ploitation will be possible before there is a need to consider restricting fishing during the shoaling period.

As a species of fish becomes of interest to anglers, a need for sound management of the fishery is often seen. This is particularly true in the case of species which have suffered severe reduction due to habitat alteration, over-exploitation, or other causes. In addition to the life history study, the authors have attempted to obtain greater utilization of river redhorse by sport fishermen through the publication of a popular article (Hackney and Tatum, 1966) and public educational media.

Attempts to sell the public on the utilization of lightly sought non-game fish are well taken. However, when a demand is developed for fishes formerly thought of in this respect, the biologist must be prepared to take whatever actions are necessary to preserve the fishery thus created.

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CENTRARCHID FOOD HABITS IN A NEW AND OLD RESERVOIR DURING AND FOLLOWING BASS SPAWNING

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ABSTRACT

Stomach contents were examined from 1,288 longear sunfish, 827 green sunfish, 1,099 bluegill, 246 largemouth bass, 144 smallmouth bass, and 304 spotted bass collected from shoreline areas of a reservoir in the process of filling and from one 15 years old, during and following bass spawning, 3 May-25 June, 1965. Young-of-the-year and bass 8.0 inches or more in length are not included.

This study suggests that in the new reservoir the food supply was ample in relation to the centrarchid population demand. In the older reservoir the opposite was true, resulting in more efficient utilization of all available foods, including appreciable quantities of bass eggs and young. However, availability was influenced to a marked extent by size of predators and prey as well as abundance. The result was food "skimming," whereby the larger fish usurped the tendipedids and large cladocerans, leaving only smaller prey available for newly hatched largemouth young.

INTRODUCTION

Haskell (1965) deplored the emphasis on measuring fish mortality without identifying causes. Among questions he asked was, "how availability of food affects survival?" This report provides information on the problem by describing centrarchid food habits during and following the spawning of black bass in a reservoir undergoing initial filling and in one 15 years old. The study parallels previous food habits work on young largemouth bass *(Micropterus salmoides)* from both waters, and of the longear sunfish *(Lepomis megalotis)*, green sunfish *(L. cyanellus)*, bluegill *(L. macrochirus)*, largemouth bass, smallmouth bass *(M. dolomieui)*, and spotted bass *(M. punctulatus)* in the older reservoir (Applegate and Mullan, 1967; Applegate, Mullan and Morais, in press).

In previous studies, midge larvae were found to have "bridged the gap" from a *Cladocera-Cyclops* to a fish diet for the faster growing young-of-the-year largemouth bass in new Beaver Reservoir. Concurrently, tendipedids were almost absent from largemouth young stomachs in older Bull Shoals Reservoir. However, older centrarchids less than four inches in length were found to rely year-round on the same cladocerans consumed and tendipedids absent from young largemouth stomachs. Significant predation of black bass eggs and fry was also indicated in the older reservoir.

DESCRIPTION AND METHODS

Bull Shoals and Beaver Reservoirs, located on the White River in the Arkansas-Missouri Ozarks, have been described (Mullan and Applegate, 1965). Bull Shoals has 45,440 surface acres and water levels fluctuated five feet below power pool (654 fsl) during the May-June study (Figure 1). Beaver Reservoir began filling in 1964, and attained 16,200 acres or 57% of power pool area in June 1965. Water levels (Figure 1) were rising during the whole of the study period at Beaver.

Nineteen electroshocker collections were made at Bull Shoals and 13 at Beaver Reservoir 3 May through 25 June 1965. Collections beginning 18 May were the source of the reported food of young largemouth (Applegate and Mullan, 1967). Collecting sites were along mid-reservoir shorelines, and were sampled only once or infrequently to minimize alteration of the normal fish complex. Mature bass (8.0+ inches total length) were not collected for the same reason.

A maximum of 20-25 stomach contents per collection were pooled within species-size groups of 0-1.9, 2.0-3.9 and 4.0-7.9 inches. A total of 3900 stomachs were examined. Volumetric measures of macroorganisms were made by water displacement in a calibrated centrifuge tube. Counts of microorganisms, in a Sedgwick-Rafter cell, were converted to volumes based on water displacement of large quantities of the organism. Known species series were used as an aid in identifying fish eggs and fry. In most instances identification was qualitative; i.e., fry, bass fry, bass eggs, etc. Fry and fingerling largemouth were generally distinguishable from spotted bass using criteria described by Applegate (1966).

