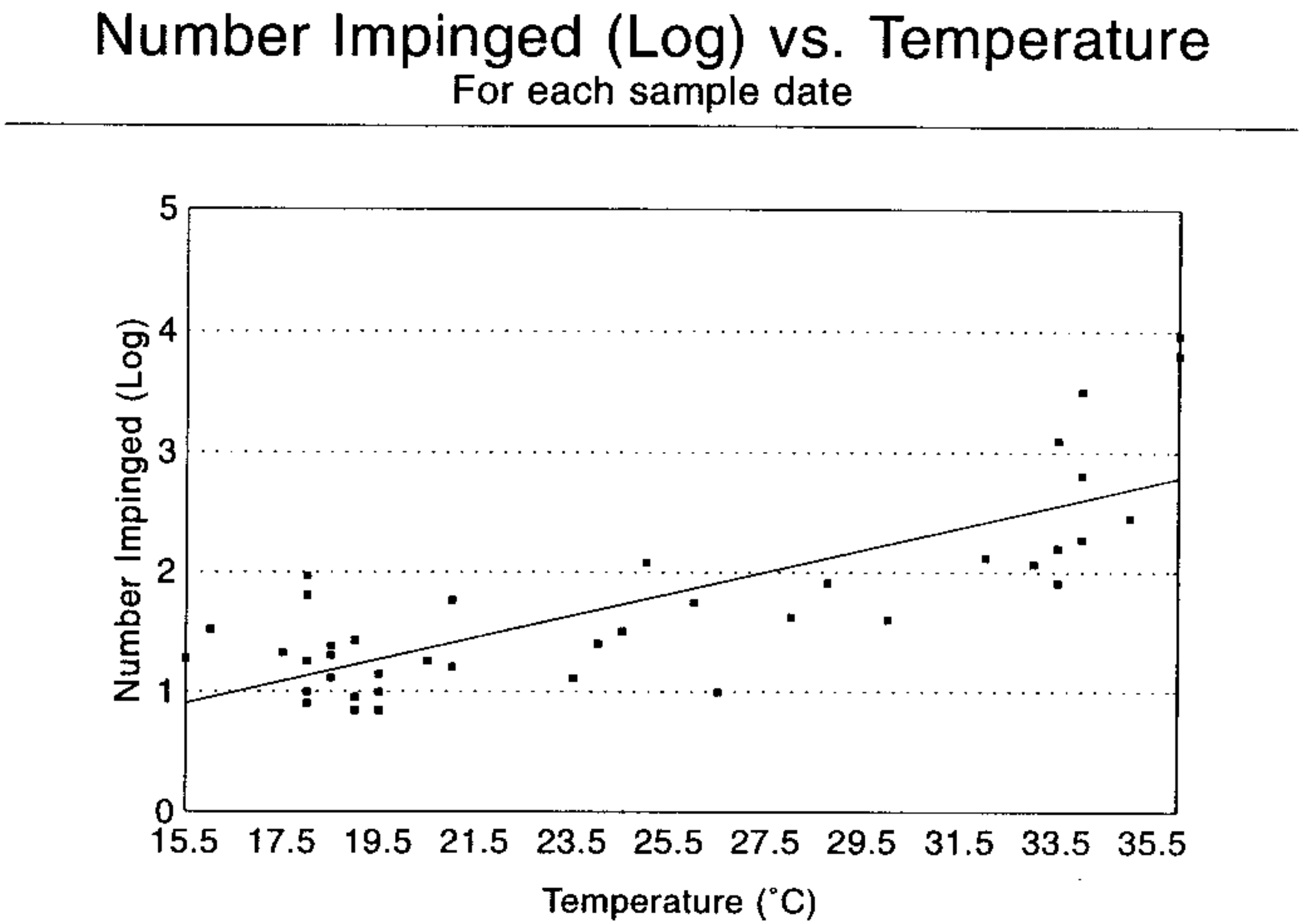


Figure 6. Plot of water temperature and number of fishes impinged (log) with best fit line. Results of linear regression analysis are shown on graph.

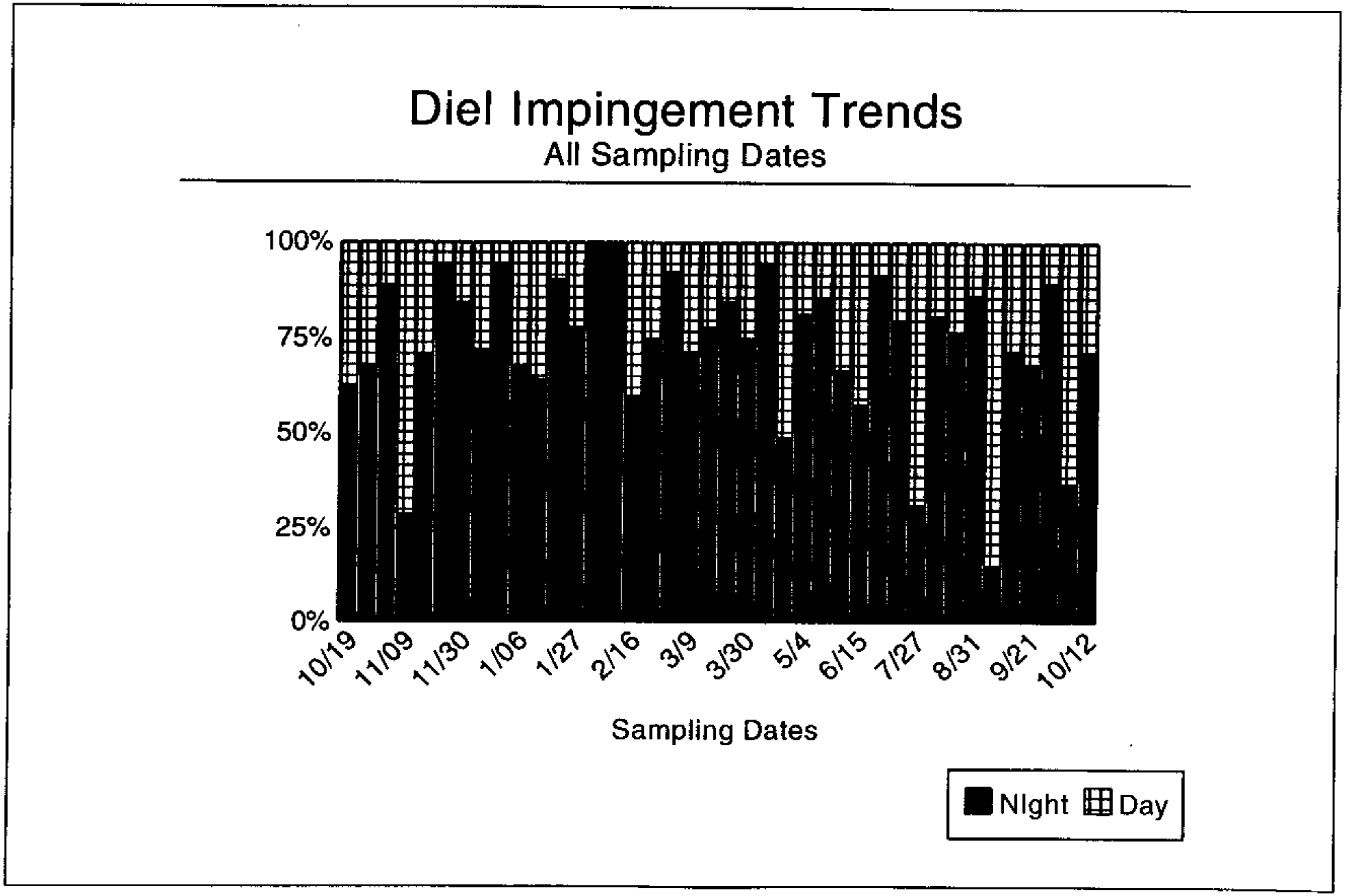


Figure 7. Percent comparisons of numbers impinged during the day and night for each sampling date.

Discussion

This discussion will address the results of this study, but potential impact upon SCR will not be addressed until the results of the entrainment and lake survey studies have been presented.

The total estimated impingement of fish at the CPSES intake structure (249,852) is low in comparison to the results of impingement studies at other warm water reservoirs. Annual fish impingement estimates were as high as 30 million at the Arkansas Nuclear One SES, and 900,000 at the Allen SES in South Carolina (Freeman and Sharma 1977). Estimated impingement losses at the SES's of the Tennessee Valley Association (TVA) ranged from 20,000 to 5 million, and averaged about 700,000 (Freeman and Sharma 1977).

The species composition of the impingement collections was dominated by threadfin shad, comprising 96% of the total. The remaining 4% of the species collected were comprised mostly of bluegill sunfish, inland silversides, and green sunfish. Thus, most fishes lost to impingement were species which are often preyed upon by top-end predator species. Only 0.6%, of the fish collected were top-end predator species, the most common of which was the largemouth bass. Identifying the species place in the food chain is important when assessing impact because this often dictates the species capacity for compensating for population loss. These results are very similar to many other impingement studies performed at warm water lakes and rivers (Freeman and Sharma 1977). Species of forage fish were always most numerous, with threadfin shad, or gizzard shad, typically comprising at least 90% of the total impingements. This is to be expected since forage species typically greatly out number predator species, but the degree of difference here indicates that forage fish are more susceptible to impingement.

Most of the impinged fish collected were small, typically less than 120 mm in length. For some species, individuals this size are juveniles, the loss of which is less significant than the loss of mature, breeding age individuals. Largemouth bass followed this trend with impingements exclusively limited to juvenile fish. The impingement of bluegill sunfish and green sunfish was greater for fish less than 120 mm (75% and 95%), and individuals less than 90 mm, which are more likely to be juvenile, comprised about 60% and 40%. Threadfin shad and inland silversides usually do not grow larger than 120 mm, and their impingements were of both adults and juvenile sizes. The reason greater numbers of small fish were impinged may be the physical limitations of small fish to resist intake currents, the presence of larger numbers of small fish in the vicinity of the intake, or a combination of these factors. Visual observations of large numbers of adult sized channel catfish and sunfish in the waters directly in front of the intake, and their absence in the collections further indicates that impingement was size selective.

The seasonal variation of impingement rates observed in this study was different from those reported in other impingement studies (Freeman and Sharma 1977). The typical trend for fish impingement is for it to increase during the winter months, sometimes by several orders of magnitude. For this study, impingement rates were highest during the summer months of July, August and September. Impingement did increase slightly in late December, but was two orders of magnitude higher during the summer. Although threadfin shad were responsible for much of the increase of total impingement, all species had higher impingement rates at this time. The reason seasonal variation of impingements were different for this study most likely involves water temperature range. All studies used for comparison took place further north, where water temperatures ranged from 4 to 9°C in the winter and 27 to 32°C in the summer (Freeman and Sharma 1977). The water temperature range measured in SCR for this study was 15 to 36°C .

Intolerance to the extreme water temperatures is one possible explanation for the larger number of fish impinged during the summer. A regression analysis of water temperature and the number impinged (Log) showed only a moderate relationship (R^2 = O.63). A regression of water temperature and the real numbers impinged showed almost no relationship ($R^2 = 0.15$). A plot of these data revealed two extra high values above the best fit line at the highest temperature. It is possible that the fish were exhibiting a threshold tolerance of temperature increases. This is especially possible for threadfin shad which are sensitive to extreme ranges and fluctuations in environmental conditions such as temperature and dissolved oxygen concentrations (Burns 1966).

Another possible explanation of the observed seasonal trend is that young of the year (y-o-y) fish were first reaching an impingeable size. Entrainment data show that the *Dorosoma* larvae were already abundant on April 1 and were present until May 18. They can grow approximately 25 mm per month until they reach 75 mm (Burns 1966)) The first y-o-y threadfin shad (measuring about 50 mm) appeared in impingement samples on June 1, and on July 13 they began to appear in large numbers, 4 to 6 times more abundant than those measuring over 75 mm. It can not be concluded that the appearance of y-o-y fish alone accounted for the drastic impingement increase, but it did contribute.

Summary of Impingement Study

The objective of impingement sampling was to determine what was being impinged, when and why, and to estimate the number lost in order to assess potential impacts upon the fish populations. It was hypothesized that fish impingement does not correlate with water temperature.

The estimated number of fish impinged from October 19, 1993 to October 18, 1994 was 262,994. Threadfin shad comprised 96% of this total. The remaining 4% was primarily forage species as well. Largemouth bass was the most common top-end predator species impinged with an estimated loss of 809. Impingement appeared to be size selective with most fish measuring less than 120 mm. Impingement increased by several orders of magnitude during the months of July and August, coinciding with the highest water temperatures recorded during the study. The fish appeared to exhibit a threshold tolerance of increasing water temperature.

The species composition and size classes of fish impinged was similar to those recorded by other impingement studies at warm water reservoirs. The estimated number impinged was lower than most other impingement studies. The seasonal variation was very different from other studies which typically recorded the highest impingement rates during the winter months.

CHAPTER II

ENTRAINMENT STUDY

Materials and Methods

The entrainment study took place over the period of April 6, 1994 through August 24, 1994. Samples were collected weekly between the hours of 9:00 AM and 12:00 PM, and again between 9:00 PM and 12:00 AM. During these time frames, sampling was conducted in front of the intake of each unit for 30 minutes. There was a unit 2 outage over the period of April 27 through June 21, during which water intake was reduced for that unit. For the duration of the outage, sampling at the unit 2 intake was discontinued while sampling at unit 1 continued, with multiple depth sampling added on a biweekly basis. At unit 1, a total of 63 samples were taken, with 41 at the 1 m depth, 12 at 7 m, and 10 at 15 m. At unit 2, 26 samples were taken at the 1 m depth. Three replicates were collected for each sampling event.

Sampling was conducted immediately in front of the trash racks. Here currents created by the intake were sufficient for holding up the nets. A set of three ichthyoplankton nets with flow meters mounted across their mouths were tied with ropes to a bar mounted horizontally at the front of the boat. The nets were tied with one meter ropes to flotation devices to maintain a constant depth. The bar to which the nets were tied was detachable so it could be lowered to the desired depth for multiple depth sampling. One of the four pumps per unit was randomly selected. The boat was positioned in front of the selected pump, and the nets were deployed for 30 minutes. Upon retrieval, each net was washed down with a spray bottle and the sample was concentrated in the bucket. The sample was transferred to a labeled sample container and preserved with 10-percent formalin plus rose bengal stain. Water temperature, air temperature, dissolved oxygen, weather condition, sunrise and sunset, and moon stage were recorded. This procedure was repeated at the second unit

The volume of water filtered through the net was estimated by the following formula provided by General Oceanics:

Volume filtered (m^3) = [C/D (2.61) + 3.47]/100 * (A*D)

where: C = number of counts read from the flow meter

D = sample duration (sec)

A = area of net opening (m^2)

Multiple depth sampling was performed at 1 m. (surface), 7 m. (mid), and 15 m (bottom) depths. Two ropes were tied to the ends of the bar to which the nets were attached, and the apparatus was lowered to the desired depth. All other sampling steps were as described above.

The collected samples were returned to the Institute of Applied Sciences laboratories at the University of North Texas (UNT) for processing according to specifications given below.

Sample processing began by emptying the contents of the collection jar for a single sample into a straining bucket with a 500 micron mesh and then rinsing with tap water to remove excess Rose Bengal stain. If larvae were stained with excessive amounts of Rose

Bengal the condition was remedied by treating the specimen with alcohol solutions of different concentrations.

