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Age, Growth, Condition, and Maturity of Sunfishes of Doe Run, Meade County, Kentucky[1]

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Abstract

Measurements of 1,545 sunfish referable to 9 species indicated that rock bass, longear sunfish, green sunfish, bluegills, smallmouth bass, and spotted bass maintained successful populations in Doe Run. Rates of growth of rock bass, longear sunfish, and bluegills were equal to or greater than in other streams reported in the literature, while those of smallmouth bass, spotted bass, and green sunfish were slightly less. Largemouth bass and white crappies grew very slowly, probably because environmental conditions in Doe Run were marginal. Growth rates of male and female green sunfish, bluegills, and rock bass were similar, but male longear sunfish grew faster than females. Male longear sunfish, green sunfish, and rock bass outlived females of those species. Length–weight relationships and coefficients of condition of all species except rock bass were comparable to those of other streams. All sunfishes that spawned in Doe Run did so only in the lower reaches of the stream in late summer, probably because of the influence of constantly cool water temperatures at the stream source. The longear sunfish–rock bass–smallmouth bass was the most successful sunfish association.

Introduction

Although sunfishes (Centrarchidae) are widely distributed over the eastern United States and include several species very popular among sport fishermen, relatively little is known of their rates of growth in streams. This study presents data for 9 species of centrarchids from Doe Run, Meade County, Kentucky, prior to its impoundment to form Doe Valley Lake in July 1961. Species considered are: rock bass *Ambloplites rupestris*, green sunfish *Lepomis cyanellus*, warmouth *L. gulosus*, bluegill *L. macrochirus*, longear sunfish *L. megalotis*, smallmouth bass *Micropterus dolomieui*, spotted bass *M. punctulatus*, largemouth bass *M. salmoides*, and white crappie *Pomoxis annularis*. Two specimens of each of 2 other sunfishes, the orange-spotted sunfish *L. humilis* and the black crappie *P. nigromaculatus* were collected, but the data were too meager for satisfactory analysis. Nomenclature follows that of Bailey et al. (1970).

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Description of the Study Area

Doe Run, a limestone stream, rises as a torrent spring 4.8 km east and 0.6 km north of Ekron, Kentucky, and flows north-northeast for 15.6 km to empty into the Ohio

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River at Ohio River Mile 642.2, about 57 km downstream from Louisville. Detailed descriptions of the physical and chemical characteristics of the stream have been given by Minckley (1963) and Krumholz (1965, 1967). The portion of the stream sampled during this study did not include the headwaters since no sunfishes maintained populations in that area, but did include the stretch from Highway 1638 (Km 5) to the Ohio River, a distance of 10.8 km (Fig. 1). Within the sampling area, the stream above Km 8 had a gradient of 6.6 m/km, whereas below that point the gradient was 1.7 m/km. Downstream from Km 12.5, the channel was filled with backwater from the pool formed by Ohio River Lock and Dam No. 44 near Leavenworth, Indiana, at an elevation of 374 feet (114 m) above mean sea level (msl). In 1971, Lock and Dam No. 44 was replaced by the Cannelton Locks and Dam at Cannelton, Indiana, and the pool was raised to 383 feet (116.7 m) msl. Thus, the backwater now extends very nearly to the toe of the dam for Doe Valley Lake.

The average width of Doe Run above the backwater was about 10 m, and ranged from more than 12 m in some pools to no more than 2 m at some riffles. Maximum depths in pools was about 2 m, but in many riffles, the water was no more than 20 cm deep. In the area of relatively steep gradient, the bottom was largely a mixture of bedrock, marl, and rubble. Downstream from Km 8, the bottom was mostly silt, sand, and clay with some stones that had washed in during spates.

Prior to 1961, when the lower portion of the valley was cleared, Doe Run flowed for most of its length under a heavy canopy of riparian vegetation. The roots of many large trees had been undercut by the stream and those areas provided shelter for many sunfishes and other species as well.

Water temperatures in Doe Run manifested the moderating effects of groundwater temperatures as well as ambient air temperatures. At the spring source, the temperature rarely varied from 13.3 C. About 5 km downstream, the maximum