RESULTS

South Central Reservoir Investigations scuba biologists observed black bass spawning beginning 24 April and extending to 25 May 1965 at Bull Shoals Reservoir, with the peak occurring about 1 May in the largemouth and 12 May for spotted bass. Kramer and Smith (1960) observed the first spawning of largemouth bass 2-5 days after water temperatures reached and remained above 60°F, and a mean length of the egg and sac-fry period of 10 days at 65.4°F. These observations accord with reservoir temperatures prevailing in the 14 days prior to beginning of sampling on 3 May and finding largemouth fry in stomachs (Figures 1 and 2).

Stomach contents during this first week of May did not correlate with a maximum of largemouth egg deposition, but did indicate maximum predation of largemouth bass 4 to 10 mm in length by the sunfish (Figure 2). Bass larvae made up 41% of the diet of 4.0+-inch green sunfish and 36% of the diet of the larger bluegills (Figure 2).

Consumption of largemouth young by 4.0+-inch green sunfish declined to 1% during the second week in May. Thereafter no bass young were eaten even though shad *(Dorosoma spp.)* and sunfish young were con-

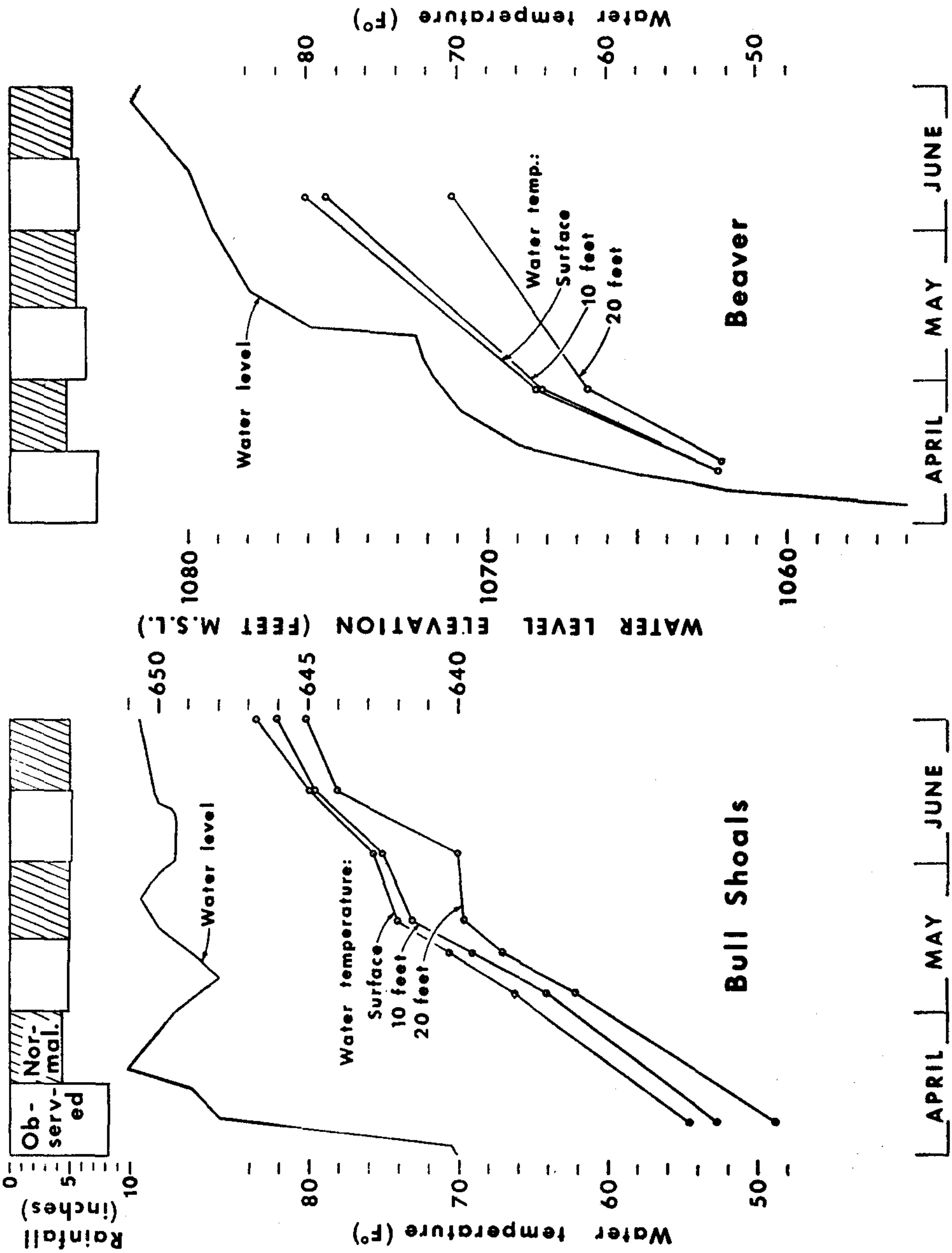

Figure 1 — Rainfall, water levels, and water temperatures prevailing at Bull Shoals and Beaver Reservoirs, April-June, 1965.

