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Limnological, Ichthyological, and Parasitological Investigations on Arkansas Reservoirs in Relation to Water Quality

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LIMNOLOGICAL, ICHTHYOLOGICAL, AND PARASITOLOGICAL
INVESTIGATIONS ON ARKANSAS RESERVOIRS
IN RELATION TO WATER QUALITY

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This report was prepared from information contained in a dissertation and theses by the graduate research assistants on this project.

DESCRIPTION OF THE STUDY AREA

Lake Fort Smith, a 525 acre (212 ha) reservoir, was impounded in 1936 as a water supply for the city of Fort Smith. The reservoir is located on Clear Creek (Frog Bayou), a tributary of the Arkansas River, in the Boston Mountains 28 miles (45 km) northeast of the city of Fort Smith in Crawford County, Arkansas. A map and morphometric characteristics of Lake Fort Smith are given in Fig. 1 and Table I (Hoffman, 1951; Nelson, 1952).

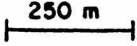
In 1956 Lake Shepherd Springs, a 750 acre (304 ha) impoundment, was created one mile upstream of Lake Fort Smith (Rorie, 1961). Both lakes have a shale substrate and are subject to periods of high turbidity. The two lakes have a water shed of 65 square mile area (168 km²) of mountainous oak-hickory forest.

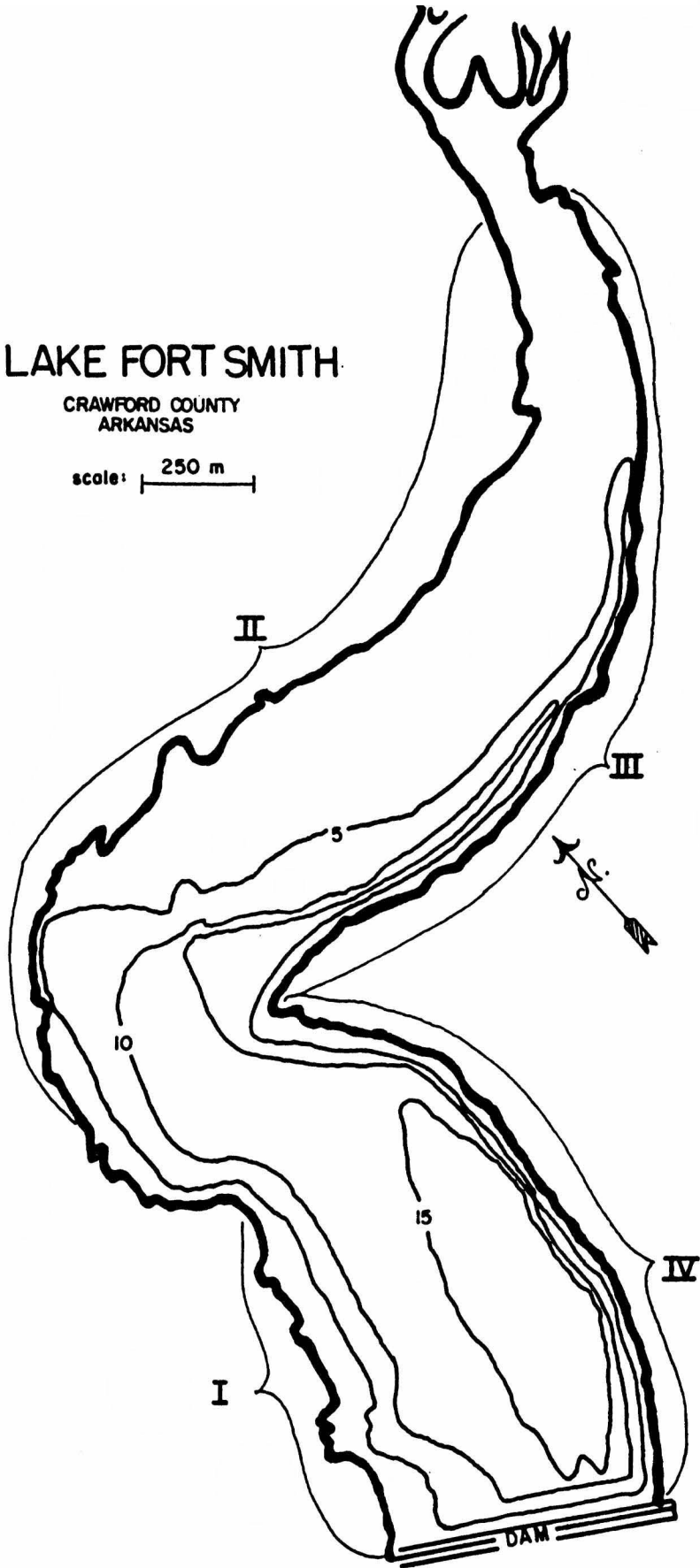
Lake Shepherd Springs has not acted as a settling basin for sediments; thus, the upper portion of Lake Fort Smith has numerous shallow areas with a mud bottom supporting various submergent and emergent aquatic plants. The lower portion of the lake has a rocky, shale substrate with only limited emergent vegetation.

**Figure 1. Map of Lake Fort Smith.
I-IV: Areas of mark and
recapture study.**

LAKE FORT SMITH

CRAWFORD COUNTY
ARKANSAS

scale:  250 m



Maximum effective length N. S.	2086.97 m
Maximum effective length N. E.	2406.87 m
Maximum length	4204.40 m
Maximum width	792.14 m
Mean width	505.75 m
Maximum depth	20.11 m
Mean depth	7.01 m
Length of shore line	11,821.07 m
Shore line development	2.29 *
Surface area	2,129,328.00 m ²
Volume of lake	14,716,744.00 m ³
Volume development	0.95 *

* Method described in Welch (1948)

TABLE I. Morphological features of Lake Fort Smith (Nelson, 1952)

INTRODUCTION

Limnological Phase

The limnological portion of this report on Lake Fort Smith represents a part of a program, begun in 1938, which was designed to follow physico-chemical and plankton changes during the aging of small impoundments in northwestern Arkansas. Two other manuscripts of long-range studies, one dealing with lakes impounded on limestone bedrock and one impounded on shale, are now in preparation. Lake Fort Smith, a municipal water supply, is of the latter type; however, some of the watershed is on limestone bedrock.

Hoffman (1951) conducted a temperature and turbidity analysis of Lake Fort Smith during 1949-1950 when temperature comparisons were made with similar records taken by him in 1938-1939. Nelson (1952) investigated the physical, chemical, and biological features of Lake Fort Smith during 1950-1951 and noted several features that made this lake unique when compared with other lakes in the same geographical region. During the fourth year of the lake's impoundment, Hoffman and Causey (1952) conducted a physical, chemical and biological study. Hoffman (1952) showed that heavy rainfall resulted in a decline of the standing crop of phytoplankton from the surface to the bottom. Zooplankters were concentrated in the 7 to 12-m level and reduced in the surface waters. Similar studies which have been conducted on other small northwestern Arkansas lakes are: Tatum (1951) on Lake Atalanta, Owen (1952) on Lake Wedington, and Hulsey (1956) on Lake Fayetteville. These three lakes are somewhat smaller than Lake Fort Smith. Rorie (1961) compared the chemical and biological features of Lake Fort Smith with Lake Shepherd Springs (ref: Shepard Spring Lake, General Highway Map, Crawford Co.,

Arkansas) which is located approximately one mile upstream.

The purposes of this phase of the investigation during the 35th and 36th years of impoundment of Lake Fort Smith were fourfold: (1) to document the physical and chemical features; (2) to establish some biological features of the phytoplankton and zooplankton communities; (3) to determine the relationship of some of the physical and chemical parameters to the biological features; (4) and to utilize the physical, chemical, and biological features to formulate a critique of the present water quality.

The future objective of the principal investigator is to correlate these data, procured during 1971-1972, with those of six former annual investigations of the physico-chemical parameters and plankton communities of Lake Fort Smith since 1938. The study, now in manuscript preparation, will also include physico-chemical data from two annual studies of Lake Shepherd Springs.

Ichthyological Phase

Largemouth and spotted bass are sympatric throughout much of their ranges. The spotted bass occurs naturally from the Ohio River system of Illinois, Indiana, and Ohio south to the Gulf states and northward through Texas to Oklahoma and Kansas. The largemouth bass occurred originally from southeastern Canada throughout the Great Lakes region southward through the Mississippi Valley to Mexico and Florida (Blair et al., 1968).

Although largemouth and spotted bass are sympatric in many areas, they segregate to a large degree due to habitat selection. Viosca (1932) and Brown (1932) stated that in streams spotted bass select areas of greater current while the largemouth bass select more lentic conditions. This preference for lotic conditions by spotted bass is probably a significant factor in the frequently noted decline in their abundance following

impoundment of a stream (Eschmeyer, 1937; Jenkins, 1953; Chance, 1958). In lakes and reservoirs largemouth bass select areas of greater vegetation than does the spotted bass. Howland (1932) reported that Ohio spotted bass were found in high numbers in areas with silt and decaying matter; however this does not apply to spotted bass of Lake Fort Smith. Dendy (1946) found that in reservoirs largemouth and spotted bass tend to segregate with respect to depth, the spotted bass being more common in cooler, deeper water. Field observations have shown that the preferred temperature for spotted bass is 23.5-24.4C compared to 26.6-27.7C for largemouth bass (Ferguson, 1958).

Largemouth and spotted bass are spring and early summer spawners. Initiation of spawning activities and egg deposition in black bass is temperature dependent (Bennett, 1965). Largemouth bass are reported to spawn at 14.4-20.0C (Miller and Kramer, 1971; Bennett, 1965); while spotted bass spawn at 17.2-21.1C (Towery, 1964; Ryan, 1968). In Beaver and Bull Shoals Reservoirs, Arkansas the peak of spawning activity of largemouth and spotted bass occurs at 15-17C (L. Vogele, pers. comm.).

The nesting and spawning behavior of black basses have been intensively studied (Carr, 1942; Howland, 1932; Reighard, 1906). The male clears and forms a circular redd. Following completion of the nest a ripe female approaches and courtship begins. Courtship is terminated by egg deposition. The fertilized eggs sink to the bottom and attach to the substrate. The female leaves the nest but the male protects and cares for the eggs.

Knowledge concerning the fecundity of largemouth and spotted bass is severely lacking. Carlander (1953), summarizing the work of earlier researchers, stated the fecundity of largemouth bass ranged from 2,000 to 109,000 eggs per female. Kelley (1962) found that the range of fecundity of largemouth bass of Maine was 5,000 to 82,000 eggs per female. He stated

that the variation in fecundity between individuals was primarily a function of age, but that length and weight were also important factors. A definite relationship between the condition of gonads and the condition of fish has been found by James (1946). This would suggest that the overall condition of a fish could be a factor in the number of eggs produced. Work relating to the fecundity of spotted bass is very meager. Towery (1964) reported the total annual egg production of this species to be 14,000 to 47,000 eggs per female, but he apparently did not determine the number of mature eggs produced. Vogele (pers. comm.) determined the fecundity of spotted bass of Bull Shoals Reservoir, Arkansas to be within the range of 3,000 to 30,000 eggs per female.

The success of a largemouth bass year class is usually determined after hatching, but before the fry are two weeks old (Kramer and Smith, 1962). Mraz et al. (1961) found stable water temperatures, absence of predation on eggs and fry, and abundance of plankton to be important factors in establishment of successful year classes. In Lake George, Minnesota wind was determined to be the most influential factor in determining year-class strength (Kramer and Smith, 1962). Von Geldern (1971) concluded that stable or rising water level during spawning, high surface water level in April and May, and low abundance of adult threadfin shad were necessary for establishment of a strong year class of largemouth bass in Lake Nacimiento, California.

Growth rates of young-of-the-year spotted and largemouth bass have been intensively studied (Brown and Tatum, 1962; Hodson, 1963; Holland and Chambers, 1971; Kramer and Smith, 1960; Lambou, 1958). Growth rates vary greatly, even within a brood (Meyer, 1970). Availability of food (Lambou, 1958) and mean daily water temperature (Kramer and Smith, 1960) have been suggested as two of the major factors affecting the growth rate of young-

of-the-year largemouth bass. Under laboratory conditions, optimum temperature for growth of largemouth bass fry is 27.5-30.0C (Strawn, 1961a).

Differential growth rates between sexes are dependent upon local conditions. Beckman (1946) and Stroud (1948) found no difference in the growth rates among the sexes of Michigan largemouth bass and Tennessee spotted bass, respectively. Padfield (1951), found female largemouth bass to grow faster than males in Alabama while Pardue and Hester (1966) found the male largemouth bass to grow faster and mature earlier than females in Alabama ponds. A comparison of previous age and growth studies reveals that while bass in the northern portion of the U. S. grow slower than those in the southern part, they tend to live longer. From the northern waters the maximum age of largemouth bass was reported as 15 years in Wisconsin (Bennett, 1937), 13 years in Wisconsin (Mraz and Threinen, 1955), and 9 years in Maine (McCaig and Mullan, 1960) whereas from the southern waters the maximum ages were 6 years in Tennessee (Hargis, 1965), 7 years in Virginia (Rosebery, 1950), and 5 years in Oklahoma (Jenkins, 1953). Although much less data are available, the same trend appears to apply to spotted bass.

The numerous age and growth studies dealing with largemouth bass allow several generalizations regarding the growth of this species in the U. S. Largemouth bass tend to grow faster in larger bodies of water (Roach and Evans, 1948; Jenkins and Hall, 1953) and in newer impoundments (Jenkins and Hall, 1953; Tharratt, 1966; Bryant and Houser, 1971). Turbidity (Jenkins and Hall, 1953) and high population densities (Cooper et al., 1963; Kramer and Smith, 1960) tend to retard the growth rate of this species.

Food habits of largemouth and spotted bass appear to vary with local conditions. In general, fry and fingerling bass utilize entomostracans and small aquatic organisms very heavily (Applegate and Mullan, 1967; Hodson,

1963; Holland and Chambers, 1971). The diet of adult largemouth and spotted bass is usually composed of fish (Aggus, 1972; Dendy, 1946), crayfish (Finkelstein, 1960; Snow, 1971), or insects (Smith and Page, 1969). Aggus (1972) found the diet of largemouth more diverse than that of the spotted bass.

The lack of data pertaining to the life history of spotted bass is surprising in view of its value as a sport fish. While the life history of largemouth bass has been intensively investigated, the spotted bass remains one of the least understood game fishes. Therefore, this investigation deals with the dynamics of ecological life history of spotted bass as well as largemouth bass in Lake Fort Smith, Arkansas, with a comparison of the two species. An attempt is made to evaluate the environmental effects on the life history of each species.

Parasitological Phase

The environment of a parasite is of dual character. Both the host and the host's environment form the habitat of a parasite. A community of parasites inhabiting one host forms its own biocoenosis living under a mutual set of environmental factors. In studying such parasitocoenoses, not only the host but also the host's environment must be taken into consideration. This is especially true for ectoparasites. The community approach to fish parasites has been grossly neglected and much is yet to be understood concerning fish parasite communities and how they are affected by their environment.

Seasonal changes in the parasitocoenoses of fishes are related to seasonal, environmental, and physico-chemical changes which influence the reproduction, migration patterns, and feeding ecology of the hosts, determine

the abundance of intermediate hosts, or directly affect the development and infectivity of parasites. Except for reports by Bogitsh (1958), Chubb (1963), Connor (1953), Holl (1932), Crane and Mizelle (1968), Spall and Summerfelt (1969), and Rawson and Rogers (1972), knowledge of seasonal variation in parasitic incidence in fishes is limited. Even more limited is our knowledge of the action of physico-chemical factors on abundance of parasites. The present study will attempt to gain insight into the seasonal changes of parasitism in relation to water quality in Lake Fort Smith, Crawford County, Arkansas.

The objectives of this study were to (1) determine the species and extent of helminth and crustacean parasites in selected game fishes (channel catfish, Ictalurus punctatus (Rafinesque); largemouth bass, Micropterus salmoides (Lacepede); spotted bass, M. punctulatus (Rafinesque); warmouth, Lepomis gulosus (Cuvier); bluegill, L. macrochirus Rafinesque; black crappie, Pomoxis nigromaculatus (Lesueur); and white crappie, P. annularis (Rafinesque) from Lake Fort Smith, (2) correlate parasitism with age and sex of the hosts, (3) determine seasonal fluctuations of parasites from largemouth bass, warmouth, and bluegill, and correlate the seasonal changes with physico-chemical factors, (4) describe and evaluate parasite community structure by use of species diversity indices, and (5) compare this study with a previous survey of Lake Fort Smith fish parasites (Houghton, 1963; Becker and Houghton, 1969) to determine any qualitative and/or quantitative changes since the previous study.

METHODS AND MATERIALS

Limnological Phase

Plankton samples were initially collected with a 10-liter Juday closing plankton trap equipped with a number 25 silk bolting-cloth net at 1-m intervals from the surface through the 15-m level. Two samples were taken at each depth and combined to provide a 20-l sample. In February of 1972 a change was made to a low water pressure, rubber impellar water pump (Garringer brand) mounted to an electric motor which was powered by a gasoline-fueled generator. Twenty liters of lake water were pumped through a number 25 silk bolting-cloth plankton net and then concentrated to 20 ml. All plankton samples were preserved in 3% formalin solution. A 5-ml subsample was later removed from each 20-ml sample. These subsamples, taken from the surface through the meter 5 samples, were combined to provide a composite subsample for analysis. Identical procedures were performed to provide composite subsamples for analyses representing 6-10 m and 11-15 m. Numbers of organisms or cells per liter were derived by determining the mean of two 1-ml direct counts using a Sedgwick-Rafter counting chamber.

Temperatures were recorded with a Yellow Springs Instrument Company tele-thermometer. Hydrogen ion concentrations were determined in the field with a portable Analytical Instruments Company pH meter. A Secchi disk was used to measure transparency. Turbidity was recorded in Jackson Turbidity Units using a wavelength of 450 m μ . Water samples were collected with a 1-l Kemmerer water sampler at the surface, at meter one, at each subsequent odd meter level through meter 15, and immediately above the bottom. Chemical analyses of nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, ortho-phosphate, metaphosphate, and silica followed the methods outlined in the

Hach Chemical Company guide "Colorimetric Procedures and Chemicals for Water and Waste Water Analysis" (1971). Determinations were performed using a previously calibrated Bausch and Lomb "Spectronic-20" colorimeter-spectrophotometer. Colorimeter calibrations were analyzed periodically with standard solutions to assure accuracy.

The titration method was used to analyze total alkalinity by the methyl orange indicator method and dissolved oxygen by the azide modification of the iodometric analysis (APHA, AWWA, WPCF, 1971). Relative abundances of dissolved solids were determined with a conductivity bridge in the laboratory.

Ichthyological Phase

During July, 1970 and July, 1972, a total of 327 largemouth bass and 394 spotted bass was collected by electrofishing, gill netting, angling, rotenone, and seining.

Electrofishing was done by a boat mounted 230 volt AC generator which adequately sampled largemouth and spotted bass during the spring, summer, and fall, but was highly inefficient in sampling spotted bass during the winter.

Gill nets were the most efficient means of sampling spotted bass during the winter. Largemouth bass did not appear nearly as vulnerable to gill nets. Gill netting was employed only during the winter.

Rotenone was used once (July, 1971) to study the structure of the fish community of Lake Fort Smith in a cove of 2.5 hectares (6.2 acres) by blocking off with a 65 m block-off net. Liquid rotenone was applied at a concentration of 1 ppm. Fish were picked up for three days and classified according to species and maturity.

Seining proved very useful in securing young-of-the-year basses. Seining was performed only during the summer using 6 m bag and minnow seines of 6.2 mm mesh. Due to the presence of large rocks and the contagious distribution of young basses no effort was made to standardize the seining efforts.

Total and standard lengths of all fish were measured to the nearest millimeter, and weight was taken to the nearest gram. Scale samples were taken from the left side of the fish between the lateral line and the spinous dorsal fin at approximately the tip of the appressed pectoral fin. Plastic impressions of the scales were made using a Carver laboratory press. The plates were heated electrically to 95 C and a pressure of 1050 kg/sq cm was maintained for 10 seconds. Scale impressions were viewed on an Eberbach scale projector, and the best impression studied. Measurements were recorded from the focus to each annulus and the edge of the anterior field. All fish were considered to have an annulus at the edge of the scale starting January 1 (Hile, 1950).

The relationship of scale radius to body length was determined by step up polynomial analyses. Male, female, and immature fish were tested separately to determine the effects of sex and maturity on the scale radius-body length relationship. Samples from different years were pooled to minimize the influence of annual fluctuations in the scale radius-body length relationship.

Coefficients derived from the appropriate scale radius-body length relationship were used in back calculating the length of fish at previous ages. The growth parameters of the von Bertalanffy growth model, $L_t = L_{\infty} (1 - e^{-K(t-t_0)})$, were determined as described by Walford (1946) and Ricker (1958).

The length-weight relationship was expressed as $\log W = \log A + B \log L$, where W is weight in grams and L is length in millimeters. Sexes were treated separately to test for differences due to sex. Coefficient of condition (K) was determined as $K = W \times 10^5 / L^3$. Condition coefficients were computed for individual age groups to determine the relationship of aging and condition.

The instantaneous mortality rates were computed from catch curves (Ricker, 1958) and from parameters derived from the von Bertalanffy growth equation (Beverton and Holt, 1956).

Immediately after removal, stomachs were placed in individual vials containing 10% formalin for a period of one week, at which time they were removed, washed in cold water, and placed in vials containing 40% isopropanol until examined. The stomachs were split longitudinally and the entire contents carefully flushed into a petri dish. The contents were examined under a binocular dissecting microscope, and all items identified to the lowest possible taxon. The remainder was observed under 30X, and zooplankters were removed and preserved on glass slides with CMCS-CMC-10. Mounted plankters were later identified under a compound microscope. This method was efficient in sampling only the larger zooplankters.

In view of the small size and rare occurrence of several of the food organisms and the inherent inaccuracy of the volumetric method, the stomach contents were analyzed by the frequency occurrence, numerical, and gravimetric methods. Frequency of feeding (percent of stomachs containing a measurable amount of food) and mean diet weight (total weight of food divided by the number of stomachs examined containing food) were computed for immatures, males, and females of each species for each season.

The feeding intensity in relation to the time of collection was analyzed to determine diel trends in feeding. For this fishes were collected at 3-hour intervals.

The effect of several physico-chemical factors on the mean diet weight and frequency of feeding were tested by multiple regression analysis.

The time of spawning for each species was determined by field observations, gonado-somatic indices, and examination of the gonads. Spawning sites were analyzed to determine differences in habitat selection and degree of competition for nesting sites. The age at first spawning was determined by means of gonadal observation and results of the age and growth analyses.

Due to compression within the ovary and preservation, many ova were not spherical. To overcome any tendency to select for the longest or shortest diameter the measurement of each ova was taken parallel to the horizontal axis of the ocular micrometer (Clark, 1934). Ova were measured using an ocular micrometer fitted in a dissecting microscope calibrated at a magnification of 20 diameters.

To determine if the ova are homogeneously distributed throughout the ovaries the frequency distributions of ova diameters from inner and outer sections of cross sectional discs from the anterior, middle, and posterior thirds of the right and left ovaries of a mature female spotted bass were compared by Kolmogorov-Smirnov two sample tests.

Each ovary was removed from the preservative, trimmed of nonovarian tissue, blotted dry, and allowed to air dry for 15 minutes. The entire ovary was then weighed to the nearest milligram. A cross sectional disc was removed from the middle of one of the ovaries and from this sample a wedge-shape subsample was also weighed to the nearest milligram. The diameters of all ova exceeding 0.20 mm in the subsample were measured.

The ova in the last normal mode of the ova diameter frequency distributions of mature ova were considered to be mature. The number of mature ova in both ovaries was calculated by a proportionality formula:

$$\frac{\text{Number of ova in subsample}}{\text{Weight of subsample}} = \frac{\text{Total number of ova}}{\text{Total weight of the ovaries}}$$

The relationships of fecundity to total length, standard length, condition, age, and weight were analyzed by regression analyses.

Parasitological Phase

The fishes used in this study were collected from Lake Fort Smith from July 1970 through June 1971, from the northern sector of area I, at the junction of areas II and III, and III and IV in the littoral zone. At least two collection trips were made each month. Most fishes were captured by electrofishing. Gill nets were used to supplement electrofishing, especially during the winter, and some fishes were captured by angling. All fishes were taken to the laboratory alive to await dissection and examination for parasites.

A scale sample was consistently taken from each fish between the dorsal fin and the lateral line. Age determinations were made from the scale annuli.

Each fish was completely examined for helminth and crustacean parasites using a dissecting microscope.

The recovered parasites were prepared for identification using conventional methods (Becker and Heard, 1965; Becker, Heard, and Holmes, 1966).

Temperature, pH, dissolved oxygen, ammonium, nitrate, orthophosphate, methyl orange alkalinity, and turbidity were sampled at each collection date by other investigators on the project. Seasonal changes in these physico-chemical data were correlated with seasonal changes in parasitism.

The data were analyzed with the aid of an IBM 360-50 computer. Multiple correlation-regression analysis (CORREG, University of Arkansas Computing Center) was used to correlate parasitism with seasonal changes in physico-chemical factors. Significance was considered at the .05 level. Species diversity indices based on methods derived from information theory (Margalef, 1958) were calculated in order to quantitatively describe the structure of the parasite community in each host.

RESULTS AND DISCUSSION

Limnological Phase

Physical and Chemical Parameters for 1971-1972

TEMPERATURE

Semimonthly temperatures taken from December 15, 1971 through November 27, 1972 indicated that Lake Fort Smith should be classified as a warm monomictic lake (Reid, 1961). Temperatures did not drop below 4 C at any depth. Water temperature data are summarized in Tables II and III and graphically depicted in Fig. 2.

The highest temperature at meter one was 29.5 C on July 19, 1972, and the lowest was 5.2 C on February 14, 1972. The mean temperature at the 1-m level, during stratification, was 23.3 C; during overturn it was 8.8 C. Stratification was first observed April 7, 1972 and continued until overturn, which was in progress by November 27, 1972. At that time the mean temperature between the surface and meter 15 was 8.99 C. The mean temperature at the 15-m level during the stratification period was 12.22 C.

DISSOLVED OXYGEN

Average semimonthly dissolved oxygen concentrations per collecting trip at selected depth intervals are graphically given in Fig. 3 and tabulated in Tables II and III. Mean concentrations ranged from a maximum of 11.48 mg/l O₂ between meters 6 and 10 on March 1, 1972 compared to a low of 0.2 mg/l O₂ between meters 11 and 15 on September 14, 1972. During thermal stratification, oxygen depletion (< 0.1 mg/l O₂) was not observed. Oxygen depreciation (< 4.0 mg/l O₂) in the hypolimnion was first observed in July 1972 and continued through October 1972. Concentrations as low as 0.1 mg/l O₂ in the hypolimnion were recorded on several collecting trips. On March 1

and April 24, 1972, there were significantly greater concentrations of oxygen between meters 11 and 15 than near the surface to the 5-m depth.

HYDROGEN ION

Hydrogen ion concentrations at meter one ranged from 7.0 to 8.8. The annual mean pH at meter one was 7.5. Nelson (1952) reported a pH range similar to that found in this investigation, although his maxima during the summer were slightly lower. Hydrogen ion data for 1971-1972 are summarized in Tables II and III.

ALKALINITY

Mean methyl orange alkalinity values in Lake Fort Smith ranged from a low of 10.3 mg/l on April 24, 1972 to a maximum of 35.8 mg/l on August 18, 1972 between the surface and the profundal zone (Fig. 4 and Table II).

Lake Fort Smith can be classified as a soft-water lake because of its comparatively low total alkalinity values. It should be noted, however, that some of the other lakes in northwestern Arkansas do not have this characteristic. Meyer (1971) observed methyl orange alkalinity values as high as 141 to 155 mg/l in Lake Fayetteville. Alkalinity during this study was the result of bicarbonates, since carbonates were rarely present.

TURBIDITY

Turbidity in Lake Fort Smith appeared to be a result of rainfall. The mean maximum turbidity, 124 JTU, was recorded on December 15, 1971, after a period of extended rainfall the preceding week (approximately 8 in.). During the summer months, the outlet valves are opened in the Lake Shepherd Springs

dam to maintain a high water level in Lake Fort Smith. Although Lake Shepherd Springs has not acted as a settling basin for sediments, it does settle the water somewhat in periods of limited summer inflow, thus creating less turbid water in Lake Fort Smith. Average turbidity data for each collecting trip are summarized in Fig. 5 and Tables II and III.

TRANSPARENCY

Secchi disk data are presented in Fig. 6 and Table III. The minimum Secchi disk reading was 16 cm on December 28, 1971. During this investigation low transparencies were recorded from December 15, 1971 until June 21, 1972, and then they steadily increased through the summer months until the maximum of 570 cm was observed on September 14, 1972. Nelson (1952) and Rorie (1961) also reported low transparencies during the winter months in Lake Fort Smith. During 1950-1951 Nelson (1952) recorded a maximum transparency of 249 cm. The higher readings in 1972 may be the result of drought conditions, with decreasing water flow allowing for increased sediment fallout in Lake Shepherd Springs and the upper portion of Lake Fort Smith.

NITRITE NITROGEN

Semimonthly distributions of nitrite nitrogen are given in Tables IV and V. The highest mean during this investigation was 0.019 mg/l on September 14 and October 25, 1972 between the 11 and 15-m depth, and the lowest was 0.0 mg/l on December 28, 1971. The Public Health Service in Standard Methods (APHA, AWWA, WPCF, 1971) reported that nitrite nitrogen rarely exceeds 0.1 mg/l in drinking water.

NITRATE NITROGEN

Nitrate nitrogen represents the most highly oxidized phase in the nitrogen cycle and normally reaches important concentrations in the final stages of biological activity (APHA, AWWA, WPCF, 1971). Mean concentrations of samples taken between the surface and the bottom ranged from 0.12 mg/l to 0.75 mg/l. Rorie (1961) found a range of 0.09 mg/l to 1.2 mg/l in 1959-1960, while Nelson (1952) reported a range of 0.58 mg/l to 2.39 mg/l for the years 1950-1951. Hrbáček (1964) reported that nitrates were a limiting factor only in oligotrophic lakes. Although Lake Fort Smith is apparently oligotrophic, the ample nitrate nitrogen appeared not to be the limiting factor on productivity. Tables IV and V present semimonthly distributions of nitrate nitrogen.

AMMONIA NITROGEN

Mean ammonia nitrogen concentrations between the surface and the bottom ranged from 1.85 mg/l to 0.74 mg/l on September 14 and November 8, 1972, respectively (Table V). The mean between meters 11 and 15 ranged from 0.86 mg/l on December 15, 1971 to 2.24 mg/l on October 25, 1972 (Table IV). The highest average ammonia nitrogen concentrations between the surface and the bottom were found on March 1 and September 14, 1972 (Table V). During the winter, concentrations between the surface and the 5-m level were greater than in the other seasons; however, significant increases were found at the 15-m level and just above the bottom during the autumn months (Fig. 7).

ORTHOPHOSPHATE

The mean concentration of orthophosphate between the surface and the bottom ranged from a maximum of 1.48 mg/l on December 15, 1971 to 0.04 mg/l

on July 19, 1972. Semimonthly distributions of orthophosphate are presented in Tables IV and V. Hutchinson (1967) reported that spring algal blooms in natural bodies of water deplete the phosphates. The diatoms peaked in Lake Fort Smith on April 24, 1972, and this bloom coincided with a decrease in orthophosphate from the previous collecting date, April 7, 1972 (Tables IV and VII).

METAPHOSPHATE

Phosphorus, an essential element to the growth of organisms, can often be the nutrient that limits the growth that a body of water can support. Most relatively uncontaminated lake districts are known to have surface waters that contain 10 to 30 mg/l of total phosphorus; however, in some waters that are not obviously polluted, higher values may occur (Gales et al. 1966). Between the surface and the bottom of Lake Fort Smith, the metaphosphate per meter ranged from 0.02 mg/l on December 28, 1971 to 0.65 mg/l on April 7, 1972 (Table V). Chu (1943) reported that Tabellaria spp. are less tolerant of excess phosphate than other genera of diatoms. However, the phosphates in Lake Fort Smith may not have attained concentrations to inhibit T. flocculosa growth.

SILICA

The major source of silica in natural waters is from the decomposition of aluminosilicate minerals in the drainage basin from which the waters flow. Many natural waters contain less than 10 mg/l, but the amounts may range up to 60 mg/l or higher (Hutchinson, 1957). During the present investigation, the mean range for samples from the surface to the profundal zone was 1.35 mg/l to 2.69 mg/l (Table V). Deevey (1957) reported that the silica

content of surface waters in Texas and Mexico ranged from 4 to 50 mg/l, with a mean of 20.9 mg/l. Kilham (1971) hypothesized that declining ambient silica concentrations may influence the sequence of seasonal succession of diatoms, but he emphasized that a great deal more study is needed.

SPECIFIC CONDUCTANCE

Specific conductance is a simple determination of a water's capacity to convey an electric current and is an excellent measurement of the total dissolved solids in a solution. Data from Lake Fort Smith revealed mean specific conductance values ranging between 32.5 and 57.0 micromhos/cm. These relatively low values strongly suggest that Lake Fort Smith is oligotrophic. Some of the ions that influence conductance are: sodium, potassium, magnesium, calcium, carbonate, sulfate radical, and chlorine (Rodhe, 1949). Specific conductance was not monitored throughout this study; however, available data are summarized in Tables II and III.

Biological Parameters

PHYTOPLANKTON

General

The productivity in any body of water is limited by many factors, e.g., light penetration, dissolved nutrients, pH, and temperature. In most lakes primary productivity is largely confined to the upper strata of water (euphotic zone), although it is not limited to that area. Because of the abundance of some of the common phytoplankters appearing in the lower strata of Lake Fort Smith (e.g., Table VII) and the tendency of zooplankters to migrate, remarks regarding plankton communities and seasonal appearances on each

collection date will refer to the average standing crop per meter between the surface and the 15-m level. In the text, references to average annual standing crop per meter will consist of averages per trip for the surface to 15 m unless otherwise stated. Twenty-four semimonthly collecting trips were made.

Major algal community relationships that developed throughout this investigation are shown in Fig. 8. The Cyanophyta were dominant at the beginning of the winter sampling period, with Aphanizomenon flos - aquae contributing most to this association. In the spring Melosira spp., Tabellaria flocculosa, and Fragilaria crotonensis dominated the relatively large diatom communities. The two Melosira representatives were Melosira ambigua and Melosira distans var. alpigena. By July 5, 1972 the spring diatom dominated community was present in relatively small standing crops and was replaced by a Chrysophyceae community. The Chrysophyceae were primarily represented by Dinobryon cylindricum. A Chrysophyceae-chlorophyta association was found on August 18, 1972 that developed into a Chlorophyte dominated community by September 14, which continued through November 8, 1972. Sphaerocystis schroeteri was the most common chlorophyte during this time, comprising 94.7% of the green algae on September 14, 1972. Coelosphaerium naegelianum, a cyanophyte, was present from September through November.

Chrysophyceae

D. cylindricum was the dominant species of the Chrysophyceae, representing 85.5% of the cells/l (c/l) between the surface and meter 15. Dinobryon bavaricum and Mallomonas sp. were relatively insignificant, comprising 6% and 8.5%, respectively. D. bavaricum did not appear until August 2, 1972 and occurred sporadically into November. Although not abundant, D. bavaricum was more numerous than D. cylindricum on two occasions, September 14 and 27,

1972 (Table VI). Mallomonas sp. frequently appeared throughout the sampling period.

Rodhe (1948) reported that Dinobryan divergens has a low phosphorus requirement and that it does not appear until the phosphate phosphorus has been reduced by the major spring species. Although no significant mathematical correlations were found between phosphates and D. cylindricum, all correlation coefficients (Carter, 1974) were negative, a result which suggests that decreasing phosphate concentrations intensify D. cylindricum growth. Average semimonthly standing crops of D. cylindricum are illustrated in Fig. 9.

Bacillariophyceae

According to Hutchinson (1967) diatoms are the most important members of the fresh-water phytoplankton. In Lake Fort Smith, diatoms were represented by six major genera. Melosira was the most common genus and was present in relatively large numbers throughout the year. Major diatom blooms occurred in the spring, with their peak densities in April (Fig. 8). Melosira spp. pulsed on April 7, 1972 with an average standing crop of 10,612 c/l and erratically declined until the middle of August (Table VII). Tabellaria flocculosa pulsed in April and May, whereas the Asterionella formosa population climaxed in late April and May (Figs. 10 and 11, respectively). T. flocculosa, present throughout most of this investigation, pulsed at an average standing crop of 3,252 c/l on April 7, 1972. In a study of environmental requirements of freshwater phytoplankton, Rodhe (1948) stated that Melosira islandica var. helvetica had an upper optimum temperature limit of 5 C, and may be followed in the spring by A. formosa, whose upper optimum thermal limit is about 15 C. During this investigation, Melosira spp. and T. flocculosa maximum blooms were found when the water temperature average was 12.5 C in the upper 10 m. When the water temperature in the upper 10 m averaged 14.4 C on April 24, 1972,

the Melosira spp. dominance was succeeded by Fragilaria crotonensis (Table VII). The shorter pulse duration of F. crotonensis, compared to the other major diatoms, is probably a reflection of a narrower range of tolerance to its environment. A. formosa bloomed at water temperatures between 12 and 16 C and was not found in significant numbers when the average temperature in the upper 10 m exceeded 16 C. Patrick (1971) reported that diatoms have a fairly narrow range of tolerance to light and temperature. However, Lund (1949) and Chandler (1944) have shown that the spring diatom increases are more closely correlated with illumination than with increased temperature. Carter (1974) found no significant correlations between diatoms and illumination (length of day); however, Synedra spp. and Melosira spp. were significantly correlated with temperature. One may infer from this that temperature has a greater effect upon these members of the diatom community in Lake Fort Smith than length of day.

In the discussion of silica, it was reported that many authors believe silica may be a limiting factor upon the productivity of diatoms. Lund (1954) found Asterionella and Tabellaria to be limited out in nature by concentrations of 0.5 mg/l SiO₂. In view of the silica concentrations found during this study, silica was probably not a limiting factor upon the diatom community in Lake Fort Smith.

On two collecting dates, April 7 and 24, 1972, Melosira spp. c/l were considerably more numerous in the 11 to 15-m strata than in the shallower ones (Table VII). Lund (1954) noted increased numbers of M. italica subarctica in deeper water and attributed this phenomenon to its "relatively high sinking-rate and inability to grow appreciably at high light intensities and perhaps higher temperatures."

Seasonal and vertical abundances of selected diatoms are presented in Table VII.

Chlorophyta

Fourteen Chlorophyta (green algae) genera were identified. Sphaerocystis schroeteri accounted for 77.3% of the total number of chlorophytes. Second in abundance was the species Dictyosphaerium pulchellum (8.4%), followed by Kirchneriella obesa (6.6%). The monocyclic seasonal cycle of S. schroeteri climaxed on September 14, 1972, with an average standing crop of 4,814 c/1 per meter between the surface and meter 15 (Fig. 12). Pediastrum simplex, D. pulchellum, K. obesa, and Staurastrum spp. exhibited monocycles culminating in the late fall. Eudorina elegans, Microspora sp., and Mougeotia sp. were also monocyclic, but their blooms occurred in the spring.

The role of the phylum Chlorophyta in seasonal succession is described in Fig. 8. During this investigation green algae were dominant from September 14 through November 8, 1972. Chlorophytes accounted for 20% of the total algae and were outnumbered only by the Bacillariophyceae. Certain algae may occasionally be an important "grazing" source for herbivorous zooplankters. It may be inferred from Figs. 8 and 12 that the major food source for the pulse of zooplankton "grazers" may have been some green algae, particularly S. schroeteri.

Seasonal and vertical abundances of the Chlorophyta during this investigation are presented in Table VIII.

Cyanophyta

Cyanophyta or blue-green algae were tabulated according to the number of filaments or colonies per liter. This taxon comprised only 4% of the total algae. The two species Coelosphaerium naegelianum and Aphanizomenon flos-aquae comprised 98.1% of the Cyanophyta (Table IX). A. flos-aquae was present in significant numbers only on six collecting dates. C. naegelianum first became evident on September 14, 1972, and remained as the most common

cyanophyte through November. The maximum mean number of C. naegelianum per meter between the surface and meter 15 was 77 colonies/l on November 8, 1972.

Pyrrhophyta

Pyrrhophyta, also known as dinoflagellates, were composed of only two species, Peridinium wisconsinense (73.7%) and Ceratium hirundinella (26.3%). Both species pulsed on September 14, 1972 between the surface and meter 15; P. wisconsinense peaked with 36 c/l and C. hirundinella with 135 c/l.

Table VI summarizes the seasonal and vertical distribution of the Pyrrhophyta for each sampling date.

ZOOPLANKTON

General

The tables concerned with the zooplankton data give semimonthly averages for the depths from surface to 5, 6 - 10, 11 - 15, and surface to 15 m (Tables X, XI, and XII). Unless otherwise stated in the text, the average standing crop per meter for an individual collecting date is taken from the surface to the 15-m level, and the annual standing crop for this level consists of averages per collecting trip (24 trips).

The zooplankton annual standing crop was 111 organisms/l (o/l) of which Rotatoria comprised 24%, Cladocera 4%, Copepoda 12%, and Protozoa 60%. An unidentified member of the Peritricha was the most common zooplankter, and Codonella cratera was the second most abundant. The Rotatoria and Copepoda displayed dicyclic seasonal distributions, whereas the Cladocera and Protozoa were primarily monocyclic. The number of organisms per collecting trip is presented in Fig. 3.

Rotatoria

In Lake Fort Smith the standing crop per meter of the rotifer community ranged from 3 o/l on March 15 to 81 o/l on September 14, 1972. The annual standing crop of rotifers per meter was 28 o/l.

Pennak (1953) reported that most plankton communities average between 40 and 500 rotifers per liter; but the waters of mountain lakes and large oligotrophic lakes sometimes contain less than 20 rotifers per liter, especially during the cold months. A relatively small number of species (16) were identified during this investigation. This is in partial agreement with the findings of Haring and Meyers (1928), who reported that alkaline waters (above a pH of 7.0) contain relatively few species but a large number of organisms. However, with a pH range of 6.93 to 8.40 in the surface to 5-m level, both few species and small numbers were found during the present study.

The Rotatoria pulse on September 14, 1972 (81 o/l) was predominately Polyarthra sp. (43%), Ptygura sp. (23%), and Keratella spp. (18%). Conochilus unicornis (40%), Collotheca sp. (23%) and Polyarthra sp. (21%) were the most common species in the spring pulse (53 o/l) on May 24, 1972 (Table X).

The phylum Rotatoria comprised 24% of the zooplankton standing crop. Polyarthra sp. was the most common rotifer representing 33% (10 o/l) of the annual rotifer standing crop (28 o/l). Keratella spp. was the second most abundant rotifer (6 o/l) followed by Kellicottia bostoniensis, C. unicornis, and Ptygura sp. (2 o/l each). Semimonthly distributions of selected rotifers are presented in Table X.

At the time of the day that the collections were made (i.e., noon - 4:30 p.m.), the largest numbers of rotifers were usually found in the upper 5 m; however, Polyarthra sp. and Keratella spp. were often found to be

numerous between the 6 and 10-m level. K. bostoniensis was found primarily between meters 10 and 15. Polyarthra sp. and Keratella spp. occurred at the deepest strata only during periods of circulation.

Cladocera

Cladocera are of great importance in the aquatic food chain for both young and adult fish. Various studies of the stomach contents of young fish show from 1 to 95 per cent Cladocera by volume (Pennak, 1953).

Cladocera comprised only 4% of the annual zooplankton standing crop. In Lake Fort Smith Ceriodaphnia lacustris exhibited the largest annual standing crop (1.3 o/l) at the surface to 15-m level; however, 41% of the average standing crop of this species was present on one sampling date, September 14, 1972 (Fig. 15). Other annual standing crops of Cladocera at this level were Bosmina longirostris (0.9 o/l), Diaphanosoma leuchtenbergianum (0.7 o/l), Daphnia spp. (0.5 o/l), and Holopedium gibberum (0.2 o/l). Pennak (1953) reported that species of Holopedium are confined to calcium-poor water.

All identified Cladocera species pulsed in September 1972 except H. gibberum, which pulsed on July 5 (Table XII). In studies of other north-western Arkansas reservoirs, Applegate and Mullan (1967) and Damico (1972) found maximum pulses of Cladocera in the spring. The maximum pulse in Lake Fort Smith, however, occurred in September (34 o/l). The absence of a spring pulse in Lake Fort Smith was partially attributed to predation by larval fish, particularly gizzard shad (Dorosoma cepedianum) because their larval populations are larger when compared to other species (Damico, 1972). This food competition among the larval and juvenile fish communities may have eliminated the Cladocera spring pulse in Lake Fort Smith. Recent studies, particularly those of Brooks and Dodson (1965), Cramer and Marzolf

(1970), and Wells (1970) have shown that the effects of planktivorous fish populations result in the elimination of larger zooplankton species and replacement by smaller forms. However, in a food-habit study of the largemouth bass (Micropterus salmoides) and the spotted bass (M. punctatus) in Lake Fort Smith, Olmsted (1974) states that relatively large numbers of cladocerans were found in the stomach contents of these fish species in the fall of 1972.

Copepoda

No attempt was made to identify the species of Copepoda to species during this investigation. The total number of copepods per sampling trip was characterized by a bimodal curve, the September pulse being the larger (Fig. 14). Nauplii were the most numerous forms (75.7%) throughout the sampling period, while calanoid and cyclopoid forms of Copepoda comprised 17.3% and 7%, respectively, of the annual standing crop. The lowest standing crop of Copepoda per liter was recorded on August 31, 1972 (3 o/l) immediately preceding the maximum pulse of 42 o/l on the September 14, 1972 collection date. When the lake was thermally stratified, copepods were generally confined to the upper 10 m (Table XI).

Protozoa

An unidentified Peritricha was the most numerous protozoan (76.2%) during this study. Its dicyclic occurrence showed pulses in the winter and spring months of 1972. Virtually absent in the summer and fall months, this peritrich was not present when the average temperature exceeded 16 C in the upper 10 m.

C. cratera and Diffflugia sp. comprised 19.6% and 4.2%, respectively, of the Protozoa. Semimonthly standing crops of Protozoa are presented in Table XI.

SUMMARY AND CONCLUSIONS

Limnological Phase

The limnological portion of this investigation consisted of the collecting, evaluating and correlating of data relative to the following factors from Lake Fort Smith, Arkansas; net plankton (phytoplankton and zooplankton), nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, orthophosphate, metaphosphate, silica, turbidity, transparency, hydrogen ion concentrations, methyl orange alkalinity, dissolved oxygen, temperatures, and specific conductance.

Temperature data available from Lake Fort Smith for a period of 35 years indicate that it may be classified as a monomictic lake stratifying from April or May through October and circulating for the remaining months. However, during occasional cold winters a thin, temporary ice covering may appear. During the circulation period, the vertical temperature may either be homothermal or have such a slight gradient that a small amount of wind is able to initiate overturn. Chemical analyses taken during thermal stratification showed that nitrate nitrogen, ammonia nitrogen, pH, metaphosphate, and dissolved oxygen revealed vertical stratification. The analyses also showed that the hypolimnion was never completely depleted of dissolved oxygen on any of the collecting trips ($< 0.1 \text{ mg/l O}_2$).

High turbidities were present during the winter and spring months of 1971-1972. Turbidity and transparency were considered important factors affecting phytoplankton and zooplankton production. This relationship was probably an indirect result of rainfall. The first records of specific conductance values ever determined for Lake Fort Smith were considerably lower when compared to those of other lakes now being studied in northwestern Arkansas.

The Cyanophyta, because of the complexity of the colonies, were counted as colonies or filaments per liter, while members of the other phytoplankton phyla were enumerated as cells per liter. Species of Bacillariophyceae were the most abundant algae, contributing 69% of the phytoplankton; in fact, Melosira spp. yielded the largest annual standing crop. A. flos-aquae and D. cylindricum were the most numerous species of the Cyanophyta and Chrysophyceae, respectively. S. schroeteri, which bloomed in the fall, was the most abundant chlorophyte. It may have been a major food source for a relatively large zooplankton pulse that occurred on September 14, 1972.

The blue-green algae, although not numerous enough to be obnoxious to drinking water, were most abundant during the winter months, and diatoms were predominant in the spring. The Chrysophyceae were most numerous on July 5 and 19 and August 18, 1972, and the cyanophytes were again abundant on May 24 and August 2, 1972. Chlorophytes were abundant on April 24 and from August 2 through November 8, 1972.

Zooplankton productivity during 1971-1972 was exceedingly poor. The numbers of zooplankters per collecting trip (24 trips) were as follows: Protozoa, 66 o/l; Rotatoria, 28 o/l; Copepoda, 13 o/l; and Cladocera, 3.6 o/l.

Of considerable concern in recent years has been the question of the impact of man's activities upon the quality of the water that he uses. Water chemistry data from samples collected from Lake Fort Smith were within the guidelines established by the Report of the Committee on Water Quality Criteria (FWPCA, 1968). When compared to the limestone watershed drainage of other Ozark lakes and reservoirs, the shale watershed of Lake Fort Smith makes it unique. Relatively low methyl orange alkalinity (temporary hardness) values indicate an excellent soft-water supply. Lake Fort Smith has shown little effect of eutrophication since impoundment in 1936.

