the combined assessment of weight and frequency of occurrence. Diversity indices, as described by Mathur (1977), were calculated for each data set using all identifiable food categories. The fullness index was defined as the weight of stomach contents (mg) divided by the weight of that fish (g).

Three sampling anomalies should be noted. First, collections made during June, July, and August 1979 were accidentally discarded; therefore, new collections were made during those months in 1980. Second, bluegill collected in July and August 1980 were not taken from the area of Station 1, as no fish could be found there at that time. The collections were taken from areas near Station 1.5 (see Fig. 1.2, herein). Third, during January 1979, the ambient station was ice-covered and no collection could be made.

## RESULTS

### Food Composition and Contrasts Between Stations

Food habits of bluegills collected from heated and ambient areas of Coffeen Lake did not appear to be greatly dissimilar (Tables 8.1 and 8.2 and Appendix 8.1). Differences in gastropod and bryozoan untilization were most pronounced, the former being more predominant in stomachs of fish from heated areas and the latter more predominant at ambient sites. Chironomids and other aquatic insects appeared to be more prevalent in stomachs from the ambient location; the differences in utilization apparently reflected similar differences in abundance of those specific food resources (Section 7, herein). Another distinction between the two areas was the greater reliance of bluegill from the heated station on plant material and algae. Food items of nearly equal importance at both heated and ambient stations included: terrestrial arthropods, microcrustaceans, and fish eggs.

Diversity values were calculated to provide a qualitative assessment of feeding at heated and ambient locations (Table 8.3). Those values demonstrated that the diet of bluegills from the ambient station were consistently more diverse, only during October and November 1978 were diversity values higher at the heated station.

Table 8.1. Composition of the diet of 108 bluegills collected from the heated station of Coffeen Lake, October 1978-August 1980. Food items are listed in order of decreasing importance according to their index of signficance value. Mean total length was 126 mm, range 90-154 mm.

| Food item | Index of significance | Percent weight | Percent frequency of occurrence |
|---|---|---|---|
| Unidentified organic matter | 55.2 | 35.8 | 85 |
| Plant material | 33.8 | 16.3 | 70 |
| Terrestrial Arthropoda | 32.8 | 14.0 | 77 |
| Gastropoda | 16.8 | 13.5 | 21 |
| Inorganic matter | 13.0 | 5.3 | 32 |
| Algae | 12.3 | 6.6 | 23 |
| Chironomidae | 11.7 | 2.0 | 68 |
| Microcrustaceans | 7.6 | 1.1 | 52 |
| Other aquatic insects | 7.5 | 1.4 | 40 |
| Fish eggs | 6.3 | 2.5 | 16 |
| Fish scales | 2.6 | 0.3 | 22 |
| Bryozoa | 1.3 | 0.3 | 6 |
| Astacidae | 1.2 | 0.7 | 2 |
| Oligochaeta | 0.09 | 0.002 | 4 |
| | | 99.8 | |

Table 8.2. Composition of the diet of 110 bluegills collected from the ambient station of Coffeen Lake, October 1978-August 1980. Food items are listed in order of decreasing importance according to their index of signficance value. Mean total length was 126 mm, range 91-151 mm.

| Food item | Index of significance | Percent weight | Percent frequency of occurrence |
|---|---|---|---|
| Unidentified organic matter | 54.0 | 32.8 | 89 |
| Terrestrial Arthropoda | 34.7 | 18.8 | 64 |
| Plant material | 23.8 | 14.5 | 39 |
| Chironomidae | 19.6 | 5.2 | 74 |
| Other aquatic insects | 12.9 | 3.6 | 46 |
| Bryozoa | 12.1 | 9.1 | 16 |
| Fish eggs | 9.1 | 5.5 | 15 |
| Microcrustaceans | 7.1 | 1.0 | 51 |
| Algae | 6.4 | 4.5 | 9 |
| Fish scales | 4.7 | 1.5 | 15 |
| Gastropoda | 3.8 | 1.8 | 8 |
| Inorganic matter | 2.8 | 1.6 | 5 |
| Oligochaeta | -- | -- | -- |
| Astacidae | -- | -- | -- |
|  |  | 99.9 |  |

Table 8.3. Monthly diversity (D) of the diet values at heated and ambient stations in Coffeen Lake.

| Date | Diversity (D) Heated | Diversity (D) Ambient |
|---|---|---|
| Oct. 1978 | 1.99 | 1.46 |
| Nov. 1978 | 1.93 | 0.56 |
| Jan. 1979 | 1.18 | * |
| Mar. 1979 | 1.28 | 1.55 |
| May 1979 | 1.61 | 2.46 |
| Sept. 1979 | 1.78 | 1.84 |
| June 1980 | 1.23 | 2.08 |
| July 1980 | 2.27 | 2.77 |
| Aug. 1980 | 1.95 | 2.08 |

*no collection, ice covered

## Seasonal Variations in Diet

During November and January, utilization of terrestrial arthropods by bluegills was very low at both the heated and ambient stations; in the absence of that food resource the percent composition of microcrustaceans and plant material increased sharply (Fig. 8.1 and Appendix 8.1). In spring, (March and May) fish eggs became the principal food item at both the heated and ambient stations. Fish eggs appeared in the diet in March at the heated station but were not found until May at the ambient station. Bryozoa became a predominant food item beginning in May and became increasingly important throughout June and July at the ambient station (Appendix 8.1). During the summer months (June, July, August) temperatures at the heated station (Appendix 3.3, herein) often exceeded the upper avoidance temperature (33°C) of bluegill (Beitinger and Magnuson 1979). During this time gastropods became the predominant food item of bluegills from the heated station, but were much less important at the ambient station. Principal food items at the ambient station during the summer months were chironomids and bryozoans. During August, utilization of gastropods, chironomids and bryozoans all decreased sharply and were replaced by terrestrial arthropods and plant material at both stations (Appendix 8.1). In the autumn (September and October), the diet was similar to that found in August, as terrestrial arthropods and plant material were the predominant food items. However, gastropods and bryozoans were nearly absent from the diet during autumn.

## Feeding Intensity

Empty stomachs were uncommon in this study as 1.0 and 4.5 percent of the stomachs from the heated and ambient stations, respectively, were empty. To further investigate differential feeding rates at the two stations, a fullness index was determined for each specimen and monthly means were tested using an Approximate t-test (Parker 1979). Stomachs of bluegill from the heated station contained significantly ($P<0.05$) more food by weight during March and June, but there was no statistical difference between stations for the other six months.

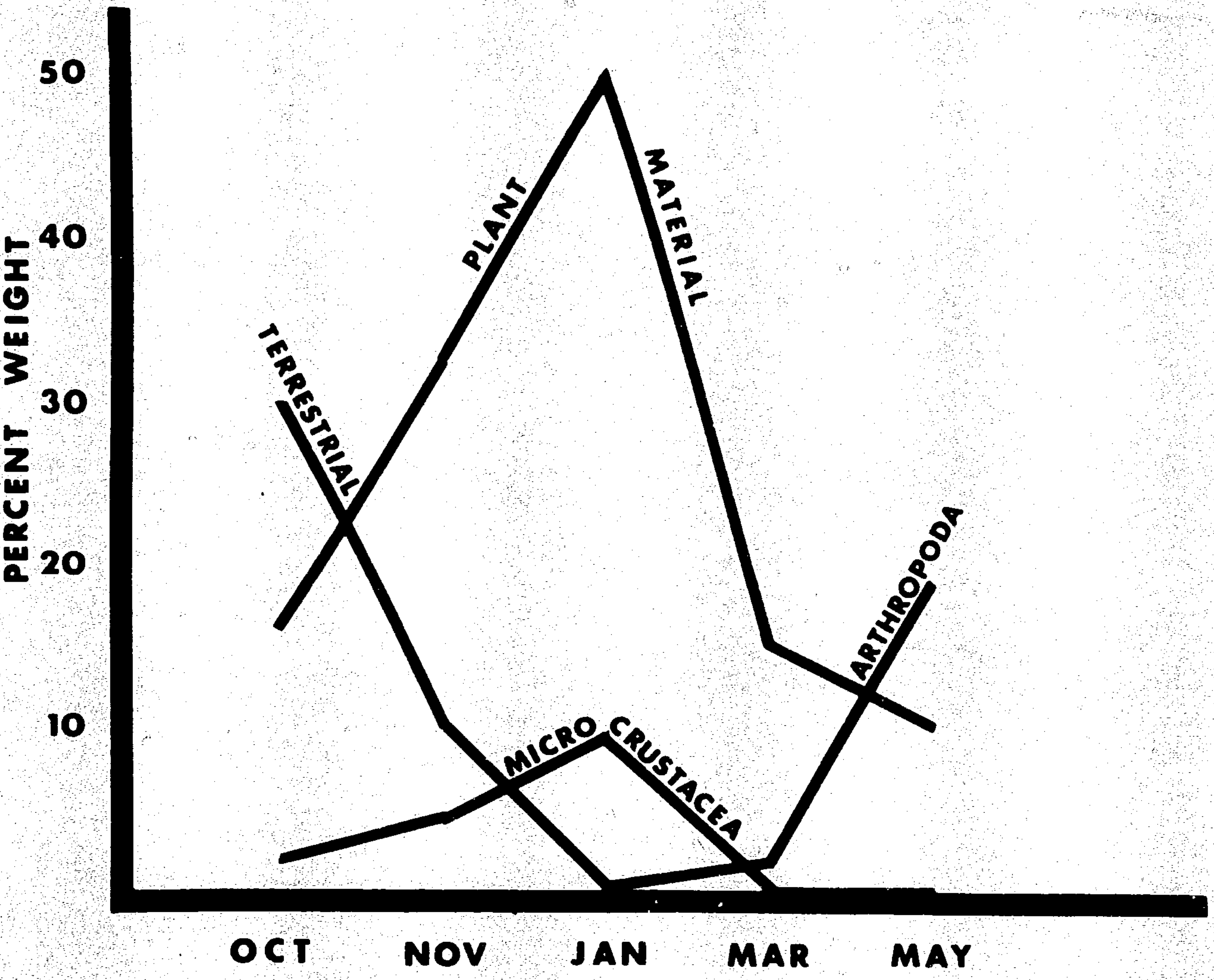

Fig. 8.1. Seasonal fluctuations in utilization of selected major food items (especially depicting changes during wintertime conditions), of bluegills from the heated area of Coffeen Lake.

# DISCUSSION

Bluegills from both heated and ambient areas of Coffeen Lake consumed substantial quantities of terrestrial arthropods. However, that does not necessarily imply that bluegills were utilizing that resource because autochthonous foods were scarce. Several factors may have contributed to the extensive use of terrestrial arthropods as food by bluegill. First, overhanging forest vegetation dominates the Coffeen Lake shoreline and thus provides an interface between aquatic and terrestrial ecosystems. Second, the feeding behavior and morphological adaptations of bluegills (Keast and Webb 1966) augment that fish's potential for capturing those types of prey. Third, the opportunistic nature by which the bluegill feeds suggests that the most abundant and accessible food resources are readily exploited. For instance, bluegills examined in this study from the September collections contained enormous quantities of aphids, almost to the exclusion of all other food items.

Food habits of bluegills from Lake Sangchris (Sule et al. 1981), a cooling lake in nearby Christian and Sangamon counties, differed from that of bluegills examined in this study. Bluegills from Lake Sangchris relied more heavily upon microcrustaceans, chironomids, and other aquatic arthropods bluegills, whereas bluegills from Coffeen Lake exhibited a much greater preference for terrestrial arthropods. In addition, gastropods, bryozoans, and fish eggs, all important components of the diet of Coffeen Lake bluegills, were not found in stomachs of bluegill from Lake Sangchris. Bryozoans have been considered to be of little relative importance in the diet of freshwater fishes; however, Applegate (1978) found them to be a predominant summer food item of bluegills in Bull Shoals Reservoir.

Differential feeding intensity of bluegills has been investigated in a cursory manner in other cooling lakes. Sarker (1977) and Sule et al. (1981) found that the percentage of empty stomachs was lower in samples taken from heated locations as opposed to ambient locations. That same trend held true for this investigation. Both Sarker (1977) and Sule et al. (1981) suggested that bluegills in heated waters fed more frequently because of higher digestive and metabolic rates. However, mean Fullness Indices calculated for this study were significantly higher ($P<0.05$) at the heated station for only two of eight collection dates.

As reported in Section 7 (herein) benthic food resources were sparse in the area of Station 1. In addition, the major component of the littoral benthic community, oligochaetes, was rarely utilized as food by bluegills. Thus, bluegills from the heated station necessarily shifted to other food resources, some of which have been reported to be of limited value, i.e., algae (Kitchell and Windell 1970). Beitinger and Fitzpatrick (1979) stated that bluegills in natural populations are often food limited and fish under such constraints can reduce maintenance metabolic costs by seeking lower water temperatures. However, in Coffeen Lake, intra- and interspecific competition for food and space is probably so severe that many fish were unable to occupy preferred temperature regimes. Multiple factors acting synergistically probably contributed to the stunted condition of bluegills (Section 15, herein) in Coffeen Lake. However, two of the more important factors limiting the growth and affecting the body condition of Coffeen Lake bluegills were quality and quantity of the daily ration and accelerated rates of maintenance metabolism.

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# SECTION 9

# FOOD HABITS OF FIRST YEAR LARGEMOUTH BASS FROM HEATED AND AMBIENT AREAS OF COFFEEN LAKE

by

Dennis L. Newman and Lance G. Perry

## ABSTRACT

Stomachs of 90 young-of-the-year largemouth bass, collected monthly from June through September in Coffeen Lake, were examined for food content. First year bass were primarily insectivorous during the month of June but transference to piscivory was completed by July. The data suggested that a piscivorous diet commenced at about 70 mm for most individuals and Dorosoma sp. were preferred over other species as prey. Specimens collected from the heated area in September had apparently only consumed insects, whereas those collected from ambient locations on that date exhibited a more typical piscivorous diet. Food competition between first-year bass and bluegills is probably negligible in Coffeen Lake since piscivory becomes the predominant feeding strategy early in life for bass while bluegills retain an insectivorous habit throughout life.

## INTRODUCTION

The suitability of an aquatic habitat for survival and growth of fishes is largely dependent upon the quantity and accessability of suitable food items. This dependency is most pronounced during periods of transition to exogenous feeding, and, for piscivorous species, during the transition from the insectivorous to the piscivorous feeding mode. Growth of largemouth bass in Coffeen Lake is known to be quite rapid once a length of 200 mm is reached (Section 15, herein), but the growth rate, and thus feeding success, of smaller individuals was uncertain. A high density of small sunfishes (*Lepomis* spp.) in Coffeen Lake, including numerous stunted bluegills, suggested that competition for littoral invertebrates may exert some constraints on growth of fishes utilizing that resource. Since young largemouth bass and bluegills commonly inhabit shallow, near-shore littoral areas, an investigation was conducted to identify and quantify food items utilized by bass during their first year of life and to compare their feeding habits with those of bluegills in Coffeen Lake.

## MATERIALS AND METHODS

Ten to twelve young-of-the-year largemouth bass were collected from heated and ambient areas of Coffeen Lake (Section 13, herein) by electroshocking at monthly intervals from June through September. All collecting efforts were conducted at mid-day. Specimens were placed on ice in the field, weighed, measured, and stored in 10% formalin until analyzed. Stomach contents were removed and weighed to the nearest 0.1 mg while still moist and sorted into categories under a dissecting stereomicroscope. Percent frequency of occurrence and percent weight (Windell and Bowen 1978) were calculated for each food category.

## RESULTS AND DISCUSSION

Stomach contents of 90 young-of-the-year largemouth bass were examined. Principal food items included fish (Lepomis spp. and Dorosoma sp.), aquatic anthropods (primarily chironomids and zygopterans), and terrestrial arthropods. The diet of first year bass in Coffeen Lake shifted from microcrustaceans and aquatic arthropods to an almost total reliance on fish as bass increased in length. Young largemouth bass apparently preferred Dorosoma sp. rather than Lepomis spp. as prey as evidenced by an overall greater frequency of occurrence and greater percentage weight of the former. However, Lepomis spp. larvae were collected in greater numbers than Dorosoma larvae in Coffeen Lake and they were found to be more concentrated in near-shore areas (Section 10, herein), suggesting a greater availability as prey. Nonetheless, it appears that young bass in Coffeen Lake avoided Lepomis spp. and selected Dorosoma as the principal prey-fish. In West Point Reservoir, Alabama, young largemouth bass also avoided bluegills, but as length of bass increased bluegills were consumed with no selection or avoidance (Timmons et al. 1980).

First year bass from the June collection were primarily insectivorous. Stomachs from the ambient station contained chironomids, other aquatic arthropods, and microcrustaceans (Table 9.1). The diet of bass from heated areas was slightly more diverse and one fish had begun to prey on fish. Stomach contents of bluegill collected during June revealed only a slight overlap in food items between the two species. Bluegill from the heated station consumed mainly terrestrial arthropods and gastropods, while bluegill from ambient areas fed principally upon bryozoans and chironomids (Section 8, herein).

By the time the July sample of young bass was collected, the transfer to piscivory was complete. Except for two specimens, fish were found in every stomach which contained food (Table 9.2). Fish comprised 97 and 98 percent of the total weight of food items at heated and ambient stations, respectively. It appeared that the piscivorous diet commenced at approximately 70mm total length in Coffeen Lake and that fish immediately became the dominant food resource. Largemouth bass from Lake Sangchris began consuming fish at 80 mm total length but insects remained the principal food item until 140mm total length (Sule et al. 1980). In Pickwick Reservoir, Tennessee, first year largemouth bass began preying upon fish at 20-39mm (Warden and Hubert 1980), but the shift to piscivory was more gradual in that lake than it was in Coffeen Lake.

The diet of young bass collected in August was essentially unchanged from that of July; *Dorosoma* sp. and unidentified fish comprised the bulk of the diet (Table 9.3). The food of bass from the September collection differed slightly from previous months, however. *Dorosoma* and unidentified fish remained the predominant food items at the ambient station, but young bass from the heated station consumed no fish and fed primarily upon terrestrial arthropods (Table 9.4). Such an interruption in piscivorous feeding is unusual as evidenced by other investigations (Popova 1957, Timmons et al 1980) and may have been a temporary and localized occurrence in Coffeen Lake. Nonetheless, the timing of the interruption suggests that the sustained high summertime water temperatures in the heated area of the lake may have influenced prey-fish distribution and abundance either directly through an avoidance of the high temperatures, or indirectly through a lack of sufficient cover or forage items. A relatively low condition of young bass from heated areas was found in fall samples (Section 15, herein) and probably reflects the limited prey-fish availability at that time and location.

Although young bass and bluegills typically congregate in littoral areas during the growing season (Keast and Webb 1966, Section 13, herein), food competition between the two species is apparently negligible in Coffeen Lake because of the early transfer to piscivory among bass while bluegills retain a primarily insectivorous feeding strategy throughout life (Section 8, herein). In addition, the rapid growth rate of first year bass (Section 15, herein) implies that feeding dynamics are not critical factors limiting the success of the population.

Table 9.1. Food of young-of-the-year largemouth bass from heated and ambient areas of Coffeen Lake, June 1980. Sample size is given in parentheses. Mean TL = 48mm and 36mm for heated and ambient, respectively.

| | Heated (12) | | Ambient (11) | |
|---|---|---|---|---|
| Food Item | Percent frequency of occurrence | % Wt. | Percent frequency of occurrence | % Wt. |
| Microcrustaceans | 58 | 5.0 | 91 | 32.7 |
| Chironomidae | 75 | 5.2 | 91 | 37.2 |
| Other Aquatic Arthropods | 42 | 24.5 | 45 | 28.6 |
| Terrestrial Arthropods | 8 | 0.5 | 0 | 0 |
| Plant material | 8 | 1.9 | 0 | 0 |
| Fish<br>*Lepomis* spp. | 8 | 58.0 | 0 | 0 |
| Unidentified organic matter | 58 | 4.9 | 18 | 1.5 |
| | | 100.0 | | 100.0 |

Table 9.2. Food of young-of-the-year largemouth bass from heated and ambient areas of Coffeen Lake, July 1980. Mean TL = 83mm and 74mm for heated and ambient areas, respectively. Sample size is given in parentheses.

| | Heated (10) | | Ambient (10) | |
|---|---|---|---|---|
| Food Item | Percent frequency of occurrence | % Wt. | Percent frequency of occurrence | % Wt. |
| Chironomidae | 0 | 0 | 11 | 0.2 |
| Other aquatic arthropods | 0 | 0 | 33 | 0.6 |
| Fish | | | | 6 |
| *Lepomis* spp. | 0 | 0 | 11 | 2.0 |
| *Dorosoma* sp. | 33 | 40.4 | 11 | 42.4 |
| Unidentified | 78 | 56.7 | 78 | 53.9 |
| Unidentified organic matter | 78 | 2.9 | 11 | 0.2 |
| Inorganic matter | 0 | 0 | 22 | 0.8 |
| | | 100.0 | | 100.0 |

Table 9.3. Food of young-of-the-year largemouth bass from heated and ambient areas of Coffeen Lake, August 1980. Mean TL = 107mm and 127mm for heated and ambient areas, respectively. Sample size is given in parentheses.

| Food Item | Heated (11) |  | Ambient (12) |  |
|---|---|---|---|---|
|  | Percent frequency of occurrence | % Wt. | Percent frequency of occurrence | % Wt. |
| Other aquatic arthropods | 22 | 1.0 | 8 | 0.2 |
| Fish |  |  |  |  |
| *Dorosoma* sp. | 0 | 0 | 17 | 65.4 |
| Unidentified | 33 | 98.0 | 58 | 33.3 |
| Unidentified organic matter | 55 | 1.0 | 17 | 1.0 |
|  |  | 100.0 |  | 100.0 |

Table 9.4. Food of young-of-the-year largemouth bass from heated and ambient areas of Coffeen Lake, September 1980. Mean TL = 126mm and 124mm for heated and ambient areas, respectively. Sample size is given in parentheses.

| Food Item | Heated (12) Percent frequency of occurrence | Heated (12) % Wt. | Ambient (12) Percent frequency of occurrence | Ambient (12) % Wt. |
|---|---|---|---|---|
| Other aquatic arthropods | 33 | 11.2 | 22 | 0.2 |
| Terrestrial arthropods | 78 | 85.5 | 11 | 0.1 |
| Fish | | | | |
| *Lepomis* spp. | 0 | 0 | 11 | 22.0 |
| *Dorosoma* sp. | 0 | 0 | 22 | 57.6 |
| *Unidentified* | 0 | 0.0 | 44 | 20.1 |
| Unidentified organic matter | 11 | 3.3 | 0 | 0 |
| | | 100.0 | | 100.0 |

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## SECTION 10

# DISTRIBUTIONAL ECOLOGY AND RELATIVE ABUNDANCE OF ICHTHYOPLANKTON

by

Dennis L. Newman

## ABSTRACT

A quantitative ichthyoplankton study was conducted during the spring and summer of 1980. The general objective was to determine spatio-temporal variations in relative abundance of larval fishes in order to more thoroughly assess the potential impact of entrainment. During the course of the study 89,563 larval fishes were collected; four taxonomic groups were represented - *Lepomis* spp. (67.9%), *Dorosoma cepedianum* (31.8%), *Pomoxis annularis* (0.2%), and *Cyprinus carpio* (two specimens). Statistical treatment of data indicated that densities of *Lepomis* spp. and *Dorosoma* larvae in the intake area were not significantly different from densities collected at "non-intake" stations of similar thermal regime, thereby demonstrating that the Coffeen Power Station intake area was not an area of high potential impact for these species. A conclusion of similar importance was that the ambient area of Coffeen Lake (an area far removed from the cooling water intake) supported significantly higher densities of *Lepomis* spp., *Dorosoma*, and *Pomoxis* larvae and therefore should be considered a major fish nursery area. The spatial distribution of larval fishes was apparently affected by the thermal gradient in this lake as densities of larvae increased with increased distance from the thermal discharge. Spawning of *Lepomis* spp. and *Dorosoma* was also affected by the thermal input; the initiation of spawning began first at the heated stations; the peak spawn occurred at the same time in both heated and ambient locations, but the duration of spawning was more abrupt at the heated stations.

# INTRODUCTION

Assessing the ecological impact of entrainment losses on fish communities has proven a difficult task, primarily because of intrinsically large variability in year-class strength and stock recruitment (Voigtlander 1980). One common approach has been to estimate the number of adults which would have resulted from the entrained larvae (Goodyear 1978). However, it was believed more important to investigate the relative abundance of larval life stages. Thus, by comparing larval densities lakewide we were able to determine the relative "biological productivity" (EPA 1979) of the cooling water intake area.

Quantitative ichthyoplankton surveys have previously been employed for assessment of a number of ecological problems such as determining species distributions (Storck et al. 1978), predicting year-class strength (Hempel 1973), predicting entrainment losses (Cloutman and Edwards 1977), and estimating larval fish population densities in lakes (Forney 1975).

The general objective of this study was to determine spatio-temporal variations in abundance and species composition of the larval fish community in Coffeen Lake. Specifically, we attempted to assess the impact of entrainment losses, compare ichthyoplankton densities in the intake and non-intake areas, and to delineate locations in the lake which may have served as nursery areas. Secondary objectives were to examine the synchrony of catches for each population to determine if spawning times varied between sampling sites and to determine if the distribution of ichthyoplankton was related to the thermal gradient.

# METHODS AND MATERIALS

Ichthyoplankton collections were made at 7 day intervals during daylight hours from 27 March to 20 August 1980. Collection sites for this investigation did not necessarily correspond to those selected as major sampling stations for other Coffeen Lake studies (see Section I, herein). Rather, stations for this investigation were selected in order to sample diverse habitat types throughout the thermal gradient and as complimentary collections to the entrainment study. Description of sampling sites with respect to heated and ambient areas, depths, and habitats is included in Table 10.1, and sampling sites are depicted in Fig. 10.1.

Larval fishes were collected with paired side-towed beam nets as described by Graser (1977). With this sampling system no net bridles are used and the depressor is in the same vertical plane as the net opening; both of these designs are important in reducing net avoidance by fish. The nets were 0.5 m in diameter (mesh size = 0.500 mm) and net length was 2.5 m. Elevation of the horizontal towing bar, 1.75 m above the water surface, facilitated washing of the nets, which was completed after each tow. The cod ends were constructed from 7.62 cm diameter rigid polyvinylchloride (PVC) pipe; the anterior ends were threaded, allowing the buckets to be easily removed. General Oceanics model 2030 flowmeters were mounted in the mouths of each net so that the volume of water filtered was determined after each tow.

Because Graser (1977) reported a progressive loss of filtration efficiency at water velocities less than 1.0 m/sec, and Miller (1973) experienced specimen damage at speeds greater than 1.34 m/sec, boat speed was held at 1.10 m/sec during all tows. Consistent boat speed was accomplished using a General Oceanics model 2031 flowmeter lowered from the bow in conjunction with a General Oceanics model 2035 flowmeter readout positioned in view of the boat driver.

Samples were preserved in 10% formalin, returned to the laboratory, sorted and stored in 5% formalin. Larvae were identified according to Hogue et al. (1976), and enumerated. Polarized stereomicroscopy was utilized for viewing specimens.

Table 10.1. The depth, duration, habitat type, and thermal characteristic of each sampling site in Coffeen Lake during the spring and summer of 1980.

| Sampling Sites | Depth | Habitat Type | Thermal Characteristics | Total Duration |
|---|---|---|---|---|
| 1 | Surface | Shallow cove | Heated, discharge arm | 3 min |
| 2 | Surface | Mid-lake | Heated, discharge arm | 3 min |
| 3 | 2 meters | Mid-lake | Heated, discharge arm | 3 min |
| 4 | Surface | Intake cove | Transitional | 3 min |
| 5 | 2 meters | Intake cove | Transitional | 3 min |
| 6 | Surface | Intake cove | Transitional | 3 min |
| 7 | 5 meters | Intake cove | Transitional | 3 min |
| 8 | Oblique (5m & up) | Intake cove | Transitional | 5 min |
| 9 | Surface | Mid-lake | Ambient | 3 min |
| 10 | 2 meters | Mid-lake | Ambient | 3 min |
| 11 | Surface | Shallow cove | Ambient | 3 min |
| 12 | Surface | Mid-lake | Heated | 3 min |
| 13 | 2 meters | Mid-lake | Heated | 3 min |
| 14 | Surface | Shoreline (large cove) | Heated | 3 min |
| 15 | Surface | Shallow shoreline | Transitional | 3 min |
| 16 | Surface | Mid-lake | Transitional | 3 min |
| 17 | Surface | Shallow cove | Transitional | 3 min |
| 18 | Surface | Shallow shoreline; major tributary | Ambient | 3 min |

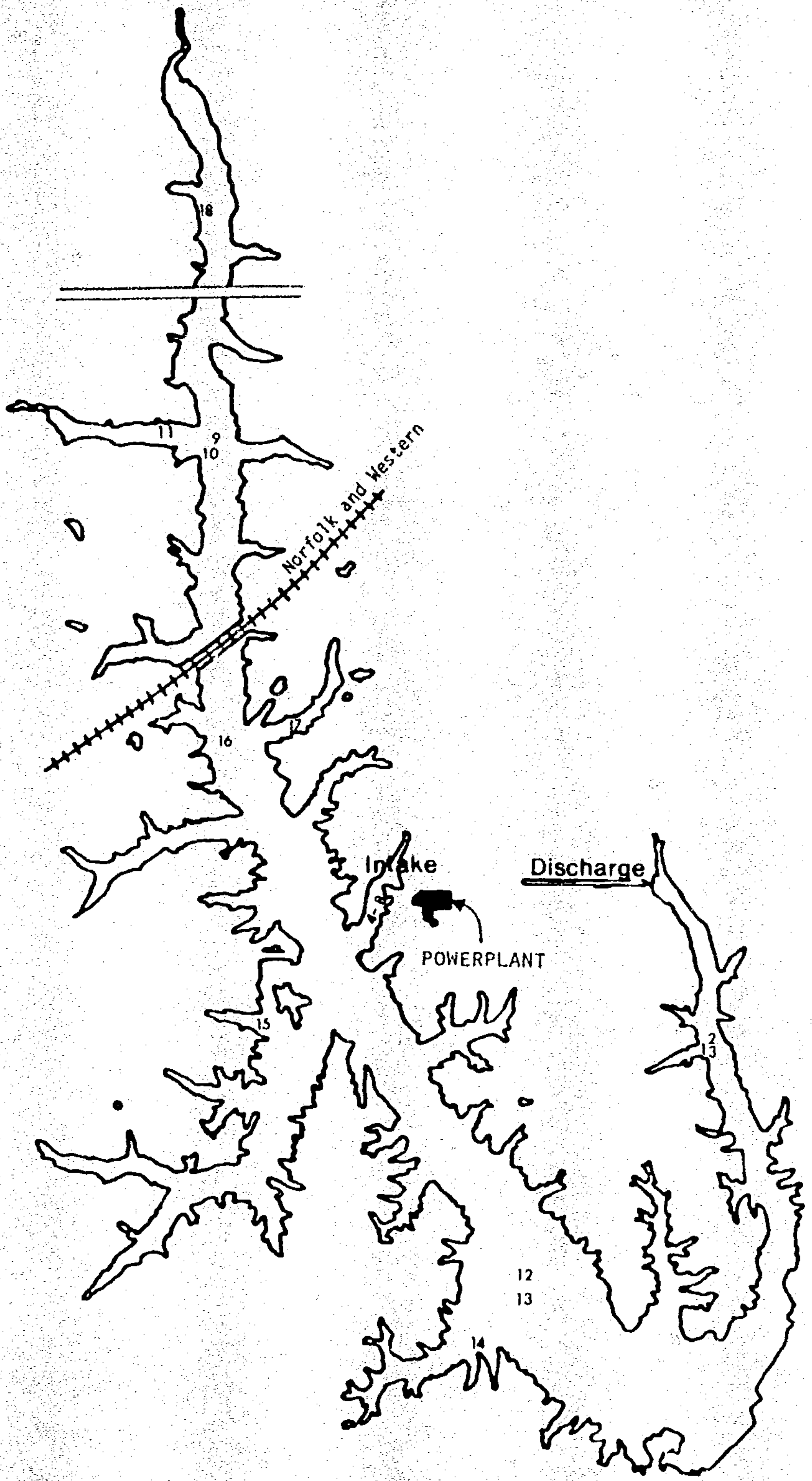

Figure 10.1. Ichthyoplankton tow sites used during the spring and summer of 1980 at Coffeen Lake.

Catch rates were expressed as numbers of larvae per 10 $m^3$ of water sampled. Those data were subsequently transformed to logarithms in order to achieve homogeneity of variances. Due to the presence of zero values in the catch data, one unit was added to all data before transformation. Analysis of variance, Duncan's multiple range test and selected station comparisons were performed using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) (Goodnight 1979). Two-way analyses of variance were performed for each of three genera, Lepomis, Dorosoma, and Pomoxis; main effects were weeks and stations. For those analyses the 18 sampling stations were grouped into three lake temperature zones or areas; they were heated, transitional, and ambient, as defined in Table 10.1.

## RESULTS AND DISCUSSION

Ichthyoplankton sampling began 27 March 1980 but the first larvae were not collected until 23 April. Larval fishes were taken in each subsequent weekly collection through 20 August when sampling was terminated. During the course of the study 89,563 larval fishes were collected; representing four taxonomic groups. Lepomis spp., which included four species (bluegill, green sunfish, longear sunfish, and orangespotted sunfish) and their hybrids accounted for 60,855 larvae or 67.9% of the total catch. This represents an extraordinary number of Lepomis larvae when compared to other larval fish studies conducted in central Illinois (Storck et al. 1978, Bergmann 1981). Gizzard shad, Dorosoma cepedianum, larvae accounted for 28,487 specimens or 31.8% of the total catch. White crappie, Pomoxis annularis, larvae were rather uncommon, as only 219 specimens (0.2% of the total catch) were collected. Lastly, two carp, Cyprinus carpio, larvae were also collected. Since reproductive success of carp in Coffeen Lake has been reported to be limited (Section 15, herein), low catches of carp larvae were expected. Largemouth bass larvae were not collected during this study, even though six sampling sites were located in shallow coves or near shoreline areas where bass typically congregate. Bass are difficult to collect, however, because of their diurnal behavioral responses (Elliott 1976). Further analyses and discussion will include only the three most commonly collected genera, Lepomis, Dorosoma, and Pomoxis.

### *Lepomis* spp.

*Lepomis* spp. larvae were first captured on 23 April in the thermally-altered portions of the lake, but not until 21 May in the ambient areas. Surface water temperatures on the dates of first capture ranged from 21.1 to 22.8°C. *Lepomis* spp. densities were highest on 4 June, when mean lakewide density equaled 283.9 larvae/ 10 $m^3$. Densities subsequently decreased until 30 July when a second smaller peak occurred (Table 10.2). Kindschi et al. (1979) collected *Lepomis* spp. larvae in Rough River Lake, Kentucky from 30 May to 25 August, with a maximum density of 24.0 larvae/10 $m^3$ reported on 11 July. Bergmann (1981) reported peak catches of *Lepomis* spp. on 10 June in the discharge arm and 17 June in the intake arm of Lake Sangchris, Illinois.

Significant week, station, and a week-station interaction were revealed by the analysis of variance for densities of larval *Lepomis* spp. (Table 10.3). Duncan's multiple range test demonstrated that mean densities by station were all significantly different and that mean densities increased progressively from heated to transitional to ambient stations (Table 10.3). Since the mean density at the ambient zone was much higher than that of the transitional zone, while the temperature of those areas were not greatly dissimilar, it appears that factors other than thermal regime caused the ambient area of the lake to be more productive.

Selected comparisons among sampling stations were designed to yield more specific information about the spatial distribution of *Lepomis* spp. larvae in Coffeen Lake. Data concerning larval densities within the intake area were of obvious importance to the concomitant entrainment study (Section 12, herein). Surface tows within the intake cove had significantly higher larval densities than either the 2-meter (C1) or the 5-meter tow (C2) (Table 10.4). Determination of the relative "productivity" (EPA 1977) of the intake area in terms of larval fishes is essential. The density of *Lepomis* spp. larvae within the Coffeen Lake intake area were not significantly different from the "non-intake" stations of similar thermal regime (C7) (Table 10.4). Additionally, densities from the two intake surface tows were compared to surface tows within just the transitional region (C8) and again no significant

Table 10.2. Mean densities (number/10 m$^3$) of Lepomis spp. larvae collected from Coffeen Lake from 23 April to 20 August 1980.

| | Weeks | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 4/23 | 4/30 | 5/07 | 5/14 | 5/21 | 5/28 | 6/04 | 6/11 | 6/18 | 6/25 | 7/02 | 7/09 | 7/16 | 7/23 | 7/30 | 8/06 | 8/13 | 8/20 | Mean |
| 1 | - | - | - | 0.6 | 5.3 | 11.4 | 437.2 | 83.8 | 10.5 | 1.1 | - | - | - | - | 9.5 | - | - | - | 31.1 |
| 2 | - | - | - | 0.5 | 0.6 | 0.3 | 7.0 | 1.0 | - | 0.5 | - | - | - | - | - | - | - | 0.2 | 0.6 |
| 3 | - | - | - | - | - | 0.2 | 0.8 | 1.0 | 1.0 | 0.2 | - | - | - | - | 0.5 | 0.8 | 1.0 | - | 0.3 |
| 4 | - | - | - | 0.3 | 0.6 | 0.2 | 67.2 | 29.1 | 0.4 | 0.3 | 0.7 | - | - | 0.3 | 1.0 | 0.3 | 4.0 | 9.4 | 6.3 |
| 5 | - | - | - | - | - | - | 2.6 | 0.8 | - | 0.5 | 0.4 | - | - | - | 2.7 | 0.4 | 0.3 | 1.4 | 0.5 |
| 6 | - | - | - | - | - | 0.2 | 36.4 | 2.6 | 1.0 | 0.4 | 0.3 | - | - | - | 19.2 | 5.8 | 38.0 | 13.2 | 6.5 |
| 7 | - | - | - | - | - | - | 2.4 | 0.6 | - | 0.2 | 0.2 | - | - | - | 1.6 | 0.4 | - | 0.2 | 0.3 |
| 8 | - | - | - | - | - | 0.2 | 16.2 | 1.0 | 0.1 | 0.2 | 0.1 | - | - | - | 0.8 | 2.1 | 0.5 | - | 1.2 |
| 9 | - | - | - | - | - | 1.3 | 479.6 | 91.0 | 10.1 | 5.4 | 14.6 | 0.2 | 1.6 | 0.4 | 5.2 | 7.2 | 6.9 | 6.4 | 35.0 |
| 10 | - | - | - | - | 0.2 | - | 3.0 | 4.7 | 32.0 | 9.6 | 3.8 | 0.4 | 5.6 | 0.1 | 0.6 | 3.3 | 3.0 | 0.2 | 3.7 |
| 11 | - | - | - | - | - | 4.7 | 631.8 | 713.2 | 220.9 | 183.0 | 87.9 | 0.9 | 4.6 | 3.5 | 23.2 | 66.6 | 23.2 | 8.0 | 109.5 |
| 12 | - | 0.2 | - | 0.2 | - | 0.3 | 21.2 | 1.0 | 0.3 | - | - | - | - | - | 10.8 | 0.4 | 1.0 | 0.2 | 2.0 |
| 13 | - | - | - | - | - | 0.4 | 2.2 | 0.4 | - | 0.3 | 0.2 | - | - | - | 1.1 | 0.2 | 0.3 | - | 0.3 |
| 14 | - | - | - | - | 0.2 | 0.2 | 1511.6 | 11.9 | 0.2 | 0.9 | - | - | 0.2 | - | 5.0 | 1.6 | 0.2 | 0.7 | 85.1 |
| 15 | 0.1 | - | - | - | 0.2 | 0.2 | 303.7 | 9.2 | 0.6 | - | 1.5 | - | 0.2 | - | 43.2 | 2.2 | 2.5 | 7.9 | 20.6 |
| 16 | - | - | - | - | - | - | 14.4 | 2.6 | - | - | 0.2 | - | - | - | 3.3 | 1.3 | 0.4 | 0.6 | 1.3 |
| 17 | - | - | - | - | 0.3 | - | 860.4 | 16.0 | 0.9 | 3.5 | 9.8 | - | 0.4 | - | 15.8 | 14.6 | 6.4 | 26.6 | 53.1 |
| 18 | - | - | - | - | - | 3.6 | 713.3 | 1356.6 | 232.3 | 62.8 | 170.4 | 41.0 | 5.9 | 0.8 | 5.7 | 40.0 | 11.4 | 13.9 | 147.6 |
| Mean | 0.01 | 0.01 | - | 0.1 | 0.4 | 1.3 | 283.9 | 129.3 | 28.4 | 14.9 | 16.1 | 2.4 | 1.0 | 0.3 | 8.3 | 8.2 | 5.5 | 4.9 | |

Table 10.3. Two-way ANOVA and Duncan's multiple range test for density of larval *Lepomis* spp. Tests were performed using transformed data, but mean densities shown are the antilogs.

