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OBSERVATIONS ON THE FOOD OF FINGERLING LARGEMOUTH BASS IN CLEAR LAKE, LAKE COUNTY, CALIFORNIA[1]

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Clear Lake, a 40,000-surface-acre, seminatural lake situated in central Lake County at an elevation of 1,325 feet, contains an assemblage of native and exotic warmwater fishes. Murphy (1951) presented a general description of the lake and the history of its fishery. Fishing success has varied considerably through the years (Murphy, 1951; Pintler, 1957).

Since 1948, management efforts to improve the largemouth bass *(Micropterus salmoides)* fishery have resulted in liberalized angling regulations to increase the catch (a minimum size limit for largemouth bass was eliminated and night fishing for all species was allowed), and in attempts to maintain, establish, and improve cyprinid forage fish populations.

The hypothesis that prompted these latter efforts was developed and described by Murphy (1951). He concluded that a close correlation existed between the survival of bass-of-the-year and the strength of that year's crop of cyprinid forage fish, and theorized that the Clear Lake bass population could be increased by augmenting the supply of the forage species.

His hypothesis was based in part on a study of the food habits of bass-of-the-year at Clear Lake during mid-August 1948 (Murphy, 1949). This study demonstrated that fish were the primary food of young bass over 2.8 inches fork length, and indicated that the Sacramento blackfish *(Orthodon microlepidotus)* was the most important species consumed. Bluegill *(Lepomis macrochirus)* fry, though abundant, appeared relatively unimportant as forage for young bass.

Inasmuch as there was evidence the native cyprinid populations had been seriously reduced since the early 1940's, it was recommended that these species be protected. As a result, the commercial blackfish fishery that had been operating on the lake for many years was banned in September, 1948.

A nonnative forage fish, the golden shiner *(Notemigonus crysoleucas)*, was introduced in 1950 to augment tile supply of native minnows.

The value of blackfish as forage has continued to be a subject for considerable debate. In 1954, an apparent increase in the blackfish population led the California Fish and Game Commission to permit a

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limited harvest of mature blackfish by commercial fishermen. This intensified the controversy over the forage fish problem.

In the hope of resolving this problem, additional food habit studies, closely comparable to that of 1948, were conducted in mid-August of 1956, 1957, and 1958.

The objectives of the 1948 study were to determine what food habit changes occurred as the bass increased in size, what forage fish species were most utilized by fingerling bass, and the extent of cannibalism within the year-class. The later studies were designed primarily to test the conclusions of the earlier study.

Fingerling bass were collected and their stomach contents analyzed in 1956, 1957, and 1958 by McCammon (1957), McCammon and LaFaunce (1958), and LaFaunce (1959), respectively. These workers prepared the original draft of the present paper, but final responsibility for its total content rests with the second junior author (C.M.S.).

This paper, taken largely from these earlier reports, summarizes and compares the results of all four Clear Lake studies. Additionally, it relates these results to pertinent information from other areas.

PROCEDURES

The equipment and procedures used in all four studies were essentially the same. All of the specimens were collected with a 40- by 6-foot, 1-inch bar measure seine along the northwest shore of the lake between the town of Lakeport and Rodman Slough. The collection dates were : August 10-12, 1948; August 13-14, 1956; August 21-22, 1957; and August 21-22, 1958. In the 1948 collection, selection was exercised in order to obtain adequate numbers of fish of all sizes (Murphy, 1949), but no size selection was exercised in the later collections. All of the specimens were preserved in formalin and taken to the laboratory for stomach analysis. In the 1957 and 1958 collections, these specimens were suffocated in a tub of water before preservation to reduce regurgitation of food.

Fork length was recorded for each fish. Stomach contents were stored and classified, and an effort was made to identify each forage fish to species. In the last three studies, fish remains that were unidentifiable from external features were cleared and stained in a mixture of potassium hydroxide and alizarine red S in order to facilitate recognition.

