FOOD OF LARVAL BLACK CRAPPIES IN RELATION TO ELECTRICAL POWER GENERATION, KEOWEE RESERVOIR, SOUTH CAROLINA

D. HUGH BARWICK, U. S. Fish and Wildlife Service, Southeast Reservoir Investigations, Clemson, SC 29631

Abstract: Food of larval (5.0-10.9 mm, TL) black crappies (*Pomoxis nigromaculatus*) from Keowee Reservoir, SC, was determined in 1973, before commercial power generation began from a 2,580-MW nuclear power plant, and in 1976 after 3 years of commercial power generation. Although water temperatures were higher in 1976 than in 1973, food of the larvae appeared to be unchanged by operation of the plant. The principal organisms eaten were *Diaphanosoma* sp. and copepod nauplii.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32: 485-489

As larval fish develop beyond the yolk-sac stage and begin feeding, they are at a critical stage (Braum 1967), during which they are not only threatened by starvation but also are particularly vulnerable to adverse environmental conditions. They are less mobile than juveniles and adults, and are often unable to avoid water currents and temperature changes associated with electrical power generation.

The young of black crappie, a significant species in the sport fishery of Keowee Reservoir, are potentially subjected to such adverse conditions. Ruelle et al. (1977) reported a decline in numbers of young-of-the-year black crappies in Keowee Reservoir in 1976 as compared with 1973, and suggested that this decline may have been related to electrical power generation. To investigate one of the factors possibly influencing survival, I sought to determine whether food of larval crappies was affected by the environmental changes that resulted from electrical power generation in the reservoir.

Study Area and Sampling Periods

Keowee Reservoir (7,435 ha) is in the upper Savannah River drainage of northwestern South Carolina. It was built by Duke Power Company primarily to provide condenser cooling water for Oconee Nuclear Station and to serve as the lower reservoir for a pumped storage project.

Oconee Nuclear Station is a 2,580-MW electrical generating station. A concrete skimmer wall across the water intake canal extends from about 1.0 m above the surface to a depth of 19.8 m at full pool (full pool is 243.8 m above mean sea level). The wall allows water to enter the intake canal only from depths greater than 19.8 m (the intake level extends from 19.8 to 27.4 m). Temperature of the water used for once-through cooling is increased about 10C before it is discharged back into Keowee Reservoir.

Limited tests of the first of 3 reactors at Oconee Nuclear Station were begun in May 1973, but commercial production of electricity did not begin until July. The second and third reactors began commercial production in September and December 1974. During the sampling period 7 May to 14 June 1973, power production averaged only 6.5% of the station's rated capacity; during the sampling period 27 April to 8 June 1976, the average was 41.3%.

Cooling water discharged during steam-electric power generation usually increases water temperatures in the receiving basin (outfall). However, the cool hypolimnetic water (from beneath the skimmer wall) used for condenser cooling at Oconee Nuclear Station was discharged at temperatures similar to or lower than those in a control area (11 km from the plant) in late spring and summer. After depletion of the cool hypolimnetic water in late summer, water temperatures in the outfall area remained higher than natural water temperatures until the following spring.

Water temperatures during periods of fish collection in 1973 and 1976 were similar within each year in control and outfall areas: at depths of 1.0 and 5.5 m, the ranges were 17.0-27.0 C and 15.5-20.0 C, respectively, in 1973 and 18.0-22.9 C and 17.5-21.3 C in 1976

(Fig. 1). Water temperatures differed between years, however, those in 1976 being higher. At 1.0 m depths these differences between years in water temperatures at control and outfall areas probably resulted from meterological conditions, since the presence of the skimmer wall precluded the elevation of water temperatures by the operation of the Oconee Nuclear Station at this time of the year. On the other hand, the higher water temperatures at 5.5 m depths in both the control and outfall areas in 1976 undoubtedly resulted from operation of the station.

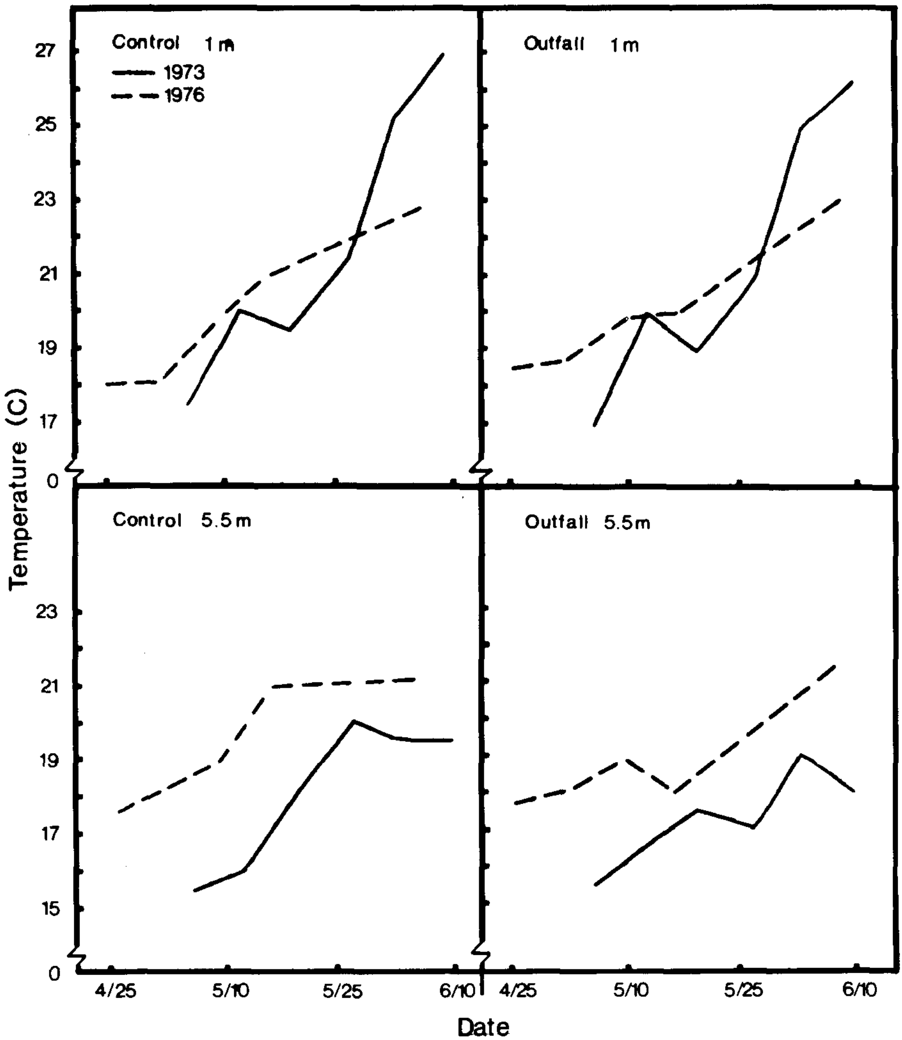

Fig. 1. Water temperatures at depths of 1.0 and 5.5 m in control and outfall areas of Keowee Reservoir, South Carolina, 1973 and 1976.

