POPULATIONS OF SPOTTED SUNFISH AND FLORIDA LARGE-MOUTH BASS IN A CONSTANT-TEMPERATURE SPRING [1]

DAVID K. CALDWELL, HOWARD T. ODUM,[2] THOMAS R. HELLIER, JR., AND FREDERICK H. BERRY [3]

Department of Biology, University of Florida
Gainesville, Florida

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POPULATIONS OF SPOTTED SUNFISH AND FLORIDA LARGE-MOUTH BASS IN A CONSTANT-TEMPERATURE SPRING[1]

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ABSTRACT

Populations of spotted sunfish, *Lepomis punctatus punctatus* (Valenciennes) and Florida largemouth bass, *Micropterus salmoides floridanus* (LeSueur) have been studied in the fertile biotic communities of Silver Springs, Florida. This large limestone spring has a constant temperature, nearly constant chemical environment, and stable biological communities, but a seasonal change in light intensity and general productivity. Studies of the scales of these two species have shown rings which are possibly rhythmic but not related to temperature. Strong rings in spotted Sunfish are apparently too numerous to be annuli and their formation is not correlated with the time of year. The spotted sunfish population reproduces mainly in spring and summer, although there is evidence for some scattered winter breeding. Age groups do not stand out distinctly in length-frequency diagrams. Reproduction by Florida largemouth bass appears to be chiefly limited to spring and summer. Thus, even with a constant temperature, there are apparently cycles in the life history of these fishes which cause the periods of increased reproduction to coincide with periods of greater food production. Recaptures of tagged bass and measurements of spotted sunfish in cages within the springs indicated moderate growth rates. Tagging with individual color combinations for visual study indicated little movement by the spotted sunfish, but a high mortality. Data are included on the length-weight and body-scale relationships, degree of scale regeneration, and food. The seasonal activities of centrarchid populations are adjusted to make use of the maximum flow of productive energy in spring and summer and are thus correlated with the photoperiodic cycle.

INTRODUCTION

Although the fluctuations in chemical and physical properties of most aquatic environments are large and irregular, an intricate adjustment may develop between the environmentally controlled primary production of organic matter by plants and the growth and reproduction of fish. The mechanisms by which the fish populations are self-regulated to maintain these adjustments are thus pertinent to the management of fisheries. Annulus formation, annual fluctuations in population size, changes in growth rate, and periodicity of breeding are examples of phenomena which must be adjusted to basic energy flows in the community. Unfortunately,

[1] These studies were aided by a contract between the Biology Branch, Office of Naval Research, Department of the Navy, and the University of Florida, NR 163-106.

[2] Present address: Institute of Marine Science, The University of Texas, Port Aransas, Texas.

[3] Present address: United States Fish and Wildlife Service, Brunswick, Georgia.

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Biology, University of Florida
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it is often difficult to isolate the exact role played by internal rhythms and external controlling factors in situations where many changes are occurring simultaneously. If one could ideally contain a natural community of fishes under constant limnological conditions some insight might be gained as to the role played by single factors.

The conditions in Silver Springs, Marion County, Florida, one of the large springs near the center of the state, are nearly ideal for "natural experimentation." A large outflow of hard water from limestone caverns maintains a continual stream with a constant temperature of 73° F. and a constant chemical state. In this rich and clear medium, the subtropical sun maintains a dense community of organisms with a high degree of stability. Among external influences only the factors of light intensity and day length change seasonally. Odum[4] found that primary production in December is about one-third of that in May. A special state law prohibits fishing in Silver River, which is used mainly as a recreational attraction. The communities of the headwater zone (20 acres) are somewhat isolated by 4 miles of a more swift and turbulent section of the river that begins about a mile below the first spring.

A general account of Silver Springs with evidence of physical and chemical stability is provided by the Florida Geological Survey (Ferguson *et al.*, 1947). Qualitative and quantitative descriptions of the communities of mainly eel grass (*Sagittaria*), invertebrates, fishes, community trophic structure, metabolisms, limnological characteristics, and productivity have been provided by Odum.[5] The algae were described by Whitford,[6] and the fishes by Hubbs and Allen (1944).

The purpose of this paper is to report some studies on the fish populations in this unusual environment. The investigation was begun by Odum with the assistance of W. C. Sloan in 1953 as part of a general productivity study. Systematic collections and tagging were initiated in March 1954 by Odum and Caldwell, continued through that summer by Berry, until June 1955 by Caldwell and Hellier, and completed by the group in the summer of 1955. A total of 34 trips were made with the generous assistance of volunteers.[7]

Although other centrarchids are present in the spring (Hubbs and Allen, 1944), most of the data were obtained on the spotted sunfish and the Florida largemouth bass, which are by far the most abundant fishes in their respective roles as carnivore and top carnivore. Some idea of the dominance of centrarchids among the larger fish can be obtained from visual estimates in which 68 percent of 2,287 fishes counted were sunfishes and bass

[4] Odum, Howard T. 1953. Productivity in Florida springs. Progress report to the Office of Naval Research. [Processed]

[5] Odum, Howard T. 1953, 1954, 1955. Productivity in Florida springs. First, second, third, and fourth progress reports to the Office of Naval Research. [Processed]

[6] Whitford, Larry A. 1954. The species of algae and their distribution in Florida Springs. In: Productivity of Florida springs. Third semi-annual report to the Office of Naval Research. [Processed]

[7] Mrs. F. Berry, J. Campos, R. Crossman, Mrs. T. Hellier, W. Hook, J. Howell, Mrs. D. Hynes, D. Hynes, M. Huish, J. McCrone, D. Wilder, R. Winslow, and J. Yount.