Relative phytoplankton composition and pulse densities, which are often used as indicators of eutrophication, have changed little since 1938 (two years after impoundment). Dense phytoplankton blooms, which often impart obnoxious odors and tastes to water supplies, were absent during this investigation, and no mention of this type of phenomenon has been reported in previous Lake Fort Smith investigations.

Thus, Lake Fort Smith could be characterized as an oligotrophic, relatively non-productive lake, which provides an excellent source of water for public use and, because of its present water quality, should be continued to be utilized for this purpose.

TABLES**Limnological Phase**

DATE	TEMP. (°C)	D. O. (mg/l)	pH	M. O. ALKAL. (mg/l)	Sp. COND. (μ mhos/cm)	TURB. (JTU)
12-15-71	10.0	8.4	7.1	12.3	----	124
12-28-71	10.8	12.5	7.2	12.4	----	120
01-12-72	9.0	12.5	7.2	13.0	----	109
01-26-72	6.5	11.7	7.2	10.7	----	102
02-14-72	5.2	10.4	7.2	10.6	----	94
03-01-72	8.5	11.0	7.0	11.5	----	88
03-15-72	11.3	10.3	7.0	----	----	67
04-07-72	14.4	10.4	7.0	----	----	63
04-24-72	18.5	9.2	7.2	10.3	----	60
05-09-72	18.2	9.4	7.0	10.7	----	74
05-24-72	24.9	8.7	7.2	11.9	----	66
06-07-72	26.2	8.3	8.1	10.4	----	56
06-21-72	28.5	7.9	7.6	14.1	----	47
07-05-72	25.1	8.6	7.8	22.4	----	61
07-19-72	29.5	7.8	7.7	21.8	----	39
08-02-72	29.0	8.4	8.1	17.7	----	45
08-18-72	27.6	8.2	8.4	35.8	35.5	40
08-31-72	26.6	7.8	8.8	18.1	32.5	17
09-14-72	27.5	8.0	7.6	17.3	57.0	21
09-27-72	24.9	8.5	7.9	20.6	50.0	17
10-11-72	20.9	8.4	7.4	21.6	50.0	41
10-25-72	17.1	8.6	---	20.2	50.0	27
11-08-72	14.1	9.6	7.4	18.8	47.0	18
11-27-72	9.1	9.6	---	14.6	47.0	32

TABLE II. Temperature, dissolved oxygen, and pH data for meter one. Methyl orange alkalinity, specific conductance, and turbidity between the surface and the bottom.

	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7	Apr 24
TEMPERATURE (°C)	S-5	9.91	10.54	8.91	6.45	4.71	7.51	9.45	12.30	14.56
	6-10	9.90	10.50	8.90	6.40	4.60	7.20	9.20	12.70	14.20
	11-15	9.90	10.45	8.90	6.40	4.38	7.06	8.43	9.98	8.66
	S-15	9.90	10.50	8.90	6.42	4.56	7.26	9.03	11.66	12.47
DISSOLVED OXYGEN (mg/l)	S-5	8.05	10.03	11.25	11.20	10.20	9.33	10.60	10.27	9.22
	6-10	8.20	10.00	10.60	11.20	10.20	11.50	10.70	10.20	8.80
	11-15	8.82	9.50	10.60	11.20	10.20	11.48	10.73	9.28	10.70
	S-15	8.36	9.84	10.82	11.20	10.20	10.77	10.68	9.92	9.57
TURBIDITY (JTU)	S-5	119	117	110	102	94	87	69	62	58
	6-10	120	115	111	103	92	88	65	59	56
	11-15	130	128	105	103	95	88	68	67	58
	S-15	123	120	109	103	94	88	67	63	57
HYDROGEN ION (pH)	S-5	7.15	7.16	7.23	7.13	7.05	7.05	7.05	7.05	7.23
	6-10	7.20	7.00	7.30	7.40	7.00	7.10	7.20	7.20	7.20
	11-15	7.20	7.10	7.30	7.30	7.10	7.10	7.20	7.20	6.80
	S-15	7.18	7.09	7.28	7.28	7.05	7.08	7.15	7.15	7.08
METHYL ORANGE ALKALINITY (mg/l)	S-5	11	11	12	9	12	12	-----	-----	14
	6-10	13	16	14	12	11	12	-----	-----	16
	11-15	13	16	14	12	11	12	-----	-----	15
	S-15	12	14	13	11	11	12	-----	-----	15
CONDUCTIVITY (micromhos/cm)	S-5	-----	-----	-----	-----	-----	-----	-----	-----	-----
	6-10	-----	-----	-----	-----	-----	-----	-----	-----	-----
	11-15	-----	-----	-----	-----	-----	-----	-----	-----	-----
	S-15	-----	-----	-----	-----	-----	-----	-----	-----	-----
TRANSPARENCY (cm)		20	16	28	38	38	61	76	84	71

TABLE III. Values for selected physico-chemical factors, 1971-1972.

	Depth	May 9	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18
TEMPERATURE (°C)	S-5	14.59	15.91	17.14	25.13	25.00	27.30	27.40	26.70
	6-10	13.70	14.40	14.90	14.80	16.20	18.20	17.80	19.30
	11-15	10.93	10.80	11.08	10.84	14.28	12.22	11.76	11.90
	S-15	13.07	13.70	14.37	16.92	18.49	19.24	18.99	19.30
DISSOLVED OXYGEN (mg/l)	S-5	9.33	9.30	7.82	7.25	8.37	7.90	8.60	8.27
	6-10	8.80	7.40	6.90	5.40	5.70	3.90	3.20	3.90
	11-15	7.60	6.52	6.71	6.71	4.88	2.38	1.80	0.60
	S-15	8.58	7.74	7.14	6.45	6.32	4.73	4.53	4.26
TURBIDITY (JTU)	S-5	80	62	46	30	42	58	20	41
	6-10	60	71	63	59	67	43	16	36
	11-15	75	67	62	63	78	19	17	32
	S-15	72	67	57	51	62	40	18	36
HYDROGEN ION (pH)	S-5	7.03	6.93	7.63	7.30	7.80	7.53	7.98	8.25
	6-10	7.00	6.60	6.80	6.50	6.80	6.50	6.80	7.30
	11-15	6.90	6.40	6.50	6.60	6.60	6.30	6.70	6.90
	S-15	6.98	6.64	6.98	6.80	7.07	6.78	7.16	7.48
METHYL ORANGE ALKALINITY (mg/l)	S-5	12	12	11	14	22	20	20	41
	6-10	12	11	10	15	23	20	16	36
	11-15	11	11	10	15	23	20	17	32
	S-15	12	11	10	15	23	20	18	36
CONDUCTIVITY (micromhos/cm)	S-5	-----	-----	-----	-----	-----	-----	-----	37
	6-10	-----	-----	-----	-----	-----	-----	-----	32
	11-15	-----	-----	-----	-----	-----	-----	-----	36
	S-15	-----	-----	-----	-----	-----	-----	-----	35
TRANSPARENCY (cm)		75	100	139	220	192	237	263	295

TABLE III, Cont'd.

	Depth	Aug 31 1972	Sep 14	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	<u>Annual Data</u> Avg. Per Trip
TEMPERATURE (°C)	S-5	26.40	27.20	24.80	20.70	17.00	13.80	9.10	16.77
	6-10	21.90	21.10	23.20	20.20	16.90	13.00	9.00	14.09
	11-15	13.28	13.92	14.32	14.80	14.56	-----	8.86	10.77
	S-15	20.53	20.74	20.77	18.57	16.15	-----	8.99	13.88
DISSOLVED OXYGEN (mg/l)	S-15	7.97	8.07	7.70	8.23	8.66	8.97	9.60	9.01
	6-10	5.00	4.30	6.00	7.50	9.00	8.40	9.60	7.77
	11-15	0.44	0.20	0.23	1.30	3.90	5.85	9.60	6.30
	S-15	4.47	4.19	4.64	5.68	7.19	7.74	9.60	7.69
TURBIDITY (JTU)	S-5	17	15	18	18	16	9	33	55.2
	6-10	18	15	18	17	17	8	30	56.1
	11-15	20	21	25	28	26	32	32	60.0
	S-15	18	17	20	21	20	16	32	57.1
HYDROGEN ION (pH)	S-5	8.40	7.53	7.85	7.47	-----	7.43	-----	7.42
	6-10	7.30	7.00	7.40	7.00	-----	7.40	-----	7.04
	11-15	6.90	6.50	6.90	6.80	-----	7.40	-----	6.89
	S-15	7.53	7.01	7.38	7.09	-----	7.41	-----	7.12
METHYL ORANGE ALKALINITY (mg/l)	S-5	17	18	18	16	17	17	15	16.0
	6-10	18	15	18	17	17	17	15	16.0
	11-15	20	21	25	28	26	22	14	17.6
	S-15	18	18	20	20	20	19	15	16.6
CONDUCTIVITY (micromhos/cm)	S-5	31	47	45	43	46	44	44	42.1
	6-10	32	47	44	40	43	43	41	40.3
	11-15	34	60	58	61	59	51	42	50.1
	S-15	32	51	49	48	49	46	42	44.2
TRANSPARENCY (cm)		340	570	340	280	200	175	220	169.5

TABLE III. Cont'd.

	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7
NITRITE NITROGEN (mg/1)	S-5	.006	.004	.003	.004	.004	.006	.005	.006
	6-10	.009	.001	.001	.005	.004	.001	.005	.006
	11-15	.009	.000	.002	.007	.003	.001	.005	.007
	S-15	.008	.002	.002	.005	.004	.003	.005	.006
NITRATE NITROGEN (mg/1)	S-5	.13	.23	.13	.23	.15	.19	.74	.19
	6-10	.11	.24	.12	.25	.14	.20	.73	.19
	11-15	.11	.24	.13	.21	.13	.21	.73	.20
	S-15	.12	.24	.13	.23	.14	.20	.73	.19
AMMONIA NITROGEN (mg/1)	S-5	1.40	1.30	1.20	1.47	1.40	1.61	.93	1.00
	6-10	.97	1.34	.91	1.11	1.28	1.61	.94	1.10
	11-15	.86	1.34	.94	1.08	1.33	1.60	.96	1.26
	S-15	1.08	1.33	1.02	1.22	1.34	1.61	.94	1.12
O-PHOSPHATE (mg/1)	S-5	----	.25	.10	.12	.07	.05	.02	.76
	6-10	----	.10	.04	.06	.08	.05	.07	.13
	11-15	----	.09	.15	.06	.08	.07	.09	.05
	S-15	----	.13	.10	.08	.08	.06	.06	.31
M-PHOSPHATE (mg/1)	S-5	----	----	.31	.40	.08	.17	.17	1.41
	6-10	----	----	.22	.42	.05	.16	.16	.14
	11-15	----	----	.37	.51	.04	.11	.41	.15
	S-15	----	----	.30	.44	.06	.15	.25	.57
SILICA (mg/1)	S-5	----	----	2.84	2.23	2.59	2.87	2.46	----
	6-10	----	----	2.44	2.46	2.54	2.58	2.50	----
	11-15	----	----	2.42	2.59	2.82	2.56	2.57	----
	S-15	----	----	2.57	2.43	2.65	2.67	2.51	----

TABLE IV. Semimonthly means of nitrite nitrogen, nitrate nitrogen, ammonia nitrogen, orthophosphate and metaphosphate in Lake Fort Smith from December 15, 1971 through November 27, 1972.

	Depth	Apr 24 1972	May 9	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18
NITRITE NITROGEN (mg/1)	S-5	.017	.006	.005	.005	.005	.007	.004	.004	.007
	6-10	.017	.005	.003	.008	.008	.012	.006	.005	.009
	11-15	.018	.009	.002	.005	.006	.016	.009	.002	.018
	S-15	.017	.007	.003	.006	.006	.011	.006	.004	.011
NITRATE NITROGEN (mg/1)	S-5	.13	.15	.19	.17	.11	.14	.15	.14	.15
	6-10	.15	.13	.18	.16	.19	.15	.14	.14	.14
	11-15	.13	.17	.22	.19	.20	.21	.17	.19	.17
	S-15	.14	.15	.20	.17	.17	.17	.15	.16	.15
AMMONIA NITROGEN (mg/1)	S-5	.95	1.00	1.08	1.38	.93	.91	1.14	----	1.03
	6-10	.97	1.07	.97	1.39	1.04	1.05	1.10	----	.89
	11-15	.96	.93	1.10	1.46	1.13	1.00	1.08	----	.99
	S-15	.96	1.00	1.05	1.41	1.03	.99	1.11	----	.97
O-PHOSPHATE (mg/1)	S-5	.15	.15	.18	.14	.09	.09	.02	.07	.05
	6-10	.06	.10	.04	.11	.04	.04	.04	.06	.12
	11-15	.06	.13	.04	.17	.13	.10	.06	.05	.04
	S-15	.09	.13	.09	.14	.09	.08	.04	.06	.07
M-PHOSPHATE (mg/1)	S-5	.14	.12	.10	.05	.04	.13	.17	.13	.08
	6-10	.08	.08	.24	.15	.24	.12	.15	.15	.05
	11-15	.09	.07	.21	.06	.10	.05	.09	.12	.11
	S-15	.10	.09	.18	.09	.13	.10	.14	.13	.08
SILICA (mg/1)	S-5	----	2.26	----	2.45	----	----	2.17	1.55	1.97
	6-10	----	2.48	----	2.97	----	----	2.07	1.44	1.92
	11-15	----	1.99	----	2.21	----	----	2.46	1.12	2.06
	S-15	----	2.24	----	2.54	----	----	2.23	1.37	1.98

TABLE IV. Cont'd.

	Depth	Aug 31 1972	Sep 14	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	Annual Data
									Avg. Per Trip
NITRITE	S-5	.004	.014	.004	.009	.011	.006	.006	.006
NITROGEN (mg/l)	6-10	.002	.013	.002	.007	.014	.003	.005	.006
	11-15	.005	.019	.005	.012	.019	.005	.005	.008
	S-15	.004	.015	.004	.009	.015	.005	.005	.007
NITRATE	S-5	.10	.26	.14	.12	.17	.15	.12	.18
NITROGEN (mg/l)	6-10	.10	.20	.14	.13	.17	.15	.15	.18
	11-15	.13	.17	.13	.14	.17	.20	.14	.20
	S-15	.11	.21	.14	.13	.17	.17	.14	.19
AMMONIA	S-5	.86	1.70	.78	1.00	1.05	.00	.88	1.09
NITROGEN (mg/l)	6-10	.77	1.50	.95	.80	1.18	.84	1.00	1.08
	11-15	.96	2.18	1.13	1.40	2.24	1.44	.90	1.23
	S-15	.86	1.79	.95	1.07	1.49	.76	.93	1.13
O-PHOSPHATE (mg/l)	S-5	.07	.10	.09	.16	.16	.22	.31	.15
	6-10	.07	.12	.03	.04	.05	.08	.04	.07
	11-15	.07	.10	.03	.06	.08	.06	.08	.08
	S-15	.07	.11	.05	.09	.10	.12	.14	.10
M-PHOSPHATE (mg/l)	S-5	.05	.13	.13	.04	.04	.12	.16	.19
	6-10	.07	.15	.12	.16	.08	.23	.10	.15
	11-15	.09	.17	.17	.09	.06	.14	.11	.15
	S-15	.07	.15	.14	.10	.06	.16	.12	.16
SILICA (mg/l)	S-5	2.12	2.26	1.66	1.73	1.94	1.46	----	2.16
	6-10	1.16	1.97	2.22	1.86	2.31	2.22	----	1.56
	11-15	1.97	2.14	2.41	1.64	2.29	1.90	----	2.17
	S-15	1.75	2.12	2.10	1.74	2.18	1.86	----	2.18

TABLE IV. Cont'd

DATE	NO ₂	NO ₃	NH ₄	O-PO ₄	M-PO ₄	Si
12-15-71	.008	.13	1.10	1.48	----	----
12-28-71	.003	.23	1.32	.14	.02	----
01-12-72	.002	.13	1.05	.08	.32	----
01-26-72	.005	.23	1.24	.08	.45	2.40
02-14-72	.003	.14	1.36	.07	.06	2.69
03-01-72	.003	.20	1.60	.06	.16	2.67
03-15-72	.005	.75	0.94	.13	.14	2.49
04-07-72	.006	.19	1.12	.35	.65	----
04-24-72	.017	.13	0.96	.10	.11	----
05-09-72	.007	.16	0.96	.13	.08	2.19
05-24-72	.004	.19	1.06	.10	.17	----
06-07-72	.006	.17	1.41	.15	.07	2.46
06-21-72	.006	.16	1.03	.09	.11	----
07-05-72	.011	.16	0.97	.09	.04	----
07-19-72	.007	.16	1.11	.04	.13	2.27
08-02-72	.004	.16	-----	.06	.12	1.35
08-18-72	.012	.15	0.99	.06	.09	1.99
08-31-72	.004	.12	0.87	.08	.06	2.08
09-14-72	.016	.21	1.85	.10	.15	2.15
09-27-72	.004	.14	0.95	.05	.15	2.07
10-11-72	.009	.13	1.04	.10	.08	1.72
10-25-72	.015	.17	1.51	.10	.06	2.15
11-08-72	.005	.18	0.74	.13	.13	1.79
11-27-72	.005	.13	0.91	.16	.13	----

TABLE V. Means for nitrite nitrogen, nitrate nitrogen, ammonia nitrogen, orthophosphate, metaphosphate and silica between the surface and the bottom for Lake Fort Smith from December 15, 1971 through November 27, 1972. All values are expressed in mg/l.

CHRYSOPHYCEAE	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar.1	Mar 15	Apr 7	Apr 24
<u>Dinobryon</u>	S-5	27	0	0	0	0	0	0	9	326
<u>cylindricum</u>	6-10	39	0	0	0	0	0	0	0	0
Imhof	11-15	17	0	0	0	0	0	0	0	0
	S-15	28	0	0	0	0	0	0	3	109
<u>Dinobryon</u>	S-5	0	0	0	0	0	0	0	0	0
<u>bavaricum</u>	6-10	0	0	0	0	0	0	0	0	0
Imhof	11-15	0	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0	0	0
<u>Mallomonas</u> sp.	S-5	3	27	10	22	4	1	0	106	4
	6-10	5	7	2	39	0	3	0	125	5
	11-15	1	1	13	30	0	3	0	55	3
	S-15	3	12	8	30	1	2	0	95	4
<u>Chrysophyceae</u>										
Avg. Standing Crop	S-15	31	12	8	30	1	2	0	98	113
<hr/>										
PYRRHOPHYTA										
<u>Ceratium</u>	S-5	0	0	0	0	0	0	0	1	2
<u>hirundinella</u>	6-10	0	0	0	0	0	0	0	1	1
(O.F. Muell.)	11-15	0	0	0	0	0	0	0	0	3
Dujardin	S-15	0	0	0	0	0	0	0	1	2
<u>Peridinium</u>	S-5	0	0	0	0	0	0	0	8	8
<u>wisconsinense</u>	6-10	0	0	0	0	0	0	0	9	9
Eddy	11-15	0	0	0	0	0	0	0	33	3
	S-15	0	0	0	0	0	0	0	17	7
<u>Pyrrhophyta</u>										
Avg. Standing Crop	S-15	0	0	0	0	0	0	0	18	9

TABLE VI. Semimonthly standing crops of Chrysophyceae and Pyrrhophyta. All values expressed in cells per liter.

CHRYSOPHYCEAE	Depth	May 9 1972	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18	Aug 31
<u>Dinobryon</u> <u>cylindricum</u> Imhof	S-5	53	0	29	351	5,602	2,019	32	2,019	32
	6-10	87	86	13	0	0	24	179	1,204	142
	11-15	4	33	44	0	0	0	21	37	13
	S-5	48	40	29	117	1,867	681	77	1,087	62
<u>Dinobryon</u> <u>bavaricum</u> Imhof	S-5	0	0	0	0	0	0	78	6	0
	6-10	0	0	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0	0	3
	S-15	0	0	0	0	0	P	26	2	1
<u>Mallomonas</u> sp.	S-5	3	0	2	4	1	3	7	0	1
	6-10	0	0	0	0	1	7	10	0	88
	11-15	0	0	0	2	0	6	2	0	4
	S-15	1	P	1	2	1	5	6	0	31
Chrysophyceae Avg. Standing Crop	S-15	49	40	29	119	1,868	686	110	1,089	94
<hr/>										
PYRRHOPHYTA										
<u>Ceratium</u> <u>hirundinella</u> (O. F. Muell.) Dujardin	S-5	0	15	19	45	45	28	184	169	28
	6-10	0	0	1	1	10	6	2	8	0
	11-15	0	0	3	1	5	3	0	3	2
	S-15	0	5	8	16	20	12	62	60	20
<u>Peridinium</u> <u>wisconsinense</u> Eddy	S-5	2	20	11	298	597	248	294	145	210
	6-10	0	2	4	16	225	185	83	24	107
	11-15	0	2	7	4	25	47	17	12	29
	S-15	1	8	7	106	252	160	131	60	115
Pyrrhophyta Avg. Standing Crop	S-15	1	13	15	122	302	172	193	120	136

TABLE VI. Cont'd.

CHRYSOPHYCEAE	Depth	Sep 14 1972	Sep 27	Oct 11	Oct 25	Nov . 8	Nov 27	Annual Data	
								Avg. Per Trip	% Total Chrysophyceae
<u>Dinobryon</u>	S-5	29	24	134	106	83	30	468	
<u>cylindricum</u>	6-10	37	0	64	156	28	19	87	
Imhof	11-15	30	0	12	28	57	0	12	
	S-15	32	8	70	97	56	16	184	85.5
<u>Dinobryon</u>	S-5	127	201	118	100	5	0	26	
<u>bavaricum</u>	6-10	49	6	54	73	14	0	8	
Imhof	11-15	67	0	43	13	6	3	6	
	S-15	81	69	72	62	8	1	13	6.0
<u>Mallomonas</u> sp.	S-5	3	107	20	21	98	61	21	
	6-10	137	87	12	18	47	38	26	
	11-15	4	31	2	3	46	14	9	
	S-15	48	75	11	14	64	38	19	8.5
Chrysophyceae									
Avg. Standing Crop	S-15	161	152	153	173	128	55	217	
								Avg. Per Trip	% Total Pyrrhophyta
PYRRHOPHYTA									
<u>Ceratium</u>	S-5	325	231	154	51	35	4	56	
<u>hirundinella</u>	6-10	55	18	4	55	19	2	9	
(O. F. Muell.)	11-15	24	22	15	8	12	1	8	
Dujardin	S-15	135	90	57	38	22	2	23	26.3
<u>Peridinium</u>	S-5	699	533	227	47	7	2	136	
<u>wisconsinense</u>	6-10	299	84	73	31	4	1	48	
Eddy	11-15	86	107	63	3	5	1	19	
	S-15	361	241	121	27	5	1	68	73.7
Pyrrhophyta									
Avg. Standing Crop	S-15	496	332	179	65	27	4	92	

TABLE VI. Cont'd.

BACILLARIOPHYCEAE	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7
<u>Melosira</u> spp.	S-5	1,558	588	836	1,287	422	765	2,293	5,581
	6-10	3,101	1,074	988	1,399	395	873	1,822	6,031
	11-15	1,755	923	814	1,159	419	688	1,256	20,223
	S-15	2,138	862	879	1,282	412	775	1,790	10,612
<u>Tabellaria</u> <u>flocculosa</u> (Roth) Kutz.	S-5	45	0	4	10	0	277	824	3,225
	6-10	51	6	12	22	48	172	737	3,019
	11-15	25	11	6	33	26	98	353	3,513
	S-15	40	6	7	22	25	182	638	3,252
<u>Asterionella</u> <u>formosa</u> Hassal	S-5	0	0	4	0	6	23	8	1,055
	6-10	0	0	0	0	11	10	15	568
	11-15	0	0	0	0	27	23	23	273
	S-15	0	0	1	0	15	19	15	632
<u>Fragilaria</u> <u>crotonensis</u> Kitton	S-5	14	0	0	0	37	15	40	57
	6-10	2	5	29	0	143	7	0	81
	11-15	8	7	0	0	251	35	52	31
	S-15	8	4	10	0	144	19	31	56
<u>Synedra</u> spp.	S-5	4	2	3	39	13	18	18	19
	6-10	9	3	4	35	11	21	22	6
	11-15	4	0	2	34	8	12	10	12
	S-15	6	2	3	36	11	17	17	12
Others *	S-5	0	0	0	0	0	0	6	0
	6-10	0	0	0	0	0	0	35	0
	11-15	0	0	0	0	0	0	10	0
	S-15	0	0	0	0	0	0	17	0
Bacillariophyceae									
Avg. Standing Crop	S-15	2,192	873	901	1,339	606	1,012	2,508	14,565

* Others - Rhizosolenia, Surirella, Navicula, Meridion, Cyclotella, ptelligera.

TABLE VII. Semimonthly standing crops of Bacillariophyceae. All values expressed in cells per liter.

BACILLARIOPHYCEAE	Depth	Apr 24 1972	May 9	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18
<u>Melosira</u> spp.	S-5	403	1,137	245	372	811	177	93	274	192
	6-10	955	771	1,259	419	429	481	174	724	600
	11-15	5,860	1,715	659	748	542	193	341	261	239
	S-15	2,406	1,208	721	513	594	284	203	420	344
<u>Tabellaria</u> <u>flocculosa</u> (Roth) Kutz.	S-5	1,670	2,648	2,612	833	1,423	76	13	0	0
	6-10	1,434	430	581	466	496	138	10	7	0
	11-15	49	444	308	367	273	95	10	0	0
	S-15	1,051	1,174	1,167	555	731	103	11	2	0
<u>Asterionella</u> <u>formosa</u> Hassal	S-5	1,430	4,022	1,102	192	53	4	0	0	0
	6-10	1,033	466	947	121	67	2	0	0	0
	11-15	608	268	631	119	0	0	0	0	0
	S-15	1,024	1,585	893	144	40	2	0	0	0
<u>Fragilaria</u> <u>crotonensis</u> Kitton	S-5	12,701	723	372	110	157	80	62	75	27
	6-10	12,789	988	236	184	85	79	20	19	51
	11-15	41,529	1,163	275	169	109	146	14	13	94
	S-15	22,340	958	294	154	117	102	32	36	57
<u>Synedra</u> spp.	S-5	7	11	2	2	6	1	0	1	0
	6-10	4	4	2	5	1	1	0	1	1
	11-15	5	2	2	5	2	2	0	1	0
	S-15	5	6	2	4	3	1	0	1	P
Others *	S-5	0	0	0	0	0	0	89	24	24
	6-10	1	0	0	0	0	0	25	44	38
	11-15	1	0	0	0	0	0	0	0	2
	S-15	1	0	0	0	0	0	38	23	21
Bacillariophyceae										
Avg. Standing Crop	S-15	26,826	4,931	3,078	1,371	1,485	492	284	481	423

* Others - Rhizosolenia, Surirella, Navicula, Meridion, Cyclotella stelligera.
P - Present

TABLE VII. Cont'd.

BACILLARIOPHYCEAE	Depth	Aug 31	Sep 15	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	Annual Data	
									Avg. Per Trip	% Total Bacillariophyceae
<u>Melosira</u> spp.	S-5	38	156	636	572	212	1,026	1,422	879	43.5
	6-10	100	365	224	505	239	1,484	1,468	1,078	
	11-15	136	121	156	318	135	1,265	1,787	1,738	
	S-15	91	214	339	465	195	1,258	1,559	1,232	
<u>Tabellaria flocculosa</u> (Roth) Kutz.	S-5	0	0	25	8	16	6	13	572	13.3
	6-10	0	0	0	0	0	34	6	320	
	11-15	0	0	4	0	6	33	22	237	
	S-15	0	0	10	3	7	24	14	376	
<u>Asterionella formosa</u> Hassal	S-5	0	0	0	4	0	0	11	330	6.4
	6-10	0	0	0	0	0	3	4	135	
	11-15	0	0	0	0	0	8	0	83	
	S-15	0	0	0	1	0	4	5	182	
<u>Fragilaria crotonensis</u> Kitton	S-5	2	6	32	21	49	163	25	615	36.4
	6-10	12	5	2	20	43	219	17	626	
	11-15	42	0	2	80	108	276	84	1,854	
	S-15	19	4	12	40	67	219	42	1,032	
<u>Synedra</u> spp.	S-5	1	1	3	2	1	3	1	7	0.2
	6-10	1	0	3	2	1	2	1	6	
	11-15	0	0	3	4	2	16	2	5	
	S-15	1	P	3	3	1	7	1	6	
Others *	S-5	2	0	0	0	0	0	0	6	0.2
	6-10	0	0	2	1	0	0	1	6	
	11-15	1	0	0	1	0	0	2	1	
	S-15	1	0	1	1	0	0	1	4	
Bacillariophyceae										
Avg. Standing Crop	S-15	112	218	364	513	271	1,513	1,622	2,832	

* Others - Rhizosolenia, Surirella, Navicula, Meridion, Cyclotella stelligera.
P - Present

TABLE VII. Cont'd.

CHLOROPHYTA	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7
<u>Sphaerocystis</u> <u>schroeteri</u> Chodat	S-5	12	4	16	58	0	4	32	80
	6-10	14	8	0	96	0	2	7	6
	11-15	0	12	4	72	0	7	6	5
	S-15	9	8	7	75	0	4	15	30
<u>Dictyosphaerium</u> <u>pulchellum</u> Wood	S-5	0	0	0	0	0	0	0	0
	6-10	54	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0	0
	S-15	18	0	0	0	0	0	0	0
<u>Pediastrum</u> <u>simplex</u> (Meyen) Lemmermann	S-5	0	0	0	0	0	0	0	0
	6-10	0	0	0	0	60	0	0	24
	11-15	0	0	0	8	16	0	0	0
	S-15	0	0	0	3	25	0	P	8
<u>Kirchneriella</u> <u>obesa</u> (W. West) Schmidle	S-5	0	0	0	0	0	0	0	0
	6-10	0	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0	0
<u>Eudorina</u> <u>elegans</u> Ehrenberg	S-5	0	0	0	0	0	0	0	0
	6-10	0	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0	0
<u>Mougeotia</u> sp.	S-5	9	1	5	3	5	23	55	2
	6-10	19	0	1	1	0	18	96	12
	11-15	14	8	0	0	1	22	77	15
	S-15	14	3	2	1	2	21	76	10
Others*	S-5	6	1	0	38	14	56	81	7
	6-10	0	1	0	0	0	34	48	31
	11-15	0	0	0	0	0	31	92	18
	S-15	2	1	0	13	5	40	74	19
Chlorophyta Avg. Standing Crop	S-15	43	12	9	92	32	66	165	67

* Others: Microspora, Micrasterias, Spondylosum, Closterium, Cosmarium, Ulothrix, Spirogyra, Pleurotaenium
P - Present or less than 0.5

TABLE VIII. Semimonthly standing crops of Chlorophyta. All values expressed in cells per liter.

CHLOROPHYTA	Depth	Apr 24 1972	May 9	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18
<u>Sphaerocystis</u>	S-5	305	144	119	173	214	455	178	557	1,661
<u>schroeteri</u>	6-10	335	14	10	12	50	87	58	192	603
Chodat	11-15	1,617	20	2	0	45	6	0	8	219
	S-15	752	59	44	62	103	183	79	252	828
<u>Dictyosphaerium</u>	S-5	26	58	47	49	26	22	0	240	156
<u>pulchellum</u>	6-10	16	0	5	17	12	37	16	8	167
Wood	11-15	91	59	39	24	104	49	104	66	0
	S-15	44	39	30	30	47	36	40	105	108
<u>Pediastrum</u>	S-5	16	0	0	0	0	0	0	0	0
<u>simolex</u>	6-10	0	0	0	0	0	16	0	0	0
(Meyen)	11-15	0	0	0	0	0	0	16	24	0
Lemmermann	S-15	5	0	0	0	0	5	5	8	0
<u>Kirchneriella</u>	S-5	80	0	16	13	0	0	0	40	0
<u>obesa</u>	6-10	0	0	36	52	0	16	0	80	30
(W. West)	11-15	0	0	20	0	0	0	0	12	0
Schmidle	S-15	27	0	24	22	0	5	0	44	10
<u>Eudorina</u>	S-5	208	24	0	24	92	96	18	10	20
<u>elegans</u>	6-10	238	0	0	0	24	4	70	34	34
Ehrenberg	11-15	701	0	0	4	20	4	32	16	32
	S-15	382	8	0	9	45	35	40	20	29
<u>Mougeotia</u> sp.	S-5	11	2	0	0	2	0	0	0	0
	6-10	14	2	0	0	1	0	0	0	0
	11-15	3	1	0	0	0	0	0	0	0
	S-15	9	2	0	0	1	0	0	0	0
Others*	S-5	5	7	52	7	0	3	0	1	1
	6-10	30	0	46	4	9	0	0	0	1
	11-15	9	6	0	32	0	0	0	0	0
	S-15	15	4	33	14	3	1	0	P	1
Chlorophyta										
Avg. Standing Crop	S-15	1,235	112	131	137	200	265	164	429	975

* Others: Microspora, Micrasterias, Spondylosum, Closterium, Cosmarium, Ulothrix, Spirogyra, Pleurotaenium
P - Present or less than 0.5

TABLE VIII. Cont'd.

CHLOROPHYTA	Depth	Aug 31 1972	Sep 14	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	Annual Data	
									Avg. Per Trip	% Total Chlorophyta
<u>Sphaerocystis</u>	S-5	440	7,205	4,223	5,352	2,360	666	88	1,056	
<u>schroeteri</u>	6-10	296	6,690	1,480	1,929	2,511	504	88	625	
Chodat	11-15	149	548	750	470	652	562	136	220	
	S-15	295	4,814	2,151	2,917	1,841	577	104	634	77.3
<u>Dictyosphaerium</u>	S-5	25	338	484	410	66	17	0	82	
<u>pulchellum</u>	6-10	149	298	835	275	92	56	0	85	
Wood	11-15	68	94	153	22	50	19	0	39	
	S-15	81	243	491	236	69	31	0	69	8.4
<u>Pediastrum</u>	S-5	7	0	172	32	8	86	16	14	
<u>simplex</u>	6-10	14	0	29	136	16	136	0	18	
(Meyen)	11-15	56	22	8	152	50	56	56	19	
Lemmermann	S-15	25	7	70	107	25	93	24	17	2.1
<u>Kirchneriella</u>	S-5	0	0	32	48	284	572	122	50	
<u>obesa</u>	6-10	14	0	80	124	982	302	56	74	
(W. West)	11-15	125	0	16	41	189	450	65	38	
Schmidle	S-15	46	0	43	71	485	441	81	54	6.6
<u>Eudorina</u>	S-5	18	44	0	0	0	0	0	23	
<u>elegans</u>	6-10	8	2	0	0	0	0	0	17	
Ehrenberg	11-15	0	1	0	0	0	8	0	34	
	S-15	9	16	0	0	0	3	0	25	3.0
<u>Mougeotia</u> sp.	S-5	0	0	0	0	0	5	10	6	
	6-10	0	0	0	39	0	13	3	9	
	11-15	0	0	0	12	6	1	7	7	
	S-15	0	0	0	17	2	6	7	7	0.8
Others*	S-5	0	7	3	2	0	21	7	13	
	6-10	0	0	1	76	5	40	107	18	
	11-15	0	0	0	4	2	13	86	12	
	S-15	0	2	1	27	2	25	67	15	1.8
Chlorophyta										
Avg. Standing Crop	S-15	456	5,083	2,755	3,375	2,424	1,176	282	820	

* Others: Microspora, Micrasterias, Spondylosum, Closterium, Cosmarium, Ulothrix, Spirogyra, Pleurotaenium
P - Present or less than 0.5

TABLE VIII. Cont'd.

CYANOPHYTA	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7	Apr 24
<u>Aphanizomenon</u>	S-5	0	0	1,381	3	594	0	0	0	5
<u>flos-aquae</u>	6-10	512	711	296	3	141	0	0	0	9
(L.) Ralfs	11-15	1,917	376	1,047	24	0	0	0	0	40
	S-15	810	362	908	10	245	0	0	0	18
<u>Coelosphaerium</u>	S-5	0	1	0	0	0	0	0	0	2
<u>naegelianum</u>	6-10	0	0	0	0	0	0	0	0	0
Unger	11-15	0	1	0	0	0	0	0	0	0
	S-15	0	1	0	0	0	0	0	0	1
<u>Anabaena</u>	S-5	0	0	0	0	0	0	0	0	30
<u>circinalis</u>	6-10	0	0	0	0	0	0	0	0	13
Rabenhorst	11-15	0	0	0	0	0	0	0	0	68
	S-15	0	0	0	0	0	0	0	0	37
Others*	S-5	1	1	0	0	0	0	0	0	10
	6-10	0	0	0	0	0	0	11	0	10
	11-15	1	0	0	0	0	0	10	0	16
	S-15	1	0	0	0	0	0	7	0	12
Cyanophyta										
Avg. Standing Crop	S-15	810	363	908	10	245	0	7	0	68

* Others: Anacystis sp., Anabaena spp.

P - Present or less than 0.5

TABLE IX. Semimonthly standing crops of Cyanophyta. All values expressed in filaments per liter.

CYANOPHYTA	Depth	May 9 1972	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18	Aug 31
<u>Aphanizomenon</u>	S-5	0	662	208	0	0	0	697	22	0
<u>flos-aquae</u>	6-10	0	378	13	3	0	0	942	9	0
(L.) Ralfs	11-15	0	177	3	0	0	0	90	9	0
	S-15	0	406	75	1	0	0	576	13	0
<u>Coelosphaerium</u>	S-5	0	0	0	1	9	4	0	1	0
<u>naegelianum</u>	6-10	0	0	0	0	1	1	1	5	1
Unger	11-15	0	0	0	2	2	0	0	1	0
	S-15	0	0	0	1	4	2	P	2	P
<u>Anabaena</u>	S-5	2	2	1	0	1	0	0	0	0
<u>circinalis</u>	6-10	1	2	0	0	2	0	0	0	0
Rabenhorst	11-15	1	5	1	0	1	0	0	0	0
	S-15	1	3	1	0	1	0	0	0	0
Others*	S-5	0	0	2	2	0	0	0	0	1
	6-10	1	0	0	0	0	0	0	2	0
	11-15	0	1	0	0	0	0	0	1	2
	S-15	P	P	1	1	0	0	0	1	1
Cyanophyta										
Avg. Standing Crop	S-15	2	409	76	3	5	2	577	17	1

* Others: Anacystis sp., Anabaena spp.

P - Present or less than 0.5

TABLE IX. Cont'd.

CYANOPHYTA	Depth	Sep 14 1972	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	Annual Data	
								Avg. Per Trip	% Total Cyanophyta
<u>Aphanizomenon</u>	S-5	0	0	44	0	0	0	151	
<u>flos-aquae</u>	6-10	0	0	0	0	0	0	126	
(L.) Ralfs	11-15	0	0	0	0	13	0	154	
	S-15	0	0	15	0	4	0	143	91.0
<u>Coelosphaerium</u>	S-5	20	84	62	73	80	17	15	
<u>naegelianum</u>	6-10	16	40	57	82	60	25	12	
Unger	11-15	4	23	79	46	92	22	11	
	S-15	13	49	66	67	77	21	13	7.1
<u>Anabaena</u>	S-5	0	0	0	0	0	0	2	
<u>circinalis</u>	6-10	0	0	0	0	0	0	1	
Rabenhorst	11-15	0	0	0	0	0	0	3	
	S-15	0	0	0	0	0	0	2	1.0
Others*	S-5	0	5	0	0	5	2	1	
	6-10	1	5	0	0	1	1	1	
	11-15	0	1	0	0	18	1	2	
	S-15	P	4	0	0	8	2	2	0.9
Cyanophyta									
Avg. Standing Crop	S-15	14	53	81	67	90	23	160	

* Others: Anacystis sp., Anabaena spp.

P - Present or less than 0.5

TABLE IX. Cont'd.

ROTATORIA	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15
<u>Polyarthra</u> sp.	S-5	36	18	2	6	1	3	2
	6-10	37	9	1	4	0	0	0
	11-15	19	6	2	2	0	1	0
	S-15	31	1	2	4	P	1	1
<u>Keratella</u> spp.	S-5	17	21	9	7	1	1	0
	6-10	14	16	10	6	0	0	1
	11-15	24	14	8	6	1	1	0
	S-15	18	17	9	6	1	1	P
<u>Conochilus</u> <u>unicornis</u> Hlava	S-5	1	0	0	0	0	4	2
	6-10	0	0	0	0	0	2	1
	11-15	0	0	0	0	0	1	0
	S-15	P	0	0	0	0	2	1
<u>Kellicottia</u> <u>bostoniensis</u> Ahlstrom	S-5	3	7	7	2	2	1	2
	6-10	4	7	2	4	1	1	0
	11-15	3	6	4	5	2	1	0
	S-15	3	7	4	4	2	1	1
<u>Ptygura</u> sp.	S-5	0	0	0	0	0	0	0
	6-10	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0
<u>Collotheca</u> sp.	S-5	1	4	0	0	0	0	0
	6-10	2	6	3	0	0	0	0
	11-15	1	3	1	0	0	0	0
	S-15	1	4	1	0	0	0	0
<u>Hexarthra</u> <u>mira</u> Hudson	S-5	1	0	0	0	0	0	0
	6-10	1	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0
	S-15	1	0	0	0	0	0	0
<u>Synchaeta</u> <u>pectinata</u> Ehrenberg	S-5	0	0	0	4	2	3	0
	6-10	0	0	1	3	4	1	0
	11-15	0	1	1	3	0	0	0
	S-15	0	P	1	3	2	1	P
Others*	S-5	2	2	6	10	16	5	1
	6-10	3	1	1	9	6	3	0
	11-15	6	1	3	11	14	2	0
	S-15	4	2	4	13	14	4	P
Rotatoria Avg. Standing Crop	S-15	58	41	20	27	17	10	3

* Others: Synchaeta oblonga Ehrenberg, Gastropus sp., Conochiloides sp., Lecane sp., Monostyla sp., Trichocerca sp., Asplanchna priodonta Ehrenberg

P - Present on sampling date or less than 0.5

TABLE X. Semimonthly standing crops of Rotatoria. All values expressed in organisms per liter.

ROTATORIA	Depth	Apr 7 1972	Apr 24	May 9	May 24	Jun 7	Jun 21	Jul 5
<u>Polyarthra</u> sp.	S-5	11	20	39	28	4	18	7
	6-10	1	1	2	3	1	0	1
	11-15	1	1	1	1	2	0	1
	S-15	4	8	14	11	2	6	3
<u>Keratella</u> spp.	S-5	6	10	6	6	7	22	49
	6-10	1	3	2	1	0	2	10
	11-15	0	9	5	1	2	1	4
	S-15	2	7	4	3	3	8	21
<u>Conochilus unicornis</u> Hlava	S-5	0	0	3	64	0	5	15
	6-10	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0
	S-15	0	P	1	21	0	2	5
<u>Kellicottia bostoniensis</u> Ahlstrom	S-5	3	1	1	1	0	0	0
	6-10	1	2	2	1	0	0	0
	11-15	1	1	1	0	0	0	0
	S-15	2	1	1	1	0	0	0
<u>Ptygura</u> sp.	S-5	0	0	0	0	0	0	1
	6-10	0	0	0	0	0	0	1
	11-15	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	1
<u>Collotheca</u> sp.	S-5	0	2	5	36	0	0	0
	6-10	0	2	0	0	0	0	0
	11-15	0	0	3	0	0	0	0
	S-15	0	1	3	12	0	0	0
<u>Hexarthra mira</u> Hudson	S-5	0	1	0	1	0	42	0
	6-10	0	0	2	2	0	0	0
	11-15	0	0	1	0	2	0	0
	S-15	0	P	1	1	1	14	0
<u>Synchaeta pectinata</u> Ehrenberg	S-5	1	1	2	2	0	0	1
	6-10	1	1	0	1	0	0	0
	11-15	0	0	0	1	0	0	0
	S-15	1	1	1	1	0	0	P
Others*	S-5	0	5	3	10	3	5	5
	6-10	1	0	0	0	0	1	2
	11-15	1	0	0	0	0	2	0
	S-15	1	2	2	5	1	3	3
Rotatoria Avg.								
Standing Crop	S-15	10	21	26	53	7	33	32

* Others: Synchaeta oblonga Ehrenberg, Gastropus sp., Conochiloides sp., Lecane sp., Monostyla sp., Trichocerca sp., Asplanchna priodonta Ehrenberg

P - Present on sampling date or less than 0.5

TABLE X. Cont'd.

ROTATORIA	Depth	Jul 19 1972	Aug 2	Aug 18	Aug 31	Sep 14	Sep 27	Oct 11
<u>Polyarthra</u> sp.	S-5	9	10	19	1	78	25	32
	6-10	11	43	9	2	26	2	3
	11-15	0	2	0	0	1	2	3
	S-15	7	18	9	1	35	1	13
<u>Keratella</u> spp.	S-5	3	7	8	2	31	13	2
	6-10	4	2	3	1	10	2	1
	11-15	1	1	1	1	3	3	1
	S-15	3	3	4	1	15	6	1
<u>Conochilus</u> <u>unicornis</u> Hlava	S-5	4	7	1	0	0	4	20
	6-10	3	1	1	2	0	0	0
	11-15	0	1	0	0	0	0	0
	S-15	2	3	1	1	P	1	7
<u>Kellicottia</u> <u>bostoniensis</u> Ahlstrom	S-5	0	0	1	0	0	0	2
	6-10	0	0	1	1	3	1	0
	11-15	0	0	1	1	0	1	0
	S-15	0	0	1	1	1	1	1
<u>Ptygura</u> sp.	S-5	0	1	41	30	55	5	0
	6-10	0	0	0	0	1	0	0
	11-15	0	0	0	0	1	0	0
	S-15	0	P	14	10	19	2	P
<u>Collotheca</u> sp.	S-5	0	0	0	0	0	0	0
	6-10	0	0	0	0	0	0	0
	11-15	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0
<u>Hexarthra</u> <u>mira</u> Hudson	S-5	8	12	5	1	8	1	0
	6-10	0	3	0	1	0	0	0
	11-15	0	0	0	1	0	0	0
	S-15	3	5	2	1	3	P	P
<u>Synchaeta</u> <u>pectinata</u> Ehrenberg	S-5	0	0	0	0	0	0	0
	6-10	0	0	0	0	0	0	0
	11-15	1	0	0	0	0	0	0
	S-15	P	0	0	0	0	0	0
Others*	S-5	3	2	12	4	23	7	10
	6-10	0	0	1	2	1	5	4
	11-15	0	0	0	1	3	0	1
	S-15	1	1	4	2	9	4	5
Rotatoria Avg. Standing Crop	S-15	16	31	35	17	81	24	26

* Others: Synchaeta oblonga Ehrenberg, Gastropus sp., Conochiloides sp., Lecane sp., Monostyla sp., Trichocerca sp., Asplanchna priodonta Ehrenberg

P - Present on sampling date or less than 0.5

TABLE X. Cont'd.

ROTATORIA	Depth	Oct 25 1972	Nov 8	Nov 27	Annual Data	
					Avg. Per Trip	% Total Rotatoria
<u>Polyarthra</u> sp.	S-5	21	28	9	18	
	6-10	15	5	6	8	
	11-15	1	3	0	2	
	S-15	12	12	5	10	32.9
<u>Keratella</u> spp.	S-5	4	8	1	10	
	6-10	3	1	0	4	
	11-15	1	4	1	4	
	S-15	3	4	1	6	21.3
<u>Conochilus</u> <u>unicornis</u> Hlava	S-5	6	2	1	6	
	6-10	7	1	1	1	
	11-15	1	1	0	P	
	S-15	5	1	1	2	8.1
<u>Kellicottia</u> <u>bostoniensis</u> Ahlstrom	S-5	0	8	7	2	
	6-10	2	8	8	2	
	11-15	1	25	13	3	
	S-15	1	14	9	2	8.1
<u>Ptygura</u> sp.	S-5	0	0	0	6	
	6-10	0	0	0	P	
	11-15	0	0	0	P	
	S-15	0	0	0	2	6.8
<u>Collotheca</u> sp.	S-5	0	0	0	2	
	6-10	0	0	0	1	
	11-15	0	0	0	P	
	S-15	0	0	0	1	3.4
<u>Hexarthra</u> <u>mira</u> Hudson	S-5	0	0	0	3	
	6-10	0	0	0	P	
	11-15	0	0	0	P	
	S-15	0	P	0	1	4.6
<u>Synchaeta</u> <u>pectinata</u> Ehrenberg	S-5	0	0	0	1	
	6-10	0	0	0	1	
	11-15	0	0	0	P	
	S-15	0	0	0	1	1.7
Others*	S-5	10	9	3	7	
	6-10	8	5	4	2	
	11-15	1	2	2	2	
	S-15	6	5	3	4	13.1
Rotatoria Avg.						
Standing Crop	S-15	27	37	19	28	

* Others: Synchaeta oblonga Ehrenberg, Gastropus sp., Conochiloides sp.,
Monostyla sp., Trichocerca sp., Asplanchna priodonta Ehrenberg,
Lecane sp.

P - Present on sampling date or less than 0.5

TABLE X. Cont'd.

