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GROWTH, FOOD, AND HABITAT OF AGE 0 SMALL-MOUTH BASS IN CLAIR ENGLE RESERVOIR, CALIFORNIA [1]

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A total of 342 age 0 smallmouth bass, *Micropterus dolomieui*, from Clair Engle Reservoir, Trinity County, were collected with seines from July through September 1979 as part of growth, diet, and habitat studies. Mean length in mid-September was 84 mm; a relatively low value. Protected habitat areas were favored during spring and early summer. Fish tended to move to more exposed habitats as they became larger and weather conditions moderated. Favored bottom substrates included shale, rocky-rubble, sand and gravel, and areas with stumps and submerged logs. No bass were collected in areas with exclusively mud bottoms. Aquatic dipterans (primarily chironomid larvae and pupae) dominated the age 0 bass diet.

INTRODUCTION

Clair Engle Reservoir, formed in 1960 by the closure of Trinity Dam, on the Trinity River, is part of the U.S. Bureau of Reclamation Central Valley Project in northern California. Soon after impoundment a fishery developed for largemouth bass, *Micropterus salmoides*, and smallmouth bass, *M. dolomieui*. Bass were introduced when old dredge ponds were flooded during reservoir filling, and both species established naturally reproducing populations. The smallmouth bass fishery is the larger, and fishing effort for this species has increased dramatically over the years. Other species contributing significantly to the fishery include brown trout, *Salmo trutta*, rainbow trout, *S. gairdneri*, and kokanee salmon, *Oncorhynchus nerka*.

As bass populations increased, a trophy smallmouth bass fishery developed. To prevent over-exploitation of the smallmouth bass population, the California Department of Fish and Game imposed a 30.5-cm minimum length limit in 1976. Although this size limit has been successful elsewhere for conserving smallmouth bass populations (Surber 1969), it is not clear that this regulation alone will be sufficient to maintain a quality fishery in Clair Engle Reservoir. Preliminary data indicated rapid growth of smallmouth bass in the reservoir (J. Thomas, unpubl. data), although Coleman (1978) found that the reservoir was cold and unproductive, with low standing crops of zooplankton. Knowledge of the food, growth, and habitat of age 0 smallmouth bass in this reservoir should enable the refinement of the management plan for the population.

STUDY AREA

Clair Engle Reservoir is about 40 km northwest of Redding, California, on the upper reaches of the Trinity River, at an elevation of 724 m above mean sea level. The reservoir has a maximum capacity of 3.1 billion m^3 of water; it is 30 km long and 0.8 to 3.2 km wide, with a shoreline of 240 km and a surface area of 66 km^2. The reservoir is 136 m deep at the dam and is deep throughout most

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of its length.

The reservoir is considered oligotrophic and is similar to other deep mountain lakes in California (Coleman 1978). It has seven major tributaries: Trinity River, East Fork Trinity River, Swift Creek, Feeney Creek, Papoose Creek, East Fork Stuart Fork, Stuart Fork. Most of the inflow is snowmelt from nearby mountains. The steep banks are devoid of aquatic plants and most trees were removed before the reservoir was filled.

METHODS

Nine stations were sampled with seines at 2-wk intervals during April–June 1979 and April–May 1980, and weekly during July–September 1979 (Figure 1). Stations were selected on the basis of preliminary seine surveys and the most productive seinable areas within different habitats were assigned station numbers. Stations were classified into three habitat "types", based on a visual description of the sampling areas. Habitat 1 (stations 2, 6 and 7) was characteristic of protected areas near major tributaries; habitat 2 (stations 4 and 5) was characeristic of sheltered, gently sloping littoral areas; and habitat 3 (stations 3, 8, and 9) was characteristic of unprotected steeply sloping littoral areas. Station 1 (a representative of habitat 3) was sampled only once in early July and was not included in the fish growth and food analyses by habitat type.

Stations associated with streams (habitat 1), were cooler than other areas and were protected from winds. Some macrophytes and flooded terrestrial vegetation were in the areas when water levels were high. The bottom substrate consisted of sandy-gravel, flooded weeds, dead small rooted shrubs, and a few submerged logs and rock piles. Turbidity was low during the sample period. The sheltered flat areas (habitat 2) were protected from heavy winds and waves, since they were in small bays with narrow outlet channels. Aquatic plants were scarce, and at high water levels little terrestrial vegetation was flooded. Tree stumps were the major cover. Bottom substrate ranged from a sandy-mud mixture to rocky rubble. Water in this area was moderately turbid even during fairly calm weather. The open water areas (habitat 3) were steeply sloped with shale, gravel, or rock shorelines and little vegetation. During windy periods the shoreline was subject to erosion by wave action, and nearshore turbidity was high.

