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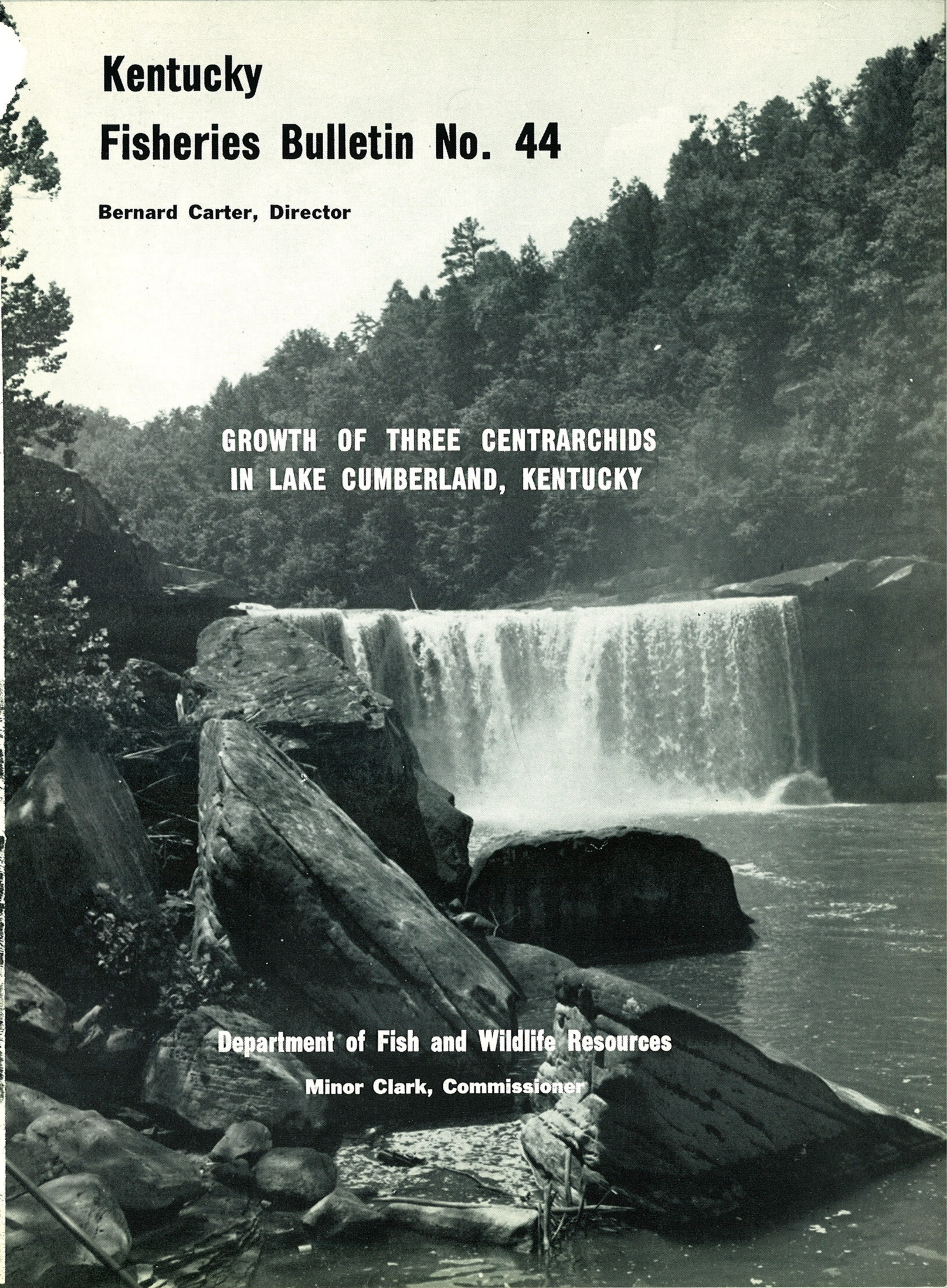

GROWTH OF THREE CENTRARCHIDS IN LAKE CUMBERLAND, KENTUCKY

Department of Fish and Wildlife Resources

Minor Clark, Commissioner

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By

Bernard T. Carter

Kentucky Department of Fish and Wildlife Resources

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ABSTRACT

Growth characteristics of the largemouth bass, the Kentucky bass, and the white crappie and the changes that occurred in these characteristics during the first five years of impoundment of Lake Cumberland are reported in this paper. A description of the pattern of early scalation and the length of the fish at which scalation is completed is given for the largemouth bass and the white crappie. Length-weight-age distribution of each species is discussed in terms of harvestability.

INTRODUCTION

Many studies of the growth of the largemouth bass, *Micropterus salmoides* (Lacépède), the Kentucky or spotted bass, *Micropterus punctulatus* (Rafinesque), and the white crappie, *Pomoxis annularis* Rafinesque, in large impoundments have been made by others. One of the earliest of these studies was made when Eschmeyer and Jones (1941) studied the growth of two of these species in Norris Reservoir, Tennessee, during its first five years of impoundment. Stroud (1949) determined the rates of growth of five centrarchids and two percids in Cherokee and Douglas Reservoirs, Tennessee, and Hiwassee Reservoir, North Carolina.

The present study was designed to furnish information on growth rates, ages at harvestable total lengths, relationship of scale growth to body growth, total length when scalation is initiated, the early pattern of scalation, the total length of the fish when scalation is complete, and the relationship of total body length to body weight for three of the principal sport fishes in Lake Cumberland.

DESCRIPTION OF THE LAKE AND SAMPLING AREA

Lake Cumberland was created in the winter of 1950-1951 by the completion of Wolf Creek Dam on the Cumberland River. The lake has a surface area of 50,250 acres at conservation pool elevation (723 feet msl), is approximately 100 miles long, has a shoreline of more than 1,000 miles, and drains an area of 5,810 square miles.

The upper portion of the lake above Burnside, Kentucky, is located within the Cumberland Plateau Physiographic Region (Fenneman, 1938; 329-342, 411-427) and the immediate watershed is typified by deep narrow valleys and steep wooded hillsides. The basic rock structure of the Cumberland Plateau is composed of horizontal layers of Pottsville sandstones and conglomerates interspersed with layers of shale. These rocks have given rise to relatively unproductive soils. Water falling within this watershed and eventually impounded in Lake Cumberland is therefore relatively low in the nutrient minerals believed to be of importance to high fish production.

The vegetative cover of the immediate watershed is composed primarily of species indigenous to the mixed mesophytic forest climax. However, the upland plateau areas, outside the ownership of the Daniel Boone National Forest, are for the most part in pastureland. Some cultivation is practiced but is confined to small plots of plowed areas.

The lower and greater portion of Lake Cumberland is located within the eastern edge of the Highland Rim Physiographic Region; however, spurs of the Cumberland Plateau extend into the Highland Rim Region, and it is difficult to define exactly the physiography of this section of the lake. The valley floors, now inundated, can be placed correctly in the Highland Rim Region which is best characterized by its underlying limestone rock strata. The upland portions, although primarily a part of the Highland

Rim, are invaded by terminal thrusts of the Cumberland Plateau. The surrounding watershed of this portion of the lake is also infertile (Fenneman, *op. cit.*); however, the upland topography is much less rugged and broken.

The primary vegetation is essentially the same as that of the Cumberland Plateau except that the forest is confined more to the steep hillsides bordering the lake and its tributary streams. Most of the upland watershed is rolling pastureland. Cultivation is more extensive in this area but is not intensive.