METHODS

Larval black crappies for food studies came from weekly, daytime catches in a frame trawl (1.3 m^2 aluminum frame; 6.1 m long, 0.8 mm mesh net) fished at depths of 1.0 and 5.5 m in the control and outfall areas. Young fish 5.0-10.9 mm in total length with undifferentiated fins, that had begun feeding, were included in the study. All specimens were preserved in 10% formalin after capture. The entire digestive tract was later excised, and food organisms were removed and identified.

Zooplankton was sampled simultaneously with a No. 10 Wisconsin net (0.076 mm mesh) mounted in the opening of the frame trawl. Zooplankton samples were preserved in 10% formalin after capture and counted as described by Cowell (1967).

Larval black crappies were grouped into 2 length classes (5.0-7.9 and 8.0-10.9 mm) to insure that possible food differences during critical periods of development were not overlooked. To test for changes in number of food organisms per digestive tract, I used the nonparametric Mann-Whitney test (Conover 1971) because the shape of the fish distribution curve was not known and sample sizes were small.

RESULTS AND DISCUSSION

Diaphanosoma sp. and copepod nauplii were the major organisms found in the larvae (Tables 1 and 2). *Diaphanosoma* were highly selected as food and constituted 82-90% of the total food organisms eaten in both sampling areas in both years. Other organisms eaten were from the genera *Diaptomus, Mesocyclops, Tropocyclops, Cyclops, Daphnia, Ceriodaphnia* and *Bosmina.* Since food of larvae and relative abundance of zooplankton were similar at both the 1.0 and 5.5 m depths in both sampling areas, data were combined for the 2 depths, by area, for analysis.

Table 1. Percentage composition (by number) of food organisms found in the digestive tracts of black crappie larvae (5.0-10.9-mm total length) collected from control and outfall areas of Keowee Reservoir, South Carolina, 1973 and 1976. (Number of larvae shown in parentheses).

	Control		*Outfall*	
Food item	*1973* (*60*)	*1976* (*30*)	*1973* (*37*)	*1976* (*26*)
Copepoda				
Diaptomus	2	1	1	0
Mesocyclops	0	1	0	1
Nauplii	11	11	9	15
Others[a]	0	1	0	0
Cladocera				
Diaphanosoma	87	85	90	82
Others[b]	0	1	0	2

[a]Includes *Tropocyclops* and *Cyclops*

[b]Includes *Daphnia*, *Ceriodaphnia*, and *Bosmina*

Larvae 5.0-7.9 mm long from the outfall area ate significantly ($P \leq 0.05$) more *Diaphanosoma* than did those in the control area in 1973, and significantly more in 1973 than in 1976. However, the numbers of *Diaphanosoma* eaten by larvae 8.0-10.9 mm long were not significantly different within sampling areas between years or between sampling areas within years. No significant differences were found in the numbers of copepod

Table 2. Mean numbers of the 2 most common organisms found in the digestive tracts of 2 length classes of black crappie larvae collected from control and outfall areas of Keowee Reservoir, South Carolina.

Area, year, and fish length (mm)	*No. of fish*	*Food organism*	
		Copepod nauplii	*Diaphanosoma*
Control			
1973			
5.0-7.9	20	0.45	2.75
8.0-10.9	40	0.48	4.08
1976			
5.0-7.9	12	0.92	2.33
8.0-10.9	18	0.28	4.44
Outfall			
1973			
5.0-7.9	6	0	5.17
8.0-10.9	31	0.48	4.16
1976			
5.0-7.9	14	0.43	2.14
8.0-10.9	12	0.33	3.58

nauplii or the total numbers of food organisms eaten by the 2 length classes of larvae within sampling areas between years or between sampling areas within years.

In other studies, *Bosima* sp., *Cyclops* sp., and copepod nauplii were the most important food organisms in the diet of larval black crappies(Sivells 1949; Bulkley et al. 1976). In Keowee Reservoir *Diaphanosoma* sp. was by far the most important food. *Bosima* sp. and *Cyclops* sp., although seldom eaten were available as food to larvae and were more abundant in some areas of Keowee Reservoir than were *Diaphanosoma* sp. (Table 3).

Table 3. Mean number of food organisms per liter of water in control and outfall areas of Keowee Reservoir, South Carolina, from 7 May to 14 June 1973 and 27 April to 8 June 1976.[a]

Food item	*Control*		*Outfall*	
	1973	*1976*	*1973*	*1976*
Copepoda				
Diaptomus	0.05	0.01	0.06	0.15
Mesocyclops	tr	0.11	0.02	0.06
Cyclops	tr	0.07	0.01	0.07
Nauplii	0.20	0.67	0.34	0.65
Cladocera				
Daphnia	tr	0.03	0	tr
Bosmina	0.10	tr	0.01	0.07
Diaphanosoma	0.01	0.10	0.08	0.04
Ceriodaphnia	tr	0	tr	0

[a] tr = trace (less than 0.005)

The difference in numbers of *Diaphanosoma* sp. eaten by larvae 5.0-7.9 mm long from control and outfall areas in 1973 probably was not associated with environmental conditions resulting from plant operation. Plant operation during the 1973 sampling period did not produce water temperatures in the outfall area that were significantly different from those in the control area. Therefore, changes in environmental conditions in the outfall area due to power generation were considered insignificant.

It might appear that food of larvae in 1976 may have been affected by plant operation. Larvae 5.0-7.9 mm long captured from the outfall area in 1973 ate significantly more *Diaphanosoma* sp. than did larvae captured from the outfall area in 1976. Plant operation was higher during 1976, and therefore, larvae were subjected to environmental conditions that resulted from increased power generation.

Significant differences in the number of *Diaphanosoma* sp. eaten by larvae collected in control and outfall areas in 1973 appeared to be related to the abundance of these organisms; they were considerably more abundant in the outfall area (Table 3). Significant differences in the numbers eaten by larvae collected in the outfall area in 1973 and 1976 could also be related to the abundance of these plankters, which was greater in the outfall area in 1973 than in 1976 (Table 3).

The data available suggest that the operation of Oconee Nuclear Station, which elevated water temperatures as much as 3 C at 5.5 m, had no detrimental effect on the food of black crappie larvae. The withdrawal of hypolimnetic water from beneath the skimmer wall helped to maintain similar water temperatures throughout the reservoir during a period when larval black crappies might have been adversely affected by a heated effluent.

LITERATURE CITED

Braum, E. 1967. The survival of fish larvae with reference to their feeding behavior and food supply. Pages 113-131 *in* Shelby D. Gerking (ed.). The biological basis of freshwater fish production. Blackwell Scientific Publ., Oxford.