The sample was placed into a Petri dish and fish eggs and larvae were sorted into taxonomic groups and counted. Identification of ichthyoplankton was to genera, and sometimes family. References for identification included Hogue et al. (1976), Snyder et al. (1977), Jones et al. (1978), and Hardy (1978). Each taxonomic group was stored in its own vial and labeled accordingly. Representatives of each identified taxon were set aside as vouchers for quality control. Damaged/unidentified larvae were classified as "Damaged", counted, and their number incorporated in the total number of larvae for the sample. The density of fish eggs and larvae were then calculated for each collection.

Data analysis began by determining the percent composition of ichthyoplankton collections by genus for eggs, larvae, and juveniles. Seasonal trends were noted. The calculated densities and total volume of water withdrawn by the intake were used to estimate total entrainment of eggs and larvae for each genera. As stated in McFarlane et al. (1978), it has previously been shown that the best estimate of plankton density is obtained by simply dividing the total number of organisms collected at a station by the total volume of water sampled. This provides the best estimate of density, but gives no indication of the variance associated with that estimate. Analysis of variance (ANOVA) was used to determine significant differences of densities between depths.

Potential impact on fish populations was estimated with a simple population modeling approach described by Horst (1975) and used by NUS Corp. (1976). In this model the number of ichthyoplankton entrained is converted to an estimate of the number of adult fish that would have been produced had the ichthyoplankton not been entrained. If the entrained stage is an egg, the estimate of the number of adults lost is calculated as follows:

$$N_a = SN_e = \frac{2}{F} N_e$$

where: N_a = number of adults in mature age classes

S = survival from egg to adult stage

N_e = number of eggs entrained

F = total life time fecundity of a female

2 = number of adults needed to be produced by a breeding pair to maintain a stable population

Horst (1975) described fish lifetime fecundity as the number of eggs produced in the lifetime of a species. The average lifetime of a species can be estimated only roughly and is determined by mortality rates among age classes as well as by life span. It is necessary to make the assumption that the limited data available from various locations and times are roughly representative of the indigenous populations of SCR. If the entrained stage is a larva:

$$N_a = S_1 N_1 = \frac{2}{FS_e} \times N_1$$

where: N_a, 2, and F are defined as above

S_l = survival from larva a to adult stage

N_l = number of larvae entrained

S_e = survival from egg to larva

The following assumptions are made in this analysis:

- There is 100% mortality of entrained eggs and larvae on passage through the plant.
- The populations are at equilibrium and the total lifetime fecundity produces 2 adults.
- That 0.5% of the eggs produced by species with high fecundity and/or randomly broadcast eggs and little parental protection survive to the larval stage.
- That 75% of the eggs produced by a species which exhibits nesting behavior and a high degree of parental care survive to the larval stage.

These models were applied to all genera represented in the sample collections. If a genus had more than one species present in SCR then the most prominent species was selected, or all species were selected and the ichthyoplankton of that genera was attributed to each species for calculation of the worst case scenario for each species.

Results

A total of 29,678,474 eggs, 44,427,723 larva, and 1,355,441 juveniles representing six genera was estimated to have been entrained during the period of April 6, 1994 through August 30, 1994 (Figure 8). The density of ichthyoplankton in water strained by the nets averaged 0.043 per m^3, and ranged from 0 to 0.286 per m^3. No

Estimated Entrainment

April 6, 1994 thru August 31, 1994

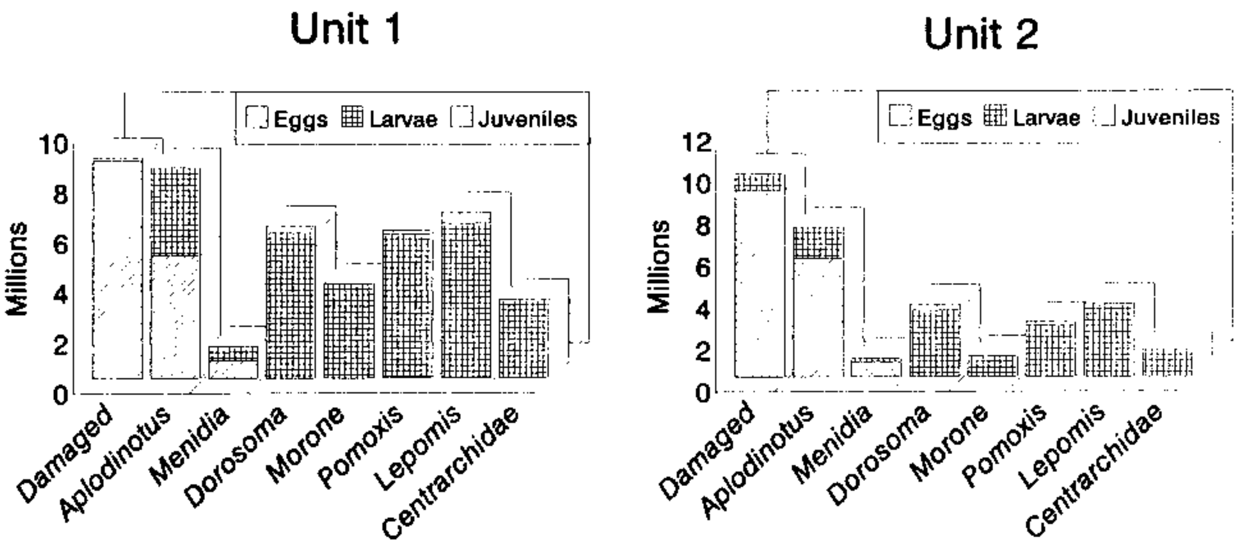


Figure 8. Total estimated entrainment by each unit's intake for each genera collected over the April 6 through August 30, 1994 sampling period. Unit 2 underwent a two month outage during which cooling water intake, and thus entrainment, was reduced.

ichthyoplankton were present in 19 of the 67 sampling events. The average volume of water filtered for all replicates was 50 m^3 over each 30 minute period.

Eggs comprised 40% of the estimated ichthyoplankton entrained. More than half (17.6 million) of the eggs were labeled damaged since they lacked characteristics for identification. This was usually attributed to the fact they were unfertilized. Of the remaining eggs, two genera were represented, with most of these eggs belonging to *Aplodinotus* (10.6 million) and the rest to *Menidia* (1.5 million). Genus compositions for units 1 and 2 were similar.

Fifty-eight percent of the estimated ichthyoplankton entrained was larval fish of 5 genera. The most common genera were *Lepomis*, comprising 23% (10 million), and *Dorosoma* and *Pomoxis* at about 19% (8 million) each. An additional 11% (4 million) were identified as Centrarchids because they were too small to be identified at the genus level. *Aplodinotus* and *Morone* each comprised about 15% of the collections, and *Menidia* 2%. Again, the units 1 and 2 genus compositions were similar.

The remaining two percent of the estimated ichthyoplankton entrained was identified as juveniles of 3 genera. The species compositions were different for units 1 and 2 with no *Lepomis* juveniles collected at the unit 2 intake. The estimated entrainment of juveniles was comprised of *Lepomis* at 33% (0.4 million), *Dorosoma* at 42% (0.6 million), and *Pomoxis* at 25% (0.3 million).

Sample collections showed distinct seasonality of ichthyoplankton densities, species compositions, and life stages. Fish eggs were collected from April 6 through June 22, and on August 24 (Figure 9). Densities were highest from April 27 through June 15.

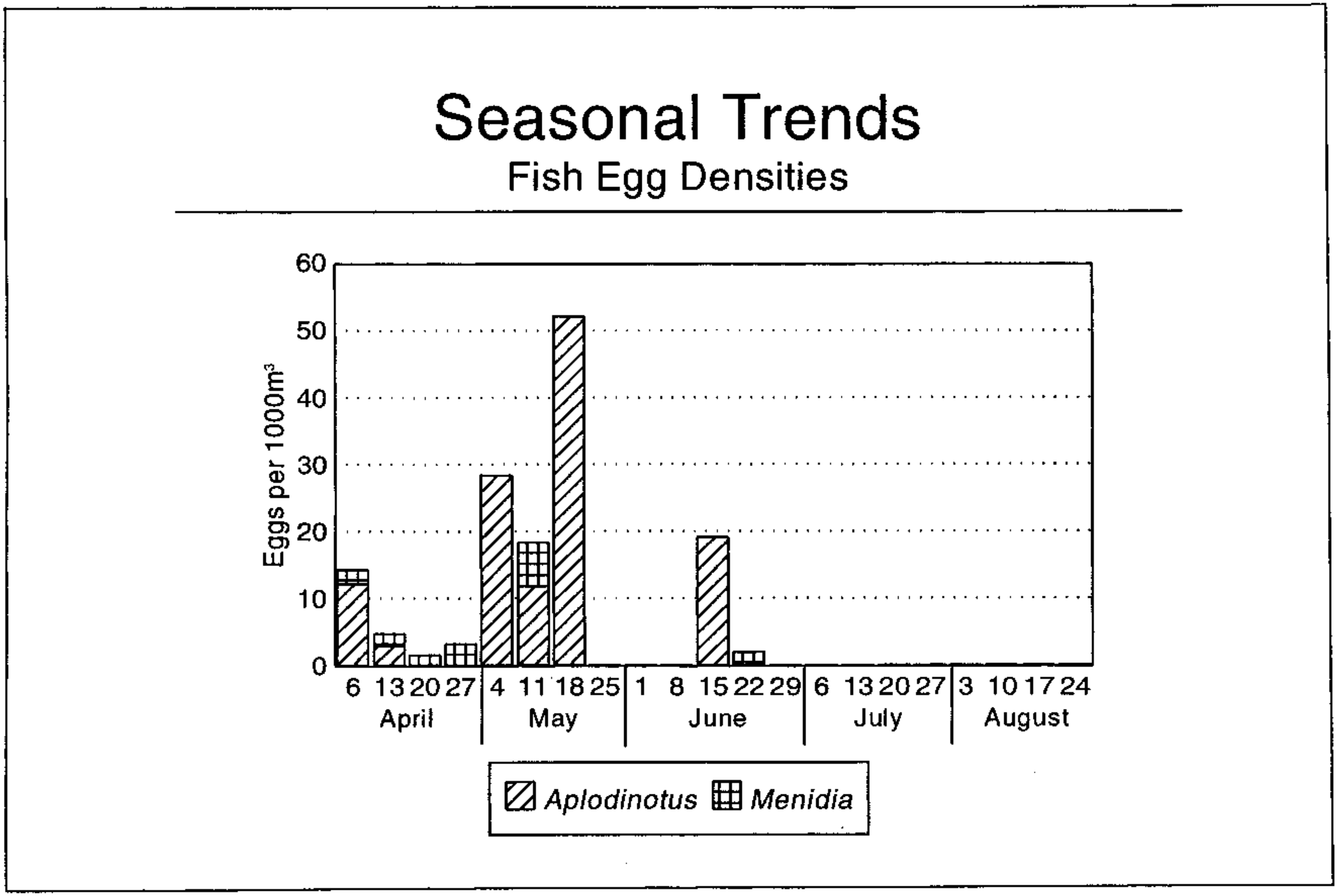


Figure 9. Seasonal trends of fish egg densities for each genus collected over the period of April 4 through August 31, 1994

Aplodinotus and *Menidia* eggs had similar patterns, both were collected over the period of April 6 through May 18, then again on June 15 and 22. *Aplodinotus* eggs varied in density, peaking on May 18 at about 50 per 1000 m³, while *Menidia* egg densities remained consistently low at about 5 per 1000 m³. Damaged eggs often outnumbered undamaged eggs.

The presence of larval fish in the collections can be separated into 3 periods (Figure 10). The first period was April 6 through May 18. It was dominated by *Dorosoma* for which densities were highest, at about 50 per 1000 m³, on the first collection date, and gradually declined throughout the period after which they were not collected. Small numbers of *Menidia* were recorded twice in this period, and once in the next period. *Pomoxis* larvae in low densities were recorded once in this period.

There were no fish larva collected on May 25 and June 1. The second period began on June 8 and ended July 13. The first part of this period was dominated by *Aplodinotus* which were collected on the first 3 dates, peaking on June 22. This date also had a high density of larvae identified as Centrarchids, along with a few *Morone* and *Menidia*. The following three weeks, until the end of this period, only *Lepomis* and *Pomoxis* were collected in low to moderate densities.

Again, no larvae were collected for two dates, July 20 and 27. The third period was the month of August. *Aplodinotus* larvae appeared in high densities on the first date, along with low densities of Centrarchids. For the remaining three dates, only *Lepomis*, *Pomoxis*, and *Morone* were collected. They all appeared on each date, and in densities nearly equal to each other. Densities were high on August 10 and 17, and declined about

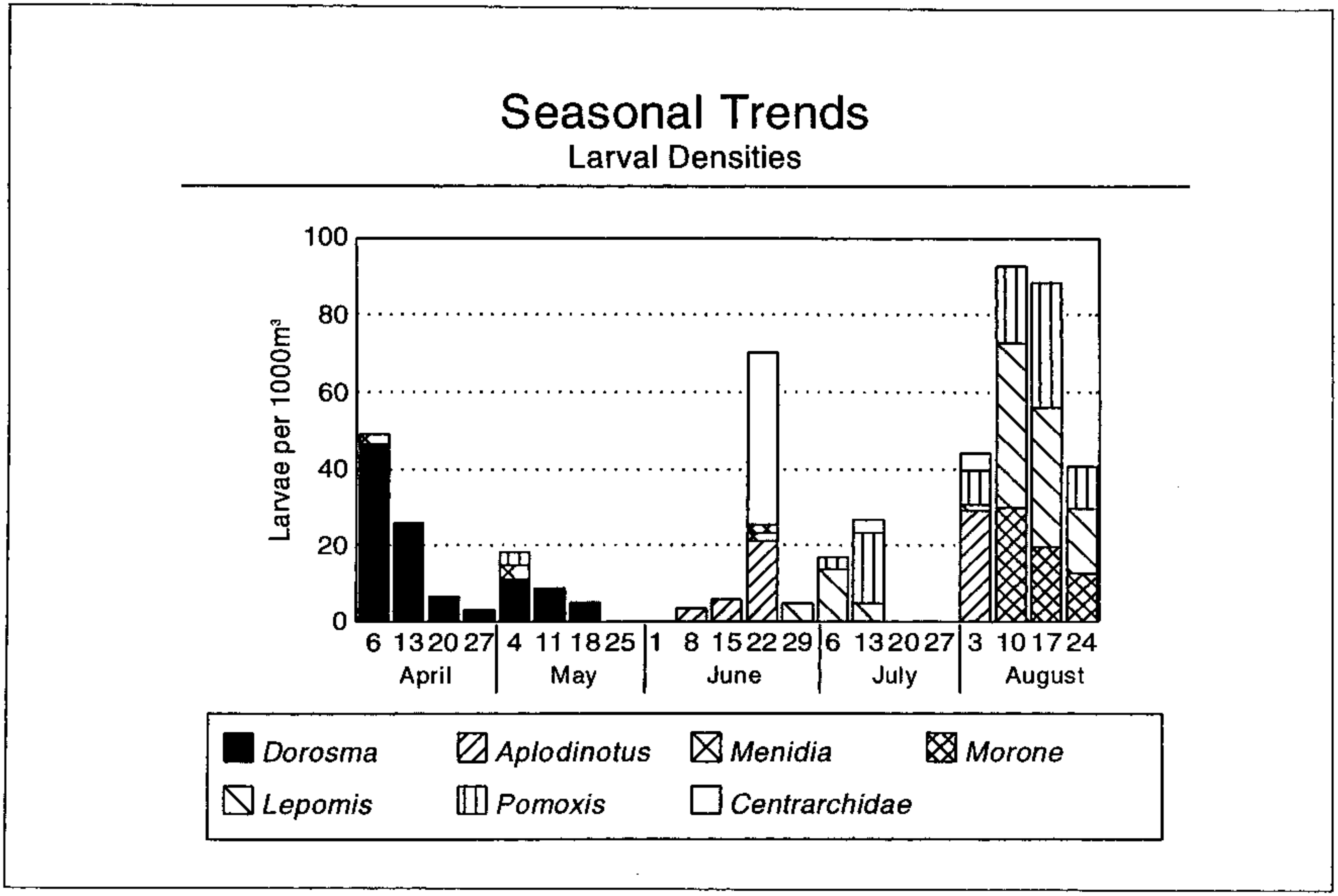


Figure 10. Seasonal trends of fish larvae densities for each genus collected over the period of April 4 through August 31, 1994.