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ANALYSIS OF VARIANCE

| Source | Degrees of Freedom | Mean Square | F-value |
|---|---|---|---|
| Weeks | 17 | 7.051 | 46.3* |
| Stations | 2 | 18.273 | 119.99* |
| Week-station interaction | 34 | 1.149 | 7.54* |
| Error | 594 | 0.152 | |

DUNCAN'S MULTIPLE RANGE TEST**

| Station | Mean | Grouping*** |
|---|---|---|
| Heated | 0.66 | C |
| Transitional | 0.96 | B |
| Ambient | 5.71 | A |

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* Statistically significant at the 0.001 probablity level

** Alpha level = 0.05

*** Means with the same letter are not significantly different

Table 10.4. One-way analysis of variance of station densities with selected orthogonal comparisons, dependent variable was *Lepomis* spp. Underlined station numbers indicate stations with the higher mean value.

| Source | Degrees of Freedom | Mean Square | F value |
|---|---|---|---|
| Stations | 17 | 3.793 | 11.20** |
| C1 = (Sta 4+6 vs 5) | (1) | 1.470 | 4.34* |
| C2 = (Sta 4+6 vs 7) | (1) | 2.101 | 6.20* |
| C3 = (Sta 1+2+3+12+13+14 vs 9+10+11+18) | (1) | 31.888 | 94.12** |
| C4 = (Sta 1+2+3 vs 9+10+11) | (1) | 13.225 | 39.04** |
| C5 = (Sta 1+11+14+15+17 vs 2+9+12+16) | (1) | 7.953 | 23.47** |
| C6 = (Sta 2+9+12+16 vs 3+5+10+13) | (1) | 0.886 | 2.62 |
| C7 = (Sta 4+5+6+7+8 vs 1+2+3+12+13+14+15+16+17) | (1) | 0.381 | 1.15 |
| C8 = (Sta 4+6 vs 15+16+17) | (1) | 0.033 | 0.10 |
| C9 = (Sta 9+11 vs 18) | (1) | 1.360 | 4.01* |
| Error | 630 | 0.339 | |

*Statistically significant at 0.05 probability level
**Statistically significant at 0.01 probability level

difference was found (Table 10.4). Thus, the intake area of Coffeen Lake was not an area of high larval density. Differences between stations exhibiting thermal extremes were also examined and larval densities were found to be significantly higher in ambient areas as opposed to heated areas of the lake; comparison three (C3) (Table 10.4) contrast (C3) was designed to compare all heated stations to all ambient stations, whereas, comparison four (C4) (Table 10.4) contrasted stations within heated and ambient areas which were very similar with respect to depth and habitat sampled. In other comparisons, *Lepomis* spp. densities were found to be significantly higher near shore than at mid-lake stations (C5), but no statistical difference was found between surface and 2-meter tows (C6) taken from similar habitats. Storck et al. (1978) also reported that bluegill densities were significantly higher near shore than at mid-lake stations, but he found that bluegill densities were significantly higher in surface tows than subsurface tows at Lake Shelbyville, Illinois. Lastly, the two surface tows from the main body of the ambient area (Stations 9 and 11) were compared (C9) to the surface tow collected at Station 18 (located nearest the major tributary), the mean density was significantly higher at the tributary station. Consistently elevated turbidity levels at the station near the tributary may have contributed to the disparate catches, by reducing net avoidance of larvae.

A one-way analysis of variance was performed to detect differences in weekly mean densities of *Lepomis* spp. larvae within selected lake areas. Weekly mean densities of *Lepomis* larvae were significantly different within the heated area (Table 10.5), the ambient area (Table 10.6), and the intake area (Table 10.7). Mean larval densities were highest on 4 June at all three lake areas. However, within the ambient area the number of larvae found on 4 June was not statistically different from that observed the following two weeks, suggesting a protracted spawning period. It appeared that spawning was much more abrupt in the heated and intake areas, as larval density on 4 June in those areas was significantly higher than all other weeks. The onset of spawning occurred earlier in the heated areas than in ambient locations, spawning peaks occurred a this same time, but the duration and intensity of spawning were dissimilar between areas. Larval densities within the intake area (Table 10.7) indicated that entrainment rates were potentially highest on 4 June and relatively low thereafter.

Table 10.5. One-way analysis of variance and Duncan's multiple range test of weekly mean densities of *Lepomis* spp. larvae among heated stations. Dependent variable was *Lepomis* spp. densities. All hypotheses were tested using transformed data, but mean densities shown are the antilogs.

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ANALYSIS OF VARIANCE

| Source | d.f. | Mean Square | F-value |
|---|---|---|---|
| Week | 17 | 1.334 | 9.77* |
| Temperature | 1 | 0.019 | 0.14 |
| Temperature$^2$ | 1 | 0.025 | 0.19 |
| Error | 196 | 0.136 | |

DUNCAN'S MULTIPLE RANGE TEST**

| Weeks | 6/04 | 6/11 | 7/30 | 5/28 | 6/18 | 5/21 | 6/25 | 8/06 | 8/13 | 5/14 | 8/20 | 4/30 | 7/02 | 7/16 | 4/23 | 5/07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Means | 28.2 | 3.7 | 2.6 | 0.8 | 0.8 | 0.5 | 0.4 | 0.4 | 0.3 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

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* Statistically significant at 0.001 probability level

** Means underscored by the same line were not significantly different (alpha = 0.05)

Table 10.6. One-way analysis of variance and Duncan's multiple range test of weekly mean densities of Lepomis spp. larvae among ambient stations. Dependent variable was Lepomis spp. densities. All hypotheses were tested using transformed data, but mean densities shown are the antilogs.

ANALYSIS OF VARIANCE

| Source | d.f. | Mean Square | F-value |
|---|---|---|---|
| Week | 17 | 2.991 | 12.06* |
| Temperature | 1 | 2.024 | 8.16* |
| Temperature$^2$ | 1 | 2.007 | 8.09* |
| Error | 124 | 0.248 | |

DUNCAN'S MULTIPLE RANGE TEST**

Weeks / Means

| 6/04 | 6/11 | 6/18 | 7/02 | 6/25 | 8/06 | 8/13 | 7/30 | 8/20 | 7/16 | 7/09 | 5/28 | 7/23 | 5/21 | 4/23 | 4/30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 167.7 | 144.6 | 62.5 | 32.4 | 28.3 | 16.2 | 8.7 | 5.3 | 4.8 | 3.9 | 2.3 | 1.7 | 0.9 | 0.0 | 0.0 | 0.0 |
| — | — | — | | | | | | | | | | | | | |
| | | — | — | — | | | | | | | | | | | |
| | | | — | — | — | — | | | | | | | | | |
| | | | | | — | — | — | — | — | | | | | | |
| | | | | | | — | — | — | — | — | — | | | | |
| | | | | | | | — | — | — | — | — | — | | | |
| | | | | | | | | | | — | — | — | — | — | — |

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* Statistically significant at 0.001 probability level

** Means underscored by the same line were not significantly different (alpha = 0.05)

Table 10.7. One-way analysis of variance and Duncan's multiple range test of weekly mean densities of *Lepomis* spp. larvae among intake stations. Dependent variable was *Lepomis* spp. densities. All hypotheses were tested using transformed data, but mean densities shown are the antilogs.

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ANALYSIS OF VARIANCE

| Source | d.f. | Mean Square | F-value |
|---|---|---|---|
| Week | 17 | 0.971 | 11.75* |
| Error | 162 | 0.083 | |

DUNCAN'S MULTIPLE RANGE TEST**

| Weeks | 6/04 | 7/30 | 8/20 | 6/11 | 8/13 | 8/06 | 7/02 | 6/25 | 6/18 | 5/28 | 5/21 | 5/14 | 7/23 | 4/23 | 4/30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Means | 12.8 | 2.7 | 2.3 | 2.2 | 2.1 | 1.2 | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.05 | 0.05 | 0.0 | 0.0 |

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* Statistically significant at 0.001 probability level

** Means underscored by the same line were not significantly different (alpha = 0.05)

### Dorosoma (Gizzard Shad)

Gizzard shad larvae were initially collected 23 April in the thermally-altered portions of the reservoir and were found one week later at the ambient stations. Surface water temperatures on the dates of first capture ranged from 17.1 to 21.0°C. Highest lakewide mean density was recorded on 4 June when 130.6 larvae were collected per 10 $m^3$ of water sampled (Table 10.8). In a similar study at Lake Sangchris, another Illinois cooling lake, maximum densities were found during the three-week period from 27 May to 10 June (Bergmann 1981); maximum densities were recorded for this study during a similar time period, 28 May to 11 June (Table 10.8).

A two-way analysis of variance indicated that differences in Dorosoma larval densities attributable to week, station and a week-station interaction were all significant at the 0.1% probability level (Table 10.9). Duncan's multiple range test indicated that mean station densities were all significantly different and that mean densities increased with increasing distance from the heated water. Comparisons identical to those utilized for Lepomis spp., are presented in Table 10.10. Comparison one (C1) indicated that shad densities within the intake area were signficantly higher at a depth of 2 meters than at the surface; but surface and 5- meter tows were not significantly different (C2). Densities of larval shad in the intake area were not significantly different from "non-intake" stations of similar thermal regime (C7, C8). The mean density of shad larvae at all ambient stations was significantly higher than mean density of all heated stations (C3). Additionally, a comparison (C4) of highly similar stations within two dissimilar thermal regions indicated that densities of larval shad were significantly higher in the ambient portions of Coffeen Lake. Other comparisons indicated that: (1) larval densities at shoreline and mid-lake stations were not significantly different, (2) larval densities at surface and 2-meter depths were similar, and (3) larval densities from Station 18 (nearest the major tributary) were not significantly different from those collected in the main body of the ambient area. In Lake Shelbyville, Storck et al. (1978) also found that shad larvae were equally abundant at mid-lake and shoreline stations but, in contrast to this study, they found that shad larvae were more abundant at the surface than at subsurface tow sites.

Table 10.8. Mean densities (number/10 m$^3$) of gizzard shad larvae collected from Coffeen Lake from 23 April to 20 August 1980.

| | Weeks | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 4/23 | 4/30 | 5/07 | 5/14 | 5/21 | 5/28 | 6/04 | 6/11 | 6/18 | 6/25 | 7/02 | 7/09 | 7/16 | 7/23 | 7/30 | 8/06 | 8/13 | 8/20 | Mean |
| 1 | - | 0.6 | - | 0.3 | 6.5 | 14.8 | 3.8 | 0.2 | - | - | - | - | - | - | - | - | - | - | 1.4 |
| 2 | - | 0.6 | 0.6 | 0.2 | 3.4 | 5.9 | - | - | - | - | - | - | - | - | - | - | - | - | 0.6 |
| 3 | - | 0.5 | 0.8 | 0.3 | 5.0 | 14.8 | 6.2 | 3.6 | 9.6 | - | - | - | - | - | - | - | - | - | 2.3 |
| 4 | 0.2 | - | 0.8 | 1.3 | 1.6 | 8.4 | 15.0 | 0.3 | 0.2 | - | - | - | - | - | - | - | - | - | 1.5 |
| 5 | - | - | 1.1 | 28.0 | 12.6 | 94.8 | 39.6 | 11.2 | 2.2 | 1.9 | - | - | - | - | - | - | - | - | 10.6 |
| 6 | - | - | 0.8 | 1.0 | 0.4 | 10.2 | 1.6 | - | 0.2 | - | - | - | - | - | - | - | - | - | 0.8 |
| 7 | - | 0.2 | 0.7 | 0.2 | 3.1 | 15.4 | 21.2 | 7.3 | 2.7 | 0.2 | 0.2 | - | - | - | - | - | - | - | 2.8 |
| 8 | - | 0.4 | 0.6 | 4.9 | 6.9 | 47.6 | 18.6 | 6.8 | 0.7 | 0.8 | - | - | - | - | - | - | - | - | 4.9 |
| 9 | - | - | 0.4 | 5.4 | 9.1 | 154.0 | 873.0 | 145.8 | 13.1 | - | 0.2 | - | - | - | - | - | - | - | 66.7 |
| 10 | - | - | 1.4 | 0.6 | 8.4 | 99.0 | 15.8 | 11.6 | 12.8 | 0.4 | 0.2 | - | - | - | - | - | - | - | 8.3 |
| 11 | - | 0.3 | 0.2 | 5.2 | 15.3 | 31.3 | 198.1 | 114.6 | 0.9 | 0.3 | - | - | - | - | - | - | - | - | 20.3 |
| 12 | - | 0.2 | 0.5 | 9.1 | 2.8 | 11.8 | 2.1 | 0.2 | - | - | - | - | - | - | - | - | - | - | 1.5 |
| 13 | - | 0.2 | 0.2 | 1.8 | 0.9 | 23.8 | 24.4 | 10.3 | 0.6 | - | - | - | - | - | - | - | - | - | 3.4 |
| 14 | - | - | 0.3 | 0.5 | 13.1 | 21.8 | 26.4 | - | 0.4 | - | - | - | - | - | - | - | - | - | 3.5 |
| 15 | - | - | 0.8 | 5.7 | 3.5 | 35.6 | 7.8 | 0.2 | - | - | - | - | - | - | - | - | - | - | 3.0 |
| 16 | - | - | 0.8 | 2.6 | 1.6 | 106.6 | 2.2 | 0.2 | - | - | - | - | - | - | - | - | - | - | 6.3 |
| 17 | - | 0.2 | 0.4 | 3.2 | 5.8 | 33.8 | 33.7 | - | - | - | - | - | - | - | - | - | - | - | 4.3 |
| 18 | - | - | 0.6 | 7.5 | 15.6 | 210.0 | 1061.2 | 278.7 | 3.5 | 1.6 | 0.2 | 0.2 | - | - | 0.3 | - | 0.3 | - | 87.8 |
| Mean | 0.01 | 0.2 | 0.6 | 4.3 | 6.4 | 52.2 | 130.6 | 32.8 | 2.6 | 0.3 | 0.03 | 0.01 | - | - | 0.02 | - | 0.02 | - | |

Table 10.9. Two-way ANOVA and Duncan's multiple range test for density of larval Dorosoma spp. Tests were performed using transformed data, but mean densities shown are the antilogs.

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ANALYSIS OF VARIANCE

| Source | Degrees of Freedom | Mean Square | F-value |
|---|---|---|---|
| Weeks | 17 | 8.472 | 138.8* |
| Stations | 2 | 4.333 | 71.0* |
| Week-station interaction | 34 | 0.771 | 12.6* |
| Error | 594 | 0.061 | |

DUNCAN'S MULTIPLE RANGE TEST**

| Station | Mean | Grouping*** |
|---|---|---|
| Heated | 0.60 | C |
| Transitional | 0.83 | B |
| Ambient | 2.23 | A |

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* Statistically significant at the 0.001 probablity level

** Alpha level = 0.05

*** Means with the same letter are not significantly different

Table 10.10. One-way analysis of variance of station densities with selected orthogonal comparisons, dependent variable was gizzard shad densities. Underlined station numbers indicate stations with the higher mean value.

| Source | Degrees of Freedom | Mean Square | F value |
|---|---|---|---|
| Stations | 17 | 0.794 | 2.62** |
| C1 = (Sta 4+6 vs 5) | (1) | 2.436 | 8.04** |
| C2 = (Sta 4+6 vs 7) | (1) | 0.393 | 1.30 |
| C3 = (Sta 1+2+3+12+13+14 vs 9+10+11+18) | (1) | 8.015 | 26.45** |
| C4 = (Sta 1+2+3 vs 9+10+11) | (1) | 4.488 | 14.81** |
| C5 = (Sta 1+11+14+15+17 vs 2+9+12+16) | (1) | 0.010 | 0.03 |
| C6 = (Sta 2+9+12+16 vs 3+5+10+13) | (1) | 0.644 | 2.12 |
| C7 = (Sta 4+5+6+7+8 vs 1+2+3+12+13+14+15+16+17) | (1) | 0.524 | 1.73 |
| C8 = (Sta 4+6 vs 15+16+17) | (1) | 0.254 | 0.84 |
| C9 = (Sta 9+11 vs 18) | (1) | 0.356 | 1.17 |
| Error | 630 | 0.303 | |

**Statistically significant at 0.01 probability level

A one-way analysis of variance and Duncan's multiple range tests were utilized to test for significant differences among weeks and subsequently to determine whether weekly mean densities within selected lake areas were statistically different. Weekly mean densities of larval shad within the heated area were significantly different (Table 10.11) and peak densities, which occurred on 28 May, were significantly higher than all other weeks. The mean densities of collections preceding and following 28 May were statistically equal. Larval shad densities within the ambient area were significantly different (Table 10.12); peak density occurred on 4 June at the ambient stations, a week later than at the heated stations. According to statistical treatment of larval tow data,the potential period of peak entrainment for larval shad occurred during a two week period of 28 May and 4 June (Table 10.13). Periods of potential moderate entrainment occurred during the middle of May (14 May and 21 May) and the middle of June (11 June).

Pomoxis (White crappie)

Pomoxis larvae (larvae were not identified to species; however, only P. annularis, white crappie, adults have been reported from Coffeen Lake) were first collected on 7 May from the transitional temperature stations. Surface water temperatures at that time ranged from 17.5 to 18.5°C. Crappie larvae were not collected until one week later (14 May) at the ambient stations, when surface water temperatures were approximately 20°C. Crappie larvae were subsequently collected each week through 11 June. Pomoxis densities were highest on 4 June, the mean of all station means equaled 1.2 larvae/10 $m^3$. Kindschi et al. (1979) collected Pomoxis larvae from 30 April through 25 July and recorded a maximum density (13.0/10 $m^3$) on 6 June from Rough River Lake, Kentucky. Krause and Van Den Avyle (1979) reported that peak densities (1.0/10 $m^3$) occurred in late May in Center Hill Reservoir, Tennessee. Larval Pomoxis were uncommon in collections from Lake Shelbyville (Storck et al. 1978) and were altogether absent from Lake Sangchris ichthyoplankton collections (Bergmann 1981). Thus, from the information available, it appears that the date of peak larval densities in Coffeen Lake were in synchrony with those reported by other investigators.

Table 10.11. One-way analysis of variance and Duncan's multiple range test of weekly mean densities within the heated stations. Dependent variable was gizzard shad densities. All hypotheses were tested using transformed data, but mean densities shown are the antilogs.

---

ANALYSIS OF VARIANCE

| Source | d.f. | Mean Square | F-value |
|---|---|---|---|
| Week | 17 | 1.070 | 20.21* |
| Temperature | 1 | 0.000 | 0.00 |
| Temperature$^2$ | 1 | 0.001 | 0.03 |
| Error | 196 | 0.053 | |

DUNCAN'S MULTIPLE RANGE TEST**

Weeks

| 5/28 | 6/04 | 5/21 | 5/14 | 6/11 | 6/18 | 5/07 | 4/30 | 4/23 | 6/25 | 7/02 | 7/09 | 7/16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Means

| 13.8 | 5.2 | 3.6 | 1.0 | 1.0 | 0.7 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ——— | | | | | | | | | | | | |
| | ——— | ——— | | | | | | | | | | |
| | | | ——— | ——— | ——— | ——— | | | | | | |
| | | | | | ——— | ——— | ——— | | | | | |
| | | | | | | | ——— | ——— | ——— | ——— | ——— | ——— |

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* Statistically significant at 0.001 probability level

** Means underscored by the same line were not significantly different (alpha = 0.05)

Table 10.12. One-way analysis of variance and Duncan's multiple range test of weekly mean densities within the ambient stations. Dependent variable was gizzard shad densities. All hypotheses were tested using transformed data, but mean densities shown are the antilogs.

ANALYSIS OF VARIANCE

| Source | d.f. | Mean Square | F-value |
|---|---|---|---|
| Week | 17 | 3.881 | 46.36* |
| Temperature | 1 | 0.150 | 1.79 |
| Temperature$^2$ | 1 | 0.115 | 1.38 |
| Error | 124 | 0.084 | |

DUNCAN'S MULTIPLE RANGE TEST**

```
                                              Weeks

6/04  5/28  6/11  5/21  6/18  5/14  5/07  6/25  7/02  7/30  4/30  8/13  7/09  4/23  7/16  7/23  8/06  8/20

                                              Means

232.6 99.2  78.1  11.2   3.8   3.7   0.5   0.4   0.1   0.1   0.1   0.1   0.0   0.0   0.0   0.0   0.0   0.0
_____
      __________
                  ____
                        __________
                                    __________________________________________________________________
```

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* Statistically significant at 0.001 probability level

** Means underscored by the same line were not significantly different (alpha = 0.05)

Table 10.13. One-way analysis of variance and Duncan's multiple range test of weekly mean densities within the intake stations. Dependent variable was gizzard shad densities. All hypotheses were tested using transformed data, but mean densities shown are the antilogs.

---

ANALYSIS OF VARIANCE

| Source | d.f. | Mean Square | F-value |
|---|---|---|---|
| Week | 17 | 1.793 | 27.46* |
| Error | 162 | 0.065 | |

DUNCAN'S MULTIPLE RANGE TEST**

Weeks

| 5/28 | 6/04 | 5/21 | 6/11 | 5/14 | 6/18 | 5/07 | 6/25 | 4/30 | 4/23 | 7/02 | 7/09 | 7/16 | 7/23 | 7/30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Means | | | | | | | | | | | | | | |
| 22.8 | 13.8 | 3.3 | 3.0 | 2.4 | 0.9 | 0.8 | 0.4 | 0.1 | 0.03 | 0.03 | 0.0 | 0.0 | 0.0 | 0.0 |
| ——— | ——— | | | | | | | | | | | | | |
| | | ——— | ——— | ——— | | | | | | | | | | |
| | | | | | ——— | ——— | ——— | ——— | | | | | | |
| | | | | | | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |

---

* Statistically significant at 0.001 probability level

** Means underscored by the same line were not significantly different (alpha = 0.05)

A two-way analysis of variance performed on the transformed data demonstrated that larval densities were significantly different among weeks, stations, and that there was a week-station interaction (Table 10.14). A Duncan's multiple range test, performed on station means, indicated that mean crappie density was significantly higher at stations in the ambient area than at stations in the other thermal zones. Furthermore, mean densities of the heated and transitional stations were not significantly different (Table 10.14). Given the small sample size further statistical analysis seemed unwarranted. However, inspection of station means (Table 10.15) yielded further information concerning spatial distribution. *Pomoxis* larvae were not collected from the discharge arm (Stations 1, 2, and 3) of Coffeen Lake and only one specimen was taken from the other three stations located in the heated zone (Stations 12, 13, and 14). The majority of the crappie larvae collected during this study came from two tow sites (Stations 10 and 18), both located in the ambient area of the reservoir. Since larval *Pomoxis* densities were highest in the ambient area of Coffeen Lake, that spawning activity was apparently more intense in that region of the lake.

## Summary

In summary, densities of *Lepomis* spp. and *Dorosoma* larvae in the intake area were not significantly different from densities collected at "non-intake" stations of similar thermal regime, thereby demonstrating that the intake area of the Coffeen Power Station was not an area of high potential impact for those species. The initiation of spawning did not differ greatly between heated and ambient areas of the lake; however, it did appear that duration of spawning was altered at the heated stations. The spatial distribution of larval fishes (*Lepomis* spp., *Dorosoma*, and *Pomoxis*) was apparently affected by the thermal gradient in this lake, as was evidenced by the progressive increase in mean larval densities found at stations more distant from the thermal discharge. The ambient area of Coffeen Lake (that portion of the lake north of the railroad causeway, see Fig. 10.1) supported significantly higher densities of *Lepomis*, *Dorosoma*, and *Pomoxis* and therefore should be considered a major fish nursery area. It is relevant that this nursery area in Coffeen Lake was far removed from the area of cooling water intake so that entrainment effects were minimized.

Table 10.14. Two-way ANOVA and Duncan's multiple range test for density of larval *Pomoxis* sp. Tests were performed using transformed data, but mean densities shown are the antilogs.

ANALYSIS OF VARIANCE

| Source | Degrees of Freedom | Mean Square | F-value |
|---|---|---|---|
| Weeks | 17 | 0.071 | 12.56* |
| Stations | 2 | 0.142 | 25.05* |
| Week-station interaction | 34 | 0.055 | 9.73* |
| Error | 594 | 0.006 | |

DUNCAN'S MULTIPLE RANGE TEST**

| Station | Mean | Grouping*** |
|---|---|---|
| Heated | 0.001 | B |
| Transitional | 0.02 | B |
| Ambient | 0.14 | A |

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* Statistically significant at the 0.001 probability level

** Alpha level = 0.05

*** Means with the same letter are not significantly different

Table 10.15. Mean densities (number/10 m³) of [illegible] sp. larvae collected from [illegible] 23 April to 20 August 1980.

| Station | [illegible] | | | | | | | | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/23 | 4/30 | 5/07 | 5/14 | 5/21 | 5/28 | 6/04 | 6/11 | 6/18 | 6/25 | 7/02 | 7/09 | 7/16 | 7/23 | 7/30 | 8/06 | 8/13 | 8/20 | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 5 | - | - | - | - | 0.3 | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 6 | - | - | 0.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 7 | - | - | - | - | 0.3 | 0.8 | 0.4 | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 8 | - | - | 0.2 | 0.1 | 0.2 | - | 0.1 | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 9 | - | - | - | 0.3 | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 10 | - | - | - | 0.4 | 0.5 | 0.2 | 0.4 | 0.2 | - | - | - | - | - | - | - | - | - | [illegible] |
| 11 | - | - | - | 0.2 | - | 0.3 | 0.4 | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 12 | - | - | - | 0.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | - | - | 0.9 | - | 0.2 | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 16 | - | - | - | 0.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 17 | - | - | - | 0.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | [illegible] |
| 18 | - | - | - | - | - | - | [illegible] | [illegible] | - | - | - | - | - | - | - | - | - | [illegible] |
| Mean | - | - | 0.1 | 0.1 | 0.1 | [illegible] | [illegible] | [illegible] | - | - | - | - | - | - | - | - | - | |

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## SECTION 11

# ABUNDANCE OF LITTORAL FISH LARVAE IN COFFEEN LAKE AS DETERMINED BY LIGHT-TRAPPING

by

Lance G. Perry

## ABSTRACT

Floating larval fish traps were placed in littoral areas in the discharge arm and at mid-lake locations in Coffeen Lake. Two traps were illuminated with fluorescent lighting and two were left dark during nighttime sampling periods. A total of 2,531 larvae, representing five taxonomic groups, were collected. *Lepomis* spp. larvae were most abundant in trap samples, comprising 98.3% of the total numerical catch. Lighted trap catches accounted for 99.8% of the total suggesting that illumination served as an effective attractant at night, particularly for *Lepomis* larvae. Light-trapping was ineffective for capturing larvae of the largemouth bass, a species which is not frequently encountered with conventional larval fish sampling methods.

## INTRODUCTION

In conjunction with investigations of larval fish ecology in Coffeen Lake (Section 10, herein), a light-trapping technique was employed to determine the effectiveness of this method for capturing larvae, such as those of the largemouth bass, which are not representatively sampled by more conventional methods. Tow-nets and benthic sleds are of little utility in heavily-structured littoral regions where many fish larvae congregate. Consequently, this investigation was conducted to collect littoral fish larvae with stationary, portable traps, and to evaluate the effectiveness of trap illumination as an attractant during periods of darkness.

## MATERIALS AND METHODS

Four plexiglass traps were constructed according to the design of Breder (1960) as described in Bagenal and Braum (1978). The traps were modified from that design by enlarging the sampler size. Approximate dimensions of the box component were: 25.5 cm deep, 25.5 cm wide, and 39.0 cm long. The guide wings were 15.5 cm deep, 102.0 cm long, and tapered to form an aperture 1 cm in width. A portable, fluorescent light was attached to the top panel of the box, which was removable. Each light was powered by a 6-volt , rechargable battery and was designed for 12h of continuous operation on a full charge. Styrofoam blocks were attached to the outside of each wing and to the back panel of the box to provide buoyancy. In operation, the trap remained suspended in the water column, extending to a depth of 20 cm below the surface with the top 5 cm remaining above the surface. A fine-mesh net which fit flush over the aperture was used to collect specimens as the trap was lifted out of the water, allowing the contents to flow out the aperture and through the net. Water remaining after that procedure was poured through the net by inverting the trap.

four traps were set once weekly from 5 May to 30 June 1980. Each was placed in littoral areas near vegetational or woody cover. Two traps were placed in discharge arm coves and two in coves at mid-lake locations (Fig. 13.1, Section 13, herein). Traps were set at 2100h, one illuminated (light on) and one dark (light off) at each location. Specimens from each trap were collected and preserved (10% formalin) at 0800h, thus approximately 12h of nighttime sampling effort per trap. Identification procedures followed those given in Section 10, herein.

## RESULTS AND DISCUSSION

A total of 2,531 larval fishes, representing five taxonomic groups, were collected in larval traps. Included were gizzard shad (Dorosoma cepedianum), golden shiner (Notemigonus chrysoleucas), blackstripe topminnow (Fundulus notatus), largemouth bass (Micropterus salmoides), and sunfishes (Lepomis spp.). Sunfishes were collected in large numbers (98.3% of the total catch) but other species were comparatively few in number (Table 11.1). All specimens were larvae in the sense that fin development, and attainment of other juvenile characteristics, had not been completed (Blaxter 1969). Golden shiner larvae and most of the larval sunfishes had traces of yolk material remaining, indicating that they were captured soon after hatching. Larval gizzard shad and largemouth bass were nearing completion of the juvenile form at the time of capture.

Several golden shiner larvae were captured on the first day of trapping (5 May) at the mid-lake location but traps located in the discharge were empty (Table 11.1). Largemouth bass were first collected on 12 May in the discharge and on 26 May at mid-lake, but they were never common in trap samples. June collections primarily consisted of Lepomis spp. larvae, and they occasionally were found in high numbers (Table 11.1).

The effectiveness of illumination as an attractant at night was evident upon examination of the data since the vast majority of catches (99.8% of total) occurred in lighted traps (Table 11.1). Only catches of sunfishes were of sufficient magnitude to draw conclusions, however. Other species were rare in comparison and may have only represented incidental catches. Sunfishes presumably exhibit a positive phototactic response soon after hatching and thus were susceptible to capture by the trapping method employed in this study. They were first encountered in the discharge arm and were generally more abundant in trap samples from that location (Table 11.1). Newman (Section 10, herein) first collected larval Lepomis spp. in tow-nets on 23 April in the discharge area of Coffeen Lake; their occurrence in the ambient area was about four weeks later which generally corresponded with the timing of Lepomis spp. catches in trap samples from the discharge. Tow-net catches (Section 10) suggested a greater density of Lepomis spp. larvae in thermal transition areas (mid-lake) compared to heated areas, a result which was not supported by the trapping data.

Gizzard shad larvae were found to be abundant in the lake as judged by tow-net catches (Section 10, herein), but they were encountered most often in limnetic regions. Their rarity in trap samples may thus reflect a low density in littoral regions. Largemouth bass, however, are known to occupy littoral areas early in life. Their infrequent occurrence in trap samples probably was related to the early life history strategy of this species. As larvae, largemouth bass are a strong-schooling, parentally-guarded species (Heidinger 1975) and they have been shown to exhibit a nocturnally-inactive behavior and a tendency to remain near the nest site during most of the larval period (Elliott 1976). Since only developmentally advanced larvae were encounted in this study, it is assumed that they had dispersed from the school and assumed an independent existence at the time of capture. Shoreline seining would probably provide better estimates of bass abundance and distribution at that stage of development.

Light trapping has been used successfully by others to capture larval fishes. Kindschi et al. (1979) collected 1,445 larval and juvenile fishes in lighted traps, of which 80% were sunfishes, while no fish were collected in unlighted traps. Faber (D. J. Faber, pers. comm.) also found that light trapping at night in littoral regions was a useful method of determining the distribution of a wide-variety of freshwater species.

Table 11.1. Number of fish larvae collected in traps (light or dark) at weekly intervals in Coffeen Lake. Date of collections, trap locations, and species letter codes (G=golden shiner, B=largemouth bass, L=*Lepomis* spp., S=gizzard shad, and T=blackstripe topminnow) are given.

| Date | Discharge | | Mid-lake | |
|---|---|---|---|---|
| (1980) | Light | Dark | Light | Dark |
| 5 May | - | - | 8 (G) | - |
| 12 May | 5 (B) | - | 1 (G) | - |
| 19 May | 1 (L) | - | 4 (G) | - |
| 26 May | 1 (L)<br>1 (S) | 0 | 2 (B) | - |
| 2 June | 1238 (L) | - | 1 (B) | - |
| 9 June | 245 (L)<br>1 (S) | -<br>- | 392 (L)<br>6 (S)<br>3 (B)<br>1 (T) | 1 (B) |
| 16 June | 302 (L)<br>3 (S) | -<br>- | 17 (L)<br>1 (B) | 1 (B)<br>1 (L) |
| 23 June | 227 (L) | - | 52 (L) | 3 (L) |
| 30 June | 9 (L) | - | 2 (L)<br>2 (S) | - |

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## SECTION 12

## IMPINGEMENT AND ENTRAINMENT

by

Dennis L. Newman

## ABSTRACT

A one-year impingement and entrainment study was conducted to assess the impact of the Coffeen Power Station's cooling water intake system upon the ichthyofauna of Coffeen Lake. Impingement sampling consisted of 69 24-hour surveys conducted weekly during the warmer months and twice weekly from late autumn to early spring. A total of 7,477 fish weighing 109.2 kg were collected; gizzard shad and bluegill comprised 97% numerically and 90% by weight of the total impingement sample. Impingement rates were highest during the coldest months of the year; 83% of the total impingement sample was taken during January, February, and March. Mortality due to impingement incurred only minor losses to the Coffeen Lake fishery. White crappie populations suffered the greatest percent loss to the standing crop, 3.4% numerically and 1.6% by weight. Losses to the bluegill and gizzard shad populations were small and further reductions were deemed advantageous. The condition (KTL) of impinged fish (gizzard shad and bluegill) was significantly (P 0.05) lower than the condition of similar sized fish collected by electrofishing indicating that the impingement process was selectively eliminating fish which were in poor body condition.

The primary entrainment sampling methodology incorporated two low-volume pump sampling systems operated on a 24-hour basis. A total of 3,430 larval fishes were collected in entrainment sampling conducted from 25 April through 9 September; nearly 84% of those larvae were gizzard shad. Peak entrainment density occurred on 12-13 June when 18.05 larvae were collected per $10m^3$ of water sampled. A conservative evaluation of entrainment mortality was calculated using a weekly "instantaneous standing crop" of larval fishes in the reservoir. Percent loss to the larval gizzard shad standing crop ranged

from 0.04 to 13.3%, but entrainment mortality only amounted to 1.4% when standing crop was at a maximum. Losses to the Lepomis spp. standing crop ranged from 0.05 to 8.6%. These losses appear minimal given the natural mortality rate of larvae of these species.

# INTRODUCTION

Section 316(b) of the Federal Water Pollution Control Act of 1972, PL 92-500, requires "that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." Thus, Section 316(b) specifically refers to the impingement and entrainment of aquatic organisms at cooling water intake structures.

Entrainment involves planktonic and nektonic organisms small enough to pass through the intake screens. As these organisms travel through the cooling system they are subjected to multiple stresses (Kelso and Milburn 1979). The principal causes of damage are mechanical (pressure changes and physcial abrasions), biocidal, and thermal stresses. Impingement refers to the blocking of larger organisms against the travelling intake screens. Extensive reviews concerning impingement losses and impacts at inland water locations have been written by Freeman and Sharma (1977) and Kelso and Milburn (1979).

A one-year study was conducted to assess the ecological impact of the Coffeen Power Station's cooling water intake system upon the ichthyofauna of Coffeen Lake. Some investigators have attempted to assess adverse impact without baseline data on existing populations. The present study was conducted in synchrony with a three-year investigation of all major biotic categories in Coffeen Lake. In addition, quantitiative ichthyoplankton collections were made during the 1980 spawning season (Section 10, herein). The purpose of this investigation was to utilize that broad data base to determine the impact of entrainment and impingement upon the Coffeen Lake fishery.