COPEPODA	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7
Calanoid	S-5	6	7	3	2	0	0	1	2
	6-10	4	7	2	2	1	0	0	0
	11-15	5	4	6	3	1	0	0	0
	S-15	5	6	4	2	1	P	P	1
Cyclopoid	S-5	1	5	0	0	0	0	1	0
	6-10	0	0	0	0	0	0	0	0
	11-15	1	1	0	0	0	1	1	0
	S-15	1	2	0	0	0	P	1	0
Nauplii	S-5	6	11	8	13	5	6	4	20
	6-10	11	8	11	13	7	7	5	5
	11-15	8	10	6	8	3	3	8	3
	S-15	8	10	8	11	5	5	6	9
Copepoda									
Avg. Standing Crop	S-15	14	18	12	14	6	6	7	10
<hr/>									
PROTOZOA									
<u>Codonella</u> <u>cratera</u> (Leidy)	S-5	2	4	5	6	1	19	22	1
	6-10	1	10	3	7	1	18	4	0
	11-15	0	7	3	7	1	11	2	0
	S-15	1	7	4	7	1	16	9	P
<u>Diffugia</u> sp.	S-5	0	0	0	0	0	0	0	0
	6-10	1	0	0	0	0	0	0	0
	11-15	0	0	0	0	3	0	0	0
	S-15	P	0	0	0	1	0	0	0
Peritricha	S-5	35	180	262	150	20	5	12	272
	6-10	51	202	250	160	16	7	10	51
	11-15	63	194	274	156	19	10	2	51
	S-15	50	192	262	155	18	7	8	125
Protozoa									
Avg. Standing Crop	S-15	51	189	266	162	20	23	17	125

TABLE XI. Semimonthly standing crops of Copepoda and Protozoa. All values expressed in organisms per liter.
P-Present or less than 0.5.

COPEPODA	Depth	Apr 24 1972	May 9	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18
Calanoid	S-5	2	1	3	3	1	1	2	3	2
	6-10	1	0	1	1	2	3	2	3	1
	11-15	0	0	0	0	1	0	0	0	0
	S-15	1	P	1	1	1	1	1	2	1
Cyclopoid	S-5	1	0	4	3	1	0	0	1	1
	6-10	1	0	0	1	5	3	0	1	0
	11-15	0	0	0	0	1	1	1	0	0
	S-15	1	P	1	1	2	1	P	1	P
Nauplii	S-5	14	11	35	31	10	4	7	12	12
	6-10	7	1	7	12	4	6	9	6	3
	11-15	2	1	2	4	3	3	1	1	1
	S-15	8	4	15	16	6	4	6	6	5
Copepoda Avg. Standing Crop	S-15	9	5	17	18	9	7	7	9	7
<hr/>										
PROTOZOA										
<u>Codonella</u> <u>cratera</u> (Leidy)	S-5	10	272	3	23	21	11	2	8	2
	6-10	2	81	1	5	5	12	9	11	1
	11-15	1	20	0	3	4	2	3	3	2
	S-15	4	124	1	10	10	8	5	7	2
<u>Diffflugia</u> sp.	S-5	1	2	27	6	6	4	16	4	6
	6-10	1	0	1	2	2	1	6	0	2
	11-15	1	0	2	1	1	2	7	2	1
	S-15	1	1	10	3	3	2	10	2	3
Peritricha	S-5	68	287	127	26	0	0	0	0	0
	6-10	70	92	30	22	0	0	1	0	0
	11-15	36	26	22	12	2	2	0	0	0
	S-15	58	135	60	20	1	1	P	0	P
Protozoa Avg. Standing Crop	S-15	63	260	71	33	14	11	15	9	5

TABLE XI. Cont'd.

COPEPODA	Depth	Aug 31 1972	Sep 14	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	Annual Data	
									Avg. Per Trip	% Total Copepoda
Calanoid	S-5	1	15	11	9	4	7	2	4	17.3
	6-10	2	6	1	0	6	2	3	2	
	11-15	0	0	0	1	0	1	3	1	
	S-15	1	7	4	3	3	3	3	2	
Cyclopoid	S-5	1	4	3	3	2	1	1	1	7.0
	6-10	0	2	1	2	2	3	1	1	
	11-15	0	1	0	0	1	0	2	P	
	S-15	P	2	1	2	2	1	1	1	
Nauplii	S-5	1	61	31	40	23	22	5	16	75.7
	6-10	2	35	14	18	15	5	6	9	
	11-15	1	1	0	10	6	11	10	4	
	S-15	1	32	15	23	15	13	7	10	
Copepoda Avg. Standing Crop	S-15	3	42	20	28	20	17	11	13	
PROTOZOA									Avg. Per Trip	% Total Protozoa
<u>Codonella</u> <u>cratera</u> (Leidy)	S-5	0	31	24	33	10	53	9	24	19.6
	6-10	1	9	7	16	11	23	7	10	
	11-15	1	6	10	12	1	15	9	5	
	S-15	1	15	14	20	7	30	8	13	
<u>Diffflugia</u> sp.	S-5	4	52	5	2	1	0	0	6	4.2
	6-10	1	7	5	3	1	0	0	1	
	11-15	0	6	4	1	0	0	0	1	
	S-15	2	22	5	2	1	0	0	3	
Peritricha	S-5	0	0	0	0	0	0	116	65	76.2
	6-10	0	0	0	0	0	1	130	46	
	11-15	0	0	0	0	0	0	120	41	
	S-15	0	0	0	P	0	P	122	51	
Protozoa Avg. Standing Crop	S-15	2	37	18	22	8	31	130	66	

TABLE XI. Cont'd.

CLADOCERA	Depth	Dec 15 1971	Dec 28	Jan 12 1972	Jan 26	Feb 14	Mar 1	Mar 15	Apr 7
<u>Bosmina</u>	S-5	0	1	1	2	0	0	1	0
<u>longirostris</u>	6-10	1	1	1	1	1	0	0	0
(O. F. Muller)	11-15	0	0	1	0	3	0	1	1
	S-15	P	1	1	1	1	P	1	1
<u>Diaphanosoma</u>	S-5	0	0	0	0	0	0	0	2
<u>leuchtenbergianum</u>	6-10	0	0	0	0	0	0	0	0
Fisher	11-15	0	0	0	1	0	0	0	0
	S-15	0	0	0	P	0	0	0	1
<u>Ceriodaphnia</u>	S-5	0	0	0	0	0	0	0	0
<u>lacustris</u>	6-10	0	0	0	0	0	0	0	0
Birge	11-15	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0	0
<u>Daphnia</u> spp.	S-5	2	5	0	1	1	0	0	0
	6-10	0	2	1	0	1	0	0	0
	11-15	2	1	1	0	1	0	0	0
	S-15	1	3	1	P	1	0	0	0
<u>Holopedium</u>	S-5	0	0	0	0	0	0	0	0
<u>gibberum</u>	6-10	0	0	0	0	0	0	0	0
Zaddach	11-15	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	0	0	0	0
Cladocera									
Avg. Standing Crop	S-15	2	3	2	2	2	P	1	1

P - Present or less than 0.5

TABLE XII. Semimonthly standing crops of Cladocera. All values expressed in organisms per liter

CLADOCERA	Depth	Apr 24 1972	May 9	May 24	Jun 7	Jun 21	Jul 5	Jul 19	Aug 2	Aug 18
<u>Bosmina</u>	S-5	0	0	0	0	0	0	0	1	2
<u>longirostris</u>	6-10	0	0	0	0	0	0	0	0	0
(O. F. Muller)	11-15	0	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	P	P	0	P	1
<u>Diaphanosoma</u>	S-5	1	1	0	0	1	1	1	2	1
<u>leuchtenbergianum</u>	6-10	0	0	0	0	0	0	1	0	1
Fisher	11-15	0	0	0	0	0	0	0	0	0
	S-15	P	P	0	0	P	P	1	1	1
<u>Ceriodaphnia</u>	S-5	0	0	0	0	1	0	1	4	4
<u>lacustris</u>	6-10	0	0	0	0	1	0	0	0	1
Birge	11-15	0	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	1	0	P	1	2
<u>Daphnia</u> spp.	S-5	0	1	3	1	1	1	0	1	0
	6-10	0	0	1	0	0	0	0	0	0
	11-15	0	0	1	0	0	0	0	0	0
	S-15	P	P	2	P	P	P	0	P	P
<u>Holopedium</u>	S-5	0	0	0	0	0	9	0	0	0
<u>gibberum</u>	6-10	0	0	0	0	0	0	0	0	0
Zaddach	11-15	0	0	0	0	0	0	0	0	0
	S-15	0	0	0	0	P	3	0	0	0
Cladocera										
Avg. Standing Crop	S-15	P	1	2	P	1	4	1	3	3

P - Present or less than 0.5

TABLE XII.. Cont'd.

CLADOCERA	Depth	Aug 31 1972	Sep 14	Sep 27	Oct 11	Oct 25	Nov 8	Nov 27	Annual Data	
									Avg. Per Trip	% Total Cladocera
<u>Bosmina</u> <u>longirostris</u> (O. F. Muller)	S-5	0	29	8	1	1	0	0	2	
	6-10	0	0	2	0	1	0	0	P	
	11-15	0	1	1	0	0	1	0	P	
	S-15	P	10	4	P	1	P	0	0.9	23.6
<u>Diaphanosoma</u> <u>leuchtenbergianum</u> Fisher	S-5	1	20	4	1	1	0	0	2	
	6-10	1	6	1	1	0	1	0	1	
	11-15	0	0	0	0	1	0	0	P	
	S-15	1	9	2	1	1	P	0	0.7	18.8
<u>Ceriodaphnia</u> <u>lacustris</u> Birge	S-5	1	31	12	7	10	4	1	3	
	6-10	0	9	5	2	3	1	0	1	
	11-15	0	0	0	0	0	1	0	P	
	S-15	P	13	6	3	4	2	P	1.3	35.6
<u>Daphnia</u> spp.	S-5	0	2	3	0	0	1	1	1	
	6-10	0	1	0	0	0	1	0	P	
	11-15	0	0	0	0	1	1	5	1	
	S-15	P	1	1	P	P	1	2	0.5	16.2
<u>Holopedium</u> <u>gibberum</u> Zaddach	S-5	0	3	0	0	0	1	0	1	
	6-10	0	0	0	0	0	0	0	0	
	11-15	0	0	0	0	0	0	0	0	
	S-15	0	1	0	P	0	P	0	0.2	0.8
Cladocera Avg. Standing Crop	S-15	1	34	12	4	6	4	2	3.6	

P - Present or less than 0.5

TABLE XII. Cont'd.

FIGURES

Limnological Phase

Figure 2: Semimonthly temperature ranges at the 1-m level.

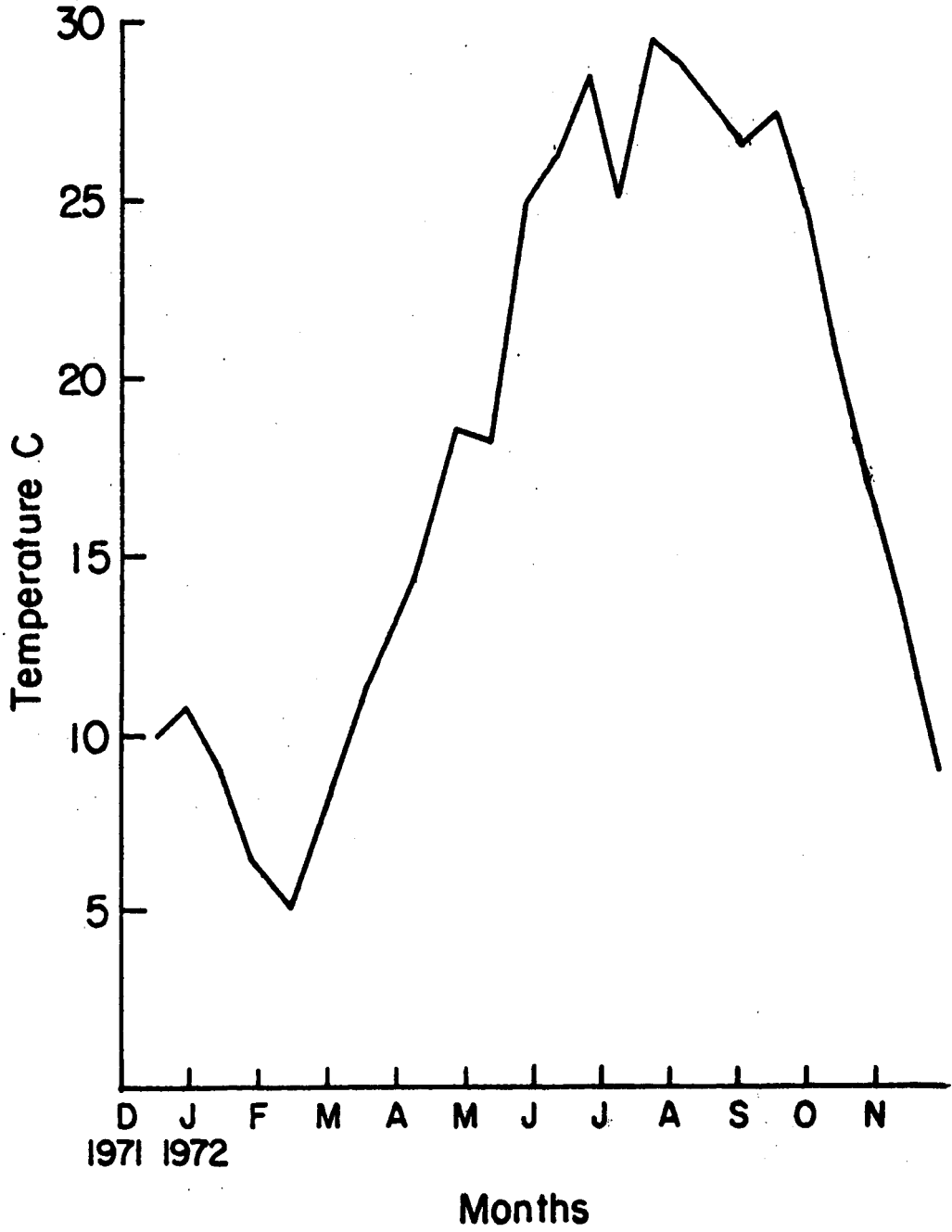


Figure 3: Semimonthly dissolved oxygen concentrations at selected depth intervals.

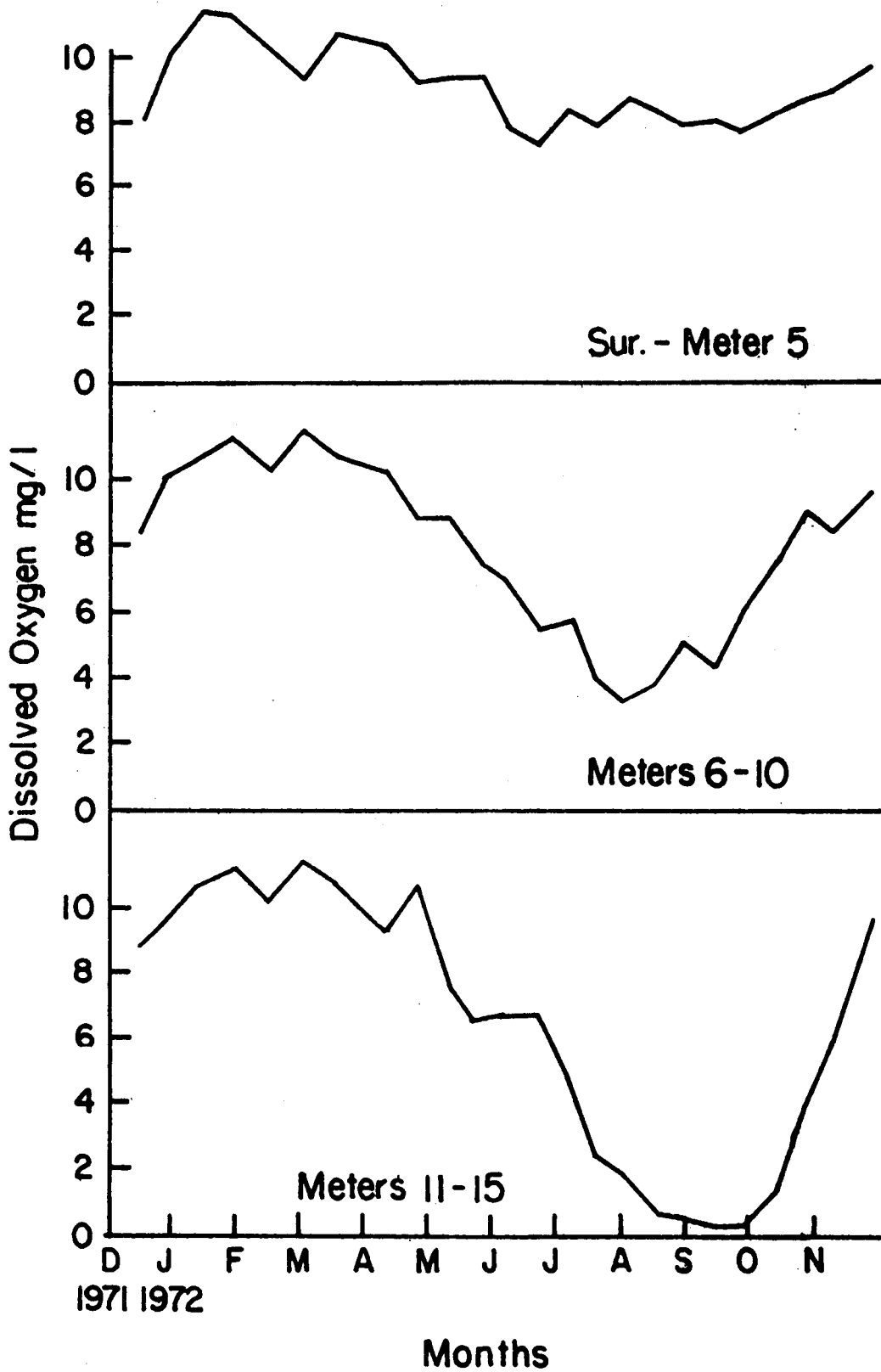


Figure 4: Average semimonthly distributions of methyl orange alkalinity between the surface and the bottom.

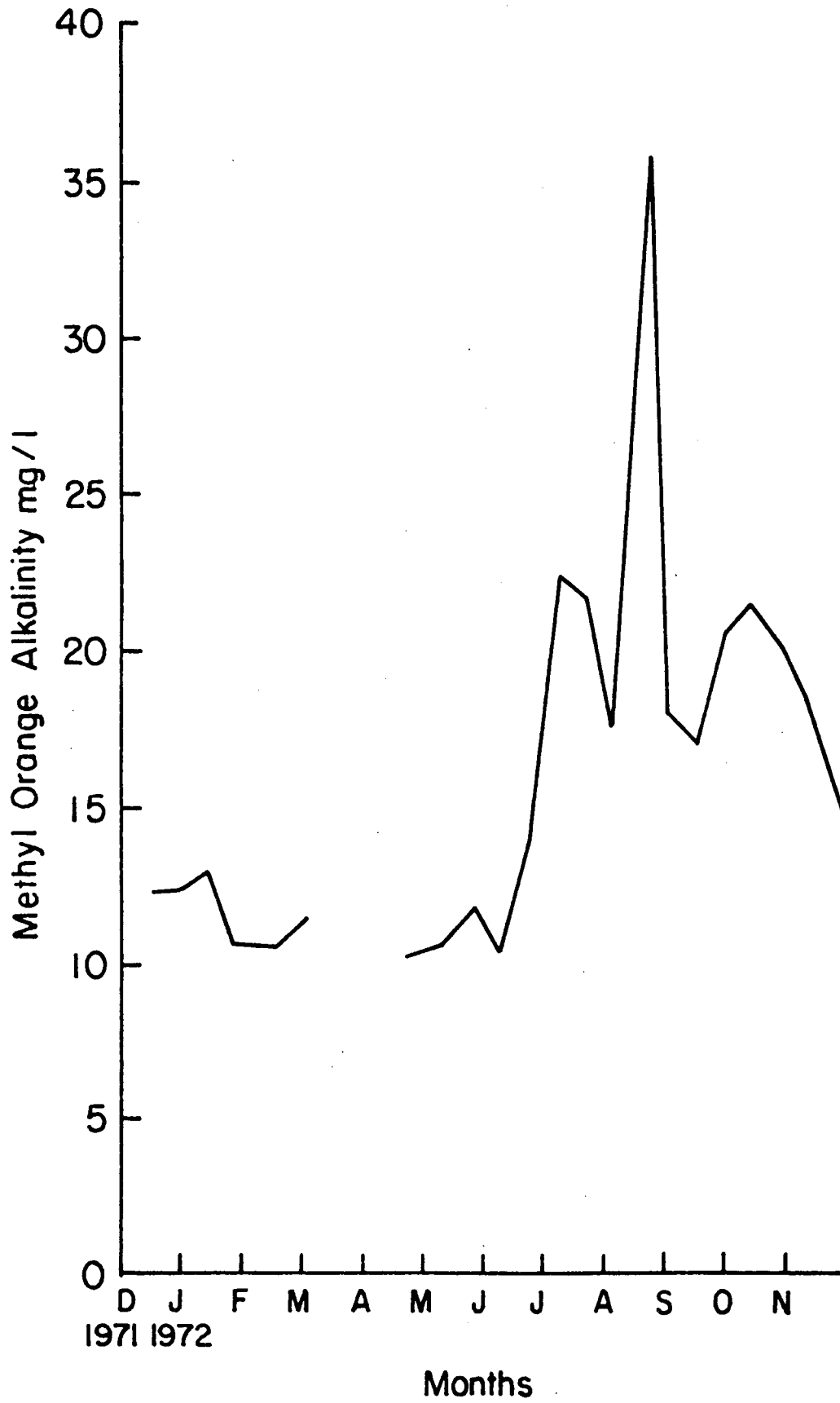


Figure 5: Average semimonthly turbidity values in JTU between the surface and the bottom.

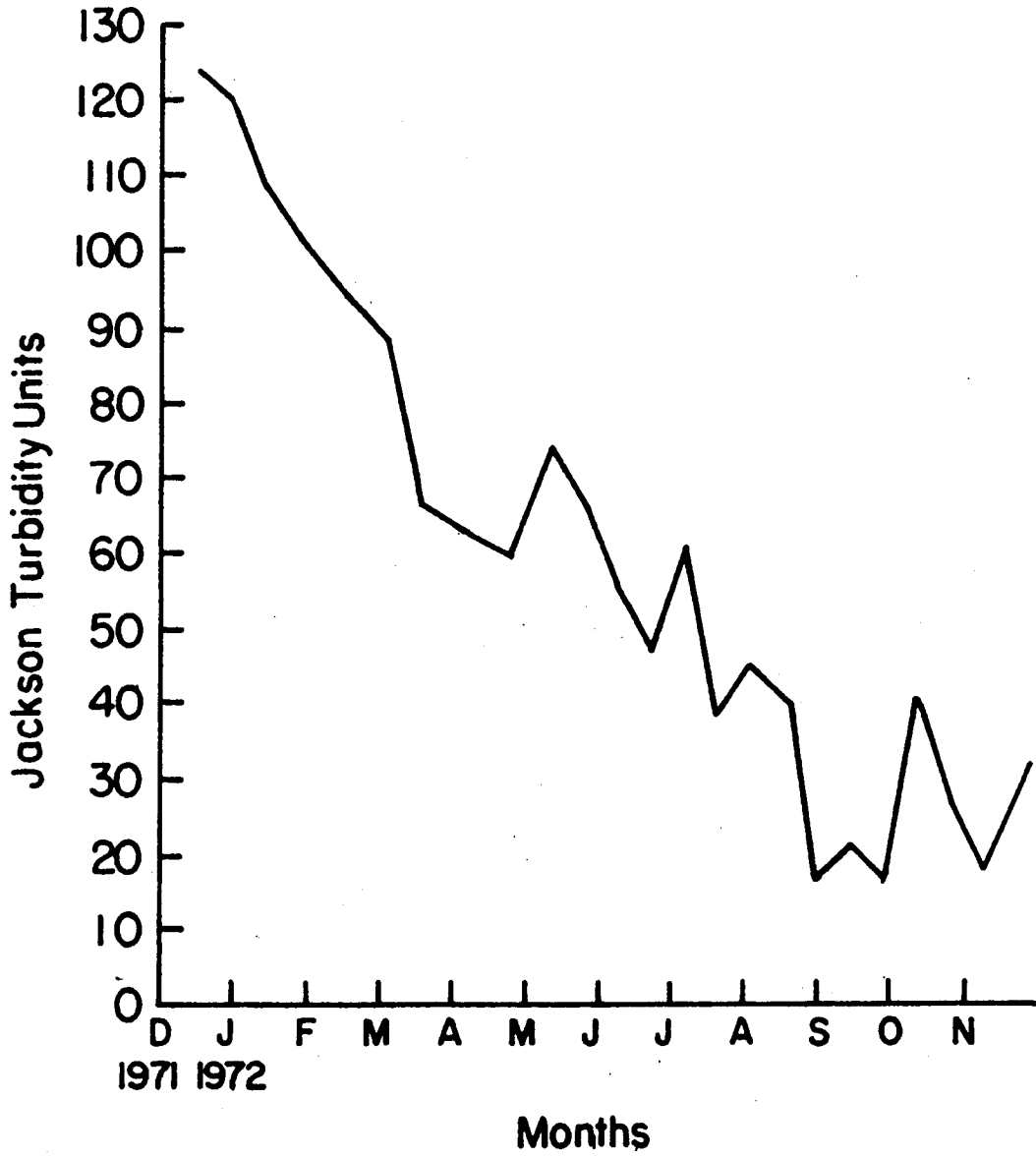


Figure 6: Semimonthly transparency readings in cm for 1971-1972.

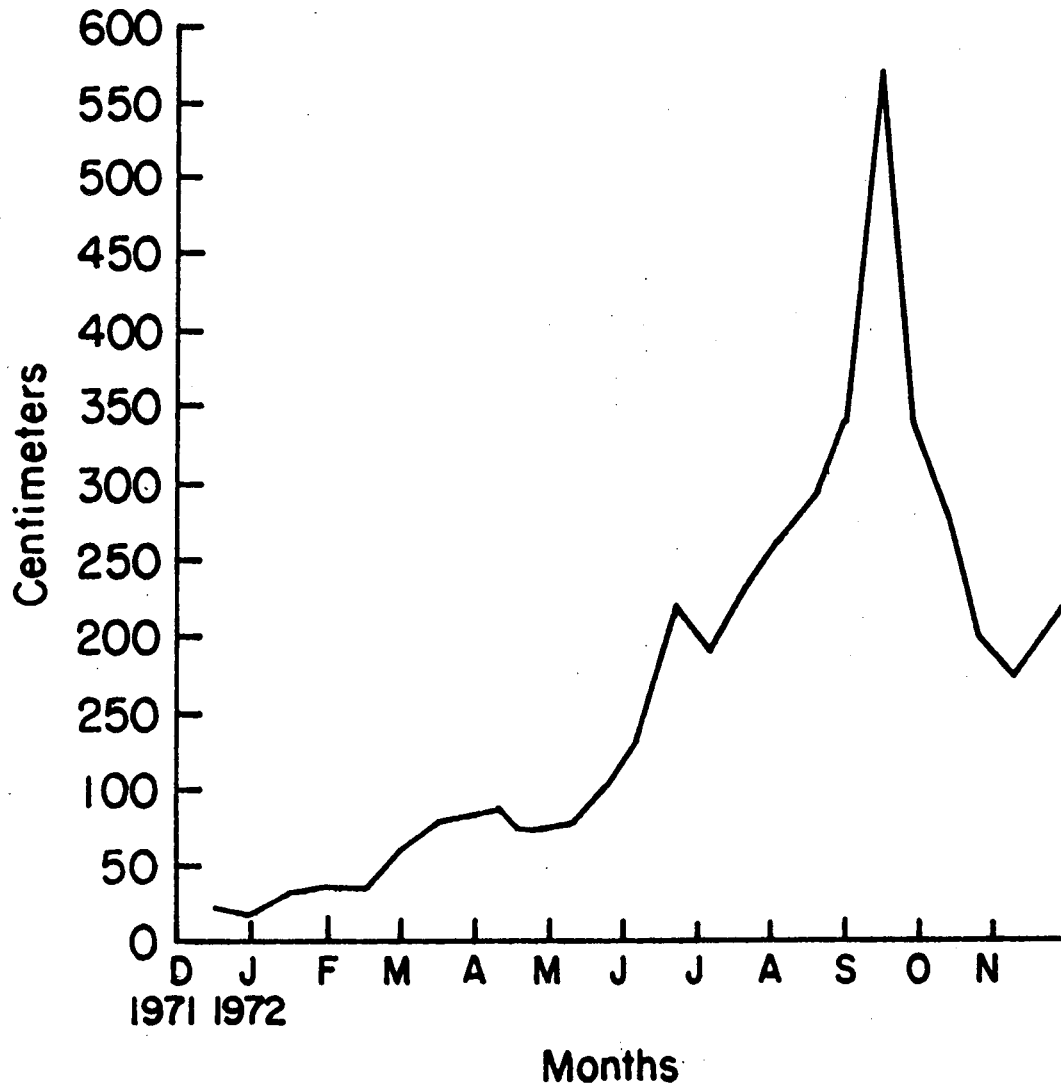


Figure 7: Seasonal vertical profiles of ammonia nitrogen between the surface and the bottom.

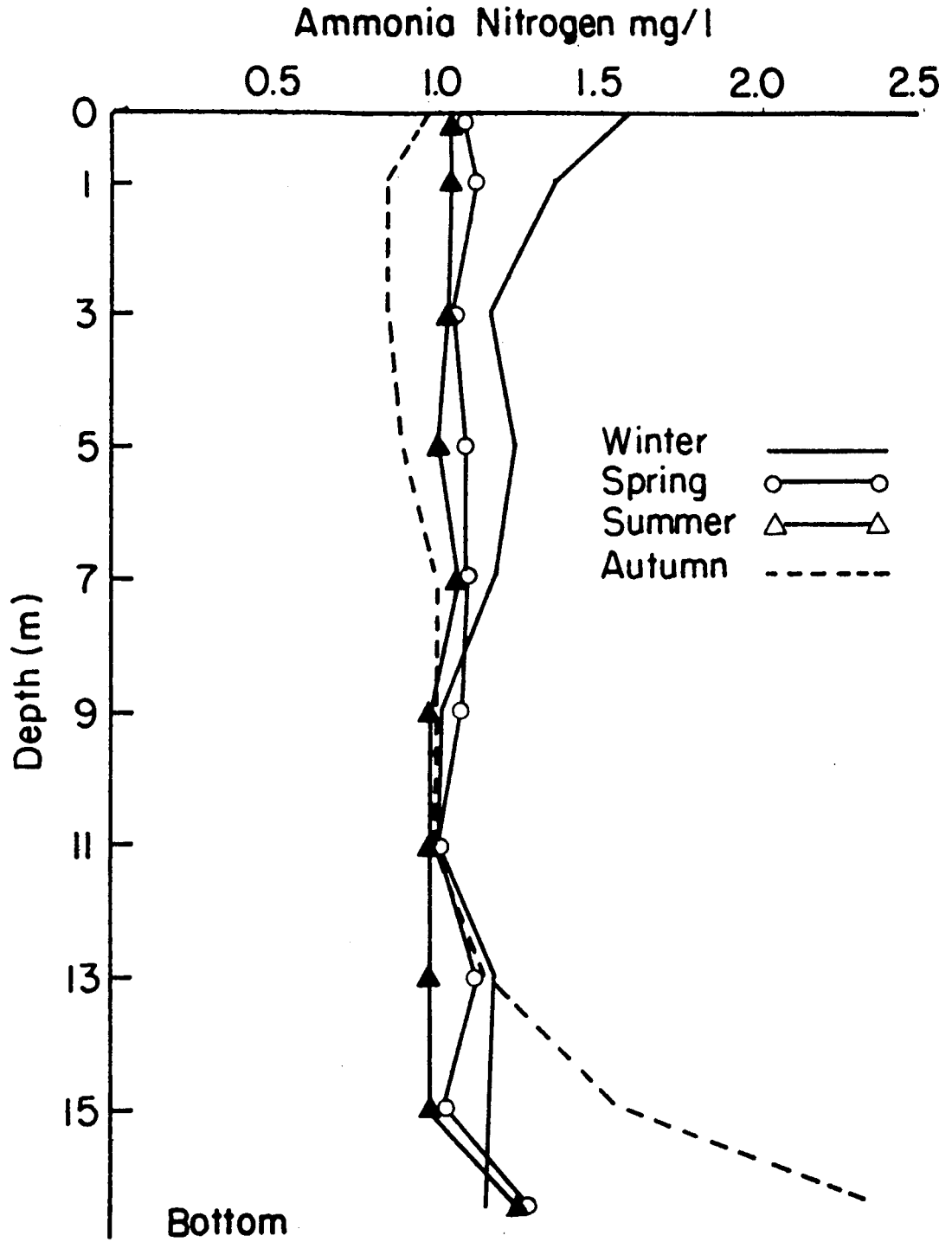


Figure 8: Seasonal semimonthly distributions of Cyanophyta, Chlorophyta, Bacillariophyceae, and Chrysophyceae between the surface and the 15-m level.

Cyanophyta with less than 50 colonies/l and Bacillariophyceae, Chlorophyta, and Chrysophyceae with less than 500 cells/l are omitted.

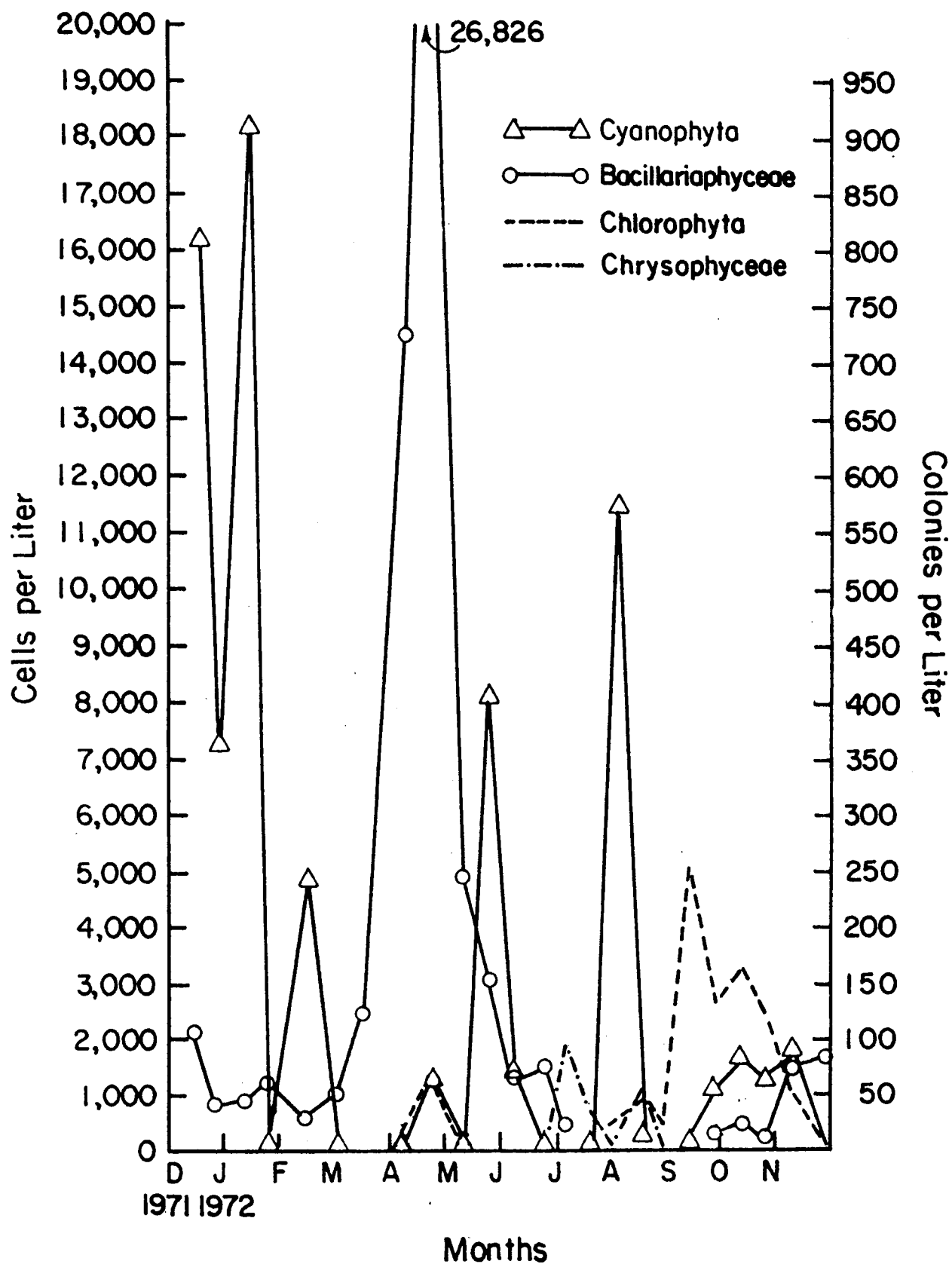


Figure 9: Semimonthly standing crops of the chrysophyte Dinobryon cylindricum between the surface and meter 15.

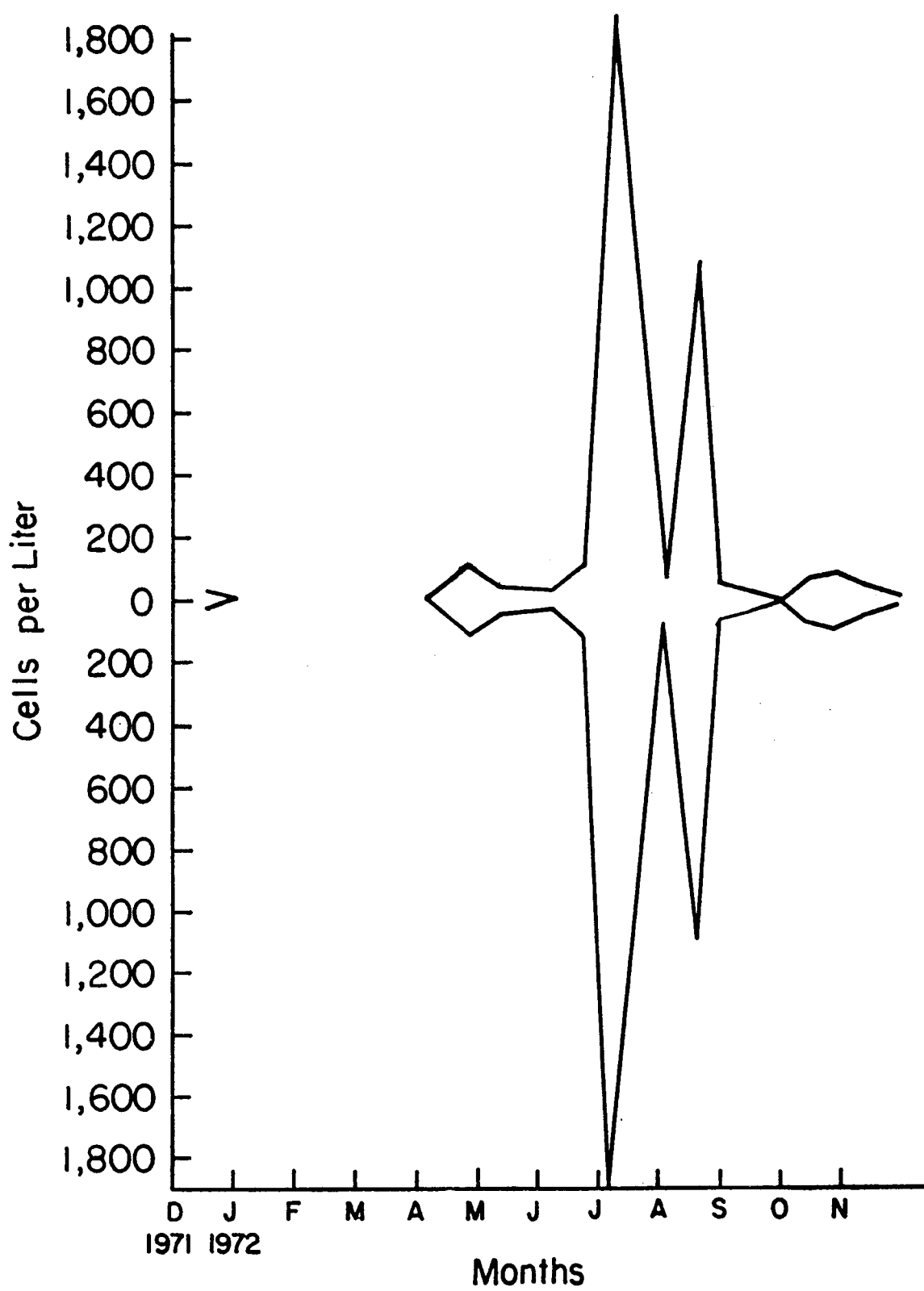


Figure 10: Semimonthly standing crops of the diatom, Tabellaria
flocculosa between the surface and meter 15.

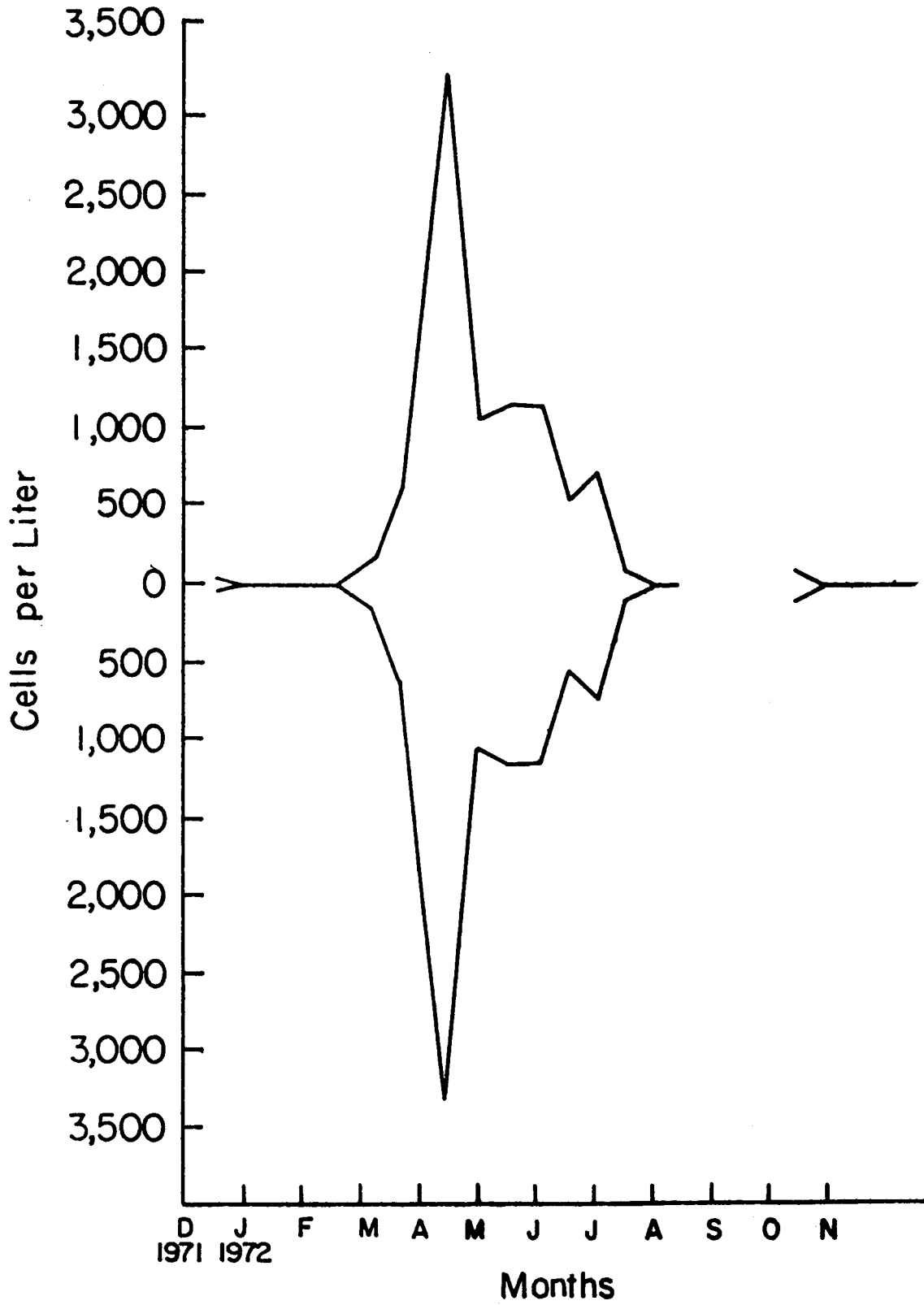


Figure 11: Semimonthly standing crops of the diatom, Asterionella formosa between the surface and meter 15.

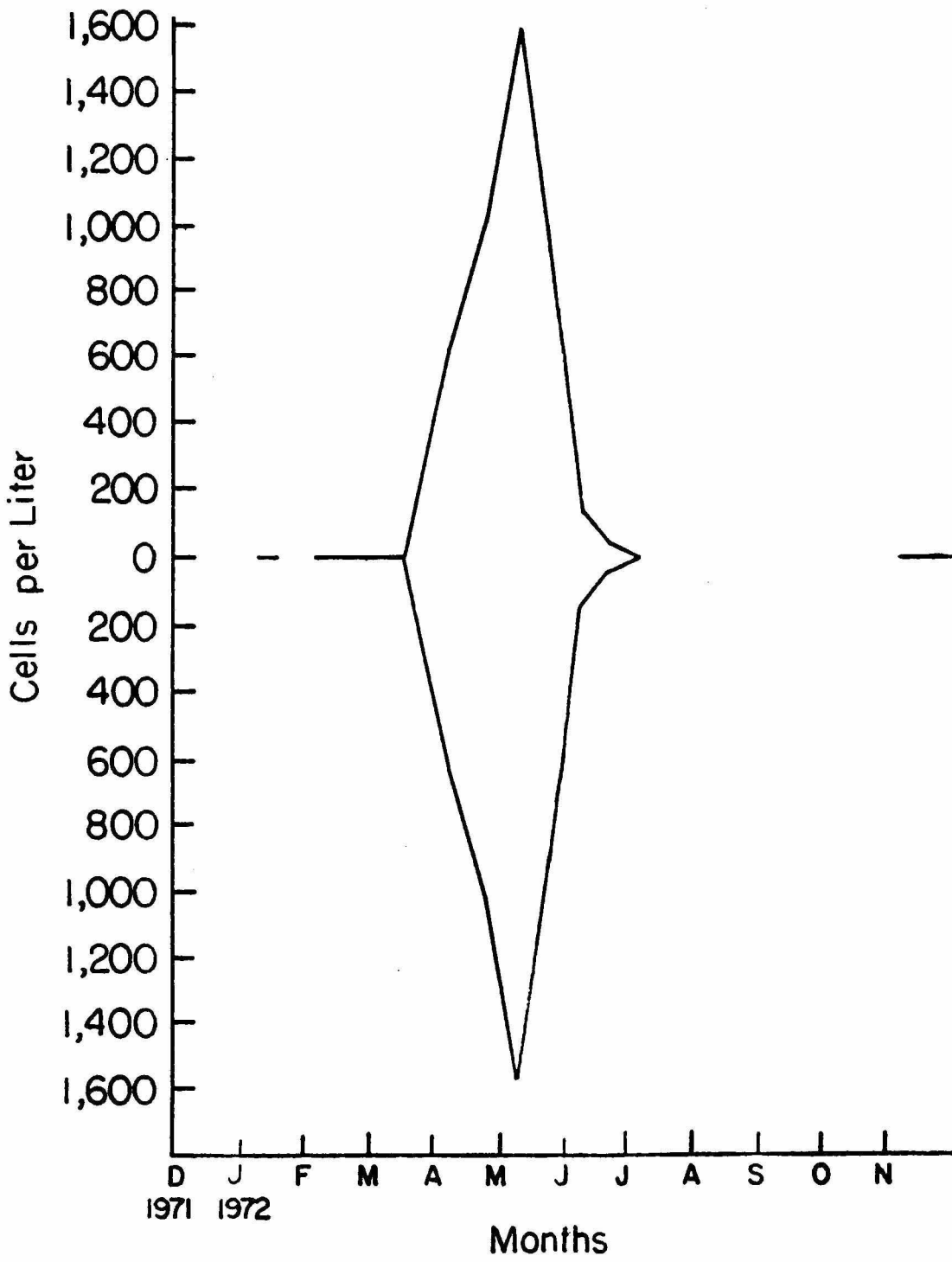


Figure 12: Semimonthly standing crops of the chlorophyte,
Sphaerocystis schroeteri between the surface and
meter 15.