Bulkley, R. V., V. L. Spykermann, and L. F. Inmon. 1976. Food of the pelagic young of walleyes and five cohabiting fish species in Clear Lake, Iowa. Trans. Am. Fish. Soc. 105:77-83.

Conover, W. J. 1971. Practical nonparametric statistics. John Wiley & Sons, Inc., N.Y. 462 pp.

Cowell, B. C. 1967. The Copepoda and Cladocera of a Missouri River reservoir: a comparison of sampling in the reservoir and the discharge. Limnol. Oceanogr. 12:125-136.

Ruelle, R., W. Lorenzen, and J. Oliver. 1977. Population dynamics of young-of-the-year fish in a reservoir receiving heated effluent. Pages 46-67 *in* W. Van Winkle (ed.). Proc. Conf. on Assessing Effects of Power-Plant-Induced Mortality on Fish Populations. Pergamon Press, N.Y.

Sivells, H. C. 1949. Food studies of black crappie fry (*Pomoxis nigromaculatus*). Tex. J. Sci. 1:38-40.

LIFE HISTORY OF WARMOUTH IN LAKE CONWAY, FLORIDA[a]

VINCENT GUILLORY[b], Florida Game and Fresh Water Fish Commission, P.O. Box 1903, Eustis, FL 32726

Abstract: Life history data were collected on Lake Conway warmouth (*Lepomis gulosus*) from May 1976 to August 1977. Dominant food items progressed from zooplankton to insects to crayfish with warmouth size. The sex ratio was 1.87 males to 1.00 females. Spawning was protracted, extending from April to August. Fecundity increased with length and ranged from 304 to 8504 ($\bar{x}$ = 1981). Condition factor increased directly with length. Length-weight regressions were computed separately for warmouth less than and greater than 100 mm. Age structure was not discernible. No warmouth fishery existed.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32: 490-501

Warmouth range from Kansas to Iowa to southern Wisconsin, lower Michigan, Lake Erie, and western Pennsylvania, south to Florida and the Rio Grande (Hubbs and Lagler 1947). In most areas warmouth are attractive to anglers because of their gameness, susceptibility toward baits, and plumpness. The species probably attains its greatest importance as a food and sport fish in the lower Mississippi Valley and states bordering the Gulf of Mexico.

Detailed life history studies on warmouth have been conducted in Georgia (Germann et al. 1974), Iowa (Lewis and English 1949), and Illinois (Larimore 1957). Other studies concerned with growth, length-weight relationships, or population structure of warmouth have been cited by Carlander (1977). Little data, with the exception of brief generalized annotations (Carr 1939; Chable 1947; McLane 1955), exist on Florida warmouth. Caution must be exercised when extrapolating life history data from other portions of the warmouth's range because other fishes exist as distinct subspecies or races in peninsular Florida. Consequently, a life history evaluation of the species was begun in Lake Conway. The purpose of this paper is to present data pertinent to abundance, habitat preference, food habits, reproduction, length-weight relationships, population structure, and angler use of Lake Conway warmouth.

R. Land, M. Rebel, and D. Jones helped collect specimens and perform preliminary laboratory and data analyses. B. Guillory assisted with data summarization. J. Crumpton, H. Royals, D. Holcomb, S. Hardin, W. Johnson, D. Levine, and V. Williams reviewed a preliminary draft of this paper. The U. S. Army Corps of Engineers Waterways Experiment Station funded the study.

MATERIALS AND METHODS

The study area was located on Lake Conway, a complex of three interconnected small lakes near Orlando, FL. A detailed description of the area was presented by Guillory et al. (1977).

Studies were begun in May 1976 and were terminated in August 1977. Monthly collections were made by seine, Wegener ring, and electrofisher. Semi-annual blocknet-rotenone samples were also taken.

All speciments were weighed to the nearest 0.1 g and total length (TL) and standard length (SL) were measured to the nearest mm. Specimens selected for laboratory analysis were fixed in 10% formalin, washed, and later transferred to 45% isopropanol.

---

[a]Contribution number 70 of the Eustis Fisheries Research Laboratory.

[b]Present address: Louisiana Dept. of Wildl. and Fisheries, P.O. Box 37, Grand Isle, LA.

A total of 280 fish collected by electrofishing and seining were analyzed for stomach contents, sex, and gonad stage according to Nikolsky (1963). The number of fish examined per 25 mm (SL) size group is as follows: 54, 50-75 mm; 68, 76-100 mm; 54, 101-125 mm; 28, 126-150 mm; 38, 151-175 mm; 25, 176-200 mm; and 13, 201-225 mm. Stomach contents were weighed to the nearest 0.01 g, identified, and enumerated.

Ovaries were removed from 42 gravid females for analysis of fecundity. Egg counts were made by subsampling gravimetrically - a known weight of eggs was counted with total fecundity estimated by proportion. Ovary contents included several classes of eggs, but only mature ova were enumerated. Fecundity was plotted against total length; this was transformed to a straight line by logarithmic transformation, a regression line derived, and the correlation coefficient calculated.

During development, fish typically pass through several stages or stanzas, each of which may have divergent length-weight relationships (Tesch 1971). To estimate the "breaking point" in length-weight regressions, a stratified sample of lengths and weights was plotted on double logarithmic graph paper. By visual inspection, divergent regression lines associated with different size intervals were determined to be above and below 100 mm TL. Separate length-weight regressions then were calculated for each size group according to Carlander (1977). Two-hundred and fifty warmouth were included in the 100 mm and below size interval, 225 in the 101-225 mm size group.

Condition factors were calculated according to the formula presented by Tesch (1971): $K_{TL} = (W/L^3) \times 10^5$, where W is the weight in g and L is the total length in mm. The number of fish evaluated per 20 mm size class is listed herein: 15, 20-40 mm; 73, 41-60 mm; 98, 61-80 mm; 92, 81-100 mm; 73, 101-120 mm; 38, 121-140 mm; 29, 141-160 mm; 23, 161-180 mm; 22, 181-200 mm; and 12, 201-220 mm.

Scales for age and growth determinations were removed from the left side of the fish near a point where the tip of the pectoral fin, when laid backward, touched the third row of scales below the lateral line. A microfiche reader was used for scale magnification (Dauble and Gray 1977).

The Lake Conway sport fishery was measured from 1 July 1976 to 30 June 1977 with a stratified roving creel survey utilizing non-random probability sampling as described by Pfeiffer (1965) and Ware et al. (1972). Data analysis was provided through the Southeastern Cooperative Fish and Game Statistics Project at North Carolina State University.

RESULTS AND DISCUSSION

Abundance and Habitat

According to standing crop estimates obtained by blocknet-rotenone, an average of 482 warmouth weighing 3.27 kg were found per ha. In blocknet collections this species was numerically sixth most abundant and in biomass ranked fifth. Among centrarchids, bluespotted sunfish (*Enneacanthus gloriosus*), bluegill (*Lepomis macrochirus*), redear sunfish (*L. microlophus*), and largemouth bass (*Micropterus salmoides*) were more abundant numerically and contributed more biomass.