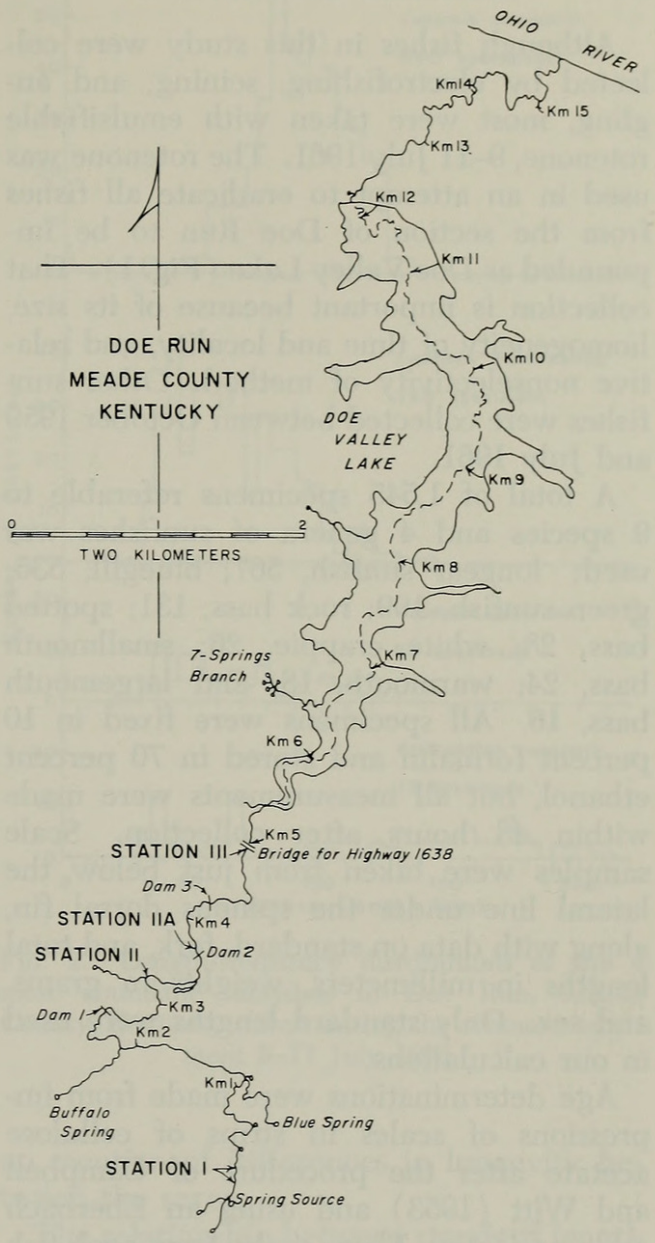

FIG. 1. Map of Doe Run, Meade County, Kentucky, showing stream kilometers, locations of dams, bridge for Highway 1638, and extent of Doe Valley Lake. The broken line through Doe Valley Lake shows the course of the stream prior to impoundment (after Krumholz 1967).

water temperature recorded by Minckley (1963) was 20.0 C in August 1960 and the minimum was 6.1 C in March 1961. Another 3 km downstream, the maximum was 25.6 C and the minimum was 1.7 C. Dissolved oxygen in Doe Run was near or over saturation at all times, and pH was circumneutral. Discharge at the source ranged from less than 0.1 to about 17 m^3/sec.

MATERIALS AND METHODS

Although fishes in this study were collected by electrofishing, seining, and angling, most were taken with emulsifiable rotenone, 9–11 July 1961. The rotenone was used in an attempt to eradicate all fishes from the section of Doe Run to be impounded as Doe Valley Lake (Fig. 1). That collection is important because of its size, homogeneity of time and locality, and relative nonselectivity of method. Other sunfishes were collected between October 1959 and July 1961.

A total of 1,545 specimens referable to 9 species and 4 genera of sunfishes was used: longear sunfish, 567; bluegill, 536; green sunfish, 199; rock bass, 131; spotted bass, 28; white crappie, 26; smallmouth bass, 24; warmouth, 18; and largemouth bass, 16. All specimens were fixed in 10 percent formalin and stored in 70 percent ethanol, but all measurements were made within 48 hours after collection. Scale samples were taken from just below the lateral line under the spinous dorsal fin, along with data on standard, fork, and total lengths in millimeters, weights in grams, and sex. Only standard lengths were used in our calculations.

Age determinations were made from impressions of scales in strips of cellulose acetate after the procedure of Campbell and Witt (1953) and using an Eberbach scale projector. Three scales from each fish were chosen for impressions, and the annuli on those scales were compared. A single scale was chosen for measuring the annual increments, and growth was calculated for each year of life using the formula:

$$L' = C + S'/S\,(L - C)$$

where L' = computed standard length at time of annulus formation,
L = observed standard length at time of capture,
S' = radius of scale at annulus,
S = radius of scale at time of capture, and
C = correction factor,

with the assumption that body length is proportional to scale growth (Van Oosten 1929, Hile 1936, Whitney and Carlander 1956, and others). The correction factor, C, is the intercept of the curve formed by plotting standard length against scale radius.

The only occurrences of sunfishes above Highway 1638 (Fig. 1) were of occasional green sunfish, bluegills, and an orange-spotted sunfish, all adults, probably displaced from nearby sinkholes. No young-of-the-year sunfishes were found upstream from the bridge despite intensive collecting. Similarly, none of the basses, crappies, or other sunfishes were collected upstream from the bridge.

Each spring, numerous sexually mature green sunfish, bluegills, and longear sunfish became concentrated in a large pool just below the swift-flowing culvert of the highway bridge, but there was no spawning in the area, probably because of the coolness of the water (Minckley 1963). Witt and Marzolf (1954), Swingle and Smith (1950), and others have stated that temperatures above a certain minimum (21.1 C) are required to induce spawning in those sunfishes. Several longear sunfish and bluegills caught from the area were resorbing ova at the time of capture (Minckley 1963).

AGE AND GROWTH

Longear Sunfish

The longear sunfish was the most abundant sunfish in Doe Run prior to the impoundment of Doe Valley Lake. Of the 567 specimens used in this study, 440 (78%) were taken during the rotenone treatment of 9–11 July 1961. The longear sunfish made up 36.7 percent of all sunfishes taken during the study.