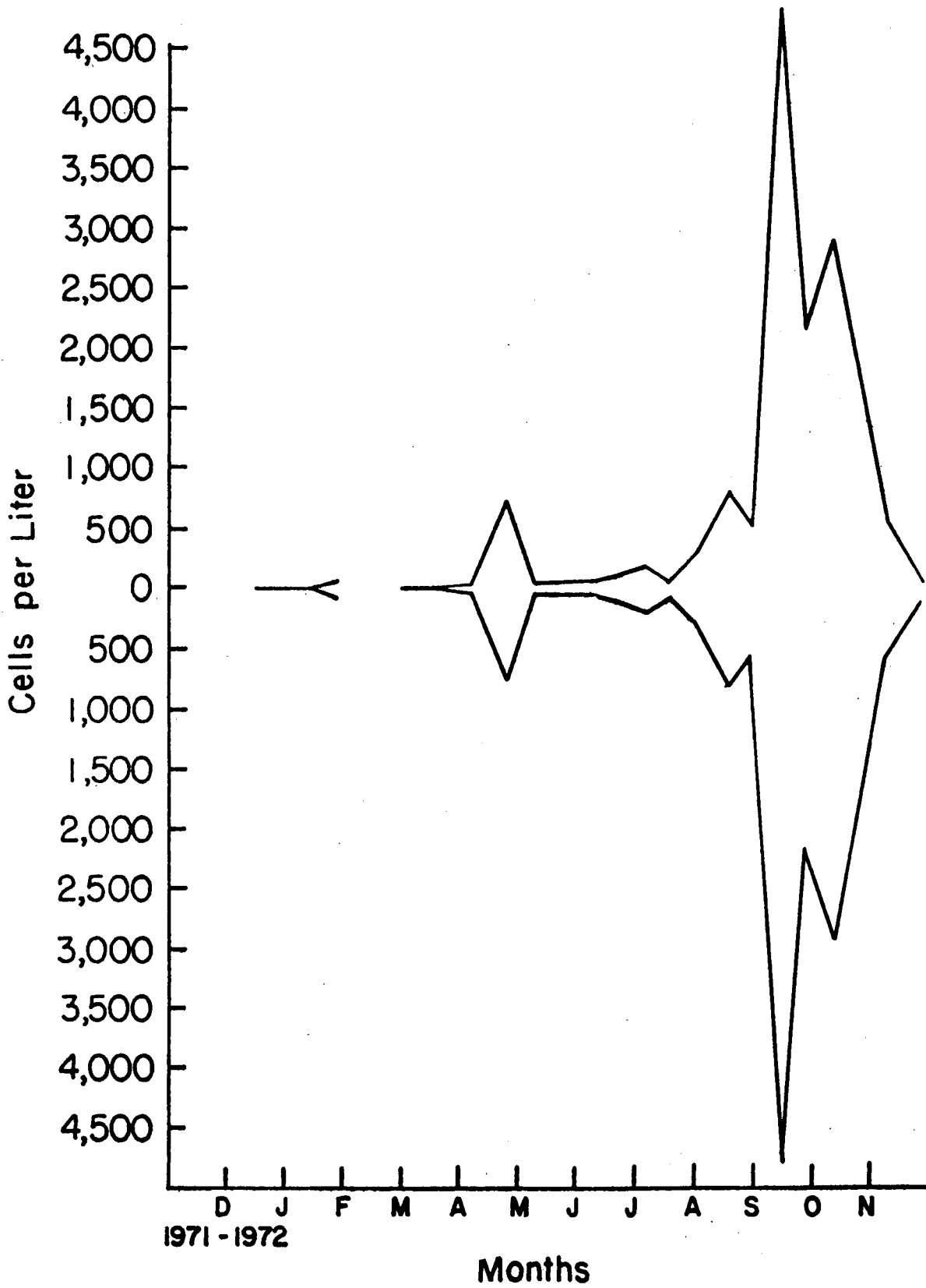


Figure 13: Semimonthly distribution of average number of zooplankters per meter between the surface and meter 15.

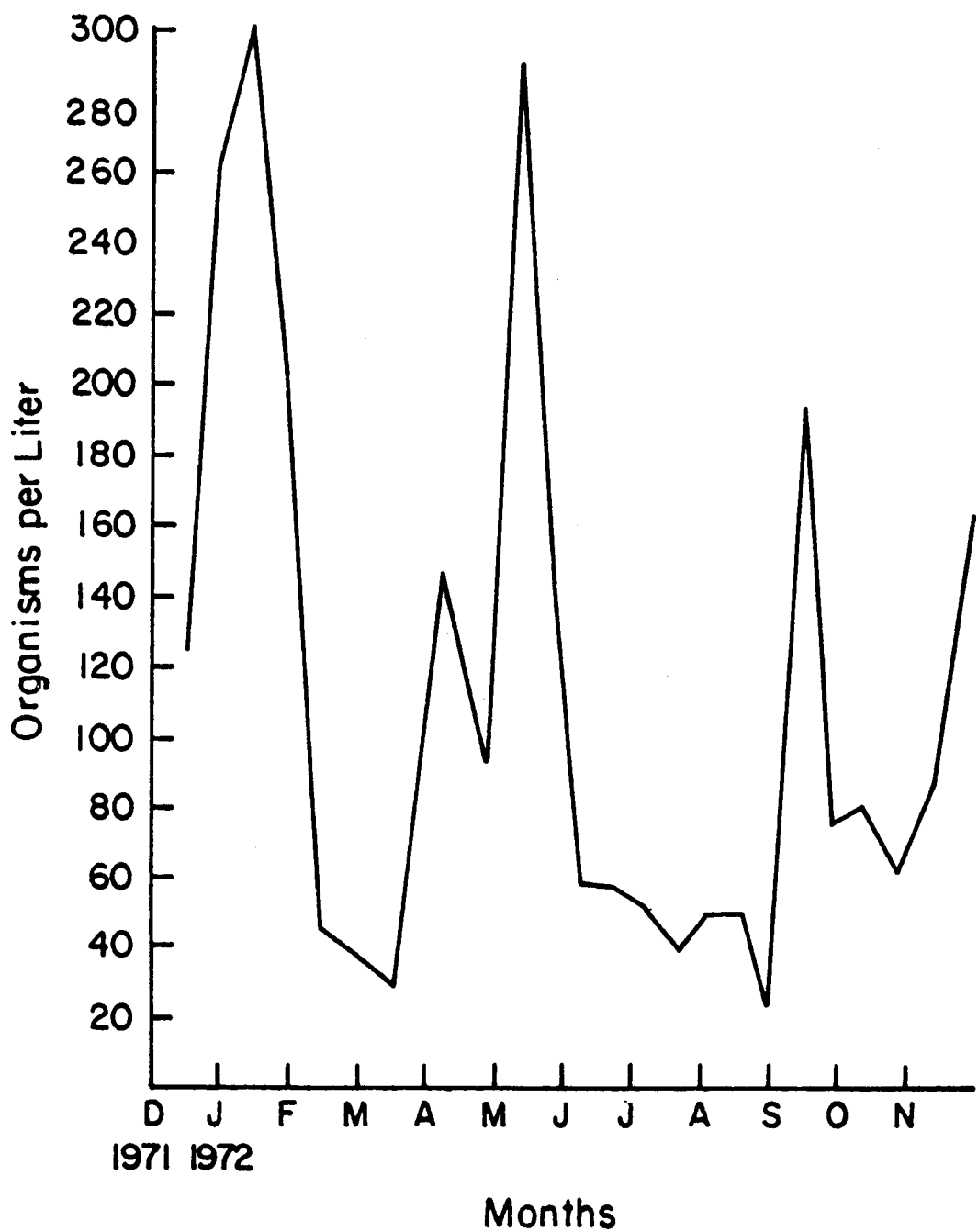


Figure 14: Average semimonthly distributions of Rotatoria and Copepoda between the surface and meter 15.

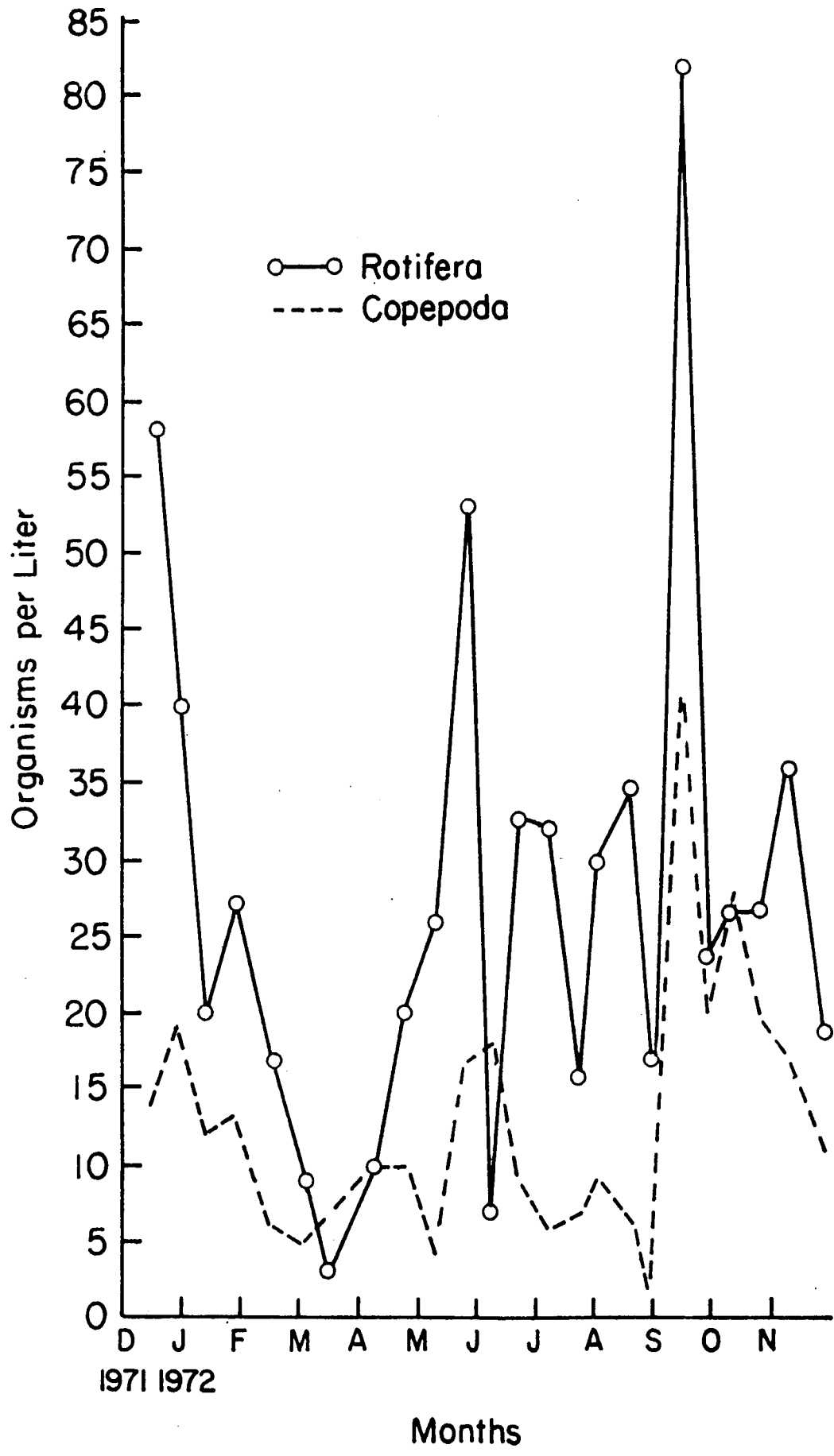
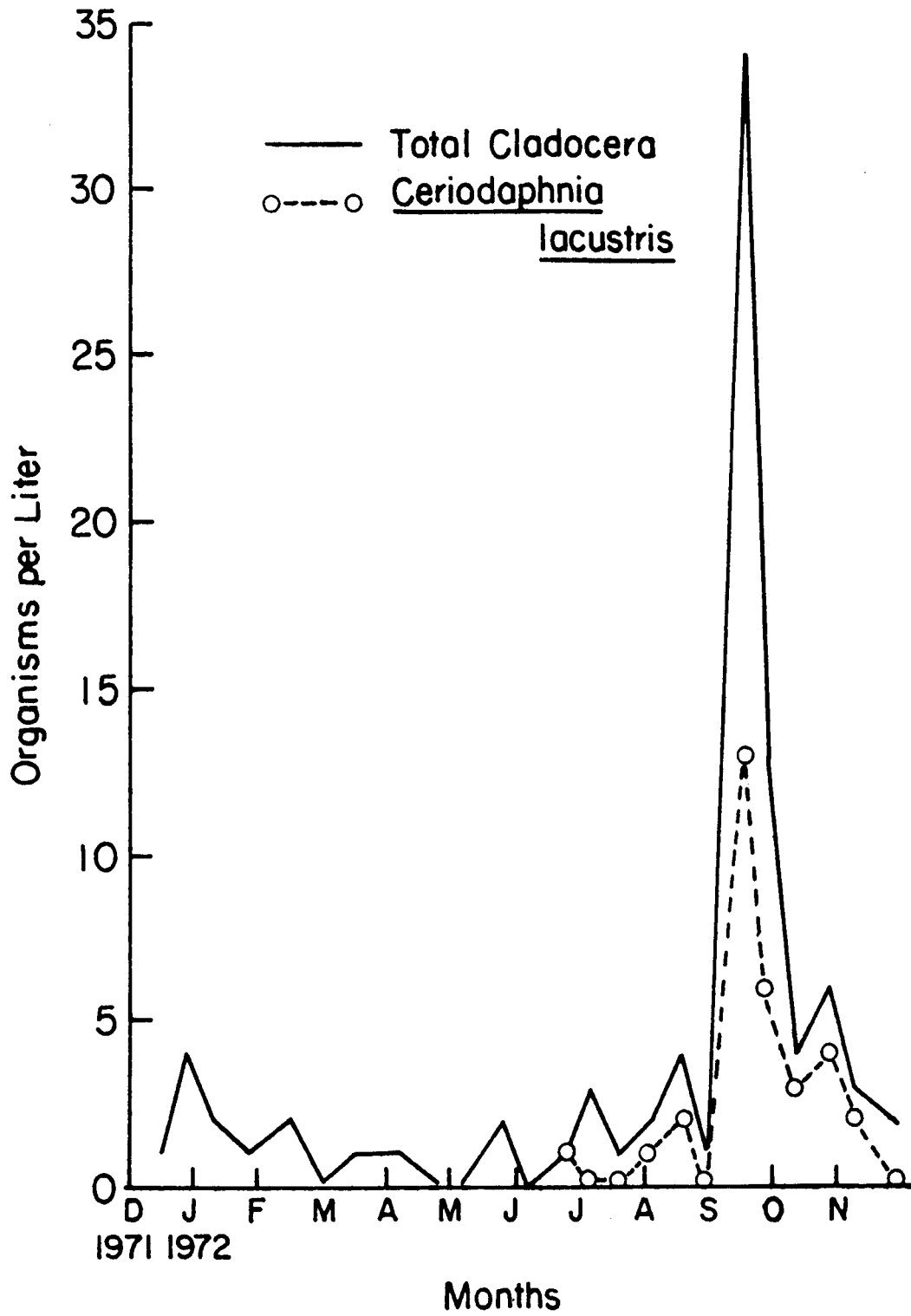


Figure 15: Graphical description of the relationship of the cladoceran, Ceriodaphnia lacustris to the total number of Cladocera at the surface to the 15-m level.



Ichthyology Phase

Structure of Fish Community and Distribution of Black Basses

In order to assess the interrelationship between the largemouth bass and spotted bass, their abundances were estimated from a rotenone sample and the mark-recapture method. A 2.5 hectare cove in the upper portion of the lake was rotenoned in July 1971 and from this a standing crop of 106 lb/acre was estimated (Table 2) with gizzard shad as a major contributor. Most of the shad were adults and thus could not serve as forage for the black basses. Spotted bass were notably absent from this sample as the rotenoned area was of muddy bottom with dense vegetation while the spotted bass prefer clear rocky substrate in Lake Fort Smith. The spotted bass were absent from a 1958 rotenone sample taken from this cove but a rotenone sample from the main channel yielded 10.23 adults/ha (Cole and Finkelstein, 1959).

Population sizes of largemouth and spotted bass were estimated from mark-recapture technique. All the basses exceeding 100 mm in total length were marked by the removal of the anal fin. This study was conducted during June 8 - June 18, 1971. The population estimates by the Schnabel, modified Schnabel, and Schumacher methods are shown in Table 3. The later two methods gave accurate estimates with narrow confidence limits. It is apparent that largemouth bass were twice as abundant as spotted bass in Lake Fort Smith. Creel census data for 1957 - 58 (Cole and Finkelstein, 1959) revealed that while largemouth bass accounted for 17% of the sportfish harvest of Lake Fort Smith, spotted bass contributed less than 1%. Mark-recapture data of this study indicate that spotted bass have become relatively more abundant in Lake Fort Smith in the last 15 years.

Distribution of Black Basses in Lake Fort Smith

Largemouth and spotted bass demonstrate a considerable degree of segregation in Lake Fort Smith. Segregation did not usually occur over large areas of the reservoir, but rather in response to microhabitat differences within these areas. This is well substantiated by the results of the mark and recapture study and the cove rotenone sample. The numbers of spotted and largemouth bass captured in each of the four areas (Figure 1) during six nights of shocking in 1971 are given in Table 4. The ratio of the number of largemouth bass to spotted bass suggests that within each of the major areas there were differences in the relative abundance of the two species, but probably not of sufficient magnitude to conclude that the two species were actively segregating. However, the cove rotenone sample, taken within two weeks of the mark and recapture study, indicates the intensity with which segregation occurs in response to microhabitat differences. While 324 largemouth bass were recorded in the rotenone sample, spotted bass were represented by a single juvenile. The rotenone sample was taken in Area II where mark and recapture estimates yielded a largemouth to spotted bass ratio of 2.04.

Location of capture of individuals of each species were analyzed to determine factors influencing relative abundance of the two species. Areas III and IV, which supported relatively more spotted bass than Areas I and II, were characterized by rocky substrate and steeply sloping shores. Emergent vegetation within these areas was restricted to small localized areas. Although largemouth and spotted bass were both found in this type of habitat, it appeared to represent optimum habitat for Lake Fort Smith spotted bass. Spotted bass were absent from areas with mud bottom and dense emergent vegetation.

The differences in distribution of black basses in Lake Fort Smith appears to be dependent primarily upon abundance of emergent vegetation and type and slope of bottom. Results indicate that largemouth bass have a wider tolerance in respect to these factors than do spotted bass and are thus more generally distributed within Lake Fort Smith. The restriction of spotted bass to a narrower range of specific environmental parameters results in the tendency toward segregation of the two species noted in this study. This segregation was likely an important factor in the differences in efficiency of individual gear in sampling each species.

Age and Growth, Length-Weight Relationship, and Condition Factor

ANNULUS FORMATION

Published information concerning the time of annulus formation in black basses is meager. Accurate knowledge of the time of annulus formation greatly facilitates age determination in fishes. To determine peak time of annulus formation the percent of fish possessing a current annulus in each age group was determined for each species. Fish were pooled into 10 day intervals from May 1 to July 30. For scales possessing current annuli, an indication of the time of annulus formation could be gained by consideration of the marginal increment--the distance from the last annulus to the outside radius of the scale.

Sufficient data were available to analyze only the first four age groups of each species. With regard to the number of fish possessing a current annulus in each 10 day period, it appears that annulus formation in young spotted bass of Lake Fort Smith occurs earlier and during a shorter period of time than in older individuals. This is true for the Lake Fort Smith bluegill also (Hogue, 1973). One- and two-year-old spotted bass usually

form their annuli within the first 10 days of June. Three-year-old spotted bass usually form their annuli about mid-June, but one three-year-old spotted bass examined had still not formed its annulus by mid-July. Data for four-year-old spotted bass were skimpy but indicated that annuli are probably formed in the latter part of July.

Data for largemouth bass are much less complete but suggest a pattern similar to that of spotted bass. The first week of June is the peak period of annulus formation in one- and two-year-old largemouth bass. No three-year-old largemouth bass collected during June 1 - 10 possessed current annuli but the exact time of annulus formation could not be determined with available data.

Data pertaining to the average marginal increments for both species are shown in Figures 2 and 3. The trend is the same in both species. Largemouth and spotted bass form their first annulus in June. As the basses aged annuli were formed later in the year, with the third annulus being formed in July. The tendency for the period of annulus formation to be of longer duration in older fish was well shown in three-year-old spotted bass. It appears that annulus formation in this group began in June and extended well into August.

Jenkins and Hall (1953) found largemouth bass in Oklahoma to form annuli in the period of mid-April to mid-June. These authors also noted a tendency for younger largemouth bass to form their annuli earlier than older bass. It is generally assumed that the annulus is laid down when rapid growth is resumed after the long winter period of little or no growth. Rounsefell and Everhart (1953) theorized that in general the time of annulus formation can be readily correlated with water temperature. Since older largemouth and spotted bass form their annuli later than younger members, although exposed to similar temperature regimes, factors other than temperature must be impor-

tant in determining the time of annulus formation. The possible effects of stage of maturity and food habits in relation to time of annulus formation will be considered later.

TOTAL LENGTH-SCALE RADIUS RELATIONSHIP

Scales from 380 spotted and 313 largemouth bass were used to determine the relationship between total length and scale radius by step-up polynomial analyses. The general model for this analysis is

$$L = \theta_0 + \theta_1 S + \theta_2 S^2 + \dots + \theta_n S^n$$

where L is the total length of the fish in millimeters, S is the scale radius (43X) and θ_0 to θ_n are constants. A third degree polynomial, $L = 27.90426 + 1.58482 S + 0.00453 S^2 + 0.00002 S^3$, best expressed the relation for spotted bass while a linear equation, $L = 24,14429 + 1.93932 S$, was fitted to largemouth bass data. The smallest spotted and largemouth bass whose scales were examined were 35 mm and 43 mm, respectively.

Total length-scale radius relationships were computed separately for male, female, and immature individuals of each species (Table 5). Analysis of spotted bass revealed significant differences between the total length-scales radius relationships of males and immatures ($F = 1.867^{**} 126,253$) and females and immatures ($F = 1.703^{**} 129,250$), but not between males and females. Identical procedures applied to largemouth bass indicated a significant difference between immatures and males ($F = 3.309^{**} 109,199$), but the differences between immatures and females, and between males and females were not significant. The equations describing the relationship for the pooled data of males and females were $L = 40.4858 + 1.8275 S$ for the largemouth bass and $L = 60.0230 + 1.5336 S$ for the spotted bass.

AGE COMPOSITION, SEX RATIOS AND MORTALITY

Age composition of a population of fishes yields information concerning senescence of the population, year-class strength, and survival. The age compositions of Lake Fort Smith black basses are given in Table 6. Yearling and 2⁺ were the most commonly represented ages in both largemouth and spotted bass. The age distributions would suggest that the black bass populations of Lake Fort Smith are probably fairly stable and show no apparent indications of expansion or senescence. The small sample size and effects of gear selectivity do not allow generalizations regarding the strength of various year classes.

Sex ratios are of value in the study of population structure, reproductive potential, and differential mortality. The number of males and females in each age group of largemouth and spotted bass were not significantly different from the expected 1:1 ratio. Various authors have stated that female largemouth bass or spotted bass tend to live longer than males (Beckman, 1946; Bryant and Houser, 1971; Padfield, 1951; Stroud, 1948). The Lake Fort Smith data were inconclusive for older age groups, but any differences in longevity of sexes of black basses in that reservoir appear slight.

BACK CALCULATED LENGTHS

Lengths at earlier ages for males and females of each species were calculated using the total length-scale radius relationships (Tables 7 and 8). Largemouth showed a much greater tendency for differential growth by sexes than the spotted bass. Calculated lengths of fish exceeding four years of age are based on few specimens, and care should be taken in making generalizations. In addition, marginal scale increments became so small in fish five

years of age or older that annuli tended to be stacked making accurate age determination difficult.

MONTHLY GROWTH

The observed lengths of fish of different ages collected in each month are shown in Tables 9 and 10. The greatest portion of the annual growth of spotted and largemouth bass of Lake Fort Smith occurs during a relatively short period of time. This period of growth appears to be initiated later and be of shorter duration in older fish. Young-of-the-year basses showed consistent growth from June, when they first entered the catch, until October and November for largemouth and spotted bass, respectively. During this period largemouth grew at a monthly rate of 17.4 mm, and spotted bass at a monthly rate of 13.4 mm. The period of greatest growth in yearling largemouth bass was July and August, and for yearling spotted bass from June to September. The corresponding monthly growth rates were 35.1 mm for largemouth bass and 18.2 mm for spotted bass. Two-year-old largemouth and spotted bass experienced greatest growth during the periods June through August (14.1 mm/month) and July through October (14.6 mm/month), respectively. During their third year the period of most active growth was restricted to August for largemouth bass and August and September for spotted bass. The monthly averages of observed lengths seem to support the earlier conclusion of annuli being formed later in older fish.

Any attempt to explain earlier cessation of growth in the fall by older fish would be highly theoretical. The phenomenon is perhaps related to differences in food or feeding habits between the age groups. Perhaps a sounder physiological explanation is that in older, mature fish a greater proportion

of body weight is invested in gonadal development. The seasonal development and redevelopment of gonads requires a great amount of energy that might otherwise be utilized for growth in length. Since young-of-the-year bass showed very little gonadal development they tended to grow continuously in length throughout the period favorable for growth. Cessation of growth in young-of-the-year bass is probably more dependent upon water temperature than any other factor. Mraz et al. (1961) stated that growth in largemouth bass ceases at temperatures below 10 C (50 F). Lake Fort Smith first reached 10 C in 1971-72 winter during mid-December. This suggests that the period of slow growth during the winter is dependent to a great extent upon low temperatures, particularly among younger fish. It appears that in older fish physiological factors are also operative.

The period of active growth appears to be longer in spotted bass than in largemouth bass. This may be a reflection of differential temperature optima between the two species. The temperature preferendum for spotted bass is 23.5-24.4 C while the preferendum for largemouth bass is 26.6-27.7 C (Ferguson, 1958). Thus, spotted bass can probably more efficiently utilize the environment during cooler periods than can the largemouth, and for this reason its period of accelerated growth is of greater duration. It is of interest that the mid-point of the period of accelerated growth was usually August in both species. Lake Fort Smith usually reaches its maximum temperature (27 C) during the latter part of July (J. Carter, pers. comm.). Thus, it would appear that when physiological factors are taken into account there is a sound positive relationship between water temperature and growth rate.

The apparent accelerated growth of the bass during early winter and shrinkage during late winter (Tables 9 and 10) is a reflection of gear selectivity. During the winter a large number of fish were collected by gill

nets which showed selectivity for larger members of the age groups represented. When gill nets were implemented in early winter it caused an apparent jump in the growth rate of the bass and when they were phased out in late winter it caused an apparent shrinkage in total length. Fish from April through November were collected mostly by electroshocking and more nearly reflect the true growth rates, and the fluctuations within this period are attributable to sample size.

Comparison of observed lengths of November fish with April fish of the next age group reveals that limited growth does occur during the winter. This continued growth throughout the winter, although slight, was probably a causal factor in poorly developed annuli noted during this study.

COMPARISON OF GROWTH IN LENGTH OF MALES AND FEMALES

Data indicated that the growth of male and female spotted bass was very similar, but suggested that male largemouth bass grew faster than females (Tables 8 and 9).

Back calculated lengths of the first four age groups of males and females of both species were subjected to factorial analysis of variance and it revealed a highly significant difference in growth of sexes of largemouth bass ($F = 15.3$; d.f. = 1,28), but no difference in growth rates of sexes of spotted bass ($F = 1.4$; d.f. = 1,28). In neither species was there a significant interaction between age and sex with relation to total length.

Previous studies have shown little agreement on the subject of differential growth rates of sexes of black bass. Beckman (1946) and Stroud (1948) found no difference in the growth rates among the sexes of largemouth bass as well as spotted bass. Padfield (1951) generalized that female largemouth bass grow faster than males, particularly in environments unfavorable for rapid growth. Faster growth and earlier maturation by male largemouth bass

has also been reported (Pardue and Hester, 1966; Stroud, 1948). The contrast in these findings would indicate that any difference in growth rate of sexes of black bass could be attributed to environmental rather than hereditary factors. Differences in habitat selection by sexes could be reflected in growth rates due to differences in illumination, water chemistry, temperature, and quality and quantity of food.

COMPARISON OF CALCULATED GROWTH IN LENGTH WITH FINDINGS OF OTHER STUDIES

The growth of largemouth and spotted bass from Lake Fort Smith were compared with that reported from other waters (Tables 11 and 12). The lengths for Lake Fort Smith bass are weighted means based on back calculations of mature fish. Although male and female largemouth bass of Lake Fort Smith grew at different rates they were combined for comparison of growth with other studies.

Spotted bass of Lake Fort Smith showed exceptionally poor growth at older ages compared to spotted bass of other waters. Largemouth bass also showed poor growth, and back calculated lengths were roughly comparable to those reported from several northern waters. Rate of growth of black basses increased since the previous study on Lake Fort Smith (Strawn, 1961 b). Strawn's sample sizes (124 largemouth bass and 15 spotted bass) were rather small and comparisons should be made with reservation.

Several factors might have contributed to the slow growth rate of black basses in Lake Fort Smith. Growth of largemouth bass is generally better in large bodies of water (Jenkins and Hall, 1953; Roach and Evans, 1948). Lake Fort Smith is not a large body of water by modern standards, which could influence the growth rate of its fishes. Several authors (Applegate and Mullan, 1967; Bryant and Houser, 1971; Jenkins and Hall, 1953; Tharratt,

1966) have reported growth of black bass to be faster the first few years after impoundment, then to decline steadily as the reservoir ages. Since Lake Fort Smith was impounded in 1936 it can be assumed that the reservoir is past its prime as far as growth of black bass is concerned. Jenkins and Hall (1953) also noted that largemouth bass tend to grow slower in more turbid waters. The high turbidity of Lake Fort Smith from early fall to mid-summer probably has an inhibitory effect on the growth of its fishes. Perhaps the factor of greatest influence, however, is the low fertility of the reservoir. Lake Fort Smith is located over shale and drains primarily oak-hickory forest. There is little agriculture in the drainage basin and no major sources of nutrient input. Extensive precautions are taken to prevent enrichment of the water since the reservoir is the water supply for the city of Fort Smith, Arkansas. Water chemistry and qualitative and quantitative analysis of plankton reveals that little eutrophication has occurred in the last several decades. These rather sterile conditions are believed to be the primary factors in the slow growth recorded for both species.

It is a rather popular theory that fish growth is slower at higher latitudes than near the equator. This has been attributed to differences in the length of the growing season (Gerking, 1966). While this generalization has merit, the slow growth of black basses in Lake Fort Smith indicates the overriding importance of local conditions in the determination of growth rates of fishes.

GROWTH PARAMETERS

The growth patterns of largemouth and spotted bass were subjected to mathematical analysis to derive several parameters that would be of value in assessing the Lake Fort Smith fishery. Since the male and female largemouth

have different growth rates they were treated separately. The data for spotted bass were pooled with regard to sex.

A variety of growth models have been used in the study of growth of fishes. Of these, von Bertalanffy's method is one of the most efficient and the parameters are reputed to have biological significance. Von Bertalanffy's growth equation is expressed as $L_t = L_{oo} (1 - e^{-K(t - t_o)})$ where L_t is length at age t , L_{oo} is asymptotic length, K is the rate constant (coefficient of catabolism) and t_o is the age at which the fish would be of zero length.

The appropriate equations for Lake Fort Smith black basses are

$$\text{Largemouth Males} \quad L_t = 670 (1 - e^{-.182 (t + .432)})$$

$$\text{Largemouth Females} \quad L_t = 530 (1 - e^{-.257 (t + .256)})$$

$$\text{Spotted Bass} \quad L_t = 350 (1 - e^{-.511 (t - .330)})$$

The mean calculated lengths for each age obtained using the above equations were comparable to values obtained by use of the total length-scale radius equations indicating that the parameters of the growth processes were adequately described by the von Bertalanffy growth equation.

The age at which an average spotted bass and an average male or female largemouth bass would reach 95% of its maximum attainable length were calculated by the equation $t_1 = t_o - \frac{\ln(1-p)}{K}$ where t_1 is the age at which the fish would reach the chosen percentage (p) of growth. Spotted bass reach 95% of their maximum attainable length at 6.2 years while male and female largemouth bass reach the corresponding lengths at 16.9 and 11.7 years of age, respectively. The associated weights at t_1 were 439 grams for spotted bass, 1610 and 3295 grams for female and male largemouth bass, respectively.

In general, the estimated ages at which Lake Fort Smith black basses attain 95% of their maximum length appear reasonable. The oldest spotted bass collected in the present study were six-years-old, and the calculated length for 6-year-old male and female spotted bass was 331.5 mm, almost exactly 95% of the L_{∞} of 350 mm. The oldest male largemouth bass collected were 6-years-old and had attained 69.6% L_{∞} , a value in good agreement with previous calculations. The oldest female largemouth bass was 7-years-old. The calculated length of 7-year-old largemouth bass was 451.8 mm, or 85.3% L_{∞} . Thus, all estimated $L_{.95}$ values are consistent with observed values.

It has been postulated that the value of L_{∞} reflects primarily the adequacy of the food supply while the rate constant K is mainly a function of variation in water temperature (Beverton and Holt, 1957). The fact that the values for L_{∞} and K differed so much between male and female largemouth bass indicates that physiological factors must also be operative. The larger K , smaller L_{∞} , and shorter life expectancy for female largemouth bass could result partially from greater stress associated with spawning. The short duration of the present study and the lack of previous applications of mathematical models to the growth of black basses makes sweeping generalizations difficult. Hopefully after a sufficient base of knowledge has been acquired parameters of growth models can be more fully interpreted.

Mortality and Survival

Mortality and survival rates of a population are important parameters of its structure and are also indicative of the general nature of conditions operating upon it. Mortality rates were estimated from age frequencies and growth parameters.

The natural logs of frequencies of each age group were fitted with a straight line by the least squares method. Young-of-the-year and yearling basses were excluded because one-year-olds represented the modal value in the catch curve of each species. Sexes were pooled to obtain mortality rates for the population as a whole. The resultant equations were

$$\text{Largemouth Bass } N_t = N_o e^{-0.927t}$$

$$\text{Spotted Bass } N_t = N_o e^{-0.915t}$$

where N_t is number of fish at t years, N_o is the initial number of fish, t is the number of years, and i is the instantaneous mortality rate. The associated values for "a" (annual mortality rate) were 60.5% and 60.2% for largemouth and spotted bass, respectively. Survival ($1 - a$) for largemouth and spotted bass were 39.5% and 39.9%. These values would suggest that there is no difference in the mortality rates of largemouth and spotted bass in Lake Fort Smith.

Using growth parameters obtained from von Bertalanffy growth equation instantaneous mortality rates were calculated as

$$i = \frac{K(L_{\infty} - \bar{L})}{\bar{L} - L_r}$$

where \bar{L} is the average length of the fish in the catch that are as large as or larger than the first fully recruited length L_r (Beverton and Holt, 1956). Back calculated lengths were used and again 2-year-old bass were considered the youngest fully recruited age group. Since growth and growth parameters for male and female

largemouth bass differed, mortality rates were calculated for each sex separately, but based on growth data sexes of spotted bass were pooled. The instantaneous mortality rate calculated by this method for spotted bass was 1.21 (annual survival = 29.82%) and compared favorably with the value obtained by the catch curve method. The instantaneous mortality rates for largemouth bass calculated by this method was 2.18 for both males and females, much higher than the combined value obtained from age group frequencies. This difference was due primarily to the small number of older age group fish which resulted in a small \bar{L} value. Comparison of the numbers of one- and two-year-old largemouth bass and spotted bass collected shows that largemouth bass are recruited at an earlier age than spotted bass. This is the result of the size selective nature of the sampling gear and faster growth of largemouth bass. This phenomenon causes a reduction in the \bar{L} values and an increase in the instantaneous mortality rates of largemouth bass. It is felt that the i value obtained by the age group frequency method is more reliable, and that annual mortality and survival rates based on it approach reality.

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR

Determination of the relation of length to weight is of practical value since it allows conversion of length to weight and vice versa. The length-weight relationship is expressed as

$$W = aL^b$$

where W is the weight in grams, L is the length in millimeters, a and b are empirically determined constants.

Regression equations were derived for immatures, males, and females of each species by logarithmic transformations. The appropriate equations are

	Largemouth Bass	Spotted Bass
Immatures	$\log W = -4.7352 + 2.8949 \log L$	$\log W = -4.9591 + 2.9915 \log L$
Males	$\log W = -5.2620 + 3.1310 \log L$	$\log W = -5.1733 + 3.0970 \log L$
Females	$\log W = -5.3171 + 3.0379 \log L$	$\log W = -5.2916 + 3.1467 \log L$

The regression coefficients for male largemouth bass and female spotted bass were significantly different from the cube relationship at the 0.05 level. Thus, the regressions of length and weight were shown to differ for the sexes in each species. In both species there was very little difference in the weight of young males and females of the same length; however, at older ages there was a decided tendency for females to weigh more than males of the same length.

The coefficient of condition (condition factor, ponderal index) was computed for each species as

$$K(TL) = \frac{W \times 10^5}{L^3}$$

where W is the weight in grams, L is the total length in millimeters, and $K(TL)$ is a constant.

Coefficients of condition for each age group of immatures, males, and females of each species were computed (Table 13). In both species the male and female two-year-olds were more plump than immature individuals of the same age suggesting that earlier maturity is associated with increased condition factors. This higher condition of mature fish is undoubtedly related

to gonadal development and production of sexual products. Coefficients of condition for males and females of each species were very similar. In largemouth bass females demonstrated higher condition factors than males of the same age at all ages. In spotted bass, two-year-old males showed higher coefficients of condition than females of the same age, in older spotted bass females were slightly superior in condition. This was a reflection of males reaching sexual maturity at an earlier age than females. Both sexes of both species exhibited increasing coefficients of condition with increased length. Extreme values were shown by old "pot bellied" lunkers.

Three-year-old specimens of each species were partitioned by sex and season of collection to evaluate seasonal variation in condition. The trend for each sex of each species was similar. In all cases the maximum condition was observed in the fall (September, October and November), while the lowest condition was usually noted during winter (December, January and February). Summer (June, July and August) males were plumper than spring (March, April and May) males, but the trend was reversed in females. The higher condition of spring females was most likely related to the weight of sexual products prior to spawning. Cooper (1950) found that K for largemouth bass was higher in June, July, and October than during other months in a Texas lake.

Condition coefficients of Lake Fort Smith black bass were compared with previously reported values (Tables 14 and 15). Largemouth bass of Lake Fort Smith had the poorest condition coefficient of any shown in Table 14. When this is considered in addition to the poor growth of largemouth bass in the reservoir it is apparent that Lake Fort Smith represents sub-optimum habitat for this species. The condition of largemouth bass in the present study is appreciably lower than during a 1958 study on the same reservoir. It is possible that the construction of Lake Sheppard Springs

in 1957 has acted as a settling basin for many nutrients and has thus reduced the productivity of Lake Fort Smith. Also, discharges from Lake Sheppard Springs allow maintenance of stable water levels in Lake Fort Smith and this could be a factor in the slow growth and poor condition of the largemouth bass. There is little published information concerning K(TL) values for spotted bass. Available results indicate that Lake Fort Smith spotted bass are very similar in condition to spotted bass of Alabama, but much poorer in condition than spotted bass reported from Louisiana. The reasons put forth for poor condition in largemouth bass probably apply also to spotted bass of Lake Fort Smith.

AGE AT SEXUAL MATURITY

Determination of age at maturity is important in assessing the contribution of age groups in spawning. A system of classification based on gonadal characteristics was established as a measure of maturity (Table 16).

In determining the age at which the fish matured, those in stages II - VI were considered mature. On this basis 0.0%, 34.2%, 85.5%, and 100.0% of the spotted bass in age groups I⁺ - IV⁺ were considered mature. Comparable values for largemouth bass were 2.0%, 43.0%, and 100.0% for the first three age groups. Thus, largemouth bass in Lake Fort Smith start the maturation process at an earlier age than spotted bass and all are mature during their third year of life. Towery (1963 and 1964) found that maturity in Mississippi largemouth and spotted bass was related to length as well as age. His findings regarding age at maturity correspond very closely with the results reported above.

Food and Feeding Habits

SEASONAL FOOD TRENDS

The calendar months were partitioned into four seasons of biological and climatological significance. Fish collected during December, January, and February were designated as winter fish; those from March, April, and May as spring fish; those from June, July, and August as summer fish; and those from September, October, and November as autumn fish. Data were recorded separately for juveniles, males, and females to determine the effect of maturity and sex on seasonal food trends. Results are shown graphically in Figure 4.

Winter

Largemouth Bass

Immature--Fish accounted for 63.6% of the total number of food items consumed and 94.7% of the total weight of the diet of immature largemouth bass during winter. The remainder of the diet was composed of insects; macrocrustaceans were entirely lacking. All identifiable fish were lepomids and all insects were either hemipterans (Corixidae) or ephemeropterans. Four Bosmina, from December fish, were the only zooplankters represented. Only 34.5% of the fish examined contained measureable amounts of food.

Male--Fifty percent of the male largemouth bass collected during winter contained measurable amounts of food. Fish, crayfish, and insects were identified, accounting for 99.3%, 0.6%, and 0.1% of the total weight of the diet, respectively. Fish were represented primarily by Lepomis cyanellus and to a lesser extent by Fundulus olivaceus and Labidesthes sicculus. All insects identified were mayflies. The only zooplankter recorded was a copepod in February. Although the frequency of feeding was low, the mean diet weight value was 3.149 g, nearly twice as high as for any other season.

Female--Although only 41.7% of the winter females contained food, the

mean diet weight was 2.210 g, about the same as spring and intermediate to the summer and fall values. Fish, crayfish, and insects accounted for 90.1%, 9.8%, and 0.1%, of the total weight of the diet, respectively. All identified fish were either Lepomis gulosus or L. cyanellus, and all insects were either corixids or ephemeropterans. No zooplankters were recorded.

Spotted Bass

Immature—Immature spotted bass fed very little during winter. Only 27.3% contained food, and the mean diet weight was 0.008 g. With the exception of 74 Daphnia recorded in December, the entire winter diet was composed of fish. The only fish identified to species was a bluegill.

Male—Feeding of male spotted bass during the winter appeared relatively heavy with 74.1% of the stomachs containing food and a mean diet weight of 4.274 g. Crayfish and fish accounted for 95.7% and 4.3% of the total weight of the diet, respectively. Insects were entirely lacking. With the exception on one small channel catfish all identifiable fish were lepomids. A single copepod was recorded during December.

Female—Female spotted bass did not feed as heavily as males during the winter. Only 63% contained food, but the mean diet weight of 3.824 g was the highest of any season. The heavy dependence on large crayfish caused high mean diet weight values for both male and female spotted bass during the winter. Crayfish and fish contributed 93.2% and 6.8% to the total weight of the diet, respectively, while a single chironomid larva did not contribute significantly. None of the fishes were identifiable to species. Two Daphnia from a December fish were the only zooplankters recorded.

Spring

Largemouth Bass

Immature—Immature largemouth bass greatly increased their feeding during

the spring when 73.3% contained food. The mean diet weight was 0.303 g. The rate and intensity of feeding progressively increased throughout the spring. Fish and insects accounted for 91.8% and 8.2% of the total weight of the diet, respectively. Macrocrustaceans were lacking. Centrarchids (primarily Lepomis macrochirus and L. cyanellus) and darters (primarily the channel darter Percina copelandi) were the identifiable fishes. Ephemeropterans, corixids, dipterans, coleopterans, hymenopterans, and megalopterans were important in that order. Zooplankters included 746 Daphnia, five copepods, four Bosmina, two ostracods, and an unidentified cladoceran. All but the two ostracods were recorded in April.

Male--The mean diet weight for spring largemouth bass males, of which 78.4% contained food, was 0.907 g. Feeding increased steadily throughout the spring. Insects dominated the early spring diet, fish dominated the mid spring diet, and crayfish were the most important food item in the late spring diet. For the entire period, crayfish, fish, and insects accounted for 53.5%, 42.6%, and 3.9% of the total weight of the diet, respectively, Lepomids (L. macrochirus and L. cyanellus) were the important fishes. The insects were ephemeropterans, coleopterans, orthopterans, dipterans, and hemipterans. Six Bosmina in April and a Daphnia and four copepods during May were the only zooplankters recorded.

Females--Spring females exhibited a feeding frequency of 75.3% and a mean diet weight of 2.214 g. The major food items and their associated percent of total weight of the diet were fish, 91.4%; crayfish, 6.4%; and insects, 1.9%. One snail recorded in April accounted for the remaining 0.2%. Insects decreased in importance throughout the spring, crayfish remained steady, and fish greatly increased in importance in May. The diversity of

insects consumed was great and included representatives of the orders Ephemeroptera, Plecoptera, Hemiptera, Diptera, Odonata, Hymenoptera, and Coleoptera. One ostracod each in March and April were the only zooplankters recorded.

Spotted Bass

Immature—Both feeding frequency (80.8%) and mean diet weight (0.208 g) increased sharply after winter. The major food items and their associated percent of total weight of diet were fish, 85.5%; insects 13.2%; crayfish, 1.1%; and fish eggs, 0.2%. Insects decreased in importance as spring progressed while fish increased in importance. Once again the diversity of insects consumed was great with the orders Ephemeroptera, Hemiptera, Orthoptera, Diptera, Coleoptera, and Hymenoptera being represented. Channel darters and bluegill were the only fish recognizable to species. Fish eggs consumed were those of largemouth bass. Zooplankton increased in importance as spring progressed and were a major food item in May. During March and April only one ostracod, one Asplanchna, one copepod, and 401 Daphnia were observed.

Male—Although the frequency of feeding of spring males (74.4%) was very similar to winter males (74.1%), the mean diet weight dropped from 4.274 g to 1.230 g. Crayfish, fish, Amphibia, and insects accounted for 38.5%, 37.2%, 19.3%, and 4.9% of the total weight of the diet, respectively. All identifiable fish in the spring diet were Lepomis sp. and Micropterus sp. The lone amphibian reported was a mud puppy (Necturus maculosus). Insects were the most important in mid and late spring and were represented by Coleoptera, Ephemeroptera, Plecoptera, Diptera, and Odonata. Zooplankters were unimportant in the diet with only seven Daphnia, one copepod, and one ostracod recorded.

Female—Spring females demonstrated a feeding frequency of 81.0% and a mean diet weight of 3.202 g. The major food items and their associated percent of the total weight of the diet were crayfish (77.7%), fish (21.0%), and insects (1.3%). All identifiable fish were bluegill. Insects were recorded only during April and May and were represented by Ephemeroptera, Odonata, Plecoptera, Coleoptera, Diptera, and Hymenoptera. Zooplankters were absent from the diet.

Summer

Largemouth Bass

Immature—Although 89.1% of the juvenile largemouth bass contained food during the summer, the mean diet weight was only 0.022 g. Fish accounted for 95.1% of the total weight of the diet and insects the remaining 4.9%. Macrocrustaceans were lacking from the diet. There was great variation in the species of fishes utilized within the season. Dorosoma cepedianum, Micropterus sp., and postlarval fishes dominated the June diet; centrarchids (primarily lepomids), Percina sp. and postlarve were important in July; and centrarchids were the only identifiable fishes in the August diet. Insects included Ephemeroptera, Hemiptera, and Diptera. The zooplankton portion of the diet was diverse and represented by one amphipod, two ostracods, 17 Daphnia, 37 Ceriodaphnia, and 47 copepods.

Male--Both the frequency of feeding (71.4%) and mean diet weight (0.450 g) were lower for male largemouth bass during the summer than during the spring. Fish, crayfish, and insects accounted for 89.9%, 8.3%, and 1.8% of the total weight of the diet, respectively. The pattern of fish consumption was very similar to that of immature fish. Bluegill and postlarval shad were the important fishes during June, brook silversides were the only identifiable fish in July, and in August the important fishes were

centrarchids and log perch. Insects were utilized very little and were represented by Ephemeroptera, Diptera, and Hymenoptera. With the exception of 11 copepods recorded during June, zooplankters were lacking.

Female—Summer females exhibited the highest frequency of feeding (85.7%) and mean diet weight (4.023 g) of any time during the year. Fish, crayfish, and insects accounted for 83.7%, 11.8%, and 4.5% of the total weight of the diet. Once again postlarval shad were important in the June diet, but centrarchids were dominant during July and August. Insects were recorded only during August and were terrestrial representatives of Orthoptera and Ephemeroptera. Zooplankters were insignificant in the summer diet and were represented only by four copepods and one ostracod.

Spotted Bass

Immature—Although 80.9% of the immature spotted bass contained food during the summer the mean diet weight was low (0.074 g). Crayfish were uncommon in the diet, accounting for only 2.1% of the total weight of the diet while fishes contributed 86.7% and insects 11.2%. In early summer, shad, and leptomids were important in the diet while in late summer channel darters and brook silversides dominated the diet. Insects were represented by Diptera, Ephemeroptera, Hemiptera, Hymenoptera, Orthoptera, and Homoptera. Zooplankters contributed significantly to the diet and were represented by 47 Daphnia, 19 Bosmina, five Ceriodaphnia, two Bosminopsis, one Alona, 12 unidentified cladocerans, four amphipods, and 13 copepods.

Male—Although 86.4% of the male spotted bass contained food during the summer, the mean diet weight was only 0.613 g. Insects were very important and accounted for 21.9% of the total weight of the diet while crayfish and fish accounted for 36.6% and 41.8%, respectively. Bryozoan

statoblasts which were observed did not contribute significantly to the diet. All fish recorded during June were shad; and shad, bluegill, and channel darters were important throughout the remainder of the summer. The insects were mainly terrestrial in origin and all were recorded in mid and late summer. The important orders of insects were Homoptera, Diptera, Trichoptera, Odonata, Plecoptera, and Orthoptera. Zooplankters were of moderate importance and represented by eight Bosmina, four Daphnia, one Ceriodaphnia, 18 unidentified cladocerans, three ostracods, one nauplius, and two copepods.

