STUDIES OF THE AGE, GROWTH, AND FOOD OF KNOWN-AGE, YOUNG-OF-YEAR BLACK CRAPPIE AND OF STUNTED AND FAST-GROWING BLACK AND WHITE CRAPPIES OF SOME OKLAHOMA LAKES

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1948

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Submitted to the faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
August, 1956

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ACKNOWLEDGEMENTS

The writer is indebted to Mr. V. C. Graham, Holdenville State Fish Hatchery Superintendent, for the collection of fish from a population of known-age black crappie and to Dr. Frank Bernard Cross, Dr. D. Homer Buck, Mr. T. K. Chamberlain and the employees of the Corps of Engineers at the Canton Reservoir Project for their assistance in the collection of fishes from Canton and Fort Supply reservoirs. The Oklahoma Game and Fish Department permitted the writer to collect specimens and data for the study while employed by the Fisheries Division to investigate fish populations in 1950. Appreciation is expressed to the following personnel who were engaged in fisheries work for the Oklahoma Game and Fish Department: Mr. H. C. Ward, Mr. William H. Thompson, Dr. Howard Clemens, Mr. James McArthur, Mr. Gordon Hall, Mr. Mayo Martin, and Mr. Kermit Sneed. The writer is indebted also to Drs. Charles H. Brett and J. R. Dogger, formerly with the Entomology Department, Oklahoma A. and M. College for their help in the identification of food items. The Zoology Department of Oklahoma A. and M. College and the Oklahoma Cooperative Wildlife Research Unit provided financial support and equipment. Grateful appreciation is expressed to Dr. W. H. Irwin, the writer's advisor, for guidance and assistance.

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INTRODUCTION

This is a report of studies intended to reveal the scale and body growth relationships and the food of young-of-year black crappie, and to resolve the differences between the populations of fast-growing crappies of new lakes and the populations of stunted crappies of older lakes.

The trend of fishing success in man-made impoundments of the Southwest reaches a climax in the early years of the life of the lake (Irwin, 1948). This highly productive climax is usually followed by a decline in fishing success. Most lakes tend to be free of soil turbidity during the first few years and then gradually develop into muddy-water impoundments. These trends in turbidity and fishing success seem to be associated, yet fishing success also declines for some bodies of clear water. Leonard (1951) and Martin (1952) both reported upon clear lakes which were unproductive and contained slow-growing game fishes.

Most of the older lakes are commonly said to be "over-populated" with stunted fishes, one of which usually is the white crappie, Pomoxis annularis Rafinesque, or the black crappie, Pomoxis nigromaculatus (LeSueur). Many factors may contribute directly or indirectly to stunting; however, the scope of this study is confined to the theory that both the amount and kind of food may be causal factors.

The age, growth, and food of black and of white crappies of two relatively new lakes were studied. The crappies of the new lakes had made relatively rapid growth and their large populations consisted of only a few age groups. Similar studies were made of the crappie

populations of older lakes and ponds, 13 to 25 years old, all of which contained stunted crappies. The crappie populations of the older lakes and ponds contained many small fishes and few "keeper size" fishes.

Results of the studies showed: that body-scale relationships for the white crappie may be curvilinear if stunting is prevalent; that proportionally faster growth of scales than of fish length, low coefficients of condition, and a resistance to shrinkage from fixation were characteristics of stunted white crappie; and that the faster-growing crappies contained larger volumes of fish items as food, mostly Dorosoma cepedianum (LeSueur) and minnows, whereas the slower-growing crappies contained mostly centrachid fish-items.

Studies of young-of-year black crappie were made from a series of fry which were $2\frac{1}{2}$ to $13\frac{1}{2}$ weeks of age. Results of the studies showed: that scales developed as tiny platelets in the "key-scale area" when the fish were about 24 mm. in length; that the body-scale relationship was approximately linear (intercept 19.9 mm.); and that the fry were carnivorous and fed almost entirely upon zooplankton and insect larvae.

METHODS

Wire traps, hoop and gill nets, and rotenone were used to collect the fishes from the six impoundments sampled. A dip net was used to collect the known-age black crappie. The wire traps (Buck and Cross, 1951) with one-inch mesh chicken wire netting, were used extensively in Lake Carl Blackwell and Boomer Lake. The traps although bulky to transport relieved the need for extra help, reduced the possibility of wet clothing, and lessened the time required to check the catches. Wire traps and hoop and gill nets were used to collect specimens from Fort Supply and Canton reservoirs. Rotenone was used in the Lexington Gunnery Range Pond and Fisher's Pond.

The fishes collected by means of hoop nets, wire traps, and gill nets may have been held captive for as long as 24 hours before examination. Fishes collected by the use of rotenone were taken while they were dying or shortly after death. Cognizance was given to the fact that fish collected by the use of rotenone may have contained food which they were induced to eat because of the effect of the rotenone (Krumholz, 1950).

Length and Weight

The total lengths of the fish were measured to the nearest millimeter. The total length used was that length from the most anterior point of the fish, mouth closed, to the most posterior tip, tail lobes compressed. All fishes were weighed to the nearest one hundredth of a pound except the known-age black crappie and the crappies

collected from the two ponds. The known-age black crappie were weighed on a chainomatic balance to the nearest milligram after they had been fixed in 10 percent formalin, washed in water, and stored in 65 percent alcohol. No attempt was made to correct for length or weight changes due to the preservatives. Secondly, the fishes takes from the two ponds were weighed to the nearest gram and the weights converted to the nearest hundredth of a pound.

When the first collections were made from Boomer Lake it was believed that because of the time limitations it might be necessary to preserve the fish before they could be weighed or measured. It was suggested that changes in the lengths and weights would be caused by fixation. To offset these errors, correction factors for length and weight changes were derived for a series of white crappie from Boomer Lake which were fixed in 10 percent formalin. Each fish was weighed to the nearest tenth of a gram, measured to the nearest millimeter, tagged, and preserved in 10 percent formalin. The fish were remeasured and re-weighed after 10 days and were found to be shorter and heavier after fixation than before. Significant changes in the measurements or weights of the fish did not occur after the initial 10-day period of preservation. The changes were not consistently proportional to the live measurements and varied with length groups. Individual conversion figures were derived by dividing the weight and length of each preserved fish into the respective weight and length determined before preservation. The individual conversion figures were grouped and averaged to obtain the factors presented in Appendix A. The storage of fish in formalin was not found to be necessary. The data proved to be valuable because a comparison of the conversion factors with the age, growth, and coefficients of condition showed that the more severely the fish were stunted, the less they

shrank in length.

The plumpness or coefficient of condition of the fishes was determined by the use of a modification of the formula for a cubical parabola, $W = CL^3$. The modified formula which was used is the one which is in customary use, $C = \frac{W\ 10^5}{L^3}$. The coefficient of condition, C, is found by solving the equation when W is weight in pounds and L is length in inches.

The length-weight relationships were determined by use of the equation for the general parabola, $W = CL^n$, expressed in logarithmic form, $\log W = \log C + n \log L$. Values of log C and n were computed from the following formulas which are simply solutions of normal equations:

$$\log C = \frac{\Sigma \log W \cdot \Sigma \log L^2 - \Sigma \log L\ (\Sigma \log L \log W)}{N \cdot \Sigma \log L^2 - (\Sigma \log L)^2}$$

$$n = \frac{\Sigma \log W - N \cdot \log C}{\Sigma \log L}$$

(Beckman, 1948).

Age and Growth

Scales were taken from an area on the left side of the fish below the lateral line under the origin of the dorsal fin. Scales from each fish were placed in a scale envelope, bearing all pertinent data.

Age and growth determinations were made by use of a scale reader similar to that described by Van Oosten, Deason, and Jobes (1934). The scales were measured in millimeters along the anterior radii from the foci to each annulus and to the edge of the scale. The measurements were made for three scales of each fish and were averaged. The point of measure at each annulus was the first complete circulus anterior to the incomplete circuli. Regenerated scales were not measured.

The scales of the known-age black crappie were measured in a similar manner. Key scales or scales located in the immediate vicinity of the key scales were used. "Key scales" refer to the three scales in the second row below the 15th, 16th, and 17th lateral-line scales. The scales or sections of skin from the fish were mounted in water for study and measurements.

Individual measurements of the anterior radii (scale length) were plotted against the total fish length (body length) for the fish of each lake. Except as indicated differently, the calculations of the growth rates were made by means of direct-proportion nomographs using the appropriate intercept values of the relationships of body length to scale length as points of origins. Individual fish lengths and scale lengths were used in the calculations of regressions in preference to the mean values of grouped fish.

Food

The stomachs were removed from the fish as soon as the collections were made, wrapped separately in cheese cloth, numbered individually for identification, and placed in 10 percent formalin.

The fixed viscera were washed in water to rid them of excess quantities of formalin before beginning the analyses of the stomach contents. The contents were removed from the stomach and drained of excess liquid. The volumes of food were determined by a method similar to that used by Ball (1948). The food from each stomach was placed in a graduated centrifuge tube from which readings in hundredths of a cubic centimeter could be made. A known amount of water was added to the tube submerging the food. The volume of the food was determined by subtract-

ing the volume of the water from the volume which represented both the water and the food.

The items of food from each stomach were sorted into different taxonomic groups, were counted, and when practicable, the volumes were determined. The total lengths of fishes found as food items were measured for whole fishes and estimated for partly-digested remains.

The stomach contents of each known-age black crappie were removed and weighed immediately on a chainomatic balance to the nearest tenth of a milligram. The organisms from each stomach were counted; however, when large numbers were present the numbers were estimated.

KNOWN-AGE, YOUNG-OF-YEAR BLACK CRAPPIE

The young-of-year black crappie studied were reared at the Holdenville State Fish Hatchery from a spawn which hatched the last week in April 1949. When the spawn hatched, it was removed to a pond which contained no other fish. Approximately 10 specimens were collected by means of dip nets and preserved on the same day of each week from May 14 through August 30, 1949. The fish were fixed in 10 percent formalin, washed in water, and preserved in 70 percent isopropnol.

A total of 120 fish varying in age from $2\frac{1}{2}$ to $13\frac{1}{2}$ weeks was studied. In order to simplify presentation of the data one-half week was dropped from the age of all specimens.

Age and Growth

Measurements of the specimens showed that with an increase in age the variations in lengths and weights increased considerably (Table 1).

The length-weight relationship was determined for 117 of the specimens. The relationship was found to be expressed by the formula, $\text{Log } W = -3.6068 + 3.3514 \text{ Log } L$, in which W (weight) is in hundred thousandths of a pound and L (total length) is in thousandths of an inch (Figure 1). Measurements were made in metric units and converted to thousandths of inches and hundred thousandths of pounds for calculation purposes.

The coefficient of condition, C, was determined for the different age and length groups using the formula $C = \frac{W\ 10^5}{L^3}$ where W was weight in ten thousandths of a pound and L was length in thousandths of an inch.

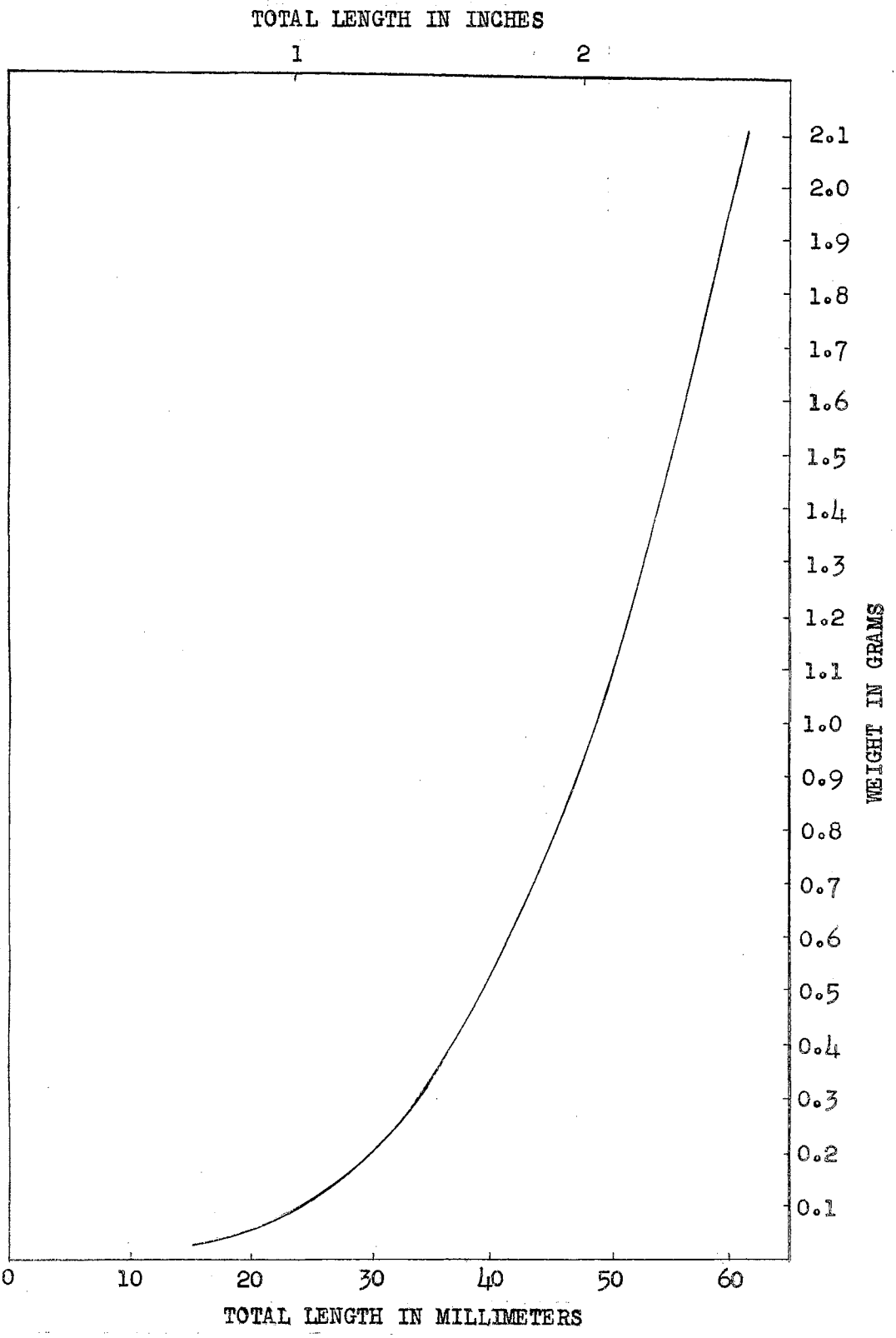

FIGURE 1. Length-Weight Relationship of Young-of-Year Black Crappie, Holdenville State Fish Hatchery, Hughes County, Oklahoma. May 14 to August 20, 1949. Individual Computation.

TABLE 1. Total Lengths and Weights of 120 Young-of-Year Black Crappie by Age Groups, Holdenville State Fish Hatchery, Hughes County, Oklahoma. May 14 to August 20, 1949.

Age in Weeks	Number of Fish	Length in Millimeters Mean	Range	Weight in Milligrams Mean	Range
2	11	18.4	16 - 20	35.8	25 - 46
3	10	22.6	20 - 24	73.1*	56 - 92*
4	10	27.0	24 - 30	135.7	100 - 200
5	10	32.2	29 - 38	284.2	190 - 450
6	9	33.2	30 - 38	324.2	227 - 465
7	10	36.9	34 - 40	406.3	316 - 546
8	10	41.7	39 - 45	611.3	510 - 741
9	10	42.3	39 - 46	610.5	481 - 752
10	10	43.8	41 - 47	719.6	591 - 986
11	10	44.9	40 - 50	769.7	506 - 1110
12	10	46.2	41 - 50	829.3	577 - 1052
13	10	49.9	45 - 57	1024.2	658 - 1480

*Based on nine specimens.

The results show that the coefficient of condition increased until the fish were about six weeks old or 1.4 inches in length. Fish older than six weeks or longer than 1.4 inches did not differ distinctly in plumpness (Tables 2 and 3).

Neither scales nor indications of their development were found on the two-week-old fish, which ranged in length from 16 to 20 mm.

Scales were present on the posterior body region of five of the 10 three-week-old fish. Three specimens, 24, 24, and 24.5 mm. in length, had scales in the key-scale area. The scales had only one or two circuli. The seven fish which did not have scales in the key-scale area ranged from 21 to 23 mm. in length.

The three-week-old fish with the fewest scales had two adjoining rows of six scales each and a single scale immediately above the upper row. The patch of 13 scales was immediately anterior to the caudal peduncle with the dorsal row of six scales on the lateral line. Another specimen, in which the pattern of scales appeared indicative of scale

TABLE 2. Mean Lengths, Mean Weights, and Coefficients of Condition of Young-of-Year Black Crappie by Length Groups, Holdenville State Fish Hatchery, Hughes County, Oklahoma. May 14 to August 20, 1949.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Millionths of a Pound	Coefficient of Condition C
0.6 - 0.79	11	0.727	79	20.6
0.8 - 0.99	11	0.898	172	23.8
1.0 - 1.19	12	1.119	371	26.5
1.2 - 1.39	12	1.266	631	31.1
1.4 - 1.59	20	1.500	1,007	29.8
1.6 - 1.79	30	1.702	1,467	29.8
1.8 - 1.99	19	1.885	2,022	30.2
2.2	2	2.225	3,200	29.1

TABLE 3. Mean Lengths, Mean Weights, and Coefficients of Condition of Young-of-Year Black Crappie by Age Groups, Holdenville State Fish Hatchery, Hughes County, Oklahoma. May 14 to August 20, 1949.