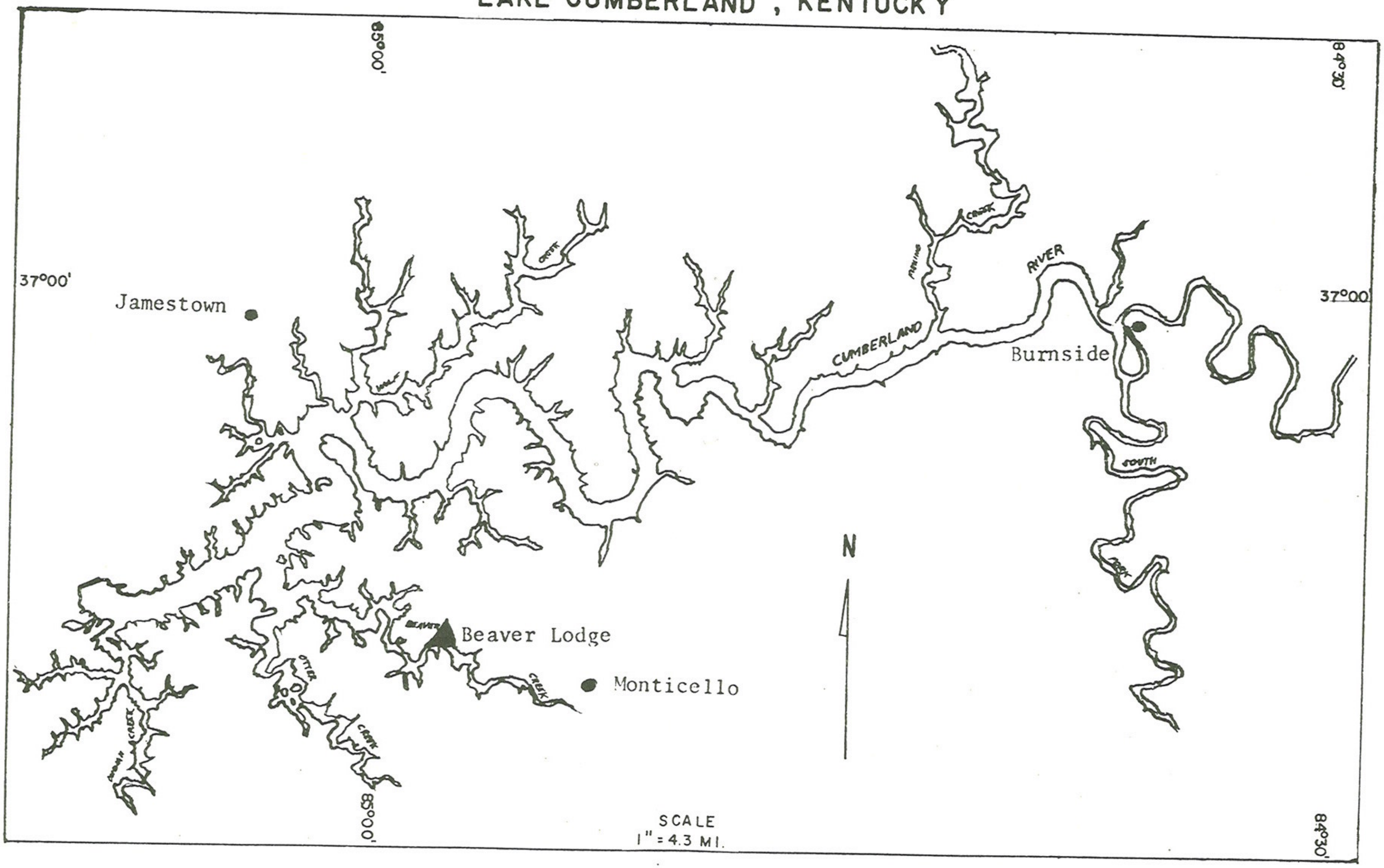
The sampling area included both the Beaver Creek and Otter Creek sections in the southwestern part of Lake Cumberland (see map). This area is located within the Highland Rim Physiographic Region and is typical of the eastern edge of the region. Both streams arise in Wayne County, Kentucky, and are physically similar. The watersheds of the two streams are well protected from erosion by proper land management; only during periods of extremely heavy rainfall does the water become turbid, and then it clears rapidly. The area is excellent game fish habitat having clear water and rocky or gravel bottom materials. Rotenone population studies conducted almost yearly since 1951 by the Kentucky Division of Fisheries (in print) have shown this area to be well populated with the three species studied in this report.

MATERIALS AND METHODS

All fishes used in this study were either caught by sport fishermen or taken in rotenone studies from the Beaver Creek-Otter Creek area of the lake during 28 separate collecting trips from 1952 through 1957.

All scale samples and body measurements of fishes more than four inches in total length were taken from fish caught by fishermen and brought into the sampling station at Beaver Lodge Fishing Dock. This

LAKE CUMBERLAND , KENTUCKY



dock is located in the Beaver Creek arm of the lake approximately eight miles above the confluence of Beaver and Otter Creeks with the main stem of the lake. Most of the smaller fishes, four to eight inches in length, were collected by fishermen at the specific request of the author because fishes in this size range are seldom kept.

Scale samples and body measurements in tenths of inches and hundredths of pounds from 482 largemouth bass, 317 Kentucky bass and 530 white crappies were secured in this manner.

In addition to the above samples, 95 largemouth bass, 62 Kentucky bass and 10 white crappies smaller than four inches in total length were collected during one rotenone population study conducted in the area during July, 1954. These fishes were preserved in formalin for a period of 24 hours, taken to the laboratory, measured to the nearest millimeter and weighed to the nearest gram. The metric measurements were later converted into inches and pounds. No consideration was given to possible shrinkage which may have occurred as a result of the action of the preservative.

Scale samples were taken from the right side of each fish below the lateral line and approximately below the origin of the spinous dorsal fin. Plastic impressions were made of scales from fishes larger than four inches following the method described by Turner (1953). Scales from fishes smaller than four inches long were stained with an aqueous solution of Alizarin Red-S, mounted on glass slides in water, and measured immediately. All scale measurements were made with a microprojector at a magnification of 32 times. Measurements were made from the focus to the anterior edge of the scale along an imaginary radius in the center of the scale. All regenerated scales were discarded, and no attempt was made to determine the incidence of regeneration.

BODY-SCALE RELATIONSHIP

Whitney and Carlander (1956) discussed in detail the problems involved in constructing a true regression line which represents the actual proportional growth of body and scale. The relationship of body growth to scale growth may be different for each year-class; it may differ within the same species living in different sections of the same lake, or it may even differ between sexes. This relationship may be linear or curvilinear. In order to eliminate some of the inherent factors affecting the determination of the body-scale relationship of a species, a regression would have to be determined from a large sample over many size ranges of each year class for each distinct section of the lake. As this was impossible in the present study, body-scale relationships have been assumed to be linear, and regression lines showing these approximate relationships have been constructed by the method of least squares. Bennett, Thompson, and Parr (1940) observed a straight-line relationship for largemouth bass. Ricker and Lagler (1942) found a direct proportion growth of scale radii and body length for largemouth bass between 20 mm. and 30 mm. fork length.

The relationship of body length to scale radius is represented by the equation $L = a + bS$; where L = total length, a is the intercept of the regression line with the length axis, b is the slope, and S is the scale radius (Lee, 1920).

Some workers have suggested that intercept a could be interpreted to represent the length at which scales first appear on the body, although as Lagler (1952; 120-134) points out, this may not be accepted entirely because the intercept is negative in some species. In an effort to determine if the calculated intercept a could in any way be correlated with the observed lengths at which fish first form scales, an examination of the initial pattern of scalation of a number of small fish of each species was made.