Guillory (1979) analyzed the assemblages of fish in Lake Conway. Warmouth were placed in the *L. gulosus - E. gloriosus* assemblage, where associated species are mathematically grouped together and the two species with the highest degree of affinity bear the complex name. The *L. gulosus - E. gloriosus* assemblage included warmouth, bluespotted sunfish and brown bullhead (*Ictalurus nebulosus*). As a group, these species usually were exclusively associated with dense stands of vegetation in shallow littoral zones and were most prevalent in areas with the following characteristics: submergent vegetation [especially *Vallisneria* ("eel grass") and *Potomogeton* (pondweed)]; organic detritus or silt substrate; and water depths over 30 cm. Other species associated with vegetation in Lake Conway and collected with warmouth included bluefin killifish

(*Lucania goodei*), mosquitofish (*Gambusia affinis*); swamp darter (*Etheostoma fusiforme*), least killifish (*Heterandria formosa*), golden topminnow (*Fundalus chrysotus*), and flagfish (*Jordanella floridae*).

The close association of warmouth with vegetation is further illustrated by the comparison of electrofishing data in vegetated versus sand-bottomed littoral habitats (Guillory et al. 1979). A t-test on numeric and biomass data and a chi-square test on frequency of occurrence data showed that statistically greater ($p = < .05$) warmouth numbers, biomass, and occurrences were in vegetative habitats. In electrofishing samples a total of 4.7 warmouth per hour weighing 98.1 g were collected in vegetation as compared to 0.2 fish weighing 0.2 g in non-vegetated zones.

Food Habits

Warmouth smaller than 76 mm fed primarily on aquatic insects, especially Chironomidae (midge) larvae and Trichoptera (caddisfly) larvae (Table 1); insects encountered in lesser numbers included Zygoptera (damselfly) nymphs, Comphidae (dragonfly) nymphs, Dytiscidae (predaceous diving beetle), Corixidae (water boatmen), and Culicinae (mosquito) larvae. Zooplankton (Cladocera and Ostracoda) ranked next to insects numerically. Other food items in this size category included *Hyalella* (scud), *Palaemonetes* (freshwater shrimp), vegetation, eggs, and fish remains.

Table 1. Size variation in percentage number (No.) and percentage frequency of food organisms in stomachs of 280 Lake Conway warmouth.

	50-75 mm SL		76-125 mm SL		126-175 mm SL		176-225 mm SL	
No. *F*	*No.*	*F*	*No.*	*F*	*No.*	*F*	*No.*	*F*
Vegetation	3.5	11.1	4.5	8.2	7.0	9.1	6.7	5.3
Cladocera	9.3	14.8	---	---	---	---	---	---
Ostracoda	2.3	7.4	---	---	---	---	---	---
Amphipoda (*Hyalella*)	5.8	11.1	1.8	3.3	7.0	3.0	13.4	5.3
Decapoda								
Palaemonidae (*Palaemonetes*)	1.2	3.7	5.4	9.8	7.0	6.1	6.7	5.3
Astacidae (*Procambarus*)	---	---	8.0	14.8	34.9	36.1	73.3	57.9
Odonata								
Zygoptera	1.2	3.7	---	---	---	---	---	---
Anisoptera								
Comphidae	2.3	3.7	9.8	16.4	4.7	6.1	---	---
Libellulidae	---	---	2.7	1.6	4.7	3.0	---	---
Coleoptera (*Dytiscidae*)	1.2	3.7	---	---	---	---	---	---
Hemiptera (*Corixidae*)	1.2	3.7	---	---	---	---	---	---
Diptera	1.2	3.7	---	---	---	---	---	---
Culicinae	4.7	3.7	---	---	7.0	3.0	---	---
Chironomidae	25.6	44.4	33.9	14.8	2.3	3.0	---	---
Trichoptera (Leptoceridae)	26.7	25.9	8.0	6.6	---	---	---	---
Insect remains	4.7	14.8	---	---	2.3	3.0	---	---
Oligochaeta	---	---	3.7	1.6	---	---	---	---
Gastropoda (Physidae)	---	---	1.8	3.3	---	---	---	---
Osteichthyes								
Brown bullhead	---	---	---	---	2.3	3.0	---	---
Mosquitofish	---	---	1.8	3.3	---	---	---	---
Bluefin killifish	---	---	1.8	3.3	---	---	---	---
Bluespotted sunfish	---	---	5.4	8.2	9.3	9.1	---	---
Fish remains	2.3	7.4	7.1	13.1	9.3	12.1	---	---
Eggs	5.8	7.4	.9	1.6	---	---	---	---
Unidentified	2.3	7.4	4.5	8.2	2.3	3.0	---	---
Number examined	54		122		66		38	
Number empty	12		26		10		14	

In the next size group (76-125 mm), aquatic insects (primarily dragonfly nymphs, midge larvae, and caddisfly larvae) again dominated (Table 1). Fish became the second most numerous food item. Mosquitofish, bluefin killifish, and bluespotted sunfish were identified. *Procambarus* (crayfish), first found in this size range, and freshwater shrimp were other important prey. Vegetation, Oligochaeta (aquatic earthworm), and Physidae (pouch snail) were also ingested by warmouth.

Crayfish was the dominant food item in 126-175 mm warmouth, yielding 24.9% of the total by number and appearing in 36.4% of all stomachs (Table 1). Collectively, fish and aquatic insects were equally abundant, although each group displayed divergent trends from the previous size class - fish increased slightly whereas insects showed a pronounced decline. Scuds and freshwater shrimp were other food items.

The largest warmouth (176-225 mm) fed predominately on crayfish, which occurred in 57.9% of all stomachs and comprised 73.3% of the total numerically (Table 1). The other obvious dietary feature of warmouth in this size class was the reduction in diversity. Scuds, freshwater shrimp, and vegetation were the only other food items; in warmouth over 200 mm, only crayfish and vegetation were found. Fish and aquatic insects, prevalent in smaller warmouth, were conspicuously absent.

Overall, vegetation, 5 crustacean taxonomic categories, 8 insect groups, aquatic earthworms, pouch snails, 4 species of fish, and eggs were identified in Lake Conway warmouth.

As described above, warmouth exhibited both qualitative and quantitative variations in selection of food items with respect to 4 major size groups. To further illustrate this phenomenon of differential prey selection with warmouth size, food habit data were subjected to additional analysis by 25 mm size groups. The numerical distribution of selected groups of food organisms versus warmouth size is depcted in Fig. 1. Zooplankton was present only in the smallest size group. Fish comprised an important dietary constituent for medium size (101-175 mm) individuals but were insignificant in smaller warmouth (< 100 mm) and absent in the larger individuals (> 175 mm). Crayfish first appeared in the 75-100 mm size group and steadily increased in number until they dominated in warmouth over 125 mm. Insects, prominent in warmouth less than 100 mm, decreased in medium size fish (101-175 mm), and were absent from larger fish. Although the scud/freshwater shrimp category became more important with size, they were absent from the largest size group (201-225 mm).