Age in Weeks	Number of Fish	Mean Length in Inches	Mean Weight in Millionths of a Pound	Coefficient of Condition C
2	11	0.727	79	20.6
3	9	0.888	161	23.0
4	10	1.063	299	24.9
5	10	1.268	626	30.7
6	9	1.308	714	31.9
7	10	1.453	895	29.2
8	9	1.649	1,346	30.0
9	10	1.665	1,345	29.1
10	10	1.724	1,585	30.9
11	10	1.768	1,695	30.7
12	10	1.819	1,827	30.4
13	9	1.960	2,244	29.8

development, had scales in the following places.

1. The lateral-line row of scales was complete.
2. Scales in the first row above the lateral line extended from the caudal peduncle to a point about midway between the anterior and posterior ends of the dorsal fin.

3. Scales in the first row below the lateral line extended from the caudal peduncle to a point immediately posterior to the origin of the dorsal fin.

4. Scales in the second row below the lateral line were in two places, in the tail region anterior to the caudal peduncle and in the body region posterior to the origin of the dorsal fin.

Examination of the skins showed small, opaque spots or discs in unscaled areas where scales would be expected to develop. Figure 2 illustrates the opaque discs along the lateral line and the more developed scales below. Scale development was not apparent on the anterior half of the body above the lateral line of the fish illustrated in Figure 2. Development of the lateral-line scales of this specimen differed from that of the other specimens. The inner circuli of the scales shown in Figure 2 were sharp and distinct under magnification, whereas the outermost edges of the scales were broad and refracted light similar to an opaque object.

The body-scale relationship was determined because growth calculations are based upon this relationship. A linear relationship was assumed and the resulting linear regression was $Y = 19.9 + 0.803\ X$, in which Y is fish length and X is the anterior scale radius. In the determinations, the anterior radii of three scales were measured and the mean was plotted against the total fish length. Figure 3 shows the plotted points and the calculated line of linear regression.

Food

A consistent difference in the amount of stomach contents was found between the fish of 2 and 5 weeks of age and the fish of 6 to 13 weeks

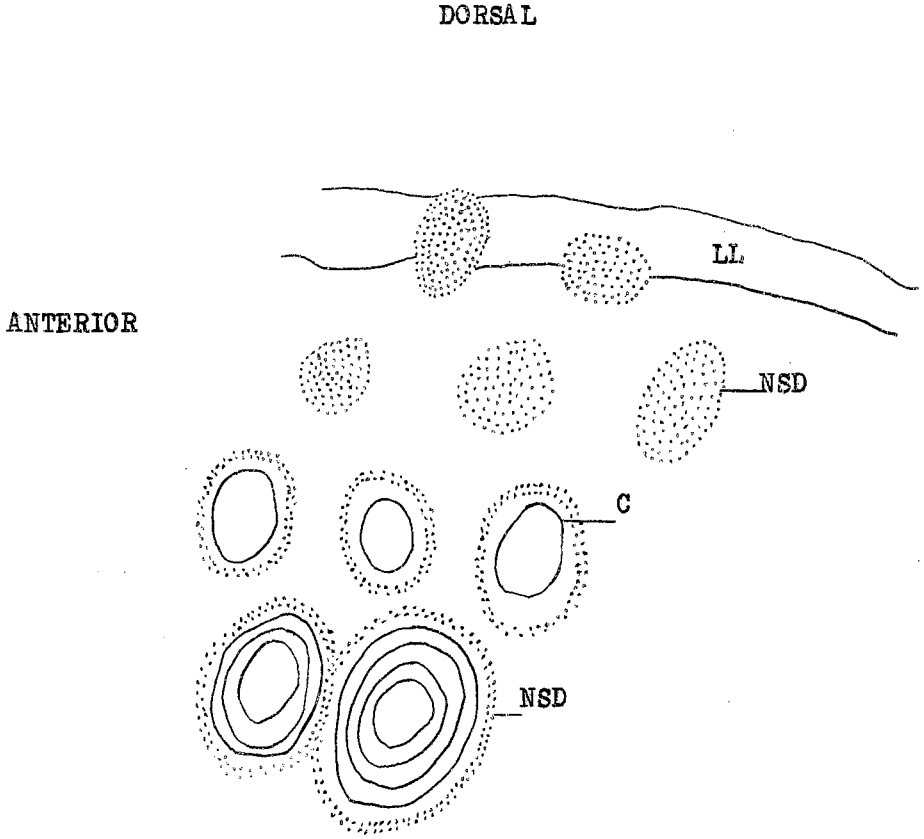

FIGURE 2. Scale Development in the Key-Scale Area of a Three-Week-Old Black Crappie, 24.5 Millimeters in Total Length and 92 Milligrams in Weight. Holdenville State Fish Hatchery, Hughes County, Oklahoma, May 21, 1949. LL, Lateral Line; NSD, New Scale Development; C, Circulus. Magnification 75 X.

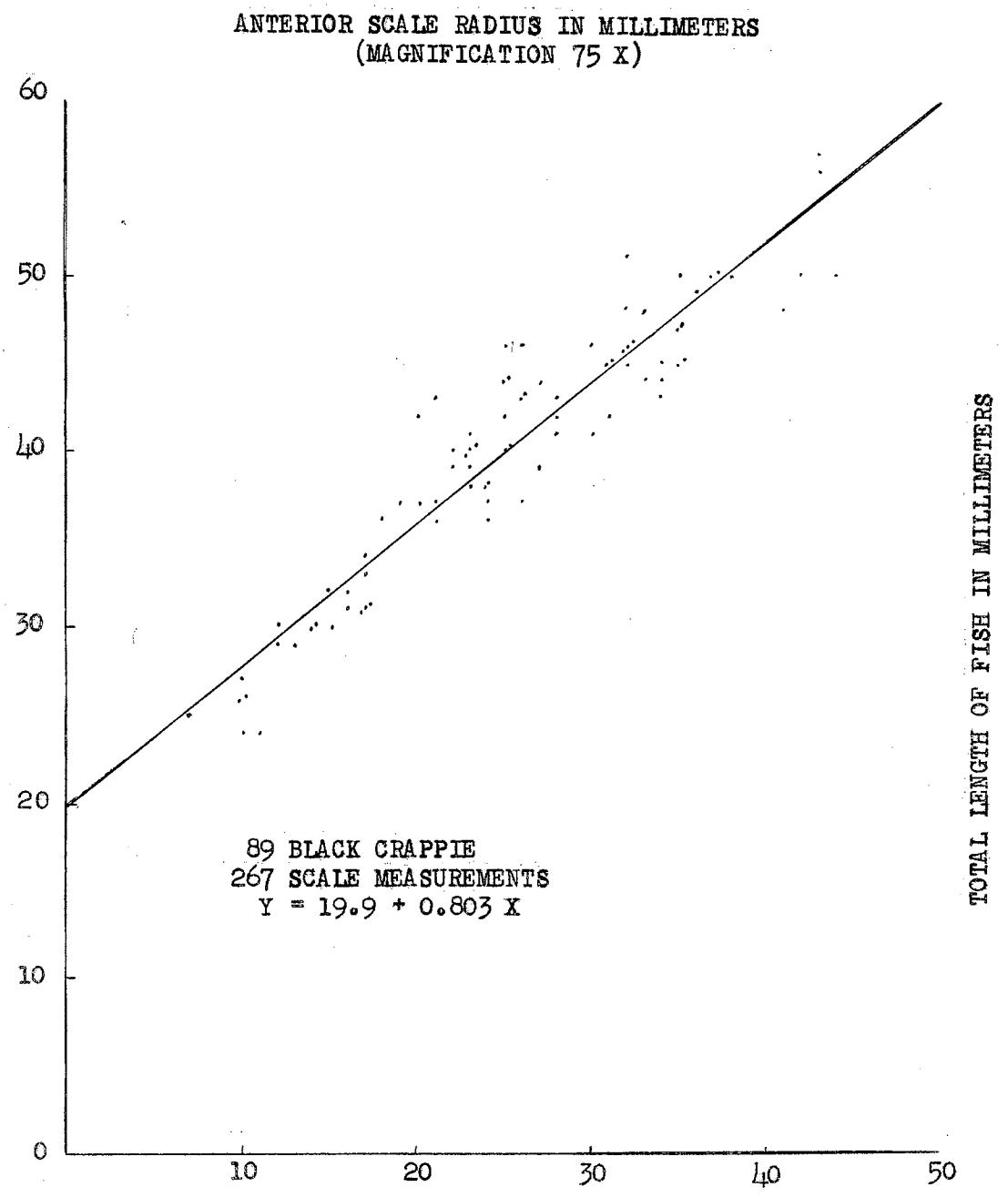

FIGURE 3. Body-Scale Relationship of Known-Age Black Crappie, Holdenville State Fish Hatchery, Hughes County, Oklahoma. May 14 to August 20, 1949. Individual Computation.

of age (Appendix B). The fish of six weeks of age fed on large numbers of larval insects which may suggest an increased supply. The high volumes for the older fish were caused by large numbers of crustaceans and large larval insects. The coefficients of condition stopped increasing when the fish reached an age of six weeks although their stomachs contained large volumes of food (Table 3 and Appendix B).

Only one stomach of the 118 fish was empty. This suggested that the fish were frequent feeders, at least in daylight hours. The varying amounts of food found in the stomachs may suggest that the individual fish fed sporadically or that some individuals were more successful than others. Variations in both body functions and feeding success may explain the variable sizes of fish of the same age.

Although the availability of food was not determined, the wide variety of organisms found in the stomachs suggests that good populations of zooplankton and bottom fauna were present and that the fish were opportunistic feeders (Appendix C). One larval fish was found in the stomach of a two-week-old fish and no other indication of cannibalism was found.

POPULATIONS COMPRISED MAINLY OF FAST-GROWING CRAPPIES

The samples of fast-growing crappies were taken from Fort Supply and Canton reservoirs. Both reservoirs were constructed by the Corps of Engineers, U. S. Army, for flood-control and water conservation purposes.

The first water was impounded in Fort Supply Reservoir, Wolf Creek, Woodward County, in 1940. The 1800 surface-acre lake was partially drained during the summer of 1947. A luxuriant growth of vegetation was established on the exposed basin before the second inundation in 1948. Fishes taken from the Fort Supply Reservoir were caught during August 26, 1949 to July 27, 1950 after the second inundation.

Storage of water in Canton Reservoir on the North Canadian River, Blaine and Dewey counties, began in April 1948. By July 1948, the surface area of water was about 3350 surface acres. The water area remained relatively constant until February 1949. Considerable fluctuation of the water level occurred between February and July 1949 and the maximum surface acreage during that time was about 8000 acres on May 30, 1949. The reservoir had a water area of about 5000 surface acres from August 1949 to July 1950. A rise in July and August, 1950, increased the area to about 11,000 acres. Two and one-half months were required after this rise to reduce the lake to an area of about 5000 surface acres. Fishes taken from Canton Reservoir were caught mostly in the fall and winter between August 23, 1949 and October 8, 1950.

The fishes were taken by means of hoop nets, wire traps, and gill nets. Both lakes were found to contain large numbers of crappies in excellent condition. The crappie fishing in Fort Supply Reservoir was

good although not as fully exploited as at Canton Reservoir where winter fishing was phenomenal because of crappie concentrations in one cove (Buck and Cross, 1951).

Age and Growth of White Crappie from Fort Supply Reservoir

Large numbers of 8.0- to 9.9-inch white crappie were taken from Fort Supply Reservoir in 1949; however, only 39 were retained for study. The 39 white crappie were in their second year of life (age-group one) and were calculated to have averaged 3.5 inches long at the end of their first year. Only one specimen of another size group was taken. It was a 12.7-inch white crappie which was in its third year of life (age-group two) and was calculated to have been 5.9 inches long at the end of its first year and 9.8 inches long at the end of its second year.

Five white crappie, age-group one, were caught by hook and line from the stilling basin in 1949. They averaged 6.2 inches in length and 0.11 pound in weight and had an average coefficient of condition of 46.1. These average measurements were substantially lower than average measurements for fish of the same age from the reservoir, although their average calculated total-lengths for the first year of life were the same.

The white crappie collected during 1950 were mostly 6.4 to 8.7 inches in length. Of these, 10 males and 18 females which averaged 7.7 inches in length and 0.25 pound in weight were of age-group one and were calculated to have had a mean length of 3.9 inches at the end of their first year of life. Seven males and 10 females which averaged 7.5 inches in length and 0.25 pound in weight were of age-

group two and were calculated to have had mean lengths of 3.9 inches at the end of their first year and 5.1 inches at the end of their second year. One fish of 6.8 inches in length had only one annulus on most of its scales; however, a second annulus was found near the edge of some of its scales.

Five large females of 10.1 to 11.2 inches in length were collected in 1950 which also represented age-groups one and two. Of these, one 11.1-inch specimen had only one annulus on its scales and was calculated to have had a length of 4.0 inches at the end of its first year. The other four, mean length of 10.6 inches, were of age-group two and were calculated to have had mean lengths of 3.8 inches at the end of their first year and 9.8 inches at the end of their second year. The age and growth determinations may suggest that some of the fish had not formed annuli during 1950 or that considerable variation existed in the rates of growth. It is also possible that storage of flood waters in the reservoir prior to the collection, or some other factor, may have caused some of the fish to form a second annulus during 1950.

The body-scale relationship for the white crappie taken during 1949 was quite similar to the relationship for crappie collected during 1950 (Figure 4). The coefficients of condition for the fish collected in 1949 and in 1950 were not significantly different and the data were combined for presentation (Table 4).

Age and Growth of Black Crappie from Fort Supply Reservoir

Black crappie were not collected in 1949 although their presence in the lake was unquestioned. Thirty-two specimens of two distinct size and age groups were collected during 1950 (Table 5).

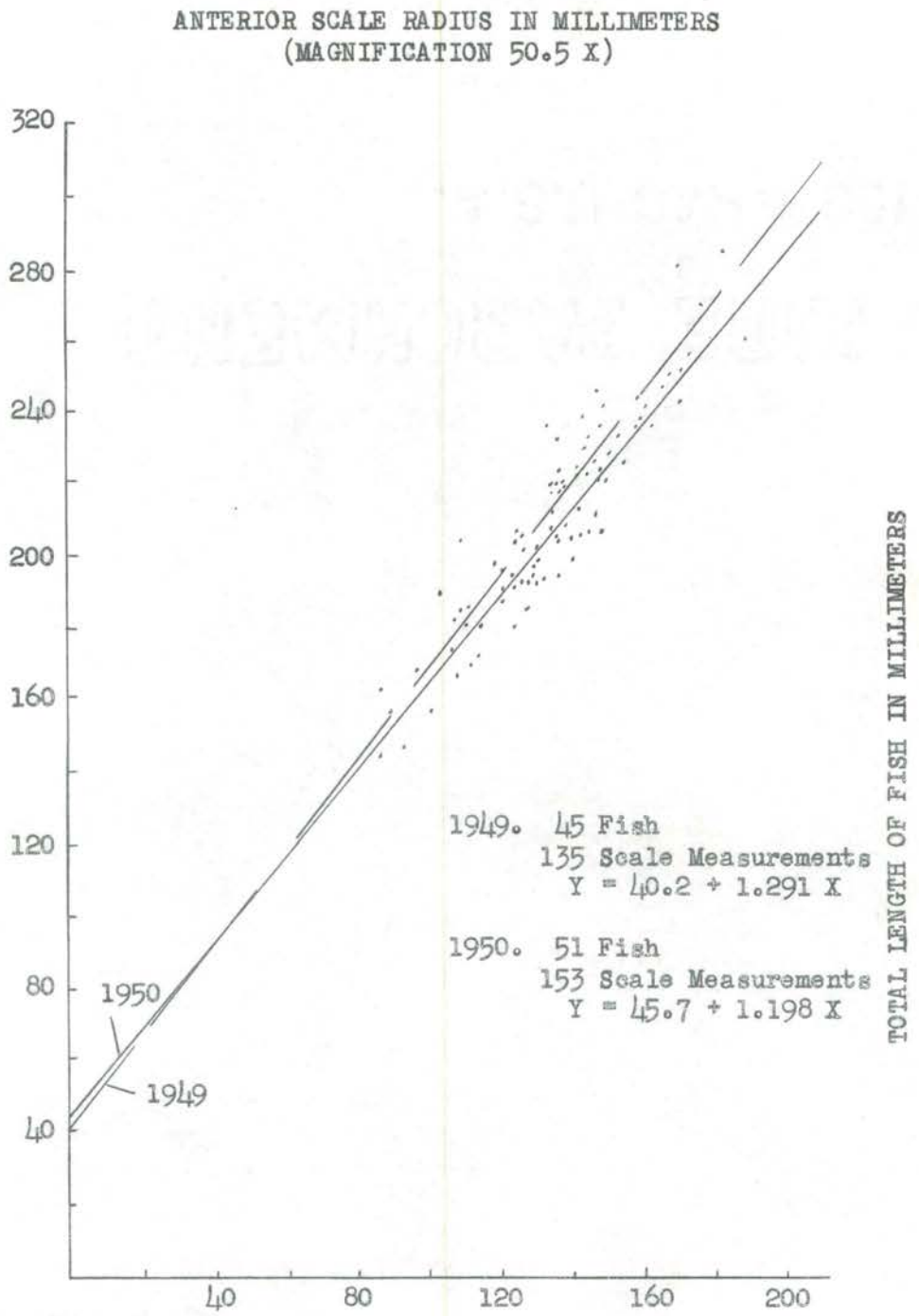

FIGURE 4. Body-Scale Relationships of White Crappie, Fort Supply Reservoir, Woodward County, Oklahoma. July 25 to 27, 1950 and August 26 to September 24, 1949. Individual Computation.

