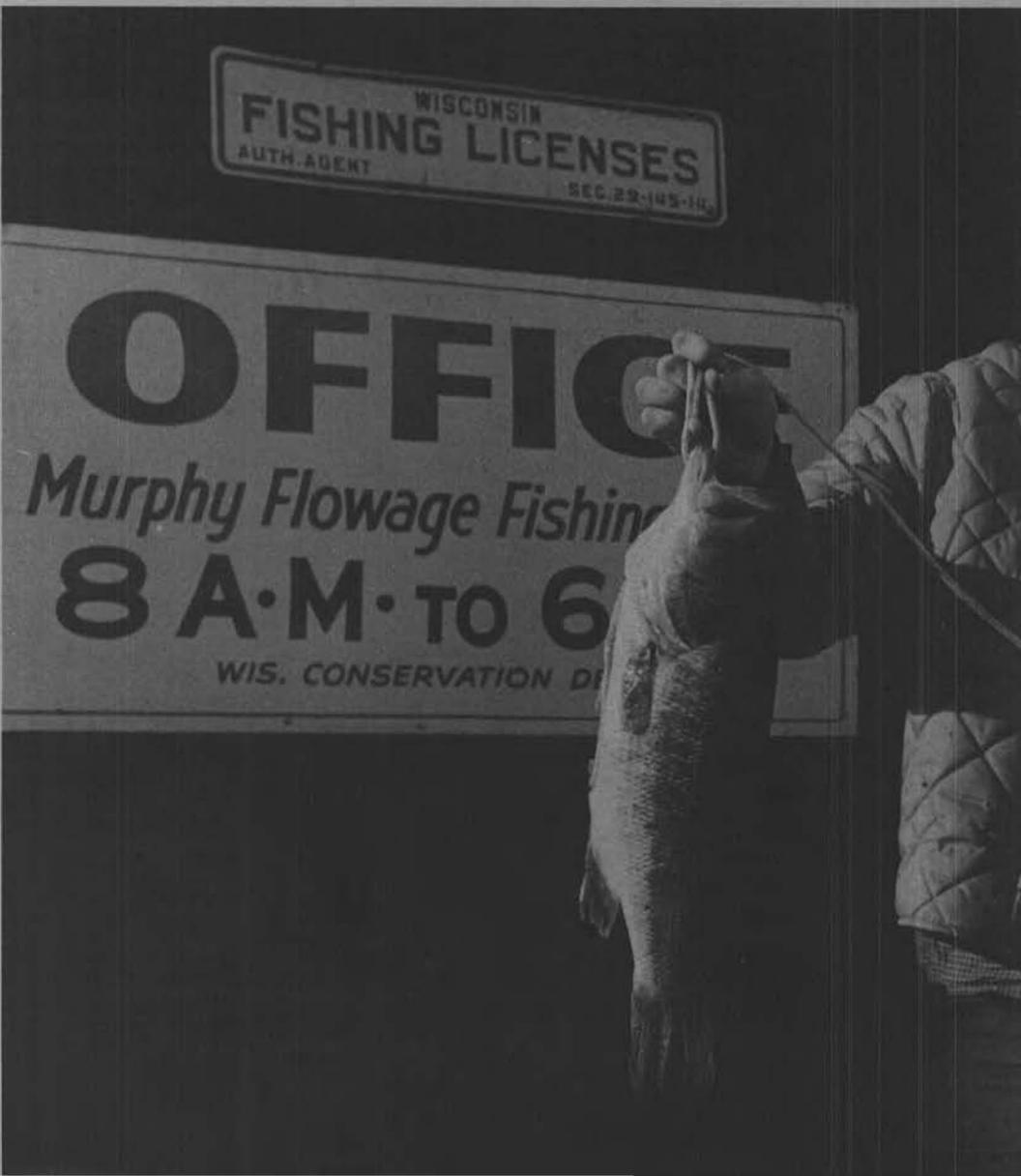


DEPARTMENT OF NATURAL RESOURCES  
Madison, Wisconsin 53701

**HARVEST AND FEEDING HABITS  
OF LARGEMOUTH BASS IN  
MURPHY FLOWAGE, WISCONSIN**



**Technical  
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**1971**

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The author is a Fishery Biologist with the Bureau of Research at Spooner, Wisconsin.

Edited by Susan Nehls

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By Howard E. Snow

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## ABSTRACT

From 1955 through 1969, the harvest and feeding habits of largemouth bass in Murphy Flowage were studied under liberalized fishing regulations and a compulsory creel census. The annual harvest of bass by anglers averaged 2.7 fish or 2.8 pounds per acre. Bass fishing was most productive during May and June and before 8 a.m. and after 8 p.m., the catch of female bass exceeding the catch of male bass during all months except June.

In contrast to almost equal use of live baits and artificial lures, about 75 percent of all bass were taken on artificial lures. The introduction and subsequent popularity of new lures affected the annual percentages of bass taken on different types of artificial lures. The greatest number and the largest fish were taken on artificial lures.

Feeding habits were influenced by degree of satiation, sex of fish, spawning activities, water temperature and time of day.

Of the total weight of all items consumed by bass, crayfish comprised 54.6 percent, fish (mainly bluegills and bullheads), 38.8 percent and insects, 1.5 percent. As bass increased in size, the size of bluegills and crayfish consumed increased, but the size of bullheads consumed did not. The ratio of prey length to predator length, however, generally decreased with increasing sizes of bass for crayfish and bullheads but not for bluegills.

Factors found to affect bass selectivity of bullheads, bluegills and crayfish were preference, accessibility and abundance, respectively. Prior to an overwinter drawdown, crayfish were the most important item consumed, bullheads were positively selected and bluegills were neither selected nor avoided. After the drawdown, which was accompanied by a known decline in aquatic vegetation abundance and an apparent decline in crayfish abundance, consumption of bluegills increased.

In environments where bullheads and/or abundant crayfish are present in the same body of water as bluegills, drawdown might be used to alter the feeding habits of bass to make bass more selective predators on bluegills.

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The purpose of this paper is to summarize information on the harvest, method of capture, feeding habits and related data on the largemouth bass, *Micropterus salmoides* (Lacepede), in Murphy Flowage. This study differs from most other bass feeding studies because it covers an extended period of time and concerns bass which were caught by anglers and were therefore in the active process of feeding at the time of capture. No bag, season or size limits have been in effect on this native population of bass at any time since the first segment of the study was started in 1955.

Other Murphy Flowage studies conducted concurrently with the bass studies have made it possible to relate various fishing and population parameters to the largemouth bass population. Total fishing pressure is compared with the harvest of bass to determine times of highest fishing success. Environmental changes are compared with food availability and utilization by bass to determine changes in feeding habits. The times and methods of the most productive fishing for bass are shown.

Several investigators have questioned the effectiveness of largemouth bass as a predator on bluegills (Lewis, 1968 and Bennett, 1951). The bluegill population in Murphy Flowage is extremely abundant and relatively slow growing. Therefore, one of the most important objectives of this report was to determine the extent to which bass utilize the bluegills. I hoped to answer these questions: (a) whether certain species or sizes of forage items are selected or whether items are utilized in the same ratio that they exist in the environment, (b) whether or not any management technique could alter the feeding habits of bass if bluegills are not a major food item and (c) whether or not bass compete for the same forage as do other predators such as northern pike. Standing crop estimates of all species, food studies of the major predators and environmental changes are presented to provide answers to these and other questions.

Findings from this Murphy Flowage study should provide basic information on the feeding ecology of largemouth bass and also a basis for improved management of this species.

## DESCRIPTION OF AREA

Formed in 1937 by the impoundment of Hemlock Creek, a trout stream, Murphy Flowage is located in northwestern Wisconsin in the headwaters region of the Red Cedar River, a tributary of the Chippewa and Mississippi rivers. The flowage has an elevation of 1,258 feet and is located within a hilly rocky region known as the Barron Hills. Although the maximum depth of Murphy Flowage is 14 feet, over 70 percent is less than 10 feet in depth. The 180-acre flowage has a volume of 874.2 acre-feet of water and has 6.8 miles of irregular shoreline. The average annual alkalinity is 37 ppm and the mean annual flow at the outlet is 18.4 cfs (Fig. 1). Beard (1969) found 24 species of aquatic plants present in Murphy Flowage in 1967. *Potamogeton Robbinsii* was the most abundant species and covered an area of approximately 104 acres. Other common species in order of decreasing abundance were *Nuphar* spp., *Ceratophyllum demersum*, *Myriophyllum* spp. and

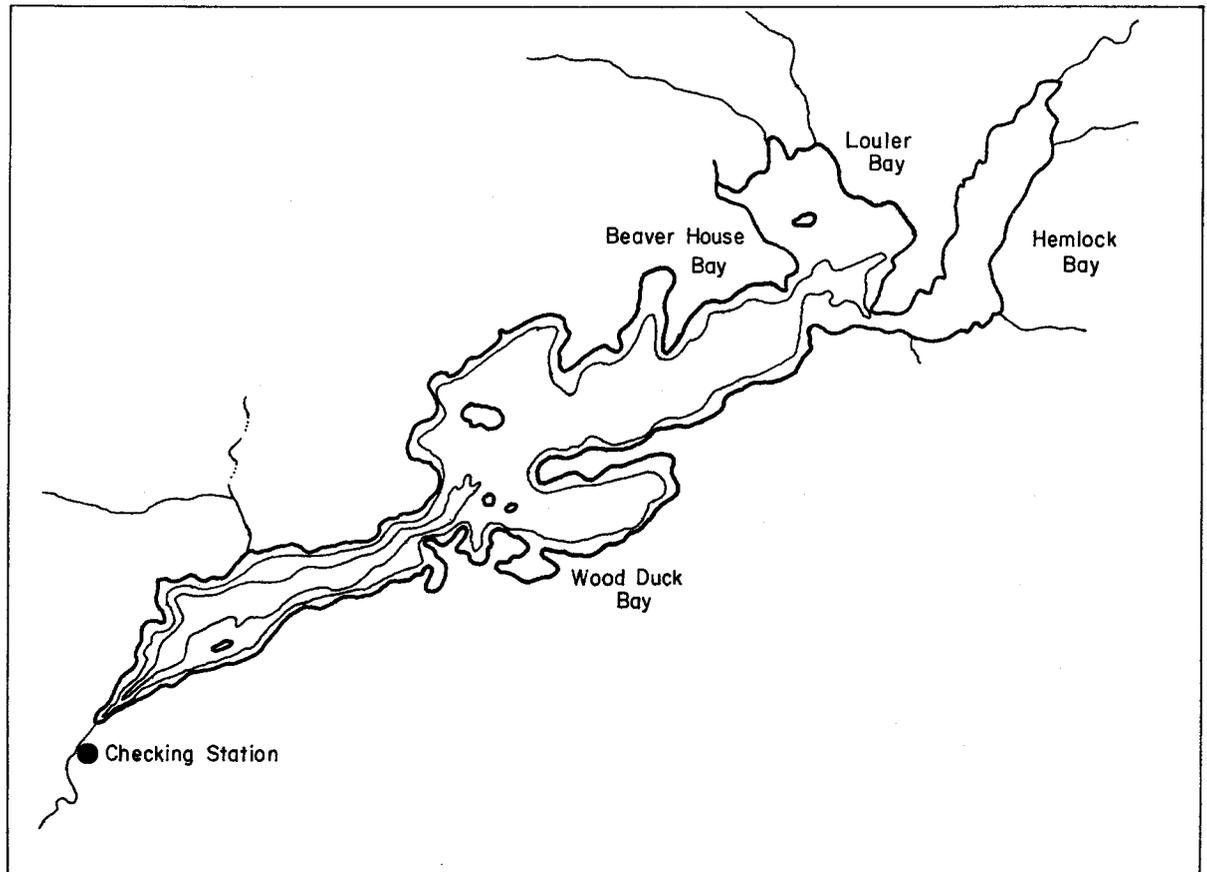
*Potamogeton amplifolius*. Clearly, a large percentage of the total area is covered by dense aquatic vegetation.

The total biomass of fish at Murphy Flowage approximates 325 pounds per acre (25 pounds of game fish and 300 pounds of panfish). The largemouth bass, *Micropterus salmoides* (Lacepede), comprises about 30 percent of the total pounds per acre of game fish and the northern pike, *Esox lucius* Linnaeus, about 60 percent. The bluegill, *Lepomis macrochirus* Rafinesque, comprises about 80 percent of the total pounds per acre of panfish. Other panfish present are the black crappie, *Pomoxis nigromaculatus* (LeSueur); pumpkinseed, *Lepomis gibbosus* (Linnaeus); rock bass, *Ambloplites rupestris* (Rafinesque); yellow perch, *Perca flavescens* (Mitchill) and brown bullhead, *Ictalurus nebulosus* (LeSueur). The white sucker, *Catostomus commersoni* (Lacepede); the tadpole madtom, *Noturus*

*gyrinus* (Mitchill) and several species of minnows are present in limited numbers. Muskellunge, *Esox*

*masquinongy* (Mitchill), have been stocked but are not numerous.

Figure 1. Contour map of Murphy Flowage.



### SPORT FISHERY

The long term nature of this study makes it possible to compare various fishing statistics over a wide range of conditions. Fishing pressure, harvest and fishing quality have displayed considerable annual and seasonal variation throughout the 15-year study.