Frequency of occurrence and volume of each food category were recorded in the analysis of each study. The number of individual food items was also recorded during the 1957 and 1958 studies. When it was impractical to count the total number of a certain organism in a stomach (e.g., cladocerans), the number was estimated. Volumetric determinations were obtained by measuring water displacement, using graduated centrifuge tubes.

RESULTS

Bass sizes varied considerably in the different collections (Table 1), even though they were made at approximately the same time of year. Size selection in the 1948 sample probably biased that distribution toward the larger sizes. Since size selection was not exercised in the later collections, the length frequencies for those studies probably

TABLE 1

Length Frequency Distributions of Largemouth Bass-of-the-year Collected in Clear Lake in August, 1948, 1956, 1957, and 1958

Fork length (inches)	Number of fish collected			
	1948	1956	1957	1958
1.3 - 1.4	8	—		
1.5 - 1.6	22	10	1	
1.7 - 1.8	12	43	1	1
1.9 - 2.0	26	68	7	9
2.1 - 2.2	46	60	10	6
2.3 - 2.4	43	31	27	10
2.5 - 2.6	21	20	25	22
2.7 - 2.8	13	7	28	17
2.9 -3.0	11	6	25	24
3.1 - 3.2	13	3	22	24
3.3 - 3.4	9	1	12	11
3.5 - 3.6	7	2	22	16
3.7 - 3.8	11		10	12
3.9 - 4.0	4		10	20
4.1 - 4.2	4		17	22
4.3 - 4.4	6	—	3	15
4.5 - 4.6	2	—	2	18
4.7 - 4.8	1		2	12
4.9 - 5.0	—		—	6
5.1 - 5.2			—	6
5.3 - 5.4				4
5.5 - 5.6		—	—	5
5.7 - 5.8			—	—
5.9 - 6.0	—	—	—	1
Totals	259	251	224	261
Mean fork length (inches)	2.5	2.1	3.0	3.6

reflect fish sizes in the study area. Differences in mean sizes of the fish in the collections had a decided effect upon the kinds of food consumed.

In all of the studies, fish were the most important food from the standpoint of volume, ranging from 56 percent in 1956 to almost 99 percent in 1958. The amount of fish in the total volume of food consumed was roughly proportional to the mean size of the fish, whereas the inverse was true for insects and crustaceans.

A definite change in food habits with increasing size of the young bass was noted in all collections (Figures 1 and 2). (In the 1948 study, 10 specimens with empty stomachs were included in the graphs, while in the later studies only those specimens which actually contained food were used.)

The data from the later studies on the transition of food habits with increasing size of the bass substantiate the data from the 1948 study. Crustaceans and insects were the primary foods of smaller bass, while fish became of major importance as the bass grew. The length at which this shift in diet occurred varied somewhat among the four studies, being about 3.0 inches in 1948, 2.5 inches in 1956, 3.0 inches in 1957, and 2.0 inches in 1958. In all of the studies, bass over these sizes consumed food items in addition to fish, but the amounts were minor.