TABLE 4. Mean Lengths, Mean Weights, and Coefficients of Condition of White Crappie According to Size Groups, Fort Supply Reservoir, Woodward County, Oklahoma. August and September 1949 and July 1950.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Coefficient of Condition C
6.4 - 6.9	6	6.6	0.16	55.7
7.0 - 7.9	23	7.5	0.23	54.5
8.0 - 8.9	37	8.4	0.32	54.0
9.0 - 9.9	19	9.4	0.45	54.2
10.1 - 10.6	3	10.4	0.60	53.3
11.1 - 11.2	2	11.2	0.74	52.7
12.7	1	12.7	1.14	55.7

TABLE 5. Mean Lengths, Mean Weights, and Coefficients of Condition of Black Crappie According to Size Groups, Fort Supply Reservoir, Woodward County, Oklahoma. July 25 to 27, 1950.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Coefficient of Condition C
5.7 - 5.9	3	5.8	0.11	56.4
6.0 - 6.9	10	6.4	0.15	57.2
9.5 - 9.9	4	9.8	0.54	57.4
10.0 - 10.8	13	10.4	0.69	61.3
11.2	2	11.2	0.84	59.8

First-year growths were relatively slow and second-year growths were quite rapid. The 13 fish of 5.7 to 6.9 inches in length were of age-group one. They averaged 6.3 inches in length and 0.14 pound in weight and were calculated to have had an average length of 2.7 inches at the end of their first year of life. The larger black crappie which averaged 10.3 inches in length and 0.68 pound in weight were of age-group three. They were calculated to have averaged 3.0 inches in length at the end of their first year, 6.9 inches in length at the end of their second year, and 9.4 inches at the end of their third year.

The absence of age-group two may be a result of the small sample

or indicative of relatively small numbers in the group. Also, the two age-groups could have been successive year classes with age-group three having formed an annulus in 1950 and age-group one yet to form an annulus in 1950. Figure 5 shows the body-scale relationship of 31 black crappie taken from Fort Supply Reservoir in 1950.

Age and Growth of White Crappie from Canton Reservoir

A total of 148 white crappie was taken from Canton Reservoir for study. White crappie of 6 to 9 inches long from Canton Reservoir were in slightly poorer condition than fish of similar size from Fort Supply Reservoir (Tables 4 and 6). White crappie more than 10 inches long from Canton Reservoir were in slightly better condition than comparable fish from Fort Supply Reservoir.

TABLE 6. Mean Lengths, Mean Weights, and Coefficients of Condition of White Crappie According to Size Groups, Canton Reservoir, Blaine and Dewey Counties, Oklahoma. August 23, 1949 to October 8, 1950.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Coefficient of Condition C
2.4 - 2.8	5	2.7	0.007	35.6
3.2 - 3.9	6	3.6	0.017	36.4
4.9	2	4.9	0.04	34.0
5.7 - 5.9	4	5.8	0.07	35.9
6.0 - 6.9	20	6.5	0.12	43.7
7.0 - 7.9	22	7.5	0.19	45.0
8.1 - 8.9	33	8.5	0.31	50.5
9.0 - 9.9	35	9.4	0.45	54.2
10.0 - 10.6	20	10.3	0.62	56.7
11.8	1	11.8	1.00	60.9

The length-weight relationship was determined by grouping the white crappie into classes of one-inch length intervals and using average lengths and weights for computations. The relationship was expressed

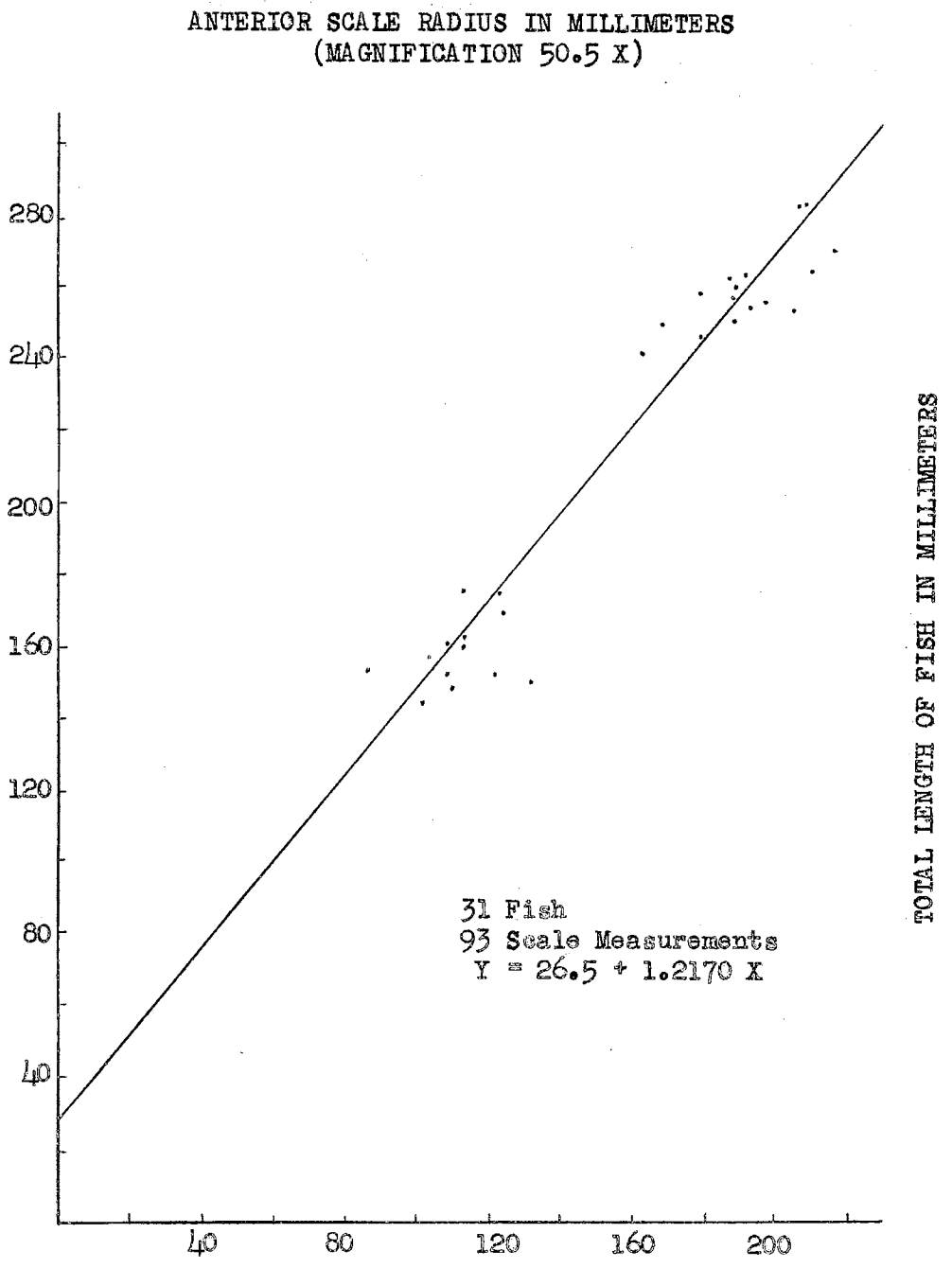

FIGURE 5. Body-Scale Relationship of Black Crappie, Fort Supply Reservoir, Woodward County, Oklahoma. July 25 to 27, 1950. Individual Computation.

by the formula Log W = -3.7056 + 3.4311 Log L, in which W (weight) is in pounds and L (total length) is in inches (Figure 6).

The 1948 year-class was the dominant group (numerically) of the crappie caught by nets, traps, or hook and line methods (Buck and Cross, 1951). White crappie of all ages and lengths made "good" growths during the first year of water impoundment. White crappie of the 1947 year class had calculated average lengths of 3.9 inches at the end of their first year of life, 9.2 inches at the end of their second year, and 11.9 inches at the end of their third year. White crappie of the 1948 year class had calculated average lengths of 4.1 inches at the end of their first year of life, 7.8 inches at the end of their second year, and 10.4 inches at the end of their third year.

Age and Growth of Black Crappie from Canton Reservoir

Only a very small number of black crappie were taken from Canton Reservoir (Table 7). Buck and Cross (1951) reported a catch ratio of

TABLE 7. Mean Lengths, Mean Weights, and Coefficients of Condition of Black Crappie According to Size Groups, Canton Reservoir, Blaine and Dewey Counties, Oklahoma. August 23, 1949 to October 8, 1950.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Coefficient of Condition C
6.0 - 6.9	6	6.4	0.14	53.4
7.1 - 7.4	3	7.3	0.20	51.4
8.2 - 8.7	2	8.4	0.33	55.7
9.0 - 9.8	7	9.3	0.50	62.2

one black crappie to 33 white crappie. They reported growth rates of black crappie for the first year of impoundment to be good, although somewhat slower than the growth of white crappie. The average calcu-

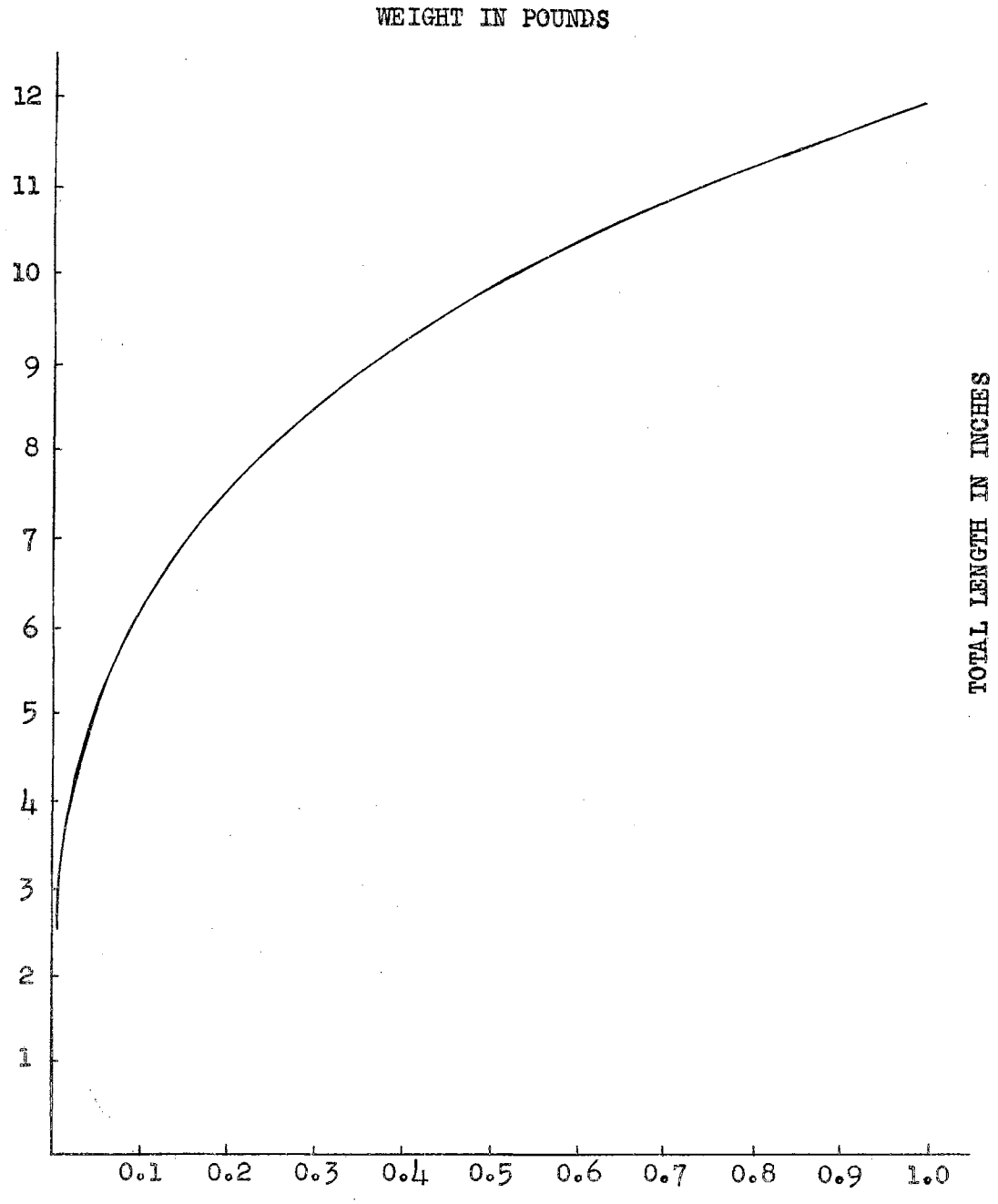

FIGURE 6. Length-Weight Relationship of White Crappie, Canton Reservoir, Blaine and Dewey Counties, Oklahoma. August 23 to October 8, 1950. Fish Grouped in Classes of One-Inch Length Intervals for Computation.

lated lengths of the 1947 year class were 2.3 inches at the end of the first year of life, 7.1 inches at the end of the second year, and 8.9 inches at the end of the third year. The average calculated lengths of the 1948 year class were 3.6 inches at the end of the first year of life, 7.1 inches at the end of the second year, and 9.4 inches at the end of the third year.

Food of White Crappie from Fort Supply Reservoir

Although a large number of white crappie were taken from Fort Supply Reservoir during 1949, practically all of the fish were of the same size group, 8 to 10 inches in total length. The white crappie were collected on August 26 and September 24, 1949. The 39 fish 8 to 10 inches in length had fed almost entirely on gizzard shad, Dorosoma cepedianum (LeSueur). Only one of the fish had eaten items other than gizzard shad, one mayfly larva (Ephemerida) and one adult beetle (Coleoptera).

Comparison of data of the two collections of 1949 revealed the following findings.

1. The average lengths of gizzard shad eaten by 8- to 9-inch white crappie were 2.4 inches in August and 2.4 inches in September; whereas, the average lengths of gizzard shad eaten by 9- to 10-inch white crappie were 2.4 inches in August and 2.6 inches in September.
2. The average number of gizzard shad per stomach and the average volume of stomach contents for the 8- to 10-inch fish were considerably larger in August (3.7 shad, 5.7 ml.) than in September (1.8 shad, 2.6 ml.).
3. The average number of gizzard shad per stomach and the

average volume of stomach contents were smaller for the 8- to 9-inch white crappie (2.2 shad, 3.6 ml.) than for the 9- to 10-inch white crappie (3.4 shad, 5.4 ml.).

The stomach of the 12.7-inch white crappie contained 14.0 ml. of food. The items consisted of one gizzard shad, 4.5 inches long, and two Cyprinus carpio Linnaeus, 2.3 and 3.5 inches long.

The six white crappie, 3.4 to 7.4 inches in length, taken from the stilling basin in September 1949, had eaten four minnows of which three were readily identifiable by hook marks as those used for bait. One cicadellid, one adult and one larval beetle, two adult dipterans, 29 Chironomus larvae and pupae, two Chaoborus larvae, and small numbers of copepods and cladocerans constituted the remainder of the food items.

All of the 28 white crappie collected in July 1950 contained food items, principally gizzard shad (Appendix D). Specimens of Argulus, an ectoparasitic crustacean of fish, were found in two stomachs which contained minnows. Copepods and cladocerans were found only in the stomachs of the 6- to 8-inch white crappie. Both adult and larval insects were found in stomachs of fish of 6.4 to 8.7 inches in length; however, only a few were found in fish longer than 8.1 inches.

The gizzard shad eaten by the white crappie collected in 1950 were smaller than the gizzard shad eaten by white crappie collected in 1949; however, the larger white crappie had eaten the larger gizzard shad. The 6.4- to 6.9-inch white crappie had eaten 1.3- to 2.2 inch gizzard shad (average, 1.8 inches); the 7.1- to 7.9-inch white crappie had eaten 2.0- to 2.3-inch gizzard shad (average, 2.1 inches); the 8.0- to 8.7-inch white crappie had eaten 1.5- to 2.5-inch gizzard shad (average, 2.1 inches); and the 10.6- to 11.1-inch white crappie had eaten 2.2-inch gizzard shad.

Food of Black Crappie from Fort Supply Reservoir

The 27 black crappie which were collected in 1950 from Fort Supply Reservoir were caught in the same net and trap sets with the 28 white crappie. The black crappie had fed principally on minnows instead of gizzard shad (Appendix E). Specimens of Argulus were found only from stomachs which contained minnows, as was observed in the examination of white crappie. This would seem to indicate that the parasitic crustaceans had been attached to minnows which were eaten by the crappies. The principal minnow in the stomach contents was Hybognathus placita Girard, specimens of which were 0.8 to 0.9 inch long. One 10.8-inch black crappie contained 55 partly-digested specimens of Hybognathus placita. Identification was possible because of the manner in which the long intestines of the minnows were coiled and the knowledge of what minnows existed in the area.

Copepods and cladocerans were found only in stomachs of black crappie of 5.7 to 6.9 inches in length; whereas, all size-groups had fed upon adult and larval insects to about the same extent. The occurrence of a thysanopteran in the stomach contents was most unexpected and was best explained by the presence of a broken plant gall in the same stomach.

Food of White Crappie from Canton Reservoir

Collections of white crappie were made from Canton Reservoir on August 23, 24, and September 23, 1949 and on January 20 and October 8, 1950. Specimens were collected by gill and hoop nets in August 1949 and by wire traps in September 1949 and January and October, 1950.

Twenty-three white crappie 8.3 to 10.6 inches in length, were taken in October 1950 from wire traps that had not been examined for about 10 weeks. Only one of the 23 stomachs was empty. Each of the other stomachs contained 1 to 7 gizzard shad. One stomach contained a 4.0-inch white crappie and another contained a 2.0-inch bluegill, Lepomis macrochirus Rafinesque. It seems unlikely that the crappie could have captured such a large number of fish while they were in the wire traps.

A summary of the stomach contents of white crappie from Canton Reservoir is presented in Table 8. White crappie as small as 3.8 inches

TABLE 8. Summary of Stomach Contents of White Crappie According to Length Groups, Canton Reservoir, Blaine and Dewey Counties, Oklahoma. August 23, 1949 to October 8, 1950.