Surface water temperature was taken with a pocket thermometer during each sampling period at the station where data collection began.

Age 0 smallmouth bass were collected with two seines, one 9.1 by 1.2 m with 3.2-mm mesh, and another 15.2 by 1.8 m, with 5.9-mm mesh (bar measure). Both seines were used during each sampling period. Fish were preserved in 10% buffered formalin and later measured fork length (FL), (to the nearest millimetre) and weighed (to the nearest gram) 30 s after they were blotted on clean filter paper. Mean lengths and weights of bass were compared by habitat and month using the Student-Newman-Keuls procedure (Sokal and Rohlf 1969). Total bass catch, by habitat and time, were compared using Friedman's test (Langly 1971).

We determined length-weight relation, $W = aL^b$, using the computer program "Growth" (Mawson and Reed 1969), as modified by Collins (1977), where: W = weight in grams, L = FL in millimeters, and a and b are constants. Fork length was converted to total length (TL) by the formula, TL = 1.04 *FL* (Fry and Watt 1957)

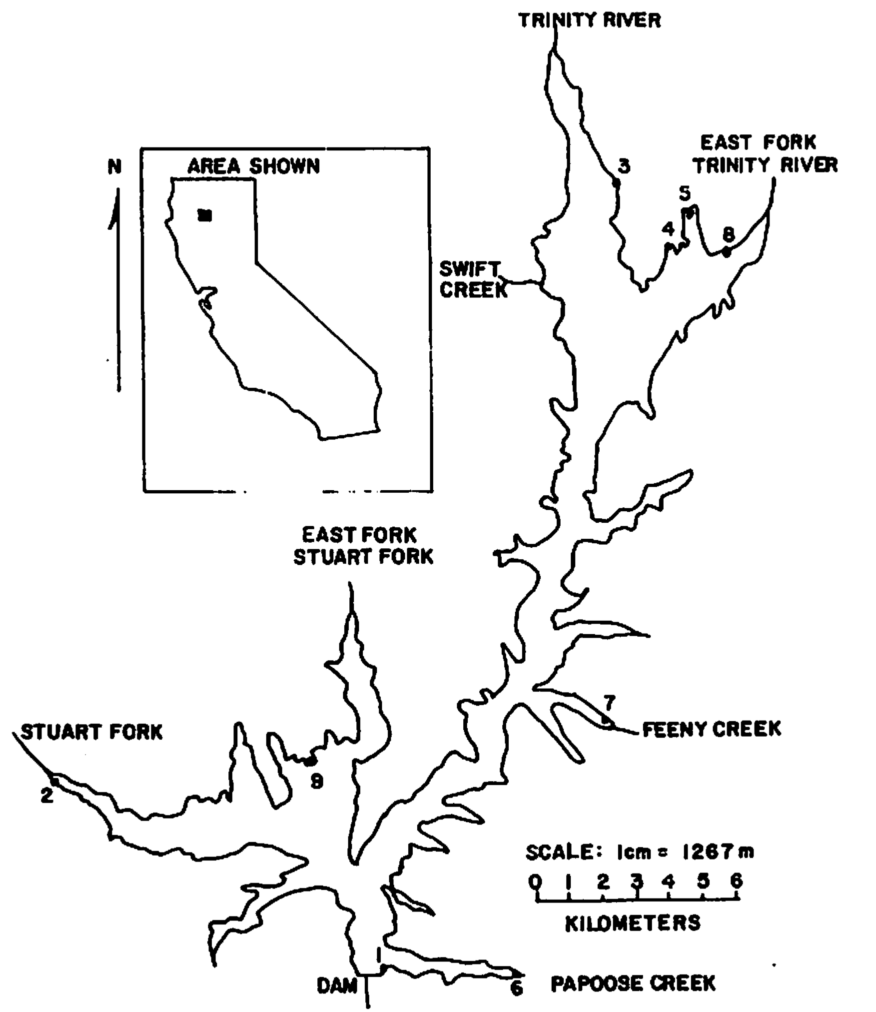

FIGURE 1. Clair Engle Reservoir California, showing sampling stations in three types of habitats: (1) protected areas near major tributaries (Stations 2, 6, and 7); (2) sheltered gently sloping littoral areas (Stations 4, and 5); and (3) unprotected steeply sloping littoral areas (Stations 1, 3, 8, and 9).