Female—Although the frequency of feeding (93.5%) of summer female spotted bass was the highest of any season, the mean diet weight (0.761 g) was the lowest of any season. Crayfish, fish, and insects accounted for 48.4%, 29.0%, and 22.6% of the total weight of the diet, respectively. All identifiable fish during June were shad while during July channel darters and sunfish were dominant with fewer numbers of brook silversides and shad recorded. During August fishes were relatively unimportant and were represented only by lepomids and shad. Insects were unimportant in the diet until August when insects of terrestrial origin (Ephemeroptera, Homoptera, and Coleoptera) became important. Token amounts of Diptera, Odonata, and Arachnida were also recorded. Zooplankton was of less importance in the diet of females and was represented by 12 Daphnia, three Alona, two Bosmina, three unidentified cladocerans and two copepods.

Fall

Largemouth Bass

Immature—Immature largemouth bass exhibited a feeding frequency of 77.8% and a mean diet weight of 0.195 g during the fall. Fish and insects

contributed 99.2% and 0.8% of the total weight of the diet, respectively. Crayfish were entirely lacking. During early fall the important fishes were brook silversides and bluegill while in mid and late fall bluegill dominated the diet. The lone insect reported was a mayfly during September. The occurrence of 13 Ceriodaphnia, three Diaphanosoma, one Bosmina, nine unidentified cladocerans and 50 copepods suggested that zooplankton was of moderate importance in the fall diet of immature largemouth bass.

Male—Male largemouth bass fed moderately during the fall demonstrating a feeding frequency of 75.0% and a mean diet weight of 1.159 g. The major food items and their associated percent of total weight of the diet were fish (83.0%), crayfish (16.6%), and insects (0.4%). The September fish were centrarchids (primarily bluegill), while the October and November fish were centrarchids (again primarily bluegill) and brook silversides. The only insects recorded were representatives of Hemiptera, Diptera, and Ephemeroptera. Plankton figures significantly in the September diet but was poorly represented in the October and November diets. In all, one Bosmina, one Daphnia, 27 Ceriodaphnia, seven Alonella, 18 Diaphanosoma, and 14 copepods were recorded.

Female—Both frequency of feeding (84.6%) and mean diet weight (1.329 g) values were lower for autumn females than for summer females. Frequency of feeding decreased as fall progressed. Autumn females were essentially piscivorous with fish accounting for 99.9% of the total weight of the diet. The remaining 0.1% of the diet was composed of Ephemeroptera and Hemiptera. The dominant fishes were centrarchids (primarily bluegill), shad, and brook silversides. Although a total of 190 zooplankters were recorded in September, none were observed in either October or November. The dominant microcrustaceans were Diaphanosoma, Ceriodaphnia, copepods, and Bosmina. Much less common in

the diet were ostracods, Bosminopsis, Alona, Daphnia and unidentified cladocerans.

Spotted Bass

Immature--During the fall immature spotted bass exhibited the highest frequency of feeding (84.6%) and mean diet weight (0.287 g) of any season. Fish, crayfish, and insects contributed 92.1%, 5.4%, and 2.5% of the total weight of the diet, respectively. Centrarchids were the only family of fishes consumed, and all identifiable centrarchids were bluegill. Insects were relatively unimportant in the diet and were dominated by homopterans. Insects of lesser importance were Diptera, Ephemeroptera, and Odonata. The zooplankters observed and the number recorded were Ceriodaphnia (30), Daphnia (22), Bosmina (17), unidentified cladocerans (17), copepods (15) nauplii (2), and Chaoborus (3).

Male--Although the mean diet weight for male spotted bass during the fall was only 1.155 g, the frequency of feeding was 94.4%, the highest of any season of the year. Crayfish, fish, insects, and turtles all contributed significantly to the diet accounting for 67.8%, 15.8%, 10.1%, and 6.3% of the total weight of the diet, respectively. Utilization of fishes decreased progressively from early fall to late fall. Brook silversides were the only fish identified during the fall. Insects composed a significant portion of the diet and were represented by Ephemeroptera, Homoptera, Diptera, Plecoptera, Hemiptera, Hymenoptera, and Orthoptera. Most insects were terrestrial forms. The turtle recorded was a small Sternothaerus odoratus. Zooplankton was relatively unimportant in the diet and was represented only by one Bosmina, one Diaphanosoma, one unidentified cladoceran, and one copepod.

Female--During the fall female spotted bass exhibited a feeding fre-

quency of 84.2% and a mean diet weight of 1.064 g. Feeding frequency decreased as fall progressed. Crayfish, fish, and insects accounted for 64.1%, 33.3%, and 2.6% of the total weight of the diet, respectively. Crayfish increased in importance and fish decreased in importance as fall progressed. All identifiable fishes were either leptomids, brook silversides, or Percina sp. Insects were much less important in the diet in late fall than during early fall. Insects were represented by members of Orthoptera, Diptera, Ephemeroptera, and Hymenoptera. Most insects were terrestrial forms. Zooplankters were entirely lacking in the diet during late fall while during early and mid fall two Daphnia, eight Bosmina, two Diaphanosoma, 16 unidentified cladocerans, and six copepods were recorded.

The above results suffer from a source of error that is common to seasonal food studies. Food digestion rates during the summer may be 5-6 times as fast as those during the winter (Molnar and Tolg, 1962). Frequency of feeding and mean diet weight are both biased by this source of error. Without detailed knowledge of digestion rates, comparison of winter and summer diets is somewhat artificial. This problem is further compounded by differential digestion rates for different prey organisms. Crayfish and many insects possess a thick cuticle that greatly retards digestion and allows identification of the organism even when severely fragmented. Other organisms, such as small fishes and some invertebrates, may undergo rapid digestion and lose their identity at an early stage of digestion. These problems could induce significant bias in assessing the relative importance assigned to different foods.

These limitations in mind, several conclusions regarding differences in diets of largemouth and spotted bass can be drawn. The most obvious difference is the heavier utilization of crayfish by spotted bass. The only instance

in which crayfish were not the most important item (gravimetrically) in the diet of adult spotted bass was males collected during the summer. Conversely, the only instance in which fish were not the most important item (gravimetrically) in the diet of adult largemouth bass was males collected during the spring. This tendency for largemouth bass to be more piscivorous than spotted bass has been reported by several authors (Finkelstein, 1960; Aggus, 1972). Whether this difference in diet represents active selection by the basses is difficult to assess. Dendy (1946) noted that in Norris Reservoir spotted bass selected cooler temperatures than largemouth bass. This thermal selection led to differences in the distribution of the two species. The differences in food habits noted above may thus be a reflection of habitat selection rather than prey selection per se.

Although several authors (Lambou, 1961; Snow, 1971; Taub, 1972) theorized that crayfish are highly vulnerable to predation by bass during warmer months, highest utilization of crayfish in Lake Fort Smith was noted during the fall and winter. A similar pattern was reported by Aggus (1972) in Bull Shoals Reservoir, Arkansas, who suggested that crayfish may serve primarily as a winter maintenance food and contribute to gamete production, but little to actual growth of black basses. The continued heavy utilization of crayfish by Lake Fort Smith spotted bass throughout the growth season indicates that in some instances crayfish may contribute to growth of black basses. In noting the abundance of crayfish in the winter diets of black basses Aggus explained "during warmer months, crayfish may be more active and better able to avoid predation in the rocky substrates. Reduced mobility of crayfish during cooler portions of the year, and decreases in abundance of other forage items may render them more vulnerable to predation by bass."

Lake Fort Smith spotted bass appear to support this hypothesis, but

largemouth bass show a pattern of crayfish utilization that would suggest that factors other than prey avoidance are operative. Largemouth bass fed on crayfish most heavily during spring and continued to feed on them throughout the remainder of the year. It is likely that during the spawning period largemouth bass moved into rockier areas, and that these areas supported greater numbers of crayfish. Thus, it is highly probably that the seasonal differences in crayfish utilization by spotted bass is due to prey avoidance while in largemouth bass it is dependent to a great extent upon habitat selection.

The basic dissimilarities in the diets of mature largemouth and spotted bass in Lake Fort Smith suggests that there is little competition between the species with regard to feeding. Spring was the only season during which there was an appreciable degree of similarity in the diets of the two species, and then only between the males. The similarities in food habits at this time is believed to be a reflection of habitat selection and behavior accompanying spawning. Immature individuals of both species were almost entirely piscivorous in their feeding and apparently compete to a large degree. The species of forage fishes utilized by immature largemouth and spotted bass were very similar in all seasons, further indicating competition between the two groups. Bluegill were important throughout the year and were supplemented by darters during the spring; shad, darters, and silversides during the summer; and silversides during the fall. The finding that trends in occurrence of forage fishes in the stomachs of black basses followed closely the spawning and post-spawning periods of each species of forage fish in Lake Fort Smith would indicate that black basses are opportunistic, rather than selective, in their feeding. Differences in the diets of males and females of each species during each season were slight except for largemouth bass during the

spring. Crayfish were present in nearly the same amounts as fishes in the diet of males while they were nearly absent from the diet of females. Thus, it appears that with regard to feeding there is a high degree of interspecific competition among the immature individuals of the two species, but almost no interspecific competition among the mature fishes. Instead, data would indicate that the greatest competition for food among mature black basses exists between sexes of the same species. A similar finding was reported by Ryan (1968), who stated that food preferences of spotted bass were not biased by sex. However, Ryan's conclusions that food preferences were not affected by time of year or size of fish are strongly refuted by this study.

Spotted bass were more insectivorous than largemouth bass. During the winter and spring the insects were mostly aquatic immature forms while during the summer and fall the majority were terrestrial forms. The heavier consumption of terrestrial insects would suggest that spotted bass forage more in the shallower littoral areas than does the largemouth bass. It is also possible that the species differ in their selection for, or exclusion of, insects in the diet.

A tendency for larger basses to feed on larger prey has been reported by several authors (Miller and Kramer, 1971; Smith and Page, 1969; Snow, 1971; Tarrant, 1960). Wright (1970) studying forage size preference of largemouth bass concluded that there was no significant correlation of size of bass and size of forage. In Lake Fort Smith larger basses consumed larger and a greater variety of organisms than smaller basses. This phenomenon can have a significant effect on the overall food and feeding habits of a species. Ivlev (1961) demonstrated the preference of predators in devouring foods of the largest possible size with morphological features imposing a limiting and optimum size of the principally utilized prey.

Thus, if an abundance of large forage is available, competition for food organisms between large and small fish may be insignificant. If, however, large organisms are not present in abundance, competition between large and small fish is greatly increased.

The heavy utilization of bluegill throughout the year by black basses of Lake Fort Smith may be indicative of poor forage condition for the basses. Although Ball (1948) found that bluegill were the staple food of largemouth bass in Third Sister Lake in Michigan even though several species of small minnows and darters were also abundant; Aggus (1972), Dendy (1946), and Lewis and Helms (1964) indicated that bluegill were not heavily utilized when other forage was abundant. The majority of the studies indicate that bluegill are much less favorable forage for black basses than many other fishes, particularly shad. An indication of the potential significance of shad as forage was their heavy utilization by black basses in the early summer in Lake Fort Smith when young shad were abundant. By late summer shad were uncommon and juvenile bluegill were the dominant forage fish in the reservoir (Table 2). Ivlev (1961) concluded that preferred foods may be selected until a minimum density is reached at which time there is a rather abrupt change to less desirable foods. It can be assumed that predation on bluegill by black basses would be reduced if suitable forage was available. One aspect of the life history of bluegill that enhances its status as a forage fish in Lake Fort Smith is that it spawns several months later than black basses and has a protracted spawning period lasting several months. This provides black basses with an abundance of young-of-the-year forage throughout the summer.

Threadfin shad (Dorosoma petenense) have been introduced into Lake Fort Smith by the Arkansas Game and Fish Commission several times in an attempt to provide better forage. Threadfin shad which have been intro-

duced into Beaver and Bull Shoals Reservoirs, Arkansas have multiple spawns (Kilambi and Baglin, 1969). This provides excellent forage throughout most of the year. Also, adult threadfin shad are small enough that they can be effectively cropped by black basses and are thus not as likely to overpopulate a body of water as gizzard shad. Data in Table 2 show the high standing crop of adult gizzard shad in Lake Fort Smith which are too large to serve as good forage for black basses. However, it appears that all attempts to establish threadfin shad in Lake Fort Smith have been unsuccessful. Strawn (1963) determined that threadfin shad die quickly at 5.0 C, but will survive the winter in a lake that does not go below 9.0 C (the minimum temperature for the winter 1971-1972 was 4.7 C recorded February 14, 1972. J. Carter, pers. comm.) and it is believed that the failure to establish threadfin shad in the reservoir was due to total winter kills.

DAILY FEEDING TRENDS

Three diel collections were made to gain information concerning changes in feeding intensity and food items utilized on a 24-hour basis. Summer was the only season during which adequate samples could be taken, and one collection was made each in June, July, and August. An attempt was made to obtain a sample of five fish of each species at four-hour intervals by electroshocking. Immediately after collection the fish were measured, weighed, and the stomachs excised to prevent further digestion. Feeding intensity values ($FI = \frac{w}{W} \times 100$ where w = weight of the food in grams, W = weight of the fish in grams) were computed for each fish. Feeding intensity values for each period were averaged for comparison with other periods.

The trend in feeding intensity was the same in both species. Peaks in feeding intensity occurred immediately preceding sunset and soon after sunrise. The lowest feeding intensity values were noted from midnight to

sunrise. Snow (1971) reported heavy feeding in the dusk and dawn hours by largemouth bass. The evening feeding peak was usually the larger of the two. Dubets (1954) found the greatest number of empty stomachs in largemouth bass to occur between 0200-0800 hours. This heavy feeding during crepuscular periods may have been due to several factors. The reduced light levels of dusk and dawn may have triggered the feeding response in Lake Fort Smith black basses, or the feeding may have been in response to prey behavior. Zooplankters commonly demonstrate diel migrations, and it could be expected that secondary consumers would respond to these actions. Since black basses of Lake Fort Smith are tertiary or quaternary consumers, their feeding habits would likely be affected by these migrations. These results tend to support the conclusion of Mraz et al. (1961) who stated that largemouth bass are sightfeeders and hunt for their food. The success of sport fishermen in catching black basses at night indicates that the basses do possess the ability, if not the propensity, to feed at night.

Sample size and nature of the food habits during the summer preclude any sweeping generalizations regarding differences in the types of foods consumed at different times of the day. However, the findings suggest that insects are utilized relatively more heavily at sunset than during any other time of the day. Since the majority of these insects were terrestrial, this may be in response to the black basses moving into shallower water in the evening to feed.

EFFECTS OF ENVIRONMENTAL FACTORS ON FEEDING

Seasonal variations in the feeding frequency and mean diet weight of black basses of Lake Fort Smith have been clearly shown. Throughout the year a number of physical and chemical factors fluctuate, many of which are re-

puted to have a direct influence on the biology of aquatic organisms. In an effort to elucidate the factors influencing the feeding biology of black basses, selected variables were analyzed with respect to the feeding frequency and mean diet weight of immature, male, and female populations of spotted and largemouth bass throughout the year by multiple regression analyses.

Using feeding frequency and mean diet weight of each sex or maturity group of each species as dependent variables, seven physical and chemical parameters were used as independent variables in multiple regression analyses. An attempt was made to use parameters that could easily be related to the physiology and behavior of fishes. With these objectives in mind, water temperature, dissolved oxygen, turbidity, hydrogen ion concentration, alkalinity, ammonia, and photoperiod were chosen as the factors to be investigated.

Physical and chemical data (Table 17) were supplied by Mr. John Carter and Mr. Forrest Payne, graduate students under contract with WRRC to monitor the data of Lake Fort Smith. They used the procedures of analyses of physical and chemical factors outlined in Colorimetric Procedures and Chemicals for Water and Wastewater Analysis.

Multiple regression analysis was performed with the stepdown option in order to reduce the number of independent variables to be considered in each instance. Stepdown was performed at the 0.80 level. The reduced models for feeding frequency and mean diet weight for male, female, and immature largemouth and spotted bass are listed in Tables 18 and 19.

Although the percent of variability accounted for in each of the tests was appreciable (44.4% to 92.4%) usually very few factors were significant at the 0.05 level. An exception was noted in relation to feeding frequency of male spotted bass where dissolved oxygen, ammonia, and water temperature

all significantly affecting feeding frequency.

There was a definite tendency for the independent variables to account for a larger percentage of the variability in frequency of feeding than for mean diet weight. It can be theorized that physical and chemical factors are instrumental in triggering the feeding response in black basses; but once feeding has commenced, the extent of feeding may be determined by such factors as prey density, predator interaction, degree of satiation, etc.

A higher degree of the variability in feeding of immature fish was accounted for than in either males or females of the same species, indicating that the feeding of immature fish was more closely related to physical and chemical factors. In more mature fish physiological factors such as spawning probably exerted an influence on feeding. Apparently very little has been written concerning the effect of spawning on the food habits of black basses. Snow (1971) stated that since a higher percentage of males were caught in June than in any other month male bass were more susceptible to capture at that time due to their pugnacious behavior of guarding the spawning nest. He concluded that this would be reflected in food habits. More direct evidence of the effect of spawning on food habits of fishes has been shown for other species. Spawning has been shown to cause both quantitative and qualitative changes in the food habits of white bass (Olmsted and Kilambi, 1969). Thus, it is feasible that as fish age physiological factors become increasingly important in the control of food and feeding habits.

There were differences between the two species with regard to the factors influencing food and feeding habits. While dissolved oxygen and temperature were the most important factors affecting spotted bass, turbidity and pH appeared to be the significant factors for largemouth bass. Mraz et al. (1961) stated that largemouth bass are sight feeders. It would be expected

that increased turbidity would exert an inhibitory effect on the feeding of largemouth bass.

It is somewhat surprising that the physical and chemical factors considered accounted for such a large portion of the variation in feeding of black basses. Similar analyses performed on white bass in Beaver Reservoir accounted for only 9.0% of the annual variation in feeding intensity (Olmsted and Kilambi, 1971). There are, however, several differences in the life histories of these fishes that may account for this large difference. White bass of Beaver Reservoir preyed heavily on schooling shad. When white bass encountered these schooling shad they gorged themselves and then would often go considerable periods of time without feeding. This heavy feeding upon chance encounter made it extremely difficult to correlate feeding with prevailing physical and chemical factors. Lake Fort Smith black basses fed primarily on small centrarchids and crayfish that were common in the littoral zone. This type of feeding is much more subject to environmental conditions and does not rely so heavily on chance encounters and is thus more easily correlated with environmental factors. Another aspect of the life histories that differed greatly was spawning behavior. White bass were potamodromous and remained in the streams for several months, which significantly altered their food habits. Lake Fort Smith black basses, on the other hand, spawned in the shallow areas of the reservoir. This also contributed to the high R^2 values obtained during the present study. A final factor that could have caused high R^2 values is that Lake Fort Smith is an older, stabilized reservoir. Beaver Reservoir was a young reservoir and had not yet reached a stabilized condition at the time of the white bass study. The reservoir was thus subject to wide variation in nutrient input, flow rate, etc. These factors all made it difficult to relate white bass feeding with environmental

factors. Results of this study suggest that the models are more realistic for stabilized reservoirs that represent simpler ecosystems.

Therefore, elucidation of influences of environmental factors on the feeding biology of fishes must be determined for each species, and most likely for separate bodies of water. It is highly probably that a completely different set of environmental factors are important in the feeding biology of these two species at the northern extremes of their ranges.

Spawning and Fecundity

TIME OF SPAWNING

Time of spawning of Lake Fort Smith black basses was determined from field observations, condition of gonads, and gonado-somatic indices. Field observations of spawning activity were severely hampered by high turbidity. With the approach of spawning time mature basses moved into shallower areas of the reservoir, resulting in increased collecting success. In addition, coloration and general condition of the fishes were suggestive of spawning time. Based on field observations the peak of spawning activity during 1972 occurred approximately the first week of May for both species of black bass.

Results of observations of gonads corroborate conclusions based on field observations. In comparison to some centrarchids, the spawning periods of largemouth and spotted bass appear to be of rather short duration. Spawning usually began in the latter part of April or first part of May and was essentially complete by the end of May. No ripe females were collected the first week of June. Several authors have stated that spotted bass spawn earlier than largemouth bass. Bennett (1965) found that spotted bass spawn at 18 C and largemouth bass at 19 C. Towery (1963 and 1964) observed a greater

difference between the species in spawning times and concluded that spotted bass spawn at a temperature of 17 C and largemouth bass at a temperature of 20 C. In Lake Fort Smith both species were participating in active spawning at 15 C.

The possibility of black basses spawning more than once in any particular year has received a great deal of attention but still remains an unsettled question. James (1946) believed that largemouth bass spawn the entire complement of eggs at one time while Stranahan (1908) stated that largemouth bass were capable of spawning several times during the spring and early summer. Thus, it appears that the occurrence of multiple spawning of black basses is dependent upon local conditions. In Lake Fort Smith there was no evidence to suggest the occurrence of multiple spawning in either largemouth or spotted bass. During examination of gonads no ripe females were noted after May. Further evidence will be presented later supporting a single spawning period for Lake Fort Smith black basses.

A gonado-somatic index of the form

$$GSI = \frac{WG}{WF} \times 100$$

was computed for each individual where, WF = weight of the fish in grams, and WG = weight of the gonads in grams. Results of analysis of gonado-somatic indices (Figures 5 and 6) in relation to time of spawning agree closely with field observations and examination of gonads. Although examination of gonads indicated that only 2% of the one-year-old largemouth bass and no one-year-old spotted bass were mature, analysis of GSI suggests that there is at least a degree of seasonal development in the gonads of yearling black basses in Lake Fort Smith. If the drop in value of GSI during the summer is not associated with spawning it is evidently the result of either

arrested growth or partial resorption of the gonads during the summer. It is of interest to note that the maximum value of GSI for one-year-old large-mouth females occurred during August and September, approximately four months after peak spawning activity of older bass. Lake temperatures at this time were 24.8-27.4 C, much higher than temperatures to which black bass embryos are usually exposed. In addition, no larval bass were collected during August or September. Thus, it is reasonable to assume that gonadal development of yearling black basses in Lake Fort Smith is not related to spawning during that season.

Maximum GSI values for males tended to occur slightly later in the spawning season than females. This may be due to sampling error or to the fact that the weight of gametes extruded by males is small in comparison to that of females. Also, Stranahan (1908), Beeman (1906) and numerous other authors have observed that males often father more than one nest. Thus, males may retain a quantity of milt after their first spawning which would tend to protract the peak of the GSI.

It can be noted from Figures 5 and 6 that the maximum GSI increases with each age group. This is attributable to two factors. First, the proportion of mature individuals increases in each age group for the age groups represented. With fewer immature individuals, the resulting GSI values are appreciably higher. Also, it appears that older fish invest a larger proportion of their annual weight gain into the development of gonads. The sample size was unsuitable for correlation analysis, but visual inspection suggests a positive relationship between size of fish and maximum GSI. This would appear feasible when one considers the basic assumptions concerning the growth of fishes. Growth in fishes is generally accepted to be indeterminate (Brown, 1957), but in older fishes the annual increment

becomes so small that it is valid to consider growth to be asymptotic. If feeding and metabolic efficiency remain relatively constant as the fish approaches its ultimate length, a larger proportion of the annual production can be invested in gamete production. Most likely, however, in very old fish feeding and metabolic efficiency would decrease thus limiting the maximum attainable GSI.

GSI values for Lake Fort Smith spotted bass were compared with Vogele's (1973) GSI values for spotted bass of Bull Shoals Reservoir and found to be appreciably smaller. When this is considered in addition to the poor growth and condition of Lake Fort Smith black basses, the poor nature of this reservoir for production of black basses becomes even more apparent.

SPAWNING SITES

The high turbidity of Lake Fort Smith during the spring prevented thorough analysis of spawning sites of largemouth and spotted bass. Observations were recorded as to collection site of black basses during the spawning seasons and the areas were later analyzed when transparency increased.

The spawning substrate requirements of largemouth bass appear to be much more general than those for spotted bass. Largemouth bass apparently spawn in nearly all parts of the reservoir and over both muddy and rocky substrates. Spotted bass on the other hand, demonstrated a preference for rocky or gravely substrates for spawning. Thus, the majority of the spawning spotted bass were collected in the lower one-half of the reservoir.

The importance of natural protection in selection of spawning sites is well documented (Carr, 1942; Hunsaker and Crawford, 1964). Carr (1942) concluded that an open passageway from the nest was the single most important factor in nest selection of largemouth bass. Transparency is often important

in determining the depth of nesting (Vogele, pers. comm.). Thus nest site selection by black basses is a complex phenomenon dependent not only on substrate, but on a number of physical and biotic parameters.

DISTRIBUTION OF OVA

Results of the Kolmogorov-Smirnov analyses of distribution of ova within and between ovaries of spotted bass showed that only two of the 24 combinations tested were significant at the 0.01 level. Ova diameters from the inner section of the posterior region of the right ovary were involved in both significant comparisons. It is highly probable that the sample of ova measured for this location did not accurately reflect the true ova diameter distribution and it was concluded that ova of spotted bass are homogeneously distributed within and between the ovaries. With the exception of immature ova being more common in the outer area of the ovary and mature ova more common near the lumen of the ovary, ova have been found to be homogeneously distributed in the ovaries of Bull Shoals spotted bass (Vogele, pers. comm.). Thus, for both largemouth and spotted bass a pie-shape wedge was taken from a disc removed from near the middle of the largest ovary in estimating the fecundity of a particular fish. Ova diameter frequencies were plotted and the largest normal curve extracted by probability paper techniques. The number of ova contained within this normal curve was substituted into the following equation to estimate the fecundity of the fish.

$$\frac{\text{Number of ova in subsample}}{\text{Weight of subsample}} = \frac{\text{Total number of ova}}{\text{Total weight of ovaries}}$$

Since selected females from January through May were used in fecundity estimates, it is not realistic to use all ova measurements in estimating size

of ova at maturity. When only those frequencies from May fish were considered it was found that the smallest mature ova in largemouth bass averaged 1.25 mm and the smallest mature ova in spotted bass averaged 1.70 mm. Kelley (1962), working in Maine, considered all largemouth bass ova exceeding 0.75 mm in diameter as mature. Nothing has been written concerning average size of spotted bass eggs at maturity. The average values for Lake Fort Smith largemouth and spotted bass are presented only for comparative purposes since results of this study support Vogele's (1973) claim that the size of smallest mature ova varies from individual to individual and must be determined for each fish separately.

FECUNDITY OF LARGEMOUTH AND SPOTTED BASS

Fecundity is here defined as the total number of ova contained in the last normal curve of ova diameter frequency distributions from both ovaries of a female in one season. Whether this number represents the actual deposition complement is an unanswered question. Vogele (pers. comm.) states that his data and observations would indicate that at best this method yields a liberal estimate of the deposition complement.

Vital statistics of the individuals used in fecundity estimates are given in Table 20. Fecundity estimates of largemouth bass ranged from 2942 to 30,709 eggs per female with a mean of 10,464. Fecundity estimates for spotted bass ranged from 1727 to 9552 eggs per female with a mean of 4304.

The fecundity estimates for largemouth bass reported here compare favorably with those of previous studies. Carlander (1953) reported in his review that the fecundity ranged from 2000 to 109,000 eggs. The range of fecundity of Maine largemouth bass was reported to be 5000 to 82,000 eggs (Kelley, 1962). The Lake Fort Smith estimates fall at the lower end of the

previous studies for two reasons. First, the methods used during this study excluded inclusion of ova considered mature in some earlier studies. For example, if all ova exceeding 0.75 mm would have been considered as in Kelley's (1962) study, results would be very similar to those he reported. Second, in view of the poor growth and condition, the Lake Fort Smith largemouth bass would likely be less fecund than largemouth bass of other waters. There has been little previous published work pertaining to fecundity of spotted bass. Towery (1964) stated that Mississippi spotted bass produced 6000 to 47,000 eggs, but he did not distinguish between mature and immature eggs and it is thus difficult to draw comparisons. It appears that spotted bass of Bull Shoals Reservoir, Arkansas are nearly twice as fecund as Lake Fort Smith spotted bass. However, the fish examined by Vogele were much larger than the Lake Fort Smith specimens, and this could account for the discrepancy.

There was considerable variation in the fecundity of individuals of the same species. The ranges of age, length, and weight of individuals in the samples suggested that it would be informative to investigate the relationship of these variables to the fecundity of each species.

As a measure of the intensity of their relation to fecundity, correlation coefficients of fecundity with total length, standard length, weight, age, and condition factor were computed for each species (Table 21). All factors were positively correlated with fecundity, and all correlations except fecundity with condition factor of spotted bass were significant at the 0.01 level.

The variations in fecundity as related to age, weight, and length were computed. In each instance the data were fitted by step up polynomial fit analysis. The final equations are

Largemouth

$$\text{Length: } Y = 335638.52 - 2920.46 X + 8.23 X^2 - 0.01 X^3$$

$$\text{Weight: } Y = 14112.57 - 72.61 X + 0.18 X^2 + 0.01 X^3 + 0.01 X^4$$

$$\text{Age: } Y = -5919.78 + 4680.96 X$$

Spotted Bass

$$\text{Length: } Y = 30482.31 - 233.26 X + 0.48 X^2$$

$$\text{Weight: } Y = -1179.71 + 14.39 X$$

$$\text{Age: } Y = 134509.86 - 97643.77 X + 23113.25 X^2 - 1722.63 X^3$$

These equations are graphically depicted in Figures 7 and 8. The curves tend to show a common trend where there is an initial slight decrease in fecundity with increased length, weight, and age followed by a phase with a sharp increase in fecundity with increases in parameters of size. Fecundity in older, larger fish approaches an asymptotic value or shows a slight decrease.

These results agree very closely with those of Kelley (1962) for largemouth bass of Maine. He found that fecundity decreased sharply in fish exceeding seven years of age. The decrease in fecundity of older fish in Lake Fort Smith was not as marked as in Kelley's study. This may be partially due to the fact that the oldest fish examined in this study was two years younger than Kelley's oldest fish. In an attempt to account for the decrease in fecundity with older age Orton (1929) suggested that the physiological strain associated with spawning increases with increasing age. He further suggested that death might result if the rate of egg production did not decrease during senescence.

Regressing fecundity on age, length, and weight Kelley (1962) found the low point to occur in about the first third of the curves. In an attempt to explain this phenomenon he hypothesized that it may have resulted from the small numbers of fish sampled or from an unsuspected attribute of the species.

Either of these explanations may apply to the occurrence of this phenomenon in Lake Fort Smith black basses, but it seems that there is another possibility that has merit. The youngest individuals examined may have belonged to age groups in which there were also immature individuals. Since maturity in Lake Fort Smith black basses is related to size as well as age, this would imply that the largest individuals of that age group were examined and the smaller individuals excluded because of immaturity. In older fish no such selection was exercised. Thus, if larger individuals of an age group are more fecund than smaller members a phenomenon such as that occurring in the first portion of the curves could be produced. In view of the lack of information concerning fecundity of black basses and factors influencing it, much work needs to be done before questions such as this can be resolved.

ANNUAL CYCLES IN FREQUENCY DISTRIBUTION OF OVA DIAMETERS

An indication of time of greatest gamete production and possibility of multiple spawns within a species can be gained by monitoring annual cycles in the frequency distribution of ova diameters. Since the mean size of the eggs of largemouth bass increases with the weight of the female (Merriner, 1971), an attempt was made to monitor ova diameters throughout the year of fish of approximately equal size.

The ova diameter frequencies through the months for largemouth and spotted bass are shown in Figures 9 and 10. Although spotted bass eggs were larger than largemouth bass eggs, the pattern of seasonal development was similar for the two species. June ovaries were characterized by large, oil filled ova in the process of resorption. The ovigerous tissue was tough and invested with a great deal of connective tissue and when it was attempted to tease the ova out they were either punctured or contained within a

gelatinous mass. This made measurements of June ova very difficult, and a large enough number could not be measured to detect modes in ova distributions. During July and August (and also September for largemouth bass) all ova were less than 0.4 mm in diameter. Ova enlargement began in late fall and by January or February a mode of mature ova were developing. It appears that the ova that are destined to be mature can be delineated by December or January, but a great deal of development and enlargement occurs during April and May. The lack of ova exceeding 0.4 mm in any summer fish examined would appear to preclude the possibility of multiple spawns in Lake Fort Smith black basses after June.

CONCLUSIONS

The ecological life histories of largemouth and spotted bass in 212 hectare Lake Fort Smith, Arkansas were compared on the basis of data collected from 327 largemouth bass and 394 spotted bass.

Cove rotenone sampling revealed the lack of suitable forage fishes in Lake Fort Smith. Although gizzard shad were abundant, the majority were adult and too large to serve as forage for black basses. Threadfin shad, a preferred food of black basses have been introduced into the reservoir on several occasions, but apparently have not become established due to winter kills. The most abundant fish of suitable forage size were juvenile sunfishes--particularly bluegill.

Largemouth bass are slightly more than twice as abundant as spotted bass in Lake Fort Smith. However, indications are that spotted bass have increased greatly in relative abundance during the last 15 years. Whether this increase in abundance of spotted bass is related to impoundment of Lake Sheppard Springs is undetermined.

Black basses are highly segregative during some times of the year. While largemouth bass are common in areas with mud bottoms and abundant emergent vegetation, spotted bass are seldom found under these conditions. Continued sedimentation in the future will undoubtedly favor the largemouth bass.

Annuli are formed between June and late summer. Younger fish formed annuli earlier and during a shorter period of time than older fish. Feeding and spawning, both of which are somewhat temperature dependent, are the chief factors affecting time of annulus formation. Continued feeding and slow growth during the winter caused poorly

defined annuli.

Regressions were calculated for body length-scale length relation to be used in back calculations. Males and females of each species demonstrated homogeneity in body length-scale length, but mature and immature fish differed significantly.

Back calculated lengths were similar to observed values. There was no difference in the growth of sexes of spotted bass, but male largemouth bass grew significantly faster than females. The period of active growth was longer for spotted bass than largemouth bass, but largemouth grew at a faster rate within that period. This period of active growth occurred later and was of shorter duration with increasing age. It appears that temperature is the primary factor controlling the length of the period of active growth in young fish, but physiological factors prevail in older fish.

The growth of Lake Fort Smith black basses is slow relative to growth in other waters. Condition of black basses in the reservoir approaches the poorest ever reported. Local conditions are of greater importance in determining growth rates and condition of black basses than length of the growing season.

All 3-year-old largemouth bass were mature, but it was not until their fourth year that all spotted bass were mature. The sex ratio did not differ significantly from a 1:1 ratio in any age group indicating that there was no differential mortality between sexes in either species. The instantaneous mortality rates (i) were .927 (annual survival = 39.5%) and .915 (annual survival = 39.9%) for largemouth and spotted bass, respectively.

Crayfish were the major food item in the spotted bass diet,

while fishes dominated the diet of largemouth bass. There was very little interspecific competition between adults for food, but intraspecific competition between the sexes was intense. Interspecific competition between immature basses was high as young of both species were highly piscivorous.

Bluegill were the major forage fish for both species. There was a high degree of seasonal variation in the forage fishes utilized, but this was believed to be a reflection of relative abundance of the forage fishes rather than selection by the basses.

Environmental factors had a great influence on the feeding of black basses, particularly immature individuals. Indications are that dissolved oxygen and temperature are important factors inhibiting feeding of spotted bass while turbidity greatly inhibits the feeding of largemouth bass. It appears that environmental factors are important in triggering feeding in black basses, but once feeding has commenced intensity is governed primarily by biological factors.

The peak of spawning of black basses of Lake Fort Smith occurred in May, at a water temperature of 15 C. The spawning substrate requirements of spotted bass appeared to be more restricted than those of largemouth bass. While largemouth bass spawned over vegetation, mud, and gravel, spotted bass appeared to utilize only rocky areas. No difference between the species with regard to time of spawning could be detected. There was no indication that either largemouth or spotted bass of Lake Fort Smith spawn more than once a year.

Largemouth bass produced over twice as many eggs as spotted bass. Fecundity estimates of largemouth bass ranged from 2942 to 30,709 eggs per female with a mean of 10,464. Fecundity estimates for spotted

bass ranged from 1727 to 9552 eggs per female with a mean of 4304. Total length, standard length, weight, age, and condition factor were all significantly correlated with fecundity in both largemouth and spotted bass.

Age and growth, condition, and fecundity all indicate that Lake Fort Smith is suboptimum habitat for both largemouth and spotted bass. The fact that the reservoir serves as a water supply limits the management techniques that can be applied to rectify the situation. Probably the greatest reason for poor production in Lake Fort Smith is the infertility of the reservoir. However, artificial fertilization is highly undesirable because of the subsequent threat of noxious blue green algae, vegetation, and overall depression of water quality.

Another management technique that would be of considerable value is winter drawdown. This would allow aeration of bottom soils, help control vegetation, and concentrate the small sunfishes for higher predation. As drawdown continued sunfishes would be forced out of the vegetation and other cover and be more susceptible to predation. Also, the rising water levels during the spring would be conducive to formation of strong year classes of game fishes. However, since Lake Fort Smith is a water supply reservoir it would not be advisable to perform drastic drawdowns.

Finally, introduction of a good forage fish would enhance the production of black basses. A good forage fish would be one such as threadfin shad which are primary or secondary consumers, attain a small maximum size, and are fecund. However, unlike threadfin shad, it should be able to endure the harsh winter conditions of Lake Fort Smith.

There are means of improving the fishery of Lake Fort Smith, but as long as it remains a water supply reservoir the local anglers must accept mediocre fishing or fish elsewhere.

TABLES**Ichthyology Phase**

Table 2 Standing crops of fish collected in 2.5 hectare (6.2 acre) July rotenone sample from Lake Fort Smith, Arkansas

Species	Maturity	Number	Wt. Kilograms	Kg/Hectare	Pounds/Acre
<u>Dorosoma cepedianum</u>	Adult	1054	152.128	60.860	54.050
<u>Dorosoma cepedianum</u>	Intermediate	117	4.990	1.995	1.772
<u>Dorosoma cepedianum</u>	Juvenile	207	0.185	0.073	0.065
<u>Ictalurus punctatus</u>	Adult	34	33.593	13.439	11.935
<u>Ictalurus punctatus</u>	Intermediate	1	0.036	--	--
<u>Fylodictis olivaris</u>	Adult	1	0.614	0.245	0.218
<u>Fylodictis olivaris</u>	Intermediate	1	0.112	0.044	0.039
<u>Fylodictis olivaris</u>	Juvenile	2	0.081	0.032	0.028
<u>Ictalurus natalis</u>	Adult	2	0.275	0.110	0.098
<u>Ictalurus natalis</u>	Intermediate	15	0.888	0.355	0.315
<u>Ictalurus natalis</u>	Juvenile	20	0.166	0.066	0.059
<u>Micropterus salmoides</u>	Adult	66	12.785	5.114	4.542
<u>Micropterus salmoides</u>	Intermediate	34	1.174	0.470	0.417
<u>Micropterus salmoides</u>	Juvenile	224	0.244	0.097	0.087
<u>Micropterus punctulatus</u>	Juvenile	1	0.002	--	--
<u>Lepomis gulosus</u>	Adult	341	24.990	9.997	8.878
<u>Lepomis gulosus</u>	Intermediate	423	5.633	2.253	2.001
<u>Lepomis gulosus</u>	Juvenile	895	3.449	1.379	1.225
<u>Pomoxis annularis</u>	Adult	30	5.770	2.308	2.050
<u>Pomoxis annularis</u>	Intermediate	68	0.953	0.382	0.339
<u>Pomoxis nigromaculatus</u>	Adult	13	2.523	1.009	0.896
<u>Pomoxis nigromaculatus</u>	Intermediate	16	0.144	0.057	0.051
<u>Pomoxis nigromaculatus</u>	Juvenile	5	0.042	0.017	0.015
<u>Lepomis macrochirus</u>	Adult	210	11.391	4.556	4.047
<u>Lepomis macrochirus</u>	Juvenile & Intermediate	14586	23.800	9.520	8.455
<u>Lepomis cyanellus</u>	Adult	42	1.685	0.674	0.599
<u>Lepomis cyanellus</u>	Intermediate	103	1.074	0.430	0.382
<u>Lepomis cyanellus</u>	Juvenile	870	1.249	0.500	0.444

Species	Maturity	Number	Wt. Kilograms	Kg/Hectare	Pounds/Acre
<u>Lepomis megalotis</u>	Adult	7	0.314	0.126	0.112
<u>Lepomis megalotis</u>	Intermediate	4	0.045	0.018	0.016
<u>Lepomis megalotis</u>	Juvenile	115	0.341	0.136	0.121
<u>Lepomis microlophus</u>	Adult	44	3.893	1.557	1.383
<u>Lepomis microlophus</u>	Intermediate	66	1.316	0.547	0.486
<u>Lepomis microlophus</u>	Juvenile	154	1.059	0.423	0.376
<u>Stizostedion vitreum</u>	Intermediate	1	0.140	0.056	0.050
<u>Percina capelandi</u>	Adult	2	0.002	--	--
<u>Percina caprodes</u>	Intermediate	12	0.014	0.006	0.005
<u>Pimephales notatus</u>	Intermediate	119	0.154	0.062	0.055
<u>Fundulus olivaceus</u>	Intermediate	28	0.039	0.015	0.013
<u>Notemigonus chrysoleucas</u>	Intermediate	3	0.024	0.010	0.009
<u>Notemigonus chrysoleucas</u>	Adult	1	0.186	0.074	0.066
<u>Moxostoma erythrurum</u>	Intermediate	1	0.033	0.014	0.012
<u>Lepisosteus osseus</u>	Adult	1	1.453	0.580	0.516
<u>Labidesthes sicculus</u>	Adult	1	0.002	--	--
<u>Gambusia affinis</u>	Adult	28	0.016	0.007	0.006
Total		19,996	299.005	119.598	106.215

Table 3. Population estimations of black bass^{bs} of Lake Fort Smith and associated 95% confidence intervals (11821 m shoreline).

Species	Schnabel estimate	Modified Schnabel estimate	Schumacher estimate
Largemouth & Spotted bass			
Estimate	2069	1989	1799
95% Confidence	780-3299	1481-2976	1402-2868
Spotted Bass			
Estimate	638	567	502
95% Confidence	385-1869	354-1283	362-2169
Largemouth Bass			
Estimate	1414	1336	1232
95% Confidence	977-2561	943-2220	953-1739

Table 4 . Relative abundance of largemouth and spotted bass in four areas of Lake Fort Smith.

	I	Area II	III	IV
Largemouth Bass	14	49	20	54
Spotted Bass	6	24	24	33
Ratio of Largemouth Bass to Spotted Bass	2.33	2.04	0.83	1.64

Table 5 Total length-scale radius relationships of male, female, and immature spotted and largemouth bass

Largemouth Bass

Immatures $L = -27.4389 + 6.7298 S + 0.1406 S^2 + 0.0016 S^3 - 0.0001 S^4$

Males $L = 111.4464 + 0.7047 S + 0.0041 S^2$

Females $L = 45.9163 + 1.8040 S$

Spotted Bass

Immatures $L = 11.0183 + 2.4805 S - 0.0069 S^2$

Males $L = 63.9906 + 1.4944 S$

Females $L = 57.6223 + 1.5604 S$

Table 6 . Age composition (%) of spotted and largemouth bass in Lake Fort Smith

Age Group	Spotted Bass	Largemouth Bass
0 ⁺	12.66	16.03
1 ⁺	30.87	34.29
2 ⁺	27.97	29.49
3 ⁺	17.94	14.42
4 ⁺	7.39	4.17
5 ⁺	2.37	0.64
6 ⁺	0.79	0.32
7 ⁺	0.00	0.62

Table 7. Average calculated growth rate of male and female largemouth bass

		<u>Males</u>					
		<u>Total length (mm) at each annulus</u>					
Age							
Group	Number	1	2	3	4	5	6
1	21	163.1					
2	46	160.7	240.5				
3	23	154.9	236.7	296.8			
4	5	164.1	262.2	324.0	359.6		
5	1	157.0	272.7	319.6	382.8	417.1	
6	1	172.2	272.7	329.6	366.2	417.1	465.8
Weighted							
mean		160.1	241.6	303.2	366.2	417.1	465.8

		<u>Females</u>						
		<u>Total length (mm) at each annulus</u>						
Age								
Group	Number	1	2	3	4	5	6	7
1	26	141.9						
2	46	139.5	243.9					
3	22	135.1	240.4	307.7				
4	8	125.7	267.4	327.1	363.4			
5	1	109.1	181.2	253.4	280.4	329.2		
6	0	0.0	0.0	0.0	0.0	0.0	0.0	
7	2	140.6	226.3	298.5	348.1	393.2	425.7	451.8
Weighted								
mean		137.8	244.0	310.2	353.1	371.8	425.7	451.8

Table 8. Average calculated growth rate of male and female spotted bass

		<u>Males</u>					
		Total length at each annulus (mm)					
Age Group	Number	1	2	3	4	5	6
1	19	141.8					
2	49	128.6	205.6				
3	36	127.7	197.5	259.6			
4	12	135.8	206.6	248.9	286.0		
5	4	157.4	212.7	253.4	294.9	318.0	
6	11	113.3	222.3	261.3	292.6	333.0	353.9
Weighted mean		131.9	203.3	256.7	288.5	321.0	353.9

		<u>Females</u>					
		Total length at each annulus (mm)					
Age Group	Number	1	2	3	4	5	6
1	21	128.5					
2	42	124.0	201.1				
3	32	128.3	200.0	266.0			
4	16	136.2	214.5	261.9	300.2		
5	5	144.7	209.0	253.9	294.5	324.1	
6	2	113.0	186.4	227.7	268.3	305.7	331.5
Weighted mean		128.3	203.1	262.3	296.2	318.9	331.5

Table 9 . Monthly growth rates of spotted bass by age-groups.

Age of Fish		Month of Year											
		1	2	3	4	5	6	7	8	9	10	11	12
0	Average length	--	--	--	--	--	31.5	52.1	74.9	94.8	101.9	112.0	97.0
	Number of fish	--	--	--	--	--	6	11	8	10	13	1	3
1	Average length	105.0	117.4	94.0	111.9	111.3	118.9	152.3	169.6	183.9	209.5	184.2	211.4
	Number of fish	1	5	1	15	14	14	11	9	14	14	14	5
2	Average length	--	198.2	191.5	198.5	203.2	194.8	205.6	233.3	257.3	263.8	259.4	280.1
	Number of fish	--	5	6	8	16	9	9	11	11	17	7	7
3	Average length	276.4	291.4	284.9	272.8	270.4	264.6	262.9	285.4	321.5	312.5	295.0	315.6
	Number of fish	5	8	7	8	12	5	8	5	2	4	1	3
4	Average length	328.3	307.0	312.0	310.0	309.0	--	320.3	362.0	--	343.0	305	329.3
	Number of fish	3	7	3	2	1	--	4	1	--	3	1	3
5	Average length	--	345.6	370.0	357.5	350	--	--	--	--	--	346.0	334.0
	Number of fish	--	3	1	2	1	--	--	--	--	--	1	1
6	Average length	--	370.0	--	--	--	--	--	--	--	--	--	385.0
	Number of fish	--	1	--	--	--	--	--	--	--	--	--	2

Table 10. Monthly growth rates of largemouth bass by age-groups.

Age of Fish		Month of Year											
		1	2	3	4	5	6	7	8	9	10	11	12
0	Average length	--	--	--	--	--	40.0	68.6	99.7	117.4	127.4	--	134.9
	Number of fish	--	--	--	--	--	2	17	3	11	7	--	10
1	Average length	138.7	134.2	149.4	143.6	157.0	152.3	193.4	222.5	232.1	227.5	227.5	247.5
	Number of fish	15	5	8	12	11	6	11	8	11	2	4	14
2	Average length	253.3	251.6	248.0	250.0	252.9	247.3	275.9	289.6	283.7	285.6	314.0	294.5
	Number of fish	3	3	8	14	13	4	7	7	15	7	5	6
3	Average length	303.0	311.8	304.3	291.8	310.4	306.0	307	341.5	--	341.0	349.0	--
	Number of fish	4	5	9	5	12	4	11	2	--	2	1	--
4	Average length	363.5	396.3	327.0	348.0	362.5	--	436.0	--	--	--	--	--
	Number of fish	2	3	1	4	2	--	1	--	--	--	--	--
5	Average length	--	--	--	--	--	--	466.0	--	470.0	--	--	--
	Number of fish	--	--	--	--	--	--	1	--	1	--	--	--
6	Average length	--	--	--	501.0	--	--	--	--	--	--	--	--
	Number of fish	--	--	--	1	--	--	--	--	--	--	--	--
7	Average length	--	--	--	523.0	520.0	--	--	--	--	--	--	--
	Number of fish	--	--	--	1	1	--	--	--	--	--	--	--

Table 11. Comparison of Growth Attained by Largemouth Bass in Different Waters.

Locality and Reference	Calculated length in mm at each annulus														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lake Fort Smith, AR (Present Study)	138	244	310	353	372	426	452								
Lake Fort Smith, AR (Strawn, 1961b)	99	194	257	305	349	394	440								
Center Hill Reservoir TN (Hargis, 1965)	160	295	365	427	451	476									
Claytor Lake, VA (Rosebery, 1950)	114	257	345	399	427	452									
Brown's Lake, WI (Mraz and Threinen, 1955)	91	170	229	272	305	345	412	452	467	478	498	521	510		
Quabbin Reservoir, MA (M ^C Caig and Mullan, 1960)	103	234	325	381	417	445	467	478	489						
Fort Gibson, Reservoir, OK (Houser, 1958)	145	259	335	412	478	518	559								
Oklahoma Average (Jenkins and Hall, 1953)	140	246	318	379	434	472	506	531	574						
Wisconsin (Bennett, 1937)	84	188	267	318	356	384	414	442	460	475	495	506	513	523	533
Beaver Reservoir, AR (Bryant and Houser, 1971)	152	277	333	396	462	474									

Table 12 . Comparison of Growth Attained by Spotted Bass in Different Waters.