Length Group in Inches	Number of Stomachs Examined	Number of Empty Stomachs	Number of Stomachs Containing Items			
			Fish	Crustaceans	Insects	
					Adults	Larvae
2.4 - 2.8	5	0	0	5	0	1
3.1 - 3.9	6	0	2	5	1	3
4.9	1	0	0	1	0	0
5.7 - 5.9	4	0	0	4	0	1
6.0 - 6.9	20	4	4	12	0	10
7.0 - 7.9	22	7	10	5	0	6
8.1 - 8.9	33	9	23	1	0	1
9.0 - 9.8	26	4	22	0	0	0
10.0 - 10.6	12	1	11	0	0	1
11.8	1	0	1	0	0	1

in length had swallowed minnows; however, gizzard shad were not found in stomachs of white crappie less than 6.7 inches in length. The average lengths of shad items and the average volumes of stomach contents increased with the increased lengths of white crappie (Table 9). Crustaceans were found in the stomachs of 7- to 9-inch fish only from collections made in August 1949. Adult insects were scarce in the stomach contents; however, practically all sizes of white crappie had eaten insect larvae.

TABLE 9. Volume of Stomach Contents, Number of Fish Items per Stomach, and Lengths of Gizzard Shad Eaten by White Crappie, Canton Reservoir, Blaine and Dewey Counties, Oklahoma. August 23, 1949 to October 8, 1950.

Crappie Length-Groups in Inches	Number of Stomachs Examined	Volume of Stomach Contents (ml)		Number of Fish per Stomach		Estimated Total Lengths of Shad in Inches	
		Maximum	Mean	Maximum	Mean	Range	Mean
2.4 - 2.8	5	0.1	0.03	0	0.0	-	-
3.1 - 3.9	6	0.4	0.12	1	0.3	-	-
4.9	1	Trace	Trace	0	0.0	-	-
5.7 - 5.9	4	0.1	0.10	0	0.0	-	-
6.0 - 6.9	20	0.7	0.11	3	0.4	2.7	2.7
7.0 - 7.9	22	3.6	0.95	2	0.6	2.2 - 2.7	2.5
8.1 - 8.9	33	5.4	1.47	4	1.1	1.6 - 3.5	2.7
9.0 - 9.8	26	9.5	2.20	6	2.1	1.3 - 3.5	2.7
10.0 - 10.6	12	9.9	4.70	7	3.2	1.3 - 3.5	3.0
11.8	1	2.8	2.8	1	1.0	3.5	3.5

The kinds and numbers of food items of white crappie from Canton Reservoir (Appendix F) were about the same as for white crappie from Fort Supply Reservoir. Gizzard shad comprised the bulk of the fish items and only a few minnows were found. Unlike the results of the Fort Supply studies, mayfly larvae were not represented as food items and immature midges (Chironomus, Chaoborus) comprised the bulk of the insects.

Stomach analyses by Buck and Cross (1951) showed that 64 percent of 409 stomachs were empty and that 28 percent of the stomachs contained gizzard shad. They found that the incidence of shad in the stomachs of white crappie which were caught in gill nets during July and August 1950 was much higher than for crappie taken by other means. Also, they found that about 75 percent of their total catch of white crappie in gill nets contained recently-eaten shad. The authors theorized that the crappie entered the gill nets while pursuing shad.

Food of Black Crappie from Canton Reservoir

Only 18 black crappie, 6.0 to 9.8 inches, were obtained for study from Canton Reservoir. Gizzard shad constituted the bulk of the stomach contents and was the only identifiable fish item. Crustacean and adult and larval insects were found only in small quantities.

Buck and Cross (1951) found that gizzard shad were the most common food of the 5.0- to 11.5-inch black crappie and that shad were taken more extensively by larger ones. They reported that insect larvae, chiefly Chaoborus, were found occasionally in the stomachs of 5.0- to 6.5-inch black crappie.

POPULATIONS COMPRISED MAINLY OF STUNTED CRAPPIES

Lakes

Considerable differences exist between the ages and the sizes of Lake Carl Blackwell and Boomer Lake. The dam which impounds about 3300 surface acres in Lake Carl Blackwell, seven miles west and one mile north of Stillwater, Oklahoma, was constructed in 1938. The dam which impounds about 210 surface acres in Boomer Lake, about two miles north of Stillwater, Oklahoma, was constructed in 1924. The Carl Blackwell Dam was constructed for flood control purposes and Boomer Dam was constructed to form a water supply reservoir. In accordance with early water treatment policies Boomer Lake received many dosages of copper sulfate or "bluestone".

The rates of fisherman success for both reservoirs in recent years were based on observations and reports since creel census data was not available. Crappie fishing in Boomer Lake was very poor. Many small crappie could be taken, but "keeper-size" crappie rarely were caught. Crappie fishing in Lake Carl Blackwell was considered to be fair, and good catches were generally made in the early spring by experienced or lucky anglers.

Collections of fishes from both lakes were made with the aid of wire traps. The traps were set in all parts of Boomer Lake and collections were made from September 23, 1950 to April 27, 1951. Traps were set only in one small arm of Lake Carl Blackwell, Arm No. 10, and collections were made between January 4, 1950 and April 27, 1951.

Age and Growth of White Crappie from Lake Carl Blackwell and Boomer Lake.

White crappie of 5.0 to 6.5 inches were caught regularly in Boomer Lake, and more fish of this size were caught than are shown in Table 10. The

TABLE 10. Coefficients of Condition of White Crappie According to Length Groups, Boomer Lake and Lake Carl Blackwell, Payne County, Oklahoma.

Length Group in Inches	Boomer Lake Sept. 1950 - April 1951		Lake Carl Blackwell January - April 1951	
	Number of Fish	C	Number of Fish	C
4.5 - 4.9	19	38.0	5	38.5
5.0 - 5.4	116	41.3	31	38.4
5.5 - 5.9	73	36.2	62	37.8
6.0 - 6.4	43	36.5	39	37.8
6.5 - 6.9	14	37.9	30	36.6
7.0 - 7.4	18	37.5	24	40.2
7.5 - 7.9	8	36.4	10	40.7
8.0 - 8.4	5	38.1	11	43.5
8.5 - 8.9	4	38.6	11	47.1
9.0 - 9.4	6	39.7	4	42.4
9.5 - 9.9	1	44.1	8	49.3
10.0 - 10.4	2	43.9	4	49.0
10.5 - 10.8	2	38.3	6	45.7
11.0 - 11.4			8	51.2
11.5 - 11.9	2	46.9	4	50.0
12.0 - 12.4			6	53.4
12.6			2	56.0
13.2	1	41.7		
14.0 - 14.2	1	54.5	2	54.9

different size groups of white crappie were more easily obtained from Lake Carl Blackwell and the data in Table 10 represent nearly all of the fish taken. The numbers of 4.5- to 4.9-inch white crappie taken are not indicative of the populations because the wire traps were inefficient in retaining fish of this size.

The plumpness of the fish, coefficient of condition, varied considerably with the dates of collection and to some extent with the length of the fish. Samples of the 5.0- to 5.9-inch crappie from Lake Carl Blackwell increased in plumpness from January through April; however,

samples of the 6.0- to 7.4-inch crappie decreased in plumpness in February and then increased through March and April (Appendix G). The 4.5- to 6.4-inch crappie from Boomer Lake had relatively high coefficients of condition in September and April. A sharp drop in condition of crappie from Boomer Lake occurred in October and was followed by an increase in November and a gradual decline through March (Appendix H).

The length-weight relationships of white crappie from Lake Carl Blackwell and Boomer Lake (Figure 7) were determined by using mean lengths in inches and weights in pounds of specimens grouped into one-half inch length intervals. The length-weight relationship of white crappie from Lake Carl Blackwell was expressed by the formula $\log W = -3.7341 + 3.4128 \log L$. The length-weight relationship of white crappie from Boomer Lake was expressed by the formula $\log W = -3.6087 + 3.3003 \log L$. Comparisons of the results show that the white crappie from Lake Carl Blackwell were slightly heavier than white crappie of comparable lengths from Boomer Lake.

Considerable difficulty was encountered in reading the scales of some of the white crappie from Lake Carl Blackwell. Scales from some of the small fish had false annuli near the true annuli. When the false annuli were paired with true annuli, the false annuli were located nearer to the foci of the scales. Normally, the scales of white crappie from Lake Carl Blackwell and Boomer Lake exhibited distinct annuli and were easy to read. The scales of three fish, 7.2 to 8.6 inches in length, taken from Lake Carl Blackwell April 16 to 23, 1951, showed that new annuli had been forming on the anterior tips of the scales. No other scales from fish of Lake Carl Blackwell or Boomer Lake gave indications that new annuli were being formed.

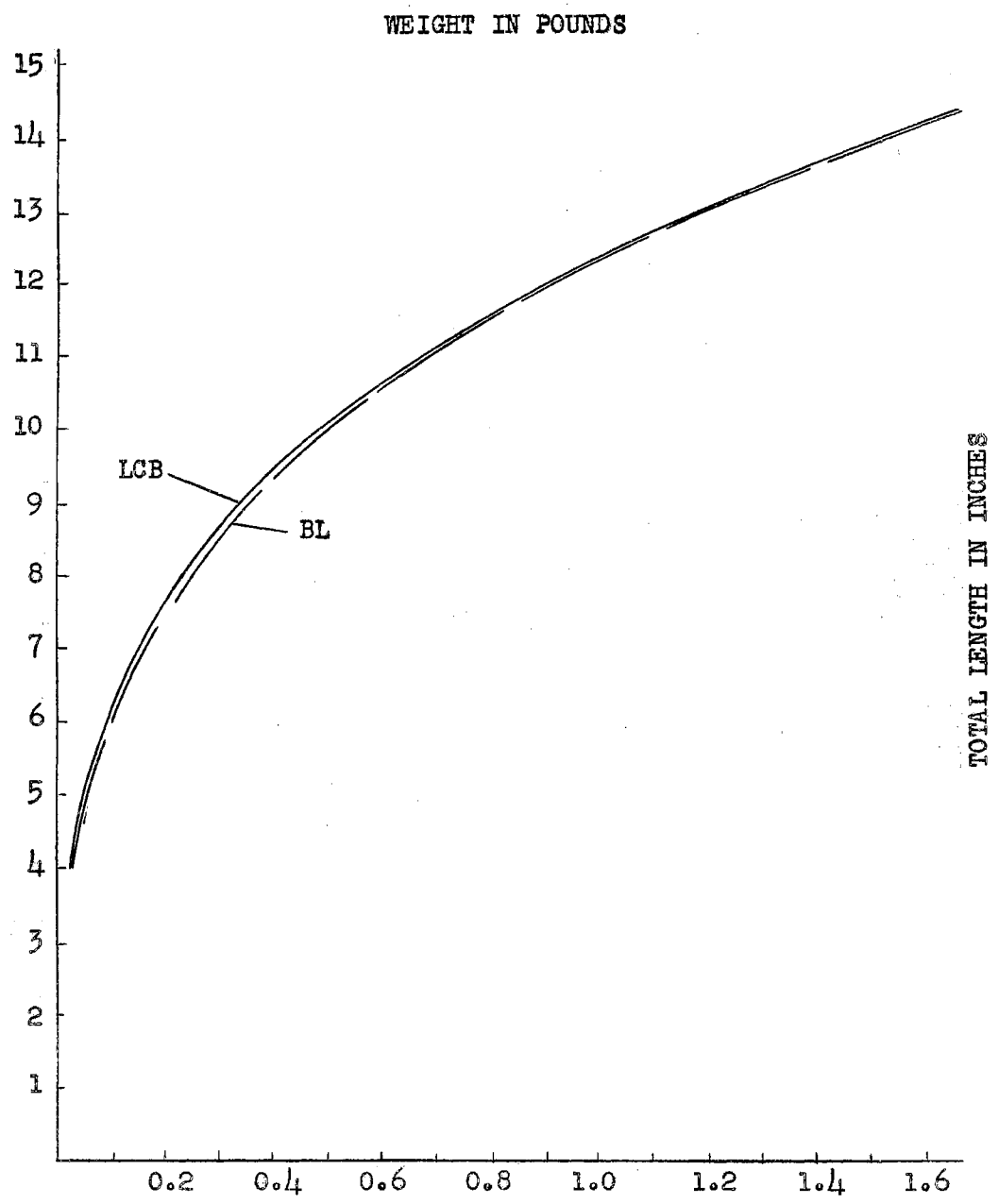

FIGURE 7. Length-Weight Relationship of White Crappie, Lake Carl Blackwell and Boomer Lake, Payne County, Oklahoma. September 23, 1950 to April 27, 1951. Fish were Grouped in Classes of One-Half Inch Length Intervals for Computation. LCB, Lake Carl Blackwell; BL, Boomer Lake.

The plotting of scale lengths against fish lengths indicated curved regressions for data for the fish from each lake. The measurements of the fish from each lake were tested using the second degree polynomial, $Y = a + bX + cX^2$, to determine if significant departures from linear regressions existed. The calculated sums of squares of the errors of estimates and degrees of freedom for both the linear regression and the curved regression of each sample are shown in Tables 11 and 12. The

TABLE 11. Test of Significance of Departure from Linear Regression of the Body-Scale Relationship of White Crappie, Lake Carl Blackwell, Payne County, Oklahoma. January 4 to April 27, 1951.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Deviations from Linear Regression	261	0.2220	
Deviations from Curved Regression	260	0.1720	0.00066
Curvilinearity of Regression	1	0.0500	

$$F = \frac{0.0500}{0.00066} = 75.76$$

TABLE 12. Test of Significance of Departure from Linear Regression of the Body-Scale Relationship of White Crappie, Boomer Lake, Payne County, Oklahoma. September 23, 1950 to April 27, 1951.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Deviations from Linear Regression	309	0.3870	
Deviations from Curved Regression	308	0.3445	0.001119
Curvilinearity of Regression	1	0.0425	

$$F = \frac{0.0425}{0.001119} = 37.98$$

reduction in sum of squares, tested against the mean square remaining after curvilinear regression, proved significant in each instance. The result of fitting a linear regression to the data of white crappie from Lake Carl Blackwell was $Y = 27 + 1.2140X$, and the result of fitting the second degree polynomial was $\log Y = 1.862057 + 0.003327X - 0.00000229867X^2$ (Figure 8). The result of fitting a linear regression to the data of white crappie from Boomer Lake was $Y = 55.3 + 0.9399X$, and the result of fitting the second degree polynomial was $\log Y = 1.8333 + 0.0038117X - 0.00000046685X^2$ (Figure 9).

Nomographs based on the curved regressions were used to calculate the fish lengths at the time the annuli were formed. The intercepts of the curved regressions were used as points of origins in calculating the growths. The extremely wide ranges in lengths of the different age groups indicated that both very poor and good growths had been made by white crappie from Lake Carl Blackwell. A frequency distribution by age and length groups revealed a distinct "group" of large specimens of different ages from Lake Carl Blackwell (Table 13). The overlap of size ranges was less pronounced for the different age groups of crappie of Boomer Lake (Table 14). The majority of the fish from Boomer Lake were of age group two, whereas the fish from Lake Carl Blackwell were more evenly distributed among the age groups (Tables 14 and 15).

The average calculated growths of crappie from each lake were markedly similar despite the differences in size overlap of the age groups. Growth calculations revealed slow growth for fish of 4 to 7 inches in length and faster growth for longer fish. The calculated yearly lengths for the older fish were smaller than for the younger fish. This tendency was less consistent for crappie from Boomer Lake. Growth calculations remained constant even though collection dates varied.

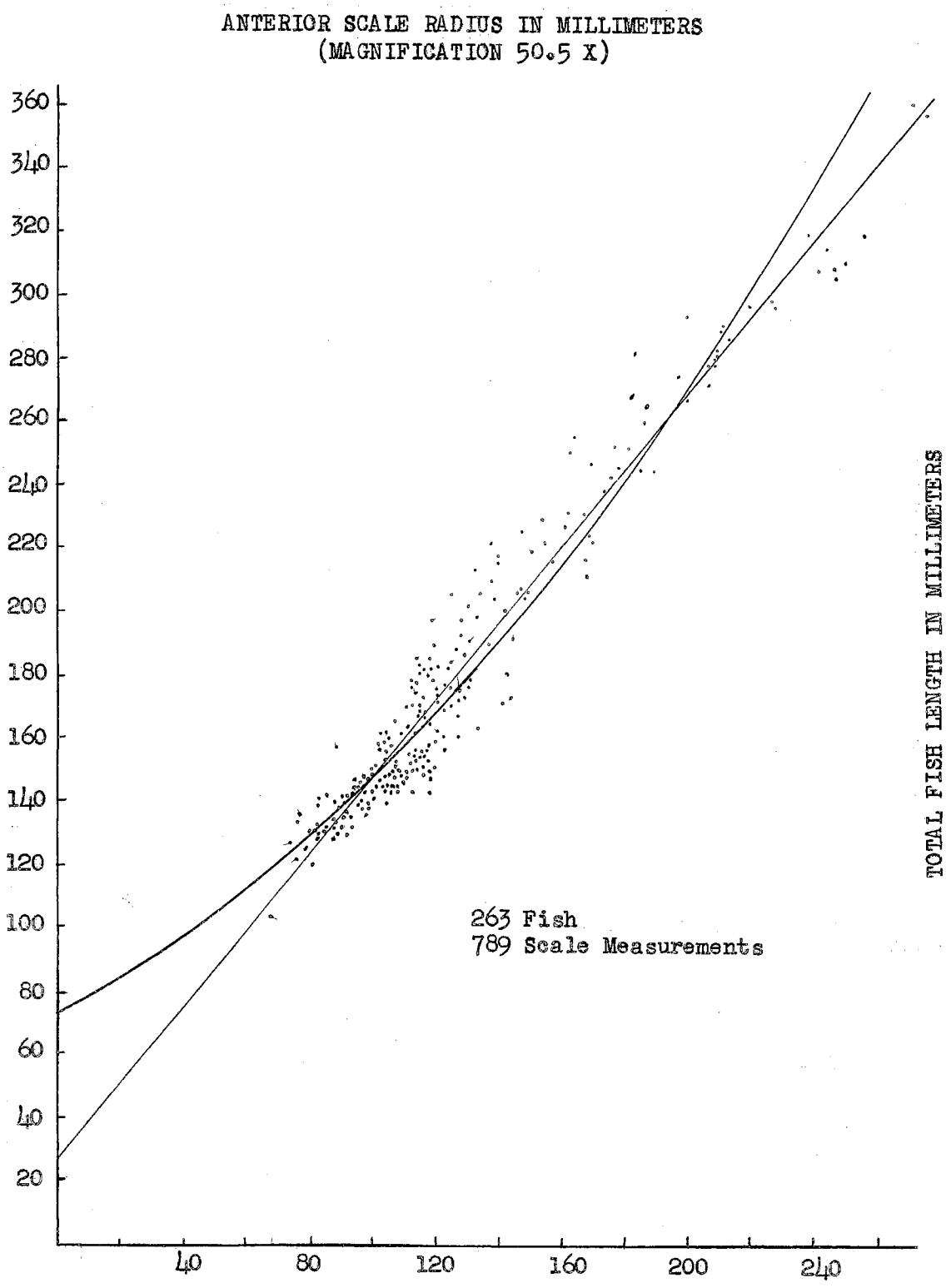

FIGURE 8. Body-Scale Relationships of White Crappie, Lake Carl Blackwell, Payne County, Oklahoma. January 4 to April 27, 1951. Individual Computations.