Stomach contents for each fish were examined microscopically and food items identified using keys published by Pennak (1953); Fernald and Shepard (1955); Usinger (1963); Edmondson (1966); Comstock (1972); Borr, Delong and Triplehorn (1976); and Leumkuhl (1979). Unidentified food material and empty stomachs were recorded.

Abundance of food items in each fish stomach was characterized by three methods: volumetric, numerical, and frequency of occurrence (Larimore 1957, Windell 1971, Clady 1974, George and Hadley 1979). Major food groups (those 0.05 ml or more in total volume and representing more than 0.1% by number) were tabulated by habitat and time of collection. Volumes of benthic organisms, fish, and aquatic and terrestrial insects were measured by water displacement in a calibrated centrifuge tube. Volumes of zooplankton, ostracods, and amphipods were estimated by making several measurements for each species and computing an average volume per individual of a species, and then multiplying by the number of individuals of that species per stomach (Langdon 1979). Frequency of occurrence consisted of the number of stomachs containing food of a given group, expressed as a percentage of the total of 221 full stomachs that were examined (Windell and Bowen 1979).

Stomach contents from each fish also were evaluated by using the Index of Relative Importance (IRI: Pinkas, Oliphant, and Iverson 1971), for each food item: $IRI = (N + V)FO$, where N = percentage of total number, V = percentage of total volume, and FO = percentage frequency of occurrence.

RESULTS

Catch By Habitat

A total of 342 age 0 smallmouth bass were collected from all habitats (Table 1). Age 0 bass were caught only during July-September 1979. The catch decreased significantly from 208 in July to 30 fish in September $P<0.05$) but did not differ significantly by habitat type. Age 0 bass were caught throughout the reservoir in rocky-rubble areas and in areas with stumps and vegetation, but no bass were caught in areas with mud bottoms. Reservoir water level was maximum and stable from mid-May to mid-July and all stations were seinable. Water level dropped 9.5 m from mid-July through September and most stations were difficult to seine.

TABLE 1. Numbers of Young-of-the-Year Smallmouth Bass Collected in Different Habitats from Clair Engle Reservoir, California, Summer 1979.

Habitat	*July*	*August*	*September*
1[a]	107	39	11
2[b]	55	27	8
3[c]	46	38	11
Total	208	104	30

[a] Protected areas near major tributaries.
[b] Sheltered, gently sloping littoral areas.
[c] Unprotected steeply sloping littoral areas.

Growth

Mean FL of age 0 smallmouth bass increased from 32 mm in early July to 84 mm by mid-September and mean weight from 0.6 g to 8.7 g (Figure 2). Age 0 bass from the three habitats averaged the same size in July (Table 2). Fish captured in habitat 1 during August were significantly smaller than fish from habitats 2 and 3 ($P<0.05$; mean 54.3 mm FL and 2.4 g versus 63.1 mm and 4.0 g). Fish captured in habitat 1 during September were significantly shorter than fish from habitats 2 and 3 ($P<0.05$; mean 72 mm versus 78.4 mm) but were significantly lighter only than fish from habitat 3 ($P<0.05$; mean 5.9 g versus 7.3 g). The allometric length-weight relation was as follows: weight $= 1.790 \times 10^{-4} \times \text{Length}^{2.948}$, $r = 0.932$ (Figure 3).