Aside from the first year of the study, the pattern of fishing pressure falls into three groups (Table 1). From 1956 to 1959, fishing pressure was over 100 hours per acre. During and after a panfish removal program in 1960 and 1961, the pressure fell within a range of 60.5 to 74.9 hours per acre (1960-64). The second year after northern pike stocking in December, 1963, the pressure declined further to a range of 40.6 to 56.2 hours per acre (1965-69). The 224-percent variation in pressure which has occurred can be attributed in part to: (1) a decline in fishing quality resulting from the removal and stocking programs and from the declining growth and increasing abundance of the major panfish species, and (2) an intentional decline in publicity after 1960.

averaged 1.8 fish per hour and varied from a high of 3.3 to a low of 1.3 (Table 1). This extreme annual variation is related in part to changes in the density of fish populations but can be attributed largely to seasonal variation in fishing pressure (Snow, unpublished). In years when ice conditions are good, the winter catch rate per hour makes the annual catch rate higher than in years when ice conditions are bad. The winter catch rate has varied from 1.2 to 8.5 fish per hour, while summer catch rates have ranged from 1.2 to 2.0.

In contrast to the variation in the number of fish caught per hour, the pounds of fish caught per hour has been quite stable, varying annually from 0.3 to 0.6 pounds per hour. The variations that do exist are the result of seasonal changes in fishing pressure similar to those that affect the number of fish caught per hour.

The total harvest by anglers was 373,515 fish which, on an annual basis, amounted to 138.3 fish weighing 30.4 pounds per acre (Table 1). The average annual percentage composition (by species) of the numbers of fish caught was: bluegill 83.8, yellow

perch 4.4, black crappie 3.7, northern pike 2.1, rock bass 2.1, pumpkinseed 1.9, largemouth bass 1.7, brown bullhead 0.1 and muskellunge 0.1. Although

largemouth bass comprised only 1.7 percent of the total number of fish harvested, they made up 8.0 percent of the total harvest by weight.

**STUDY AREA  
CONTINUED**

## STUDY PERIOD

The time periods covered by various segments of this study vary considerably. Data on annual fishing pressure, harvest and success cover the period from April, 1955 through April, 1970. Data on the anticipated bait and on monthly catch and pressure

cover the period from April, 1957, (the first year of machine tabulation of data), through October, 1969. All data on stomach analyses cover the period from 1960 through 1964, and on the actual bait used, from 1960 through 1969.

TABLE 1

Annual Fishing Pressure, Harvest and Fishing Quality for all Species of Fish in Murphy Flowage, 1955-1969

Year	Pressure		Harvest				Quality	
	No. Fishing Trips	Hours Fished per acre	No. Fish		Pounds Fish		Fish Caught Per Hour	
			Total	Per Acre	Total	Per Acre	No.	Lbs.
1955	2,718	62.7	14,067	78.1	3,986	22.1	1.3	0.4
1956	4,156	104.5	31,595	175.5	8,191	45.5	1.7	0.4
1957	4,802	105.6	36,005	200.0	8,441	45.8	1.9	0.4
1958	5,993	131.4	43,519	241.8	10,043	55.8	1.8	0.4
1959	5,305	114.6	44,837	249.1	9,036	50.2	2.2	0.4
1960	3,689	73.3	43,288	240.5	7,826	43.5	3.3	0.6
1961	3,554	66.5	23,508	130.6	5,301	29.6	2.0	0.4
1962	3,987	74.9	23,134	128.6	5,288	29.4	1.7	0.4
1963	3,779	74.1	27,228	151.3	5,682	31.6	2.0	0.4
1964	3,112	60.5	17,944	99.7	3,951	22.0	1.7	0.4
1965	2,574	47.6	12,593	70.0	2,671	14.8	1.5	0.3
1966	2,288	40.6	11,907	66.1	2,552	14.2	1.6	0.4
1967	2,382	45.4	15,312	85.1	3,773	21.0	1.9	0.4
1968	2,304	46.0	11,211	62.3	2,601	14.4	1.4	0.3
1969	2,959	56.2	17,310	96.1	3,428	19.0	1.7	0.3
AVG.	3,576	73.8	24,901	138.3	5,491	30.4	1.8	0.4

## ESTIMATES OF FISHING EFFORT, HARVEST AND SUCCESS

Complete angling records have been collected by means of a compulsory creel census which has been in effect since April 30, 1955. Each angler was required to obtain a free permit at the Department checking station before fishing and to return the permit and present all fish caught for inspection and measurement at the close of the day's fishing.

At the beginning of each fishing trip, the anticipated bait to be used and other data were recorded for each angler. At the end of each trip these data were recorded: the amount of time spent fishing, the number of each species caught, the actual bait that bass were caught on and the actual time of capture based on the angler's estimate to the nearest ½ hour interval. Since 1957, some of these and other pertinent data have been recorded in code form for machine tabulation (Churchill and Snow, 1964).

All largemouth bass were examined by Department personnel and were measured to the nearest

1/10 inch in total length and 1/100 pound in total weight. Sex was determined by dissection and visual examination of the gonads. Dissection of fish was not performed if anglers objected to it or if they might have been inconvenienced by it during peak rush hours.

Throughout this report an angling year includes the open water season plus the ensuing ice fishing season. All annual figures given therefore include data from two calendar years, on the average from April 15 of one year to April 15 of the following year. Neither a bag, season or size limit was in effect on Murphy Flowage at any time during the study. Angling was permitted from 4 a.m. to 10 p.m. in the summer and from 8 a.m. to 6 p.m. in the winter. Because 98.5 percent of the total catch of largemouth bass occurred during the open water seasons, all data, except totals in the "Sport Fishery" section, cover only this period.

**METHODS**

**STOMACH ANALYSES**

When possible, the bass were dissected and their stomachs examined. Stomachs which felt empty were not opened for further analyses. Stomachs which felt as if they contained any amount of food were classified as full and were removed, wrapped in cheese cloth or put in perforated plastic bags and preserved in 10-percent formalin solution. Information from the whole fish on total length, sex, time caught and actual bait used was recorded and kept with each stomach. A total of 573 stomachs with food were collected during the five open water seasons. Since only one stomach was from a fish taken in April, all information presented on stomach contents covers the period from May 1 through October 31.

Stomach contents were identified to species whenever possible and weighed to the nearest gram. Fish food items were measured to the nearest 1/10 inch in total length and crayfish, to the nearest 1/10 inch (from the tip of the acumen to the posterior edge of the telson with the body fully extended). When digestion had progressed sufficiently so that a

food item could not be identified to species, either it was classified into one of the major taxonomic groups, or if this was not possible, the item was recorded as "remains." Numerical tabulations of food items consisted of determining percent frequency of occurrence, percent total weight, relative size and number per stomach, and are based on 573 stomachs containing food.

Because of the methods of collection it is possible that some stomachs with small amounts of food were not collected. Those that would have been omitted would likely have contained less than two grams of food since this was about the minimum weight of total contents recorded. Additional errors could be the result of regurgitation, since several hours could have elapsed between the time of capture and examination of the stomach. These and other possible sources of error can affect the results, especially regarding the percentage of empty stomachs, and must be kept in mind when comparisons are made with other studies.

**HARVEST**

**NUMBERS OF FISH CAUGHT**

**ANNUAL HARVEST**

The annual catch of largemouth bass, which varied less than the catch of any other species, averaged 478 fish and ranged from a low of 302 to a high of 808 fish. On a per-acre basis, this averaged 2.7 fish, weighing 2.8 pounds per acre. At no time did the annual catch exceed 5 fish or 5 pounds per acre (Table 2). These results are quite similar to those reported for Gladstone Lake, Minnesota (Maloney et al., 1962) where the yield of bass was 3.2 pounds per acre, but are considerably less than harvests reported for some areas further south where an annual yield as

high as 29.5 pounds per acre was found in Alabama's public fishing lakes (Byrd, 1959).

**MONTHLY AND SEASONAL HARVEST**

The total catch of largemouth bass from 1955 through 1969 was 7,176 fish. Of this total, 29.7 percent, were taken in June and 73.1 percent during the three-month period from May through July (Table 3). Approximately two percent of the total catch was taken in the last half of April when the spring break-up of ice made open water fishing

TABLE 2  
Annual Harvest of Largemouth Bass, 1955-1969

Year	Total Fish Caught		Fish Caught Per Acre	
	Number	Pounds	Number	Pounds
1955	561	577.6	3.1	3.2
1956	808	830.5	4.5	4.6
1957	529	528.1	2.9	2.9
1958	547	611.5	3.0	3.4
1959	531	589.8	3.0	3.3
1960	398	439.5	2.2	2.4
1961	424	422.8	2.4	2.3
1962	500	512.2	2.8	2.8
1963	449	496.8	2.5	2.8
1964	413	426.7	2.3	2.4
1965	302	264.6	1.7	1.5
1966	318	346.3	1.8	1.9
1967	398	367.1	2.2	2.0
1968	535	586.7	3.0	3.3
1969	463	426.2	2.6	2.4
TOTAL	7,176	7,426.4	39.8	41.3
AVG.	478	495.0	2.7	2.8

TABLE 3  
Monthly Harvest of Largemouth Bass, 1955-1969

Month*	Total Fish Caught		Average Total Length (In Inches)
	Number	Percent	
April	116	1.6	13.2
May	1,377	19.2	12.1
June	2,128	29.7	11.7
July	1,732	24.2	11.7
August	1,107	15.4	11.3
September	560	7.8	11.3
October	53	0.7	11.6
December	31	0.4	11.2
January	30	0.4	11.2
February	27	0.4	10.4
March	15	0.2	14.7
Total	7,176	100.0	
Average			11.7

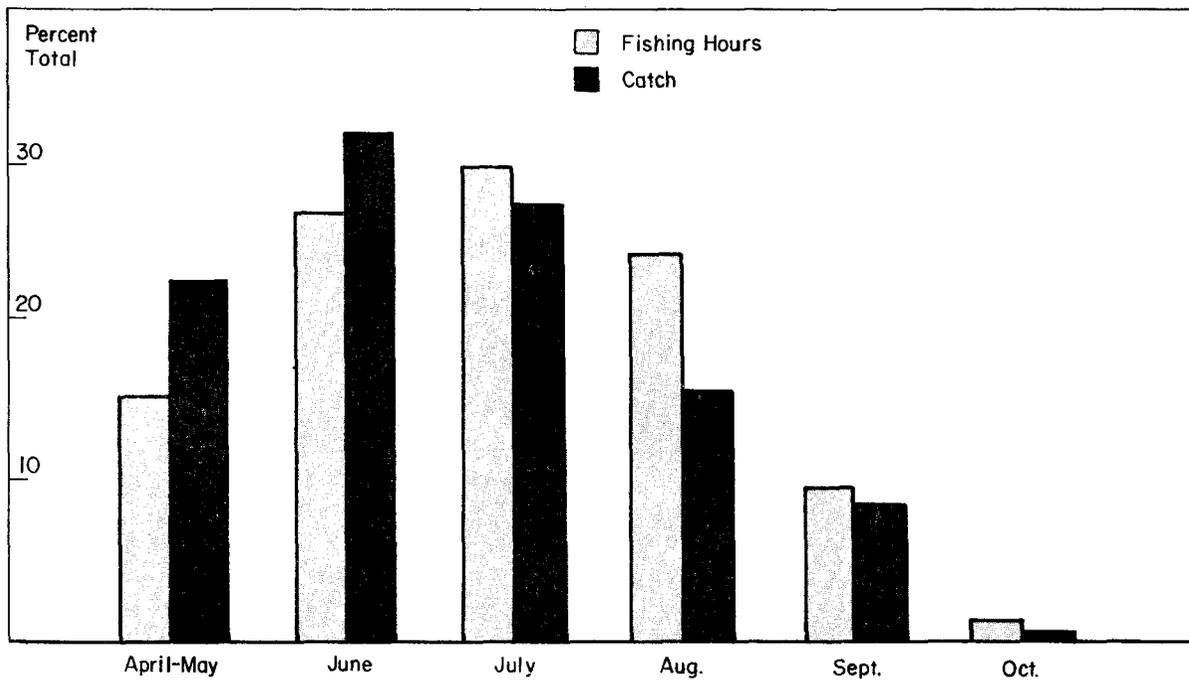
\*No Bass were caught in November.

possible. Only 1.4 percent of the total catch was taken in the winter months. Comparisons showed that these monthly averages were quite similar to the actual monthly catch statistics for each year, during most years of the study.

The most successful months for bass fishing were May and June (Fig. 2). In proportion to the total fishing effort, these months produced the highest proportion of the catch. For example, 15

percent of the total fishing hours produced 21 percent of the total catch of bass during May. (Approximately one percent of the total catch and fishing pressure occurred in the last half of April, so these data were included with the data for May in figure 2.) The third most successful month, after May and June, was September when 9 percent of the total fishing hours produced 8 percent of the total catch of bass.

Figure 2. Monthly distribution of total fishing hours and total catch of largemouth bass, 1957-1969.

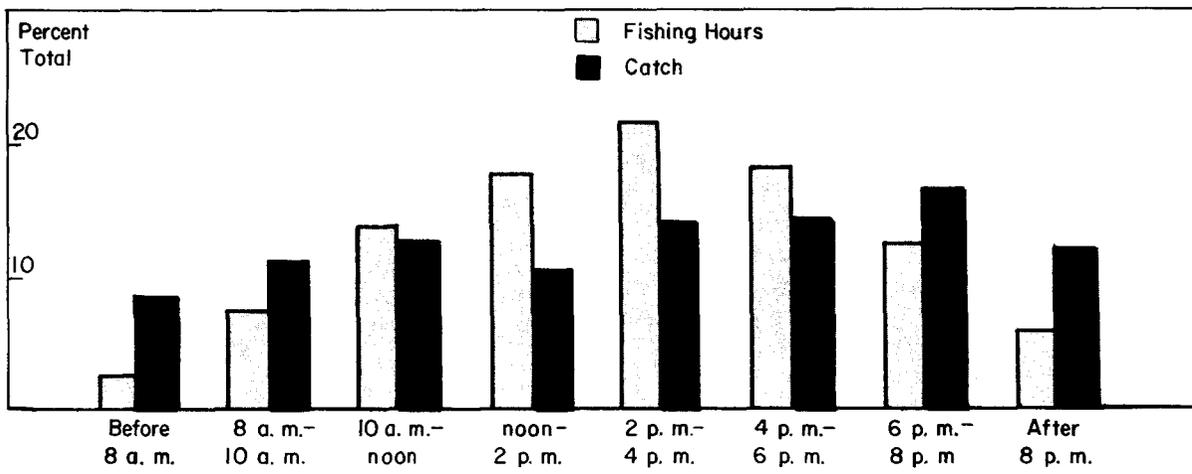


**HOURLY HARVEST**

The actual time of capture was recorded for 3,148 largemouth bass from 1960 to 1968. Although the actual time was recorded in half-hour intervals, the data were usually summarized in two-hour intervals.