50% on August 24.

Three species of juvenile fish were collected in low densities on three dates throughout the sampling period (Figure 11). *Dorosoma* were collected on April 27 and May 4, while *Lepomis* and *Pomoxis* juveniles were collected on August 17.

Multiple depth analysis revealed no significant difference in ichthyoplankton densities in collections at 1 m, 7 m, and 15 m depths, so densities were assumed to be uniform across all depths (Kruskal Wallis one-way multiple sample test, $p = 0.05$) (Figure 12) .

Calculations of possible adult fish loss due to entrainment based on the model are listed in Table 1. Since entrainment estimates are for the genus level, representative species for each genus entrained were selected for each sample collection to show seasonal trends over the sampling period. However, the two species belonging to *Dorosoma* have fecundities which are very different, so adult loss was calculated for each species using the half of the estimated *Dorosoma* entrained. Also, the larvae which could not be identified past Centrarchidae were assumed to be each Centrarchid species for which adult loss was calculated. Thus, the estimated number of Centrarchids entrained was added to the estimates for *Lepomis* and *Pomoxis*. The *Micropterus* genus was included in this model, although none were collected, because of the possibility that the larvae identified as Centrarchidae may have belonged to this genus.

Discussion

The objective of the entrainment study was to determine what was being entrained, when it was happening, and the factors involved, and to estimate the loss of eggs, larvae,

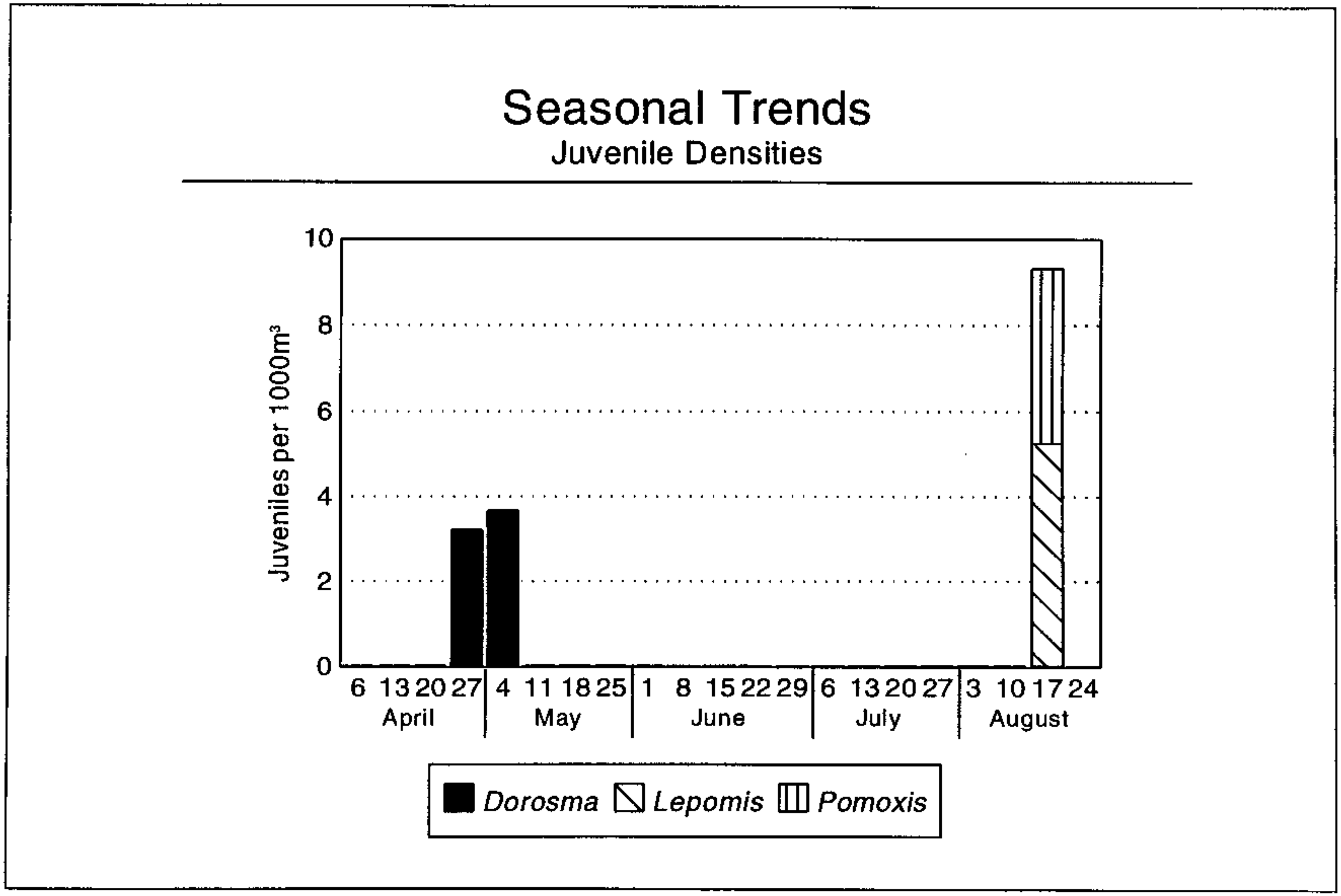
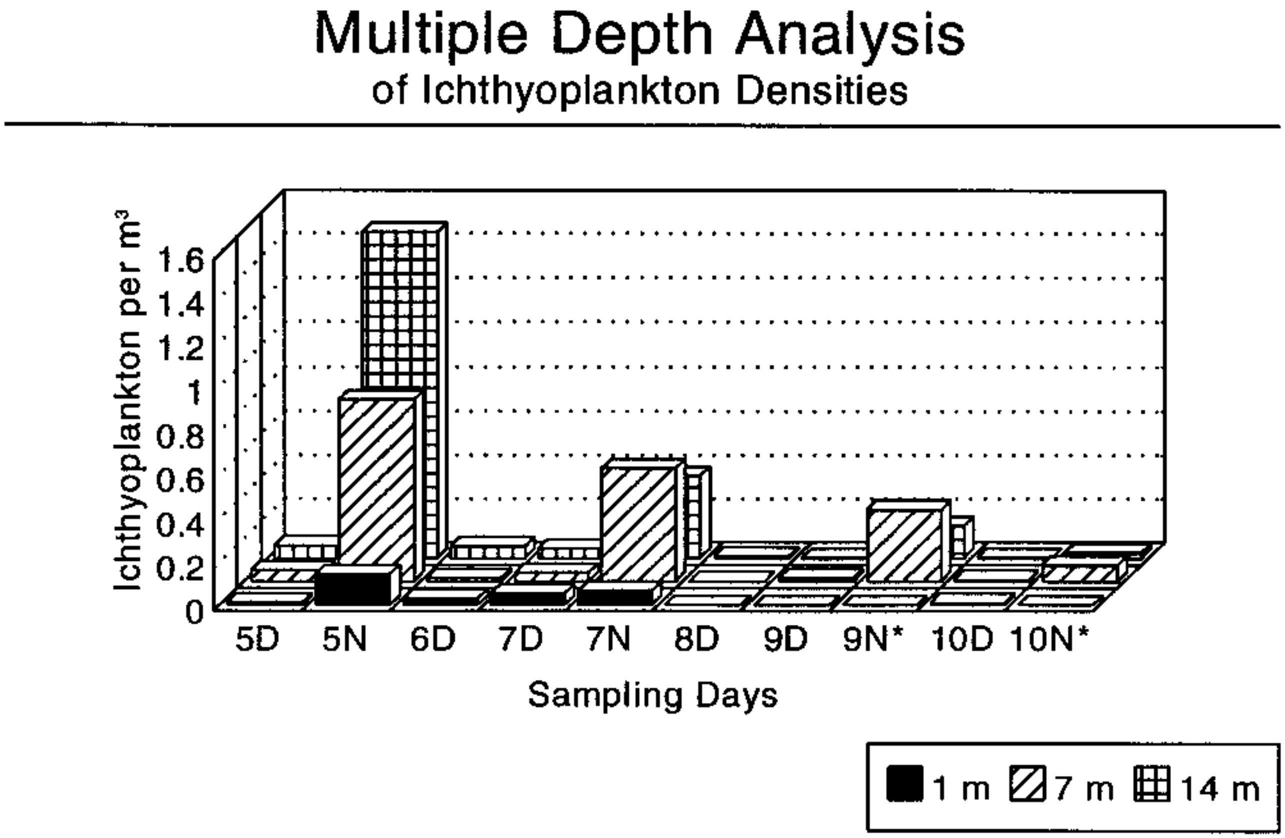
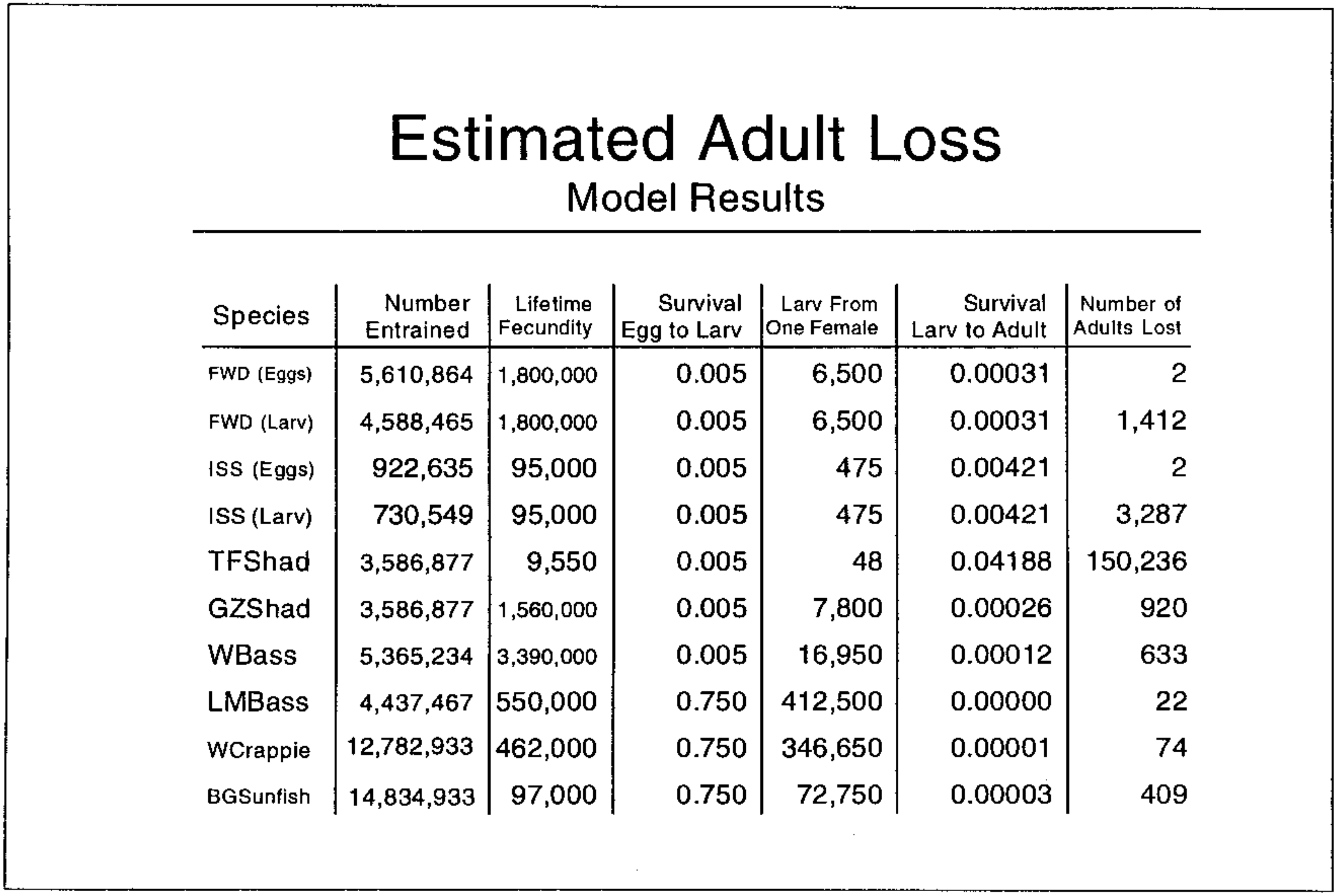


Figure 11. Seasonal trends of juvenile fish densities for each genus collected over the period of April 4 through August 31, 1994.



Kruskal Wallis one-way multiple sample test, $p<0.05$
* Indicates siginificant difference between depths
D = day, N = night

Figure 12. Ichthyoplankton densities at 1 m, 7 m, and 14 m depths for each sampling period during the multiple depth analysis study.



Estimated Adult Loss

Model Results

Species	Number Entrained	Lifetime Fecundity	Survival Egg to Larv	Larv From One Female	Survival Larv to Adult	Number of Adults Lost
FWD (Eggs)	5,610,864	1,800,000	0.005	6,500	0.00031	2
FWD (Larv)	4,588,465	1,800,000	0.005	6,500	0.00031	1,412
ISS (Eggs)	922,635	95,000	0.005	475	0.00421	2
ISS (Larv)	730,549	95,000	0.005	475	0.00421	3,287
TFShad	3,586,877	9,550	0.005	48	0.04188	150,236
GZShad	3,586,877	1,560,000	0.005	7,800	0.00026	920
WBass	5,365,234	3,390,000	0.005	16,950	0.00012	633
LMBass	4,437,467	550,000	0.750	412,500	0.00000	22
WCrappie	12,782,933	462,000	0.750	346,650	0.00001	74
BGSunfish	14,834,933	97,000	0.750	72,750	0.00003	409

Table 1. The results of the equivalent adult loss model and the numbers used in the calculation of these results.

and juveniles in order to assess potential impacts on the SCR fish populations.

The estimates of ichthyoplankton entrained by the CPSES are similar to those calculated in entrainment studies at other power plants. The Prairie Island Nuclear Generating Plant on the Mississippi River entrained 8.3 million eggs and 61.6 million larvae (NUS 1976), and the Allen S. King Generating Plant on Lake St. Croix in Minnesota entrained 43.6 million eggs and 23.5 million larvae (NUS 1977). Slightly lower entrainments were recorded at the Savannah River Plant in South Carolina with a loss of 13.7 million eggs and 39.2 million larvae (McFarlane 1978).