Studies elsewhere on closely related centrarchid fishes in waters with seasonal changes permit comparisons that show the effect of the nearly constant environment in Silver Springs. To further such comparisons, efforts have been made to determine population characteristics in spite of the relatively small samples necessitated by the small area, restricted collecting privileges, and the lack of a fishery. Data are reported by species in sections on spawning, length-weight relationships, length-frequency distributions (spotted sunfish only), growth rings on scales, and growth rates.

Methods

Most of the fish were taken with a 25-foot bag seine of ½-inch stretched mesh. Some of the larger specimens were collected with a spear gun and a small cast net. The current flow (0.1 to 1.0 meter per second), deep channel (3 to 7 meters), clear water (horizontal underwater visibility, 105 meters), and obstructions such as logs, presented some unusual problems, especially since all work had to be done at night to insure a more representative sample and in order not to interfere with the glass-bottom boats. Gill nets, trot lines, and traps were tried but were relatively unsuccessful. Seining in the shallows along the edges of the run and boils of the spring in beds of eel grass yielded the only reasonably satisfactory samples. Heavy plant beds and soft bottoms made even this fishing difficult.

The fish that were not tagged were preserved in the field in 10-percent formalin; measurements, weights, and scale samples were taken in the laboratory. Those fish tagged were measured and a scale sample was taken before return to the water. Standard lengths were measured in millimeters and weights in grams. Scales were placed between glass slides in a 2- by 2-inch lantern slide projector and examined on a screen at a magnification of × 21. Lengths from scale measurements were calculated graphically by direct proportion (Carlander and Smith, 1944).

Spotted Sunfish

Maturity and spawning.—Although Hubbs and Allen (1944) reported this species to spawn only in April and June, the absence of distinct modes in frequency distributions (Fig. 1), the presence of young fish in most months, and the appearance of at least a few ripe adults (Fig. 2) at all times of the year suggest that spotted sunfish breed most of the year in Silver Springs. Similar breeding was reported by Kilby (1955) for this species at Bayport, Florida, in a brackish-water community fed by the run of the large freshwater Weekiwachee Springs. Studies by Sloan (1956) on this run indicate a relatively small seasonal variation of temperature. Carr (1947), reported only a late-spring spawning for spotted sunfish in "ordinary Florida streams", but had made no definite search for winter spawning. McLane[8] observed breeding activity in other Florida springs between March 25 and September 9. There may thus be a correlation between a long period of spawning of this species and nearly constant temperatures.

[8] McLane, William M. 1955. The fishes of the St. Johns River system. Ph.D. Dissertation, University of Florida.

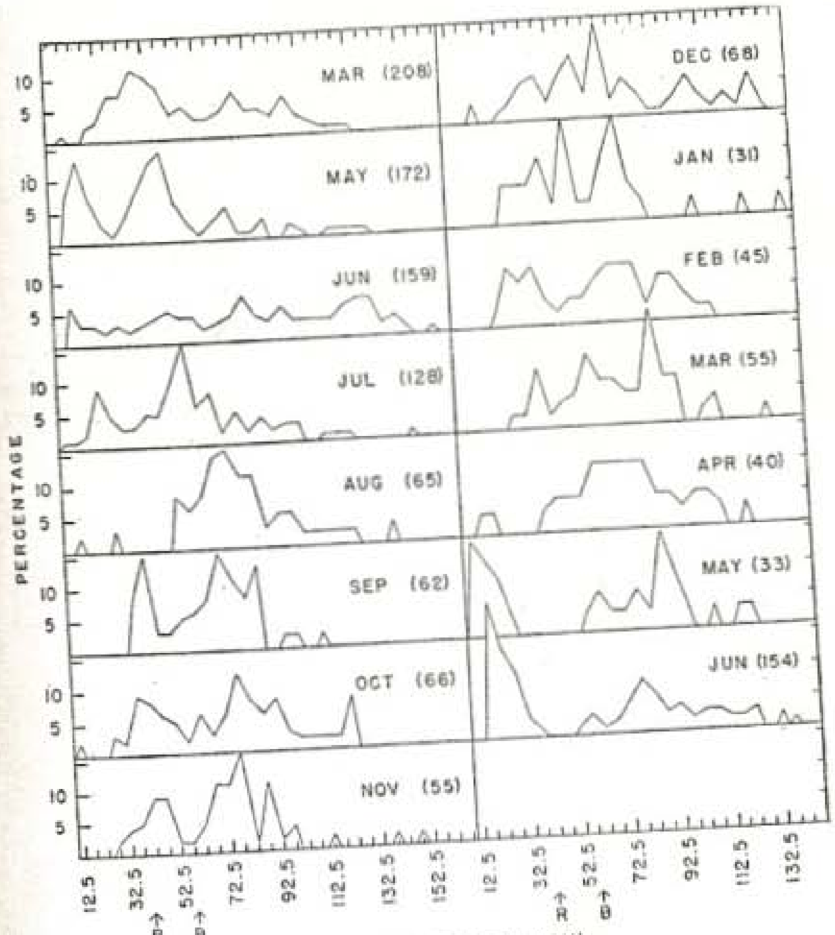

FIGURE 1.—Frequency distribution (standard length) of the spotted sunfish from March 1954 through June 1955. The small arrow lettered "R" indicates the mean calculated standard length at which the first scale ring was formed. The small arrow lettered "B" indicates the standard length of the smallest fish with ripe gonads.