In proportion to the total hours fished, the most successful time of the day to catch largemouth bass was before 8 a.m. or after 8 p.m. (Fig. 3). Before 8 a.m., 2.5 percent of the fishing hours produced 8.5 percent of the total fish caught while after 8 p.m., 6 percent of the fishing hours produced 12 percent of

Figure 3. Diurnal distribution of total catch of all bass taken during open-water seasons, 1960-69.



the total bass caught. The time of capture reached two peaks throughout the day: one between 10 a.m. and 12 a.m., when 13 percent of the total number of bass harvested were caught, and another between 6 p.m. and 8 p.m. when 17 percent were caught. These diurnal peaks were somewhat similar to those found in 1960 and 1961 when pronounced peaks occurred between 8 a.m. and 10 a.m. and between 6 p.m. and 8 p.m. (Churchill and Snow, 1964).

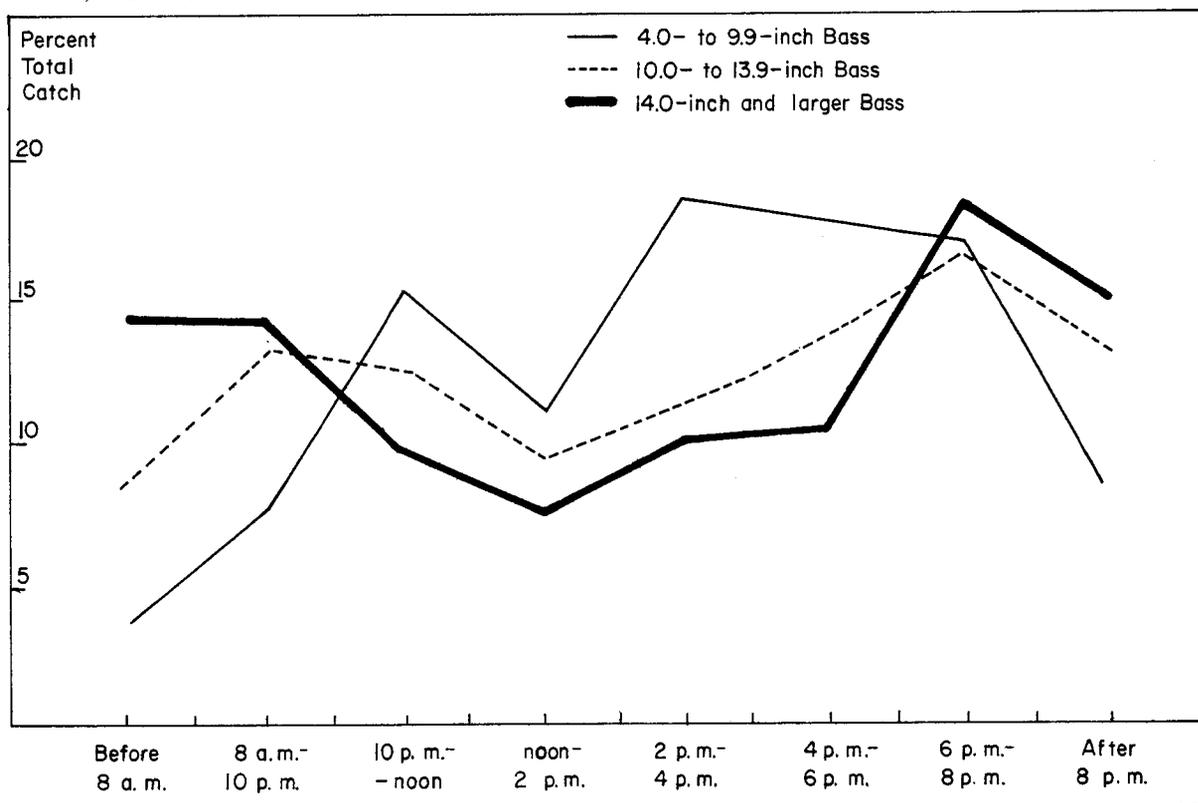
The peaks in the diurnal distribution of the total catch were not the same for all sizes of fish. As the bass increased in size, a greater percentage of them were caught before 10 a.m. and after 6 p.m., while more smaller bass were caught during all intervening hours (Fig. 4). The catch of bass less than 10.0 inches was lowest before 8 a.m. and after 8 p.m. and was highest during the 2-4 p.m. period, when most anglers are fishing.

The catch of bass in the two other size groups

generally highest before 10 a.m. and during 6 p.m. to 8 p.m. The decline in the catch for all sizes of bass during the 12 noon to 2 p.m. time interval was due at least in part to the anglers who took time out for lunch and to the fish, especially the larger bass, which were apparently inactive during this time period.

Only two differences were found between the diurnal distribution of the total catch for different months and the average distribution for different years (Fig. 3). During May, the peaks in the total catch were less pronounced and the catch was spread more evenly throughout the day, while in September, an exceptionally high percentage of bass (26.8) were taken during the 6 p.m. to 8 p.m. interval compared to the average percentage (17.4) of bass taken during the same time interval for all months combined. These differences may be related to pre-spawning activity and increasing water temperature in May and decreasing water temperature in September.

*Figure 4. Diurnal distribution of total catch of three size groups of bass taken during open-water seasons, 1960-69.*

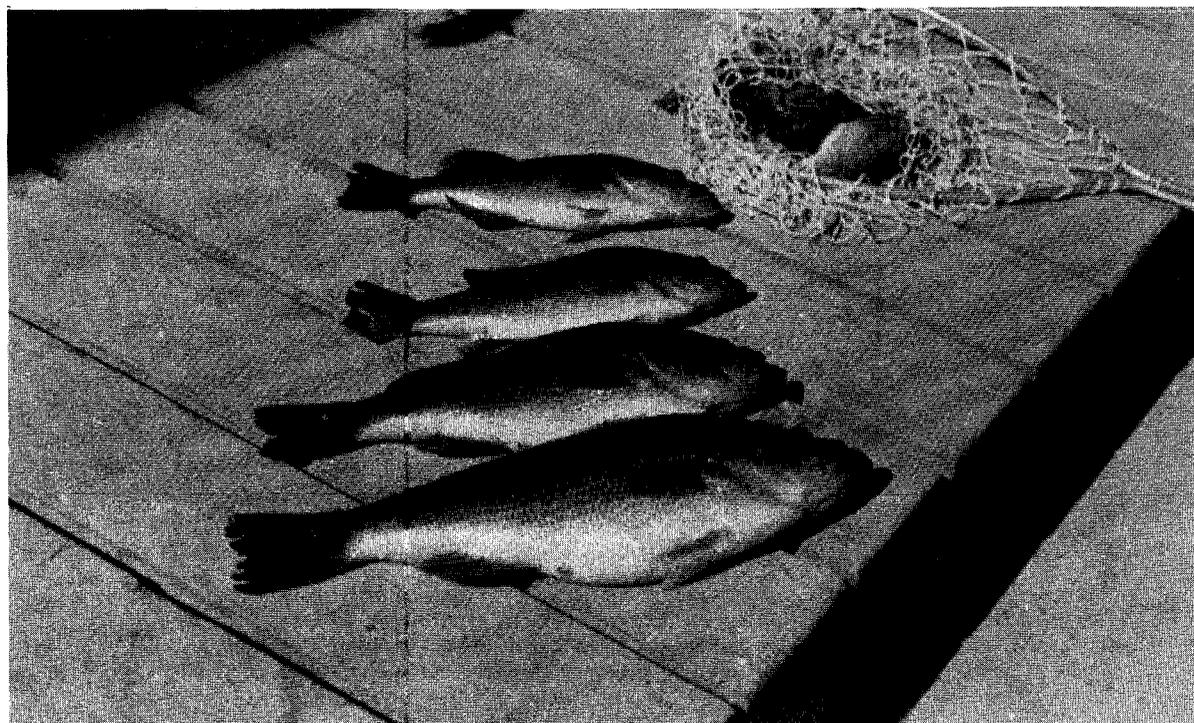


**LENGTH OF FISH CAUGHT**

The mean length of all bass caught was 11.7 inches and annually varied from 11.2 to 12.1 during the 15-year study period. During the open water seasons, the largest bass (averaging 13.2 inches in total length) were caught in April and the smallest, (averaging 11.3 inches) were taken in August and September (Table 3). During the entire year, the

smallest bass were caught in February and averaged 10.4 inches in length.

The average total length of all bass caught was 11.7 inches. Of the 7,164 bass taken between 1955 and 1969, 1,970 bass under 10.0 inches were kept by anglers. Of this 1,970 fish, 599 were less than 8.0 inches long and 1,371 were between 8.0 and 9.9



*A compulsory creel census has provided a complete record of all largemouth bass caught on Murphy Flowage since 1955.*

inches in total length.

Between 1960 and 1969, sex was determined for 3,582 largemouth bass, 53 percent of which were females. Annually the percentages varied 11 percent, from a low of 49 percent females in 1962 to a high of 60 percent in 1963. During all years, except 1962,

the percentage of females caught was 50 percent or higher. This high percentage of females caught is likely due to the fact that (a) females may exist in the natural environment in a higher ratio than males and (b) females grow faster, eat more and thus may be more vulnerable to angling than males.

## SEX OF FISH CAUGHT

The conclusions throughout this paper concerning sex of fish are based on the assumption that males and females exist in the environment in approximately a 1:1 ratio. This assumption cannot be validated in Murphy Flowage inasmuch as the only fish sexed were caught by anglers. Because females appeared to be more vulnerable to angling than males, the sex ratio of the angler harvest may not reflect that for the actual bass population. Although the sex ratios found in this study may appear to be biased, they are likely close to the true sex ratios for all the bass in Murphy Flowage in that they correspond roughly to the sex ratios found by another researcher: In a Michigan study of 1,213 bass collected from 175 lakes by means of netting and angling, Beckman (1946) found that 49 percent were males and 51 percent were females.

During all months except June, the percentage of females was equal to or higher than the percentage of males. The percentage of females caught was highest in April at 59 percent and lowest in June at 49 percent (Table 4). The high percentage of females in April and May could be related to the physiological

response of female fish to increased gonad development above that of the males during these months. The monthly distribution of the average annual catch by sex shows that during June, more males than

TABLE 4  
Sex Ratios of the Monthly Bass Harvest, 1960-69

Month	Total Catch		Percent of Each Sex Caught	
	No.	Percent Females	Females*	Males**
April	64	59	2	1
May	688	57	20	23
June	1,092	49	27	32
July	911	54	25	25
August	518	59	15	12
Sept.	285	58	11	7
Oct.	24	50	1	1
AVG.		51		
TOTAL	3,582		101	101

\*Based on a sample of 1,948 females caught.

\*\*Based on a sample of 1,724 males caught.

females are caught than during any other month. This increase in the harvest of male bass during June is undoubtedly a function of spawning behavior that leads males on the spawning nest in June to react more readily to the angler's lure than they would react in other months.

The diurnal distribution of the total catch showed little variation between the times of the day during

which different sexes of bass were caught. In fact, the percent of each sex caught in hourly intervals throughout the day differed by 1.6 percent or less. Small differences that did occur were likely the result of sampling variation.

Further comparison of bass sex ratios to bass feeding habits and methods of capture is made in other sections of this report.

### SUMMARY

The annual harvest of bass by anglers averaged 2.7 fish weighing 2.8 pounds per acre. Approximately three-fourths of the total harvest were caught in the three-month period from May through July. May and June were the most successful months to fish and before 8 a.m. and after 8 p.m. were the most successful times to fish. The average length of all bass

caught was 11.7 inches. Of the total catch, 53 percent were females; this percentage varied annually, from 49 to 60 percent and monthly, from 49 to 59 percent. Only during June did the catch of males exceed the catch of females. At this time male bass are on the spawning nest and apparently react more readily to the lure than they do during other months.

### ANTICIPATED BAIT USE

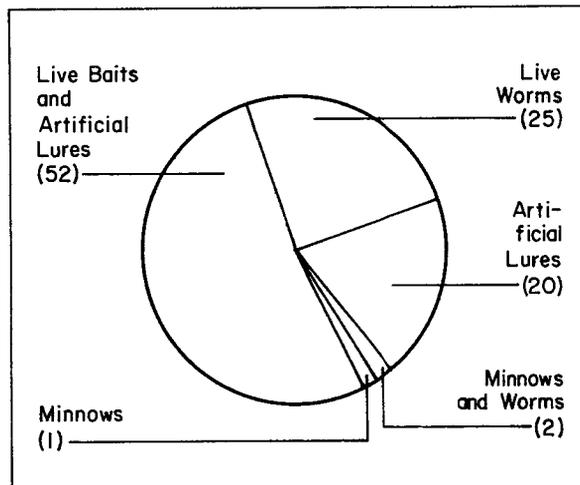
Results from the complete creel census at Murphy Flowage have shown that anglers use a variety of baits, but have a tendency to favor live bait. Of 27,208 anglers interviewed at the beginning of each fishing trip from 1960 through 1969, 52 percent expected to use a combination of live baits and artificial lures. Anglers hoping to use live bait exclusively accounted for 28 percent, of whom 25 percent anticipated using worms, 1 percent, minnows and 2 percent, a combination of both of these baits. Anglers expecting to fish with artificial lures exclusively accounted for 20 percent of the total (Fig. 5).