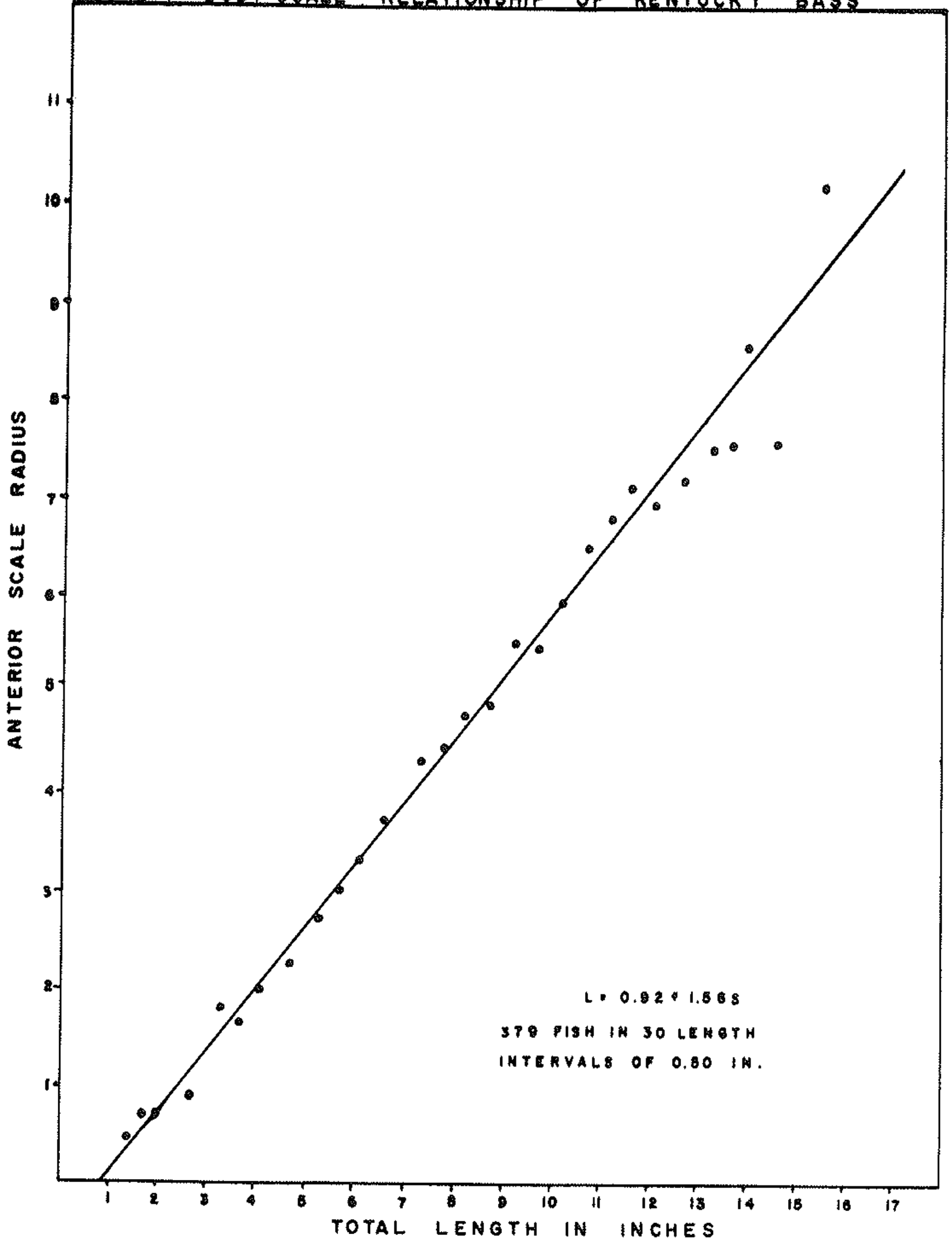
Kentucky Bass

Sixty-two Kentucky bass were examined, but the smallest of these fish was 1.38 inches long and was completely scaled. It was therefore impossible to determine the early history of scalation for this species. The equation expressing the direct proportional relationship of body growth to scale growth is $\underline{L} = 0.92 + 1.56\underline{S}$ (Figure 1).

Largemouth Bass

Ninety-five largemouth bass ranging in size from 0.94 to 3.90 inches in total length were examined to determine the length at which scales are first formed and the early pattern of scalation. No fish examined was completely without scales. The smallest fish, 0.94 inch in length, had only one row of rudimentary scales formed along the lateral line anterior to the caudal peduncle region. The caudal peduncle was fully scaled. Fish 1.05 inches in length had their sides, dorsal regions, and caudal regions fully scaled. The ventral region anterior to the origin of the anal fin was unscaled. This pattern was evident until the fish had reached a length of 1.26 inches. At that time, rudimentary scales were forming over the previously unscaled ventral region except in the area at the base of the pelvic fins. Fish 1.36 inches long were fully scaled except at the base of the pelvics. All fish more than 1.40 inches long were fully scaled. Thus, scales are first formed on Lake Cumberland largemouth bass prior to the time the fish reach a total length of 0.94 inch, but complete scalation does not occur until the fish have reached a length of 1.40 inches.

FIGURE-1 BODY-SCALE RELATIONSHIP OF KENTUCKY BASS



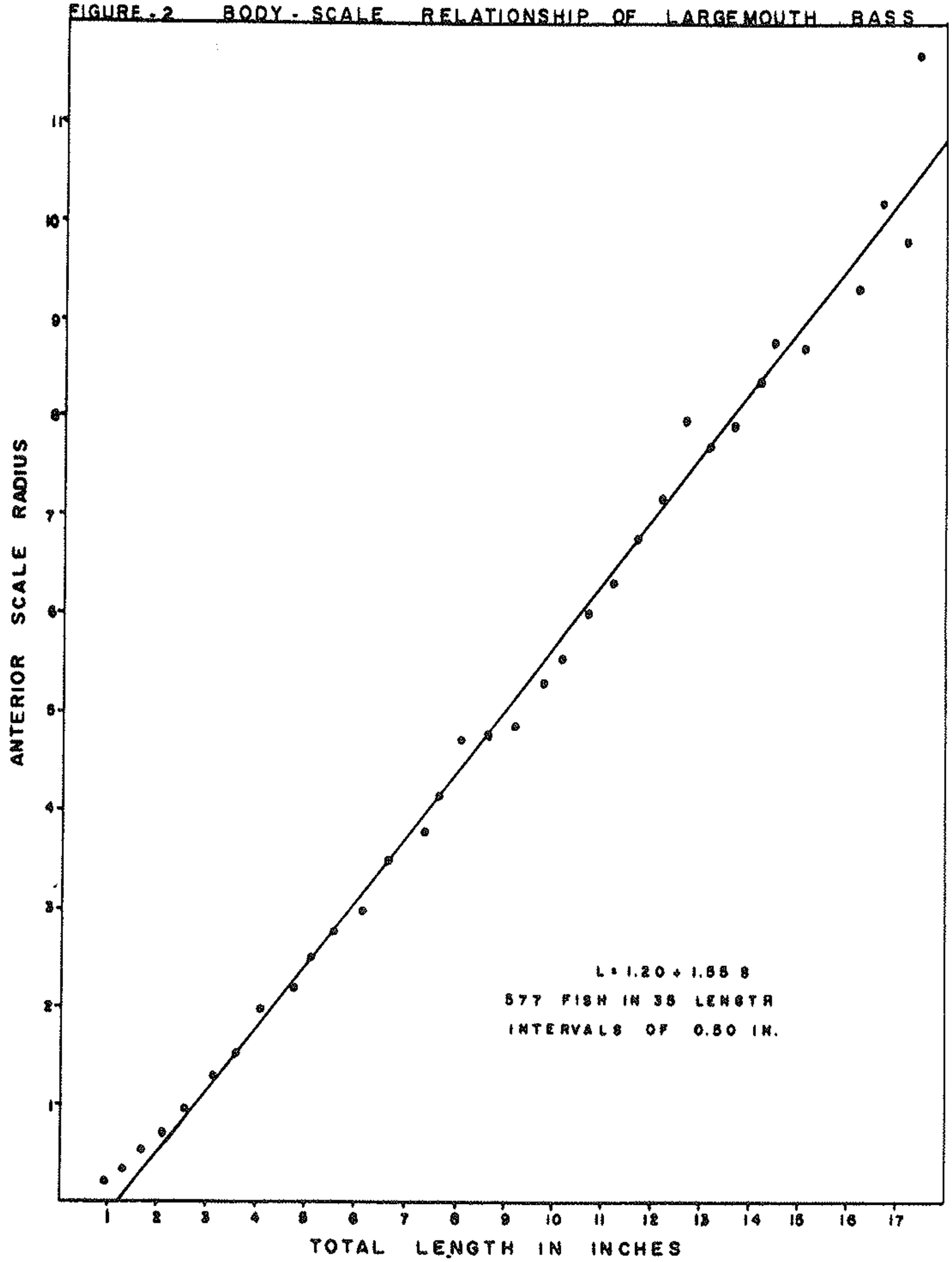
The regression line determined for largemouth bass and expressed in the equation $\underline{L} = 1.20 + 1.55\underline{S}$ has an intercept of 1.20 inches (Figure 2). Therefore, it is apparent that this computed intercept is intermediate between the size at which scalation is initiated and that at which it is completed.