Spawning activity increased greatly, however, during the summer in Silver Springs, and winter spawning was limited (Fig. 2). It was observed also that spotted sunfish begin breeding at a small size. Ripe gonads were found in one 55-millimeter fish. Carr (1947) observed a 2-inch (approximately 51 millimeters) fish extruding eggs. In Silver Springs no develop-

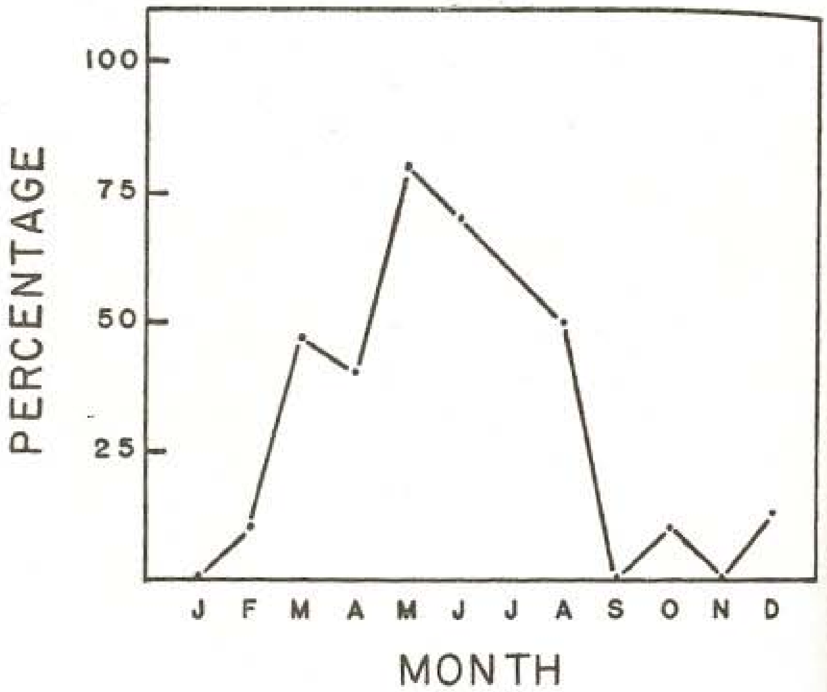

FIGURE 2.—Percentage of spotted sunfish with well-developed gonads in different months. Each point is based on 10 or more individuals with standard lengths 65 millimeters or above.

ing gonads were found in a sample of 30 fish between 40 and 55 millimeters from March and July.

Length-frequency distribution.—The length-frequencies for the spotted sunfish by month (Fig. 1) reveal no distinct separation of groups. The presence of small fish in most months and other evidences of breeding cited earlier indicate a steady replacement to the population. Odum [9] offered evidence of a high degree of community stability in Silver Springs. If the populations of centrarchids are also relatively stable, it is possible that a close balance exists between replacement and mortality.

The seining introduced some size selection. The smallest fish are hard to find in the rolls of plants and readily escape the seine by edging into the muck at the base of the grass. Many of the largest fish escape by swimming around the wings of the net. The total sampled catch contained maximum numbers in the 35- to 69-millimeter size range. On a weight basis, however,

[9] Odum, Howard T. 1955. Productivity in Florida springs. Progress report to the Office of Naval Research. [Processed]

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size of fish (Table 1).

TABLE 1.—*Length-weight relation*
[Grouped i

Mean standard length (millimeters)	Weight ((Mean
12.9	0.12
17.5	0.26
21.9	0.46
27.4	0.9
31.6	1.4
37.1	2.4
42.2	3.5
47.0	5.1
52.3	7.1
56.9	9.1
62.2	11.6
67.1	14.5
71.9	17.8
76.7	21.6
81.4	26.0
87.0	31.2
91.8	37.5
97.1	46.4
104.0	60.0
107.2	58.7
111.5	66.2
116.0	80.0
121.8	85.1
127.3	95.5
132.5	112.4
137.7	130.9
142.0	127.1

[1]From length-weight equation given in text

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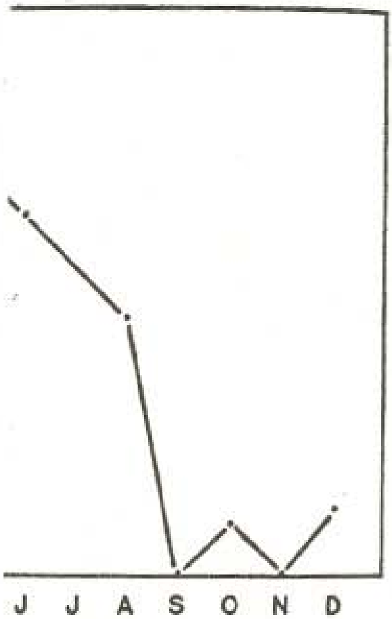

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the population is greatest at the 70- to 104-millimeter size, where greater weight per individual offsets the decreasing number of individuals.

The length-frequencies for March give some suggestion of a peak at 47 millimeters. This peak moves to the right for several months at a rate (0.2 millimeter per day) somewhat larger than the growth rate of the caged fish (0.12 millimeter per day) described later. During the remainder of the year there was little evidence of progression of modes due to growth.