While more anglers tend to use live bait, the difference between the uses of live baits and artificial lures is not great. Eighty percent of the anglers planned to use live bait, compared to 72 percent who anticipated using artificial lures. These results are quite similar to those found on Murphy Flowage from 1857 through 1961) by Churchill and Snow (1964); data in the present report (covering the period from 1957 through 1969) indicates, however, that use of artificial baits has increased and use of live worms has declined in recent years. Since all types of fishing baits are suitable for catching bass, it was impossible to determine which anglers were fishing exclusively for bass. Therefore, the data in figure 5 includes the baits used by all anglers fishing for all species.

Use of specific types of baits has varied considerably from year to year, as new lures are introduced and become popular. For example, prior to 1962, only 1.6 percent of the annual catch of bass were taken on artificial worms, while in 1962, 19.5 percent were taken on artificial worms and in 1963, 26.3 percent. The increased popularity of lightweight balsa wood lures is reflected in the catch of bass on "other underwater lures," the catch increasing from an average of about 18 percent before 1965 to 41.8 percent in 1968. The increased use of the artificial worm and "other underwater lures" was accompanied by a decline in the percent taken on surface lures, mainly poppers, and a decline in the percent taken on minnows and live worms.

Other specific baits (namely, frogs and crayfish, spoons and spinners, poppers and other surface lures) have shown some annual variation, but no apparent trends or explanations for these variations were found.

Figure 5. Anticipated bait use by all anglers, 1960-69.



## METHODS OF CAPTURE

### VARIATION BY YEARS AND BY MONTHS

**ANNUAL AVERAGES.** In contrast to the almost equal use of artificial and live bait, the actual bait on which bass were caught is drastically different. Information on the method of capture was recorded for 3,856 bass or 93 percent of the total catch for 1960-69. Of this total, around 75 percent were taken

on artificial lures. The percent taken on artificial lures has varied from a low of 65.8 percent in 1960 to a high of 81.3 percent in 1967 (Table 5). Although annual variations in the use of artificial lures and live baits have been small, there has been a trend toward an increase in the percent of bass caught on artificial lures in most recent years. This increase corresponds

BAITS AND  
METHODS  
OF CAPTURE  
CONTINUED

TABLE 5  
Percent of Total Annual Bass Caught By Various Types of Baits, 1960-69

Type of Bait	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Avg.
<b>Live Bait</b>											
Worms	21.0	15.9	18.8	16.9	19.0	23.4	18.9	15.8	19.0	16.4	18.3
Minnows	12.2	6.1	5.5	6.3	6.9	7.3	2.6	2.9	1.8	7.8	5.7
Crayfish and Frogs	1.0	0.6	0.5	-	0.5	-	.7	-	-	-	0.3
All Live	34.2	22.6	24.8	23.2	26.4	30.7	22.2	18.7	20.8	24.2	24.3
<b>Artificial Lures</b>											
<b>Underwater Lures</b>											
Spoons and Spinners	16.8	24.6	15.4	14.9	15.9	16.1	16.9	9.9	15.7	13.4	15.8
Artificial Worms	2.6	1.4	19.5	26.3	15.9	8.7	19.2	18.9	15.6	15.8	15.1
Other Underwater Lures	16.1	18.6	16.6	16.7	22.7	18.5	26.4	35.3	41.8	39.7	26.3
<b>Surface Lures</b>											
Poppers	14.8	15.7	13.3	11.9	9.0	18.5	3.3	6.0	3.9	2.8	9.4
Other Surface Lures	15.5	17.1	10.3	7.0	10.1	6.6	12.0	11.2	2.2	4.1	9.1
All Artificial	65.8	77.4	75.2	76.8	73.6	69.3	77.8	81.3	79.2	75.8	75.7
<b>TOTAL NO. FISH CAUGHT ON ALL TYPES OF BAIT</b>	304	345	435	444	378	286	307	385	509	463	3,856

to the slight increase in the intended use of artificial lures previously mentioned.

**MONTHLY AVERAGES.** The trends of the monthly harvest of bass from April to October were much the same for bass taken on live worms, live minnows and artificial lures of the surface variety (Fig. 6). Of the various types of bait used, a significantly high percent of bass were captured in April and May on underwater lures. The successful use of this particular type of artificial lure is most likely related to bass behavior during these two months: in early spring, bass stay in deeper water, remaining there until water temperatures begin to increase. Because they inhabit these deeper waters, bass are thus more readily taken on underwater lures than on any other type of lure or bait.

### SIZE OF FISH CAUGHT

As a group, larger bass were caught more readily on artificial lures rather than on live bait (Fig. 7). This conclusion is supported not only by the average lengths, but also by the length frequency distribution of the bass caught. The average length of bass caught on artificial lures was 12.4 inches compared to 9.7 inches for those bass taken on live bait (Table 6). Of 2,813 bass caught over 10.0 inches in length, 87 percent were taken on artificial lures; of 1,090 bass under 10.0 inches, only 46 percent were caught on artificial lures. The fact that the largest bass were caught on artificial lures is even better reflected by a

comparison of the percents of the largest and of the smallest bass caught. Of 93 fish caught over 18.0 inches in length, 91 percent were taken on artificial lures. Of 320 fish taken under 8.0 inches in length, 21 percent were taken on artificial lures (Table 7).

There were also considerable differences in the size of fish caught within each of the main groups of artificial lures and live baits. Among artificial lures, the largest fish were caught on large surface lures and averaged 13.2 inches; the smallest fish were caught on

TABLE 6  
Average Length of Bass Caught By Various Types  
of Bait, 1960-69

Method of Capture	Avg. Length in Inches
<b>Live Bait</b>	
Worms	9.1
Minnows	11.7
Crayfish and Frogs	10.6
Avg. for Live Bait	9.7
<b>Artificial Lures</b>	
<b>Underwater Lures</b>	
Spoons and Spinners	12.0
Artificial Worms	12.6
Other Underwater Lures	12.4
<b>Surface Lures</b>	
Small Ones	11.6
Large Ones	13.2
Avg. for Artificial Lures	12.4
<b>AVG. FOR ALL TYPES OF BAIT</b>	11.7

Figure 6. Percent of bass caught on various types of baits by month, 1960-69.

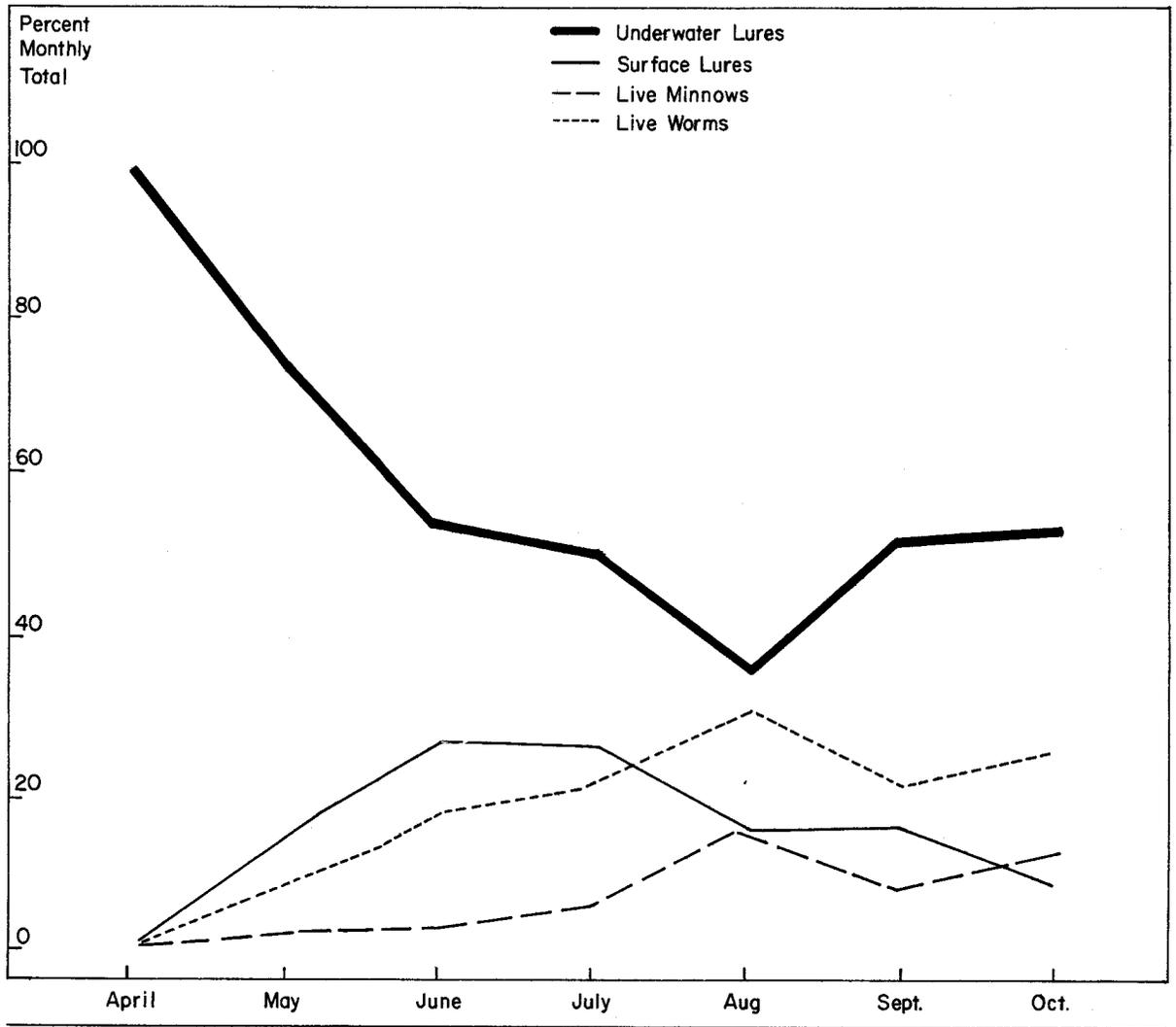


Figure 7. Relationship between size of bass caught on artificial lures and size of bass caught on live baits, 1960-69.

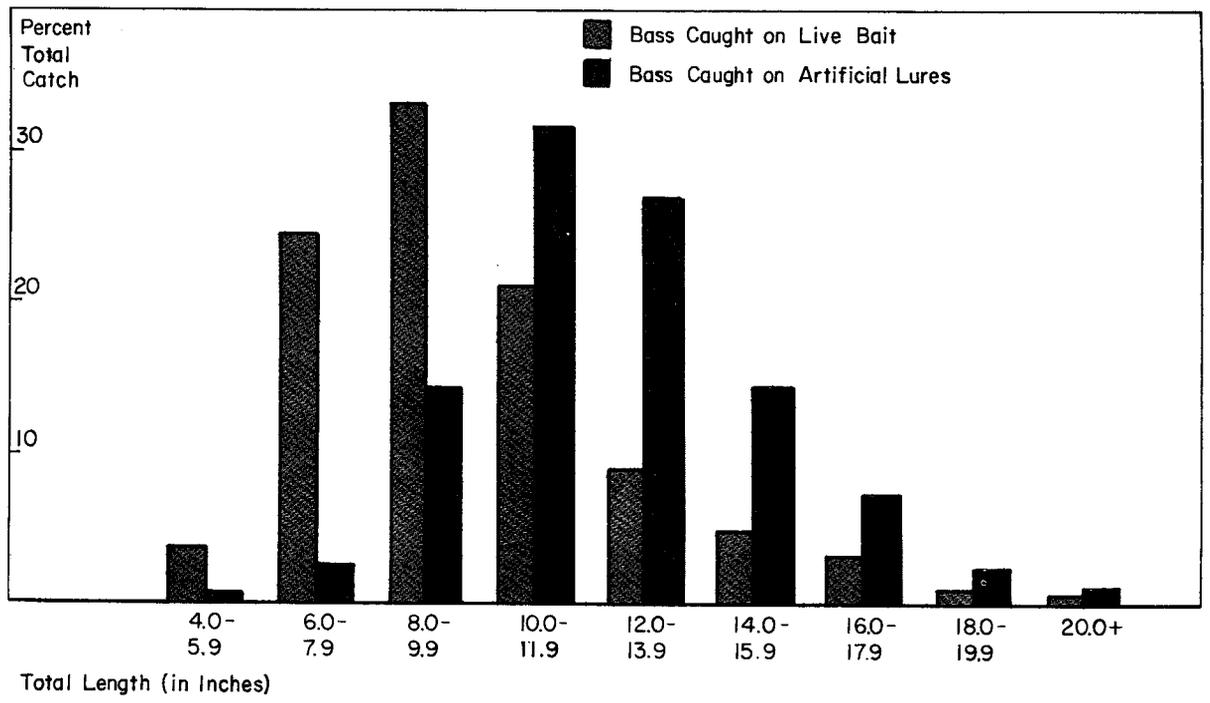


TABLE 7

Length Distribution and Method of Capture of Bass Caught by Anglers, 1960-69

Total Length (in Inches)	Live Bait				Artificial Lures							Total for All Baits
	Worms	Minnows	Crayfish & Frogs	Total Live	Underwater Lures			Surface Lures				
					Spoons & Spinners	Art. Worms	Other	Poppers	Other	Art.		
4.0- 5.9	33	1	-	34	-	-	-	2	-	2	36	
6.0- 7.9	200	18	2	220	17	11	8	26	2	64	284	
8.0- 9.9	261	70	3	334	102	68	164	76	26	436	770	
10.0-11.9	148	55	3	206	203	181	346	124	93	947	1,153	
12.0-13.9	50	38	1	89	172	177	269	77	106	801	890	
14.0-15.9	21	19	2	42	75	93	130	32	80	410	452	
16.0-17.9	6	20	-	26	34	38	75	19	33	199	225	
18.0-19.9	2	3	-	5	4	19	24	9	9	65	70	
20.0-21.9	-	3	-	3	2	5	9	-	4	20	23	
Total Fish	721	227	11	959	609	592	1,025	365	353	2,944	3,903	

small surface lures and averaged 11.6 inches in length. Among live baits, the largest bass were caught on minnows and averaged 11.7 inches, and the smallest, on worms at 9.1 inches (Table 6).