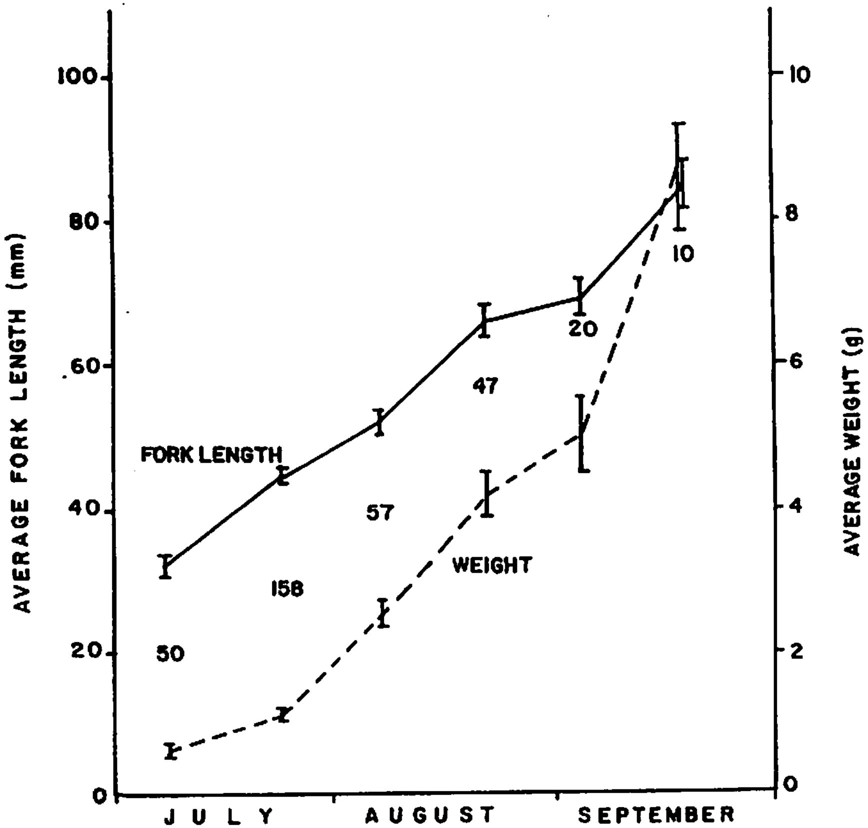

FIGURE 2. Size of young-of-the-year smallmouth bass from Clair Engle Reservoir California, July–September 1979. Mean ±standard error; numbers between weight and length curves show numbers of fish in each collection.

TABLE 2. Mean Size of Young-of-the-Year Smallmouth Bass from Clair Engle Reservoir, California, Summer 1979.

	July			*August*			*September*		
Habitat	*Length (mm)*	*Weight (g)*	*N*	*Length (mm)*	*Weight (g)*	*N*	*Length (mm)*	*Weight (g)*	*N*
1	42.1	1.2	107	54.3[a]	2.4[b]	39	72.0[a]	5.9[c]	11
2	46.1	1.5	55	62.6	3.7	27	77.4	6.7	8
3	46.6	1.5	23	63.6	4.3	38	79.5	7.3	11

[a] Significantly shorter than fish from habitats 2 and 3 (SNK; $P<0.05$).
[b] Significantly lighter than fish from habitats 2 and 3 (SNK; $P<0.05$).
[c] Significantly lighter than fish from habitat 3 (SNK; $P<0.05$).

Food

Of the 327 fish stomachs collected, 96% contained food. Food was analyzed only from the 221 fish (68% of the total) that had full stomachs.

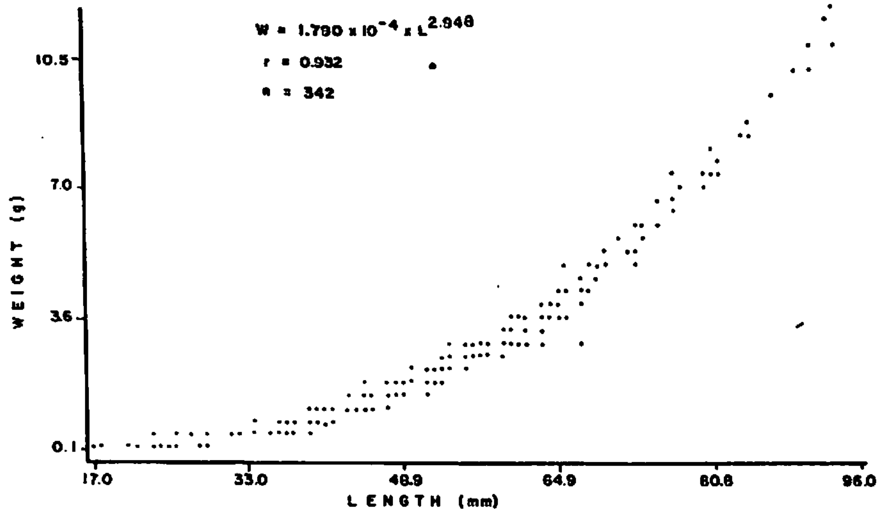

FIGURE 3. Length-weight relation of 342 young-of-the-year smallmouth bass from Clair Engle Reservoir California, July–September 1979.