Length-weight relation.—The relationship of standard length to preserved weight was graphed for each month of the study. The resulting length-weight regressions did not vary materially from month to month, sexes combined. In a sample of 21 individuals, fresh wet-weight was 93 percent of preserved weight. Specimens from all months were used to determine the relationship between standard length in millimeters (L) and preserved weight in grams (W) as follows:

$$\log W = -4.32 + 3.002 \log L$$

The coefficient of condition (K), or relative plumpness, was determined for the Silver Springs fish as defined by $K = W \times 10^5 / L^3$. The K value for the Silver Springs spotted sunfish averaged 4.82 and varied little with size of fish (Table 1).

TABLE 1.—*Length-weight relationship of spotted sunfish from Silver Springs*
[Grouped in 5-millimeter classes]

Mean standard length (millimeters)	Weight (grams)		Calculated weight[1] (grams)	Mean K	Number of fish
	Mean	Range			
12.9	0.12	0.1– 0.2	0.10	5.59	7
17.5	0.26	0.1– 0.4	0.26	4.85	28
21.9	0.46	0.3– 0.6	0.50	4.38	36
27.4	0.9	0.5– 1.5	0.99	4.38	33
31.6	1.4	1.0– 2.1	1.5	4.44	28
37.1	2.4	1.7– 3.3	2.5	4.70	32
42.2	3.5	2.7– 4.6	3.6	4.66	49
47.0	5.1	4.0– 7.3	5.0	4.91	50
52.3	7.1	5.9– 8.2	6.9	4.96	49
56.9	9.1	7.1–12.1	8.9	4.94	72
62.2	11.6	9.5–13.6	11.6	4.82	76
67.1	14.5	11.6–17.3	14.5	4.80	53
71.9	17.8	15.1–22.5	17.9	4.79	68
76.7	21.6	18.0–27.3	21.7	4.79	59
81.4	26.0	22.0–31.4	26.0	4.82	38
87.0	31.2	27.8–38.6	31.7	4.74	28
91.8	37.5	33.3–46.9	37.3	4.85	14
97.1	46.4	43.3–52.0	44.1	5.07	9
104.0	60.0	58.3–61.7	54.2	5.33	2
107.2	58.7	55.9–62.5	59.3	4.76	6
111.5	66.2	56.8–75.3	66.8	4.78	4
116.0	80.0	....	75.2	5.13	1
121.8	85.1	74.8– 96.1	87.1	4.71	5
127.3	95.5	78.9–109.1	99.4	4.63	3
132.5	112.4	105.2–119.5	112.1	4.83	2
137.7	130.9	120.2–142.0	125.8	5.01	3
142.0	127.1	....	138.0	4.44	1

[1]From length-weight equation given in text

A constant ratio was found between standard and total length. Standard length may be converted to total length by multiplying by 1.27 and total length to standard length, by 0.79.

Tagging and growth in cages.—A total of 267 spotted sunfish were marked with plastic Peterson disc tags (nickel pins) or with monel-metal clamp tags. The fish marked were in the 20 acres of the ¾-mile headwater community. Spotted sunfish tagged with various color combinations were observed and identified with the aid of face masks as late as a month after marking, in the general area where tagged. Recaptures within a week after tagging were exactly in the tagging localities. However, only one spotted sunfish was retaken more than 2 weeks after tagging. This fish, marked with a Peterson tag, was at liberty 85 days (Table 2), during the fall. The fish was probably adult when tagged (142 millimeters) and showed a 3-millimeter decrease in standard length. The decrease of length may have been a result of injury due to tagging, low food production in the fall, or measuring error. The fish was recovered at the point of tagging.

Fourteen days after some intensive tagging in the Paradise Park area of the springs in late March 1954 Robert Haubrich, wearing a face mask, searched 2 hours among the plants but observed only two tagged fish.

Several explanations may be offered for the limited returns from tagging. Since fish were readily observed in the tagging areas the first few days after tagging, but were absent after a few weeks, and since intensive search did not reveal the missing tagged fish elsewhere in the spring, migration probably can be discounted. We received no reports of recovery of any of our tags downstream in the Oklawaha River outside the area of the spring and its run. This species is frequently taken by sport fishermen in an area where the Florida State Game and Fresh Water Fish Commission has conducted a number of tagging studies (waters fed in part by Silver Springs), and the public is thus educated to return tags. Sport fishing is not permitted in Silver Springs itself.

Peterson-tagged fish kept in enclosures died within 2 weeks, whereas untagged fish were kept without mortality for longer periods (Table 2). Three fish marked with metal clamp tags on the opercle and kept in cages had the following history: after 3 weeks one tag worked out and the hole was healing, one tag was producing a large sore, and the third fish had undergone a decrease in length. A high mortality, possibly accentuated by the tagging, may in part explain the low rate of tag returns.

The growth of spotted sunfish kept in hardware-cloth enclosures was measured after 2- to 3-week periods (Table 2). One fish was retained 10 months. The enclosures, 1 to 3 square meters in area, were placed over *Sagittaria* beds characteristic of the springs community in zones where a steady current passed through the cages. The size of the fish decreased in one cage but growth occurred in 2 other, more favorably situated, enclosures. The average change, included the decreases in length, indicates growth of 0.12 millimeter per day. This figure is probably an underestimate for the summer season in view of the artificial conditions in the enclosures. The figure is used, however, to interpret the ring patterns of the scales.