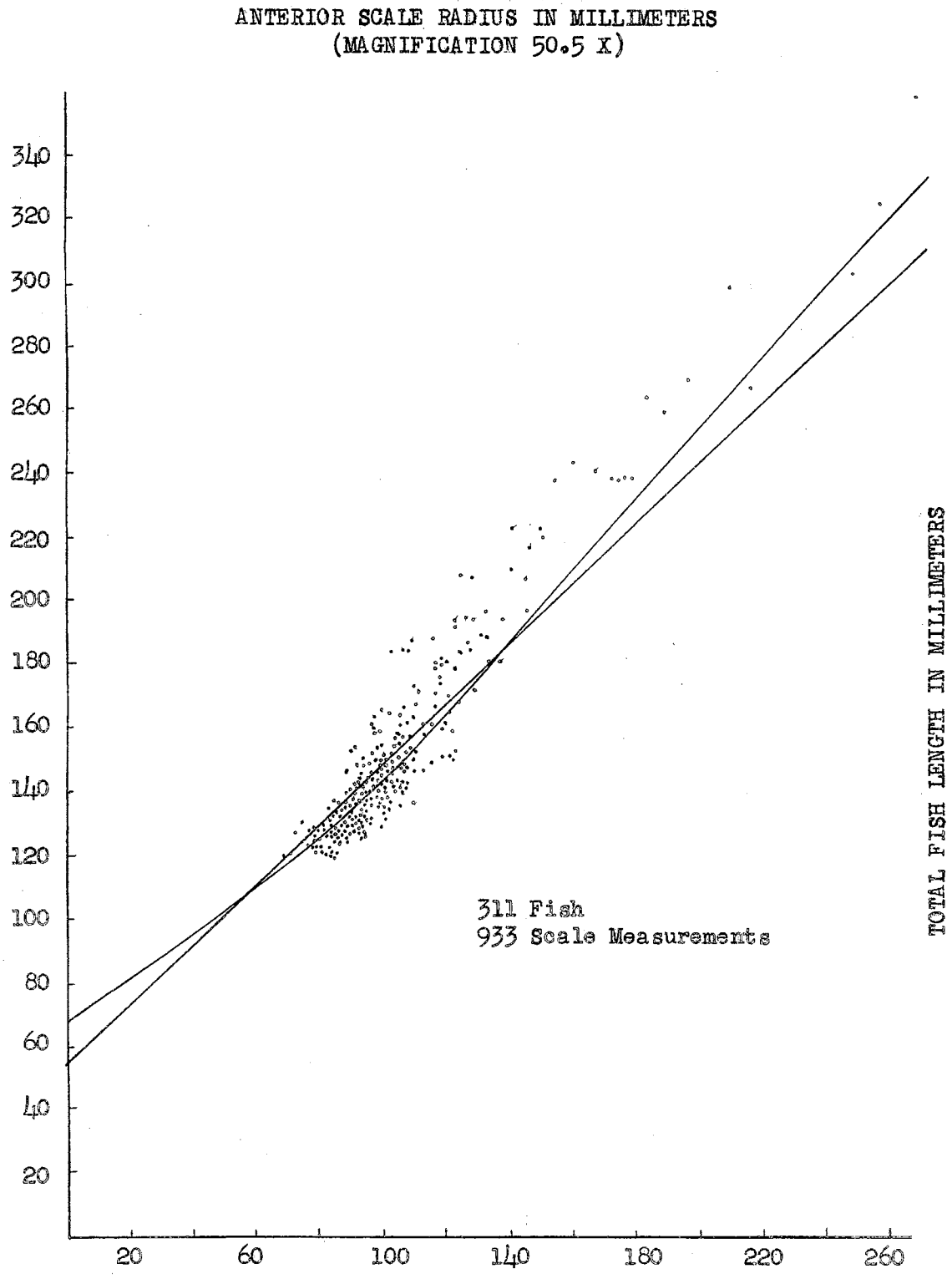

FIGURE 9. Body-Scale Relationships of White Crappie, Boomer Lake, Payne County, Oklahoma. September 23, 1950 to April 27, 1951. Individual Computations.

TABLE 13. Number of White Crappie by Length and Age Groups, Lake Carl Blackwell, Payne County, Oklahoma. January 4 to April 27, 1951.

Length in Inches	Number of Annuli					
	I	II	III	IV	V	VI
4.5 - 4.9	4					
5.0 - 5.4	14	15				
5.5 - 5.9	3	46	6			
6.0 - 6.4	5	10	19	5		
6.5 - 6.9	1	9	13	6		
7.0 - 7.4	4	5	11	4		
7.5 - 7.9		2	5	3		
8.0 - 8.4		5	2	2	2	
8.5 - 8.9		3		5	3	
9.0 - 9.4				4		
9.6 - 9.9		1	3		4	
10.0 - 10.4		1		1	1	1
10.5 - 10.8			1	1	4	
11.0 - 11.4		1	3	4		
11.5 - 11.8				3	1	
12.0 - 12.4				3	2	
12.6				2		
14.0					1	

Food of White Crappie from Boomer Lake. White crappie were collected during the period September 25, 1950 to April 27, 1951, and 320 specimens were used for stomach analysis (Table 16). Fewer fish were caught during the latter part of the collection period, although trapping effort remained fairly constant. Also, fewer small crappie were collected during the latter part of the collection period to avoid excessive duplication.

Eighty-one percent or 259 of the 320 stomachs examined contained food. Fish collected in September, October, and the first part of November contained the highest percentage of empty stomachs, and fish collected in March and April contained the lowest percentage of empty stomachs.

The percentages of empty stomachs increased slightly (16 to 27 percent) with increased length of fish from 4.6 to 7.7 inches. Only

TABLE 14. Lengths, Weights, and Average Calculated Lengths of White Crappie, Boomer Lake, Payne County, Oklahoma. September 23, 1950 to April 27, 1951.

Age	Number of Fish	Total Length in Inches		Weight in Pounds		Average Calculated Total Lengths in Inches at Each Annulus					
		Range	Mean	Range	Mean	1	2	3	4	5	6
I	31	4.6 - 5.6	5.0	0.04 - 0.06	0.05	3.9					
II	219	4.8 - 7.7	5.6	0.04 - 0.19	0.07	3.8	4.8				
III	43	5.9 - 8.7	7.0	0.07 - 0.26	0.14	4.1	5.4	6.2			
IV	15	7.4 - 10.6	9.0	0.15 - 0.51	0.30	3.9	5.2	6.5	7.6		
V	5	8.1 - 14.2	10.8	0.21 - 1.56	0.66	3.8	5.1	6.2	7.4	9.5	
VI	2	11.9 - 13.2	12.6	0.82 - 0.96	0.89	3.7	4.8	5.7	6.2	8.0	10.0

TABLE 15. Lengths, Weights, and Average Calculated Lengths of White Crappie, Lake Carl Blackwell, Payne County, Oklahoma. January 4 to April 27, 1951.

Age	Number of Fish	Total Length in Inches		Weight in Pounds		Average Calculated Total Lengths in Inches at Each Annulus					
		Range	Mean	Range	Mean	1	2	3	4	5	6
I	31	4.5 - 7.4	5.7	0.04 - 0.17	0.07	3.9					
II	97	5.1 - 11.0	6.2	0.05 - 0.85	0.11	3.8	5.2				
III	64	5.7 - 11.4	7.1	0.07 - 0.78	0.17	3.7	5.0	6.2			
IV	43	6.0 - 12.6	8.8	0.08 - 1.14	0.39	3.7	4.7	6.0	7.4		
V	18	8.0 - 14.0	10.2	0.23 - 1.51	0.58	3.7	4.8	5.9	7.1	8.7	
VI	1		10.1		0.47	3.6	4.5	5.4	6.2	7.5	8.8

TABLE 16. Summary of Stomach Contents of White Crappie According to Size Groups, Boomer Lake, Payne County, Oklahoma. September 23, 1950 to April 27, 1951.

Length Group in Inches	Number of Stomachs Examined	Number of Empty Stomachs	Volume of Stomach Contents (ml.)		Number of Stomachs Containing Items			
			Maximum	Mean	Fish	Crustaceans	Insects	
							Adults	Larvae
4.6 - 4.9	19	3	0.4	0.17	0	16	10	8
5.0 - 5.9	196	35	1.2	0.15	8	139	68	87
6.0 - 6.9	58	13	2.8	0.26	10	25	17	27
7.0 - 7.7	26	7	2.6	0.47	9	6	5	10
8.1 - 8.7	8	2	4.1	0.65	4	1	2	4
9.4 - 9.6	7	0	5.2	1.56	7	0	0	1
10.2 - 10.5	2	0	0.6	0.35	2	1	0	2
11.8 - 11.9	2	0	4.3	2.70	2	0	0	0
13.2	1	1						
14.2	1	0	1.2	1.20	1	0	0	1

three (14 percent) of the 21 fish ranging in length from 8.1 to 14.2 inches contained empty stomachs. The trend in numbers of empty stomachs may be the result of decreased feeding upon crustaceans and insects and increased feeding upon fish items (Table 16). The distribution of the crappie according to size and this correlation of food habits exemplifies the so-called pyramid of numbers (Elton, 1927).

The total volume of food of the 4.6- to 4.9-inch crappie consisted of 70 percent, copepods and cladocerans; 20 percent, larval insects; 5 percent, terrestrial insects; 4 percent, adult aquatic insects; and 1 percent, Uroglena. Mayflies were the principal insect larvae found in the food and water boatmen (Corixidae) were the principal adult aquatic insects. The terrestrial insects eaten were leaf hoppers (Cicadellidae), aphids (Aphididae), and ants (Formicidae).

The total volume of food of the 5.0- to 5.9-inch white crappie consisted of 54 percent, copepods and cladocerans; 22 percent, larval insects; 9 percent, terrestrial insects; 7 percent, adult aquatic insects; 7 percent, fish; and 1 percent, spiders (Araneida). Mayflies were the principal insect larvae found in the food; however, midges and dragonflies (Anisoptera) were also common larval forms. The terrestrial insects were mostly leaf hoppers, aphids, and ants. The aquatic adult insects were water boatmen and water striders (Trepobates knighti Drake and Harris). All of the identifiable fish items were sunfishes, probably bluegill and orangespotted sunfish, Lepomis humilis (Girard). A 5.0-inch crappie was the smallest specimen taken from Boomer Lake which contained fish remains. Most of the 5- to 6-inch crappie which had eaten fish were 5.7 to 5.9 inches in length, and the fish items ranged from 1.0 to 1.5 inches in length.

The total volume of food of the 6.0- to 6.9-inch white crappie was comprised of 65 percent, fish; 18 percent, insect larvae; 8 percent, copepods and cladocerans; 6 percent, terrestrial insects; and 3 percent, adult aquatic insects. The identifiable fish items were 10 centrarchids (1.4 to 2.3 inches long) and one Hybognathus placita. A 6.0-inch crappie had eaten a 1.8-inch orangespotted sunfish, and a 6.6-inch crappie had eaten a 2.3-inch sunfish. Mayflies were the principal larval insect food; however, midges, dragonflies, and beetles were common larval forms. Water boatmen were the only adult aquatic insects found as food items. The terrestrial insects were ants, leaf hoppers, other hemipterans, and beetles.

The total volume of food of the 7.0- to 7.9-inch crappie consisted of 92 percent, fish; 5 percent, larval insects; 2 percent, adult insects; and 1 percent, crustaceans. Sunfishes (1.8 to 2.5 inches long) were the predominate food items and only one minnow, Hybognathus placita, was found. The 7.0-inch crappie swallowed 1.8-inch bluegill and unidentified sunfish of 2.5 inches in length. The larval insects found as food were midges and mayflies, and the adult insects were water boatmen, other hemipterans and beetles.

The total volume of food of the 8.1- to 14.2-inch crappie consisted of 98 percent, fish; 2 percent, mayfly larve; and trace quantities of cladocerans, amphiopods, larval midges and sialids, and adult corixids. White crappie comprised about half of the fish items by volume. An 8.5-inch white crappie had eaten a 2.4-inch white crappie, a 9.4-inch white crappie had eaten a 2.7-inch white crappie, and a 9.6-inch white crappie had eaten a 3.0-inch white crappie. Other centrarchids and unidentifiable fish comprised the remaining fish items. Scales of carp, Cyprinus carpio Linnaeus, were found in one stomach.

The foods of the 320 white crappie taken from Boomer Lake are shown in Appendix I. Only three identifiable fish other than centrarchids were found as food items. Two were Hybognathus placita and the other consisted of two carp scales which possibly could have been taken as such and not as part of a food item.

Cladocerans, copepods, mayfly and midge larvae, and adult corixids were recovered from crappie taken throughout the period September 23, 1950 to April 27, 1951. Adult dipterans were found as food items in each collection, except those taken in February. Leaf hoppers were found in stomachs of crappie collected during September, October, November, December, and February. Ants appeared as food items in September, October, and November. Aphids were found in stomachs of fish collected in November and in February. Larval sialids were taken only from fish collected in February. Uroglena, the only plant eaten other than miscellaneous seeds and stems, was taken from fish collected in September and the early part of October.

The occurrence of miscellaneous seeds and small portions of plant stems in the stomachs was quite regular. These items composed practically all of the detritus and their presence may indicate that the fish were eating anything in or on the water.

Food of White Crappie from Lake Carl Blackwell. White crappie were collected during the period January 4 to April 27, 1951, and the stomach contents of 222 specimens were examined (Table 17). The fish were caught throughout the period in about equal numbers.

Seventy-five percent or 173 of the 222 stomachs examined contained food. Fish collected in March contained the lowest percentage of empty

TABLE 17. Summary of Stomach Contents of White Crappie According to Size Groups, Lake Carl Blackwell, Payne County, Oklahoma. January 4 to April 27, 1951.

Length Group in Inches	Number of Stomachs Examined	Number of Empty Stomachs	Volume of Stomach Contents in Milliliters		Number of Stomachs Containing Items			
			Maximum	Mean	Fish	Crustaceans	Insects	
							Adults	Larvae
4.5 - 4.9	5	0	0.2	0.10	0	5	0	3
5.0 - 5.9	80	17	0.4	0.13	1	55	3	41
6.0 - 6.9	60	12	2.3	0.26	9	40	4	37
7.0 - 7.9	30	8	3.2	0.80	13	7	1	17
8.0 - 8.9	17	4	7.0	2.24	13	2	1	10
9.0 - 9.9	9	3	2.4	1.11	5	1	0	5
10.0 - 10.8	10	2	11.5	2.27	6	0	0	3
11.0 - 11.7	6	1	13.5	3.53	5	0	0	3
12.1 - 12.6	5	2	18.0	6.22	3	0	0	0

stomachs, and fish collected in April contained the highest percentage of empty stomachs.

White crappie of 4.5 to 4.9 inches in length had eaten only crustaceans and larval insects. Cladocerans and copepods comprised about half of the total volume of food, and the remainder consisted of mayfly and midge larvae.

The total volume of food of the 5.0- to 5.9-inch white crappie consisted of 54 percent, cladocerans and copepods; 39 percent, mayfly larvae; 5 percent, midge larvae; and 2 percent, the remains of a sunfish. Trace quantities of Psychomyiidae and Coleoptera larvae and Cicadellidae and Diptera adults were also found as food.

The total volume of food of the 6.0- to 6.9-inch white crappie consisted of 59 percent, fish; 25 percent, larval insects; and 16 percent, cladocerans and copepods. Centrarchids (1.1 to 2.5 inches long) constituted about half of the fish, and gizzard shad (2.0 to 2.4 inches long), Hybognathus placita, and unidentifiable fish comprised the remainder. A 6.2-inch crappie contained sunfish and specimens of Hybognathus placita of 2.5 inches in length. The larval insects were mostly mayflies; however, larval forms of Chironomus, Chaoborus, Sialidae, Psychomyiidae, Coleoptera, and Ceratopogoniae occurred in small amounts. Trace quantities of adult insects, Corixidae and Diptera, were found also as food items.

The total volume of food of the 7.0- to 7.9-inch white crappie consisted of 64 percent, gizzard shad; 27 percent, larval insects; and 9 percent, cladocerans and copepods. The gizzard shad were 1.6 to 4.0 inches long and a 4.0-inch shad had been swallowed by a 7.4-inch crappie. The larval insects were mostly mayflies; however, small numbers of

Sialidae, Coleoptera, Chironomus, Chaoborus, and Ceratopogoniae larvae were found. Traces of adult insects were found also as food.