The oldest specimens were in Age Group VI and the youngest were in Age Group I; no young of the year were collected. The age composition (Table 1) and the length-frequency distribution (Fig. 2) of the 440 individuals taken with rotenone indicated that three-fourths were more than 3 years old and of a greater length than 70 mm. That population composition corresponds

TABLE 1.—LENGTH-FREQUENCY DISTRIBUTIONS OF 442 LONGEAR SUNFISH OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length (mm)	Age group						Total
	I	II	III	IV	V	VI	
30–39	5						5
40–49	5						5
50–59	10	6					16
60–69	8	18					26
70–79		39	15				54
80–89		20	74	3			97
90–99			62	26			88
100–109			5	61	6		72
110–119				26	22	2	50
120–129				3	16	4	23
130–139					2	2	4
Total	28	83	156	119	46	8	440

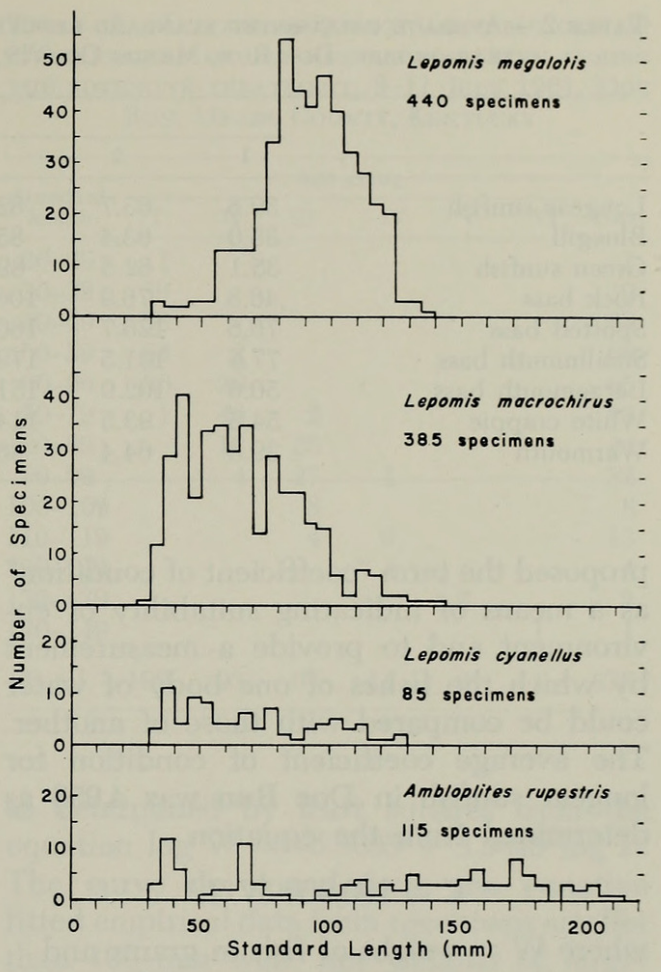

FIG. 2. Length-frequency distributions of the 4 most abundant sunfishes in Doe Run, Meade County, Kentucky, taken during the rotenone treatment 9–11 July 1961.

closely with that reported from the Black River, Missouri (Patriarche and Lowry 1953), but contains a greater percentage of older individuals than reported for Clear Creek, Illinois (Lewis and Elder 1952), and Beaver Creek, Kentucky (Tompkins and Carter 1951).

Calculations of growth rates of 560 individuals, based on a straight-line relationship between body length and length of scale, and corrected for an intercept of 10 mm in body length, showed that longear sunfish reached average lengths of 40, 63, 83, 99, 112, and 119 mm for Age Groups I through VI, respectively (Table 2). The factor for converting standard length to total length is 1.251 based on actual measurements of all longear sunfish taken from Doe Run.

Although female longear sunfish had an average length slightly greater than that of males at the end of the first year's growth (Table 3), males grew faster each succeeding year, and were an average of 8.7 mm longer at the end of the fifth growing season. In Doe Run, male longear sunfish lived longer than females, and the percentage of males in the population increased with increasing age until only males of Age Group VI survived (Table 3). Hubbs and Cooper (1935) also found that male longear sunfish grew faster than females, but made no mention of differences in longevity between the sexes.

The relationship between standard length and weight of longear sunfish in Doe Run was calculated by least squares as:

$$\text{Log } W = -4.80156 + 3.2504 \log L$$

where W = weight of fish in grams and
L = standard length in millimeters.

Lewis and Elder (1952) reported a length–weight relationship for longear sunfish in Clear Creek, Illinois, somewhat lower than that for Doe Run (log W = –4.77 + 3.16 log L). Hile (1931) presented average weights for several groups of longear sunfish in Indiana, but his values were for stunted populations in lakes, and the weights were lower than those for corresponding lengths in Doe Run. Hile (1936)

TABLE 2.—AVERAGE CALCULATED STANDARD LENGTHS IN MILLIMETERS OF SUNFISHES AT THE END OF EACH YEAR OF LIFE, DOE RUN, MEADE COUNTY, KENTUCKY, NOVEMBER 1959 TO JULY 1961

	Calculated length at end of year							
	1	2	3	4	5	6	7	8
Longear sunfish	39.8	63.7	82.5	98.7	111.7	119.4		
Bluegill	35.0	63.4	85.6	105.6	123.7	135.0		
Green sunfish	35.1	62.5	89.6	110.2	127.7			
Rock bass	46.8	76.9	106.9	132.0	155.1	174.0	192.1	206.0
Spotted bass	76.6	126.7	160.8	193.9	228.2	253.0		
Smallmouth bass	77.5	131.5	179.5	224.1	260.1			
Largemouth bass	56.6	102.9	151.0	199.0	227.0			
White crappie	54.5	93.5	114.0					
Warmouth	39.8	64.4	86.7	107.7				

proposed the term "coefficient of condition" as a means of indicating suitability of environment and to provide a measurement by which the fishes of one body of water could be compared with those of another. The average coefficient of condition for longear sunfish in Doe Run was 4.958 as determined from the equation

$$K = 100{,}000\ W/L^3$$

where W = weight of fish in grams and
L = standard length of fish in millimeters.