TABLE 2.—*Growth of individual fish, tagged or confined in enclosures*

Species and date of first measurement	Initial standard length (millimeters)	Number of days free	Increase (millimeters)		Mean[1] weight (grams)	Weight change (grams per day)	Percentage weight change per day
			Total	Per day			
Spotted sunfish							
Tagged (plastic)							
August 31, 1954	142	85	−3	−0.035	129.5	−0.1	−0.08
Enclosures							
June 9, 1953	120	300	46	0.15	74.8	0.22	0.30
June 29, 1955	122	13	1	0.08	43.3	0.10	0.23
do.	92	13	5	0.38	20.4	0.25	1.22
July 25, 1955	122	18	2	0.11	88.0	0.26	0.40
do.	73	18	2	0.11	19.4	0.09	0.46
do.	79	18	2	0.11	24.6	0.11	0.43
do.	55	18	3	0.17	8.6	0.08	0.88
do.	120	18	0	0.00	82.6	0.00	0.00
do.	98	18	−1	−0.06	44.4	−0.07	−0.15
do.	83	18	0	0.00	27.4	0.00	0.00
do.	108	18	−1	−0.06	59.5	−0.08	−0.17
do.	98	18	1	0.06	45.7	0.08	0.17
do.	80	18	−0.5	−0.03	24.3	−0.03	−0.11
August 12, 1955	107	12	8	0.67	65.7	1.18	1.80
do.	98	12	2	0.17	46.5	0.25	0.53
do.	97	12	2	0.17	44.8	0.17	0.38
do.	79	12	1	0.13	24.6	0.15	0.61
do.	75	12	1	0.13	20.6	0.07	0.34
do.	58	12	0	0.00	9.3	0.00	0.00
do.	82	12	0	0.00	26.4	0.00	0.00
do.	97	12	2	0.17	44.8	0.17	0.38
do.	120	12	2	0.17	83.7	0.18	0.21
Mean	161.9	..	.	0.12	46.0	0.13	0.309
Florida largemouth bass							
Tagged							
July 11, 1954	124	105	10	0.095	82.6	0.17	0.21
July 25, 1954	112	82	19	0.23	70.5	0.37	0.53
do.	110	122	18	0.15	66.3	0.23	0.35
Sept. 24, 1954	116	21	−1	−0.05	60.1	−0.07	−0.12
do.	120	82	4	0.05	70.2	0.08	0.11
do.	105	96	2	0.02	47.1	0.03	0.06
Mean	114.5	..	..	0.08	66.1	0.135	0.19

[1]Determined from calculated weight (using the equation given in text) at initial and final measuring

Scales and growth rings.—Scales from the side of the fish were projected and measurements made of growth rings and the anterior radius on two unregenerated scales from each fish. The continuous breeding season, lack of distinct modes that would point to age groups in length-frequency distributions, and a constant high temperature make difficult the interpretation of the numerous distinct "growth rings." Thus, in order to obtain an unbiased analysis, scales were measured systematically by one observer, at first without any attempt to determine age. Only the strong rings with "cutting over" were measured; the basis for selection was the arbitrary but consistent judgment of the same observer (Hellier). In this procedure, different numbers of rings were sometimes measured on different scales from the same fish.

The anterior radius (millimeters, × 21), *R*, plotted against standard length in millimeters, *L*, formed a pattern of points that could be fitted reasonably well to a straight line. For fish 70 to 150 millimeters long (dry scales about a year old):

$$R = -9.7 + .56\ L.$$

For fish 20 to 70 millimeters standard length (fresh scales):

$$R = .63\ L.$$

Ring measurements were converted to calculated standard lengths by direct proportion. One set of values was then obtained for each fish by averaging any two values that were similar. The first two rings on fish smaller than 70 millimeters did not appear distinctly enough on most of the larger fishes to qualify under the arbitrary "ring definition" that was used. Therefore the mean calculated standard length for the first two rings (labeled A and B) reported in Figure 3 was obtained from the small fish only. The remainder of the lengths are the means of the values computed from the first and subsequent rings on the larger fish. With this procedure, extra rings on some fishes are counteracted by omission of other faint rings. The data of regression of length on rings in Figure 3 are thus a summary of estimates from the distinct rings, obtained objectively.

In order to interpret the meaning of the rings, some idea is needed of the time between rings, although the likelihood is small that the time intervals between rings are constant. Data on growth given previously indicated that 44 millimeters per year (0.12 millimeters per day) was a minimal estimate of the possible summer growth rates of larger fish (90 to 120 millimeters, standard length). If growth ceases in winter, the rate would be half (22 millimeter per year). The movement of peaks on the length-frequency graph (Fig. 1) suggests a growth of 30 millimeters per year confined to the summer season. From the increments between rings in Figure 3, it is seen that 5 to 12 millimeters per year would need to be added for fish of this size if the rings were annuli. If this reasoning is correct, the rings are added more frequently than once a year and are not annuli.

The proximity of the last ring to the scale margin is indicated by month in Figure 4. Rings apparently are laid down in every month. An examination of small fish, 30 to 47 millimeters long, in January, May, and November showed recent formation of the first ring. Thus the formation of the first ring is related more to the size than to the season. The laying down of more than one distinct ring per year in centrarchids is well known, as described by the phrase "false annulus" (Sprugel, 1954). In the Silver Springs spotted sunfish false annuli may be the rule.

37.8 percent of the scales of this species were found to be regenerated.