## PLANT DESCRIPTION

Coffeen Power Station located in Montgomery County, Illinois is owned and operated by Central Illinois Public Service Company. Two generating units, both coal-fired, produce a gross capacity of 945 MeW. However, both units at Coffeen have experienced low annual capacity factors in comparison to industry averages (CIPS 1977). Unit 1 (350 GMeW) and Unit 2 (595 GMeW) were put into commercial service in 1965 and 1972, respectively. Life expectancy for both units was projected to be 30 years.

Water for the once-through or open-cycle cooling system is derived from Coffeen Lake, a 446 hectare reservoir. Intake water is provided by four circulating water pumps and four low pressure service pumps (see Tables 12.1 and 12.2). The intake structure is partitioned into three equal-sized bays (Fig. 12.1). Figure 12.2 illustrates the horizontal spacing of cooling water intakes in relation to the intake bays. The zone of intake water withdrawal is not limited; there is no skimmer wall (Fig. 12.3). Circulating water intake pipes are located near the lake bottom; the center of each pipe is 36.5 ft. below normal pool.

The vertical travelling screens (mesh 0.95 cm) are designed to protect pumps and condenser equipment from damage. These six travelling screens (see Tables 12.1 and 12.2) are the site where larger aquatic organisms are impinged. Under normal operating procedure the travelling screens are backwashed once during each 8-hour shift. Fish and debris are washed into a sluiceway which then empties into the "fish trap" (Fig. 12.1). For purposes of this study a 0.95-cm mesh screen was placed over the existing screen in the fish trap. There is no fish bypass system; fish which collect in the fish trap are disposed of by CIPS maintenance personnel.

The terminal portion of the ice melting line or intake deicing system is depicted in Figures 12.1 and 12.3. Recirculated warm water may be released from these lines, approximately 20 ft. below normal pool water level. This system was not used during the winter of 1979-80.

Table 12.1. Salient physical characteristics of Coffeen Power Station (Unit 1) cooling water intake system.

| Item | Characteristics |
|---|---|
| Circulating water pumps | |
| type | vertical, dry pit, one stage |
| number | 2 |
| capacity (each) | 73,250 gpm |
| total head | 54 ft. |
| drivers | 1250 hp, 277 rpm |
| Low pressure service water pumps | |
| type | single stage horizontal, centrifugal |
| number | 2 |
| capacity (each) | 9000 gpm |
| total head | 130 ft. |
| drivers | 350 hp, 1200 rpm |
| Screen wash pumps | |
| number | 2 |
| capacity (each) | 630 gpm |
| developed head | 140 ft. |
| Travelling screens | |
| number | 2 |
| speeds | 10 fpm/2.5 fpm |
| basket width | 10'-0" |
| Condenser | |
| type | two shell, horizontal, two pass, divided water boxes |
| surface | 220,000 sq. ft. |
| tube size | 1" O.D. |
| designed temp. rise | 22° F |

Table 12.2. Salient physical characteristics of Coffeen Power Stations (Unit 2) cooling water intake system.

| Item | Characteristics |
|---|---|
| Circulating water pumps | |
| type | vertical, dry pit, one stage |
| number | 2 |
| capacity (each) | 126,500 gpm |
| total head | 54 ft. |
| drivers | 2000 hp, 240 rpm |
| Low pressure service water pump | |
| type | single stage horizontal, centrifugal |
| number | 2 |
| capacity (each) | 21,000 gpm |
| total head | 140 ft. |
| drivers | 900 hp, 900 rpm |
| Screen wash pumps | |
| number | 2 |
| capacity (each) | 1260 gpm |
| developed head | 130 ft. |
| Travelling screens | |
| number | 4 |
| speeds | 10 fpm/2.5 fpm |
| basket width | 10'-0" |
| Condenser | |
| type | two shell, horizontal, two pass, divided water boxes |
| surface | 330,000 sq. ft. |
| tube size | 1" O.D. |
| designed temp. rise | 22° F |

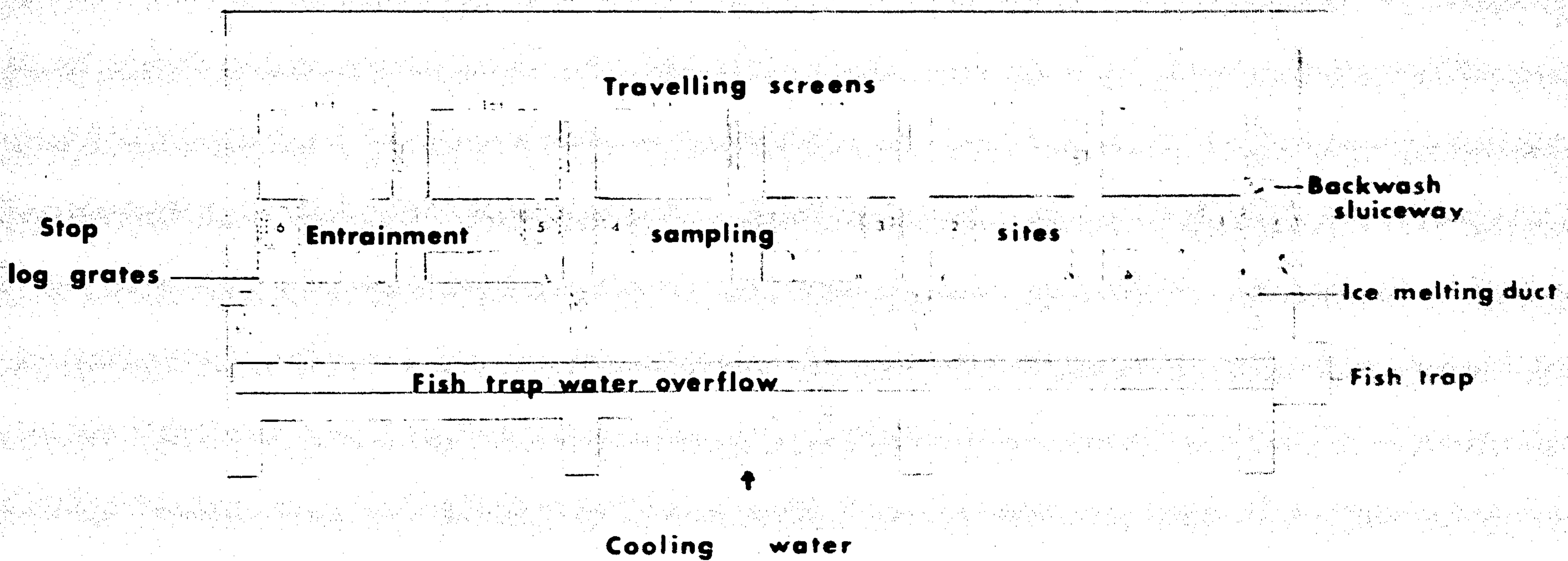

Figure 12.1 Top view of the Coffeen Power Station cribhouse showing the sampling sites (grates 1-6) for primary entrainment sampling and also showing the fish trap where impinged fish were collected.

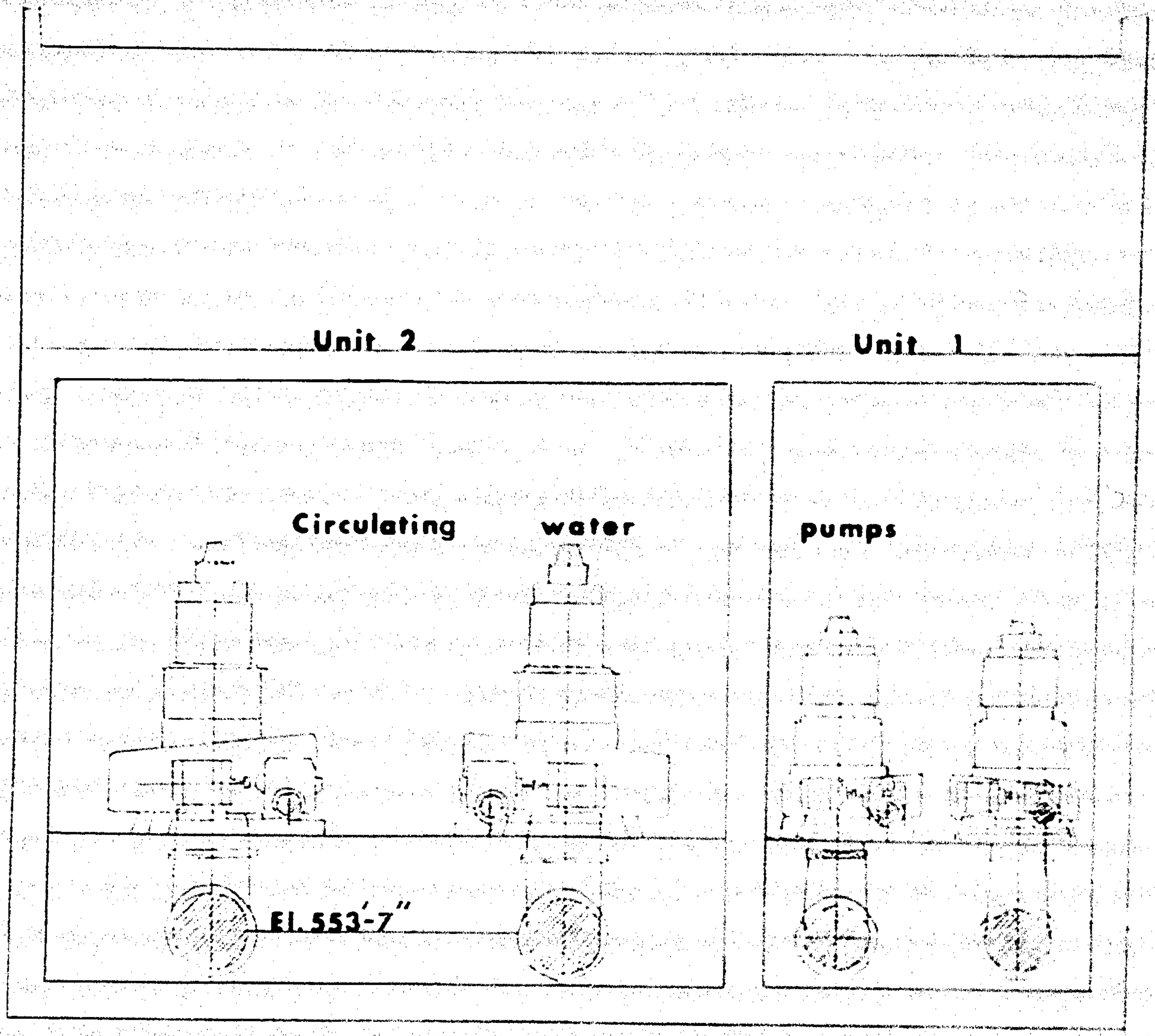

Figure 12.2 Front view of the Coffeen Power Station cribhouse depicting the location of the circulating water pumps and their intakes.

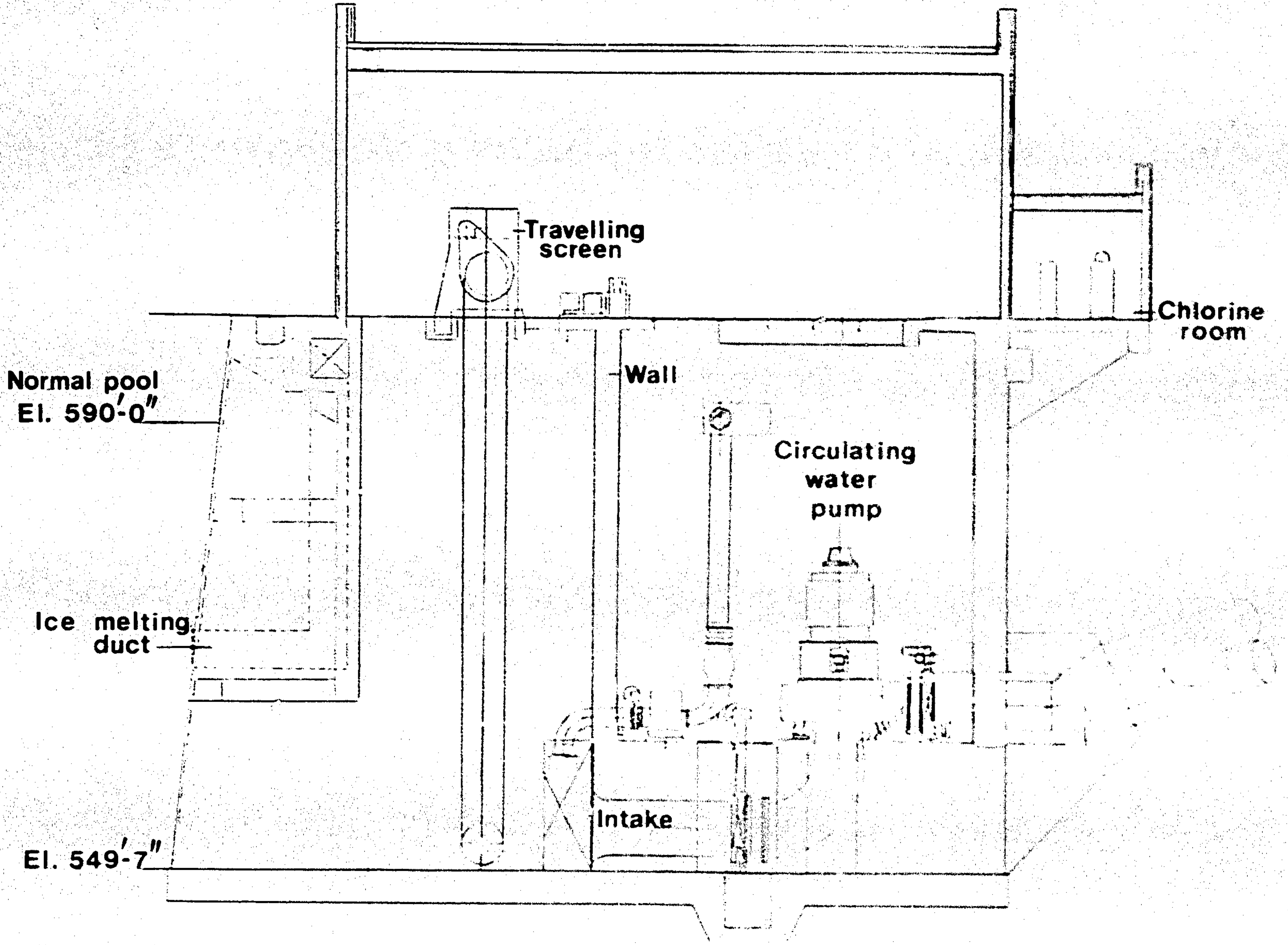

Figure 12.3 Side view of the Coffeen Power Station cribhouse showing the location and depth of the circulating water intakes, as well as the vertical travelling screens.

## IMPINGEMENT

### MATERIALS AND METHODS

The impingement study consisted of 69, 24-hour samples; this number approximated the 20 percent (of 365 days) minimum sampling intensity recommended by Murarka et al. (1977). Samples were collected at weekly intervals in October, November, May, June, July, August, September, and the latter half of April. During December, January, February, March, and the first half of April, sampling was increased to twice weekly. Periods of increased sampling effort corresponded to periods of expected high impingement rates.

Impinged fish were identified, counted, measured (total length), and weighed (grams). When the number of individuals for a given species exceeded 100, the total number of fish was counted, the total weight determined and a subsample taken for individual lengths and weights. The size of the random subsample depended upon the total count.

Each 24-hour survey consisted of backwashing all travelling screens and removing all fish from the "fish trap" to initiate the collection and repeating the procedure 24 hours later when the sample was obtained. Natural History Survey biologists were present during each of these processes. Specimens from impingement samples which had obviously been dead longer than 24 hours were excluded from analysis. Water temperature, dissolved oxygen and the number of circulating and low pressure service water pumps in operation were recorded during each survey. Monthly impingement estimates were calculated from the formula:

$$\text{Estimated monthly impingement} = \frac{\text{Number of fish in monthly samples}}{\text{Number of surveys per month}} \times \text{Days in month}$$

## RESULTS AND DISCUSSION

A total of 2,477 fish weighing 109.2 kg were collected in 69 impingement surveys conducted from November 1979 through October 1980 (Table 12.1). Gizzard shad (*Dorosoma cepedianum*) dominated impingement samples both numerically and by weight (Table 12.3). Gizzard shad and bluegill (*Lepomis macrochirus*) combined comprised 97 percent numerically and 90 percent by weight of the total impingement sample. Noticeably uncommon in the impingement surveys were the two principal sportfish of Coffeen Lake, largemouth bass (*Micropterus salmoides*) and channel catfish (*Ictalurus punctatus*). Other fishes taken in impingement surveys included: white crappie (*Pomoxis annularis*), orangespotted sunfish (*L. humilis*), hybrid sunfish (*Lepomis* spp.), green sunfish (*L. cyanellus*), and black bullhead (*Ictalurus melas*). Twenty one fish species have been collected from Coffeen Lake by the Natural History Survey since sampling began in September 1978 (Section 13, herein). Carp (*Cyprinus carpio*) and longear sunfish (*L. megalotis*), two species commonly collected during regular fish population surveys were not found in any of the 69 impingement samples.

An examination of monthly impingement samples (Table 12.4) it revealed that impingement rates fluctuated with the seasons. Impingement rates were highest during the coldest months of the year; 83 percent of the total impingement occurred during January, February and March. Mean water temperatures at the intake during those months were consistently below 10°C and the lowest mean temperature recorded was 5.8°C (Appendix 12.1). In a nationwide review of impingement at inland sites, Freeman and Sharma (1977) concluded that high impingement rates during winter months were due to the poikilothermic nature and high mortality of shad at low ambient temperatures. Impingement data from the Coffeen Power Station supported that conclusion; gizzard shad comprised a larger percentage of the impingement sample during January, February, and March than during any other months. Gizzard shad were especially predominant in February, a period of consistently low water temperatures. Impingement rates were extremely low during the autumn (September, October and November); approximately two fish per survey were collected. Impingement rates were somewhat higher in the spring (April, May and June), probably as a result of the high densities of juvenile shad and bluegill present at that time. Seasonal fluctuations in

Table 12.3. Numbers and weights (grams) of fish collected in 69 impingement surveys at Coffeen Generating Station from November 1979 through October 1980.

| Taxa | No. | % No. | Wt. | % Wt. |
|---|---|---|---|---|
| Gizzard shad | 6,903 | 92.3 | 95,112 | 87.1 |
| Bluegill | 373 | 5.0 | 3,405 | 3.1 |
| White crappie | 107 | 1.4 | 5,923 | 5.4 |
| Orangespotted sunfish | 35 | 0.5 | 572 | 0.5 |
| Unidentified Sunfish | 21 | 0.3 | 1 | * |
| Channel catfish | 12 | 0.2 | 1,051 | 1.0 |
| Largemouth bass | 9 | 0.1 | 2,652 | 2.4 |
| Unidentified fishes | 7 | 0.1 | 1 | * |
| Hybrid Sunfish | 6 | 0.1 | 207 | 0.2 |
| Green Sunfish | 2 | * | 102 | 0.1 |
| Black Bullhead | 2 | * | 140 | 0.1 |
|  | 7,477 | 100.0 | 109,166 | 99.9 |

*denotes less than 0.1

Table 12.4. Numbers and weights (grams) of fish from 24-nour impingement surveys at Coffeen Power Station. Numbers in parentheses represent the number of 24-hour surveys in each month.

| Species | November 1979 (4) | | | | December 1979 (8) | | | | January 1980 (9) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Wt. | % | No. | % | Wt. | % | No. | % | Wt. | % |
| Gizzard Shad | 2 | 40.0 | 29 | 6.5 | 285 | 92.8 | 5,505 | 85.3 | 864 | 95.5 | 14,015 | 88.3 |
| Bluegill | 1 | 20.0 | 31 | 7.0 | 18 | 5.9 | 384 | 5.9 | 17 | 1.9 | 300 | 1.9 |
| White Crappie | -- | | -- | | 4 | 1.3 | 567 | 8.8 | 8 | 0.9 | 1,231 | 7.7 |
| Orangespotted Sunfish | -- | | -- | | -- | | -- | | 16 | 1.8 | 327 | 2.1 |
| Channel Catfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Largemouth Bass | 1 | 20.0 | 244 | 55.1 | -- | | -- | | -- | | -- | |
| Hybrid Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Green Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Unidentified Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Black Bullhead | 1 | 20.0 | 139 | 31.4 | -- | | -- | | -- | | -- | |
| Unidentified fishes | -- | | -- | | -- | | -- | | -- | | -- | |
| | 5 | 100 | 443 | 100 | 307 | 100 | 6,456 | 100 | 905 | 100.1 | 15,873 | 100.0 |

Table 12.4. Numbers and weights (grams) of fish from 24-hour impingement surveys at Coffeen Power Station. Numbers in parentheses represent the number of 24-hour surveys in each month. (continued)

| Species | February 1980 (9) | | | | March 1980 (8) | | | | April 1980 (6) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Wt. | % | No. | % | Wt. | % | No. | % | Wt. | % |
| Gizzard Shad | 2,646 | 97.6 | 35,053 | 94.4 | 2,437 | 93.7 | 31,938 | 90.1 | 33 | 50.0 | 529 | 35.9 |
| Bluegill | 47 | 1.7 | 798 | 2.1 | 139 | 5.3 | 3,218 | 9.1 | 26 | 39.4 | 578 | 39.3 |
| White Crappie | 6 | 0.2 | 769 | 2.0 | 15 | 0.6 | 208 | 0.6 | 3 | 4.5 | 298 | 20.1 |
| Orangespotted Sunfish | 5 | 0.2 | 127 | 0.3 | 7 | 0.3 | 47 | 0.1 | 3 | 4.5 | 23 | 1.6 |
| Channel Catfish | 4 | 0.2 | 341 | 0.9 | 3 | 0.1 | 17 | 0.02 | -- | | -- | |
| Largemouth Bass | 1 | 0.04 | 15 | 0.04 | -- | | -- | | -- | | -- | |
| Hybrid Sunfish | 3 | 0.1 | 75 | 0.2 | -- | | -- | | 1 | 1.5 | 45 | [illegible] |
| Green Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Unidentified Sunfish | -- | | -- | | -- | | -- | | -- | | | |
| Black Bullhead | -- | | -- | | -- | | -- | | -- | | | |
| Unidentified fishes | -- | | -- | | -- | | -- | | -- | | | |
| | 2712 | 100.0 | 38,178 | 99.9 | 2,601 | 100.0 | 35,428 | 99.9 | 66 | [illegible] | [illegible] | [illegible] |

Table 12.4. Numbers and weights (grams) of fish from 24-hour impingement surveys at Coffeen Power Station. Numbers in parentheses represent the number of 24-hour surveys in each month. (continued)

| Species | May 1980 (4) | | | | June 1980 (4) | | | | July 1980 (5) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Wt. | % | No. | % | Wt. | % | No. | % | Wt. | % |
| Gizzard Shad | 35 | 38.0 | 740 | 30.7 | 17 | 22.4 | 324 | 22.7 | 14 | 24.6 | 32 | 2.5 |
| Bluegill | 42 | 45.6 | 832 | 34.5 | 21 | 27.6 | 722 | 50.6 | 12 | 21.0 | 399 | 30.6 |
| White Crappie | 9 | 9.8 | 703 | 29.1 | 10 | 13.2 | 379 | 26.6 | 24 | 42.1 | 636 | 48.8 |
| Orangespotted Sunfish | 4 | 4.3 | 48 | 2.0 | -- | | -- | | -- | | -- | |
| Channel Catfish | -- | | -- | | -- | | -- | | 3 | 5.3 | 221 | 17.0 |
| Largemouth Bass | -- | | -- | | -- | | -- | | 3 | 5.3 | 13 | 1.0 |
| Hybrid Sunfish | 2 | 2.2 | 89 | 3.7 | -- | | -- | | -- | | -- | |
| Green Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Unidentified Sunfish | -- | | -- | | 21 | 27.6 | 1.0 | 0.1 | -- | | -- | |
| Black Bullhead | -- | | -- | | -- | | -- | | 1 | 1.8 | 1.0 | 0.1 |
| Unidentified fishes | -- | | -- | | 7 | 9.2 | 1.0 | 0.1 | -- | | -- | |
| | 92 | 99.9 | 2,412 | 100.0 | 76 | 100.0 | 1,427 | 100.1 | 57 | 100.1 | 1,302 | 100.0 |

Table 12.4. Numbers and weights (grams) of fish from 24-hour impingement surveys at Coffeen Power Station. Numbers in parentheses represent the number of 24-hour surveys in each month. (continued)

| Species | August 1980 (4) | | | | September 1980 (4) | | | | October 1980 (4) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Wt. | % | No. | % | Wt. | % | No. | % | Wt. | % |
| Gizzard Shad | 567 | 89.1 | 900 | 29.5 | -- | | -- | | 3 | 25 | 43 | 3.0 |
| Bluegill | 43 | 6.8 | 1,083 | 35.5 | 4 | 50 | 53 | 3.5 | 3 | 25 | 7 | 0.4 |
| White Crappie | 22 | 3.5 | 497 | 16.3 | 2 | 25 | 155 | 10.3 | 4 | 33 | 430 | 29.7 |
| Orangespotted Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Channel Catfish | 2 | 0.3 | 472 | 15.4 | -- | | -- | | -- | | -- | |
| Largemouth Bass | -- | | -- | | 2 | 25 | 1,298 | 86.2 | 2 | 17 | 1,082 | 67.0 |
| Hybrid Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Green Sunfish | 2 | 0.3 | 102 | 3.3 | -- | | -- | | -- | | -- | |
| Unidentified Sunfish | -- | | -- | | -- | | -- | | -- | | -- | |
| Black Bullhead | -- | | -- | | -- | | -- | | -- | | -- | |
| Unidentified fishes | -- | | -- | | -- | | -- | | -- | | -- | |
| | 636 | 100.0 | 3,054 | 100.0 | 8 | 100.0 | 1,506 | 100.0 | 12 | 100.0 | 1,617 | 100.0 |

in impingement rates did not appear to be linked to fluctuations in the cooling water flow rate (Appendix 12.1). Edwards et al. (1976) demonstrated that impingement rates could not be explained on the basis of intake velocity. Rather, it appears that certain environmental factors such as water temperature and sky cover are better predictors of variations in impingement rates (Lifton and Storr 1977). Porak and Tranquilli (1981) noted that high impingement rates by the Kincaid Generating Station at Lake Sangchris seemed to be associated with low water temperatures. At Coffeen Power Station mean water temperatures at the intake were negatively correlated (r = -0.595, 0.1% level) with impingement rates. The model used to describe the correlation accounted for 35 percent ($r^2 = 0.354$) of the variation observed. Impingement rates may also be linked to extremely high water temperatures. Numbers of fish impinged increased in August (Table 12.4) as mean water temperatures at the intake remained above 32°C and surface water temperatures exceeded 35°C.

Estimated annual impingement by species for the period November 1979-October 1980 is presented in Table 12.5. Annual impingement losses appeared to be minimal and would not be expected to detrimentally impact the Coffeen Lake fishery. Data presented in Table 12.6 describe the impact of annual impingement at Coffeen Power Station in terms of percent loss to the standing crop of fishes in Coffeen Lake. This was accomplished by utilizing fish standing crop estimates derived from four cove rotenone samples (Section 14, herein). Mortality due to impingement incurred losses to the fish populations of Coffeen Lake ranging from 0.04-1.6% by weight and 0.03-3.4% by number.

From a fisheries management perspective a much more substantial reduction in the standing crop of gizzard shad and bluegill would certainly be considered advantageous (Carlander 1955, Jenkins 1957, Parker 1958, Smith 1958, Anderson 1973). Bluegill from Coffeen Lake were stunted and consequently very few individuals reach "minimum quality length" as defined by Anderson (1978). Gizzard shad serve as the primary forage species in Coffeen Lake; however, it appeared that they grew beyond usable length by the middle of their second summer. Anderson (1973) recommended low to intermediate adult gizzard shad biomass densities (27 to 90 kg/ha) in order to achieve a balanced fish community.

Table 12.5. Estimated annual impingement at the Coffeen Power Station, November 1979 through October 1980.

| Taxa | Numbers | Weight (g) |
|---|---|---|
| Gizzard shad | 27,131 | 328,104 |
| Bluegill | 1,898 | 43,866 |
| White crappie | 646 | 32,179 |
| Orangespotted sunfish | 144 | 2,204 |
| Largemouth bass | 60 | 20,079 |
| Channel catfish | 59 | 6,193 |
| Others | 268 | 2,999 |
|  | 30,206 | 435,624 |

Table 12.6. Estimated impact on the standing crop of fishes in Coffeen Lake due to impingement mortality by the Coffeen Power Station. Percent loss (weight and numbers) = estimated annual impingement (Table 8.5)/standing crop x 446 hectares.

| Species | Average standing crop (N=4) | | Percent loss | |
|---|---|---|---|---|
| | kg/ha | no./ha | wt. | no. |
| Gizzard shad | 267.5 | 10,197 | 0.3 | 0.6 |
| Bluegill | 52.1 | 2,245 | 0.2 | 0.2 |
| White crappie | 4.5 | 42 | 1.6 | 3.4 |
| Orangespotted sunfish | 2.2 | 188 | 0.2 | 0.2 |
| Largemouth bass | 7.7 | 255 | 0.6 | 0.05 |
| Channel catfish | 34.5 | 460 | 0.04 | 0.03 |

A comparison of estimated annual impingement at Coffeen Power Station with two other electrical generating stations located in central Illinois is presented in Table 12.7. All three power plants are coal-fired and withdraw cooling water from an adjacent cooling water reservoir. Total impingement was substantially lower at Coffeen than at either Kincaid or Dallman Power Stations. Kelso and Milburn (1979) found a correlation between generating capacity and annual impingement when various Great Lakes power stations were compared. That relationship was not found in this example; other factors (intake design, density of fishes with a propensity toward impingement and the degree to which fishes were attracted to the intake) were evidently more important. Lake surface area was included in Table 12.7 in order to give some indication of the relative impact of differing impingement losses. Bennett (1970) concluded that surface area was a better predictor of the carrying capacity of a body of water than either volume or depth.

As a means to further evaluate the impingement process at Coffeen Power Station, the coefficient of condition, (KTL) (Carlander 1969), of impinged fish was compared to (KTL) of fish collected by electrofishing in the intake cove. Mean (KTL) factors were tested (t-test) for species collected approximately the same day. Mean lengths of those groups compared for condition values were first tested (t-test) for statistical equality ($P<0.05$). In all cases, condition of impinged fish was significantly ($P<0.001$) lower than condition of fish collected by electrofishing (Table 12.8). These data implied that impinged fish were in poor body condition prior to being impinged, consequently their susceptibility to the impingement process may have been increased. Thus, the impingement process was selectively eliminating fish which were already stressed or weakened. Similar findings have been reported by Geo-Marine (1980) and Porak and Tranquilli (1981).

Certain operational anomalies existed during the study period which may have contributed to a slight underestimation of impingement rates. Carry-over of fish was observed for all travelling screens but in varying degrees. Fish could not be removed from the screens and the magnitude of the problem could not be quantified. The bulk of the carry-over problem was limited to one of six intake screens; CIPS personnel rectified the situation by cleaning the jet sprayers on

Table 12.7. A comparison of estimated annual impingement at three electrical generating stations located in central Illinois.

| Location | Annual Impingement | | GMeW | Lake surface area |
|---|---|---|---|---|
| | Number | Weight | | |
| Coffeen Power Station<br>Coffeen Lake | 30,206 | 435.6 kg | 945 | 446 ha |
| Kincaid Power Station*<br>Lake Sangchris | 158,853 | 3,062.8 kg | 1,232 | 876 ha |
| Dallman Power Station†<br>Lake Springfield | 995,501 | 8,498.0 kg | 360 | 1,713 ha |

*Porak and Tranquilli (1981)
†Geo-Marine (1980)

Table 12.8. Comparison of condition [K(TL)] of fish impinged at the Coffeen Generating Station to those collected by electrofishing in the intake cove.

| Date | Sample Size (N) Shock | Sample Size (N) Impinged | Mean K(TL) Shock | Mean K(TL) Impinged | t-value |
|---|---|---|---|---|---|
| | | Gizzard Shad | | | |
| 28 Nov. 1979 | 53 | 54 | 0.727 | 0.518 | 9.89* |
| 18 Jan. 1980 | 27 | 27 | 0.943 | 0.496 | 9.33* |
| 25 Mar. 1980 | 12 | 15 | 0.704 | 0.506 | 9.11* |
| 30 May 1980 | 25 | 23 | 0.918 | 0.541 | 10.90* |
| | | Bluegill | | | |
| 25 Mar. 1980 | 16 | 16 | 1.448 | 1.218 | 4.17* |

*Statistically significant at 0.001 probability level.

that screen on 26 February 1980. A second anomaly concerned the inoperability of travelling screen number one (Unit 1) during the initial 189 days of the 365 day impingement study. Since stop-logs were positioned in front of that travelling screen, and no water was pumped through that area, the resultant 1/6th reduction in intake screen surface area may have translated into some reduction in impingement rates.

# SECTION 12

# ENTRAINMENT

## MATERIALS AND METHODS

Three methods of sampling were employed to study the entrainment of fish larvae and eggs at Coffeen Power Station. The primary method incorporated two sampling systems as depicted in Figure 12.4. The pumps were low volume centrifugal pumps (2 hp., electric) with a capacity of 0.44 $m^3/s$ at 3.05 m of head. Water was pumped through 3.81 cm (diameter) reinforced hose from the intake bay into a plankton net (mesh size 0.505 mm) suspended in a 55-gallon drum. The water level in the barrel was maintained such that the discharge hose remained submerged. The volume of each sample was measured by water meters (Rockwell model W-160 DR) placed at the terminal portion of both sampling systems. Twenty-four hour samples were collected twice each week from 5 May to 11 July 1980; from 14 July to 8 September samples were collected at weekly intervals. Samples were taken through the six grate openings located immediately in front of the travelling screens (Fig. 12.1). To conduct a 24-hour survey both pump samplers were assembled in front of the same circulating water pump (one which was operating) but at different grate openings. During each 24-hour survey, the two samples were pumped from two different depths. Samples were preserved in 10% formalin (with rose bengal), sorted and stored in vials containing 5% formalin. Larvae were counted and identified to the lowest possible taxon using the most recent keys available. Fish eggs were counted but not identified to a taxonomic level. Larvae and eggs were expressed as numbers per 10 $m^3$ of water sampled.

The second sampling method involved towing paired plankton nets during daylight hours at weekly intervals from 26 March to 20 August 1980. Five tows were made in the intake cove, with each tow beginning immediately in front of the intake structure. Table 10.1 (see Section 10, herein) gives further explanation as to depth and duration of each tow. Ichthyoplankton tows in the area of the intake have been found to yield a more accurate assessment of entrainment than either stationary nets or in-line taps (Lee F. Graser, pers. comm).

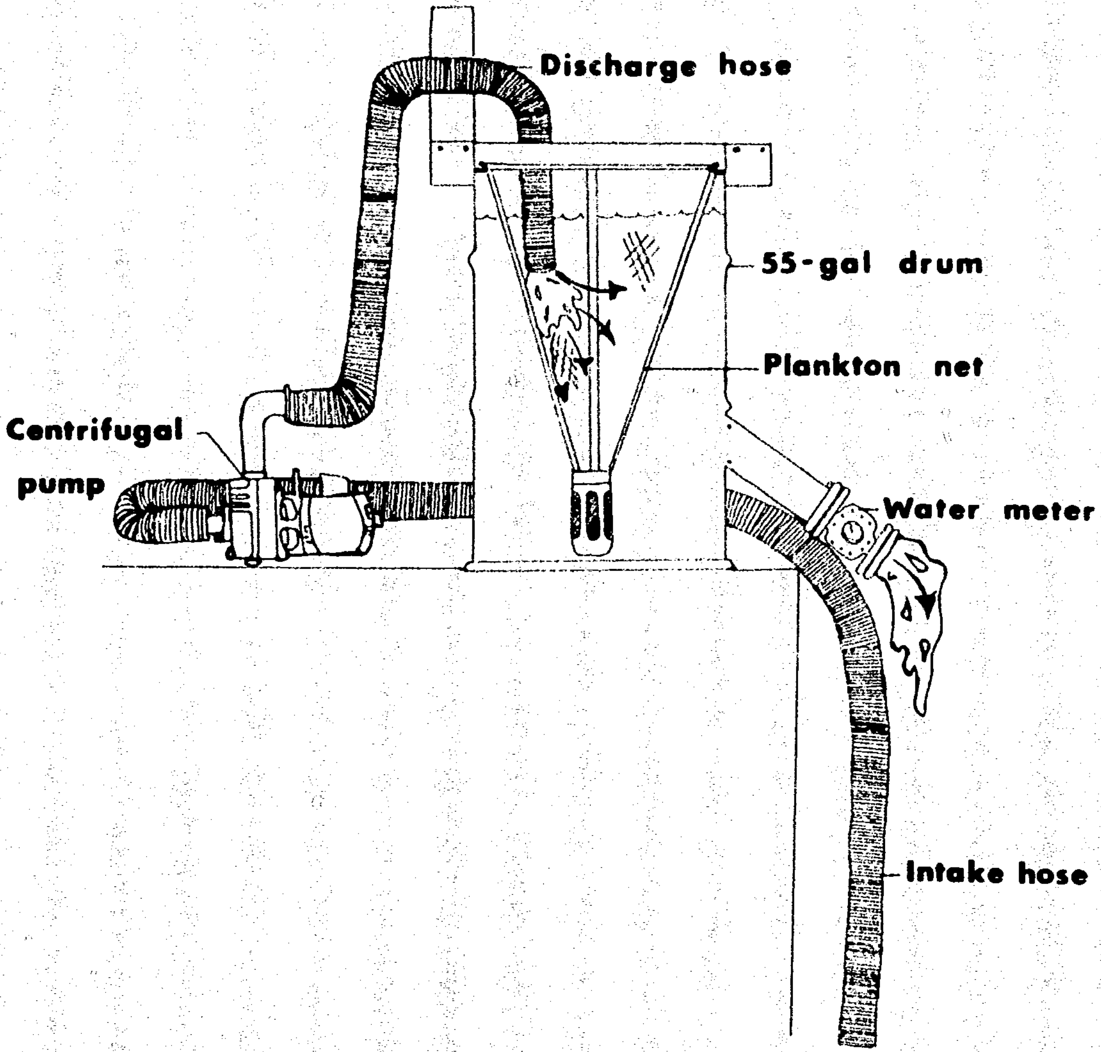

Figure 12.4 Low volume pump sampling system employed as the primary sampling method for the entrainment investigation.