In their study, Lewis and Elder (1952) reported an average coefficient of condition of 3.56 for 164 longear sunfish from Clear Creek, Illinois, much lower than that for fish from Doe Run.

Of the 402 longear sunfish sexed in this study (Table 3), 95 percent of the females in Age Group II were sexually mature as indicated by enlarged ovaries, whereas only 9 percent of the males in that age group had enlarged testes. In Age Group III, all females were mature, but only 64 percent of the males were in spawning condition. In Age Group IV, all females were sexually mature, but 4 percent of the males were not. The smallest mature female (Age Group I) was 59 mm long and was the only mature individual in the group. The smallest mature male (Age Group II) was 79 mm long and was the only mature male in that group.

Although no young-of-the-year longear sunfish were collected during the study, it is obvious that spawning took place each year. Such successful spawning took place in the large pools and quiet waters in the lower reaches of the stream. It is noteworthy that spawning had not yet occurred by 9 July 1961 when the stream was treated with rotenone.

TABLE 3.—STANDARD LENGTHS IN MILLIMETERS AND NUMBERS OF LONGEAR SUNFISH OF EACH SEX FROM THE 6 AGE GROUPS, DOE RUN, MEADE COUNTY, KENTUCKY, 9–11 JULY 1961, BASED ON 402 INDIVIDUALS. THE FIGURES IN PARENTHESES INDICATE THE NUMBERS OF SPECIMENS

	Age group					
	I	II	III	IV	V	VI
Male	38.3 (162)	63.2 (161)	83.4 (150)	100.3 (113)	111.8 (46)	119.4 (8)
Females	39.1 (240)	62.3 (237)	79.1 (176)	93.4 (59)	104.1 (8)	— —

Bluegill

Among Doe Run sunfishes, the bluegill was second in abundance prior to the rotenone treatment. Of the 536 specimens reported here, 385 (72%) were taken with rotenone, and based on the entire study, the bluegill made up 34.7 percent of all sunfishes in the stream.

Relatively little is known of the growth of bluegills in small streams, but its growth in lentic waters has been studied extensively. The relatively large population of bluegills in Doe Run is believed to be unusual since it is not usually considered a

stream fish. Trautman (1942, 1957) noted that introductions of bluegills into flowing waters in Ohio were unsuccessful, except when some individuals reached oxbows, overflow ponds, or large quiet pools.

The oldest bluegill from Doe Run was a single member of Age Group VI, and members of Age Groups I, II, and III made up more than 95 percent of those taken with rotenone (Table 4). The length-frequency distribution of 385 individuals (Fig. 2) displays the normal pattern of decrease in numbers each succeeding year of age; however, the paucity of larger individuals may suggest a rather unfavorable environment.

Growth rate was calculated for 521 bluegills based on a straight-line relationship between body length and scale length, corrected for an intercept of 9.8 mm in body length. In Doe Run, bluegills attained average lengths of 35, 63, 86, 106, 124, and 135 mm for Age Groups I through VI, respectively (Table 2). The conversion factor for standard to total length is 1.279 based on measurements of all bluegills caught from Doe Run. The growth rate in Doe Run was higher than that reported from other streams except those in Oklahoma studied by Finnell et al. (1956) and Jenkins et al. (1952). The growth rate in Beaver Creek, Kentucky (Tompkins and Carter 1951), was slightly slower the first 2 years, but the small size of their sample makes any comparison questionable. Purkett (1958a) reported that bluegills grew at their fastest rate in the middle portions of streams in Missouri. The habitat in Doe Run is most similar to that described for those streams in Missouri. Growth in the Missouri streams was slower than in Doe Run in the early years of life but may have been faster in the fourth and fifth years.

There was no apparent difference in growth rates of male and female bluegills in Doe Run. The sex ratios through the first 4 years of life was very near 1:1. Of the 7 individuals in Age Group V, 5 were males, and the lone individual in Age Group VI was a male.

All bluegills from Doe Run were used in calculating the length–weight relationship as determined by least squares from the equation $\log W = -5.5035 + 3.5845 \log L$. The curve developed from the equation fitted empirical data from specimens smaller than 100 mm well, but weights of larger individuals were slightly lower.

TABLE 4.—LENGTH-FREQUENCY DISTRIBUTIONS OF 376 BLUEGILLS OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT, 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length	Age group						Total
	I	II	III	IV	V	VI	
20–29	1						1
30–39	39						39
40–49	58						58
50–59	64	2					66
60–69	36	29					65
70–79	1	40	2				43
80–89		18	26				44
90–99		4	27	1			32
100–109			8				8
110–119			4	9			13
120–129				4			4
130–139					2		2
140–149						1	1
Total	199	93	67	14	2	1	376

The coefficient of condition of Doe Run bluegills determined from all specimens, ranged from 2.358 to 5.662 with an average of 3.779.