Food and parasites.—The role of the spotted sunfish as both a carnivore and a herbivore in Silver Springs was indicated by a few analyses of stomach contents. Qualitatively similar wads of algae and small invertebrates were found in the smallest and largest fish and in the fish sampled from January and May. The thick beds of *Sagittaria* are covered with a

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nd largest fish and in the fish sampled
beds of *Sagittaria* are covered with a

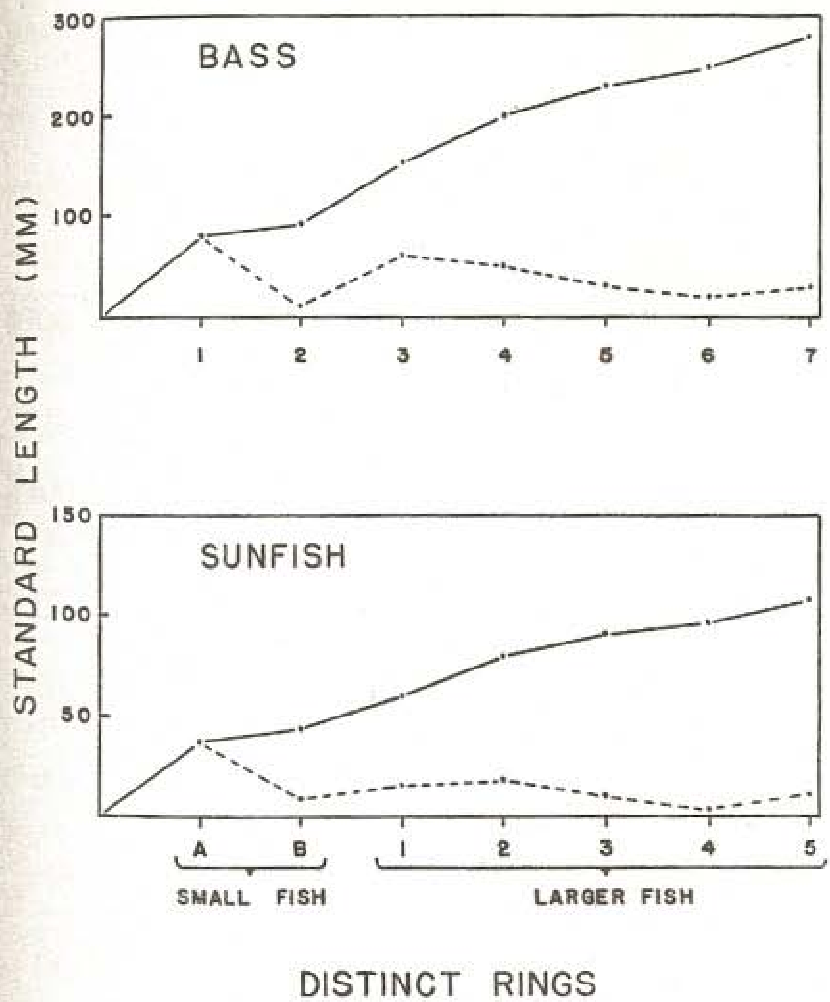


FIGURE 3.—Mean calculated standard lengths corresponding to distinct scale rings in the Florida largemouth bass and the spotted sunfish. Increments of standard length increase between rings are indicated by the broken line. The first two rings (A and B) for the spotted sunfish were obtained from scales of individuals smaller than 70 millimeters. These data were obtained without any attempt to assign annuli.

dense periphyton containing diatoms, filamentous algae, and dense invertebrate populations, especially midges and caddisflies. Gammarids and shrimps are dominant about the bases of the plants. The stomach contents resemble the periphyton. Apparently the plant and animal material is taken up to-