Locality and Reference	Calculated length in mm at each annulus						
	1	2	3	4	5	6	7
Lake Fort Smith, AR (Present Study)	100	200	263	295	317	331	
Lake Fort Smith, AR (Strawn, 1961b)	66	150	233	277	318	398	
Center Hill Reservoir, TN (Hargis, 1965)	170	264	352	406	422		
Claytor Lake, VA (Rosebery, 1950)	79	178	272	333	384	409	455
Norris Reservoir, TN (Eschmeyer, 1937)	155	292	356	429			
Norris Reservoir, TN (Stroud, 1948)	114	259	333	386	401		
Illinois River, OK (Leonard and Jenkins, 1952)	114	193	252	307	345		
Grand Lake, OK (Jenkins, 1953)	104	213	300	356	396	419	

Table 13. Coefficients of condition for each age group of immature, male, and female largemouth and spotted bass.

Largemouth Bass			
Age-Group	Immature	Male	Female
1 ⁺	1.08	--	--
2 ⁺	1.09	1.12	1.13
3 ⁺	--	1.16	1.17
4 ⁺	--	1.19	1.20
5 ⁺	--	1.21	1.21
6 ⁺	--	1.22	1.23
7 ⁺	--	--	1.24

Spotted Bass			
Age-Group	Immature	Male	Female
1 ⁺	1.07	--	--
2 ⁺	1.07	1.12	1.11
3 ⁺	--	1.15	1.16
4 ⁺	--	1.16	1.18
5 ⁺	--	1.18	1.19
6 ⁺	--	1.19	1.20

Table 14. Condition coefficients of largemouth bass of Lake Fort Smith as compared with largemouth of the same and other waters

Location	Total Length	K(TL)	Source
Lake Fort Smith, AR	30-100	1.11	Present Study
	101-200	1.12	
	201-300	1.14	
	301-400	1.15	
	401-500	1.16	
Lake Fort Smith, AR	71-544	1.21	Cole, Trenary, and Finkelstein, 1958
Alabama	51	1.56	Swingle, 1965
	76-254	1.27	
	279-406	1.39	
	432-533	1.51	
Spavinaw Lake, OK	--	1.38	Jackson, 1954
Lake Carl Blackwell, OK	--	1.24-1.59	Zweiacker, 1972
Clear Lake, IA	51-530	1.62	Thompson, 1965
Ohio	--	1.66	Roach, 1948

Table .15. Condition coefficients of spotted bass of Lake Fort Smith as compared with spotted bass of the same and other waters

<u>Location</u>	<u>Total Length</u>	<u>K(TL)</u>	<u>Source</u>
Lake Fort Smith, AR	35-100	1.04	Present Study
	101-200	1.10	
	201-300	1.15	
	301-385	1.17	
Louisiana	25-295	1.47	Viosca, 1952
Alabama	150-280	1.15	Swingle, 1965

Table 16. Classification of maturity stages of largemouth and spotted bass.

Stage	Classification	Diagnostics
I	Immature	Young individuals which have not yet engaged in reproduction, transparent gonads very small and products have not yet begun developing.
II	Developing	Gonads are opaque and increasing rapidly in size. Eggs are granular in appearance to naked eye.
III	Maturity	Sexual products are mature, gonads are near maximum weight but products are not extruded under pressure.
IV	Ripe	Sexual products are extruded when light pressure is applied to abdomen.
V	Spent	Gonads are empty and red and contain only residual products.
VI	Resting	Sexual products are discharged and gonads are translucent and of small size. Eggs are not detectable to naked eyes.

Table 17. Physical and Chemical Characteristics of Lake Fort Smith, Arkansas*¹

Date	Temperature (C)	Dissolved Oxygen (PPM)	Turbidity (JTU)	pH	M.O. Alkalinity (PPM)	Ammonia (PPM)
July, 1970	20.4	4.8	99.5	7.3	33.8	0.63
August, 1970	18.5	5.3	97.6	7.0	24.0	0.44
September, 1970	22.3	5.3	98.2	6.9	22.9	0.35
October, 1970	18.1	5.2	58.9	6.7	22.9	0.69
November, 1970	10.5	10.0	55.3	6.8	14.9	0.65
December, 1970	8.4	10.3	46.0	6.8	20.8	0.46
January, 1971	5.6	11.5	50.0	6.8	18.4	0.48
February, 1971	4.2	12.0	92.0	6.8	13.9	0.89
March, 1971	6.2	11.4	17.3	6.9	15.1	0.33
April, 1971	13.0	9.9	19.3	6.9	14.0	0.38
May, 1971	14.6	9.3	28.5	6.9	13.4	0.55
June, 1971	17.1	7.5	14.0	6.6	13.6	0.67
December, 1971	9.9	8.3	124.0	7.2	12.3	1.10
January, 1972	8.9	10.8	109.0	7.3	13.0	1.05
February, 1972	4.7	10.2	94.0	7.1	10.6	1.36
March, 1972	9.6	10.7	67.0	7.1	11.0	1.60
April, 1972	13.5	9.5	62.0	7.1	10.5	1.02
May, 1972	14.6	8.6	74.0	6.9	10.7	0.96
June, 1972	17.3	6.5	53.0	6.9	14.1	1.20

* Data represent the average of values for the top five meters for two collections in each month.

1. Data provided by Carter & Payne.

Table 18. Models for relationship of environmental factors and feeding frequency and mean diet weight for largemouth bass.

	T Statistic	Probability Larger T	Mean	Standard Reg. Coef.	R ² x100
Immatures:					
Feeding Frequency					92.4%
Temperature	0.6269	0.558	13.108	-0.2896	
Dissolved oxygen	-2.0645	0.099	7.442	-1.5007	
Ammonia	-1.4225	0.217	0.757	-0.3774	
pH	2.5444	0.059	6.450	2.6027	
Alkalinity	-0.8329*	0.443	15.608	-0.3404	
Turbidity	-2.8675	0.043	71.550	-0.6772	
Mean Diet Weight					81.2%
Temperature	1.0027	0.374	13.108	0.9563	
Dissolved oxygen	-1.2272*	0.289	7.442	-1.5772	
Turbidity	-3.3881*	0.041	71.550	-1.9759	
pH	2.4855	0.079	6.450	5.2700	
Alkalinity	-0.6630	0.544	15.608	-0.4909	
Photoperiod	-2.0185	0.123	10.842	-3.3179	
Ammonia	0.5723	0.598	0.757	0.2645	
Males:					
Feeding Frequency					44.4%
pH	2.8235*	0.020	6.450	0.6660	
Mean Diet Weight					69.5%
Temperature	1.1242	0.313	13.108	1.2308	
Dissolved oxygen	1.8835	0.124	7.442	2.6607	
Photoperiod	-2.8233	0.045	10.842	-3.7583	
pH	0.4700	0.658	6.450	0.7313	
Ammonia	-0.9117	0.405	0.756	-0.4797	
Alkalinity	1.3878	0.227	15.608	1.187	
Females:					
Feeding Frequency					88.3%
Temperature	1.1006	0.335	13.108	0.8412	
Dissolved oxygen	-0.6398	0.558	7.442	-0.6589	
Turbidity	-0.7582	0.491	71.550	-0.3543	
pH	-0.2393	0.823	6.450	-0.4065	
Photoperiod	0.6961	0.525	10.841	0.9170	
Ammonia	2.1395	0.109	0.757	0.7924	
Alkalinity	-0.3956	0.713	1.561	-0.2347	
Mean Diet Weight					
No significant terms					

Table 19. Models for relationship of environmental factors and feeding frequency and mean diet weight for spotted bass.

	T Statistic	Probability Larger T	Mean	Standard Reg. Coef.	R ² x100
Immatures:					
Feeding Frequency					83.0%
Temperature	1.784	0.307	14.641	1.0078	
Dissolved oxygen	0.9470	0.399	7.992	1.0427	
Turbidity	0.4728	0.661	62.275	0.2444	
pH	-0.2965	0.782	6.917	-0.1491	
Alkalinity	0.7549	0.493	17.675	0.5186	
Photoperiod	0.9653	0.390	12.250	0.4358	
Ammonia	-0.2517	0.814	0.680	-0.1170	
Mean Diet Weight					61.0%
Photoperiod	-0.8593	0.430	12.250	-0.4954	
Dissolved oxygen	-1.6889	0.156	7.992	-1.6263	
Ammonia	-1.3371	0.241	0.680	-0.6149	
pH	0.8130	0.454	6.917	0.5376	
Alkalinity	-1.4833	0.201	17.675	-1.2284	
Turbidity	-1.1089	0.319	62.275	-0.7644	
Males:					
Feeding Frequency					74.8%
pH	1.0888**	0.313	6.917	0.2233	
Dissolved oxygen	-4.0370*	0.008	7.992	-1.7087	
Ammonia	-2.5752*	0.041	0.680	-0.6387	
Temperature	-3.6681*	0.011	14.641	-1.7071	
Mean Diet Weight					60.5%
Ammonia	-1.1492	0.284	0.680	-0.3171	
Dissolved oxygen	-2.0646	0.075	7.992	-1.0145	
Temperature	-3.0789*	0.018	14.641	-1.6775	
Females:					
Feeding Frequency					70.9%
Temperature	-1.1892	0.290	14.642	-1.1221	
Dissolved oxygen	-2.1558	0.090	7.992	-2.6845	
Ammonia	-1.0935	0.325	0.680	-0.5955	
pH	1.9596	0.113	6.917	0.9021	
Alkalinity	-2.6488	0.053	17.675	-1.9194	
Turbidity	-1.0632	0.338	62.275	-0.4989	
Mean Diet Weight					61.9%
Temperature	0.6298	0.563	14.642	0.8074	
Dissolved oxygen	1.2483	0.283	7.992	2.0601	
Turbidity	0.9772	0.385	62.275	0.7510	
pH	-0.9483	0.398	6.917	-0.7149	
Alkalinity	0.5552	0.609	17.675	0.5718	
Photoperiod	1.0541	0.353	12.250	0.7133	
Ammonia	0.460	0.680	0.680	0.5704	

Table 20. Vital statistics of females used in analyses of fecundity of largemouth and spotted bass

Date	Length (mm)		Weight (g)	Age (years)	K(TL)	Fecundity
	Standard	Total				
<u>Largemouth Bass</u>						
1/6/72	290	347	536	4	1.28	7062
2/5/71	357	425	1148	4	1.50	29540
1/6/72	262	320	379	3	1.15	7767
2/15/72	252	315	338	3	1.08	7540
2/15/72	222	278	273	3	1.27	5800
3/9/72	227	277	220	3	1.04	4425
3/16/72	209	254	170	2	1.04	6200
3/20/71	253	305	356	3	1.25	6509
4/10/72	244	296	290	3	1.12	9468
4/10/72	208	252	288	2	1.06	5157
4/14/72	225	278	259	2	1.21	2942
4/24/72	296	355	505	4	1.13	11224
4/27/72	433	523	2337	7	1.64	30709
5/7/71	235	291	281	3	1.14	5936
5/26/71	266	322	378	3	1.13	5501
5/27/71	440	520	2103	7	1.50	21627
<u>Spotted Bass</u>						
12/18/71	265	321	395	4	1.19	6457
1/7/72	226	274	256	3	1.24	2333
1/7/72	227	275	272	3	1.31	2253
1/14/71	229	281	251	3	1.13	2625
1/14/71	240	305	306	4	1.08	4600
1/28/72	286	346	558	4	1.35	5113
1/28/72	304	370	688	6	1.36	8637
2/16/72	249	301	367	4	1.35	1727
2/17/72	256	312	347	4	1.14	2759
2/18/71	233	288	280	3	1.17	2862
2/18/71	234	289	288	3	1.19	2907
2/18/71	240	294	269	3	1.06	3826
3/3/72	239	295	306	3	1.19	3691
3/9/72	247	302	300	4	1.09	3172
3/9/72	240	290	275	3	1.13	2073
3/18/71	310	370	712	5	1.41	9062
3/20/71	206	250	182	3	1.16	1842
4/23/71	298	353	565	5	1.28	7768
4/23/71	253	313	366	4	1.19	3982
5/4/72	290	350	562	5	1.31	9552
5/7/71	226	274	256	3	1.24	2333

Table 21. Correlation coefficients for the fecundity estimates.

Factors	Mean		Correlation Coef.
Largemouth Bass		df	
Total length	334.88	15	0.90**
Standard length	278.06	15	0.88**
Weight	616.31	15	0.89**
Age	3.56	15	0.76**
Condition factor	1.22	15	0.87**
Spotted Bass			
Total length	309.67	20	0.88**
Standard length	254.14	20	0.88**
Weight	381.05	20	0.87**
Age	3.76	20	0.77**
Condition factor	1.22	20	0.48*

FIGURES**Ichthyology Phase**

Figure 2. Average monthly marginal scale increments of largemouth bass in Lake Fort Smith.

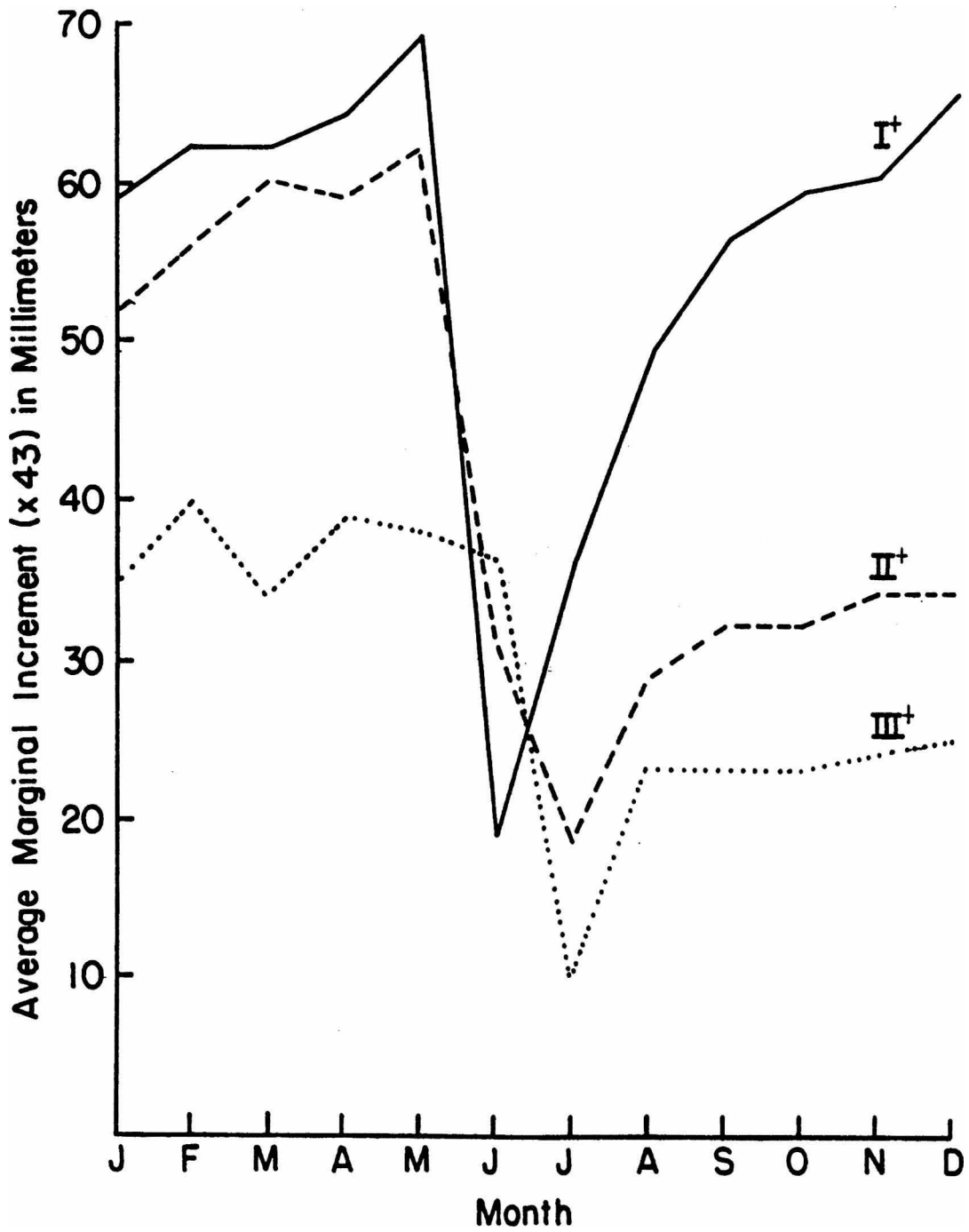


Figure 3. Average monthly marginal scale increments of spotted bass of
Lake Fort Smith.

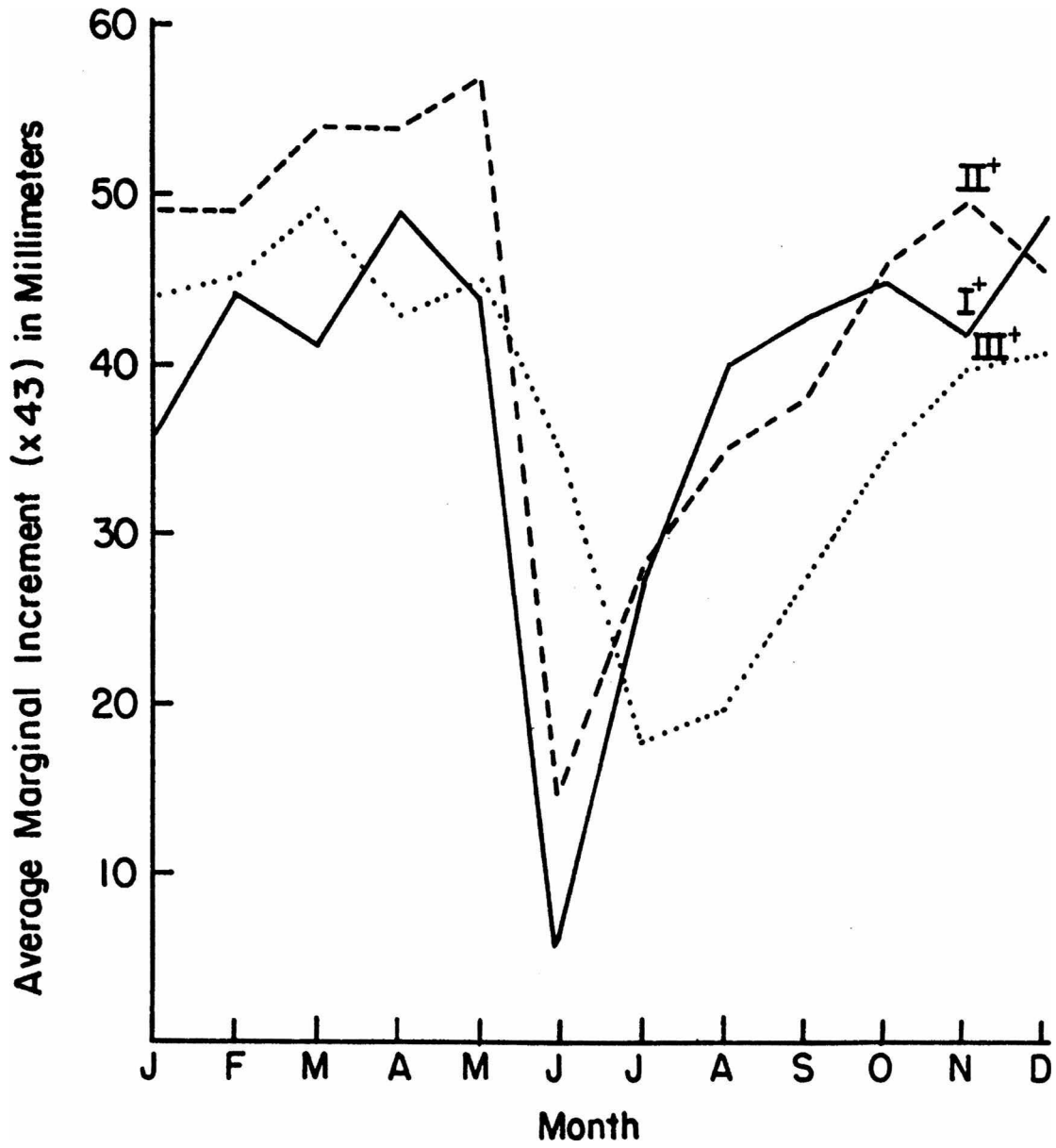


Figure 4 Gravimetric importance of major food items in seasonal diet of largemouth and spotted bass.

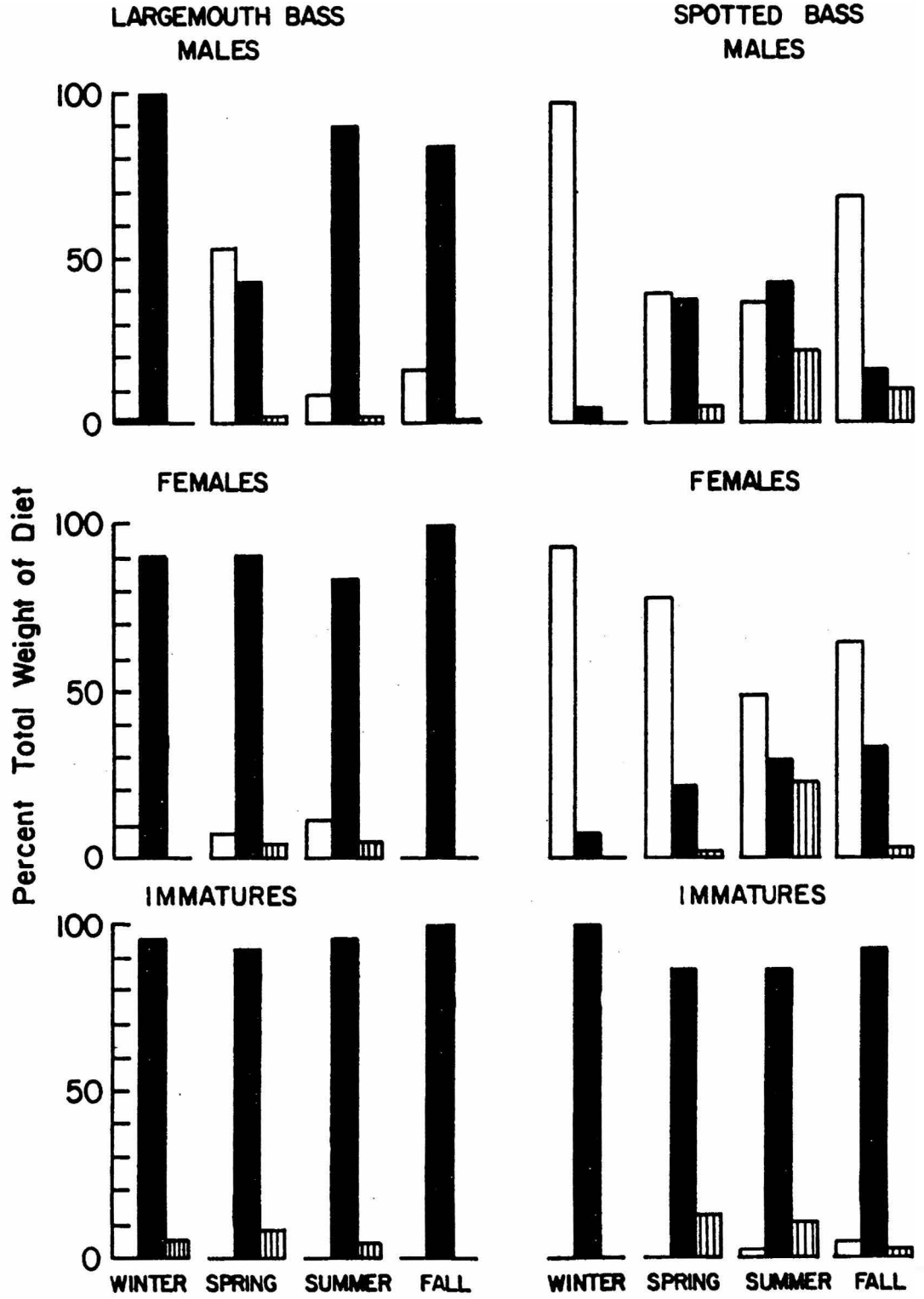


Figure 5 Monthly changes in the gonado-somatic index of three age groups of largemouth bass.

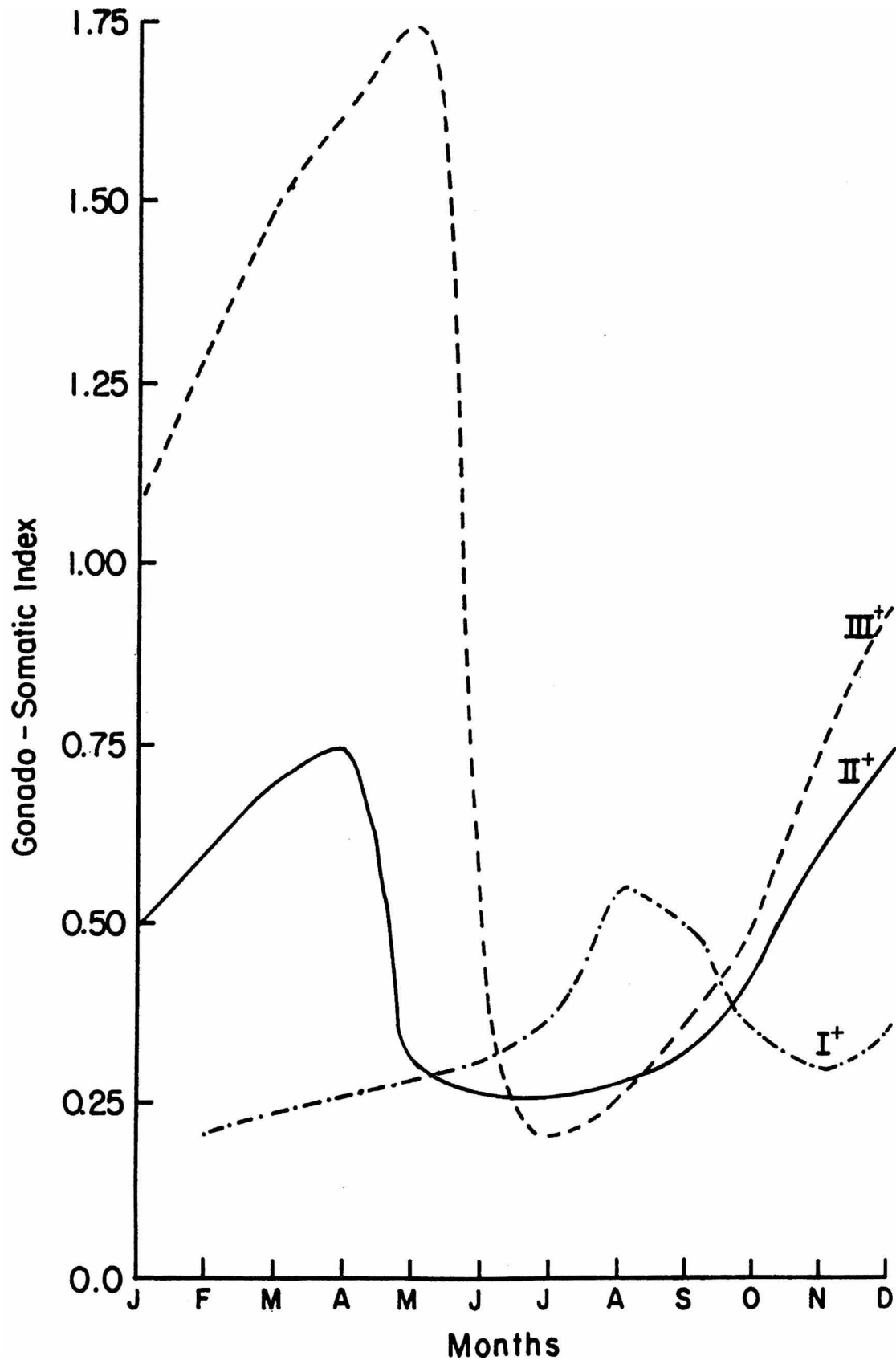


Figure 6 Monthly changes in the gonado-somatic index of three age groups of spotted bass.

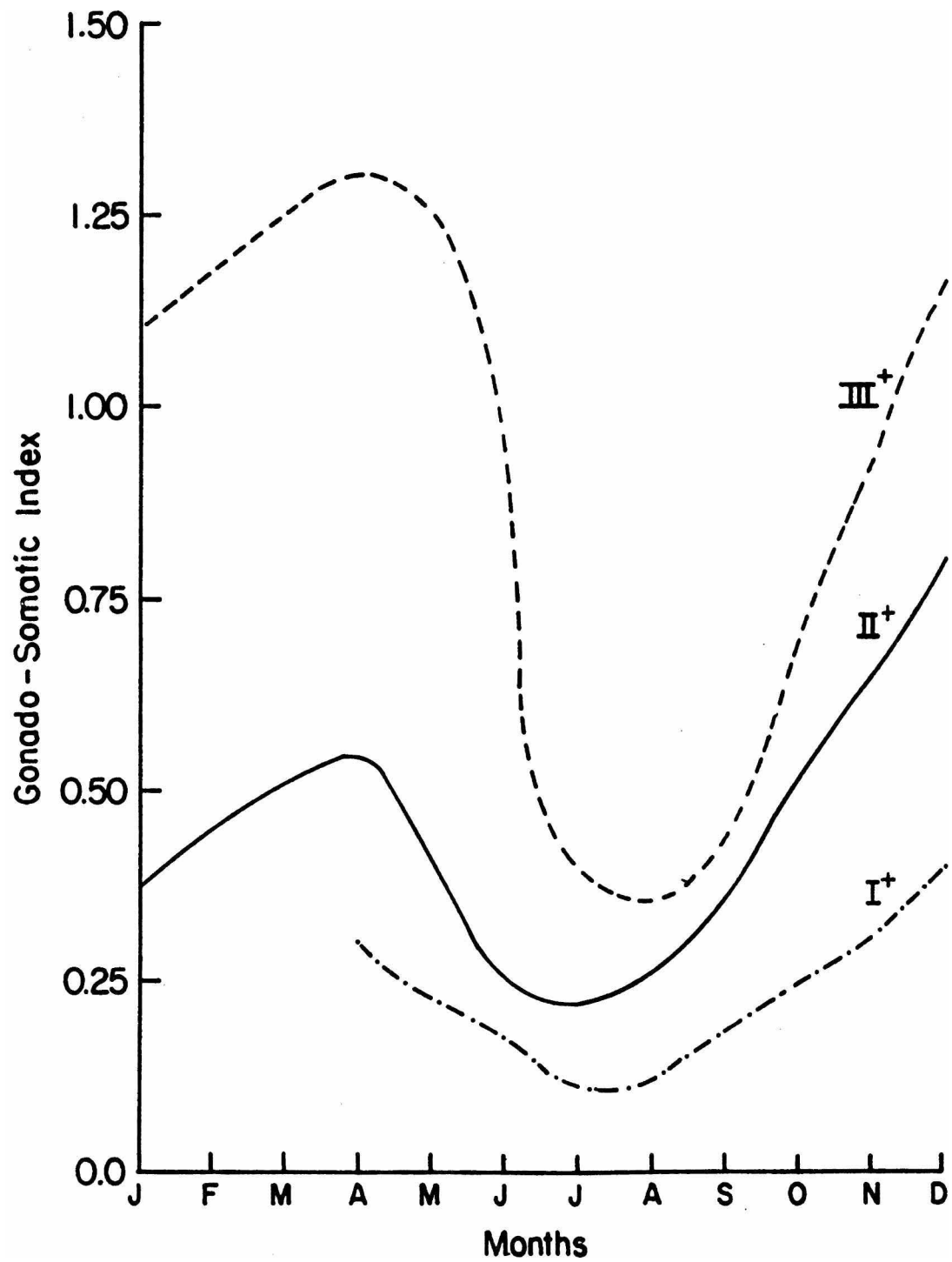


Figure 7 Relationship of age, length, weight, and fecundity in spotted bass.

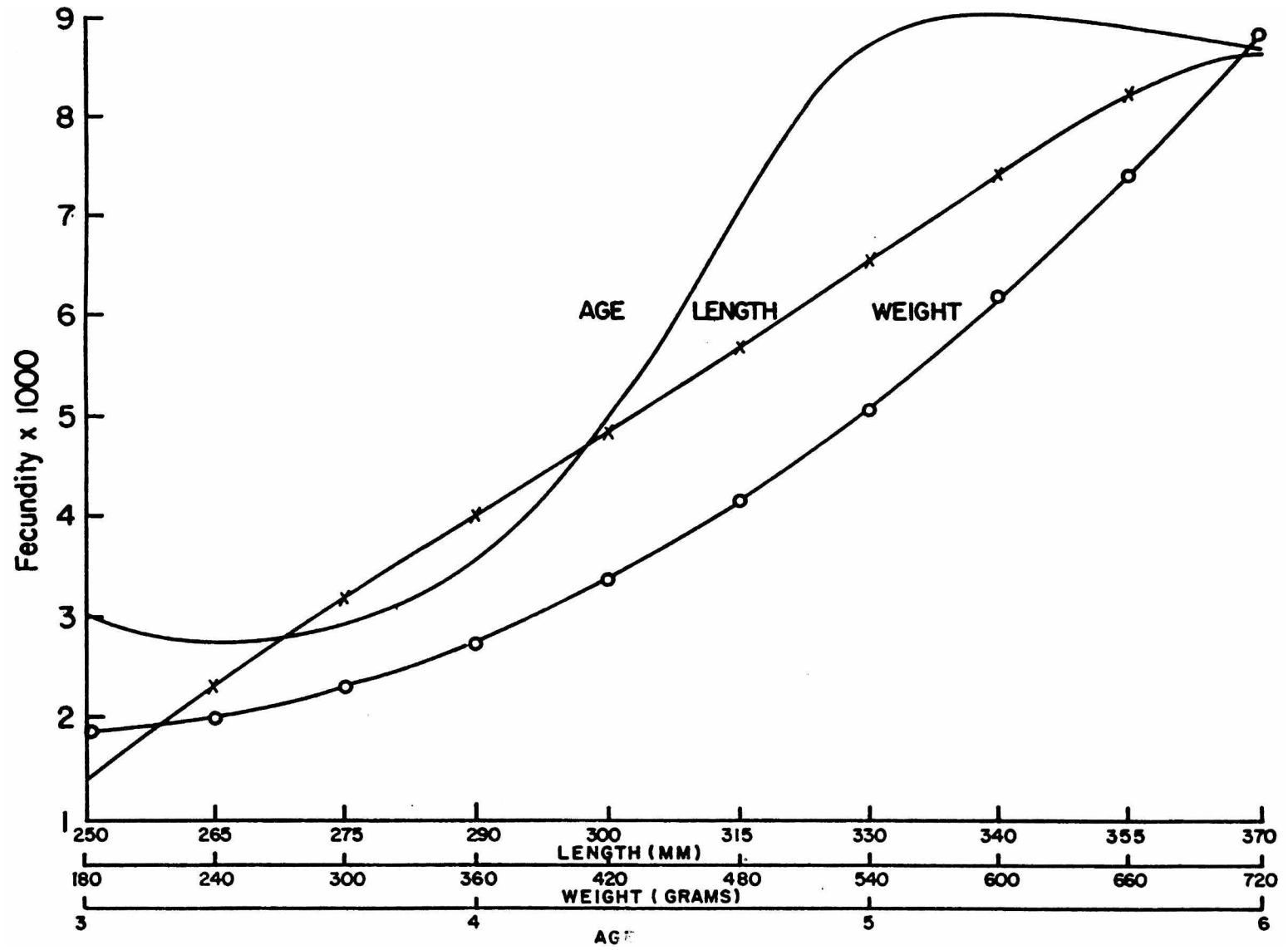


Figure 8 Relationship of age, length, weight, and fecundity in largemouth bass.

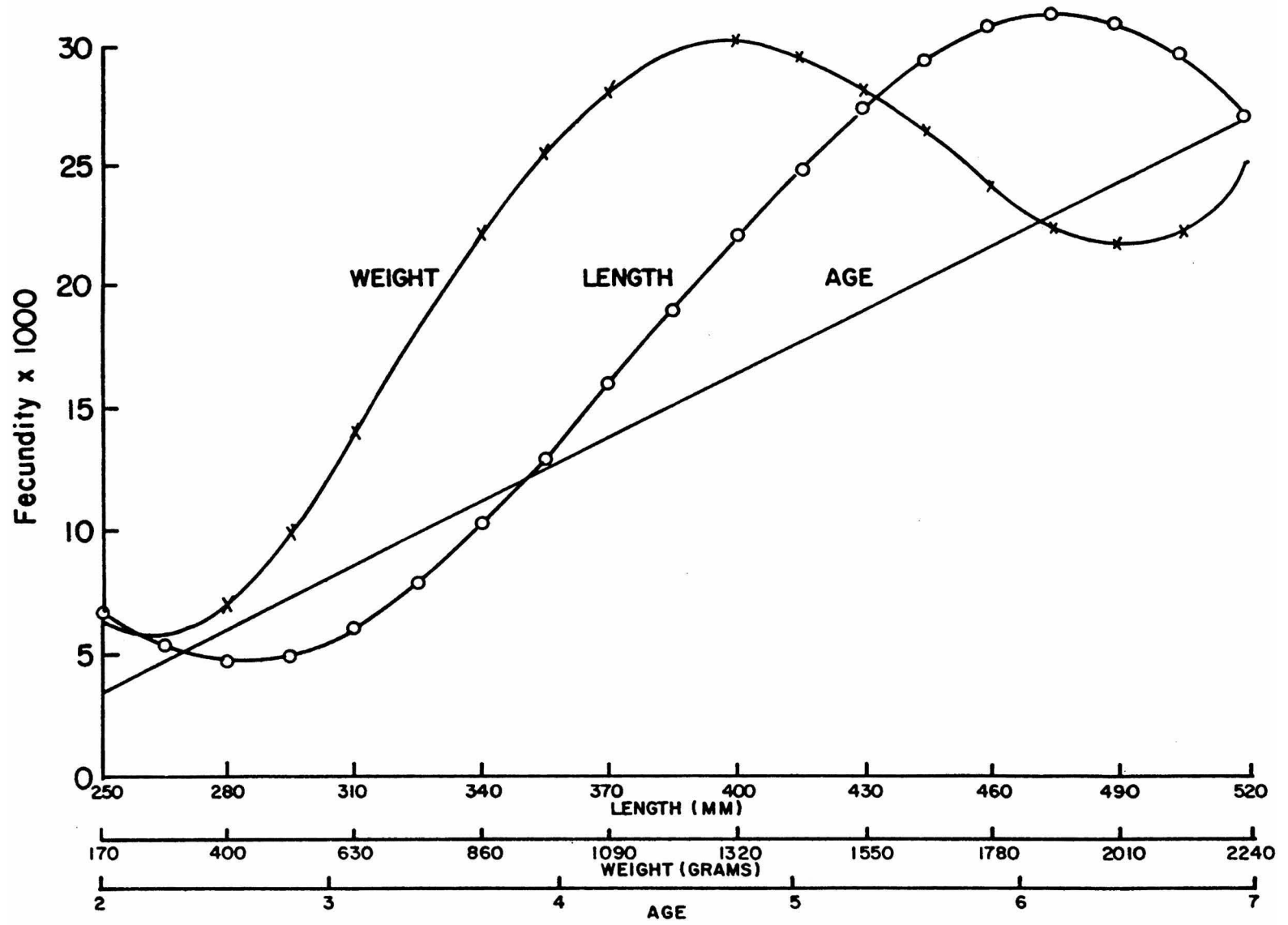


Figure 9 Monthly development of ova of largemouth bass.

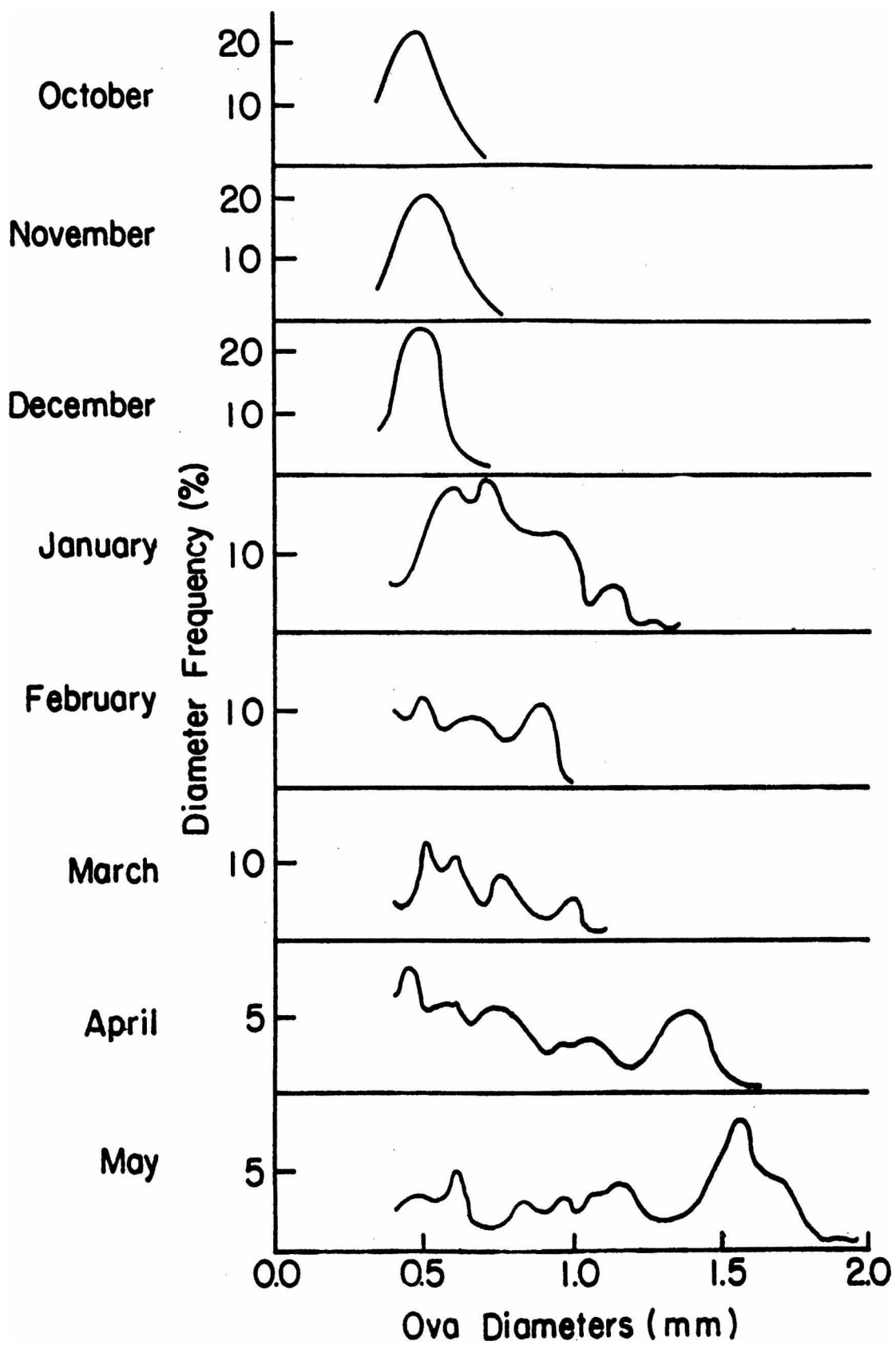
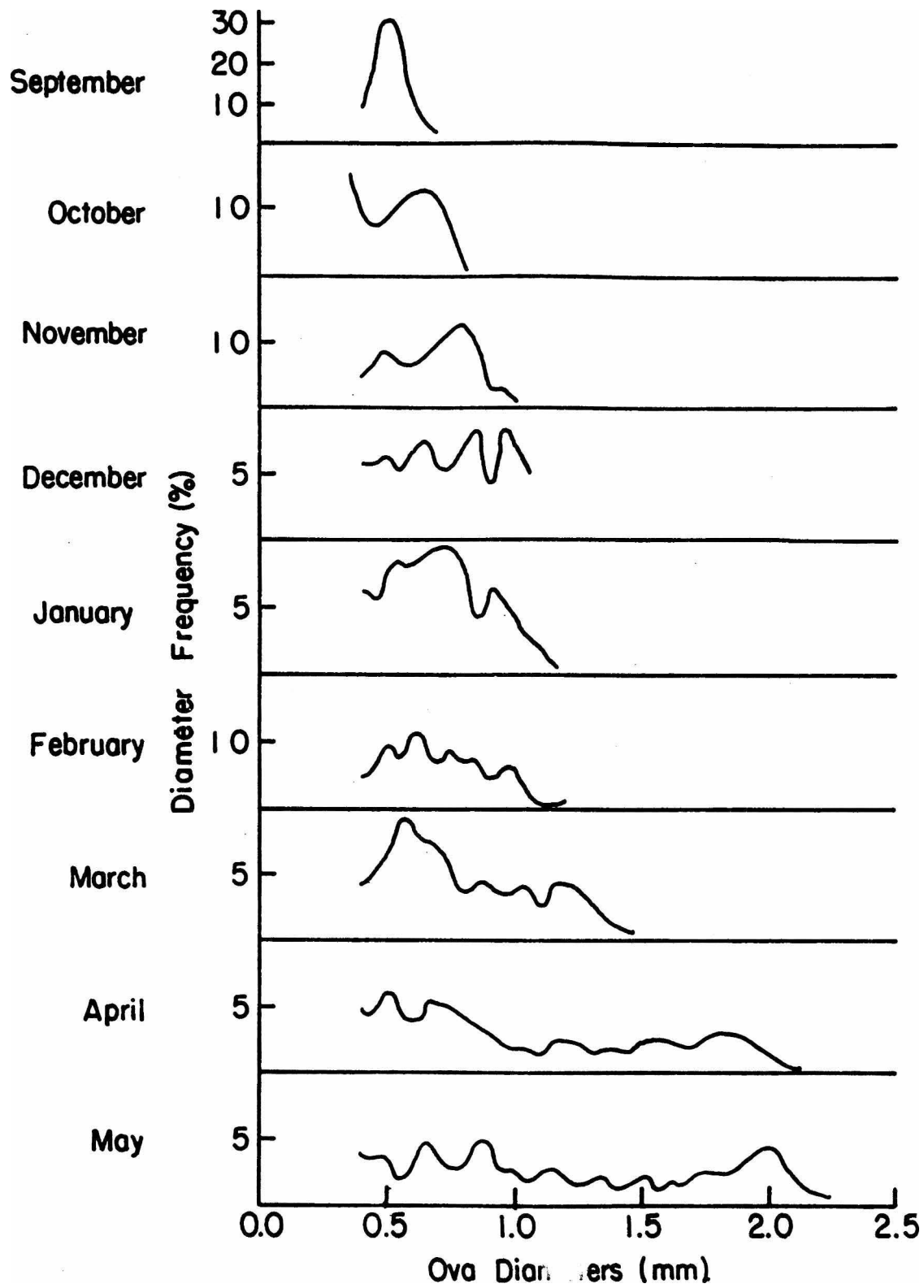


Figure 10 Monthly development of ova of spotted bass.



Parasitology Phase

Of the 385 fishes examined in this study, all had at least one species of helminth or crustacean parasite for an overall infection rate of 100%. Thirty-eight species of parasites were found from the seven host species. Table 1 shows the number of hosts collected in each month, and Table 2 lists the parasites and charts host specificity. Mean monthly physico-chemical values are given in Table 3.

Relationships Between Physico-Chemical Factors and Fish Parasites

One of the objectives of this study was to correlate seasonal changes in physico-chemical factors with seasonal abundance of fish parasites. It was hoped that these correlations would have some predictive value which could be expressed in the following multiple regression equation:

$$y = a + b_1T + b_2H + b_3O + b_4N + b_5Nt + b_6P + b_7M + b_8Tb + b_9S + b_{10}A$$

where y = an estimate of the parasite population on a given fish

a = constant for the simplified model (intercept)

b_1 = partial regression coefficient

T = temperature

H = pH

O = dissolved oxygen

N = ammonia

Nt = nitrate

P = ortho-phosphate

M = methyl orange alkalinity

Tb = turbidity

S = sex of host

A = age of host

Although many of the parasites of fishes from Lake Fort Smith exhibited significant correlations with various physico-chemical factors, these factors accounted for a relatively small percentage of the variance. Table 4 gives multiple coefficients of determination (multiple r^2) of full models from correlation-regression analyses for the parasites of largemouth bass,

warmouth, and bluegill. These values show the percent of variance accounted for by the combined effects of all physico-chemical factors, age, and sex of the host. The F values show whether or not these combined effects significantly affect the parasite populations.

In general, ectoparasites (monogenetic trematodes and crustaceans) had larger multiple r^2 values than endoparasites. This would be expected since ectoparasites are in direct contact with the external environment and should be more directly affected by physico-chemical factors. In general, the physico-chemical factors which seemed to exert the most influence on ectoparasites were turbidity and temperature as will be seen later.