Of all bass taken under 10.0 inches, 47 percent were caught on worms while only 3 percent of the bass over 10.0 inches were taken on this bait. The

percentage of small fish caught on worms is similar to that reported by Bennett (1954) in Ridge Lake, Illinois, where 55.4 percent of the small bass were taken on worms. In Ridge Lake, however, 16.5 percent of the large bass were taken on worms, this percentage being considerably higher than that reported for Murphy Flowage.

## SUMMARY

In contrast to the almost equal use of live baits and artificial lures, approximately 75 percent of all bass caught were taken on artificial lures. The introduction and subsequent popularity of new lures appeared to affect the annual percentages of bass taken on different types of artificial lures, but did not affect the overall percentage taken on all types of artificials. Comparison of the percent of bass caught monthly on various types of baits showed some variation in bait

use, particularly regarding the use of underwater lures in early spring. This variation was apparently the result of seasonal bait preferences of the anglers and environmental factors affecting the fish.

Not only were the largest number of fish caught on artificial lures, but also the largest size of fish caught. Of the various types of lures and baits, live worms produced the smallest fish and large surface lures, the largest fish.

## FACTORS INFLUENCING FEEDING BEHAVIOR

### DEGREE OF SATIATION

During the five open water seasons from 1960 to 1964, the total catch of largemouth bass was 2,184 fish, from which, 1,817 stomachs were examined. Of the stomachs examined, 1,244 or 68 percent were empty. For most years, this annual percentage remained quite constant, varying only from 68 to 71 percent. The figure is a low one inasmuch as only stomachs with no traces of food were classified as empty. Had the number of stomachs containing only small amounts of food been included in the sample, the percent of empty stomachs would have been higher.

This contention that degree of satiation is an

important factor affecting feeding behavior is also supported by a comparison of the percentage of empty stomachs and the method of capture reported by other workers. Seaburg and Moyle (1964) found that 35 percent of the bass collected by seining in Maple Lake, Minnesota had empty stomachs. In a study of largemouth bass in Venard Lake, Illinois, Larimore (1957) reported that empty stomachs were found in only 8 percent of the 5.5 to 9.0-inch bass collected by electrofishing, while in Murphy Flowage, 75 percent of the same sized bass which were caught by anglers had empty stomachs. The high percentage of empty stomachs found in feeding bass caught by anglers compared to the low percentage, in nonfeed-

## FOOD

ing bass caught by seining or electrofishing substantiates the conclusion that degree of satiation is an important factor affecting feeding behavior.

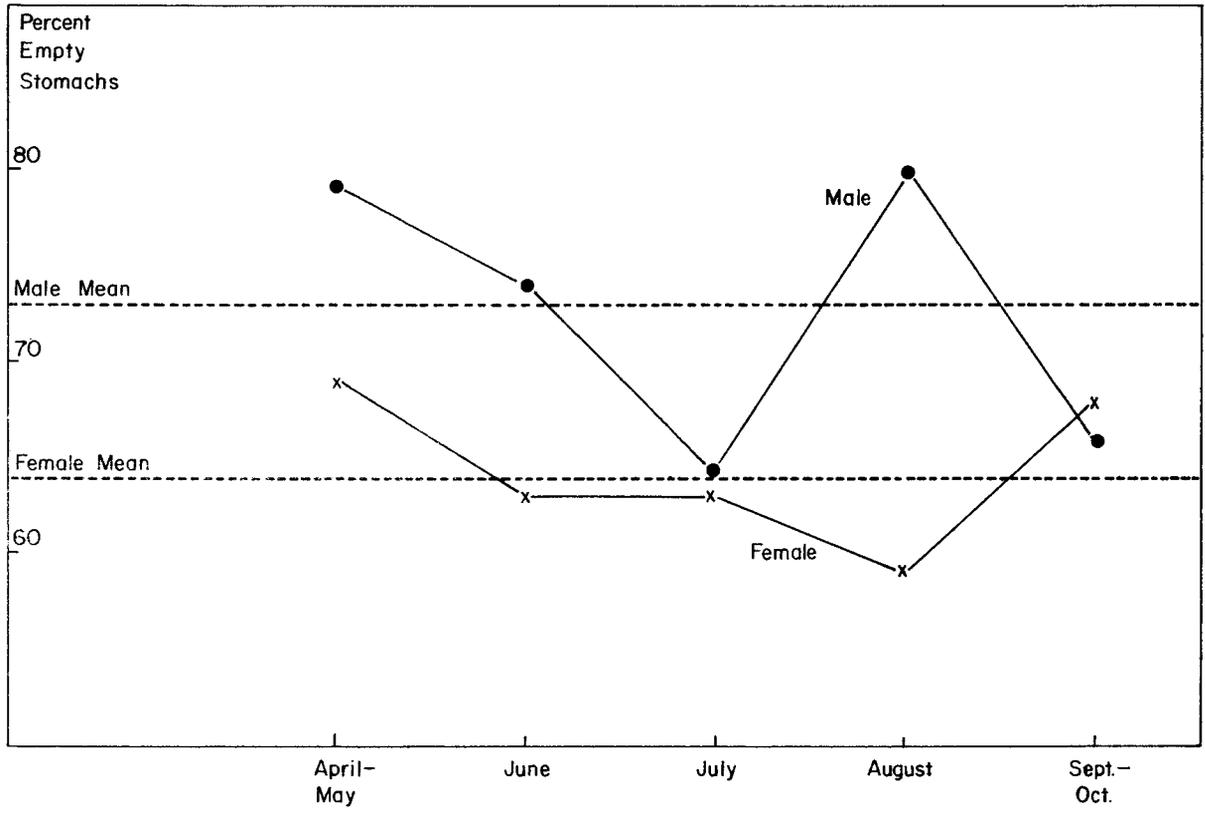
The high percentage of empty stomachs is an indication that bass generally feed because of hunger. However, since all stomachs examined were taken from actively feeding bass, those bass that had food items in their stomachs, on the average, must have been more active feeders than bass with empty stomachs. Thus for any group of bass (grouped by size, sex, etc.), the group that is a more actively feeding one will have a lower percent empty or higher

percent of full stomachs than the other group(s).

**SEX**

Females were found to be more active feeders than males. During all years, except 1962, the percentage of females caught by anglers was 50 percent or higher. Furthermore, 64 percent of the females caught had empty stomachs, compared to 73 percent of the males which had empty stomachs (Fig. 8). Likewise, during most of the day, the percentage of females caught with empty stomachs was lower than that for males.

*Figure 8. Monthly distribution of the percent of male and female bass caught with empty stomachs, 1960-64.*



**SPAWNING ACTIVITY**

A third factor found to affect the feeding behavior of bass was the behavior of male bass during June when peak spawning activity occurs. A higher percentage of males are caught in June than in any other month. Male bass are apparently more susceptible to capture at this time, due to their pugnacious behavior of guarding the spawning nest.

**ENVIRONMENTAL FACTORS**

In addition to degree of satiation, sex, and spawning activity, environmental factors, such as water temperature and time of day also affect feeding behavior. Monthly comparisons of the percent of empty stomachs by sex have shown the tendency for males to become more inactive and females, more active feeders during August. For unknown reasons, unless they are physiological ones, 80 percent of all

males caught in August had empty stomachs, compared to only 60 percent of the females which had empty stomachs in that month. The fact that females had fuller stomachs and thus appeared to be more active feeders during August, one of the most important growing months, is a likely explanation for the differences in growth rates of male and female bass reported in the literature (Carlander, 1953 and Beckman, 1946).

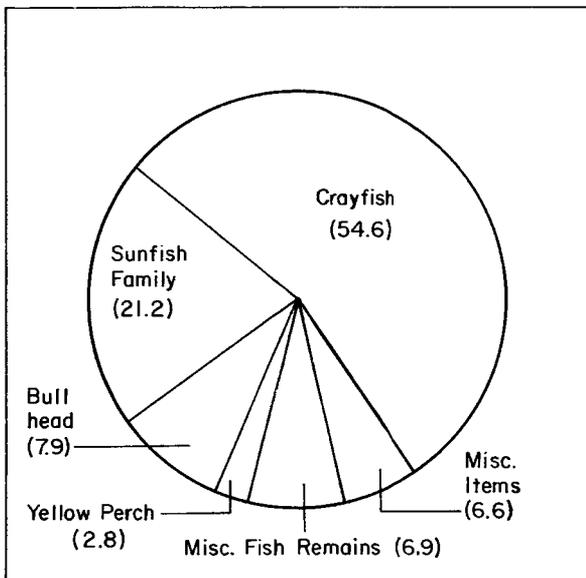
While degree of satiation is an important factor in feeding behavior, it should be kept in mind that it is not the only factor. It has previously been shown that in proportion to fishing pressure, bass fishing is most successful in early morning and early evening hours. This was the time bass fed regardless of whether they had full or empty stomachs. Therefore, during peak feeding hours, degree of satiation does not affect feeding behavior as much as it does at other times of the day.

## STOMACH CONTENTS

### CRAYFISH

First in bulk in the diet of largemouth bass, crayfish comprised 49.9 percent of the total number and 54.6 percent of the total weight of all items consumed (Fig. 9 and Table 8). They were found in 66.3 percent of all stomachs containing food items and there was an average of 1.4 crayfish per stomach. Seasonally, frequency of occurrence was highest during summer and lowest in fall, while percentage of total weight was highest in summer and lowest in spring.

Figure 9. Percentage of total weight of food items in stomachs, 1961-64.



These results approximate those reported for several other waters. Bennett (1948), Lambou (1961) and Hemen et al. (1969), among others, have reported high utilization of crayfish; Lewis and Helms (1964) have reported high utilization of crayfish and

black bullheads. Thus, according to these findings, when crayfish are present in a body of water, they can constitute a high portion of the total diet of largemouth bass.

### FISH

Second in total bulk, fish comprised 33.6 percent of the total number and 38.8 percent of the total weight consumed. They were found in 51.3 percent of all stomachs containing food items and there was an average of 1.2 fish per stomach containing them. Seasonally, the frequency of occurrence and percentage of total weight was highest in spring and lowest in fall while percentage of total items consumed was highest in fall and lowest in summer (Table 8).

Members of the Centrarchidae family comprised the bulk of forage fish utilized by bass (Table 9). The total weight for all members of this group comprised 21.2 percent of all food consumed. Had the unidentified fish remains been identified as centrarchids, the total would have been as high as 27.1 percent. This is equivalent to 70 percent by weight of all fish consumed. The most important species consumed was the bluegill which comprised 10.3 percent of the total weight. Other centrarchid species of lesser importance were the black crappie and the largemouth bass which comprised 1.8 and 0.5 percent of the total weight consumed. The percentage of total weight consumed was highest in spring for all major species (Table 9).

The second most important group of fish utilized by bass were members of the catfish family, Ameiuridae. Two species were represented—the brown bullhead and the tadpole madtom.\* Together they comprised 7.9 percent of the total weight consumed.

The only other species of fish identified was the yellow perch which comprised 2.8 percent of the total weight consumed. Unidentified minnows comprised 1.1 percent of the total weight. All minnows

\*Throughout the rest of this last unit on food, the term, bullheads, applies to both brown bullheads and tadpole madtoms.

TABLE 8

Percent of Total Number Of Items Consumed and Percent Frequency of Occurrence of Items from the Stomachs of Largemouth Bass Caught by Anglers between April, 1960 and October, 1964\*

Food Items	Spring (April-June)		Summer (July-Aug.)		Fall (Sept.-Oct.)		Total (April-Oct.)	
	272 Stom.-506 Items		244 Stom.-421 Items		57 Stom.-105 Items		573 Stom.-1,032 Items	
	Freq. Occur.	Percent Cons.	Freq. Occur.	Percent Cons.	Freq. Occur.	Percent Cons.	Freq. Occur.	Percent Cons.
Crayfish	61.4	42.9	71.7	58.1	48.1	50.5	66.3	49.9
Fish	56.3	35.4	44.3	29.5	41.8	41.9	51.3	33.6
Insects	16.2	13.0	7.0	4.3	2.5	1.9	11.3	8.3
Tadpole or Frog	1.1	0.6	1.2	0.7	2.5	1.9	1.4	0.8
Plant Remains	9.9	5.3	7.4	4.3	3.8	2.9	8.4	4.7
Inorganic Materials	1.1	1.8	2.5	2.9	-	-	1.6	2.0
Misc. Items**	1.8	1.0	0.4	0.2	1.3	0.9	1.2	0.7

\*Based on the stomach contents of 573 fish from 6.0 to 20.0 inches in total length.

\*\*These include annelids, pelecypods, mammals and unidentified animal remains.