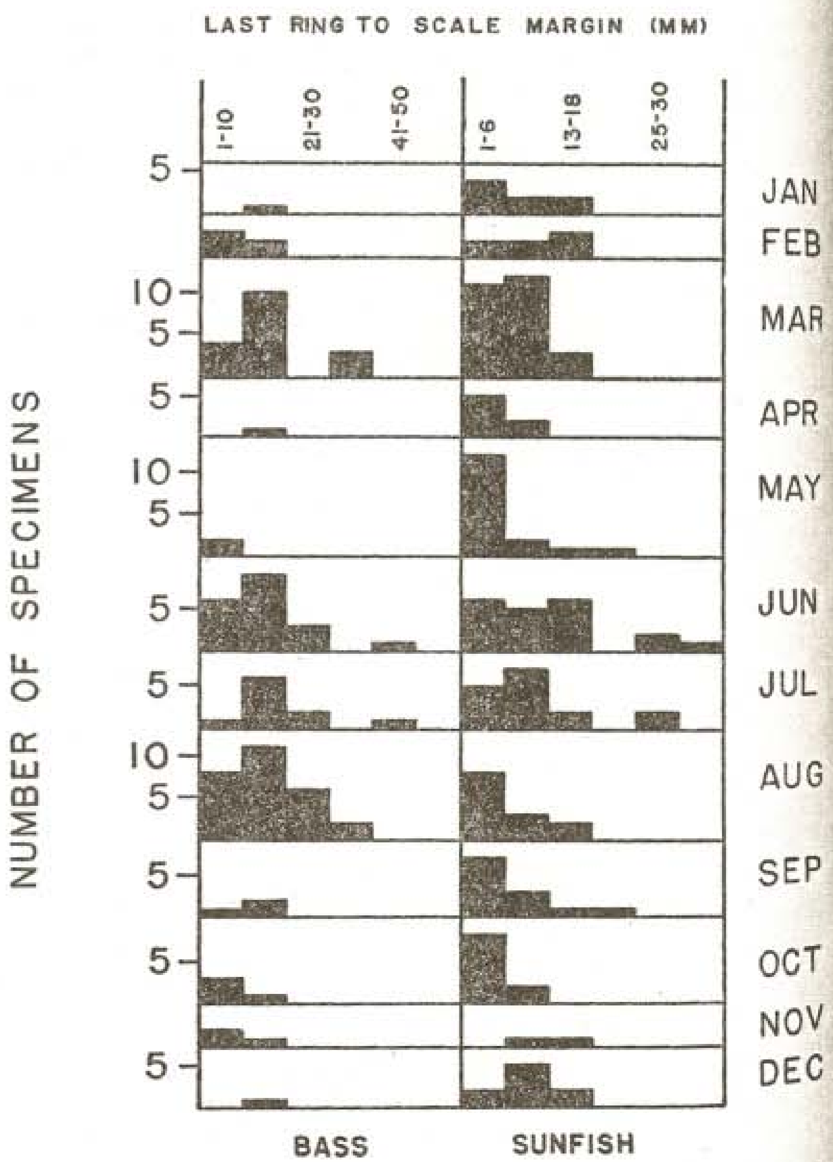
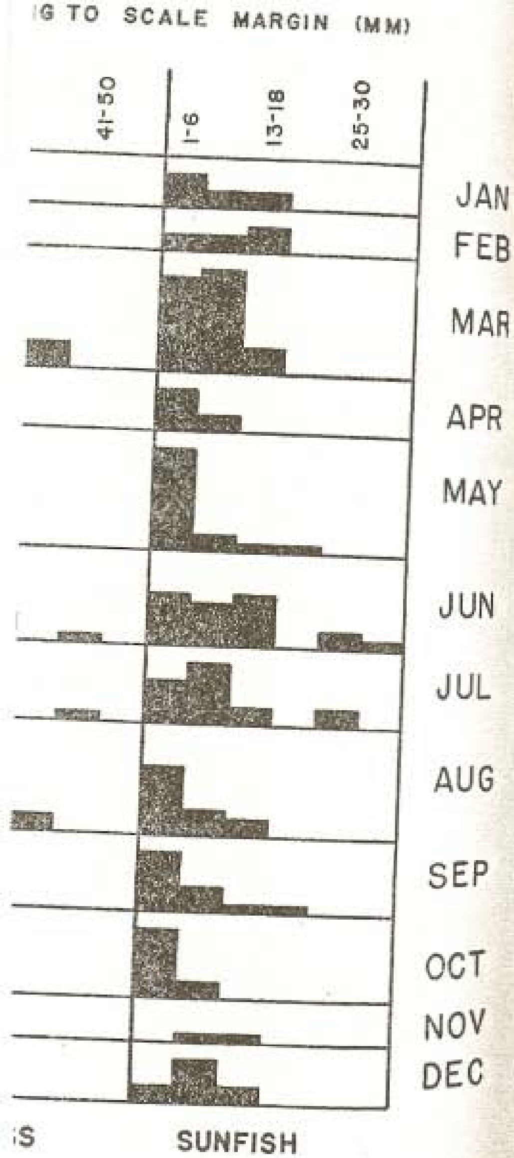


FIGURE 4.—Frequency distribution of Florida largemouth bass was spotted sunfish according to the growth increment since the last distinct scale ring. Frequency interval is 10 millimeters calculated standard length.



of Florida largemouth bass was spotted sunfish since the last distinct scale ring. Frequency inter- -ters calculated standard length.

gether. The stomach contents of 10 fish were divided into animal and plant portions and oven-dried. The separation was not perfect because of the small size of many of the components. For December, 0.57 gram of plant and 0.16 gram of animal material were found; for May, 0.063 gram of plant and 0.033 gram of animal material. The algae are apparently passed through undigested since the filamentous materials were found in the intestines as well as in the stomach. Because the animal portions may be digested more readily than the plant portions, there is no certainty that the wads of filamentous algae in the stomach are as important to the nutrition of the spotted sunfish as their presence suggests. The diet is similar for the smallest fish. Stomachs from ten individuals less than 63 millimeters in standard length in January contained 0.071 gram of plant material and 0.30 gram of animal material.

Although no study was made, it was noted that almost every spotted sunfish opened for examination of the gonads was infested with Acanthocephala.

Florida Largemouth Bass

Tagging and growth.—The tagging was slightly more successful with the Florida largemouth bass than with the spotted sunfish. Six bass were recovered from 72 individuals tagged, (Table 2). The records suggest that growth was more rapid during the summer than in the fall. This difference would indicate a correlation between growth and plant production and thus ultimately with the light. Krumholz[10] reported seasonal growth patterns correlated more with light than with temperature.

Florida largemouth bass showed more movement than the spotted sunfish. Fish tagged with colored plastic tags were seen 2 days later ½ mile from the place of first capture, and one tagged bass was seen 2 miles downstream from the point of tagging (the color combination was not distinguished and thus the time period between tagging and observation is not known).

Length-weight relation.—Although only 53 individuals, between 18 and 242 millimeters, standard length, were weighed and measured, an approximate length-weight relationship (preserved weights) was obtained:

$$\log W = -4.5 + 2.95 \log L.$$

The length-weight relationship and coefficient of condition for different sizes of bass are shown in Table 3.

The ratio of total length to standard length remained nearly constant at 1.24 for fish 18 to 242 millimeters long.

Spawning.—Breeding activities by the Florida largemouth bass were observed in Silver Springs from February through August. Ripe gonads were found from March to September. Bass less than 25 millimeters in

[10] Krumholz, L. A. 1954. A summary of findings of the ecological survey of White Oak Creek, Roane Co., Tenn. 1950–1953. U. S. Atomic Energy Commission Technical Information Service ORO-132.