The third sampling technique was an attempt to simulate the intake velocities which are conventionally believed to entrain fish larvae and eggs. Sampling was conducted using two modified Waite-O'Grady samplers (Waite and O'Grady 1980) in the area immediately in front of the trash bars. The Waite-O'Grady sampler (Fig. 12.5) was conceptualized as a means to more accurately and conveniently sample zooplankton. However, it has also been used successfully as an instrument to predict entrainment losses as part of a power plant siting study. For the purpose of this study, several modifications were necessary, including a larger pump (1750 gph), a larger net mesh size (0.56 mm) and a larger plexiglass tube (8 inch O.D.). The initial intention was to operate the Waite-O'Grady samplers over a 24-hour period; this was attempted at weekly intervals from 3 April to 2 May. However, the pumps were incapable of that kind of sustained operation. Therefore, a less intensive sampling scheme was designed. Beginning 8 May and continuing at weekly intervals until 13 June, 15 minute replicate samples were taken at the surface, 4, and 8 meters. This procedure was completed once during daylight hours and again after sunset.

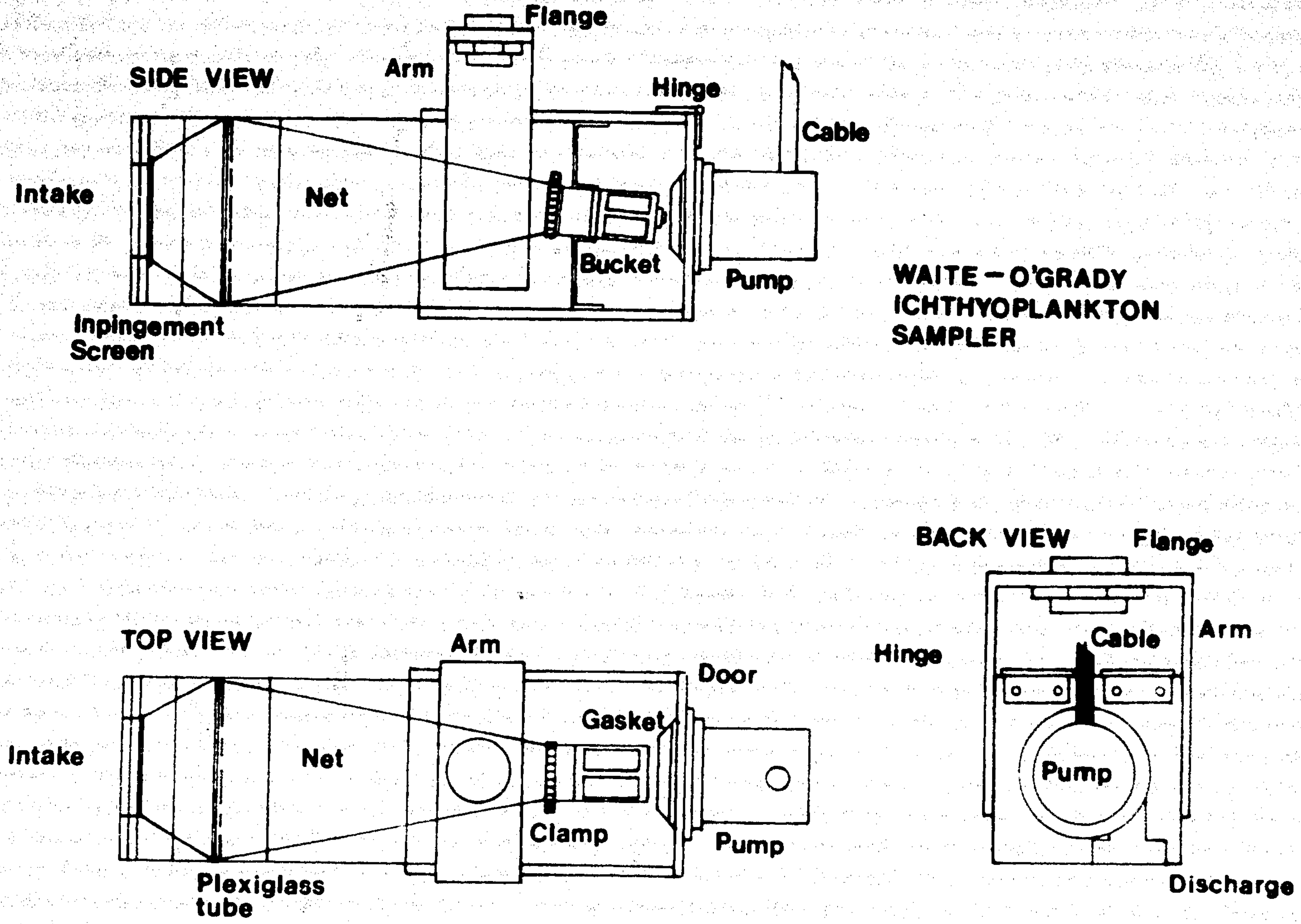

Fig. 12.5. Schematic design of the Waite-O'Grady sampler.

## ENTRAINMENT

## RESULTS AND DISCUSSION

A total of 732 fish eggs were collected in primary entrainment samples. Peak density was recorded 12-13 May, when 5.45 eggs were collected per $10m^3$ of water sampled (Table 12.9). Fish eggs were collected only during the month of May; during that time an estimated 7.3 million eggs were entrained by the Coffeen Power Station. However, the loss of several million fish eggs appears minimal given the prolific reproductive capabilities of most fish species. The estimate of total eggs entrained was derived from mean egg density ($2.1/10m^3$) multiplied by mean cooling water flow rate for May ($15.45\ m^3/sec$) multiplied by 26 sampling days. Porak and Tranquilli (1981) collected 218 fish eggs and calculated a total estimate of 2.2 million eggs during the 1976 spawning season at Lake Sangchris. Fish eggs were not identified to a taxonomic level, but given the size of the eggs and early date of capture the majority were probably gizzard shad eggs.

A total of 3,430 larval fishes were collected in primary entrainment sampling conducted 25 April through 9 September 1980 (Table 12.10). Gizzard shad larvae dominated entrainment samples, comprising 83.6% of the total catch. *Lepomis* spp. larvae comprised 14.3% of the total entrainment sample and were the only other taxa collected consistently. White crappie, although relatively common in ichthyoplankton tows, were rare in primary entrainment samples. Largemouth bass larvae were not collected and channel catfish were uncommon in the 29 entrainment samples. This sampling system was designed to alleviate the problem of mutiliated and thereby unidentifiable larvae. However, a small percentage (1.2%) were damaged beyond recognition. Porak and Tranquilli (1981) collected 21,720 larval fishes at the Kincaid Power Station in sampling systems nearly identical to the primary system utilized in this study. At the Kincaid Station the percentage of gizzard shad larvae collected was similar to the percentage found in this study but the percentage of *Lepomis* spp. larvae was much smaller.

Larvae first appeared in entrainment samples on 15-16 May but were not collected in great numbers until 26-27 May. Peak density at Lake Sangchris occurred on 24

Table 12.9. Number and entrainment rate (No./10m$^3$) of fish eggs collected by primary entrainment sampling at the Coffeen Power Station.

| Date | No. | No./10m$^3$ |
|---|---|---|
| 5 - 6 May | 60 | 2.4 |
| 8 - 9 May | 1 | 0.02 |
| 12 - 13 May | 240 | 5.45 |
| 15 - 16 May | 0 | 0.0 |
| 19 - 20 May | 215 | 3.5 |
| 22 - 23 May | 147 | 2.35 |
| 26 - 27 May | 0 | 0.0 |
| 29 - 30 May | 69 | 3.1 |
|  | 732 |  |

Table 12.10. Total number and percent of total of fish larvae collected by primary entrainment sampling conducted 25 April through 9 September 1980 at the Coffeen Power Station.

| Taxa | Number | Percent |
|---|---|---|
| Gizzard shad | 2,869 | 83.6 |
| *Lepomis* spp. | 490 | 14.3 |
| White crappie | 8 | 0.2 |
| Channel catfish | 20 | 0.6 |
| Bullheads | 1 | 0.03 |
| Unidentifiable larvae | 42 | 1.2 |
| Total | 3,430 | 99.9 |

May when 44.7 larvae were collected per 10 $m^3$ of water sampled (Porak and Tranquilli 1981). Peak density at the Coffeen Power Station occurred 12-13 June when 18.05 larvae were collected per 10 $m^3$ of water sampled (Table 12.11). Densities of fish larvae were highest from late May through late June (26-27 May to 23-24 June). Following the 23-24 June collection, entrainment densities declined and remained below 1.0/10$m^3$ except for a small increase in early August attributable to a second peak in Lepomis spp. spawning activity. Gizzard shad were collected from the middle of May to the middle of July with peak densities reported in early June. Lepomis spp. exhibited two peaks in density, one in early June and another in early August. White crappie were collected from the middle of May to the middle of June. Channel catfish were collected only in June, with peak density occurring on 9-10 June.

To assess the impact of entrainment upon the fishery of Coffeen Lake an "instantaneous standing crop" of larval fishes was estimated and the percent loss to that standing crop was determined. This evaluation of entrainment losses was conservative, i.e., worst case, in two regards. First, entrainment mortality was assumed to be 100 percent, however, recent studies have demonstrated that a wide range in mortalities of entrained organisms (1% to 100%) exists and varies from plant to plant and between species (Marcy 1971, Cannon et al. 1978, Schubel and Marcy 1978). Second, "instantaneous standing crops" were calculated not from the mean of all ichthyoplankton tows (Section 10, herein) but from the lower 68% confidence limit in order to yield a more conservative estimate of the abundance of larval fishes in the reservoir. Data presented in Table 12.12 demonstrated that the percentage of the larval gizzard shad standing crop entrained increased progressively from 7 May until 18 June. At maximum standing crop (4 June) the entrainment process accounted for a loss to the standing crop of 1.4 percent. The continued increase in percent loss after 4 June probably reflected the increased size of larvae and the ability of the entrainment sampling system to collect larger specimens than could be captured in ichthyoplankton tows. After 18 June larval densities of shad in the reservoir were too low to calculate a standing crop estimate. Entrainment induced mortality of Lepomis spp. larvae appeared to have minimal effect on the standing crop of those larval fishes. Peak standing crop of Lepomis spp. larvae occurred 4 June and percent loss due to entrainment was extremely low (0.05%) at

Table 12.11. Entrainment rates (No./10 m$^3$) of larval fishes at the Coffeen Power Station 5 May through 9 September 1980.

| Collection Period | Gizzard Shad | *Lepomis* | *Pomoxis* | Channel Catfish | Unidentifiable fishes | Total |
|---|---|---|---|---|---|---|
| 5 - 6 May | — | — | — | — | — | — |
| 8 - 9 May | — | — | — | — | — | — |
| 12 - 13 May | — | — | — | — | — | — |
| 15 - 16 May | 0.02 | — | — | — | — | 0.02 |
| 19 - 20 May | 0.02 | — | — | — | — | 0.02 |
| 22 - 23 May | 0.19 | — | 0.02 | — | — | 0.21 |
| 26 - 27 May | 2.90 | — | — | — | 0.30 | 3.20 |
| 29 - 30 May | 5.80 | — | 0.09 | — | 0.30 | 6.19 |
| 2 - 3 June | 10.05 | 0.80 | — | — | — | 10.85 |
| 5 - 6 June | 10.95 | 1.60 | 0.02 | — | — | 12.57 |
| 9 - 10 June | 1.40 | 0.45 | — | 0.25 | — | 2.10 |
| 12 - 13 June | 16.85 | 0.90 | 0.05 | 0.05 | 0.20 | 18.05 |
| 16 - 17 June | 3.90 | 1.20 | 0.01 | — | — | 5.11 |
| 19 - 20 June | 1.45 | 0.50 | — | — | — | 1.95 |
| 23 - 24 June | 2.50 | 0.62 | — | 0.10 | 0.30 | 3.52 |
| 26 - 27 June | 0.60 | 0.07 | — | 0.02 | 0.02 | 0.71 |
| 30 June - 1 July | 0.60 | 0.20 | — | 0.02 | 0.02 | 0.84 |
| 3 - 4 July | 0.20 | — | — | — | — | 0.20 |
| 7 - 8 July | 0.40 | 0.07 | — | — | — | 0.47 |
| 10 - 11 July | 0.60 | 0.04 | — | — | — | 0.64 |
| 14 - 15 July | 0.22 | 0.07 | — | — | 0.02 | 0.31 |
| 21 - 22 July | — | — | — | — | 0.03 | 0.03 |
| 28 - 29 July | — | 0.12 | — | — | — | 0.12 |
| 4 - 5 Aug | — | 1.02 | — | — | — | 1.02 |
| 11 - 12 Aug | 0.30 | 3.30 | — | — | 0.04 | 3.64 |
| 18 - 19 Aug | — | 0.20 | — | — | — | 0.20 |
| 25 - 26 Aug | — | 0.20 | — | — | — | 0.20 |
| 2 - 3 Sept | — | 0.30 | — | — | — | 0.30 |
| 8 - 9 Sept | — | — | — | — | — | — |

Table 12.12. Weekly "instantaneous standing crop" of gizzard shad larvae and the percent loss to that standing crop attributable to entrainment mortality.

| Date | Standing crop ($x10^3$) | Percent loss |
|---|---|---|
| 7 May | 1,411.3 | — |
| 14 May | 7,599.1 | 0.04 |
| 21 May | 14,329.7 | 0.10 |
| 28 May | 104,758.9 | 0.55 |
| 4 June | 156,595.6 | 1.40 |
| 11 June | 41,795.0 | 4.60 |
| 18 June | 4,233.8 | 13.30 |

that time (Table 12.13). The highest percent loss (8.6%) to the *Lepomis* standing crop occurred 13 August, approximately two weeks after the acceptance of a second peak in spawning activity on 30 July.

As a means to innovatively sample the entrainment of fish larvae, two modified Waite-O'Grady samplers were constructed and operated on a weekly schedule immediately in front of the Coffeen Power Station intake screens. A total of six larval fish were collected in Waite-O'Grady samplers. Each weekly sample (8 May-13 June) consisted of a total sampling effort of 180 minutes. Obviously, this method, as applied in this investigation, was wholly ineffectual. Ineffectiveness of the samplers was apparently related to the poor performance of the submersible bilge pumps.

Table 12.13. Weekly "instantaneous standing crop" of *Lepomis* spp. larvae and the percent loss to that standing crop attributable to entrainment mortality.

| Date | Standing crop (x$10^3$) | Percent loss |
|---|---|---|
| 28 May | 1,736.9 | — |
| 4 June | 501,811.6 | 0.05 |
| 11 June | 128,099.0 | 0.11 |
| 18 June | 30,396.4 | 0.60 |
| 25 June | 11,941.4 | 0.61 |
| 2 July | 15,740.9 | 0.13 |
| 9 July | 298.5 | 4.40 |
| 16 July | 1,465.5 | 1.10 |
| 23 July | 298.5 | — |
| 30 July | 15,469.6 | 0.20 |
| 6 Aug | 11,127.2 | 2.10 |
| 13 Aug | 8,684.7 | 8.60 |
| 20 Aug | 8,684.7 | 0.52 |

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# SECTION 13

## SPECIES COMPOSITION, ABUNDANCE, AND DISTRIBUTION OF COFFEEN LAKE FISHES

by

Lance G. Perry and John A. Tranquilli

## ABSTRACT

One-hundred-ninety-two quantitative fish samples were collected in Coffeen Lake, a thermally altered reservoir. Sampling was conducted bimonthly at four sampling stations from September 1978 through July 1980. A total of 22 species, representing 14 genera, seven families, and various *Lepomis* hybrids were collected. Gizzard shad (*Dorosoma cepedianum*) and bluegill (*Lepomis macrochirus*) dominated the numerical catches, representing 40.8% and 28.2%, respectively, of the total fish catch. Six species accounted for 94% of the total catch by weight; they were, in order of decreasing abundance: carp (*Cyprinus carpio*), gizzard shad, largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), bluegill, and white crappie (*Pomoxis annularis*). Greatest fish biomass was obtained at the thermally ambient sampling station followed by the heated station. Golden shiners (*Notemigonus chrysoleucas*), black bullheads (*Ictalurus melas*), and white crappies were found to be distributed primarily in ambient areas. Gizzard shad, although more widely distributed, were also found in greatest abundance at ambient locations. Channel catfish were encountered most frequently at the heated sampling station which suggested a positive response to the elevated thermal regime. Other species were equally distributed throughout the lake or exhibited a spatial distribution which was unrelated to the thermal gradient. Surface water temperatures were found to exert a highly significant influence on distributions of most species. Several other environmental variables are discussed as potentially important factors governing the distribution of fishes in Coffeen Lake.

# INTRODUCTION

Electrical power generation from fossil fuels requires the use of large volumes of surface water to dissipate waste heat and occasionally to transport other by-products of the generation process. Construction of cooling lakes is a common approach to insuring a ready-supply and sufficient volume of water to meet these demands. Although such lakes are usually corporately constructed, owned and operated, the Clean Water Act amendments of 1977 (PL 92-500) still apply, i.e., lake water quality must be suitable for protection and propagation of fish, shellfish, and wildlife by 1984. Consequently, impacts of chemically and thermally enriched effluents in cooling water impoundments are of some concern, and have prompted a considerable amount of research focusing on cause-effect relationships in those systems (Gibbons and Sharitz 1974, Esch and McFarlane 1976, Thorp and Gibbons 1978, Talmage and Coutant 1980). Nonetheless, many of the long-term effects of excess heat, a by-product inherent in both bituminous and nuclear production processes, remain largely speculative. Elevation of ambient water temperatures to levels that are directly lethal to fishes is one potential impact of artificial temperature increases, but that factor alone probably does not pose a great threat to fish communities in view of the temporary and localized nature of such events. Less obvious but equally important are stresses that are induced at sublethal temperatures, insofar as they exceed optima, since these may tend to alter normal physiological and behavioral functioning of exposed fishes. Sublethal heat stresses could be manifested through various pathways: by a reduction in dissolved oxygen, by increased susceptibility to pollutants, diseases, or parasites, by modification of innate behavioral responses associated with reproductive activities, predator-prey interactions, or territoriality, and by alteration of normal daily and seasonal activities such as feeding and movements. Thermal impacts are not necessarily detrimental to fishes, however. Benefits of thermal loading may include enhanced spawning success and longer growing seasons (Gammon 1973, Tranquilli et al. 1981).

Currents established by circulation of cooling water may produce a more favorable distribution of nutrients in closed-system cooling lakes (Drew and Tilton 1970). In short, the process of electrical power generation may promote changes in the natural thermal and chemical regimes of receiving systems which in turn may influence trophic level interactions and promote changes in the natural processes of fishes at the individual, population, and community levels of organization.

A multifaceted study of the fishes of Coffeen Lake, a cooling water impoundment for Central Illinois Public Service Company's Coffeen Power Station, was initiated in September 1978 as part of a comprehensive investigation designed to evaluate the suitability of the lake for supporting a desirable aquatic community. Data collection and analysis were conducted in an effort to assess the status and general well being of the lake fishery and to aid in relating those findings to the physicochemical and thermal characterisitics of the lake. Major objectives of this investigation were (1) to ascertain the species composition of the Coffeen Lake fish community, (2) to estimate the relative numerical and biomass densities of those species, and (3) to determine spatiotemporal distributions of major species and identify environmental variables that influence their distribution.

## MATERIALS AND METHODS

Three methods of collection were utilized for sampling the fish community. These included a 230-volt AC boom-type electroshocker, 45.7-m (150 ft.) experimental gill nets each with a series of six 7.6-m (25 ft.) panels of 12.7, 24.5, 31.8, 38.1, 50.8, and 63.5-mm bar measure mesh, and a 7.6 m (25 ft.) bag seine. This combination of methods was chosen to obtain samples which were representative of the various habitat types within the lake and representative of the broad size range of fishes which typically comprise a lake community. Differences in conductivity between sampling stations necessitated the use of two types of electrodes with the electroshocking apparatus. Electrodes constructed of flexible steel conduit (2.5 cm diameter) were used at Station 4 (Fig. 13.1) where conductivity was lowest. Because conductivities at Stations 1, 2, and 3 were generally higher, a ramification of the high total dissolved

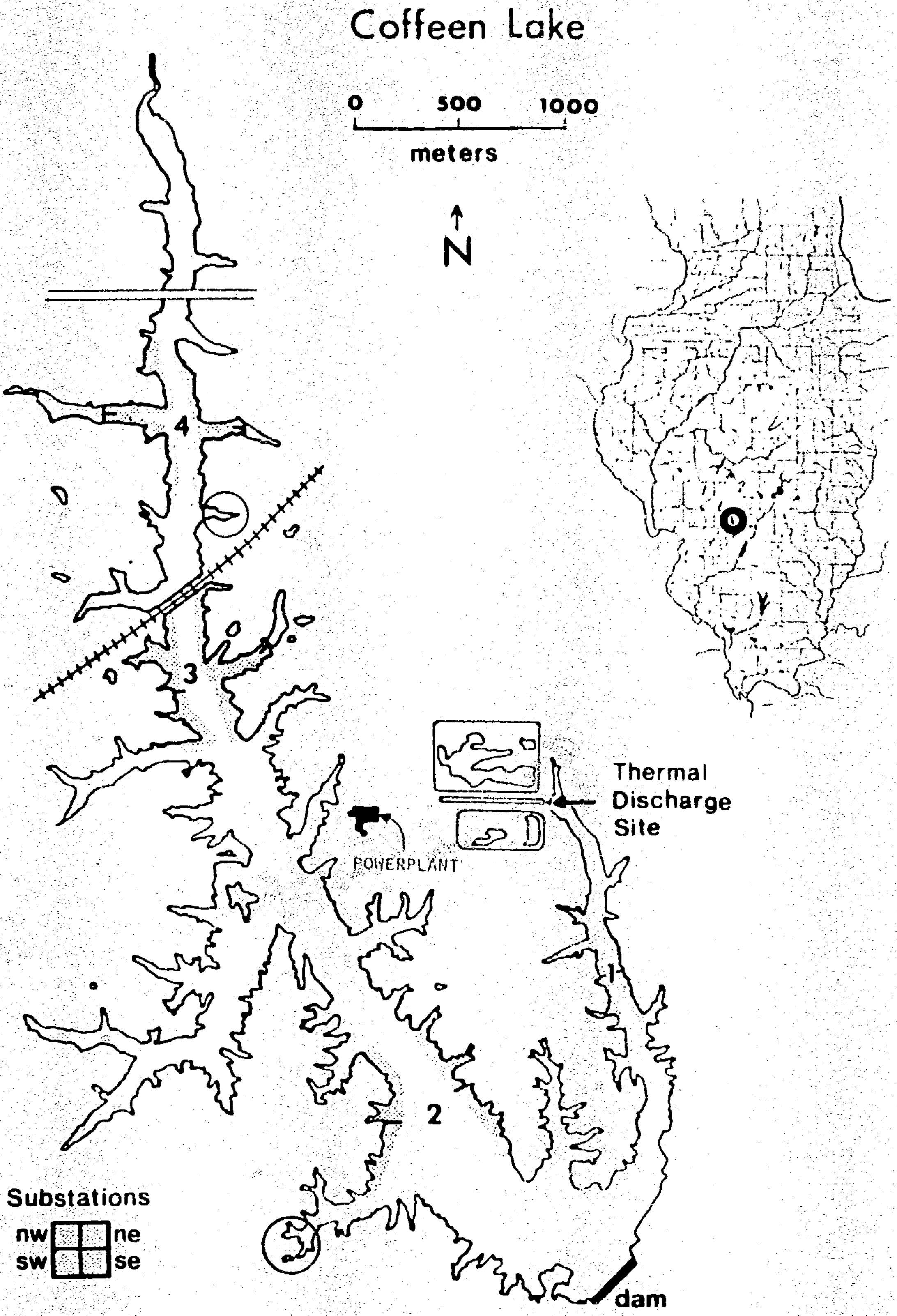

Fig. 13.1. Stations (1, 2, 3, and 4) and substations (southwest, northwest, northeast, and southeast) utilized for bimonthly sampling of Coffeen Lake fishes. Coves utilized in obtaining standing crop estimates are encircled.

solids content of the water (Section 3, herein), braided steel cables (6.4-mm diameter) were utilized to reduce contact area between the surface of each electrode and the water. The smaller electrodes proved to be more efficient at immobilizing fishes in areas of high conductivity, presumably because they established a more concentrated field of electrical charge compared to that produced by the larger electrodes. This method of electrode exchange was followed to eliminate or at least minimize differences in catch rates which may have occurred as an artifact of the conductivity gradient. Our observations indicated approximately equal electrofishing effectiveness at the four sampling stations (see below) after this pattern of electrode exchange was adopted.

Electroshocking, gill netting, and seining were conducted every other month from September 1978 through July 1980. Each bimonthly collection included four replicate substation samples (southwest, northwest, northeast, and southeast) from each of the four sampling stations[1] (Fig. 13.1). Each substation sample (=one unit of effort) consisted of pooled catches from: one 24-h experimental gill net set, one shoreline bag seine haul approximately 15-m in distance, and 15 minutes of daytime electroshocking parallel to the shoreline. Usually nine field days during mid-month were required to obtain the complete lakewide series of samples. Day one was devoted to gill netting at Station 1 and seining at all stations. Gill net samples from Stations 2, 3, and 4 were obtained on days 2-5 while electroshocking was conducted on days 6-9, usually one station per day. All fishes were identified to species (except Lepomis spp. hybrids) with the aid of Smith (1979). Number of individuals and total weight (sum of individual weights) in grams were recorded for each species.

Distributions of the 13 most dominant species and Lepomis hybrids (Table 13.1) were analyzed statistically by utilizing biomass (catch/unit effort in grams transformed to $\text{Log}_{10}(X + 1)$) as a dependent variable in a 3-way analysis

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[1] The bimonthly sampling schedule was followed throughout the study except at Station 4 in January 1979 when an ice cover prevented collecting attempts. The January 1980 sample was collected between 20-21 December 1979 (gill net and seine portions) and 17 January 1980 (electroshocking portion). An additional Station 4 sample was obtained on 19-20 February 1981 (Tables A13.1 and A13.2, Appendix to this document), immediately after ice-out, and was included with the January 1979 series to complete that sample.

Table 13.1. Total catch of fishes collected at biomonthly intervals (September 1978 through July 1980) in Coffeen Lake. Numbers (NO), weights (WT) in grams, percentage composition (% NO, % WT), and sampling methods are given.

| | GILL NET | | | | SEINE | | | | SHOCK | | | | TOTALS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO | %NO | WT | %WT | NO | %NO | WT | %WT | NO | %NO | WT | %WT | NO | %NO | WT | %WT |
| *GIZZARD SHAD | 3450 | 49.9 | 280029 | 25.8 | 918 | 21.9 | 18515 | 31.2 | 11293 | 41.4 | 378921 | 19.5 | 15661 | 40.8 | 677465 | 22.0 |
| *CARP | 225 | 3.3 | 259203 | 23.9 | 0 | 0.0 | 0 | 0.0 | 375 | 1.4 | 713421 | 36.8 | 600 | 1.6 | 972624 | 31.5 |
| *GOLDEN SHINER | 74 | 1.1 | 5385 | 0.5 | 6 | 0.1 | 84 | 0.1 | 72 | 0.3 | 2243 | 0.1 | 152 | 0.4 | 7712 | 0.3 |
| OTHER CYPRINIDS | 0 | 0.0 | 0 | 0.0 | 229 | 5.5 | 386 | 0.7 | 31 | 0.1 | 1194 | 0.1 | 260 | 0.7 | 1590 | 0.1 |
| CARPSUCKER SPP | 9 | 0.1 | 7175 | 0.7 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 9 | 0.0 | 7175 | 0.2 |
| WHITE SUCKER | 3 | 0.0 | 1228 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 | 0.0 | 1228 | 0.0 |
| *BLACK BULLHEAD | 125 | 1.8 | 12969 | 1.2 | 20 | 0.5 | 30 | 0.1 | 57 | 0.2 | 4227 | 0.2 | 202 | 0.5 | 17226 | 0.6 |
| *CHANNEL CATFISH | 1271 | 18.4 | 316296 | 29.2 | 4 | 0.1 | 471 | 0.8 | 155 | 0.6 | 21869 | 1.1 | 1430 | 3.7 | 338636 | 11.0 |
| *YELLOW BULLHEAD | 73 | 1.1 | 8248 | 0.8 | 3 | 0.1 | 120 | 0.2 | 73 | 0.3 | 4812 | 0.2 | 149 | 0.4 | 13180 | 0.4 |
| BLACKSTRIPE TOPMINNOW | 0 | 0.0 | 0 | 0.0 | 98 | 2.3 | 139 | 0.2 | 7 | 0.0 | 14 | 0.0 | 105 | 0.3 | 153 | 0.0 |
| YELLOW BASS | 3 | 0.0 | 1538 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 | 0.0 | 1538 | 0.0 |
| WHITE BASS | 3 | 0.0 | 438 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 | 0.0 | 438 | 0.0 |
| *BLUEGILL | 355 | 5.1 | 13126 | 1.2 | 2081 | 49.5 | 23788 | 40.1 | 8388 | 30.8 | 175133 | 9.0 | 10824 | 28.2 | 212047 | 6.9 |
| *GREEN SUNFISH | 147 | 2.1 | 7535 | 0.7 | 168 | 4.0 | 3578 | 6.0 | 2027 | 7.4 | 48891 | 2.5 | 2342 | 6.1 | 60064 | 1.9 |
| *LARGEMOUTH BASS | 305 | 4.4 | 68612 | 6.3 | 192 | 4.6 | 4017 | 6.8 | 1745 | 6.4 | 497062 | 25.6 | 2242 | 5.8 | 569691 | 18.5 |
| *LONGEAR SUNFISH | 137 | 2.0 | 5093 | 0.5 | 244 | 5.8 | 3621 | 6.1 | 1643 | 6.0 | 28132 | 1.5 | 2024 | 5.3 | 36846 | 1.2 |
| *ORANGESPOTTED SUNFISH | 25 | 0.4 | 208 | 0.0 | 82 | 2.0 | 731 | 1.2 | 134 | 0.5 | 1914 | 0.1 | 241 | 0.6 | 2853 | 0.1 |
| *HYBRID SUNFISHES | 120 | 1.7 | 5081 | 0.5 | 134 | 3.2 | 2742 | 4.6 | 1117 | 4.1 | 31733 | 1.6 | 1371 | 3.6 | 39556 | 1.3 |
| *WHITE CRAPPIE | 586 | 8.5 | 91575 | 8.4 | 21 | 0.5 | 1073 | 1.8 | 159 | 0.6 | 30405 | 1.6 | 766 | 2.0 | 123053 | 4.0 |
| TOTALS | 6911 | | 1083799 | | 4200 | | 59295 | | 27276 | | 1939971 | | 38387 | | 3083065 | |

of variance with year, month, and station as independent class variables, and surface water temperatures as linear and quadratic covariables. A mixed model was specified since years and months were assumed to be random temporal observations while station locations were established (fixed) by us. The main effects of months, stations, and treatments (month-by-station interaction) were subdivided into selected comparisons to facilitate detection of spatial and temporal differences in fish biomass. The log transformation was performed prior to analysis to stabilize variances of treatment means. Biomass, rather than numerical density, was used in the model as a measure of fish abundance since the total weight of a species is less affected by annual variation in reproductive success than is numercial abundance. A series of partial correlation coefficients were also calculated to identify relationships between catch/effort of fishes and selected biotic and abiotic variables. The latter included physiochemical parameters and biomass densities of phytoplankton, zooplankton and benthos, data which were collected commensurate with the fishery data (Sections 3, 5, 6, and 7, herein). The partial correlation procedure allows measurement of the interrelationship between fish catch and one other variable while all remaining variables are held constant.

Knowledge of the extent of the thermal plume in Coffeen Lake allowed stations to be designated as either heated or ambient based upon the degree of thermal enrichment at each site. Station 1, located near the thermal discharge, was subjected to the greatest temperature elevation, followed respectively by Stations 2, 3, and 4, each progressively farther removed from the discharge (Fig. 13.1). Station 4 exhibited little if any thermal influence (Section 2, herein) and was accordingly designated as ambient. In addition, Station 4 was partially separated from the other sampling stations by a railroad causeway (Fig. 13.1) which prevented longitudinal water movement except for that which occurred through two concrete culverts built into that structure. Sampling stations are referred to by number or as the "heated" or "ambient" station. In other Sections of this report, only the terms "heated" and "ambient" are used to designate a sampling location. Those terms refer to the following locations: heated = entire lake reach extending from the thermal outfall to Station 2 inclusive, and ambient = entire lake reach north of the railroad causeway (Fig. 13.1).

## RESULTS

From September 1978 to July 1980, a total of 22 species, representing 14 genera and seven families, were collected in 192 quantitative bimonthly samples. Hybrid sunfishes (Lepomis spp.) were also commonly encountered but specific identities represented in those crosses could not be determined with certainty. Gizzard shad (Dorosoma cepedianum) and bluegill (Lepomis macrochirus) dominated the numerical catch, representing 40.8% and 28.2% of the two-year total, respectively (Table 13.1). Green sunfish (Lepomis cyanellus) ranked third in numerical abundance (6.1%) followed by largemouth bass (Micropterus salmoides, 5.8%), longear sunfish (Lepomis megalotis, 5.3%), channel catfish (Ictalurus punctatus, 3.7%), hybrid sunfish (Lepomis spp., 3.6%), and white crappie (Pomoxis annularis, 2.0%). Each of the remaining species contributed less than 2% to the total numerical catch; these included carp (Cyprinus carpio), goldfish (Carassius auratus), golden shiner (Notemigonus chrysoleucas), fathead minnow (Pimephales promelus), bluntnose minnow (P. notatus), red shiner (Notropis lutrensis), river carpsucker (Carpiodes carpio), quillback (C. cyprinus), white sucker (Catostomus commersoni), black bullhead (Ictalurus melas), yellow bullhead (I. natalis), blackstripe topminnow (Fundulus notatus), yellow bass (Morone mississippiensis), white bass, (M. chrysops), and orangespotted sunfish (Lepomis humilis).

Six species accounted for 94% of the total fish biomass during the two-year study (Table 13.1). They were, in order of decreasing abundance: carp (31.5%), gizzard shad (22.0%), largemouth bass (18.5%), channel catfish (11.0%), bluegill (6.9%), and white crappie (4.0%). Other specific biomass contributions were: green sunfish (1.9%), hybrid sunfish (1.3%), and longear sunfish (1.2%). The remaining species each contributed less than 1% to the total catch by weight. As indicated above, numbers of carp were low but their consistently large body sizes contributed greatly to the total fish biomass.

Electroshocking was the most effective method overall for capturing fishes as evidenced by numerical and weight catches: 71% and 63%, respectively, of the two year total (Table 13.1). In comparison, gill netting efforts accounted for 18% by number and 35% by weight whereas respective seining contributions were 11% and 2%.

Electroshocking was most selective for carp and largemouth bass, gill netting for carp, the catfishes, and white crappie, and seining for the smaller minnows and sunfishes.

The total biomass of fishes captured during the two-year sampling period was highest at Station 4 (1078.6 kg), followed by Station 1 (699.2 kg), Station 3 (677.4 kg) and Station 2 (625.0 kg). Monthly catches, in order of decreasing biomass were: May (848.5 kg), March (587.1 kg), September (561.6 kg), November (390.2 kg), July (368.8 kg), and January (324.0 kg). Further classification of catches by year, month, and station are given in Tables A13.1 and A13.2 (Appendix of this report) and Appendix Tables 11.1 and 11.2 (Tranquilli and Larimore 1980). Greater monthly catches during spring and fall seasons were expected since fishes are most active and abundant in shallow water at those times, and moderate surface water temperatures generally prevail. Within-lake locations characterized by extreme water temperatures (Stations 1 and 4) produced higher catches than thermally intermediate stations, but the Station 4 (ambient) catch was most pronounced since catches from all stations within or near the cooling loop generally were 35-70% lower than the Station 4 total.