The pattern of scalation is: first the caudal region is scaled, then an area along the lateral line, and soon thereafter, the sides and dorsal region. The ventral region anterior to the anal fin is the last area to become completely scaled.

White Crappie

Ten white crappies ranging from 1.32 to 1.77 inches in total length were examined. Those fish 1.32 to 1.42 inches possessed only a single row of imbedded rudimentary scales; this row extended along the mid-dorsal line from the posterior base of the soft dorsal fin to the caudal fin. Fish 1.54 to 1.57 inches in length had an additional row of scales which extended along the mid-ventral line from the posterior base of the anal fin to the caudal fin. Fish 1.65 inches in length had scales present over the entire dorsal and ventral surfaces and over the entire caudal peduncle, but there were no scales on the sides anterior to the caudal peduncle. Fish 1.69 to 1.77 inches long were completely scaled except for scattered areas on the sides. These unscaled areas could have resulted from handling; the scales in these areas may have been accidentally removed. The other possibility, of course, is that scalation had not been completed at this length. The next smallest fish available for examination was 3.0 inches long and was completely scaled. Thus scales are first formed on Lake Cumberland white crappie prior to the time the fish reach a length of 1.32 inches, but complete scalation does not occur until the fish have reached a total length of 1.77 inches.

FIGURE. 2 BODY - SCALE RELATIONSHIP OF LARGEMOUTH BASS



The regression line determined for white crappie and expressed in the equation $\underline{L} = 1.45 + 1.55\underline{S}$ has an intercept of 1.45 inches (Figure 3). This intercept closely approximates the length at which the fish were in the process of first forming scales (fish 1.42 inches long had only one row of rudimentary scales formed).

The pattern of scalation may be described as follows: scales first form on the dorsal mid-line in one row extending between the posterior base of the soft dorsal fin to the caudal fin. The same pattern is later repeated between the posterior base of the anal fin and the caudal fin. Scale formation is then extended anteriorly in the dorsal and ventral regions. The sides of the fish are the last portion of the body to be scaled.

AGE AND GROWTH

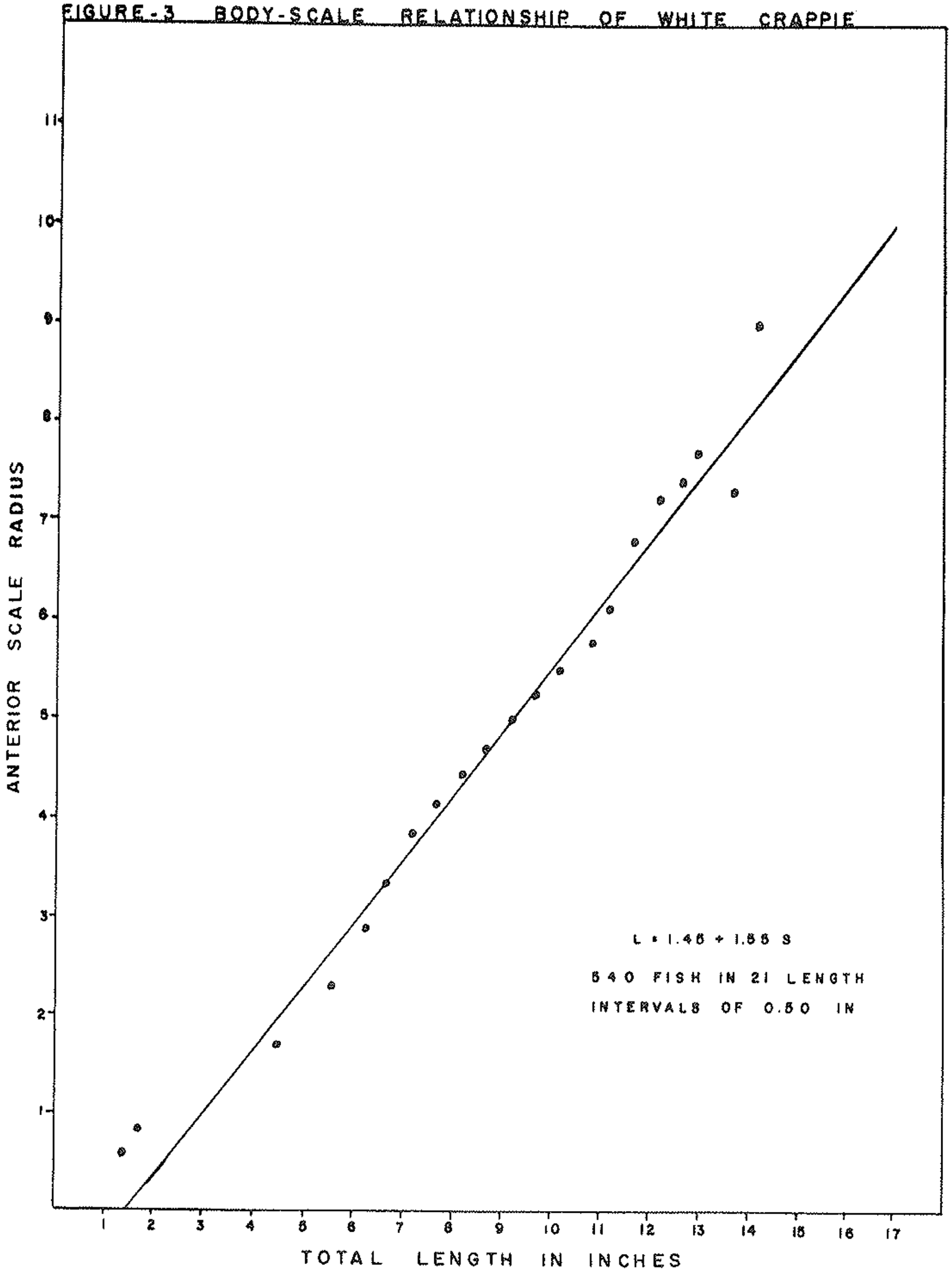
Calculations of fish lengths from scale lengths were made following the suggestions of Van Oosten (1953), whereby averages of the scale and body measurements of each specific age group were used instead of calculating lengths at each annulus for each individual fish.

In order to determine more accurately the growth rates of each species and to determine the trends in growth from year to year, an analysis was made of the growth rates of each year class. The equation used is: $L_x = a + \frac{S_x(L-a)}{S_t}$ (Van Oosten, 1929); where L_x = total length at annulus x, $\underline{a}$ is the intercept of regression line, $\underline{S_x}$ is the scale radius at annulus x, $\underline{L}$ is the total length and $\underline{S_t}$ is the total scale radius.

Kentucky Bass

The age and growth rates for each year-class of Kentucky bass from 1951 through 1955 are listed in Table I. Admittedly, the total

FIGURE-3 BODY-SCALE RELATIONSHIP OF WHITE CRAPPIE



sample of 261 fish is small, but it is believed to be large enough to provide reasonably reliable information.

Scale samples were taken from six specimens ranging in length from 14.0 to 15.5 inches and the ages were estimated to be four or five years, but the poor quality of the scale samples prevented positive determination of the exact number and position of the annuli. Scales from 41 Kentucky bass between 11 and 14 inches were collected for study; however, because most of these fish were collected in mid-March and the third annulus had not been formed at that time, age group III is not represented in the table.