Aquatic dipterans dominated the diet of age 0 smallmouth bass by volume, number, and frequency of occurrence (Table 3). Chironomid larvae dominated the food items by volume (49.5%), followed by Ephemeroptera (15.9%)—mostly nymphs of Baetidae. Chironomid pupae, the second most abundant dipteran, were the third most abundant food item by volume (11.0%). These three groups accounted for 76.5% of the volume of food eaten by age 0 bass.

Chironomid larvae dominated the diet by numbers (28.0%) and chironomid pupae ranked third numerically (15.0%). The copepod, *Diaptomus franciscanus*, ranked second numerically (22.2%), and the cladoceran, *Diaphanasoma brachyurum*, ranked fourth (12.8%). The other 33 food items accounted for only 22.8% of the total number of items eaten.

Frequency of occurrence for larvae and pupae of Chironomidae were 83.7 and 75.6%, respectively. They were followed by Cladocera, Ephemeroptera, and Copepoda.

Indices of Relative Importance and percentage IRI were determined for the 12 most important food categories (Table 4). The most important age 0 smallmouth bass food was chironomid larvae and pupae (IRI, 42 and 17%, respectively). The next two most important food items were *Diaptomus franciscanus* and *Diaphanasoma brachyurum*. These four food organisms accounted for at least 84% of the IRI each month. Chironomid larvae were the most important age 0 smallmouth bass food in all habitats in July, and in habitats 2 and 3 in August (Table 4). *Eurycercus lamellatus* was the most important food item in August in habitat 1. The most important food organisms in September were *Diaptomus franciscanus* in habitat 1, *Diaphanasoma brachyurum* in habitat 2, and chironomid pupae in habitat 3.

TABLE 3. Stomach Contents of 221 Young-of-the-Year Smallmouth Bass from Clair Engle Reservoir, California, July–September 1979.

	Volume		*Number*		*Occurrence*	
Food Items	*ml*	*%*	*N*	*%*	*Frequency*	*%*
Ceriodaphnia laticaudata	T[a]	T	38	0.2	3	1.4
Chydorus sphaericus	T	T	105	0.5	34	15.4
Daphnia galeata mendotae	0.14	1.1	1392	6.3	17	7.7
Daphnia pulex	0.08	0.6	548	2.4	55	24.9
Diaphanasoma brachyurum	0.28	2.2	2770	12.6	108	48.9
Eurycercus lamellatus	0.39	3.1	1951	8.9	122	55.2
Polyphemus pediculus	T	T	215	1.0	4	1.8
Diaptomus franciscanus	*0.49*	*3.9*	*4900*	*22.2*	*64*	*29.0*
Cyclops bicuspidatus	T	T	159	0.7	39	17.6
Ostracoda	T	T	2	T	1	0.5
Amphipoda	0.08	0.6	109	0.5	15	6.8
Heptageniidae (nymphs)	T	T	1	T	1	0.5
Caenidae (nymphs)	T	T	1	T	1	0.5
Baetidae (nymphs)	1.98	15.9	238	1.1	80	36.2
Gomphidae (nymphs)	0.13	1.0	9	T	1	0.5
Libellulidae (nymphs)	0.14	1.1	5	T	3	1.4
Zygoptera—damselflies	0.51	4.1	41	0.2	30	13.6
Corixidae	T	T	5	T	3	1.4
Leptoceri	0.02	0.2	16	0.1	5	2.3
Chironomidae (larvae)	6.17	49.5	6171	28.0	185	83.7
Chironomidae (pupae)	1.37	11.0	3294	15.0	167	75.6
Dixidae	T	T	1	T	1	0.5
Muscidae (larvae)	T	T	2	T	1	0.5
Brachycera	T	T	1	T	1	0.5
Corydalus sp. (larvae)	0.16	1.3	8	T	7	3.2
Dytiscidae (larvae)	T	T	3	T	3	1.4
Cleridae	T	T	1	T	1	0.5
Eupelmidae	T	T	2	T	1	0.5
Formicoidae	T	T	1	T	1	0.5
Chalcidoidae	T	T	1	T	1	0.5
Emphididae	T	T	10	T	3	1.4
Mycetophilidae	T	T	1	T	1	0.5
Cicadellidae—leafhoppers	T	T	1	T	1	0.5
Psyllidae (Chermidae)	T	T	2	T	1	0.5
Delphacidae	T	T	1	T	1	0.5
Ictalurus sp.	0.17	1.4	5	T	3	1.4
Green Sunfish	0.17	1.4	5	T	3	1.4
(*Lepomis cyanellus*)	0.06	0.5	2	T	2	0.9
Trout or Kokanee	0.30	2.4	12	0.1	8	3.6
Unidentifiable items	T	T	—	—	—	—
Total	12.47	99.9	22024	99.8		

[a] T = (<0.05 ml or < 0.1%)

The number of food items in the stomachs of young fish decreased from July to September. However, the size of the organisms eaten increased. For example, as bass increased in size during the season they ate larger food items such as fish and damselflies.