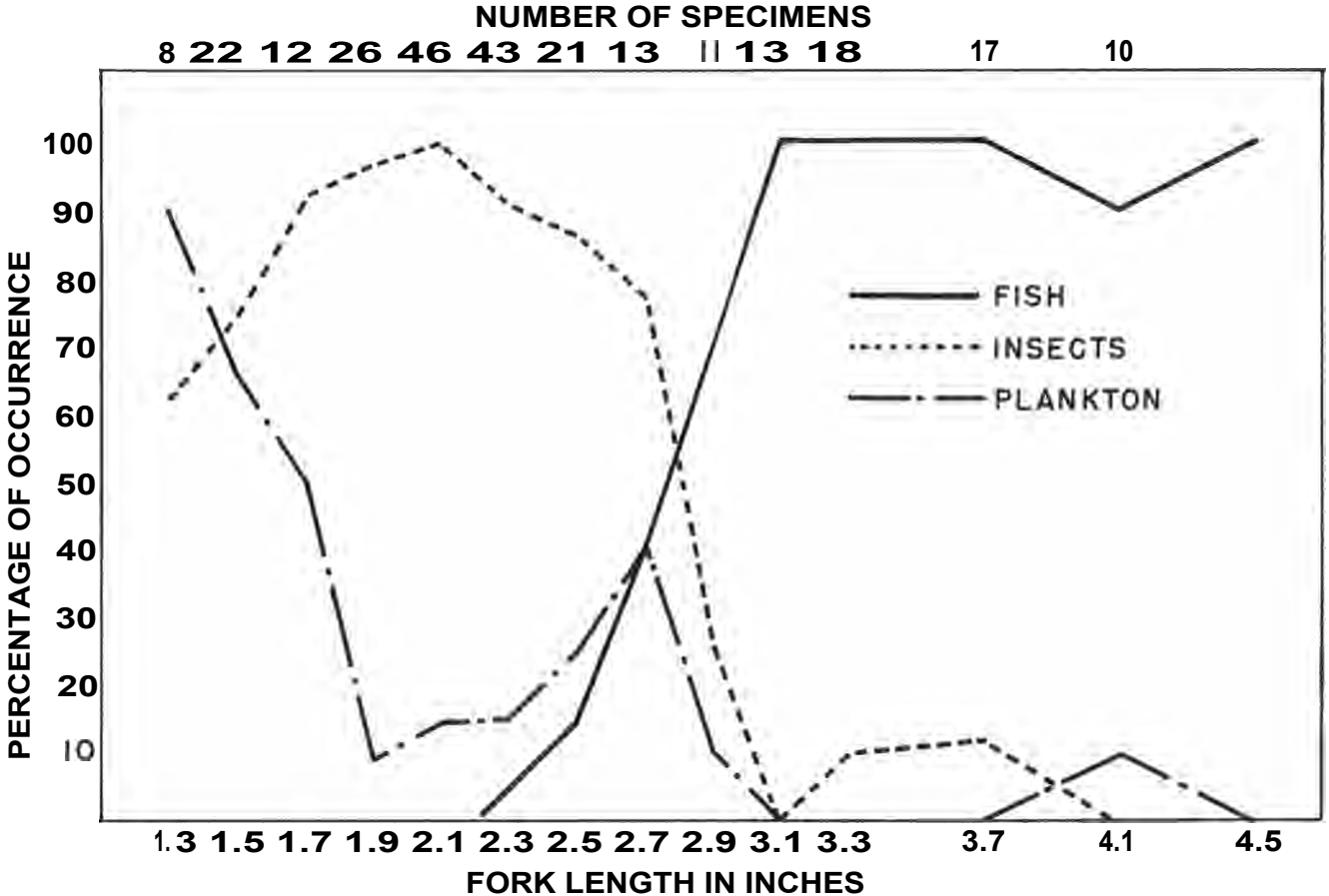

FIGURE 1. Composition of the stomach contents of fingerling largemouth bass. (After Murphy, 1949.)