Table I. *Calculated total lengths of 261 Kentucky bass*

Year class	Number	Avg. total length at capture	Calculated total length in inches I	II
1951	78	10.3	6.0	10.4
1952	133	9.6	5.5	8.0
1953	10	9.5	3.8	7.1
1954	34	5.8	3.6	
1955	6	7.1	3.5	
Totals and Averages	261	9.3	5.3	8.8

The data in Table I reveal a declining rate of growth from 1951, the first year of impoundment, until 1953, after which time the rate leveled off. Stroud (1948) reported the growth of Kentucky bass during the first ten years of impoundment in Norris Reservoir, Tennessee. Here, the species grew less during the first year of impoundment than did the Lake Cumberland bass (5.1 inches total length compared to 6.0 inches) but did not show the steady declining rate of growth exhibited by the Lake

Cumberland fish. The grand average length attained by Kentucky bass at the end of the first year of life during the first ten years of impoundment of Norris Reservoir was 4.9 inches. The weighted average for Kentucky bass of this age group in Lake Cumberland was 5.3 inches. However, if the apparently stabilized growth rates have continued, the ten-year average body length for the first year of life will be lower in Lake Cumberland than that reported for Norris Reservoir.

Growth compensation during the second year of life was not apparent.

Largemouth Bass

The ages and rates of growth determined from a sample of 462 largemouth bass during the first five years of impoundment are presented in Table II. Although it is possible that fishing methods may have been somewhat selective for largemouth bass, it is believed that the larger sample of this species in the total collection of basses simply reflects its numerical superiority in the combined bass population.

Table II. *Calculated total lengths of 462 largemouth bass*

Year class	Number	Avg. total length at capture	Calculated total length in inches			
			I	II	III	IV
1951	286	11.1	6.7	9.8	13.4	18.6
1952	122	11.3	7.2	11.5	15.5	18.1
1953	20	12.3	6.0	11.5	15.7	
1954	30	10.2	5.4	11.0		
1955	4	9.9	5.8			
Totals and Averages	462	11.1	6.7	10.4	14.1	18.5

It will be noted that growth of the young-of-the-year fish during the first year of impoundment was less than during the second year. This same phenomenon was observed in Norris Reservoir by Eschmeyer and Jones (*op. cit.*). They suggest that the reasons for this slower growth the first year of impoundment may be: (1) a less abundant supply of food in 1936 as compared to 1937, the second year of impoundment, and (2) a scarcity of predators in 1936.

In Lake Cumberland there was apparently no paucity of food for largemouth bass in 1951. The results of population studies conducted by the Kentucky Division of Fisheries indicate that there were approximately 20,000 one- to two-inch gizzard shad, *Dorosoma cepedianum* (Le Sueur), per acre present in the Beaver Creek-Otter Creek area of the lake in July of that year. However, these same studies reveal that there were also present more than 1,000 fingerling largemouth bass and Kentucky bass per acre. Although there was apparently no scarcity of available food, interspecific and intraspecific competition for this food and for space must have been great. Additionally, as pointed out by Eschmeyer and Jones (*op. cit.*) for Norris Reservoir, there were few predators to hold in check the size of the 1951 year classes. In 1952, spawning and predation were more in balance and the resultant growth was greater.

From the data available, the rate of growth of the largemouth bass during the first year of life has more or less stabilized since 1953; however, growth compensation is in evidence. At the end of the second year of growth, fish of the 1953 year class were equal in length to those of the 1952 year class and were slightly longer at the end of the following year. Fish of the 1954 year class, although the slowest growing during their first year, were only 0.5 inch smaller than those of the 1952 and 1953 year classes at the end of the second year of growth.

White Crappie

The ages and rates of growth determined for 531 white crappies during the first five years of impoundment are presented in Table III.

Table III. *Calculated total lengths of 531 white crappies*

Year class	Number	Avg. total length at capture	Calculated total lengths in inches		
			I	II	III
1951	333	9.8	3.6	6.9	10.0
1952	89	9.0	2.3	5.0	7.6
1953	47	9.9	2.1	4.6	6.9
1954	38	8.2	2.2	4.5	7.7
1955	24	7.1	2.0		
Totals and Averages	531	9.4	3.1	6.2	9.1

From examination of Table III, it would seem that a discrepancy in analysis, or some other error, had been made in the growth calculations of the 1955 year class, since the average total length at capture of the fish included in this year class is greater than the calculated lengths of age group II in all other year classes. There was, however, no error. The 24 fish included in the 1955 year class were collected in March, 1957, prior to annulus formation. The scale samples used for measurement were excellent. Therefore, it must be assumed that had these same fishes been selected for scale study in June, 1957, the 1957 annulus would have indicated a growth to approximately 7.0 inches at age group II. This growth, occurring during the 1956 growing season is 2.5 inches greater than the growth of the 1954 year class during the 1955 growing season. Further examination of Table III indicates that the growing season of 1956 must have been very favorable. The 1954 year class fish grew 0.9 inch more in length during the 1956 growing season than did the 1953 year class fish during the 1955 growing season. The reasons for these differences in growth are unknown.

Stroud (*op. cit.*), in a study of the growth rates of the white crappie in three TVA reservoirs, found this species to average 1.5 to 2.9 inches at age I, 6.8 to 8.7 inches at age II, and 9.2 to 11.6 inches at the end of the third year of life. He concluded that this growth was rapid. In Kentucky Lake, the most famous crappie fishing lake in Kentucky, E. R. Carter (1953) reported the following rates of growth for the white crappie: age group I - 4.6 inches, II - 7.9 inches, and III - 10.4 inches. Roach and Evans (1948) reported white crappie growth in large lakes in Ohio to range from: I - 1.45 to 6.45 inches, II - 4.20 to 8.27 inches, III - 6.18 to 11.76 inches, IV - 7.77 to 13.61 inches, V - 8.93 to 14.50 inches and VI - 10.00 to 12.38 inches.

The average growth of the white crappie in Lake Cumberland appears to have been similar to that described by Stroud (*op. cit.*) and Roach and Evans (*op. cit.*). However, it was less than that reported by Carter (*op. cit.*). The growth rates of the 1951 year class and quite possibly that of the 1955 year class (see above discussion) may have approached the Kentucky Lake growth rates. Therefore, it may be stated that Lake Cumberland white crappie were growing neither very rapidly nor very slowly but were maintaining what is apparently an average rate of growth.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of each species was determined using the methods and procedures outlined by Beckman (1945). In the logarithmic equation $\log \underline{W} = \log \underline{C} + \underline{N}(\log \underline{L})$, where $\underline{W}$ is the weight in pounds, $\underline{C}$ is a constant, N is a constant and L is the length in inches, the following values can be substituted:

Kentucky bass: $\log W = -3.6157 + 3.2708 \log L$

Largemouth bass: $\log W = -3.6187 + 3.2738 \log L$

White crappie: $\log W = -3.7270 + 3.3462 \log L$

In the arthimetic equation $W = CL^n$ this same relationship can be expressed as:

Kentucky bass: $W = 2.423 \times 10^{-6} L^{3.2708}$

Largemouth bass: $W = 2.406 \times 10^{-6} L^{3.2738}$

White crappie: $W = 1.875 \times 10^{-6} L^{3.3462}$

Figures 4, 5 and 6 are graphical interpretations of the length-weight relationship of 371 Kentucky bass, 577 largemouth bass and 540 white crappies, respectively. The curves were constructed by use of the above logarithmic equations from fish grouped in 0.10-inch length intervals. The points plotted on the graphs represent actual lengths and weights of fish grouped in 0.50-inch intervals.

LENGTH-WEIGHT-AGE DISTRIBUTION

The tables included in this section are designed to show at what age and length each species can be expected to make a substantial contribution to the sport fish catch in Lake Cumberland. Lengths at which each of the species become of desirable size to the angler have been arbitrarily established and are represented by the dotted lines in the tables.