Since full models did not account for more than 45% of the variance, they had little predictive value. Therefore, it was not deemed necessary or useful to model the parasite populations in terms of the above regression equation. It seems apparent from the results of this study that some factors which were not monitored in this study exert an important effect on abundance of fish parasites.

Monogenetic Trematodes

Acolpenteron ureteroecetes Fischthal and Allison, 1940.

Hosts: largemouth bass, spotted bass.

Sites of infection: kidneys, ureters.

Acolpenteron ureteroecetes was the only endoparasitic monogenetic trematode infecting the fishes of Lake Fort Smith. This parasite seems to be quite rare and too few were collected to arrive at any conclusions concerning seasonal abundance or other natural history attributes.

Actinocleidus fergusonii Mizelle, 1938.

Host: bluegill.

Site of infection: gills.

Actinocleidus fergusonii was a common parasite with an average infection of 4.84 individuals per host. This parasite showed no statistically significant correlations with physico-chemical factors, sex, or age of the host.

No significant antagonism was observed among A. fergusonii and other gill parasites. In fact, A. fergusonii showed significant positive correlations with Urocleidus dispar, U. ferox, and U. acer ($r = 0.2182, 0.2443,$ and 0.2977 , respectively, 113 df). Apparently these worms can coexist well together and to some degree share factors which similarly govern their abundance.

Actinocleidus flagellatus Mizelle and Seamster, 1939.

Host: warmouth.

Site of infection: gills.

Actinocleidus flagellatus was a common gill parasite of warmouth. Statistical analysis revealed no significant correlations between A. flagellatus and physico-chemical factors, age, or sex of the host. This species fluctuated around a mean of 9.6 individuals per host during alternate months except for January and February when the parasite load remained constant at an average of 7.0 individuals per fish. The lowest population density of the year (0.9 individuals per host) in September was followed in October by the highest population density of the year (18.0 individuals per host).

There did not appear to be any antagonistic interaction among A. flagellatus and other gill parasites. In fact, there was significant positive correlation of A. flagellatus with Urocleidus chaenobryttus, U. grandis,

and Clavunculus sp. ($r = 0.4116, 0.2868, \text{ and } 0.4252$, respectively, 73 df), indicating that these monogeneans tend to be found together.

Actinocleidus fusiformis (Mueller, 1934)

Hosts: largemouth bass, spotted bass.

Site of infection: gills.

Actinocleidus fusiformis was common on largemouth bass with an infection rate of 57.3% and an average infection of 5.3 parasites per host. Only 3.7% of the spotted bass had this parasite with an average number of 0.05 individuals per host. Therefore, A. fusiformis is not considered to be a significant part of the parasite community on spotted bass in Lake Fort Smith.

There was no significant correlation of A. fusiformis with age or sex of the host. Positive correlations for A. fusiformis existed with Urocleidus furcatus and U. principalis ($r = 0.3023 \text{ and } 0.6347$, respectively, 87 df), indicating these organisms tend to be associated with each other.

Anchoradiscus triangularis (Summers, 1937).

Host: bluegill.

Site of infection: gills.

Only seven specimens of Anchoradiscus triangularis were observed during this study. This species probably occurs throughout the year in small numbers since it was collected during both the summer and winter months.

Clavunculus bursatus (Mueller, 1936).

Hosts: bluegill, largemouth bass, spotted bass.

Sites of infection: gills, lining of the mouth.

Clavunculus bursatus was primarily a parasite of largemouth and spotted bass, being found on 45.0% and 33.4%, respectively. It was the largest in

size but least abundant of the monogenetic trematodes found on black basses of Lake Fort Smith. C. bursatus was observed on only 4.3% of the bluegill in Lake Fort Smith, indicating that it was less successful on bluegill than black basses.

C. bursatus on largemouth bass did not display any significant correlations with physico-chemical factors. It was found in small numbers (usually an average of one or less per host) throughout most of the year except for an increase in May and June with a peak of 4.2 individuals per host in June. This ~~does~~ not agree with the observations of Rawson and Rogers (1972).

Seasonal abundance of C. bursatus on bluegill from Lake Fort Smith corresponded closely to that of largemouth bass, but in smaller numbers. This species was found only during August and June at a rate of 0.2 parasites per host. As with largemouth bass, no significant correlations with physico-chemical factors were observed.

C. bursatus did not display any correlations with age or sex of any of its hosts from Lake Fort Smith.

There appeared to be no antagonism of C. bursatus with other gill parasites. There was significant positive correlation of C. bursatus with Urocleidus furcatus, Actheres micropteri, and Ergasilus centrarchidarum ($r = 0.4552, 0.2497, \text{ and } 0.3195$, respectively, 87 df), indicating these species can coexist well together and even tend to be associated with each other.

Clavunculus sp.

Host: warmouth.

Site of infection: gills.

Warmouth were infected with what appeared to be an undescribed species

of Clavunculus which will be described at a later date. As far as is known, this represents the first report of the genus Clavunculus on warmouth. Due to the erratic abundance of this species throughout the year, there were no significant correlations with physico-chemical factors, although turbidity almost had a statistically significant negative correlation ($r = -0.2089$, 73 df). Peak abundance occurred during August (3.0 parasites per host) and March (2.3 parasites per host). The population decline from August to September occurred when turbidity increased from 22 to 56 JTU. When the population increased from February to March the turbidity dropped from 42 to 20 JTU. Age or sex of the host did not appear to have any significant effect on abundance of Clavunculus sp. Since the combined effects of physico-chemical factors, age, and sex of the host only accounted for 15.0% of the variance ($r^2 = 0.1495$), other factors not monitored in this study probably greatly affected the abundance of this species.

Clavunculus sp. showed significant positive correlations with other monogenetic trematodes, including Urocleidus chaenobryttus, U. grandis, and Actinocleidus flagellatus ($r = 0.3959$, 0.2352 , and 0.4252 , respectively, 73 df). Therefore, no antagonistic relationships were indicated.

Cleidodiscus floridanus Mueller, 1936.

Host: channel catfish.

Site of infection: gills.

Cleidodiscus floridanus was abundant on the gills of channel catfish with an infection of 100% and an average number of 86.6 parasites per host. Since only 10 hosts were collected throughout the study, few conclusions can be inferred. It probably occurs in substantial numbers throughout most of the year, since it was collected during both the summer and winter months.

Cleidodiscus vancleavei Mizelle, 1936.

Hosts: white crappie, black crappie.

Site of infection: gills.

Cleidodiscus vancleavei was the only monogenetic trematode found on crappie. This species infected 85.2% of the white crappie and 86.7% of the black crappie with an average number of 18.3 and 14.5 worms per host, respectively. Small sample size of the hosts limits any further comments concerning this parasite.

Urocleidus acer (Mueller, 1936).

Host: bluegill.

Site of infection: gills.

Urocleidus acer displayed a general tendency of abundance in the summer and winter with declines during the fall and spring. Two main peaks occurred, one at 2.7 parasites per fish in January and another at 4.8 parasites per fish in June. Because one peak occurred in winter and the other in the summer, no significant correlations with physico-chemical factors were made.

Other gill parasites did not appear to have any antagonistic effect on U. acer. In fact, U. acer showed significant positive correlations with most other gill parasites on bluegill ($r = 0.2648, 0.4414, \text{ and } 0.2977$ for Urocleidus dispar, U. ferox, and Actinocleidus fergusonii, respectively, 113 df).

Urocleidus chaenobryttus Mizelle and Seamster, 1939.

Host: warmouth.

Site of infection: gills.

Urocleidus chaenobryttus was the most common monogenetic trematode of warmouth. Greatest population density was in June (35.4 parasites per host) while the lowest was 5.2 individuals per host in September. This species displayed a significant positive correlation with nitrate ($r = 0.2393$, 73 df) and negative correlations with methyl orange alkalinity and turbidity ($r = -0.2449$ and -0.3992 , respectively, 73 df). These three factors accounted for 5.7%, 6.0%, and 15.9%, respectively, of the variance ($r^2 = 0.0573$, 0.0600, and 0.1594, respectively). Of these three factors, turbidity appeared to be the most important one influencing the abundance of U. chaenobryttus. There were no significant correlations with sex or age of the host.

U. chaenobryttus was positively correlated with Urocleidus grandis, Actinocleidus flagellatus and Clavunculus sp. ($r = 0.6225$, 0.4116, and 0.3959, respectively, 73 df), indicating no antagonistic relationships.

Urocleidus dispar (Mueller, 1936).

Host: bluegill.

Site of infection: gills.

Urocleidus dispar exhibited large fluctuations in abundance throughout the year, making determination of seasonal trends difficult. Turbidity showed a significant negative correlation ($r = -0.2455$, 113 df). This may partially explain the decline of U. dispar from August to September. Turbidity increased from 22 to 56 JTU during that period.

U. dispar showed no significant correlation with sex of the host but did with age ($r = 0.2782$, 113 df). Older fish tended to have more U. dispar than younger ones.

U. dispar displayed significant positive correlations with U. ferox, U. acer, and Actinocleidus fergusonii ($r = 0.2025$, 0.2648, and 0.2182, respectively, 113 df), indicating no antagonistic relationships.

Urocleidus ferox Mueller, 1934.

Host: bluegill.

Site of infection: gills.

Urocleidus ferox was the most common monogenetic trematode infecting bluegill in Lake Fort Smith, with an annual average of 11.1 parasites per host. U. ferox was present in moderate numbers in July and August (12.5 and 11.7 per host, respectively) and then declined in the fall. Abundance fluctuated throughout the winter and spring, then increased to its highest peak of the year at 37.7 parasites per fish in June. Significant correlations with ortho-phosphate and turbidity occurred ($r = 0.3602$ and -0.2423 , respectively, 113 df). Although, temperature was not statistically significant ($r = 0.1780$, 113 df), there was adequate positive correlation such that it could not be completely ignored. Turbidity may be the most important factor governing seasonal abundance of U. ferox in Lake Fort Smith.

Abundance of U. ferox increased with the age of the host ($r = 0.2660$, 113 df), but there was no difference between the sexes of the host.

All other monogenetic trematodes of the bluegill displayed significant positive correlations with U. ferox ($r = 0.2025$, 0.4414 , 0.2443 , 0.2139 , and 0.5711 for U. dispar, U. acer, Actinocleidus fergusoni, Anchoradiscus triangularis, and Clavunculus bursatus, respectively, 113 df).

Urocleidus furcatus (Mueller, 1937).

Hosts: largemouth bass, spotted bass.

Site of infection: gills.

Urocleidus furcatus was common on largemouth bass with an infection rate of 80.9% and an average of 27.2 parasites per host. Only 5.6% of the spotted bass had this parasite, with an average of 0.2 parasites per fish. Therefore, U. furcatus was not considered to be an important component of

the parasite community of spotted bass.

There appeared to be a definite seasonal trend in abundance of U. furcatus on largemouth bass. U. furcatus was present in relatively high numbers throughout the summer months. A precipitous decline occurred during September and October with the minimum of 1.3 parasites per fish occurring in October. The population increased steadily throughout the winter and spring to reach a peak of 54.0 individuals per host in June. U. furcatus exhibited significant positive correlation with temperature and negative correlation with turbidity ($r = 0.2527$ and -0.4547 , respectively).

U. furcatus did not correlate significantly with sex of largemouth bass. However, abundance of U. furcatus tended to increase with the age of the host ($r = 0.3489$, 87 df).

There appeared to be no antagonism between U. furcatus and other gill parasites. In fact all other gill parasites of largemouth bass showed significant positive correlation ($r = 0.5842$, 0.3023 , 0.4552 , 0.4361 , and 0.3545 for U. principalis, Actinocleidus fusiformis, Clavunculus bursatus, Achtheres micropteri, and Ergasilus centrarchidarum, respectively, 87 df).

Urocleidus grandis Mizelle and Seamster, 1939.

Host: warmouth.

Site of infection: gills.

Urocleidus grandis exhibited two peaks during the year, a minor one in August (8.0 parasites per host) and a large one in April (28.2 parasites per host). Summer abundance in general was slightly higher than winter abundance. U. grandis exhibited a significant negative correlation with turbidity ($r = -0.3285$, 73 df). Declines in abundance from August to September (8.0 and 0.9 per host, respectively) and April to May (28.2 and 4.8 per host, respectively) coincided with increases in turbidity during the same periods.

There were no significant correlations of U. grandis with age or sex of the host.

U. grandis displayed significant positive correlations with Actinocleidus flagellatus and Clavunculus sp. ($r = 0.6225$ and 0.2352 , respectively, 73 df), which also inhabit the gills of warmouth.

Urocleidus principalis (Mizelle, 1936).

Hosts: largemouth bass, spotted bass.

Site of infection: gills.

Urocleidus principalis was the most common monogenetic trematode infecting largemouth and spotted bass. This species infected 80.9% of the largemouth bass with an average of 47.4 parasites per fish while 59.3% of the spotted bass were infected with an average of 5.9 parasites per fish.

On largemouth bass, U. principalis exhibited three peaks of abundance during the year, in August (82.0 parasites per fish), January (80.8 parasites per fish), and April (106.2 parasites per fish). U. principalis correlated significantly with dissolved oxygen, nitrate, methyl orange alkalinity, and turbidity ($r = 0.3351$, 0.2902 , -0.3233 , and -0.3483 , respectively, 87 df). Temperature appears to have a relatively negligible effect on the abundance of this species ($r = -0.1274$, 87 df). Therefore, the significant positive correlation of U. principalis with dissolved oxygen may indicate a definite preference for high concentrations of dissolved oxygen. Turbidity probably exerted a major influence on the decline in early fall. It is not known at this time what actual influence nitrate and methyl orange alkalinity may have on U. principalis.

U. principalis had no significant correlations with age or sex of the host.

There appeared to be no antagonism between U. principalis and other gill

parasites. U. principalis displayed significant positive correlations with U. furcatus and Actinocleidus fusiformis ($r = 0.5842$ and 0.6347 , respectively, 87 df).

For an extended discussion of the results and probable causes of seasonal fluctuations of monogenetic trematodes recovered in the present study see Cloutman (1974). Although there was variation in seasonal abundance of the various species of monogenetic trematodes, a few general patterns seemed to develop. Every species except Clavunculus bursatus infecting largemouth bass, exhibited a decline in abundance from August to September which was correlated with increase in turbidity. Rawson and Rogers (1972) also noted a tendency for fall decreases in monogenetic trematodes of largemouth bass which they attributed to a rapid decrease in temperature. It is doubtful that temperature had much effect in initiating the decline of monogenetic trematodes in Lake Fort Smith from August to September because temperature only changed from 29.6 C to 27.5 C, and turbidity increased from 22 to 56 JTU. Most Monogenea appeared to be moderately abundant during the summer months in Lake Fort Smith. Rawson and Rogers (1972) reported evidence that Monogenea of largemouth bass have an optimum temperature of 28 C. This could explain trends toward summer abundance. However, several Lake Fort Smith species also displayed mid-winter peaks during January and February. This phenomenon was also reported by Crane and Mizelle (1968) and Rawson and Rogers (1972). The occurrence of population peaks in both winter and summer tended to reduce the correlation coefficients, thus showing an apparent lack of temperature influence. However, temperature may have more influence on monogenetic trematodes than the data from this study indicate. Winter increases are best explained by the previously stated phenomenon that fish are incapable of activating antibodies below certain critical temperatures which vary from 5 to 15 C depending on the species of fish

(Jackson, et al., 1969). These critical limits for prevention of antibody activation against monogenetic trematodes are not known for the fish species investigated in Lake Fort Smith. Therefore caution should be exercised in drawing conclusions based on this factor alone. Based on the preceding discussion, it appears that high summer temperatures and low winter temperatures may have the same effect of increasing monogenetic trematode populations, although different mechanisms may be involved. High temperatures may directly enhance survival of the worms, while low temperatures may indirectly enhance the worms by lowering host resistance.

Although what appears to be of only minor importance, dissolved oxygen, nitrate, and ortho-phosphate occasionally exhibited significant positive correlations with monogenetic trematode infections while methyl orange alkalinity occasionally had significant negative correlations. Because of complicated interrelationships of physico-chemical parameters, caution should be exercised in attempting to interpret these factors.

Of all the physico-chemical factors correlated with monogenetic trematodes, turbidity appears to be the most important. However, turbidity seldom accounted for more than 10% of the variance. In only four species, Urocleidus chaenobryttus, U. furcatus, U. grandis, and U. principalis, did turbidity account for more than 10% of the variance ($r^2 = 0.1594, 0.2067, 0.1079, \text{ and } 0.1213$, respectively). Therefore, seasonal abundance of monogenetic trematodes must be governed by the interaction of several other physico-chemical and biological factors along with turbidity. The precise influence of physico-chemical and biological factors on monogenetic trematodes is inconclusive.

None of the monogenetic trematodes studied from Lake Fort Smith displayed any correlation with sex of the host.

Urocleidus dispar, U. ferox, and U. furcatus were the only monogenetic trematodes showing significant relationships with age of the host. These parasites tended to increase in older hosts.

None of the monogenetic trematodes exhibited any antagonism toward other gill parasites. In fact, many had significant positive correlations, indicating they may coexist well together. Apparently, some environmental or biological factors may have similar effects on most gill parasites.

Digenetic Trematodes

Alloglossidium corti (Lamont, 1921).

Host: channel catfish.

Site of infection: intestine.

Alloglossidium corti was a common inhabitant in the intestine of channel catfish from Lake Fort Smith. Eighty percent of these fish were infected with an average of 33.7 worms per fish. No further comments can be made from the available data because of small host sample size.

Bucephalidae Poche, 1907.

Host: warmouth.

Site of infection: intestine.

Only two specimens of a species belonging to the family Bucephalidae were found in warmouth. The poor condition of the two specimens prevented identification beyond family. This parasite appeared to occur incidentally in Lake Fort Smith and did not represent a significant portion of the fish parasite community.

Clinostomum marginatum (Rudolphi, 1819).

Hosts: warmouth, bluegill, spotted bass.

Sites of infection: Encysted in muscles or gills.

Clinostomum marginatum, commonly called the yellow grub, has been reported from so many fish that it is safe to assume that it is capable of infecting any North American freshwater fish (Hoffman, 1967).

Van Cleave and Mueller (1934) reported that C. marginatum does not survive through the winter. However, Fischthal (1949) found no overwintering effect in catfish. Edney (1940) reported a longevity of 3 years and 9 months, so it is doubtful that C. marginatum experiences a winter kill. C. marginatum was rare in Lake Fort Smith, and not enough specimens were collected to arrive at any specific conclusions concerning this species.

Crepidostomum cornutum (Osborn, 1903).

Hosts: channel catfish, warmouth, bluegill, white crappie, largemouth bass, spotted bass.

Sites of infection: caeca, intestine, stomach.

Crepidostomum cornutum displayed little host specificity, but was found most often in warmouth and bluegill from Lake Fort Smith. Too few C. cornutum were found in largemouth bass to warrant discussion. In the warmouth, C. cornutum occurred in small numbers (average less than one parasite per host) from June through November. In December the population peaked at 8.3 parasites per host but declined during January. Abundance was moderately high throughout the spring with a peak of 8.3 parasites per host in May. C. cornutum was present in higher numbers in bluegill. In bluegill, C. cornutum displayed two main peaks, one in August (32.7 worms per host) and one in April (15.7 parasites per fish). When seasonal abundance of C. cornutum from warmouth and bluegill are compared, it is obvious that C. cornutum was present throughout the year but showed different trends in seasonal abundance among different hosts. Therefore, it is pos-

tulated that seasonal trends in abundance were manifestations of host activity rather than a direct influence of physico-chemical factors on the parasite.

Sex of the host had no significant effect on abundance of C. cornutum, but abundance tended to increase among older fish ($r = 0.3494$, 73 df and 0.1878 , 113 df for warmouth and bluegill, respectively).

C. cornutum did not appear to have any antagonistic relationships with any other intestinal parasites of warmouth or bluegill from Lake Fort Smith.

Diplostomulum scheuringi Hughes, 1929.

Hosts: warmouth, bluegill, white crappie, black crappie, largemouth bass, spotted bass.

Site of infection: vitreous humor of the eyes.

Diplostomulum scheuringi was a common parasite of a variety of fishes of Lake Fort Smith and was the only parasite found within the eyes.

In all three hosts (largemouth bass, warmouth, and bluegill) studied for seasonal abundance, D. scheuringi displayed a low population in the summer, a gradual increase in the fall, peaks during the winter, and a gradual decrease in the spring. Warmouth was the most heavily infected host (64.1% infection with 8.0 parasites per host).

Temperature was the only physico-chemical factor with which D. scheuringi had a significant correlation in all three host species ($r = -0.2420$, 87 df; -0.3720 , 73 df; and -0.2785 , 113 df for largemouth bass, warmouth, and bluegill, respectively).

In no case was there an effect of host sex on the abundance of D. scheuringi. In the warmouth, D. scheuringi tended to increase significantly with the age of the host ($r = 0.2441$, 73 df), while the other hosts showed no significant increase with age of the host.

Pisciamphistoma stunkardi (Holl, 1929)

Hosts: warmouth, bluegill, white crappie, black crappie, largemouth bass, spotted bass.

Sites of infection: intestine, caeca.

Pisciamphistoma stunkardi was found in all centrarchid hosts studied but was common only in the warmouth.

In largemouth bass and bluegill, P. stunkardi was collected in such small quantities that conclusions concerning seasonal abundance should be made with caution. Incidence of P. stunkardi in warmouth was very low in July and August (0.2 and 0.0 per host, respectively), then increased to a moderate level during the fall and winter. An increase occurred in March with a peak of 16.0 parasites per fish, which was followed by a decline to moderate levels during the spring. In warmouth, P. stunkardi correlated significantly with temperature, dissolved oxygen, nitrate, and methyl orange alkalinity ($r = -0.3293, 0.3758, 0.3641, \text{ and } -0.2105$, respectively, 73 df). Since the life cycle of P. stunkardi is unknown and physico-chemical factors are often interrelated it would be presumptuous to postulate which of these factors actually exert the most influence on seasonal abundance of P. stunkardi.

No correlations were observed between age or sex of the host and P. stunkardi.

There was no evidence for antagonism between P. stunkardi and other intestinal helminths.

Posthodiplostomum minimum (MacCallum, 1921).

Hosts: warmouth, bluegill, white crappie, black crappie, largemouth bass, spotted bass.

Sites of infection: kidneys, liver, spleen, mesenteries, pericardium, gonads.

Metacercariae of Posthodiplostomum minimum were the most common digenetic trematode in fishes of Lake Fort Smith.

The seasonal abundance of P. minimum in largemouth bass, warmouth, and bluegill from Lake Fort Smith varied. In the largemouth bass relatively high abundance was observed during the summer with a peak of 124 parasites per fish in July, and in the winter months with a peak of 142.4 per host in February. In the warmouth, P. minimum displayed peaks in March and June (31.7 and 44.0 per host, respectively) with moderate infections during the remainder of the year. P. minimum in bluegill increased during the fall from moderate numbers in July and August (21.6 and 6.5 per host, respectively). The population declined greatly in December (5.0 per host), and remained low until April when a moderate increase occurred (41.3 per host). In June the population displayed a precipitous increase (118.6 per host). When all three host species are taken into consideration, there is no general seasonal pattern. It does not appear feasible to directly correlate seasonal abundance of P. minimum in terms of physico-chemical properties of the water since it is certain that P. minimum is present throughout the year, although in varying frequency among different hosts. Therefore, it seems more plausible to postulate that seasonal abundance of this parasite is affected by physiological or behavioral attributes of the host which were not monitored in this study. Another factor which cannot be ignored is the possible bias which may have been created because of relatively small sample size of the hosts and the large range in numbers this parasite displayed.

Comparative seasonal data are available from Spall and Summerfelt (1969). They observed greater average numbers of P. minimum in white

crappie during the summer months in Lake Carl Blackwell, Oklahoma. They attributed their increase in spring and summer samples to an increase in numbers of infected snails (Miller, 1954) and the development and release of cercariae. Hoffman (1958) has observed that snails do not release cercariae when subjected to a change from 22-28 C to 15 C, and cercariae do not infect fish at 15 C but do above 18 C. Colley and Olson (1963) observed that survival rates of P. minimum at various temperatures were 3.7% at 1.5 C, 36% at 3.5 C, 63.6% at 15 to 30 C, and 21.9% at 36 C. Based on these experimental studies, P. minimum should not be capable of significant increases during the winter.

P. minimum showed no correlation with sex of the host. In largemouth bass and warmouth, P. minimum increased significantly with the age of the host ($r = 0.3107$, 87 df and 0.4363 , 73 df, respectively). There was no significant increase with age in bluegill.

P. minimum had a significant negative relationship with Proteocephalus ambloplitis plerocercoids in largemouth bass ($r = -0.2403$, 87 df). These two species occupied the same organs in the host. In warmouth and bluegill, there was a nonsignificant negative relationship. It is difficult to say whether this negative relationship is an antagonistic relationship or whether it is a difference in susceptibility based on physiology or ecology of the host.

Vietosoma parvum Van Cleave and Mueller, 1932.

Host: channel catfish.

Site of infection: intestine.

Vietosoma parvum was common in channel catfish (80.0% infection with 133.8 parasites per host). No further comments can be made concerning this parasite because of the small number of hosts collected.

In general, digenetic trematodes are difficult to correlate with physico-chemical factors because of their complex life cycles and endoparasitic habits. The free-swimming larval stages are the only phases of the life cycle when digenetic trematodes are directly affected by physico-chemical factors. The effects of physico-chemical factors on larvae and intermediate hosts must be considered to interpret effects of physico-chemical factors on abundance of digenetic trematodes. Since larvae and intermediate hosts were not studied during this project, the data are insufficient to adequately discuss effects of physico-chemical factors on digenetic trematodes.

Sex of the host did not affect the abundance of any digenetic trematodes from Lake Fort Smith. Crepidostomum cornutum, Diplostomulum scheuringi, and Posthodiplostomum minimum, at least in some instances, tended to increase in abundance with increased age of the host.

No antagonism was detected among any of the intestinal digenetic trematodes or other intestinal helminths in any of the fishes. There was, however, some negative correlation between Posthodiplostomum minimum and Proteocephalus ambloplitis plerocercoids in the viscera of some fishes. More conclusive data are needed to determine whether this is some sort of antagonism or difference in susceptibility of the host to the parasites.

Cestodes

Bothriocephalus cuspidatus Cooper, 1917.

Hosts: warmouth, bluegill, spotted bass.

Sites of infection: intestine, caeca.

Bothriocephalus cuspidatus was common in bluegill but appeared to be incidental in warmouth and spotted bass.

B. cuspidatus was found only in the winter and spring, suggesting an

annual cycle for this parasite. In bluegill, B. cuspidatus showed significant correlations with temperature, dissolved oxygen, and nitrate ($r = -0.2135$, 0.2635 , and 0.2077 , respectively, 113 df). It is difficult to say what physiological mechanisms were involved to trigger the appearance of the population during the winter since the above physico-chemical factors accounted for only a small portion of the variance.

B. cuspidatus was not influenced by age or sex of the host, and there appeared to be no antagonistic relationships with other intestinal helminths.

Corallobothrium fimbriatum Essex, 1927.

Host: channel catfish.

Site of infection: intestine.

Too few channel catfish were collected in this study to draw any conclusions concerning the natural history of Corallobothrium fimbriatum from Lake Fort Smith.

Corallobothrium giganteum Essex, 1927.

Host: channel catfish.

Site of infection: intestine.

Adult Corallobothrium giganteum are found in the intestine of ictalurid catfishes. Too few channel catfish were collected in this study to determine anything about the natural history of C. giganteum.

Proteocephalus ambloplitis (Leidy, 1887).

Hosts: channel catfish, warmouth, bluegill, white crappie, black crappie, largemouth bass, spotted bass.

Sites of infection: plerocercoids in mesenteries, liver, kidneys, pericardium, gonads; adults in intestine.

Proteocephalus ambloplitis plerocercoids were found in all species of hosts examined during this study, but adults were found only in warmouth and largemouth bass. Plerocercoids were much more numerous than adults.

In the bluegill, plerocercoids remained at a low level throughout most of the year except for a peak in August (6.0 per host), while in warmouth they declined in late winter and spring (0.3-1.7 per host). In the largemouth bass, a decrease occurred in winter and spring (0.8-4.4 per host). This decrease corresponded with the appearance of adult worms during the same period. During this same period the plerocercoids migrate from the viscera into the lumen of the gut to become adults as explained by Fischer and Freeman (1969). In Lake Fort Smith, peak abundance of adults occurred in January at 6.2 C, but peak percent infection of adults occurred in February (50.0%) at 4.4 C. Unfortunately, no largemouth bass were collected in March. It is possible that largemouth bass may have had higher infections in March than in January or February based on the results of Fischer and Freeman (1969). Adult P. ambloplitis in largemouth bass displayed significant negative correlation with temperature ($r = -0.2609$, 87 df), while plerocercoids showed nonsignificant positive correlation with temperature.

There was no significant correlation of P. ambloplitis with age or sex of the host.

Adult P. ambloplitis showed no antagonism with other intestinal helminths, but plerocercoids showed negative correlation with Posthodiplostomum minimum as previously discussed.

Bothriocephalus cuspidatus and Proteocephalus ambloplitis displayed annual cycles of abundance. Adults appeared in winter and spring and disappeared for the rest of the year. Temperature appeared to be the most important factor measured in this study which may govern the annual cycle,

although it accounted for only 4.6% of the variance in B. cuspidatus ($r^2 = 0.0456$) and 6.8% of the variance in P. ambloplitis ($r^2 = 0.0681$).

Nematodes

Camallanus oxycephalus Ward and Magath, 1917.

Hosts: channel catfish, warmouth, bluegill, white crappie, black crappie, largemouth bass, spotted bass.

Sites of infection: intestine, caeca, stomach.

Camallanus oxycephalus was found in all host species examined in this study.

In largemouth bass, abundance of C. oxycephalus remained about the same throughout the year except for a peak in July (5.1 per host). In warmouth, C. oxycephalus displayed peaks in March and June (2.0 and 1.2 per host, respectively). In bluegill, C. oxycephalus had small peaks in January, March, and June (1.7, 1.5, and 1.5, respectively). No consistent correlations were made with physico-chemical factors in the three hosts. Peaks in abundance at various times of the year may be due to the feeding habits of the hosts.

There was no effect of host sex on the abundance of C. oxycephalus. In warmouth and bluegill, C. oxycephalus increased significantly with the age of the host ($r = 0.2968$, 73 df and 0.2893 , 113 df, respectively).

There was no indication of antagonism between C. oxycephalus and other intestinal helminths.

Contraecaecum spiculigerum (Rudolphi, 1809).

Hosts: warmouth, bluegill, largemouth bass, spotted bass.

Sites of infection: lining of the mouth, eye orbit, coelom.

Contraecaecum spiculigerum was relatively common in Lake Fort Smith

and displayed little host specificity, although certain species such as largemouth bass were more heavily infected than others.

C. spiculigerum in largemouth bass had no significant correlations with seasonal changes in physico-chemical factors but had small peaks in August and May (1.7 and 2.3 per host, respectively). The numbers of C. spiculigerum in the warmouth were so small that any interpretations concerning seasonal abundance would be meaningless. The abundance of C. spiculigerum in bluegill remained low throughout most of the year (0.1 - 1.5 per host), never showing any significant peaks. It is doubtful that there is any significant seasonal change in abundance of C. spiculigerum in Lake Fort Smith. This agrees with the results of Spall and Summerfelt (1969).

There was no significant influence of age or sex of the host on C. spiculigerum from Lake Fort Smith.

Spinitectus carolini Holl, 1928.

Hosts: channel catfish, warmouth, bluegill, white crappie, black crappie, largemouth bass, spotted bass.

Sites of infection: intestine, caeca, stomach.

All host species examined in this study were infected with Spinitectus carolini.

The incidence of S. carolini in largemouth bass was low from July through December (0.0 - 0.9 per host), then increased from late winter through June (2.1 - 4.6 per host). In warmouth, the only major peak of abundance occurred in January (12.7 per host). In bluegill, abundance was relatively constant throughout the year except for a large peak in August (39.0 per host). When all three host species are considered together, there was no consistent pattern of abundance. Therefore, it is doubtful that seasonal changes in water quality directly affect the abundance of S. carolini.

There was no significant correlation of S. carolini with sex of the host, but infection tended to increase with the age of the host in warmouth and bluegill ($r = 0.2671$, 73 df and 0.3272 , 113 df, respectively).

There was no sign of antagonism between S. carolini and other intestinal helminths.

None of the three nematodes found in this study displayed any consistent patterns of seasonal abundance. Therefore, it is believed that seasonal changes in physico-chemical factors did not significantly affect their abundance. Perhaps seasonal differences in feeding habits of the different hosts is the reason for different peaks of abundance.

None of the nematodes were significantly affected by host sex. Numbers of Camallanus oxycephalus and Spinitectus carolini tended to increase with the age of the host while Contracaecum spiculigerum showed no correlation with age of the host.

None of the nematodes found in this study indicated any antagonistic relationships with other parasites inhabiting the same habitat in the host.

Acanthocephalans

Neoechinorhynchus cylindratus (Van Cleave, 1913).

Hosts: warmouth, bluegill, white crappie, largemouth bass, spotted bass.

Sites of infection: larva encysted in liver, adult in intestine.

Neoechinorhynchus cylindratus was the only acanthocephalan collected in this study. The bluegill from Lake Fort Smith had a low incidence and intensity of infection (4.3% incidence of infection with an average of 0.09 parasites per fish), while largemouth bass were heavily infected (100% infection rate with an average of 41.1 parasites per fish). Young-of-the-year bass which were too small to eat bluegill were often heavily infected. This

might indicate that the bass were able to acquire N. cylindratus directly from the ostracod intermediate host, although they probably acquired some by eating infected bluegill.

Juvenile stages of N. cylindratus encysted in the liver of bluegill were found only in August, October, and December (0.4, 0.1, and 0.2 per host, respectively) and were quite uncommon. This low infection was probably due to the lack of ostracods in the diet of bluegill. Ostracods are seldom utilized as food items by bluegill in Lake Fort Smith (Henderson, 1972). In warmouth, adults were found in the intestine throughout the year, usually in small numbers. Two peaks of abundance occurred, one in August and one in March (4.5 and 7.3 per host, respectively). The numbers of adults in the intestine of largemouth gradually increased from a low in July to a peak in February (15.1 and 85.3 per host, respectively), then displayed a general gradual decline. Therefore, N. cylindratus from largemouth bass in Lake Fort Smith tended to have high winter and low summer abundance, and exhibited significant correlations with temperature, pH, dissolved oxygen, nitrate, and methyl orange alkalinity ($r = -0.3075, -0.2398, 0.3708, 0.3604, \text{ and } -0.3199$, respectively, 87 df). It is possible that host feeding habits governed the seasonal abundance of N. cylindratus more than the direct influence of physico-chemical factors since abundance in warmouth differed from that observed for largemouth bass. Ostracods were ingested by largemouth bass in small quantities throughout most of the year (L. L. Olmsted, personal communication) while the food habits of warmouth from Lake Fort Smith are unknown.

There was no significant effect of host sex or age on the abundance of N. cylindratus, nor did there appear to be any antagonism between N. cylindratus and other helminths residing in the same host organs.

Branchiurans

Argulus mississippiensis Wilson, 1916.

Hosts: warmouth, bluegill, largemouth bass.

Site of infection: body surface.

Argulus mississippiensis was an uncommon parasite of Lake Fort Smith fishes. This parasite appeared to be a relatively insignificant part of the parasite community. A. mississippiensis infected warmouth more than other host species examined, but even warmouth had a relatively low incidence of infection (8.9% infection with an average of 0.1 parasites per fish).

A. mississippiensis was collected from February through June on warmouth, and only in June from bluegill and largemouth bass. Therefore, there seems to be a general trend of abundance in late spring. Bauer (1959) stated that Argulus remain on fish, surrounded by mucus in the winter. This was not noted on the fishes from Lake Fort Smith. In largemouth bass, A. mississippiensis showed significant correlations with ortho-phosphate and turbidity ($r = 0.3517$ and -0.2382 , respectively, 87 df). In warmouth, there were significant correlations with nitrate, ortho-phosphate, methyl orange alkalinity, and turbidity ($r = 0.2301$, 0.3197 , -0.2819 , and -0.2873 , respectively, 73 df). In bluegill, only ortho-phosphate correlated significantly with A. mississippiensis ($r = 0.1911$, 113 df). Since high nitrate and ortho-phosphate are characteristic of eutrophic conditions, this parasite may become more abundant as Lake Fort Smith eutrophicates. Turbidity may have the same influence on A. mississippiensis as it seems to have on monogenetic trematodes, i.e., the eggs of the parasites may adhere to particles in the water and settle to the bottom or be carried away.

There was no significant effect of host sex or age on the abundance of A. mississippiensis, nor did there appear to be any antagonism between A. mississippiensis and other ectoparasites on the body surface of the host.

Copepods

Achtheres micropteri Wright, 1882.

Hosts: warmouth, black crappie, largemouth bass, spotted bass.

Sites of infection: gills, lining of the mouth.

Achtheres micropteri was common in Lake Fort Smith.

In largemouth bass, A. micropteri was found in relatively low numbers throughout most of the year except for a peak in August (1.3 per host) and a slight increase in spring (0.2 - 0.8 per host). In warmouth, A. micropteri was uncommon except for a peak in May (2.0 per host). The only significant correlation of A. micropteri with physico-chemical factors was a negative correlation with turbidity in largemouth bass ($r = 0.2197$, 87 df).

There was no significant correlation of A. micropteri with sex of the host. In largemouth bass, abundance of A. micropteri tended to increase with the age of the host ($r = 0.2939$, 87 df). There was no evidence of antagonism between A. micropteri and other ectoparasites.

Ergasilus centrarchidarum Wright, 1882.

Hosts: largemouth bass, spotted bass.

Site of infection: gills.

Ergasilus centrarchidarum was quite host specific, being found only on the black basses from Lake Fort Smith. This species exhibited definite seasonal abundance on largemouth bass. It was abundant during the summer months (5.2 - 27.3 per host) but was rare from October through May (0.2 -

0.9 per host). The few females that were collected during the cold months did not have egg sacs, perhaps indicating that no reproduction occurs during cold periods. It appears that the optimum temperature for E. centrarchidarum was approximately 24 C and egg production stopped at approximately 17 C. E. centrarchidarum on largemouth bass was correlated significantly with temperature, oxygen, ortho-phosphate, and turbidity ($r = 0.3507, -0.2534, 0.3857, \text{ and } -0.3292$, respectively, 87 df). It is possible that turbidity had the same effect on E. centrarchidarum as that proposed for monogenetic trematodes, i.e., the eggs of the parasites may adhere to particles in the water and settle to the bottom or be carried away. The data from this study contradict Baer (1952) who stated that parasitic copepods continuously produce eggs without seasonal fluctuations.

E. centrarchidarum was not significantly affected by age or sex of the host, and no antagonistic relationships with other gill parasites were indicated.

Lernaea cruciata (Lesueur, 1824).

Hosts: warmouth, largemouth bass.

Site of infection: burrowed through skin into muscle.

At the time of this investigation, the anchor worm, Lernaea cruciata, was of minor importance in Lake Fort Smith. Too few were collected to arrive at any conclusions concerning abundance or other natural history attributes.

Mollusks

Glochidia.

Hosts: warmouth, bluegill, white crappie, largemouth bass, spotted bass.

Sites of infection: gills, lining of the mouth.

The species of unionid clams in Lake Fort Smith are unknown and it was not possible to identify the glochidia to species. Glochidia displayed three peaks of abundance during the year in largemouth bass, warmouth, and bluegill. These peaks occurred in October, April, and June for all three hosts with a peak of 19.6 per host in June on largemouth. This may indicate the presence of three separate species of glochidia. Therefore, it is not possible to draw conclusions concerning seasonal abundance since it is not known exactly how many species are involved in this study.

Wilson (1916) suggested the possibility of antagonism between glochidia and copepods because he observed that fishes with glochidia on the gills did not have very many copepods and vice versa. However, in the present study there was no indication of antagonism between glochidia and other gill parasites.

Leeches

Illinobdella moorei Meyer, 1940.

Hosts: warmouth, bluegill, spotted bass.

Site of infection: fins.

Illinobdella moorei was most commonly found on warmouth. Although it was found on only two other host species it probably parasitized other fishes in Lake Fort Smith in low numbers.

On warmouth, I. moorei infection peaked in August and March (2.0 and 2.3 per host, respectively), with a general trend toward increase during the winter. On bluegill, I. moorei was present only in March and June (0.8 and 0.1 per host, respectively). I. moorei on warmouth correlated significantly with temperature, dissolved oxygen, nitrate, and ortho-phosphate ($r = 0.2403, 0.3111, 0.2408, \text{ and } 0.2559$, respectively, 73 df). On bluegill, I. moorei

correlated significantly only with dissolved oxygen ($r = 0.2279$, 113 df).

I. moorei was not significantly correlated with age or sex of the hosts.

Comparison of the Lake Fort Smith Parasitofauna of
1961 with 1970-1971

In making the comparisons of the parasitofauna collections of 1961 (Houghton, 1963; Becker and Houghton, 1969) and the present study, the former investigation will hereafter in this section be designated as the "1961" survey.

As a reservoir ages, the parasitofauna undergoes successional changes (Bauer, 1954). One of the objectives of this study was to determine any changes in the parasitofauna of Lake Fort Smith fishes which might have occurred during the years subsequent to a 1961 survey of fish parasites in Lake Fort Smith (Houghton, 1963; Becker and Houghton, 1969). In the 1961 survey only percent infection and the range of the numbers of parasites in each host species were given without regard to seasonal abundance and age of host so that caution should be exercised in quantitative comparisons. It does seem, however, that some changes have occurred during the past few years. Table 5 gives comparisons of the 1961 and 1970-1971 percent infection and ranges of parasite numbers. No conclusions can be drawn concerning the Monogenea and Crustacea because these groups were not included in the 1961 survey.

In general, the range in numbers of parasites in their respective hosts in the present study was larger than in the previous study. This is presumed to be due to the larger number of fish hosts collected in the present study. Therefore, it is doubtful that very many of the parasites increased in abundance as the larger numbers in the ranges might imply. It appears that abundance of most parasites did not change to any significant degree.

Three species, an unknown species of Bucephalidae, Vietosoma parvum, and Bothriocephalus cuspidatus, observed in this study were not found in the 1961 survey. It is probable that these species may have been overlooked.

There seems to have been a tremendous increase in the prevalence of Posthodiplostomum minimum subsequent to the 1961 survey. In that study, P. minimum was found only in two largemouth bass with a maximum of 14 observed in one fish. During the present study P. minimum was present in all centrarchid species examined, often in large numbers (up to 1,249 in one bluegill). Wisniewski (1958) and Esch (1971) observed higher prevalence of larval parasites in fishes from eutrophic lakes than in oligotrophic lakes. It seems that the metacercariae of P. minimum were following this pattern of increase as Lake Fort Smith aged. An acanthocephalan, Leptorhynchoides thecatus (Linton), was observed in small quantities during the 1961 survey, but not in the present study. Thus, it appears that L. thecatus has disappeared from Lake Fort Smith. It is postulated that the amphipod intermediate host could not tolerate the conditions of Lake Fort Smith after impoundment and was eliminated, thus interrupting the life cycle of the parasite. The presence of L. thecatus in Lake Fort Smith in the 1961 survey, 25 years after impoundment, may have been the result of the parasite being carried into the reservoir from upstream, although Lake Shepard Springs, constructed in 1956 on Clear Creek 2 miles above Lake Fort Smith, has reduced the chances of this parasite entering from upstream. The possibility exists that L. thecatus may be occasionally reintroduced into Lake Fort Smith via bait fishes, but it is doubtful that a viable population could be sustained.

Lake Fort Smith Parasite Community Structure

Community structure is referred to as the complex of individuals belonging

to the different species in an ecosystem (Wilhm and Dorris, 1968). Biotic communities are typically characterized by the presence of a few species with many individuals, or many species with a few individuals. In the past, parasitologists have relied on lengthy species lists and verbal descriptions to characterize parasite communities. This method of describing community structure is often so lengthy and cumbersome that conclusions and comparisons based on such information are difficult to interpret. In an attempt to reduce large amounts of data into a simple expression of community structure, several diversity indices have been devised, including those by Gleason (1922), Fisher, Corbet, and Williams (1943), Williams (1944, 1964), and Menhinick (1964). However, these diversity indices have limitations because they assume specific distributions which may or may not exist in nature, and they are not independent of sample size (Hurlbert, 1971). Diversity indices derived by Margalef (1958) and Patten (1962) from information theory possess neither of these limitations (Wilhm and Dorris, 1968).

In this study, species diversity indices were calculated using equations from Patten (1962), as later modified by Wilhm and Dorris (1968).

For a discussion of the equations used to calculate community diversity, maximum diversity, minimum diversity, individual diversity, and redundancy, see Cloutman (1974).

For the purposes of the present paper, parasite community structure will be defined as the complex of individuals belonging to the different parasite species inhabiting a fish host. This can be used synonymously with the term "parasite mix" which was coined by Noble (1960). Since diversity indices do not include descriptions of interrelationships of the parasites in the parasite mix, they can not be utilized as a quantitative measure of parasitocoenoses. However, diversity indices can be used to quantitatively express

changes in community structure which result from interactions that occur in a parasitocoenosis.

Mean values of community diversity, redundancy, and individual diversity of parasite communities for each host species are presented in Table 6. High individual diversity values indicate parasite communities with complex organization. Therefore warmouth harbored the most complex parasite communities in Lake Fort Smith while black and white crappie had the least complex parasite communities. Since large redundancy values indicate the high predominance of one or more species in the community, causing a reduction in complexity, redundancy is inversely related to individual diversity. Therefore, host species with high individual diversity values have low redundancy values and vice versa. Large redundancy values were usually associated primarily with large numbers of Posthodiplostomum minimum. The hosts with high community diversity values had the greatest total number of parasites per fish. Largemouth bass and channel catfish displayed the largest number of parasites but their parasite communities were not as complex as those of warmouth or bluegill. The two crappie species had the least significant parasite communities because the parasite populations were low in both number of individuals and species. In general, monogenetic trematodes and P. minimum had the most influence on community diversity although Neoechinorhynchus cylindratus was also important in largemouth and spotted bass.

The differences in community structure among the different host species was probably due to a combination of several factors. Since the host is a habitat, it would seem that the host species which provide the most diverse habitat should have the most diverse parasitofauna. However, it may be that the host of a less diverse parasitofauna may offer a very diverse habitat

but is physiologically unsuitable for many parasites. Habitat selection of the hosts is also probably an important factor. Crappie were the least infected fish in Lake Fort Smith probably because they were limnetic than other fishes and therefore tended to avoid areas with high density of intermediate hosts.

Seasonal Changes in Community Structure in Relation
to Changes in Physico-Chemical Factors

Individual diversity did not fluctuate greatly on a seasonal basis for largemouth bass, warmouth, or bluegill (Figs. 1-3). When individual diversity increased, redundancy tended to decrease, and vice versa (Figs. 1-6). Community diversity displayed greater seasonal fluctuations than individual diversity. Mean monthly values of community diversity are shown in Figures 7-9.

LARGEMOUTH BASS

In largemouth bass, a decline in individual diversity occurred in October, followed by a gradual increase through February. Since the contribution to diversity by rare species is small (Wilhm and Dorris, 1968), changes in the more abundant species have the greatest effect on diversity. The decline of individual diversity in October was the result of concurrent large declines in populations of several species of parasites (most importantly monogenetic trematodes) which normally were present in moderate to high numbers, and relative stability of other species which occurred in moderate to large numbers (most notably Neoechinorhynchus cylindratus). This had the effect of lowering community diversity and increasing redundancy which produced a decrease in complexity. Thus there was a decline in individual

diversity. In largemouth bass, individual diversity was correlated significantly with temperature and turbidity ($r = 0.2286$ and -0.3206 , respectively, 87 df). Age and sex of the host had no significant effect on individual diversity. The combined effect of all physico-chemical factors, age, and sex of the host had a highly significant effect on individual diversity, accounting for 42.94% of the variance ($F = 5.8705$, 10 and 78 df; $P < 0.000001$).

Redundancy values had no significant correlations with physico-chemical factors, but community diversity had significant correlations with dissolved oxygen, nitrate, methyl orange alkalinity, and turbidity ($r = 0.2758$, 0.3074 , -0.3250 , and -0.4201 , respectively, 87 df). Community diversity showed positive correlations with age of the host ($r = 0.2785$, 87 df) although individual diversity did not. This means that the complexity of the parasite community did not increase significantly with age of the host although there were more individuals in the community. High community diversity values indicate either large biotopes of extreme exploitation of the available resources of a given biotope (Patten, 1962). It is probably that higher community diversity values of parasite communities of older fish were the result of a combination of both large biotopes and extreme exploitation by the parasite. Greater exposure time would allow more exploitation of the host by the parasites. All physico-chemical factors, age, and sex of the host combined accounted for only 8.45% of the variance in redundancy ($F = 0.7195$, 10 and 78 df; $P < 0.7048$) but accounted for 43.52% of the variance in community diversity ($F = 6.0097$, 10 and 78 df; $P < 0.000001$). Therefore, in largemouth bass the factors analyzed in this study exerted highly significant influences on individual diversity and community diversity, but only accounted for less than half of the variance. Therefore, some other factors not

monitored in this study were also important influences on parasite community structure of largemouth bass.