The entrainment estimations for this study represent a worst case scenario since they are based upon continuous operation of all eight pumps. Pump operation varied throughout the sampling period with 6 pumps operating before the unit 2 outage on April 27, and all 8 operating during the warmer months after the Unit 2 outage. The accuracy of the estimates are, however, affected by various biotic factors. Sampling gear avoidance by post larvae and juveniles may have affected accuracy by lowering the estimates. The accuracy of estimates are also affected by the inherent patchiness of ichthyoplankton populations due to spatial and temporal variations in densities (Jenson and Loftus 1976).

The proper solution for dealing with high variability is to increase sampling and the number of replicates, especially during peak periods. However, sampling ichthyoplankton is very labor intensive, from collection to laboratory analysis, and this is not practical for most studies. The recommended sampling procedure is weekly sampling over 24-hr periods, and possibly biweekly during peak periods and monthly during periods of very low densities (Jude 1976).

Extrapolating the few larvae collected to the total number that is entrained is an uncertain calculation. The amount of water filtered with sampling nets each 24 hr period was about 0.0001% of the average 24-hr intake volume. Even increasing the sampling by a factor of 10 would not change that number significantly.

The collection of fish eggs was largely dependant upon the reproductive strategies of the different genera. As would be expected, fish which broadcast semi-buoyant eggs into the open water will have eggs entrained as opposed to those which lay adhesive eggs over vegetation or are nest builders. Two genera in SCR are open water spawners and they were the only ones for which eggs were collected in samples. One of these was *Aplodinotus*, which is an open-water spawner whose successful reproduction depends upon the release of massive numbers of gametes. The eggs contain oil globules which makes them semi-buoyant, and capable of dispersing with the water currents. Their eggs were the most numerous in the collections. *Menidia* are also open water spawners. They are less prolific than *Aplodinotus*, but their egg survival is better ensured by filaments which cling to substrate. This substrate may be free floating which accounts for their presence in the collections.

The presence of larvae and juveniles in the intake waters and sample collections depends upon factors such as their movement patterns, where they were spawned in relation to the intake, and their mobility. Larvae tend to move into the water column to feed, regardless of where they were as eggs. Thus, it is understandable that larvae of almost all major genera in SCR were collected in entrainment samples.

The cove where the intake structure is located is lined with riprap which is suitable spawning habitat for many species. Fortunately, the shallow areas are limited by the steeply sloping shoreline, reducing the amount of spawning activity that occurs. Larval collections were predominantly of the genera *Lepomis* and *Pomoxis*. The rocky outcroppings provided by the riprap of the intake cove are particularly attractive spawning sites for *Pomoxis* (Goodson 1966). *Lepomis* can also find suitable spawning areas here. *Micropterus* would find suitable spawning sites here, but they were not collected unless some of their early stage larvae were identified as Centrarchidae. In reservoirs where tributary streams, or rivers, are nonexistent, as is the case at SCR, white bass (*Morone*) will spawn where wind driven currents occur over riprap (Chadwick et al 1966.). These requirements are met at the mouth of the intake cove, which helps explain the presence of their larvae in the collections. Another genus which will spawn in rocky areas is *Ictaluridae*, but these were not collected.

The presence of larvae of the open water spawners, *Aplodinotus* and *Menidia*, is dependant upon water currents, and they were collected in numbers slightly less than their egg collections. The *Cyprinid* and *Dorosoma* genera typically spawn over aquatic plants. The waters near the intake are void of plants which explains the absence of *Cyprinid* larvae, but raises questions about the abundance of *Dorosoma* larvae. One possible explanation may be that *Dorosoma* are open water fish, while *Cyprinids* are bottom oriented. The larvae may follow these patterns which subjects *Dorosma* to higher entrainment and/or collection rates.

The sharp reduction in numbers of juveniles in sample collections was probably due to their increased mobility, enabling them to dodge sampling nets. The avoidance of sampling gear may result from visual cues or hydrostatic pressure cues (Bowels and Merriner 1977). While juveniles may detect and avoid sampling gear they may not detect danger with intake currents and will continue to accrue losses which will reduce the accuracy of entrainment estimates (Cannon and Lauer 1976).

The entrainment of ichthyoplankton is inherently seasonal because it is limited to the time period from when they are spawned until they grow to an impingeable size. Thus, the entrainment of each species is dependant upon the time it spawns and it's early growth rate. This leads to distinct seasonality of ichthyoplankton species compositions, as was exhibited by the results of this study.

Early sample collections were dominated by *Dorosma* larvae. Their presence on the first sampling date indicates spawning occurred before sampling started. This is supported by the fact that their typical spawning temperature is 20°C, which was recorded three weeks prior to sampling (Burns 1966). They grow approximately 25 mm per month until they reach 75 mm (Burns 1966). They were collected in entrainment samples until May 18, while y-o-y Threadfin shad, measuring about 50 mm, were first collected in impingement samples on June 1 and in large numbers on July 13.

Aplodinotus eggs were also collected early in the study, and larval collections followed a few weeks behind. Low densities of *Menidia* eggs and larva were recorded until June 22 which is in agreement with their spawning behavior. *Menidia* have daily spawns of 200 to 1200 eggs per female starting in April and lasting until temperatures reach 31°C, which occurred after June 15 (Hubbs 1982). The second half of the study was dominated by *Lepomis*, *Pomoxis*, and *Morone* larvae. The collection of *Morone* larvae in August does not relate well with the fact they prefer spawning temperatures of 14 to 24°C, and usually grow about 90 mm by early August (Chadwick et al. 1966). Larval *Pomoxis* collections in August were also in disagreement with the preferred spawning temperatures of 14 to 20°C, which were not recorded after March 16 (Emig 1966). *Lepomis* spawn throughout the summer which relates to collection data showing them to be present from June 22 till the end of the study.

Summary of Entrainment Study

The estimated entrainment of ichthyoplankton for the period of April 4, 1994 through August 31, 1994 was 29.7 million eggs, 44.4 million larvae, and 1.3 million juveniles. These estimates are similar to those recorded in other studies. More than half the eggs were labeled damaged, most because they were unfertilized. The remaining eggs were mostly freshwater drum, and a few inland silversides. Larvae of seven genera were collected, with the *Lepomis*, *Pomoxis*, and *Dorosoma* genera each accounting for about 20% of these collections. Modeling for equivalent adult loss due to entrainment resulted in estimates which ranged from 22 for largemouth bass to 300,000 for threadfin shad. Entrainment rates and species compositions exhibited definite seasonal trends. *Dorosoma* larvae and *Aplodinotus* eggs were collected early in the sampling period, while *Lepomis*, *Morone*, and *Pomoxis* larvae were collected toward the end of the period.

CHAPTER III

LAKE SURVEY

Materials and Methods

Fishery surveys of SCR involved gillnet and electrofishing sampling , and were performed November 15-17, 1993 and again June 21-23 1994. Locations of sampling sites are shown in Figure 13.

Gillnet sampling was performed with 200 ft monofilament experimental gill nets with 25 ft panals. Mesh size ranged from 0.5" to 4.0". The first evening of the sampling period, gill nets were deployed overnight (12 hrs) at three of the five pre-established sites. The following morning, the nets were retrieved, and the fishes collected were identified, measured (standard length to the nearest millimeter) and weighed (to nearest 50 g). The evening of the same day, gill nets were deployed overnight at the two remaining sites. The nets were retrieved the following morning and the fish were processed as above. For each of the taxonomic groups collected, a representative was retained as a voucher specimen.

Electrofishing was conducted the first night of each lake survey sampling period between the hours of 10:30 PM and 3:30 AM. Each of the five sites was sampled for a 30 minute period. Fishes collected were processed with the same preservation and recording procedures as utilized in gillnet collections.

The data collected was analyzed to determine the percent composition of each species. Minimum, maximum, and average lenghts ranges were determined for each

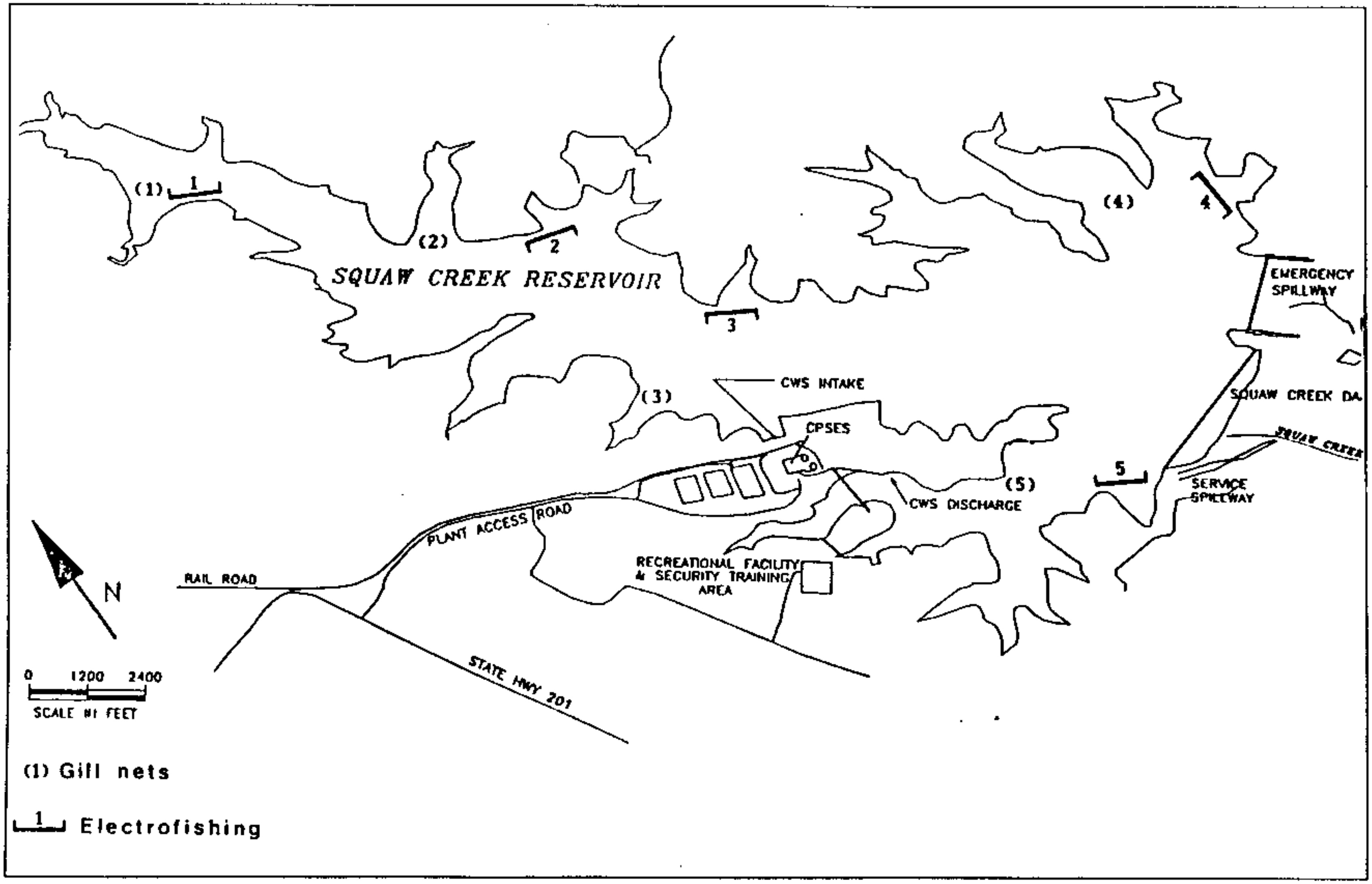


Figure 13. Map of SCR showing gillnetting and electroshocking sampling locatations. Also shown is the CPSES and it's circulatory water system intake and discharge locations.

species collected by each sampling method. Spacial distrubutions of species collected were evaluated by comparisons of species compositions at each site. The results were compared to those of an earlier fishery study conducted by Hellier et. al (1987) on SCR.

Results

Electrofishing was hampered by the high conductivity of the water in SCR which allows electric currents to pass around fish instead of through them. Many fish were seen fleeing the boat and dodging the nets. Most collections were made near the shore in very shallow water (<1 m). The two sampling periods had very different sample compositions. During the November period, 171 fish of 10 species were collected, with sunfish comprising 79% of the total (Figure 14). During the June period, 469 fish of 5 species were collected with threadfin shad comprising 76% and inland silversides 19% of the total. Minimum, maximum, and average lengths of fish collected in electrofishing samples are shown for each species in Figure 15. Most of the fish were small, with weights below the minimum capacity of our measuring equipment so biomass is not reported. Contrary to this were carp and gizzard shad for which adult sizes were collected. All Threadfin shad and inland silversides collected in November were adult size, but in June, adult and juvenile sizes were recorded. The sunfish collected averaged about 100 mm which is a borderline adult size, meaning many were juvenile size.

During the November period, species compositions were similar between sites 1, 2, 4, and 5, with 4 to 6 species collected at each site (Figure 16). The largest collection was made at Site 2, with large numbers of bluegill and green sunfish. Site 3 was different

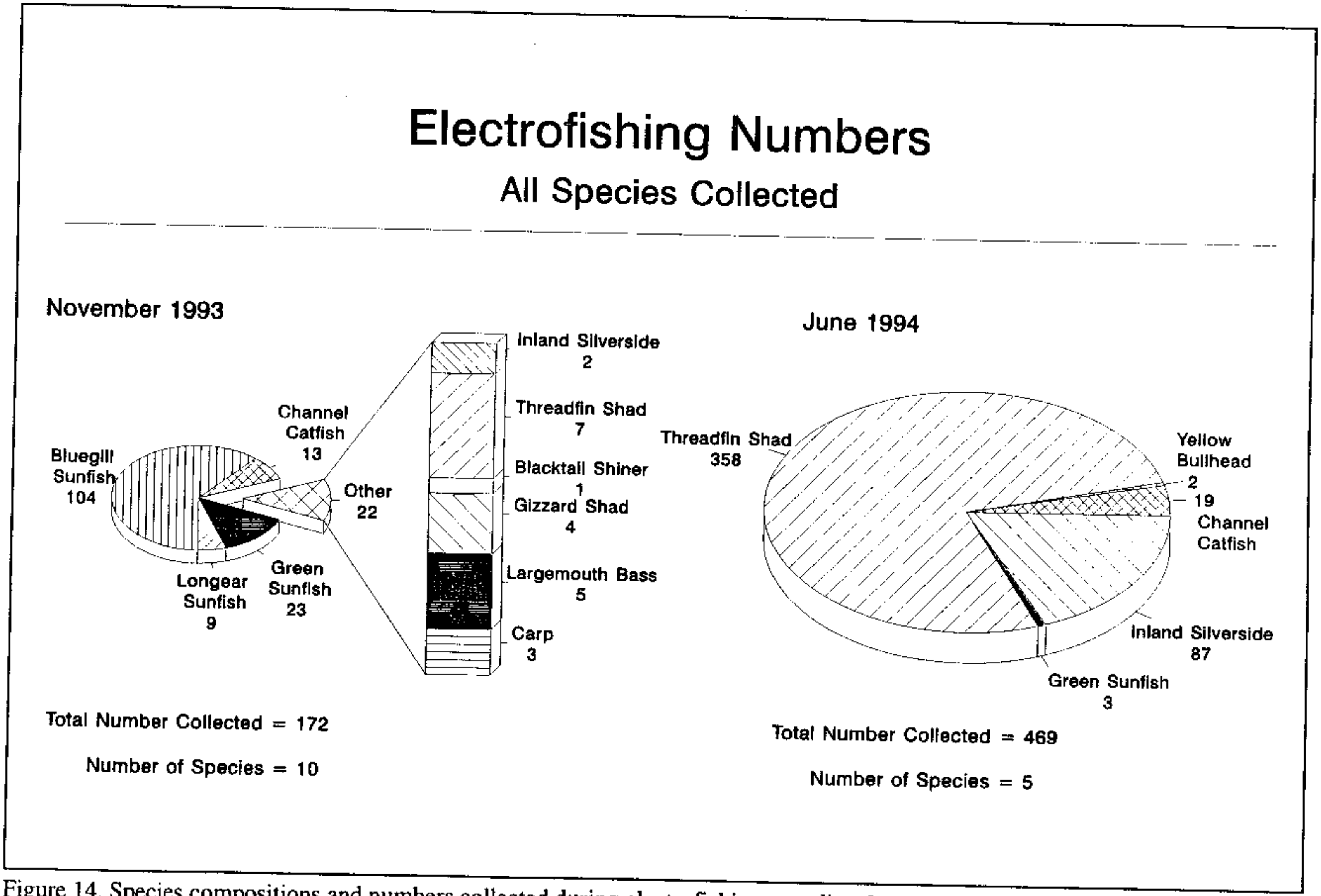


Figure 14. Species compositions and numbers collected during electrofishing sampling for each SCR fisheries survey.