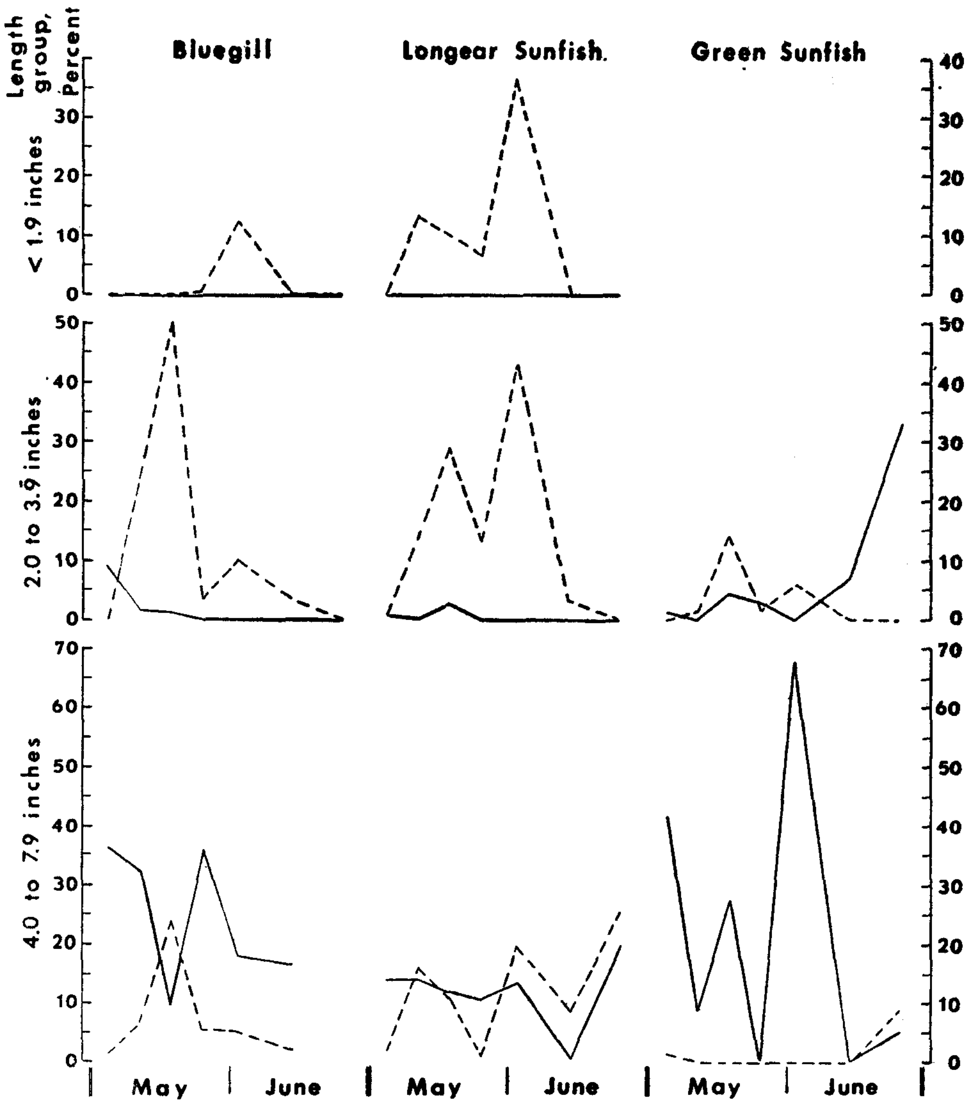

Figure 2 — Percentage of total volume of fish larvae (solid line) and fish eggs (dashed line) eaten by bluegill, longear and green sunfish, Bull Shoals Reservoir, 3 May-25 June 1965.

sumed. Large bluegill and longear sunfish also ingested moderate to heavy quantities of bass young in May and newly hatched sunfish in June (Figure 2).