The influence of fish size on other aspects of feeding is shown in Fig. 2. Here the number of taxonomic categories, percentage empty stomachs, mean number of organisms per stomach, and average weight of stomach contents are plotted against warmouth size. Weight and percentage empty stomachs displayed an increase with size whereas the number of taxonomic groups and number of organisms were inversely proportional to size. Small warmouth apparently feed more frequently and consume larger numbers and types of smaller prey (zooplankton and insects primarily) than do larger individuals. Large warmouth feed less often on larger prey and devour fewer numbers and types of food items (fish, crayfish, and freshwater shrimp). Based on diversity of food items, smaller warmouth are more opportunistic and less selective than larger individuals.

McLane (1955) found that St. Johns River warmouth less than 75 mm fed principally on small crustaceans, insect larvae, and nymphs while individuals over 75 mm in length had a diet composed primarily of decapod crustacea, larger insect nymphs, and fish. Other studies have found similar results: a sequence of food items from entomostracea to insects to fish and crayfish (Germann et al. 1974; Larimore 1957; Lewis and English 1949).

Food habit data suggest that warmouth are selective in their feeding with respect to habitat. They feed predominantly in dense vegetation as most food items (especially scuds, decapods, odonates, caddisflies, pouch snails, and all 4 species of fish) are intimately associated with such habitats in Lake Conway. Furthermore, the continued

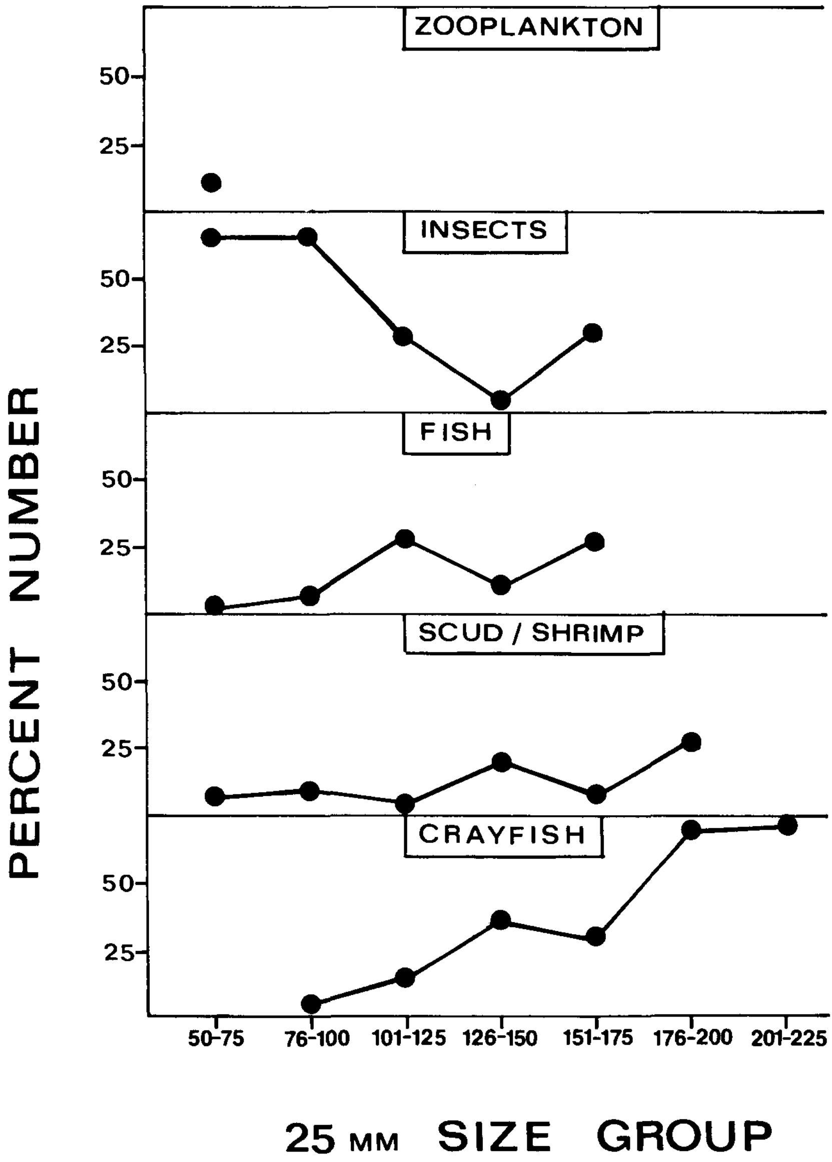

Fig. 1. Utilization of zooplankton, insects, fish, scud/shrimp, and crayfish by various sizes of Lake Conway warmouth.

