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ABSTRACT

Kettle Island Bay is an important spawning site and nursery area for largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus), and pumpkinseed (Lepomis gibbosus). Intensive sampling for young-of-the-year fish, macrobenthos, and zooplankton was done once weekly from June 1 to September 30, 1978, to determine seasonal growth, food habits, prey selection, and niche overlap. Cold weather in May and June, 1979, delayed the spawning of largemouth bass and black crappie by about three weeks.

Growth of largemouth bass, black crappie, and pumpkinseed fingerlings was as good as, or superior, to the growth reported for populations in the more southern parts of their ranges. The young largemouth bass grew to a maximum average size of 86.5 mm long and 14.2 g in weight and the largest individual was 147 mm long and weighed 54.8 g. The largest average size for black crappie was 77.2 mm long and weighed 6.22 g with the largest individual 92 mm long and weighing 10.7 g. The young pumpkinseed grew to an average of 44.3 mm in total length and weighed 1.89 g while the largest fingerling was 63 mm long and weighed 4.09 g. Growth of largemouth bass and black crappie was isometric for the first year but the pumpkinseed fry became slightly heavier, proportionately, as length increased. The Fulton's condition factor increased with the length of the largemouth bass and pumpkinseed fingerlings and the average value was 1.41 and 1.74, respectively. The value

for the condition factor did not vary much from 1.27 for the black crappie fingerlings.

The number of gillrakers increased with the length of the young black crappie to a maximum of 30 but the number of gill rakers decreased with the increasing length of the young largemouth bass and pumpkinseed to a value of 8.

Zooplankton densities (often over 1,000,000 animals/m^3) and macrobenthos biomass (up to 31 g/m^2) were high compared to other waters and showed that food was not in short supply in the bay.

Young-of-the-year largemouth bass switched from a diet of zooplankton to one of small fishes at a length of 35 mm and macrobenthos never accounted for more than 32 percent of stomach content weight. Tadpoles entered the diet when the bass were about 66 mm long.

Young-of-the-year black crappie were primarily planktivores and the amount of macrobenthos in the diet increased as the crappie grew. Black crappie were the only species that ate large quantities of Chaoborus and calanoid copepods. Pelagic fish fry were a very important part of the diet of black crappie fry, accounting for up to 88.6 percent of the stomach contents of crappie 26 mm long.

Macrobenthic organisms were the major prey of pumpkinseed longer than 20 mm although zooplankton usually represented at least 15 percent of the diet. Chironomid larvae were the principal benthic prey and Daphnidae were the chief planktonic prey of young pumpkinseed. Gastropods and pelecypods entered the diet once the pumpkinseed attained a length of 38 mm.

Largemouth bass fed mostly in the late morning and early afternoon, black crappie fed mostly in the morning but had a slight feeding peak near sunset, and pumpkinseed fed at a relatively constant rate from late morning until just before sunset.

The values of the selectivity indices of young largemouth bass, black crappie, and pumpkinseed changed seasonally and with the time of day due to changes in prey availability and also due to the growth of the fish.

Values for Levin's niche overlap index were only above a value of 0.70 when both largemouth bass and black crappie fed on the very abundant fish fry and common forms of zooplankton. The niche overlap values for pumpkinseed and black crappie only exceeded 0.70 when both fish species were eating the very common zooplankton forms. The niche overlap indices for largemouth bass and pumpkinseed seldom exceeded a value of 0.30.

The Mann-Witney U-test and the Wilcoxon paired ranking test were ineffective in detecting differences in the diets of two fish species. The Chi-square contingency tables showed that increasing values for the Levin's niche overlap index corresponded with increasing similarity of the diets of the two fish species.

Competition was not occurring in Kettle Island Bay because there was no resource in short supply and there is considerable partitioning possible due to the morphological adaptations for food procurement of the young largemouth bass, black crappie, and pumpkinseed.

RESUME

La Baie de l'Ile Kettle est une frayère importante pour l'achigan à grande bouche (Micropterus salmoides), la marigane noire (Pomoxis nigromaculatus), et le crapet-soleil (Lepomis gibbosus). Un échantillonage hebdomadaire intense fut effectué pour les saumoneaux, le macrobenthos, et les zooplanctons à partir du premier juin jusqu'au 30 septembre en 1978 afin de déterminer les taux de croissance, les diètes, la sélection des proies, et le chevauchement des niches. Le mauvais temps aux mois de mai et juin, 1979, a retardé le frai de l'achigan à grande bouche et de la marigane noire par trois semaines.

La croissance des tacons de l'achigan à grande bouche, la marigane noire, et le crapet-soleil fut égale, ou superiure, à la croissance des populations dans les distributions plus au sud.

La plus grande longueur totale moyenne des tacons de l'achigan à grande bouche était 86.5 mm et le plus grand poids moyen était 14.2 g. Le plus grand spécimen mesurait 147 mm et pesait 54.8 g.

La plus grande longueur totale moyenne des saumoneaux de la marigane noire était 77.2 mm avec le plus grand poids moyen de 6.22 g. Le plus grand spécimen mesurait 92.0 mm et pesait 10.7 g.

La plus grande longueur totale moyenne des tacons du crapet-soleil était 44.3 mm avec le plus grand poids moyen de 1.89 g. Le plus grand spécimen mesurait 63 mm et pesait

4.09 g.

La croissance de l'achigan à grande bouche et de la marigane noire était isométrique pour la première année mais les tacons du crapet-soleil devinrent plus pesant, en proportion, avec longueur croissante.

Le coéfficient de condition de Fulton augmenta avec la longueur croissante des saumoneaux de l'achigan à grande bouche et du crapet-soleil et les valeurs moyennes étaient 1.41 et 1.74, respectivement. Le coéfficient de condition était de 1.27 pour les tacons de la marigane noire.

Le nombre de branchiospines augmenta jusqu'à 30 avec la longueur de la marigane noire mais diminua avec la longueur jusqu'à 8 dans le cas des tacons d'achigan à grande bouche et de crapet-soleil.

Les densités des zooplanctons (souvent plus de 1,000,000 animaux/m^3) et les biomasses du macrobenthos (jusqu'à 31 g/m^2) ont demontrées que la nourriture n'est pas un facteur limitant dans la baie.

Les tacons de l'achigan à grande bouche ont changés d'une diète de zooplanctons à une diète de poisson à une longueur de 35 mm. Le macrobenthos n'a jamais compté plus de 32 pour cent des contenus stomacaux. Les têtards constituaient une part importante des contenus stomacaux chez les achigans plus long que 66 mm.

Les saumoneaux de la marigane noire étaient des planctivores mais elles mangent plus de benthos a mesure qu'ils croissent. La marigane noire était la seule espèce a mangé des <u>Chaoborus</u> et des calanoides. Les saumoneaux pelagiques étaient très importants pour la nourriture des tacons de la marigane noire, comptant pour 88.6 pour cent de la diète des marigane s de 26 mm de longueur.

Les organismes macrobenthiques étaient les plus importantes proies des crapet-soleil plus long que 20 mm, mais le zooplancton demeurait très important constituent toujours au moins 15 pour cent de la diète. Les larves de chironomids étaient la principale proie benthique et les Daphnidae étaient la principale proie planctonique. Les gastéropdes et pélécypodes entraient dans la diète des crapet-soleil plus long que 38 mm.

L'achigan à grande bouche se nourrissait principalement de la fin de l'avant-midi jusqu'au début de l'aprés-midi, la marigane noire se nourrissait principalement du matin mais possédait un faible pic d'alimentation près du coucher du soleil, et le crapet-soleil se nourrissait d'une façon relativement constante de la fin de l'avant-midi jusqu'au coucher de soleil.

Les valeurs pour les indices de la sélectivitée des saumoneaux de l'achigan à grande bouche, marigane noire, et crapet-soleil ont changés avec la saison et l'heure à cause des changements des proies disponibles et la croissance des poissons.

Les valeurs des indices de chevauchement de niche de Levins entre l'achigan à grande bouche et la marigane noire ont dépassés 0.70 seulement quand les deux espèces se sont nourrit de saumoneaux et des types de zooplancton qui étaient abondantes. Les valeurs des indices du chevauchement de niche entre la marigane noire et le crapet-soleil ont dépassé 0.70 seulement quand les deux espèces ont mangés les types de zooplancton les plus abondants. Les valeurs des indices du chevauchement de niche entre l'achigan à grande bouche et le crapet-soleil n'ont dépassés 0.30 que rarement.

Les tests de Mann-Witney et de Wilcoxon étaient inefficace pour détecter les différences entre les diètes des deux espèces de poissons. Les tests Chi carré ont démontrés que les augmentations des valeurs des indices de chevauchement de niche de Levins s'accordent avec la similarité des dietès.

La compétition n'existe pas dans la Baie de l'Ile Kettle parce qu'il y a beaucoup de nourriture disponible et il y a beaucoup de ségrégations des diètes possibles parce que les trois especès sont bien adaptées pour se prôcurer leurs nourritures.

INTRODUCTION

Largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus), and pumpkinseed (Lepomis gibbosus) are very important game and pan fishes yet there is little published information pertaining to the biology of these three species in Canadian waters. The range of largemouth bass extends as far north as Lake Temiskaming in the Ottawa River as does that of pumpkinseed (Scott & Crossman, 1973). The Ottawa River is the northern limit of the distribution of black crappie and they do not occur upstream of the Chaudière Falls in Ottawa, Ontario (McAllister & Coad, 1974; Hanson & Qadri, 1980).

The young-of-the-year of most fish species are usually ignored in studying freshwater systems. It is essential to gather information on this critical stage in a fish's life because an event that adversly affects the growth and survival of the young will affect the entire population (McCaig & Mullan, 1960; Li et al., 1975; and Timmons et al., 1980). Gerking (1962) calculated the often quoted value of 91 kg/acre for the production of bluegill (Lepomis macrochirus) in ponds but Chadwick (1976) and Mahon (1976) discovered that the actual production was about six times greater because Gerking had miscalculated the biomass and mortality of the young fish.

Young-of-the-year largemouth bass have a compressed fusiform body shape, strong jaws, and a relatively large mouth. Some information is available on the growth and food habits of the young-of-the-year of some Ontario populations (Keast, 1965; Keast & Webb, 1968; Hamilton & Powles, 1979) and there are a number of recent studies from the more southerly part of the range in the United States (Miller & Kramer, 1971; Tucker, 1973; Timmons <u>et al</u>., 1980). The feeding periodicity of largemouth bass has only been shown for very young fry (Elliot, 1976). The selectivity indices of young largemouth bass for some food types have been discussed by Elliot (1976), Moyle & Holzhauser (1978), and Timmons et al. (1980).

Young-of-the-year black crappie have a deep body with extreme lateral compression, a moderately sized mouth, and protrusable mandible and premaxilla. There has only been one study published on the growth and food habits of young black crappie in Canadian waters (Hanson & Qadri, 1979) and there are few studies available for American waters (Sivells, 1949; and Tucker, 1973). Only the feeding periodicity of adult black crappie in aquaria has been reported (Childers & Shoemaker, 1954). Selectivity indices have not been applied previously to young black crappie.

Young-of-the-year pumpkinseed have a gibbose body shape, a small protusable mouth, and molariform pharyngeal teeth. There are only two studies, based on a small sample size and for a limited time period, that mention the food habits of young pumpkinseed in Canadian waters (Reid, 1930; Keast, 1978) and there are only a few studies from American waters (Ewers & Boesel, 1934; Sadzikowski & Wallace, 1976), again based on small numbers of fish. Selectivity indices have not been reported for field studies of pumpkinseed.

In order for competition to occur there must be a resource in short supply, usually food. It is unfortunate that most earlier authors did not study the availability of food when examining the food habits of fish because it is difficult to determine if competition was occurring without this information. If two or more morphologically similar or closely related fish species did not evolve together there may not be enough morphological differences or behavioral adaptations for habitat or food partitioning to occur and some displacement may take place (Nilsson, 1963; Werner & Hall, 1976, 1977; and Robinson & Tash, 1979). Extreme competition in fish is most likely to result in reduced growth (Jenkins, 1955; McCaig & Mullan, 1960; and Li et al., 1975) which could result in extensive overwinter mortality of young-of-the-year fish (Hunt, 1969; Oliver et al., 1979; Shelton et al., 1979). There are many examples where closely related fish species share the same habitat (Nilsson, 1958, 1978; Keast, 1965; Gibbons & Gee, 1972; and Werner et al., 1977) but the partitioning of resources by young-of-the-year fish has seldom been reported as undertaken by the present study.

This study was undertaken to collect information on the seasonal growth and condition of young-of-the-year largemouth bass, black crappie, and pumpkinseed in Kettle Island Bay, an important nursery area in the Ottawa River, and to compare this data to populations in other parts of their ranges. A second purpose of this study was to test, using selectivity indices, how the morphology of the species relates to their use of the available food resources and to compare this to populations in other parts of the distribution. The final aim of this work was to detect and explain competition for the available resources between these three species of sunfish during the first year of life in Kettle Island Bay.

DESCRIPTION OF THE STUDY SITE

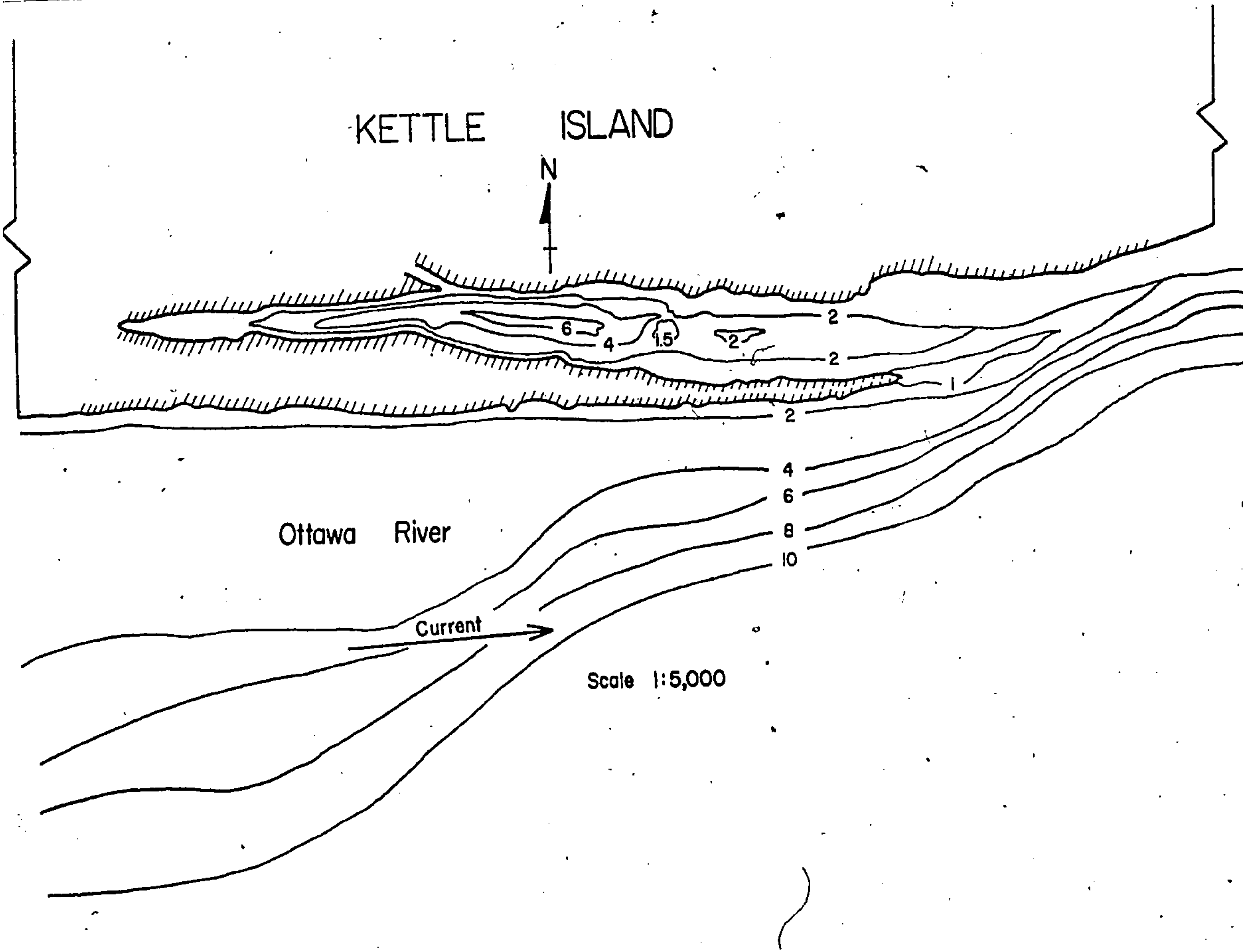
Kettle Island Bay (75°39'0" W; 45°28'8" N) is a long narrow bay, five hectares in area. The average depth of the study area was 3.0 m and the maximum depth was 6.0 m (Fig. 1). The underlying substrate was sand but there was progressively more detritus and organic debris covering the sand as one sampled deeper into the bay. Sunken logs were common and there were sunken stumps scattered along much of the north shoreline.

Emergent vegetation consisted of *Sagittaria latifolia*, *Scirpus atrovirens*, *Polygonum natans*, and *Pontederia cordata*. Dense growths of *Elodea canadensis* with varying amounts of *Ceratophyllum demersum* and *Vallisneria americana* to a depth of about 1.0 m. Thick patches of *Potamogeton natans*, *P. crispus*, *P. perfoliatus*, and *P. pectinatus* grew with some *Vallisneria* and *Ceratophyllum* from about 1.0 to 2.5 m depths. Occasional patches of *Potamogeton natans* occurred as deep as 3.0 m. *Nymphaea odorata* and *Nuphar variegatum* grew with the *Potamogeton* spp. on the two underwater humps at 1.5 and 2.0 m depths as well as across the mouth of the bay. Thick growths of *Elodea* were found beneath the *Nymphaea* and *Nuphar* growing across the mouth of the bay. The sandbar at the mouth of the bay was flanked by beds of *Vallisneria*. Scattered patches of *Myriophyllum heterophyllum* and *Cabomba caroliniana* were found throughout the bay, particularly on the north side. There were occasional patches of *Utricularia inflata* near the emergent vegetation. Heavy growths of *Spirogyra* spp. were evident in strips along much of the south side of the bay in late August. Large colonies of the bryozoan *Pectinella magnifica* were often seen attached to the stems and roots of the *Potamogeton* and to fallen trees.

Water temperatures and conductivity were measured with a Model 33 Salinity-Conductivity-Temperature meter and the oxygen concentration was measured with a Model 57 Oxygen meter (both meters were manufactured by Yellow Springs Instument Co., Ltd., Yellow Springs, Ohio). A Model 610 A Expand Portable pH meter (Corning Medical-Corning Glass Works, Medfield, Massachusetts) was used for the measurement of pH. Total hardness and carbon dioxide concentrations were measured with a DR-EL "Direct Reading" Portable Engineer's Laboratory (Hach Chemical Co., Inc., Ames, Iowa).

The water temperature at a depth of 0.1 m is shown for each sample date during 1978 in Fig. 2. All values were taken at 10:00 h. Table 1 summarizes the chemical and physical parameters measured for Kettle Island Bay at a depth of 0.1 m at about 10:00 h on sample dates in 1978 and 1979. Low values for total hardness were usually measured after heavy rains. Thermal stratification of Kettle Island Bay

Figure 1. Depth contours of Kettle Island Bay in meters.


KETTLE ISLAND
N
Ottawa River
Current
Scale 1:5,000
2
2
2
1
1.5
4
6
2
4
6
8
10

had already developed by June (Fig. 3) and the hypolimnion generally began at a depth of about 4.0 m. The thermocline usually started at a depth of about 2.0 m and it disappeared with the fall overturn in late September, 1978, although the water temperature was still about 14 C. The oxygen profiles of Kettle Island Bay for the 1979 sampling periods are shown by Figure 4. The "anoxic" layer (about 1.0 mg/L) moved upwards as the summer progressed until August when the retreat downwards was probably due to a series of severe storms from an easterly direction that caused some mixing of river water with the water of the bay and also caused some mixing of surface water with the deeper layers. The oxygen concentration reached a value as high as 4.0 mg/L at a depth of 6.0 m during the overturn in late September. The low oxygen concentrations below 3.0 m probably excludes fish from feeding there for any extended period of time throughout most of the sampling period. The concentration of carbon dioxide at a depth of 6.0 m had a mean and standard error of 84.4 + 12.93 mg/L for both years compared to a value of 7.95 + 0.19 mg/L near the surface. The concentration of carbon dioxide was 16 mg/L both near the surface and at a depth of 6.0 m during the overturn. The conductivity profiles for Kettle Island Bay (Fig. 5) show a sharp increase in conductivity occurred between 2.0 and 4.0 m in depth which indicates chemical stratification. The values for total hardness seldom differed between surface and deep samples which suggests that organic nutrients may have been trapped

Figure 2. Seasonal water temperatures of Kettle Island Bay at a depth of 0.1 m from the surface in 1978.

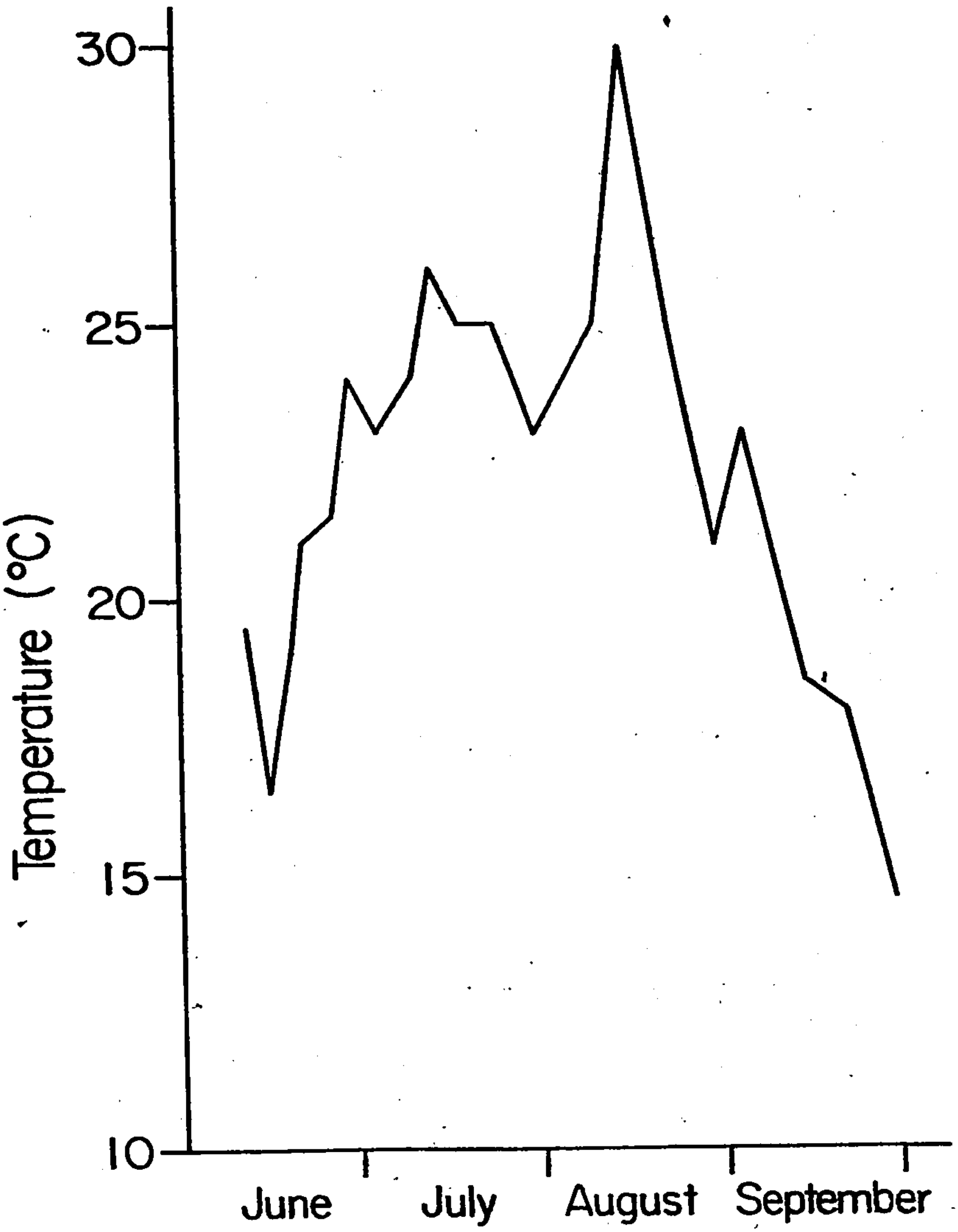

30
25
20
15
10
Temperature (°C)
June
July
August
September

Table 1. Average values of physical and chemical parameters of Kettle Island Bay at a depth of 0.1 m from the surface during 1978 and 1979.

Parameter	No.	Mean ± S.E.	Range
pH	22	7.22 ± 0.04 mg/L	6.9 - 7.6
Total Hardness	22	30.77 ± 1.39 mg/L	20.0 - 45.0
Carbon Dioxide	22	7.95 ± 0.19 mg/L	4.0 - 12.0
Oxygen	22	8.44 ± 0.19 mg/L	7.0 - 11.0
Conductivity	4	58.75 ± 2.93 µMhos/mL	52.0 - 65.0

Figure 3. Temperature profiles of Kettle Island Bay during 1978 and 1979.

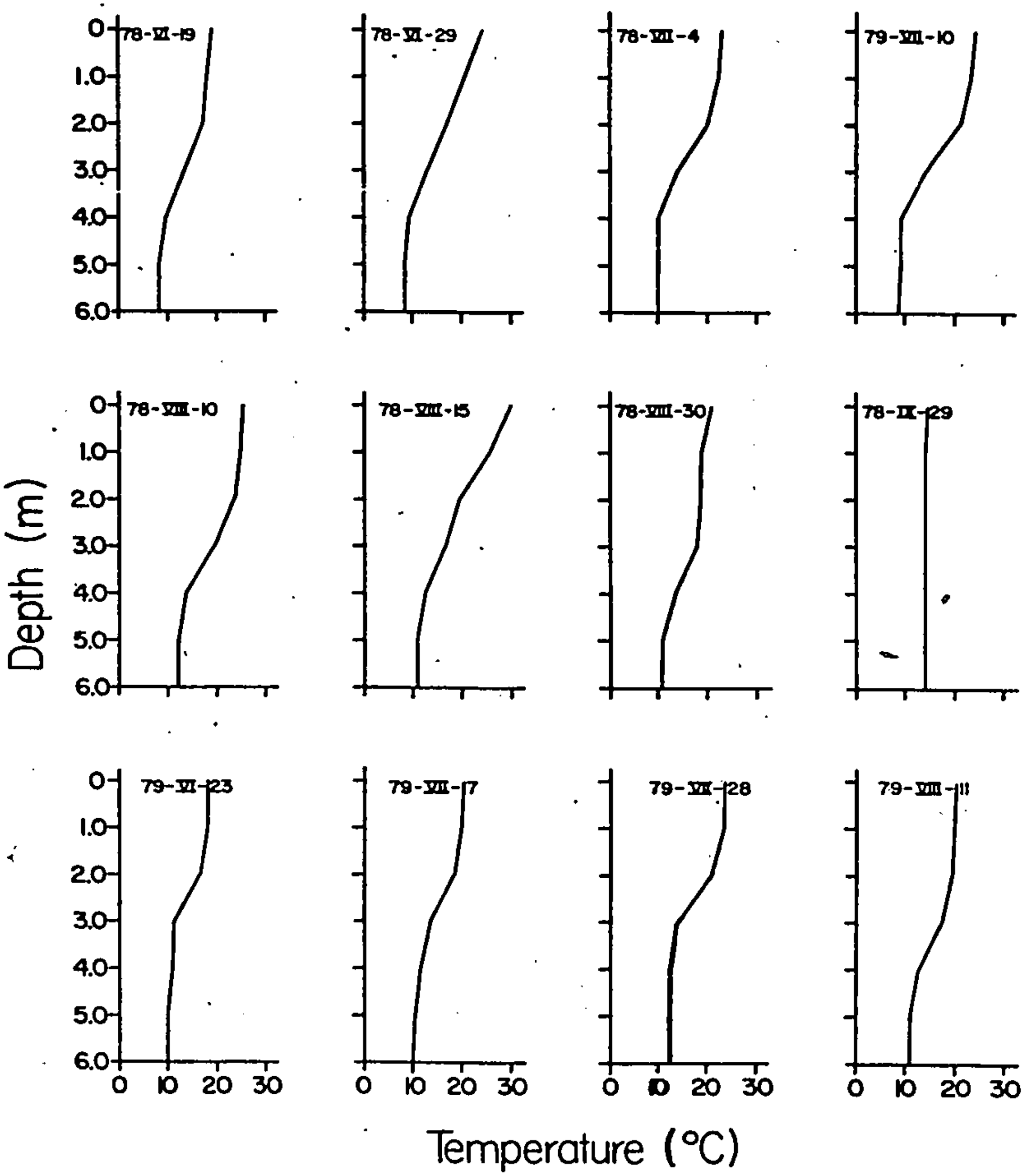

78-VI-19
78-VI-29
78-VII-4
79-VII-10
78-VIII-10
78-VIII-15
78-VIII-30
78-IX-29
79-VI-23
79-VII-17
79-VII-28
79-VIII-11
0
1.0
2.0
3.0
4.0
5.0
6.0
Depth (m)
0 10 20 30
Temperature (°C)

Figure 4. Oxygen profiles of Kettle Island Bay during 1979.

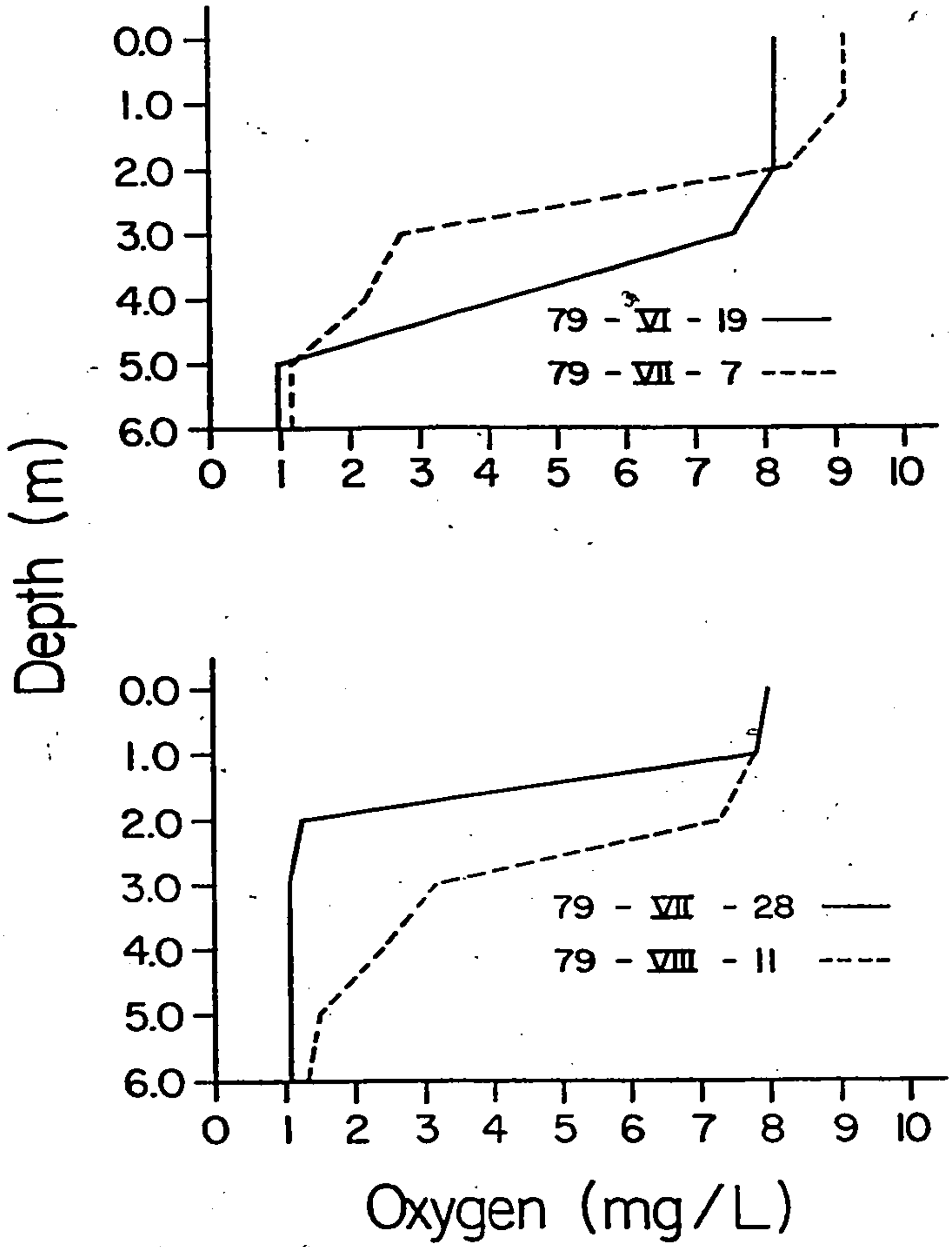
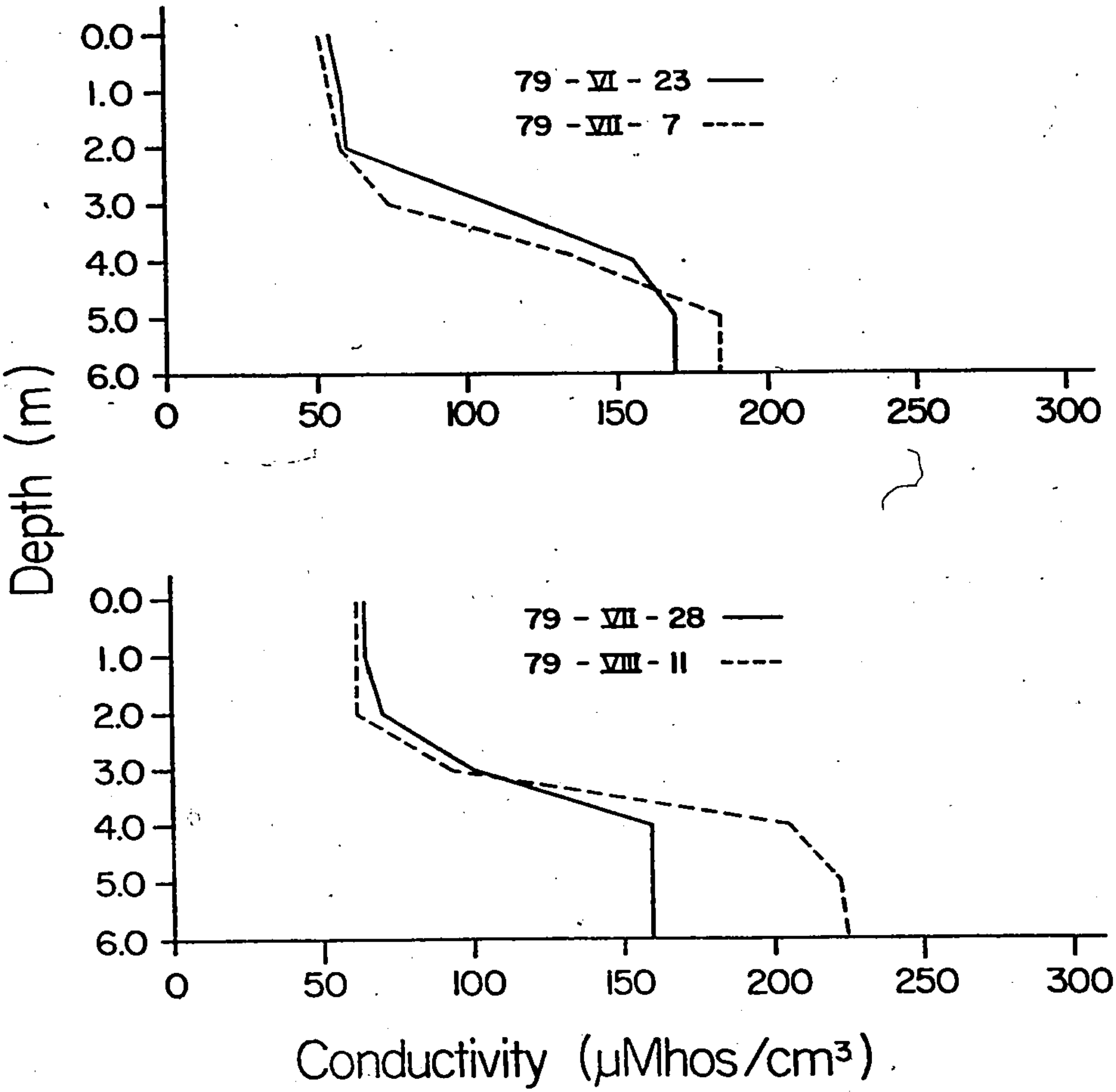

0.0
1.0
2.0
3.0
4.0
5.0
6.0
0 1 2 3 4 5 6 7 8 9 10
79 - VI - 19
79 - VII - 7
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0 1 2 3 4 5 6 7 8 9 10
79 - VII - 28
79 - VIII - 11
Oxygen (mg/L)

Figure 5. Conductivity profiles of Kettle Island Bay in 1979.


79 - VI - 23
79 - VII - 7
79 - VII - 28
79 - VIII - 11
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
50
100
150
200
250
300
Conductivity (µMhos/cm³)

below the thermocline until the fall overturn started. The amount of suspended solids varied greatly in both years of sampling due to wind direction and intensity.

MATERIALS AND METHODS

Sampling of Zooplankton and Macrobenthos

Sampling for zooplankton was done by methods modified from Lind (1974). Water samples were collected with a grey, five liter van Dorn bottle. Ten liters of water were taken at each of the 0.3, 1.0, and 2.0 m depths in the littoral zone and at a depth of 5.5 m in the middle of the bay. Each sample was filtered through a 30 X 45 cm plankton net with a 0.0833 mm mesh (measured with an ocular micrometer at 100 X). All sampling equipment was washed between collections to avoid cross-contamination of samples and any sample that contained macrophytes or substrate was rejected and redone. The resulting concentrate was thoroughly mixed to obtain 100 mL of two percent Formalin solution which served to kill and preserve the zooplankton. These samples were examined by mixing them well, drawing off 10 mL, and emptying this 10 mL into a petri dish that had a 1.0 mm grid on the bottom. The zooplankton in five randomly chosen 10 X 10 mm squares were identified and counted. This was repeated twice more for each 100 mL sample. The same dish was used for all samples. The density of each zooplankton type was determined by multiplying by a factor of 14,500 to give the number/m^3. In addition, the relative percentage of numbers was calculated for each type of zooplankton. Greater accuracy was required for diel comparisons in the 1979 samples and total counts of 10 mL subsamples were done. The density of each zooplankton type was estimated for 1.0 m^3 by multiplying by a factor of 1,000. Counts of the entire 100 mL sample were done to determine the numbers of the more scarce zooplankton types. The zooplankton were identified throughout this study as: calanoid copepods, cyclopoid copepods, Daphnidae (except *Simocephalus* spp. which were considered separately due to their dark coloration), Bosminidae, Chydoridae, *Diaphanasoma* spp., *Leptadora kindti*, ostracods, rotifers, and other. All samples were collected before macrobenthos and fish were taken to avoid introducing microcrustaceans and detritus into the water column. A total of 163 zooplankton samples were examined in 1978 and 1979. The seasonal and diel densities and relative abundances were based on only the 0.3 and 1.0 m depth samples combined because fish were not captured any deeper than 1.5 m. The relative percentage of numbers of each zooplankton type was used in the calculation of selectivity indices.

Sampling for macrobenthos was done with a 15.25 X 15.25 cm Ekman dredge (Wildlife Supply Co., Saginaw, Michigan) that has a screen to prevent organisms from escaping through the top of the dredge. Samples were collected at about 10:00 h at depths of 0.3, 1.0, 2.0 m in the littoral zone and at a depth of 5.5 to 6.0 m in the middle of the bay. Sampling was done after zooplankton had been collected but before seining for fish. One sample consists of three grabs at one of the above mentioned depths. The grabs were taken two to three meters apart to partly reduce sample bias due to clumping of the benthos. Samples were washed through a sieve with 246 meshes/cm^2 and the material that was retained was washed into 24 ounce jars and stored at about 4 C in the laboratory until sorted by hand, usually within 48 hours. Organisms were identified (mostly to order level), counted, and the wet weight of blotted specimens was taken (in mg on a Mettler Micro-Gramatic Balance, Type M5 8A, Mettler Instruments, Zurich, Switzerland). The number and biomass of each type of macrobenthos per m^2 was calculated by multiplying by a factor of 14.35. A total of 100 samples of macrobenthos were analyzed during 1978 and 1979. The seasonal densities and relative percentages of both weight and numbers were estimated from the 0.3 and 1.0 m samples combined because fish were not captured at depths greater than 1.5 m. The 5.5 m depth samples, however, were used to find the peak periods of abundance of Chaoborus spp. Macrobenthos numbers and weights were only taken at 10:00 h and were considered constant all day because the dredge retains all organisms larger than the mesh as it falls through the water and it also retained the aquatic macrophytes which were shaken into the sieve with the substrate. This does not mean that the vulnerability of the benthos was constant because changes in the numbers of macrobenthic organisms in the water column was observed to occur both in this study and by earlier authors (Mundie, 1959; Keast, 1968), but that these changes could not be adequately measured. The relative frequencies of the macrobenthos were used in the calculation of the selectivity indices for the young sunfish.

Capture of Fish and Handling of Data

Sampling for young-of-the-year largemouth bass, black crappie and pumpkinseed was done by towing a dark green 6.4 mm mesh seine, 30.5 X 1.85 m with a 1.85 m bag in the middle, out from shore and back with a five meter long boat and a 20 HP outboard motor. A minimum of three seine hauls were made for each sample. Seining was undertaken weekly, sometimes twice a week, at 10:00 h from June 1 until September 29, 1978. Sampling was discontinued on this date because six seine hauls yielded but 25 black crappie, indicating that most of the crappie had left the bay. The south side of Kettle Island Bay was chosen for consistency as the available food differs between sides of the bay (unpublished data) and also the large number of stumps on the north side made seining difficult. The 10:00 h sampling time was chosen because the three sunfish species actively fed around this time of the day. Samples were taken at four hour intervals on three dates in 1978 and on four dates, two weeks apart, in 1979 to determine the feeding periodicity of the three species of sunfishes. Sampling was discontinued on August 23, 1979, because most of the young bass had moved into the tall reeds and could not be captured at all times of the day.

Additional sampling methods used included a 0.5 m scoop net, 1.0 mm mesh, to capture largemouth bass and black crappie fry in June, 1979, because spawning had been delayed and the fish were small enough to swim through the meshes of the seine. A backpack electrofisher (Type VII, Smith-Root Inc., Vancouver, Washington) from August 1 to September 30, 1979, along the shore of Kettle Island to determine when the young bass were dispersing out of the bay.

The numbers of fish species and their proportions, as shown in Appendix A, do not accurately depict the community of Kettle Island Bay because seining was done so as to avoid the non-target fish species and many large fish were allowed to escape the net. All fish not used in this study were returned alive in an effort not to alter the population of fish in the bay more than necessary.

From 30 to 40 specimens of young-of-the-year largemouth bass, black crappie, and pumpkinseed were randomly selected for detailed examination for each sample in 1978. In 1979, 20 specimens of each species of sunfish were randomly chosen for examination for each four hour sample period on each sampling date. The fish were immediately killed with a five percent Formalin solution and no evidence of regurgitation of stomach contents was ever found. The total length, fork length, and standard length (in millimeters) and the wet weight (in grams) were recorded immediately upon returning to the laboratory. The fish lengths were measured on a plexiglass measuring board and blotted specimens were weighed on a top loading balance (Type PL 1200, Mettler Instruments, Zurich, Switzerland). Mouth length was measured from the tip of the premaxilla to the posterior end of the maxilla; mouth width as the distance across the inside of the mouth at the angle of the jaw when it was opened fully; and eye diameter as the horizontal diameter of the exposed eyeball. These measurements were made with fine tipped calipers to the nearest 0.5 mm.

The number of functional gill rakers were counted on the first gill arch on the left side of each fish. A functional gill raker was one that protruded above the epidermis that covers each gill arch. The length of the longest gill raker on the lower gill arch and the distance between this gill raker and the one immediately below were measured for a representative sample of all sizes of the young-of-the-year of the three sunfish species. A total of 41 largemouth bass, 47 black crappie, and 30 pumpkinseed were so examined. These measurements were made with an ocular micrometer (at 40 X) and were converted to actual size in millimeters.

Fish samples were stored in five percent formalin, each fish identified with a numbered tag in its mouth, until the stomach contents were inspected. Specimens larger than 60 mm in total length had a slit made in the belly to speed the penetration of the formalin solution.

Conversion factors for fork length (FL) and standard length (SL) to total length (TL), in millimeters, were calculated to be:

Largemouth Bass

$$FL = 0.961\ TL + 0.013;\ n = 104.$$

$$SL = 0.809\ TL - 0.023;\ n = 96.$$

Black Crappie

$$FL = 0.932\ TL - 1.440;\ n = 60.$$

$$SL = 0.741\ TL + 1.128;\ n = 65.$$

Pumpkinseed

$$FL = 0.944\ TL - 1.440;\ n = 71.$$

$$SL = 0.760\ TL + 0.628;\ n = 71.$$

Total length, in millimeters, was used throughout the study.

Seasonal growth curves were drawn using the average length and weight for each species of sunfish, separately, on sample dates and the relative growth rates, for both length and weight, were determined at two week intervals by the methods of Ricker (1975). Fulton's condition factor "K" is given by:

$$K(TL) = \frac{\text{weight X } 10^5}{\text{length}^3},\ \text{(Ricker, 1975)}$$

for total length in millimeters and wet weight in grams. The condition factor was calculated for each fish and the means and 95 percent confidence intervals are presented for largemouth bass, black crappie, and pumpkinseed separately for each sample date. The length-weight relationships were determined by linear regression by least squares method using total length in millimeters and wet weight in grams.

The relationships of mouth length, mouth width, and eye diameter to total length were also determined using linear regression by least squares method. The mean values of these same three characters were tested for fish 25, 40, 50, and 75 mm in length, with a _t_-test, to determine whether differences existed between the young sunfishes.

The relationships of gill raker length and the gap between gill rakers to total length were calculated by linear regression. The gill raker length and the gap between gill rakers were expressed as percentages of total length for all sizes of the three species, the means and 95 percent confidence intervals calculated, and the differences between the three species shown with a _t_-test. Changes in the number of gill rakers on the first gill arch with the length of the fish were examined and compared for the young sunfishes.

Stomach-Content Analysis

Organisms from the stomachs of young-of-the-year largemouth bass, black crappie, and pumpkinseed kept for each sample date (or time period for diel feeding studies) were identified and the number of prey organisms per fish, percent occurrence, and percent of stomach weight were compiled on a weekly basis for vertebrate and macrobenthic prey. The percent weight for all of the zooplankton prey combined was also calculated. The zooplankton prey were compiled as the number of organisms per fish, percent occurrence, and percent numbers because the zooplankton were too small and numerous to separate and weigh each type that was present in the stomachs. Vertebrate prey was identified to species, where possible, and invertebrate food items were identified as described earlier. The percent numbers of zooplankton and macrobenthos were used in calculating the seasonal and diel selectivity indices. The percent numbers of all food types combined and the percent weights were used in the calculation of the niche overlap indices.

Feeding periodicity was determined from the weight of the stomach contents, as a percentage of body weight, for 581 largemouth bass, 639 black crappie, and 364 pumpkinseed. Averages for each time period were plotted against the hour of day to show peaks in stomach fullness. The percentage of empty stomachs was also plotted against the time of day, for each species separately, to confirm the peaks in feeding activity. In all, a total of 1494 largemouth bass, 1857 black crappie, and 911 pumpkinseed stomachs were examined in detail during 1978 and 1979.