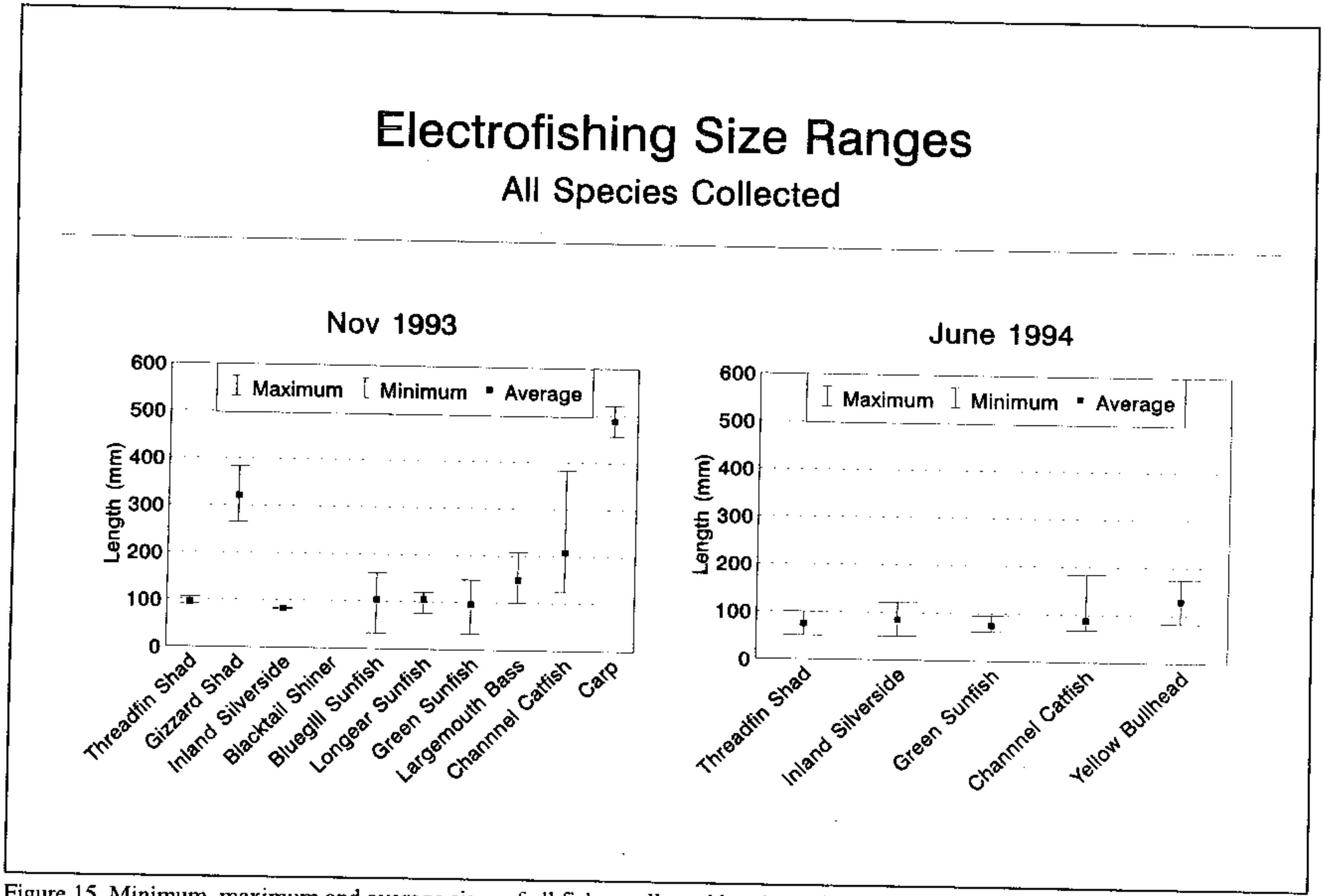


Figure 15. Minimum, maximum and average sizes of all fishes collected by electrofishing for both SCR fisheries surveys.

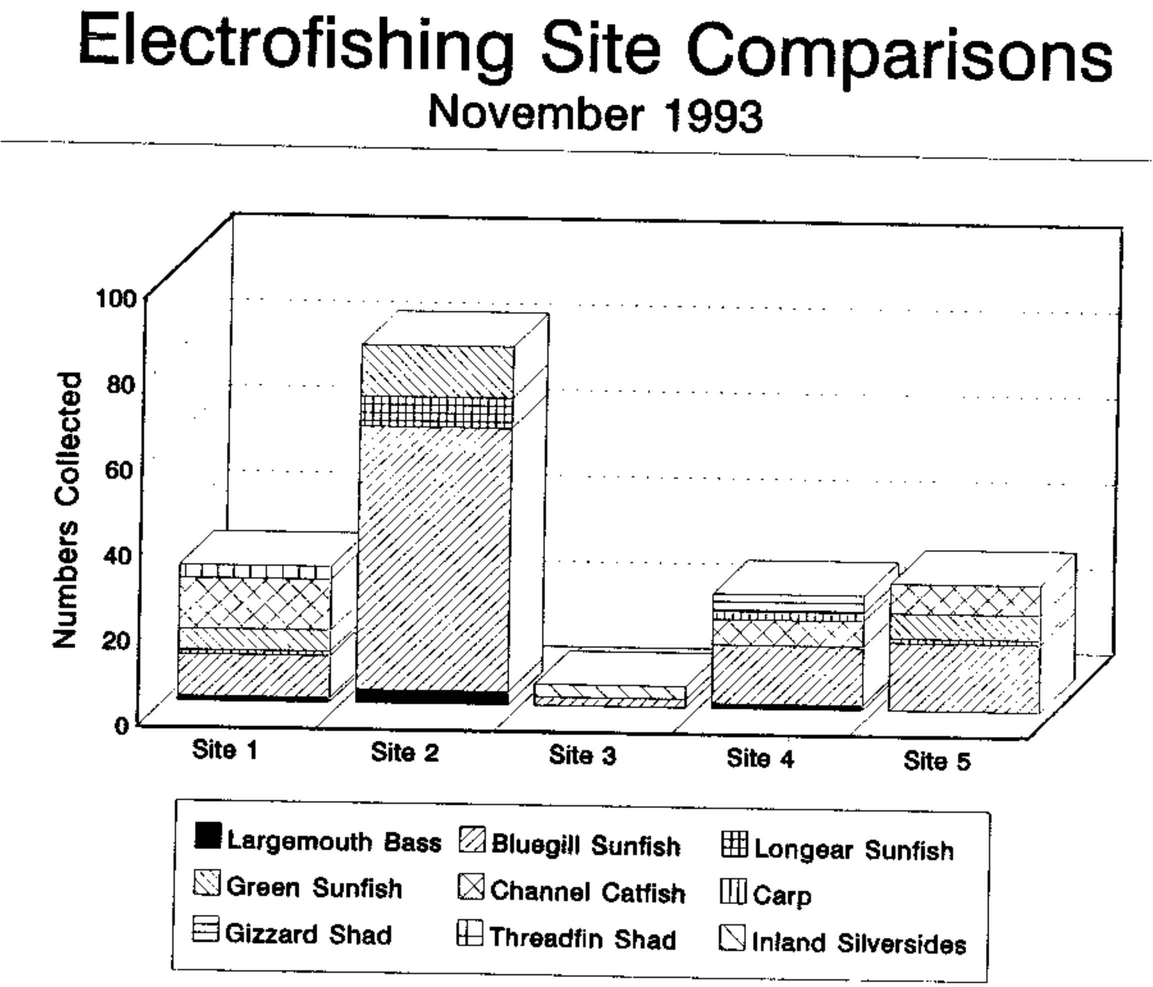


Figure 16. Species compositions at each sampling site for the November electrofishing.

from the rest with only inland silversides and bluegill sunfish collected, and much lower numbers. During the June period, species collected were similar between sites (Figure 17). Numbers varied, decreasing from site 1 to site 5. Threadfin shad were mostly responsible for this trend with about 200 collected at site 1, about 50 at sites 2, 3, and 4, and almost none at site 5.

Gill net sampling collected a total of 367 fish of 12 species with a total biomass of 231 kg (Figure 18). The two sampling periods were very similar in species composition with all but one species collected during both periods. Numbers were higher for the first period by about 50 fish. The numbers collected for each period were almost equal for more than half of the species, while catches of largemouth bass, white bass, white crappie, and carp were 2 to 5 times higher during the first period. The smallmouth bass was the only species with considerably higher catch rates during the second period.

This sampling technique was effective for the collection of adult size fish. Maximum, minimum, and average lengths of species collected for each period are shown in Figure 19. The average lengths of each species were very similar for both collection periods, while size ranges varied according to differences in numbers collected in each period.

During the November period, species compositions were very similar for each site (Figure 20). The numbers collected varied by less than 10 for sites 1, 2, 4, and 5. Site 3 had less than half of the numbers collected for the other sites. During the June period, species compositions varied more, as did the numbers collected (Figure 21). Site 5 had the highest numbers, while site 3 had very low numbers and only 2 species.Largemouth

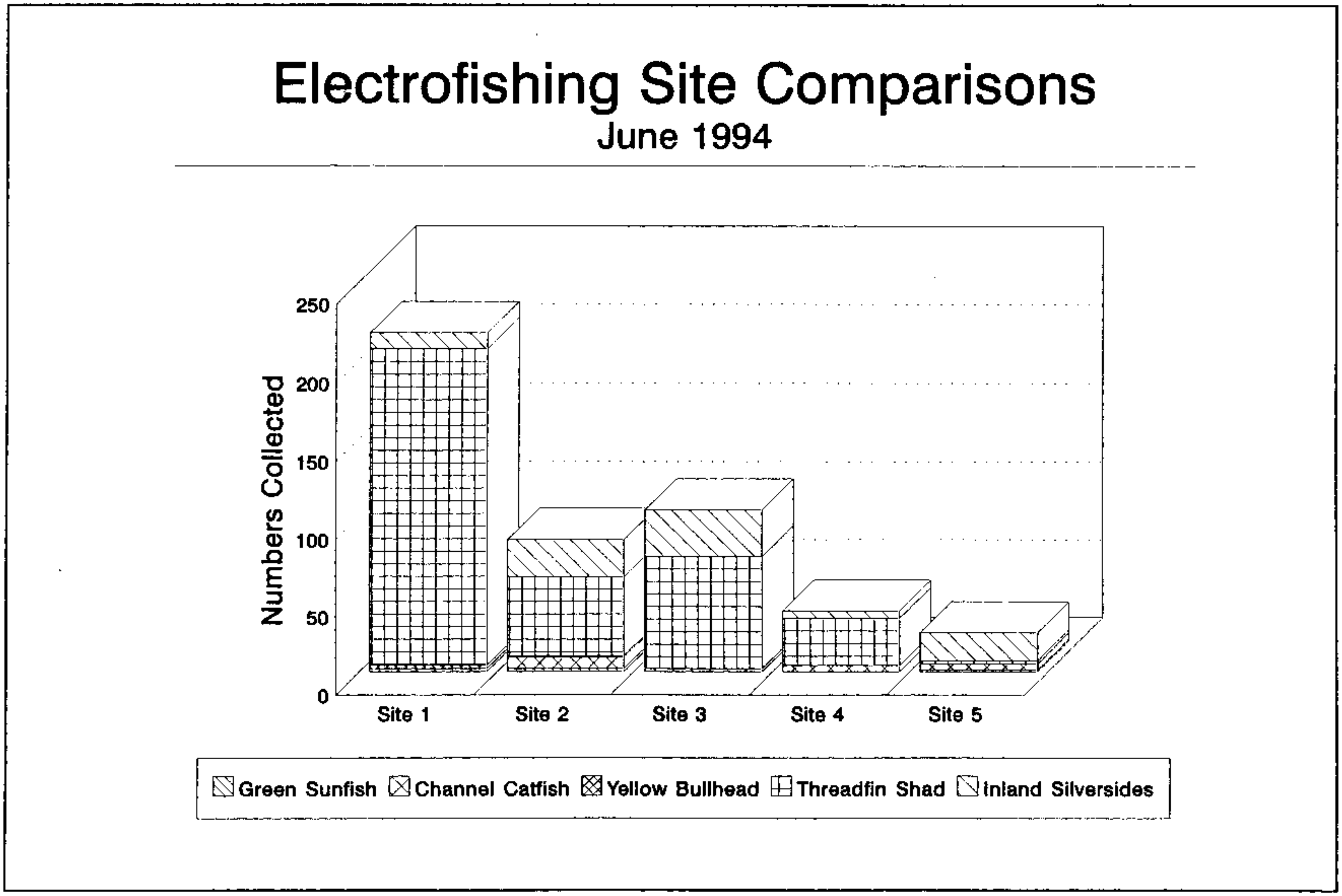


Figure 17. Species compositions at each sampling site for electrofishing samples collected during the June SCR fisheries survey.