The total volume of food of the 8.0- to 12.6-inch crappie consisted of 75 percent, gizzard shad; 19 percent, other fishes; and 6 percent, larval insects. The larval insects found as food were specimens of Anisoptera, Chironomus, Chaoborus, Sialidae, Coleoptera, and Psychomyiidae. Only traces of adult insects and crustaceans were found.

The 8- to 9-inch white crappie had swallowed 2.0- to 4.0-inch gizzard shad; 9- to 10-inch crappie, 2.0- to 3.5-inch shad; 10- to 11-inch crappie, 1.5- to 4.5-inch shad; 11- to 12-inch crappie, 2.0- to 4.0-inch shad; and 12- to 13-inch crappie, 2.5- to 5.0-inch shad. A 9.4-inch crappie had swallowed a 5.0-inch unidentified fish; 10.2-inch crappie, 5.5-inch crappie; 10.6-inch crappie, 4.5-inch shad; and 12.6-inch crappie, 5.0-inch shad.

The size of gizzard shad eaten by the white crappie increased with the size of crappie and with the later collections. Four gizzard shad were taken from the stomachs of the 6- to 7-inch crappie collected during January, and only one gizzard shad was taken from the 6- to 7-inch crappie collected in February. Thereafter, gizzard shad was not found as food of the 6- to 7-inch crappie. Gizzard shad was found as food for the 7- to 8-inch crappie only during January, February, and March; however, it was found as food for the larger size crappie throughout the study. By volume, gizzard shad comprised about 63 percent of the food of the white crappie from Lake Carl Blackwell (Appendix J).

Seventy-seven white crappie longer than 6.9 inches were taken from Lake Carl Blackwell from January through April 1950 while a comparable fishing effort during the same period at Boomer Lake produced only six

crappie longer than 6.9 inches. Two of the six specimens from Boomer Lake contained fish items (0.3 fish per stomach), whereas, 45 of the 77 specimens from Lake Carl Blackwell contained fish items (2.7 fish per stomach). The average volume of stomach contents for the six crappie from Boomer Lake was 0.47 ml. as compared with the much higher values found for crappie of similar lengths from Lake Carl Blackwell (Table 17).

Considerably more larval insects and fish and fewer adult insects were found as food of crappie from Lake Carl Blackwell than of crappie from Boomer Lake. Only seven of 140 crappie of 5 to 7 inches in length from Lake Carl Blackwell contained adult insects, whereas 29 of 83 comparable size crappie from Boomer Lake contained adult insects.

A fish hook, size 1/0, was taken from the stomach of an 8.2-inch crappie. The fish was in good condition and the partly oxidized hook apparently was disintegrating in the fish's stomach.

Ponds

Two ponds, each less than an acre in surface area, were treated with rotenone and the fish collected during August 14 to 16, 1950. Although the two ponds contained different species of crappies, the populations were quite similar. The ponds were about 20 years old and contained many small fishes of which only a few were "keeper size".

The Lexington Gunnery Range Pond, located on the Lexington Public Hunting Ground in Cleveland County, had relatively clear water and contained black crappie but no white crappie. Fisher's Pond, located about two miles southeast of Edmond, Oklahoma, had turbid water and contained white crappie but no black crappie. All of the large crappies of both ponds were studied, whereas, the small crappies were so numerous that

only samples of the different length-groups were examined. Young-of-year crappie were not found in either pond.

The largest fishes of each pond had higher coefficients of condition than the smallest ones, however the coefficients of condition for the 3.6- to 6.3-inch crappies decreased with increase in size of fish (Tables 18 and 19).

TABLE 18. Mean Lengths, Mean Weights, and Coefficients of Condition of White Crappie According to Size Groups, Fisher's Pond, Oklahoma County, Oklahoma. August 14, 1950.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Coefficient of Condition C
4.0 - 4.9	14	4.3	0.04	44.0
5.1 - 5.7	14	5.3	0.05	33.6
10.0	1	10.0	0.50	50.0
12.6	1	12.6	0.99	49.5
13.1 - 13.9	4	13.6	1.61	64.0
14.3	1	14.3	1.94	66.3

TABLE 19. Mean Lengths, Mean Weights, and Coefficients of Condition of Black Crappie According to Size Groups, Lexington Gunnery Range Pond, Cleveland County, Oklahoma. August 16, 1950.

Length Group in Inches	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Coefficient of Condition C
3.6 - 3.8	13	3.7	0.02	39.5
4.4 - 4.9	19	4.8	0.04	38.9
5.0 - 5.6	20	5.2	0.05	35.6
6.3	1	6.3	0.07	28.0
7.0	1	7.0	0.17	49.6
8.4	1	8.4	0.28	47.2
9.4	1	9.4	0.43	51.8
10.8	1	10.8	0.60	47.6

Age and Growth of Crappies from Fisher's Pond and Lexington Gunnery Range Pond. Few check marks (false annuli) were observed on the scales of the

white crappie from Fisher's Pond. Erosion or absorption of the scales was not apparent and the annuli on the scales were distinguished readily.

Check marks were common on the scales of black crappie from the Lexington Gunnery Range Pond and erosion or absorption of the scales of the large black crappie was evident. Erosion of the scales was most pronounced in the area of the annuli. Scales of the two largest black crappie had six annuli; however, erosion was so severe that the yearly growth rates could not be determined. Scales from each of the two fish showed different numbers of annuli because the amount of erosion varied with individual scales.

The body-scale relationships of black crappie from the Lexington Gunnery Range Pond and of white crappie from Fisher's Pond were determined by linear regression (Figures 10 and 11).

When the body-scale data for the white crappie from Fisher's Pond were plotted a curvilinear relationship seemed to exist. The second degree polynomial, $Y = a + bX + cX^2$, was used to test the significance of departure from linear regression. The calculated sums of squares of error of estimates and degrees of freedom for both the linear regression and the curved regression were determined. The reduction in sum of squares, tested against the mean square remaining after curvilinear regression, did not prove to be significant (Table 20). Therefore, the assumption of curvilinear regression was disregarded.

Calculated growths show that the black crappie of Lexington Gunnery Range Pond required one year longer than the white crappie of Fisher's Pond to attain a length of five inches. The data presented in Tables 18, 19, 21, and 22 show that few crappies in the ponds had attained lengths longer than 5.7 inches or had lived more than three years.

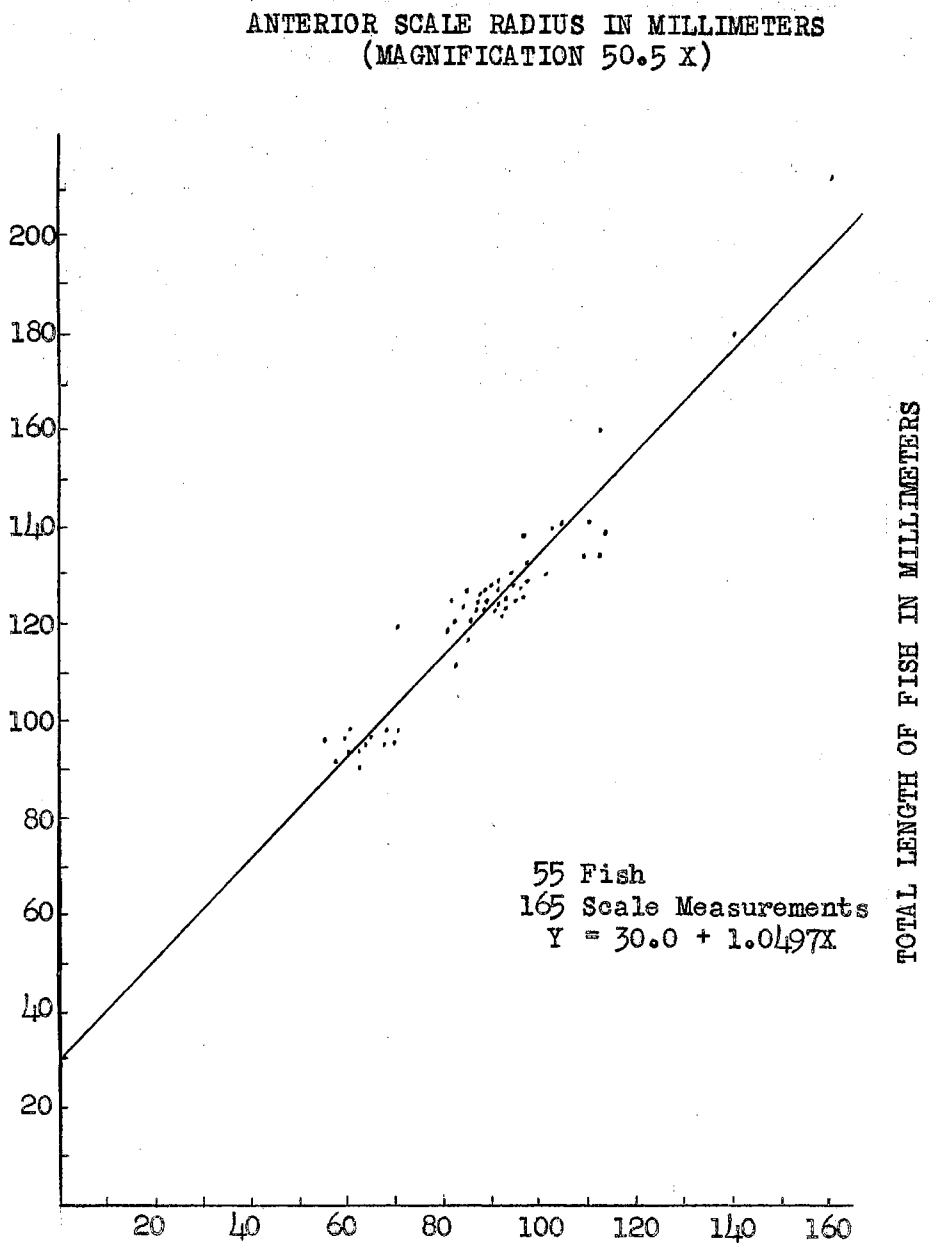

FIGURE 10. Body-Scale Relationship of Black Crappie, Lexington Gunnery Range Pond, Cleveland County, Oklahoma. August 16, 1950. Individual Computation.

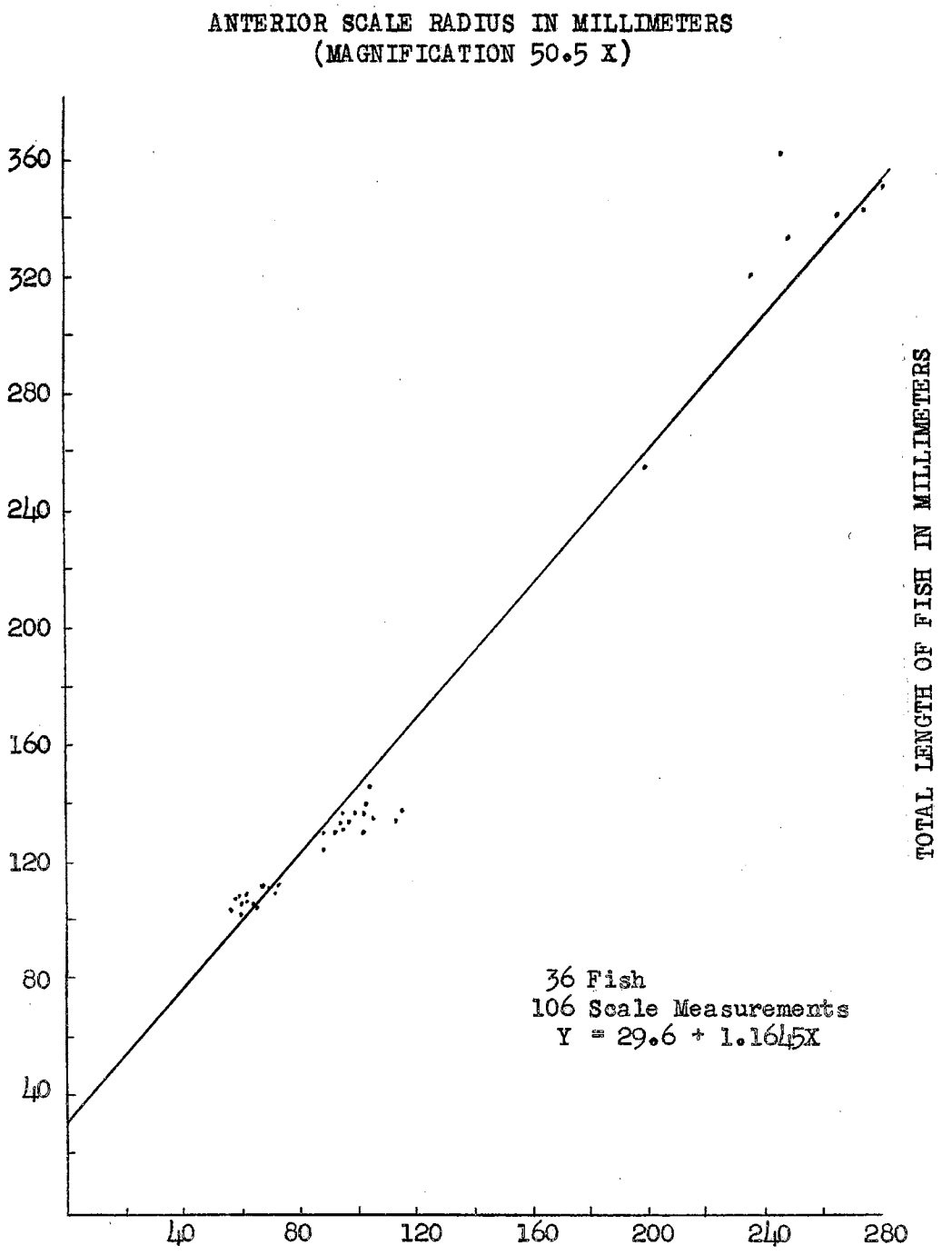

FIGURE 11. Body-Scale Relationship of White Crappie, Fisher's Pond, Oklahoma County, Oklahoma. August 14, 1950. Individual Computation.

TABLE 20. Test of Significance of Departure from Linear Regression of the Body-Scale Relationship of White Crappie, Fisher's Pond Oklahoma County, Oklahoma. August 14, 1950.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Deviations from Linear Regression	34	0.014409	
Deviations from Curved Regression	33	0.013406	0.000406
Curvilinearity of Regression	1	0.001003	

$$F = \frac{.001003}{.000406} = 2.47$$

The few white crappie, of Fisher's Pond, which were 10 to 14 inches long attained lengths of about six inches during their second year of life and about eight to nine inches during their third year (Table 21).

Food of White Crappie from Fisher's Pond. The stomach contents of 36 white crappie from Fisher's Pond were examined. Twenty-eight of the crappie were 4.0 to 5.7 inches in length and eight were 10.0 to 14.3 inches long.

The total volume of food of the 4.0- to 5.7-inch crappie consisted of 87 percent, crustaceans; 9 percent, fish; and 4 percent, insects (Appendix K). The crustaceans, in order of abundance, were ostracods, copepods, and cladocerans. The fish items, larvae of 0.2 to 0.4 inch in length, had been eaten by crappie of 4.3 to 4.4 inches in length.

Only seven fish and three midge larvae were found in the stomachs of the 10.0- to 14.3-inch crappie. The condition of the seven fish items indicated that only one might have been swallowed after the application of rotenone. Four of the fish items were identifiable only as sunfishes, one was a white crappie, and one was an orangespotted sunfish.

TABLE 21. Mean Lengths, Weights, and Calculated Lengths of White Crappie According to Age Groups, Fisher's Pond, Oklahoma County, Oklahoma. August 14, 1950.

Age Group	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Average Calculated Lengths in Inches at Each Annulus					
				1	2	3	4	5	6
I	13	4.2	0.03	2.8					
II	15	5.3	0.05	2.4	4.5				
III	1	10.0	0.50	2.6	4.6	7.9			
IV	5	13.4	1.42	3.1	6.0	9.2	12.3		
V	1	13.6	1.75	2.5	6.2	8.8	10.8	12.5	
VI	1	14.3	1.94	3.4	6.1	7.9	10.4	13.2	14.1

TABLE 22. Mean Lengths, Weights, and Calculated Lengths of Black Crappie According to Age Groups, Lexington Gunnery Range Pond, Cleveland County, Oklahoma. August 16, 1950.

Age Group	Number of Fish	Mean Length in Inches	Mean Weight in Pounds	Average Calculated Lengths in Inches at Each Annulus			
				1	2	3	4
I	13	3.7	0.02	2.1			
II	8	4.7	0.04	2.0	3.6		
III	31	5.1	0.05	1.9	3.5	4.4	
IV	2	6.7	0.13	2.0	2.8	4.7	5.6

Food of Black Crappie from Lexington Gunnery Range Pond. The stomachs of 56 black crappie were examined and all were found to contain food. Most of the fish items had been eaten recently, probably after the rotenone was applied to the water.

The stomachs of the large black crappie, 7.0 to 10.8 inches long, contained only fish items. One of the items was a minnow, Notropis lutrensis, one was a black crappie, and the others were sunfish of 0.7 to 2.5 inches in length. A 7.0-inch black crappie had swallowed sunfish of 2.5 inches in length. The stomach of an 8.4-inch black crappie contained 9.1 ml. of food, including a 3.7-inch black crappie, and the stomach of a 10.8-inch crappie contained 10.0 ml. of food.

A 6.3-inch black crappie had eaten four sunfish fry, 0.5 inch long, and 34 midge larvae.

The food of the black crappie of 3.6 to 5.6 inches in length is presented in Appendix L. Specimens as small as 3.6 inches long had eaten fry of 0.5 inch lengths and 5.0-inch crappie had eaten orange-spotted sunfish as long as 1.5 inches.