Selectivity and Niche Overlap Indices

The most commonly used selectivity index is that proposed by Ivlev (1961) as:

$$E = \frac{r_i - p_i}{r_i + p_i}, \text{ where}$$

r_i = the relative abundance of prey item "i" in the stomach

p_i = the relative abundance of prey item "i" in the habitat.

This index has a major weakness because the relative prey densities are not considered. A value of -1.0 results when an item is not eaten, regardless of its availability, and the importance of rare items is exaggerated e.g., if $r_i = 0.01$ and $p_i = 0.001$, then $E = 0.82$, which indicates a strong preference for the item. The linear selectivity index, $L = r_i - p_i$ (Strauss, 1979), would only give a value of $L = 0.009$ because the relative availability of the prey is taken into consideration. The linear index "L" shows selection and avoidance in proportion to the availability of the prey items, is defined for all r_i and p_i, and is approximately normal in distribution (Strauss, 1979). For these reasons the linear selectivity index was used in the present study. The relative abundances of vertebrate prey could not be estimated due to the selectivity of the seine and because there was a constant movement of prey fish between Kettle Island Bay and the main river channel. Thus, selectivity indices could only be determined for the major macrobenthic and planktonic prey items.

The measurement of niche overlap has received considerable treatment in the recent literature. Different indices are suggested (e.g., Hurlbert, 1978) only to be shown as ineffective shortly afterwards (e.g., Petraitus, 1979; and Abrams, 1980, referring to Hurlbert, 1978). The majority of niche overlap indices are symmetrical, that is the overlap of species "a" on species "b" is the same as the overlap of species "b" on "a". An exception is Levin's (1968) niche overlap index:

$$\alpha_{jk} = \frac{\sum_{i=1}^{s} p_{ij} p_{ik}}{\sum_{i=1}^{s} (p_{ij})^2}, \text{ where}$$

α_{jk} = the overlap of species "k" on species "j"

p_{ij} = the proportion of food item "i" in the diet of "j"

p_{ik} = the proportion of food item "i" in the diet of "k"

May (1975) states that the Levin's niche overlap index restricts one to measuring indirect competition (resource partitioning) as in the present work, it is mathematically sound, and it is biologically more relevant than the symmetrical niche overlap indices. This symmetry is innappropriate when, for example, species "a" is a generalist with a wide range of foods eaten and species "b" has a more restricted diet (a specialist). It is obvious that species "b" cannot possibly share all of the food resources of species "a" although it is possible that species "a" shares all of the food resources used by species "b". Thus the use of symmetrical niche overlap indices (the majority of indices proposed are symmetrical) is questionable because they imply that the two species share all of the same resources, which probably is not the case (also noted by Keast, 1978). The Levin's niche overlap index was used for this study to show overlap in food usage between young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay in the same manner as applied by Price (1971), Keast (1977, 1978), and George & Hadley (1979). The niche overlap index values presented in this study is the average of niche overlap index values based on the proportions of numbers of prey items and on the proportion of the weight of stomach contents that the item represents. This helps minimize biases imposed by the weight of a few large items in a small number of stomachs or the occurrence of many small food items in only a few stomachs. By calculating niche overlap indices for each sample date or time period it is possible to show the change in overlap due to seasonal or diel changes in feeding activity and prey availability or due to growth of the fish. Because the three fish species were caught in the same habitat the niche overlap indices refer only to feeding habits in this study.

In order to determine the sensitivity of other statistics to differences in the diets between two fish species, Chi-squared contingency tables (2 X 2 and 2 X C), Mann-Witney U-tests, and Wilcoxon paired ranking tests were applied to the same data that gave values for Levin's niche overlap index between 0.0 - 0.10, 0.11 - 0.20, 0.21 - 0.30, ..., 0.91 - 1.00.

RESULTS

A total of 4,262 young-of-the-year largemouth bass, black crappie, and pumpkinseed were examined in detail from the many thousands of young sunfish that were captured by seining in Kettle Island Bay during 1978 and 1979. Rock bass (Ambloplites rupestris) were the only other young-of-the-year centrarchid consistently captured but they were only found in the thick Elodea beds and could not be captured in large numbers. Young-of-the-year smallmouth bass (Micropterus dolomieui) were ocassionally found in the catch but they strayed into the bay from the main river channel. Young-of-the-year yellow perch (Perca flavescens) were very common in the bay. Appendix A shows that large numbers of silvery minnow (Hybognathus nuchalis), golden shiner (Notemigonus crysoleucas), and emerald shiner (Notropis atherinoides) were captured. These figures do not include the multitude of minnow fry that were also caught. Adult black crappie, pumpkinseed, yellow perch, northern pike (Esox lucius), and brown bullhead (Ictalurus nebulosus) were consistently caught and an additional 17 species were occasionally caught, sometimes in very large numbers.

Visual observation of the young largemouth bass, black crappie, and pumpkinseed suggested that there was little or no habitat separation by height in the water column. The three sunfish species congregated near openings in the weed beds and along the regions of transition from dominance of one type of aquatic macrophyte to another. On bright clear days, or when the wind was of moderate strength (20 - 25 kmph), the young sunfishes were seldom seen in water less than 0.5 m deep. The only exception to this observation were those fish that were hiding in the thick reed beds.

Spawning of Largemouth Bass, Black Crappie, and Pumpkinseed

A sample of largemouth bass eggs was collected on June 6, 1978, from a nest guarded by a male with a white scar on his head. The water temperature was 20 C and these eggs hatched on the same day in an aquarium back in the laboratory. The fry were an average of 5.0 mm in length and weighed an average of 0.0015 g on the following day. This same male bass was seen guarding fry on June 29 and July 29, 1978. Samples of eggs were also taken from the nests of other male bass on June 11 and June 22, 1978. This indicates that largemouth bass had a fairly long spawning period, about six weeks, in 1978 and that successive spawnings by the same male occurred in Kettle Island Bay.

There were a considerable number of smaller eggs, about 30 percent of the total number, mixed in with the largemouth bass eggs that were collected. These eggs hatched at about the same time as the largemouth bass eggs in the laboratory and a number of these were raised to a length of 40 mm when they were positively identified as golden shiner fry. Golden shiner eggs were absent from largemouth bass nests examined in July, 1978. The golden shiner fry were not collected with the bass fry being protected by male bass. Largemouth bass nests were not examined for the presence of golden shiner eggs in 1979.

The first young-of-the-year largemouth bass were collected by seining on June 15, 1978 and these fry were an average (± 95 percent confidence intervals) size of 25.7 ± 0.63 mm in length and 0.22 ± 0.0235 g in weight. The first largemouth bass fry were captured with a scoop net on June 23, 1979, and these fry were only an average of 12.0 ± 0.13 mm long and 0.025 ± 0.0015 g in weight. The 1979 year class did not attain an average length of 25 mm until July 6, a delay of about three weeks. Male largemouth bass were not observed guarding fry after mid-July in 1979.

Nesting activity of black crappie was not observed during either year of this study, although extensive search was done. The black crappie seem to nest deeper than the maximum of about 1.0 m in depth seen for the largemouth bass and pumpkinseed of Kettle Island Bay. The first young-of-the-year black crappie were collected by seining on June 11, 1978 and these fry were an average size (± 95 percent confidence limits) of 18.8 ± 0.40 mm long and 0.084 ± 0.007 g in weight. Black crappie fry were not captured until June 23, 1979, (using a scoop net) and these fry were an average of 13.4 ± 1.82 mm long and weighed 0.033 ± 0.017 g, which also represents a delay in spawning of about three weeks.

Although a single pumpkinseed nest (without eggs) was found at a depth of 0.5 m at a water temperature of 16.5 C on June 15, 1978, extensive nesting activity was not seen until June 24, when water temperatures exceeded 20 C, and was observed until July 26, 1978. Most of the nests were in patches cleared in the *Elodea* beds in water less than 1.0 m deep. Some spawning activity of pumpkinseed was occurring on June 23, 1979, but intense spawning activity was not seen until June 30. The first young-of-the-year pumpkinseed were caught by seine on July 10, 1978, at an average size (± 95 percent confidence limits) of 18.9 ± 3.78 mm long and 0.102 ± 0.062 g in weight. Pumpkinseed fry were not caught until late July in 1979 at which time they were about 29 mm long which was how long the 1978 year class were in late July, 1978. It is evident that the period of cool weather in May and early June of 1979 delayed the breeding period of the three sunfish species, although the delay for pumpkinseed seems to have been minimal.

Growth of Largemouth Bass, Black Crappie, and Pumpkinseed During the First Growing Season

The increase in length of young largemouth bass was rapid until the first week of August in 1978 and this growth slowed somewhat until late August (Fig. 6) when an average length of 86.5 mm was attained. At this time the majority of bass fingerlings larger than 80 mm long dispersed out of the bay. Weekly electrofishing outside of Kettle Island Bay in 1979 showed that the fingerlings had moved into the reedy areas and dispersed along the shoreline of Kettle

Figure 6. Seasonal increase in length (mm) of young-of-the-year largemouth bass of Kettle Island Bay. Means and 95 percent confidence intervals are presented. Curves fitted by eye.

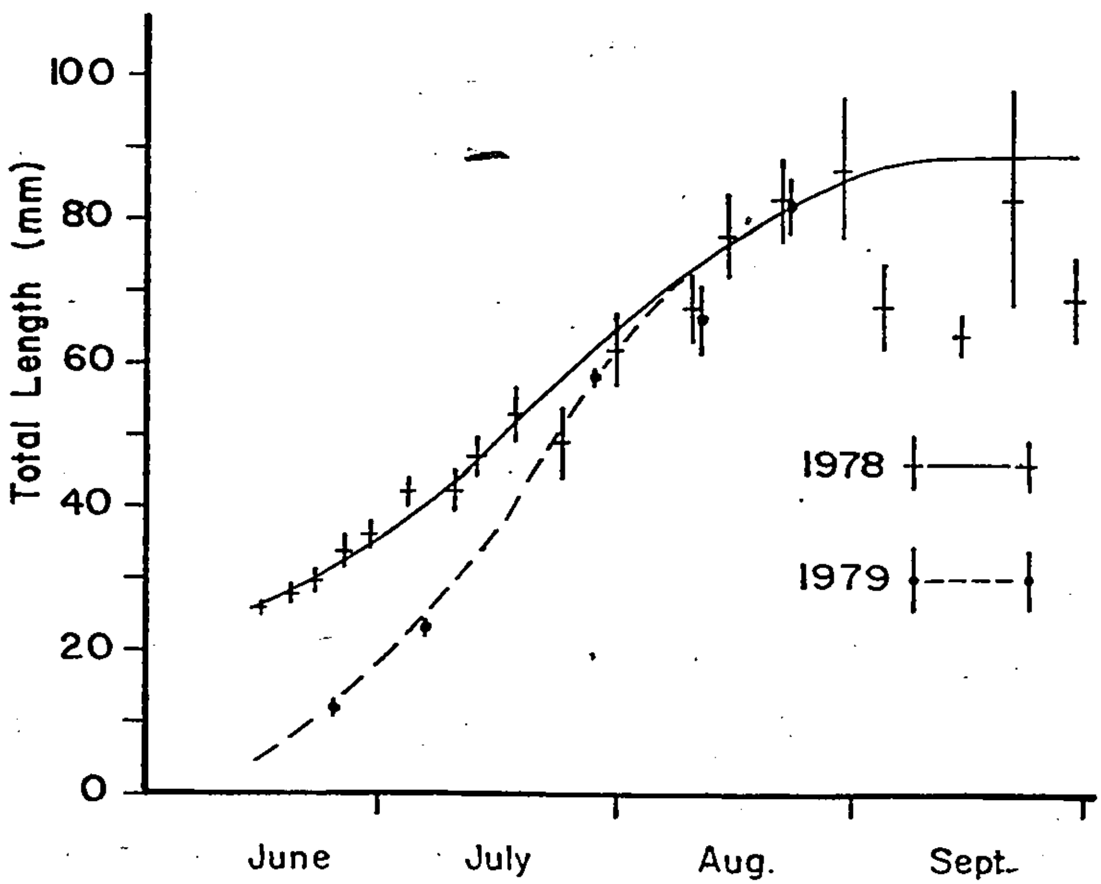
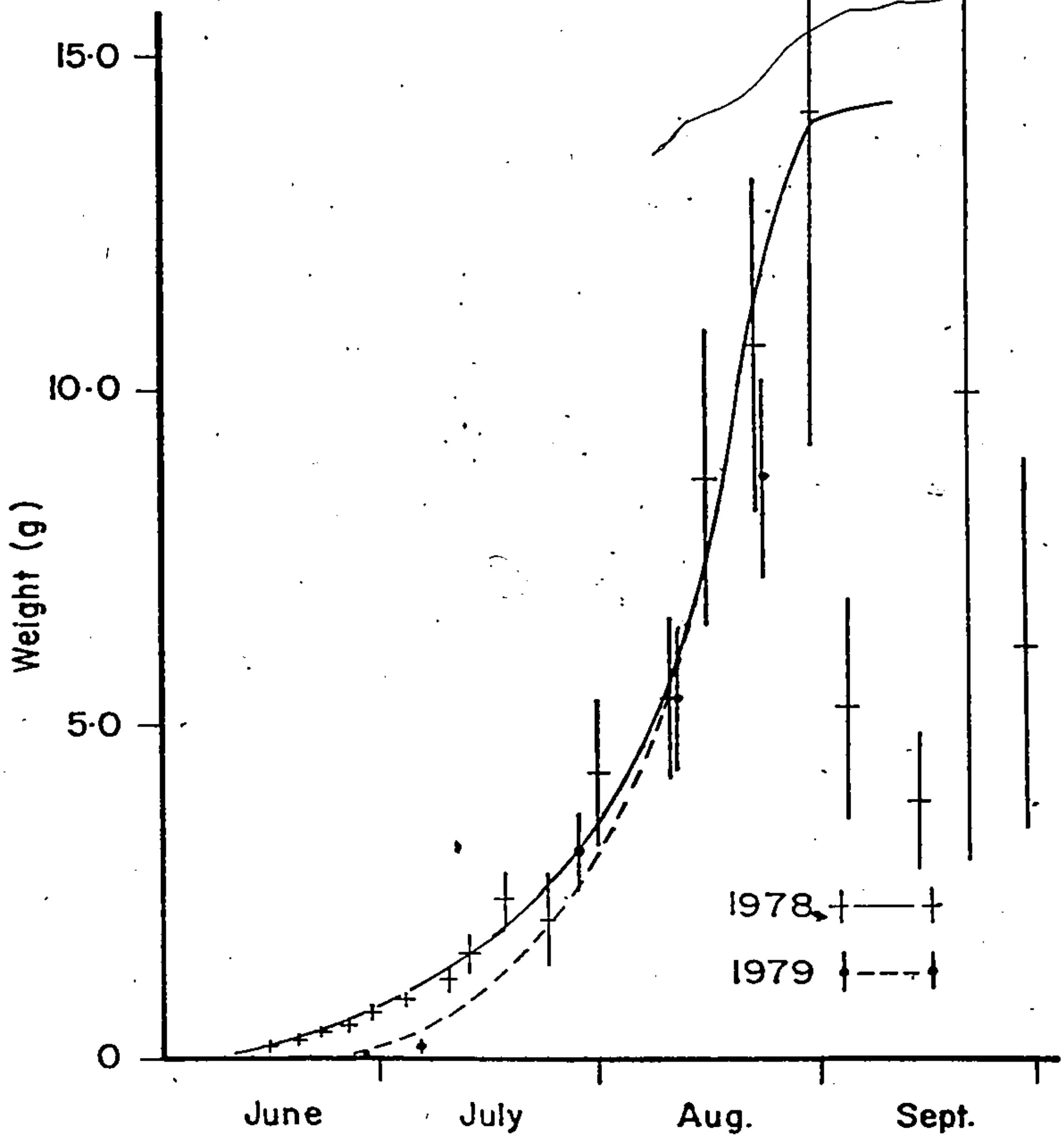

100
80
60
40
20
0
Total Length (mm)
June
July
Aug.
Sept.
1978
1979

Figure 7. Seasonal increase in weight (g) of young-of-the-year largemouth bass of Kettle Island Bay. Means and 95 percent confidence intervals are presented. Curves fitted by eye.


15·0
10·0
5·0
0
Weight (g)
June
July
Aug.
Sept.
1978
1979

Island. The maximum average size of largemouth bass at the end of the first growing season was unknown because the fingerlings had left the bay with about one month of water temperatures above 15 C left in the growing season. Many specimens larger than 100 mm long and 15.0 g were captured in August, 1978 and 1979, inside Kettle Island Bay and the relative frequency of fingerlings greater than 100 mm long increased through September, 1979, outside of the bay. The largest largemouth bass fingerling collected was 147 mm long and weighed 54.81 g on August 30, 1978.

Growth in weight was rapid from mid-July until the end of August in 1978 at which time an average weight of 14.2 g was attained (Fig. 7). The 1979 year class of largemouth bass reached the same average length and weight as the 1978 year class by the end of July despite the later commencement of spawning. The 1979 year class was also initially more uniform in size as is shown by the narrower 95 percent confidence intervals about the means for both length and weight.

The relative rate of growth of largemouth bass fingerlings in 1978 (Table 2) shows that growth in length was most rapid during the last two weeks of June and decreased thereafter. The relative rate of growth in weight was most rapid in June but remained high until late August. The low value around July 15 was probably due to the entry of several broods of smaller fry into the catch.

The increase in length of young-of-the-year black crappie was most rapid from mid-July until mid-August (Fig. 8). The

Figure 8. Seasonal increase in length (mm) of young-of-the-year black crappie of Kettle Island Bay. Means and 95 percent confidence intervals are presented. Curves fitted by eye.

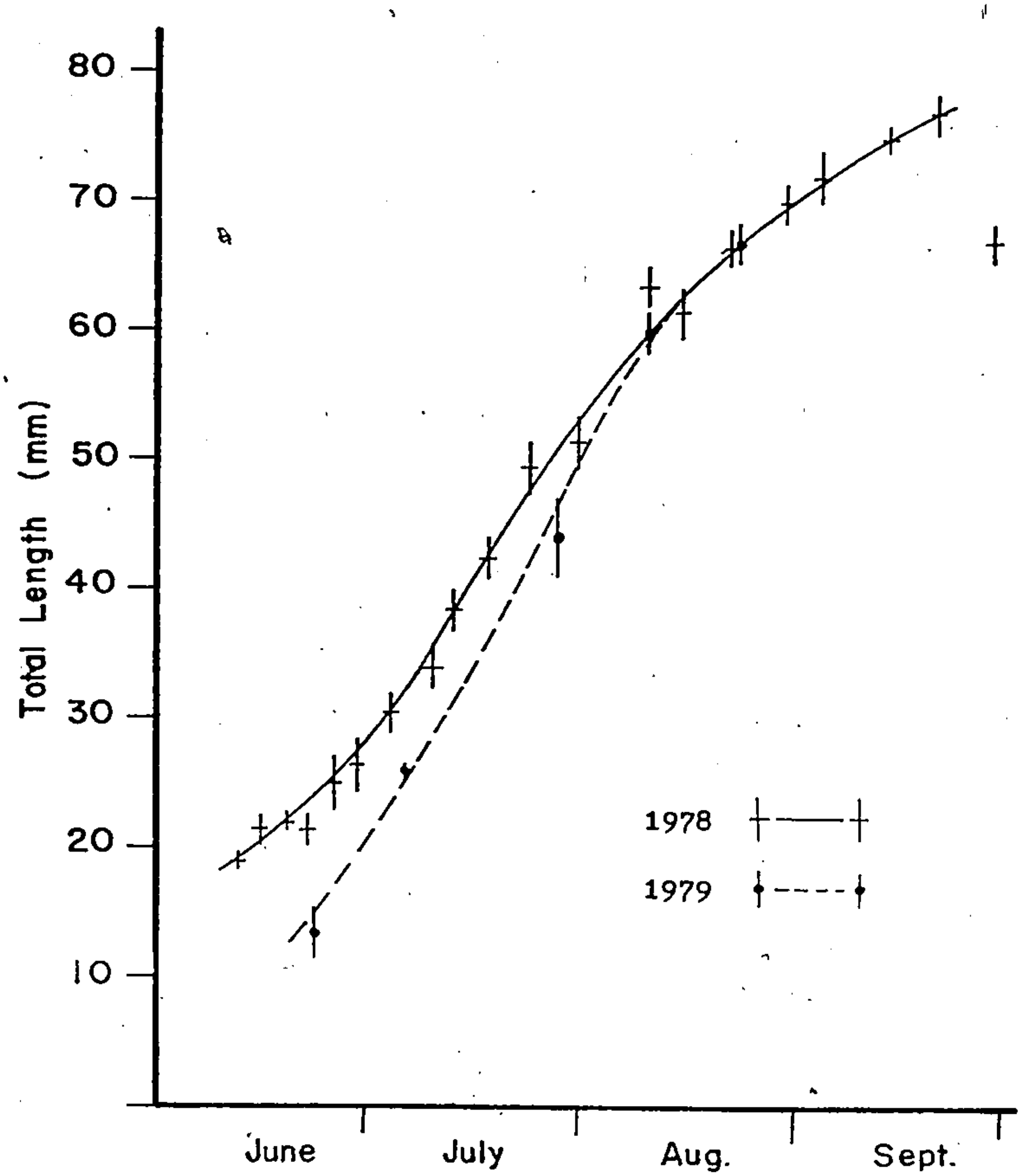
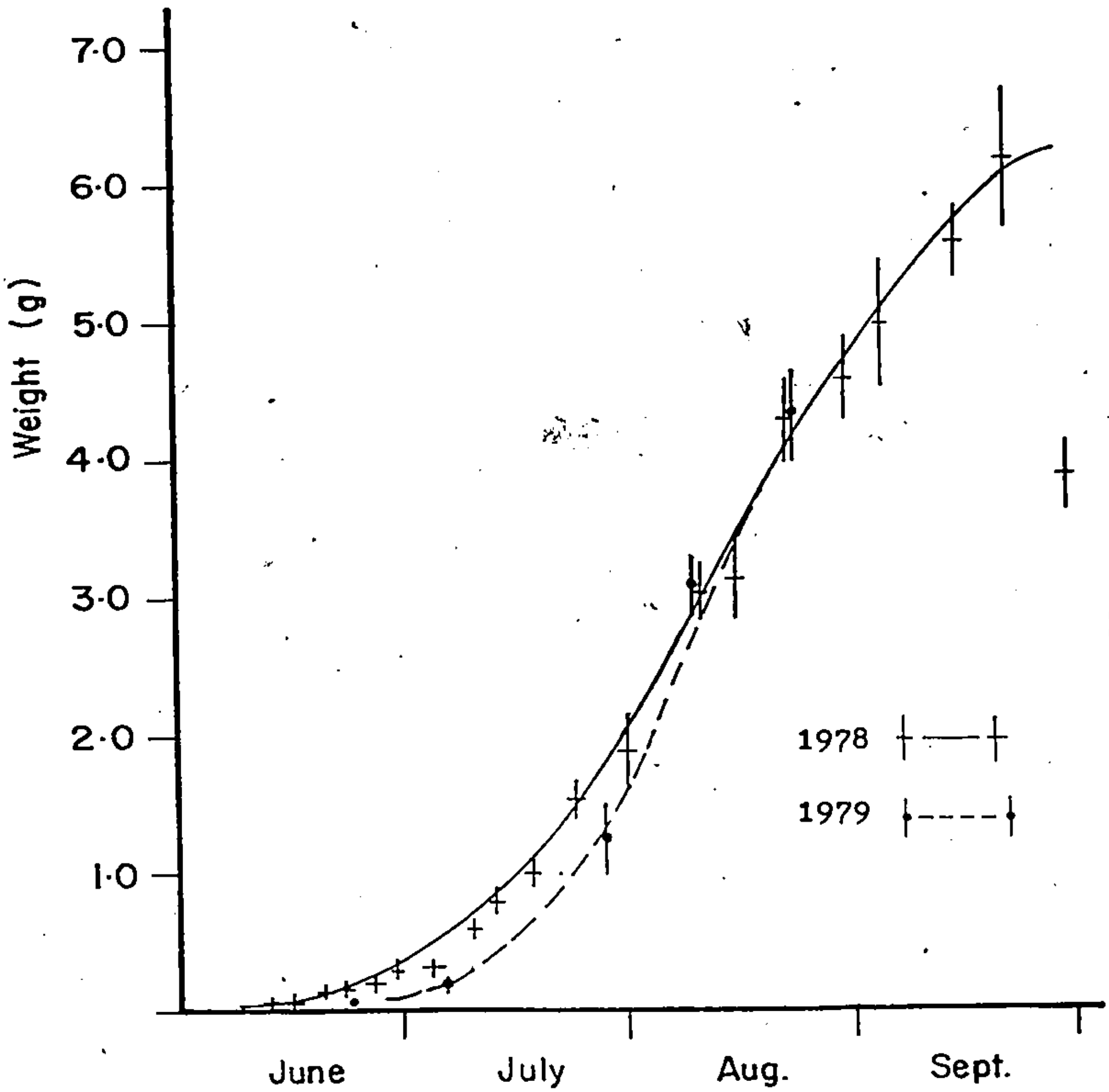

80
70
60
50
40
30
20
10
Total Length (mm)
1978
1979
June
July
Aug.
Sept.

Figure 9. Seasonal increase in weight (g) of young-of-the-year black crappie of Kettle Island Bay. Means and 95 percent confidence intervals are presented. Curves fitted by eye.


7·0
6·0
5·0
4·0
3·0
2·0
1·0
Weight (g)
June
July
Aug.
Sept.
1978
1979

maximum average size attained was 77.2 mm long and a weight of 6.22 g at the end of September, 1978. The largest black crappie fingerling examined was 92 mm long and weighed 10.7 g. The increase in weight was greatest in August and September, 1978 (Fig. 9). The 1979 year class of black crappie had grown to the same average size as the 1978 year class by early August. The growth curves for length and weight were the same after this date.

The relative rate of growth for black crappie fingerlings was greatest in mid-July for length and was greatest in early July for weight (Table 2) during 1978.

The increase in length of young-of-the-year pumpkinseed was rapid until late August during 1978. At this time large numbers of small fry from later spawnings became susceptible to siening which decreased the average size of the pumpkinseed caught (Fig. 10). The increase in weight of pumpkinseed fingerlings was greatest in August but the entry of the small fry caused the mean weight to be depressed for most of September in 1978 (Fig. 11). Although the spawning of some pumpkinseed was delayed in 1979, the fry were the same size as the 1978 year class when sampled in late July. The greatest average size of young pumpkinseed occurred at the end of September, 1978, when fingerlings were 44.3 mm long and weighed 1.89 g. The largest pumpkinseed fingerling captured was 63 mm long and weighed 4.09 g. Many specimens over 50 mm long and 2.50 g in weight were caught, particularly during September, in Kettle Island Bay during 1978.

Figure 10. Seasonal increase in length (mm) of young-of-the-year pumpkinseed of Kettle Island Bay. Means and 95 percent confidence intervals are presented. Curve fitted by eye.

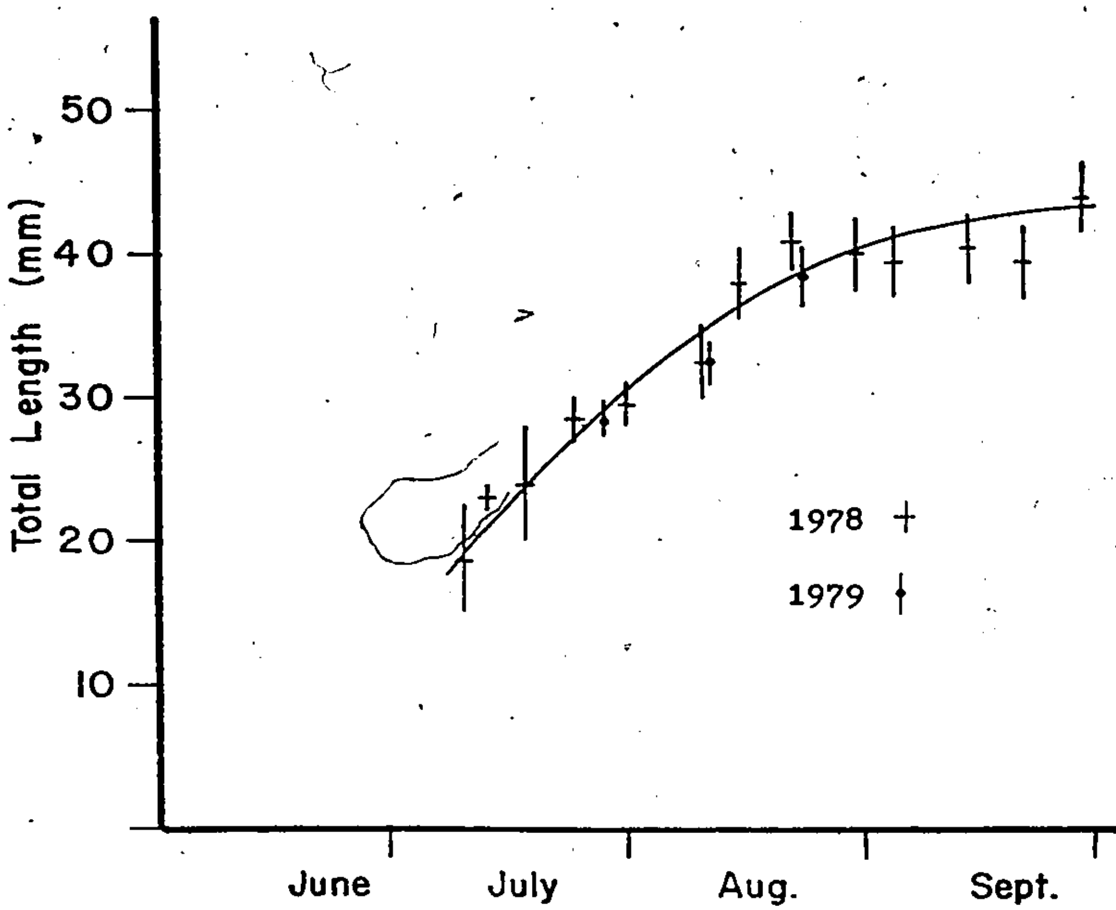

Total Length (mm)
50
40
30
20
10
1978
1979
June
July
Aug.
Sept.

Figure 11. Seasonal increase in weight (g) of young-of-the-year pumpkinseed of Kettle Island Bay. Means and 95 percent confidence intervals are presented. Curve fitted by eye.

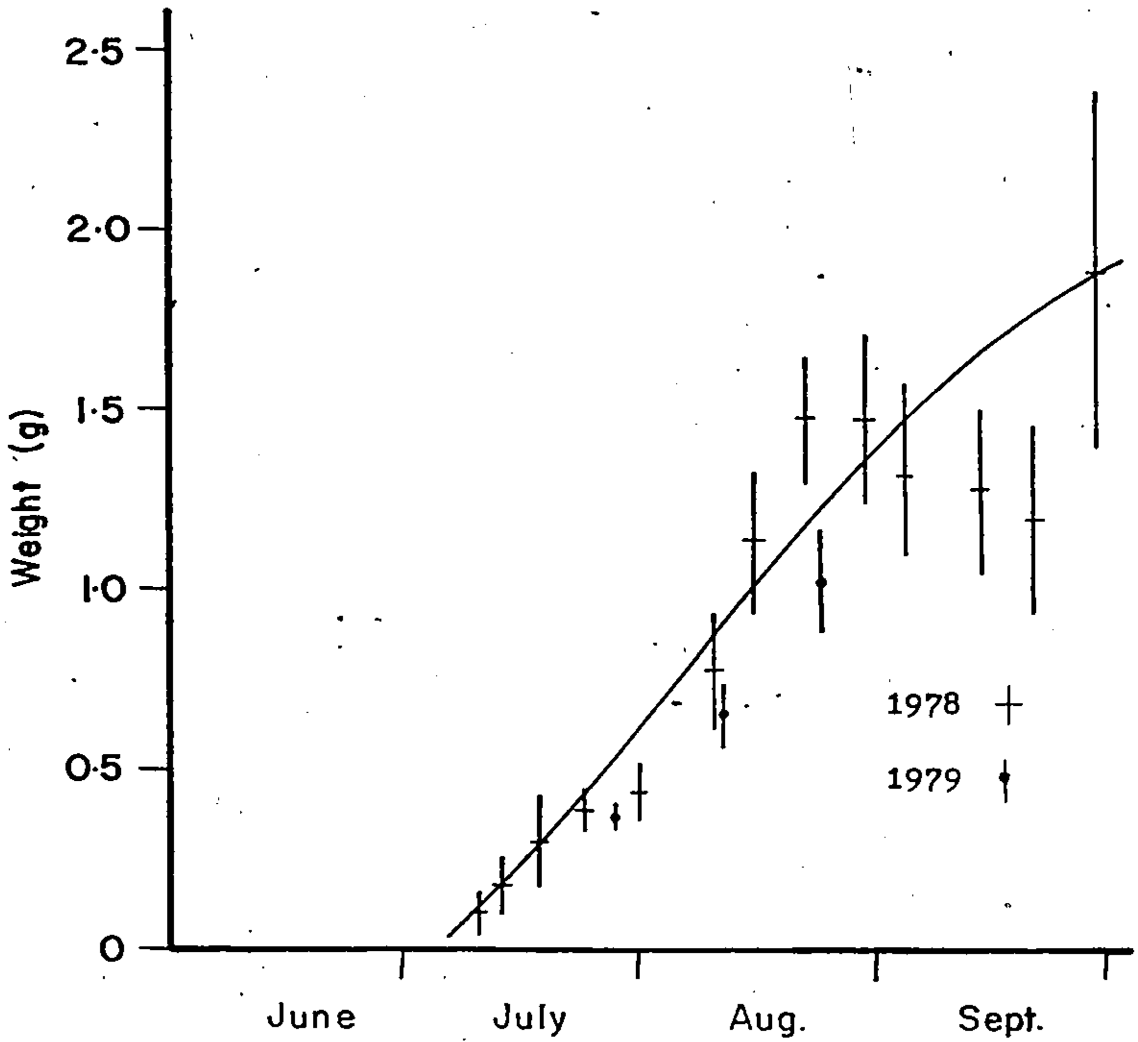

2·5
2·0
1·5
1·0
0·5
0
Weight (g)
June
July
Aug.
Sept.
1978
1979

Table 2. Relative rate of growth (as a percentage) of young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay in 1978.

Date	June 12- June 25	June 26- July 9	July 10- July 23	July 24- Aug. 6	Aug. 7- Aug. 20	Aug. 21- Sept 6,	Sept 7- Sept 21
			Largemouth Bass				
Total length (mm)	31.4	25.5	16.1	37.2	20.9	5.9	N/a
Weight (g)	148.4	121.2	74.5	157.5	99.4	32.8	N/a
No. of fish	153	94	100	69	147	110	-
			Black Crappie				
Total length (mm)	34.3	35.8	44.6	28.3	5.1	7.9	7.2
Weight (g)	135.7	192.9	163.8	98.8	40.8	17.3	23.9
No. of fish	145	100	106	80	67	221	72
			Pumpkinseed				
Total length (mm)	N/a	N/a	52.7	14.3	26.3	0.0	12.5
Weight (g)	N/a	N/a	285.3	96.4	92.2	0.0	43.8
No. of fish	-	-	27	71	69	200	75

The relative rate of growth of pumpkinseed fingerlings was greatest for length in early August and was greatest for weight from late July to mid-August during 1978 (Table 2). The relative growth rate for late August to early September also shows the effect of the entry of the smaller fry into the catch at the end of August, 1978.

Length-Weight Relationships and Condition Factors

The length-weight relationships for young-of-the-year largemouth bass and black crappie of Kettle Island Bay showed that growth was isometric. The length-weight relationship for young-of-the-year pumpkinseed showed that growth was slightly allometric with the fish becoming proportionately heavier as length increased. The length-weight relationships were:

Largemouth Bass

log WT = 3.042 log TL - 4.913; n = 60; r = 0.9966.

Black Crappie

log WT = 3.085 log TL - 5.000; n = 77; r = 0.9677.

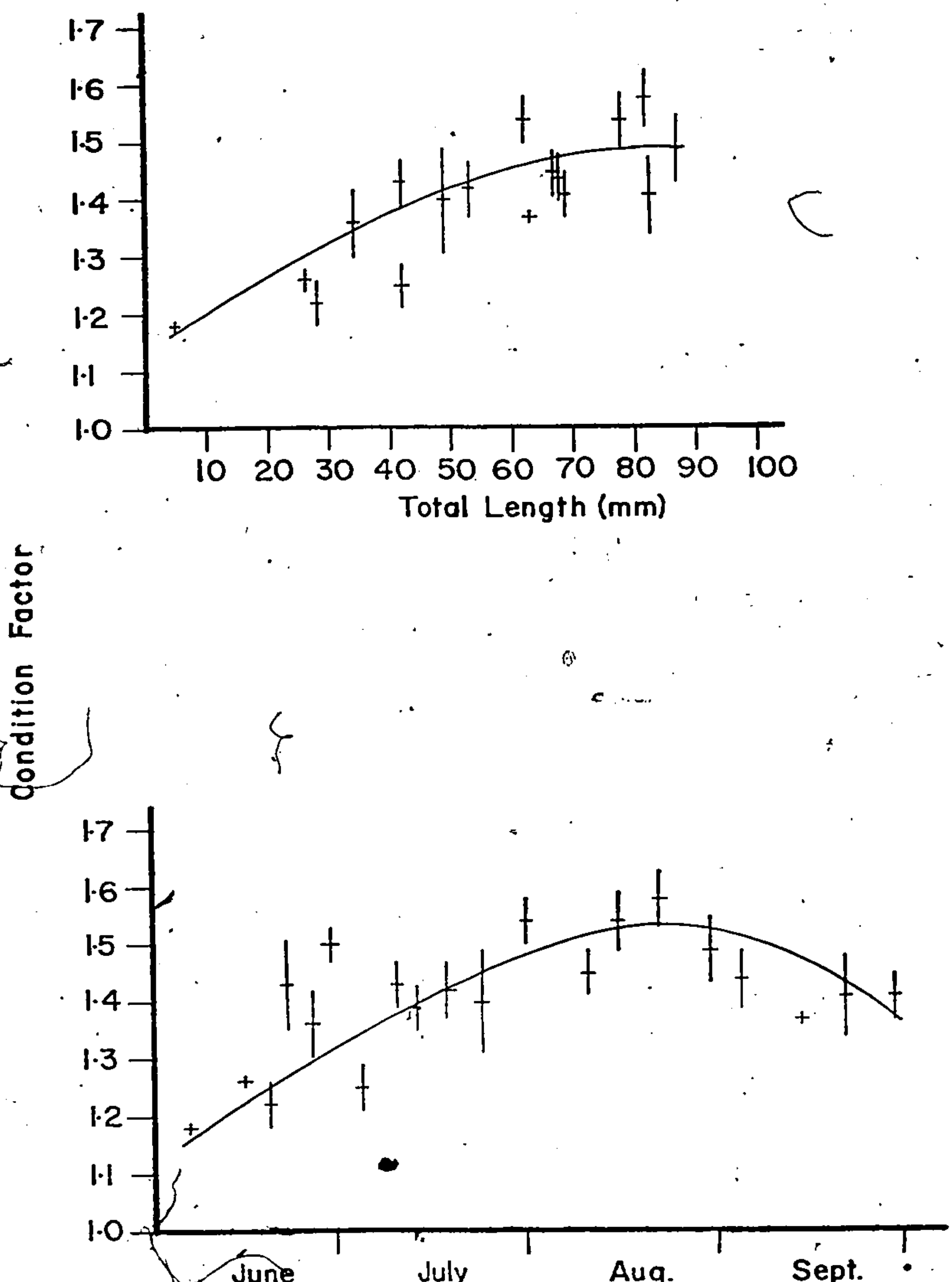
Pumpkinseed

log WT = 3.183 log TL - 5.043; n = 54; r = 0.9982.

The condition factor for young-of-the-year largemouth bass increased with the length of the fish from an average value of 1.22 at a length of 28.4 mm to a value of 1.50 for bass fingerlings longer than 80 mm (Fig. 12). The drop in the average value for the condition factor in September coincides with the dispersal of the larger bass from the

Figure 12. Changes in the values of Fulton's condition factor with total length for young largemouth bass in 1978. Means and 95 percent confidence intervals are presented. Curve fitted by eye.

Figure 13. Seasonal values of Fulton's condition factor for young largemouth bass in 1978. Means and 95 percent confidence intervals are presented. Curve fitted by eye.



1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
10
20
30
40
50
60
70
80
90
100
Total Length (mm)
Condition Factor
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
June
July
Aug.
Sept.

Figure 14. Changes in the values of Fulton's condition factor with total length for young black crappie in 1978. Means and 95 percent confidence intervals are presented. Curve fitted by eye.

Figure 15. Seasonal values of Fulton's condition factor for young black crappie in 1978. Means and 95 percent confidence intervals are presented. Curve fitted by eye.

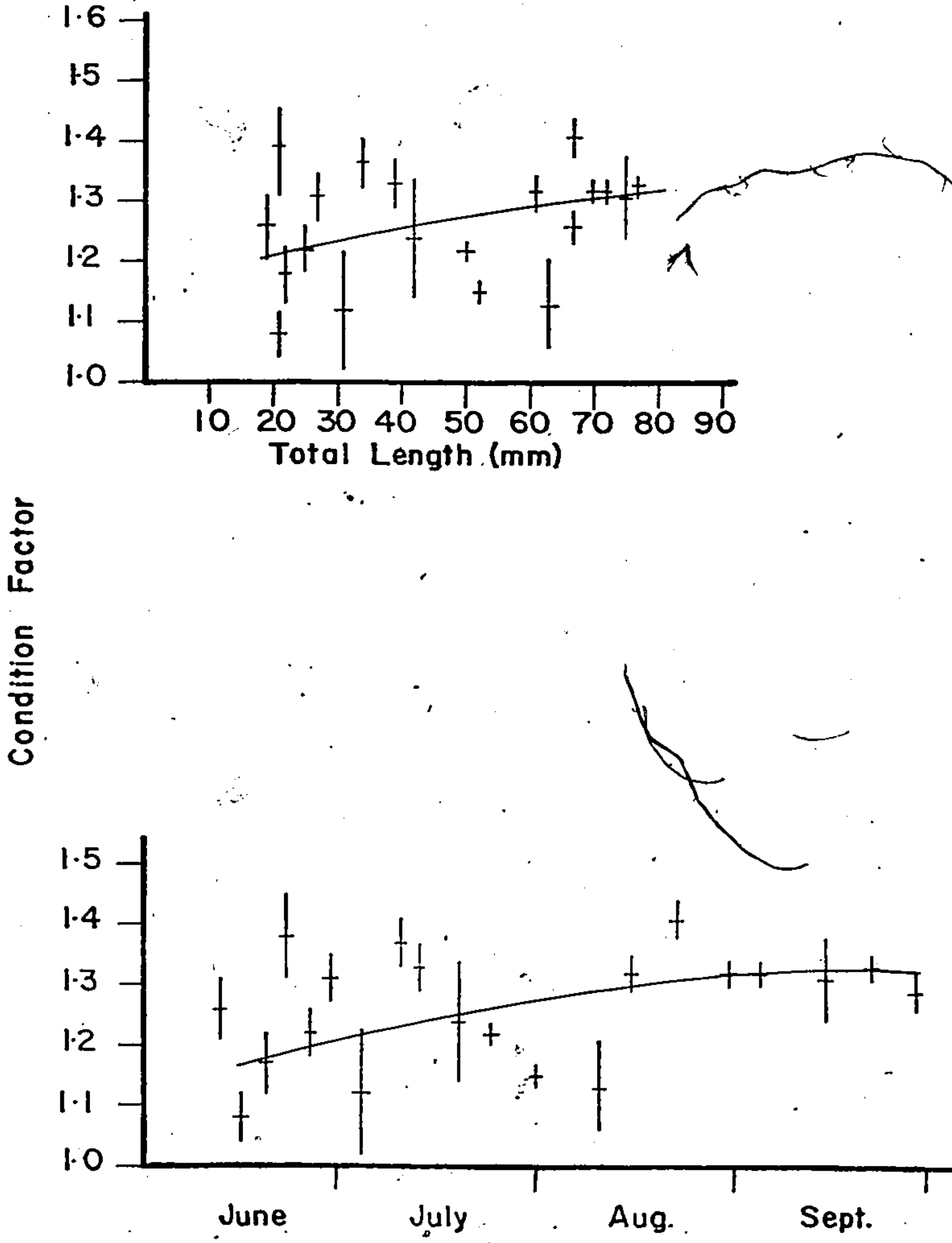
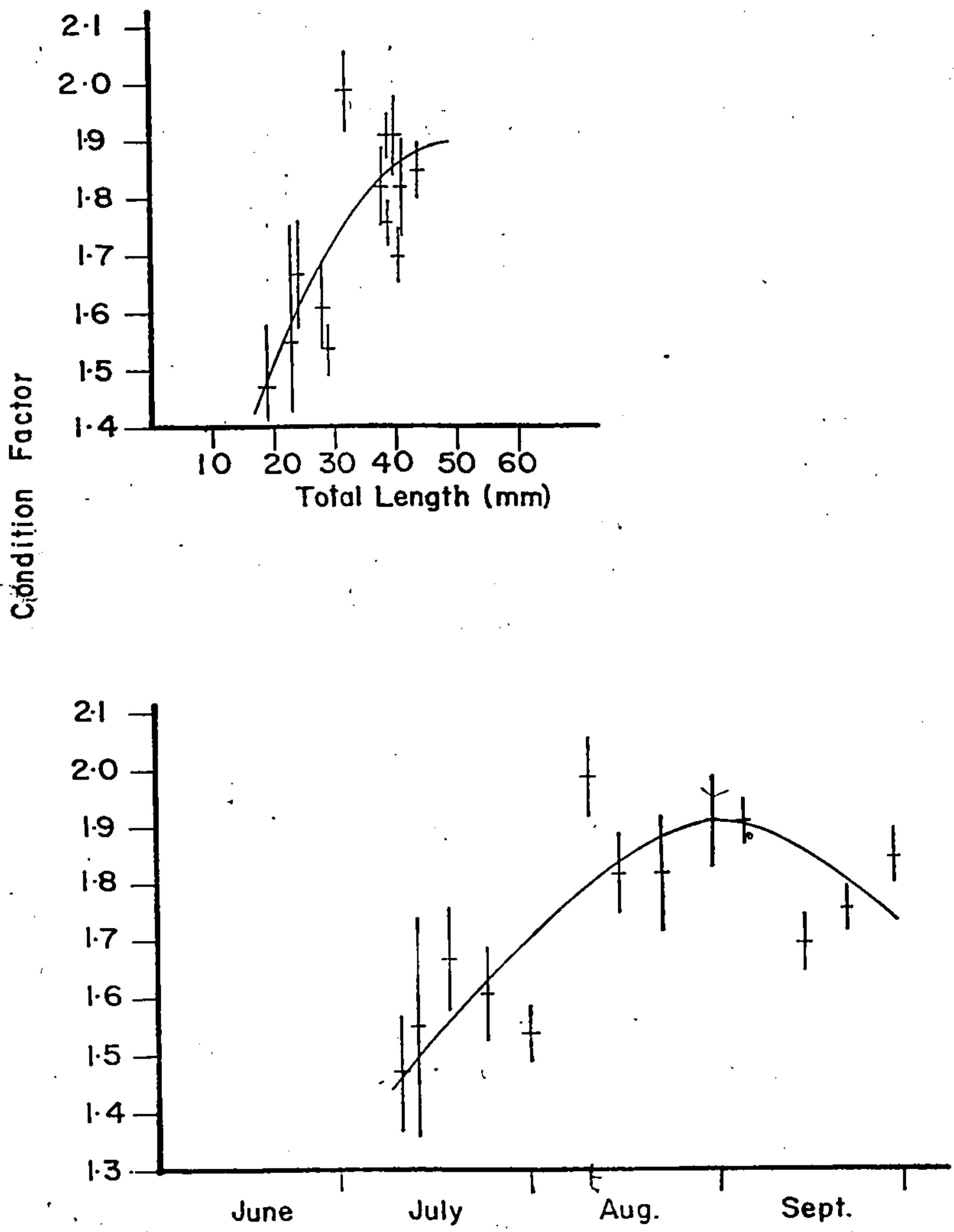

1·6
1·5
1·4
1·3
1·2
1·1
1·0
10 20 30 40 50 60 70 80 90
Total Length (mm)
Condition Factor
1·5
1·4
1·3
1·2
1·1
1·0
June
July
Aug.
Sept.