Sunfish 2.0-3.9 inches in length utilized very little fish as food (Figure 2). Utilization involved bass sac-fry in early May and sunfish fry in June. However, it was this size group of sunfishes that preyed most heavily on fish eggs (Figure 2). Overall results reflect significant depredation of bass eggs during the interval 10 through 19 May by all except the larger green and the smallest bluegill sunfish. Fish eggs eaten in June were from longear sunfish nests.

The bass in Bull Shoals were largely piscivorous (Table 1 and Figure 3). In 4.0 to 7.9-inch largemouth, utilization of newly hatched bass

TABLE 1 — PERCENTAGE OF TOTAL VOLUME OF FOODS EATEN BY CENTRARCHIDS, EXCLUSIVE OF YOUNG-OF-THE-YEAR, COLLECTED FROM BULL SHOALS (1) AND BEAVER (2) RESERVOIRS DURING MAY AND JUNE 1965.

Length group	Species	Reservoir	Number examined	Number with food	Total volume (cc)	Percent of total volume											
						Fish	Fish eggs	Terrestrial foods	Aquatic insects	(Tendipedidae)	Acari	Malacostraca	Microcrustacea	Mollusca	Bryozoa	Filamentous algae	Detritus
0-1.9 inches	Bluegill	(1)	86	86	3.7	—	0.8	—	23.3	(23.3)	2.1	—	73.7	—	—	—	—
	Bluegill	(2)	60	60	1.1	—	—	—	89.5	(89.5)	—	—	10.5	—	—	—	—
	Longear	(1)	304	293	7.6	—	9.1	0.1	49.5	(45.0)	tr	—	41.2	—	—	—	—
2.0-3.9 inches	Bluegill	(1)	303	300	35.6	2.0	18.6	5.0	41.8	(39.4)	1.1	—	17.2	0.4	2.0	3.1	8.8
	Bluegill	(2)	205	203	22.1	—	0.9	12.5	86.6	(85.2)	tr	—	tr	—	—	—	—
	Green sunfish	(1)	446	429	27.5	7.1	3.6	18.6	52.3	(37.9)	0.7	1.6	12.7	1.2	0.2	—	1.9
	Green sunfish	(2)	36	35	5.2	—	—	68.9	30.5	(20.9)	0.2	—	—	—	—	—	0.4
	Longear sunfish	(1)	462	449	41.9	0.7	15.4	7.7	64.7	(58.3)	0.2	—	4.2	0.8	0.7	0.7	4.9
	Longear sunfish	(2)	27	27	5.3	—	—	—	99.5	(96.7)	tr	—	0.5	—	—	—	—
	Spotted bass	(1)	91	89	16.8	86.0	—	—	12.8	(7.7)	—	—	0.6	—	—	—	0.6
	Smallmouth bass	(1)	59	53	7.6	78.6	tr	0.7	16.8	(16.1)	0.1	—	3.4	—	—	—	0.3
4.0-7.9 inches	Bluegill	(1)	332	330	173.6	25.5	8.1	18.4	24.1	(23.3)	0.3	—	3.0	tr	6.1	0.6	13.1
	Bluegill	(2)	113	113	147.7	—	0.7	67.9	24.5	(21.8)	tr	3.7	tr	—	0.3	—	2.8
	Green sunfish	(1)	300	238	91.9	32.7	0.9	23.6	21.1	(17.6)	—	13.5	tr	tr	1.6	—	6.5
	Green sunfish	(2)	45	31	28.4	11.6	0.4	61.1	6.3	(4.6)	—	12.7	—	0.7	—	—	7.2
	Longear sunfish	(1)	445	428	118.5	12.0	10.8	18.6	42.1	(39.7)	—	3.1	1.0	0.1	0.3	—	12.0
	Longear sunfish	(2)	50	41	29.0	—	—	76.2	19.8	(18.3)	—	—	0.4	—	—	—	3.6
	Largemouth bass	(1)	161	131	78.9	99.1	—	0.6	0.3	(0.0)	—	—	—	—	—	—	tr
	Largemouth bass	(2)	85	68	56.5	33.6	—	58.4	—		—	8.0	—	—	—	—	—
	Spotted bass	(1)	194	132	90.3	93.1	—	0.8	3.6	(2.2)	—	—	—	—	—	—	2.3
	Spotted bass	(2)	19	12	10.1	30.1	—	39.9	—		—	30.0	—	—	—	—	—
	Smallmouth bass	(1)	85	62	40.8	95.6	—	0.3	2.8	(0.3)	—	0.3	—	—	—	—	1.0