TABLE 3.—*Length-weight relationship of Florida largemouth bass from Silver Springs*
[Grouped in 10-millimeter classes]

Mean standard length[1] (millimeters)	Weight (grams)		Calculated weight[2] (grams)	Mean[3] K	Number of fish
	Mean	Range			
18.7	0.2	....	0.2	3.06	3
23.4	0.3	0.2– 0.6	0.3	2.34	9
31.7	0.8	0.6– 0.9	0.8	2.51	3
44.7	2.2	1.4– 2.9	2.3	2.46	6
54.5	3.9	3.0– 4.8	4.2	2.41	2
62.3	6.0	4.8– 6.9	6.2	2.48	4
72.0	9.2	8.1–10.3	9.5	2.46	2
83.0	16.0	....	14.5	2.80	1
94.5	23.1	20.6–25.5	21.3	2.74	2
103.5	27.5	24.0–29.2	27.8	2.48	4
122.4	44.6	41.9–47.2	45.6	2.43	5
135.0	59.4	55.7–62.9	60.9	2.41	3
141.0	72.6	....	69.2	2.59	1
156.7	91.8	90.8–93.5	94.5	2.39	3
163.0	94.95	90.6–99.3	106.1	2.19	2
202.0	162.0	....	199.9	1.97	1
215.0	224.5	....	240.1	2.26	1
242.0	311.0	....	340.5	2.19	1

[1]Length groups without representatives are omitted
[2]From length-weight equation given in text
[3]Grand average K, 2.45

length were taken on May 26, 1955, May 28, 1954, and June 15, 1955. This evidence suggests that the spawning by Florida largemouth bass in Silver Springs occurs at the same time as in ordinary variable-temperature environments in Florida. McLane (1948) found Florida largemouth bass smaller than 30 millimeters in the St. Johns River in April, May, and June only. If spawning takes place at other times of the year in Florida springs it is certainly limited.

Scales and growth rings.—Scales of Florida largemouth bass were treated in the manner already described for the spotted sunfish. The scale samples of this species were 42.3 percent regenerated. There is good evidence, however, that most of the rings in the bass are, on the average, annuli. The growth rate, averaging 0.083 millimeter/per day (30.3 millimeters/per year) was determined from the tag recoveries for fish 112 to 124 millimeters long. When this rate is compared with the increments between growth rings in Figure 3 (10 to 60 millimeters/per year), comparable values are found.

The irregular shapes of the curves in Figure 3 result from the objective manner of reading the scales. When some of the first rings were not measured because they were indistinct, the remainder of the rings on the fish were then included in the means of the next younger ring. Thus the regression of standard length on "distinct rings" is probably slightly steeper than the actual rate. Whether this tendency to overestimate the growth per ring is counteracted by the tendency to underestimate the growth per ring due to inclusion of spurious rings is not known. At any rate, the

ship of Florida largemouth bass from Silver Springs
ped in 10-millimeter classes]

ht (grams)			
Range	Calculated weight[2] (grams)	Mean[3] K	Number of fish
....	0.2	3.06	3
0.2– 0.6	0.3	2.34	9
0.6– 0.9	0.8	2.51	3
1.4– 2.9	2.3	2.46	6
3.0– 4.8	4.2	2.41	2
4.8– 6.9	6.2	2.48	4
8.1–10.3	9.5	2.46	2
....	14.5	2.80	1
20.6–25.5	21.3	2.74	2
24.0–29.2	27.8	2.48	4
41.9–47.2	45.6	2.43	5
55.7–62.9	60.9	2.41	3
....	69.2	2.59	1
90.8–93.5	94.5	2.39	3
90.6–99.3	106.1	2.19	2
....	199.9	1.97	1
....	240.1	2.26	1
....	340.5	2.19	1

mitted

, 1955, May 28, 1954, and June 15, 1955. e spawning by Florida largemouth bass in ne time as in ordinary variable-temperature ane (1948) found Florida largemouth bass he St. Johns River in April, May, and June t other times of the year in Florida springs

ales of Florida largemouth bass were treat- cribed for the spotted sunfish. The scale .3 percent regenerated. There is good evi- he rings in the bass are, on the average, ing 0.083 millimeter/per day (30.3 milli- d from the tag recoveries for fish 112 to rate is compared with the increments be- (10 to 60 millimeters/per year), compar-

rves in Figure 3 result from the objective ten some of the first rings were not meas- t, the remainder of the rings on the fish of the next younger ring. Thus the regres- tinct rings" is probably slightly steeper tendency to overestimate the growth per lency to underestimate the growth per s rings is not known. At any rate, the

method gives an objective definition of the relationship of rings and length. The curve in Figure 3 for growth per annulus (ring) falls within the range of values for some largemouth bass stocks elsewhere as summarized by Carlander (1950). The curve indicates, however, that the growth per ring in Silver Springs is less than the mean of bass growth in other localities.

Data presented by Viosca (1943, 1953) suggest that much more rapid growths occur in southern waters in successional communities where no climax of "balance" has been achieved. In Silver Springs, where a relatively high degree of stability apparently has existed, at least since the modification of the margins about 15 years ago (Hubbs and Allen, 1944), slower growth more like that in stable ponds may exist. Thus, as indicated by Viosca, when conditions are more nearly in climax the energy goes into avenues not leading to net growth of bass. This view is consistent with the general ecological idea of net production and accumulation of organic matter during succession and a balance between production and losses during climax or steady state. The high primary production of the Silver Springs community is apparently expressed as a high density (visual estimate of 2.1 centrarchids/per square meter) with moderate growth per individual.

Acknowledgments

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