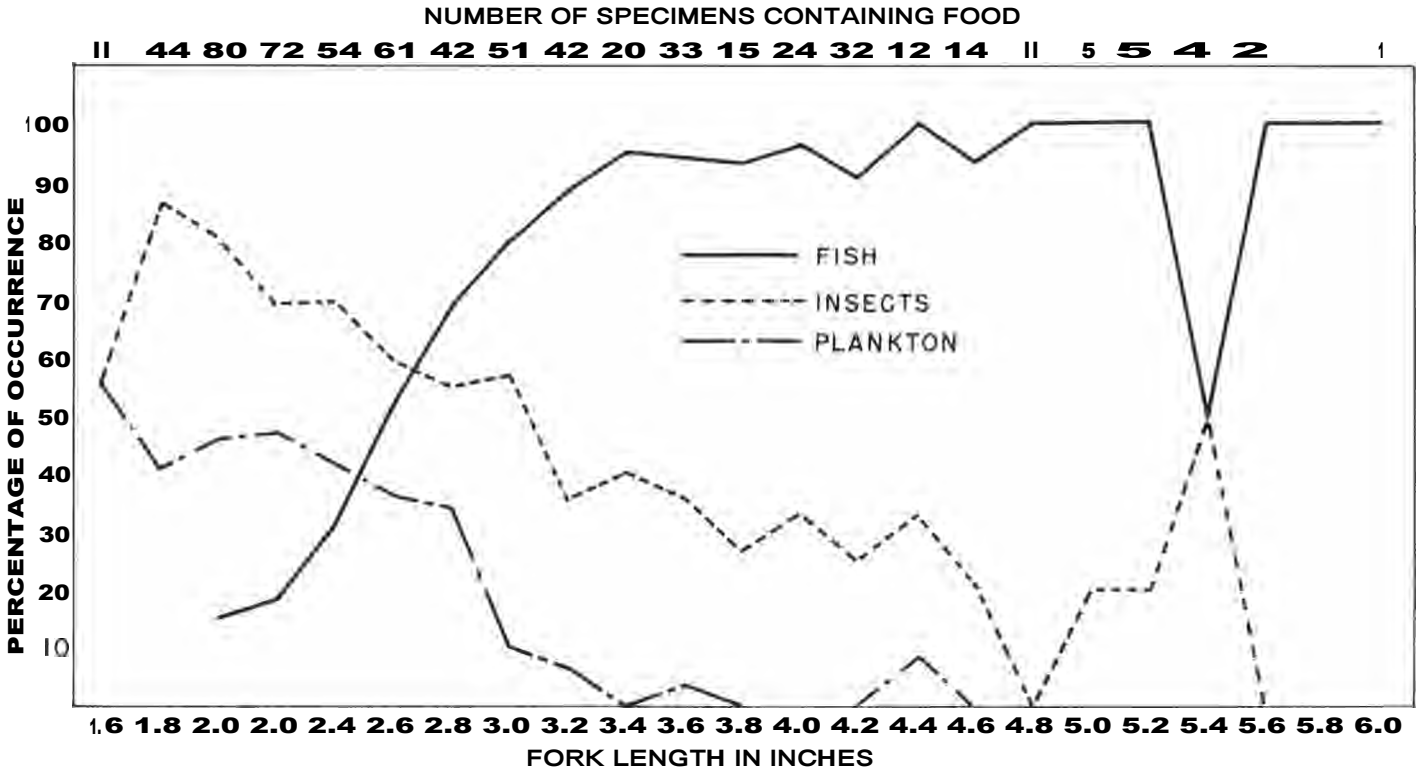

FIGURE 2. Relationship between length of largemouth bass and consumption of major food items during mid-August 1956, 1957, and 1958.