The analysis of variance model selected for evaluation of fish distribution accounted for 27% to 74% of the variation in catch/effort of the species examined (Table 13.2). Significant differences in average catch/effort between years (i.e., averaged over all months and stations sampled during a given year) were detected for three species: yellow bullhead, channel catfish, and hybrid sunfishes (Table 13.2). All were found to be more abundant during the first year. Actual (untransformed) means for those species are presented in Table 13.3. It is assumed that those between-year differences in catch effort reflect differing species densities, atmospheric conditions, or variation in thermal outputs during the two year study. Annual variation of the latter two variables would in turn influence thermochemical cycles and water level fluctuations in the lake, factors which could influence catch rates of certain species. Since years were specified as random variables in the model, a random pattern in annual catch rates is assumed, and average catch/effort would thus exhibit a definite annual trend only after repeated sampling. Similarly, the year-by-month interaction, which accounted for a significant amount of variation in

Table 13.2 Analysis of variance of catch/effort for selected Coffeen Lake fishes. Dependent variable was weight in grams ($\log_{10}(x + 1)$). Degrees of freedom (d.f.), sum of squares (SS), mean squares (MS), and F-statistics are given for effects of year, month, station, associated interactions, selected contrasts (K and C), and for linear and quadratic effects of water temperature. Multiple correlation coefficients ($R^2$) are also given. Levels of significance for F-statistics are: * = 5%, ** = 1%.

| Source of variation | d.f. | Gizzard Sha |  |  | Carp |  |  | Golden Shiner |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | SS | MS | F | SS | MS | F | SS | MS | F |
| Year | 1 | 0.00 | 0.00 | 0.01 | 5.71 | 5.71 | 3.69 | 0.49 | 0.49 | 0.79 |
| Month | 5 | 1.16 | 0.23 | 1.48 | 48.38 | 9.68 | 6.26** | 6.17 | 1.23 | 1.99 |
| C1 = Jan vs Jul | (1) | 0.12 | 0.12 | 0.75 | 0.79 | 0.79 | 0.51 | 5.21 | 5.21 | 8.40** |
| C2 = (Jan+Mar) vs (Jul+Sep) | (1) | 0.16 | 0.16 | 1.02 | 0.03 | 0.03 | 0.02 | 5.16 | 5.16 | 8.31** |
| Year x Month | 5 | 2.13 | 0.43 | 2.71* | 24.37 | 4.87 | 3.15** | 10.56 | 2.11 | 3.41** |
| Station | 3 | 2.18 | 0.73 | 4.63** | 12.37 | 4.12 | 2.67* | 22.25 | 7.42 | 11.96** |
| K1 = Sta. 1 vs Sta. 4 | (1) | 0.77 | 0.77 | 4.90* | 4.54 | 4.54 | 2.94 | 14.31 | 14.31 | 23.07** |
| K2 = (Sta. 1+2) vs (Sta. 3+4) | (1) | 0.34 | 0.34 | 2.17 | 4.17 | 4.17 | 2.70 | 12.27 | 12.27 | 19.78** |
| Month x Station | 15 | 14.71 | 0.98 | 6.23** | 36.44 | 2.43 | 1.57 | 12.94 | 0.86 | 1.39 |
| C1 x K1 | (1) | 0.31 | 0.31 | 1.99 | 0.01 | 0.01 | 0.01 | 0.18 | 0.18 | 0.28 |
| C2 x K1 | (1) | 0.49 | 0.49 | 3.14 | 0.01 | 0.01 | 0.01 | 0.14 | 0.14 | 0.22 |
| Temperature (linear) | 1 | 5.16 | 5.16 | 32.82** | 4.29 | 4.29 | 2.78 | 0.93 | 0.93 | 1.49 |
| Temperature$^2$ (quadratic) | 1 | 3.43 | 3.43 | 21.79** | 6.00 | 6.00 | 3.88 | 0.00 | 0.00 | 0.00 |
| Residual | 160 | 25.17 | 0.16 |  | 247.41 | 1.55 |  | 99.24 | 0.62 |  |
| Corrected Total | 191 | 97.78 |  |  | 501.75 |  |  | 160.77 |  |  |
| $R^2$ |  | 0.74 |  |  | 0.51 |  |  | 0.38 |  |  |

Table 13.2 Analysis of variance of catch/effort for selected Coffeen Lake fishes. Dependent variable was weight in grams ($\log_{10}(x + 1)$). Degrees of freedom (d.f.), sum of squares (SS), mean squares (MS), and F-statistics are given for effects of year, month, station, associated interactions, selected contrasts (K and C), and for linear and quadratic effects of water temperature. Multiple correlation coefficients ($R^2$) are also given. Levels of significance for F-statistics are: * = 5%, ** = 1% (cont).

| Source of variation | d.f. | Black Bullhead |  |  | Yellow Bullhead |  |  | Channel Catfish |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | SS | MS | F | SS | MS | F | SS | MS | F |
| Year | 1 | 0.61 | 0.61 | 0.89 | 4.35 | 4.35 | 4.49* | 5.03 | 5.03 | 8.15** |
| Month | 5 | 8.86 | 1.77 | 2.59* | 11.12 | 2.22 | 2.29* | 3.91 | 0.78 | 1.27 |
| C1 = Jan vs Jul | (1) | 3.41 | 3.41 | 4.99* | 0.13 | 0.13 | 0.13 | 0.09 | 0.09 | 0.15 |
| C2 = (Jan+Mar) vs (Jul+Sep) | (1) | 3.90 | 3.90 | 5.71* | 0.00 | 0.00 | 0.00 | 0.09 | 0.09 | 0.15 |
| Year x Month | 5 | 3.87 | 0.77 | 1.13 | 5.67 | 1.13 | 1.17 | 4.91 | 0.98 | 1.59 |
| Station | 3 | 64.55 | 21.52 | 31.46** | 1.30 | 0.43 | 0.45 | 6.31 | 2.10 | 3.41* |
| K1 = Sta. 1 vs Sta. 4 | (1) | 21.39 | 21.39 | 31.28** | 0.03 | 0.03 | 0.04 | 2.41 | 2.41 | 3.91* |
| K2 = (Sta. 1+2) vs (Sta. 3+4) | (1) | 21.06 | 21.06 | 30.79** | 0.10 | 0.10 | 0.11 | 1.83 | 1.83 | 2.96 |
| Month x Station | 15 | 15.83 | 1.06 | 1.54 | 31.76 | 2.12 | 2.18** | 35.40 | 2.36 | 3.83** |
| C1 x K1 | (1) | 3.27 | 3.27 | 4.78* | 2.79 | 2.79 | 2.88 | 4.43 | 4.43 | 7.18** |
| C2 x K1 | (1) | 4.85 | 4.85 | 7.09** | 2.82 | 2.82 | 2.91 | 8.75 | 8.75 | 14.17** |
| Temperature (linear) | 1 | 6.91 | 6.91 | 10.10** | 0.65 | 0.65 | 0.67 | 9.41 | 9.41 | 15.26** |
| $\text{Temperature}^2$ (quadratic) | 1 | 3.38 | 3.38 | 4.94* | 0.92 | 0.92 | 0.95 | 6.79 | 6.79 | 11.00** |
| Residual | 160 | 109.43 | 0.68 |  | 155.10 | 0.97 |  | 98.72 | 0.62 |  |
| Corrected Total | 191 | 226.20 |  |  | 213.69 |  |  | 208.66 |  |  |
| $R^2$ |  | 0.52 |  |  | 0.27 |  |  | 0.53 |  |  |

Table 13.2 Analysis of variance of catch/effort for selected Coffeen Lake fishes. Dependent variable was weight in grams ($\log_{10}(x + 1)$). Degrees of freedom (d.f.), sum of squares (SS), mean squares (MS), and F-statistics are given for effects of year, month, station, associated interactions, selected contrasts (K and C), and for linear and quadratic effects of water temperature. Multiple correlation coefficients ($R^2$) are also given. Levels of significance for F-statistics are: * = 5%, ** = 1% (cont).

| | | Bluegill | | | Green Sunfish | | | Largemouth Bass | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | SS | MS | F | SS | MS | F | SS | MS | F |
| Year | 1 | 0.06 | 0.06 | 0.43 | 0.02 | 0.02 | 0.08 | 0.05 | 0.05 | 0.14 |
| Month | 5 | 5.62 | 1.12 | 7.64** | 7.21 | 1.44 | 4.97** | 7.60 | 1.52 | 4.54** |
| C1 = Jan vs Jul | (1) | 0.00 | 0.00 | 0.00 | 0.09 | 0.09 | 0.30 | 0.05 | 0.05 | 0.16 |
| C2 = (Jan+Mar) vs (Jul+Sep) | (1) | 0.02 | 0.02 | 0.13 | 0.26 | 0.26 | 0.91 | 0.25 | 0.25 | 0.74 |
| Year x Month | 5 | 1.01 | 0.20 | 1.37 | 7.99 | 1.60 | 5.50** | 0.89 | 0.18 | 0.53 |
| Station | 3 | 1.82 | 0.61 | 4.11** | 1.83 | 0.61 | 2.10 | 6.44 | 2.15 | 6.40** |
| K1 = Sta. 1 vs Sta. 4 | (1) | 0.01 | 0.01 | 0.07 | 0.01 | 0.01 | 0.05 | 0.63 | 0.63 | 1.87 |
| K2 = (Sta. 1+2) vs (Sta. 3+4) | (1) | 0.07 | 0.07 | 0.49 | 0.21 | 0.21 | 0.71 | 0.67 | 0.67 | 2.01 |
| Month x Station | 15 | 3.23 | 0.22 | 1.46 | 6.18 | 0.41 | 1.42 | 7.70 | 0.51 | 1.53 |
| C1 x K1 | (1) | 0.13 | 0.13 | 0.90 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.07 |
| C2 x K1 | (1) | 0.43 | 0.43 | 2.91 | 0.00 | 0.00 | 0.00 | 0.05 | 0.05 | 0.15 |
| Temperature (linear) | 1 | 1.87 | 1.87 | 12.72** | 0.01 | 0.01 | 0.03 | 4.09 | 4.09 | 12.22** |
| Temperature$^2$ (quadratic) | 1 | 1.61 | 1.61 | 10.94** | 0.03 | 0.03 | 0.11 | 3.69 | 3.69 | 11.03** |
| Residual | 160 | 23.57 | 0.15 | | 46.49 | 0.29 | | 53.61 | 0.34 | |
| Corrected Total | 191 | 59.10 | | | 79.05 | | | 124.19 | | |
| $R^2$ | | 0.60 | | | 0.41 | | | 0.57 | | |

Table 13.2 Analysis of variance of catch/effort for selected Coffeen Lake fishes. Dependent variable was weight in grams ($\log_{10}(x + 1)$). Degrees of freedom (d.f.), sum of squares (SS), mean squares (MS), and F-statistics are given for effects of year, month, station, associated interactions, selected contrasts (K and C), and for linear and quadratic effects of water temperature. Multiple correlation coefficients ($R^2$) are also given. Levels of significance for F-statistics are: * = 5%, ** = 1% (cont).

| Source of variation | d.f. | Longear Sunfish | | | Orangespotted Sunfish | | | Lepomis Hybrids | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MS | F | SS | MS | F | SS | MS | F |
| Year | 1 | 0.15 | 0.15 | 0.89 | 0.06 | 0.06 | 0.23 | 2.24 | 2.24 | 5.58* |
| Month | 5 | 1.91 | 0.38 | 2.20 | 20.10 | 4.02 | 15.89** | 7.54 | 1.51 | 3.77** |
| C1 = Jan vs Jul | (1) | 0.08 | 0.08 | 0.45 | 0.28 | 0.28 | 1.09 | 0.00 | 0.00 | 0.00 |
| C2 = (Jan+Mar) vs (Jul+Sep) | (1) | 0.07 | 0.07 | 0.41 | 0.05 | 0.05 | 0.21 | 0.15 | 0.15 | 0.38 |
| Year x Month | 5 | 3.55 | 0.71 | 4.09** | 5.66 | 1.13 | 4.48** | 10.43 | 2.09 | 5.21** |
| Station | 3 | 6.22 | 2.07 | 11.93** | 9.12 | 3.04 | 12.02** | 1.16 | 0.39 | 0.96 |
| K1 = Sta. 1 vs Sta. 4 | (1) | 0.13 | 0.13 | 0.75 | 0.32 | 0.32 | 1.26 | 0.13 | 0.13 | 0.33 |
| K2 = (Sta. 1+2) vs (Sta. 3+4) | (1) | 0.01 | 0.01 | 0.08 | 0.15 | 0.15 | 0.58 | 0.24 | 0.24 | 0.59 |
| Month x Station | 15 | 10.43 | 0.70 | 4.00** | 15.11 | 1.01 | 3.98** | 9.81 | 0.65 | 1.63 |
| C1 x K1 | (1) | 0.53 | 0.53 | 3.05 | 1.69 | 1.69 | 6.66* | 0.01 | 0.01 | 0.02 |
| C2 x K1 | (1) | 0.52 | 0.52 | 2.98 | 2.58 | 2.58 | 10.20** | 0.31 | 0.31 | 0.77 |
| Temperature (linear) | 1 | 0.75 | 0.75 | 4.34* | 1.85 | 1.85 | 7.30** | 2.98 | 2.98 | 7.45** |
| Temperature$^2$ (quadratic) | 1 | 0.98 | 0.98 | 5.67* | 2.40 | 2.40 | 9.47** | 2.99 | 2.99 | 7.47** |
| Residual | 160 | 27.79 | 0.17 | | 40.49 | 0.25 | | 64.09 | 0.40 | |
| Corrected Total | 191 | 52.50 | | | 96.64 | | | 127.24 | | |
| $R^2$ | | 0.47 | | | 0.58 | | | 0.50 | | |

Table 13.2 Analysis of variance of catch/effort for selected Coffeen Lake fishes. Dependent variable was weight in grams ($\log_{10}(x + 1)$). Degrees of freedom (d.f.), sum of squares (SS), mean squares (MS), and F-statistics are given for effects of year, month, station, associated interactions, selected contrasts (K and C), and for linear and quadratic effects of water temperature. Multiple correlation coefficients ($R^2$) are also given. Levels of significance for F-statistics are: * = 5%, ** = 1% (cont).

| | | White Crappie | | |
|---|---|---|---|---|
| Source of variation | d.f. | SS | MS | F |
| Year | 1 | 2.73 | 2.73 | 3.78 |
| Month | 5 | 3.93 | 0.79 | 1.09 |
| C1 = Jan vs Jul | (1) | 0.11 | 0.11 | 0.16 |
| C2 = (Jan+Mar) vs (Jul+Sep) | (1) | 0.15 | 0.15 | 0.21 |
| Year x Month | 5 | 15.94 | 3.19 | 4.42** |
| Station | 3 | 22.34 | 7.45 | 10.32** |
| K1 = Sta. 1 vs Sta. 4 | (1) | 11.17 | 11.17 | 15.48** |
| K2 = (Sta. 1+2) vs (Sta. 3+4) | (1) | 13.37 | 13.37 | 18.53** |
| Month x Station | 15 | 70.39 | 4.69 | 6.50** |
| C1 x K1 | (1) | 5.54 | 5.54 | 7.68** |
| C2 x K1 | (1) | 10.21 | 10.21 | 14.15** |
| Temperature (linear) | 1 | 9.75 | 9.75 | 13.50** |
| $\text{Temperature}^2$ (quadratic) | 1 | 7.95 | 7.95 | 11.02** |
| Residual | 160 | 115.46 | 0.72 | |
| Corrected Total | 191 | 285.94 | | |
| $R^2$ | | 0.60 | | |

Table 13.3. Average (N = 96) catch/effort (g) of Coffeen Lake fishes by sampling year. Sampling was conducted at bimonthly intervals at four sampling stations from September 1978 through July 1979 and from September 1979 through July 1980. Species tested statistically (t) and those differing significantly between years (*) are denoted (see Table 13.2).

| Species | 1978-1979 | 1979-1980 |
|---|---|---|
| t Gizzard shad | 3,912 | 3,146 |
| t Carp | 6,330 | 3,801 |
| t Golden shiner | 38 | 42 |
| Other cyprinids | 8 | 9 |
| Carpsucker spp. | 45 | 0 |
| White sucker | 2 | 10 |
| t Black bullhead | 94 | 85 |
| t Yellow bullhead* | 84 | 54 |
| t Channel catfish* | 2,180 | 1,348 |
| Blackstripe topminnow | 1 | 1 |
| Yellow bass | 2 | 14 |
| White bass | 0 | 5 |
| t Bluegill | 1,180 | 1,029 |
| t Green sunfish | 353 | 272 |
| t Largemouth bass | 3,499 | 2,435 |
| t Longear sunfish | 211 | 173 |
| t Orangespotted sunfish | 16 | 14 |
| t Lepomis hybrids* | 279 | 132 |
| t White crappie | 701 | 581 |

catch/effort of eight species (Table 13.2), would be expected to influence catches of many fishes since species densities and atmospheric and plant-induced effects were not identical during the same months of different years; for example, during May of 1979 versus May of 1980. As was true for the annual samples discussed above, our average year-by-month catches represent two random samples (a given month sampled during each of two years) selected from a hypothetical series of samples which are expected to be ordered in a random pattern with respect to fish biomass. Although year and year-by-month variables together accounted for a significant amount of variability in fish catch, and thus increased sensitivity of the F-tests by removing that variation from residual error (Table 13.2), they are of less ecological interest than month, station, and associated interactions (treatments) since the latter were selected to illustrate specific spatiotemporal trends in fish distribution and to detect responses to the artificial thermal gradient.

The average catch/effort (averaged over all stations) of eight species differed significantly between sampling months (Table 13.2). These included carp, black bullhead, yellow bullhead, bluegill, green sunfish, largemouth bass, orangespotted sunfish, and hybrid sunfishes. Actual mean monthly catches of those species are presented in Table 13.4. Two comparisons of warm vs. cold months were made (C1 and C2, Table 13.2) and indicated significantly higher catches of black bullheads and golden shiners during warm months. Monthly biomass differences among the remaining species were not accounted for by those comparisons, but carp were encountered in greatest abundance in March and May and in lowest densities in July and September; yellow bullhead catches were highest in September and November and were homogenously low in January, March, and July; bluegill catches were highest in May and lowest in January; catches of green sunfish were highest in September and lowest in January; largemouth bass catches were highest in May and lowest in July; catches of orangespotted sunfish were highest in May and lowest in September; and Lepomis hybrids were encountered most frequently in March and September and in lowest densities in July (Table 13.4). Average catch/effort of gizzard shad, channel catfish, longear sunfish, and white crappie were similar over all sampling months as evidenced by F-test results (Table 13.2).

Table 13.4. Average (N = 32) catch/effort (g) of Coffeen Lake fishes by sampling month. Sampling was conducted at four sampling stations at bimonthly intervals from September 1978 through July 1980. Species tested statistically (t) and those differing significantly between months (*) are denoted (see Table 13.2).

| Species | Months | | | | | |
|---|---|---|---|---|---|---|
| | Jan | Mar | May | Jul | Sep | Nov |
| t Gizzard shad | 1,675 | 1,843 | 5,514 | 4,079 | 5,321 | 2,740 |
| t Carp* | 3,511 | 9,659 | 8,360 | 2,679 | 2,767 | 3,419 |
| t Golden shiner | 69 | 41 | 53 | 13 | 45 | 20 |
| Other cyprinids | 12 | <1 | 36 | 1 | <1 | <1 |
| Carpsucker spp. | 0 | 0 | 0 | 0 | 136 | 0 |
| White sucker | 0 | 7 | 15 | 0 | 0 | 16 |
| t Black bullhead* | 114 | 62 | 74 | 35 | 102 | 152 |
| t Yellow bullhead* | 44 | 49 | 66 | 47 | 96 | 110 |
| t Channel catfish | 786 | 760 | 1,633 | 2,085 | 3,671 | 1,648 |
| Blackstripe topminnow | <1 | <1 | <1 | <1 | 2 | 2 |
| Yellow bass | 0 | 0 | 0 | 0 | 42 | 6 |
| White bass | 0 | 0 | 2 | 12 | 0 | 0 |
| t Bluegill* | 486 | 986 | 2,753 | 595 | 1,256 | 550 |
| t Green sunfish* | 140 | 234 | 199 | 229 | 721 | 354 |
| t Largemouth bass* | 2,630 | 3,795 | 6,584 | 767 | 1,819 | 2,208 |
| t Longear sunfish | 165 | 188 | 231 | 158 | 284 | 126 |
| t Orangespotted sunfish* | 5 | 14 | 49 | 18 | <1 | 4 |
| t *Lepomis* hybrids* | 145 | 272 | 229 | 97 | 284 | 207 |
| t White crappie | 343 | 438 | 719 | 711 | 1,005 | 630 |

Spatial location of the sampling sites also influenced average catch/effort (averaged over all sampling months) of most (10 of 13) species examined. Selected comparisons of heated and ambient locations (K1 and K2, Table 13.2) accounted for a significant amount of variation in the biomass of five species. Golden shiner, black bullhead, and white crappie were found to be most abundant at semi-ambient and ambient areas (Stations 3 and 4, respectively) of the lake. Gizzard shad exhibited a similar affinity for the ambient location but were generally less restricted in distribution than the aforementioned species (Table 13.5). The greatest mean density of channel catfishes was found at the heated station (Station 1) which suggested a positive response to the thermal effluent and an ability to adapt to the elevated temperature regime which is characteristic of that part of the lake. As was the case for gizzard shad, however, channel catfish were commonly encountered at all stations (Table 13.5). Three species (yellow bullhead, green sunfish, and hybrid sunfishes) were found to be evenly distributed throughout the lake while catches of the five remaining species differed between stations for reasons other than those implicit in the heated vs. ambient comparison. In general, catch/effort of carp increased with increasing distance from the thermal outfall, catches of bluegill and longear sunfish were highest at the heated location, and catches of largemouth bass and orangespotted sunfish were relatively higher at both heated and ambient stations compared to thermally intermediate ones (Table 13.5).

Influences of interacting month and station variables were related to signficiantly different catches of seven species: gizzard shad, black bullhead, yellow bullhead, channel catfish, longear sunfish, orangespotted sunfish, and white crappie. Four of those species (black bullhead, channel catfish, orangespotted sunfish and white crappie) responded differently to heated and ambient location on a seasonal basis as judged by selected comparisons of warm vs. cold months in association with heated and ambient stations (C x K comparisons, Table 13.2). Those interactions are illustrated in Fig. 13.2. Black bullhead, channel catfish, and white crappie catches increased during warm months, but the magnitude of increase was more pronounced at either the heated or ambient location. For black bullhead and white crappie, the increase at the ambient station exceeded that which occurred at the heated station, while the heated station increase was relatively more pronounced among channel catfishes.

Table 13.5. Average (N = 48) catch/effort (g) of Coffeen Lake fishes by sampling stations. Sampling was conducted at bimonthly intervals from September 1978 through July 1980. Species tested statistically (t) and those differing significantly between stations (*) are denoted (see Table 13.2).

| | Stations | | | |
|---|---|---|---|---|
| Species | 1(heated) | 2 | 3 | 4(ambient) |
| t Gizzard shad* | 3,528 | 3,155 | 2,830 | 4,602 |
| t Carp* | 2,461 | 4,875 | 5,009 | 7,918 |
| t Golden shiner* | 5 | 32 | 23 | 101 |
| Other cyprinids | 0 | <1 | <1 | 33 |
| Carpsucker spp. | 0 | 0 | 91 | 0 |
| White sucker | 0 | 0 | 0 | 26 |
| t Black bullhead* | 18 | 12 | 38 | 290 |
| t Yellow bullhead* | 47 | 58 | 79 | 90 |
| t Channel catfish* | 2,521 | 1,337 | 1,165 | 2,032 |
| Blackstripe topminnow | 0 | <1 | 2 | 1 |
| Yellow bass | 0 | 0 | 32 | 0 |
| White bass | 0 | 0 | 5 | 4 |
| t Bluegill* | 1,490 | 904 | 1,040 | 983 |
| t Green sunfish | 221 | 257 | 425 | 348 |
| t Largemouth bass* | 3,455 | 1,876 | 2,219 | 4,319 |
| t Longear sunfish* | 290 | 106 | 198 | 173 |
| t Orangespotted sunfish* | 12 | 5 | 3 | 44 |
| t *Lepomis* hybrids | 276 | 150 | 210 | 188 |
| t White crappie* | 242 | 253 | 744 | 1,325 |

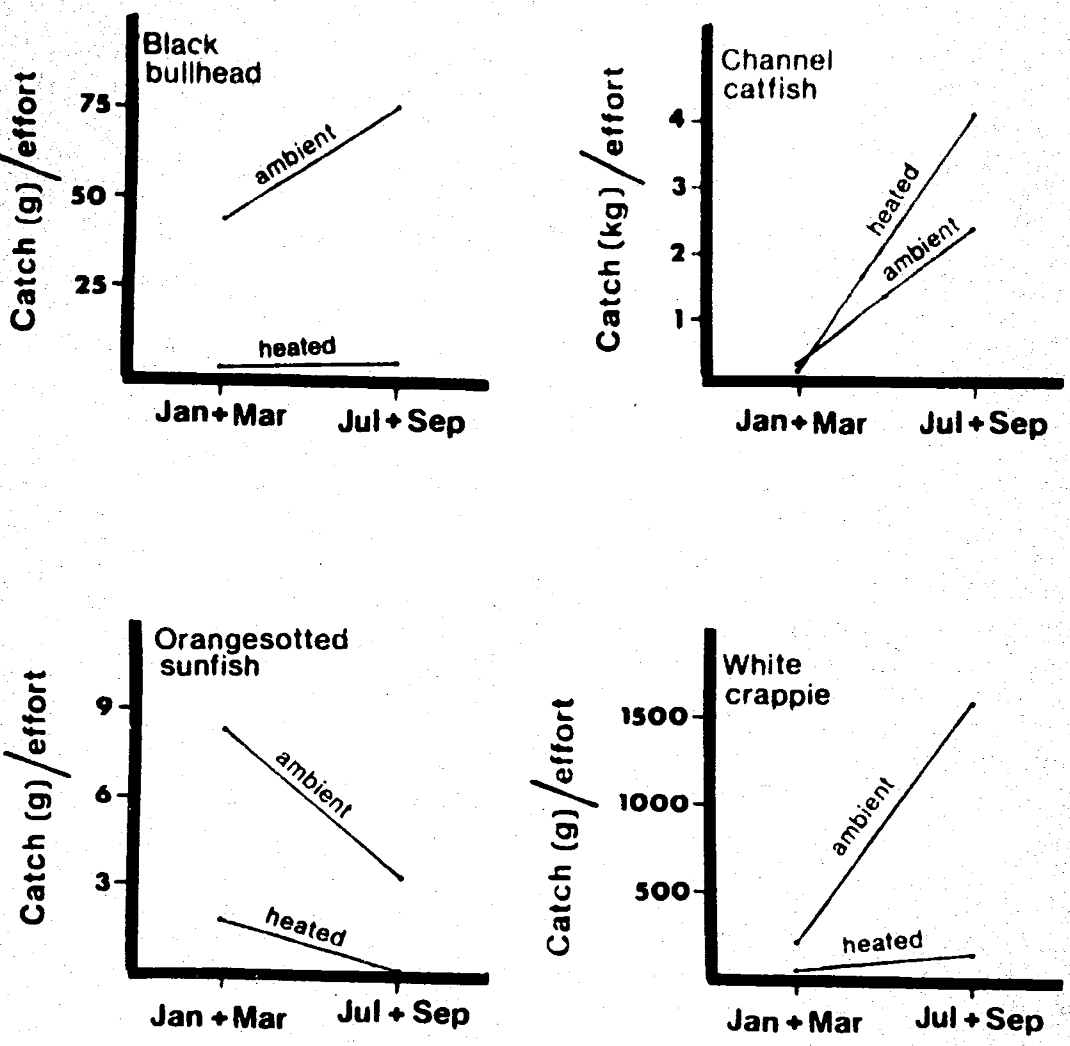

Fig. 13.2. Significant differences in catch/effort of selected Coffeen Lake fishes due to month-by-station interaction effects. Heated and ambient refer to Stations 1 and 4, respectively.

Orangespotted sunfish catches were generally higher during cold months than during warm months and between-month differences in magnitude of catch were more pronounced at the ambient location (Fig. 13.2).

Surface water temperature was a significant environmental factor governing fish distribution as judged by significant correlations between temperature and fish density (Table 13.2). Species which responded to increasing temperatures in a positive manner included gizzard shad, black bullhead, channel catfish, bluegill, largemouth bass, longear sunfish, orangespotted sunfish, hybrid sunfish, and white crappie. For those species, significant correlations between catch/effort and water temperature were detected for both linear and quadratic covariables. The linear correlation was a more precise descriptor of the catch-temperature relationship for gizzard shad, black bullhead, channel catfish, bluegill, largemouth bass, and white crappie while the quadratic regression model was more accurate in describing that relationship among longear sunfish, orangespotted sunfish, and hybrid sunfishes, indicating increasing catches with increases in water temperature up to a point, after which a decline in catch occurred as temperatures rose further.

Partial correlations were made between catch/effort of five major forage and game species and 21 environmental variables measured concurrently at each station (Table 13.6). In this analysis, water temperature was identified as a highly significant influence on catches of gizzard shad, largemouth bass and *Lepomis* sunfishes (pooled catches of *Lepomis* spp.). The linear temperature relationships were positive indicating increasing catches with increasing water temperatures, while the parabolic (quadratic) correlations, which described the catch/temperature relationship more precisely, were negative, indicating that highest catches of these species were obtained at moderate temperatures, and the decline in catch/effort at high temperatures was more extreme than was the decline at low temperature.

Several other environmental variables were identified as potentially important factors governing distributions of certain species. A positive correlation was found between total phosphorous levels and channel catfish densities (Table 13.6). For largemouth bass, a positive correlation was detected between

Table 13.6. Partial correlation coefficients ($r_{1\cdot2...21}$) between average catch/effort of selected Coffeen Lake fishes* and 21 environmental variables measured concurrently with fish catch. Significance probability levels are: * = 10%, ** = 5%, and *** = 1%).

| Variable | Gizzard Shad | Channel Catfish | Largemouth Bass | Lepomis spp. | White Crappie |
|---|---|---|---|---|---|
| * Total benthos | 0.32 | 0.05 | -0.34 | -0.28 | 0.18 |
| * Oligochaeta | -0.26 | -0.39 | -0.14 | 0.03 | -0.45* |
| * Ephemeroptera | -0.26 | 0.06 | -0.18 | -0.31 | 0.02 |
| * Chaoborus | -0.03 | 0.12 | -0.30 | -0.10 | -0.15 |
| * Chironomidae | -0.08 | -0.35 | -0.21 | 0.17 | -0.28 |
| Total zooplankton | -0.26 | -0.01 | 0.45* | 0.07 | -0.19 |
| Total phytoplankton | 0.02 | 0.23 | -0.03 | -0.33 | 0.33 |
| Chlorophyta | -0.08 | 0.20 | 0.61** | 0.39 | 0.16 |
| Bacillariophyta | 0.14 | 0.08 | -0.06 | -0.19 | 0.04 |
| Cyanophyta | 0.00 | 0.38 | 0.29 | 0.52** | 0.35 |
| Temperature (linear) | 0.55** | 0.18 | 0.80*** | 0.49* | -0.03 |
| Temperature$^2$ (quad) | -0.69*** | -0.36 | -0.85*** | -0.51* | -0.27 |
| Turbidity | 0.14 | -0.19 | -0.12 | -0.36 | -0.18 |
| Alkalinity | 0.33 | 0.40 | 0.44* | 0.49* | 0.34 |
| Hardness | -0.07 | -0.32 | -0.22 | -0.34 | -0.39 |
| Sulfate | -0.06 | 0.00 | -0.19 | -0.37 | 0.08 |
| TDS | 0.10 | 0.04 | 0.05 | 0.19 | -0.06 |
| pH | 0.24 | 0.14 | -0.02 | 0.07 | 0.21 |
| Dissolved oxygen | -0.40 | -0.39 | 0.08 | 0.06 | -0.37 |
| Total phosphorus | -0.01 | 0.46* | 0.19 | 0.46* | 0.26 |
| Total nitrogen | -0.38 | -0.40 | -0.10 | 0.36 | -0.43 |

*Biomass values transformed to $\text{Log}_{10}$ (x+1).

catch/effort and total zooplankton biomass, green algal (Chlorophyta) biomass, and alkalinity level. Sunfish (Lepomis spp.) catches were positively correlated with blue-green algae (Cyanophyta) and alkalinity, and white crappie exhibited a negative correlation with oligochaete biomass densities. The importance of water temperature in governing distributions of certain fishes is clear upon examination of these data as well as those obtained in the larger analysis of variance model (Table 13.2).

## DISCUSSION

The current assemblage of fishes in Coffeen Lake, as judged by the species composition of bimonthly samples and cove rotenone samples (Section 14, herein), is comprised of seven families, 22 species, and various Lepomis hybrids. The composite species list previously cited for Coffeen Lake (Lopinot 1970, Ecology Consultants, Inc. 1977, McNurney and Tranquilli 1979) included seven species not found in this study: lake chub (Couesius plumbeus), emerald shiner (Notropis atherinoides), common shiner (N. cornutus), creek chubsucker (Erimyzon oblongus), mosquitofish (Gambusia affinis), warmouth (Lepomis gulosus), and yellow perch (Perca flavescens). Species identified in this study that were not previously reported include: goldfish, red shiner, fathead minnow, river carpsucker, quillback, white sucker, tadpole madtom (Noturus gyrinus), yellow bass, and white bass. The presence of substantial populations of channel catfish, largemouth bass, and white crappie in Coffeen Lake is partly explained by efforts to stock those species in the mid-1960's (Ill. Dept. Cons., Div. Fish. files). Other extant species were apparently part of the original McDavid Branch fish community or represent incidental introductions.

Methods employed in this investigation were similar to those used by Tranquilli et al. (1979) for sampling fishes in two other central Illinois reservoirs: Lake Sangchris, a cooling water reservoir in Sangamon and Christian Counties operated by Commonwealth Edison Co., and Lake Shelbyville, a flood control reservoir in Shelby and Moultrie Counties operated by the Army Corps of Engineers. When equivalent units of fishing effort in the three lakes were compared (gill netting, seining, and electroshocking efforts adjusted to represent equivalent units of sampling effort), the catch of fishes in Coffeen

Lake (53 kg/unit effort) was found to be similar to that of Lake Sangchris (59 kg/effort) but lower than that of Lake Shelbyville (86 kg/effort). The Coffeen fish fauna (22 species) was less diverse than the Shelbyville assemblage (44 species) but comparable to the Sangchris community (20 species). Carp ranked first and gizzard shad second in biomass at each of the three lakes. Largemouth bass ranked third in biomass at the two cooling lakes and fourth at Lake Shelbyville. Predatory gamefish catches by weight were: 25.7% in Coffeen Lake, 26.6% in Lake Sangchris, and 25.6% in Lake Shelbyville, based upon the total weight of all fishes. Contributions of major sport fishes in those three lakes, respectively, were: channel catfish-5.9%, 4.7%, and 2.6%, largemouth bass-17.4%, 16.3%, and 5.6%, and white crappie-2.5%, 1.0%, and 2.3%. McNurney and Tranquilli (1979) listed several general characteristics of five central Illinois reservoirs (including Coffeen Lake) based upon comparable fisheries and limnological surveys. The lakes typically supported large populations of gizzard shad, catfishes, and sunfishes. Carp were usually low in number but comprised a large portion of the total fish biomass. Piscivorous species generally represented 23-35% of the standing crop biomass of all species. The findings of this study are generally consistent with that characterization.

Largemouth bass are the most important predators in Coffeen Lake and Lake Sangchris as judged by standing crop and catch/effort data. Tranquilli et al. (1981) maintained that a high productivity of largemouth bass over an 11-year period in Lake Sangchris was a result of enhanced spawning success and longer growing seasons in thermally-enriched areas. Drew and Tilton (1970) found that cooling lakes in Texas also remained highly productive over a long period of time. They attributed their findings to reduced stratification and a more beneficial distribution of nutrients in those lakes. In addition to those phenomena, the Coffeen Lake bass population may benefit in part from relatively low fishing mortality since the lake is not open to fishing by the general public. Trepassing fishermen were frequently observed on the lake, but their impact on the bass population is unknown.

The self-sustaining capability of the channel catfish population in Coffeen Lake was surprising in view of the inability of this species to reproduce in other Illinois reservoirs that are not fed by major tributaries and which contain large populations of predatory species. In Lake Sangchris, Tranquilli et al. (1981) speculated that elevated temperatures and continuous currents produced by thermal discharges may have enhanced spawning success of this species. In the Wabash River, Indiana, populations of channel catfish may have increased in numbers in thermally exposed areas because of more successful reproduction (Gammon 1973). Thus, thermal effluents and associated currents are implicated as environmental components of Coffeen Lake that may benefit propagation of channel catfish.

The orientation of fishes to a thermal discharge, or their spatial distributions relative to such inputs, has been studied in other cooling lakes throughout the U.S. Witt et al. (1970) found that gizzard shad were attracted in winter to a thermal outfall in Thomas Hill Reservoir, Missouri. Coutant (1974), in studies of Bull Run Steam Plant on the Clinch River, Tennessee, demonstrated a similar thermal attraction among shad during the spring, a response that ceased once the discharge of heated water was interrupted. Tranquilli et al. (1981) collected significantly more shad in heated areas relative to ambient areas of Lake Sangchris, but the species was found to be widely distributed throughout the lake. In contrast, McNeely and Pearson (1974) found shad to be evenly distributed throughout a Texas cooling lake during all seasons, and Rutledge (1975), in studies of Lake Arlington, Texas, found no difference in relative abundance of shad between sampling stations or between seasons. Although the catch/effort of gizzard shad in this study was highest at the ambient station, their density in the thermal discharge area was higher than that at either of two thermally-intermediate stations.

The affinity of channel catfishes for thermally-elevated areas, as demonstrated in this study, is supported by Dryer and Benson (1957) who found aggregations of channel catfish in the discharge harbor of the New Johnsonville Steam Plant on Kentucky Lake from mid-March through July. Gammon (1973) found that channel catfish preferred the moderately elevated water temperatures below a thermal outfall to either the warmer discharge canal area or the ambient area above the outfall. Seasonal concentrations of channel catfish in thermally affected areas of Lake Sangchris were reported by Tranquilli et al. (1981). The black bullhead, a species closely related to the channel catfish, apparently does not respond well to thermal elevations as evidenced by their infrequent occurrence in areas receiving those inputs (Neill and Magnuson 1974, Tranquilli et al. 1981, and this study).

Evidence of a thermoselective response by largemouth bass has been demonstrated less frequently than it has been for the species discussed above. Witt et al. (1970) found greater densities of this species in heated areas of a Missouri cooling lake during the winter, and Neill and Magnuson (1974) noted occasional concentrations of bass in heated areas relative to reference areas of Lake Monona, Wisconsin. Tranquilli et al. (1981) determined that bass densities in Lake Sangchris differed seasonally between heated and ambient locations in that concentrations were high in winter and low in summer at heated locations while the ambient location yielded low catches in winter and relatively higher catches in summer. Rutledge (1975), however, found no difference in the spatiotemporal distribution of bass relative to a thermal discharge in Lake Arlington, Texas. Largemouth bass in Coffeen Lake were widely distributed and generally were more abundant at heated and ambient locations relative to thermally-intermediate ones.

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# SECTION 14

## STANDING CROP ESTIMATES OF COFFEEN LAKE FISHES

by

Lance G. Perry and John A. Tranquilli

### ABSTRACT

Two estimates of the standing crop biomass of fishes were obtained from each of two locations in Coffeen Lake by cove-rotenone techniques. The average biomass of all species was 436.9 kg/ha. Major contributing species in order of decreasing biomass densities were gizzard shad, Lepomis sunfishes, channel catfish, carp, and largemouth bass. Between-cove differences in biomass densities of fishes are discussed and average biomass values for selected species are compared to averages derived from other reservoirs throughout the United States.

## INTRODUCTION

Estimation of the standing crop biomass of fishes in lakes and reservoirs is often accomplished by applying rotenone, a fish toxicant, to a selected cove or other isolated section of the lake habitat. Unlike most other fish collecting methods, this technique is neither size-selective nor species-selective when appropriately conducted, and thus is of great utility for making direct comparisons of biomass densities between species populations of a given lake, and between populations inhabiting different lakes or within-lake habitats. Primary objectives of this study were (1) to estimate the standing crop biomass of fishes inhabiting Coffeen Lake, a thermally altered reservoir, (2) to identify factors which may influence spatial differences in biomass densities, and (3) to compare densities of selected Coffeen Lake species to known biomass densities of conspecifics in other heated and unheated reservoirs.