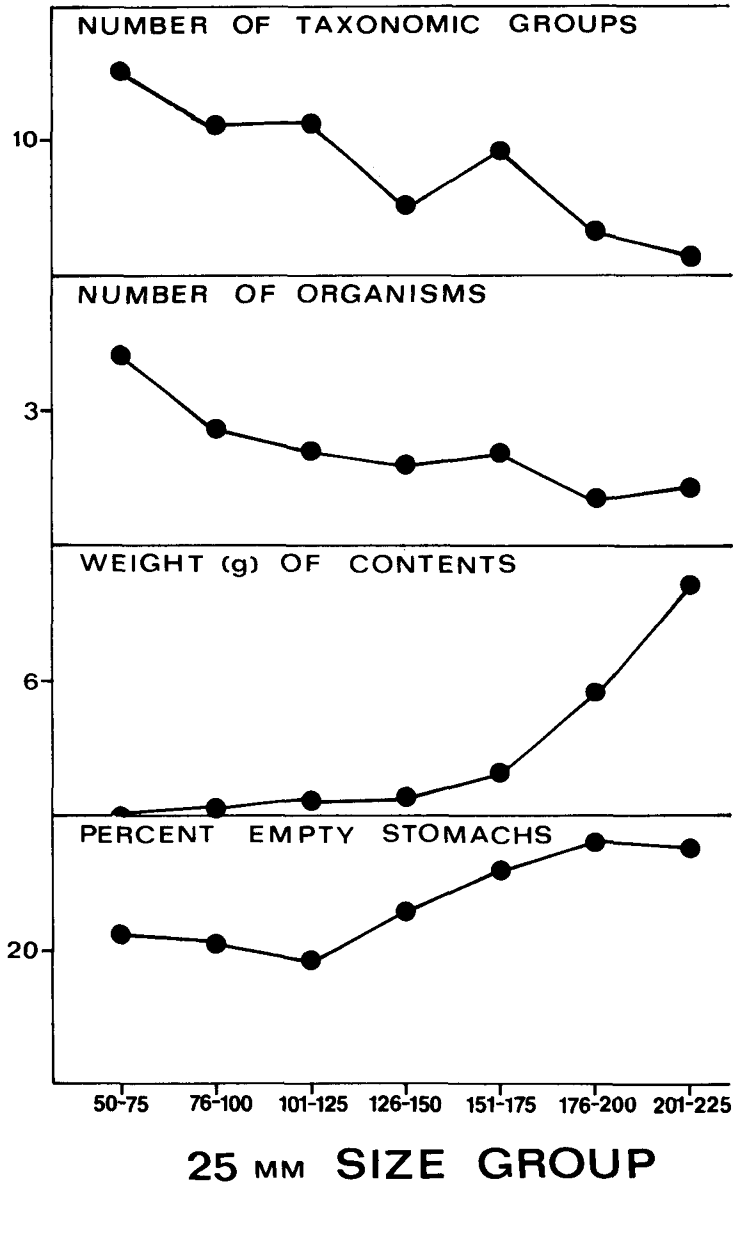

Fig. 2. Relationship between food habits (number of taxonomic groups, mean number of organisms, percentage empty stomachs, and mean weight of stomach contents) and size in Lake Conway warmouth.

presence of vegetation in stomachs of the predaceous warmouth suggests that vegetation is incidentally ingested while capturing prey.

Sex Ratios

Sixty-five percent of warmouth were males. The sex ratio of males to females was 1.87:1.00. According to the chi-square test, the number of males was significantly ($p \leq < .05$) greater than females. Males were slightly more abundant in the first 2 size groups, equal in the third size group, and then exhibited pronounced increases in the larger size groups (Fig. 3).

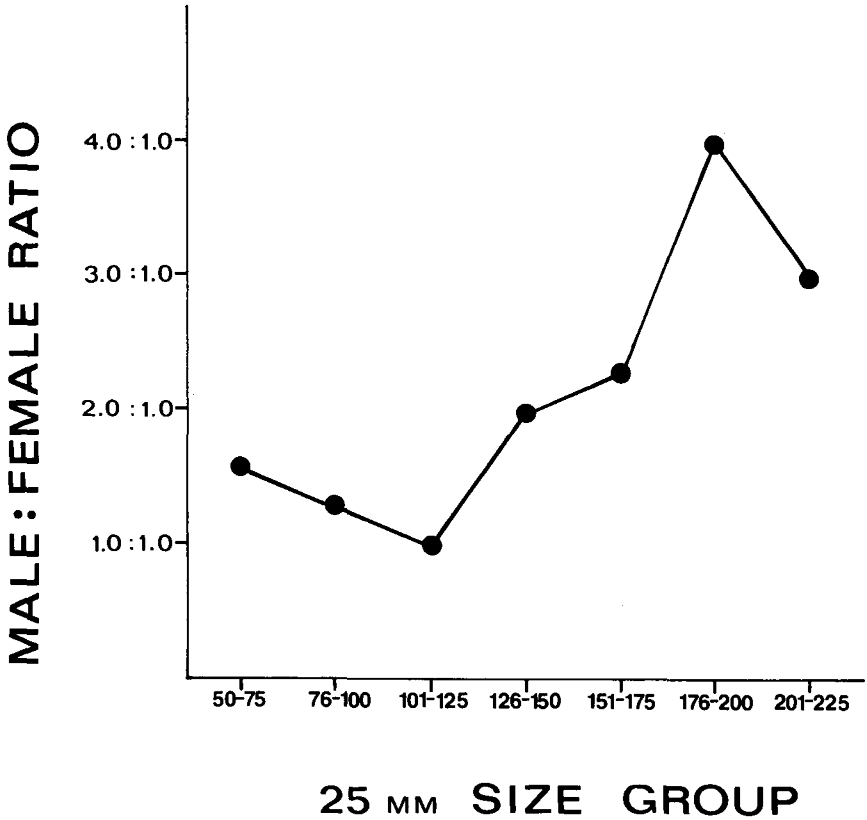

Fig. 3. Variation in male:female sex ratios by size for Lake Conway warmouth.

Increased numbers of females in intermediate size groups and of males in larger sizes may be due to a greater growth rate and longevity of males over females (Larimore 1957) and the greater longevity of males. This would result in a "piling up" of females in the intermediate size groups as preceding age-groups or size classes "catch up" with the older, slower growing females. The longer life span and greater growth rate of males leads to a disproportionate recruitment of males among larger fish.

Reproduction

Lake Conway warmouth have an extended spawning season. In 1976, gravid or spent warmouth were observed from May through August. The following year, spent individuals were also found during April. Spawning was maximal during late April and May. At the time of the initial 1976 spawning, water temperature was approximately 15 C, later increasing to 32 C in July and August.

In the Suwannee River and Okefenokee Swamp in Georgia, Germann et al. (1974) found that spawning began in April, peaked in early May, and terminated in late July or August. Larimore (1957) observed central Illinois warmouth nesting from mid May to August with peak spawning occurring in June. Warmouth in Biven's Arm in Gainesville, FL began spawning in April when water temperatures reached 13 C (Carr 1939).

The lengthy spawning season of warmouth is ascribed to a continual maturation of gonadal products rather than to a difference in the time of maturation of individuals. Ovaries contained several ovum sizes representing various stages of development. In some areas, individual warmouth were observed to spawn several times during 1 spawning season (Larimore 1957; Toole 1946).

The smallest male with mature gonads was 57 mm in SL, the smallest female, 62 mm. These sizes correspond to those listed elsewhere for mature warmouth - 79 to 89 mm TL for Illinois (Larimore 1957) and 102 to 152 mm TL for Georgia (Germann et al. 1974). Both Larimore and Germann et al. concluded that size is probably more important than age for attainment of sexual maturity; depending on growth rate, warmouth may spawn at age I or II.

Nesting was not observed; however, gravid and spent specimens were found in "eel grass" beds in 25-75 cm of water. The observed density of warmouth, however, was not suggestive of gregariousness common to other spawning centrarchids. Larimore (1957) reported that nests are usually built near a stump, clump of vegetation, or other cover, at depths of 5 cm to 1.5 m. McLane (1955) and Carr (1939) also found nests constructed in dense roots extending above the bottom.

Fecundity ranged from 304 to 8504 ova per fish, with a mean of 1981. Average fecundity increased with size (Fig. 4). The regression equation between fecundity and length was $\log F = 0.1619 + 1.418 \log L$, where F equals the number of mature ova and L equals the standard length in mm. The correlation coefficient of + 0.37 and the steady increase in average fecundity with size implies a direct relationship between fecundity and length but with a high degree of variability in number of eggs within specific size groups.

Germann et al. (1974) found an average of 11,768 eggs per individual with a range of 6,816 to 22,850. Illinois warmouth egg counts ranged from 4,500 to 63,200 (Larimore 1957).