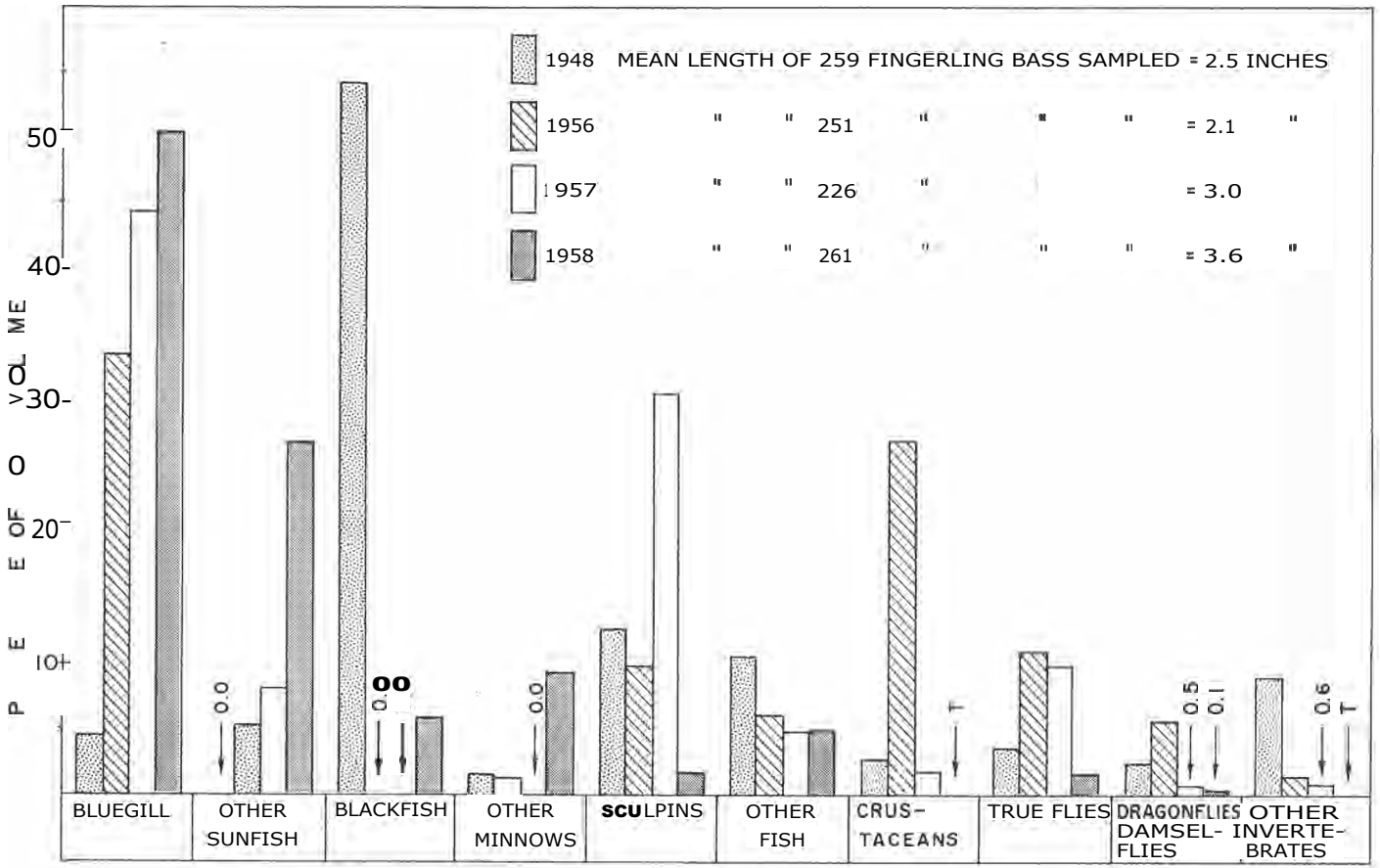

FIGURE 3. Volumetric comparison of food items consumed by fingerling largemouth bass in Clear Lake, 1948, 1956, 1957, and 1958.

This information provides additional evidence that largemouth bass as small as 2.0 inches long can utilize suitable forage fish. The 1958 data also indicate that bass will switch to a fish diet at a length appreciably less than the commonly accepted 3 inches, if forage fish of appropriate size are available. Kramer and Smith (1960) reported that in Lake George, Minnesota, a few largemouth bass fingerlings in a size group of 20-29.9 mm (0.8-1.2 inches) contained fish remains. Nelson (1962) also found fish in the diet of small largemouth bass at Fort Randall Reservoir, South Dakota. He observed that after bass reached 2.5 inches total length fish became their primary food. Apparently the limiting factors are the size and availability of the forage species.