Kentucky Bass

This species reached desirable size at nine inches at which time it was in its third summer of life. Most of the Kentucky bass caught by fishermen were between nine and eleven inches long. Available data

FIGURE-4 LENGTH-WEIGHT RELATIONSHIP OF KENTUCKY BASS

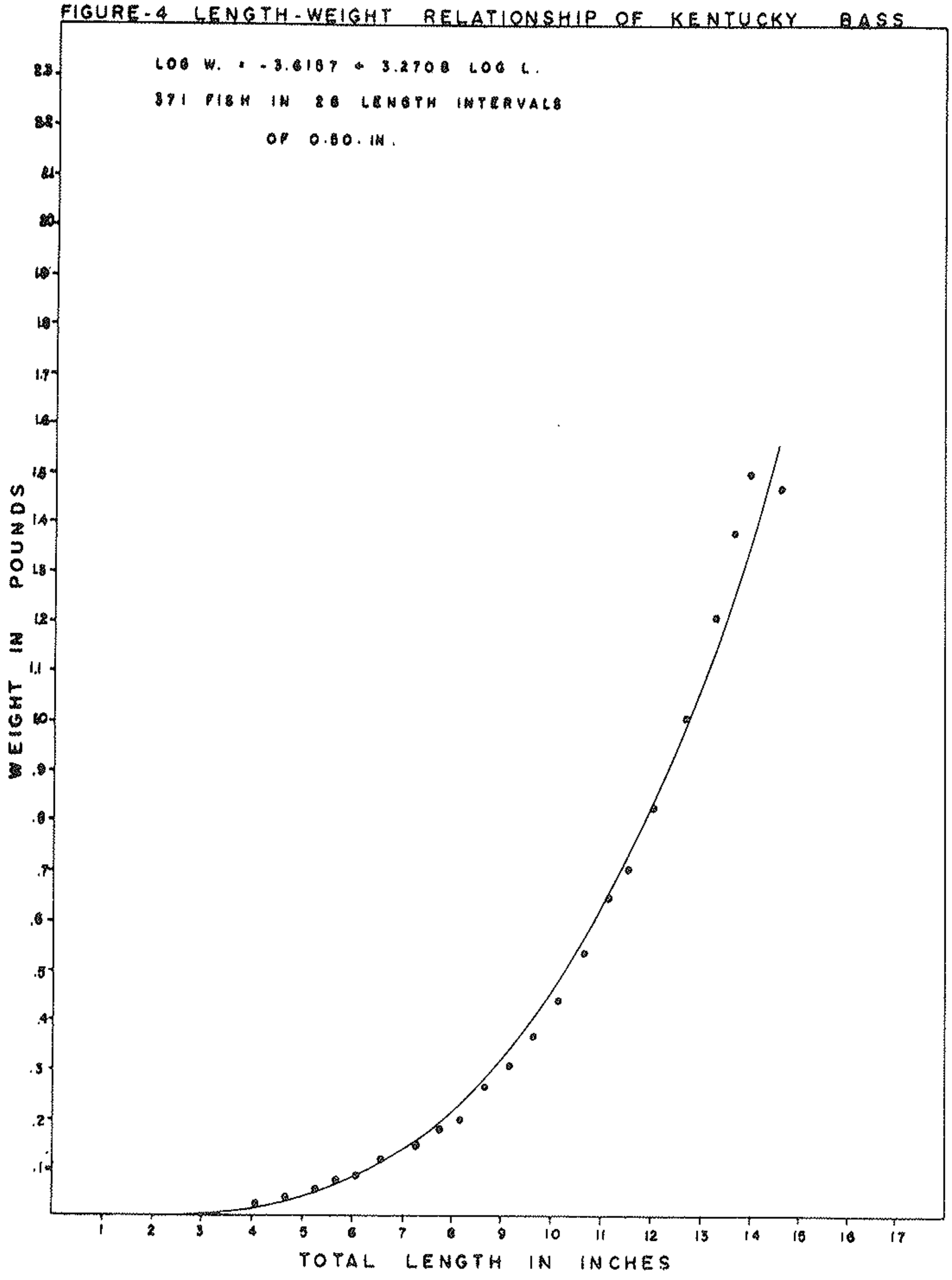


FIGURE - 5 LENGTH-WEIGHT RELATIONSHIP OF LARGEMOUTH BASS

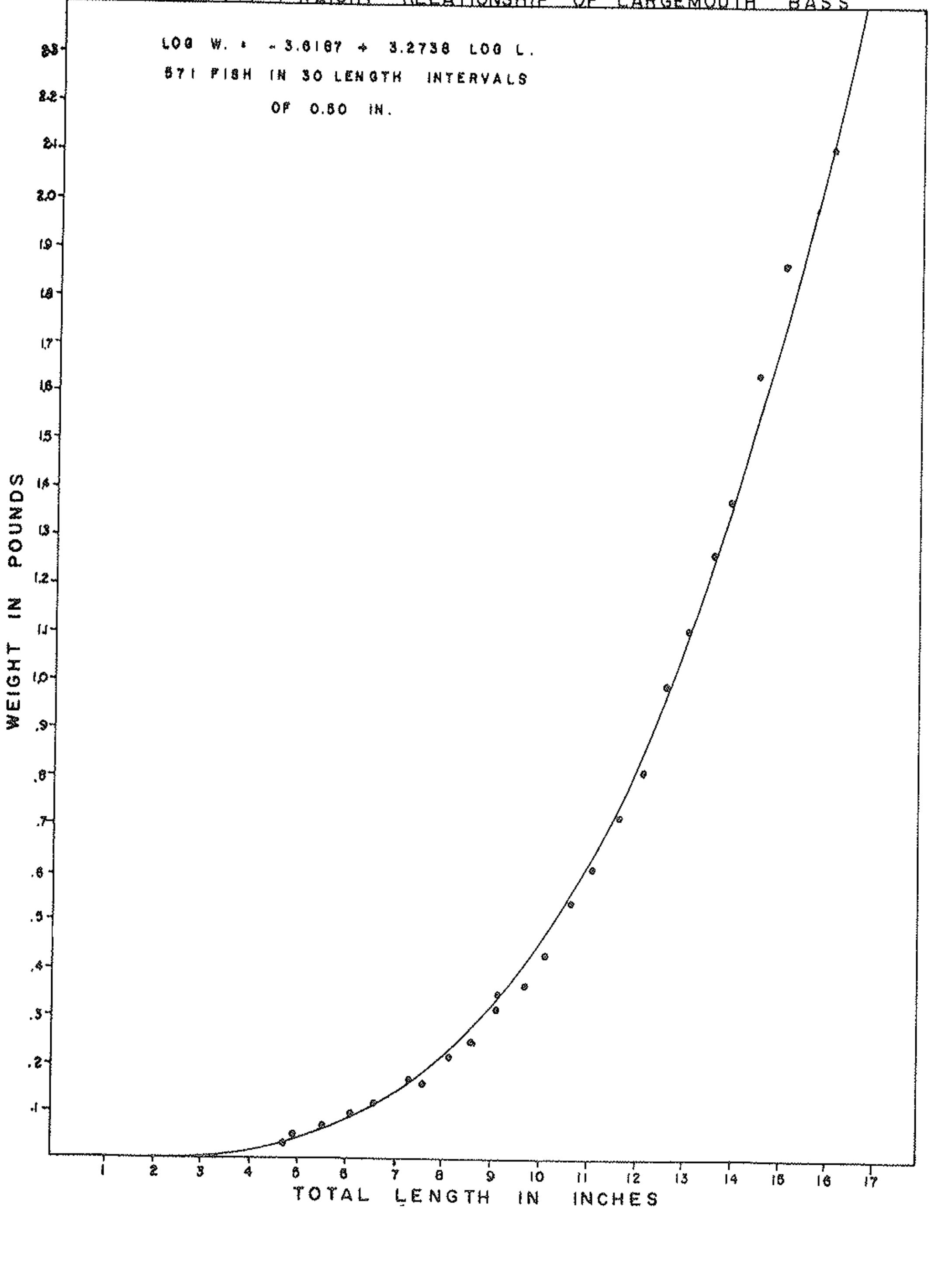
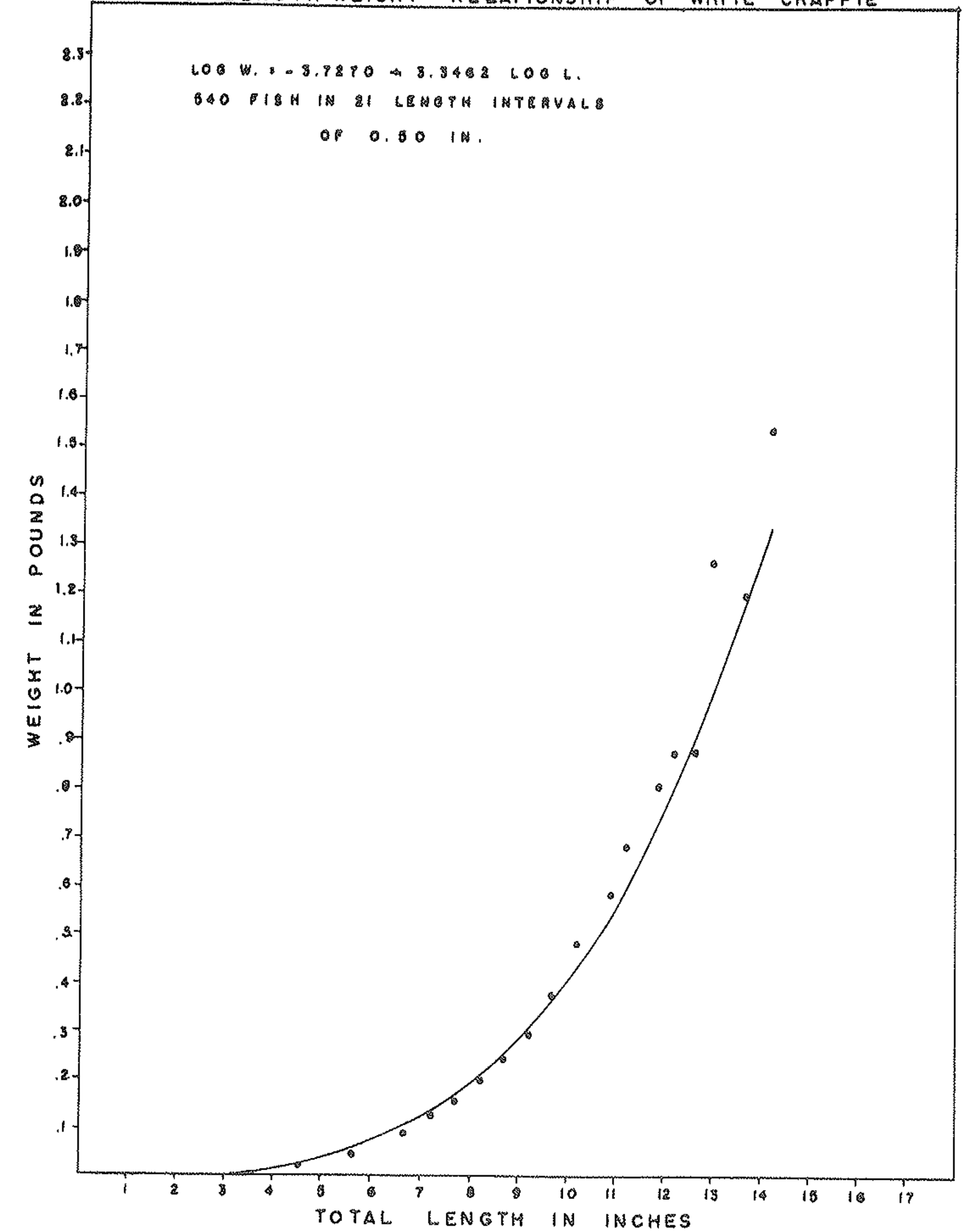