WARMOUTH

In warmouth, individual diversity tended to decrease in summer and increase in winter. However, this change was not very large and no individual species seemed to be responsible for the change any more than others. Changes in individual diversity correlated significantly with temperature, dissolved oxygen, ammonium, nitrate, and methyl orange alkalinity ($r = 0.3794, 0.5479, -0.2310, 0.3997, \text{ and } -0.3576$, respectively, 73 df).

Redundancy did not significantly correlate with any physico-chemical factors, but community diversity correlated significantly with temperature, dissolved oxygen, nitrate, methyl orange alkalinity, and turbidity ($r = -0.2867, 0.4010, 0.4187, -0.3426, \text{ and } -0.2328$, respectively, 73 df). Both individual diversity and community diversity increased significantly with the age of warmouth ($r = 0.2846 \text{ and } 0.4593$, respectively, 73 df), indicating both more complex and larger communities in older fish. The combined effect of all physico-chemical factors, age, and sex of the host had a highly significant effect on individual diversity, accounting for 32.45% of the variance ($F = 3.0744, 10 \text{ and } 64 \text{ df; } P < 0.0031$). Physico-chemical factors, age, and sex of the host combined accounted for only 12.97% of the variance of redundancy ($F = 0.9535, 10 \text{ and } 64 \text{ df; } P < 0.4924$), but 42.49% of the variance of community diversity ($F = 4.7290, 10 \text{ and } 64 \text{ df; } P < 0.00005$). Although the factors analyzed in this study significantly influenced individual diversity and community diversity of warmouth, over 50% of the variance remained unaccounted for.

BLUEGILL

Values of individual diversity for bluegill were consistent for most of the year except for a small decline in September and October, which was due mainly to a general decrease in monogenetic trematodes and an increase in Posthodiplostomum minimum. There were significant correlations of individual diversity with dissolved oxygen and nitrate ($r = 0.2053$ and 0.2135 , respectively, 113 df), and ortho-phosphate, methyl orange alkalinity, and turbidity were close to significant.

Redundancy did not correlate significantly with any physico-chemical factors, and community diversity significantly correlated only with turbidity ($r = -0.2328$, 113 df). It appears that the negative effects of turbidity on monogenetic trematode populations had the greatest influence on the decrease of community diversity. There was no significant effect of host age on individual diversity. However, community diversity tended to increase with the age of the host ($r = 0.4125$, 113 df). Therefore, size, but not complexity, of the parasite community increased with the age of bluegill. The combined effects of all physico-chemical factors, age, and sex of the host had a highly significant effect on individual diversity, accounting for 19.39% of the variance ($F = 2.5020$, 10 and 104 df; $P < 0.0099$). Combined physico-chemical factors, age, and sex of the host accounted for only 8.28% of the variance of redundancy ($F = 0.9384$, 10 and 104 df; $P < 0.5021$), but accounted for 30.80% of the variance of community diversity ($F = 4.6294$, 10 and 104 df; $P < 0.00002$). The combined factors considered in this study contributed significant influences on individual diversity and community diversity, but other factors not considered accounted for over half of the variance.

Succession of Parasite Communities After
Impoundment of Reservoirs

A few Russian investigators have discovered that fish parasites undergo successional development in newly constructed reservoirs (Bauer, 1954; Bauer and Stolyarov, 1958; and Izyumova, 1959). These findings stimulated a long term pre- and postimpoundment survey of parasites of black basses from Beaver Reservoir in northwestern Arkansas to determine succession of the parasitofauna after impoundment. The data from this project has accumulated in several Master's theses (Holmes, 1964; Heard, 1965; Evans, 1968; Owen, 1969; Drach, 1970; and Norman, 1971), and one publication (Becker, Heard, and Holmes, 1966). Long and cumbersome discussions of each species of parasite are presented in each of these reports, which has inhibited the syntheses of data into a simple integrated view of the entire parasite community. Patten (1962) has stated that diversity indices derived from information theory may be used as indicators of successional activity of a community. Diversity indices are applied here on the Beaver Reservoir data to show simple representations of the parasite community as it goes through succession. Therefore, succession of parasites after impoundment can be described at the community level in a simple, integrated fashion.

Parasite community structure of Beaver Reservoir black basses (small-mouth bass, Micropterus dolomieu Lacepede; largemouth bass; and spotted bass) is represented by individual diversity, redundancy, and community diversity values in Table 7. Prior to impoundment in December 1963 parasite community structure of the three hosts was similar. Individual diversity was relatively low, indicating relatively low complexity. Redundancy was relatively high, indicating a predominance of certain species. There was relatively low community diversity, indicating the parasite community in each fish was relatively small. Therefore, the fishes in the river environment

maintained a moderate parasite community. During the first year after impoundment, individual diversity decreased, redundancy increased, and community diversity decreased in largemouth and spotted bass, indicating their parasite communities were being depleted. Almost all species of parasites decreased to some extent. This is probably due mainly to the spreading of the hosts as the reservoir filled. The lesser density of both intermediate and fish hosts reduced the chances of parasites finding a host.

Smallmouth bass were depleted after impoundment to such an extent that not enough hosts were collected to further monitor their parasites.

In 1965, there was a large increase in individual diversity for largemouth bass, but only a small increase for spotted bass. With increases in individual diversity, there were corresponding decreases in redundancy and increases in community diversity. These results indicated that the intermediate and definitive hosts adjusted to their recently changed environment and increased in population density. This allowed the parasite community to reestablish itself. In fact, the parasite community in largemouth bass was larger and more complex than it was before impoundment. In spotted bass, the parasite community had not quite reestablished itself up to the preimpoundment level. During 1966 and 1967, individual diversity from largemouth bass increased slightly but seemed to be stabilizing. Redundancy increased after the reduction in 1965. Values of community diversity continued to increase in 1966 and 1967. This pattern of development seemed to follow the theoretical pattern suggested by Patten (1962). According to Patten, an increase in community diversity associated with decrease in redundancy would represent initial stages of succession, whereas concurrent increases in community diversity and redundancy are indicative of approaching climax. Stability is indicated when no change occurs in either community diversity or redundancy. In spotted bass, individual diversity increased in 1966 with concurrent decrease in redundancy

and increase in community diversity. In 1967, individual diversity decreased, redundancy increased, and community diversity decreased, showing a slight deviation from the succession pattern of the largemouth bass parasite community.

The parasites of largemouth and spotted bass in Beaver Reservoir displayed a definite pattern of community succession. In the two preimpoundment years monitored, there was a moderate parasite community. During the year following impoundment the parasite community declined to a low level. In the following three years the parasite community gradually increased to become much larger and more complex than it was during preimpoundment. The community seemed to be stabilizing and approaching climax in 1967.

When the present Lake Fort Smith study is compared with the Beaver Reservoir investigations cited above, it appears that the parasite community structure of the black basses from Lake Fort Smith was similar to that of 1966 and 1967 in Beaver Reservoir. Individual diversity values were slightly greater from Lake Fort Smith whereas community diversity values were slightly less (Tables 6 and 7). Both Beaver Reservoir and Lake Fort Smith probably had relatively stable parasite communities during the time of this investigation, although gradual changes are certain to occur as the reservoirs age.

SUMMARY

A total of 385 hosts was examined in this investigation to determine the species and extent of helminth and crustacean parasites in seven selected game fishes from Lake Fort Smith, Crawford County, Arkansas. Parasite abundance was correlated with age and sex of the host. Seasonal abundance of parasites was determined and correlated with seasonal changes in physico-chemical factors. Parasite community structure was determined by diversity equations derived from information theory. The results of this study were compared with a previous fish parasite survey from Lake Fort Smith to determine any qualitative or quantitative changes subsequent to that study. Pre- and postimpoundment parasite community structure from black basses in Beaver Reservoir was studied to determine succession of parasite communities in a newly formed reservoir.

All fishes examined in this study were infected with at least one species of helminth or crustacean parasite for an overall infection rate of 100%. Thirty-eight species of parasites were found from the seven host species.

None of the parasites examined during this investigation displayed a predilection for either host sex. Therefore, it is doubtful that sex of the host affected abundance of any of the parasites examined in this study.

Some parasites showed significant correlations with age of the host while others did not. All significant correlations were positive, indicating that parasite populations tended to increase in abundance as host age increased. In this study, exposure time is apparently the major factor to consider when contemplating relationships between parasites and age of their hosts.

Seasonal abundance of the different species of parasites varied. Some species such as Ergasilus centrarchidarum were more abundant during the

summer months. Others such as Diplostomulum scheuringi, Pisciamphistoma stunkardi, Bothriocephalus cuspidatus, adult Proteocephalus ambloplitis, and Neoechinorhynchus cylindratus were more abundant during the cold months. Many monogenetic trematodes displayed peaks in both winter and summer. In almost all cases, monogenetic trematodes declined in the fall. Generally, ectoparasites showed higher correlations with physico-chemical factors than endoparasites. It appeared that temperature and turbidity were the most important physico-chemical factors which affected fish parasite abundance in Lake Fort Smith. The combined effects of physico-chemical factors, age, and sex of the host always accounted for less than 50% of the variance in abundance of the parasites. Therefore, there were factors not monitored during this study which may have exerted a major influence on abundance of parasites. The data from this investigation were somewhat inconclusive and further research is needed to determine all of the factors which govern abundance of fish parasites.

Few changes in the parasitofauna in Lake Fort Smith from 1961 to 1970-1971 were observed. Leptorhynchoides thecatus was present in 1961 but absent during the present study, and it appears that Posthodiplostomum minimum increased greatly from 1961 to 1970-1971. Other parasites seem to have remained relatively stable since 1961.

This study was a pioneer effort in quantitatively describing fish parasite community structure by use of diversity indices derived from information theory. Values of individual diversity, redundancy, and community diversity showed that warmouth had the most complex parasite communities in Lake Fort Smith. Largemouth bass and channel catfish had the largest parasite communities but they were not as complex as those of warmouth or bluegill. The two crappie species had the least significant parasite communities because their parasites were low both in numbers of individuals and

species. In general, monogenetic trematodes, Posthodiplostomum minimum, and Neoechinorhynchus cylindratus had the most influence on community diversity. Individual diversity did not fluctuate greatly on a seasonal basis in largemouth bass, warmouth, or bluegill. When individual diversity increased, redundancy tended to decrease, and vice versa. Community diversity displayed greater seasonal fluctuations than individual diversity. Seasonal changes in individual diversity and community diversity seemed to be correlated mostly with temperature, dissolved oxygen, and turbidity. There was no difference in community structure between the sexes of the hosts. Community diversity showed positive correlation with age of largemouth bass, warmouth, and bluegill. In warmouth, individual diversity increased with the age of the host, but did not in largemouth bass and bluegill. Therefore, older warmouth had larger and more complex parasite communities than younger warmouth. Older largemouth bass and bluegill had larger parasite communities, but the complexity was the same as in younger hosts. The combined effects of physico-chemical factors, age, and sex of the host accounted for less than 50% of the variance of community diversity, redundancy, and individual diversity in largemouth bass, warmouth, and bluegill. Therefore, other factors not monitored during this study may have accounted for the majority of the variance in fish parasite community structure in Lake Fort Smith.

The parasites of largemouth and spotted bass in Beaver Reservoir displayed a definite pattern of community succession. In the two preimpoundment years monitored, there was a moderate parasite community. During the year after impoundment the parasite community declined to a low level. In the following three years the parasite community gradually increased to become much larger and more complex than it was during preimpoundment. The community seemed to be stabilizing and approaching climax in 1967.

When the present Lake Fort Smith study is compared with the Beaver Reservoir investigations, it appears that the parasite community structure of the black basses from Lake Fort Smith was similar to that of 1966 and 1967 in Beaver Reservoir. Both Beaver Reservoir and Lake Fort Smith probably had relatively stable parasite communities at the time of this investigation, although gradual changes are certain to occur as the reservoirs age.

TABLES**Parasitology Phase**

Table 1. Monthly and annual numbers of hosts collected from Lake Fort Smith during 1970-1971.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Channel catfish	2	3	2	0	1	1	0	1	0	0	0	0	10
Warmouth	6	2	9	7	13	3	3	3	3	11	10	5	75
Bluegill	11	21	7	11	9	5	7	3	6	9	13	14	115
White crappie	0	0	1	1	3	1	5	7	5	2	2	0	27
Black crappie	2	1	0	2	5	2	2	1	0	0	0	0	15
Largemouth bass	7	3	10	9	11	5	7	4	0	13	10	9	89
Spotted bass	8	14	16	9	2	1	0	1	0	0	0	3	54
Total	36	44	45	39	44	18	24	20	14	35	35	31	385

Table 2. Species and host specificity of fish parasites from Lake Fort Smith (1970-1971).

C indicates channel catfish.
W indicates warmouth.
B indicates bluegill.
WC indicates white crappie.
BC indicates black crappie.
L indicates largemouth bass.
S indicates spotted bass.
a indicates adult.
l indicates larva.

	Host					
<u>Monogenea</u>						
<u>Acolpenteron ureteroecetes</u>					L	S
<u>Actinocleidus fergusoni</u>		B				
<u>Actinocleidus flagellatus</u>		W				
<u>Actinocleidus fusiformis</u>					L	S
<u>Anchoradiscus triangularis</u>		B				
<u>Clavunculus bursatus</u>		B			L	S
<u>Clavunculus sp.</u>		W				
<u>Cleidodiscus floridanus</u>	C					
<u>Cleidodiscus vancleavei</u>			WC	BC		
<u>Urocleidus acer</u>		B				
<u>Urocleidus chaenobryttus</u>		W				
<u>Urocleidus dispar</u>		B				
<u>Urocleidus ferox</u>		B				
<u>Urocleidus furcatus</u>					L	S
<u>Urocleidus grandis</u>		W				
<u>Urocleidus principalis</u>					L	S
<u>Digenea</u>						
<u>Alloglossidium corti</u>	C					
<u>Eucephalidae</u>		W				
<u>Clinostomum marginatum</u>		W	B			S
<u>Crepidostomum cornutum</u>	C	W	B	WC		L S
<u>Diplostomulum scheuringi</u>		W	B	WC	BC	L S
<u>Pisciamphistoma stunkardi</u>		W	B	WC	BC	L S
<u>Posthodiplostomum minimum</u>		W	B	WC	BC	L S
<u>Victosoma parvum</u>	C					

	Host						
Cestoda							
<u>Bothriocephalus cuspidatus</u>		W	B				S
<u>Corallobothrium fimbriatum</u>	C						
<u>Corallobothrium giganteum</u>	C						
<u>Proteocephalus ambloplitis</u> (a)		W					L
<u>Proteocephalus ambloplitis</u> (1)	C	W	B	WC	BC	L	S
Nematoda							
<u>Camallanus oxycephalus</u>	C	W	B	WC	BC	L	S
<u>Contracaecum spiculigerum</u>		W	B			L	S
<u>Spinitectus carolini</u>	C	W	B	WC	BC	L	S
Acanthocephala							
<u>Neoechinorhynchus cylindratus</u> (a)		W		WC		L	S
<u>Neoechinorhynchus cylindratus</u> (1)			B				
Crustacea							
<u>Argulus mississippiensis</u>		W	B			L	
<u>Achtheres micropteri</u>		W				L	S
<u>Ergasilus centrarchidarum</u>						L	S
<u>Lernaea cruciata</u>		W				L	
Molluska							
Glochidia		W	B	WC		L	S
Amelida							
<u>Illinobdella moorei</u>		W	B				S

Table 3. Mean monthly physico-chemical values from Lake Fort Smith (1970-1971) (Payne, unpublished).

	Temp (C)	pH	Dissolved Oxygen (ppm)	NH ₄ (ppm)	NO ₃ (ppm)	Ortho- phosphate (ppm)	M. O. Alkalinity (ppm)	Turbidity (JTU)
Jul	28.2	7.1	6.5	1.200	.037	.113	26.4	9.0
Aug	29.6	7.3	8.1	0.033	.049	.088	23.1	22.0
Sep	27.5	7.2	7.7	0.096	.050	.040	19.6	56.0
Oct	16.8	6.8	8.3	0.675	.093	.037	18.1	38.0
Nov	11.2	6.7	9.6	0.709	.118	.141	16.7	56.0
Dec	8.1	6.8	10.8	0.290	.143	.317	18.4	47.0
Jan	6.2	6.9	11.9	0.463	.147	.124	18.7	49.0
Feb	4.4	6.9	11.8	0.485	.125	.167	14.7	42.0
Mar	8.6	6.9	11.5	0.471	.137	.074	13.2	20.0
Apr	14.1	6.8	10.5	0.371	.131	.040	12.4	20.0
May	18.6	7.0	9.5	0.503	.113	.080	13.6	28.0
Jun	24.5	6.8	8.6	0.598	.128	.290	12.8	13.0

Table 4. Multiple coefficient of determination (r^2) values, F values, and degrees of freedom (df) of full models from multiple correlation-regression analysis of combined effects of physico-chemical factors, age, and sex of the host on parasites of largemouth bass (L), warmouth (W), and bluegill (B) from Lake Fort Smith (1970-1971).

* indicates the combined effects of physico-chemical factors, age, and sex have a significant ($P = .05$) effect on the parasite, and

** indicates a highly significant ($P = .01$) effect.

Parasite Species	Multiple r^2	F Value	df
Monogenea			
<u>Actinocleidus fergusoni</u>	0.1616	2.0051*	10, 104
<u>Actinocleidus flagellatus</u>	0.1960	1.5602	10, 64
<u>Actinocleidus fusiformis</u>	0.4460	6.2787**	10, 78
<u>Clavunculus bursatus</u> (L)	0.2160	2.1488*	10, 78
<u>Clavunculus bursatus</u> (B)	0.1441	1.7516	10, 104
<u>Clavunculus</u> sp.	0.1495	1.1252	10, 64
<u>Urocleidus acer</u>	0.1939	2.5020**	10, 104
<u>Urocleidus chaenobryttus</u>	0.2508	2.1430*	10, 64
<u>Urocleidus dispar</u>	0.2567	3.5921**	10, 104
<u>Urocleidus ferox</u>	0.2953	4.5386**	10, 104
<u>Urocleidus furcatus</u>	0.4049	5.3071**	10, 78
<u>Urocleidus grandis</u>	0.1777	1.3827	10, 64
<u>Urocleidus principalis</u>	0.4312	5.9139**	10, 78
Digenea			
<u>Crepidostomum cornutum</u> (L)	0.1053	0.9177	10, 78
<u>Crepidostomum cornutum</u> (W)	0.2846	2.5475*	10, 64
<u>Crepidostomum cornutum</u> (B)	0.2139	2.8305**	10, 104
<u>Diplostomulum scheuringi</u> (L)	0.2706	2.8941**	10, 78
<u>Diplostomulum scheuringi</u> (W)	0.4165	4.5680**	10, 64
<u>Diplostomulum scheuringi</u> (B)	0.1776	2.2463*	10, 104
<u>Pisciamphistoma stunkardi</u> (L)	0.1683	1.5782	10, 78
<u>Pisciamphistoma stunkardi</u> (W)	0.2607	2.2568*	10, 64
<u>Posthodiplostomum minimum</u> (L)	0.1821	1.7362	10, 78
<u>Posthodiplostomum minimum</u> (W)	0.2751	2.4290*	10, 64
<u>Posthodiplostomum minimum</u> (B)	0.0773	0.8711	10, 104
Cestoda			
<u>Bothriocephalus cuspidatus</u> (W)	0.2737	2.4112*	10, 64
<u>Bothriocephalus cuspidatus</u> (B)	0.1124	1.3168	10, 104
<u>Proteocephalus ambloplitis</u> adults (L)	0.2275	2.2965*	10, 78
<u>Proteocephalus ambloplitis</u> larvae (L)	0.0823	0.6998	10, 78
<u>Proteocephalus ambloplitis</u> larvae (W)	0.2081	1.6822	10, 64
<u>Proteocephalus ambloplitis</u> larvae (B)	0.1692	2.1185*	10, 104

Parasite Species	Multiple r^2	F Value	df
Nematoda			
<u>Camallanus oxycephalus</u> (L)	0.2151	2.1379*	10, 78
<u>Camallanus oxycephalus</u> (W)	0.2061	1.6617	10, 64
<u>Camallanus oxycephalus</u> (B)	0.2129	2.8140**	10, 104
<u>Contracaecum spiculigerum</u> (L)	0.1164	1.0279	10, 78
<u>Contracaecum spiculigerum</u> (W)	0.1838	1.4416	10, 64
<u>Contracaecum spiculigerum</u> (B)	0.0970	1.1169	10, 104
<u>Spinitectus carolini</u> (L)	0.1875	1.8003	10, 78
<u>Spinitectus carolini</u> (W)	0.2729	2.4018*	10, 64
<u>Spinitectus carolini</u> (B)	0.3521	5.6519**	10, 104
Acanthocephala			
<u>Neoechinorhynchus cylindratus</u> (L)	0.2126	2.1059*	10, 78
<u>Neoechinorhynchus cylindratus</u> (W)	0.1797	1.4022	10, 64
<u>Neoechinorhynchus cylindratus</u> (B)	0.1738	2.1885*	10, 104
Crustacea			
<u>Argulus mississippiensis</u> (L)	0.2780	3.0028**	10, 78
<u>Argulus mississippiensis</u> (W)	0.2912	2.6288**	10, 64
<u>Argulus mississippiensis</u> (B)	0.0933	1.0697	10, 104
<u>Achtheres micropteri</u> (L)	0.2441	2.5182*	10, 78
<u>Achtheres micropteri</u> (W)	0.2153	1.7565	10, 64
<u>Ergasilus centrarchidarum</u> (L)	0.3827	4.8350**	10, 78
Annelida			
<u>Ilinoabdella moorei</u> (W)	0.2078	1.6788	10, 64
<u>Ilinoabdella moorei</u> (B)	0.1531	1.8800	10, 104

Table 5. Comparison of the 1961 and 1970-1971 Lake Fort Smith fish parasite surveys.

- indicates the parasite was not studied in 1961, and
... indicates the parasite had a mean number of less than
0.1 individuals per fish.
Numbers in parentheses after dates indicate number of hosts.

Host	Parasite	Range of Parasites/ Fish (1961)	% Infected Fish (1961)	Range of Parasites/ Fish (1970)	% Infected Fish (1970)	Mean # of Parasites/ Fish (1970)
Channel catfish 1961 (3) 1970 (10)	<u>Cleidodiscus floridanus</u>	-	-	19-240	100.0	86.6
	<u>Alloglossidium corti</u>	0-8	66.7	0-238	80.0	33.7
	<u>Crepidostomum cornutum</u>	0-3	33.3	0-5	10.0	0.5
	<u>Vietosoma parvum</u>	0	0.0	0-730	80.0	133.8
	<u>Corallobothrium fimbriatum</u>	5-18	100.0	0-2	20.0	0.3
	<u>Corallobothrium giganteum</u>	0	0.0	0-40	50.0	6.3
	<u>Proteocephalus ambloplitis</u>	0-3	33.3	0-29	50.0	4.5
	<u>Camallanus oxycephalus</u>	0	0.0	0-12	20.0	1.3
	<u>Spinitectus carolini</u>	0	0.0	0-29	80.0	5.9
Warmouth 1961 (21) 1970 (75)	<u>Actinocleidus flagellatus</u>	-	-	0-65	85.3	9.6
	<u>Clavunculus sp.</u>	-	-	0-7	37.3	1.0
	<u>Urocleidus chaenobryttus</u>	-	-	0-70	90.6	18.6
	<u>Urocleidus grandis</u>	-	-	0-20	64.0	3.1
	<u>Bucephalidae</u>	0	0.0	0-1	2.6	...
	<u>Clinostomum marginatum</u>	0-1	5.0	0-1	2.6	...
	<u>Crepidostomum cornutum</u>	0-1	5.0	0-25	37.3	2.6
	<u>Diplostomulum scheuringi</u>	-	-	0-45	66.7	8.0
	<u>Pisciamphistoma stunkardi</u>	0-9	66.7	0-15	61.3	2.4
	<u>Posthodiplostomum minimum</u>	0	0.0	0-126	57.3	9.8
	<u>Bothriocephalus cuspidatus</u>	0	0.0	0-1	1.3	...
	<u>Proteocephalus ambloplitis</u>	0-5	28.6	0-8	45.3	1.2
	<u>Camallanus oxycephalus</u>	0-7	19.0	0-4	33.3	0.4
	<u>Contracaecum spiculigerum</u>	0	0.0	0-9	4.0	0.1
	<u>Spinitectus carolini</u>	0-16	14.3	0-37	64.0	2.7
	<u>Neoechinorhynchus cylindratus</u>	0	0.0	0-11	37.3	0.6
	<u>Argulus mississippiensis</u>	-	-	0-2	9.3	0.1
	<u>Achtheres micropteri</u>	-	-	0-12	10.6	0.3
	<u>Lernaea cruciata</u>	-	-	0-1	1.3	...
<u>Glochidia</u>	-	-	0-52	10.6	1.7	
<u>Illinobdella moorei</u>	-	-	0-5	17.3	0.5	

Host	Parasite	Range of Parasites/ Fish (1961)	% Infected Fish (1961)	Range of Parasites/ Fish (1970)	% Infected Fish (1970)	Mean # of Parasites/ Fish (1970)
Bluegill 1961 (21) 1970 (115)	<u>Actinocleidus fergusonii</u>	-	-	0-21	77.4	4.8
	<u>Anchoradiscus triangularis</u>	-	-	0-1	6.0	0.1
	<u>Clavunculus bursatus</u>	-	-	0-2	4.3	0.1
	<u>Urocleidus acer</u>	-	-	0-11	49.6	1.8
	<u>Urocleidus dispar</u>	-	-	0-19	74.8	4.4
	<u>Urocleidus ferox</u>	-	-	0-160	73.9	11.1
	<u>Clinostomum marginatum</u>	0	0.0	0-1	0.9	...
	<u>Crepidostomum cornutum</u>	0-53	57.1	0-163	67.8	11.1
	<u>Diplostomulum scheuringi</u>	-	-	0-18	33.1	3.1
	<u>Pisciamphistoma stunkardi</u>	-	-	0-1	2.6	...
	<u>Posthodiplostomum minimum</u>	0	0.0	0-1249	79.1	36.9
	<u>Bothriocephalus cuspidatus</u>	0	0.0	0-5	8.7	0.2
	<u>Proteocephalus ambloplitis</u>	0-26	81.0	0-78	23.7	1.6
	<u>Camallanus oxycephalus</u>	0-8	23.8	0-5	35.3	0.6
	<u>Contracaecum spiculigerum</u>	0	0.0	0-3	10.4	0.1
	<u>Spinitectus carolini</u>	0-25	66.7	0-122	84.4	12.7
	<u>Neoechinorhynchus cylindratus</u>	0-6	5.0	0-4	4.3	0.1
	<u>Argulus mississippiensis</u>	-	-	0-1	0.9	...
	<u>Glochidia</u>	-	-	0-13	13.9	0.5
	<u>Illinobdella moorei</u>	-	-	0-2	3.5	0.1
White crappie 1961 (22) 1970 (27)	<u>Cleidodiscus vancleavei</u>	-	-	0-37	85.2	18.3
	<u>Crepidostomum cornutum</u>	0	0.0	0-1	3.7	...
	<u>Diplostomulum scheuringi</u>	-	-	0-21	11.1	0.9
	<u>Pisciamphistoma stunkardi</u>	0-8	40.9	0-20	14.8	0.9
	<u>Posthodiplostomum minimum</u>	0	0.0	0-20	22.2	1.7
	<u>Proteocephalus ambloplitis</u>	0	0.0	0-2	11.1	0.1
	<u>Camallanus oxycephalus</u>	0-75	77.3	0-15	92.6	4.1
	<u>Spinitectus carolini</u>	0-12	18.2	0-4	14.8	0.3
	<u>Neoechinorhynchus cylindratus</u>	0	0.0	0-4	3.7	0.1
<u>Glochidia</u>	-	-	0-1	3.7	...	

Host	Parasite	Range of Parasites/ Fish (1961)	% Infected Fish (1961)	Range of Parasites/ Fish (1970)	% Infected Fish (1970)	Mean # of Parasites/ Fish (1970)
Black crappie 1961 (10) 1970 (15)	<u>Cleidodiscus vanceleavei</u>	-	-	0-60	86.7	14.5
	<u>Diplostomulum scheuringi</u>	-	-	0-11	13.3	0.8
	<u>Pisciamphistoma stunkardi</u>	0-1	20.0	0-4	26.7	0.7
	<u>Posthodiplostomum minimum</u>	0	0.0	0-22	13.3	1.5
	<u>Proteocephalus ambloplitis</u>	0	0.0	0-2	6.6	0.1
	<u>Camallanus oxycophalus</u>	15-75	100.0	1-30	100.0	12.9
	<u>Spinitectus carolini</u>	0-35	10.0	0-3	6.6	0.2
Spotted bass 1961 (2) 1970 (54)	<u>Acolpenteron ureterocoetes</u>	-	-	0-2	3.7	0.1
	<u>Actinocleidus fusiformis</u>	-	-	0-2	3.7	0.1
	<u>Clavunculus bursatus</u>	-	-	0-8	33.4	1.1
	<u>Urocleidus furcatus</u>	-	-	0-11	5.6	0.2
	<u>Urocleidus principalis</u>	-	-	0-55	59.3	5.9
	<u>Clinostomum marginatum</u>	0	0.0	0-2	1.8	...
	<u>Crepidostomum cornutum</u>	0	0.0	0-36	5.6	0.7
	<u>Diplostomulum scheuringi</u>	-	-	0-2	5.6	0.1
	<u>Pisciamphistoma stunkardi</u>	0	0.0	0-1	11.1	0.1
	<u>Posthodiplostomum minimum</u>	0	0.0	0-20	46.3	1.6
	<u>Bothriocephalus cuspidatus</u>	0	0.0	0-1	1.8	...
	<u>Proteocephalus ambloplitis</u>	50-68	100.0	0-145	98.2	30.5
	<u>Camallanus oxyccephalus</u>	0-7	50.0	0-41	92.6	9.6
	<u>Contracaecum spiculigerum</u>	0	0.0	0-5	9.3	0.3
	<u>Spinitectus carolini</u>	0	0.0	0-6	24.1	0.6
	<u>Neoechinorhynchus cylindratus</u>	5-22	100.0	0-81	96.4	20.5
	<u>Achtheres micropteri</u>	-	-	0-4	14.8	0.2
	<u>Ergasilus centrarchidarum</u>	-	-	0-9	37.0	1.3
<u>Glochidia</u>	-	-	0-128	1.8	2.4	
<u>Ulinobdella moorei</u>	-	-	0-4	5.6	0.1	

Host	Parasite	Range of Parasites/ Fish (1961)	% Infected Fish (1961)	Range of Parasites/ Fish (1970)	% Infected Fish (1970)	Mean # of Parasites/ Fish (1970)
Largemouth bass 1961 (22) 1970 (89)	<u>Acolpenteron ureterocoetes</u>	-	-	0-2	2.2	...
	<u>Actinocleidus fusiformis</u>	-	-	0-32	57.3	5.3
	<u>Clavunculus bursatus</u>	-	-	0-21	45.0	1.4
	<u>Urocleidus furcatus</u>	-	-	0-160	80.9	27.2
	<u>Urocleidus principalis</u>	-	-	0-244	80.9	47.4
	<u>Clinostomum marginatum</u>	0-7	11.1	0	0.0	0.0
	<u>Crepidostomum cornutum</u>	0	0.0	0-1	2.2	...
	<u>Diplostomulum scheuringi</u>	-	-	0-3	11.2	0.2
	<u>Pisciamphistoma stunkardi</u>	0-2	13.6	0-3	11.2	0.2
	<u>Posthodiplostomum minimum</u>	0-14	11.1	0-483	71.9	58.1
	<u>Proteocephalus ambloplitis</u> adults	0	0.0	0-11	7.9	0.3
	<u>Proteocephalus ambloplitis</u> larvae	0-54	59.1	0-52	63.0	5.0
	<u>Camallanus oxycephalus</u>	0-46	36.4	0-29	50.5	1.5
	<u>Contracaecum spiculigerum</u>	0-1	5.0	0-8	26.9	0.8
	<u>Spinitectus carolini</u>	0-6	18.2	0-17	38.2	1.8
	<u>Leptorhynchoides thecatus</u>	0-3	5.0	0	0.0	0.0
	<u>Neoechinorhynchus cylindricus</u>	0-62	81.8	2-287	100.0	41.1
	<u>Argulus mississippiensis</u>	-	-	0-1	3.4	...
	<u>Achtheres micropteri</u>	-	-	0-4	31.4	0.3
	<u>Ergasilus centrarchidarum</u>	-	-	0-88	47.2	4.9
<u>Lernaea cruciata</u>	-	-	0-1	3.4	...	
<u>Glochidia</u>	-	-	0-159	7.9	3.0	

Table 6. Mean individual diversity (\bar{d}), redundancy (R), and community diversity (d) values of parasite communities from Lake Fort Smith fishes (1970-1971).

	Channel catfish	Warmouth	Bluegill	White crappie	Black crappie	Largemouth bass	Spotted bass
d	1.15	2.11	1.90	0.83	0.87	1.85	1.77
R	.5109	.2786	.2776	.4799	.4820	.3459	.2698
d	274.38	145.18	141.14	23.59	33.35	371.76	137.23

Table 7. Mean yearly individual diversity (\bar{d}), redundancy (R), and community diversity (d) values of parasite communities from Beaver Reservoir black basses.

Largemouth bass

	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>
d	0.75	0.97	0.51	1.67	1.72	1.73
R	.5816	.5075	.6845	.2898	.3137	.3357
d	109.80	162.56	105.78	205.02	256.45	466.10

Spotted bass

	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>
d	1.19	1.01	0.54	0.76	1.75	1.42
R	.3972	.5041	.7215	.6001	.2631	.3556
d	98.24	185.18	97.96	115.78	173.82	151.01

Smallmouth bass

	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>
d	0.88	1.11	-	-	-	-
R	.5760	.4681	-	-	-	-
d	13.82	82.34	-	-	-	-

FIGURES

Parasitology Phase

Figures 1-3. Monthly mean values of individual diversity (\bar{d}) of parasite communities from Lake Fort Smith fishes (1970-1971).

FIGURE 1 LARGEMOUTH BASS

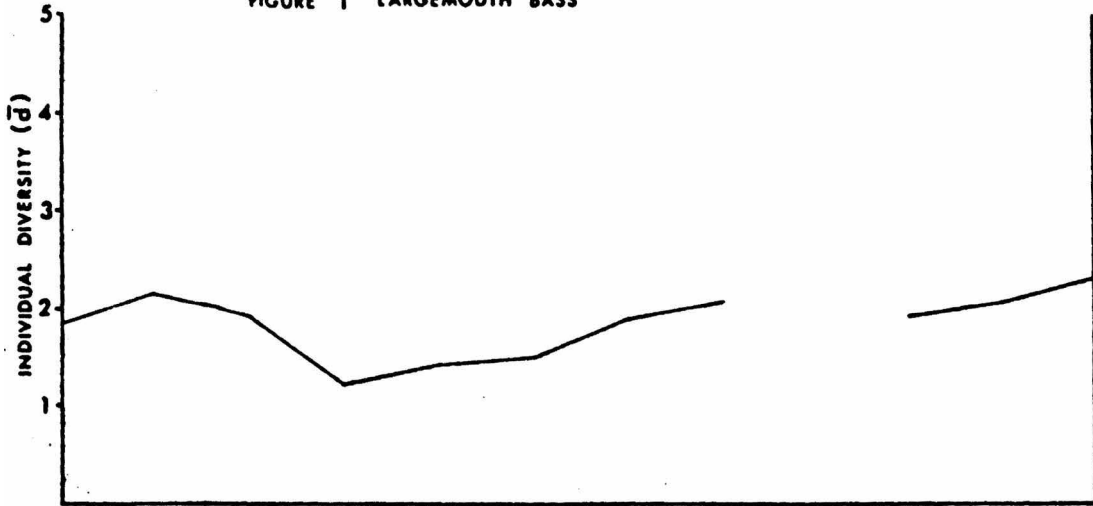


FIGURE 2 WARMOUTH

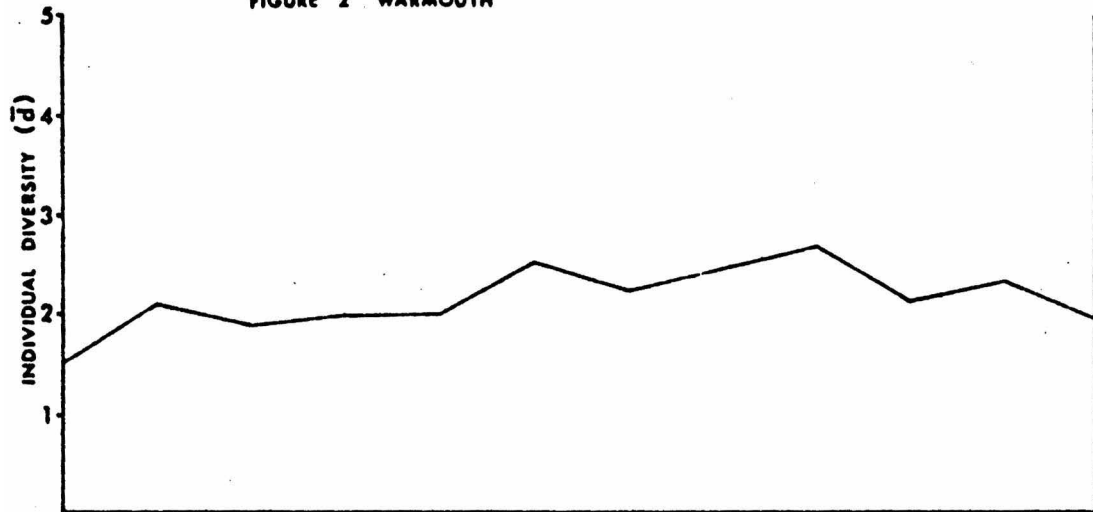


FIGURE 3 BLUEGILL



Figures 4-6. Monthly mean values of redundancy (R) of parasite communities from Lake Fort Smith fishes (1970-1971).

FIGURE 4 LARGEMOUTH BASS

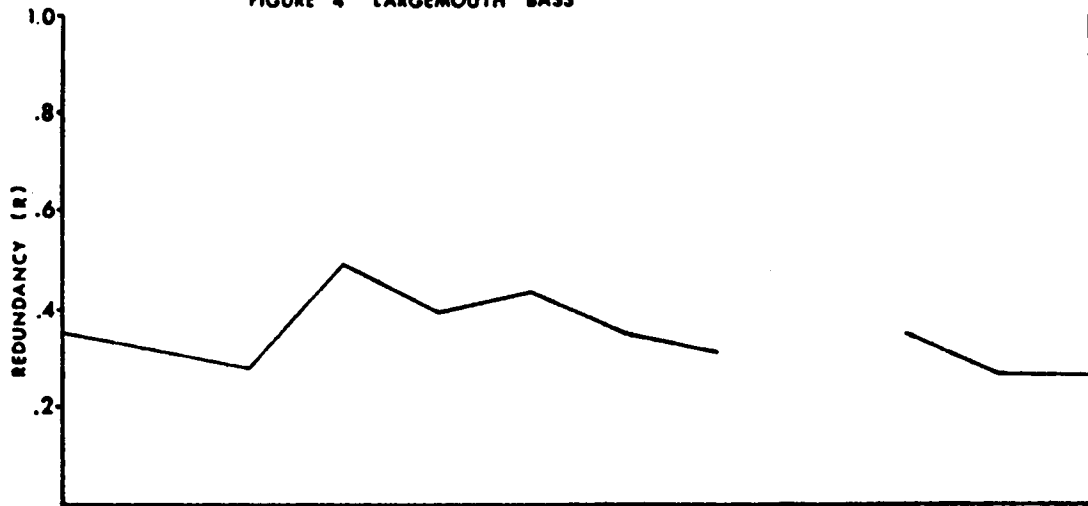


FIGURE 5 WARMOUTH

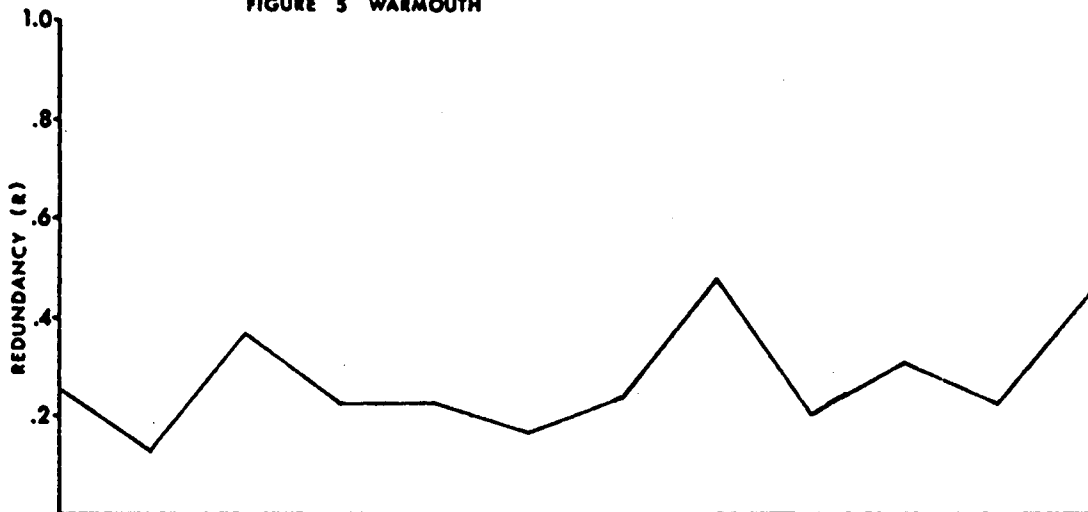
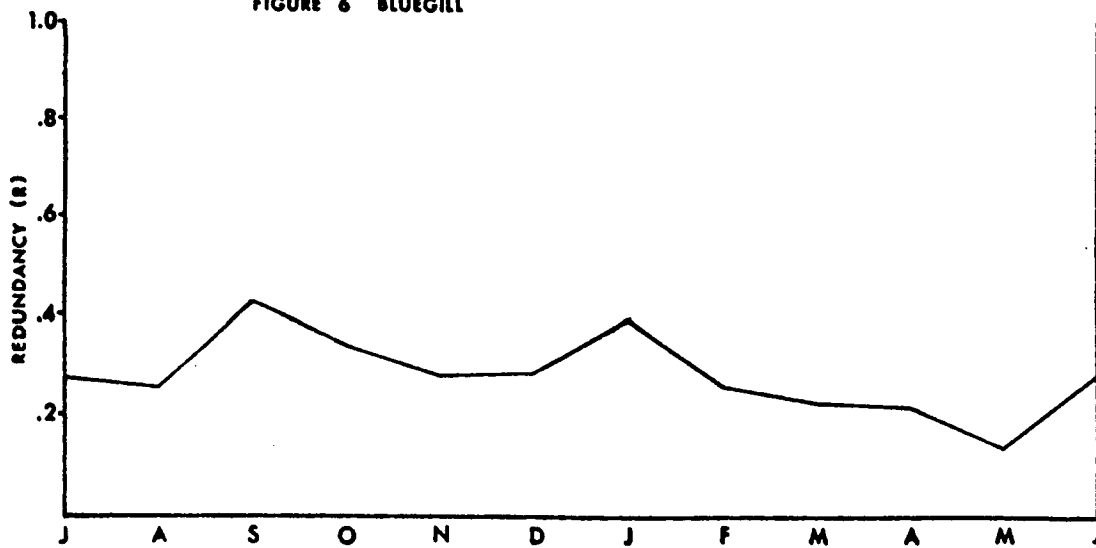


FIGURE 6 BLUEGILL



Figures 7-9. Monthly mean values of community diversity (d) of parasite communities from Lake Fort Smith fishes (1970-1971).

FIGURE 7 LARGEMOUTH BASS

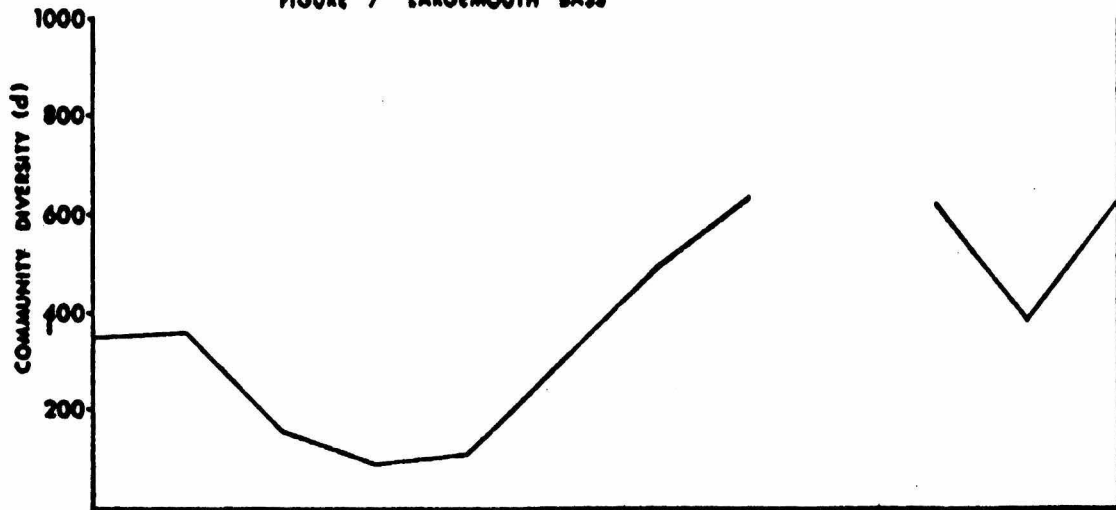


FIGURE 8 WARMOUTH

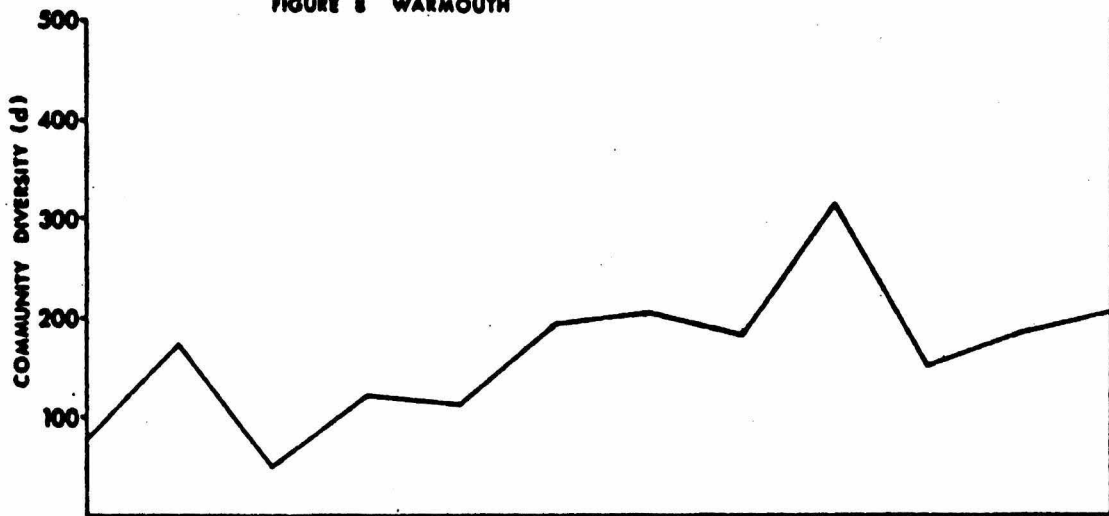
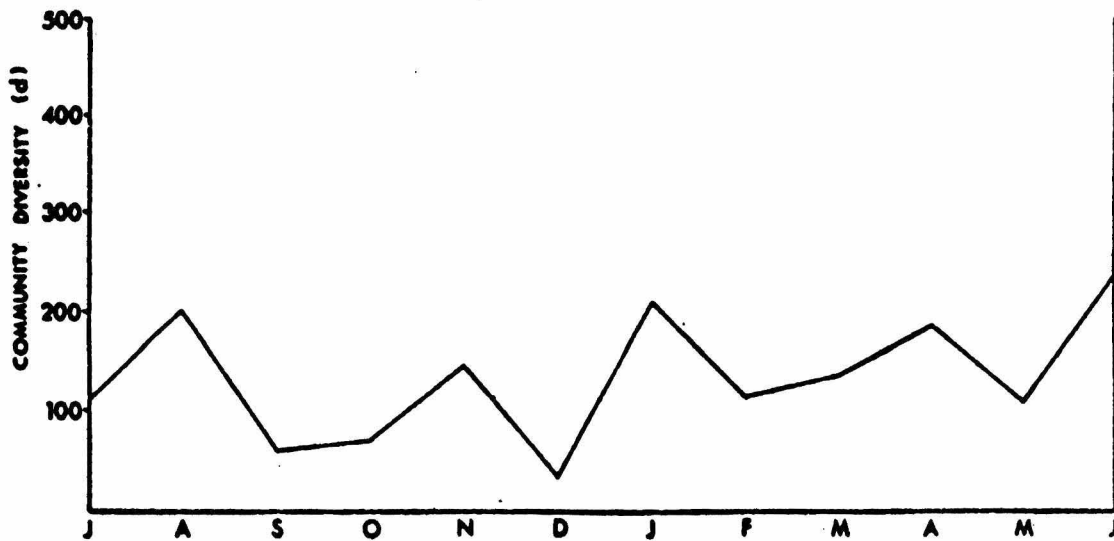


FIGURE 9 BLUEGILL



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