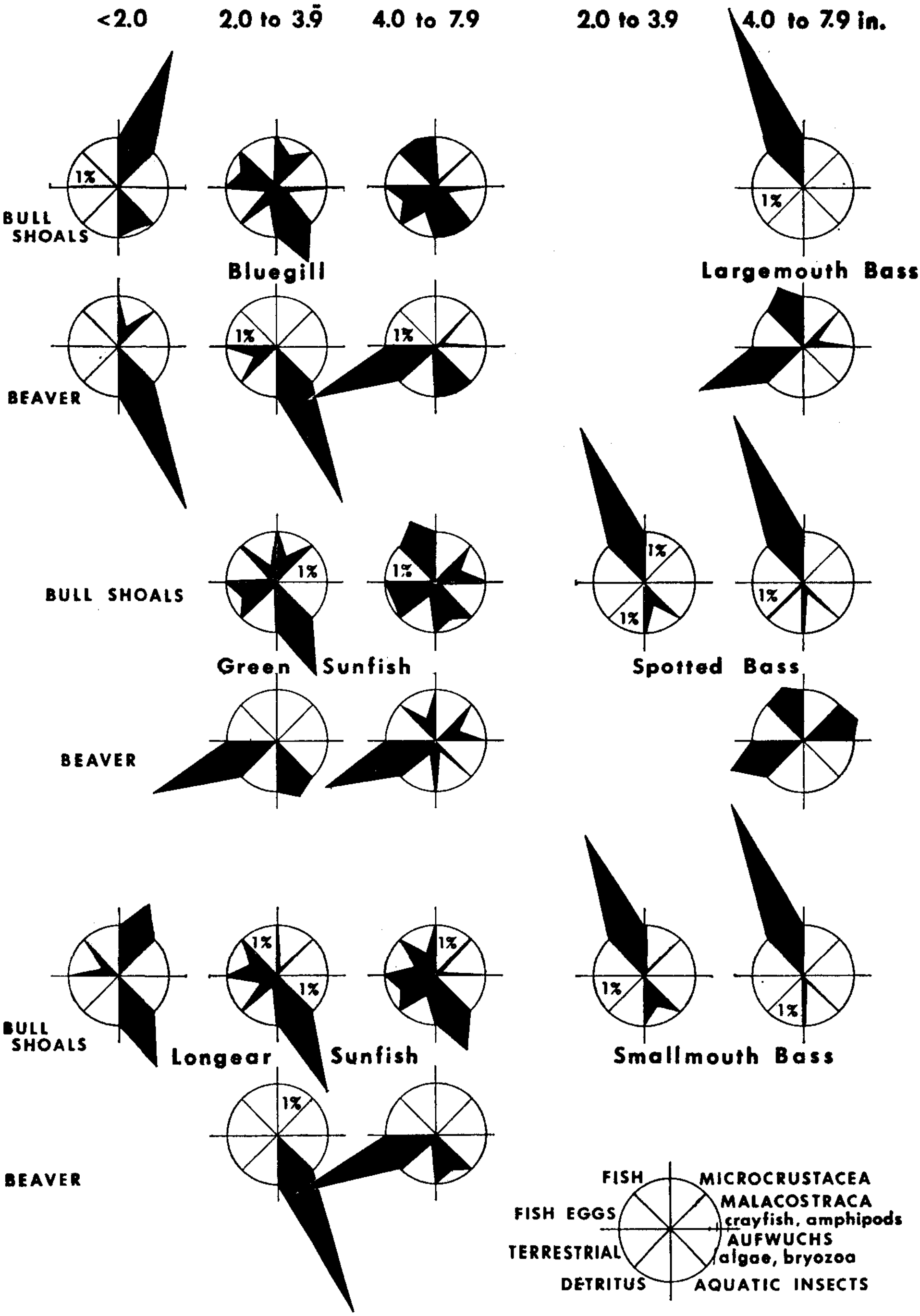

Figure 3 — Food of principal centrarchids collected by electroshocker from Beaver and Bull Shoals Reservoirs, 3 May-25 June 1965, grouped in size categories of 0-1.9, 2.0-3.9, and 4.0-7.9 inches total length. Area within the radius of a food category section represents 25 percent of stomach volume.

amounted to less than 1% of the diet. Prey was primarily shad, sunfish, and non young-of-the-year black basses. Consumption of bass young by similar size spotted and smallmouth bass ranged from 5% to about 25% (if a proportion of the unidentified fry are included). For example, 26% of the spotted bass diet during the first week of June consisted of largemouth bass averaging 32 mm in length. Another 36% of the total food consisted of the same size fingerlings which could not be identified. Peak use of both categories by all three bass species occurred during the last week in May and the first week in June when mean lengths of largemouth young-of-the-year ranged from 24 to 32 mm.