Figure 16. Changes in the value of Fulton's condition factor with total length for young pumpkinseed in 1978. Means and 95 percent confidence intervals are presented. Curve fitted by eye.

Figure 17. Seasonal values of Fulton's condition factor for young pumpkinseed in 1978. Means and 95 percent confidence intervals are presented. Curve fitted by eye.


2·1
2·0
1·9
1·8
1·7
1·6
1·5
1·4
10 20 30 40 50 60
Total Length (mm)
Condition Factor
2·1
2·0
1·9
1·8
1·7
1·6
1·5
1·4
1·3
June
July
Aug.
Sept.

bay leaving only the smaller fingerlings with their lower average condition factors (Fig. 13). The overall mean value for the condition factor of young-of-the-year large-mouth bass of Kettle Island Bay during 1978 was 1.41.

The condition factor for young-of-the-year black crappie of Kettle Island Bay seemed to have a weak increase with the length of the fish (Fig. 14) and the season (Fig. 15) but was probably best described by the mean of means for all sample dates in 1978, 1.27.

The condition factor for young-of-the-year pumpkinseed of Kettle Island Bay increased with the length of the fry from a value of 1.47 at a length of 18.6 mm to a value of 1.85 at an average length of 44.3 mm (Fig. 16). The slope of the length-weight relationship also indicates that the values of the condition factor should increase with increasing length. The seasonal values of the condition factor (Fig. 17) also suggest that the value of the condition factor increase with length because the values dropped in September when the average length of the fry had decreased due to the entry of the latter broods into the catch. The mean of means for the values of the condition factor of young-of-the-year pumpkinseed during 1978 was 1.74.

Relationships of Mouth and Eye Size to Total Length

The growth of the mouth length (ML), mouth width (MW), and eye diameter (ED) was essentially isometric for the young-of-the-year largemouth bass, black crappie, and pumpkinseed. The relationships were:

Largemouth Bass

$$ML = 0.146\ TL - 0.445;\ n = 115;\ r = 0.9958.$$
$$MW = 0.172\ TL - 0.663;\ n = 115;\ r = 0.9946.$$
$$ED = 0.041\ TL - 1.323;\ n = 115;\ r = 0.9790.$$

Black Crappie

$$ML = 0.122\ TL - 0.368;\ n = 77;\ r = 0.9958.$$
$$MW = 0.148\ TL - 0.808;\ n = 77;\ r = 0.9924.$$
$$ED = 0.073\ TL + 0.188;\ n = 77;\ r = 0.9887.$$

Pumpkinseed

$$ML = 0.088\ TL - 0.187;\ n = 50;\ r = 0.9758.$$
$$MW = 0.088\ TL - 0.187;\ n = 50;\ r = 0.9758.$$
$$ED = 0.066\ TL - 0.554;\ n = 50;\ r = 0.9812.$$

Appendix B gives the results of *t*-tests between average values of mouth length, mouth width, and eye diameter of young-of-the-year largemouth bass, black crappie, and pumpkinseed at selected lengths. The mouth size of the pumpkinseed was always significantly smaller ($P < 0.001$) than that of the largemouth bass and black crappie fingerlings of the same length. The mouth size of largemouth bass and black crappie was about the same up to a length of 50 mm and largemouth bass had the larger mouth when both species reached 75 mm in length. Black crappie had a significantly larger eye than pumpkinseed ($P < 0.02$) and largemouth bass ($P < 0.05$) at all sizes inspected. The eye size of the young largemouth bass and pumpkinseed was the same ($P < 0.300$) for all lengths tested.

The number of gill rakers changed with the length of the young largemouth bass, black crappie, and pumpkinseed as follows:

Largemouth Bass	
15.7 to 42.4 mm long	12 - 13 gill rakers
46.8 to 67.8 mm long	10 - 11 gill rakers
68.0 mm long and up	8 (rarely 9) gill rakers
Black Crappie	
19.0 to 22.0 mm long	22 - 24 gill rakers
25.0 to 39.0 mm long	25 - 27 gill rakers
42.0 to 52.0 mm long	28 gill rakers
64 mm long and up	29 - 30 gill rakers
Pumpkinseed	
18.6 to 29.4 mm long	10 - 11 gill rakers
32.5 mm long and up	8 (rarely 9) gill rakers

The number of functional gill rakers decreased with the length of largemouth bass and pumpkinseed fingerlings but increased with the length of the black crappie.

Gill raker length (GRL) and the gap between the gill rakers (GRG) were a relatively constant proportion of total length (TL) for young-of-the-year largemouth bass, black crappie, and pumpkinseed. The relationships were found to be:

Largemouth Bass

$$GRL = 0.0330\ TL + 0.0520;\ n = 41;\ r = 0.9923.$$

$$GRG = 0.0080\ TL - 0.0510;\ n = 41;\ r = 0.9558.$$

Black Crappie

$$GRL = 0.0414\ TL - 0.0548;\ n = 47;\ r = 0.9907.$$

$$GRG = 0.0013\ TL + 0.0700;\ n = 47;\ r = 0.9556.$$

Pumpkinseed

$$GRL = 0.0084\ TL + 0.3159;\ n = 30;\ r = 0.8641.$$

$$GRG = 0.0046\ TL + 0.0630;\ n = 30;\ r = 0.9815.$$

Appendix C presents the results of the _t_-tests comparing the mean values of gill raker length and the gap between the gill rakers (both expressed as a percentage of total length) for a representative sample of largemouth bass, black crappie, and pumpkinseed fingerlings. The black crappie had significantly longer gill rakers and a narrower gap between gill rakers ($P < 0.001$) than either the largemouth bass or pumpkinseed. Largemouth bass had significantly longer gill rakers ($P < 0.001$) and a wider gap between adjacent gill rakers ($P < 0.01$) than the pumpkinseed fingerlings.

Seasonal Food Availability in Kettle Island Bay in 1978

The major numerical peaks of amphipods occurred in late July (2,980 animals/m^2) and mid-September (2,160 animals/m^2). There were usually more than 500 amphipods/m^2 except in late June (Fig. 18). Amphipods accounted for more than 10 percent of macrobenthos numbers in July and the percentage

Figure 18. Seasonal densities of macrobenthos in Kettle Island Bay in 1978. Trichopterans ————
Amphipods — — — — —
Chironomids -·-·-·-·-·-

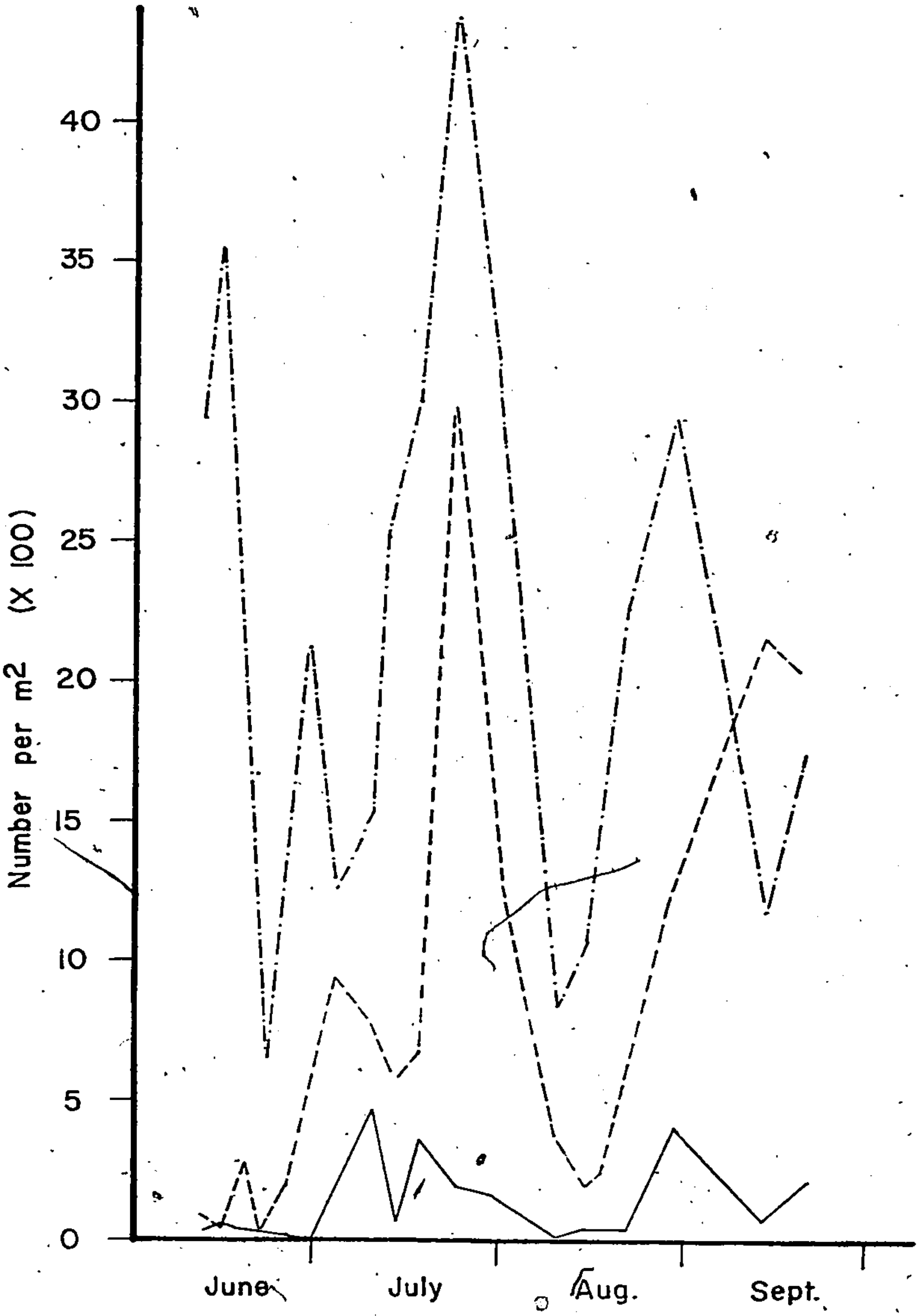

Number per m2 (X 100)
40
35
30
25
20
15
10
5
0
June
July
Aug.
Sept.

Figure 19. Seasonal biomass (g) of macrobenthos in Kettle Island Bay in 1978. Trichopterans ———— Amphipods — — — — — Chironomids -·-·-·-·-·

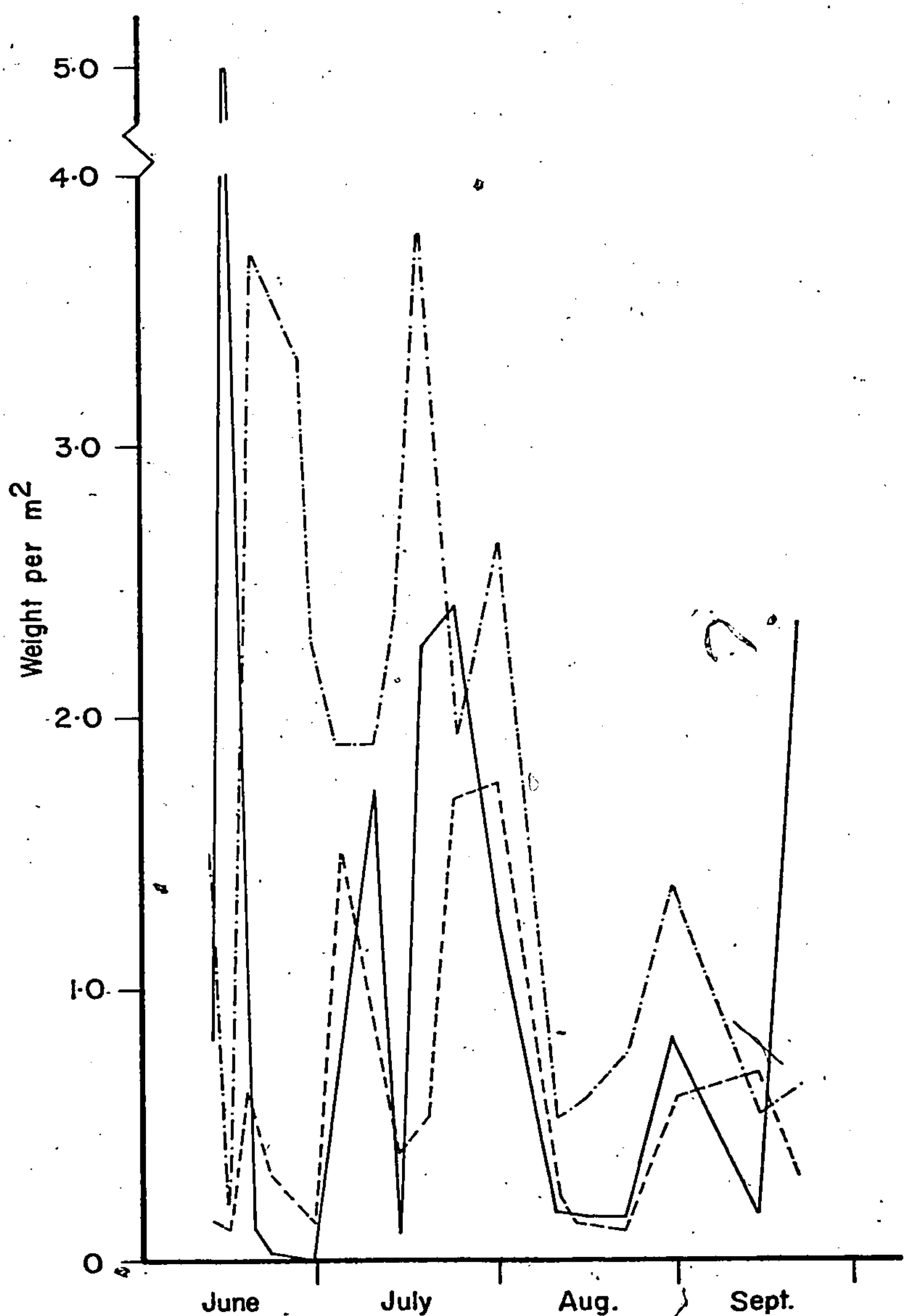

5·0
4·0
3·0
2·0
1·0
0
Weight per m^2
June
July
Aug.
Sept.

Figure 20. Seasonal density and biomass (g) of *Chaoborus* at a depth of 6.0 m in Kettle Island Bay in 1978.

Number/m^2 ————

Weight/m^2 - - - - -

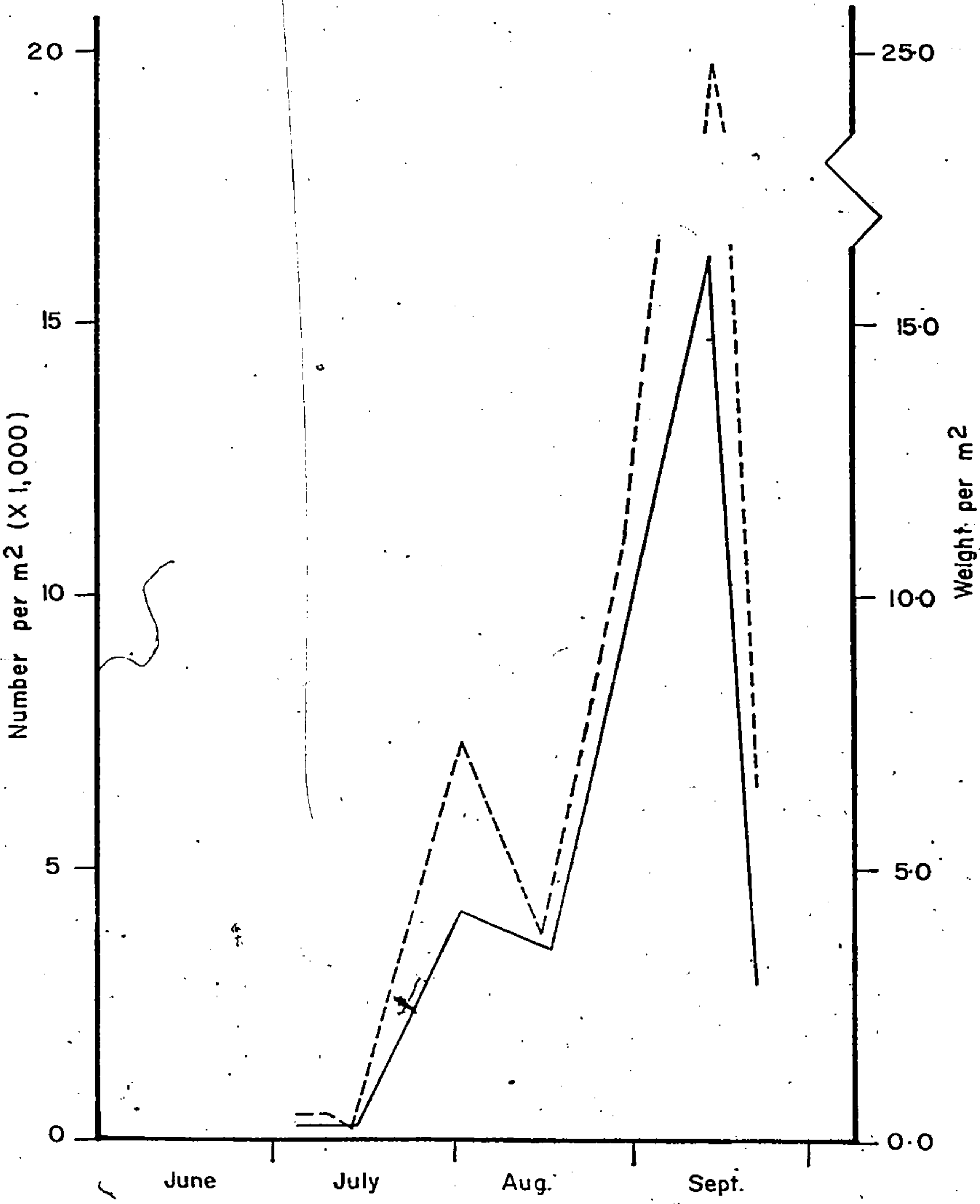

20
15
10
5
0
Number per m2 (X 1,000)
25·0
15·0
10·0
5·0
0·0
Weight per m2
June
July
Aug.
Sept.

Figure 21. Relative proportions of macrobenthos numbers in Kettle Island Bay in 1978.

Trichopterans ————————

Amphipods – – – – –

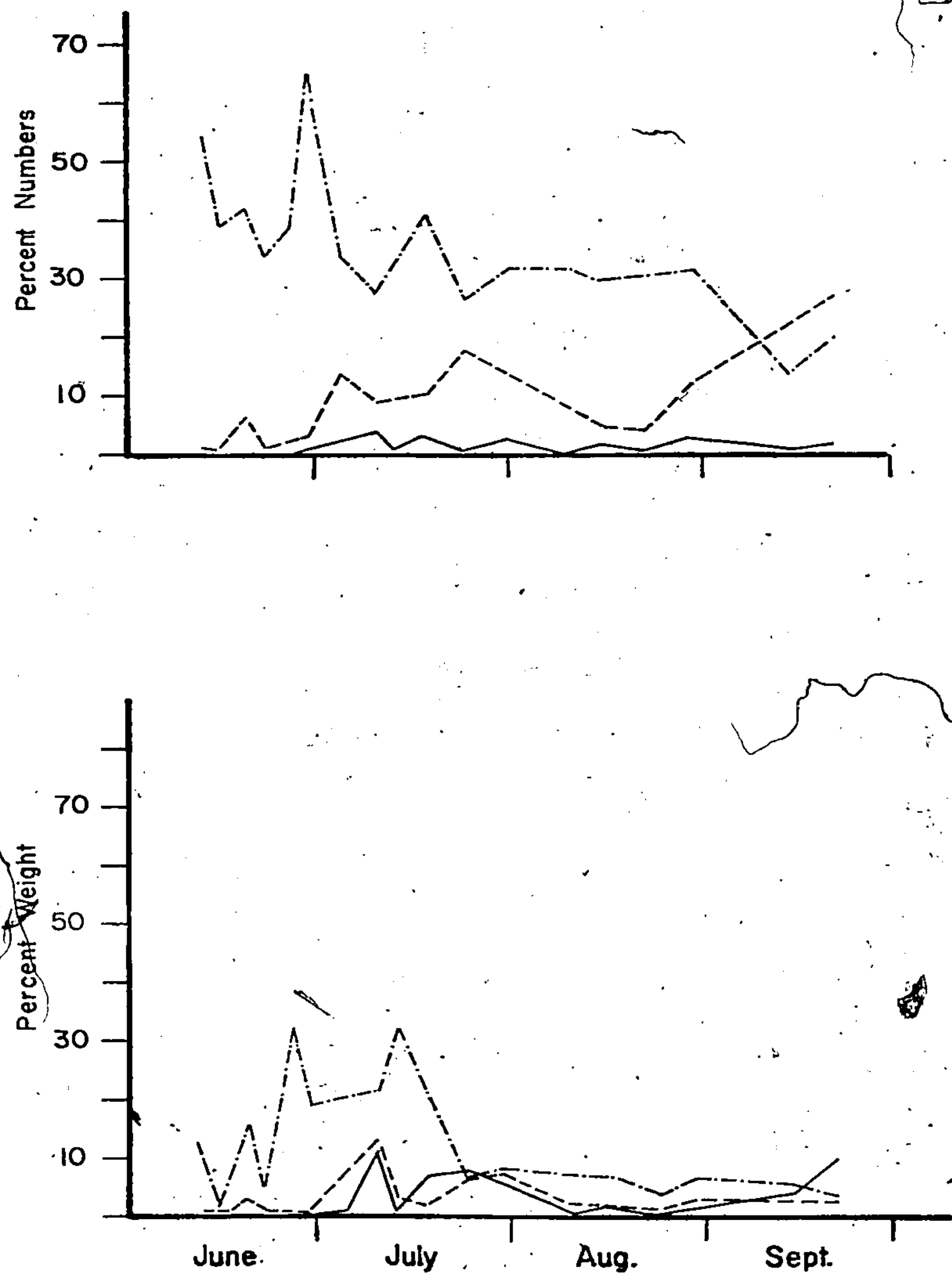
Chironomids –·–·–·–·–·

Figure 22. Relative proportions of the biomass of macrobenthos in Kettle Island Bay in 1978.

Trichopterans ————————

Amphipods – – – – –

Chironomids –·–·–·–·–·



Percent Numbers
70
50
30
10
Percent Weight
70
50
30
10
June.
July
Aug.
Sept.

increased to 30 percent in September (Fig. 21). The maximum biomass/m^2 occurred in early and late July (Fig. 19) when levels as high as 1.5 g/m^2 were noted. Amphipods comprised more than 10 percent of the biomass of benthos only early in July (Fig. 22). The three species of amphipods that were identified in samples from Kettle Island Bay are *Hyallela azteca*, *Gammarus fasciatus*, and *Crangonyx pseudogracilis*.

The density of chironomids was usually in excess of 1,000 animals/m^2 and peaks of over 2,900 chironomids/m^2 were determined from mid-July, late July, and early September samples (Fig. 18). Chironomids represented as much as 64 percent of macrobenthos numbers in early July and usually exceeded 30 percent of the numbers (Fig. 21). The major peaks in biomass of over 3.8 g/m^2 occurred in mid-June and late July with a smaller peak of 1.5 g/m^2 occurring in early September (Figure 19). Chironomids formed 20 to 30 percent of the macrobenthos biomass until the middle of July and then declined to 5 to 10 percent of the biomass until the end of sampling in September (Fig. 22).

Chaoborus were seldom detected in the littoral zone but they were the principle constituent of the samples taken at a depth of 6.0 m in the middle of the bay. A minor peak in *Chaoborus* numbers and biomass, representing a small emergence of adults, was noticed in early August and there was a rapid increase in numbers to over 16,000 animals/m^2 and in biomass to almost 25 g/m^2 in mid-September (Fig. 20) after which the emergence of many adults from pupae resulted in a decline in numbers and biomass.

Peaks in trichopteran numbers were seen in the middle of July and early in September (about 475 animals/m^2) and the number/m^2 did not surpass 500 on any sample date (Fig. 18). There was a peak in biomass of 5.0 g/m^2 squared in June due to the movement of a large sized species inshore prior to pupation and emergence (Fig. 19). Biomass values as high as 1.5 g/m^2 were detected in the middle of July, at the end of July, and at the end of September, again due to the inshore movement of the larvae prior to pupation. Trichopteran pupae were often collected on the sample dates with a high biomass present. Trichopterans formed less than four percent of macrobenthos numbers (Fig. 21) and less than 12 percent of the biomass (Fig. 22).

Peaks in the numbers and biomass of the other macrobenthic organisms (e.g. gastropods and pelecypods) are not reported here because they were not major food items of the young-of-the-year largemouth bass, black crappie, or pumpkinseed. Their numbers and biomass were included in the calculation of the percent numbers and percent biomass.

Table 3 summarizes the average weight per organism of the macrobenthic prey items of young largemouth bass, black crappie, and pumpkinseed based on the benthos samples from Kettle Island Bay during 1978. Gastropods were of a maximum average weight of 13.0 mg in August but usually weighed about 5.0 mg. The average weight of pelecypods (Sphaeridae) decreased from about 6.0 mg in June to an average of about 1.7 mg in late July, primarily due to the presence of many

Table 3. Average weight (mg) of macrobenthos of Kettle Island Bay during 1978.

Date	Gastropods	Pelecypods	Amphipods	Chironomids	Chaoborus	Odonatans	Trichopterans
June							
12	0.9	6.4	0.9	0.5	-	3.8	57.0
15	8.5	6.3	2.3	1.0	-	37.9	180.5
19	7.3	6.0	2.2	1.0	-	11.6	10.4
22	6.1	6.0	3.1	0.9	-	-	6.4
26	5.2	5.2	1.6	2.2	-	3.6	-
29	7.0	2.2	1.2	1.1	3.2	97.1	- -
July							
4	4.7	3.4	1.2	1.5	1.3	10.6	1.8
10	2.9	2.7	2.1	0.9	1.6	0.7	10.4
13	5.0	4.2	0.9	0.5	1.0	7.8	4.7
18	3.6	3.5	0.7	0.9	1.8	0.9	1.5
24	4.2	2.2	0.7	0.4	-	289.0	10.3
31	8.4	1.7	1.4	0.9	1.8	48.7	8.6
August							
10	13.0	3.5	0.7	0.8	1.2	73.6	17.8
15	3.3	1.8	0.9	0.5	1.0	1.8	4.5
22	5.1	4.5	0.5	0.9	1.0	2.2	3.5
31	5.1	2.2	0.5	0.5	1.4	1.6	2.0
September							
4	-	-	-	-	-	-	-
14	3.5	2.1	0.3	0.3	1.5	1.2	12.5
21	4.5	2.0	0.2	0.4	2.2	2.2	10.3
29	-	-	-	-	-	-	-

small clams as a result of the reproductive period. Amphipods were often larger than 1.5 mg in weight in June but had a mean weight of less than 1.0 mg, again primarily due to newborn and juveniles after reproduction occurred. Chironomids did not have an average weight of more than 1.0 mg after July 4 although large numbers were present in the bay through the month of July. The average weight of a Chaoborus larvae was as high as 3.2 mg at the end of June when most of the specimens were actually pupae and the average weight was greater than 2.0 mg again in September during the peak in numbers and biomass due to the large number of pupae present. Very large specimens of trichopteran larvae were present on June 12 and 15 as was suggested in Figure 19. The tremendous fluctuations in the average weight of odonatans was mostly due to the irregular occurrence of anisopteran nymphs and the emegence of zygopteran adults.

Calanoid numbers reached a maximum density of 95,000 animals/m^3 in the early part of September (Fig. 23) and smaller peaks of over 50,000 calanoids/m^3 in early July and in early August. Calanoids comprised a maximum relative density of almost 20 percent of the zooplankton in the littoral zone of Kettle Island Bay during the September numerical peak (Fig. 27). Cyclopoid copepod numbers fluctuated widely (Fig. 23) but always exceeded 20,000 cyclopoids/m^3 and attained densities of over 275,000 animals/m^3 in late July and again in early September. These maxima were equivalent to 40 percent of the zooplankton numbers and cyclopoids never represented

Figure 23. Seasonal density of zooplankton of Kettle Island Bay in 1978. Calanoida ————

Cyclopoida – – – – –

Daphnidae -·-·-·-·-·

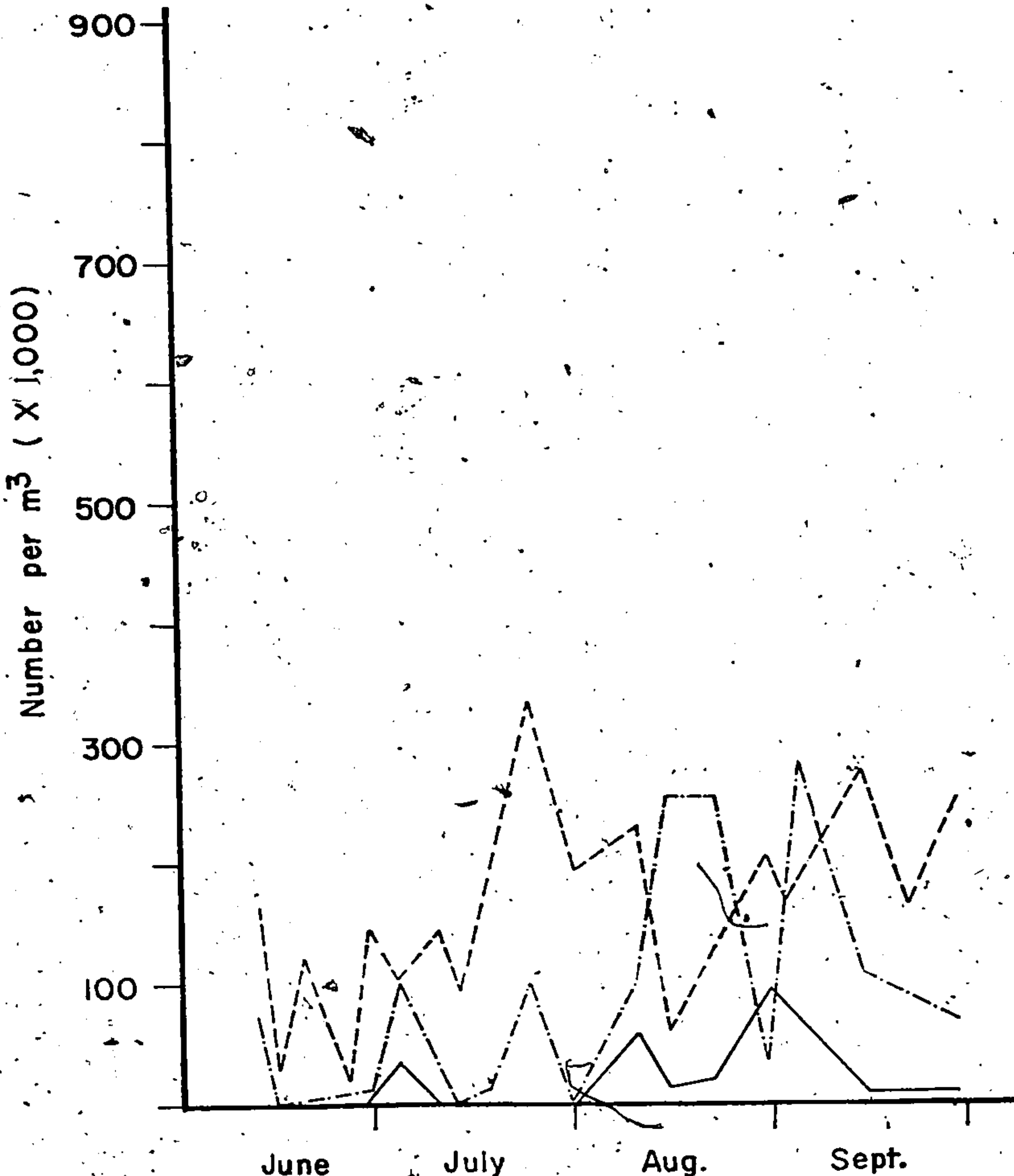

900
700
500
300
100
Number per m3 (X 1,000)
June
July
Aug.
Sept.

Figure 24. Seasonal density of zooplankton of Kettle Island Bay in 1978. Bosminidae ———————

Diaphanasoma – – – – –

Polyphemus -·-·-·-·-

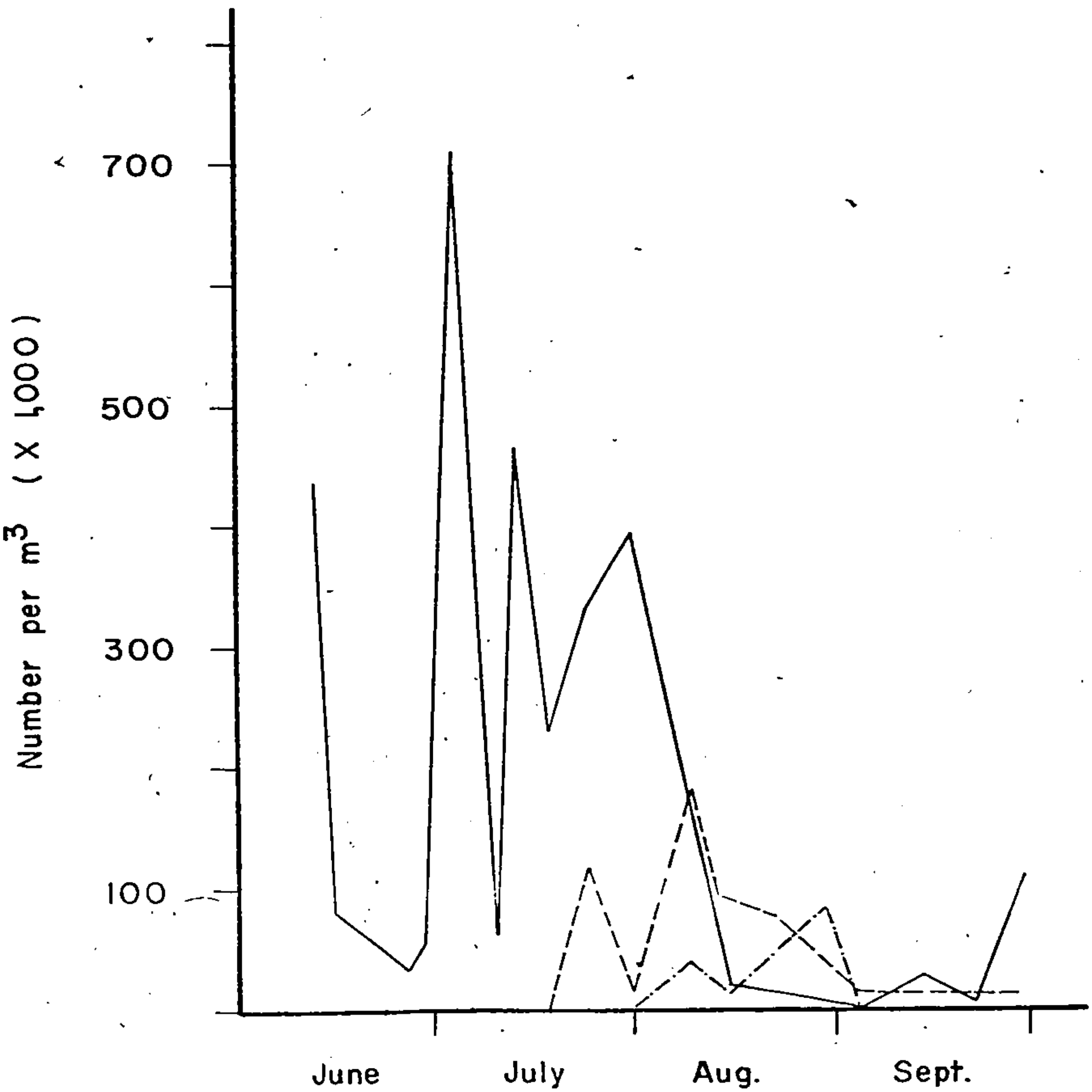
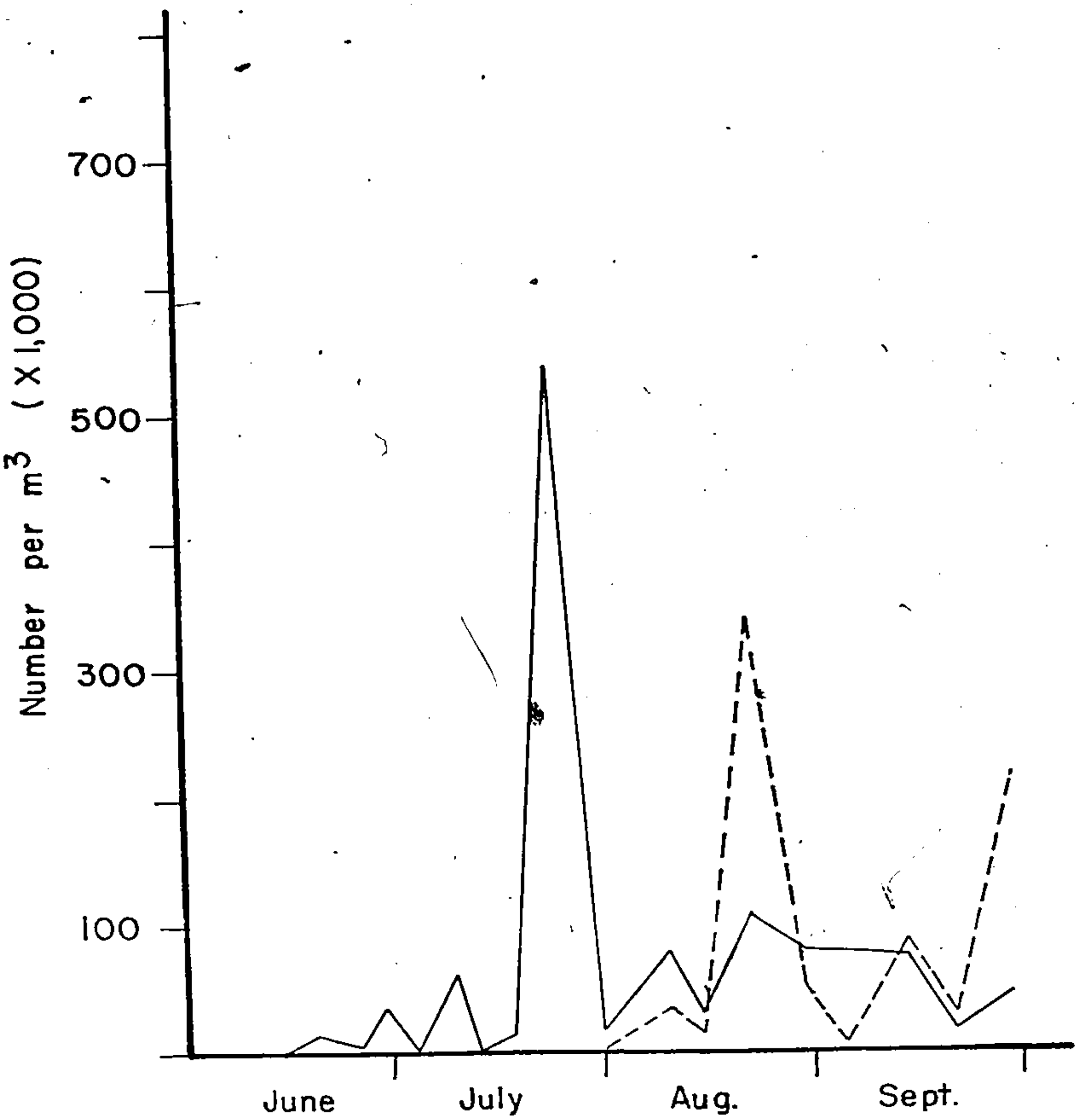

Number per m^3 (X 1,000)
700
500
300
100
June
July
Aug.
Sept.

Figure 25. Seasonal density of zooplankton of Kettle Island Bay in 1978. Ostracoda ————

Chydoridae - - - - -



Number per m^3 (X1,000)
700
500
300
100
June
July
Aug.
Sept.

Figure 26. Relative proportions of zooplankton of Kettle Island Bay in 1978. Bosminidae ———————
Chydoridae — — — — —
Daphnidae -·-·-·-·-·

Figure 27. Relative proportions of zooplankton of Kettle Island Bay in 1978. Calanoida ———————
Cyclopoida — — — — —

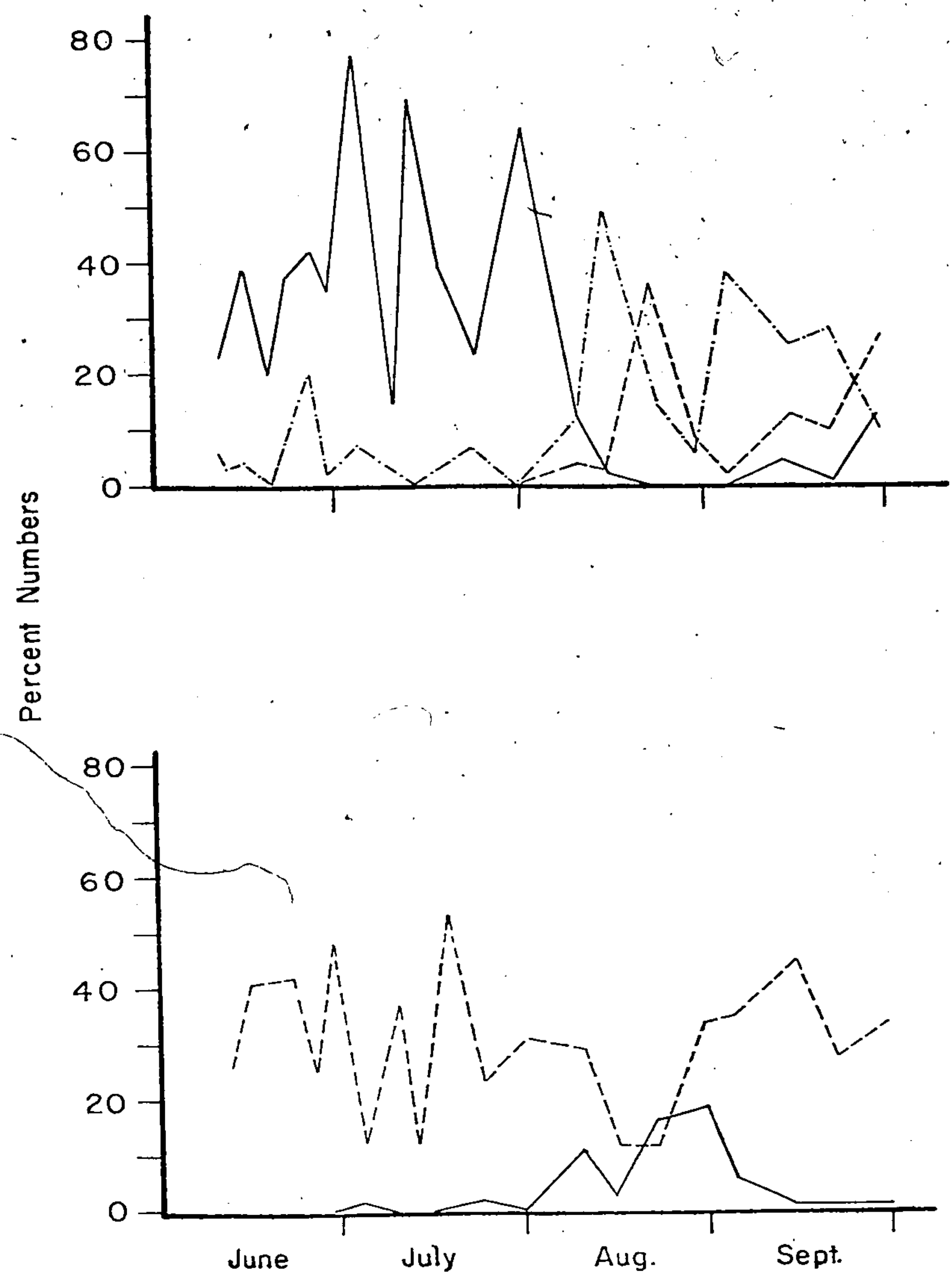
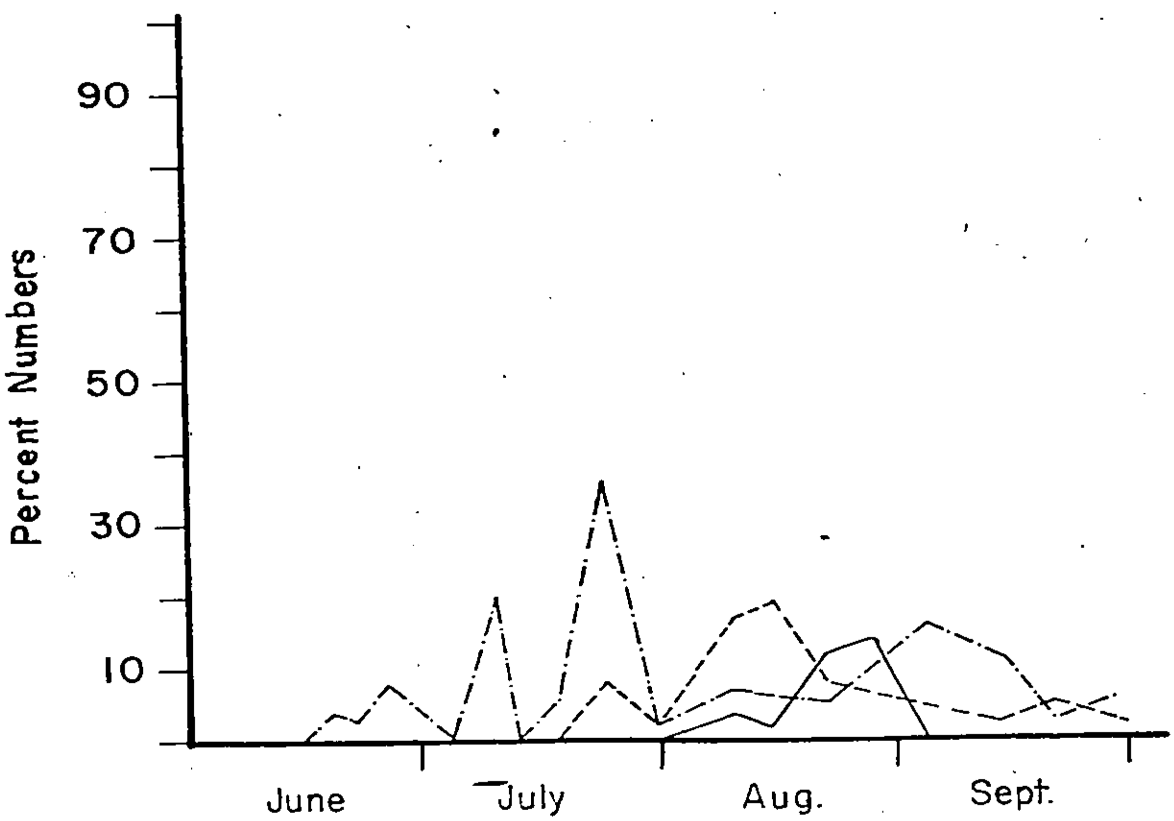

80
60
40
20
0
Percent Numbers
80
60
40
20
0
June
July
Aug.
Sept.

Figure 28. Relative proportions of zooplankton of Kettle Island Bay in 1978. <u>Polyphemus</u>

<u>Diaphanasoma</u>

Ostracoda


Percent Numbers
90
70
50
30
10
June
July
Aug.
Sept.

than 19 percent of the zooplankton (Fig. 27).