TABLE 9

Percent of Total Weight of Items Consumed by Largemouth Bass Caught by Anglers from 1961 through 1964\*

Food Items	April- June 1,992 grams	July- August 1,445 grams	Sept.- Oct. 303 grams	Total 3,740 grams
Crayfish	49.6	61.3	58.7	54.6
Fish				
Centrarchids				
Bluegills	14.1	6.8	2.5	10.3
Black Crappies	1.0	3.0	-	1.8
Largemouth Bass	0.2	1.0	-	0.5
Unidentified Centrarchids	9.8	7.9	4.6	8.6
Cattfish				
Brown Bullheads	3.1	2.2	4.8	2.9
Tadpole Madtoms	6.0	3.9	3.4	5.0
Yellow Perch	3.0	1.5	6.9	2.8
Unidentified Minnows	0.1	2.8	-	1.1
Unidentified Remains	6.9	3.7	8.8	5.8
SUBTOTAL	44.2	32.8	31.0	38.8
Amphibians				
Tadpoles	0.4	0.1	-	0.3
Frogs	0.3	1.4	7.5	1.3
Insects				
Coleoptera (adults)	0.1	Tr.	-	0.1
Hemiptera (adults)	Tr.	-	-	Tr.
Homoptera (adults)	0.1	0.1	-	0.1
Hymenoptera (adults)	-	Tr.	-	Tr.
Odonata				
(adults)	1.4	0.3	0.2	0.9
(larvae)	0.3	-	0.2	0.2
Orthoptera (adults)	-	Tr.	-	Tr.
Trichoptera (larvae)	Tr.	-	-	Tr.
Unidentified Remains	0.2	0.2	-	0.2
SUBTOTAL	2.1	0.6	0.4	1.5
Other Items				
Annelids	0.1	-	-	Tr.
Pelecypods	0.1	0.1	-	0.1
Mammals**	1.2	-	1.8	0.8
Unidentified Animal Remains	Tr.	0.1	-	0.1
Plant Remains	1.0	1.6	0.6	1.2
Inorganic Materials	1.0	2.0	-	1.3
SUBTOTAL	3.4	3.8	2.4	3.5

\*Based on the stomach contents of 487 fish, from 6.0 to 20.0 inches in total length.

\*\*Mammals were short-tailed shrews, *Blarina brevicauda*.

were native species except one fish which was a bait minnow.

### INSECTS

As a group, insects comprised 8.3 percent of the total number and 1.5 percent of the total weight of all items consumed. They were found in 11.3 of all stomachs containing food. Aside from unidentified remains, 7 different orders were represented. Odonata was the predominate order consumed; it comprised 1.1 percent of the food taken, of which 0.9 percent were adults and 0.2 percent were larvae. As a group, insects were a relatively unimportant part of the diet

for the size groups of largemouth bass (6.0-20.0 inches) studied in Murphy Flowage.

### MISCELLANEOUS ITEMS

Other items utilized by bass are listed by decreasing percentage of total weight: frogs and inorganic materials, plant materials, mammals, tadpoles and annelids, pelecypods and unidentified animal remains. Found in two stomachs, the mammals were identified as short-tailed shrews, *Blarina brevicauda*. The inorganic items were stones of which there were several, the largest weighing 19.5 grams.

### SIZE OF PREDATOR

#### RELATIONSHIP TO SIZE OF PREY

The only species present in sufficient numbers to

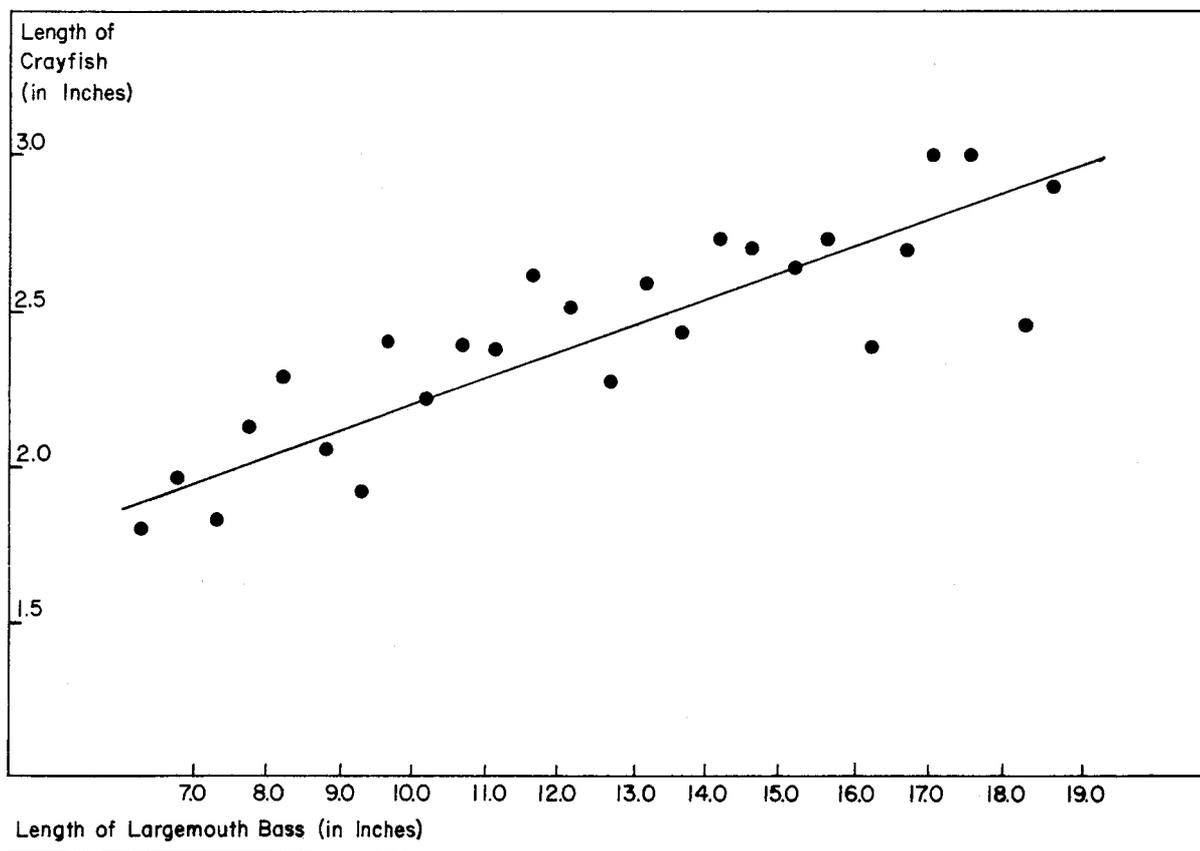
statistically test the relationship between the size of the bass (or predator) and the size of its forage items

(or prey) were crayfish, bluegills and bullheads. The numbers of these prey species used in the comparison of sizes involved 239 crayfish from 200 stomachs, 32 bluegills from 28 stomachs and 71 bullheads from 62 stomachs. The relationship between total length of largemouth bass and the length of crayfish and bluegills was positively correlated and was significant beyond the 0.01 level. However, the relationship between lengths of bullheads and bass was not significant at either the 0.01 or 0.05 level (Fig. 10-12). Although statistical tests were not made for

other prey species, the available data suggest that the forage size of other centrarchids and yellow perch also increases as the predator becomes larger.

Although the relationship between predator and prey size is significant for the two major food items, this does not mean that any particular sized predator consumed only one size of prey. A considerable size range of forage was consumed by one size of predator; however, the average and usually the maximum and minimum length of forage increased with the size of the predator. The average lengths of

Figure 10. Relationship between bass length and crayfish length, 1960-64.



bluegills consumed in Murphy Flowage were approximately one inch less than the maximum lengths of bluegills that bass in other waters could swallow (Lawrence, 1958). Information on the maximum size of crayfish that bass can swallow is not known; however, since the average size of crayfish consumed increased with the size of the bass, a similar relationship must also exist between the average size consumed and the maximum size that can be consumed. The relationship between size of bass and size of bullheads consumed is considerably different than that for bluegills and crayfish. The average size of bullheads consumed did not increase with the size of bass. Generally, all sizes of bass fed on approximately the same range of bullheads (1.0-4.5 inches).

These results are quite similar to those reported by Tarrant (1960) who found a positive correlation between bass size and the size of green sunfish (*Lepomis cyanellus*) consumed. In contrast to these results, Wright (1970) found no significant relation-

ship between bass size and the size of gizzard shad (*Dorosoma cepedianum*) consumed.

The relative size of the prey, that is the ratio (in percent) of prey length to predator length, generally decreased with increasing size of the predator for crayfish and bullheads but not for bluegills. The relative size of crayfish averaged 20 percent and decreased from 28 percent for small bass to 15 percent for larger bass. Relative size of bullheads averaged 21 percent and decreased with increasing sizes of bass from 33 to 10 percent. A decrease in relative size with increasing size of bass was not apparent for bluegills. Relative size for bluegills averaged 25 and varied from only 21 to 28 percent (Table 10). With the exception of the relative sizes found for bluegills, these results are similar to those reported by Popova (1966) who found that relative size for young predators reached 40-50 percent; for adult predators, 20-25 percent; and for very large predators, 10 percent.

Figure 11. Relationship between bass length and bluegill length, 1960-64.

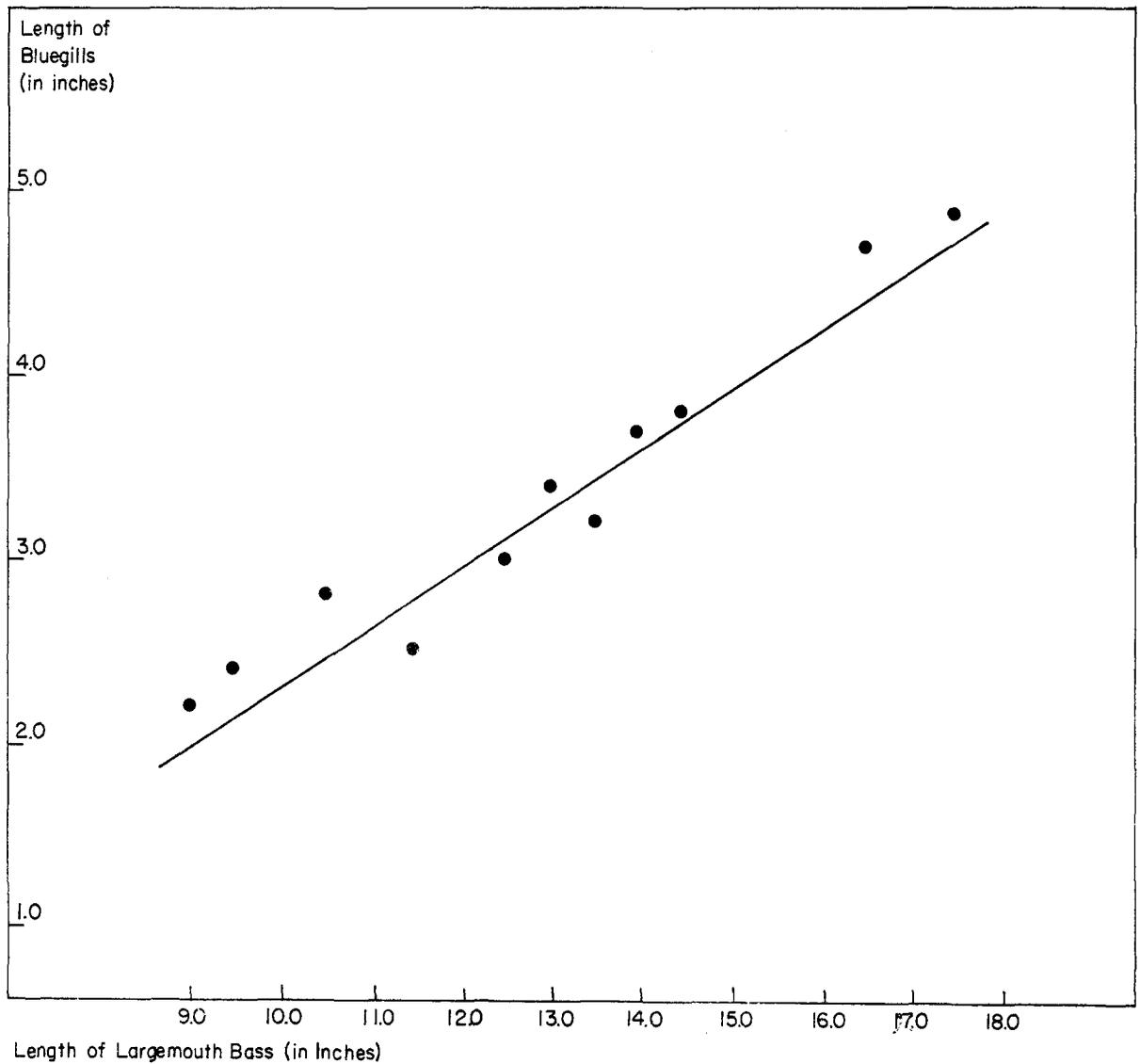


TABLE 10  
Percent Relative Sites of Three Main Forage Items Consumed

Length of Bass (in Inches)	Crayfish	Bullheads	Bluegills
6.5- 7.4	28	21	--
7.5- 8.4	25	23	--
8.5- 9.4	24	33	24
9.5-10.4	22	23	25
10.5-11.4	21	21	24
11.5-12.4	21	22	21
12.5-13.4	19	18	24
13.5-14.4	19	19	23
14.5-15.4	19	19	26
15.5-16.4	17	20	--
16.5-17.4	16	12	28
17.5-18.4	17	10	28
18.5-plus	15	--	--
AVERAGE	20	21	25

Figure 12. Relationship between bass length and bullhead length, 1960-64.