Spotted and smallmouth bass 2.0-3.9 inches in length were only slightly less piscivorous than larger specimens (Table 1 and Figure 3), but the majority of the prey consisted of bass young. Weekly totals beginning 3 May through 3 June for spotted bass were: 3% unidentified fry, 47% unidentified fry, 98% bass fingerlings, 93% bass fingerlings, 95% bass fingerlings and 5% unidentified. Usage by smallmouth 18 May through 3 June ranged from 66 to 100%. Largemouth averaging 18 mm in length first appeared in electrofishing samples on 18 May coincident to the beginning of the maximum incidence of bass fry in stomachs.

In Beaver Reservoir, by contrast, fish made up less than one-third of the diet of 4.0-7.9 inch spotted and largemouth bass (Table 1 and Figure 3). In the sunfish group, only the larger green sunfish were found to have included fish in their diet (10%) and the bluegill, fish eggs (1%). Shad were the principal forage fishes consumed. Only 2% of the diet of largemouth was found to consist of bass fry.

Terrestrial foods. The sunfishes in both reservoirs used substantial quantities of terrestrial foods, with Beaver Reservoir fish consuming far greater amounts (Figure 3). This was primarily due to the availability of earthworms inundated by the rising water level (Table 2). Even the piscivorous largemouth bass responded, depicted by a 53% consumption (Table 2). The only major terrestrial food common to both reservoirs was June beetles *(Phyllephaga spp.)*

Aquatic insects. Tendipedidae dominated the aquatic insects eaten in major quantities by all of the sunfishes (Table 1). Usage in the new reservoir was substantially greater.

Microcrustacea. Microcrustacea formed a far greater proportion of the food of fish from the older reservoir, with major utilization occurring in fish under 2.0 inches in length (Figure 4). Utilization in the new reservoir centered on a few large cladocerans. In the older reservoir these same forms comprised minor quantities ingested by the larger fish, and were less well represented in the smaller fish (Figure 4).

DISCUSSION

Competition for food among animals occupies a central position among all facets of the struggle for existence (Ivlev, 1961). Although the need for more knowledge is widely recognized, the complexity and detail involved in food relationships present near insurmountable obstacles to full understanding. A case in point involves the exceptional fish harvests observed in young impoundments, variously explained by the interdependent factors of an initially high primary food source and/or chronological increases in fish population densities which alter but do not impair food productivity (Stroud, in press).

Beaver Reservoir during its second year of impoundment supported a lesser fish population than the older Bull Shoals Reservoir. Relative differences in densities and population structure of centrarchids occurring in littoral areas during the study are indicated by total electrofishing catches beginning 18 May (Figure 5). Standing crops of euplankton

TABLE 2 — PERCENTAGE OF VOLUME OF TERRESTRIAL FOODS EATEN BY CENTRARCHIDS COLLECTED FROM BULL SHOALS (1) AND BEAVER (2) RESERVOIRS DURING MAY AND JUNE 1965.

Length group	Species	Reservoir	Total percent	Percent of total volume						
				Oligochaets	Insects	Molluscs (slugs)	Arachnoid (spiders)	Centipedes	Skinks	Pill bugs
0-1.9 inches	Longear sunfish	(1)	0.1		0.1					
2.0-3.9 inches	Bluegill	(1)	5.0		5.0					
	Bluegill	(2)	12.5	9.3	2.7					0.5
	Green sunfish	(1)	18.6	0.2	16.9		1.5			
	Green sunfish	(2)	68.9	68.5	0.4					
	Longear sunfish	(1)	7.7	0.5	7.2		tr			
	Smallmouth bass	(1)	0.7		0.7					
4.0-7.9 inches	Bluegill	(1)	18.4		18.4					
	Bluegill	(2)	67.9	58.2	8.9		0.2	0.4		0.2
	Green sunfish	(1)	23.6	0.1	20.2				3.3	
	Green sunfish	(2)	61.1	27.4	28.4		4.2	0.4		0.7
	Longear sunfish	(1)	18.6	tr	18.6					
	Longear sunfish	(2)	76.2	35.5	36.2	3.5	0.5	0.3		0.2
	Largemouth bass	(1)	0.6		0.6					
	Largemouth bass	(2)	58.4	53.1	5.3					
	Spotted bass	(1)	0.8		0.8					
	Spotted bass	(2)	39.9	5.9	34.0					