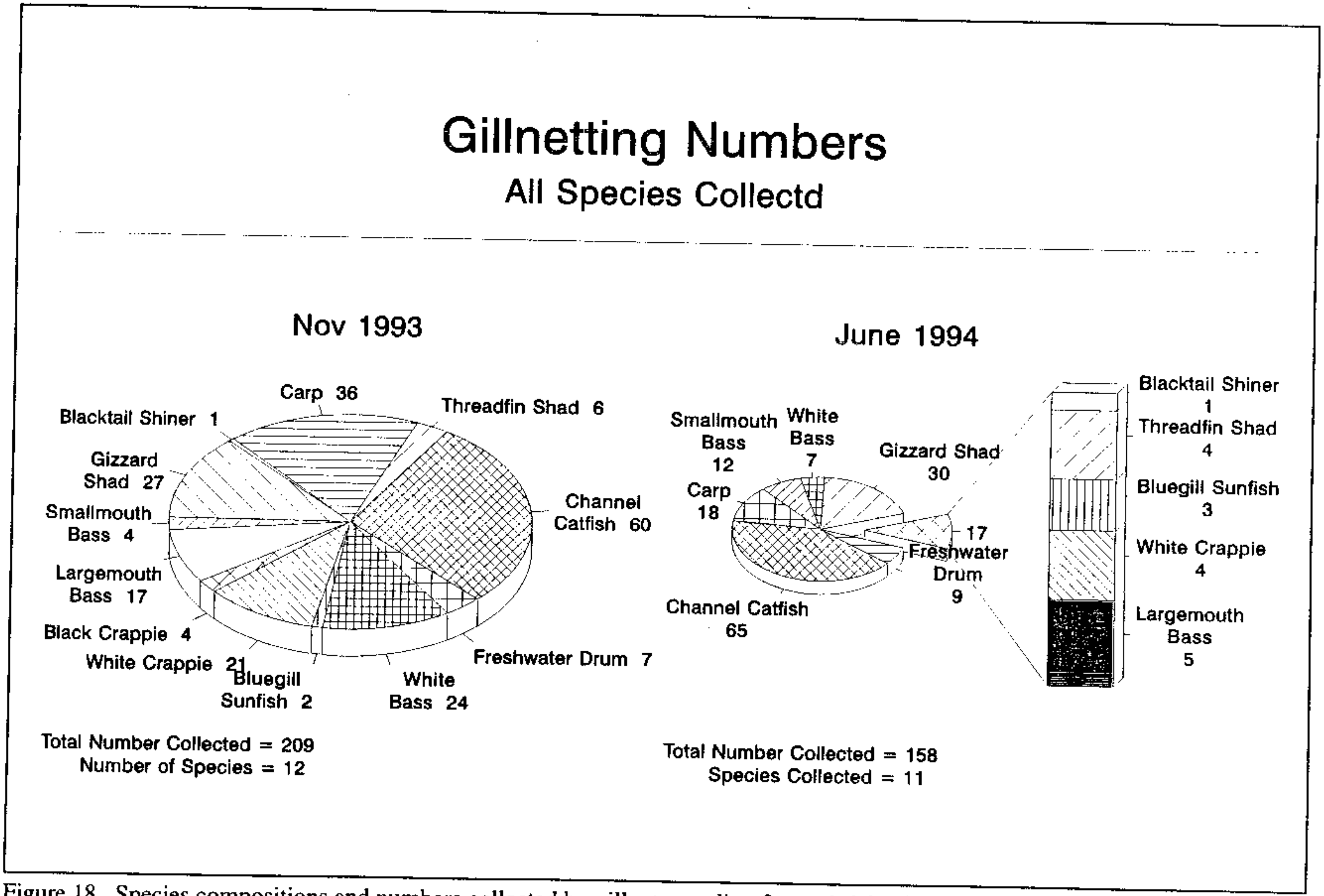


Figure 18. Species compositions and numbers collected by gillnet sampling for each SCR fisheries survey.

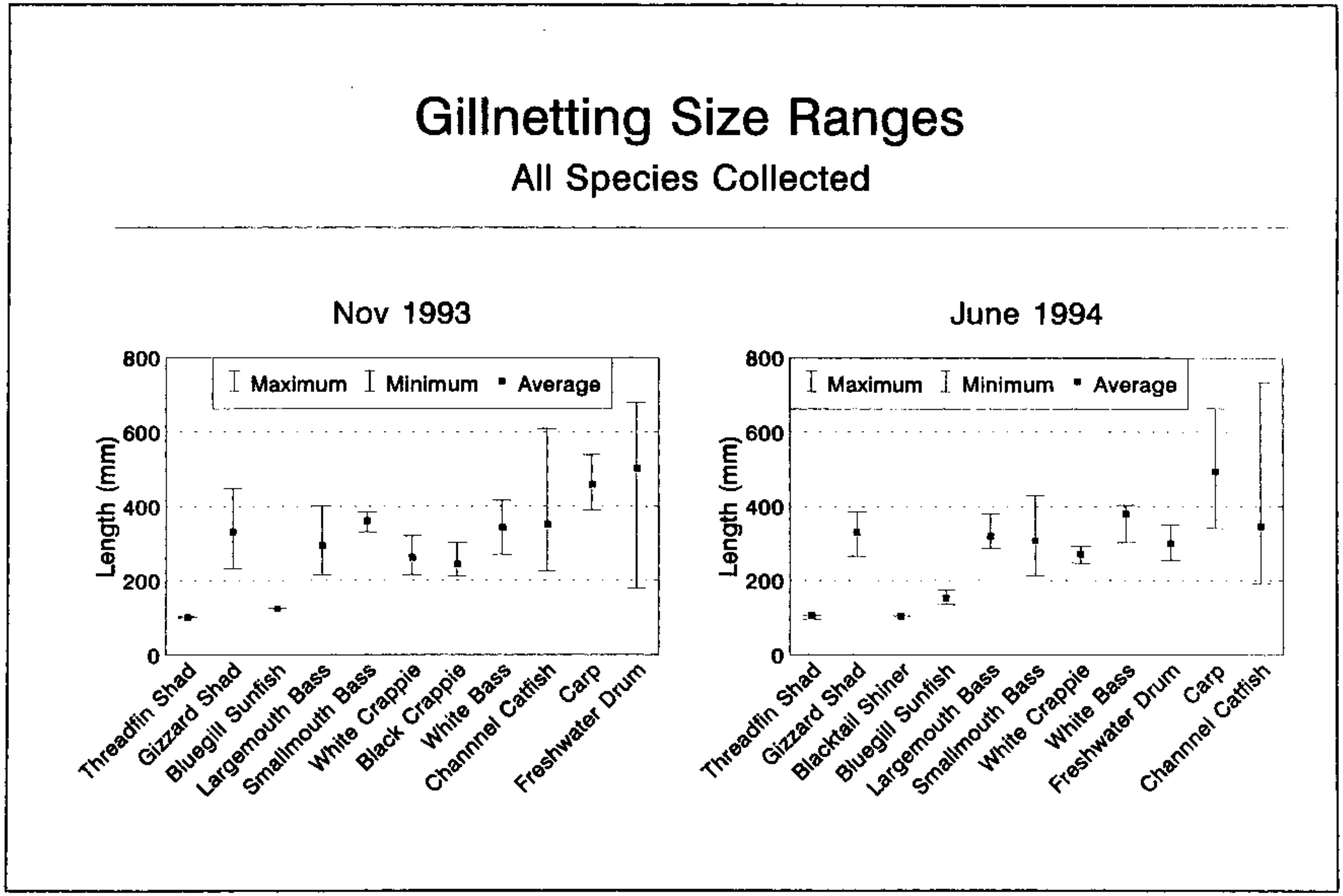


Figure 19. Minimum, maximum, and average sizes of all fishes collected by gillnet sampling for each SCR fisheries survey.

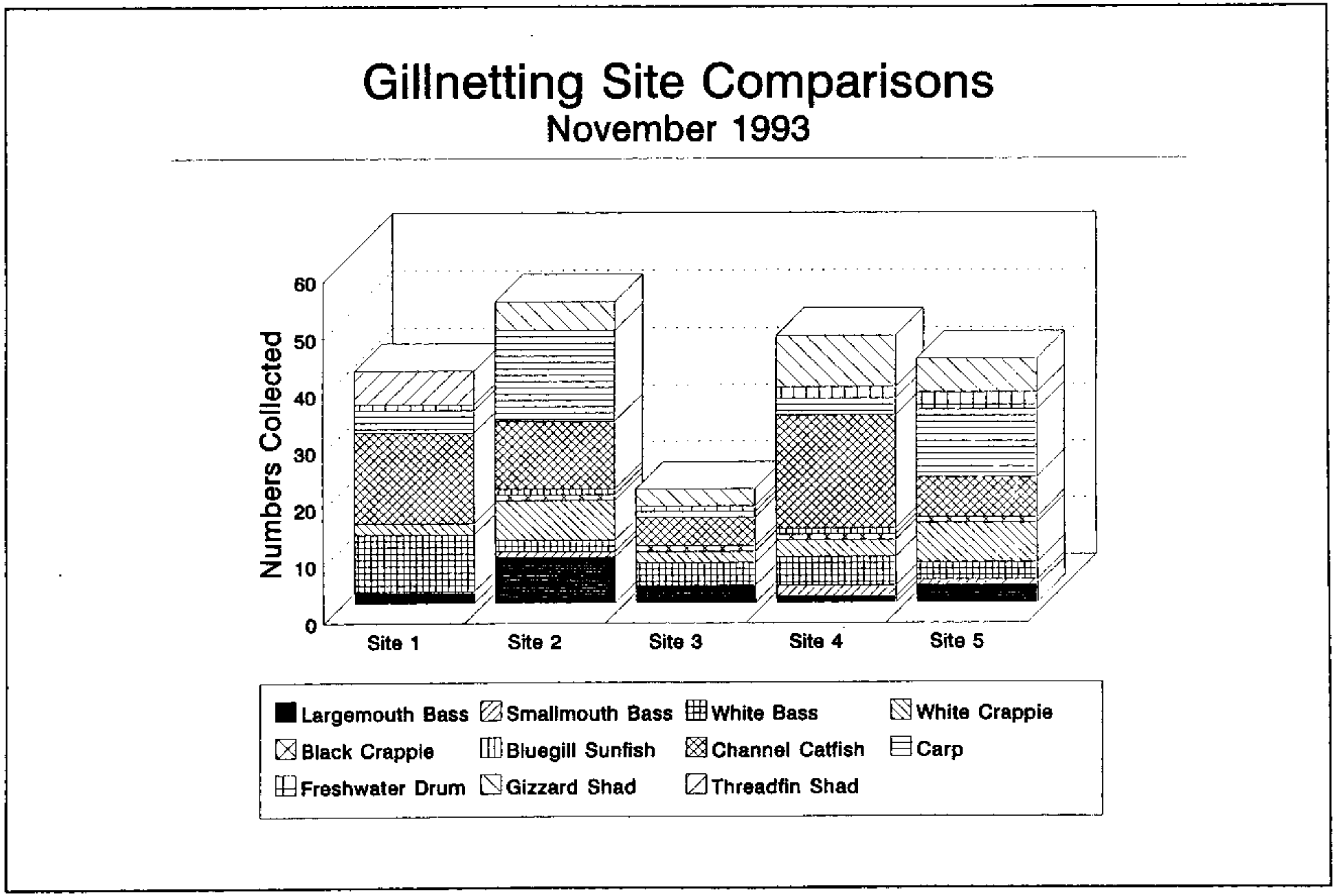


Figure 20. Species compositions at each sampling site for gillnet sampling during the November SCR fisheries survey.

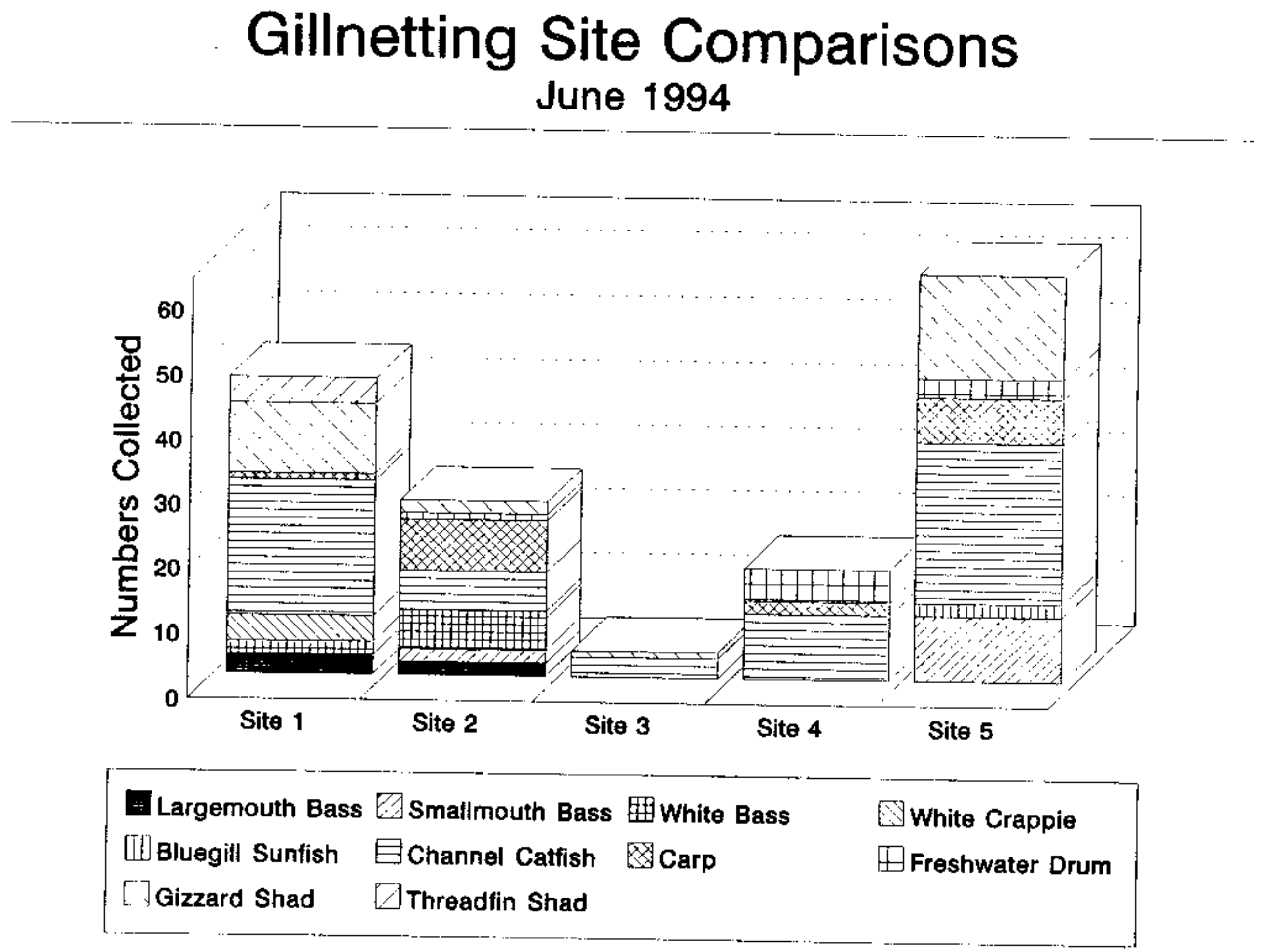


Figure 21. Species compositions at each sampling site for gillnet sampling during the June SCR fisheries survey.

bass, white bass, and white crappie were collected only at sites 1 and 2, while a large number of smallmouth bass were collected at site 5.

Discussion

The physical characteristics of SCR hamper the collection of fish for population surveys. The steep shorelines are not conducive to seining, and the conductivity of the water is too high for effective electrofishing. The lack of seine sampling and the limited success of electrofishing restricted the analysis of the young and small fish populations of SCR. Adult populations of the larger species were successfully sampled by gillnetting.