The greatest divergence between the 1948 Clear Lake study and the later data from the same water is in the relative amounts of specific food organisms consumed (Table 2). In 1948, blackfish comprised 65

TABLE 2

Food Consumed by Largemouth Bass Fingerlings in Clear Lake

Food item	Number of organisms*		Frequency of occurrence				Volume (cc.)†			
	1957	1958	1948	1956	1957	1958	1948	1956	1957	1958
Fish										
Sunfish (Centrarchidae)										
Bluegill *(Lepomis)*	38	108	6	27	35	84	3.1	6.2	13.8	43.5
Green sunfish (*Lepomis*)	1				1				0.2	
Unidentified sunfish *(Lepomis)*		*11*				*11*				5.6
Black crappie *(Pomoris)*				1				0.2		
Largemouth bass (*Micropterus*)		1				1				0.1
Unidentified centrarchid remains	14	145		5	14	90		0.8	2.3	17.5
Minnows (Cyprinidae)										
Blackfish *(Orthodon)*		1	28			1	37.8			5.0
Carp *(Cyprinus)*		2	1			2	1.0			2.4
Hitch (Lavinia)		4				4				5.3
Squawfish (*Ptychocheilus*)				1				0.2		
Unidentified cyprinid remains		1				1				0.2
Topminnows (Poeciliidae)										
Mosquitofish (Gambusia)		11		1		9		0.2		1.3
Sculpins (Cottidae)										
Sculpin (Coitus)	37	4	15	5	33	3	8.8	1.8	9.5	1.3
Catfish (Ictaluridae)										
Unidentified catfish (*Ictalurus*)		*1*				1				0.3
Unidentified fish remains	16	41	24	8	18	29	7.2	0.9	1.5	2.7
Crustaceans										
Waterfleas (Cladocera)	10,000	13	53	101	63	5	1.3	2.0	0.1	T
Amphipods (Amphipoda)	227	9	35	129	33	6	0.4	3.0	0.4	T
Insects										
True flies: larvae and pupae (Diptera)	2,182	962	65	141	112	84	2.3	2.0	3.0	1.0
Dragonflies and damselflies (Odonata)	7	10	32	50	7	5	1.4	1.0	0.1	0.1
Mayflies (Ephemeroptera)			8	4			0.1	T		
Wasp, bees, ants, etc. (Hymenoptera)	2			1	2			T	T	
True bugs (Hemiptera)	1	1			1	1			T	T
Water boatmen (Corixidae)	2		142	17	2		6.0	0.2	T	
Unidentified insect remains		3	6	2		3	0.1	T		T
Miscellaneous invertebrates										
Spiders (Arachnida)	2				2				T	
Leeches (Hirudinea)	3				3				0.2	
Unidentified invertebrates			8	4			0.1	T		

* Number of organisms not recorded In 1948 or 1956 studies.
† T = trace.

percent of all fish eaten and 54 percent of the total volume of food. No blackfish were found in the 1956 and 1957 collections, and only one was found in 1958. Bluegills were relatively unimportant in 1948, comprising only 5 percent of the fish and only about 4 percent of the total food. By contrast, bluegills comprised the majority of the fish and were the most important single food item consumed in each of the later studies (Figure 3).

Cyprinids were important in the bass diet only in the 1948 and 1958 studies, but to a much lesser degree in the latter. In 1948, blackfish made up 54.2 percent and carp *(Cyprinus carpio)* 1.4 percent of the total volume of food. In 1958, cyprinids composed 15.1 percent of the total volume, one-third of which consisted of a single 2.5-inch blackfish that had been eaten by a 5.0-inch bass.

Sculpins *(Cottus)* were of considerable importance in all but the 1958 study, when they composed only 1.5 percent of the total volume. This evidence, coupled with data that show sculpins are important food for white catfish *(Ictalurus catus)* (George W. McCammon, unpublished data), indicates they may be an important forage fish in Clear Lake from the standpoint of consistent utilization.

Crustaceans were of minor importance in the diet of the bass in all but the 1956 collection, in which cladocerans made up 11 percent and amphipods 16 percent of the total food volume. This is not surprising when related to the mean size of the bass in the 1956 collection (2.0 inches) and to the fact that microcrustaceans are utilized primarily by small fish.

Dipteran larvae and pupae made up the bulk of the insect food consumed in all collections but 1948, when water boatmen (Corixidae) were the most important insect, with dipterans second.

The only evidence of intra-year-class cannibalism was found in 1958, when one bass had been consumed.