TABLE 4. Index of Relative Importance of Major Food Items in the Diet of 221 Young-of-the-Year Smallmouth Bass from Clair Engle Reservoir, California, Summer 1979. Percent IRI in parentheses.

Food item	July habitat			August habitat			September habitat		
	1	2	3	1	2	3	1	2	3
Chironomidae (larvae)	2979(29)	15270(86)	14119(83)	458(5)	8251(58)	7540(50)	343(3)	1867(15)	2370(14)
Chironomidae (pupae)	495(5)	961(5)	1982(12)	782(8)	4114(29)	4435(30)	371(3)	764(6)	8181(48)
Diaptomus franciscanus	6(T) [b]	0(0)	116(1)	2394(25)	483(3)	804(5)	10724(81)	1947(15)	72(T)
Diaphanosoma brachyurum	1532(15)	50(T)	35(T)	181(2)	725(5)	1636(11)	183(1)	7911(62)	4970(29)
Eurycercus lamellatus	1523(15)	97(1)	60(T)	4290(44)	61(T)	131(1)	480(4)	180(1)	345(2)
Baetidae (nymphs)	2735(26)	1159(7)	546(3)	639(7)	15(T)	309(2)	51(T)	0(0)	25(T)
Daphnia pulex	189(2)	1(T)	5(T)	333(3)	120(1)	16(T)	378(3)	4(T)	45(T)
Zygoptera (Damselfly)	583(6)	113(1)	5(T)	0(0)	24(T)	28(T)	0(0)	0(0)	0(0)
Daphnia galeata mendotae	146(1)	0(0)	0(0)	265(3)	363(3)	11(T)	0(0)	0(0)	0(0)
Trout or Kokanee	0(0)	2(T)	60(T)	0(0)	22(T)	69(T)	0(0)	0(0)	0(0)
Amphipoda	1(T)	0(0)	90(1)	0(0)	0(0)	12(T)	0(0)	0(0)	1110(6)
Leptoceridae	0(0)	0(0)	0(0)	0(0)	1(T)	0(0)	519(4)	0(0)	4(T)
Others [a]	203(2)	14(T)	0(0)	396(4)	0(0)	4(T)	126(1)	0(0)	0(0)
Total	10392	17667	17018	9738	14179	14995	13175	12673	17122

[a] *Polyphemus pediculus*, Libellulidae nymphs, Green Sunfish, Gomphidae nymphs, *Ictalurus*, and *Corydalus*.
[b] T = (< 0.5%).

DISCUSSION

The mean size of age 0 smallmouth bass was the same in all habitats in July. In August and September fish caught in habitats 2 and 3 were significantly larger than fish caught in habitat 1. Age 0 bass probably moved from more protected nearby areas into more exposed habitats as they grew and as weather conditions moderated later in the summer. Habitats 2 and 3 (especially 3) were exposed to wave action, and turbidities were high during the windy spring and early summer. These conditions are generally not suitable for small bass and they avoid such areas (Tester 1930, Hubbs and Bailey 1938, Latta 1963).

First-year growth of smallmouth bass in Clair Engle Reservoir was poor in comparison with growth in other areas (Carlander 1977). Age 0 bass averaged only 87 mm TL by 18 September 1979. Carlander reported lengths of 91 mm or longer for September. Age I bass from Clair Engle were smaller than 35 of the 38 entries for age I smallmouth bass reported by Carlander (1977). Most age I fish cited by Carlander were considerably longer (mean 166 mm; range 41-343 mm) than the mean TL of 105 mm for age I smallmouth bass from Clair Engle Reservoir reported by Hannah (1980). Clair Engle Reservoir is deep, cold, and unproductive, and these characteristics may account for the poor first-year growth. Tharratt (1966) reported that age I smallmouth bass from Folsom Reservoir, California, were 149 mm long.