Length-Weight Relationship

Condition (K_{TL}) increased progressively with length (Fig. 5). Mean values ranged from 1.29 in the smallest (20-40 mm) size group to 2.20 in the largest (200-220 mm) size interval. In general, values for larger fish were comparable to those listed by Carlander (1977), although mean condition factors for the smaller size groups in Lake Conway were lower than values reported elsewhere. The direct relationship between condition factor and warmouth length has also been reported by Larimore (1957), Jenkins (1954), and Germann et al. (1974).

The length-weight relationships of 250 warmouth 40-100 mm TL and of 225 warmouth 101-225 mm TL are respectively, as follows: $\log W = -4.6609 + 2.9527 \log L$ and $\log W = -5.5670 + 3.3995 \log L$, where W is the weight in g and L is the total length in mm. The regression equation and regression lines for these 2 size groups corroborates Tesch's (1971) recommendation to calculate separate length-weight regressions based on size. In essence, the 2 regression equations show that larger warmouth (> 100 mm) are "heavier for their length" than smaller individuals. This supports the increase in mean condition factor with size.

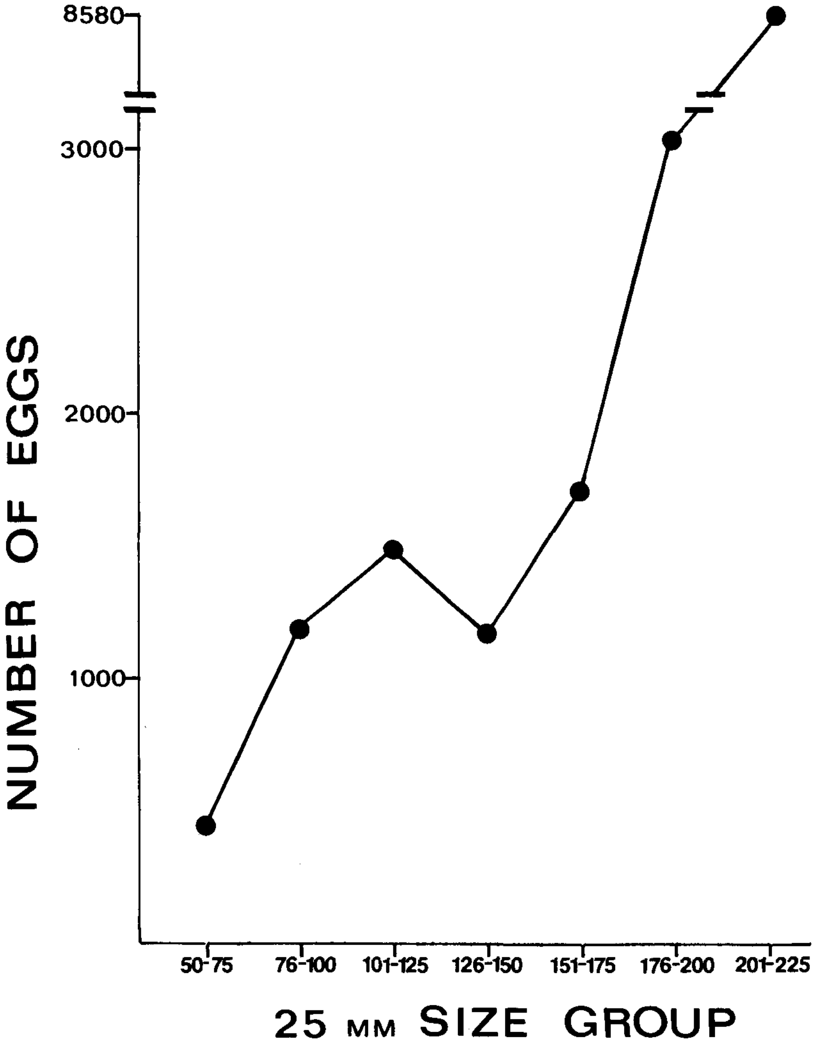

Fig. 4. Variation in fecundity by size for Lake Conway warmouth.

Age and Growth

Scales were examined to determine age and growth. This method is complicated by more uniform seasonal growth displayed by Lake Conway warmouth as compared to northern populations. Consequently, well defined annuli were not discernible and age verifications were not possible by this method.

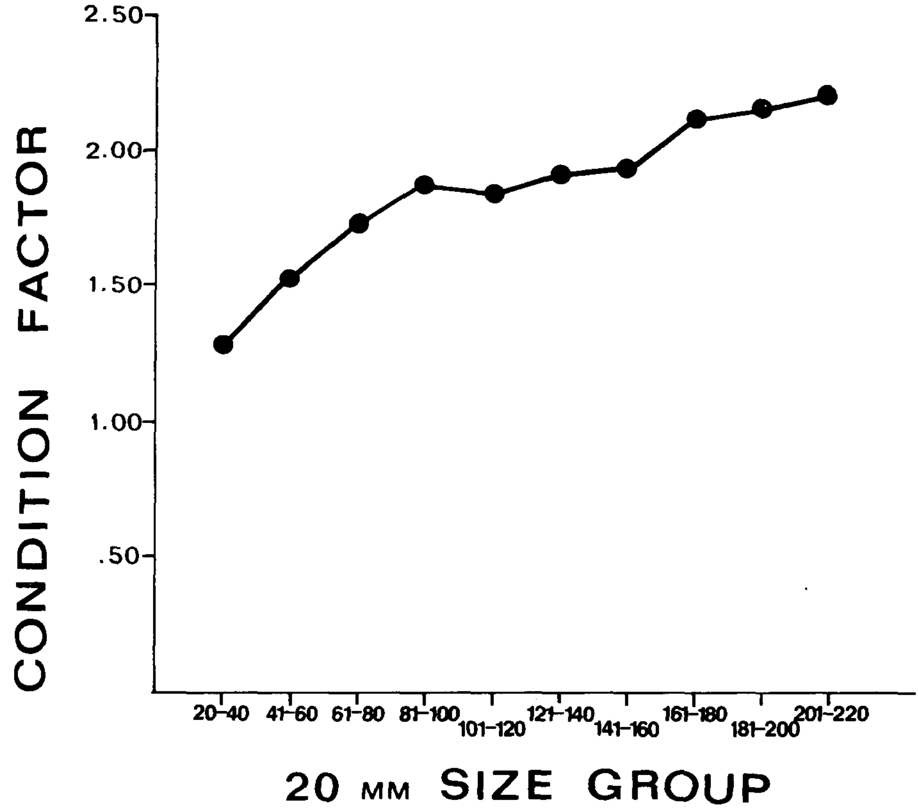

Fig. 5. Variation in condition factors (KTL) by size for Lake Conway warmouth.