DISCUSSION

Condition Factor

The fishes from Fort Supply and Canton reservoirs had higher condition factors than the fishes from Lake Carl Blackwell and much higher condition factors than the fishes from Boomer Lake and the two ponds. The condition factors tended to be lower for the crappies from the older bodies of water.

The condition factors of the 5- to 7-inch crappies from the older lakes were low and decreased with an increased length of the fishes. This decrease, illustrated in Figure 12, contrasts with the findings for fishes of the newer lakes and that of Hall, Jenkins, and Finnell (1954). Age and growth studies of the fishes with the low condition factors showed that they were of several age groups and that they had made slow growths.

The 10- to 14-inch crappies of populations which contained stunted fishes were usually in good condition. This was especially true for Fisher's Pond, where a few large white crappie were the only large carnivorous fish in the pond.

Relation of Scale Length to Fish Length

Examination of the known-age black crappie showed that the scales were first formed as tiny plates with an appreciably greater width than thickness. Also, the scales formed in the key-scale area when the fish were about 24 mm. in length and about three and one-half to four weeks of age.

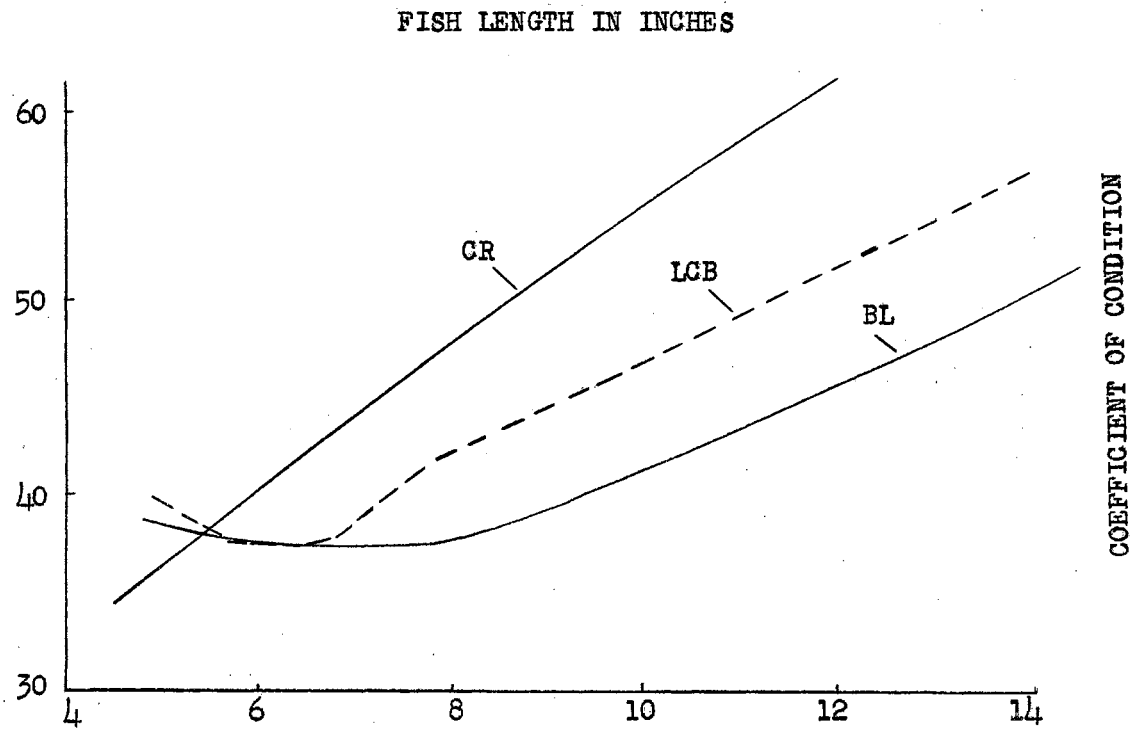

FIGURE 12. Coefficients of Condition of White Crappie from Boomer Lake (BL), Lake Carl Blackwell (LCB), and Canton Reservoir (CR).

Ward and Leonard (1952) concluded that the age of the black crappie was a determining factor in the time of scale formation. They found that three-week-old fish (average total length, 17.5 mm.) did not have scales, but 30 of 33 fish of four weeks of age (average total length, 18.8 mm.) and 19 of 20 fish of five weeks of age had scales. They found that some black crappie as small as 16 mm. in length had scales, and that all fish of 20 mm. in length had scales. The fish studied by Ward and Leonard were hatched on April 20, 1952.

The black crappie reported herein were hatched about April 27, 1949. None of the fish of $2\frac{1}{2}$ weeks of age (mean total length, 18.4 mm.; range, 16 to 20 mm.) had scales, but five of the 10 fish of $3\frac{1}{2}$ weeks of age (mean total length, 22.6 mm.; range 20 to 24 mm.) had scales. All fish of $4\frac{1}{2}$ and $5\frac{1}{2}$ weeks of age had scales. The smallest

black crappie with scales was 21 mm. long, whereas some specimens as long as 23 mm. did not have scales.

Direct-proportional methods of calculating growth are commonly used without compensating for the size of the fish at the time of scale formation. Buck and Cross (1951) showed the need for recognizing an initial fish length (before scale growth began) by comparing results of different methods. They found a highly significant difference, using direct proportion and a zero intercept, between growth increments computed from data taken from scales above the lateral line and similar data from scales below the lateral line. The calculated growth increments, for the same fish, from scales above the lateral line and from scales below the lateral line were not significantly different when the appropriate intercept values were used as the points of origin in the calculations. Thus identical results were obtained by compensating for the different relationships of scale length and fish length when scales were taken from different areas of the body.

Jenkins (1953) observed that growth calculations determined by direct proportions with an assumed intercept of zero did not correspond with empirical growths. Jenkins showed that by following the method used by Weese (1949) the average actual lengths and the average calculated lengths were approximately the same.

Studies reported herein and the works of Ward and Leonard (1952) show that scales first form on the black crappie when the fish are 16 to 24 mm. long and that scales form in the key-scale area when the black crappie are 21 to 24 mm. long. Thus, it appears there is little variation in the size of black crappie when scales began development in the key-scale area. Nevertheless, distinct differences were apparent

between the black crappie studied by Ward and Leonard and the black crappie reported herein. The difference may be a normal variation or may be a result of different environmental conditions such as temperature and food.

The data from crappies of Fort Supply Reservoir, and the two ponds show linear correlations of body-scale relationships. This agrees with the findings of Buck and Cross (1951); Wilson (1951); Hall (1950); Thompson, Ward, and McArthur (1949); Johnson (1945); and Ricker and Lagler (1942).

In contrast, the body-scale relationships for white crappie of Lake Carl Blackwell and Boomer Lake were curvilinear. Plotting of the measurements shows that the curvilinearities were caused by data for the 5- to 7-inch fish. Although the body-scale relationship for the white crappie from Fisher's Pond was linear, the data indicated that a curvilinear relationship might have existed if there had been a complete length-series of fish.

The trend toward large numbers of small fish and a few large fish, as was found in Fisher's Pond, was realized long ago as being characteristic of stunted populations. The crappie population of Boomer Lake and Lake Carl Blackwell (to a lesser extent) represent stages leading to the absence of fish of intermediate sizes.

A proportionally faster growth of scales than of fish length was found for the 5- to 7-inch fish of Boomer Lake and Lake Carl Blackwell. Also, the same size fish were shown to have low coefficients of condition. In the study of the length changes caused by formalin, it was noted that the 5- to 7-inch specimens shrank proportionally less in length than other specimens. Thus, it appears that proportionally

faster growth of scales than of fish length, low coefficients of condition, and a resistance to shrinkage are characteristics of stunted white crappie.

Age and Growth

The oldest black and white crappies, from the Lexington Gunnery Range Pond and Boomer and Carl Blackwell lakes, were in their seventh year of life. Hall, Jenkins, and Finnell (1954) in their compilation of growth data on the black and white crappies of Oklahoma waters reported ages of seven years for black crappie and eight years for white crappie.

The results of the growth calculations show that the white and black crappies of the new lakes made faster growths than crappies of the older lakes. This is in agreement with the findings of Hall, Jenkins, and Finnell (1954). The white crappie of Fort Supply and Canton reservoirs were 8 to 11 inches in length during their second year of life, whereas, white crappie of Carl Blackwell and Boomer lakes were 4.7 to 5.4 inches in length at the end of their second year of life. Black crappie from Fort Supply and Canton reservoirs were about seven inches long at the end of their second year and 9.5 inches long at the end of their third year, whereas the black crappie from the Lexington Gunnery Range Pond averaged only 5.6 inches long at the end of their fourth year.

The means of the scale lengths, fish lengths, or fish weights of the different age groups of Carl Blackwell and Boomer lakes did not vary with the time of collections during October 1950 through March 1951. The findings show that the fish did not grow from October 1950 through

March 1951. Similar data did show that fish growth occurred during September and April.

It appears that good growth is necessary during the first few years of life if many white crappie are to attain large size. This is evidenced by the growth rates of the large white crappie from Fisher's Pond and Lake Carl Blackwell (Tables 13 and 21).

The age and growth of specimens from Lake Carl Blackwell show that some individuals made good growth, whereas others made poor growth. All of the fish from Lake Carl Blackwell were taken in the same vicinity. Thus, the difference could not be correlated with different regions of the lake as was found by Wilson (1951). The faster-growing crappie may have been migrants which followed their food supply or individuals with inherent characters for fast growth.

Food

The food of the young black crappie from the Holdenville Fish Hatchery consisted largely of cladocerans, copepods, and dipterous larvae. Phytoplankton was scarce as food, indicating that young black crappie are primarily carnivores. The kind of food changed little as the black crappie became larger and older, and the absence of empty stomachs revealed the young fish to be frequent feeders. Even the smallest of the fish had eaten midge fly larvae; however, the larger and older fish had eaten the larger insect larvae.

Cladocerans and copepods were the principal crustaceans found as food items and were common as food for crappies less than seven inches in length and scarce as food for the larger fishes (Figure 13). Ostracods were common food items of the crappies from ponds and scarce for crappies

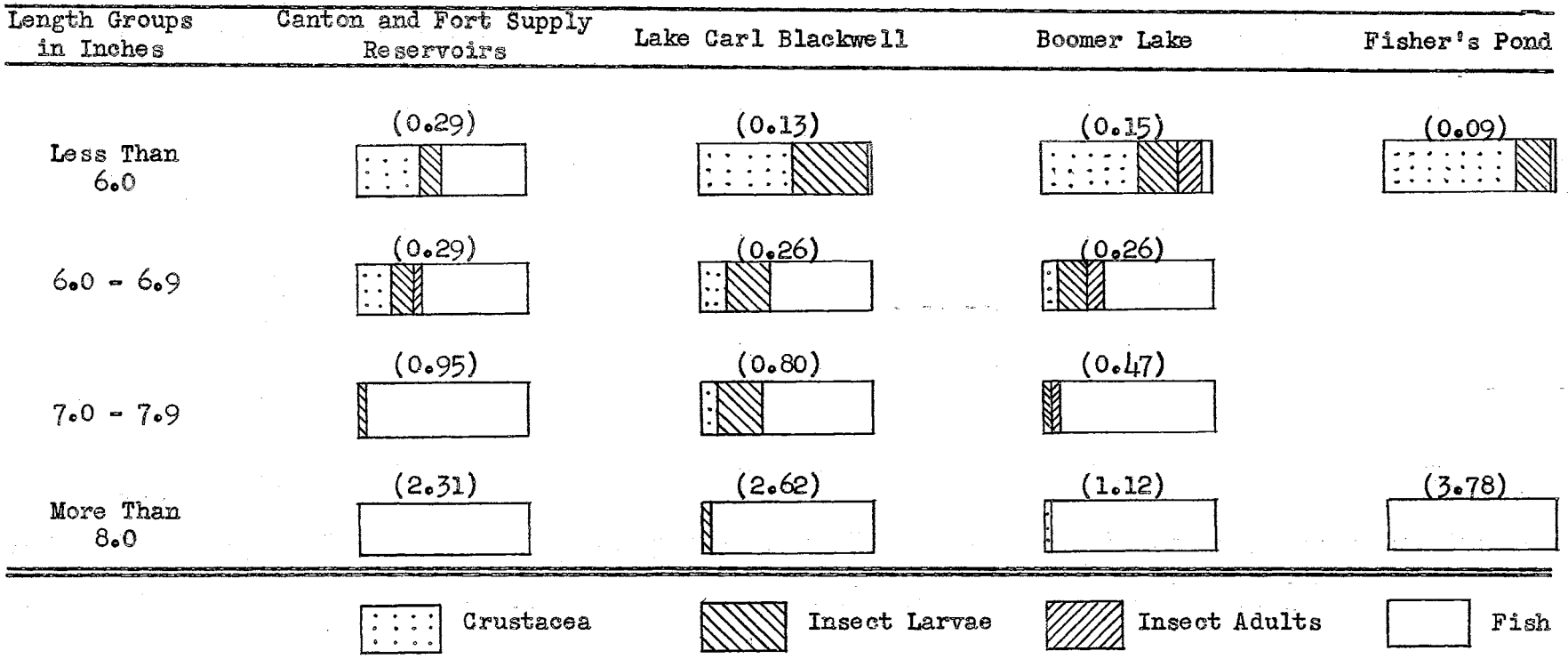

FIGURE 13. Summary of the Stomach Contents of White Crappie from Canton and Fort Supply Reservoirs, Lake Carl Blackwell, Boomer Lake, and Fisher's Pond. Average Volume of Contents in Milliliters is Shown in Parenthyses.

from lakes.

Insect larvae were eaten by crappies of all sizes from all waters. Mayfly larvae were the principal insect food and were numerous in the stomachs of black and white crappies from all lakes except Canton Reservoir. Mayfly larvae were common in the stomachs of the black crappie from Canton Reservoir, but were not found in the stomachs of the white crappie. Chaoborus and Chironomus larvae were common insect foods. Generally, the midge larvae were equally numerous as food for both black and white crappies. Stomach analyses of the fishes from Fort Supply Reservoir (July 1950) showed that the white crappie fed more extensively on Chironomus than did the black crappie.

Mayfly larvae appear to be an especially important food of the white crappie of Lake Carl Blackwell. A comparison of the food of fish from the different lakes shows that larval insects comprised a larger percent of the food of the fish from Lake Carl Blackwell than of fish from Boomer Lake and Canton and Fort Supply reservoirs (Figure 13). The average volumes of food for the 7.0- to 7.9-inch fish from Lake Carl Blackwell and Boomer Lake would be about the same if the insect larvae were disregarded.

Adult insects were eaten by the crappies of all waters, but generally were only a minor portion of the food items. They were found as food for all length groups of black crappie, but were not common food of white crappie more than 8.0 inches in length. The principal items were water boatmen and leaf hoppers. Adult insects comprised a significant proportion of the food of the white crappie of Boomer Lake during the fall and winter months but comprised only trace amounts in the food of white crappie from Lake Carl Blackwell and Canton and Fort Supply

reservoirs. Adult insects comprised a significant proportion of the food of one collection of white crappie from Fort Supply Reservoir in July (Appendix J). However, since the white crappie of Boomer Lake fed upon the adult insects over a long period of time it appears that other more preferable foods were less abundant.

Stomach examinations of crappies taken during the fall and winter months showed that fish were more common in the stomachs of specimens from Fort Supply and Canton reservoirs than in the stomachs of specimens from Lake Carl Blackwell and Boomer Lake. This appears to indicate that the fast-growing crappie had a greater supply of forage fishes than the crappies of the two older lakes. White crappie of 3.8 inches in length from Canton Reservoir contained fish items in October. White crappie less than 5.0 inches in length from Boomer Lake were not found to contain fish items at any time.

The kind of fish was the most distinct difference in the foods of the crappies from the "old" and "new" lakes. Centrarchids comprised 95 to 100 percent of the total volume of fish items eaten by crappies of Boomer Lake, Fisher's Pond, and Lexington Gunnery Range Pond. Slow growth was evident for crappies from these relatively old bodies of water. In contrast, gizzard shad and minnows comprised 97 to 100 percent of the total volume of fish items eaten by crappies of Fort Supply and Canton reservoirs. Good growth was evident for crappies of these "new" lakes. Centrarchids comprised 15 percent and gizzard shad and minnows comprised 85 percent of the total volume of fish items eaten by crappie of Lake Carl Blackwell. Both poor and good growth was evident for crappie of Lake Carl Blackwell, a lake neither "old" or "new". These conclusions seem to show that crappie do not thrive on a diet of centrarchids.

The composition of the populations from the different lakes shows that large numbers of 5- to 7-inch fishes were found in populations of stunted or slow-growing crappies. It is at this size that white crappie begin to feed almost exclusively on fish items (Tables 16 and 17, Figure 13). Thus, the evidence indicates that slow growth of crappies in the older lakes is caused by a shortage of forage fish for specimens less than seven inches in length.

RECOMMENDATIONS FOR FURTHER RESEARCH

The goal of fisheries management is to sustain maximum harvests of desirable fishes. Good management cannot be had without an understanding of the phenomena which are to be managed. New achievements in other fields are rapidly being made because of extensive knowledge of the problems to be solved. The use of new tools and new approaches provide further insight and knowledge of assumed theories. Too often, management practices and research approaches become static and it is assumed that the important facts are already known about particular subjects and methods.

The writer does not propose a cure-all or believe that a recommendation, applicable to only one or two species, is appropriate without consideration of all the species and the conditions involved. The following recommended investigations appear to be among the necessary recourses for obtaining information for better management.