Sex and gonad conditions were determined for all specimens over 80 mm long in the rotenone sample; smaller specimens were not sexually mature. About half the females in Age Group II larger than 80 mm were mature, but no males that size in that age group had reached maturity. Almost 76 percent of the females in Age Group III were mature, but only 7 percent of the males were mature. At Age Group IV, 86 percent of all fish were mature, and the 3 older specimens, all males, were mature. The smallest mature female was an 80-mm individual of Age Group II, and the smallest mature male (Age Group III) was 93 mm long.

The collection of young-of-the-year bluegills in the lower reaches of Doe Run each year prior to 1961 (Minckley 1963) indicates that the population was permanent,

TABLE 5.—LENGTH DISTRIBUTION OF 82 GREEN SUNFISH OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT, 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length	Age group					Total
	I	II	III	IV	V	
30–39	14					14
40–49	13					13
50–59	12					12
60–69	6	2				8
70–79		10				10
80–89		3				3
90–99			5	1		6
100–109			5	3		8
110–119			1	4		5
120–129				2	1	3
Total	45	15	11	10	1	82

and not maintained through ingress from the Ohio River.

Green Sunfish

The green sunfish was the third most abundant sunfish in Doe Run prior to the impoundment of Doe Valley Lake; it made up 12.9 percent of all sunfishes taken from Doe Run. Of the 199 specimens collected during the study, only 85 (43%) were taken in the rotenone sample. The rotenone sample contained a single specimen of Age Group V, the oldest, a male, and more than half the sample was made up of members of Age Group I (Table 5). The length-frequency distribution is representative of the population during the summer of 1961.

Growth rate was calculated for 186 individuals based on a straight-line relationship between body length and scale length, and corrected for an intercept of 9.6 mm. Average standard lengths for Age Groups I through V, respectively, were 35, 63, 90, 110, and 128 mm (Table 2). The conversion factor for standard to total length is 1.254 based on measurements of all green sunfish in the Doe Run collection. The growth rate in Doe Run was below average for many streams cited in the literature. In 6 Missouri streams, green sunfish from only the St. Francis and Gasconade rivers grew more slowly than those in Doe Run (Purkett 1958a, 1958b; Patriarche and Lowry 1953). In Oklahoma, green sunfish in the Little River and Illinois River systems attained average lengths by the end of 3 years that exceeded average lengths of individuals of Age Group V in Doe Run (Finnell et al. 1956, Jenkins et al. 1952).

Little difference was noted in the growth rates of male and female green sunfish in Doe Run. Hubbs and Cooper (1935) noted that the growth rate for male green sunfish in Michigan was considerably greater than that of females.

In Doe Run, males lived longer than females, and the percentage of males in the population increased with age until Age Group V when only males survived.

Length–weight relationships were determined for all green sunfish from Doe Run by least squares with the equation $\log W = -4.7064 + 3.1376 \log L$. The curve developed from that equation fitted empirical data for all specimens. Lewis and Elder (1952) reported a length–weight relationship for green sunfish in Clear Creek, Illinois, as best represented by the equation $\log W = -4.89 + 3.19 \log L$, an indication that Clear Creek individuals were lighter than their Doe Run counterparts.

The average coefficient of condition of 197 green sunfish from Doe Run was 3.520, ranging from 2.700 to 4.912. Lewis and Elder (1952) reported a mean coefficient of condition of 3.19 for 83 individuals that ranged from 55 to 199 mm in standard length. Those data indicate that conditions in Doe Run were better than in Clear Creek, at least for green sunfish.

Sex and condition of gonads were determined for all green sunfish longer than 60 mm from the rotenone sample. Two of the large females but none of the males in Age Group I were sexually mature. About a third of the males and 70 percent of the females in Age Group II had reached maturity. All individuals of older age groups were mature. The smallest mature females were 2 67-mm individuals of Age Group I; the smallest mature male was a 76-mm specimen of Age Group II.

More small green sunfish than young of

TABLE 6.—LENGTH-FREQUENCY DISTRIBUTION OF 106 ROCK BASS OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT, 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length	Age group								Total
	I	II	III	IV	V	VI	VII	VIII	
30–39	13								13
40–49	5								5
50–59	3								3
60–69	2	10							12
70–79	1	2							3
80–89		1							1
90–99		1	1						2
100–109		3	1						4
110–119		2	1	1					4
120–129			2	2	1				5
130–139			1	6	1				8
140–149				3	4				7
150–159					9	1			10
160–169					6				6
170–179					3	8			11
180–189					1	2			3
190–199							4		4
200–209						1	3		4
210–219								1	1
Total	24	19	6	12	25	12	7	1	106

any other sunfish were taken in the downstream area of Doe Run, indicating that reproduction was common in pools of that area. Minckley (1963) reported that green sunfish reproduced in Doe Valley Lake shortly after its impoundment, indicating that the species had survived the attempted eradication with rotenone.

Rock Bass

The rock bass, the fourth most abundant sunfish in Doe Run, was commonly found among the undercut roots of riparian sycamore trees *Platanus occidentalis* L. A total of 131 specimens was taken during the entire study and they made up 8.5 percent of all sunfishes. The rotenone study yielded 115 specimens. The number of large individuals made the population of interest to the angler, but there was little utilization of the fishery. The length-frequency distribution of all specimens from Doe Run is shown in Fig. 2.