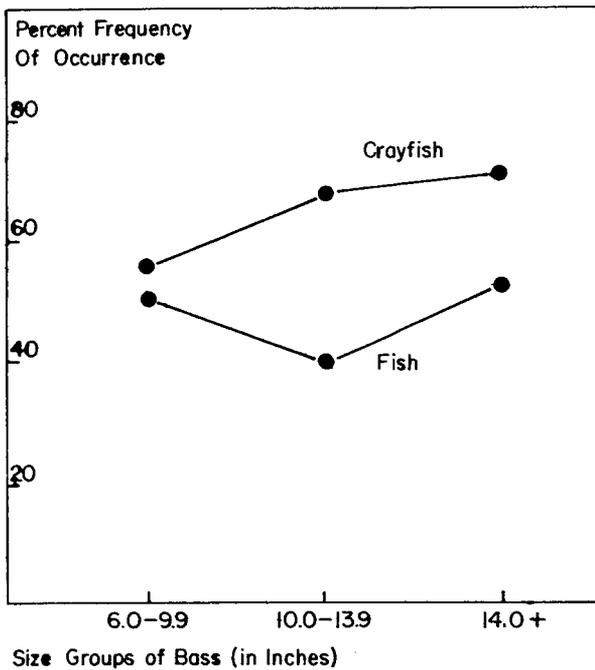
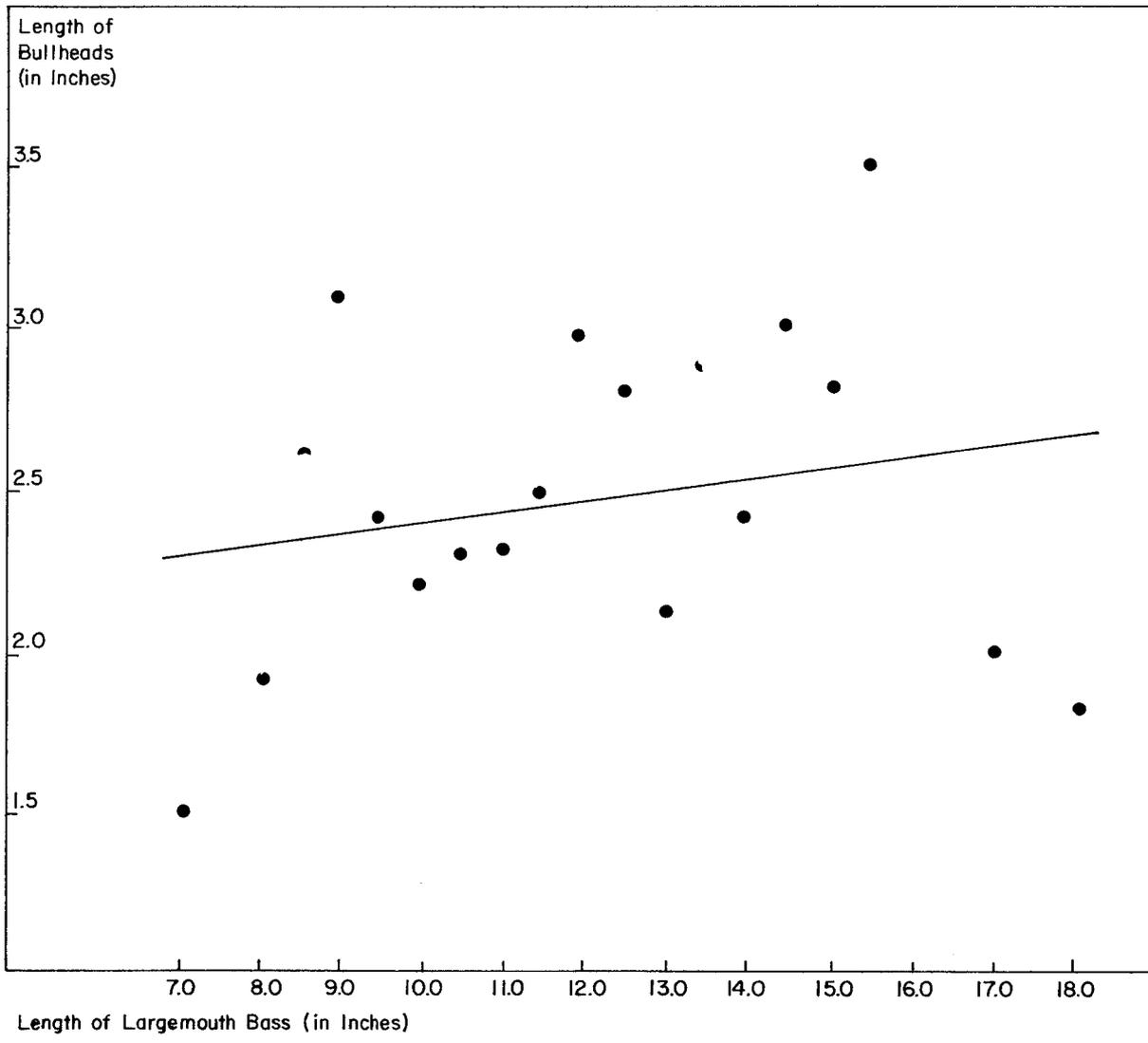


Figure 13. Relationship of various size groups of bass to percent of stomachs containing fish and crayfish, 1960-64.

## RELATIONSHIP TO FREQUENCY OF OCCURRENCE OF PREY

Comparison of data on the length of the predator indicates that the larger the bass, the greater the utilization of crayfish (Fig. 13). Crayfish were found in 56, 69 and 72 percent of the stomachs of

increasing sizes of bass, respectively. This trend did not apply to fish consumed--increasing sizes of bass were not accompanied by increased consumption of fish. Keast and Webb (1966), although reporting on bass which were smaller than those in this study, also found increased utilization of crayfish with increased size of largemouth bass.

## FOOD SELECTION

### TERMINOLOGY

The terminology used in this section conform with the definitions given by Beyerle and Williams (1968): "Selectivity is defined as the extent to which a predator eats one size or species of food rather than another. Preference is the inherited, instinctive desire to consume one size or species of food item rather than another. Abundance refers to the number of food items available to the predator, and accessibility is a measure of the degree of difficulty encountered by the predator in locating a particular food item."

### "E" VALUES

Data on the abundance of bass food items in the environment and on the occurrence of these same items in bass stomachs were analyzed to determine if the main items were selected. Ivlev (1961) has developed a quantitative means of appraising selective feeding which he terms "electivity index," as represented by the following equation:

$$E = \frac{r_i - P_i}{r_i + P_i}$$

Where  $r_i$  is the relative quantity of any food item in the stomach as a percentage of the food consumed, and  $P_i$  is the relative quantity of the same item in the environment expressed as a percentage. Values of  $E$  may range from  $-1$  to  $+1$ . Negative values of  $E$  indicate avoidance or negative selection, positive values of  $E$  indicate preference or positive selection, while a value of zero indicates no selection.

The relative abundance of bluegills in spring 1960 was determined from spring Petersen population estimates and from electrofishing samples the previous fall. The size range of bluegills consumed was 1.8-4.9 inches while Petersen estimates were for bluegills over 5.0 inches in length. Thus the Peterson estimates could not be used directly to determine the percent of bluegills in the environment.

The total number of 1.8- to 4.9-inch bluegills in the environment was estimated by a proportionate ratio involving the number of bluegills over and under 5.0 inches found in the electrofishing sample and the number of bluegills over 5.0 inches calculated from the Petersen estimate. Bluegills in the 1.8- to 4.9-inch size range were found to comprise about 85 percent of the total population.

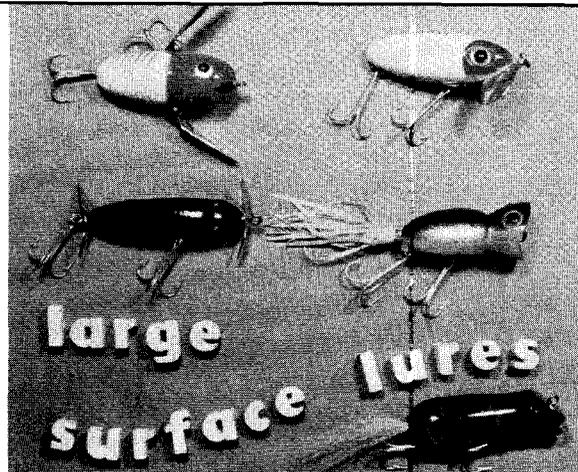
For all other forage fish except bullheads, the same proportionate ratio was used to adjust the Petersen estimates to reflect the number of fish under 5 inches in length. For bullheads, the ratio was modified to reflect the number of fish under 9 inches since the minimum size of the bullheads comprising the Petersen estimate was 9 inches.

The estimated standing crop of all sizes of fish in Murphy Flowage which were utilized by largemouth bass was approximately 3,900 per acre in May, 1960 (Snow, unpublished data). Species included were bluegills, pumpkinseeds, black crappies, rock bass, yellow perch and brown bullheads. Various studies on the standing crop of crayfish have been summarized by Momot (1967); he made three successive estimates of crayfish abundance in West Lost Lake, Michigan and found standing crops ranging from 82 to 107 pounds per acre (or 6,600 to 10,200 crayfish per acre). Of this range of various standing crops, he agreed that 100 pounds of crayfish per acre was a fairly good estimate for this area of Wisconsin (W.T. Momot, in litt., March 29, 1971). Assuming estimates of 6,600 crayfish (or 100 pounds) per acre as most representative of Murphy Flowage, the total standing crop of all species utilized by largemouth bass approximates 400 pounds or 10,500 organisms per acre. The species represented in this standing crop estimate comprised 84 percent of the total items and 95 percent of the total weight consumed by largemouth bass.

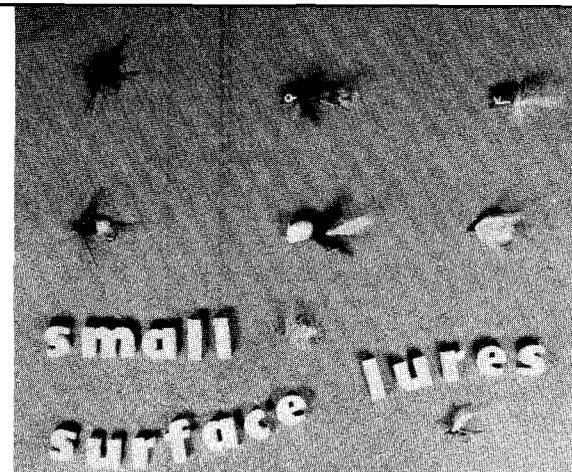
Based on these standing crop estimates, percentage of food items in the environment were determined. Of the quantity of various food items in the environment, 63 percent were crayfish, 31 percent were bluegills, and 0.4 percent were bullheads, while the proportions of these same groups in the stomachs of bass were 60 percent, 29 percent and 4 percent, respectively. Calculations of the "electivity index" for each group gave the following results: crayfish  $-0.02$ , bluegill  $-0.03$  and brown bullhead  $+0.8$ . The "E" values for crayfish and bluegill are very close to zero and indicate an absence of selection. In contrast, a positive "E" value was found for bullheads, indicating that this food item was positively selected by bass.

These "E" values appear to be reliable indicators of selectivity for several reasons:

(1) Although the electivity index for crayfish was calculated using standing crop data from a lake in Michigan, not from Murphy Flowage, the Michigan data would have to be drastically different to result in a significant change in the "E" value found. For example, a standing crop estimate of one-half the



Among artificial lures, the largest fish were caught on large surface lures (left)



and the smallest, on small surface lures (right).

Michigan value, which is very unlikely, would not affect the "E" value for bullheads but would change the "E" value for crayfish from -0.02 to +0.14 and for bluegills from -0.03 to -0.2.

(2) Although the "E" values presented are for the spring of 1960, it is believed from comparison of stomach contents and Petersen population estimates made each year, that these "E" values are representative of all years from 1960-64.

(3) The standing crop estimate for bullheads is the most questionable one of any forage item for which "E" values were determined. However, it would take a standing crop of 425 bullheads per acre before the "electivity index" would change from +0.8 to zero, the point at which no selective process is operating. In Murphy Flowage, standing crop of brown bullheads and tadpole madtoms this high is very unlikely for these reasons: First of all, intensive electrofishing surveys conducted during the past 11 years indicate the presence of a very sparse population of small bullheads. Secondly, during 15 years of intensive spring, summer and fall field work on Murphy Flowage by three to five Department personnel, schools of small bullheads were observed on only one occasion.

It is therefore believed that the estimates of relative abundance and the "E" values calculated give a fair picture of the selectivity of the largemouth bass in Murphy Flowage. To the best of my knowledge, the present study is the first one to demonstrate a quantitative relationship between bass and various forage species in a fairly large body of water (180-acre impoundment).

#### FACTORS INFLUENCING SELECTIVITY

The Murphy Flowage drawdown during the winters of 1967 and 1968 provided the opportunity to test the effect of environmental change on bass selectivity. This drawdown lowered the water level 5 feet between October and April, thereby reducing the total water area by approximately 50 percent and the total volume by approximately 70 percent. This drawdown was responsible for several important changes which bear on the discussion of factors influencing selectivity:

(1) Initially it was apparent that the drawdown

removed much of the dense vegetation found in the flowage (Fig. 14). Of the total acreage, 33 percent became more accessible to the angler as a result of this vegetation decline (Beard, 1969).

(2) As a result of drawdown, consumption of crayfish by bass decreased from 60 to 14 percent (Beard, verbal communication). Assuming that after the drawdown, bass consumed crayfish in the same ratio that they existed in the environment before drawdown, the population of crayfish was calculated to occupy 32 percent of the environment as compared to 63 percent before drawdown. That a decline in consumption of crayfish by bass is indicative that an equivalent decrease of crayfish has occurred in the environment seems to be a reasonable assumption (W.T. Momot, verbal communication, 1971). Possible environmental bases for this assumption were the receding water levels and low air temperatures prior to the fall and winter of 1967 when heavy snow cover may have reduced crayfish numbers.