The density of Daphnidae was as high as 200,000 animals/m^3 in the middle of August and in early September; and over 100,000 Daphnidae/m^3 at the beginning and at the end of the month of July (Fig. 23). 35 percent of the zooplankton was composed of Daphnidae on the occasions that Daphnidae numbers were at 200,000 animals/m^3.

The numbers of Diaphanasoma were as high as about 115,000 organisms/m^3 at the end of July and reached as much as 180,000 organisms/m^3 at the end of August (Fig. 24). The Diaphanasoma comprised as much as 19 percent of the zooplankton in the littoral zone in the middle of August (Fig. 28).

The maximum numbers of Polyphemus, 85,000 animals/m^3, appeared in early September (Fig. 24) which then represented 14 percent of the available zooplankton in the littoral zone (Fig. 28). In 1979, however, dense swarms of Polyphemus were noticed at the edge of the emergent vegetation in June and again in September and population estimates of about 3,100,000 animals/m^3 were made. The tendency of Polyphemus to swarm near the edges of the emergent vegetation probably resulted in its actual availability being badly underestimated in 1978 samples.

The highest density observed for Bosminidae, over 700,000 animals/m^3, was in early July and the density was greater than 250,000 animals/m^3 from the middle of July until the beginning of August, after which the numbers dropped to a low level (Fig. 24). Bosminidae represented over 60 percent of the zooplankton of the littoral zone at the beginning of July, mid-July, and in early August (Fig. 26).

A maximum density of 300,000 Chydoridae/m^3 was detected in samples taken in late August and a peak of 200,000 animals/m^3 was obseved at the end of September (Fig. 25). Chydoridae comprised 36 percent of the littoral zone zooplankton at the end of August and 25 percent of the numbers late in September (Fig. 26).

A density of over 500,000 Ostracoda/m^3 was evident in late August (Fig. 25) but there were seldom more than 100,000 animals at other times. Ostracods represented as much as 36 percent of zooplankton numbers in late July (Fig. 28).

Seasonal Feeding Habits of Young-of-the-year Largemouth Bass, Black Crappie, and Pumpkinseed during 1978.

The seasonal diet of the young-of-the-year largemouth bass of Kettle Island Bay during 1978 is described in Table 4 for vertebrate and macrobenthic prey and in Table 5 for the planktonic prey. The percentage of empty stomachs was higher for the largemouth bass fingerlings than for either the black crappie or pumpkinseed. As many as 21 to 40 percent of the stomachs were empty at the end of September.

Tadpoles (<u>Rana</u> <u>catesbiana</u> or <u>R</u>. <u>clamitans</u>) did not enter the diet of the young bass until the end of July and they were the most important food item during the month of August and again at the end of September.

Table 4. Seasonal diet of young-of-the-year largemouth bass in Kettle Island Bay during 1978. Vertebrate and macrobenthic prey: percent occurrence (above), percent weight (middle), and the average number/fish (below).

Total Weight of Gut Contents	% Stomachs Empty	Tadpoles	Fish	Chironomids	Amphipods	Hemipterans	Odonatans	No. of Fish	Total Length (mm)
June 15, 1978.									
0.037	17.4	00.0	13.0	8.7	00.0	00.0	00.0	23	25.7
		-	53.7	0.5	-	-	-		
		-	0.1	0.1	-	-	-		
June 19 and 22, 1978.									
0.483	6.2	00.0	52.1	29.2	2.1	00.0	00.0	48	28.7
		-	76.0	2.5	0.5	-	-		
		-	0.6	0.3	0.0	-	-		
June 26 and 27, 1978.									
0.867	10.2	00.0	44.1	32.2	17.0	15.2	00.0	59	35.2
		-	81.0	2.0	1.2	3.0	-		
		-	0.5	0.6	0.2	0.2	-		
July 4, 1978.									
1.242	5.7	00.0	57.1	42.9	11.4	22.9	00.0	34	41.7
		-	90.2	2.2	0.7	2.5	-		
		-	0.7	0.5	0.2	0.3	-		
July 10 and 13, 1978.									
1.623	00.0	00.0	28.0	74.0	38.0	35.4	2.9	68	44.6
		-	47.9	7.0	5.9	15.9	2.8		
		-	0.5	2.4	1.3	0.7	0.1		
July 18, 1978.									
1.648	3.0	00.0	45.2	54.8	29.0	25.8	9.7	31	53.3
		-	82.8	1.9	1.7	2.3	6.6		
		-	5.2	2.0	1.1	0.6	0.2		

Table 4. - Continued.

July 24, 1978.									
1,147	13.7	3.4	24.1	34.5	27.6	24.1	6.9	29	49.2
		0.9	81.0	1.3	1.8	1.8	0.5		
		0.1	0.2	0.9	0.7	0.4	0.1		
July 31, 1978.									
2.915	2.5	50.0	20.0	17.5	25.0	5.0	2.5	40	62.1
		46.8	47.5	0.5	1.5	0.9	0.6		
		0.5	0.2	0.7	1.0	0.4	0.0		
August 10, 1978.									
3.373	2.5	65.0	2.5	10.0	22.5	5.0	7.5	40	67.6
		93.1	3.0	0.2	0.1	0.2	1.5		
		0.7	0.1	0.1	0.2	0.1	0.1		
August 15, 1978.									
7.634	3.0	86.0	5.6	00.0	8.3	00.0	00.0	36	78.8
		91.2	8.0	-	0.0	-	-		
		0.8	0.1	-	0.2	-	-		
August 22, 1978.									
10.531	11.4	40.0	22.2	2.2	13.3	4.4	00.0	45	81.7
		80.4	18.5	0.0	0.0	0.1	-		
		0.4	0.6	0.0	0.2	0.1	-		
August 30, 1978.									
11.884	2.9	52.9	2.9	5.9	26.5	2.9	5.9	34	86.5
		89.0	8.3	0.0	0.0	0.1	0.1		
		0.6	0.1	0.1	0.7	0.0	0.1		
September 4, 1978.									
0.768	3.2	3.2	12.9	16.1	64.5	6.5	3.2	31	67.6
		8.0	49.4	0.5	0.4	0.4	9.5		
		0.1	0.1	0.3	0.5	0.1	0.1		
September 14, 1978.									
2.790	15.8	00.0	7.5	15.0	37.5	5.0	12.5	40	63.7
		-	89.3	0.2	0.5	0.3	2.0		
		-	0.1	0.2	0.6	0.1	0.4		

Table 4. - Continued.

September 21, 1978.									
2.064	40.0	00.0	20.0	00.0	30.0	10.0	00.0	10	82.5
		-	96.6	-	0.1	0.2	-		
		-	0.2	-	0.4	0.1	-		
September 29, 1978.									
2.019	21.0	5.9	2.9	11.8	20.6	2.9	00.0	34	69.2
		91.1	0.9	0.1	0.2	0.1	-		
		0.1	0.0	0.2	0.4	0.1	-		

Table 5. Seasonal diet of young-of-the-year largemouth bass of Kettle Island Bay during 1978. Planktonic prey: percent occurrence (above), percent numbers (middle), and average number/fish (below).

No. of Zoo-plankton	% Total Gut Weight	Cyclopoids	Daphnidae	Bosminidae	Diaphanasoma	Polyphemus	Chydoridae	Simocephalus
June 15, 1978.								
288	45.7	56.5	17.4	30.4	00.0	00.0	00.0	00.0
		76.4	2.4	20.8	-	-	-	-
		9.6	0.3	2.6	-	-	-	-
June 19 and 22, 1978.								
846	21.1	56.2	10.4	00.0	00.0	00.0	4.2	00.0
		97.5	1.8	-	-	-	0.3	-
		17.2	0.2	-	-	-	0.0	-
June 26 and 29, 1978.								
322	5.8	42.4	39.0	00.0	1.7	00.0	00.0	00.0
		46.8	53.0	-	0.2	-	-	-
		2.2	3.3	-	0.0	-	-	-
July 4, 1978.								
140	3.2	17.1	20.0	00.0	00.0	00.0	00.0	00.0
		43.6	56.4	-	-	-	-	-
		1.7	2.3	-	-	-	-	-
July 10 and 13, 1978.								
950	17.4	49.1	63.4	1.5	00.0	2.9	00.0	00.0
		27.1	66.4	0.2	-	5.8	-	-
		3.9	9.3	0.0	-	0.7	-	-
July 18, 1978.								
387	4.2	35.5	58.1	00.0	00.0	29.0	00.0	00.0
		20.9	48.8	-	-	30.2	-	-
		2.5	5.9	-	-	3.7	-	-

Table 5. - Continued.

July 24, 1978.								
1075	11.3	31.0	48.3	3.4	31.0	17.2	00.0	00.0
		6.0	22.5	0.1	50.7	20.0	-	-
		2.2	8.3	0.0	18.8	7.5	-	-
July 31, 1978.								
465	0.9	12.5	25.0	00.0	10.0	00.0	00.0	7.5
		3.2	21.7	-	14.6	-	-	60.4
		0.4	2.5	-	1.7	-	-	7.0
August 10, 1978.								
1064	1.9	7.5	12.5	7.5	31.3	15.0	00.0	2.5
		3.7	20.4	0.3	24.4	35.5	-	16.1
		1.0	5.4	0.1	6.5	9.4	-	4.3
August 15, 1978.								
502	0.8	5.6	8.3	00.0	8.3	5.6	00.0	5.6
		1.6	12.5	-	52.4	30.3	-	3.2
		0.2	1.8	-	7.3	4.3	-	0.4
August 22, 1978.								
830	1.0	6.7	26.7	00.0	4.4	13.3	00.0	11.1
		1.6	50.5	-	10.5	30.8	-	6.6
		0.3	9.3	-	1.9	5.7	-	1.2
August 30, 1978								
2073	2.2	8.8	29.4	00.0	8.8	29.4	00.0	23.5
		1.9	15.5	-	1.9	74.6	-	7.5
		1.2	9.4	-	1.2	45.5	-	4.6
September 4, 1978.								
1416	30.6	51.6	41.9	00.0	6.5	64.5	00.0	64.5
		16.0	9.7	-	1.1	50.6	-	22.5
		7.3	4.5	-	0.5	23.1	-	10.3
September 14, 1978.								
1301	7.4	20.0	27.5	00.0	00.0	62.5	00.0	45.0
		4.5	10.2	-	-	68.0	-	17.2
		1.5	3.3	-	-	22.1	-	5.6

Table 5. - Continued.

September 21, 1978.								
283	2.5	30.0	20.0	00.0	10.0	20.0	10.0	20.0
		33.4	7.3	-	8.1	44.6	0.8	5.7
		12.8	2.8	-	3.1	17.1	0.3	2.2
September 29, 1978.								
855	7.1	38.2	32.4	00.0	00.0	20.6	2.9	2.9
		77.3	9.2	-	-	12.4	0.1	0.9
		19.4	2.3	-	-	3.1	0.0	0.2

Fish prey were the most important constituent of the diet of the young bass for most of the study period. Only 46 percent of the prey fish could be identified to species. The vast majority of the unidentified fish prey did not posses spines in their fins nor did they seem to have ctenoid scales which means they were probably minnows (Cyprinidae). Of the identifiable prey species, the most commonly consumed were young-of-the-year pumpkinseed (35 percent by numbers), golden shiners of all sizes (17 percent), young-of-the-year yellow perch (11 percent), young-of-the-year largemouth bass (10 percent), and young-of-the-year black crappie (6 percent). The actual importance of the largemouth bass fry to the larger bass from earlier spawnings is much lower than indicated because a few fish ate a large number of fry each. Silvery minnows, emerald shiners, young-of-the-year brown bullhead, young-of-the-year rockbass, and Iowa darters (<u>Etheostoma</u> <u>exile</u>) were occasionally preyed upon.

Benthic invertebrates reached a maximum of importance of 32 percent of the diet in the middle of July. Amphipods accounted for up to 6 percent and chironomids for up to 7 percent of the diet, by weight, at this time. The relative proportions of both the amphipods and chironomids in the macrobenthos were high at this time. Hemipterans accounted for a maximum of 16 percent of the gut weight in one sample in the middle of July and odonatans (Zygopterans) attained peaks of 7 percent and 10 percent of the gut weight in the middle of July and early in September, respectively.

The odonatans, however, were only eaten by a few bass, but in large amounts by these few individuals.

The greatest importance of zooplankton, 46 percent of the stomach content weight, in the diet occurred in June and zooplankton were 31 percent of the diet in early September after most of the larger fingerlings had dispersed from Kettle Island Bay. Zooplankton was not eaten in significant amounts during the month of August. Cyclopoids and Daphnidae were the dominant planktonic prey of young bass during June which was when these zooplankton types were abundant. Daphnidae, cyclopoids, and Polyphemus were the most important planktonic food items of young bass in July and both Diaphanasoma and Simocephalus were eaten in large amounts during peaks in their abundance. Polyphemus were the chief zooplankton eaten during September despite their apparent low density. The low numbers of Polyphemus may be due to a bias in sampling because densities as high as 3,000,000 animals/m^3 were seen in dense swarms near shore in June and September of 1979.

Table 6 shows the stomach contents of a group of largemouth bass fry of an average length of 22 mm on July 18, 1978. The principle prey consumed were cyclopoids, Daphnidae, and Bosminidae. Of these, cyclopoids and Bosminidae were present in large numbers in the littoral zone on this date. The diet of these fry contrasts with that of the earlier hatched bass which had eaten mostly fish prey (83 percent of stomach content weight) on this date.

Table 6. Food habits of the 22 mm size class of largemouth bass in Kettle Island Bay on July 18, 1978. Macrobenthic prey; percent occurrence (above), percent weight (middle), and the average number/fish (below). Planktonic prey: percent occurrence (above), percent numbers (middle), and the average number/fish (below).

Total Weight of Gut Contents	% Stomachs Empty	Chironomids	Plankton as % of Gut Weight	Number of Zoo-plankton	Cyclopoids	Daphnidae	Bosminidae	*Diaphanasoma*	*Polyphemus*	Chydoridae	Number of Fish
0.077	00.00	50.0	89.6	1,244	100.0	100.0	55.0	55.0	25.0	20.0	20
		9.4			39.6	40.0	11.4	5.1	3.1	0.4	
		0.7			24.7	24.9	7.1	3.2	2.0	0.3	

Planktonic prey declined to less than 50 percent of the stomach content weight when the young largemouth bass had attained an average length of 30 mm (Fig. 29). Macrobenthos were eaten in greatest quantities (32 percent of the weight of stomach contents) when the young bass were an average of 45 mm long and then the importance of benthic food in the diet declined. Vertebrate prey, mostly prey fish, accounted for 50 percent of the diet when the bass fingerlings had achieved an average length of 35 mm and was almost 100 percent of the diet when a length of 60 mm was reached. Tadpoles did not become an important part of the diet of young largemouth bass until an average length of 66 mm was attained.

The seasonal feeding habits of young-of-the-year black crappie of Kettle Island Bay are presented in Table 7 for the vertebrate and macrobenthic prey and in Table 8 for the planktonic prey items. Empty stomachs were seldom observed in samples of young black crappie. The black crappie fingerlings fed predominantly upon planktonic prey. Pelagic fish fry, probably minnows and pumpkinseed, made up to 37 percent of the weight of stomach contents of the crappie fry in June and declined to one percent of the weight, or less, in July. The 24 h sampling periods demonstrated that fish fry were even more important as a food of young black crappie and this is covered in the section on feeding periodicity.

Amphipods were seldom more than one percent (by weight) of the diet of young black crappie until the end of September, when a peak of eight percent of the diet was reached, during

Figure 29. Changes in the types of food eaten by young-of-the-year largemouth bass with increasing length.

Macrobenthos ●————●

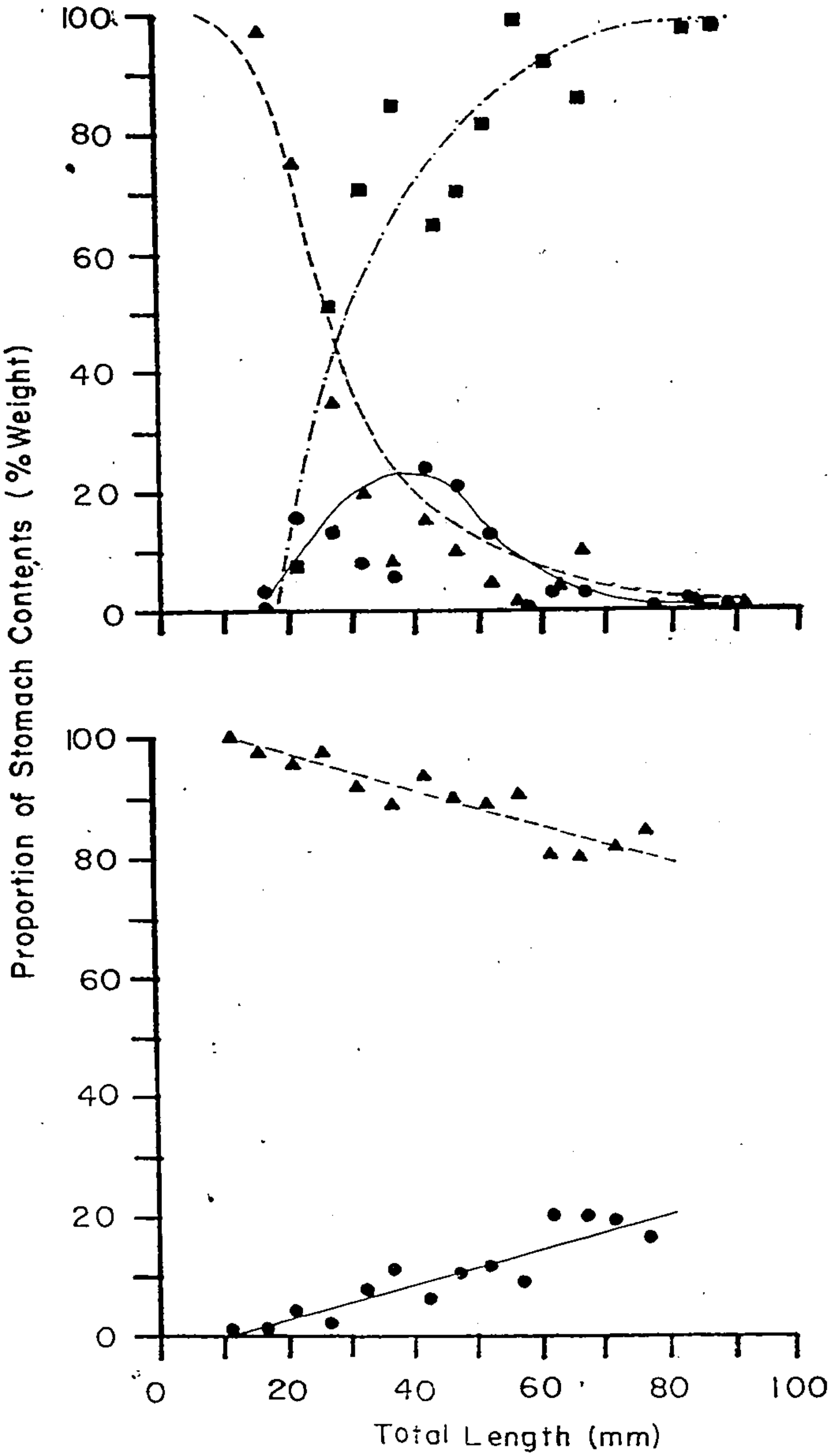
Zooplankton ▲— — — — —▲

Vertebrates ■·-·-·-·-·-■

Figure 30. Changes in the types of food eaten by young-of-the-year black crappie with increasing length.

Macrobenthos ●————●

Zooplankton ▲— — — — — —▲


Proportion of Stomach Contents (% Weight)
100
80
60
40
20
0
100
80
60
40
20
0
0
20
40
60
80
100
Total Length (mm)

a period of high amphipod availability. Chironomid prey accounted for up to eight percent of the stomach content weight during July, a period of high chironomid availability, and the importance declined thereafter. Chaoborus larvae and pupae first appeared in the diet of young black crappie in mid-July and was an important part of the diet until late September when the density of Chaoborus, in the 5.5 m depths, dropped from 17,000 animals/m^2 to less than 3,500 animals/m^2. Neuropteran larvae (Megaloptera: Sialis sp.) were significant food items of young crappie in late July and early August.

Calanoid copepods were an important food item of young-of-the-year black crappie from the end of June until the end of the sampling period. Calanoids were up to 44 percent of the zooplankton eaten in late July, during a period of rising calaoid availability, and were as much as 52 percent of the plankton eaten by young crappies in early September which was the period of peak calanoid abundance. Cyclopoid copepods were eaten in important amounts throughout the study and were the chief planktonic prey of the young crappie in mid-June and through most of August, which roughly corresponded to the periods of high cyclopoid abundance.

Daphnidae were the principal zooplankton eaten by young black crappie in the middle of August and for most of September, which coincided with the time of highest relative abundance of the Daphnidae. Bosminidae were a major prey item from the middle of June until the middle of July as they were a very abundant component of the zooplankton at

Table 7. Seasonal diet of young-of-the-year black crappie in Kettle Island Bay during 1978. Vertebrate and macrobenthic prey: percent occurrence (above), percent weight (middle), and the average number/fish (below).

Number of Fish	Total Length (mm)	Total Weight of Gut Contents	% Stomachs Empty	Fish Fry	Amphipods	Chironomids	*Chaoborus*	Neuropterans
June 12 and 15, 1978.								
62	20.1	0.054	00.0	27.4	00.0	11.3	00.0	00.0
				37.4	-	4.3	-	-
				0.3	-	0.2	-	-
June 19 and 22, 1978.								
55	21.7	0.129	00.0	18.2	00.0	32.7	00.0	00.0
				11.9	-	2.2	-	-
				0.4	-	0.4	-	-
June 26 and 29, 1978.								
57	26.1	0.465	00.0	8.8	1.8	43.6	00.0	00.0
				2.5	0.1	2.6	-	-
				0.2	0.1	1.1	-	-
July 4, 1978.								
34	30.4	0.159	00.0	5.9	00.0	38.2	00.0	00.0
				1.2	-	8.2	-	-
				0.1	-	0.6	-	-
July 10 and 13, 1978.								
75	36.4	1.182	00.0	4.0	6.7	57.3	00.0	2.7
				0.3	1.3	7.6	-	0.1
				0.1	1.2	6.1	-	0.1
July 18, 1978.								
30	42.3	1.082	00.0	00.0	16.7	36.7	3.3	10.0
				-	0.4	1.1	0.4	4.1
				-	0.3	0.8	0.4	0.4

Table 7. - Continued.

July 24, 1978.								
20	49.5	0.641	00.0	5.0	5.0	60.0	15.0	00.0
				2.3	0.1	2.7	3.5	-
				0.1	0.1	1.2	1.6	-
July 31, 1978.								
32	51.6	1.079	00.0	00.0	34.4	50.0	00.0	21.9
				-	3.2	1.7	-	7.1
				-	2.3	2.2	-	0.3
August 10, 1978.								
35	63.5	1.747	00.0	5.7	37.1	45.7	14.3	20.0
				6.2	1.0	2.8	13.1	6.2
				0.1	1.0	1.8	5.6	0.3
August 15, 1978.								
32	61.4	1.029	00.0	00.0	3.1	9.4	18.8	6.3
				-	0.1	0.2	9.3	1.0
				-	0.1	0.3	2.5	0.1
August 22, 1978.								
33	66.7	2.009	00.0	00.0	6.1	24.2	39.4	3.0
				-	0.4	0.5	37.1	0.5
				-	0.6	1.3	34.7	0.1
August 30, 1978.								
46	70.0	1.260	00.0	00.0	00.0	8.7	13.0	13.0
				-	-	0.1	11.2	5.7
				-	-	0.1	1.9	0.2
September 4, 1978.								
40	72.0	1.799	00.0	00.0	22.5	42.5	37.5	00.0
				-	0.7	0.8	18.8	-
				-	0.3	1.0	20.5	-
September 14, 1978.								
40	74.7	1.565	00.0	00.0	21.9	25.0	18.8	00.0
				-	0.8	0.8	13.3	-
				-	0.2	0.4	4.7	-

Table 7. - Continued.

September 21, 1978								
32	77.2	1.012	3.0	00.0	21.9	25.0	18.8	00.0
				-	0.8	0.8	13.3	-
				-	0.2	0.4	4.7	-
September 29, 1978.								
25	66.8	0.478	00.0	00.0	40.0	4.0	4.0	00.0
				-	8.0	0.1	0.4	-
				-	1.9	0.1	0.1	-

Table 8. Seasonal diet of young-of-the-year black crappie in Kettle Island Bay during 1978. Planktonic prey: percent occurrence (above), percent numbers (middle), and average number/fish (below).

% of Total Gut Weight	Number of Zoo-plankton	Calanoids	Cyclopoids	Daphnidae	Bosminidae	*Diaphanasoma*	*Polyphemus*
June 12 and 15, 1978.							
65.5	1,857	00.0	79.1	9.7	74.2	13.0	3.3
		-	48.0	0.7	49.1	1.5	0.7
		-	15.0	0.3	14.1	0.3	0.3
June 19 and 22, 1978.							
85.7	3,750	1.8	97.2	37.3	89.1	23.6	00.0
		0.7	44.6	1.6	51.5	1.0	-
		0.5	29.0	1.2	36.5	0.7	-
June 26 and 29, 1978.							
94.6	10,076	80.8	100.0	84.2	96.5	8.7	00.0
		14.6	24.9	4.2	55.6	0.1	-
		27.0	43.6	7.4	98.3	0.3	-
July 4, 1978.							
90.6	3,485	58.8	52.9	35.3	100.0	00.0	00.0
		9.9	1.8	2.7	85.3	-	-
		10.2	1.9	2.8	87.7	-	-
July 10 and 13, 1978.							
90.5	11,663	66.7	74.7	65.3	88.0	8.0	00.0
		25.2	16.2	7.9	50.1	0.7	-
		41.2	19.3	12.5	77.1	1.1	-
July 18, 1978.							
93.9	6,629	90.0	96.7	96.7	40.0	6.7	00.0
		18.6	42.1	23.8	15.2	8.3	-
		41.1	93.0	52.6	33.5	0.8	-

Table 8. - Continued.

July 24, 1978.							
91.3	3,764	80.0	85.0	95.0	30.0	20.0	00.0
		28.9	36.0	23.0	9.0	3.3	-
		54.4	67.7	43.2	17.0	6.0	-
July 31, 1978.							
88.7	5,919	90.0	80.0	90.0	13.3	00.0	00.0
		43.9	28.0	27.6	0.4	-	-
		86.6	55.2	54.5	0.9	-	-
August 10, 1978.							
70.3	8,541	34.3	97.1	91.4	00.0	37.1	00.0
		10.8	55.2	24.1	-	9.8	-
		26.4	134.6	58.8	-	23.9	-
August 15, 1978.							
89.3	10,460	15.6	90.6	93.8	00.0	56.3	6.3
		1.7	42.0	44.8	-	5.6	7.7
		5.3	135.1	143.9	-	18.0	24.6
August 22, 1978.							
61.4	6,366	51.5	100.0	93.9	00.0	42.4	00.0
		21.2	52.7	21.2	-	5.0	-
		40.9	101.6	40.9	-	9.6	-
August 30, 1978.							
86.0	7,490	41.3	87.0	69.6	00.0	13.0	00.0
		19.1	54.7	23.9	-	2.3	-
		31.0	89.1	38.9	-	3.8	-
September 4, 1978.							
78.9	9,622	90.0	92.5	[illegible]	2.5	5.0	7.5
		51.0	33.7	12.8	0.2	0.1	1.4
		124.5	81.0	30.8	0.4	0.3	3.5
September 14, 1978.							
80.4	10,303	80.0	70.0	90.0	12.5	40.0	2.5
		30.0	9.2	43.1	0.8	7.3	9.1
		77.3	23.8	110.9	2.0	18.8	23.4

Table 8. - Continued.

September 21, 1978.							
84.8	5,000	31.3	81.3	96.9	56.3	53.1	6.3
		2.9	20.1	46.6	18.0	9.6	1.5
		4.6	31.4	72.9	28.1	15.0	2.3
September 29, 1978.							
90.9	4,323	72.0	80.0	100.0	56.0	28.0	8.0
		24.1	12.6	51.2	5.8	2.8	3.2
		41.8	21.8	88.5	10.1	4.9	5.5

at this time. Diaphanasoma never exceeded 10 percent of the numbers of zooplankton eaten by black crappie fingerlings and Polyphemus were only an occasional prey item.

Zooplankton were the principal food type consumed by young-of-the-year black crappie in Kettle Island Bay and the proportion of macrobenthos in the diet increased with the size of the crappie (Fig. 30). Pelagic fish fry were considered a part of the zooplankton because of their small size and relative lack of mobility.

The seasonal diet of the young-of-the-year pumpkinseed of Kettle Island Bay is presented in Table 9 for macrobenthic prey and in Table 10 for planktonic prey. Empty stomachs were seldom encountered from the samples of pumpkinseed fry. Chironomids, the dominant prey eaten, represented from 18.4 to 92.7 percent of the stomach content weight throughout the study. The greatest utilization of chironomid larvae by the pumpkinseed fry occurred in July during the time of greatest availability of the chironomids. Chironomids only represented less than 50 percent of the diet at the end of July and in the middle of September.

Trichopteran larvae were an important part of the diet of young pumpkinseed in mid-August; coleopteran larvae, odonatans (Zygoptera), and isopods in the middle of September; and amphipods in early August.

Small gastropods and pelecypods (Sphaeridae) first appeared in the diet of pumpkinseed fingerlings in mid-August when the pumpkinseed had attained a mean length of 38 mm.

Table 9. Seasonal diet of young-of-the-year pumpkinseed in Kettle Island Bay during 1978. Macrobenthic prey: percent occurrence (above), percent weight (middle), and the average number/fish (below).

Total Weight of Gut Contents	% Stomachs Empty	Chironomids	Amphipods	Pelecypods	Gastropods	Trichopterans	Isopods	Coleopterans	Odonatans
July 10 and 13, 1978. (n = 10; TL = 20.6 mm)									
0.005	00.0	90.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
		51.8	-	-	-	-	-	-	-
		1.7	-	-	-	-	-	-	-
July 18, 1978. (n = 9; TL = 24.0)									
0.020	00.0	100.0	11.1	00.0	00.0	00.0	00.0	00.0	00.0
		91.5	0.5	-	-	-	-	-	-
		4.9	0.1	-	-	-	-	-	-
July 24, 1978. (n = 29; TL = 28.4)									
0.106	00.0	96.5	27.6	00.0	00.0	00.0	00.0	00.0	00.0
		92.7	2.3	-	-	-	-	-	-
		10.9	0.3	-	-	-	-	-	-
July 31, 1978. (n = 18; TL = 29.4 mm)									
0.053	00.0	55.5	11.1	00.0	00.0	00.0	00.0	00.0	00.0
		18.4	1.9	-	-	-	-	-	-
		1.6	0.1	-	-	-	-	-	-
August 10, 1978. (n = 28; TL = 32.5)									
0.200	00.0	82.1	50.0	14.3	00.0	00.0	00.0	00.0	7.1
		62.5	10.0	0.7	-	-	-	-	0.4
		13.1	1.7	0.2	-	-	-	-	0.1
August 15, 1978 (n = 40; TL = 37.9)									
0.495	3.0	87.5	27.5	30.0	40.0	50.0	00.0	00.0	5.0
		52.8	2.5	1.6	8.3	16.2	-	-	0.3
		18.4	0.6	0.5	1.2	1.4	-	-	0.1

Table 9. - Continued.

August 22, 1978. (n = 31; TL = 41.0 mm)									
0.384	00.0	93.5	25.8	00.0	64.5	38.7	00.0	00.0	00.0
		51.5	1.0	-	20.6	10.3	-	-	-
		17.4	0.3	-	2.8	0.8	-	-	-
August 30, 1978. (n = 74; TL = 40.0 mm)									
0.899	00.0	95.9	25.7	5.4	40.5	23.0	1.4	2.7	1.4
		64.7	1.5	0.7	12.0	3.4	0.2	0.1	0.2
		20.9	0.5	0.2	1.9	0.4	0.0	0.0	0.0
September 4, 1978. (n = 46; TL = 39.4 mm)									
0.342	00.0	97.8	21.7	2.2	41.3	4.3	00.0	8.7	4.3
		59.9	2.0	0.1	4.8	1.8	-	0.7	0.5
		10.5	0.3	0.0	1.2	0.1	-	0.1	0.1
September 14, 1978. (n = 40; TL = 40.5 mm)									
0.136	00.0	45.0	12.5	5.0	10.0	7.5	2.5	10.0	5.0
		27.3	1.3	0.4	1.5	5.4	5.4	10.1	5.2
		2.7	0.1	0.1	0.2	0.1	0.1	0.1	0.1
September 21, 1978. (n = 35; TL = 39.2 mm)									
0.442	00.0	100.0	37.1	8.6	14.3	25.7	11.4	17.1	2.9
		62.2	2.0	0.4	0.5	3.0	3.8	8.9	0.2
		18.8	0.5	0.1	0.3	0.4	0.3	0.5	0.1
September 29, 1978. (n = 52; TL = 44.3 mm)									
0.239	2.0	73.1	17.3	5.8	40.4	9.6	00.0	1.9	11.5
		51.3	3.2	1.3	18.4	1.8	-	4.3	3.7
		4.0	0.2	0.1	1.6	0.2	-	0.1	0.1

Table 10. Seasonal diet of young-of-the-year pumpkinseed in Kettle Island Bay during 1978. Planktonic prey: percent occurrence (above), percent numbers (middle), and the average number/fish (below).

No. of Zoo-plankton	Cyclopoids	Daphnidae	Bosminidae	Diaphanasoma	Chydoridae	Ostracods	Polyphemus	Simocephalus
July 10 and 13, 1978 (Percent of total gut weight = 48.3)								
137	50.0	80.0	70.0	20.0	00.0	00.0	00.0	00.0
	19.5	26.7	47.5	6.5	-	-	-	-
	2.7	3.6	6.5	0.9	-	-	-	-
July 18, 1978. (Percent of total gut weight = 8.0)								
39	11.1	44.4	22.2	11.1	11.1	00.0	00.0	00.0
	15.4	64.1	12.8	5.1	2.6	-	-	-
	0.7	2.8	0.6	0.2	0.1	-	-	-
July 24, 1978. (Percent of total gut weight = 3.3)								
316	3.4	69.0	6.8	27.6	00.0	37.9	00.0	00.0
	1.2	59.7	7.6	8.7	-	23.4	-	-
	0.1	6.6	0.6	0.9	-	2.8	-	-
July 31, 1978. (Percent of total gut weight = 79.1)								
855	16.7	100.0	5.5	55.5	11.1	5.5	00.0	00.0
	4.0	88.7	0.9	9.7	2.0	0.1	-	-
	0.2	42.1	0.4	4.6	0.1	0.1	-	-
August 10, 1978 (Percent of total gut weight = 25.1)								
931	17.2	78.6	7.1	39.3	14.3	42.9	3.6	00.0
	2.0	70.1	1.5	9.0	1.2	10.0	0.2	-
	0.7	25.0	0.5	3.0	0.4	3.3	0.1	-
August 15, 1978. (Percent of total gut weight = 16.3)								
1065	12.5	75.0	00.0	12.5	32.5	75.0	00.0	00.0
	0.3	63.5	-	5.8	6.3	23.9	-	-
	0.1	16.9	-	1.6	1.7	6.4	-	-

Table 10. - Continued.

August 22, 1978. (Percent of total gut weight = 16.5)								
412	00.0	71.0	00.0	9.7	2.6	64.5	3.2	3.2
	-	54.4	-	2.7	6.6	35.9	0.2	0.2
	-	7.2	-	0.4	0.9	4.8	0.1	0.1
August 30, 1978. (Percent of total gut weight = 16.2)								
2102	10.8	73.0	00.0	18.9	47.3	55.4	8.1	23.0
	0.6	57.3	-	12.4	15.7	9.6	1.0	3.4
	0.2	16.3	-	3.5	4.5	2.7	0.3	1.0
September 4, 1978. (Percent of total gut weight = 25.5)								
1208	41.3	76.1	00.0	21.7	65.2	58.7	2.2	4.4
	7.3	65.7	-	5.8	14.7	5.9	0.1	0.5
	1.9	17.3	-	1.5	3.9	1.5	0.1	0.1
September 14, 1978. (Percent of total gut weight = 42.9)								
1033	55.0	80.0	10.0	17.5	47.5	35.0	00.0	00.0
	12.8	65.4	1.0	7.5	7.0	3.8	-	-
	3.3	16.9	0.3	1.9	1.8	1.0	-	-
September 21, 1978. (Percent of total gut weight = 17.2)								
1042	65.7	80.0	25.7	2.9	62.9	25.7	00.0	00.0
	33.6	46.4	7.4	1.2	7.7	2.9	-	-
	10.0	13.8	2.2	0.4	2.3	0.9	-	-
September 29, 1978. (Percent of total gut weight = 16.1)								
519	50.0	65.4	9.6	7.7	40.4	25.0	00.0	00.0
	20.8	48.4	7.5	4.8	13.3	5.2	-	-
	2.1	4.8	0.8	0.5	1.3	0.5	-	-

Molluscs were eaten in greatest quantities in late August and in late September when the mean length of the pumpkinseed fingerlings was greater than 41 mm. Snails and fingernail clams were crushed and the shells spit out before swallowing. This was evidenced by the absence of of shells in the pumpkinseed stomachs and by actual observation of the young pumpkinseed preying on small snails in the aquarium (unpublished data). The number of categories of macrobenthos in the diet increased as the pumpkinseed grew.

The overall highest and lowest utilization of zooplankton as prey occurred in July and the lowest use coincided with the period of greatest predation by young pumpkinseed on chironomids. Zooplankton constituted over 16 percent of the stomach content weight of pumpkinseed fingerlings during August and September. Daphnidae were the principal planktonic prey of the young pumpkinseed on all sample dates and only accounted for less than 50 percent of the zooplankton in the stomachs early in July and at the end of September. In early July the density of Bosminidae reached 700,000 animals/m^3 and they were the chief plankton consumed by the pumpkinseed fry. In late September the relative proportions of cyclopoids were high and they were 34 percent of the zooplankton eaten by the pumpkinseed although Daphnidae were still 48 percent of the zooplankton eaten. Diaphanasoma usually accounted for 5 to 10 percent of the zooplankton in the stomachs. Chydoridae were of maximum importance as a food item for young pumpkinseed during their peak of abundance early in

September. The highest level of consumption of ostracods took place during a decline in Daphnidae abundance and an increase in the relative proportions of ostracods in the middle of August. Polyphemus and Simocephalus were occasionally eaten prey of young pumpkinseed.

Young-of-the-year pumpkinseed ate less zooplankton and more macrobenthos as they grew (Fig. 31). Macrobenthos accounted for more than 50 percent of the diet after a length of 20 mm was attained.

Comparison of Average Prey Sizes

The average weight of macrobenthic prey items from the stomachs of the young-of-the-year largemouth bass, black crappie, and pumpkinseed were compared with the average weight of these items in the habitat (Table 3).

The average size of tadpoles and prey fish ingested by young-of-the-year largemouth bass increased as the average length of the bass increased (Table 11). The large average size of the prey fish eaten in September was a result of the predation by the few large bass fingerlings that had remained in Kettle Island Bay. It is not known whether the hemipterans eaten by the largemouth bass fingerlings were of comparable size to those in the environment because the hemipterans could not be adequately sampled. The chironomid larvae and amphipods consumed by the young bass were of about the same average weight as those examined from the

Figure. 31. Changes in the types of food eaten by young- of-the-year pumpkinseed with increasing length.

Macrobenthos ●————————●

Zooplankton ▲- - - - - - -▲

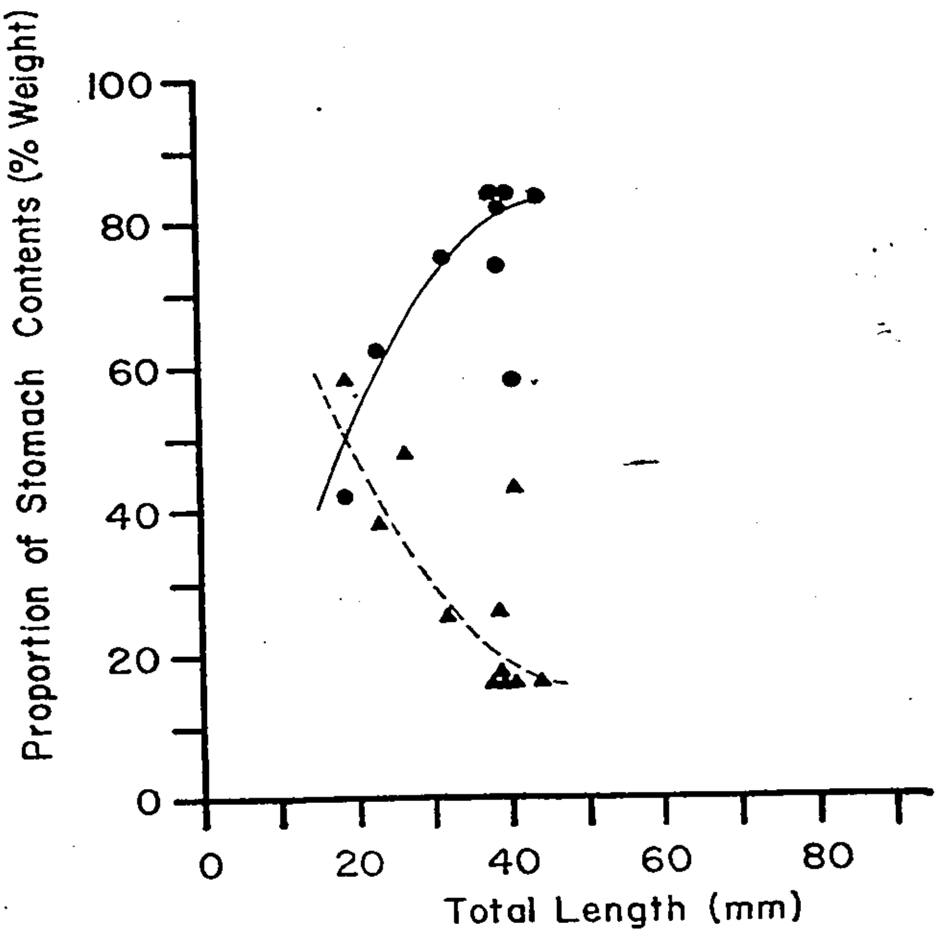

Proportion of Stomach Contents (% Weight)
100
80
60
40
20
0
0
20
40
60
80
Total Length (mm)

Table 11. Average weights (mg) of the prey items from the stomachs of young-of-the-year largemouth bass of Kettle Island Bay during 1978.

Date	No. of Stomachs Examined	Total Length	Tadpoles	Prey Fish	Amphipods	Chironomids	Odonatans	Hemipterans	Zooplankton
June									
15	23	25.7	00.0	6.5	00.0	0.1	00.0	00.0	0.058
19	25	28.4	00.0	10.1	00.0	0.7	00.0	00.0	0.100
22	23	29.4	00.0	15.5	2.5	0.8	00.0	00.0	0.207
26	19	33.8	00.0	9.2	1.3	1.1	00.0	1.8	0.133
29	40	35.8	00.0	40.0	0.7	0.5	00.0	1.6	0.181
July									
4	35	41.7	00.0	48.7	1.4	1.5	00.0	2.8	0.285
10	33	42.4	00.0	27.7	1.5	0.7	00.0	4.4	0.347
13	35	46.8	00.0	28.0	1.0	0.5	13.4	7.1	0.176
18	32	53.3	00.0	85.3	0.8	0.5	21.8	2.0	0.178
24	29	49.3	10.7	132.7	1.0	0.6	1.9	1.8	0.120
31	40	62.1	65.0	173.2	1.0	0.5	17.2	1.6	0.057
August									
10	40	67.8	120.8	101.8	1.6	0.6	11.6	3.0	0.059
15	36	77.6	232.0	304.0	00.0	0.5	00.0	00.0	0.126
22	45	82.6	470.5	177.1	0.5	0.3	00.0	3.9	0.123
30	34	86.5	556.8	984.6	1.0	0.2	6.7	16.2	0.127
September									
4	31	67.6	61.5	94.9	0.5	0.2	24.3	0.8	0.166
14	40	63.7	00.0	830.3	0.5	0.2	4.1	2.4	0.159
21	10	82.5	00.0	997.5	00.0	2.2	00.0	3.1	0.170
29	34	69.2	920.0	19.0	0.3	0.3	00.0	0.8	0.167

Young-of-the-year black crappie usually ate the smaller-than-average size of amphipods until September when the young crappie fed upon the larger sizes of amphipods (Table 12). The black crappie fingerlings ate the smaller chironomid larvae until the middle of July and then they ate chironomid larvae of the same average size as in the habitat until the end of sampling in September. The average weight of the *Chaoborus* larvae consumed by the black crappie fingerlings was usually less than the average weight of the *Chaoborus* available except at the end of August when the young crappie preyed mostly upon the pupae. The average weight of the fish fry ingested by the black crappie fry seldom surpassed 1.0 mg and these were considered to be pelagic organisms.

Young-of-the-year pumpkinseed ate amphipods that were smaller than the average weight available in Kettle Island Bay until the middle of August after which the young pumpkinseed ate amphipods of the same mean weight as were available (Table 13). The average weight of the gastropods and pelecypods eaten by the young pumpkinseed could not be compared to those available in the habitat because the shell was removed from these prey before they were swallowed. The chironomid larvae were usually of the same average weight as those examined from the macrobenthos samples from the bay. The trichopteran larvae from the pumpkinseed stomachs were usually smaller than the average weight of the larvae from the sample area.

Black crappie fry ate smaller zooplankton than the

Table 12. Average weights (mg) of the prey items from the stomachs of young-of-the-year black crappie of Kettle Island Bay during 1978.

Date	No. of Stomachs Examined	Total Length	Prey Fish	Amphipods	Chironomids	*Chaoborus*	Odonatans	Neuropterans	Zooplankton
June									
12	36	18.8	0.7	00.0	0.2	00.0	00.0	00.0	0.016
15	45	21.5	0.9	00.0	0.3	00.0	00.0	00.0	0.125
19	35	22.1	0.9	00.0	0.1	00.0	00.0	00.0	0.034
22	30	21.3	0.6	00.0	0.2	00.0	00.0	00.0	0.038
26	26	25.2	2.5	0.1	0.1	00.0	00.0	00.0	0.035
29	31	26.7	0.5	00.0	0.3	00.0	00.0	00.0	0.050
July									
4	34	30.4	0.6	00.0	0.6	00.0	00.0	00.0	0.041
10	40	34.2	0.9	0.4	0.4	00.0	00.0	00.0	0.081
13	35	38.6	0.6	0.4	0.5	00.0	0.9	0.9	0.102
18	30	42.3	00.0	0.6	0.5	0.3	1.0	6.4	0.153
24	40	49.5	14.5	0.8	0.7	0.7	00.0	00.0	0.155
31	30	51.6	00.0	0.5	1.6	1.3	00.0	5.8	0.153
August									
10	35	63.5	53.9	0.5	0.8	1.2	2.0	9.1	0.144
15	32	61.4	00.0	0.6	0.2	1.2	1.1	3.4	0.088
22	68	66.7	00.0	0.5	0.2	0.7	0.5	4.9	0.194
30	46	70.0	00.0	00.0	0.4	1.7	00.0	5.9	0.138
September									
4	40	72.0	00.0	0.9	0.4	0.4	0.8	00.0	0.147
14	40	74.7	00.0	0.8	0.3	0.9	2.2	00.0	0.122
21	32	77.2	00.0	1.1	0.7	0.9	3.1	00.0	0.173
29	25	66.8	00.0	0.8	0.3	0.6	1.7	00.0	0.100

Table 13. Average weights (mg) of the prey items from the stomachs of young-of-the-year pumpkinseed of Kettle Island Bay during 1978.