Electrofishing is typically a successful collection technique for sampling large and small fish to depths of 3 m. The conditions at SCR, however, limited our electrofishing success, with most collections made in shallow (< 1 m), near-shore water. It should be noted that in November many sunfish were seen in the shallows fleeing the boat, and in June large schools of shad were seen throughout the lake.

Gillnetting was, for the most part, successful in sampling the adult populations of SCR's larger species. When analyzing the sampling data, it should be noted that this is a passive capture technique, and fish which are more mobile are more likely to be collected. Also, gill nets are set on the bottom of the reservoir leading to bias toward bottom oriented fish.

The sample collections included 16 species of fish compared to 26 species collected in the 1986 lake survey. Part of the reason for this difference is that there was 4 sampling periods in the previous survey, and there was an extra sampling technique, seining, which accounted for 4 species of forage-type fish which were not collected by gillnetting or electrofishing during that study. Two species of sport fish for which sizable populations were reported in 1986 were missing from the recent collections. These were the walleye (*Stizostedion vitreum*) and the hybrid striped bass (*Morone chrysops* x *M. saxatilis*). Their disappearance is probably not intake related and will be discussed individually later. The black bullhead (*Ameiurus melas*) was collected in large numbers in 1986, mainly by gillnetting, but it was totally absent from the samples of this survey. The black crappie and the blacktail shiner were the only species present (in very low numbers) in this survey and not recorded in the 1986 survey.

Differences in the numbers and species collected between the November and June sampling periods was negligible for the gillnetting samples, but substantial for the electrofishing samples. One factor may be water temperature which was about 18°C in November and about 30° in June. In the deeper water where gill nets were placed, the higher temperatures in June apparently did not affect species composition, but may have been responsible for the lower catch rates by reducing fish movement. The higher temperatures appeared to affect the species composition of the shallow waters where the electrofishing collections were made. Sunfish apparently moved to deeper habitats when the water temperatures rose because they were abundant in the November samples, but almost totally absent in the June samples. Shad were much more abundant in the June sample collections, and large schools were seen near the surface throughout the reservoir. Part of the reason for their abundance at this time is the new crop of y-o-y individuals which by November would be reduced by predation. Another reason more threadfins were collected in June may have been differences in their schooling depths, from near surface in June to deeper waters in November.

Sample collections for each site show there is some variation in species and numbers of fish at different parts of the reservoir. The most notable aspect of site comparisons is that collections at site 3, which was closest to the intake, were consistently much lower than those at the other sites. The reason for this is most likely due to inadequate fish habitat. The gillnetting site sloped steeply from the shoreline into deep water, lacking adequate shallow areas to attracted forage fish. The electrofishing site sloped gently from the shoreline to deeper water, but it lacked structure and quick access to deep water.

The lake survey data provide information for analyzing parameters of SCR fish populations, such as size structure, number present, and general condition. Analysis' of population size structure and number are made with consideration of the potential bias of sampling methods, as discussed above. The data collected can not be used to estimate population numbers, but they should give good indications of the populations robustness and stability. The following is an assessment of the populaitons of the prominant species of SCR.

Major Predator Species

Largemouth bass Largemouth bass are a major predator and sport species in the reservoir. The 1986 study reported a decline in catch per unit effort since 1981. This study, however, recorded higher gillnetting collection rates than in 1986. The stocking of over 160,000 Florida strain largemouths in 1990, may have reversed the trend. Catches of juvenile bass by electrofishing and in the impingement samples indicated reproduction is occurring.

Smallmouth bass A total of 209,830 smallmouth bass were stocked in 1979, 1980, and 1982. The 1986 study reported low numbers and marginal reproduction. This study recorded much higher collection rates, nearly as high as the largemouth bass. Although no juveniles were collected, reproduction must occur since there have been no stockings since 1982. Their strong presence is surprising since smallmouths prefer cool water habitats (Emig 1966). Genetic analysis in the 1986 study revealed some smallmouth x largemouth hybrids, but these hybrids would be sterile and could not account for their continued presence. In Hellier (1977), the report by Johnson and Hale (1977) that walleye are capable of out competing smallmouth bass was given as a possible reason the SCR smallmouth bass was low. Thus, the increase in the SCR smallmouth population since the 1986 survey may be due to the loss of the walleye population

Hybrid striped bass Nearly 300,000 hybrid striped bass were stocked in 1979, 1981, and 1983. In the 1986 study, many of these fish were collected and they were considered a major predator and designated a key piscivore. However, reservoir management changed and stocking was discontinued. None were collected during the 1993 and 1994 surveys. Without reproductive capabilities, these fish have disappeared due to natural attrition and fishing pressure.

White bass White bass stockings in SCR have not been reported, but they currently have a strong presence. Collection rates for this study were much higher than in 1986. Their numbers were apparently held in check by the hybrid striped bass population, and, as the hybrids declined, the white bass filled the niche.

White Crappie Catches of white crappie were much higher than in 1986 when they were not even considered a major predator species for SCR. Condition factors were slightly higher than the 1986 study, and presence of all size classes indicate a robust population.

Channel Catfish About 17,000 channel catfish were stocked in 1986. The 1986 study reported that their populations were becoming increasingly successful. The collection rate for this study was much higher than the 1986 study. Condition factors were lower than those recorded in 1986, but size classes were robust. The presence of large numbers of y-o-y fish indicate good reproductive success.

Walleye Over 4 million walleye were stocked in 1979, and the 1986 survey reported a healthy, reproducing population. In the 1986 survey it was speculated that power plant operation might threaten this species since water temperatures might exceed their thermal tolerance limits. It seems that this prediction was correct since the walleye's thermal tolerance limit of about 32° (Goodson 1966) is exceeded by several degrees in the summer, and no walleye were collected in this survey or have been reported caught by fishermen in recent years (personal communication with SCR park manager Bill Phillips).

Major Forage Species

Threadfin Shad The fact that threadfin shad were collected in large numbers in spite of poor conditions for electrofishing is testimony to their abundance in SCR. These fish were seen in very large schools during the night-time electrofishing in June. The 1986 survey reported only a few threadfins. This species has probably benefited from thermal enrichment by the CPSES which has increased phytoplankton production upon which these fish feed. Threadfins are an effective prey species, and their abundance has no doubt benefited the SCR fishery.

Bluegill sunfish Bluegill sunfish were collected in large numbers, but were seen in even greater numbers fleeing the boat and dodging our nets. They were collected in both large and small sizes which is a good indication of a stable fishery. Too many small blue gills would indicate stunting due to lack of predation, and too many large ones would indicate over predation and a declining fishery.

Gizzard Shad Gizzard shad are an excellent forage fish for predators when small, but they can grow too large to serve as prey. The results of this survey show there is large population of adult size gizzard shad, but there were no small ones collected. However, some small gizzard shad were collected in impingement samples, so the large fish are contributing the production of forage for the predators.

Inland Silversides Inland silversides were considered to be the primary prey species in the 1986 survey, but the results for this survey indicate they may have been replaced in prominence by the threadfin shad. They were collected and seen in good numbers, and their size range indicates reproductive success.

CHAPTER IV

IMPACT ASSESSMENT

The operation of the CPSES intake structures can cause significant negative impact to SCR fish populations if losses due to impingement and entrainment decrease population numbers and/or stability. To determine if SCR fish populations have been adversely affected, impingement and entrainment estimates for each species are evaluated according to the species' ability to compensate for it's losses. Compensatory ability is dependant upon the number lost, the life stage at which loss occurs, the species' fecundity and the strength of the species presence in SCR. Impact is further assessed by evaluation of SCR population trends since the 1986 lake survey (Heiler 1987). Below are discussions of selected species and their potential to be adversly affected by the CPSES cooling water intake.

Selected Species

Threadfin shad This was the primary species of fish impinged with losses estimated to be 251,269. Entrainment losses were estimated to be about 7 million larvae for the *Dorosoma* genus. The prolific gizzard shad may have accounted for a large percentage these larvae. The Horst population model estimated the equivalent adult loss to be about 150,000. These losses are substantial, but there are several factors which lead to a conclusion of no significant impact. These fish are a forage species which have low survival rates even as adults, and they are adapted to compensating for enormous losses to maintain their populations (Burns 1966). These fish are very abundant in SCR. The total number collected in the lake surveys was 375 despite the fact none of the collection methods were condusive to their capture. Large schools were observed at the lakes surface during night sampling, and directly in front of the intake during impingement and entrainment sampling. Lastly,it appears their population has increased when compared to the results of the 1986 lake survey when very few were captured.

Bluegill sunfish These fish were the second most common species impinged with an estimated total of 4,921. Some adult sized individuals were collected, but most were a juvenile size with the average less than 100 mm. The total estimated entrainment for the Lepomis genus was just over 10 million larvae. When the model was applied, all the Lepomis larvae and the 4.4 million larvae identified at Centrarchidae were assumed to be the bluegill species. The equivalent adult fish loss was 409. The impact of these losses was not considered significant for reasons similar to those for threadfin shad. Bluegill sunfish are forage for top-end predators, and are adapted to compensating for large population losses. Most impingements were of juvenile fish which is of less consequence than the loss of adult individuals capable of spawning. Also, bluegills are present in great numbers in SCR. Many of adult size were seen in front of the inake during screen washes.

Largemouth bass This was the only top-end predator species that was impinged in significant numbers. Total estimated impingement was 805. None over 120 mm in length were impiinged, which means losses were limited to juvenile fish. *Micropterus* larvae were not collected in entrainment samples, but if the estimated 4.4 million larvae identified as centrarchidae were all largemouth bass, the total adult loss model would give an estimate of 22. The lake survey indicates this species is present in substantial numbers, and catch rates were higher than they were in the 1986 lake survey. These results indicate the intake structure has no significant upon the largemouth bass population.

Interaction of the Intake and the Fish Community

Observations of the fish community around the intake structure itself offers further insight into it's impact upon SCR. Fish are attracted to the outflow of the screen wash which pours into an area directly adjacent to the intake screens. The 2" mesh of the sump basket allows small fish to pass through during the screen wash attracting large schools of fish during the summer months when impingements are high. Channel catfish and bluegill sunfish were seen in particular abundace. This observation and the pressence of few large fish in the impingement samples indicates that cooling water intake poses little threat to the larger-sized fish community. Also, passage of impinged fish through the sump basket and out the outflow returns biomass to the system, lowering the net energy loss.

CONCLUSION

This project was designed to assess impact of CPSES cooling water intake upon the SCR fish population through analysis of fish impingement and entrainment, and a fisheries survey of SCR. Two hypothesis were tested: 1) Numbers of fishes impinged is dependant upon water temperature; and 2) Densities of ichthyoplankton are not significantly different between depths.

The loss of fishes due to impingement was estimated to be 262,994 of 14 species over the period of a year. This is much lower than many impingement studies. Threadfin shad comprised 96% of this total. Impingement appeared to be size selective with most of the fish collected measuring less than 120 mm. This means loss for most species is limited to fish of a juvenile age class. The highest rates of impingement occurred during the summer, with 92% taking place between July 27 and September 7. Impingement and water temperature had a moderate logarithmic relationship (Linear regression, $r^2 = 0.63$). The fish were probably exhibiting a threshold tolerance to increases in water temperature.

The entrainment of eggs, larvae and juveniles was estimated to be 29.6 million, 42.5 million, and 1.3 million, respectively, of 6 genera over a five month period. These numbers are similar to those recorded in other entrainment studies. The highest losses were recorded for sunfish and freshwater drum at about 10 million each. Genera compositions of entrainment collections had distinct trends which corresponded with each genera's spawning period. Differences in ichthyoplankton densities between depths was found to be significant for 2 out of 11 sampling periods (Kruskal Wallis one-way, multiple sample test, p=0.05). Thus, it was assumed densities were uniform across all depths.

A total of 1006 fish of 16 species was collected during the fisheries surveys. There appeared to be a good balance of forage species, insectivores, and piscivores. The collection rates of almost all species were higher than those recorded in a 1986 survey. Fishes of all species collected showed indications of good health: plumpness, good coloration, and lack of external parasites and abnormalities. Reproductive success is evident for all species collected. The primary forage species is probably threadfin shad for which numbers have increased since the 1986 survey. The primary top-end predator species are channel catfish, white bass and largemouth bass. The disappearance of walleye and hybrid striped bass is attributed to thermal intolerance and the lack of recent stockings respectively, and is not intake related.

The overall conclusion of this thesis is that losses due to impingement and entrainment at the CPSES intake structure are not sufficient to cause adverse impact to the fish community in SCR. There are several basis for this conclusion. The number of fishes lost were much lower than those estimated for many studies similar to this one. The species which accounted for most of the losses occur low on the food chain, and are thus adapted to compensating for large losses to their population. The small size of most fish lost indicates many were in a juvenile size class, the loss of which is less significant than the loss of reproductive size fish. Lastly, the fish populations of SCR appeared to be balanced and stable, or increasing in comparison to the previous fishery survey, and most fish exhibited indications of good health.

It is recommended that future studies have an impingement sampling scheme in which sampling frequency increases during the summer because fish impingement rates are highest at this time.

APPENDIX

Table 2. The number of fishes collected in each impingement sample for the entire study.

Date	18-19		25-26		01-02		08-09		15-16		22-23		29-30		08-09		15-16		05-06	
	Oct		Oct		Nov		Nov		Nov		Nov		Nov		Dec		Dec		Jan	
Species	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Dorosoma petenense	2	1	10	3	11	2	2	4	13	5	15	1	12	-	40	15	25	1	51	27
Dorosoma cepedianum	3	-	3	-	1	-	-	1	-	-	-	-	1	-	2	2	3	-	-	-
Menidia beryllina	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Notropis atherinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis macrochirus	1	1	3	2	10	-	-	-	2	2	1	-	3	3	4	-	3	1	10	3
Lepomis cyanellus	1	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Lepomis megalotis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis microlophus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis gulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropterus salmoides	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Pomoxis annularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Morone chrysops	-	1	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Ictalurus punctatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aplodinotus grunniens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12-hr Total	7	3	17	8	24	3	2	5	17	7	17	1	16	3	46	18	31	2	62	30
24-hr Total		10		25		27		7		24		18		19		64		33		92
Biomass Total		214		598		164		437		658		75		59		298		111		363

N = Night, D = Day

Table 2. The number of fishes collected in each impingement sample for the entire study.

Date	13-14		19-20		26-27		01-02		08-09		15-16		22-23		01-02		08-09		15-16	
	Jan		Jan		Jan		Feb		Feb		Feb		Feb		Mar		Mar		Mar	
Species	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Dorosoma petenense	7	3	14	1	1	1	1	-	4	-	3	2	3	1	4	-	2	1	5	3
Dorosoma cepedianum	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	1	-	-	2	1
Notropis atherinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Lepomis macrochirus	1	2	4	1	5	1	6	-	6	-	-	2	9	2	3	-	1	-	4	-
Lepomis cyanellus	-	-	-	-	-	-	-	-	-	-	1	-	1	1	1	-	1	-	-	-
Lepomis megalotis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis microlophus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis gulosus	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropterus salmoides	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Pomoxis annularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Morone chrysops	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Ictalurus punctatus	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Aplodinotus grunniens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
12-hr Total	9	5	19	2	7	2	8	0	10	0	6	4	15	5	12	1	5	2	11	7
24-hr Total		14		21		9		8		10		10		20		13		7		18
Biomass Total		238		84		437		95		124		76		229		612		629		317

N = Night, D = Day

Table 2. The number of fishes collected in each impingement sample for the entire study.