## MATERIALS AND METHODS

Four estimates of the standing crop biomass of fishes were obtained, two from each of two locations (Fig. 13.1, Section 13, herein). The north cove (0.51 ha), located in an area of ambient water temperatures, was sampled on 20-24 August 1979 and the south cove (1.59 ha), which was near the center of the cooling loop, was sampled on 8-11 October 1979. In 1980, sampling at the north cove was conducted on 25-27 August and at the south cove on 20-23 October. Routine procedure on the first day of sampling consisted of isolating the target area from the main lake channel with a block net. Two different nets were used. In 1979, net dimensions were 91.4-m x 3.7-m and in 1980, 91.4-m x 6.1-m. Rotenone was applied to the isolated cove and mixed approximating a 1 ppm concentration. All stressed fishes were collected as they rose to the surface, identified, enumerated, and weighed. The cove was detoxified with potassium permanganate about four hours after rotenone application. Collection of fishes continued for an additional 3 days, with the block net in place, to insure

insure complete recovery of specimens. The biomass of individuals collected during that period was calculated from known weight-length relationships of fresh specimens (first-day collections) in order to eliminate bias in weight measurements of partially decomposed specimens. All biomass values presented herein represent best estimates for recovered specimens; that is, no extrapolations were performed to estimate weights of fishes that remained after sampling was completed.

## RESULTS AND DISCUSSION

Fifteen species representing 10 genera and five families were collected in cove rotenone samples (Table 14.1). The tadpole madtom (*Noturus gyrinus*) was the only species represented which was not encountered in our bimonthly samples (Section 13, herein). Gizzard shad were dominant by number and weight in both coves sampled (Table 14.1 and 14.2). As a group, the smaller sunfishes (*Lepomis* spp.) were second in importance numerically, followed by channel catfish and largemouth bass. Bluegills ranked second, behind gizzard shad, in average catch by weight, followed by channel catfish (Table 14.2). The other *Lepomis* sunfishes, carp, and largemouth bass represented intermediate weight catches overall.

Between-cove differences in numerical abundance of fishes were most pronounced for the *Lepomis* sunfishes. Although catches were quite variable over the two-year period, the yield of small sunfishes was generally greater at the north cove (Table 14.1). Less pronounced, but also more abundant at the northern location were black bullheads and golden shiners. About equal between-cove numerical catches were evident for largemouth bass, yellow bullhead, and carp. The densities of gizzard shad, channel catfish, white crappie, and blackstripe topminnow fluctuated greatly, but no between-cove differences were suggested by the catch data.

Biomass differences between coves generally reflected numerical differences in that total weights of *Lepomis* sunfishes, black bullheads, and golden shiners were noticeably higher at the north cove (Table 14.2); gizzard shad, channel catfish, carp, largemouth bass, yellow bullhead, and white crappie densities

Table 14.1. Numerical abundance (number/hectare) of Coffeen Lake fishes collected in cove rotenone samples during 1979 and 1980. Cove locations are depicted in Fig. 13.1 (Section 13, herein). Species are listed in order of decreasing average abundance.

| Species | Lake-wide average (N = 4) | | North Cove (0.51 ha) | | South Cove (1.59 ha) | |
|---|---|---|---|---|---|---|
| | No./ha | % | 1979 | 1980 | 1979 | 1980 |
| Gizzard shad | 10,197 | 48.9 | 14,676 | 7,175 | 9,462 | 9,476 |
| Young-of-year <u>Lepomis</u> | 5,870 | 28.1 | 4,841 | 10,857 | 5,494 | 2,286 |
| Bluegill | 2,245 | 10.8 | 5,096 | 1,839 | 1,633 | 413 |
| Longear sunfish | 743 | 3.6 | 1,737 | 657 | 225 | 352 |
| Channel catfish | 460 | 2.2 | 524 | 263 | 685 | 367 |
| <u>Lepomis</u> hybrids | 346 | 1.7 | 800 | 163 | 224 | 197 |
| Green sunfish | 285 | 1.4 | 555 | 333 | 188 | 62 |
| Largemouth bass | 255 | 1.2 | 202 | 269 | 269 | 279 |
| Orangespotted sunfish | 188 | 0.9 | 410 | 161 | 181 | 1 |
| Blackstripe topminnow | 80 | 0.4 | 39 | 157 | 104 | 15 |
| Yellow bullhead | 68 | 0.3 | 82 | 71 | 80 | 40 |
| White crappie | 42 | 0.2 | 49 | 0 | 96 | 21 |
| Tadpole madtom | 32 | 0.2 | 69 | 55 | 2 | 0 |
| Golden shiner | 30 | 0.1 | 41 | 47 | 22 | 11 |
| Black bullhead | 19 | 0.1 | 59 | 10 | 4 | 4 |
| (young-of-year) | (831) | | | (3,325) | | |
| Carp | 8 | <0.1 | 6 | 12 | 9 | 5 |
| Red shiner | 2 | <0.1 | 6 | 0 | 0 | 0 |
| Totals | 21,700 | | 29,192 | 25,394 | 13,678 | 13,529 |

Table 14.2. Biomass (kilograms/hectare) of Coffeen Lake fishes collected in cove rotenone samples during 1979 and 1980. Cove locations are depicted in Fig. 13.1 (Section 13, herein). Species are listed in order of decreasing average weights.

| Species | Lake-wide average (N = 4) | | North Cove (0.51 ha) | | South Cove (1.59 ha) | |
|---|---|---|---|---|---|---|
| | kg/ha | % | 1979 | 1980 | 1979 | 1980 |
| Gizzard shad | 267.5 | 61.1 | 353.6 | 186.9 | 243.6 | 285.9 |
| Bluegill | 52.1 | 11.9 | 122.1 | 50.2 | 27.1 | 9.1 |
| Channel catfish | 34.6 | 7.9 | 40.3 | 27.5 | 41.0 | 29.4 |
| Longear sunfish | 19.8 | 4.5 | 46.6 | 18.2 | 5.4 | 9.0 |
| Carp | 13.9 | 3.2 | 15.0 | 11.1 | 20.0 | 9.5 |
| Green sunfish | 10.6 | 2.4 | 17.3 | 16.4 | 6.2 | 2.4 |
| *Lepomis* hybrids | 8.6 | 2.0 | 18.4 | 3.3 | 6.7 | 5.9 |
| Young-of-year *Lepomis* | 8.2 | 1.9 | 4.2 | 15.3 | 4.8 | 8.5 |
| Largemouth bass | 7.7 | 1.8 | 7.1 | 6.8 | 5.8 | 10.9 |
| White crappie | 4.6 | 1.1 | 4.4 | 0 | 10.5 | 3.3 |
| Yellow bullhead | 3.5 | 0.8 | 3.9 | 4.6 | 3.4 | 2.1 |
| Orangespotted sunfish | 2.2 | 0.5 | 3.9 | 3.0 | 1.8 | <0.1 |
| Black bullhead | 1.3 | 0.3 | 3.9 | 0.8 | 0.2 | 0.2 |
| (young-of-year) | (0.9) | (0.2) | | (3.4) | | |
| Golden shiner | 1.2 | 0.3 | 1.4 | 2.2 | 0.7 | 0.6 |
| Tadpole madtom | 0.1 | <0.1 | 0.2 | 0.3 | <0.1 | <0.1 |
| Blackstripe topminnow | 0.1 | <0.1 | 0.1 | 0.3 | 0.1 | <0.1 |
| Red shiner | <0.1 | <0.1 | <0.1 | 0 | 0 | 0 |
| Totals | 437.8 | | 642.9 | 353.7 | 377.3 | 376.8 |

were more comparable between coves, although highly variable for certain of those species. In general, the variation which was encountered between samples obscured any thermal influences that may have affected species densities. Thus, the greater numerical and biomass densities of certain species at the north cove could have been related to the ambient temperature regime characteristic of that location or to some other characteristic of the habitat (see Section 13, herein, for a more detailed analysis of thermal effects on fish distribution).

Total numerical catches were about 25% lower in 1980 than in 1979 but a between-year disparity in biomass density was only evident at the north cove (Table 14.2). Numbers and weights of gizzard shad, channel catfish, and adult sunfishes (Lepomis spp) were lower at the northern location in 1980 which largely accounted for the between-year difference. It is noteworthy that the surface water elevation was about 37 cm lower in 1980 than in 1979 (at the time of sampling), a factor which probably contributed to lower catches of sunfishes, and possibly other species, since much of the littoral zone vegetation was exposed above the water surface and thus inaccessible to fishes as habitat. Another anomaly of the 1980 north cove sample was the large catch of young-of-the-year black bullheads (Tables 14.1 and 14.2). Comparable densities of young bullheads were not found at the south cove or at the north cove during the previous year. Reproduction was apparently unusually successful at the northern location in 1980, and numerical and biomass densities are accordingly presented separately for the young-of-the-year group.

Differences between standing-crop biomass estimates and bimonthly catch estimates (Section 13, herein) were most pronounced for carp and largemouth bass. Percentage weights of both species were generally higher in bimonthly samples, presumably due to electroshocking selectivity for individuals of large size. Adult largemouth bass and carp, the latter represented by large adult fishes exclusively, were much more common in bimonthly catch/effort samples than in cove rotenone samples. The biomass densities of these species may have been underestimated in cove samples since Hayne et al. (1967) found that young fishes were usually overestimated in both numbers and weights by cove census techniques while fishes of large size were usually underestimated. They concluded, however, that the total standing crop of all fishes was probably a reliable estimate of the true lake-wide biomass even though estimated densities of certain species may be biased.

In order to gain a perspective on the Coffeen Lake standing crop values, species-specific comparisons were made with estimates derived from other reservoirs throughout the U.S. (Table 14.3). Two central Illinois reservoirs were included: Lake Sangchris, a cooling lake in Sangamon and Christian Counties operated by Commonwealth Edison Company, and Lake Shelbyville, a flood control reservoir in Shelby and Moultrie Counties operated by the Army Corps of Engineers. Standing crop values from midwestern reservoirs, ranging in size from 0.05 to 126 ha, were tabulated by Carlander (1955), and Jenkins (1975) presented values derived from 173 reservoirs in the mid-southern U.S. All standing crop estimates from those lakes were obtained by cove rotenone or similar techniques. No statistical data were available for analysis, so the comparisons discussed below are only subjective.

Gizzard shad standing crops in Coffeen Lake were similar to those found in the two other Illinois lakes and in the smaller midwestern reservoirs (Table 14.3). Biomass densities of carp were quite low in Coffeen Lake compared to all other locations, while channel catfish densities were noticeably higher than in most other reservoirs. Also comparatively higher in Coffeen Lake were bluegills and the total for all Lepomis species, the density of the former resembling most closely that of much smaller midwestern reservoirs. Biomass estimates for largemouth bass and white crappie in Coffeen Lake suggested intermediate densities based upon the range of average values reported. Mark and recapture estimates of largemouth bass standing crops (Section 17, herein) yielded estimates of 9.3 and 10.8 kg/ha for 1979 and 1980, respectively, which, although slightly higher than the cove rotenone estimate, still indicated an intermediate density overall. The total biomass of fishes in Coffeen Lake was second only to the Lake Shelbyville estimate and was more than twice as large as the mid-south average. Maximum values for specific biomass densities, as reported from midwestern and southern

Table 14.3. Comparative standing crop biomass estimates (kg/ha) of selected species from Illinois reservoirs (Coffeen Lake, Lake Sangchris, and Lake Shelbyville) and from other reservoirs throughout the United States. Means are given with maximum values in parentheses.

| Species | Coffeen Lake | Lake Sangchris[1] | Lake Shelbyville[1] | Midwest[2] | Mid-south[3] |
|---|---|---|---|---|---|
| Gizzard Shad | 267.5 | 275.3 | 294.0 | 204 (468) | 92 (717) |
| Carp | 13.9 | 27.0 | 70.8 | 73 (233) | 25 (261) |
| Channel catfish | 34.6 | 9.5 | 2.6 | 14 (57) | 9 (110) |
| Bluegill | 52.1 | 22.8 | 22.7 | 42 (180) | 21 (87) |
| <u>Lepomis</u> spp. | 101.5 | 25.6 | 30.5 | -- | 31 (156) |
| Largemouth bass | 7.7 | 3.5 | 12.6 | 19 (59) | 10 (59) |
| White crappie | 4.6 | 0.5 | 4.0 | 26 (85) | 5 (49) |
| All species | 437.8 | 360.9 | 449.6 | 398 (134) | 202 (1000) |

[1] Tranquilli et al. 1979
[2] Carlander 1955
[3] Jenkins 1975

reservoirs (Table 14.3), illustrate the great variation which exists in fish standing crops, and also indicates that the Coffeen Lake values are not exceptional for the species considered.

Several mathematical models have been formulated for predicting standing crops of fishes in lakes based upon selected morphometric and edaphic characteristics of the lake basin. Ryder's (1965) morphoedaphic index utilizes the ratio of total dissolved solids (TDS in ppm) and mean depth (ft) as a predictor of biomass for north-temperate lakes. Application of the index to Coffeen Lake, using 750 ppm as an average TDS (Section 3, herein) and 18.7 ft. as the mean lake depth, yielded a predicted value of 382.2 kg/ha which only slightly underestimates our estimate from cove rotenone samples. The index is not directly applicable to Coffeen Lake, however, because of its more southerly location and a large sulfate component associated with the TDS which is believed to have originated from sources other than edaphic ones (Section 1, herein). Ryder et al. (1974) cautioned against utilizing the index for predictive purposes when the lake in question has anomalous features such as high sulfates, a chemical constituent which apparently is unrelated to fish crops. Jenkins (1977) utilized a regression equation for modeling standing crops of reservoir fishes based upon TDS concentrations and chemical characteristics of lakes. Applying the regression for carbonate- bicarbonate dominated waters yielded a predicted standing crop of 475.7 kg/ha which is comparable to our actual estimate. Jenkins' sample of reservoirs, however, did not include any with a TDS value as high as that found in Coffeen Lake. Utilizing his formula for predicting the standing crop in Coffeen Lake thus requires interpolation beyond the data from which the formula was derived. In general, standing crops of fishes in Coffeen Lake appear to be similar in many respects to other lakes of comparable size and locality and no pronounced influences of the high TDS were suggested by our standing crop data.

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# SECTION 15

# AGE, GROWTH, CONDITION, AND LENGTH-FREQUENCY DISTRIBUTIONS OF SELECTED COFFEEN LAKE FISHES

by

Lance G. Perry and John A. Tranquilli

## ABSTRACT

Age and growth relationships, body condition, and population size structure were examined for gizzard shad, carp, channel catfish, bluegill, largemouth bass, and white crappie in Coffeen Lake. Adult gizzard shad were represented by a single 155 mm mode in their length frequency distribution which represented a relatively small adult size for this species. Body condition of shad was generally good when judged on a lake-wide basis. Carp were represented by large adult fishes exclusively and there was no evidence of successful reproduction of this species during the two-year study period. The length distribution of channel catfish was polymodal which obscured age and growth relationships. Body condition indices for this species were slightly below optimum values but no thermal effects or size-related differences were suggested by the data. Bluegills collected in autumn did not exceed 160 mm in length indicating a slow rate of growth for this species, and their body condition generally declined with increasing length. Factors responsible for those findings are discussed. Growth rates of largemouth bass were quite rapid for all age groups although a relatively low body condition was detected among first year bass from heated locations. Body condition of age I and older individuals was exemplary for this species. Few young-of-the-year white crappie were found but a wide range of adult sizes was evident. Body condition was relatively poor among smaller white crappies while the largest specimens exhibited good condition.

## INTRODUCTION

Many vital statistics of reservoir fish populations, including age, growth, condition, and size-structure are governed by and thus reflect, the quality of the habitat. Coffeen Lake is unique in both its biotic and abiotic characteristics, due in part to its function as a cooling-water impoundment for Coffeen Power Station. Consequently, this investigation was conducted to evaluate several basic life history phenomena of Coffeen Lake fishes and to identify impacts, if any, of the artificial thermal and chemical regimes imposed by operation of the power plant cooling system.

## MATERIALS AND METHODS

Species selected for evaluation included gizzard shad, carp, channel catfish, bluegill, largemouth bass, and white crappie since they represented major forage, game, and rough fishes and each contributed substantially to the total fish biomass of Coffeen Lake. Species-specific length-frequency histograms were constructed from total length (mm) observations obtained during late summer and early fall periods. Since large sample sizes were desired, and to minimize size-selectivity, several collecting methods were employed. Length-frequency data for gizzard shad, carp, and bluegill were acquired during the September and November 1978 and 1979 bimonthly collections described in Section 13 (herein). Length data for channel catfish were assembled from cove rotenone sampling (Section 14, herein) conducted during late August and October of 1979 and 1980. Largemouth bass length-frequencies were constructed from lake-wide electroshocking surveys conducted from 15 October to 20 November 1979 and from 29 September to 25 November 1980. Length data for white crappie were obtained from September and November (1978) bimonthly catches and from September and November (1979) bimonthly catches combined with cove rotenone samples obtained in 1979.

The Petersen method (Ricker 1975) was used for evaluating age and growth of gizzard shad, carp, channel catfish, bluegill, and white crappie. The procedure is based on the assumption that spawning occurs annually and that each age group is represented by a modal configuration in the length-frequency distribution. Usually only the younger age groups meet the latter requirement (Bagenal and Tesch 1978). Growth of largemouth bass was estimated by a mark and recapture procedure described in Section 17 (herein). Briefly, individuals of known size (all $\geq$200 mm total length) were marked and released in the spring of 1979 and again in the spring of 1980. Recapture of marked individuals in the fall or the spring following release allowed measurement of the increase in length attained by each recaptured fish during the 1979 or 1980 growing seasons, thus providing an estimate of growth during those periods. Growth rates of smaller individuals were also estimated in 1980 by a mark and recapture procedure modified from Rinne (1976). Specimens ranging in size from 100 to 109 mm total length were marked in the spring of that year by removing the second dorsal spine, those ranging from 110 to 119 mm by removing the third dorsal spine, and so on up to the 170 to 179 mm interval (last dorsal spine removed). Fish within the 180-189 and 190-199 length intervals were given anal spine clips, first two spines and third spine, respectively. All specimens were also fin clipped (left pelvic) to aid in recognition of marked individuals. Fish recaptured in the fall of 1980 or the spring of 1981 were measured and incremental length increases were calculated for each individual.

Ages of largemouth bass were determined by viewing a cross-section of the otolith (sagittae) under a dissecting stereomicroscope equipped with a polarizer and a transmitted light source. Each hyaline zone (Pannella 1974) around the nucleus was counted as one annulus (Taubert et al. 1981). All bass otoliths were obtained from specimens captured by electroshocking at heated and ambient locations (Section 13, herein) in the fall of 1980. Age groups were designated as 0, I, II, etc., corresponding to number of annuli, followed by a "+" indicating that all samples were obtained late in the growing season.

Body condition of gizzard shad, channel catfish, bluegill, largemouth bass, and white crappie were evaluated by calculating mean relative weight (Wr) values (Anderson 1980). This index relates the observed (measured) weight to a high quality standard weight derived from published values. All length and weight observations were obtained in late summer and early fall. Only data from individuals collected by electroshocking and/or first-day cove rotenone sampling were utilized to insure that all specimens were fresh when measured. Separate indices were calculated for heated and ambient locations and for each of the two cove rotenone samples.

Proportional stock densities (Anderson 1980) were calculated from length-frequency data for each of the six species. The index relates the number of "quality" size individuals to those of "stock" size (as defined by Anderson 1980) and provides a basis for interpreting the desirability of a given species size-structure based upon its function (forage or game fish) in the fish community.

## RESULTS AND DISCUSSION

### Gizzard shad

Length-frequency distributions of gizzard shad were characterized as bimodal and were similar over the two years sampled (Fig. 15.1). Young-of-the-year (age 0+) were present in each sample (modally at 95 mm in 1978), but they were not common. Their small size and strong schooling response probably contributed to an underestimate of abundance because of sampling gear avoidance. Cove rotenone sampling (Section 14, herein) which was more selective for young fishes, produced large numbers of age 0+ gizzard shad in 1979 and 1980. An average length of 95 mm by September was typical of age 0+ gizzard shad from Lakes Sangchris and Shelbyville (Joy and Tranquilli 1979) but was slightly below that attained by September young-of-the-year from other midwestern waters (Carlander 1969). Ages represented by the pronounced 155 mm modal configurations (Fig. 15.1) could not be verified but age I+ was probable in view of known age-length relationships of this species in Lake Shelbyville (Joy and Tranquilli 1979). Older individuals may also have been represented in that group, however, since age II+ and older individuals were strongly represented by a 260 mm mode in Lake Shelbyville, a mode that was not evident in Coffeen Lake. It is thus suggested that II+ and older shad may be rare in Coffeen Lake or exhibit slow growth after

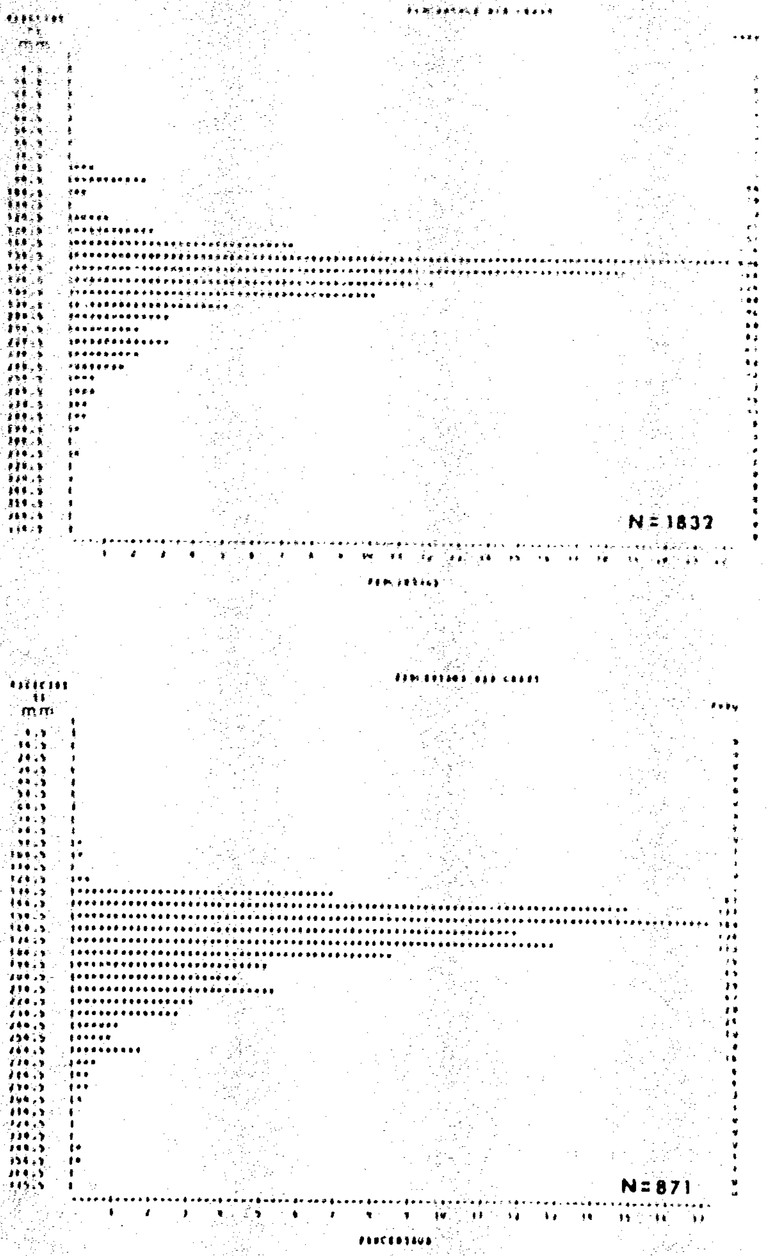

Fig. 15.1. Length-frequency distributions of gizzard shad collected in September 1978 (upper) and September 1979 (lower) in Coffeen Lake. The samples represent pooled catches from four sampling stations.

attainment of age I+. The relatively small size attained by adult shad in Coffeen Lake is reflected in proportional stock density values which were quite low compared to the recommended range (Table 15.1). Although large adult shad are less desirable as forage, their presence in a population contributes greatly to the reproductive capacity of the species, thus improving the forage base by increasing annual production (Anderson pers. comm.). Maintenance of a generally small size of gizzard shad in Coffeen Lake may be partly related to thermal influences in view of the comparably small adult size reached by this species in Lake Sangchris (Joy and Tranquilli 1979), a cooling lake which is similar in many respects to Coffeen Lake.

Body condition of gizzard shad was quite good over the range of lengths tested (Fig. 15.2) based upon a recommended relative weight value of 100 (Anderson 1980). Slightly lower values were evident for larger individuals in 1979, but no pronounced differences in condition between heated and ambient locations were suggested over the two year period.

### Carp

The carp population in Coffeen Lake was comprised exclusively of large adult fishes which precluded age and growth evaluation (Fig. 15.3). Our judgement is that spawning occurred since ripe males and gravid females were encountered in the field and spawning activities were occasionally observed along shoreline vegetation. Juvenile fishes, however, were conspicuously absent from bimonthly catch/effort and cove rotenone samples (Sections 13 and 14, herein), and only two larval carp were collected during a lake-wide larval fish sampling program (Section 10, herein). Factors responsible for the apparent lack of successful reproduction may relate to one or more of the following. First, predation on eggs and larvae may exert constraints on spawning success, promoted somewhat by the spawning strategy of this species. Carp generally scatter their eggs over beds of submerged vegetation where eggs and larvae develop without parental care. In Coffeen Lake, vegetated littoral regions are densely populated by small sunfishes which may exert heavy predation pressure on those early life stages (fish eggs were an important component in diets of Coffeen Lake bluegills, Section 8, herein).

Table 15.1. Proportional stock densities of selected Coffeen Lake fishes collected in late summer and early fall of 1978, 1979, and 1980. Values were calculated from length-frequency distributions of each species as presented herein.

| Species | Proportional stock density (%)[1] | | | Recommended Range[1] |
|---|---|---|---|---|
| | 1978 | 1979 | 1980 | |
| Gizzard shad | 2.8 | 3.2 | — | 20-60 |
| Carp | 70.1 | 85.2 | — | — |
| Channel catfish | — | 9.5 | 18.4 | — |
| Bluegill | 0.2 | 0.8 | — | 20-60 |
| Largemouth bass | — | 59.6 | 48.7 | 40-70 |
| White crappie | 74.6 | 72.3 | — | — |

[1] Anderson (1980) and pers. comm.

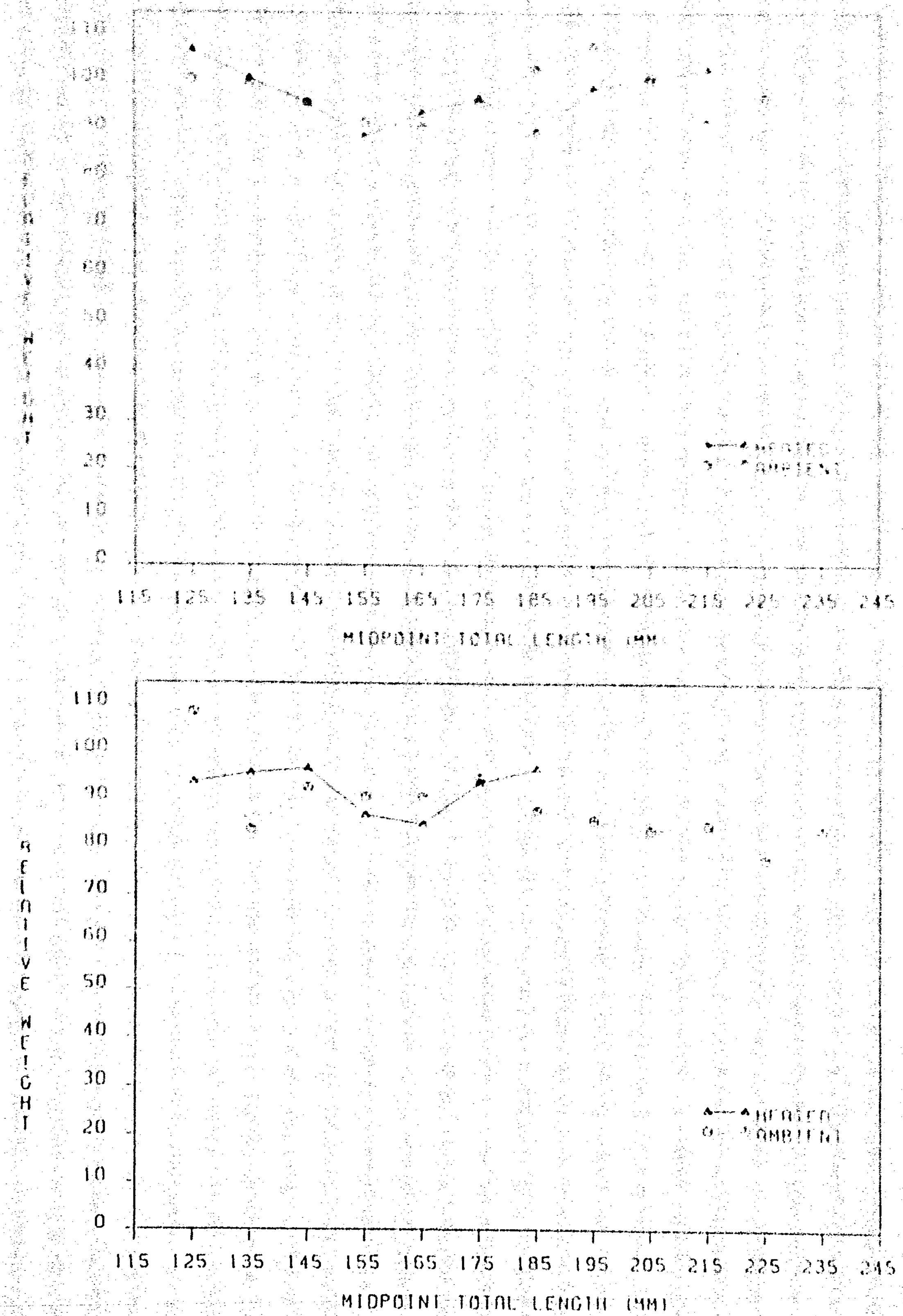

Fig. 15.2. Mean relative weight values of gizzard shad collected in September 1978 (upper) and September 1979 (lower) in Coffeen Lake. Heated and ambient refer to Stations 1 and 4 (Section 13, herein), respectively.

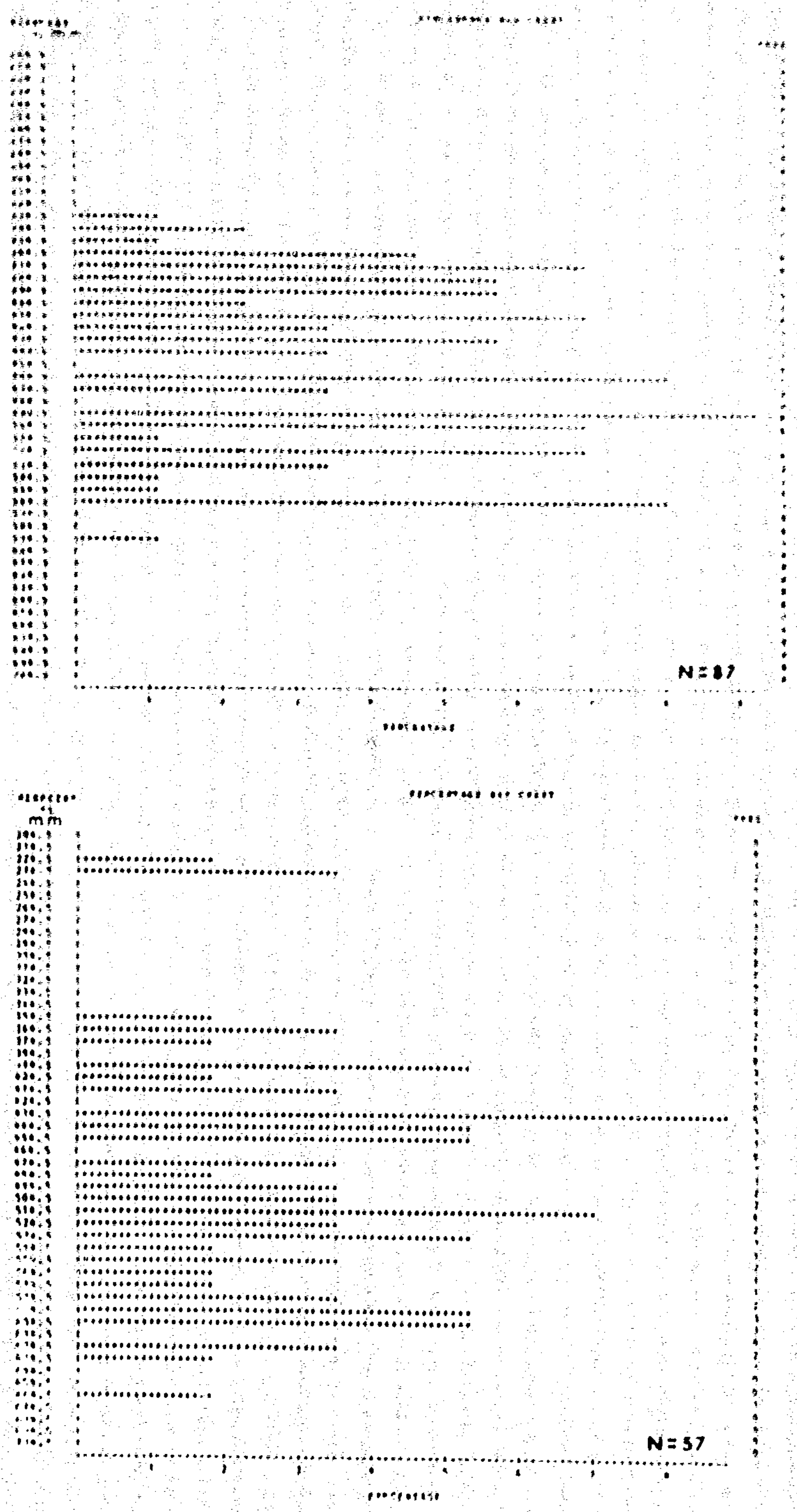

Fig. 15.3. Length-frequency distributions of carp collected in September and November of 1978 (upper) and 1979 (lower) in Coffeen Lake. The samples represent pooled catches from four sampling stations.

Secondly, low viability of spawning products, [illegible] and fry by fishes, may have deterred spawning of carp in Coffeen [illegible] spawners.

Condition of carp was not evaluated since only small sample sizes were available. Proportional stock density values (Table 15.1) reflect the high proportion of large adults and suggest a high reproductive potential. As discussed above, however, the reproductive success of this species in Coffeen Lake is probably only minimal. Tranquilli et al. (1981) reported that the carp population of Lake Sangchris was similarly composed of large adults and that their reproductive success was negligible.

Channel catfish

The channel catfish population of Coffeen Lake exhibited a polymodal length-frequency distribution which obscured age and growth relationships. A pronounced mode at 125 mm (Fig. 15.4) in 1979 was suggestive of age group 0+ and implies rapid growth for that group in comparison to Lake Shelbyville (97 mm by September, Joy and Tranquilli 1979) and other midwestern waters (Carlander 1969). However, considerably fewer young fishes were collected in 1980, and only a small mode at 85 mm was suggestive of age 0+ individuals (Fig. 15.4). Numbers of young fishes collected during that year probably were not sufficient to detect a true modal length for the 0+ age group. A modal location at approximately 200 mm was evident during both years and, although age I+ for that group may be assumed, the configurations were positively skewed and thus probably included older individuals as well. Proportional stock densities of channel catfish were low (Table 15.1) indicating few individuals of quality size, that is, ≥410 mm (Anderson 1980). Our samples of channel catfish were obtained exclusively by cove rotenone methods (Section 14, herein), however, which may have been biased in favor of smaller specimens (Hayne et al. 1967). Large adult catfishes were encountered more frequently in bimonthly samples (Section 13, herein) due to the inclusion of experimental gill net samples which were selective for a broader size range of catfishes. The true size-structure of the channel catfish population would be difficult to estimate by any collecting method given the noctural behavior of this species, their bottom-

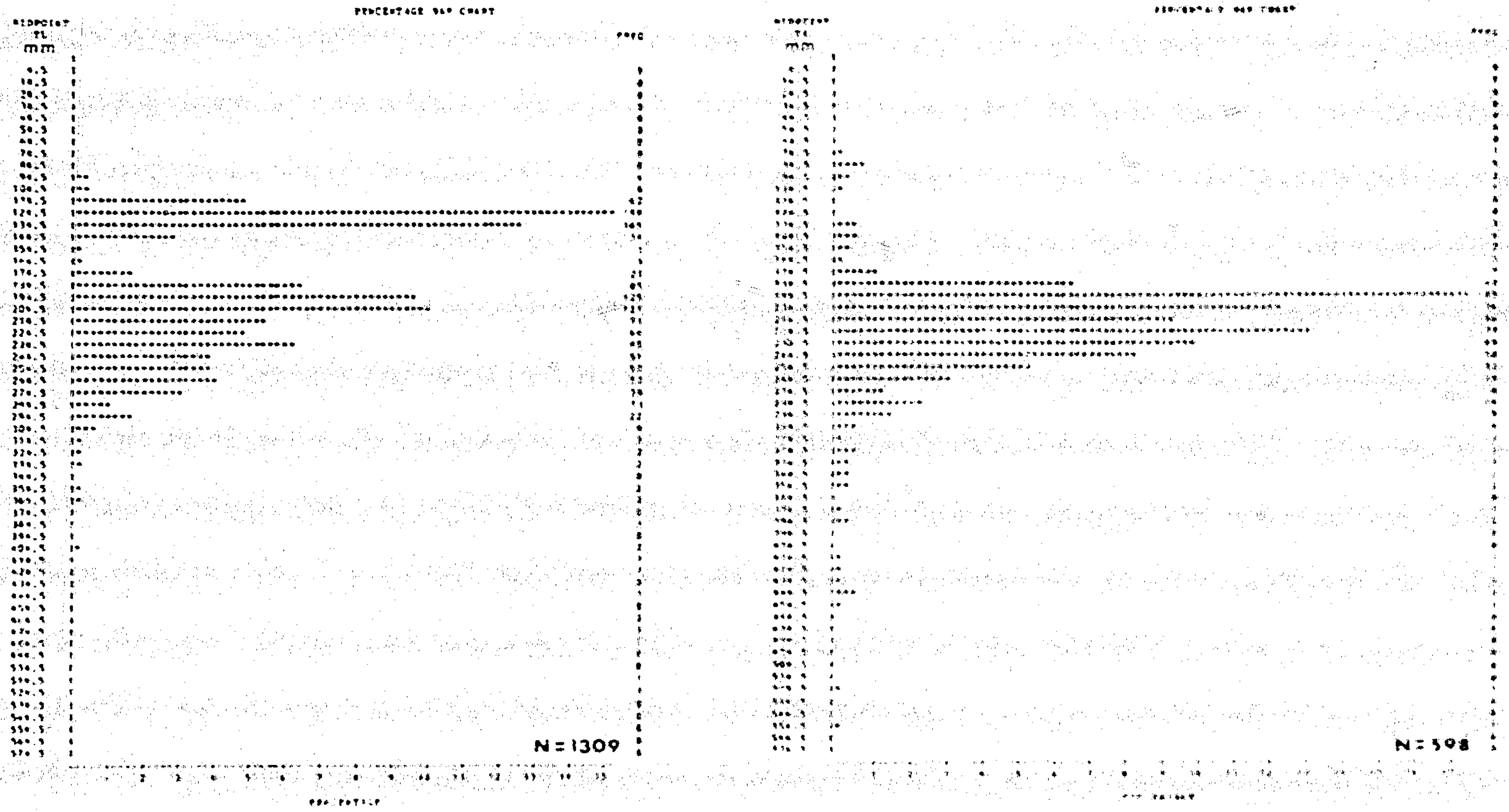

Fig. 15.4. Length-frequency distributions of channel catfish collected in cove rotenone samples (Section 14, herein) during 1979 (left) and 1980 (right). The samples represent north and south coves combined.

dwelling nature, and the need for large sample sizes and equal susceptibility to capture among all size groups.