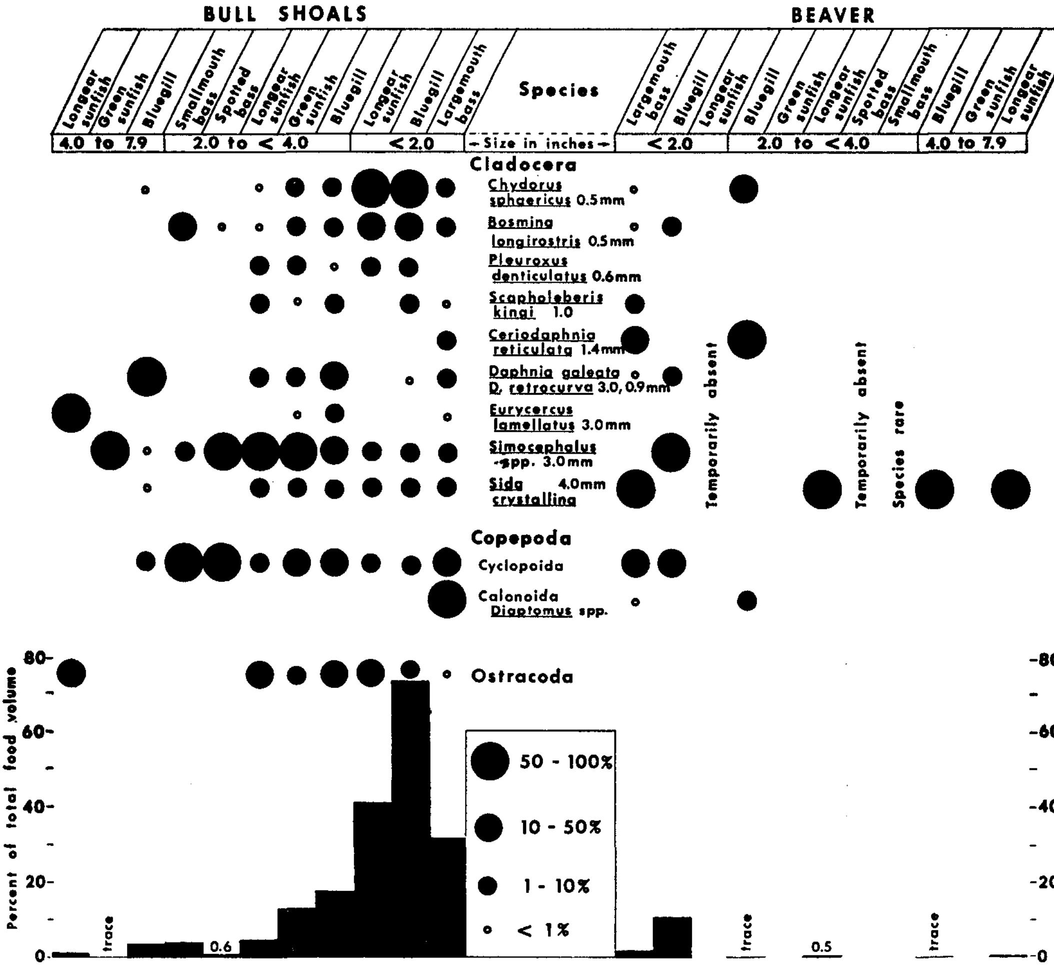

Figure 4 — Utilization of microcrustacea by centrarchids 0-1.9, 2.0-3.9, and 4.0-7.9 inches, total length, Bull Shoals and Beaver Reservoirs, May-June 1965. Size of circles indicates relative percent occurrence, with *Cladocera* (top center) arranged in order of increasing maximum size of females as listed by Ward and Whipple, 1959. Percent of total food volume indicated by histograms.

(open water forms) were similar, but tychoplankton (benthic forms) abundance was greater in the new reservoir (Applegate, et al., in press, b). Food habit studies (Applegate, et al., 1967, in press, a and c; Mullan, et al., in press) and unpublished data indicated a significantly greater abundance and availability of benthos in the new reservoir, augmented by appreciable quantities of terrestrial animal foods not present in the older reservoir.

Under these circumstances of low fish population density and high food abundance in new Beaver Reservoir, the low incidence of fish eggs and bass young in stomachs is not surprising. Conversely, the older reservoir represented a situation where food was less ample in relation to demand. This resulted in a more efficient utilization of all available foods, including a greater abundance and use of bass eggs and larvae.