DISCUSSION

As a general rule, food habit studies in which specimens are collected in a restricted area during a brief period of time do not provide adequate data upon which to base definite conclusions. At best, this type of collection indicates only the amounts and kinds of foods consumed at a given time and place. Projection of such data may seriously distort the true picture of the relationships involved. The fingerling bass food habit studies reported here follow this rule.

In some instances, short-term investigations will uncover sufficient facts to support a **working hypothesis.** However, to obtain an accurate picture of the food habits of an organism, collections must be made at regular intervals over at least one and preferably two or more growing seasons or years.

The four brief food habit studies reported herein have only limited application to the management of the Clear Lake fishery. Past environmental control practices based on the results of the 1948 study, specifically the abolition of commercial fishing for blackfish, may not have been warranted.

The following conclusions drawn from the 1948 study were inconsistent with the results of the later studies:

1) Bluegill fry are not important in the diet of bass in Clear Lake.
2) The Sacramento blackfish is a highly important forage and buffer species in Clear Lake.
3) The selection of food items by bass in Clear Lake is primarily a matter of choice and not of environmental limitations.

The first of these conclusions conflicts with the results obtained during the three later studies, as well as with considerable evidence from other waters, both in and out of California.

J. B. Kimsey (unpublished data) made fingerling bass stomach collections at regular intervals throughout two growing seasons in Salt Springs Valley Reservoir, Calaveras County. He found that although golden shiners and fathead minnows (Pimephales promelas), usually considered desirable forage species, were present in the reservoir, they were eaten only in insignificant quantities. Bluegill fry, on the other hand, were the forage species of greatest importance.

Brief bass food habit studies at Lake Havasu (Beland, 1954) and Millerton Lake (Fisher, 1951) also demonstrated that largemouth bass utilize bluegills as forage.

In an evaluation of the threadfin shad (Dorosoma petenense) in the lower Colorado River, Kimsey et al. (1957) found that bluegills and other centrarchids occupied a prominent position in the diet of largemouth bass, even in the presence of the abundant shad.

Kramer and Smith (1960) noted that in Lake George, Minnesota, the forage species most commonly taken by fingerling bass were young-of-the-year sunfish and brook silversides (Labidesthes sicculus), although the lake contained other species, including perch, darters, and minnows.

Ball (1948) found that bluegills were the staple food of largemouth bass in Third Sister Lake in Michigan, although several species of small minnows and darters were also abundant.

Murphy (1949), noting that bluegills spawned 1 to 1½ months after the bass, cited this as a point against their usefulness as bass forage. Actually, the fact that bluegills are late spawners helps to substantiate the opposite view. By spawning late, large numbers of small bluegills are present when fingerling bass are ready to change from an invertebrate to a fish diet.

In 1949, a detailed life-history study of the blackfish showed that they spawn before, or about the same time, as the bass, and that the young-of-the-year grow very rapidly (Murphy, 1950). During that year, the Age 0 blackfish attained an average fork length of approximately 2.9 inches by mid-August. If this growth rate is typical, it seems very unlikely that the bulk of Age 0 blackfish would be suitable forage for bass-of-the-year. The average fork lengths of fingerling bass around mid-August in 1948, 1956, 1957, and 1958 were 2.5, 2.1, 3.0, and 3.6 inches, respectively (Table 1). Any predator-prey relationship between Age 0 bass and Age 0 blackfish would be restricted to the larger bass and the smaller blackfish.

Unfortunately, only rough approximations give any clue to the relative abundance of blackfish or bluegills during the study periods. In

three of the studies bluegills were termed abundant or very abundant in the study area, while young blackfish were scarce or completely absent (estimates of the abundance of either species were lacking in the 1957 study). Obviously, more precise information about relative abundance would have given greater weight to the conclusions reached.