Body condition of channel catfish was quite similar over the two years sampled and little difference was detected between north and south coves (Fig. 15.5). Average relative weight values were about 80 which represent slightly low values compared to the target value of 100 (Anderson 1980). Because relative weight is a new approach to judging body condition of fishes, and since its utility has not been tested extensively, interpretation of calculated values is still somewhat subjective. No thermal-related or size-related differences in condition were suggested by the data (Fig. 15.5) and no extremely low condition values were detected. From the limited data on channel catfish it appears that the Coffeen Lake habitat supports a desirable size-structure and growth rate for this species. In addition, evidence of a positive response to the thermal effluent was provided by catch/effort data (Section 13, herein).

### Bluegill

Length-frequency distributions of bluegill were polymodal and did not exceed 160 mm, indicating slow growth rates among adults (Fig. 15.6). Age 0+ individuals probably accounted for modes within the 5-65 mm length range because of the extended spawning period of this species. Older bluegills were characterized by uniformly small-sized individuals. Proportional stock density values (Table 15.1) were quite low based upon a recommended range of 20 to 60% (Anderson 1980), indicating that the population consisted of very few individuals of quality sportfish size. Virtually all specimens were of forage-fish size and may play an important role in supporting growth of piscivorous species. A similar (stunted) bluegill population was also found at Lake Sangchris (Joy and Tranquilli 1979) suggesting that overabundance, and consequently reduced growth, may be a direct response to thermal influence, or to a similar mode of competition in cooling lakes.

No thermal effects were evident in body condition of bluegills but a general decline in condition with increasing length was evident during both years (Fig.

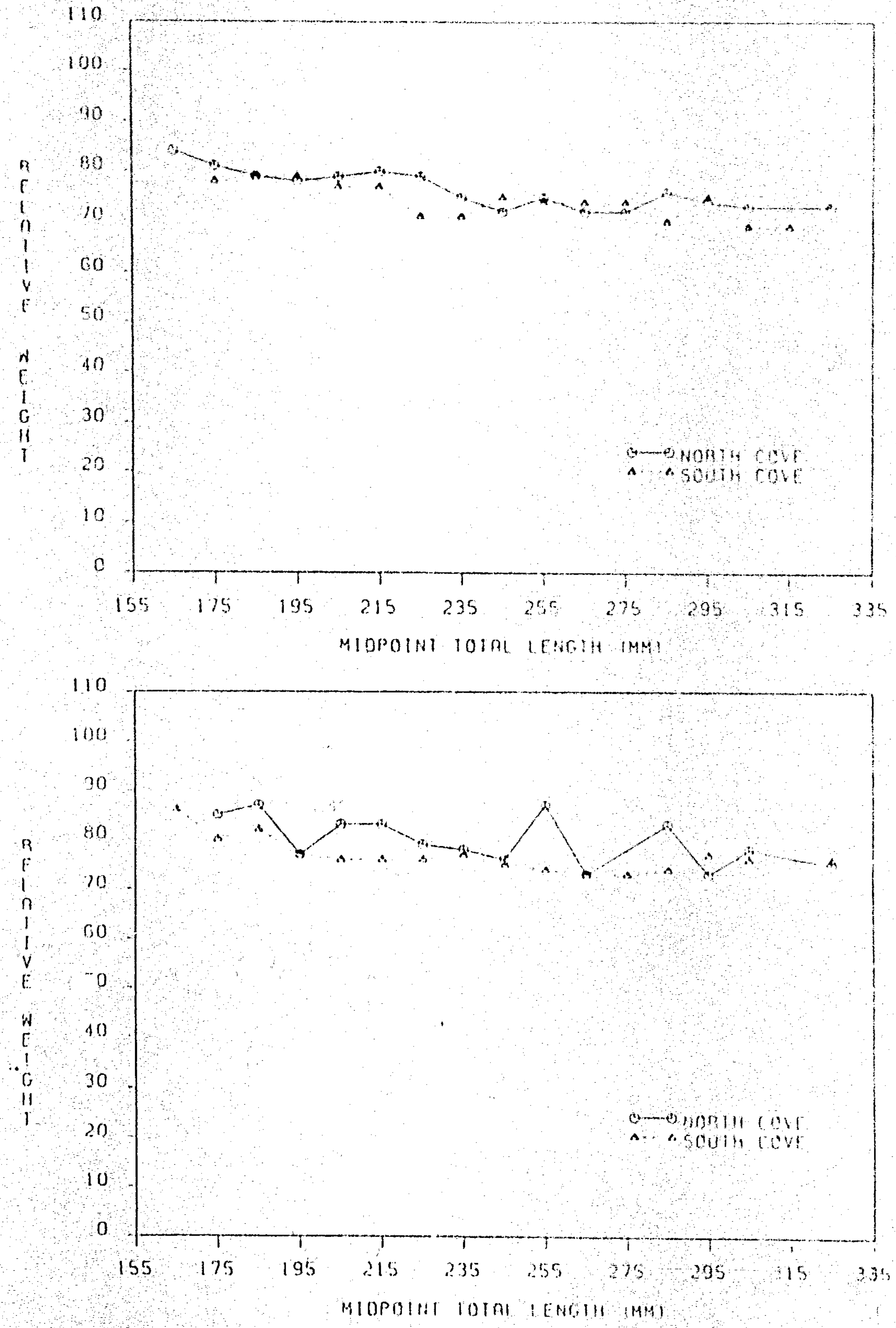

Fig. 15.5. Mean relative weight values of channel catfish collected in cove rotenone samples (Section 14, herein) during 1979 (upper) and 1980 (lower). The samples represent north and south coves combined.

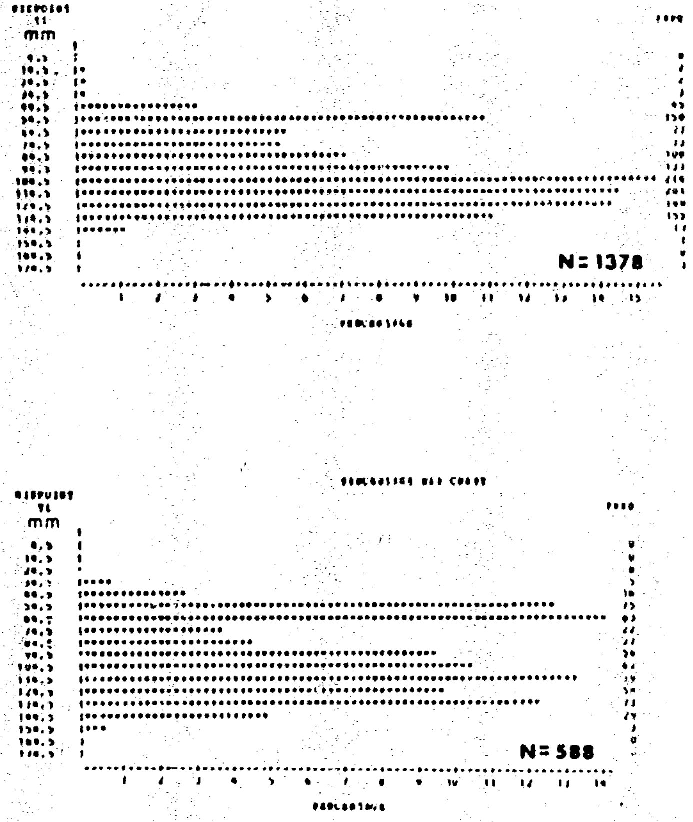

Fig. 15.6. Length frequency distributions of bluegill collected in September 1978 (upper) and September 1979 (lower) in Coffeen Lake. The samples represent pooled catches from four sampling stations.

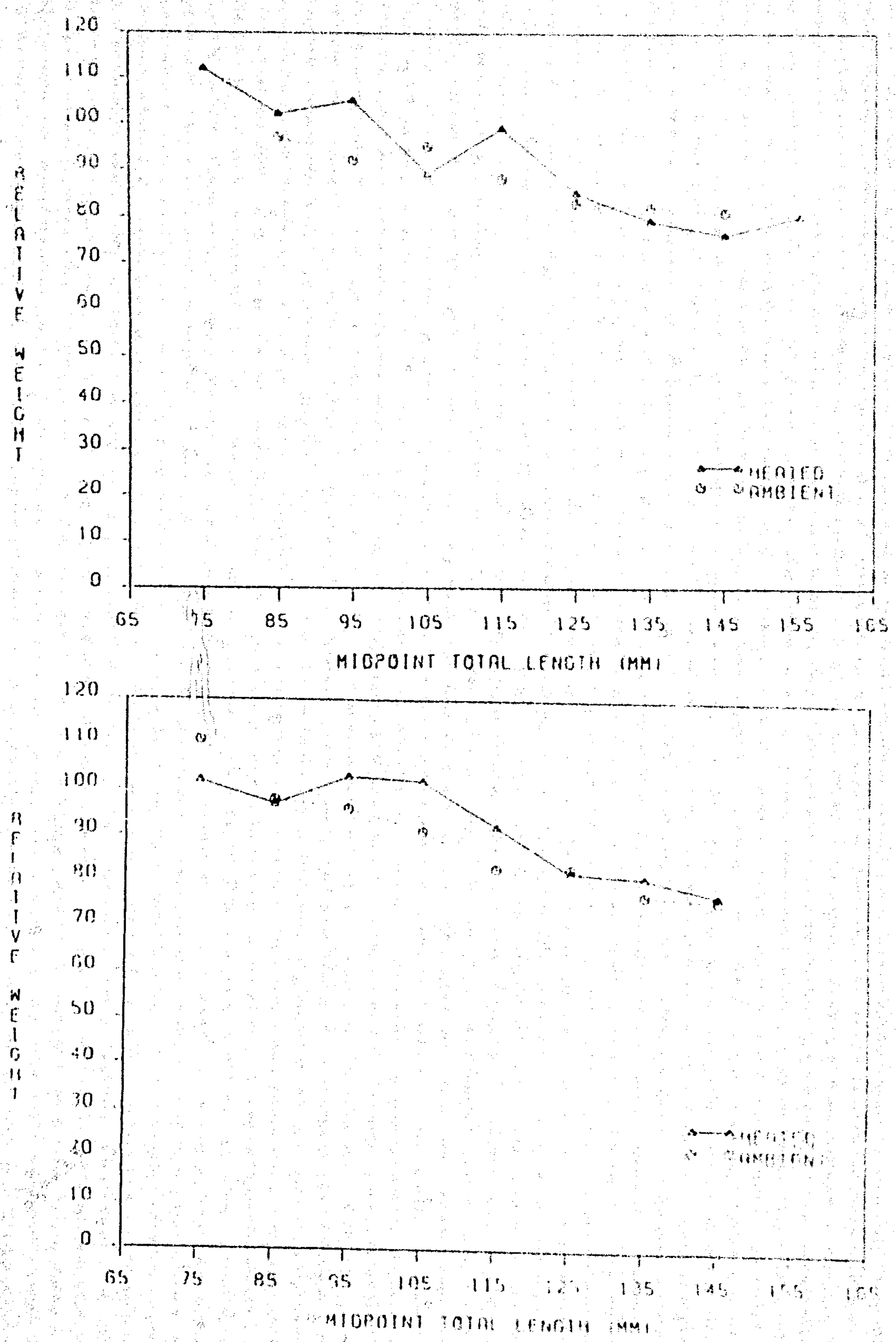

Fig. 15.7. Mean relative weight values of bluegill collected in September 1978 (upper) and September 1979 (lower) in Coffeen Lake. Heated and ambient refer to Stations 1 and 4 (Section 13, herein), respectively.

15.7). Presumably the forage base for larger individuals, which primarily consisted of aquatic and terrestrial insects (Section 8, herein), was limited and exerted some constraints on growth rates of adults, thereby contributing to the maintenance of a stunted population. Two factors which may contribute to that phenomenon include interspecific competition with other *Lepomis* species utilizing a similar food resource, or lack of sufficient predation on bluegills to relieve intraspecific competition for forage organisms. The latter situation would be realized if largemouth bass, the major predatory species in Coffeen Lake, selected gizzard shad rather than bluegills as prey because of a greater accessibility or a greater preference for the former species. An additional potential deterrent to bluegill growth is the intensity of parasitic infestations found in the Coffeen Lake bluegill population, a subject which is addressed in Section 18 (herein).

### Largemouth bass

The 1979 and 1980 samples of largemouth bass each exhibited a mode at 175 mm which was assumed to be representative of first-year growth in Coffeen Lake (Fig. 15.8). A smaller mode, at 115 mm, was also detected in 1979. Since individuals ranging up to 232 mm in the 1980 sample were found to be age 0+ (Table 15.2), a similar age-length structure probably existed in 1979 even though a strongly bimodal length distribution developed among the young of that year. Modal lengths of 175 mm suggest an exceptionally rapid rate of growth for bass during their first year of life in Coffeen Lake; greater than that exhibited by first-year individuals in Lake Shelbyville (95 mm by September) as reported by Joy and Tranquilli (1979), and in other waters of the midwest (Carlander 1977). The most recent estimates of first year growth rates in Lake Sangchris, which were established after implementation of a management strategy for this species, indicated a rate similar to that of the Coffeen Lake population (Taubert et al. 1981).

Growth of age I bass (ranging in size from 100 to 199 mm) was highly variable as determined by recapture of marked individuals, but all had increased in length by more than 100 mm during the 1980 growing season (Fig. 15.9). Length increments attained by larger individuals ($\geq$200 mm) during the 1979 and 1980

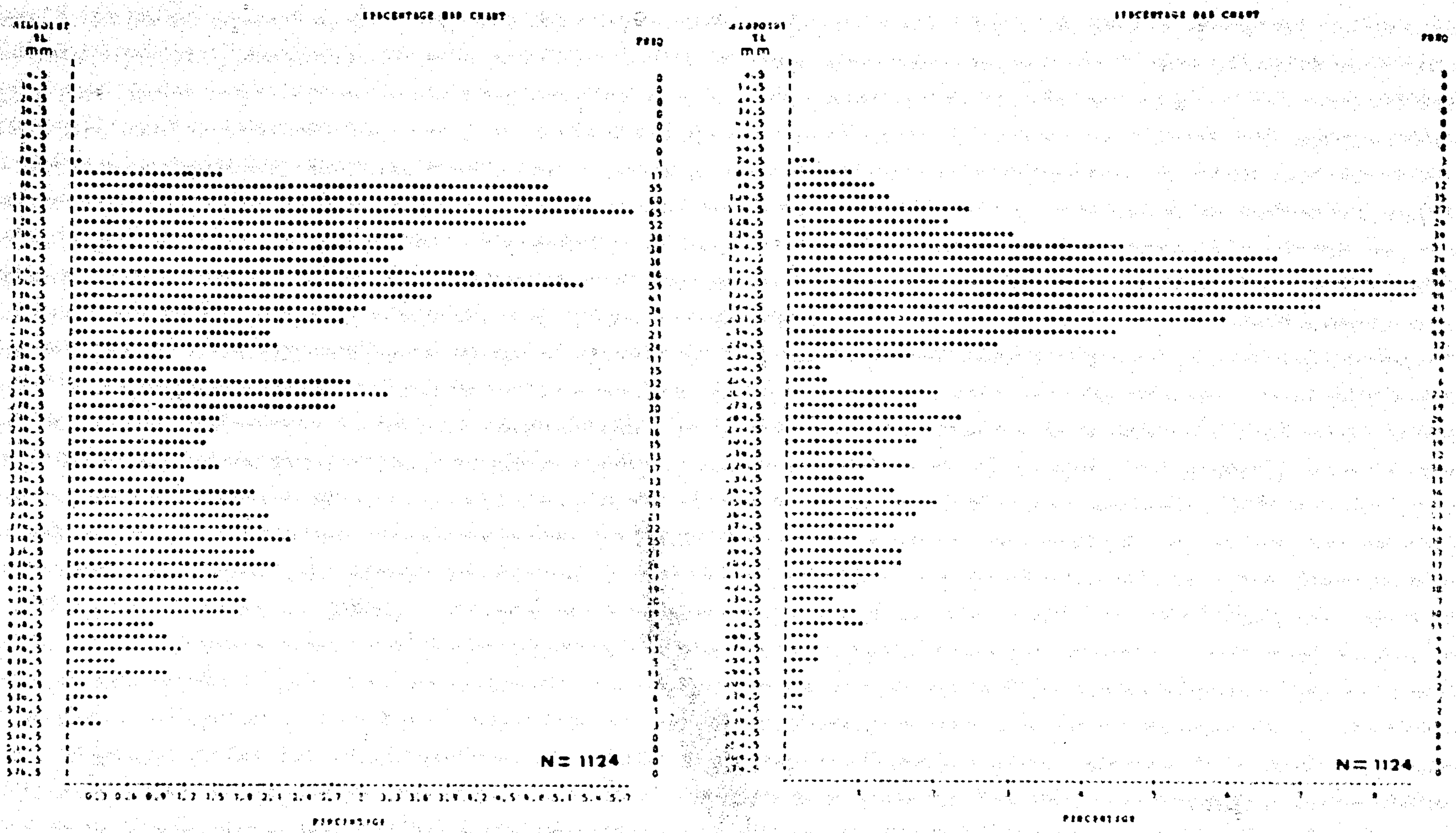

Fig. 15.8. Length-frequency distribution of largemouth bass collected lake-wide in the fall of 1979 (left) and the fall of 1980 (right) in Coffeen Lake.

Table 15.2. Ages of largemouth bass collected from heated and ambient areas of Coffeen Lake in the fall of 1980. Sample sizes (N), mean lengths, and length ranges are given. Samples from heated and ambient areas are designated by H and A, respectively.

| Age group | N | | Mean length (mm)[1] | | Length range | |
|---|---|---|---|---|---|---|
| | H | A | H | A | H | A |
| 0+ | 23 | 26 | 166 | 162 | 91-232 | 92-227 |
| I+ | 23 | 16 | 345 | 282 | 255-434 | 240-346 |
| II+ | 0 | 1 | – | 411 | – | – |
| III+ | 1 | 2 | 460 | 373 | – | 262-383 |

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[1] Specimens selected for age analysis were not necessarily representative of the length-frequency distribution of the population, or even that of the younger ages, and thus may not reflect the true mean lengths for the age groups considered.

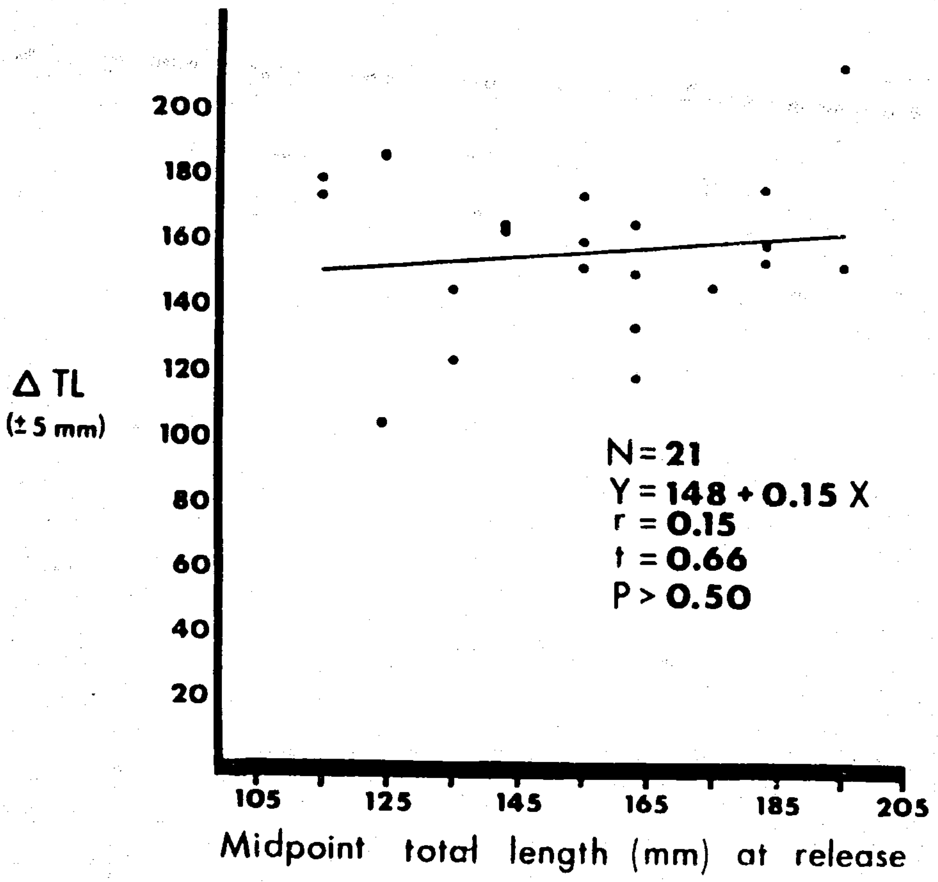

Fig. 15.9. Estimated growth increments (ΔTL) attained by largemouth bass (100 to 199 mm total length at release) during the 1980 growing season in Coffeen Lake. Sample size (N), regression equation, correlation coefficient (r), Students t-value (t), and significance probability (P) are given.

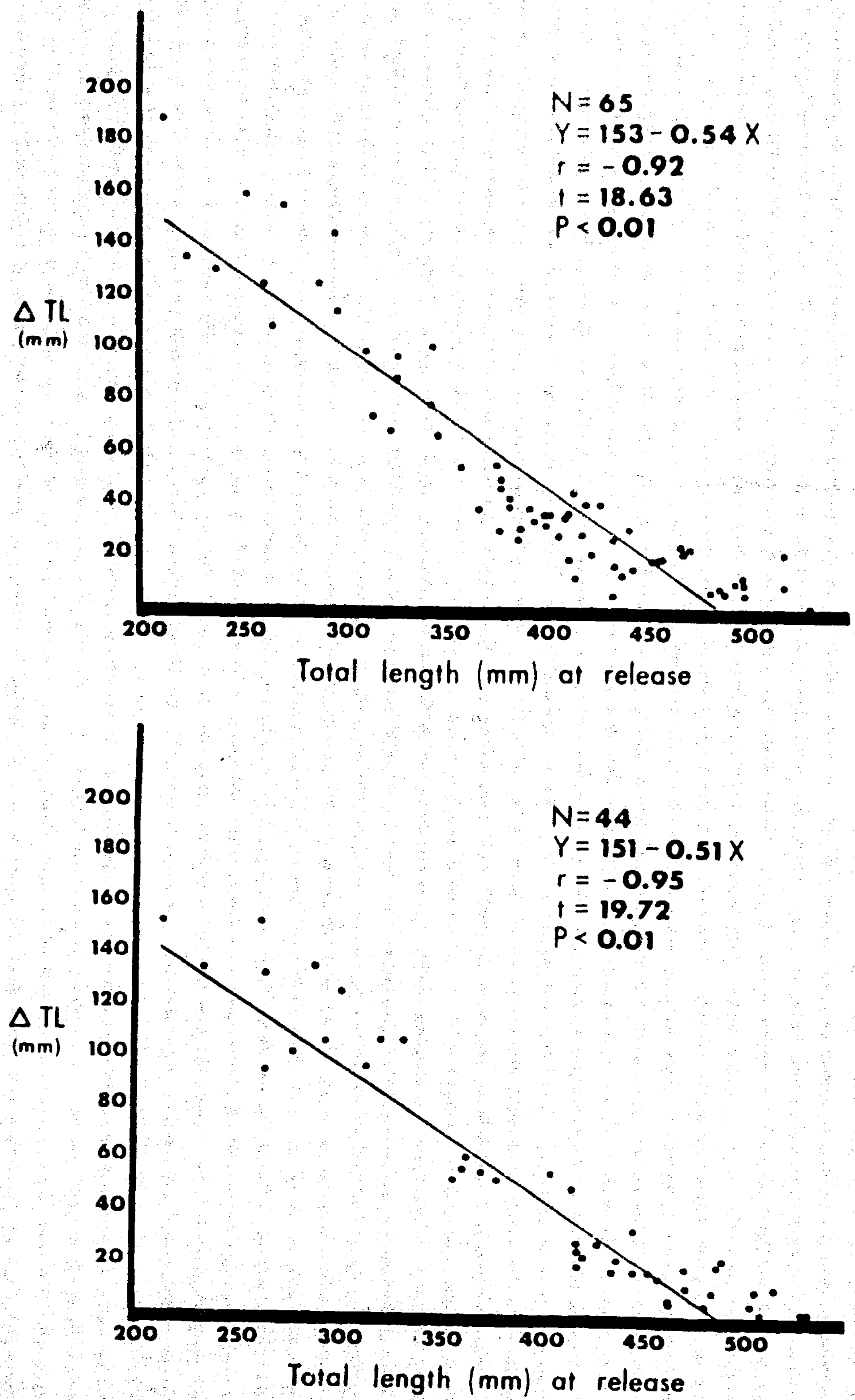

Fig. 15.10. Estimated growth increments (ΔTL) attained by largemouth bass (> 200 mm total length at release) during the 1979 (upper) and 1980 (lower) growing seasons in Coffeen Lake. Sample size (N), regression equation, correlation coefficient (r), Students t-value (t), and significance probability (P) are given.

growing seasons were described by a linear relationship with total length and were very similar over the two growing seasons (Fig. 15.10). The significance of the linear relationship allows a prediction of growth for the size group considered in that, for example, 200 mm fish can be expected to reach 350 mm in one growing season.

Overall, the age structure and growth rates of largemouth bass were exemplary for this species in the midwest and indicated that, for the two years considered, the Coffeen Lake habitat supported a rapid growth rate among all age groups. Reynolds and Babb (1978) recommended that 200 mm fish reach 300 mm in one growing season if a desireable size-structure and production rate is to be maintained in small impoundments. Although Coffeen Lake is much larger than the lakes studied by those authors, our estimated growth for 200 mm fish exceeds their recommended value by about 50%. Furthermore, our growth estimates suggested that the majority of individuals could be expected to reach sexual maturity after two growing seasons and thus spawn at age II, whereas attainment of age III before first spawning is not uncommon in midwestern lakes.

Proportional stock density values for largemouth bass (Table 15.1) were within the recommended range of 40 to 60% (Anderson 1980) during both years, indicating an optimal size structure for maintaining a high rate of production. Body condition of larger specimens (>200 mm) was quite good overall but thermal influences were implicated as having an impact on condition of smaller individuals (Fig. 15.11). Those collected from heated locations exhibited consistently lower relative weights, up to a length of about 200 mm, compared to those taken from ambient areas. That finding may be related to differences in densities of littoral invertebrates and small forage fishes between the two locations, rather than to a direct effect of elevated temperatures. Densities of benthic organisms and larval fishes were found to be higher at ambient locations (Sections 7 and 10, herein) which may have provided young bass with a more substantial forage base compared to that available at heated locations. Food habits of first-year bass from heated locations primarily consisted of insects during the month of September, even though most individuals had transferred to piscivory prior to that time. The implications of that finding are discussed in Section 9 (herein). Estimated annual growth of smaller bass,

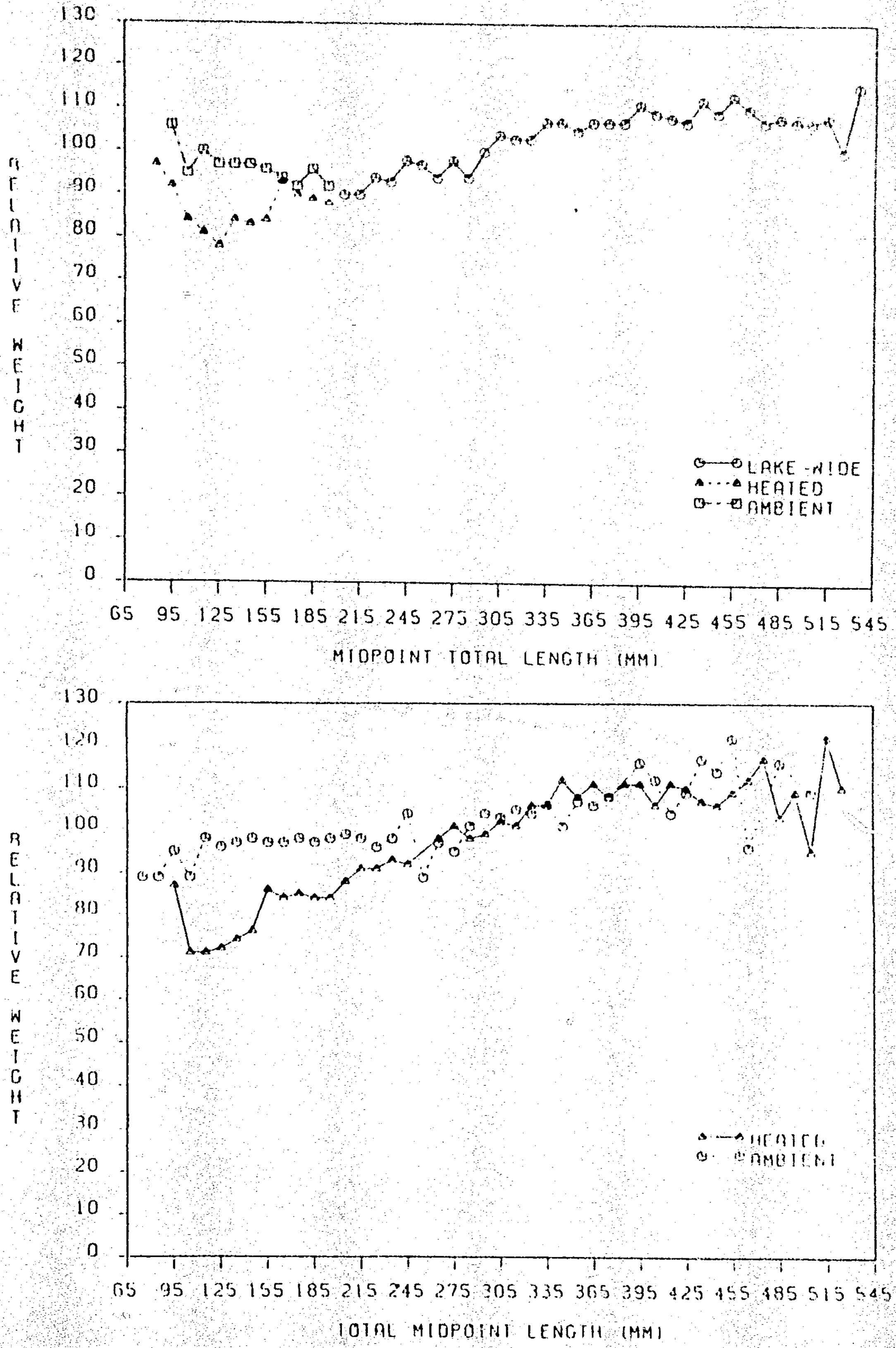

Fig. 15.11. Mean relative weight values of largemouth bass collected in the fall of 1979 (upper) and fall 1980 (lower) in Coffeen Lake. Sampling locations are given. Heated and ambient locations are defined in Section 13, herein.

when judged on a lake-wide basis (Fig. 15.9), did not reveal any limitations on their feeding success during the 1980 growing season, suggesting that poor body condition among individuals from heated areas may only have been a temporary state.

White crappie

Young-of-the-year white crappies were rare in our collections suggesting some limitations on spawning success. The adult population exhibited a wide range of sizes over the two sampling periods but the polymodal nature of length distributions precluded age assignments (Fig. 15.12). Proportional stock densities were high (Table 15.1) indicating a predominance of larger individuals. A general increase in body condition with increasing length was noted with only the largest individuals attaining the target relative weight value of 100 (Fig. 15.13). Apparently the forage base is optimal only for the largest crappies. Reasons for that occurrence are not immediately obvious since other piscivorous species inhabiting Coffeen Lake showed no sign of a shortage of forage fishes.

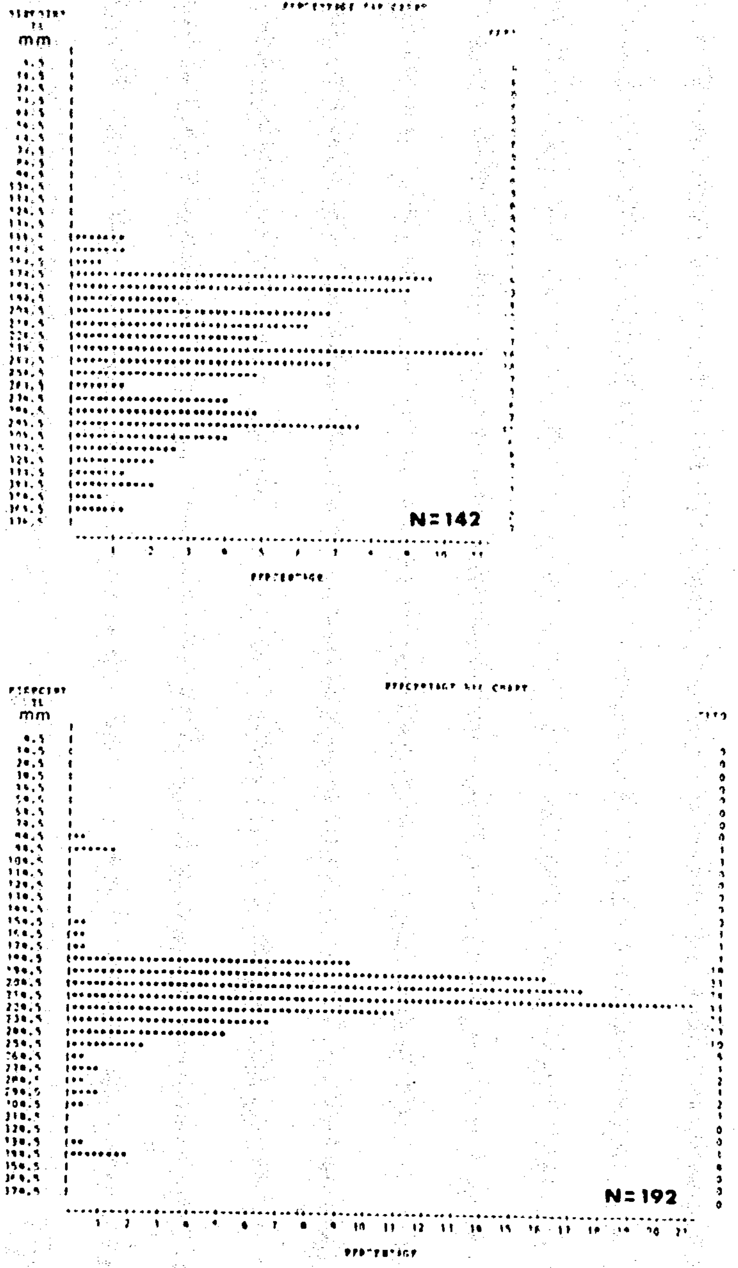

Fig. 15.12. Length-frequency distributions of white crappie collected in the fall of 1978 (upper) and the fall of 1979 (lower). Upper figure represents pooled catches from four sampling stations; lower figure represents pooled catches from four sampling stations and two rotenone coves (Section 14, herein).

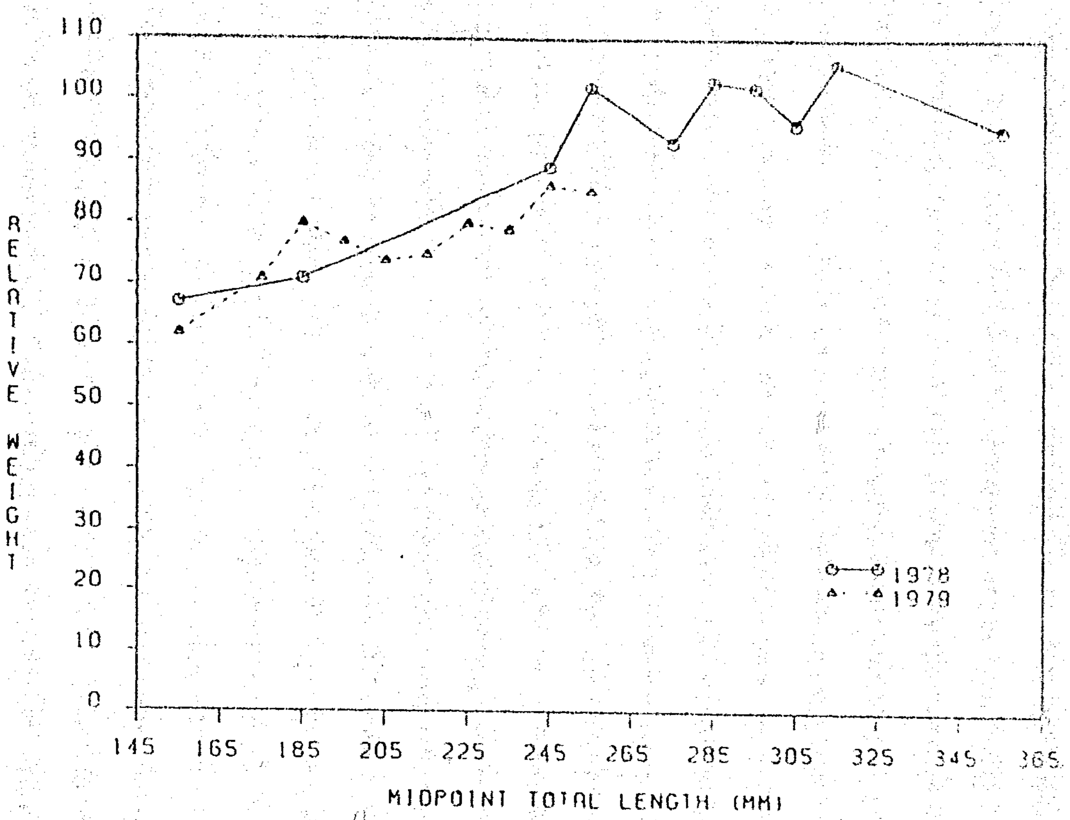

Fig. 13.13. Mean relative weight values of white crappie collected in the fall of 1978 and the fall of 1979 in Coffeen Lake. The samples represent pooled cathes from four sampling stations in 1978 and from four sampling stations and two rotenone coves (Section 14, herein) in 1979.