Date	No. of Stomachs Examined	Total Length	Gastropods	Pelecypods	Amphipods	Chironomids	Trichopterans	Odonatans	Zooplankton
July									
10	5	18.9	00.0	00.0	00.0	0.1	00.0	00.0	0.020
13	5	22.6	00.0	00.0	00.0	0.4	00.0	00.0	0.039
18	17	24.4	00.0	00.0	0.1	0.4	00.0	00.0	0.041
24	29	28.4	00.0	00.0	0.2	0.5	00.0	00.0	0.011
31	42	29.4	00.0	00.0	0.5	0.4	00.0	00.0	0.050
August									
10	28	32.5	00.0	0.3	0.4	0.3	00.0	0.4	0.052
15	40	37.9	0.9	0.4	0.5	0.4	1.5	0.7	0.076
22	31	41.0	0.9	00.0	0.4	0.4	1.5	00.0	0.154
30	74	40.4	0.8	0.4	0.4	0.4	1.1	1.6	0.069
September									
4	46	39.4	0.3	0.1	0.6	0.4	3.1	0.8	0.083
14	40	40.5	0.2	0.3	0.3	0.3	2.5	3.6	0.056
21	35	39.2	0.3	0.5	0.6	0.4	1.0	0.7	0.073
29	52	44.3	0.5	0.8	0.6	0.6	0.4	1.3	0.074

largemouth bass fry until late July when the young bass had essentially ceased feeding on zooplankton prey. In September, however, both the largemouth bass fingerlings and the young black crappie ate zooplankton of the same average weight. Largemouth bass ate larger chironomid larvae than those eaten by the young black crappie until the middle of July after which the two fish species ate chironomids of the same average weight. The young bass ate larger amphipods than those eaten by the young crappie until the month of September when it was the black crappie that was consuming the larger amphipods. The largemouth bass fingerlings ate prey fish of a much greater weight than the fry eaten by black crappie fry on the same sample dates.

The largemouth bass fingerlings consistently ate zooplankton, chironomid larvae, and odonatan nymphs of a greater average weight than eaten by the young pumpkinseed. The young pumpkinseed injested smaller amphipods than those eaten by the young bass until September when both fish species ate amphipods of the same average weight.

Black crappie fingerlings consistently ingested amphipods and zooplankton of a greater average weight than those taken by the young pumpkinseed. The weight of the chironomid larvae eaten by young black crappie was greater than the weight of chironomids eaten by young pumpkinseed until the end of August after which no real trend was apparent.

Food Selectivity

Strauss's linear selectivity index could not be applied to hemipteran or vertebrate prey items because the relative proportions of these prey items in the littoral zone of Kettle Island Bay could not be adequately measured.

The young of the year largemouth bass of Kettle Island Bay showed avoidance for Bosminidae, Chydoridae, calanoids, and ostracods as planktonic prey and Chaoborus as benthic prey for all sample dates during 1978 (Fig. 32 a to d). Daphnidae were the preferred planktonic prey item from the end of June until the beginning of August but the young bass selected for Polyphemus and had negative selectivity indices for Daphnidae in September despite the high availability of Daphnidae. Diaphanasoma were usually preyed upon in proportion to their relative abundance in Kettle Island Bay. Cyclopoids were selected for by the young bass in June but were selected against as planktonic prey for the duration of sampling.

Young largemouth bass usually showed positive selection for chironomid larvae as a benthic prey and amphipods were eaten in excess of their relative proportions in the benthos from the end of June until the middle of August.

Chironomid larvae were the preferred benthic prey item of the young-of-the-year black crappie od Kettle Island Bay until mid-July but were avoided in August and September when Chaoborus larvae were the preferred benthic prey. Amphipods,

Figure 32a. Seasonal selectivity indices for young-of-the-year largemouth bass of Kettle Island Bay in 1978. *Chaoborus* ————————

Chironomids — — — — —

Amphipods ....

Figure 32b. Seasonal selectivity indices for young-of-the-year largemouth bass of Kettle Island Bay in 1978. Calanoids ————————

Cyclopoids — — — — — —

Bosminidae ....

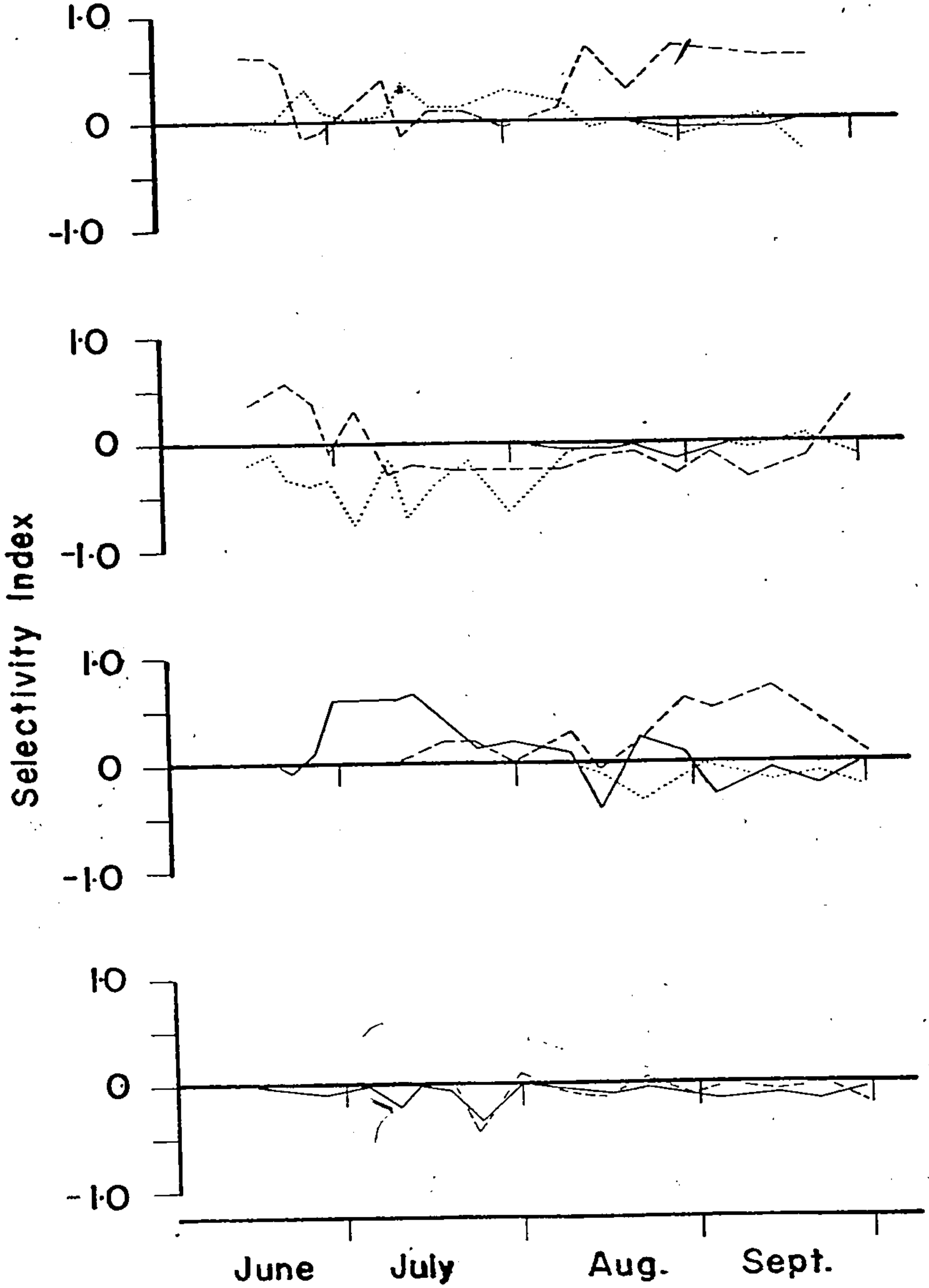
Figure 32c. Seasonal selectivity indices for young-of-the-year largemouth bass of Kettle Island Bay in 1978. Daphnidae ————————

Polyphemus — — — — — —

Chydoridae ....

Figure 32d. Seasonal selectivity indices for young-of-the-year largemouth bass of Kettle Island Bay in 1978. Ostracods ————————

Diaphanasoma — — — — — —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Selectivity Index
June
July
Aug.
Sept.

neuropteran larvae, Polyphemus, and Diaphanasoma were usually consumed in the same proportions that were available in the habitat (Fig. 33 a to f). Black crappie fingerlings showed a preference for calanoids throughout the sampling period except late in August when the young crappie ingested calanoids in proportion to their relative abundance in the zooplankton of Kettle Island Bay. Cyclopoids were selected for in August but were avoided during September when calanoids and Daphnidae were the preferred prey. Chydoridae and ostracods were not taken by the young black crappie in the bay and the selectivity indices for these items were necessarily negative. Bosminidae were a preferred food item in June and in the middle of July but were avoided in early July and in the latter half of July despite the very high numbers (up to 700,000 Bosminidae/m^3) present. In August and September the Bosminidae were eaten in proportion to their relative abundance in the zooplankton, which was low. Daphnidae were selected for from the middle of July until the middle of August and in the last half of September. Daphnidae were selected against in late June and early in September when the relative abundance of Daphnidae had declined.

The young-of-the-year pumpkinseed of Kettle Island Bay strongly preferred chironomid larvae and Daphnidae during 1978 (Fig. 34 a to d). Calanoids, Chaoborus larvae, and Polyphemus were not eaten at any time and thus the selectivity indices were negative. Amphipods and Diaphanasoma were either eaten in proportion to the numbers available or they were

Figure 33a. Seasonal selectivity indices for young-of-the-year black crappie of Kettle Island Bay in 1978.

Calanoids ————————

Cyclopoids – – – – – –

Figure 33b. Seasonal selectivity indices for young-of-the-year black crappie of Kettle Island Bay in 1978.

Chironomids ————————

Chaoborus – – – – – –

Figure 33c. Seasonal selectivity indices for young-of-the-year black crappie of Kettle Island Bay in 1978.

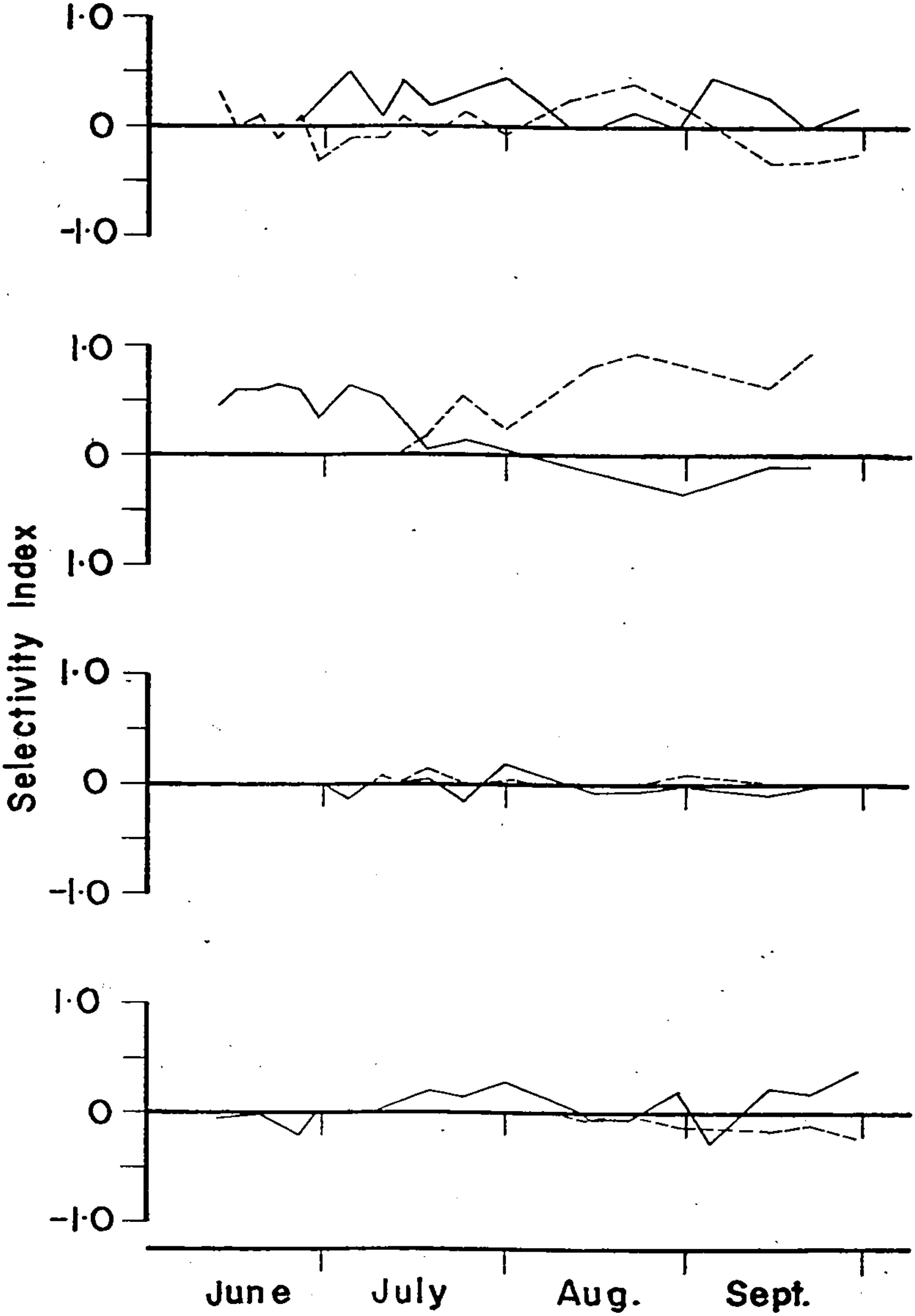
Amphipods ————————

Neuropterans – – – – – –

Figure 33d. Seasonal selectivity indices for young-of-the-year black crappie of Kettle Island Bay in 1978.

Daphnidae ————————

Chydoridae – – – – – –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Selectivity Index
June
July
Aug.
Sept.

Figure 33e. Seasonal selectivity indices for young-of-the-year black crappie of Kettle Island Bay in 1978.

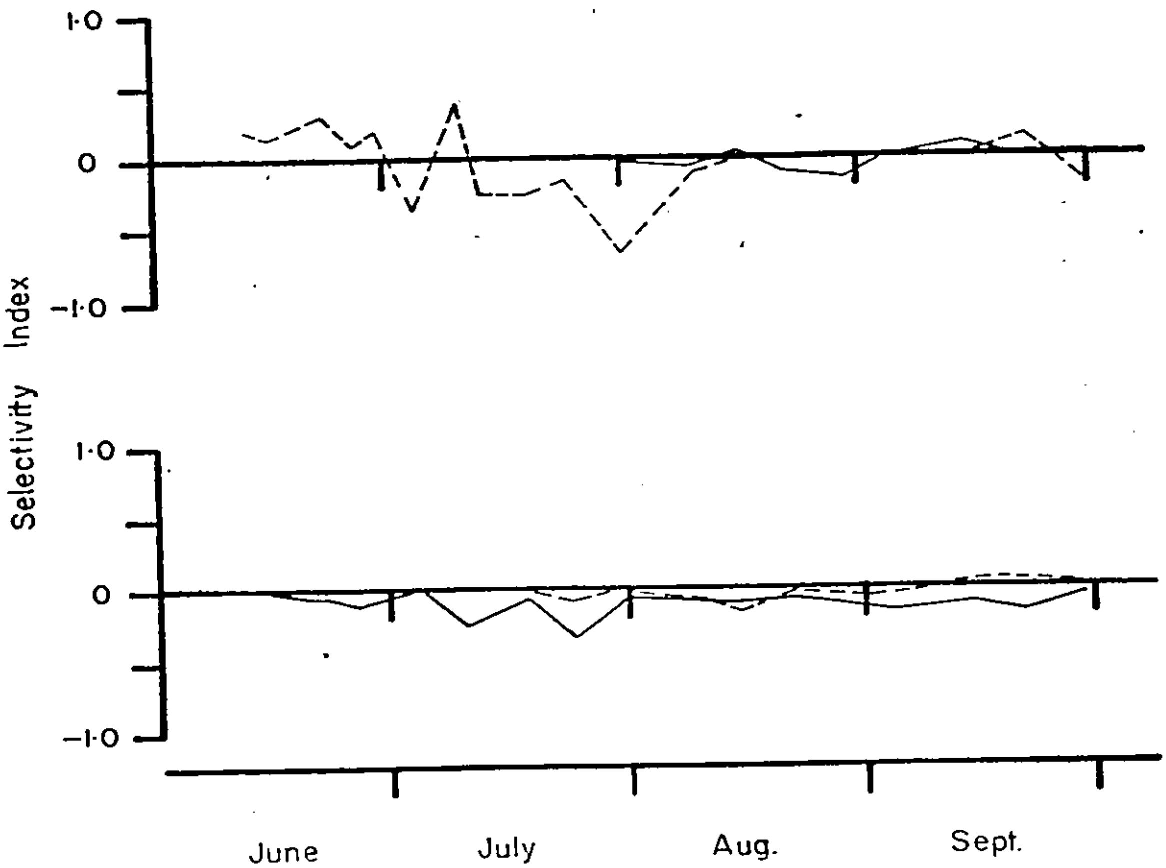
Polyphemus ————————

Bosminidae – – – – – –

Figure 33f. Seasonal selectivity indices for young-of-the-year black crappie of Kettle Island Bay in 1978.

Diaphanasoma ————————

Ostracods – – – – – –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Selectivity Index
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June
July
Aug.
Sept.

Figure 34a. Seasonal selectivity indices for young-of-the-year pumpkinseed of Kettle Island Bay in 1978.

Chaoborus ————————

Chironomids — — — — — —

Amphipods ············

Figure 34b. Seasonal selectivity indices for young-of-the-year pumpkinseed of Kettle Island Bay in 1978.

Calanoids ————————

Cyclopoids — — — — — —

Bosminidae ············

Figure 34c. Seasonal selectivity indices for young-of-the-year pumpkinseed of Kettle Island Bay in 1978.

Daphnidae ————————

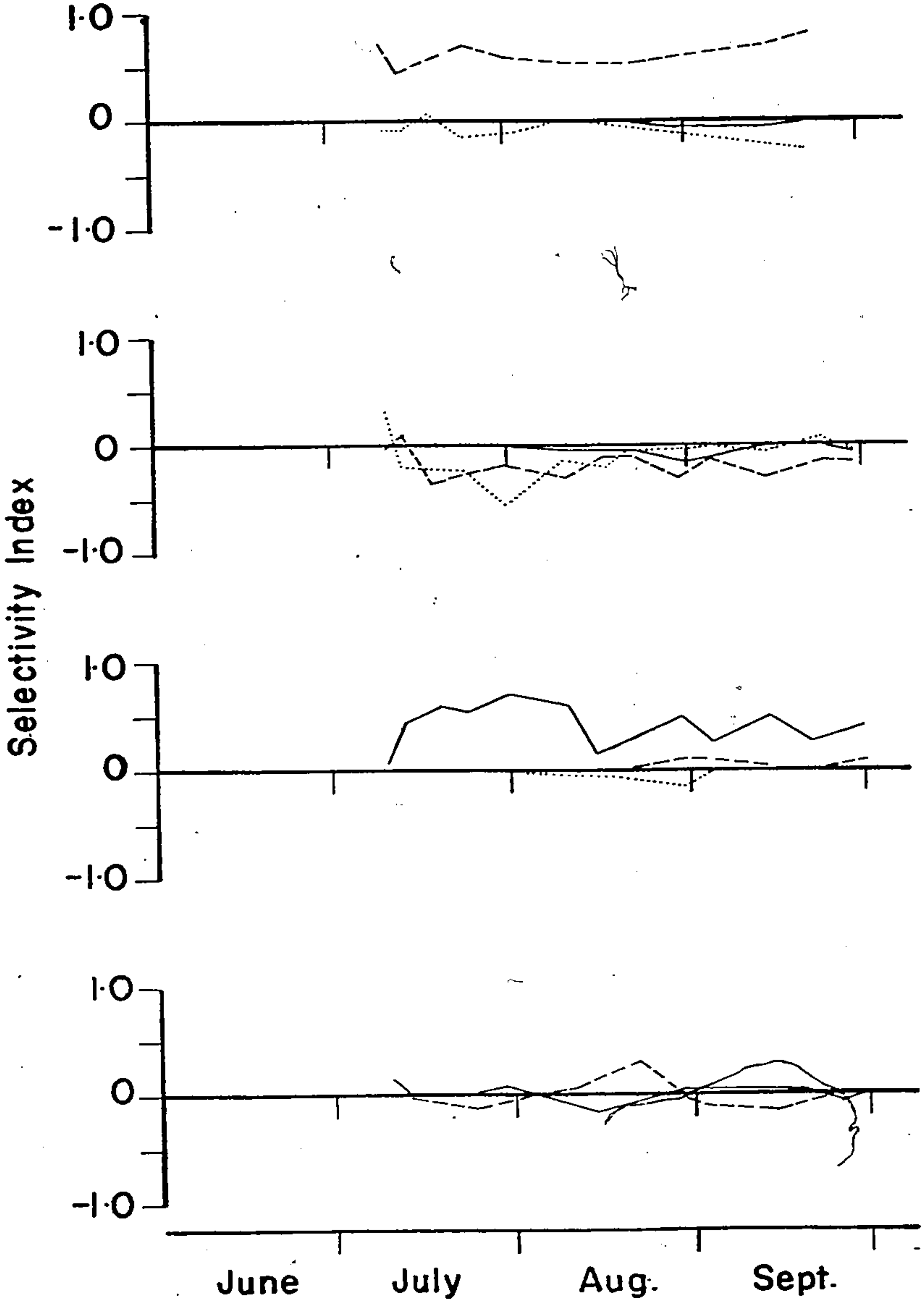
Chydoridae — — — — — —

Polyphemus ············

Figure 34d. Seasonal selectivity indices for young-of-the-year pumpkinseed of Kettle Island Bay in 1978.

Diaphanasoma ————————

Ostracods — — — — — —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Selectivity Index
June
July
Aug.
Sept.

slightly avoided. Bosminidae were a preferred prey in early July but were selected against by the young pumpkinseed for the remainder of July despite the very high densities of the Bosminidae present and they were eaten in proportion to their availability for the rest of the sampling period. Cyclopoids were usually avoided by the young pumpkinseed of Kettle Island Bay. Pumpkinseed fingerlings showed positive selection for ostracods in August but did not eat them in proportion to their abundance during the rest of the sampling period.

A positive value for the selectivity indices only shows that an item was eaten in proportions exceeding its relative abundance in the macrobenthos or zooplankton. This does not indicate the actual importance of the item in the diet because an item may occupy 40 percent of the diet but because it represents 60 percent of the available zooplankton or macrobenthos the selectivity index would be negative even though this item may be the single greatest component of the diet.

Seasonal Niche Overlap Indices

The young-of-the-year black crappie showed high overlap on the young-of-the-year largemouth bass in the middle of June, on July 10, and early in September during 1978 (Fig. 35). The highest value, 0.75, was calculated for the middle of June when both black crappie and largemouth bass fry consumed fish fry, cyclopoids, and Bosminidae. The Bosminidae and cyclopoids were the two most abundant types of zooplankton

Figure 35. Seasonal niche overlap indices for 1978

α_{jh} = black crappie on largemouth bass ————

α_{jk} = pumpkinseed on largemouth bass – – – –

Figure 36. Seasonal niche overlap indices for 1978

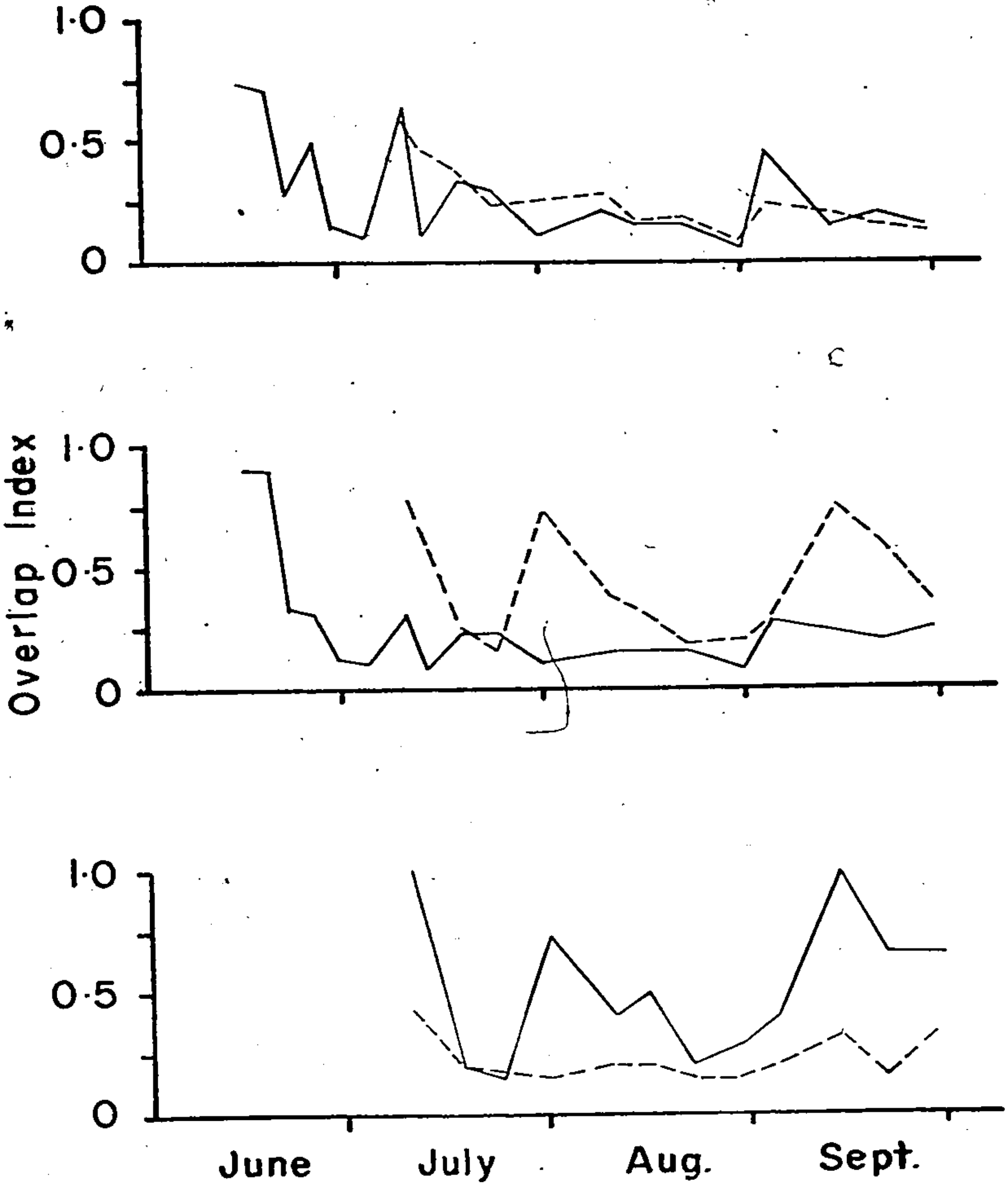
α_{hj} = largemouth bass on black crappie ————

α_{hk} = pumpkinseed on black crappie – – – –

Figure 37. Seasonal niche overlap indices for 1978

α_{kh} = black crappie on pumpkinseed ————

α_{kj} = largemouth bass on pumpkinseed – – – –



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Overlap Index
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June
July
Aug.
Sept.

in Kettle Island Bay at this time. The density of fish fry could not be estimated but large schools of fish fry were common throughout Kettle Island Bay in June and July. There was some separation on the size of fry eaten by the young black crappie and largemouth bass with the bass eating fry about 10 times larger than those eaten by the black crappie. The high value (0.70) that was calculated for July 10 was a result of black crappie and largemouth bass fingerlings eating chironomids larvae and cyclopoids, both of which were very abundant at this time. The values for the overlap indices were very low until a value of 0.45 was calculated during September due to both species eating Daphnidae and cyclopoids, the most abundant zooplankton in the bay.

The highest value (0.60) of the niche overlap index of pumpkinseed fingerlings on young largemouth bass occurred on July 10 and it was due to both species eating Daphnidae and cyclopoids. The latter were highly abundant on this date in the sample area. The niche overlap index values of young pumpkinseed on largemouth bass fingerlings (Fig. 35) did not exceed a value of 0.30 during the remainder of the study period, mostly because largemouth bass ate very little macrobenthos and ate mostly vertebrates in contrast to the mostly macrobenthic diet of the pumpkinseed fingerlings.

The niche overlap index values of young largemouth bass on young black crappie (Fig. 36) only surpassed a value of 0.30 in the middle of June (a value of 0.90) when the items shared were abundant. There were three periods when the niche overlap indices calculated for young pumpkinseed on young black crappie (Fig. 36) were high, about 0.75. The high overlap index values that were calculated for July 10 was due to both species eating cyclopoids, Bosminidae, and Daphnidae. Both the Bosminidae and the cyclopoids were very abundant in Kettle Island Bay and young pumpkinseed always showed a strong preference for Daphnidae regardless of the density of the Daphnidae. The high niche overlap index value calculated for late July was due to the high incidence of zooplankton in the stomachs of both the black crappie and pumpkinseed fry and most types of zooplankton were found in the stomachs of both fish species. The pumpkinseed preyed very heavily upon Daphnidae and, although the black crappie fry did eat some Daphnidae, the principal prey of the crappies were calanoids. In this instance the high overlap index value was more mathematical than real due to the manner by which the niche overlap indices are calculated. The high value of the overlap index in September was due to both fish species preying on Daphnidae, which were very abundant, and cyclopoids and Diaphanasoma. The pumpkinseed and black crappie fingerlings preyed on Diaphanasoma in proportion to their abundance in the bay and ate cyclopoids in lesser proportions than were present.

The niche overlap index values for young-of-the-year largemouth bass on pumpkinseed (Fig. 37) never exceeded a value of 0.50 due to the largemouth bass consuming mostly vertebrate prey. The peak values for young-of-the-year black crappie on pumpkinseed fingerlings occurred at the same time as peaks in the niche overlap index values for young pumpkinseed on black crappie and this was described previously.

On July 18, 1978, there were large numbers of a late spawning of largemouth bass in Kettle Island Bay. The average length of these largemouth bass fry was 22 mm, of the black crappie fry was 42 mm, and of the young pumpkinseed was 25 mm. The niche overlap indices for these small bass on the young pumpkinseed were found to be 0.34 and this was due to both fish species consuming Daphnidae. The niche overlap index value for the small largemouth bass on the young black crappie was calculated to be 0.96 due to mutual predation on Daphnidae, Bosminidae, and cyclopoids. Both the Bosminidae and cyclopoids were very numerous in Kettle Island Bay on this date.

In general, the high values of the niche overlap indices occurred when two or all three species of centrarchid fingerlings were preying on the more abundant food items. If the size of the food items eaten had been included in calculating the niche overlap indices, it is likely that there would have been even less overlap shown.

The results of Mann-Witney U-tests and Wilcoxon paired ranking tests were compared to selected values of the Levin's niche overlap indices, calculated from the same data, to determine the sensitivity of these two non-parametric tests to differences in the diets of two species of centrarchids (Table 14). The Wilcoxon paired ranking test proved to be ineffective for showing differences between fish diets because it showed the diets of the two sunfish species were the same

Table 14. Comparisons of values of the Levin's niche overlap index with the Mann-Witney U-test and the Wilcoxon paired ranking test for the same data. α_{kh} is the niche overlap value for species "h" on "k" and α_{hk} is the niche overlap value for species "k" on "h".

Levin's Index		Wilcoxon Test*			Mann-Witney U-test*			
α_{hk}	α_{kh}	-d	Critical Value	P	n_2	Critical Value	P	No. of pairs
0.08	0.03	8	2.0	$P > 0.05$	48.0	49.0	$P < 0.05$	8
0.11	0.18	10	2.0	$P > 0.05$	38.0	36.0	$P > 0.05$	7
0.49	0.42	10	2.0	$P > 0.05$	50.5	36.0	$P > 0.05$	7
0.88	1.03	13	2.0	$P > 0.05$	52.0	36.0	$P > 0.05$	7

* $P > 0.05$ means accept the null hypothesis: the diets of the two species are the same

Table 15. Comparison of values of the Levin's niche overlap index with Chi-squared contingency tables (2 X 2 and 2 X C) calculated from the same data. α_{hk} is the niche overlap of species "k" on "h" and α_{kh} is the niche overlap of species "h" on "k".

Levin's index		2 X 2 contingency table		2 X C contingency table		
α_{hk}	α_{kh}	P	χ^2	P	χ^2	d.f.
0.08	0.03	0.005	131.90	0.005	174.62	7
0.16	0.18	0.005	93.45	0.005	151.15	5
0.26	0.24	0.005	95.02	0.005	135.87	8
0.34	0.30	0.005	58.90	0.005	99.86	6
0.49	0.42	0.005	41.51	0.005	79.93	6
0.54	0.87	0.005	30.33	0.005	77.01	9
0.86	0.55	0.005	48.95	0.005	52.50	4
0.57	0.58	0.005	20.44	0.005	107.69	7
0.63	0.63	0.005	12.17	0.005	66.91	4
0.95	0.72	0.005	24.90	0.005	54.62	8
0.74	1.12	0.005	24.42	0.005	41.36	7
0.81	0.75	0.005	17.50	0.005	29.69	3
0.77	1.22	0.005	14.56	0.005	30.56	6
0.80	1.11	0.005	18.06	0.005	34.19	5
0.93	0.83	0.005	13.16	0.005	13.38	2
0.84	0.96	0.100	2.88	0.005	26.63	5
0.88	1.03	0.250	1.49	0.005	24.10	6
0.92	1.06	0.500	0.30	0.025	6.75	2
0.93	0.99	0.250	2.11	0.010	9.97	2
1.02	0.98	0.900	0.06	0.750	0.97	2
1.03	0.97	0.975	0.003	0.500	2.95	4

($P > 0.05$) when the Levin's overlap index showed a value of only 0.03. The Mann-Witney U-test showed that the diets of the two species of sunfishes were significantly different ($P < 0.05$) when the Levin's niche overlap index was 0.03 but it did not detect any differences in the diets when the value for Levin's niche overlap index was greater than 0.10. Thus it is evident that these two non-parametric tests are inapp-roporiate for showing differences in the diets of two fish species.

Levin's niche overlap indices were compared to values of Chi-squared contingency tables (2 X 2 and 2 X C) from the same data to confirm the validity of the Levin's niche overlap indices in detecting the differences in the diets of two species of sunfish (Table 15). The 2 X 2 contigency tables showed that the diets of the two sunfish species were different ($P < 0.05$) until the Levin's niche overlap index reached a value of 0.84. The pairings of values of the niche overlap indices of 0.54 - 0.87; 0.86 - 0.55 and 0.74 - 1.12; 0.95 - 0.72 show that the Chi-squared contingency tables were testing the lower value of each pair of Levin's niche overlap indices. The 2 X C contingency tables showed that the diets differed ($P < 0.05$) until a Levin's niche overlap index value of between 0.93 and 0.97 was reached. The difference in the sensitivity of the 2 X 2 versus the 2 X C contingency tables is expected because more prey categories are used in calculating the 2 X C tables. Both tests agree that increasingly higher values of the Levin's niche overlap index occur with increasing similarity of the diets.

Figure 38. Stomach content weight, as a percentage of body weight, at 4 h intervals from dates in 1978 and 1979. Means and standard errors are presented

Black Crappie ————————

Largemouth Bass – – – – – –

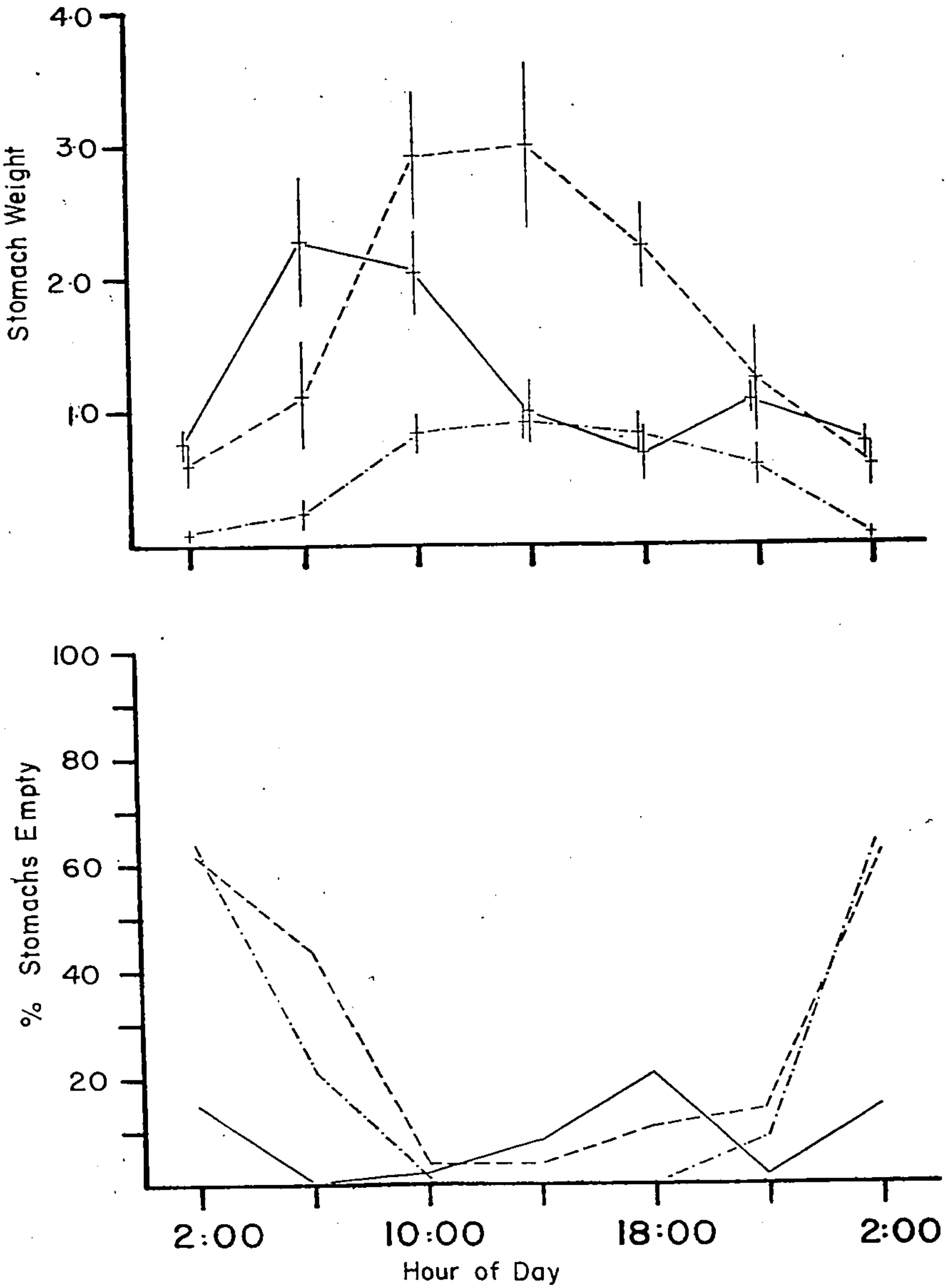
Pumpkinseed -·-·-·-·-·-·-

Figure 39. Percentage of empty stomachs at 4 h intervals from combined dates in 1978 and 1979.

Black Crappie ————————

Largemouth Bass – – – – –

Pumpkinseed -·-·-·-·-·-·


4·0
3·0
2·0
1·0
Stomach Weight
100
80
60
40
20
% Stomachs Empty
2:00
10:00
18:00
2:00
Hour of Day

Feeding Periodicity

The young-of-the-year largemouth bass of Kettle Island Bay fed mostly in the late morning and in the early part of the afternoon (Fig. 38). The young-of-the-year black crappie fed mostly in the morning and they had a minor feeding period around sunset. Young-of-the-year pumpkinseed fed more or less continuously from late morning until just before sunset.

Both the largemouth bass and pumpkinseed fingerlings fed very little at night as evidenced by the high incidence of empty stomachs, over 60 percent of the stomachs examined (Fig. 39). The highest percentage of empty black crappie stomachs, up to 20 percent, was noted in late afternoon but this was followed by a minor feeding peak around sunset that may have masked low feeding rates at night.

24 h Feeding Habits, Selectivity Indices, and Niche Overlap Indices for Young Largemouth Bass, Black Crappie, and Pumpkinseed

June 22 and 23, 1979.

The black crappie fry ate pelagic fish fry to a maximum of 76 percent of the stomach content weight at 09:00 h (Table 16). Zooplankton were the dominant prey type at all other times. Bosminidae was eaten to a peak of 92.4 percent of the diet at 13:00 h. Cyclopoids were an important part of the diet, over 22 percent by numbers, at 21:00 and 01:00 h

Table 16. Feeding habits of black crappie and largemouth bass fry of Kettle Island Bay taken at 4 h intervals on June 22 and 23, 1979. Percent occurrence (above), percent weight (middle for fish prey), percent numbers (middle for planktonic prey), and average number/fish (below).

Total Weight of Gut Contents	% Stomachs Empty	Fish Prey	Plankton as a % of Gut Weight	No. of Zoo-plankton	Cyclopoids	Daphnidae	Bosminidae	*Polyphemus*	Rotifers
Black Crappie (TL = 13.5 mm)									
			01:00 h (n = 20)						
0.002	30.0	00.0	100.0	93	30.0	40.0	55.0	00.0	5.0
		-			22.6	38.7	37.6	-	1.1
		-			1.1	1.8	1.8	-	0.1
			05:00 h (n = 20)						
0.004	00.0	10.0	72.1	163	30.0	60.0	90.0	00.0	00.0
		27.9			5.5	24.5	69.9	-	-
		0.1			0.5	2.0	5.7	-	-
			09:00 h (n = 21)						
0.006	19.0	14.3	24.1	86	9.5	9.5	71.4	4.8	9.5
		75.9			2.3	2.3	74.4	17.4	3.5
		0.2			0.1	0.1	3.1	0.7	0.1
			13:00 h (n = 23)						
0.001	9.0	00.0	100.0	92	4.3	4.3	78.3	00.0	17.4
		-			1.1	1.1	92.4	-	5.4
		-			0.1	0.1	3.7	-	0.2
			17:00 h (n = 20)						
0.004	00.0	00.0	100.0	566	40.0	5.0	45.0	00.0	60.0
		-			4.4	0.4	11.1	-	84.1
		-			1.3	0.1	3.2	-	23.8
			21:00 h (n = 20)						
0.009	00.0	00.0	100.0	1073	100.0	20.0	100.0	00.0	10.0
		-			26.9	4.8	60.5	-	7.5
		-			14.5	2.6	32.5	-	4.1

Table 16. - Continued.

Largemouth Bass (TL = 12.0 mm)									
				21:00 h (n = 20)					
0.022	00.0	00.0	100.0	2475	100.0	100.0	100.0	00.0	00.0
		-			17.0	18.3	63.9	-	-
		-			21.0	22.7	79.1	-	-
				01:00 h (n = 9)					
0.002	00.0	00.0	100.0	523	44.4	88.8	100.0	00.0	00.0
		-			1.1	4.2	94.3	-	-
		-			0.7	2.5	54.8	-	-

and decreased in use by the young crappie throughout the day. Polyphemus were only eaten at 09:00 h. Rotifers comprised over 84 percent of the number of zooplankton eaten at 17:00 h.

Largemouth bass fry were only captured during the 21:00 h and 01:00 h samples. The principal food of the largemouth bass was Bosminidae for both time periods. Cyclopoids and Daphnidae were only important at 21:00 h. The degree of fullness was much greater at 21:00 h.

The niche overlap index value for black crappie on largemouth bass was 0.97 and that of largemouth bass fry on the black crappie fry was 0.99 at 21:00 h. These high niche overlap index values were due to both fish species preying on the highly abundant Bosminidae. The niche overlap index value for black crappie fry on largemouth bass fry was 1.09 and thevalue was 0.42 for largemouth bass on black crappie at 01:00 h. The cause of this discrepancy was that both species of fish ate Bosminidae but the largemouth bass fry preyed on Bosminidae to 94 percent of the diet but the Bosminidae were only 34 percent of the black crappie diet. The black crappie ate several other types of prey resulting in the overlap of the bass fry on the crappie being lower. The high niche overlap indices at sunset were of greater importance than the values at 01:00 h because there was more food in the stomachs at sunset.

July 6 and 7, 1979

Figure 40 I and Figure 40 II show that cyclopoid numbers

Figure 40 I. Density of zooplankton in Kettle Island Bay on July 6 and 7, 1979. Cyclopoids ————

Calanoids – – – – – –

Daphnidae -·-·-·-·-·-

Figure 40 II. Density of zooplankton in Kettle Island Bay on July 6 and 7, 1979. Bosminidae ————

<u>Polyphemus</u> – – – – – –

Figure 41 I. Relative proportions of the zooplankton of Kettle Island Bay on July 6 and 7, 1979.

Cyclopoids ————

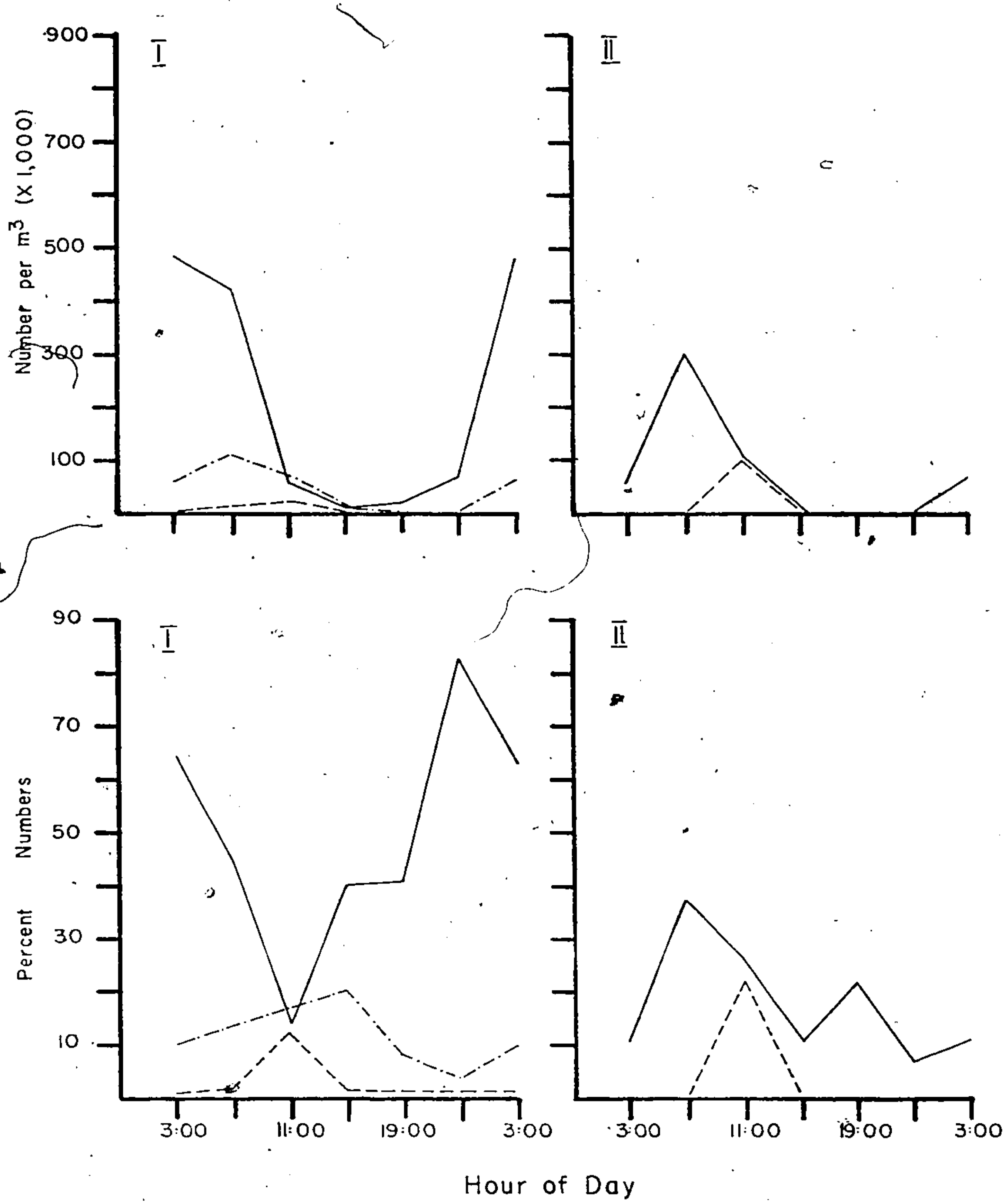
Calanoids – – – – – –

Daphnidae -·-·-·-·-·-

Figure 41 II. Relative proportions of the zooplankton of Kettle Island Bay on July 6 and 7, 1979.