Date	22-23 Mar		29-30 Mar		05-06 Apr		19-20 Apr		03-04 May		17-18 May		31-01 Jun		14-15 Jun		28-29 Jun		12-13 Jul	
Species	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Dorosoma petenense	4	1	1	-	1	-	22	22	17	1	77	10	12	4	13	5	42	4	199	50
Dorosoma cepedianum	-	-	1	1	-	1	-	3	7	4	1	2	2	3	-	-	-	-	-	-
Menidia beryllina	-	-	-	-	3	-	-	-	1	-	3	-	4	5	3	3	6	-	4	1
Notropis atherinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis macrochirus	4	1	7	3	47	2	3	2	-	1	5	3	16	10	4	5	21	2	14	5
Lepomis cyanellus	3	-	2	-	1	-	2	-	1	-	7	-	7	3	-	-	1	-	-	-
Lepomis megalotis	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Lepomis microlophus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis gulosus	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
Micropterus salmoides	-	-	-	-	-	-	-	-	-	-	7	2	13	2	2	2	2	1	3	-
Pomoxis annularis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Morone chrysops	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Ictalurus punctatus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1
Aplodinotus grunniens	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	-	-	1
12-hr Total	11	2	12	4	55	3	27	28	26	6	102	18	54	27	23	17	74	7	221	58
24-hr Total		13		16		58		55		32		120		81		40		81		279
Biomass Total		89		673		446		1263		1563		2048		1821		623		468		1026

N = Night, D = Day

Table 2. The number of fishes collected in each impingement sample for the entire study.

Date	27-28		09-10		23-24		30-31		06-07		13-14		20-21		27-28		04-05	
	Jul		Aug		Aug		Aug		Sep		Sep		Sep		Sep		Oct	
Species	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Dorosoma petenense	2667	6261	5100	1200	442	147	2728	437	155	1050	108	40	78	37	65	8	28	65
Dorosoma cepedianum	-	-	1	-	21	2	4	-	4	1	1	2	2	1	5	-	-	1
Menidia beryllina	120	36	10	10	-	2	4	-	10	1	12	6	-	-	-	-	-	-
Notropis atherinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis macrochirus	40	12	11	6	5	-	6	3	9	11	10	5	21	7	30	4	17	14
Lepomis cyanellus	24	1	10	3	12	-	1	3	2	8	-	-	4	4	3	-	2	2
Lepomis megalotis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Lepomis microlophus	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis gulosus	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropterus salmoides	8	6	3	4	2	-	-	-	-	-	1	-	-	-	-	-	-	-
Pomoxis annularis	-	-	2	-	2	-	-	-	-	-		-	-	-	-	-	-	-
Morone chrysops	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Ictalurus punctatus	-	6	1	-	-	-	-	-	-	-	1	-	1	1	1	-	-	1
Aplodinotus grunniens	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
12-hr Total	2859	6330	5138	1229	484	151	2743	443	180	1071	134	53	107	50	104	12	48	83
24-hr Total		9189		6367		635		3186		1251		187		157		116		131
Biomass Total		17986		7627		1310		3616		2308		1111		1234		508		751

N = Night, D = Day

Table 2. The number of fishes collected in each impingement sample for the entire study.

Date	11-12 Oct			Percent		Percent	
Species	N	D	Total Collected	of Total	Total Biomass	of Total	Average Weight
Dorosoma petenense	7	1	21405	95.20%	30205	56.94%	1.4
Dorosoma cepedianum	-	-	89	0.40%	4937	9.31%	55.5
Menidia beryllina	-	-	257	1.14%	449	0.85%	1.7
Notropis atherinoides	-	-	3	0.01%	7	0.01%	2.3
Lepomis macrochirus	22	10	494	2.20%	9191	17.33%	18.6
Lepomis cyanellus	1	1	118	0.52%	1262	2.38%	10.7
Lepomis megalotis	-	-	3	0.01%	104	0.20%	34.7
Lepomis microlophus	-	-	6	0.03%	348	0.66%	58.0
Lepomis gulosus	-	-	12	0.05%	183	0.34%	15.3
Micropterus salmoides	-	-	60	0.27%	200	0.38%	3.3
Pomoxis annularis	-	-	5	0.02%	903	1.70%	180.6
Morone chrysops	-	-	8	0.04%	3130	5.90%	391.3
Ictalurus punctatus	-	-	18	0.08%	541	1.02%	30.1
Aplodinotus grunniens	-	-	7	0.03%	1589	3.00%	227.0
12-hr Total	30	12	22485		53049		
24-hr Total		42					
Biomass Total		258					

N = Night, D = Day

Table 3. Water conditions and air temperature for each impingement sampling event.

Date	Sample #	Water Temperature Morn*	Water Temperature Eve*	Conductivity	Dissolved Oxygen Morn	Dissolved Oxygen Eve	Air Temperature Morn	Air Temperature Eve
10/19	1	26	27	2100	7.7	8.2	22	24
10/26	2	23	25	2000	8.0	9.3	13	22
11/02	3	19		1800	8.1		14	13
11/09	4	20	19	1800	8.5	8.6	9	13
11/16	5	18	19	1900	8.2	8.9	9	12
11/23	6	17	19	1800	8.8	8.5	7	21
11/30	7	15	16	1700	7.6	7.8	6	18
12/09	8	18	18	1800	9.0	9.5	19	22
12/16	9	16	16	1900	8.2	8.2	4	9
1/06	10	18	18	1750	9.4	9.4	10	10
1/13	11	19	20	1800	8.8	9.6	8	16
1/20	12	18	17	1800	8.7	9.4	5	9
1/27	13	20	18	1800	9.0	9.4	8	10
2/2	14	18	18	1800	9.6	9.8	-1	8
2/9	15						-7	-8
2/16	16	19	20	1800	9.8	10.6	8	17
2/23	17	18	19	1600	9.0	9.8	3	11
3/2	18	18	19	1700	8.8	10.0	3	17
3/9	19	19	19	1750	9.0	9.4	2	8
3/16	20	20	21	1800	9.2	10.1	9	22
3/23	21	23	24	2000	9.0	10.3	17	24
3/30	22	20	22	1900	8.6	9.2	7	18
4/6	23	20	22	1900	8.4		13	16
4/20	24	26	26	2150	5.5	10.2	21	22
5/4	25	24	25	1950	7.4	11.8	18	26
5/18	26						17	27
6/1	27	29	29	2250	8.4	9.4	24	80
6/15	28	30	30	2300	8.2	8.0	23	27
6/29	29	32	35	2300	6.3	7.6	28	36
7/13	30	35	35				32	34
7/27	31	36	36				34	31
8/10	32	36	36	2600	7.8	8.4	34	34
8/24	33	34	34	2750	7.1	8.0	31	28
8/31	34	34	34	2750	6.8	7.6	30	30
9/07	35	34	33	2750	6.5	7.0	26	28
9/14	36	34	34	2600	6.6	7.2	27	28
9/21	37	33	34	2750	7.8	8.2	26	30
9/28	38	32	34	2650	7.0	8.4	23	34
10/5	39	32	32	2700	6.6	7.8	23	33
10/12	40	28	28	2500	7.0	7.8	11	21

* Morn = ~6:00 am, Eve = ~ 6:00 pm

Table 4. Densities of eggs, larave and juveniles of each genus collected during Unit 1 night sampling.

	Sample	Damaged		Dorosoma		Aplodinotus		Menidia		Lepomis	Centrarcl	Morone	Pomoxis		
Date	#	E	L	L	J	E	L	E	L	L	L	L	L	J	Sum
4/6/94	1N1			0.142					0.011						0.152
4/13/94	2N1	0.008		0.059				0.007							0.073
4/20/94	3N1														
4/27/94	4N1	0.221		0.006	0.006			0.006							0.241
5/4/94	5N1	0.007	0.037	0.022	0.007	0.051			0.007				0.007		0.139
5/11/94	6N1	0.020		0.018		0.017									0.055
5/18/94	7N1					0.064									0.064
5/25/94	8N1							Sampling cancled due to weather.							
6/1/94	9N1														
6/8/94	10N1														
6/15/94	11N1	0.093				0.038									0.131
6/22/94	12N1						0.074	0.008	0.008		0.131	0.008			0.229
6/29/94	13N1									0.013					0.013
7/6/94	14N1														
7/13/94	15N1										0.014		0.028		0.042
7/20/94	16N1														
7/27/94	17N1														
8/3/94	18N1						0.027				0.005		0.011		0.043
8/10/94	19N1									0.025		0.025	0.006		0.057
8/17/94	20N1		0.008							0.024			0.016	0.008	0.056
8/24/94	21N1									0.024		0.030			0.053

* E = Eggs/m3, L = Larvae/m3, and J = Juveniles/m3

Table 5. Densities of eggs, larave and juveniles of each genus collected during Unit 1 day sampling.

	Sample	Damaged		Dorosoma	Aplodinotus		Menidia		Lepomis		Centrarchidae	Morone	Pomoxis		
Date	#	E	L	L	E	L	E	L	L	J	L	L	L	J	Sum
4/6/94	1D1	0.009													0.009
4/13/94	2D1				0.012										0.012
4/20/94	3D1			0.020											0.020
4/27/94	4D1	0.018													0.018
5/4/94	5D1	0.006			0.005										0.012
5/11/94	6D1	0.009			0.007		0.013								0.029
5/18/94	7D1			0.010	0.040										0.050
5/25/94	8D1														
6/1/94	9D1														
6/8/94	10D1					0.007									0.007
6/15/94	11D1					0.012									0.012
6/22/94	12D1	0.006				0.006									0.011
6/29/94	13D1														
7/6/94	14D1								0.049						0.049
7/13/94	15D1								0.014				0.031		0.045
7/20/94	16D1														
7/27/94	17D1														
8/3/94	18D1					0.042			0.006						0.048
8/10/94	19D1								0.059			0.047	0.039		0.146
8/17/94	20D1								0.075	0.021		0.078	0.113		0.286
8/24/94	21D1	0.018	0.011						0.030			0.021	0.023		0.102

* E = Eggs/m3, L = Larvae/m3, and J = Juveniles/m3

Table 6. Densities of eggs, larave and juveniles of each genus collected during Unit 2 night sampling.

	Sample	Damaged		Dorosoma		Aplodinotus		Menidia		Lepomis	Centrarchidae	Morone	Pomoxis		
Date	#	E	L	L	J	E	L	E	L	L	L	L	L	J	Sum
4/6/94	1N2	0.009		0.045		0.009		0.009							0.071
4/13/94	2N2			0.038											0.038
4/20/94	3N2	0.007													0.007
4/27/94		No sampling, Unit 2 outage													
5/4/94															
5/11/94															
5/18/94															
5/25/94															
6/1/94															
6/8/94															
6/15/94															
6/22/94	12N2						0.006				0.049				0.055
6/29/94	13N2									0.006					0.006
7/6/94	14N2														
7/13/94	15N2														
7/20/94	16N2														
7/27/94	17N2														
8/3/94	18N2						0.021				0.013		0.026		0.060
8/10/94	19N2											0.006	0.007		0.013
8/17/94	20N2									0.030				0.008	0.039
8/24/94	21N2												0.007		0.007

* E = Eggs/m3, L = Larvae/m3, and J = Juveniles/m3

Table 7. Densities of eggs, larave and juveniles of each genus collected during Unit 2 day sampling.

	Sample	Damaged		Dorosoma		Aplodinotus		Menidia		Lepomis	Centrarchidae	Morone	Pomoxis		
Date	#	E	L	L	J	E	L	E	L	L	L	L	L	J	Sum
4/6/94	1D2	0.025				0.040									0.066
4/13/94	2D2	0.012		0.007											0.019
4/20/94	3D2			0.007				0.007							0.013
4/27/94								No sampling, Unit 2 Outage							
5/4/94															
5/11/94															
5/18/94															
5/25/94															
6/1/94															
6/8/94															
6/15/94															
6/22/94	12D2														
6/29/94	13D2														
7/6/94	14D2									0.006			0.012		0.019
7/13/94	15D2									0.006			0.015		0.020
7/20/94	16D2														
7/27/94	17D2														
8/3/94	18D2						0.026								0.026
8/10/94	19D2									0.087		0.041	0.027		0.155
8/17/94	20D2									0.018					0.018
8/24/94	21D2									0.014			0.014		0.029

* E = Eggs/m3, L = Larvae/m3, and J = Juveniles/m3

Table 8. Numbers and biomass of all species collected by gillnetting for SCR lake surveys.

		Nov 1993					June 1994				
Common Name	Scientific Name	Total Number	Number per 200 ft net	Total Weight (g)	Weight per 200 ft net	Mean Weight (g)	Total Number	Number per 200 ft net	Total Weight (g)	Weight per 200 ft net	Mean Weight (g)
Threadfin Shad	*Dorosoma petenense*	6	1	50	10	8	4	1	15	3	4
Gizzard Shad	*Dorosoma cepedianum*	27	5	9,800	1,960	363	30	6	8,750	1,750	292
Blacktail Shiner	*Notropis atherinoides*						1	0	6	1	6
Bluegill Sunfish	*Lepomis macrochirus*	2	0	20	4	10	3	1	100	20	33
Largemouth Bass	*Micropterus salmoides*	17	3	6,900	1,380	406	5	1	3,100	620	620
Smallmouth Bass	*Micropterus dolomieui*	4	1	3,500	700	875	12	2	4,400	880	367
White Crappie	*Pomoxis annularis*	21	4	6,400	1,280	305	4	1	1,100	220	275
Black Crappie	*Pomoxis nigromaculatus*	4	1	950	190	238					
White Bass	*Morone chrysops*	24	5	13,400	2,680	558	7	1	5,800	1,160	829
Channel Catfish	*Ictalurus punctatus*	60	12	32,100	6,420	535	65	13	34,700	6,940	534
Freshwater Drum	*Aplodinotus grunniens*	7	1	17,250	3,450	2,464	9	2	2,150	430	239
Carp	*Cyprinus carpio*	36	7	47,160	9,420	1,308	18	4	33,000	6,600	1,833
	Total	208	42	137,470	27,494		158	32	93,121	18,624	

Table 9. Numbers of all species collected by electrofishing for SCR lake surveys.

		Nov 1993		June 1994	
Common Name	**Scientific Name**	**Total Number**	**Number of Fish/15 min**	**Total Number**	**Number of Fish/15 min**
Threadfin Shad	***Dorosoma petenense***	**7**	**0.7**	**358**	**35.8**
Gizzard Shad	***Dorosoma cepedianum***	**4**	**0.4**		
Inland Silverside	***Menidia beryllina***	**2**	**0.2**	**87**	**8.7**
Blacktail Shiner	***Notropis atherinoides***	**1**	**0.1**		
Bluegill Sunfish	***Lepomis macrochirus***	**104**	**10.4**		
Green Sunfish	***Lepomis cyanellus***	**23**	**2.3**	**3**	**0.3**
Longear Sunfish	***Lepomis megalotis***	**9**	**0.9**		
Largemouth Bass	***Micropterus salmoides***	**5**	**0.5**		
Channel Catfish	***Ictalurus punctatus***	**13**	**1.3**	**19**	**1.9**
Yellow Bullhead	***Amerius natalis***			**2**	**0.2**
Carp	***Cyprinus carpio***	**3**	**0.3**		
	Total	171	17.1	469	46.9

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