FIGURE-6 LENGTH-WEIGHT RELATIONSHIP OF WHITE CRAPPIE



indicate that very few fish longer than 11 inches entered the fisherman's creel and suggest that the greatest natural mortality to adult fish occurs during the third year of life (Table IV).

Table IV. *Length-weight-age distribution of 290 Kentucky bass caught by fishermen from Lake Cumberland, Kentucky*

No.	% of no.	Lgth. range in inches	Avg. length in inches	Avg. weight in pounds	Year of life
13	4.5	5.0- 5.4	5.3	0.06	1
17	5.9	5.5- 5.9	5.7	0.08	2
9	3.1	6.0- 6.4	6.1	0.08	2
11	3.8	6.5- 6.9	6.6	0.13	2
7	2.4	7.0- 7.4	7.3	0.15	2
9	3.1	7.5- 7.9	7.9	0.18	2
15	5.2	8.0- 8.4	8.2	0.21	2
20	6.9	8.5- 8.9	8.7	0.27	2
Harvestable length					
35	12.1	9.0- 9.4	9.2	0.31	3
41	14.1	9.5- 9.9	9.7	0.37	3
44	15.2	10.0-10.4	10.2	0.44	3
23	7.9	10.5-10.9	10.7	0.54	3
13	4.5	11.0-11.4	11.2	0.65	3
5	1.7	11.5-11.9	11.6	0.70	3
7	2.4	12.0-12.4	12.1	0.83	3
6	2.1	12.5-12.9	12.7	1.09	3
5	1.7	13.0-13.4	13.3	1.22	3 +
4	1.4	13.5-13.9	13.7	1.38	3 +
2	0.7	14.0-14.4	14.0	1.50	3 +
1	0.3	14.5-14.9	14.6	1.47	3 +
2	0.7	15.0-15.4	15.0	2.03	3 +
1	0.3	15.5-15.9	15.5	2.00	3 +
290	100.0				

Thus, Kentucky bass of a specific year class were available to sport fishermen in adequate numbers of desirable sizes during one year of life only.

One of the implications revealed by these data is that should Kentucky bass fail to spawn successfully during any one year, the take of this species would be negligible during the third following year.

Largemouth Bass

Largemouth bass entered the catch at an earlier age than Kentucky bass, were present in larger numbers, remained available to the fisherman in adequate numbers of desirable size for a longer period of time (greatest natural mortality of adults was apparently in their fourth year of life), and definitely grew to a larger total length (Table V).

Table V. *Length-weight-age distribution of 482 largemouth bass caught by fishermen from Lake Cumberland, Kentucky*

No.	% of no.	Lgth. range in inches	Avg. length in inches	Avg. weight in pounds	Year of life
7	1.5	5.0- 5.4	5.1	0.06	1
8	1.7	5.5- 5.9	5.6	0.07	1
9	1.9	6.0- 6.4	6.2	0.10	1
4	0.8	6.5- 6.9	6.7	0.12	1
1	0.2	7.0- 7.4	7.4	0.17	2
7	1.5	7.5- 7.9	7.7	0.17	2
8	1.7	8.0- 8.4	8.1	0.21	2
17	3.5	8.5- 8.9	8.7	0.25	2
Harvestable length					
21	4.4	9.0- 9.4	9.2	0.32	2
54	11.2	9.5- 9.9	9.8	0.37	2
75	15.6	10.0-10.4	10.2	0.43	2
59	12.2	10.5-10.9	10.7	0.55	3
42	8.7	11.0-11.4	11.2	0.61	3
25	5.2	11.5-11.9	11.7	0.72	3
31	6.4	12.0-12.4	12.2	0.81	3
30	6.2	12.5-12.9	12.7	1.00	3
30	6.2	13.0-13.4	13.1	1.12	3
16	3.3	13.5-13.9	13.7	1.27	3
16	3.3	14.0-14.4	14.2	1.38	3
4	0.8	14.5-14.9	14.6	1.65	4
5	1.0	15.0-15.4	15.1	1.87	4
0		15.5-15.9			
2	0.4	16.0-16.4	16.2	2.13	4
3	0.6	16.5-16.9	16.7	2.52	4
1	0.2	17.0-17.4	17.2	2.97	4
1	0.2	17.5-17.9	17.5	2.47	4
1	0.2	18.0-18.4	18.1	3.33	4
2	0.4	18.5-18.9	18.6	3.16	4
2	0.4	19.0-19.4	19.2	4.30	4 +
0		19.5-19.9			
1	0.2	20.0-20.4	20.2	6.25	4 +
482	99.99				

It appears that this species was better suited to the particular environment of Lake Cumberland than was the Kentucky bass. Of the total 482 largemouth bass in the sample, 72 per cent were above the former legal length limit of 10 inches as compared to 39 per cent of the sample of Kentucky bass. Eighty-seven per cent of the largemouth bass were desirable size or larger; only 66 per cent of the Kentucky bass caught were large enough to be considered desirable.