(3) Although fish numbers did not actually increase after the drawdown, the decline in the percent of crayfish in the environment changed the ratio of the percent of crayfish to the percent of fish. As a result, the percent of fish in the environment increased after drawdown.

(4) The percent of bluegills found in bass stomachs increased after drawdown from 29 to 67 percent. From this percentage, an electivity index was calculated. Although strictly speaking, the "E" value after drawdown (+0.06) was positive, it was close enough to zero to indicate that bluegills were consumed in approximately the same proportion that they existed in the environment (Table 11).

(5) These changes which accompanied the drawdown also affected bass harvest. Prior to drawdown, the main source of food for bass was crayfish. As crayfish consumption decreased and aquatic vegetation declined after drawdown, bass became more susceptible to capture; in 1968, the angler catch of 535 bass was the highest number of bass taken from the flowage since 1958. The exploitation rate of 41 percent in 1968 was likewise the highest one recorded since the study began in 1955.

On the basis of these data before and after drawdown, factors that did and did not affect bass

Figure 14. Murphy Flowage showing the distribution of aquatic vegetation before and after drawdown (after Beard, 1969).

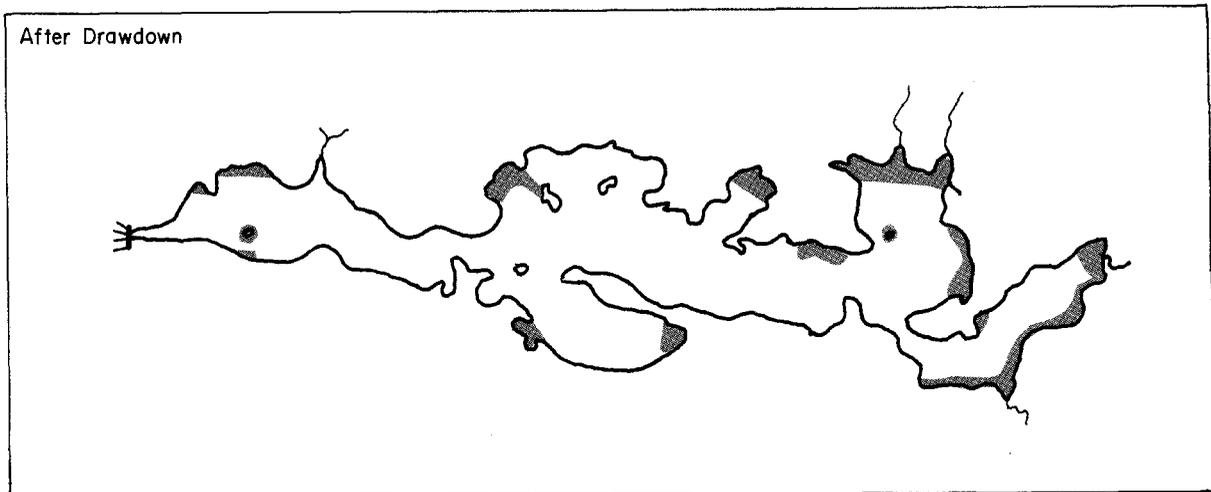
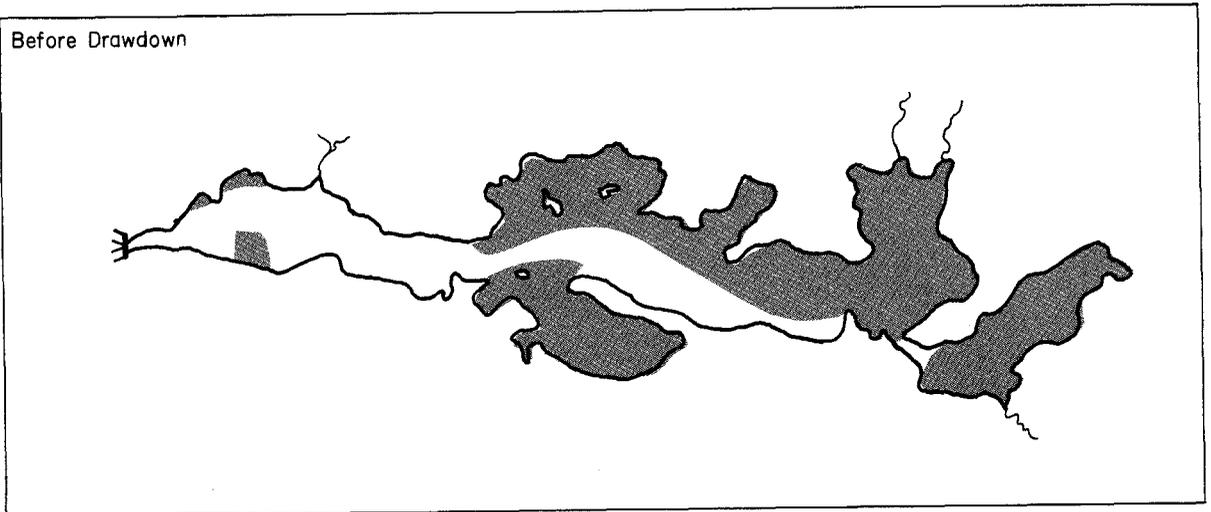


TABLE 11

"E" Values and Percent of Food Items in Bass Stomachs and in Environment in Spring Before and After Drawdown\*

Food Items	Before Drawdown (1960)			After Drawdown (1968)		
	"E" Value	Percent in Stomachs	Percent in Environment**	"E" Value	Percent in Stomachs	Percent in Environment**
Crayfish	-0.02	60	63	-0.39	14	32
Fish						
Bluegills	-0.03	29	31	+0.06	67	60
Bullheads	+0.8	4	0.4	--	0	0.1

\*Percentages of items in bass stomachs are based on stomachs collected from April through June while the percentages of items in the environment are based on population estimates made on May 15 in 1960 and May 1 in 1968.

\*\*The percentages of various food items in the environment included only those size groups which corresponded to the size groups of the same forage items found in bass stomachs.

selectivity of their 3 main forage items (crayfish, bullheads and bluegills) were determined.

Although crayfish occupied a relatively large percent of the Murphy Flowage environment, there was practically an absence of selection before drawdown ("E"=-0.02). In spite of this "E" value, crayfish were the most important item in bass stomachs before drawdown, indicating that bass probably fed on crayfish mainly because they were abundant. If the assumption is true that after drawdown a decline in the crayfish population occurred, then the fact that this decline was accompanied by an "E" value for crayfish that was even more negative than it had been before drawdown would indicate that when crayfish were not abundant, bass avoided them.

If the assumed reduction of crayfish numbers did not occur, the "E" values after drawdown would have changed considerably, however, bass would still have avoided crayfish ("E"=-0.6) and would have positively selected bluegills ("E"=+0.4), each to a greater extent than before drawdown.

Bullheads were selected as a result of bass preference. Prior to drawdown, the ratio of bullheads found in bass stomachs to bullheads found in the environment was 10:1 or greater, thus despite their low abundance in the environment, bullheads were relatively important in the diet of bass. After drawdown, no bullheads were found in bass stomachs. Because few small bullheads were ever seen or captured, it was concluded that bass preference for small bullheads may have been a factor which kept the standing crop of these fish low.

A third factor affecting bass selectivity was accessibility. Before drawdown, dense aquatic vegetation occupied much of Murphy Flowage. When this vegetation was reduced by drawdown, bluegills suddenly became more accessible to bass and were consumed in a slightly higher proportion than they existed in the environment. This increased consumption of bluegills altered the relationships between the other forage items. The most noticeable of these altered relationships is reflected by the consumption of crayfish after drawdown. (The percent of crayfish in bass stomachs declined from 67 to 14 percent and the "E" value dropped from -0.02 to -0.39.) The fact that prior to drawdown, bluegills were not as accessible to bass as bullheads is partially attributed to the schooling behavior of small bullheads.

Although the preference rating for bluegills was

quite low ("E"=+0.06), the fact remains that there was a dramatic change in the relative quantity of bluegills consumed by bass before drawdown as compared to the amount consumed after drawdown (from 29 to 67 percent, Table 11). This change occurred even though there was no noticeable change in the abundance of bluegill—there were approximately 3,200 bluegills per acre before and after drawdown. The drawdown was accompanied by a change in bass diet which was apparently related to increased accessibility of and preference for bluegills and to reduction in crayfish numbers.

These results after drawdown differ from that reported by Lewis and Helms (1964) who, in a weed-free, controlled pond study, found high vulnerability of bullheads and crayfish but remarkably low vulnerability for bluegill. In their studies, bass, when fed 1,000 bluegill and 1,000 crayfish in 20 days, consumed 5.81 crayfish but only 0.29 bluegill fingerlines per day. Bluegills were avoided, while in Murphy Flowage, they were consumed in approximately the same ratio as they existed in the environment before and after drawdown.

One factor studied which did not affect selectivity was interspecific competition. The other major predator which might have competed with bass for the same forage items was northern pike. Food studies have shown that 99 percent of the northern pike diet in Murphy Flowage was comprised of various species of fish, most of which were bluegills of the same size consumed by bass (Johnson, 1969). Prior to drawdown when bass fed mainly on crayfish (not on fish), northern pike constituted little competition with bass. Even after drawdown when bass began to consume increasing percentages of fish, no evidence of close interspecific competition between the two predators was found. The extremely high standing crop of bluegills was apparently more than enough to provide ample forage for both bass and northern pike.

Three factors which may have influenced selectivity were not studied: Satiation of the predator would have been hard to evaluate inasmuch as only stomachs containing food were used in the calculations of electivity indexes. Size of the prey and size of the predator were also not evaluated. To do so, better population estimates of small forage fish would have been needed as well as estimates of the percent of crayfish in the environment. Unfortunately, none of these data were available.

## SUMMARY

The fact that the majority of all stomachs examined were empty (68 percent) is an indication that bass generally feed because of hunger. While degree of satiation is an important factor affecting feeding behavior, it is not the only factor. Bass with empty stomachs bite better in early morning and evening hours. Therefore during peak feeding hours, degree of satiation does not affect feeding behavior as much as it does at other times of the day.

Bass sex was also found to affect feeding behavior. Female bass are more active feeders than males and

were caught in greater numbers than males in every month except June. Male bass are apparently more susceptible to capture during June because of their pugnacious behavior of guarding the spawning nest. Decreased feeding activity of male bass during August may account for differences in growth rate between males and females.

Crayfish were in 66.3 percent of all stomachs containing food and they comprised 49.9 percent of all items and 54.6 percent of the total weight consumed. Fish were found in 51.3 percent of all

stomachs, comprising 33.6 percent of all items and 38.8 percent of the total weight consumed. The most important fish consumed were the bluegill and brown bullhead. Fish and crayfish together comprised over 90 percent of the total weight of all items consumed. When utilization of fish declined, consumption of crayfish increased.

The relationship between total length of largemouth bass and the length of crayfish consumed was positively correlated and was significant beyond the 0.01 level. However, the relationship between bass and bullhead lengths was not significant at either the 0.01 or 0.05 levels. The average total length of bluegills consumed was about one inch less than the maximum size bass could swallow. The relative size of the prey generally decreased with increasing size of the predator for crayfish and bullheads, but not bluegills. Comparison of data on the frequency of occurrence of the prey with data on the size of the predator indicates that as bass increase in size, their utilization of crayfish increases but their consumption of fish does not.

Calculation of an electivity index showed that from 1960 to 1964, bullheads were positively selected by largemouth bass while crayfish and bluegills were consumed in approximately the same ratio as they existed in the environment. After an overwinter drawdown in 1967, there was a drastic change in the diet of largemouth bass. Utilization of crayfish decreased from 60 to 14 percent while consumption of bluegills increased from 29 to 67 percent. A known decline in the abundance of aquatic vegetation and an apparent decline in the abundance of crayfish altered the relationship between the food items. Calculation of "E" values after drawdown indicated that bass displayed some preference for bluegill while crayfish were still avoided.

In addition to a change in the feeding habits of bass after drawdown, there was also a dramatic change in the harvest of bass by anglers. As crayfish numbers declined after the drawdown the catch by anglers in 1968 increased to the highest level since 1958 and was accompanied by the highest exploitation rate since the study began in 1955.

## MANAGEMENT IMPLICATIONS

The ultimate management objective of a species should be to allow maximum harvest of desirable sized fish without the possibility of depletion. In Murphy Flowage, this objective could be approached through several means, one of which might be a public education program. Such a program would be aimed at informing the angler of the most successful times and methods to catch bass. This program might, for example, advise anglers to fish early morning and evening hours, particularly in May and June, and to use artificial lures.

On impounded waters other than Murphy Flowage, managers may be interested in adapting some of the findings in this report regarding bass feeding habits. Bass utilized bluegill and crayfish in Murphy Flowage in approximately the same ratio that they existed in the environment while bullheads were utilized in a higher ratio than they existed in the environment. In

addition, crayfish were the most important food item consumed. Therefore when crayfish are abundant and/or bullheads are present in the same body of water as bluegills, bass predation on bluegills may be minimized. If by some management technique such as a drawdown, crayfish and/or bullheads could be eliminated or their numbers greatly reduced, it is possible that the feeding habits of bass could be altered to make bass more effective predators on bluegills. This could be a very important management technique in environments where the water level could be controlled and where stunted panfish are present. Development of a biocide selective for crayfish might produce similar results in other waters. A program to promote the harvest of crayfish by the public or by commercial removal might also be a means by which bass utilization of bluegills could be increased.

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