Preliminary data (J. Thomas upubl. data) indicated that first-year growth of smallmouth bass in Clair Engle Reservoir was very good, but more recent data indicated that bass growth rates decreased during the years after impoundment. Hannah (1980) working with adult bass from Clair Engle, found that age I smallmouth bass from 1967 through 1969 were larger than age I fish from 1970 through 1978, and growth of older bass had declined through the 1970's. The observed decrease in growth may be due to low plankton populations (Coleman 1978), reservoir aging (Neel 1967), or both.

Aquatic insects made up the largest part of the diet of young bass, followed by crustaceans and fish. Chironomid larvae were by far the most important source of food and chironomid pupae the second most important food at Clair Engle Reservoir in 1979. Several other investigators have also found that chironomidae were an important food of young-of-the-year smallmouth bass (Wickliff 1920, Pflieger 1966, Keating 1970). Baetidae nymphs were the third most important aquatic insect, although they ranked sixth in importance overall. The Chironomidae and Baetidae accounted for 79% of the total IRI.

Crustaceans, the second most important group of food organisms eaten by bass, consisted of copepod *Diaptomus franciscanus*, the most important item, and the cladoceran *Eurycercus lamellatus*, the second most important. Our findings also agree with findings of Wickliff (1920), Hubbs and Bailey (1938), Doan (1940), Lachner (1950), and Pflieger (1966), which showed that Copepoda were the most important zooplanters eaten by young bass and that Cladocera ranked second.

Fish was the third most important food item of young bass. They were not eaten until bass were 31 mm long or longer and were important in the diet of age 0 fish caught only in habitats 2 and 3. Pflieger (1966) found that in Missouri's small Ozark streams fish were important food items for bass longer than 15 mm standard length (SL) and Wickliff (1920) indicated that fish were not an important food source until young bass were longer than 15 mm SL, but increased in importance as bass grew larger.

The diets of age 0 smallmouth bass in Clair Engle Reservoir were intermediate between those reported by Surber (1940), Lachner (1950), Pflieger (1966), Keating (1970) and Paragamian and Coble (1975) for riverine situations, and those reported by Wickliff (1920), Tester (1932), and Clady (1974) for lacustrine situations. Young smallmouth bass from the reservoir had a broad based diet consisting of food from six or more taxa. Aquatic insects were the major food source in this study, complemented by crustaceans, fish, and terrestrial insects. Keating (1970) reported similar diets in Idaho, where aquatic insects, terrestrial and flying aquatic insects, plankters, nematodes, and fish constituted the diet of young bass. Few terrestrial insects were available in Clair Engle Reservoir, perhaps due to the lack of overhanging vegetation along the shoreline.

Stomach content varied considerably by bass size, season, and habitat type. For example, chironomid larvae were less important in September than earlier, but chironomid pupae were more important in September. This change probably reflects the metamorphosis of larvae to pupae. *D. franciscanus* was a less important food item when bass were small (18 to 71 mm FL) in July than during September, when bass were larger (57–96 mm FL).

Young bass fed most of the time, as indicated by the small number of empty stomachs (only 4%). Similarly, few age 0 bass with empty stomachs were found by Wickliff (1920) or Harlan and Speaker (1956). In addition to continual feeding, many age 0 bass tended to feed on only one food at a time. For example, some stomachs might contain only *Diaptomus,* in numbers ranging from a few to hundreds. Beeman (1924) also observed a similar tendency of small bass to feed on only a single food item.

No fish were collected after September 1979 even though additional sampling was done in April and May 1980. This failure to collect fish of the 1979 year class in 1980 may indicate a change in distribution or heavy overwinter mortality or both. The 1979 year class fish may have moved from the sampling sites to other locations during the period between September and April. However, many bass of the 1977 and 1978 year classes (ages II and III) were caught in April and May 1980. Thus a change in vulnerability to the collecting gear was probably not a major factor. Age 0 smallmouth bass from Clair Engle were still small by late September and may have suffered high winter mortality. Christie and Regier (1973) and Oliver, Holeton, and Chua (1979) indicated that overwinter mortality was greater for small bass than for larger ones. Many of the smallest fish became emaciated, then lost equilibrium and died. Shuter *et al.* (1980) indicate that large bass can withstand winter starvation better than small fish and that high mortality of young bass may result from exposure to extreme temperatures.

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