Bosminidae ————

<u>Polyphemus</u> – – – – – –


I
II
Number per m3 (X 1,000)
900
700
500
300
100
I
II
Percent Numbers
90
70
50
30
10
3:00
11:00
19:00
3:00
3:00
11:00
19:00
3:00
Hour of Day

were highest during the 03:00 and 07:00 h sampling periods and the greatest relative proportions of cyclopoids was noted at 21:00 h (Fig. 41 I). The greatest density of Bosminidae was observed at 07:00 h (Fig. 40 II) which was also their peak in the proportions of zooplankton available (Fig. 41 II). Calanoids and Polyphemus reached their highest proportions of the zooplankton at 11:00 h (Fig. 41 I & II). Daphnidae densities were highest at 07:00 h but their greatest proportions were determined at 15:00 h. The actual density of all zooplankton types combined was lowest at 15:00 to 19:00 h and highest at 07:00 h.

Chironomid larvae accounted for 30 percent and amphipods 9 percent of the macrobenthos in Kettle Island Bay.

Appendix D describes the changes in the feeding habits of the young-of-the-year largemouth bass and black crappie taken at 4 h intervals. The young largemouth bass were predominantly piscivorous except at 11:00 h when amphipods, chironomid larvae, and zooplankton were eaten in large amounts. Bosminidae were the most commonly consumed type of zooplankton (95 percent of the numbers) at 03:00 h; cyclopoids (about 75 percent of the numbers) from 07:00 to 11:00 h; and Daphnidae (64 percent) at 15:00 h. Zooplankton was not found in the stomachs of the bass fingerlings sampled at 19:00 and 23:00 h but the number of fish stomachs examined was small.

The young black crappie were also predominantly piscivorous on this date except at 23:00 h when zooplankton was more than 50 percent of the stomach content weight. Bosminidae were the chief planktonic prey (62 to 95 percent of the numbers) during the 11:00 to 19:00 h sample periods; cyclopoids (67 to 80 percent of the numbers) during the 23:00 and 03:00 h sample periods; and Daphnidae (39 percent) and calanoids (27 percent) at 07:00 h.

Largemouth bass selected for amphipods as benthic prey during the 07:00 to 15:00 h sample periods and did not eat them otherwise (Fig. 42). The young bass only selected for chironomid larvae at 07:00 h and then avoided them for the rest of the 24 h sample date. Young-of-the-year largemouth bass had positive selectivity indices for cyclopoids as planktonic prey (0.35 to 0.65) from 07:00 to 11:00 h; for Daphnidae (0.50) and <u>Polyphemus</u> (0.15) at 15:00 h; and for Bosminidae (0.80) at 03:00 h.

Black crappie fingerlings showed positive selectivity indices for amphipods as benthic prey (0.60) at 03:00 h and then the young crappie avoided them for the rest of the day. The black crappie fry selected strongly (over 0.75) for chironomid larvae as benthic prey from 19:00 h to 23:00 h but avoided chironomids during the 15:00 and 07:00 h sample periods (Fig. 42).

The black crappie fry selected against cyclopoids (-0.10 to -0.45) during the 11:00 to 19:00 h time periods while selecting for Bosminidae (up to 0.80) during the same time period. The black crappie fry selected for Daphnidae (0.25) at 03:00 h. The young black crappie selected for calanoids (0.10 to 0.25) from 23:00 to 03:00 h.

Figure 42. Changes in the selectivity indices at 4 h intervals on July 6 and 7, 1979

Black Crappie ————————

Largemouth Bass – – – – – –

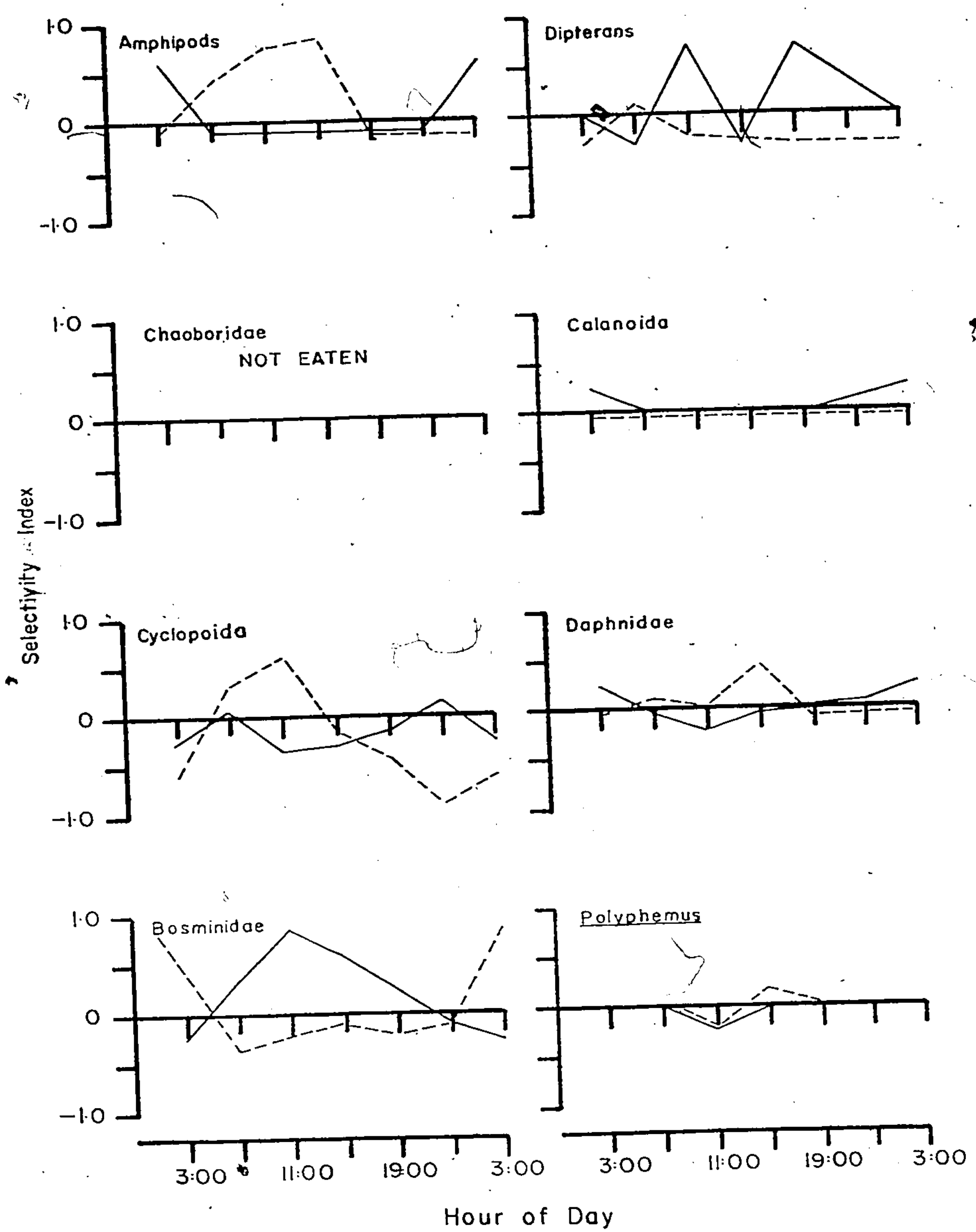
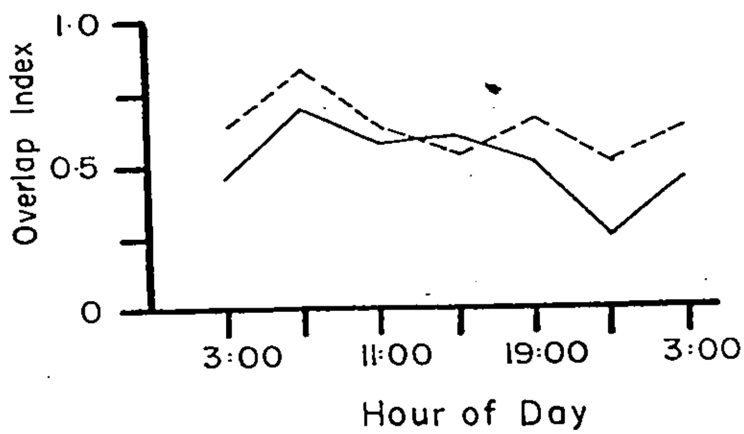

Amphipods
Dipterans
Chaoboridae
NOT EATEN
Calanoida
Cyclopoida
Daphnidae
Bosminidae
Polyphemus
1·0
0
-1·0
Selectivity Index
3:00
11:00
19:00
3:00
Hour of Day

Figure 43. Changes in the Levin's niche overlap indices at 4 h intervals on July 6 and 7, 1979.

α_{jh} is Black Crappie on Largemouth Bass ————

α_{hj} is Largemouth Bass on Black Crappie - - - - -


1·0
0·5
0
Overlap Index
3:00
11:00
19:00
3:00
Hour of Day

The niche overlap indices (Fig. 43) between the largemouth bass and black crappie fry were highest (about 0.75) at 07:00 h and were above a value of 0.50 all day. The peak value of 0.75 was due to both sunfish species preying heavily (over 82 percent of the stomach content weight) on the very numerous minnow and pumpkinseed fry. This predation on fish fry was the main reason for the overlap indices being above 0.50 all day.

July 27 and 28, 1979

The densities of Bosminidae and cyclopoids were highest (1,500,000 Bosminidae/m^3 and 500,000 cyclopoids/m^3) during the early afternoon in the littoral zone of Kettle Island Bay (Fig. 44). There were about 50,000 Daphnidae/m^3 present all day. Bosminidae attained maximum relative proportions at 18:00 h; Polyphemus and cyclopoids at 06:00 h; Daphnidae from 06:00 and 10:00 h (due to decreases in the numbers of Bosminidae); and calanoids were a small proportion of the zooplankton all day (Fig. 45 ~~I &~~ II).

Chironomid larvae accounted for 26 percent and amphipods 9 percent of the available macrobenthos numbers in Kettle Island Bay.

The vertebrate and macrobenthic food items consumed by the young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay are described in Appendix E and the planktonic food items are described in Appendix F.

Small fish were the major prey eaten by the bass finger-

Figure 44. The density of zooplankton of Kettle Island Bay at 4 h intervals on July 27 and 28, 1979

Bosminidae ————————

Cyclopoids — — — — — —

Daphnidae -·-·-·-·-·-

Figure 45 I. The relative proportions of zooplankton of Kettle Island Bay on July 27 and 28, 1979

Calanoids ————————

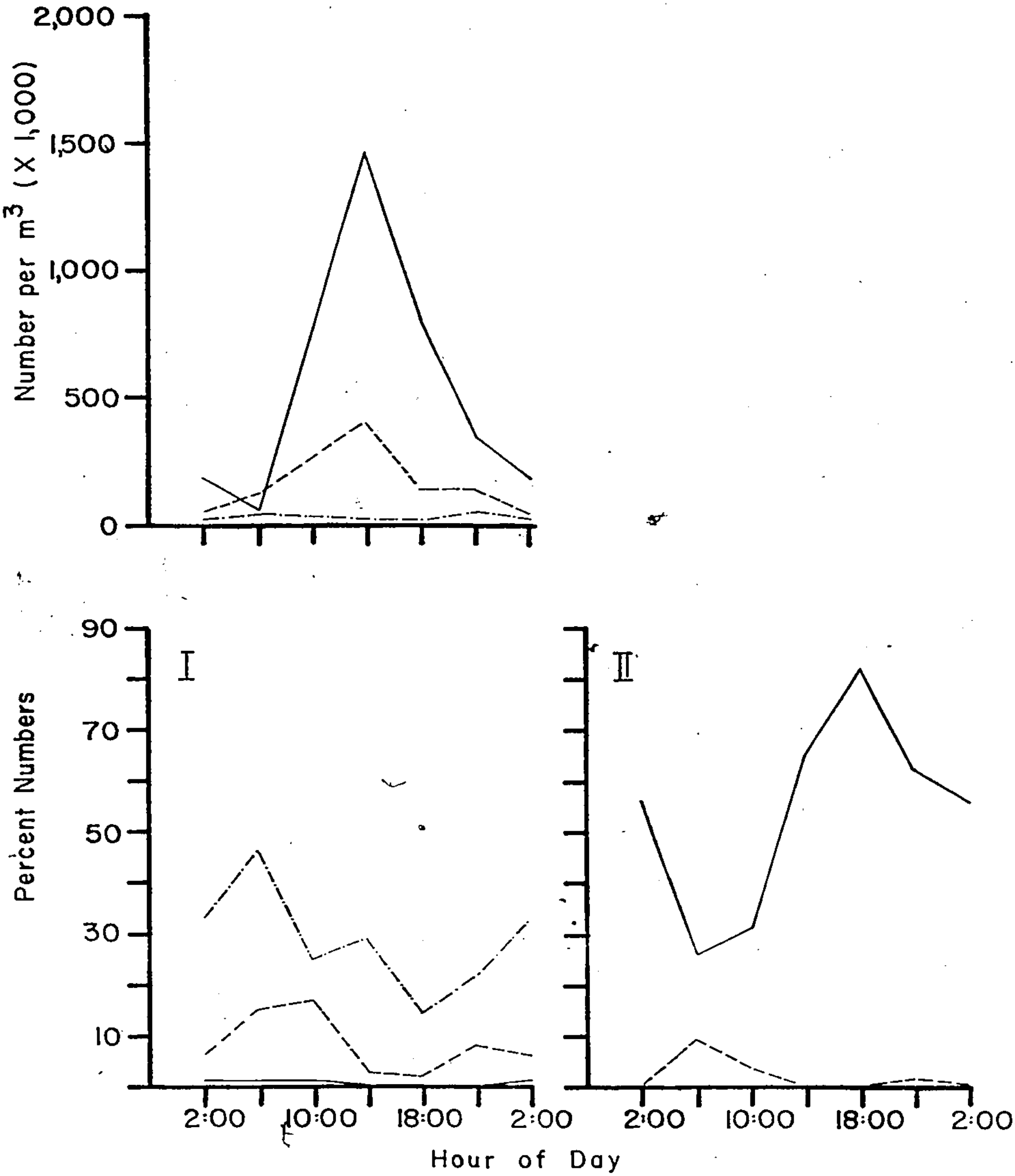
Daphnidae — — — — — —

Cyclopoids -·-·-·-·-·-

Figure 45 II. The relative proportions of zooplankton of Kettle Island Bay on July 27 and 28, 1979

Bosminidae ————————

<u>Polyphemus</u> — — — — — —


2,000
1,500
1,000
500
0
Number per m^3 (X 1,000)
90
70
50
30
10
Percent Numbers
I
II
2:00
10:00
18:00
2:00
2:00
10:00
18:00
2:00
Hour of Day

lings although tadpoles did account for 43 percent of the diet (by weight) at 06:00. Hemipterans comprised more than three percent of the weight of largemouth bass during the 14:00 to 22:00 h sample periods. Amphipods were only occasionally eaten by the bass fingerlings. Zooplankton were an insignificant part of the diet of the young-of-the-year largemouth bass.

The black crappie fingerlings preyed primarily upon zooplankton. Bosminidae were the most commonly eaten form (69 to 77 of numbers) during the 14:00 and 18:00 h time periods. Cyclopoids were the most commonly eaten zooplankton (over 65 percent of the numbers) at all other times. Fish fry were of maximum importance (7 percent of stomach content weight) during the 06:00 h time period; amphipods were four percent of stomach weight at 22:00 h; chironomid larvae were 8 percent at 22:00 h; and Chaoborus larvae were five percent of the diet at 10:00 h.

Chironomid larvae represented from 22 to 53 percent of the weight of stomach contents of the young-of-the-year pumpkinseed all day. Amphipods reached as high as 22 percent of the diet in late morning. Trichopteran larvae were 31 percent of the stomach content weight at 02:00 h but 40 percent of the stomachs were empty and this percentage weight was the result of one pumpkinseed eating a larvae.

Bosminidae were the chief planktonic prey of the pumpkinseed fry at all but 02:00 h. The majority of the pumpkinseed fry had only one or two prey items in their stomachs at

Figure 46. Selectivity indices for the major prey items calculated at 4 h intervals on July 27 and 28, 1979

Black Crappie ————————

Largemouth Bass — — — — — —

Pumpkinseed ....

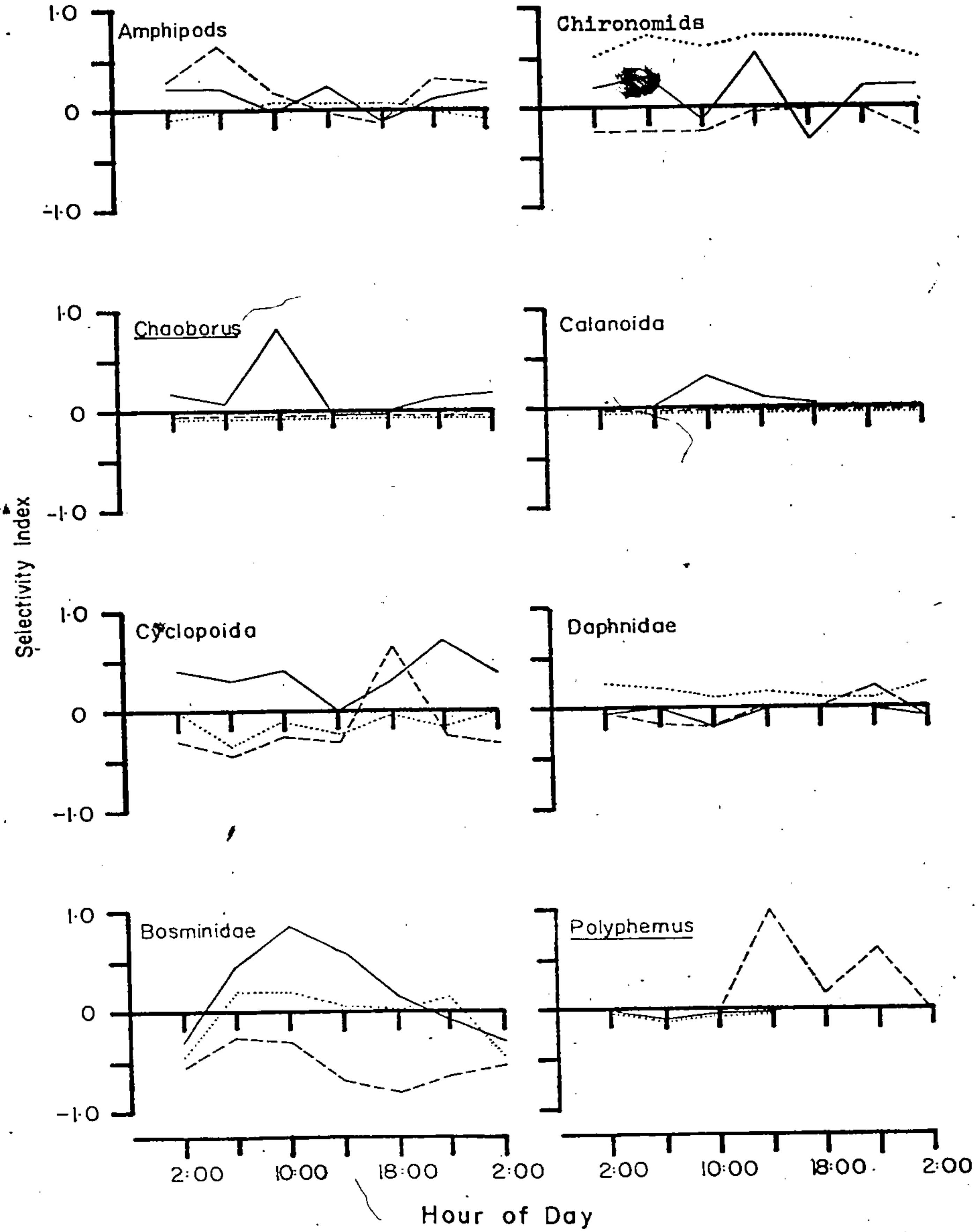

Amphipods
Chironomids
Chaoborus
Calanoida
Cyclopoida
Daphnidae
Bosminidae
Polyphemus
1·0
0
-1·0
Selectivity Index
2:00
10:00
18:00
2:00
Hour of Day

Figure 47. Niche overlap indices calculated at 4 h intervals on July 27 and 28, 1979

$\alpha_{jh} = \alpha_{hj}$ for Black Crappie and Largemouth Bass

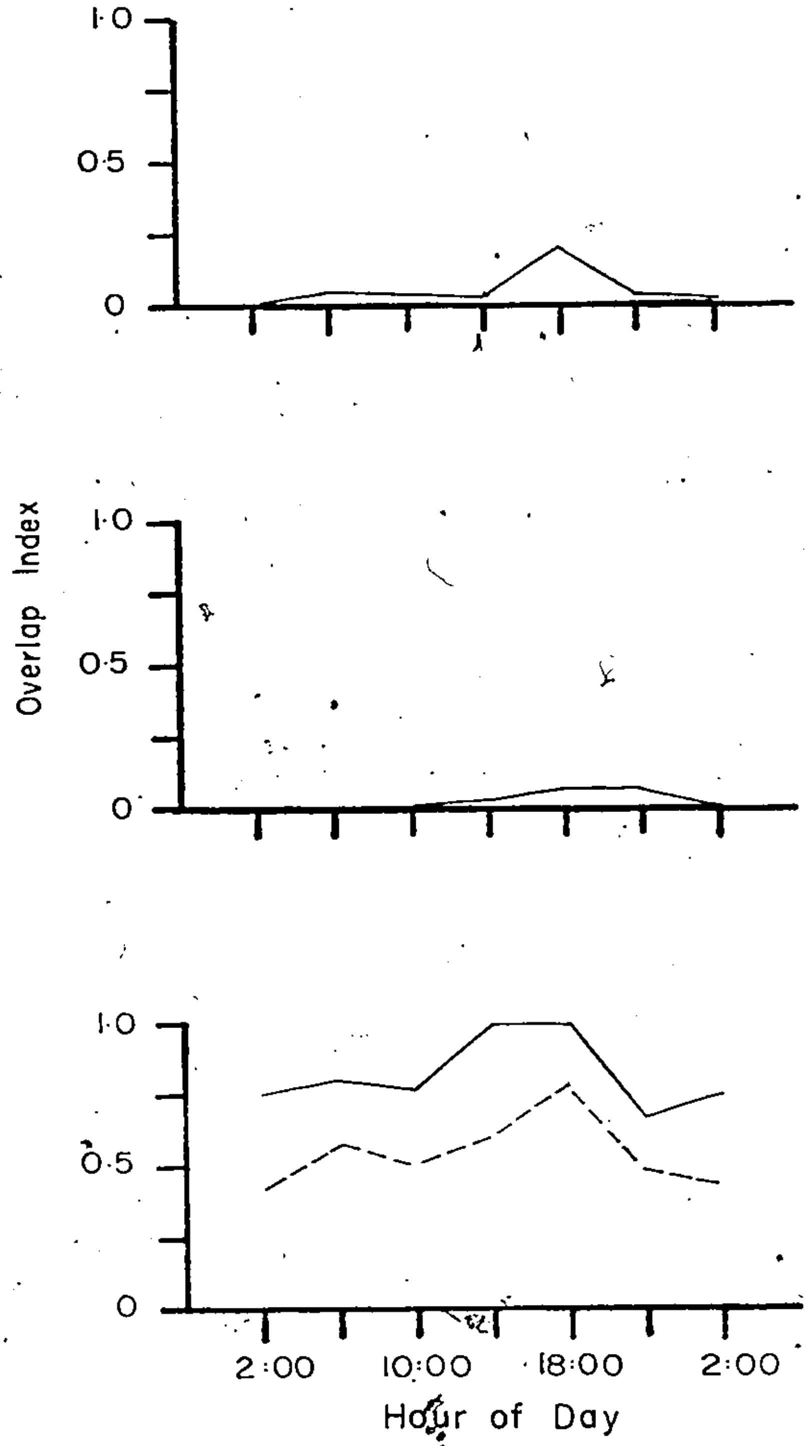
Figure 48. Niche overlap indices calculated at 4 h intervals on July 27 and 28, 1979.

$\alpha_{jk} = \alpha_{kj}$ for Pumpkinseed and Largemouth Bass

Figure 49. Niche overlap indices calculated at 4 h intervals on July 27 and 28, 1979

α_{hk} = Pumpkinseed on Black Crappie ————————

α_{kh} = Black Crappie on Pumpkinseed – – – – – –


1·0
0·5
0
Overlap Index
1·0
0·5
0
1·0
0·5
0
2:00
10:00
18:00
2:00
Hour of Day

02:00 h and the greatest proportion of these prey were cyclopoids. Daphnidae represented from 11 to 35 percent of the numbers of zooplankton eaten by the young pumpkinseed all day.

Young-of-the-year largemouth bass had positive selectivity indices for amphipods (0.30 to 0.70) during the 22:00 to 06:00 h sample periods; for cyclopoids (0.60) and Daphnidae (0.25) during the 22:00 h period; and for Polyphemus (0.15 to 0.95) during the 14:00 h to 02:00 h sample periods (Fig. 46).

The black crappie fingerlings showed positive selection for Bosminidae (0.16 to 0.83) during the 06:00 to 18:00 h periods; cyclopoids (up to 0.70) all day; calanoids (0.08 to 0.33) from 10:00 to 14:00 h; Chaoborus larvae (up to 0.75) from 22:00 to 10:00 h periods; amphipods (up to 0.20) from 22:00 until 06:00 h and during the 14:00 h period; and chironomid larvae during all but the 10:00 and 18:00 h periods (Fig. 46).

Young-of-the-year pumpkinseed showed positive selectivity indices for Daphnidae (0.10 to 0.25) and chironomid larvae (0.50 to 0.70) at all times of the day; avoided calanoids, cyclopoids, and Chaoborus larvae; and ate amphipods and Bosminidae in proportions to their abundance in the habitat (Fig. 46).

The niche overlap indices of largemouth bass with black crappie (Fig. 47) and largemouth bass with pumpkinseed (Fig. 48) were unimportant (less than 0.25) for the entire 24 h sample period.

The high niche overlap index values, over 0.70 for pumpkinseed on black crappie, between the young black crappie and pumpkinseed (Fig. 49) was due to both fish species consuming cyclopoids, Daphnidae, and Bosminidae. These were, proportionately, the most abundant zooplankton forms and the actual densities were very high: up to 1,500,000 Bosminidae/m^3, and 500,000 cyclopoids/m^3. The young pumpkinseed ate more amphipods and chironomid larvae than the black crappie fry and only the black crappie fingerlings ate calanoids and Chaoborus larvae.

August 10 and 11, 1979.

Figure 50 I and Figure 50 II show the actual densities of the major zooplankton of Kettle Island Bay at 4 h intervals and Figure 51 I and Figure 51 II show the relative proportions of these zooplankton. Bosminidae densities reached levels as high as 1,750,000 organisms/m^3 at 14:00 h and declined to below 100,000 organisms/m^3 at 02:00 h which was a result of their daily vertical migrations. This pattern was also noted on July 27 and 28, 1979 (Fig. 44). Cyclopoid numbers were as high as 400,000 organisms/m^3 at 02:00 h and were as low as 100,000 cyclopoids/m^3 at 22:00 h. The densities of calanoids, Daphnidae, and Diaphanasoma were relatively constant all day reaching 50,000 calanoids/m^3, 100,000 Daphnidae/m^3, and almost 200,000 Diaphanasoma/m^3. The relative proportions of Bosminidae were highest during the 10:00 to 22:00 h periods (about 80 percent); cyclopoids (about 60 percent) at 02:00 h; calanoids at 14:00 h; and Daphnidae

Figure 50 I. The densities of zooplankton of Kettle Island Bay at 4 h intervals on August 10 and 11, 1979

Bosminidae ————————

Calanoids — — — — — —

Daphnidae -·-·-·-·-·-

Figure 50 II. The densities of zooplankton of Kettle Island Bay at 4 h intervals on August 10 and 11, 1979

Cyclopoids ————————

Diaphanasoma — — — — — —

Figure 51 I. Relative proportions of zooplankton of Kettle Island Bay at 4 h intervals on August 10 and 11, 1979

Bosminidae ————————

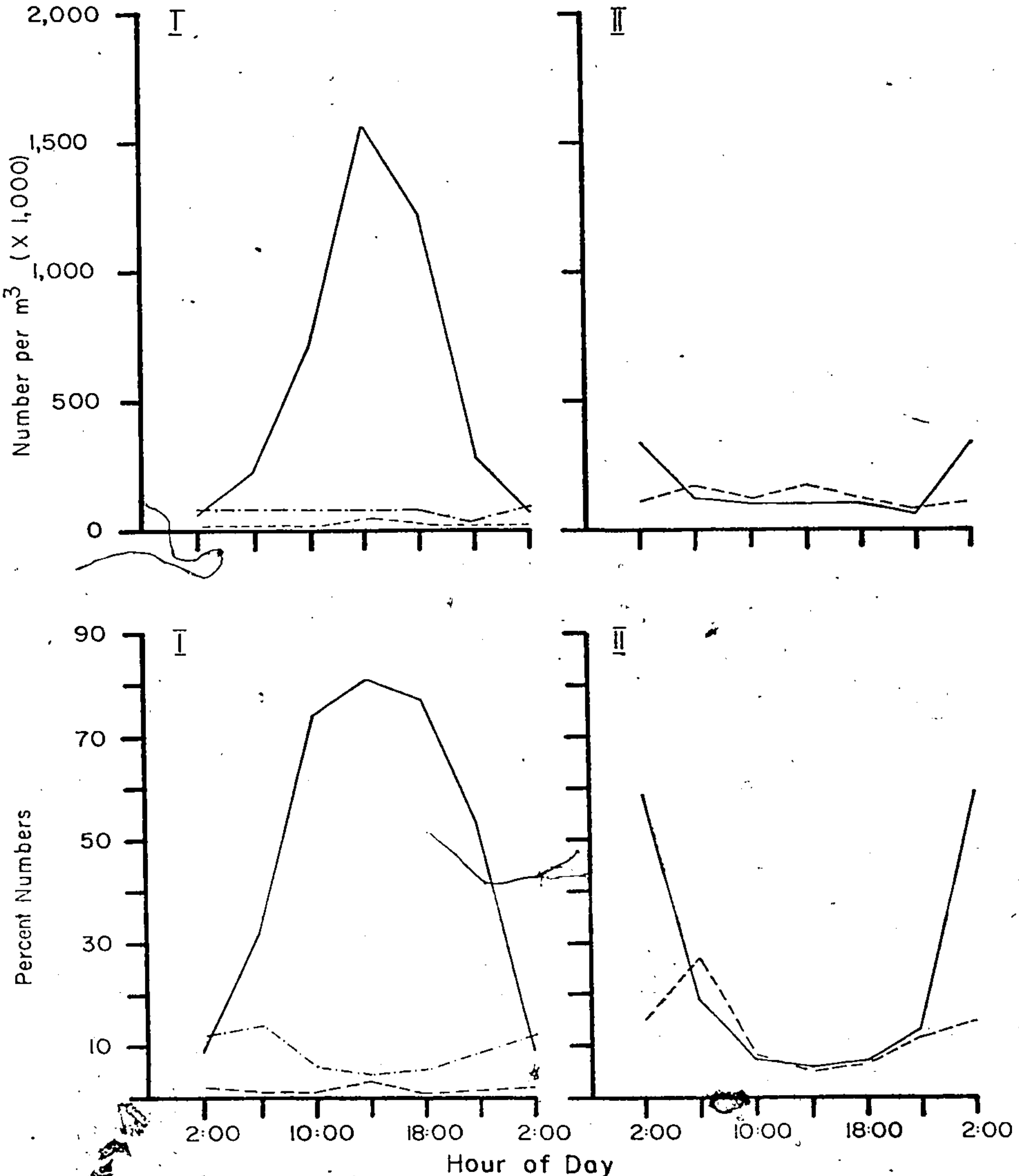
Calanoids — — — — — —

Daphnidae -·-·-·-·-·-

Figure 51 II. Relative proportions of zooplankton of Kettle Island Bay at 4 h intervals on August 10 and 11, 1979.

Cyclopoids ————————

Diaphanasoma — — — — — —


I
II
2,000
1,500
1,000
500
0
Number per m3 (X 1,000)
I
II
90
70
50
30
10
Percent Numbers
2:00
10:00
18:00
2:00
2:00
10:00
18:00
2:00
Hour of Day

(15 percent) and Diaphanasoma (28 percent) were highest at 06:00 h.

Amphipods represented 19.5 percent and chironomid larvae 13.2 percent of the numbers of macrobenthos in the benthos samples.

The vertebrate and macrobenthic prey of young-of-the-year largemouth bass, black crappie, and pumpkinseed are described in Appendix G and the zooplankton prey are described in Appendix H. Largemouth bass fingerlings did not consume zooplankton at any time on this sample date. The young largemouth bass preyed primarily on small fish except during the 18:00 h and 22:00 h sample periods when tadpoles were the main food taken. Hemipterans and amphipods were the only invertebrate food eaten by the largemouth bass fingerlings and they were not important food items.

The black crappie fingerlings preyed mostly upon zooplankton but Chaoborus larvae accounted for 30 percent of the stomach content weight during the 06:00 h sample periods. Cyclopoids were the most frequently eaten type of zooplankton, comprising 50 to 94 percent of the numbers of zooplankton eaten. Calanoids represented 21 percent of the numbers of zooplankton eaten at 18:00 h; Daphnidae were 10 to 15 percent of the diet of the young crappie during the 14:00 and 18:00 h periods; Bosminidae were 47 percent of the numbers at 14:00 h; and Diaphanasoma were 23 percent of the numbers at 02:00 h. The young black crappie occasionally ate neuropteran larvae in the morning hours.

Young pumpkinseed ate large quantities of zooplankton in the late morning and early afternoon. Daphnidae were over 60 percent of the zooplankton numbers at 06:00 and 14:00 h; Bosminidae were about 50 percent of the zooplankton numbers at 10:00 and 22:00 h; and ostracods were the only zooplankton eaten at 02:00 h and this was a result of only one fish having plankton in its stomach at this time. Most of the young pumpkinseed (65 percent) had empty stomachs at 02:00 h.

Chironomid larvae were the dominant prey item, from 68 to 82 percent of the stomach content weight, from 18:00 to 22:00 h. Amphipods represented 66 percent of the gut contents at 06:00 h.

Young largemouth bass showed high selectivity for amphipods and hemipterans, which were not important prey items, because they were the only invertebrate prey eaten by the bass fingerlings on this sample date (Fig. 52).

Black crappie had positive selectivity indices for chironomid larvae at 02:00 h (0.45); amphipods (0.55) at 10:00 h; calanoids (0.20) at 18:00 h; and cyclopoids and _Chaoborus_ larvae at all times. Bosminidae were always avoided by the young black crappie (Fig. 52).

Young pumpkinseed had positive selectivity indices for amphipods during most 4 h periods; Bosminidae at all but the 02:00 h sample period; and cyclopoids were selected for at 02:00 h. The young pumpkinseed were the only species to eat gastropods and they only ate the snails in proportion to their availability at 18:00 h.

Figure 52. Selectivity indices calculated at 4 h intervals on August 10 and 11, 1979.

Black Crappie ————————

Largemouth Bass – – – – – –

Pumpkinseed ....

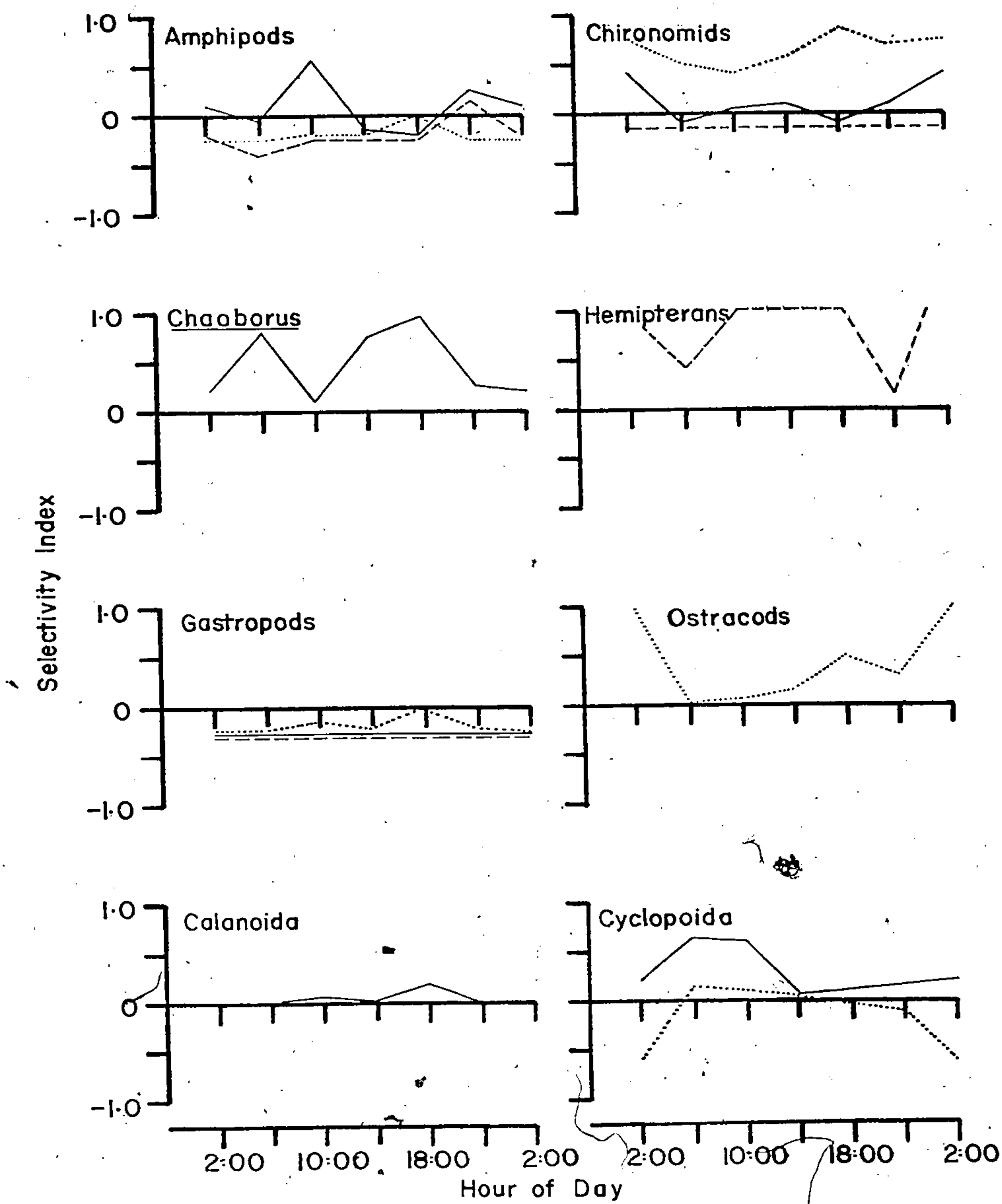
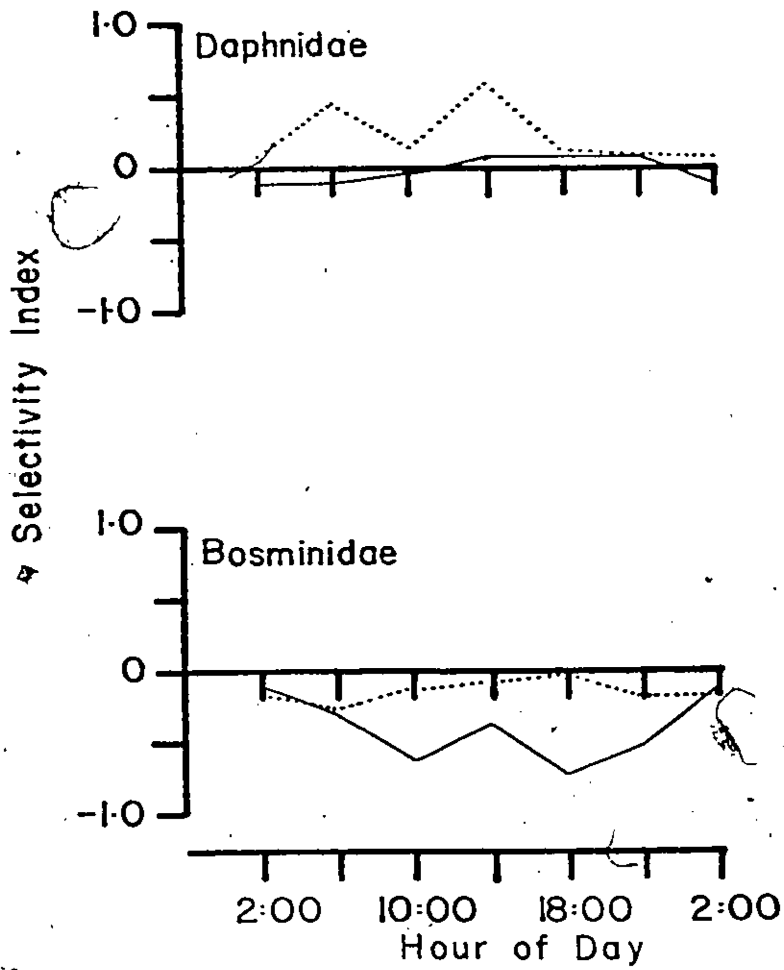

Amphipods
Chironomids
Chaoborus
Hemipterans
Gastropods
Ostracods
Calanoida
Cyclopoida
1·0
0
-1·0
Selectivity Index
2:00
10:00
18:00
2:00
Hour of Day

Figure 52. Continued


1·0
Daphnidae
0
-1·0
Selectivity Index
1·0
Bosminidae
0
-1·0
2:00
10:00
18:00
2:00
Hour of Day

The values for the niche overlap indices between the largemouth bass and black crappie fingerlings (Fig. 53) and between the largemouth bass and pumpkinseed fingerlings (Fig. 54) were negligible for all intervals tested because the young bass ate little else but vertebrate prey which the black crappie and pumpkinseed did not eat.

There were high niche overlap indices, over 0.75 for black crappie on pumpkinseed, between the young pumpkinseed and black crappie during the 10:00 h and 14:00 h sampling periods (Fig. 55). The high values at 10:00 h resulted from both fish species preying on cyclopoids and Bosminidae although the young black crappie ate proportionately more cyclopoids and young pumpkinseed ate more Bosminidae. Both prey items were very abundant in Kettle Island Bay during these two time periods. The high niche overlap indices at 14:00 h was due to both fish species preying on Bosminidae, Daphnidae, and cyclopoids. These three prey were very numerous in the bay and the young crappie ate proportionately more Bosminidae and cyclopoids while the young pumpkinseed ate more Daphnidae.

In general, the high niche overlap index values occurred due to the usage of the most abundant food items by the two fish species involved, regardless of the time of day. It must be noted, however, that high overlap index values at night are essentially meaningless because the level of feeding is so low, especially for the largemouth bass and pumpkinseed fingerlings.

Figure 53. Niche overlap indices calculated at 4 h intervals on August 10 and 11, 1979

$\alpha_{jh} = \alpha_{hj}$ for Black Crappie and Largemouth Bass

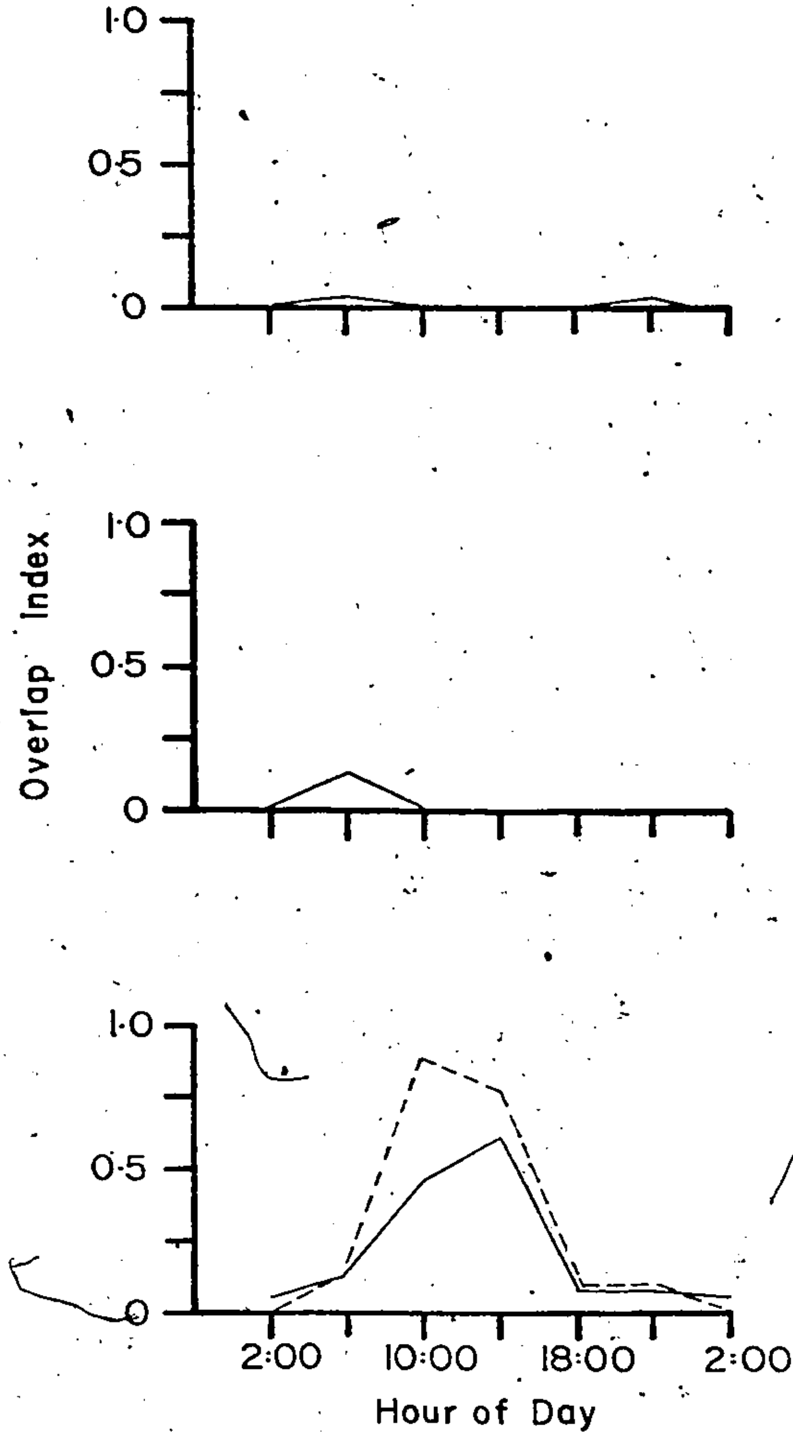
Figure 54. Niche overlap indices calculated at 4 h intervals on August 10 and 11, 1979

$\alpha_{jk} = \alpha_{kj}$ for Pumpkinseed and Largemouth Bass

Figure 55. Niche overlap indices calculated at 4 h intervals on August 10 and 11, 1979

α_{hk} = Pumpkinseed on Black Crappie ————————

α_{kh} = Black Crappie on Pumpkinseed – – – – – –


1·0
0·5
0
Overlap Index
2:00
10:00
18:00
2:00
Hour of Day

DISCUSSION

Many factors affect the spawning success and survival of the fry of largemouth bass. Largemouth bass commence spawning activities in shallow waters at a temperature of 15.6 to 24 C (Kramer & Smith, 1960b; Brauhn et al., 1972; and Carlson & Hale, 1972). The Kettle Island Bay bass were seen spawning at a water temperature of around 18 C in 1978. A delay in the commencement of spawning of three weeks due to cool water temperatures has also been reported by Kramer & Smith (1962) and Shirley & Andrews (1977). Largemouth bass abandon their nests when the water temperature drops below 15.6 C (Kramer & Smith, 1962) and the newly hatched fry will not feed at water temperatures below 15 C which results in their quickly starving to death (Strawn ,1961). The water temperatures did not drop below 16.5 C once spawning activities were initiated in 1978 or 1979 so that the breeding activities were not interrupted for the Kettle Island Bay population of largemouth bass. The nests of largemouth bass are subject to destruction due to wind and wave action because they are in shallow water (Kramer & Smith, 1962; Shirley & Andrews, 1977; and Summerfelt & Shirley, 1978) but Kettle Island Bay is protected from all but severe easterly storms which did not occurr during either spawning season.