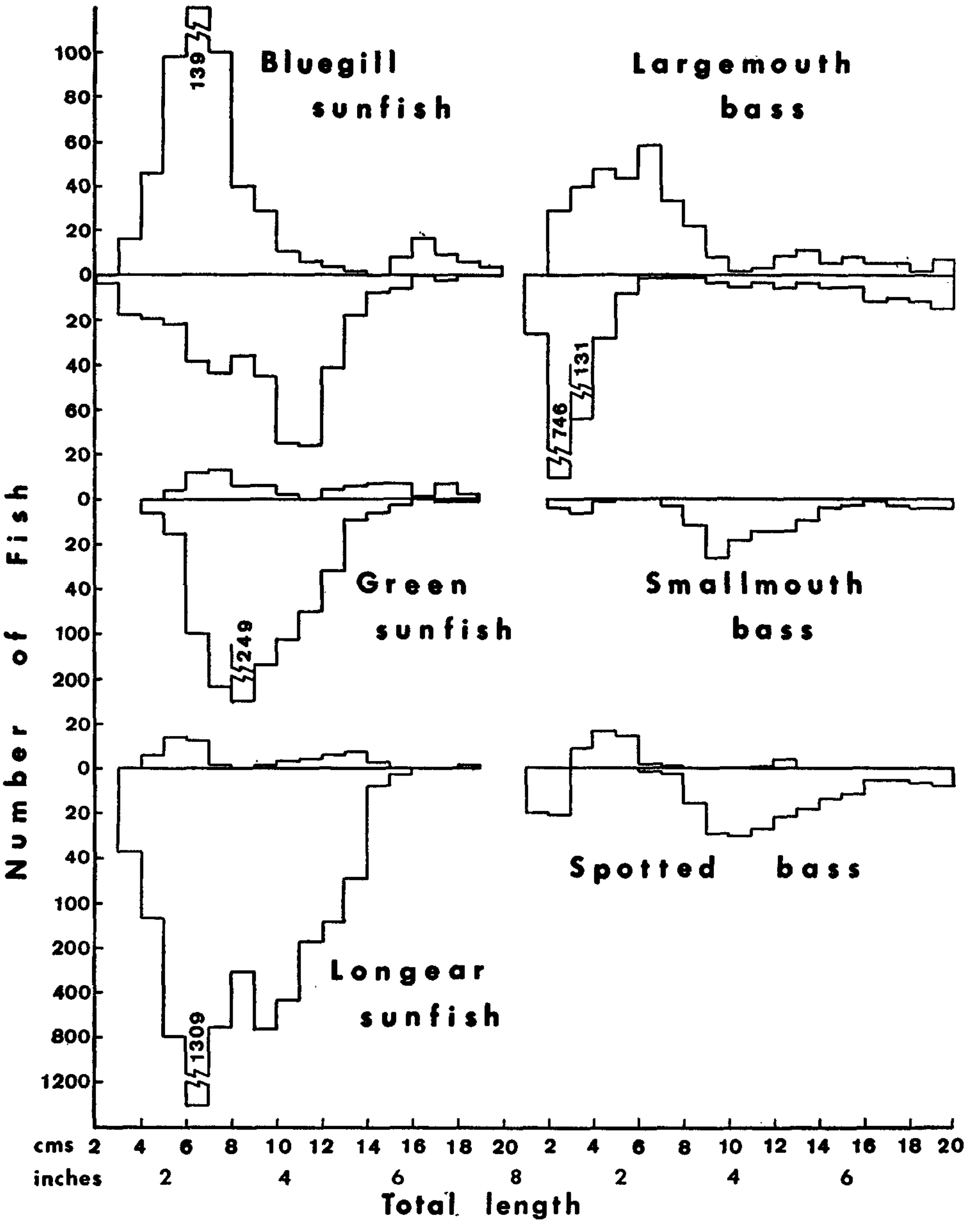

Figure 5 — Length-frequency histograms of total centrarchids under 8.0 inches in length collected electro-fishing at Beaver (top) and Bull Shoals (bottom) Reservoirs 18 May-25 June, 1965.

Ivlev (1961) demonstrated the preference of predators in devouring foods of the largest possible size, with morphological features imposing a limiting and optimum size of the principally utilized prey. This trophic principle does not exclude ingestion of smaller prey, but decreases utilization below the optimum size. The observed result was food sieving whereby the larger fish usurped the supply of tendipedids and large cladocerans in the older reservoir, leaving only smaller prey available for newly hatched largemouth young. Predator-prey size interdependence was also indicated in the chronology of predation on young bass by the different size groups of predators as well as the heavy use of fish eggs by 2.0-3.9 inch sunfishes.

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