White Crappie

This species did not reach desirable size until the third year of life. As most of the larger white crappie in the sample were caught in the early spring prior to annulus formation, those fish were for all practical purposes beginning their fourth and fifth years of life. Eleven inches was designated as an arbitrary length at which this species could be placed in the next highest year of life (Table VI).

Although white crappie grew more slowly in length than did either of the basses, they made a substantial contribution to the sport fisherman's catch. They entered the catch in desirable sizes during their third year of life and were available to the fisherman in adequate numbers for at least two years.

DISCUSSION

This study of the growth characteristics of the largemouth bass, Kentucky bass, and white crappie in Lake Cumberland disclosed a general decline in rate of growth following the first years of impoundment. The growth of Kentucky bass during its first year of life declined from a high of 6.0 inches during 1951 to a low of 3.5 inches in 1955. The growth of largemouth bass during its first year of life declined from a

Table VI. *Length-weight-age distribution of 530 white crappies caught by fishermen from Lake Cumberland, Kentucky*

No.	% of no.	Lgth. range in inches	Avg. length in inches	Avg. weight in pounds	Year of life
3	0.6	5.5- 5.9	5.6	0.05	2
3	0.6	6.0- 6.4	6.3	0.09	2
21	4.0	6.5- 6.9	6.7	0.09	2
27	5.1	7.0- 7.4	7.2	0.13	3
42	7.9	7.5- 7.9	7.7	0.16	3
----------	----------	----------*Harvestable*	*length*----------	----------	----------
32	6.0	8.0- 8.4	8.2	0.20	3
60	11.3	8.5- 8.9	8.7	0.25	3
75	14.2	9.0- 9.4	9.2	0.30	3
63	11.9	9.5- 9.9	9.7	0.38	4
77	14.5	10.0-10.4	10.2	0.49	4
54	10.2	10.5-10.9	10.9	0.59	4
40	7.5	11.0-11.4	11.2	0.69	4 +
18	3.4	11.5-11.9	11.7	0.81	4 +
8	1.5	12.0-12.4	12.2	0.88	4 +
3	0.6	12.5-12.9	12.7	0.88	4 +
1	0.2	13.0-13.4	13.0	1.27	4 +
2	0.4	13.5-13.9	13.7	1.20	4 +
1	0.2	14.0-14.4	14.2	1.54	4 +
530	100.1				

high of 7.2 inches in 1952 to a low of 5.4 inches in 1954. Young-of-the-year white crappie grew to a length of 3.6 inches during the 1951 growing season but grew only 2.0 inches during the 1955 growing season.

The data presented by Stroud (*op. cit.*) in his study of the growth rates of the basses and black crappie, *Pomoxis nigromaculatus* (Le Sueur), in Norris Reservoir, Tennessee, indicated a slight reduction of growth during the first four to six years after impoundment, after which growth tends to increase. In Norris Reservoir, young-of-the-year largemouth bass grew faster in 1942 (the seventh year) than in any previous year, and young-of-the-year Kentucky bass grew at a faster rate during 1943 than any other year of the ten-year period studied.

The data available in the present study indicate that this same phenomenon may occur in Lake Cumberland. The growth of young-of-the-year largemouth bass increased slightly in 1955. From an examination of the data presented in Table III, it appears that white crappie grew exceptionally well in 1956, and it is quite possible that the 1956 year class of this species made better growth than did the 1955 fish. There were no indications of increased growth in Kentucky bass.

Accurate predictions of the growth of fishes in large artificial impoundments are prevented by numerous uncontrollable variable factors. Drastic water fluctuations during the game-fish spawning season can practically eliminate a specific year class. As pointed out earlier, this would greatly reduce the Kentucky bass fishery three years later. Drawdown of water levels during spawning can and does sometime reduce the available forage supply. High turbidity and extreme temperature changes can cause heavy losses of eggs and fry. Exceptionally successful spawning and fry survival can create overcrowded conditions resulting in a high degree of interspecific and intraspecific competition for food and space. The physical condition of the adult fishes at the inception of spawning will, in some measure, determine the spawning success.

All of the above factors and many others, such as, disease, parasitism and water quality, determine the growth rates of fishes.

SUMMARY

1. A total of 1,496 fishes were used in this study and included: 379 Kentucky bass, 318 of which were caught by fishermen and 62 collected during a rotenone population study; 577 largemouth bass, 482 caught by fishermen and 95 collected with rotenone; and 540 white crappies,

530 caught by fishermen and 10 collected with rotenone. The scale samples and body measurements of these fishes were used to determine rates of growth during the first five years of impoundment, body-scale relationship, the pattern of early scalation and the length at which scalation is completed, length-weight relationships, and the length-weight-age distribution of the fisherman's catch.

2. All species were found to be growing at a satisfactory rate, but were not growing at an exceptionally rapid rate. Using the equation $L_x = a + \frac{S_x}{S_t}(L-a)$ the species were found to have the following average lengths at various ages: (i) Kentucky bass, I - 5.3 inches, II - 8.8 inches; (ii) largemouth bass, I - 6.7 inches, II - 10.4 inches, III - 14.1 inches, IV - 18.5 inches; (iii) white crappie, I - 3.1 inches, II - 6.2 inches, III - 9.1 inches. Older and larger Kentucky bass were collected but could not be correctly aged because of the poor quality of scale samples. Older and larger white crappie were collected but the fourth annulus had not been formed.

3. The equation used to express body-scale relationship is: $L = a + bS$.

   Kentucky bass: $L = 0.92 + 1.56S$

   Largemouth bass: $L = 1.20 + 1.55S$

   White crappie: $L = 1.45 + 1.55S$

4. The early history of initial scalation was determined for largemouth bass and white crappie and can be described as follows:

   Largemouth bass: Scales were formed prior to the time this species reached a length of 0.94 inch, but complete scalation did not occur until the fish had reached a length of 1.40 inches. The pattern of scalation was: first, the caudal region was scaled, scales then formed along the lateral line, and soon afterwards, the sides and dorsal region were scaled. The ventral region anterior to the anal fin was the last area to become completely scaled.

White crappie: Scales were first formed prior to the time the fish reached a length of 1.32 inches, but complete scalation did not occur until the fish had reached a length of 1.77 inches. The pattern of scalation was: scales first formed on the dorsal midline in one row extending between the posterior base of the soft dorsal fin to the caudal fin. The same pattern was later repeated between the posterior base of the anal fin and the caudal fin. Scale formation was then extended anteriorly in the dorsal and ventral regions. The sides of the fish were the last portion of the body to be scaled.

5. Body-scale relationship for each species is expressed by the equations: $\underline{W} = \underline{C}\underline{L}^n$ and $\log \underline{W} = \log \underline{C} + \underline{N}(\log \underline{L})$.

Kentucky bass: $\underline{W} = 2.423 \times 10^{-6}\underline{L}^{3.2708}$

$\log \underline{W} = -3.6157 + 3.2708 \log \underline{L}$

Largemouth bass: $\underline{W} = 2.406 \times 10^{-6}\underline{L}^{3.2738}$

$\log \underline{W} = -3.6187 + 3.2738 \log \underline{L}$

White crappie: $\underline{W} = 1.875 \times 10^{-6}\underline{L}^{3.3462}$

$\log \underline{W} = -3.7270 + 3.3462 \log \underline{L}$

6. In studying the length-weight-age distribution of the catch, it was found that largemouth bass reached a desirable size one year earlier in life (the second) than did either the Kentucky bass or white crappie. It was also found that Kentucky bass were available in adequate numbers of desirable sizes during only one year of life while largemouth bass and white crappie are available for two or more years.

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