Harrassment of male largemouth bass, while they guard their nests, by sunfish (Barwick & Holcomb, 1976; and Smith, 1976) did not happen in Kettle Island Bay. Golden shiners have also been reported spawning in largemouth bass nests (Kramer & Smith, 1960a, b; and Chew, 1974) and there does not seem to be any adverse effect from this action on the spawning success of largemouth bass under most conditions.

The largemouth bass in Kettle Island Bay had an extended spawning period of one and one half months which has also been recorded for this species in other waters (Bross, 1967; Aggus & Elliot, 1975; and Timmons _et al_., 1980). Consecutive spawnings by the same male bass are also reported by Kramer & Smith (1962) and Timmons _et al_. (1980). Young-of-the-year largemouth bass were always captured among the aquatic macrophytes of Kettle Island Bay and the presence of these aquatic macrophytes is considered to be essential for the survival of largemouth bass fingerlings (Trautman, 1957; Ridenhour, 1960; and Emig, 1966).

The factors that affect the success of spawning and the survival of fry of black crappie are not as well documented as for the largemouth bass. Black crappie are reported to start breeding activities at a water temperature between 14.4 and 20 C (Pearse, 1919; Goodson, 1966; and Hanson & Qadri, 1980) in water from 0.25 to 6.1 m deep (Pearse, 1919; and Schneberger, 1972). Black crappie apparently spawn at greater depths than either the largemouth bass or pumpkinseed of Kettle Island Bay (to 1.0 m) because black crappie nests have not been observed in the bay during this study or in previous studies (Hanson & Qadri, 1979, 1980). Amundrud _et al_. (1974) were unable to find black crappie nests in the shallow waters of Lake Opinicon, Ontario

There was a three week delay in the start of breeding of black crappie in Kettle Island Bay in 1979 due to cool water temperatures and this type of delay has also been reported for Clear Lake, Iowa, by Erikson (1952). Sivells (1949) found bimodal growth of black crappie fry due to cold weather interrupting spawning aotivities after they had started.

I have previously shown that black crappie have a very short spawning period in Kettle Island Bay (Hanson & Qadri, 1980) and the length-frequency data for this study also suggests that the breeding period was short, about one week. This is a contrast to the two or three month long breeding season reported for Florida (Huish, 1954a) and Minnesota (Burrows & Moyle, 1967) populations of black crappie. It is possible that the rapid warming of the waters of Kettle Island Bay results in the water temperature exceeding the maximum temperature at which the spawning of crappie will occur but this aspect of black crappie biology has yet to be studied. Nest destruction by wind and wave action did not likely occur for crappie nests in the bay because Kettle Island Bay is protected and their deeper nesting habit would minimize this factor.

The young-of-the-year black crappie were always caught among the weed beds which was also observed by Trautman (1957), Ridenhour (1960), and Goodson (1967) but is contrary to the findings of Keast (1965) for Lake Opinicon, Ontario. The importance of the aquatic vegetation has been shown in studies of resevoirs with fluctuating water levels where strong year classes are only found in years when high water levels provide cover by flooding terrestrial vegetation because aquatic vegetation is practically non-existant (Stroud, 1948; and Ball & Kilambi, 1973).

The factors that affect the spawning success and survival of fry of pumpkinseed have received very little attention in the literature although the breeding behaviour is relatively well studied. The pumpkinseed in Kettle Island Bay began nesting activities at a water temperature of 16.5 C, which is within the range of 13 to 18 C reported by Miller (1963) and Clark & Keenleyside (1967), and egg deposition was seen after a water temperature of 19 C was reached which was also found for pumpkinseed in Wisconsin waters (Johnson, 1971).

A breeding season of over one month in duration is also reported for other Ontario populations (Clark & Keenleyside, 1967; and Colgan & Ealey, 1973). Clark & Keenleyside also reported pumpkinseed abandonning their nests if the water temperature dropped rapidly, an event that did not occur in Kettle Island Bay. The cool water temperatures of May and June, 1979, did not affect the pumpkinseed as much as the largemouth bass and black crappie because the water temperature reached 19 C at about the same time during both summers. Amundrud <u>et al</u>. (1974) observed a delay of about two weeks in pumpkinseed spawning in Lake Opinicon, Ontario, due to cool water temperatures.

I found that pumpkinseed did not nest deeper than 1.0 m and Clark & Keenleyside (1967) did not find nests deeper than 0.5 m which would make pumpkinseed nests susceptible to wind and wave action.

The association of young-of-the-year pumpkinseed with thick growths of aquatic vegetation is also reported by DiCostanzo (1957), Hubbel (1966), and Keast (1978).

The high spawning success of all three sunfish species was demonstrated by the ease with which samples were collected until the young-of-the-year largemouth bass and black crappie dispersed from Kettle Island Bay in 1978 and 1979.

Growth

The wide continuous size range of the largemouth bass fingerlings at the end of August, 1978, was due to the long breeding season. The greatest mean length, 86.5 mm, was found at the end of August and then most of the larger fingerlings left the bay. Smallmouth bass also leave their nursery areas for deeper water at the end of August (George & Hadley, 1979). Despite this occurrence, the growth of the Kettle Island Bay largemouth bass fingerlings to the end of August compares favorably with the maximum average length at the end of the first growing season (Table 17) reported for young largemouth bass in Minnesota (Kramer & Smith, 1960b; Lux, 1960; and Burrows & Moyle, 1967), Illinois (Savitz, 1978), Utah (Miller & Kramer, 1971), and Ohio (Trautman, 1957).

The Kettle Island Bay population grew better than young largemouth in other parts of Ontario (Keast, 1965; Johnson & McCrimmon, 1967; and Hamilton & Powles, 1979),

Table 17. Average total length of largemouth bass at the end of the first growing season.

Length (mm)	Location	Source
300	Louisiana reservoir	Viosca (1953)
176	Lake Carl Blackwell, Oklahoma	Shirley & Andrews (1977)
195	Florida pond	Clugston (1964)
142	Folsom Lake, California	Tharrant (1966)
112 - 120[a]	Illinois ponds	Buck & Thoits (1970)
100 1st mode	Westpoint Reservoir, Alabama	Shelton *et al.* (1979)
200 2nd mode	"	"
74.4	non-cannibal class Michigan ponds	Cooper (1937)
147.3	cannibal class Michigan ponds	"
56 - 85[a]	Lake George, Minnesota	Kramer & Smith (1960b)
91	Minnesota fish	Lux (1960)
89	Minnesota state average	Burrows & Moyle (1967)
83.9	Illinois pond	Savitz (1978)
80.2 - 86.5[a]	Lake Powell, Utah	Miller & Kramer (1971)
51 - 140[a]	Ohio state average	Trautman (1957)
85.6	Nogies Creek, Ontario	Hamilton & Powles (1979)
61	Ontario ponds	Johnson & McCrimmon (1967)
51 - 70[a]	Lake Opinicon, Ontario	Keast (1965)
86.5 (62 - 147)[a]	Ottawa River, Ontario	Present study

[a] range available

Montana ponds (Brown & Logan, 1960), and Oregon ponds (Stewart et al., 1967). Superior growth is reported for resevoirs in Alabama (Shelton et al., 1979), Louisiana (Viosca, 1953), and Oklahoma (Shirley & Andrews, 1977) and in a Florida pond (Clugston, 1974).

The growth of the later broods of bass in Kettle Island Bay was good and bimodal growth patterns were not seen for these fry which contrasts to findings of other authors for more southern populations (Parsons, 1958; Aggus & Elliot, 1975; and Timmons et al., 1980). Bimodal growth patterns are reported to be caused by inadequate food of the correct size for later broods (Aggus & Elliot, 1975; Shelton et al., 1979; and Timmons et al., 1980) and by cannibalism by the earlier broods (Cooper, 1937; Eschmeyer, 1939; and Cohen & Brown, 1967). The absence of a bimodal growth pattern for Kettle Island Bay bass suggests that food is plentiful in the bay all season.

The length at the end of the first growing season is controlled by a combination of the length of the growing season, food availability, water temperature, and crowding.

Low water temperatures result in slower growth of young largemouth bass (Strawn, 1961; Kramer & Smith, 1962; and Hamilton & Powles, 1979) but the water temperature in the bay did not drop below 20 C until the first week of September, which was after the larger fingerlings had left Kettle Island Bay in 1978. Although growth was slowing at the end of August, there was probably a month of the growing season left before water temperatures were less than 15 C, the temperature at which young largemouth are reported to cease feeding (Strawn, 1961).

Crowding is reported to be a serious problem in many waters (Eddy & Carlander, 1940; Ridenhour, 1960; and others) which is one of the causes of insufficient food of the proper size (Strawn, 1961; and Buck & Thoits, 1970). This lack of adequate size food often results in cannnibalism by the large fingerlings (Cooper, 1937; Kramer & Smith, 1962; and Cohen & Brown, 1967) or by the yearling largemouth bass (Bennet et al., 1969; and Savitz, 1978). Sustained growth cannot occur without larger food items (Kerr, 1971).

All size classes of young-of-the-year largemouth bass of Kettle Island Bay grew well and the later broods ate fish and tadpoles at a length of 45 and 66 mm, respectively, much like the earlier broods in 1978. The ease of obtaining food of the correct size for the young bass in Kettle Island Bay is illustrated by the wide continuous range in the lengths of the young-of-the-year bass sampled, the early presence of vertebrate prey in the diet, the low rate of cannibalism, and the 1979 year class reaching the same average size of the 1978 year class by the end of July despite a delay of about three weeks in spawning. Thus the length of the growing season is the most likely factor limiting the maximum size of the largemouth bass fingerlings at the end of the first growing season.

The length-weight relationships (Table 18) show that young-of-the-year largemouth bass exhibit isometric growth across much of its distribution. The adult bass apparently

Table 18. Length-weight relationships for largemouth bass from various waters.

Relationship	Length (mm)	Location	Source
log WT = 2.773 log TL - 4.419	0^+	Alabama ponds	Tucker (1973)
log WT = 2.962 log TL - 4.800	12 - 80	Lake George, Minn.	Kramer & Smith (1960b)
log WT = 3.039 log TL - 5.029	5.0 - 92.2	Lake Powell, Utah	Miller & Kramer (1971)
log WT = 3.030 log TL - 4.900	58 - 332	Florida ponds	Clugston (1964)
log WT = 2.740 log TL - 4.420	15 - 110	Nogies Creek, Ont.	Hamilton & Powles (1979)
log WT = 3.333 log TL - 5.391	125 - 280	Oklahoma lakes	Jenkins (1955)
log WT = 3.136 log TL - 5.199	97 - 445	Iowa ponds	Moorman (1957)
log WT = 3.162 log TL - 5.287	56 - 551	Alanconnie L., Penn.	Cooper *et al*. (1971)
log WT = 3.042 log TL - 4.913	12 - 142	Ottawa River, Ont.	Present study

become heavier in proportion to their length but much of the available information is based on length in inches and weight in pounds or in ounces and can not be compared to the more recent studies. The slope of 3.0 means that any increase in the condition factor signifies a real improvement in the condition of the fish and is not merely caused by changing body shape.

The condition factor for the young-of-the-year largemouth bass of Kettle Island Bay (Table 19) was superior to all but the very fast growing populations in a Louisiana reservoir (Viosca, 1953) and in a Florida pond (Clugston, 1964). The good condition of the Kettle Island Bay largemouth bass fingerlings was further illustrated by the condition factor increasing with the length of the young bass. Increases in the condition factor of young-of-the-year largemouth bass is also reported by Eschmeyer (1939) and Moorman (1957). The condition factor was shown to decrease with the length of largemouth bass in ponds lacking sufficient forage fish of the correct size (Buck & Thoits, 1970; Bryant & Houser, 1971; and Savitz, 1978). The increase in the condition factor with increasing length further demonstrates that food of the correct size was not limiting the growth of the young-of-the-year largemouth bass in Kettle Island Bay.

The average length of the black crappie fingerlings of Kettle Island Bay at the end of the first growing season (Table 20) was superior to the lengths reported for crappie populations in Minnesota (Burrows & Moyle, 1967), Wisconsin

Table 19. Condition factor (C.F.) of largemouth bass from various waters at the end of the first growing season.

C.F.	Length (mm)	Location	Source
1.75	300	Louisiana reservoir	Viosca (1953)
1.68	195	Florida ponds	Clugston (1964)
1,32	175	Norris Reservoir, Tennessee	Stroud (1948)
1.41	176	Lake Carl Blackwell, Oklahoma	Shirley & Andrews (1977)
1.25	86 - 102	Alanconnie Lake, Pennsylvania	Cooper <u>et</u> <u>el</u>. (1971)
1.30	56 - 164	Michigan	Beckman (1948)
1.11	86.5	Lake Powell, Utah	Miller & Kramer (1971)
1.03	74	Oregon ponds	Stewart <u>et</u> <u>al</u>. (1967)
1.26	74.4	non-cannibal class Michigan ponds	Cooper (1937)
1.30	147.3	cannibal class Michigan ponds	"
1.50	86.5	Ottawa River, Ontario	Present study

(Pearse, 1919), Iowa (Ridenhour, 1960), and other waters; was about the same as for Indiana (Ricker & Lagler, 1942); but was inferior to growth shown by populations in Alabama ponds (Tucker, 1973), a Louisiana reservoir (Viosca, 1953), and in Lake George, Florida (Huish, 1954a).

Growth of young-of-the-year black crappie can be slowed by cool water temperatures during the summer (Sivells, 1949; Erikson, 1952; and Hanson & Qadri, 1979) resulting in a smaller length at the end of the first growing season but the adult black crappie seem to be less affected by fluctuating water temperatures (Pearse, 1919; and Neal, 1963).

Competition for zooplankton with gizzard shad (Dorosoma cepedianum), Mississippi silverside (Menidia audens), and rainbow smelt (Osmerus mordax) has resulted in reduced growth of young-of-the-year black crappie in some waters (Jenkins, 1955; McCaig & Mullan, 1960; and Li et al., 1975).

Black crappie also often overpopulate ponds which results in intense intraspecific competition and stunting of the population (Brown & Logan, 1960; and Goodson, 1966). Eddy & Carlander (1940) report that black crappie from a crowded pond were only 73 percent of the weight of crappie of the same length from an adjacent uncrowded pond. Tucker (1973) found that black crappie fry in ponds grew better if their numbers were reduced by predation from largemouth bass. There is no lack of potential predators in Kettle Island Bay as noted earlier. Goodson (1966) states that ponds with stunted black crappie usually lack small forage fish. This was not a problem in Kettle Island Bay and black crappie were mostly

Table 20. Average total length of black crappie at the end of the first growing season.

Length (mm)	Location	Source
130 - 200[a]	Alabama ponds	Tucker (1973)
142	Louisiana reservoir	Viosca (1953)
112	Lake George, Florida	Huish (1954a)
51	Lake Eustis, Florida	Huish (1954b)
114 (without shad)	Chicksaw Lake, Oklahoma	Jenkins (1955)
81 (with shad)	Rod and Gun Lake, Oklahoma	"
79 (without smelt)	Quabbin Reservoir, Massachussets	McCaig & Mullan (1960)
71 (with smelt)		"
77 (without silversides)	Clear Lake, California	Li *et al*. (1975)
69 (with silversides)		"
61	Minnesota state average	Burrows & Moyle (1967)
68	Lewis & Clark Lake, South Dakota	Vanderpuye & Carlander (1971)
60	Lake Wingra, Wisconsin	Pearse (1919)
62	Clear Lake, Iowa	Ridenhour (1960)
25 - 76[a]	Ohio state average	Trautman (1957)
74	Foots Pond, Indiana	Ricker & Lagler (1942)
68	Ottawa River, Ontario (1977)	Hanson & Qadri (1979)
77	Ottawa River, Ontario (1978)	Present study

[a] ranges given

piscivorous after a length of 110 mm (Hanson & Qadri, 1980).

Exceptional growth of black crappie fingerlings is also attributable to abundant food of an adequate size and a long growing season (Stroud, 1948; Viosca, 1953; and Huish, 1954a). In a previous study I determined that food apparently was not limiting the growth of adult black crappie in the Ottawa River but that the short length of the growing season was the factor determining the final adult size (Hanson & Qadri, 1980). In the present study the 1979 year class was able to attain the same average size as the 1978 year class by early August despite a delay of about three weeks in spawning in 1979. This type of rapid growth strongly indicates that food was abundant for the young black crappie.

Declines in the populations of black crappie of Clear Lake, Iowa (Neal, 1963), and Lake Ahquabi, Iowa (Hennemuth, 1955), were related to increased turbidity. Tucker (1973) felt that the decline in the black crappie populations was actually due to a decrease in the densities of insect prey that accompanies decreased vegetation cover which happens when turbidity increases. The decline in zooplankton density that happens when turbidity increases (Irwin & Claffey, 1966) would severely affect the growth and survival of young-of-the-year black crappie. Turbidity was not a problem in Kettle Island Bay as shown by the dense growth of aquatic macrophytes as deep as 3.0 m and the high densities of zooplankton that are usually present.

The length-weight relationships of black crappie (Table 21)

Table 21. Length-weight relationships for black crappie from various waters.

Relationship	Length (mm)	Location	Source
log WT = 2.914 log TL - 4.710	young-of-year	Alabama ponds	Tucker (1973)
log WT = 3.198 log TL - 5.252	"	South Dakota	Nelson (1974)
log WT = 3.075 log TL - 5.019	"	South Dakota	Vanderpuye & Carlander (1971)
log WT = 3.064 log TL - 5.011	53 - 302	Pennsylvania	Cooper *et al.* (1971)
log WT = 3.049 log TL - 4.912	61 - 315	Ottawa River, Ontario	Hanson & Qadri (1980)
log WT = 3.085 log TL - 5.000	13.5 - 92	"	Present study

Table 22. Condition factor (C.F.) of black crappie from various waters at the end of the first growing season.

C.F.	Length (mm)	Location	Source
1.45	200	Alabama ponds	Tucker (1973)
1.35	155	Alabama	Swingle (1965)
1.27	young-of-year	Lewis & Clark Lake, South Dakota	Vanderpuye & Carlander (1971)
1.57	130	Norris Reservoir, Tennessee	Stroud (1948)
1.40	68	Ottawa River, Ontario	Hanson & Qadri (1979)
1.41	77	Ottawa River, Ontario	Present study

from various waters shows that the value of the slope does not vary much from 3.00, indicating that the growth of the young-of-the-year from most populations is isometric. This permits the comparison of of various populations because any change in the condition factor will signify a difference in the well being of the fish and will not simply be a result of changing body shape.

The value of the condition factor for the young black crappie of Norris Resevoir (Stroud, 1948) is higher than that of the Kettle Island Bay population (Table 22) due to the association of high condition factors with very rapid growth. The condition factor does not seem to vary much during the first year of growth but it does increase with the size of the older fish, particularly after piscivory is initiated, until a maximum value for the adults of that population is reached (Huish, 1954a; Jenkins, 1955; and Hanson & Qadri, 1980). Tucker (1973) felt that the stability of the condition of black crappie fingerlings was due to their ability to feed on zooplankton for an extended part of the first year compared to other fish species. This statement would certainly appear to be true for the three species of sunfish in this study.

The condition factor can be used to detect the presence of intense interspecific competition due to the introduction of an exotic species (Jenkins, 1955) or it may be used to show that a population is overcrowded and stunting and needs to be thinned (Eddy & Carlander, 1940). In seasonal studies a sharp decline in the condition factor may also signify that a physical event, such as a period of cold and windy weather, has adversly affected the growth of the young fish (Hanson & Qadri, 1979). None of the above phenomenon seems to have been occurring during the present study because the condition of the young black crappie was good throughout.

The long breeding season of the pumpkinseed of Kettle Island Bay resulted in a wide range of sizes of young-of-the-year pumpkinseed in the catch as it did for the largemouth bass. The selectivity of the seine only for fish longer than 18 mm had the consequence that the last cohorts did not appear in the catch until early September during the 1978 sampling season.

The average length of pumpkinseed fingerlings at the end of the first growing season was 44.3 mm and better growth is only reported (Table 23) for some Ohio state waters (Traùtman, 1957), Michigan state waters (Carbine & Applegate, 1948), and in some years in Clear Lake, Iowa (DiCostanzo, 1957).

Beaulieu et al. (1979) attribute the slow growth of the pumpkinseed in Lac Vert, Quebec, to the cold, oligotrophic nature of the lake which is at the northern edge of the distribution.

Intra specific competition has been shown to have an adverse effect on the growth of pumpkinseed in other waters (Ridenhour, 1960; and Cooper et al., 1970) and the dense populations of several species of sunfishes was thought to be the reason for a shortage of food and poor growth of

Table 23. Average total length of pumpkinseed at the end of the first growing season.

Length (mm)	Location	Source
20 - 81[a]	Ohio state waters	Trautman (1957)
56	Clear Lake, Iowa	DiCostanzo (1957)
33	Clear Lake, Iowa	Ridenhour (1960)
48	Michigan state waters	Carbine & Applegate (1948)
44	Linwood Lake, Minnesota	Lux (1960)
43	Minnesota state waters	Burrows & Moyle (1967)
25	Honey Lake, California	Kimsey & Bell (1956)
26	Lac Vert, Quebec	Beaulieu *et al*. (1979)
33	Chamcook Lakes, New Brunswick	Reid (1930)
35 - 53[a]	Lake Opinicon, Ontario	Keast (1978)
44 (28 - 62)[a]	Ottawa River, Ontario	Present study

[a] range given

pumpkinseed in several Minnesota lakes (Seaburg & Moyle, 1964). The length of the growing season, however, seems to be the factor limiting the size of young-of-the-year pumpkinseed as it was for the largemouth bass and black crappie fingerlings because the Kettle Island Bay pumpkinseed grew better than many more southern populations in their first year.

The superior growth is also evidenced in that the Kettle Island Bay pumpkinseed start spawning at the end of June whereas the populations in southern Ontario finish spawning by the end of June and yet the Kettle Island Bay fingerlings are larger at the end of the first growing season. This rapid growth shows that food can not be limiting and that crowding is not occurring in Kettle Island Bay. The large number of potential predators are also a factor in reducing the potential of stunting due to overpopulation of pumpkinseed.

The length-weight relationship of young-of-the-year pumpkinseed does not vary much throughout the range (Table 24). The slope greater than 3.00 means that the condition factor will increase with the length of the fish, as has been found in the present study and elsewhere (Beckman, 1948; DiCostanzo, 1957; and others), which restricts the use of the condition factor to comparing fish of the same length (Ricker, 1975).

The young-of-the-year pumpkinseed of Kettle Island Bay were in better condition (Table 25) than the pumpkinseed from Michigan state waters (Beckman, 1948) that were the same length. The value of the condition factor was 1.67 for 26 mm

Table 24. Length-weight relationships for pumpkinseed from various waters.

Relationship	Length (mm)	Location	Source
log WT = 3.186 log SL - 4.740	38 - 165	Clear Lake, Iowa	DiCostanzo (1957)
log WT = 3.199 log SL - 4.789	-	Michigan	Beckman (1948)
log WT = 3.262 log TL - 5.213	30 - 221	Alanconnie Lake, Penn.	Cooper *et al*. (1971)
log WT = 3.195 log FL - 5.008	20 - 145	Lac Vert, Quebec	Beaulieu *et al*. (1979)
log WT = 3.156 log FL - 4.867	25 - 195	Lac Deschenes, Ontario	Boyle (1977, unpublished)
log WT = 3.183 log TL - 5.043	18 - 62	Ottawa River, Ontario	Present study

Table 25. Condition factor (C.F.) of pumpkinseed from various waters at the end of the first growing season.

C.F.	Length (mm)	Location	Source
2.09	56	Clear Lake, Iowa	DiCostanzo (1957)
1.82	25	Honey Lake, California	Hubbell (1966)
1.62 - 1.68	43 - 47	Michigan Lakes	Beckman (1948)
1.48	26	Lac Vert, Quebec	Beaulieu *et al*. (1979)
1.85	44	Ottawa River, Ontario	Present study

long pumpkinseed from Kettle Island Bay which is higher than the value for Lac Vert, Quebec (Beaulieu et al., 1979), but is lower than the value for pumpkinseed in Honey Lake, California (Hubbell, 1966). These values are not strictly comparable because the fish from the other two studies were at the end of the growing season whereas the Kettle Island Bay fish were undergoing a period of very rapid increase in length.

The importance of the final size of sunfishes at the end of the first growing season has only been demonstrated for largemouth bass and smallmouth bass. The smaller fish either suffered total overwinter mortality (Cohen & Brown, 1967; and Aggus & Elliot, 1975) or survived the winter in very poor condition and then died during the second growing season (Shelton et al., 1980). Oliver et al. (1979) suggest that there is a minimum size for overwinter survival of smallmouth bass. Forney (1966) says that there is size selective overwinter mortality, possibly by predation, of young-of-the-year walleye (Stizostedion vitreum) in Oneida Lake, New York. Hunt (1966) reports that overwinter mortality of brook char (Salvelinus fontinalis) was directly related to the size of the fry and may be related to a size dependant ability to withstand physiological stress. The basis for this differing overwinter survival is probably due to the differing metabolic rates between larger and smaller fish and because larger fish may have greater food reserves.

The relative size of various body parts have been used to explain differences in diets and resource partitioning in coexisting fish species (Keast, 1965; Keast & Webb, 1966; and Werner & Hall, 1976, 1977). The mouth size is usually the determinant of the maximum prey size (Northcote, 1954; Smart & Gee, 1979; and Wankowski, 1979) and this will often explain the difference in the food size between two closely related species of the same general body size (Pasch & Lyford, 1972; Ross, 1977; and O'Brien, 1977). The fish species with the larger mouth, proportionately, is usually the more efficient in handling the larger prey items (Werner, 1974; and Werner & Hall, 1977). This relationship of prey size with mouth size holds well for the young largemouth bass and pumpkinseed but black crappie have more gill rakers and, in the young-of-the-year, remain primarily planktivorous.

The number of gill rakers and the gap between gill rakers has been suggested to be the factor limiting the smallest size of food that a fish can eat, referring mostly to filter feeding fish (Doble & Eggers, 1978; O'Brien, 1979; and Wankowski, 1979). In studies where prey has been limited a relationship between the number of gillrakers and the partitioning of the food by size has been demonstrated between fish species of approximately the same size with mouths of about the same size (Nilsson, 1958, 1960; Janssen, 1978; and O'Brien, 1979). The presence of 29 to 31 gill rakers for young black crappie compared to 8 to 13 for young largemouth bass and pumpkinseed would permit the young crappie to prey on smaller prey if it were neccessary (Keast, 1965, 1970; Keast & Webb, 1966; and Werner <u>et al</u>., 1977).

The gap between the gill rakers of the black crappie fingerlings was a fairly constant proportion of length which contrasts with the negative allometric relationship reported for young-of-the-year white crappie, Pomoxis annularis (O'Brien, 1979). The gap between the adjacent gill rakers was also a fairly constant proportion of the length of the largemouth bass and pumpkinseed fingerlings but this aspect of their developement has not been reported elsewhere.

The young-of-the-year black crappie showed an increase in the number of functional gill rakers, a phenomenon also reported for arctic char, Salvelinus alpinus (Nilsson & Filipsson, 1971). A decrease in the number of functional gill rakers with increasing length of young largemouth bass has also been observed by Keast (1968a), and Scott & Crossman (1973) state that largemouth bass have two rudimentary gill rakers on the upper gill arch. A decrease in the number of gill rakers with the increasing length of young-of-the-year pumpkinseed has not been reported previously and this pattern of decrease in gill raker numbers may well be a general occurrence among young centrarchids that lack the extended period of planktivory of the crappie species.

The proportionately larger eye of the young-of-the-year black crappie would seem to support the statement that planktivorous fish have larger eyes than non-planktivores of the same size (O'Brien, 1979). This proportionately larger eye may partly explain why only black crappie fingerlings preyed on the Chaoborus larvae in Kettle Island Bay. Costa &

Cummins (1972) found that black crappie fingerlings were the only species from their study area that could prey on *Leptadora kindti*, which like *Chaoborus* larvae, are transparent. The retinas of centrarchids have not, as yet, been examined to determine if the sunfish species have different photoreceptor structures and organization as have been found between perches, *Perca* spp., and the pikeperches, *Stizostedion* spp. (Ali *et al*., 1977).

Food Availability

It is unfortunate that most studies on freshwater fish do not include information on the seasonal abundance of the food resource. It is important that the relative densities of the prey species be calculated if one is trying to show prey preferences.

The importance of frequent sampling to determine the availability of prey is illustrated by the large fluctuations in the prey numbers and biomass in Kettle Island Bay. The method of sampling minimized the chance that these fluctuations were due to sampling variation of prey with patchy distributions. On several occasions I compared samples taken at least 50 m apart on the south side of the bay and also with samples from the north side of the bay. There were no real differences between samples from the same side of the bay (Mann-Witney U-test, $P > 0.05$) but there were differences between sides of the bay ($P < 0.05$). Fluctuations in the numbers and biomass have been explained by vertical migration of prey organisms, onshore migrations of insect larvae prior to the emergence of adults, the presence of many species with different emergence dates, and the growth of the many young after reproduction (Hall _et al_., 1970; Mackie, 1971; and Keast, 1978).

The overall biomass of macrobenthos in Kettle Island Bay was quite high, up to 31 g/m^2, and it compares favorably with values reported for fertilized ponds (Patriarche & Ball, 1949; and Hall _et al_., 1970). A similar biomass of over 15 g/m^2 has been reported for the Volga Arm of the Rybinsk Reservoir in the U.S.S.R. (Bakanov & Striznikova, 1979). This high biomass indicates that benthic food items are not in short supply in Kettle Island Bay although they may not be equally vulnerable to young-of-the-year largemouth bass, black crappie, and pumpkinseed.

The macrobenthos of Kettle Island Bay differs from the above mentioned studies because chironomid larvae only accounted for 10 to 30 percent of the biomass compared to the 50 to 55 percent in fertilized ponds (Patriarche & Ball, 1949; and Hall _et al_., 1970) and the 65 percent reported for the Rybinsk Reservoir (Bakanov & Strizhnikova, 1979). The density of chironomids was very similar to the numbers found in Brewery Creek, a similar area of the Ottawa River (Mackie, 1971), but considerably exceeds the values of 121 to 333 animals/m^2 in Lake Opnicon, an eutrophic lake in southern Ontario (Keast, 1970). Patriarche & Ball (1949) produced similar densities by fertilizing small ponds.

Amphipod densities in Kettle Island Bay were also very similar to the densities found in Brewery Creek (Mackie, 1971) but were much higher than the 30 to 76 amphipods/m^2 in Lake Opinicon (Keast, 1970). Patriarche & Ball removed much of the vegetation from their study ponds and this reduced amphipod numbers because they require abundant plants with finely divided leaves (Mackie & Qadri, 1971).

Trichopteran densities in Kettle Island Bay were about ten times the densities reported for Lake Opinicon (Keast, 1970) and Brewery Creek (Mackie, 1971).

The high densities of zooplankton in Kettle Island Bay shows that planktonic prey was not in short supply. The littoral zone samples of copepods (calanoids and cyclopoids) reached as high as 550,000 animals/m^3, Bosminidae exceeded 1,500,000 animals/m^3, Daphnidae 250,000 animals/m^3, Chydoridae 300,000 animals/m^3, Ostracods 540,000 animals/m^3 and Polyphemus swarms sometimes reached 3,100,000 animals/m^3. These numbers are 40 to 100 times greater than values reported for Lake Opinicon, an eutrophic lake in southern Ontario but are well below densities of all zooplankton combined of 12,700,000 organisms/m^3 for an Oklahoma reservoir (Irwin & Claffey, 1966) and were within the ranges given for other eutrophic waters (Irwin & Claffey, 1966; June, 1974; and Hall et al., 1970, 1979). The diel shifts in species composition and relative proportions of the zooplankton corresponds with what is known about plankton migrations (Zaret & Suffern, 1976; Hall et al., 1970; 1979).

The size of zooplankton and their density in the environement are controlled by a wide range of abiotic and biotic factors. High zooplankton and phytoplankton numbers are correlated with low soil turbidity (Irwin & Claffey, 1966; and June, 1974). Irwin & Claffey found zooplankton of 3.3×10^6 animals/m^3 on the surface and 1.6×10^6 animals/m^3 at the bottom of ponds with less than 25 mg/L turbidity and only 4.0×10^5 animals/m^3 at the surface and essentially no animals near the bottom in ponds with 51 to 350 mg/L turbidity.

Reif (1940) reports that zooplankton are 10 times more numerous in eutrophic lakes compared to oligotrophic lakes in Minnesota. Hall et al. (1970) also found that the size distribution and density of the zooplankton increases with the nutrient levels. In addition, they found that there was a large difference between the zooplankton community of the littoral zone and that of the open water areas ~~which I~~ found was the case in Kettle Island Bay in the present study. These observations emphasize the importance of sampling zooplankton in the area where the fish were captured instead of using estimates based on surface or vertical tows in the open water areas or based on a study made several years earlier (as done by Keast, 1977, 1978).

Changes in the size composition of zooplankton communities and the species composition have occurred due to selective predation by the fish (Brooks & Dodson, 1965; Hall et al., 1970; and Hutchinson, 1971). The high density of Bosminidae in Kettle Island Bay in June and July, 1978, indicates that there was considerable predation pressure on the zooplankton because Bosminidae only occur in large numbers when predation is reducing the numbers of the larger calanoids, cyclopoids, and daphnids (Hall et al., 1970). The numbers of these larger organisms was still high despite the predation by young fish in Kettle Island Bay.

Feeding Periodicity

The feeding periodicity of the different size groups of centrarchids has received very little attention in the literature. The major feeding period of the young-of-the-year largemouth bass of Kettle Island Bay was in the late morning and early afternoon although there were always some fish with full stomachs at all times sampled. The maximum percentage of empty stomachs were always observed from night samples. Elliot (1976) reports that largemouth bass fry (25 to 27 mm) are diurnal feeders. Snow (1971) and Olmstead (1974) state that juvenile and adult largemouth bass have morning and sunset feeding periods. Neill & Magnuson (1974) found that adult largemouth bass are inactive at night, resting inactive on the bottom. Dubets (1954) observed that the greatest proportions of empty stomachs of adult bass occur at night but that there were also always some fish with full stomachs. It would seem that largemouth bass change their feeding pattern from mostly diurnal in the young to feeding at sunrise and sunset for the adults. This result is not surprising because most prey fish are more vulnerable during the periods of reduced light at sunrise and sunset (Ali et al., 1977; Hobson, 1979; and Stein, 1979).

The major feeding period of the young-of-the-year black crappie of Kettle Island Bay was in the morning and there was a minor feeding period near sunset. Adult black crappie feed at sunrise and sunset but have a large nocturnal feeding component as well (Pearse, 1919; Childers & Shoemaker, 1953; and Keast, 1968). In a previous study I found that black crappie fingerlings in aquaria were inactive after sunset (Hanson & Qadri, 1979). Young black crappie were becoming progressively less dependant on zooplankton and more dependant on amphipods, Chaoborus larvae, and chironomid larvae at the end of the first year and they depend heavily on these benthic prey during the second growing season (Reid, 1949; Keast, 1968; and Hanson & Qadri, 1980). Amphipods, chironomid larvae, and Chaoborus larvae are reported to migrate into the water column at night (Mundie, 1959; Keast, 1968; and Sarker, 1977) which would make them more accessible to black crappie. Thus black crappie, like largemouth bass, change their feeding periodicity as they grow.

The young-of-the-year pumpkinseed of Kettle Island Bay had a long diurnal feeding period with little or no feeding at night. This is contrary to the findings of Keast & Webb (1966) who observed a minor feeding period at night for adult pumpkinseed but agrees with the studies of Neill & Magnuson (1974) for adult pumpkinseed and that of Emery (1973) for all size groups. Both of the latter studies noted that pumpkinseed normally rest inactive on the bottom at night, an observation also made for both adult and young-of-the-year pumpkinseed during the present study. The extended diurnal feeding pattern is also seen with bluegill (Bauman & Kitchell, 1974).

The choice of the 10:00 h period for sampling corresponds to a period of active feeding and high stomach contents for young-of-the-year largemouth bass, black crappie, and pumpkinseed.

Feeding Habits of Largemouth Bass, Black Crappie, and Pumpkinseed Fingerlings

The seasonal feeding habits of the young-of-the-year largemouth bass of Kettle Island Bay were, in general, much like those described for other waters. Very small specimens ate cyclopoids, Daphnidae, and Bosminidae but at no time did they eat calanoids, which is contrary to reports by Ewers (1934), Applegate and Mullan (1965), and Elliot (1976). The use of cladocerans and cyclopoids by the larger bass fry (Kramer & Smith, 1962; Keast, 1965; and Hamilton & Powles, 1979) was also noted for the larger fingerlings in Kettle Island Bay on the occasions when they ate zooplankton. *Polyphemus* and *Simocephalus* are not mentioned as prey items for young bass in other studies except, perhaps, under the general heading of cladoceran prey.

The Kettle Island Bay largemouth bass fingerlings preyed on small amounts of chironomid larvae and amphipods as the major benthic prey with zygopterans and hemipterans as occasional prey. These were also the major macrobenthic prey of the young largemouth bass in other waters (Keast, 1965; Miller & Kramer, 1971; and Hamilton & Powles, 1979).

The principal identifiable food fish of the largemouth bass fingerlings of Kettle Island Bay were pumpkinseed fry, golden shiners, yellow perch, and smaller largemouth bass fingerlings although 54 percent of the prey fish could not be positively identified but were probably minnows due to the absence of spines and ctenoid scales. The young largemouth bass in Lake Opinicon, Ontario, feed on brook silversides (Labidesthes sicculus), fathead minnow (Pimephales promelas), golden shiners, and banded killifish (Fundulus diaphanus) (Keast, 1965). Bass fingerlings of Lake George, Minnesota, preyed on bluegill, brook silverside, golden shiner, and banded killifish (Kramer & Smith, 1962). The young bass on Clear Lake, California preyed mostly on the Mississippi silverside when the bass were 53 to 63 mm long and upon bluegill when the bass were over 84 mm long (Moyle & Holzhauser, 1978).

The chief food fish of the young-of-the-year largemouth bass in reservoirs is either threadfin shad, Dorosoma petenense, (McConnel & Gerdes, 1964; Emig, 1966; and Miller & Kramer, 1971) or gizzard shad (Viosca, 1953; Applegate & Mullan, 1965; and Timmons et al., 1980). Gizzard shad, threadfin shad, and Mississippi silverside do not occur in the Ottawa River. Brook silverside, fathead minnow, bluegill, and banded killifish are so rare in Kettle Island Bay as to be effectively unavailable as prey for largemouth bass. The young bass were probably preying on the most vulnerable fish species in Kettle Island Bay and this is probably the case for the other studies. Predation by largemouth bass fingerlings on smaller bass from later spawnings (cannibalism) is also seen in many other waters (Cooper, 1937; Eschmeyer, 1939; and Kramer & Smith, 1962) but the young bass were not an important part of the diet of most young bass in the bay.

The use of tadpoles as prey by young-of-the-year largemouth bass has only previously been observed by Tucker (1973) for bass 57 to 99 mm long in Alabama ponds. Tadpoles have been reported as a prey of adult largemouth bass (Lewis *et al*., 1961; and Lewis & Helms, 1964), brown trout, *Salmo trutta* (Macan, 1966), and yellow perch (Fraser, 1978). Macan (1966) also found that tadpoles very quickly became an unrecognizeable mass in the fish's stomach, most likely due to a lack of bony parts, and their importance in the diets of fish is probably underestimated.

The pattern of usage of zooplankton, insect larvae and amphipods, and vertebrate prey with the increase in length of the largemouth bass fingerlings in Kettle Island Bay (Fig. 29) differs from that seen in most other studies. Zooplankton were the main prey type only until the young bass were 35 mm long compared to 50 mm long for most other waters (McCammon et al., 1952; Kramer & Smith, 1962; and Keast, 1965, 1970). The Kettle Island Bay largemouth bass only ate macrobenthos to a maximum of 32 percent of the diet at a length of 45 mm compared to other studies where macrobenthos is the dominant prey type until the young bass are 70 mm long (Kramer & Smith, 1962; Keast, 1965, 1970; and Hamilton & Powles, 1979). Insect larvae and amphipods are the principal food of largemouth bass fingerlings at lengths as great as 99 mm (Miller & Kramer, 1971), 195 mm (McConnel & Gerdes, 1964), and 230 mm (Clady, 1974) in waters where forage fish of adequate size are scarce.

Small fish became 50 percent of the diet of the bass fingerlings of Kettle Island Bay at 35 mm long and fish prey, with tadpoles, were 100 percent of the diet of bass larger than 66 mm long. Small fish do not usually predominate in the diet of young largemouth bass from other Ontario waters until the second growing season (Keast, 1965, 1970; and Hamilton & Powles, 1979). Fish prey accounted for 50 percent of the diet of young largemouth bass at lengths of 60 to 85 mm in most other waters (Turner & Kraatz, 1920; Murphy, 1949; McCammon _et al_., 1952; and Kramer & Smith, 1962). The availability of small forage fish to largemouth bass as small as 30 mm long in Kettle Island Bay explains the slight use of insect larvae and amphipods and also the rapid growth shown by this population. An increase in the size of food eaten as the length of bass increased is also reported by Turner & Kraatz (1920), Kramer & Smith (1962), and Moyle & Holzhauser (1978).

Diel changes in the feeding habits of young largemouth bass was not a surprising result as the vulnerability of macrobenthos (Mundie, 1959; Keast, 1968; and Sarker 1977) and prey fish (Ali et al., 1977; Hobson, 1979; and Stein, 1979) changes with the time of day and zoóplankton migrations are well studied (Hall et al., 1970; and Zaret & Suffern, 1976). In the only other study of the diel feeding habits of largemouth bass fry, they were reported to eat the most common forms of zooplankton but changes in the availability of the zooplankton and the actual stomach contents were not shown (Elliot, 1976).

The more predatory feeding habits of young-of-the-year largemouth bass can be partly explained by the larger mouth (after a length of 50 mm) and more fusiform body that they possess in comparison to the smaller mouth size and more gibbose bodies of black crappie and pumpkinseed (Keast, 1965; Keast & Webb, 1966; and Werner et al., 1977). The rapid decline in the importance of zooplankton in the diet of largemouth bass is reflected by largemouth bass fingerlings having a decrease in the number of functional gill rakers as the length increased and the bass have, proportionately, the widest gap between adjacent gill rakers.

The seasonal feeding habits of the young-of-the-year black crappie of Kettle Island Bay were generally similar to the patterns reported in other studies. Sivells (1949) also determined that only the smaller crappie fingerlings prey on Bosminidae. My findings that Daphnidae were the most important cladoceran prey of black crappie larger than

35 mm long has also been seen in the Lake Erie population of crappie (Ewers, 1934) and these same black crappie are the only other study to report calanoids as an important part of the diet although cyclopoids have been described as an important part of the diet of young black crappie in many other waters (Pearse, 1919; Sivells, 1949; and Reid, 1949).

Calanoid copepods show avoidance to suction feeding fish but are susceptible to filter feeders (Janssen, 1976; and Drenner *et al.*, 1978). Young black crappie were the only species studied that ate calanoids and they are the only fish species with the morphology to permit filter feeding. Black crappie do not have the usual fusiform body shape that is associated with pelagic filter feeding fish (O'Brien, 1979) but the young crappie may filter feed by swimming rapidly while suction feeding, a method employed by wavyback tuna (*Euthynnus affinis*) to avoid the production of a suction current (Walters, 1966). The filter feeding behaviour of black crappie has never been reported however. I have observed young-of-the-year black crappie in aquaria using the form of filter feeding called gulping by Janssen (1978) when the crappie were feeding on brine shrimp (*Artemia salinas*) nauplii and *Chaoborus* larvae but I did not observe how they consumed the calanoids (unpublished data).

Chaoborus larvae were an important item in the diet of black crappie fingerlings of Kettle Island Bay at a length of only 42 mm compared to their first appearing in the diet of crappie in Alabama ponds when the crappie were 72 mm long

(Tucker, 1973). The young black crappie were feeding on _Chaoborus_ larvae during daylight hours which means the young crappie were feeding on the larvae that had remained in the weed beds or else the crappie were entering the anoxic layer where _Chaoborus_ were very abundant. There were far too many crappie with _Chaoborus_ in their stomachs to have been all eating the few _Chaoborus_ found in the littoral zone samples. Bluegill have been caught in nets set in water of low oxygen levels and many of these fish had eaten a few _Chaoborus_ larvae (Dendy, 1956). It would seem reasonable that young black crappie could enter the anoxic zone (oxygen concentrations of about 1.0 mg/L) to feed because adult black crappie have spawned under experimental oxygen levels as low as 2.5 mg/L (Seifert & Herman, 1977).

The increasing use of benthic food with the increasing length of the black crappie fingerlings occurs for most populations that have been studied (Pearse, 1919; Goodson, 1966; and Tucker, 1973). The greatest use of macrobenthic prey usually occurs during the second growing season after which small fish become the most important food category (Keast, 1965; Ball & Kilambi, 1973; and Hanson & Qadri, 1980).

Black crappie generally do not eat fish until they are at least 80 mm long (Reid, 1949) and fish are the most important food item after the crappie reach a length of 110 mm (Keast, 1968; Ball & Kilambi, 1973; and Hanson & Qadri, 1980). Fish fry have very rarely been found in the stomachs of black crappie fingerlings (Ewers, 1934; and Burris, 1956) but I suggested previously that fish fry might be important to small black crappie in Kettle Island Bay based on the stomach contents of a number of specimens 25 to 33 mm long (Hanson & Qadri, 1979).The present study has shown that fish fry may constitute up to 88.6 percent of the stomach contents of the young crappie averaging 25 mm long but were no longer present in the diet of crappie 43 mm long. During the feeding periodicity studies I found that the importance of fish fry in the stomach contents varied from 76 percent at 10:00 h to none at 14:00 h on the same day. Fish fry may not have been found in the stomachs of black crappie fingerlings from other studies because of the hour of sampling or that fish fry were not available to the fry in other waters. The availability of fish fry to the young black crappie of Kettle Island Bay explains, in part, the rapid growth of these black crappie during the first growing season.

Low percentages of empty stomachs have also been found for black crappie by Seaburg & Moyle (1964), Tucker (1973), and Ball & Kilambi (1973). Diel changes in the dietary items have not previously been noted for black crappie because the only published study of feeding periodicity was for adult black crappie in aquaria using a single prey species (minnow) and differences in prey selection were not possible (Childers & Shoemaker, 1953).

The great use of zooplankton by young-of-the-year black crappie compared to largemouth bass and pumpkinseed can be explained by the increase in the number of gill rakers with the size of the crappie until a maximum of 29 to 31 was reached, black crappie having the narrowest gap between the gill rakers at a given size, and black crappie had the longest gill rakers of the three species at a given length. The proportionately larger eye of the young black crappie may have aided the black crappie in detecting zooplankton and it is probably part of the reason that only the young black crappie could prey on Chaoborus larvae.