The oldest rock bass in the collection was of Age Group VIII, and young of the year were collected 2–6 km downstream from the bridge for Highway 1638 in the fall of 1960. The age composition of 106 specimens from the rotenone study is shown in Table 6.

Rate of growth was calculated for 121 rock bass based on a straight-line relationship between body length and scale length and corrected for an intercept of 18.3 mm. In Doe Run, the respective standard lengths for Age Groups I through VIII were 47, 77, 107, 132, 155, 174, 192, and 206 mm (Table 2). The conversion factor for standard to total length is 1.226 based on measurements of all rock bass. The rate of growth in Doe Run, although faster during the first year, was similar to that reported for the middle sections of Missouri streams by Purkett (1958a) and the Tippecanoe River, Indiana, by Scott (1949). The growth rate in Doe Run was greater than that reported for the Black River, Missouri, by Patriarche and Lowry (1953). Growth rates of rock bass from 2 Kentucky streams reported by Tompkins and Carter (1951) were much greater than in Doe Run, or any other stream for that matter, but their samples were small. In the Illinois River system

of Oklahoma (Jenkins et al. 1952), the growth rate was higher than in Doe Run.

No significant difference in growth rates of males and females was apparent in Doe Run. Still, based on the fish taken with rotenone, males outlived females. Of the specimens sexed, 62 percent of those in Age Groups II, III, and IV were females, but only 27 percent of those in Age Groups V through VIII were females. Only 1 of 7 specimens in Age Group VII was a female, and the lone fish in Age Group VIII was a male. Hile (1941) reported that the growth rate of male rock bass in Nebish Lake, Wisconsin, exceeded that of females, but that females lived longer than males.

All specimens in the Doe Run collection were used to calculate the length–weight relationship. The equation determined by least squares was log W = –4.4625 + 3.0329 log L. The curve derived from that equation fitted empirical data for all sizes. Scott (1949) determined the length–weight relationship for rock bass in the Tippecanoe River to be log W = –5.040 + 2.908 log L. Comparison of values from those curves indicates that fish from Doe Run were relatively lighter than those from the Tippecanoe River.

Most adult rock bass from Doe Run in July 1961 were not at peak sexual maturity, indicating that reproduction had not yet taken place. Young-of-the-year rock bass taken in the fall of 1960 were no longer than 24 mm standard length in September or December, a strong indication of very late spawning dates. Rock bass spawned throughout the lower reaches of Doe Run. The smallest sexually mature female was a 105-mm specimen of Age Group II, and the smallest mature male was a 110-mm individual of the same age.

Spotted Bass

Spotted bass were collected more often than either of the other black basses, but only 2 of the 28 specimens in our sample were taken with rotenone. Based on all collections, it made up 1.8 percent of the total sunfish population. The oldest specimens belonged to Age Group VI, and 4 young of the year were the youngest, and averaged 31 mm standard length.

Growth rates were determined for 24 individuals based on a straight-line relationship between body length and scale length and corrected for an intercept of 27.4 mm. That intercept is the average value reported by Bryan (1964, unpublished doctoral dissertation, University of Louisville, Louisville, Kentucky) for all his stations. In Doe Run, spotted bass attained average lengths of 77, 127, 161, 194, 228, and 253 mm for Age Groups I through VI, respectively (Table 2). The conversion factor for standard to total length is 1.225 based on measurements of all Doe Run specimens.

The growth rate of spotted bass in Doe Run was lower than that for streams in Missouri (Purkett 1958a), Oklahoma (Jenkins et al. 1952, Finnell et al. 1956), or from Slate Creek, Kentucky (Tompkins and Carter 1951). Bryan (unpublished dissertation) compared growth rates throughout its range in streams and impoundments and found no trends attributable to geography, but instead believed that local factors in the habitat were responsible for any variations.

Length–weight relationship for spotted bass from Doe Run was calculated using the equation log W = –4.9287 + 3.1778 log L. Such a relationship for spotted bass in several streams in the Ohio River valley (Bryan unpublished dissertation) was best represented by log W = –5.138 + 3.124 log L. Weight values derived from that curve are slightly lower than corresponding values from Doe Run.

The average coefficient of condition of the 28 individuals from Doe Run was 2.532 and ranged from 1.707 to 3.237. Lewis and Elder (1953) reported an average value of 2.46 for Clear Creek, Illinois, and Bryan (unpublished dissertation) reported average values that ranged from 2.27 to 2.90 for 8 stream populations. Comparison of those data indicates that spotted bass from Doe Run were in slightly better condition than the averages for the other streams.

Young-of-the-year specimens from the

lower reaches of Doe Run in September and October 1960 showed that reproduction had been successful. Large adults taken during the rotenone study had not yet reached spawning condition, but their gonads were approaching that stage. It appears that the spotted bass maintained a small permanent population in the large pools near the lower end of Doe Run.

Smallmouth Bass

The smallmouth bass was rare in Doe Run and its distribution was restricted to the lower reaches of the stream. A total of 24 specimens was taken, 14 of which were caught in the rotenone treatment. Based on all collections, it made up 1.5 percent of all sunfishes in Doe Run. Tate (1949) reported as many as 100 adult smallmouth bass ("a dense population") in a 4-km stretch of Coffin Creek, Iowa.