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## SECTION 16

# SPAWNING PERIODICITY AND FECUNDITY OF FISHES INHABITING HEATED AND AMBIENT AREAS OF COFFEEN LAKE

by

John A. Tranquilli and Lance G. Perry

## ABSTRACT

Spawning periodicity and fecundity of largemouth bass (Micropterus salmoides) and fecundity of channel catfish (Ictalurus punctatus) were examined in heated and ambient areas of Coffeen Lake, a 446-ha cooling water reservoir for a 945-MeW electric generating station in central Illinois. The objective of this study was to evaluate the effect of a thermal discharge on spawning time and egg production by these species.

Spawning time of female largemouth bass was estimated with gonosomatic indices and examination of gonad maturity stages. Spawning was found to begin in mid or late March in heated areas but not until late April or mid-May in ambient areas. The onset of spawning by female largemouth bass occurred unusually early in the heated area of Coffeen Lake and may represent the earliest recorded date for spawning by this species in any Illinois waters. The early spawn was advantageous for the piscivorous largemouth bass as it provided a head start in growth and ultimately an extended growing season.

Effective annual fecundity of largemouth bass and channel catfish from heated and ambient areas of Coffeen Lake was determined by counting only those eggs larger than 0.75mm in diameter. Comparable fecundity data for these species from heated and ambient areas of Lake Sangchris and from unheated Lake Shelbyville (Sule et al. 1979) were analyzed in conjunction with the Coffeen Lake data to provide further insight into the effects of thermal effluents on egg production. The estimate of mean fecundity for largemouth bass from the heated area of Coffeen Lake (47,920 eggs) was significantly less than that found

in fish from ambient areas (92,472 eggs). A comparison of estimated mean fecundity of bass from heated areas of both Lake Sangchris and Coffeen Lake vs. fish from ambient areas of these two cooling lakes revealed that ambient zones supported significantly greater egg production. These results suggested that thermal discharges may suppress egg production by largemouth bass. Mean fecundities of channel catfish from heated and ambient areas of Coffeen Lake were 8,031 and 8,132 eggs, respectively. No differences were found between mean fecundity of channel catfish from heated and ambient areas of Coffeen Lake or between catfish from heated areas of both Lake Sangchris and Coffeen Lake vs. fish from ambient areas of these lakes. The overall fecundity of channel catfish from Coffeen Lake, however, was found to be significantly higher than that in unheated Lake Shelbyville.

## INTRODUCTION

Spawning periodicity and fecundity of largemouth bass (Micropterus salmoides) and fecundity of channel catfish (Ictalurus punctatus) were examined in Coffeen Lake, a thermally loaded cooling lake in central Illinois. Accelerated gonadal development and earlier spawning by largemouth bass inhabiting thermally elevated areas has been demonstrated by Witt et al. (1970) in Thomas Hill Reservoir, Missouri, and by Tranquilli et al. (1981a) in Lake Sangchris, another Illinois cooling lake, but was not observed in Par Pond, a cooling lake for a nuclear production reactor in North Carolina, by Bennett and Gibbons (1975). The effect of a thermal effluent on potential egg production (fecundity) by largemouth bass, channel catfish, and two other species was examined by Sule et al. (1979), who found that (1) largemouth bass from the heated area of Lake Sangchris were less fecund than bass of comparable sizes from nearby unheated Lake Shelbyville, and (2) channel catfish from the heated area of Lake Sangchris were more fecund than channel catfish from ambient areas of that lake. Results of those investigations suggested more information was needed regarding the dynamics of reproduction for these two highly important sportfishes in habitats affected by thermal discharges, and prompted the present study.

## MATERIALS AND METHODS

Largemouth bass were selected for evaluation of spawning time because they were one of the most sought-after gamefish and the most important species in Coffeen Lake from a management perspective. Specimens were collected periodically from 28 March to 17 May 1979 at heated and ambient areas (Section 13, herein). Only mature female bass were utilized. Each fish was weighed to the nearest gram and dissected to allow removal of the gonads. Two indices were utilized for estimating time of spawning at the two study sites. First, the gonad weight of each fish was recorded to allow calculation of the gonosomatic index (GSI) which expressed gonad weight as a percentage of total body weight (Kaya and Hasler 1972). The onset of spawning is presumed to be marked by peak GSI values since gonad weight increases relative to total body weight up to the time of spawning but rapidly decreases thereafter. Secondly, an empirical judgement was made of the stage of gonad maturation and a corresponding number assigned in accordance with Nikolsky's scheme as presented in Bagenal and Braum (1971):

I = immature
II = resting stage
III = maturation
IV = maturity
V = reproduction
VI = spent condition

These indices, along with water temperature data recorded during each sampling period, were plotted by month and location to provide a means of estimating the time and duration of spawning among fishes exposed to elevated and ambient water temperatures.

Ovaries of mature female largemouth bass and channel catfish were collected prior to spawning from heated and ambient areas of the lake during March, April, and May of 1979 and 1980 for fecundity analyses. All bass were collected by electroshocking; channel catfish were collected with gill nets and trot-lines. Total lengths (mm) and weights (g) were recorded for all specimens. Gonads were excised while still fresh, split longitudinally, and preserved in modified Gilsons fluid (Simpson 1951). Sample jars were periodically agitated to free the eggs from ovarian wall tissue. After the eggs were separated, they were flushed with tap water and allowed to air dry until clumping was minimal. The remaining fragments of ovarian tissue were then removed by hand and each egg mass was weighed to the nearest milligram. Two random subsamples of ova were obtained from each sample, weighed to the nearest 0.1 mg, and counted. Number of eggs per subsample averaged 1,253 (range 353-2,262) for bass and 816 (range 301-1,455) for channel catfish. Bagenal and Braum (1978) recommended subsamples containing 200 or more eggs when utilizing this method of fecundity estimation. For both species, only eggs >0.75 mm in diameter were counted in order to eliminate immature ova from the estimates (Kelley 1962, and others). The mean number of eggs per unit weight of subsample was used to calculate effective

effective annual fecundity, that is, total number of ova per individual that mature during one spawning season.

Data analysis was accomplished by a linear regression of log egg number on log total length. Because there is a positive linear relationship between fish length and egg number, analysis of covariance (Snedecor and Cochran 1967) was used to remove the effect of length on egg number prior to comparison of mean fecundities. Adjustment of means in this manner eliminated any bias attributable to size differences between sampling sites. Raw fecundity data presented by Sule et al. (1979) were also analyzed to allow comparisons between Coffeen Lake and Lakes Sangchris and Shelbyville.

## RESULTS AND DISCUSSION

### Spawning Periodicty of Largemouth Bass

Mean gonosomatic indices of female largemouth bass from the discharge (heated) arm of Coffeen Lake ranged from 3.0 to 5.8 (Fig. 16.1). The peak was reached on 12 April but a similar value (5.4) was found on 28 March, suggesting that spawning may have commenced earlier than the peak GSI values indicated. Mean gonad maturity stage indices of bass from heated areas were in close agreement with GSI values in that most intense spawning activity ranged from mid to late April. The ranges of those values are equally important, however, and the frequency of actively spawning and spent females (eight individuals running eggs and one apparently spent) encountered in late March (Fig. 16.1) indicated that spawning activities began in either mid or late March, consistent with the relatively high GSI values observed at that time. In contrast, GSI values (ranging from 5.2 to 11.9) and gonad maturity stage indices of bass from ambient areas implied that spawning in that region began in late April and extended into mid-May (Fig. 16.1).

In 1979, female largemouth bass were first found in "spawning" condition (gonad maturity stage V) in the heated area on 27 March (Fig. 16.1). While spawning periodicity studies were not conducted in either 1980 or 1981, female largemouth bass from the heated area were examined during tagging studies (Section 17,

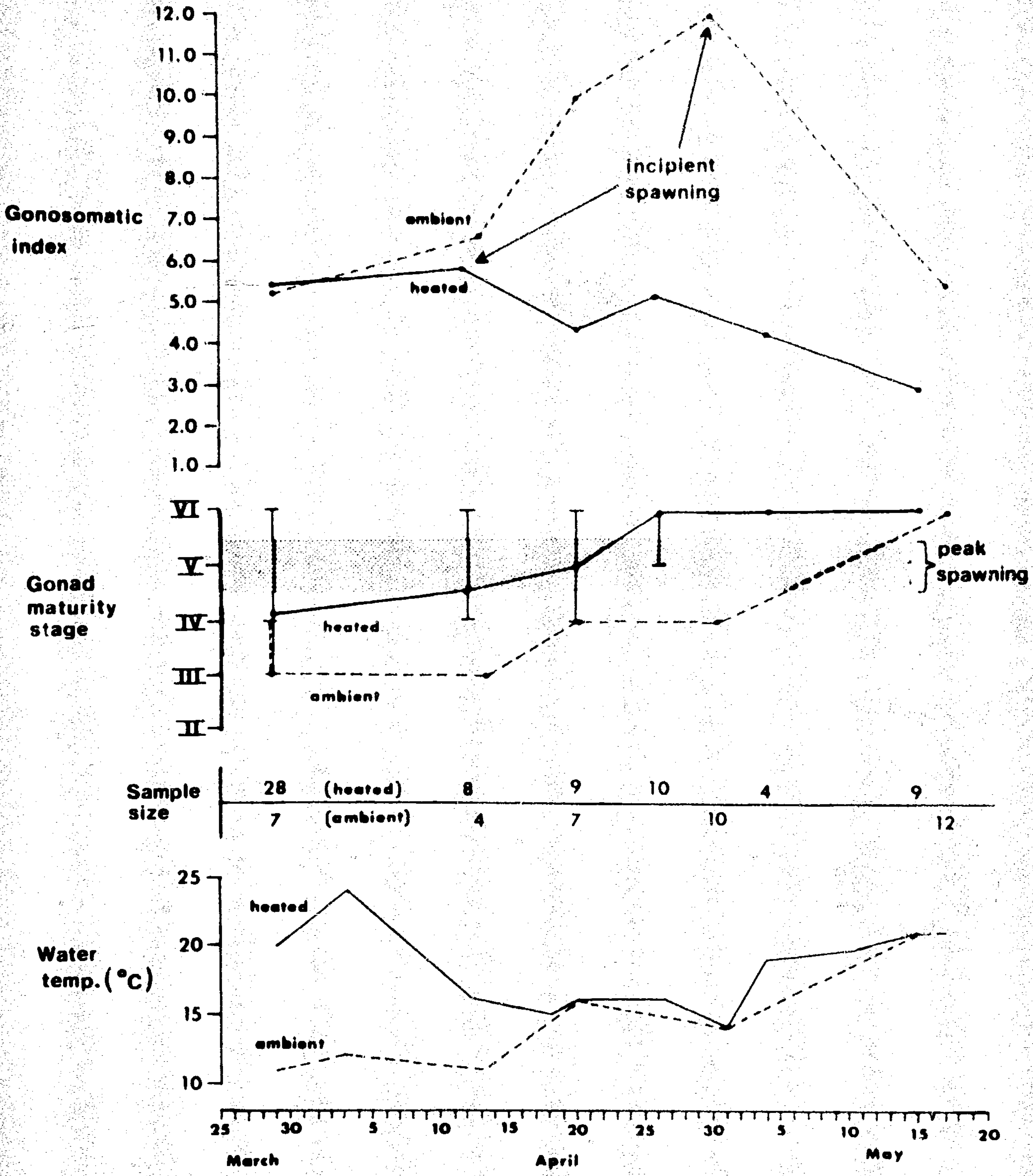

Fig. 16.1. Gonosomatic indices (means) and gonad maturity stages (means and ranges) of female largemouth bass from heated and ambient areas of Coffeen Lake during 1979. Surface water temperatures at the respective sampling sites are given.

herein) and found to be in "spawning" condition on 25 March during both of those years. The onset of spawning in Coffeen Lake was thus considerably earlier than that documented for this species in heated areas of Lake Sangchris (April 13 and May 1) by Tranquilli et al. (1981a) and may be the earliest recorded date for spawning by this species in any Illinois waters. The unusually early spawning date in Coffeen Lake as compared to nearby Lake Sangchris is probably due to its heavier thermal loading rate. The greatest benefit of early spawning activities by largemouth bass in Coffeen Lake may not have been fully realized, however, since the Coffeen Generating Station typically reduced its generation capacity in April and May of each year (Fig. 1.1, herein) for scheduled maintenance and repair work. This typically resulted in declining discharge temperatures in the heated area of the lake just as bass were beginning to spawn and probably delayed spawning by most of the fish in that area for 1 to 3 weeks. In spite of this delay, spawning activity by most fish in the heated area was still advanced over that observed in ambient areas.

The accuracy of the spawning indices utilized was dependent upon the intensity and frequency of sampling of adult females during the spawning season. Since our specimens were collected at 1-2 week intervals, peak GSI and gonad maturity stage values cannot be viewed as precise estimators of incipient spawning. Nonetheless, both indices suggested that bass in heated areas commenced spawning 3-4 weeks earlier than those in ambient areas and reached peak activity approximately three weeks earlier. Elevated water temperatures in the discharge arm probably advanced spawning time by accelerating the reproductive process or advancing the time of reproductive readiness. Surface water temperatures at the time of peak GSI values were relatively low (16°C in the heated area and 14°C in the ambient area), but higher temperatures prevailed earlier at both locations (Fig. 16.1). Presumably, temperatures suitable for spawning (15.6-23.9°C, Heidinger 1975) preceded the time of initial spawning. A more protracted spawning period in the heated area (approximately four weeks in duration compared to less than two weeks in the ambient area) may have been a ramification of the drop of water temperature in April 1979 which was coincident with reduced electrical generation.

The spawning act in fishes typically represents the culmination of a series of physiological and behavioral events that are regulated by environmental stimuli and mediated through the endocrine system. In temperate regions, where many fishes exhibit discrete spawning seasons, reproductive activities may be advanced or delayed depending upon the rate of temperature increase in spring (Breder and Rosen 1966). In that respect, cooling lakes represent a unique spawning habitat because of the input of thermally enriched effluents.

The earlier spawning time exhibited by largemouth bass in heated areas of Coffeen Lake was in agreement with observations on spawning of this species in Thomas Hill Reservoir, Missouri, (Witt et al. 1970), and in Lake Sangchris (Tranquilli et al. 1981a). These results differed somewhat from those of Bennett and Gibbons (1975), however, who found no difference in the reproductive cycle of largemouth bass in heated and ambient areas of Par Pond. They did find that young-of-the-year fishes from the heated area were significantly larger, suggesting that spawning activities and growth may have been accelerated there. Accelerated reproduction in thermal outfalls for other freshwater species has also been reported. Marcy (1976) found that ovaries of female brown bullheads (*Ictalurus nebulosus*) and white catfish (*I. catus*) developed unseasonably early during winter in the discharge canal of a nuclear power plant on the Connecticut River. Carp (*Cyprinus carpio*) in Lake Sangchris spawned at the same time in heated and ambient areas in 1975, but spawning was advanced in the heated area by approximately one month in 1976 (Tranquilli et al. 1981a).

Since large size is highly advantageous in interspecific competition among fishes, earlier spawning, especially by a piscivorous species such as the largemouth bass, is highly beneficial because it gives a head start in growth and ultimately provides an extended growing season in temperate geographical zones. Sule et al. (1981) demonstrated how this advantage was utilized by young-of-the-year largemouth bass in Lake Sangchris; when bass from heated areas reached 90 mm total length, they were able to consume fish and their average size increased more than smaller, predominately insectivorous feeding bass from ambient areas.

Catch per unit effort (C/E) and standing crop samples (Sections 13 and 14, herein) suggested good reproduction by largemouth bass in Coffeen Lake during 1978-1980 and C/E data indicated a relatively high adult stock density. Length frequency distributions indicated that there were two size modes of young-of-the-year bass in the fall of 1979. This bimodal distribution may have been attributed to differences in spawning time and in length of the growing season within heated and ambient areas of the cooling lake.

Kramer and Smith (1962) reported that unfavorable water temperatures during a critical period (after egg deposition and before young were two weeks old) was a major cause of mortality affecting year class strength of largemouth bass. In Lake Sangchris, Tranquilli et al. (1981a) maintained that the thermal effluent enhanced reproduction of largemouth bass by stabilizing water temperature fluctuations produced by variable climatic conditions and, as a result, consistently strong year classes were produced. Data collected from Coffeen Lake regarding largemouth bass population density and year class strength are consistent with that contention and indicated that production of good year classes may be a key element to maintaining a satisfactory population of largemouth bass over an extended period of time.

### Fecundity of largemouth bass and channel catfish

Estimates of mean fecundity of largemouth bass from heated and ambient areas were 47,920 and 92,472 eggs per individual, respectively (Table 16.1). Egg production was correlated with total length in a positive linear fashion as evidenced by positive slope values and linear correlation coefficient values near 1.0 (Fig. 16.2). Scatter plots of linear relationships (Fig. 16.2) suggested that pronounced within-lake spatial differences in egg production may have existed. However, because mean lengths of specimens differed between sampling locations, an adjustment of the fecundity values was necessary to allow valid comparison between groups. Comparison of mean fecundities after adjustment for length differences indicated significantly higher egg production among largemouth bass inhabiting ambient areas of Coffeen Lake (Table 16.2). Additional comparisons utilizing fecundity data from Lake Sangchris, another Illinois cooling lake, and (unheated) Lake Shelbyville (Sule et al. 1979) were

Table 16.1. Mean total length and mean egg number of largemouth bass and channel catfish from heated and ambient areas of Coffeen Lake. Sample sizes (N), standard deviations (s.d.), and ranges are given.

| Species and Location | N | Length (mm TL) | | | Egg number | | |
|---|---|---|---|---|---|---|---|
| | | Mean | s.d. | range | Mean | s.d. | range |
| Largemouth bass | | | | | | | |
| heated | 13 | 372 | 66 | 270-486 | 47,920 | 34,792 | 5,598-112,515 |
| ambient | 15 | 398 | 62 | 307-498 | 92,472 | 36,295 | 32,168-141,580 |
| Channel catfish | | | | | | | |
| heated | 15 | 368 | 95 | 254-612 | 8,031 | 6,349 | 1,453-25,476 |
| ambient | 16 | 378 | 69 | 305-567 | 8,132 | 5,204 | 3,521-22,678 |

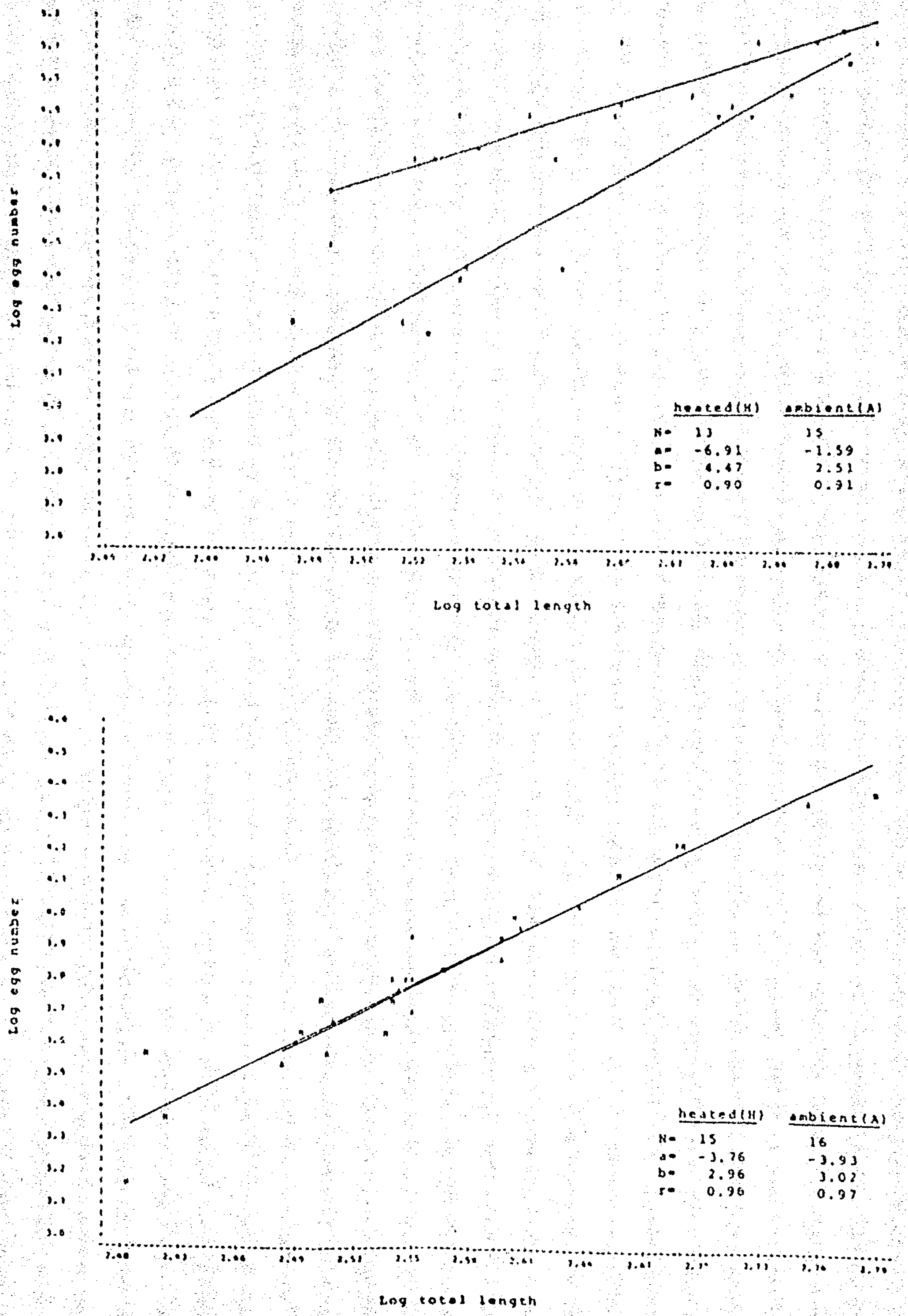

Fig. 16.2. Linear relationship between egg number and total length for largemouth bass (upper) and channel catfish (lower) from heated and ambient areas of Coffeen Lake. Sample sizes (N), regression equation parameters (a = y - intercept, b = slope), and correlation coefficients (r) are given.

Table 16.2. Comparisons of adjusted mean fecundities of fishes from heated (h) and ambient (a) areas of Coffeen Lake and Lake Sangchris, and from Lake Shelbyville. Sample sizes (N), least-squares means (LS mean), F-values, and significance levels (* = 1%, ** = 5%) are given.

| Species and comparisons | (N) | LS mean[1] | F-value |
|---|---|---|---|
| **Largemouth bass** | | | |
| Lake Coffeen (h) vs. | 13 | 54,865 | 28.75** |
| Lake Coffeen (a) | 15 | 86,453 | |
| L. Coffeen (h) + L. Sangchris (h) vs. | 34 | 58,185 | 5.28* |
| L. Coffeen (a) + L. Sangchris (a) | 40 | 69,080 | |
| Lake Coffeen (h+a) vs. | 28 | 60,030 | 0.32 |
| Lake Shelbyville | 26 | 57,067 | |
| Lake Coffeen (a) vs. | 15 | 74,234 | 14.26** |
| Lake Shelbyville | 26 | 54,927 | |
| **Channel catfish** | | | |
| Lake Coffeen (h) vs. | 15 | 8,393 | 1.69 |
| Lake Coffeen (a) | 16 | 7,792 | |
| L. Coffeen (h) + L. Sangchris (h) vs. | 30 | 7,735 | 2.87 |
| L. Coffeen (a) + L. Sangchris (a) | 33 | 7,029 | |
| Lake Coffeen (h+a) vs. | 31 | 10,637 | 6.55* |
| Lake Shelbyville | 10 | 7,569 | |
| Lake Coffeen (a) vs. | 16 | 11,966 | 1.90 |
| Lake Shelbyville | 10 | 9,353 | |

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[1] Least-squares mean = mean number of eggs after adjustment for the linear covariate (= total length). Adjustments are based upon an overall grand mean and thus may change between comparisons. Values are computed for comparison purposes only and may not represent the true mean fecundity at that location.

computed in an effort to gain insight into the nature of thermal effects on egg production in this species. The second comparison was consistent with the Coffeen Lake results in that ambient areas of the two cooling lakes supported significantly greater egg production than heated areas (Table 16.2). The data suggest that thermal influences may result in a suppression of egg production by largemouth bass. The overall average fecundity of Coffeen Lake bass did not differ significantly from that of the Lake Shelbyville population, but significantly higher production was detected in the ambient area of Coffeen Lake when compared to Lake Shelbyville estimates (Table 16.2). Estimated egg totals from Coffeen Lake ranged from 5,598 to 141,580 (Table 16.1) which is within the recorded range of 2,000-168,815 for this species (Eddy and Surber 1947, Sigler 1959, Sule et al. 1979).

The causes of spatial differences in egg production within Coffeen Lake cannot be identified with certainty because of the multiplicity of factors which influence fecundity: genetic makeup, food availability, age, previous spawning history, and others. In a thermally elevated system, the most obvious impact on egg production rates would arise from metabolic rate increases since the energy alloted to maintenance, growth, and reproduction (especially egg production) would be altered by such increases. Differences in age and previous spawning history offer another possible explanation for the reduced fecundity of largemouth bass in heated environments. Fish sampled from Coffeen Lake and Lake Sangchris could not be reliably aged by the scale reading method because of the variable effect of thermal discharge on annulus formation (Tranquilli et al. 1981b). In view of the beneficial effects of the thermal effluent on fish growth, it is possible that fish of comparable sizes from heated areas were younger (and thus less fecund) than those from ambient areas and those from unheated Lake Shelbyville. Joy (1979) inferred by analysis of fish size and age at sexual maturity that largemouth bass from Lake Sangchris probably reached sexual maturity at Age II, one year earlier than was observed in Lake Shelbyville.

Mean fecundities of channel catfish were 8,031 and 8,132 eggs per individual from heated and ambient areas, respectively (Table 16.1). A positive linear relationship between egg production and total length was detected and scatter plots suggested that fecundities were similar over the length range of fishes examined (Fig. 16.2). No within-lake differences in egg production were evident after heated and ambient values were adjusted for length differences (Table 16.2). Inclusion of Lake Sangchris fecundity data yielded results similar to the Coffeen comparisons in that no thermal influences were detected. The overall average fecundity in Coffeen Lake was found to be significantly higher than that of the Lake Shelbyville population, but the Coffeen ambient sample alone was not significantly different from that of Lake Shelbyville. The best estimate of fecundity in Coffeen Lake, however, is an average value computed from combined heated and ambient samples since the two estimates did not differ significantly. As indicated above, that value was significantly higher than the Lake Shelbyville average (Table 16.2). In contrast to our findings, Sule et al. (1979) reported that channel catfish from heated areas of Lake Sangchris produced significantly more eggs than those from ambient areas.

Total egg counts of channel catfish from Coffeen Lake ranged from 1,453 to 25,476 which was slightly below the range of 2,000-70,000 eggs reported by Carlander (1969). Several authors cited in Carlander (1969) counted all eggs in the ovary, whereas we estimated effective annual fecundity by counting only those eggs larger than a critical size. Consequently, fecundity data of most other authors are not directly comparable to those presented herein. Jearld and Brown (1971) reported a mean fecundity for channel catfish of 13,238 eggs for fish averaging 383 mm in Lake Carl Blackwell, Oklahoma, and Muncy (1959) reported a mean fecundity of 6,123 eggs for fish averaging 399 mm from the Des Moines River, Iowa. Sule et al. (1979), using methods identical to ours, reported a mean fecundity of 7,882 eggs for channel catfish, averaging 393 mm, from the heated area of Lake Sangchris, 5,601 eggs for fish averaging 370 mm from the ambient area of Lake Sangchris, and 15,488 eggs for fish averaging 536 mm from Lake Shelbyville. Since the fish from Lake Shelbyville were much larger than those from Coffeen Lake or Lake Sangchris, the specific comparisons in Table 16.2 were of low precision because of the extrapolation required to accomplish the adjustments (Snedecor and Cochran 1967).

As with largemouth bass, channel catfish from Coffeen Lake were not aged and differences in fecundity between Coffeen Lake and Lake Shelbyville were probably due to differences in size and age. Coffeen Lake, like Lake Sangchris (Tranquilli et al. 1981a), contains a naturally reproducing population of channel catfish (Section 15, herein). This is unusual because, in Illinois, channel catfish production is usually not successful in large reservoirs without major tributaries and particularly not so in those containing good populations of piscivorous largemouth bass. The unusually successful reproduction by channel catfish in these two cooling lakes suggests that either the elevated temperatures and/or the artificial current is advantageous to this species.

The fecundity data suggested that both largemouth bass and channel catfish have tremendous reproductive potential in Coffeen Lake. To maintain a stable fish population, the only reproductive requirement of any pair of spawners is that they replace themselves during their lifetime. It is therefore apparent that fecundity as an estimate [illegible] eproductive potential is not a measurement that can be used to predict f[illegible] fish stocks. The actual number of eggs produced is not nearly so important as the number of progeny that survive. In addition, there are many factors other than fecundity which govern year class strength. They include time of spawning, presence of predatory or competitor species, food availability, cover availability, water quality during the spawning season, and even the number of good spawning sites. In addition, a "compensatory response" may be generated in fish populations such that if the population is reduced, the fecundity and/or the survival rate of remaining members tends to increase (McFadden 1977). Both positive (earlier spawning) and negative (suppressed fecundity) effects of a thermal discharge were evident in this study and they underscore the difficulty of judging the ecological impacts of thermal effects in view of the interrelationships between those environmental and biological variables which ultimately govern the success of species inhabiting cooling lakes.

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## SECTION 17

# MOVEMENTS, POPULATION ESTIMATES, AND FISHERMAN EXPLOITATION OF LARGEMOUTH BASS AS DETERMINED BY MARK AND RECAPTURE ESTIMATES IN COFFEEN LAKE

by

Lance G. Perry and John A. Tranquilli

## ABSTRACT

A mark and recapture technique was utilized to determine movement patterns and to estimate population size and fisherman exploitation of largemouth bass in Coffeen Lake. Mean distances traveled by marked fish were 1,325 meters after an average of 16 days of liberation and 1,221 meters after an average of 307 days at liberty. Displacement distances (from release sites) were not related to the size of marked individuals or to number of days elapsed between release and recapture. A significantly greater average displacement was detected among individuals originally released in the heated area of the lake compared to those released in ambient areas. The population estimates for fish ≥200 mm total length were 4,958 ± 1,174 as of May 1979, and 5,466 ± 1,181 as of May 1980. Standing crop estimates derived from those values were 9.3 kg/ha and 10.1 kg/ha for the two years, respectively. Sport fishermen reported 80 catches of tagged fish and 84 catches of untagged fish. Most of the individuals caught by angling were kept.

## INTRODUCTION

The largemouth bass (Micropterus salmoides) is one of the most important sport fishes throughout the U.S. and the most sought-after gamefish in Illinois (Rogers 1980). This species was stocked in Coffeen Lake in the mid-1960's (Ill. Dept. Cons., Div. Fish. files) and presently occupies the highest trophic level in that fish community. The bass population in Coffeen Lake is of interest not only because of its sport fishery potential, but also as a reflection of the status and general well-being of lower trophic levels and, in view of its self-sustaining capability, as an indicator of the extent of chemical and thermal impacts in the lake. This investigation was undertaken to evaluate several life history phenomena of this species in Coffeen Lake. Specific objectives were: 1) to delineate patterns of movements, 2) to estimate numerical abundance, and 3) to quantify fisherman exploitation of largemouth bass.

## MATERIALS AND METHODS

A total of 1,988 largemouth bass $\geq$ 200 mm total length (range 200 to 564 mm TL) were marked and released in Coffeen Lake, 988 from 16 April to 24 May 1979 and 1,000 from 25 March to 29 April 1980. All specimens were captured by electroshocking and marked by fin clipping and tagging. Floy anchor tags (model FD-68B), each embossed with a code number and our laboratory phone number (for use by sport fishermen in reporting their catch to us), were inserted obliquely between the interneural rays of the spinous dorsal fin in the manner described by Dell (1968). In 1979 all specimens were also given a left pelvic fin clip. In 1980, a right pelvic fin clip was used on all specimens captured south of the railroad causeway, and a spinous dorsal fin clip (first three spines) was used to mark those captured north of that landmark. Marked fishes were released randomly in relation to the unmarked population. This was accomplished by distributing collecting efforts throughout the lake and releasing each marked fish near its original capture site. All release and recapture locations were recorded on a scaled topographic map of Coffeen Lake. Movements were designated as either short-term or long-term based upon the length of time elapsed between release and recapture. Short-term movements were those observed among fish recaptured during the same season (spring) in which they were released. Long-term movements were determined for fishes which were recaptured during a season (fall or spring) following their springtime release. Distances discussed herein represent minimum straight-line estimates from point of release to point of recapture within the lake basin. In order to relate movement patterns to the thermal characteristics of the lake, all release and recapture observations were classified as occurring in heated, transitional, or ambient areas. These represented, respectively, the entire lake reach from the thermal outfall to Station 2 inclusive, the lake reach from Station 2 to the railroad causeway, and the lake reach north of the railroad causeway (Fig. 13.1, Section 13, herein).

Two population censuses were conducted to estimate the numerical abundance of largemouth bass $\geq$200 mm total length in 1979 and in 1980. The following mathematical expression was used (Youngs and Robson 1978):

$$N = mc/r$$

where: $N$ = an estimate of the total number of individuals in the population
$m$ = total number of marked individuals in the population
$c$ = total number of individuals in the recapture sample
$r$ = total number of marked individuals in "c"

The recapture sample (c) for the 1979 estimate was obtained by electroshocking from 15 October to 20 November 1979. Only individuals $\geq$ 350 mm TL were included in order to eliminate recruitment due to growth during the period between release and recapture. An average increase of 150 mm during that period was predicted for individuals that were 200 mm TL during the spring of 1979.[1] The recapture sample for the 1980 estimate was collected from 25 March to 27 April 1981 and only included individuals $\geq$360 mm TL based upon an estimated growth increment of 160 mm for fish which were 200 mm TL during the spring of 1980.

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[1] Estimate was based upon a linear regression of increase in length ( TL) on total length at release. The regression is not presented herein, but it was identical to those shown in Fig. 15.10 (Section 15, herein) except a = 150 (estimate used), b = 0.51, r = 0.94, and N = 20. Growth during the 1980 growing season was similarly estimated.

Catches of tagged bass reported by sport fishermen were recorded along with date of capture, capture location, and total number of fish kept and/or released. All reports were voluntary on the part of the fishermen and no reward was offered for the information.

## RESULTS AND DISCUSSION

### Movements

From 17 April 1979 to 27 April 1981 a total of 279 tagged largemouth bass were recaptured. Of that number, 154 were recaptured after only a short period (1 to 38 days) of liberty, and their displacements from original capture sites were accordingly designated as short-term movements. All were recaptured during the same season (spring) in which they were released and thus may partly reflect the influence of our tagging procedure on their subsequent movements; that is, capture and handling of individuals for tagging purposes may have produced an irregular movement response in some fish because of the mild trauma suffered during the procedure. Such responses would be most pronounced soon after release. Long-term movements represented seasonal displacements since all recaptures were obtained during the fall or spring seasons following the springtime release and thus were assumed to reflect little if any effect of the tagging procedure. These long-term observations (N=125) were recorded after a minimum of 141 days had elapsed since the date of release and ranged up to 705 days after release.

Marked fishes recaptured after a short-term period of liberation had traveled an average distance of 1,325 meters (Table 17.1). The maximum displacement distance during that period was 6,969 meters, which is approximately equivalent to the distance from the point of thermal discharge to Station 4 (Fig. 13.1, Section 13, herein). No attempt was made to relate short-term movements to thermal characteristics of the release sites since our tagging efforts were conducted in the discharge arm first (early spring) and in the ambient area last (mid-spring) which favored detection of long-distance movements by those individuals tagged and released early in the season. Means and ranges of movements exhibited by fish recaptured after long-term periods of liberation are

Table 17.1. Means and ranges of distances traveled by tagged largemouth bass in Coffeen Lake. Sample size (N) and days elapsed between release and recapture (mean and range) are given. All observations represent short-term movements (see text).

| N | Days elapsed |  | Distance traveled (meters) |  |
|---|---|---|---|---|
|  | mean | range | mean | range |
| 154 | 16 | 1-38 | 1325 | 0-6969 |

presented in Table 17.2. Mean movement distances did not differ between groups of individuals released in heated areas compared to transitional areas (t=0.25, P>0.50), but a significantly greater average displacement from heated release sites was detected in comparison with ambient release sites (t=3.40, P<0.01). The fluctuating and occasionally extreme temperature cycle which is characteristic of the heated location may in part contribute to a greater between-season displacement among bass since power plant operation practices could contribute to considerable between-season variability in water temperatures, a factor which would demand relocation of fishes in extreme cases. The temperature cycle of the ambient area of Coffeen Lake would be expected to be more stable and predictable in the sense that only atmospheric events contribute to the temperature variability; that area thus represents the type of thermal regime that northern largemouth bass have adapted to.

Distances traveled by marked fishes were not related to either size at release or to number of days at liberty as judged by a lack of correlation between those variables and respective displacement distances (Table 17.3). Among those fishes recaptured during the fall or spring seasons following their release (long-term movements), a tendency to remain within a restricted areas was suggested by the high frequency of recaptures which occurred at or near original release sites. Approximately 60% of long-term recaptures were found within 1,000 meters of their original release sites and over half of that number were found within 200 meters of that location (Fig. 17.1). Displacement distances progressively decreased in frequency up to a maximum of 6,246 meters which was the greatest displacement observed by an individual after a long-term period of liberation.

Crossing of the main lake channel by largemouth bass was commonly observed among both short-term and long-term groups; those crossings were detected in 29% and 36%, respectively, of the total number of observations. Passages through the railroad causeway culverts were 5% and 9% for the short-term and long-term groups, respectively, with north to south and south to north movements about evenly distributed. The majority of those movements were observed among individuals originally captured and released near the structure.