White catfish are important predators in Clear Lake. Nevertheless, analysis of the stomach contents of several hundred Clear Lake white catfish in 1943 (Wales, 1943) failed to detect a single blackfish. In addition, examination of 115 white catfish stomachs collected at intervals in 1953 and 1954 from Clear Lake further indicate that catfish do not feed on blackfish (George W. McCammon, unpublished data).

Murphy (1949) detected no evidence of intra-year-class predation among bass during his study. He theorized that the factors of "availability and desirability, that mitigated against the full utilization of young bluegill, operated in the case of smaller bass." In addition, he advanced the hypothesis that in the absence of an early spawned cyprinid forage fish, the brunt of predation by older bass would be borne by bass fry.

The contention that the blackfish is a valuable buffer species, though possible, can be neither confirmed nor denied, since conclusive evidence in the form of food habit studies of larger Clear Lake bass does not exist. With the exception of one fish in 1958, the 1948 study is the only record available in which bass consumed blackfish.

In at least one instance, introduction of Sacramento blackfish into a warmwater lake in California was detrimental to a largemouth bass fishery (Douglas, 1949). An accidental introduction of blackfish into Lake Hughes, Los Angeles County, resulted in a decline in the quality of bass angling and a population eventually dominated by blackfish. It later became necessary to remove the entire population of Lake Hughes and adjoining waters by chemical treatment.

The importance of blackfish in the diet of bass-of-the-year at Clear Lake in August 1948, and the relative unimportance of the bluegill as a forage species during the same period, cannot be denied. However, succeeding food habit studies in Clear Lake, as well as many studies from other waters, indicate that this situation was atypical. Subsequent evidence showed that the blackfish is not regularly an important forage species. Nevertheless, the possibility exists that blackfish could again become important under conditions similar to those in Clear Lake in 1948. It is of interest to note that the 1948 sample was taken before elimination of the commerical blackfish fishery and during a period when the blackfish population was thought to be depleted.

With the exception of the apparent selection of blackfish by bass during the first Clear Lake study, it appears most likely that the primary factor in the utilization of a food organism by bass is the availability of a suitable sized organism. The variation in size at which the bass in each study turned to a predominantly fish diet, as well as the varying species composition in the different collections, supports this conclusion. Support also can be found in Kramer and Smith (1960), who also found that the utilization of a food organism was dependent upon its size and availability. This conclusion should be qualified, however, in that choice can play a part in food selection when food items

are equally available. Lewis *et al.* (1961), in a laboratory study, found that largemouth bass usually ate golden shiners, apparently preferring them to several other organisms of similar size and availability.

SUMMARY

A study of fingerling largemouth bass food habits in Clear Lake during mid-August, 1948, indicated the Sacramento blackfish was a far more important forage and buffer species than the bluegill.

To obtain a better understanding of bass-forage fish relationships in Clear Lake, and to test conclusions of the earlier study, additional investigations were conducted in mid-August of 1956, 1957, and 1958. Areas sampled, sampling methods, and subsequent analyses employed in these studies duplicated those of the 1948 study when possible.

The data from all four studies which relate the transition of food habits to changes in size are in agreement. Plankton and insects were the most important food for bass under 2.5 inches fork length, while fish became the major food for bass above that size.

The mean lengths of the bass sampled ranged from 2.1 inches in the 1956 collection to 3.6 inches in the 1958 collection. These differences influenced the proportions of the major food items (i.e., fish, crustaceans, and insects) consumed. The larger bass ate more fish and the smaller ones more insects and crustaceans.

The greatest differences in food habits were in the specific kinds of food eaten. In the 1948 collection, blackfish were the major food item with bluegills of only minor importance. In all of the later collections, bluegills constituted over half of the fish consumed, and were the most important single item. On the other hand, blackfish, with one exception, were not found in any of the stomachs examined during the later studies. Therefore, we conclude that blackfish are not regularly important forage for fingerling largemouth bass in Clear Lake.

We also conclude that, while species preference may play a part in the selection of a food organism by fingerling largemouth bass, size and availability are more important.

These studies emphasize the desirability of follow-up work when a management program is based on very limited data.

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