The oldest individuals in Doe Run were in Age Group V, and young of the year were taken in 1960 and 1961. The single 15-mm young-of-the-year smallmouth bass taken during the rotenone study was the only sunfish of that age group taken during 1961. Large specimens of Age Groups IV and V made up two-thirds of all smallmouth bass, an indication that the population, like those of other sunfishes, was underexploited. Minckley (1963) reported seeing an angler with a smallmouth bass from Doe Run that weighed 964 g after viscera and scales had been removed. That individual was considerably larger than any in the Doe Run collection. That small number in the collection precludes any satisfactory length-frequency distribution.

Growth rates were calculated for 20 individuals based on a straight-line relationship between body length and scale length and corrected for an intercept of 14.6 as determined by Everhart (1950). No body–scale relationship was attempted from Doe Run data. Smallmouth bass in Doe Run attained lengths of 78, 132, 180, 224, and 260 mm, respectively, at ages I through V (Table 2). In addition, 3 individuals of Age Group O, collected in mid-August 1960, averaged 33 mm standard length, and a 15-mm specimen was taken during the rotenone study. The conversion factor for standard to total length is 1.216 based on measurements of all Doe Run specimens.

Growth rate of smallmouth bass in Doe Run was slightly below average for some streams in Missouri (Purkett 1958a, Patriarche and Lowry 1953) and Oklahoma (Jenkins et al. 1952, Finnell et al. 1956), but was much greater than that reported by Suttkus (1955) for Fall Creek, New York, and somewhat higher than that in Coffin Creek, Iowa (Tate 1949). The growth rate in Elkhorn Creek, Kentucky (Tompkins and Carter 1951), one of the best-known smallmouth bass streams in the state, was much higher than that reported for any other stream.

Measurements of all specimens from Doe Run were used to calculate length–weight relationship. The equation, as determined by least squares, was $\log W = -6.011 + 3.586 \log L$. Tate (1949) reported that relationship as $\log W = -4.8128 + 3.0935 \log L$ for smallmouth bass in Coffin Creek, Iowa, indicating that they were heavier than those from Doe Run. Populations in Missouri Ozark streams (Purkett 1958a) and Fall Creek, New York (Suttkus 1955), also had length–weight relationships greater than that in Doe Run.

The average coefficient of condition of Doe Run smallmouth bass was 2.425. It was lower than that reported by Tate (1949) for Coffin Creek, Iowa, but higher than that reported by Suttkus (1955) for Fall Creek, New York. The high coefficient of condition for smallmouth bass in Doe Run indicates that the environment is favorable for the species.

Largemouth Bass

The largemouth bass was rare in Doe Run, and its distribution was limited to the large pools in the lower reaches of the stream; still, an individual was collected near the bridge for Highway 1638 in June 1961. Only 16 individuals were collected from Doe Run, and 14 of those were in the

rotenone collection. Based on all collections, the largemouth bass made up 1.0 percent of the total sunfish population in Doe Run.

The oldest individual was of Age Group V and the youngest were in Age Group I. No young of the year were taken. More than half the specimens in all collections were of Age Group II (Table 2). The growth rate was calculated for 15 individuals based on a straight-line relationship between body length and scale length corrected for an intercept of 25.4 mm. The largemouth bass in Doe Run had attained average lengths of 57, 103, 151, 199, and 227 mm for Age Groups I through V, respectively (Table 2). The conversion factor for standard to total length is 1.227 based on measurements of all specimens.

The growth rate for largemouth bass in Doe Run was very slow. They grew more slowly than in any of the streams in Missouri (Purkett 1958a), in Kentucky (Tompkins and Carter 1951), and in Oklahoma (Jenkins et al. 1952, Finnell et al. 1956). In the Clinch River, Tennessee, below Norris Dam, Eschmeyer (1944) reported that age determination of 108 largemouth bass taken after 15 November 1943 revealed that individuals up to 300 mm total length (ca. 245 mm standard length) were young of the year, none having annuli on their scales.

Measurements of all largemouth bass from Doe Run were used to calculate the length–weight relationship from the equation $\log W = -4.839 + 3.106 \log L$. The average coefficient of condition for those fish was 2.451. Eschmeyer (1944) reported a coefficient of condition of 2.19 for largemouth bass from the Clinch River. Thus, that species in Doe Run was plumper than most other stream populations even though they grew very slowly.

None of the largemouth bass from Doe Run was in breeding condition in July 1961. One female contained eggs in an early stage of development.

White Crappie

The white crappie was not collected from Doe Run until 1961 when it was taken from the backwater of the Ohio River. The 26 specimens taken during the entire study period made up 1.7 percent of the total sunfish population. All specimens were small, the largest being an individual of Age Group III; the youngest were 5 individuals of Age Group I. No young of the year were collected.

Growth rate was calculated for the 20 specimens taken with rotenone based on a straight-line relationship between body length and scale length. Those fish had attained average standard lengths of 71, 123, and 150 mm at ages I through III, respectively (Table 2). The conversion factor for standard to total length is 1.213 based on measurements of all specimens. The growth rate in Doe Run was below the average for white crappies from Slate Creek, Kentucky (Tompkins and Carter 1951), the St. Francis River, Missouri (Purkett 1958a), and Poteau River, Oklahoma (Hall 1951), but was greater than in the Salt, Gasconade, and Meramec rivers, Missouri (Purkett 1958a, 1958b), and the Little and Illinois rivers, Oklahoma (Jenkins et al. 1952, Finnell et al. 1956).