The Petersen, or length-frequency method, was also used in an attempt to "age" warmouth from fall blocknet samples (Fig. 6). Year class modes are not identifiable from these data, possibly because of the protracted spawning season which results in a long, diffused recruitment interval, leading to an obliteration of well defined modal groups for even the younger year classes. Differential growth among or between year classes would also de-emphasize sharp length-frequency modal peaks. Germann et al. (1974) superimposed length-frequency data over the calculated range and mean lengths of each age group as determined by scale analysis and concluded that the former was not reliable as a method of aging. Elsewhere, as many as 8 age groups have been reported for warmouth by Germann et al. (1974) and Larimore (1957).

Sport Fishery

In conjunction with other ongoing studies on Lake Conway, a year long creel census was conducted from 30 June 1976 to 1 July 1977. Not a single warmouth was recorded in harvest estimats, despite the presence of moderate fishing pressure (59,423 man-hours in a 737 ha lake) and the local abundance of the species. Several factors probably contribute to the absence of creeled warmouth. First, the sport fishery is dominated by largemouth

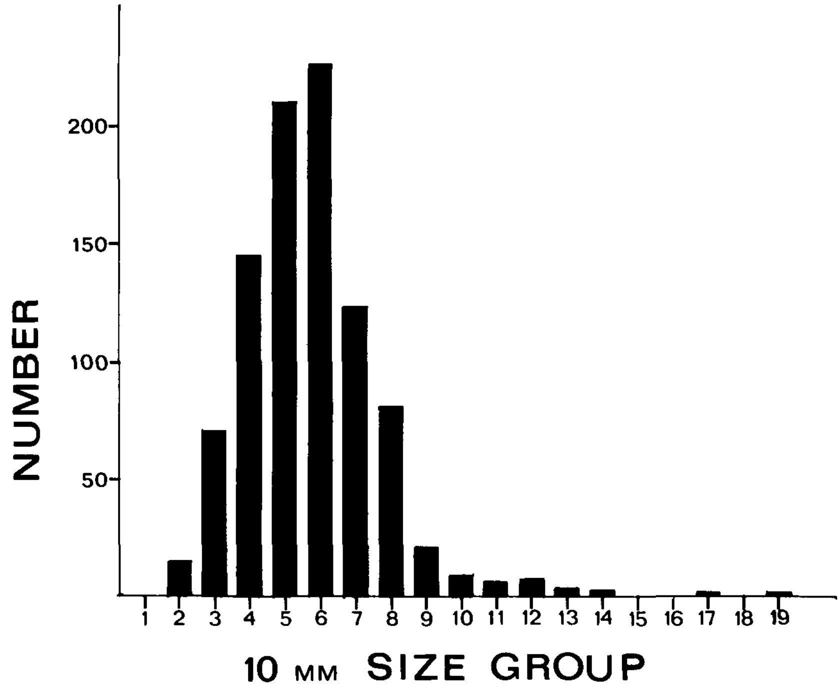

Fig. 6. Length frequency distribution of Lake Conway warmouth based on October, 1976 blocknet samples (1 = 21-30 mm; 2 = 31-40 mm; . . . . 19 = 200-210 mm).

bass fishermen, with only 2.1% of the species directed fishing pressure expended toward *Lepomis* spp. Second, warmouth are closely associated with dense submerged vegetation, a difficult habitat to fish. Finally, Lake Conway anglers do not use crayfish (the dominant food item for adult warmouth) as bait.

In other portions of its range warmouth harvest has also been proportionally lower (in reference to standing crops) than for other centrarchids. Ricker (1945), Lewis and English (1949), Kuehne (1939), and Bennett (1945) reported this phenomenon in certain Indiana, Iowa, Tennessee, and Illinois lakes, respectively. Conversely, warmouth harvest in the Okefenokee Swamp of Georgia has been estimated at 55.5% to 67.0% of the total harvest (Germann et al. 1974).

LITERATURE CITED

Bennett, G. 1945. Overfishing in a small artificial lake: Onized Lake near Alton, Illinois. Bull. Ill. Nat. Hist. Surv. 23:373-406.

Carlander, K. 1977. Handbook of freshwater fishery biology. Vol. II. Iowa St. Univ. Press. Ames. 448 pp.

Carr, A. 1939. Notes on the breeding habits of the warmouth bss. Proc. Fla. Acad. Sci. 4:108-112.

Chable, A. 1947. A study of the food habits and ecological relationships of sunfishes of northern Florida. M.S. Thesis, Univ. Fla., Gainesville. 96 pp.

Dauble, D., and R. Gray. 1977. Microfiche reader for projecting fish scale images. Progr. Fish. Cult. 39:75.

Germann, J., L. McSwain, D. Holder, and C. Swanson. 1974. Life history of the warmouth in the Suwannee River and Okefenokee Swamp, Georgia. Proc. Ann. Conf. Southeast. Assoc. Game & Fish Comm. 28:259-278.

Guillory, V. 1979. Species assemblages of fish in Lake Conway. Fla. Sci. 42:158-162.

__________, D. Jones, and M. Rebel. 1978. A comparison of fish communities in vegetated and beach habitats. Fla. Sci. 41:113-122.

__________, R. Land, D. Jones, and M. Rebel. 1977. First annual report, Lake Conway grass carp project. Fla. Game and Freshwater Fish Comm., Tallahassee. 244 pp.

Hubbs, C., and K. Lagler. 1947. Fishes of the Great Lakes region. Cranbook Inst. Sci. Bull. No. 26. 186 pp.

Jenkins, R. 1954. An estimate of the fish population in a forty-five year old Oklahoma pond. Proc. Okla. Acad. Sci. 35:69-76.

Kuehne, R. 1939. The Reelfoot Lake creel census. J. Tenn. Acad. Sci. 14:46-53.

Larimore, R. 1957. Ecological life history of the warmouth (Centrarchidae). Bull. Ill. Nat. Hist. Surv. 27:1-83.

Lewis, W., and T. English. 1949. The warmouth, *Chaenobryttus coronarious* (Bartram), in Red Haw Hill Reservoir, Iowa. Iowa State College J. Sci. 23:317-322.

McLane, W. 1955. Fishes of the St. Johns River. Ph.D. Diss., Univ. Fla., Gainesville. 360 pp.

Nikolsky, G. 1963. The ecology of fishes. Academic Press, New York. 352 pp.

Pfieffer, P. 1965. The results of a non-uniform probability creel survey on a small state-owned lake. Proc. Ann. Conf. Southeast. Assoc. Game & Fish Comm. 20:409-412.

Ricker, W. 1945. Fish catches in three Indiana lakes. Invest. Ind. Lakes Streams. 2:325-344.

Tesch, F. 1971. Age and growth. Pages 98-130 *in* W. E. Ricker (ed.). Methods for assessment of fish production in fresh water. I.B.P. Handbook No. 3. 2nd edition.

Toole, M. 1946. Utilizing stock tanks and farm ponds for fish. Bull. Tex. Game. Fish Oyster Comm. 24:1-45.

Ware, F., W. Fish, and L. Prevatt. 1972. Five year creel survey of two Florida lakes. Quart. J. Fla. Acad. Sci. 35:31-48.