The seasonal diet of young-of-the-year pumpkinseed has not been described previously. Most of the comparative material is based on small sample numbers taken during limited time periods. The young pumpkinseed of Kettle Island Bay consumed chironomid larvae as their dominant prey and they did not use amphipods extensively. Gastropods entered the diet when the young pumpkinseed reached a length of 38 mm.

Ewers & Boesel (1935) report that Daphnidae and amphipods are the main foods eaten by 13 pumpkinseed fingerlings (24 to 32 mm long) from Buckeye Lake, Ohio, and chironomid larvae were only 10 percent of the diet. Keast (1978) showed the diet of 61 young-of-the-year pumpkinseed caught in September and 64 specimens caught in October in Lake Opinicon, Ontario, based on combining three years of data of only three or four pumpkinseed fingerlings per sample day. These pumpkinseed ate chironomid larvae, isopods, and ostracods. Sadzikowski & Wallace (1976) reported that chironomid larvae, amphipods, and cladocerans were the most important foods of 30 specimens of pumpkinseed between 31 and 74 mm long taken from mid-June until late July. Ridenhour (1960) states that pumpkinseed fry eat entomostracans early in the season and then eat amphipods and insect larvae. Pumpkinseed in Lake Opinicon do not eat snails until they are 55 to 73 mm long, which is during the second growing season (Keast, 1978) and gastropods were not eaten by the pumpkinseed of Lac Vert, Quebec, until the fish were 62 mm long (Beaulieu et al., 1979). It is possible that small size snails were not available to the young pumpkinseed in either of these studies.

The young pumpkinseed of Kettle Island Bay ate prey weighing between 0.1 to 3.6 mg which is very similar to the range of 0.1 to 1.0 mg reported for pumpkinseed fingerlings in Lake Opinicon (Keast, 1978).

There were noticeable shifts in the importance of the zooplankton and macrobenthos in the diet of the young pumpkinseed of Kettle Island Bay during the diel feeding study. The young pumpkinseed had a much longer period of continuous feeding during daylight hours than either the young-of-the-year largemouth bass and black crappie. The young pumpkinseed did not feed at night or during evening hours (Fig. 38 and Fig. 39) so that any changes in prey availability during these times would not show up in the diet. This disagrees with Keast & Welsh (1968) who reported a small feeding period for adult pumpkinseed at 02:00 h.

The pumpkinseed fingerlings of Kettle Island Bay were mostly benthophagous at a length of 20 mm compared to the zooplankton still comprising 40 percent of the diet of pumpkinseed 35 to 53 mm long in Lake Opinicon (Keast, 1978) and

50 percent of the diet of pumpkinseed 24 to 32 mm long in Buckeye Lake (Ewers & Boesel, 1935). The abundance of macrobenthos of the correct size made the early transition from planktivory to benthophagy possible and would explain the superior growth of the Kettle Island Bay pumpkinseed during the first year of life despite the late breeding season.

The change from planktivory to benthophagy corresponds to the decrease in gill raker numbers as the pumpkinseed grew and the short gill raker length. The small mouth, however, allows for planktivory by particulate feeding while preventing predation on vertebrates. The presence of molariform pharyngeal teeth accounts for the ability of young pumpkinseed to consume gastropods and pelecypods but the small mouth and strength of the teeth probably prevents pumpkinseed smaller than 38 mm long from eating molluscs.

Selectivity and Niche Overlap Indices.

There have only been a limited number of studies that have included the availability of prey items and then studied the use of the prey items by the fish species.

The largemouth bass fingerlings of Kettle Island Bay showed both seasonal and diel differences in the values of the selectivity indices. The tendency of the young largemouth bass to select for large prey was shown by their selection for Daphnidae and Polyphemus instead of the more numerous Bosminidae and, on occasion, Chydoridae. There was abundant zooplankton prey available to the young bass and they could afford to ignore calanoids because of their agility and the young bass could afford to ignore Chaoborus larvae because it is a transparent prey and hard to locate. Elliot (1976) found that young bass select for the largest prey (Leptodora kindti and Cyclops sp.) over Bosmina but eat Daphnidae and calanoids in proportion to their availability when prey is scarce.

I could not calculate selectivity indices for largemouth bass fingerlings for vertebrate prey but young bass often select for silversides until the bass are of a certain length and then the bass switched to a larger prey (e.g. bluegill) in other waters (Chizar, 1974; Moyle & Holzhauser, 1978; and Timmons et al., 1980). Adult largemouth bass select for soft-rayed fish species (Lewis et al., 1961; Lewis & Helms, 1964; and Espinosa & Deacon, 1973), a phenomenon also reported for northern pike (Beyerle & Williams, 1968; Coble, 1973; and Wolfert & Williams, 1978). This selection for soft-rayed fish prey was probably also true for the bass fingerlings in the present study. Largemouth bass showed selection for waterdogs (Ambystoma tigrinum) and spinedace (Lepidomeda mollispinis) because the feeding behaviour of these prey makes them conspicuous to the bass (Espinosa & Deacon, 1973). Changes in the selectivity indices of young largemouth bass with the time of day were expected because the vulnerability of the prey increases during periods of low light and bass are opportunistic feeders.

Young-of-the-year black crappie were the only centrarchid in Kettle Island Bay that selected for calanoids. The large size and, at times, high density of calanoids made it worthwhile for young crappie to prey on them and the black crappie were the only species with the morphology to permit the filter feeding necessary for consuming calanoids. Bosminidae were only selected for when the black crappie were small and the Bosminidae were common, otherwise black crappie ignored this small cladoceran. The young black crappie seemed to shift to the largest zooplankton available during its peak in abundance, with the exception of the calanoids which were always preferred.

Chironomid larvae were the preferred macrobenthic prey of the young crappie early in the season but were avoided when the crappie began to feed on Chaoborus. It was apparent that young black crappie could detect Chaoborus larvae and the other two fish species could not but the visual acuity of these three species of sunfish has not been studied.

The selection for Bosminidae during the day by black crappie fry changed to selection for cyclopoids at night when the relative importance of the two prey organisms in the diet reversed due to a change in the relative proportions of these two prey in the zooplankton. There is no published information concerning diel prey selection by black crappie save for the observation that the diets of adult black crappie in Lake Opinicon changes due the migration of Chaoborus larvae, chironomid larvae, and amphipods into the water column (Keast, 1968), an obvious change in the vulnerability of these prey organisms to black crappie predation.

Selectivity indicies have not been applied previously to field studies of pumpkinseed. The studies by Keast (1978) were inadequate because he combined many samples over three years to give monthly data. This precludes any possibility of calculating selection because the availability of prey for the sample date is unknown.

The Kettle Island Bay pumpkinseed fingerlings selected for Bosminidae when the fish were small and the numbers of Bosminidae were very high, possibly because their small mouth prevented the pumpkinseed from preying on the large Daphnidae. Such a phenomenon was observed for yellow perch fry in West Blue Lake, Manitoba (Wong & Ward, 1972). It is also likely that the very high abundance of the Bosminidae made it very inefficient for the young pumpkinseed to avoid this prey. The young pumpkinseed in the bay selected for Daphnidae and chironomid larvae as the zooplankton and macrobenthic prey, respectively, for the duration of the sampling period. The large changes in the selectivity indices between the day and night collections of pumpkinseed was largely an artifact that was caused by the slower digestion of some food items because young-of-the-year pumpkinseed did not feed at night. The shifts in the selection for benthic and zooplankton prey during the daylight hours were real and reflect the changes in the zooplankton and macrobenthos vulnerabilities.

Confer & Blades (1975) state that pumpkinseed in aquaria avoid calanoids due to their agility but were strongly attracted to <u>Mesocyclops</u> due to its constant motion and to <u>Epischura</u>

due to its large size. They also state that the predation of pumpkinseed on *Daphnia* increased with the size of the *Daphnia*.

Eggers (1977) and Confer *et al*., (1978) have suggested that prey selection is governed by prey visibility, the ability of the prey to escape, and the fish ignoring small or hard to catch organisms.

Prey visibility is, naturally, only important when the predator is feeding visually. Pumpkinseed attack *Daphnia* with colored bodies from greater distances than they attack *Daphnia* of the same size with transparent bodies (Confer *et al*., 1978). The reaction distance of lake char (*Salvelinus namaycush*) to *Daphnia* is determined by the visibility of the body core (Kettle & O'Brien, 1978). Decreased light intensity results in decreased reaction distances for lake char, brook char, and pumpkinseed (Confer *et al*., 1978) and for bluegill (Vinyard & O'Brien, 1976) to *Daphnia*.

Differing rates of capture efficiency are due to the escape mechanisms of the prey and also to the feeding behaviour repetoire possessed by the fish species. Selection for cladocerans over the more agile calanoids and cyclopoids has been shown for young sockeye salmon, *Oncorhynchus nerka* (Doble & Eggers, 1978), yellow perch fry (Wong & Ward, 1972), lake char (Kettle & O'Brien, 1978), adult golden shiners (Hall *et al*., 1979), and adult gizzard shad (Drenner *et al*., 1978). Sockeye salmon fry (Doble & Eggers, 1978) and pumpkinseed (Drenner *et al*., 1978) change their feeding method to prey on copepods when it is energetically unwise to ignore these prey. The behaviour of johnny darters (Etheostoma nigrum) in their natural rocky habitats forces creek chubb (Semotilus atromaculatus) to prey on crayfish (Oronectes virilis) and brook stickleback (Culea inconstans), two prey that the chubb avoided in preference for the darters during aquarium studies (Newsome & Gee, 1978).

Optimal foraging or selection is only expected when a predator will incur a negligible loss of feeding efficiency by not using all of the available resources. Examples of this are when sockeye salmon fry (Eggers & Doble, 1978) and adult brown trout (Fitzmaurice, 1979) ignore small cladocerans and prey on the larger forms. This selective predation on the large forms of zooplankton may, however, result in the elimination of these larger forms (Brooks & Dodson, 1965; Dodson, 1970; and Hutchinson, 1971). The great agility of calanoids often results in the fish ignoring these larger zooplankton to prey on smaller, but easier to catch, cladocerans such as Bosminidae (Hutchinson, 1971; Doble & Eggers, 1978; and Hall et al., 1979).

Morphology is the major factor in size selective predation (Nilsson, 1978) but gill rakers only limit the smallest size of prey that can be retained if a non-selective form of predation (e.g. filter feeding) is occurring (Seghers, 1975; and Janssen, 1978).

All selectivity indices have sampling biases. The determination of prey densities can be influenced by vertical and horizontal clumping of the prey as well as the selectivity of the sampling device for certain organisms (Rapport & Turner, 1970; Vinyard & O'Brien, 1974; and Strauss, 1979). Data based on stomach content analysis may be misleading due to the procurring of very small samples and combining different dates and then several years of data in order to have large enough samples or even by comparing data from collections made in different habitats (as frequently done by Keast, 1965, 1970, 1977, 1978). These sources of error in stomach content analysis can be largely avoided by taking reasonably large samples from the habitat for all of the size classes one is studying, taking the food availability data from the same habitat when the fish are collected, collecting the fish during their peak of feeding activity, and only comparing fish from the same habitat type. One final problem is one of differential digestion of food items. Tadpoles quickly become unrecognizeable after ingestion (Macan, 1966; and the present study) which leads to an underestimation of their importance in fish diets. Only frequent diel sampling can help determine the real importance of food items.

One bias that I could not avoid is caused by fish feeding in a flurry around sunrise and sunset on organisms starting or completing vertical and horizontal migrations (Mundie, 1959; Hall <u>et al</u>., 1970; and Ali <u>et al</u>., 1977) which results in part of the stomach contents having been taken when the relative proportions of the food were very different from that found when the collections were made.

The results of the Chi-squared contingency tables confirmed that the Levin's niche overlap indices were suitable for showing increasing overlap in food usage by young-of-the-year largemouth bass, black crappie, and pumpkinseed because the value for the overlap index increased as the similarity of the diets increased. The non-parametric tests, however, did not show any but the greatest of differences in diets. It had been assumed that high values of the niche overlap index meant that the diets were similar but only this study shows evidence for this statement based on field data.

High niche overlap values, both seasonal and diel, were usually due to two or, on occasion, all three species of sunfish preying on abundant prey items. Each species had prey items that only they consumed due to morphological adaptations to facilitate the capture of these foods. There was no evidence for habitat partitioning between the young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay nor was there any obvious difference noticeable in the height each species foraged in the water column. The largemouth bass, black crappie, and pumpkinseed fingerlings all have about the same feeding times although the extended feeding period of the pumpkinseed may be a slight case of partitioning by time. The tendency of the black crappie and largemouth bass to feed to some degree at all times during daylight hours would seem to reduce the importance of this slight degree of temporal segregation to being trivial in nature.

Various combinations of factors have been proposed to explain how fish partition the available resources. It is unfortunate that earlier workers did not examine the availability of food to determine if it was limiting.

The most obvious factor in reducing food competition is differences in the morphology of the species involved (Nilsson, 1958, 1978). Segregation by the size of prey consumed is reported to be due to differences in mouth size, gill raker number and length, and body shape for young-of-the-year rock-bass and smallmouth bass (George & Hadley, 1979); bluegill and largemouth bass adults (Werner, 1977); adult bluegill and pumpkinseed (Werner & Hall, 1976); marine sculpins (Northcote, 1954; and Pasch & Lyford, 1972); and pumpkinseed, bluegill, largemouth bass, and black crappie (Keast, 1965; and Werner *et al*., 1977). The absence of a swimbladder and differences in mouth shape accounts for the habitat segregation between johnny darters and blackside darters, *Percina maculatus*, (Smart & Gee, 1979).

Green sunfish (*Lepomis cyanellus*) are morphologically intermediate between largemouth bass and bluegill yet they share the resources by the green sunfish living in very shallow water where the other two species seldom venture (Werner, 1977). Longnose dace (*Rhinichthys cataractae*) and blacknose dace (*R. atratulus*) eat essentially the same foods but they live in different parts of the streambed (Gibbons & Gee, 1972). Brown trout and arctic char inhabit the littoral zones in lakes where food is abundant but they occupy separate habitats when food is scarce (Nilsson, 1955).

Bluegill and pumpkinseed show spatial partitioning of the habitat by the bluegill foraging in the water column and the pumpkinseed feeding near the bottom when these species occur with green sunfish (Werner & Hall, 1976). Mimic shiners (*Notropis volucellus*) forage near the surface and bluntnose minnows (*Pimephales notatus*) feed near the bottom although these species occur in the same school (Moyle, 1973). The Arizona trout (*Salmo apache*) has a similar relationship with the more bottom oriented brown trout where these two species coexist (Robinson & Tash, 1979).

A final factor, partitioning by time, is rarely seen in ecological differentiation (Ricklefs, 1973) and it is ranked as lowest in importance for resource partitioning by Schoener (1974). Brown trout and Arizona trout show some temporal segregation (Robinson & Tash, 1979) as do adult black crappie from other centrarchids (Childers & Shoemaker, 1953; Keast, 1965; and Werner *et al*., 1977).

Competition in fishes is most likely to result in reduced growth (Jenkins, 1955; McCaig & Mullan, 1960; and Li *et al*., 1975) which could then result in high overwinter mortality if young-of-the-year fish are involved (Hunt, 1969; and Oliver *et al*., 1979). In order for competition to occur there must be a resource in short supply, usually food, and if two fish species did not evolve together there may not be enough adaptations for partitioning of the resource and some displacement may occur (Nilsson, 1963; Werner & Hall, 1976, 1977; and Robinson & Tash, 1979). This is one reason why careful thought must be taken before stocking exotic species into a water system as one may cause the decline of the system one sought to enhance. Competition was not occurring in the present study because there was no resource in short supply and because there was considerable partitioning possible due to the morphological adaptations of the young largemouth bass, black crappie, and pumpkinseed.

CONCLUSIONS

Kettle Island Bay is an important nursery area for largemouth bass, black crappie, and pumpkinseed. The growth of the young-of-the-year largemouth bass, black crappie, and pumpkinseed was superior to that reported for other Canadian populations and was equal to or better than the growth reported for many American waters. Growth of largemouth bass and black crappie was isometric and pumpkinseed become slightly heavier, proportionately, as length increased. The maximum size at the end of the first growing season was largely determined by the length of the growing season.

The young largemouth bass, black crappie, and pumpkinseed fed together in the littoral zone. Food was not in short supply but the three fish species used different foods due to their morphological specializations for food capture. Food of the correct size was so abundant that largemouth bass were mostly piscivorous at a length of 35 mm almost without feeding on macrobenthos and pumpkinseed fingerlings changed from feeding on zooplankton to macrobenthos at as small a size as 20 mm in length.

2 The peak feeding period for young largemouth bass was in late morning and early afternoon. Black crappie fed most actively in the morning but also had a minor feeding period near sunset. Pumpkinseed fed actively during daylight hours. Diel changes in the foods eaten reflects changes in the availability and vulnerability of the prey.

The selectivity indices of the young largemouth bass, black crappie, and pumpkinseed demonstrated the differences in morphological adaptations for food procurement between the three species.

The Levin's niche overlap indices showed increasing values with increasing similarity of the diet as shown by Chi-square contingency tables. Non-parametric statistics were ineffective for detecting differences in the diets of two species. High niche overlap values were only calculated for collections where two fish species were simultaneously feeding on the same very abundant food items.

There are many questions pertaining to the ecology of young centrarchids in Kettle Island Bay that remain to be answered. A detailed study on the size of prey eaten by the three species may serve to further separate the diets. There are several other common species in the bay, yellow perch fry, and the cyprinid species, for which the diet and degree of overlap on the sunfish diets is unknown.

A study on the rates of digestion of the various prey of the young centrarchids should be studied to determine the assimilation efficiency of the sunfish and relate this to their growth. The feeding behaviour repetoire of these three species of sunfish is largely unstudied and this is necessary to explain how black crappie feed on calanoids and <u>Chaoborus</u> larvae while the other two species of sunfish do not. The actual method of detection of the prey should be examined and the importance of the vision, olfaction, hearing, and lateral line senses in prey recognition described.

This study has demonstrated, above all, how limited our knowledge of the ecology and growth of young fish really is, especially in Canadian waters where the lack of information also applies to the adult fish.

SUMMARY

1. The spawning period of largemouth bass and pumpkinseed occupied five to six weeks but that of the black crappie was only one week long.
2. Largemouth bass and pumpkinseed spawned in water less than 1.0 m deep but black crappie nests were not seen.
3. Cold weather in May and June, 1979, delayed the spawning of largemouth bass and black crappie by about three weeks.
4. The largest average size of the largemouth bass was 86.5 mm in length and 14.2 g in late August after which most of the fry larger than 80 mm left the bay. The largest average size of black crappie was 77.2 mm in length and 6.22 g. The largest average size of pumpkinseed was 44.3 mm in length and 1.89 g.
5. The growth of largemouth bass and black crappie was isometric and the length-weight relationships were: $\log WT = 3.042 \log TL - 4.913$ and $\log WT = 3.085 \log TL - 5.000$, respectively, while the young pumpkinseed became slightly heavier, proportionately, as they grew as shown by $\log WT = 3.183 \log TL - 5.043$.
6. The average Fulton's condition factor was 1.41 for largemouth bass, 1.27 for black crappie, and 1.74 for pumpkinseed.
7. The growth of the mouth and eye of the young largemouth bass, black crappie, and pumpkinseed was essentially isometric and black crappie have, proportionately, the

largest eye, largemouth bass the largest mouth, and pumpkinseed the smallest mouth.

8. The number of gill rakers of the black crappie increased with length until a maximum of 29 to 31 was reached and the numbers of gill rakers decreased to 8 for both the largemouth bass and pumpkinseed as they grew.

9. The biomass of macrobenthos in Kettle Island Bay was up to 31 g/m^2 and the density of zooplankton often was in excess of 1,000,000 $animals/m^3$ showing that food was not limiting in the bay.

10. Fish was the principal food of young bass after a length of 35 mm was attained. Macrobenthos never accounted for more than 32 percent of the diet and tadpoles entered the diet when the bass reached 66 mm long.

11. Young black crappie were chiefly planktivores and the percentage of benthos in the diet increased with length. Pelagic fish fry were as much as 88.6 percent ~~of~~ the diet of crappie 26 mm long and only black crappie ate _Chaoborus_ and calanoids.

12. Pumpkinseed preyed mostly on chironomid larvae although Daphnidae were the most important planktonic food. Gastropods entered the diet when the pumpkinseed were 38 mm long.

13. The selectivity indices for largemouth bass, black crappie, and pumpkinseed fingerlings changed with the season and time of the day due to changes in prey availability and incresed size of the fish.

14. Niche overlap values were high between young largemouth bass and black crappie early in the season when both fish species ate the very abundant forms of zooplankton and fish fry. The values were low most of the time.
15. Niche overlap values between largemouth bass and pumpkinseed fingerlings were below 0.30 except when both fish species ate the very abundant Daphnidae.
16. The niche overlap index values for black crappie and pumpkinseed fingerlings were only above 0.75 when the two fish species were consuming certain highly abundant forms of zooplankton.
17. The Mann-Witney U-test and the Wilcoxon paired ranking test were ineffective in detecting any but the greatest of differences between the diets of two species.
18. The Chi-square contingency tables showed that the increasing values of Levin's niche overlap index correspond to increasing similarity of the diets of two fish species.

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Appendix A. Average number of fish/seine haul(based on at least 3 hauls) during 1978.

Species [1]	June					July						August				September			
	16	19	22	26	29	4	10	13	18	24	31	10	15	22	30	4	14	21	29
Young-of-year																			
Largemouth Bass	50	28	30	75	60	23	40	50	60	15	355	100	125	53	3	20	30	10	6
Black Crappie	200	140	400	200	350	130	210	500	600	310	560	450	650	475	450	110	170	250	5
Pumpkinseed	0	0	0	0	0	0	6	5	10	14	33	160	120	125	110	130	90	80	35
Rockbass	0	0	0	2	0	0	20	110	40	13	30	40	35	6	40	0	0	0	0
Yellow Perch	150	250	500	210	350	250	100	600	100	30	25	20	200	100	50	50	200	200	100
Adult Fish																			
Black Crappie	10	9	7	14	10	1	16	11	6	1	1	1	2	3	1	0	2	11	3
Pumpkinseed	8	3	6	9	17	5	18	14	14	1	4	3	7	9	4	3	8	5	5
Northern Pike	6	2	3	3	1	0	2	3	1	1	3	1	2	2	4	1	4	6	6
Yellow Perch	4	2	9	7	6	0	13	13	11	5	5	2	3	8	6	2	0	4	2
Brown Bullhead	30	25	21	0	17	2	43	6	10	1	4	2	6	0	0	4	2	8	1

Appendix A. Continued

Silvery Minnow	0	0	0	0	40	30	0	100	100	35	20	180	100	100	80	60	40	70	20
Golden Shiner	0	10	50	200	100	400	200	100	100	80	40	310	210	90	200	40	40	100	50
Emerald Shiner	0	75	100	100	30	100	100	100	200	250	20	40	130	42	100	30	40	600	125

[1]Also captured: silver lamprey (Ichthomyzon unicuspis), longnose gar (Lepisosteus osseus), rainbow smelt (Osmerus mordax), muskellunge (Esox masquinongy), central mudminnow (Umbra limi), carp (Cyprinus carpio), spottail shiner (Notropis hudsonius), white sucker (Catostomus comersonii), eastern banded killifish (Fundulus diaphanus), brook silverside (Labidesthes sicculus), bluegill (Lepomis macrochirus), smallmouth bass (Micropterus dolomieui), Iowa darter (Etheostoma exile), logperch (Percina caprodes), sauger (Stizostedion canadense), and walleye (Stizostedion vitreum).

Appendix B. t-tests for comparison of mouth length (ML), mouth width (MW), and eye diameter (ED) between selected lengths of young largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay during 1978.

Character	Mean for Black Crappie	Mean for Largemouth Bass	t	d.f.	P
Black Crappie and Largemouth Bass					
		25 mm			
ML	3.29	3.50	1.756	39	0.100
MW	3.54	3.44	0.912	46	0.400
ED	2.84	2.26	5.250	45	0.001
		40 mm			
ML	5.03	5.40	2.060	63	0.050
MW	5.73	6.33	2.763	64	0.010
ED	3.53	3.03	6.931	57	0.001
		50 mm			
ML	5.91	6.45	1.023	59	0.300
MW	6.84	7.29	0.842	31	0.500
ED	3.96	3.63	2.090	37	0.050
		75 mm			
ML	8.24	10.90	5.474	39	0.001
MW	9.35	12.74	5.534	39	0.001
ED	5.68	4.64	9.816	47	0.001

Pumpkinseed and Largemouth Bass

	Mean for Pumpkinseed	Mean for Largemouth bass	t	d.f.	P
		25 mm			
ML	2.17	3.50	8.818	35	0.001
MW	2.17	3.44	9.181	30	0.001
ED	2.20	2.26	0.499	34	0.500
		40 mm			
ML	3.34	5.40	11.893	63	0.001
MW	3.34	6.33	16.030	60	0.001
ED	3.10	3.03	0.981	54	0.300

Appendix B. - Continued.

		50 mm			
ML	3.94	6.45	14.818	58	0.001
MW	3.94	7.29	6.311	30	0.001
ED	3.71	3.63	0.475	46	0.500

Pumpkinseed and Black Crappie

	Mean for Pumpkinseed	Mean for Black Crappie	t	d.f.	P
		25 mm			
ML	2.17	3.29	8.348	29	0.001
MW	2.17	3.54	9.849	32	0.001
ED	2.20	2.84	5.109	38	0.001
		40 mm			
ML	3.34	5.03	11.144	63	0.001
MW	3.34	5.73	16.030	60	0.001
ED	3.10	3.63	4.841	65	0.001
		50 mm			
ML	3.94	5.91	13.320	74	0.001
MW	3.94	6.84	17.860	74	0.001
ED	3.71	3.96	2.480	64	0.020

Appendix C. t-tests for comparisons of gill raker length (GRL) and the gap between gill rakers (GRG), expressed as percentages of total length, between young-of-the-year largemouth bass, black crappie, and pumpkinseed from Kettle Island Bay in 1978.

Character	Mean for Black Crappie	Mean for Largemouth Bass	t	d.f.	P
Black Crappie and Largemouth Bass					
GRL	4.10	3.38	13.250	72	0.001
GRG	0.268	0.714	32.550	77	0.001
Largemouth Bass and Pumpkinseed					
	Mean for Largemouth Bass	Mean for Pumpkinseed	t	d.f.	P
GRL	3.38	1.82	14.870	42	0.001
GRG	0.714	0.650	2.915	52	0.010
Black Crappie and Pumpkinseed					
	Mean for Black Crappie	Mean for Pumpkinseed	t	d.f.	P
GRL	4.10	1.82	22.730	38	0.001
GRG	0.268	0.650	18.210	45	0.001

Appendix D. -Feeding habits of young-of-the-year largemouth bass and black crappie of Kettle Island Bay taken at 4 h intervals on July 6 and 7, 1979. Percent occurrence (above), percent weight (middle for benthic and fish prey), percent numbers (middle for planktonic prey), and average number/fish (below).

Total weight of Gut contents	% Stomachs Empty	Fish Prey	Amphipods	Chironomids	Plankton as a % of Gut Weight	No. of Zoo-plankton	Calanoids	Cyclopoids	Daphnidae	Bosminidae	Polyphemus	No. of Fish
Largemouth Bass (TL = 23.2 mm)												
03:00 h												
0.013	70.0	15.0	00.0	00.0	11.3	43	00.0	5.0	5.0	5.0	00.0	20
		88.7	-	-			-	2.3	2.3	95.3	-	
		0.2	-	-			-	0.1	0.1	2.1	-	
07:00 h												
0.070	00.0	55.0	10.0	10.0	14.5	116	00.0	60.0	50.0	5.0	00.0	20
		82.0	1.9	1.2			-	74.1	22.4	3.4	-	
		0.7	0.2	0.2			-	4.3	1.3	0.2	-	
11:00 h												
0.065	10.0	20.0	45.0	10.0	62.5	311	00.0	65.0	70.0	5.0	00.0	20
		14.7	21.0	1.7			-	76.5	16.7	6.8	-	
		0.2	0.8	0.1			-	11.9	2.6	1.1	-	

Appendix D. - Continued.

						15:00 h						
0.080	5.0	60.0	50.0	5.0	18.0	47	00.0	15.0	35.0	00.0	5.0	20
		73.1	8.9	0.1			-	23.4	63.8	-	12.8	
		0.8	0.7	0.1			-	0.6	1.5	-	0.3	
						19:00 h						
0.071	10.0	90.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	10
		100.0	-	-	-		-	-	-	-	-	
		1.6	-	-	-		-	-	-	-	-	
						23:00 h						
0.015	00.0	100.0	00.0	00.0	00.0	0.	00.0	00.0	00.0	00.0	00.0	1
		100.0	-	-			-	-	-	-	-	
		2.0	-	-			-	-	-	-	-	
Black Crappie (TL = 26.2 mm)												
						03:00 h						
0.015	60.0	20.0	10.0	5.0	24.0	16	5.0	15.0	5.0	00.0	00.0	20
		72.0	1.3	2.6			10.5	79.9	10.5	-	-	
		0.3	0.1	0.1			0.1	0.8	0.1	-	-	
						07:00 h						
0.111	00.0	95.0	00.0	00.0	11.9	122	25.0	30.0	20.0	15.0	00.0	20
		88.1	-	-			27.0	19.7	39.3	13.9	-	
		1.9	-	-			1.7	1.2	2.4	0.9	-	
						11:00 h						
0.090	00.0	50.0	00.0	00.0	47.2	696	50.0	30.0	30.0	45.0	00.0	20
		52.1	-	-			6.8	21.0	9.2	62.9	-	
		0.8	-	-			2.4	7.3	3.2	21.9	-	

Appendix D. - Continued.

						15:00 h						
0.013	60.0	5.0 54.6 0.1	00.0 - -	00.0 - -	45.4	91	5.0 1.1 0.1	15.0 3.3 0.2	5.0 1.1 0.1	25.0 94.5 4.3	00.0 - -	20
						19:00 h						
0.030	15.0	50.0 88.6 0.6	00.0 - -	10.0 2.0 0.1	9.4	107	5.0 0.9 0.1	15.0 9.3 0.5	20.0 3.7 0.2	15.0 82.2 4.4	00.0 - -	20
						23:00 h						
0.036	10.0	35.0 43.7 0.4	5.0 0.6 0.1	10.0 2.0 0.1	53.8	224	5.0 0.9 0.1	60.0 66.5 7.5	55.0 9.4 1.1	25.0 22.8 2.6	00.0 - -	20

Appendix E Feeding habits of young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay at 4 h intervals on July 27 and 28, 1979. Vertebrate and macrobenthic prey: percent occurrence (above), percent weight (middle), and average number/fish (below).

Total Weight of Gut Contents	% Stomachs Empty	Tadpoles	Fish Prey	Amphipods	Chironomids	*Chaoborus*	Trichopterans	Hemipterans	No. of Fish
Largemouth Bass (TL = 58.6 mm)									
				02:00 h					
0.597	60.0	00.0	25.0	00.0	00.0	00.0	00.0	10.0	20
		-	99.6	-	-	-	-	0.5	
		-	0.3	-	-	-	-	0.1	
				06:00 h					
1.365	30.0	40.0	35.0	15.0	00.0	00.0	00.0	5.0	20
		42.9	56.2	0.8	-	-	-	0.1	
		0.5	0.4	0.2	-	-	-	0.1	
				10:00 h					
3.688	5.0	15.0	85.0	00.0	00.0	00.0	00.0	10.0	20
		2.9	96.5	-	-	-	-	0.5	
		0.2	1.2	-	-	-	-	0.2	
				14:00 h					
0.996	5.0	5.0	70.0	00.0	00.0	00.0	00.0	45.0	20
		2.5	89.4	-	-	-	-	4.7	
		0.1	0.8	-	-	-	-	0.7	
				18:00 h					
1.315	5.0	00.0	75.0	00.0	00.0	00.0	00.0	20.0	4.3
		-	93.9	-	-	-	-	4.3	
		-	0.9	-	-	-	-	0.5	

Appendix E - Continued.

22:00 h

1,384	5.0	00.0	45.0	20.0	00.0	00.0	00.0	30.0	20
		-	89.9	0.5	-	-	-	3.7	
		-	0.5	0.2	-	-	-	0.7	

Black Crappie (TL = 43.5 mm)

02:00 h

0.166	00.0	00.0	00.0	20.0	40.0	25.0	00.0	00.0	20
		-	-	3.6	3.5	1.6	-	-	
		-	-	0.4	0.7	0.3	-	-	

06:00 h

0.900	00.0	00.0	30.0	60.0	95.0	30.0	00.0	00.0	20
		-	7.2	3.6	1.7	0.6	-	-	
		-	0.3	1.9	3.8	0.5	-	-	

10:00 h

0.727	00.0	00.0	20.0	15.0	20.0	55.0	00.0	00.0	20
		-	3.7	0.2	0.4	5.3	-	-	
		-	0.2	0.2	0.5	3.5	-	-	

14:00 h

0.312	00.0	00.0	5.0	10.0	30.0	00.0	00.0	00.0	20.
		-	1.9	0.3	0.9	-	-	-	
		-	0.1	0.2	0.6	-	-	-	

18:00 h

0.077	50.0	00.0	00.0	00.0	5.0	00.0	00.0	00.0	20
		-	-	-	0.4	-	-	-	
		-	-	-	0.1	-	-	-	

22:00 h

0.266	5.0	00.0	00.0	30.0	90.0	55.0	00.0	00.0	20
		-	-	3.5	7.6	3.1	-	-	
		-	-	1.0	4.2	0.9	-	-	

Pumpkinseed (TL = 28.3 mm)

02:00 h

0.003	40.0	00.0	00.0	00.0	15.0	00.0	5.0	00.0	20
		-	-	-	53.1	-	31.3	-	
		-	-	-	0.2	-	0.1	-	

Appendix E - Continued.

				06:00 h					
0.036	00.0	00.0	00.0	10.0	55.0	00.0	00.0	00.0	20
		-	-	1.4	25.3	-	-	-	
		-	-	0.1	2.0	-	-	-	
				10:00 h					
0.033	00.0	00.0	00.0	15.0	50.0	00.0	00.0	00.0	20
		-	-	21.9	21.9	-	-	-	
		-	-	1.6	1.6	-	-	-	
				14:00 h					
0.078	00.0	00.0	00.0	25.0	90.0	00.0	5.0	00.0	20
		-	-	5.9	48.7	-	2.2	-	
		-	-	0.4	8.0	-	0.1	-	
				18:00 h					
0.044	00.0	00.0	00.0	10.0	50.0	00.0	00.0	00.0	20
		-	-	1.8	34.8	-	-	-	
		-	-	0.2	5.6	-	-	-	
				22:00 h					
0.071	5.0	00.0	00.0	40.0	95.0	00.0	00.0	00.0	20
		-	-	2.4	44.9	-	-	-	
		-	-	0.5	5.5	-	-	-	

Appendix F. Feeding habits of young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay at 4 h intervals on July 27 and 28, 1979. Planktonic prey: percent occurrence (above), percent numbers (middle), and average number/fish (below).

Plankton as a % of Gut Weight	No. of Zoo-plankton	Calanoids	Cyclopoids	Daphnidae	Bosminidae	Diaphanasoma	Polyphemus	Ostracods	Chydoridae
Largemouth Bass				02:00 h					
00.0	0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
		-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
				06:00 h					
00.0	0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
		-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
				10:00 h					
00.0	0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
		-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
				14:00 h					
1.1	144	00.0	00.0	10.0	00.0	00.0	10.0	00.0	00.0
		-	-	4.2	-	-	95.8	-	-
		-	-	0.3	-	-	6.9	-	-
				18:00 h					
2.5	472	00.0	10.0	15.0	00.0	00.0	5.0	00.0	00.0
		-	93.2	4.8	-	-	2.[illegible]	-	-
		-	18.8	1.0	-	-	0.4	-	
				22:00 h					
4.1	345	00.0	00.0	30.0	00.0	00.0	30.0	00.0	00.0
		-	-	32.7	-	-	67.3	-	-
		-	-	5.3	-	-	10.8	-	-

Appendix F - Continued

Black Crappie				02:00 h					
91.1	821	10.0	100.0	15.0	60.0	00.0	00.0	00.0	00.0
		0.4	71.1	1.2	27.2	-	-	-	-
		0.2	29.2	0.5	11.2	-	-	-	
				06:00 h					
86.2	3,399	5.0	100.0	90.0	30.0	00.0	00.0	00.0	00.0
		0.3	74.9	12.7	11.9	-	-	-	-
		0.5	127.3	21.7	20.3	-	-	-	-
				10:00 h					
90.1	5,427	95.0	100.0	20.0	30.0	00.0	00.0	00.0	00.0
		30.0	64.5	0.5	4.7	-	-	-	-
		82.1	175.2	1.4	12.7	-	-	-	-
				14:00 h					
96.9	5,751	45.0	65.0	100.0	85.0	25.0	20.0	00.0	00.0
		9.0	6.4	5.1	77.4	2.0	0.1	-	-
		25.8	18.5	14.6	222.6	5.8	0.4	-	-
				18:00 h					
99.6	1,061	00.0	25.0	10.0	25.0	00.0	00.0	00.0	00.0
		-	29.7	1.5	68.8	-	-	-	-
		-	15.6	0.8	36.5	-	-	-	-
				22:00 h					
83.3	1,192	00.0	95.0	85.0	10.0	10.0	00.0	00.0	00.0
		-	75.4	6.5	17.9	0.2	-	-	-
		-	45.0	3.9	10.7	0.1	-	-	-
Pumpkinseed				02:00 h					
15.6	17	00.0	30.0	25.0	10.0	00.0	00.0	00.0	5.0
		-	32.3	29.4	11.8	-	-	-	5.9
		-	0.4	0.2	0.2	-	-	-	0.1
				06:00 h					
73.3	365	00.0	35.0	85.0	30.0	00.0	10.0	5.9	00.0
		-	11.0	35.1	47.1	-	6.3	0.5	-
		-	2.0	6.4	8.9	-	1.2	0.1	-

Appendix F - Continued.

				10:00 h					
68.0	239	00.0	25.0	60.0	35.0	00.0	00.0	10.0	00.0
		-	15.1	32.0	50.6	-	-	1.3	-
		-	1.8	3.9	6.1	-	-	0.2	-
				14:00 h					
44.5	592	00.0	40.0	45.0	40.0	00.0	15.0	25.0	15.0
		-	5.2	18.6	70.3	-	1.0	2.2	1.2
		-	1.6	5.5	20.8	-	0.3	0.7	0.4
				18:00 h					
63.3	403	00.0	3.0	40.0	35.0	00.0	5.0	00.0	5.0
		-	7.9	10.7	80.6	-	0.2	-	0.2
		-	2.7	3.6	27.1	-	0.1	-	0.1
				22:00 h					
50.6	593	00.0	45.0	90.0	5.0	00.0	00.0	5.0	00.0
		-	6.1	16.7	77.1	-	-	0.2	-
		-	1.8	5.0	22.9	-	-	0.1	-

Appendix G. Food habits of the young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay at 4 h intervals on August 10 and 11, 1979. A sample of 20 fish of each species was examined for each time period. Vertebrate and macrobenthic prey: percent occurrence (above), percent weight (middle), and average number/fish (below).

Tadpoles	Fish Prey	Amphipods	Isopods	Gastropods	Chironomids	Chaoborus	Trichopterans	Hemipterans	Neuropterans
Largemouth Bass (TL = 66.4 mm)									
02:00 h									
00.0	35.0	00.0	00.0	00.0	00.0	00.0	00.0	10.0	00.0
-	97.3	-	-	-	-	-	-	2.7	-
-	0.4	-	-	-	-	-	-	0.2	-
06:00 h									
10.0	25.0	15.0	00.0	00.0	00.0	00.0	00.0	10.0	00.0
34.5	61.9	0.8	-	-	-	-	-	2.7	-
0.1	0.3	0.2	-	-	-	-	-	0.1	-
10:00 h									
70.0	35.0	00.0	00.0	00.0	00.0	00.0	00.0	5.0	00.0
44.0	52.9	-	-	-	-	-	-	0.3	-
0.7	0.4	-	-	-	-	-	-	0.1	-
14:00 h									
30.0	65.0	00.0	00.0	00.0	00.0	00.0	00.0	5.0	00.0
10.0	89.7	-	-	-	-	-	-	0.4	-
0.3	0.7	-	-	-	-	-	-	0.1	-
18:00 h									
55.5	25.0	00.0	00.0	00.0	00.0	00.0	00.0	20.0	00.0
55.6	41.8	-	-	-	-	-	-	2.6	-
0.7	0.3	-	-	-	-	-	-	0.3	-

Appendix G - Continued.

22:00 h

75.0	10.0	20.0	00.0	00.0	00.0	00.0	00.0	5.0	00.0
79.7	18.0	0.5	-	-	-	-	-	0.7	-
0.8	0.1	0.2	-	-	-	-	-	0.1	-

Black Crappie (TL = 58.9 mm)

02:00 h

00.0	00.0	70.0	00.0	00.0	45.0	35.0	00.0	00.0	10.0
-	-	1.8	-	-	3.1	5.2	-	-	1.8
-	-	1.3	-	-	2.5	1.0	-	-	1.3

06:00 h

00.0	00.0	40.0	00.0	00.0	20.0	50.0	00.0	00.0	15.0
-	-	5.0	-	-	0.2	29.8	-	-	1.1
-	-	3.4	-	-	0.5	16.3	-	-	0.3

10:00 h

00.0	00.0	75.0	00.0	00.0	60.0	30.0	00.0	00.0	5.0
-	-	5.3	-	-	1.3	1.3	-	-	0.2
-	-	6.7	-	-	1.8	0.8	-	-	0.1

14:00 h

00.0	00.0	20.0	00.0	00.0	45.0	15.0	00.0	00.0	00.0
-	-	0.2	-	-	2.6	10.6	-	-	-
-	-	0.2	-	-	1.5	5.6	-	-	-

18:00 h

00.0	00.0	00.0	00.0	00.0	5.0	5.0	00.0	00.0	00.0
-	-	-	-	-	0.1	3.9	-	-	-
-	-	-	-	-	0.1	0.9	-	-	-

22:00 h

00.0	00.0	70.0	00.0	00.0	55.0	45.0	00.0	00.0	00.0
-	-	5.5	-	-	1.8	3.2	-	-	-
-	-	2.5	-	-	1.6	1.3	-	-	-

Pumpkinseed (TL = 32.4 mm)

02:00 h

00.0	00.0	5.0	00.0	00.0	45.0	5.0	00.0	00.0	00.0
-	-	9.8	-	-	86.3	3.8	-	-	-
-	-	0.1	-	-	1.2	0.1	-	-	-

Appendix G - Continued.

06:00 h

00.0	00.0	25.0	00.0	00.0	25.0	00.0	00.0	00.0	00.0
-	-	65.6	-	-	34.4	-	-	-	-
-	-	0.5	-	-	0.7	-	-	-	-

10:00 h

00.0	00.0	40.0	10.0	15.0	75.0	00.0	15.0	00.0	00.0
-	-	20.9	5.9	1.0	13.3	-	1.9	-	-
-	-	1.5	0.3	0.4	2.2	-	0.2	-	-

14:00 h

00.0	00.0	6.5	00.0	5.0	70.0	5.0	00.0	00.0	00.0
-	-	13.1	-	0.3	14.2	0.8	-	-	-
-	-	1.5	-	0.1	3.1	0.1	-	-	-

18:00 h

00.0	00.0	15.0	20.0	5.0	100.0	5.0	00.0	00.0	00.0
-	-	4.0	6.0	1.0	81.6	0.6	-	-	-
-	-	0.3	0.4	0.1	16.4	0.1	-	-	-

22:00 h

00.0	00.0	60.0	5.0	5.0	75.0	00.0	00.0	00.0	00.0
-	-	20.6	2.0	1.9	68.4	-	-	-	-
-	-	1.5	0.5	0.1	8.6	-	-	-	-

Appendix H. Food habits of the young-of-the-year largemouth bass, black crappie, and pumpkinseed of Kettle Island Bay at 4 h intervals on August 10 and 11, 1979. A sample of 20 fish of each species was examined for each time period. Zooplankton prey: percent occurrence (above), percent numbers (middle), and average number/fish (below).

Total Weight of Gut Contents	% Stomachs Empty	Plankton as a % of Gut Weight	Number of Zooplankton	Calanoids	Cyclopoids	Daphnidae	Bosminidae	Diaphanasoma	Ostracods
Largemouth Bass			02:00 h						
0.723	55.0	00.0	0	00.0	00.0	00.0	00.0	00.0	00.0
			06:00 h						
0.830	55.0	00.0	0	00.0	00.0	00.0	00.0	00.0	00.0
			10:00 h						
2.061	5.0	00.0	0	00.0	00.0	00.0	00.0	00.0	00.0
			14:00 h						
5.456	5.0	00.0	0	00.0	00.0	00.0	00.0	00.0	00.0
			18:00 h						
2.107	15.0	00.0	0	00.0	00.0	00.0	00.0	00.0	00.0
			22:00 h						
1.546	5.0	00.0	0	00.0	00.0	00.0	00.0	00.0	00.0
Black Crappie			02:00 h						
0.735	00.0	83.2	3,115	00.0	80.0	5.0	00.0	30.0	00.0
				-	76.6	0.3	-	23.0	-
				-	119.4	0.5	-	35.9	-

Appendix H - Continued

				06:00 h					
1.021	00.0	63.0	2,714	00.0	100.0	50.0	00.0	5.0	00.0
				-	85.1	3.4	-	11.4	-
				-	115.5	4.7	-	15.6	-
				10:00 h					
1.289	00.0	91.6	9,474	45.0	100.0	30.0	50.0	45.0	00.0
				7.4	67.2	1.2	16.7	5.7	-
				34.9	318.2	5.7	79.3	27.1	-
				14:00 h					
0.613	00.0	86.5	2,739	5.0	75.0	65.0	25.0	00.0	00.0
				1.5	45.7	10.2	42.5	-	-
				2.3	70.0	15.6	65.0	-	-
				18:00 h					
0.720	00.0	96.1	5,447	75.0	95.0	80.0	10.0	20.0	00.0
				21.8	49.6	15.2	6.4	6.8	-
				59.5	135.2	41.3	17.5	18.6	-
				22:00 h					
0.768	00.0	89.4	3,122	00.0	100.0	40.0	5.0	15.0	00.0
				-	93.9	2.4	0.4	3.3	-
				-	146.6	3.8	0.6	5.1	-
Pumpkinseed				02:00 h					
0.018	65.0	trace	4	00.0	00.0	00.0	00.0	00.0	5.0
				-	-	-	-	-	100.0
				-	-	-	-	-	0.2
				06:00 h					
0.016	60.0	trace	5	00.0	5.0	5.0	00.0	00.0	00.0
				-	40.0	60.0	-	-	-
				-	0.1	0.2	-	-	-
				10:00 h					
0.115	00.0	56.0	600	00.0	70.0	75.0	50.0	00.0	5.0
				-	19.0	20.7	55.3	-	4.2
				-	5.7	6.2	16.6	-	1.3
				14:00 h					
0.154	00.0	70.9	676	00.0	40.0	100.0	30.0	00.0	65.0
				-	10.5	62.0	13.0	-	14.6
				-	3.5	21.0	4.4	-	5.0

Appendix H - Continued.

				18:00 h					
0.165	00.0	8.1	108	~~00~~.0	10.0	35.0	10.0	10.0	35.0
				-	5.6	22.2	14.8	7.4	50.0
				-	0.3	1.2	0.8	0.4	2.7
				22:00 h					
0.086	00.0	7.1	43	00.0	00.0	20.0	5.0	00.0	20.0
				-	-	18.6	48.8	-	32.6
				-	-	0.4	1.1	-	0.7