All specimens from Doe Run were used to calculate the length–weight relationship from the equation $\log W = -6.1946 + 3.7658 \log L$. The average value was 2.382. Hansen (1951) reported seasonal changes in coefficient of condition among male and female white crappies from Lake Decatur, Illinois, with values for males being higher than for females.

Warmouth

Prior to the rotenone treatment, only a single warmouth had been collected from Doe Run. The rotenone study produced an additional 17 specimens. Those fish were limited to the sluggish pools in the lower reaches of the stream. Based on all data, the warmouth made up 1.2 percent of the total sunfish population.

The oldest individuals were in Age Group IV, and 2 individuals of Age Group I were the youngest. Growth rate was calculated for 18 specimens based on a straight-line

relationship between body length and scale length corrected for an intercept of 13.4 mm. The average standard lengths were 40, 64, 87, and 108 mm, respectively, for Age Groups I through IV. The conversion factor for standard to total length is 1.240 based on measurements of all specimens.

The growth rate (Table 2) was slower than that reported by Tompkins and Carter (1951) from Slate Creek, Kentucky, by Finnell et al. (1956) and Jenkins et al. (1952) for the Little and Illinois river systems, Oklahoma, and from the Mississippi River (Upper Mississippi Conservation Commission 1946). Also, it was much slower than that reported for 2 Illinois lakes by Larimore (1957).

The length–weight relationship was based on all specimens using the equation log W = –5.359 + 3.504 log L. The average coefficient of condition for warmouths in Doe Run was 4.089.

Discussion and Conclusions

Eleven centrarchids were present in Doe Run prior to the rotenone treatment of 9–11 July 1961, when most fishes used in this study were collected. Of those, 9 were present in sufficient numbers for analysis of growth rate, coefficient of condition, age at maturity, and length-frequency distribution. Except for a few isolated individuals, all sunfishes were restricted to the area downstream from the bridge for Highway 1638 (Fig. 1) by a combination of factors including obstruction of stream flow, high gradient, water temperature, and lack of suitable habitat. Lack of sufficient cover and competition with other species more suited to Doe Run's environment played a major role in limiting the sunfish population.

Populations of rock bass, longear sunfish, smallmouth bass, and spotted bass contained majorities of older individuals, indicating that the populations were mature and underexploited. The populations of bluegills and green sunfish contained relatively large numbers of young individuals, indicating reproductive success. Collectively, all other sunfishes made up less than 5 percent of the total sunfish population, and none was known to have reproduced in Doe Run, although the warmouth and the largemouth bass may have done so on occasion.

The growth rates of different sunfishes are indications of the suitability of the environment. The most abundant sunfish in Doe Run, the longear sunfish, grew faster than the average rate of other streams reported in the literature. The bluegills also grew faster than those reported from other streams, but not as fast as in lakes. The rock bass, abundant in a limited area of Doe Run, had an average growth rate comparable with that of other streams; that population contained many individuals larger than average for most Kentucky streams. The growth rates of smallmouth bass, spotted bass, and green sunfish were slightly less than those reported for other streams. However, the smallmouth bass grew faster than they did in streams of comparable size reported in the literature, Fall Creek, New York (Suttkus 1955), and Coffin Creek, Iowa (Tate 1949). Other centrarchids in Doe Run, the largemouth bass, warmouth, and white crappie grew very slowly when compared with those from other streams, indicating that environmental conditions in Doe Run probably were marginal; those species refer warmer and more sluggish or lentic waters.

Growth rates of male and female green sunfish, bluegill, and rock bass were similar, but the male longear sunfish grew noticeably faster than females. Also, males of those 4 species lived longer than females. Females of all species considered reached sexual maturity at younger ages than males.

Analyses of length–weight relationships indicated that only the rock bass was below those reported for other streams. Comparisons were hindered by the paucity of suitable material from other streams. Bennett (1938) reported that slower growing populations of smallmouth bass in Wisconsin lakes had relatively higher average weights than fast growing individuals. However, Tate (1949) found that smallmouth bass in

Coffin Creek, Iowa, that had a faster growth rate than reported by Bennett, were also heavier. It appeared that any attempt to relate length–weight relationships with growth rates may be misleading. Although the growth rates of the different species of sunfishes in Doe Run ranged from above average to below average, all species except the rock bass and white crappie were heavier than average. Within geographic regions, the relative weights of sunfishes are controlled by the food available and not solely on increase in length after embryological development. While growth can be controlled by several factors, temperature of the water and length of the growing season play dominant roles (Bennett 1938, Thompson 1941).

Of the sunfishes collected during the rotenone treatment of 9–11 July 1961, only the smallmouth bass was known to have spawned already that year. Some female longear sunfish appeared to be in peak spawning condition, as indicated by the condition of the ovaries, but no spent females were found. Other species did not appear ready to spawn. Those data indicate that spawning dates for sunfishes in Doe Run are relatively late in the year probably because of the constant coolness of the water at the source of the stream and the almost complete shading of the stream by riparian trees and their influence on water temperatures downstream.

From the information at hand, the most successful association of centrarchids in Doe Run is the longear sunfish–rock bass–smallmouth bass. Based on our collections elsewhere, that association is not uncommon for cool, clear, free-flowing, gravel-bottomed streams.

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