1. Study the size and kinds of forage fishes which are eaten by the different sizes of carnivorous fishes. An understanding of these relations appear important in evaluating the amount of "forage fish" available as food and in determining which fishes actually are important forage fish.
2. Determine the amount and kind of foods necessary for good growth. Martin (1952) found increased growth rates for crappie and other game fishes after a partial kill of the fishes of Goddard Lake. Results presented herein indicate that a substantial reduction in the number of stunted

crappie (carnivorous game fishes) would be desirable in order to reduce competition for food.

3. Study the reproductive capacities, food, growth, and requirements of important forage fishes such as Dorosoma cepedianum, Hybognathus placita, etc. Extensive selective kills of these forage fishes, at any time of the year, may prove disasterous by reducing the food supply of game fishes.

4. Continue investigations of the principles involved in age and growth determinations. Establish and utilize standard methods so that the results of different studies can be compared. Eliminate assumed intercepts in growth calculations and determine by observation if body-scale relationships are linear and if a mean intercept can be established.

SUMMARY

1. The results of growth and food studies of 120 known-age black crappie, $2\frac{1}{2}$ to $13\frac{1}{2}$ weeks old and 0.6 to 2.2 inches long are presented.

2. The results of age, growth, and food studies of populations of fast-growing and of stunted black and white crappies are presented. The populations studied were from two ponds and four lakes.

3. The coefficients of condition of the young-of-year black crappie were found to increase with age and length until the fish were about six weeks old and 1.4 inches long. Thereafter, the coefficients of condition were not significantly different for the longer or older fish.

4. The first appearance of scales was near the caudal peduncle when the black crappie were 21 to 24 mm. in total length and about four weeks old.

5. Scales were found to develop in plate-form in the "key-scale area" when the black crappie were about 24 mm. in total length.

6. The body-scale relationship of the known-age black crappie was found to be approximately linear with an intercept of 19.9 mm.

7. The black crappie fry were found to feed almost continuously upon zooplankton and insect larvae.

8. The amount of change in length and weight of white crappie caused by fixation in 10 percent formalin was determined. The fish shrank in length and increased in weight after fixation. The stunted fish shrank less in length than the non-stunted fish.

9. The coefficients of condition for fast-growing black and white crappies were found to increase steadily with the increase in length of

the fish. The coefficients of condition for crappie populations which were comprised largely of stunted fishes were consistently low for the 5- to 7-inch fish.

10. Body-scale relationships were determined for black crappie from Lexington Gunnery Range Pond and Fort Supply Reservoir and for white crappie from Fisher's Pond, Fort Supply Reservoir, Lake Carl Blackwell, and Boomer Lake.

11. The body-scale relationships of white crappie from Lake Carl Blackwell and Boomer Lake were found to be curvilinear. The data show that curvilinearity was caused by proportionally faster growth of scales than growth of fish length for the 5- to 7-inch specimens.

12. Proportionally faster growth of scales than of fish length, low coefficients of condition, and a resistance to shrinkage from fixation were found to be characteristics of the stunted white crappie.

13. Both black and white crappies of the "new" lakes grew faster than the crappies of the "old" lakes.

14. The oldest of the black and the white crappies studied were determined to be seven years old.

15. Copepods and cladocerans were common as food items for both black and white crappies of less than seven inches in length.

16. Insect larvae were common as foods for all sizes of black and white crappies.

17. The kind and size of fishes eaten by the different length-groups of crappies were determined.

18. The most common minnow found in the crappie stomachs was Hybognathus placita which appears to be an important forage fish in some lakes.

19. Stomach analyses of the crappies of Fort Supply Reservoir showed that the white crappie had fed principally on Dorosoma cepedianum and the black crappie had fed principally on Hybognathus placita.

20. The most severely stunted crappies of the older lakes were 5 to 7 inches in length. The only significant differences between the foods of fast- and slow-growing crappies were the amount and kinds of fishes eaten. The slower-growing crappies contained smaller volumes of fish items which were largely centrarchids. The faster-growing crappies contained more food and a greater percentage of fish items which were gizzard shad or minnows.

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APPENDIX

APPENDIX A. Factors for Converting Total Lengths and Weights of Preserved White Crappie from Boomer Lake to Live Lengths and Weights. Specimens Were Preserved in 10 Percent Formalin.

Number of White Crappie	Live Measurements: Total Length in Millimeters Range	Mean	Weight in Grams Range	Mean	Mean Conversion Factors for Determining Live Measurements: Length	Weight
17	122 - 129	127	18.4 - 22.5	21.2	1.014	0.940
25	130 - 139	134	20.0 - 29.7	24.8	1.015	0.943
18	140 - 149	144	27.2 - 33.8	29.8	1.013	0.940
8	150 - 159	154	30.9 - 38.7	34.4	1.007	0.940
6	160 - 166	163	37.2 - 47.6	41.7	1.009	0.935
2	173 - 174	174	50.7 - 51.4	51.0	1.012	0.934
8	180 - 188	184	54.5 - 69.0	61.7	1.012	0.920
4	191 - 196	194	67.1 - 76.3	70.3	1.020	0.920
1	222		114		1.023	0.952

APPENDIX B. Weights of Stomach Contents, in Milligrams, of Young-of-Year Black Crappie According to Age, Holdenville State Fish Hatchery, Hughes County, Oklahoma. May 14 to August 20, 1949.

	Age Groups in Weeks												
	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL
Number of Fish Examined	11	10	10	9	8	10	10	10	10	10	10	10	118
Total Contents of Stomachs in Milligrams	3.1	3.5	5.6	3.1	36.6	17.3	22.5	17.5	22.8	36.4	25.9	29.9	
Number of Empty Stomachs									1				1
Number of Stomachs Containing 0 - 0.9 mg.	9	10	7	9		5	1	4	3	2	1	1	52
Number of Stomachs Containing 1.0 - 1.9 mg.	2		3		2	3	5	2	2	1	4	3	27
Number of Stomachs Containing 2.0 - 2.9 mg.					1	1	2	2	1	2	1	1	11
Number of Stomachs Containing 3.0 - 3.9 mg.								2		1	2	2	7
Number of Stomachs Containing 4.0 - 4.9 mg.					2		1		2	1	1	2	9
Number of Stomachs Containing 5.0 - 5.9 mg.					1		1						2
Number of Stomachs Containing 6.0 - 6.9 mg.										2	1		3
Number of Stomachs Containing 7.0 - 7.9 mg.					1	1			1			1	4
Number of Stomachs Containing 8.0 - 8.7 mg.					1					1			2

APPENDIX C. Number and Rate of Occurrence of Food Items from Stomachs of 107 Young-of-Year Black Crappie According to Age and Dates of Collections in 1949, Holdenville State Fish Hatchery, Hughes County, Oklahoma. Figures in Parenthesis Indicate the Number of Stomachs in Which the Food Items were Found.

Date of Collection	5-14	5-21	5-28	6-4	6-11	6-18	6-25	7-2	7-9	7-16	7-23	7-30	TOTAL
Age of Fish in Weeks	2	3	4	5	6	7	8	9	10	11	12	13	
Number of Stomachs Examined	11	10	10	9	8	10	8	7	7	10	10	7	107
Oscillatoria fragments	0	0	0	0	0	0	0	0	10 (3)	2 (2)	70 (9)	73 (5)	155
Rotifera (*Noteus*)	0	0	1	0	0	0	0	0	0	0	0	0	1
Cladocera	0	40 (9)	161 (10)	57 (5)	54 (8)	430 (10)	181 (8)	27 (7)	66 (7)	50 (10)	74 (10)	28 (7)	1168
Eucopepoda	128 (11)	210 (9)	198 (10)	58 (7)	13 (6)	352 (10)	318 (8)	228 (7)	123 (7)	159 (10)	247 (10)	128 (7)	2162
Ostracoda	0	0	0	0	4 (2)	11 (4)	14 (8)	11 (5)	28 (6)	38 (10)	104 (10)	77 (4)	287
Amphipoda	0	2 (1)	0	0	0	0	2 (2)	1	3 (1)	0	0	0	8
Hydracarina	0	0	0	0	0	0	0	0	1	0	0	2 (2)	3
Ceratopogoniae larvae	0	0	0	0	0	0	5 (2)	1	2 (2)	5 (4)	13 (6)	5 (4)	31
Chironomus larvae	4 (2)	2 (1)	40 (9)	18 (7)	135 (8)	27 (4)	4 (4)	2 (2)	1	2 (2)	6 (2)	2 (2)	243
Chaoborus larvae	0	0	0	4 (1)	29 (5)	0	2 (1)	0	19 (1)	21 (4)	1	1	77
Hydroporus larvae	0	0	5 (4)	0	2 (1)	1	0	0	0	0	0	0	8
Ephemerida larvae	0	0	0	0	3 (2)	1	2 (2)	1	0	0	0	0	7
Unidentified Insect larvae	0	1	0	0	1	0	4 (2)	0	3 (2)	1	0	1	11
Fish larva	1	0	0	0	0	0	0	0	0	0	0	0	1

APPENDIX D. Number, Rate of Occurrence, and Volume of Food Items of 28 White Crappie, 6.4 to 11.1 Inches in Length, Fort Supply Reservoir, Woodward County, Oklahoma. July 25 to 27, 1950.

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Fish	24	47	25.4	
Unidentified	4	4	1.2	4.1
Dorosoma cepedianum	18	40	22.9	77.6
Cyprinidae	3	3	1.3	4.4
Crustacea	7		Trace	
Argulus	2	2		
Eucopepoda	2			
Cladocera	3			
Ostracoda	1			
Insecta adults	23	148	2.6	8.8
Unidentified	1	2		
Unidentified Hemiptera	2	3		
Corixidae	22	142		
Notonectidae	1	1		
Insecta larvae	14	32	1.5	5.1
Unidentified	1	1		
Ephemerida	13	17		
Anisoptera	2	2		
Chironomus	7	10		
Ceratopogoniae	1	1		
Culicinae	1	1		
Plant Material	1	1	Trace	

APPENDIX E. Number, Rate of Occurrence, and Volume of Food Items of 27 Black Crappie, 5.7 to 11.2 Inches in Length, Fort Supply Reservoir, Woodward County, Oklahoma. July 25 to 27, 1950.

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Fish	18	142	22.3	
Unidentified	4	4	0.5	1.9
Dorosoma cepedianum	2	3	1.8	6.8
Cyprinidae	12	135	20.0	76.1
Unidentified	5	12		
Hybognathus placita	7	122		
Fundulus kansae	1	1		
Crustacea	9		0.2	0.8
Argulus	4	4		
Eucopepoda	2			
Cladocera	4			
Insecta adults	22	127	2.5	9.5
Unidentified	1	1		
Corixidae	19	117		
Notonectidae	3	3		
Stratiomyidae	1	1		
Unidentified Coleoptera	1	1		
Dytiscidae	4	4		
Insecta larvae	12	20	1.0	3.8
Ephemerida	8	14		
Dytiscidae	1	1		
Gyrinidae	1	1		
Chironomus	1	2		
Chaoborus	1	1		
Culicinae	1	1		
Thysanoptera	1	1	Trace	
Plant Material (gall)	3	3	0.3	1.1

APPENDIX F. Number, Rate of Occurrence, and Volume of Food Items of 130 White Crappie, 2.4 to 11.8 Inches in Length, Canton Reservoir, Blaine and Dewey Counties, Oklahoma. August 23 to October 8, 1950.

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Fish	73	150	191.3	99.1
Unidentified	10	16	3.8	
Dorosoma cepedianum	63	127	180.8	
Cyprinidae			0.7	
Unidentified	3	3		
Notropis lutrensis	1	1		
Hybognathus placita	1	1		
Centrarchidae			6.0	
Pomoxis annularis	1	1		
Lepomis macrochirus	1	1		
Crustacea	31	-	1.2	0.6
Eucopepoda	20	-		
Cladocera	27	-		
Insecta adult	1	1	Trace	Trace
Corixidae	1	1		
Insecta larvae	22	158	0.6	0.3
Sialidae	1	1		
Zygoptera	1	1		
Chironomus	10	20		
Chaoborus	15	136		

APPENDIX G. Coefficients of Condition of White Crappie by Length Groups and Dates of Collections in 1951, Lake Carl Blackwell, Payne County, Oklahoma.

Length Group in Inches	January 4 - 8		February 27 - March 1		March 9 - 21		April 12 - 27	
	Number of Fish	C	Number of Fish	C	Number of Fish	C	Number of Fish	C
5.0 - 5.4	11	36.3	7	38.4	6	39.1	5	39.0
5.5 - 5.9	25	36.2	5	36.2	11	38.8	13	42.1
6.0 - 6.4	14	36.5	6	34.4	6	36.5	12	42.4
6.5 - 6.9	8	36.6	7	34.2	8	35.8	6	42.9
7.0 - 7.4	4	41.9	4	36.7	7	38.7	9	42.9

APPENDIX H. Coefficients of Condition of White Crappie by Length Groups and Dates of Collections, Boomer Lake, Payne County, Oklahoma.

Length Group in Inches	Sept. 23 - Oct. 3, 1950		Oct. 27 - Nov. 4, 1950		Nov. 30 - Dec. 1, 1950		Jan. 1 - 4, 1951		Feb. 19 - 27, 1951		March 15 - 21, 1951		April 10 - 27, 1951	
	Number of Fish	C	Number of Fish	C	Number of Fish	C	Number of Fish	C	Number of Fish	C	Number of Fish	C	Number of Fish	C
4.5 - 4.9	6	43.3	5	34.1	3	36.2	2	36.2	0	-	3	34.1	0	-
5.0 - 5.4	21	42.7	35	35.5	23	39.1	17	37.8	6	37.0	13	35.5	3	41.2
5.5 - 5.9	16	37.8	23	35.1	11	37.8	9	37.8	8	34.2	4	34.2	9	42.3
6.0 - 6.4	15	37.8	11	33.6	6	35.2	2	42.0	6	35.2	1	37.0	3	37.6

APPENDIX I. Number, Rate of Occurrence, and Volume of Food Items of 320 White Crappie, 4.6 to 14.2 Inches in Length, Boomer Lake, Payne County, Oklahoma. September 23, 1950 to April 27, 1951.

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Fish	43	51	46.6	56.3
Unidentified	19	20	11.9	
Centrarchidae	28	28	34.7	
Unidentified	23	22	17.6	
Pomoxis annularis	3	3	11.7	
Lepomis macrochirus	1	1	2.6	
Lepomis humilis	1	1	2.8	
Hybognathus placita	2	2	0.6	
Cyprinus carpio	1	1	Trace	
Crustacea	188		19.4	23.4
Eucopepoda	152		8.0	
Cladocera	186		11.4	
Amphipoda	1	1	Trace	
Insecta adults	101	385	6.0	7.4
Unidentified	11	26	0.3	
Diptera	6	9	Trace	
Lepidoptera	1	1	0.2	
Formicidae	9	23	0.6	
Hemiptera unidentified	14	46	1.0	
Corixidae	60	113	2.3	
Gerridae	1	8	0.2	
Homoptera unidentified	2	6	0.1	
Cicadellidae	20	77	0.7	
Aphididae	5	75	0.6	

APPENDIX I. (Continued)

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Insecta larvae	140	976	10.4	12.5
Sialidae	2	2	0.1	
Ephemerida	72	143	6.6	
Anisoptera	5	6	0.8	
Coleoptera	6	6	0.4	
Psychomyiidae	2	2	Trace	
Chironomus	58	370	1.0	
Chaoborus	66	440	1.5	
Ceratopogoniae	4	7	Trace	
Araneida	1	6	0.2	0.2
Hydrachnidae	1	1	Trace	
Uroglena	3		0.2	0.2

APPENDIX J. Number, Rate of Occurrence, and Volume of Food Items of 222 White Crappie, 4.5 to 12.6 Inches in Length, Lake Carl Blackwell, Payne County, Oklahoma. January 4 to April 27, 1951.

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Fish	55	135	132.6	
Unidentified	13	23	9.8	6.0
Centrarchidae	6	7	17.9	10.9
Unidentified	5	5	5.4	
Lepomis humilis	1	1	1.5	
Pomoxis annularis	1	1	11.0	
Cyprinidae	2	2	1.4	0.9
Unidentified	1	1	0.4	
Hybognathus placita	1	1	1.0	
Dorosoma cepedianum	39	103	103.5	63.2
Crustacea	110	-	9.9	6.0
Cladocera	104	-	6.4	
Copepoda	85	-	3.5	
Ostracoda	2	-	Trace	
Insecta adults	9	10	0.3	0.2
Unidentified	3	3	0.1	
Diptera	3	4	0.1	
Corixidae	2	2	0.1	
Cicadellidae	1	1	Trace	
Insecta larvae	119	835	20.9	12.8
Ephemerida	90	376	17.6	
Anisoptera	1	1	0.1	
Coleoptera	4	5	0.6	
Sialidae	4	4	0.4	
Cicadellidae	1	1	Trace	
Corixidae	2	2	0.1	
Psychomyiidae	3	4	0.2	
Chironomus	75	325	1.5	
Chaoborus	34	115	0.4	
Ceratopogoniae	2	2	Trace	

APPENDIX K. Number, Rate of Occurrence, and Volume of Food Items of 28 White Crappie, 4.0 to 5.7 Inches in Length, Fisher's Pond, Oklahoma County, Oklahoma. August 14, 1950.

Food Items	Number of Stomachs Containing Items	Number of Items	Percentage Volume of Total Items
Fish larvae	4	15	9.2
Crustacea	28	-	87.1
Eucopepoda	28	-	
Cladocera	19	-	
Ostracoda	28	-	
Insecta	10	23	3.7
Unidentified adult	1	1	
Psychomyiidae larva	1	1	
Chaoborus larvae	2	3	
Chironomus larvae	8	16	
Ceratopogoniae larvae	2	2	

APPENDIX L. Number, Rate of Occurrence, and Volume of Food Items of 51 Black Crappie, 3.6 to 5.6 Inches in Length, Lexington Gunnery Range Pond, Cleveland County, Oklahoma. August 16, 1950.

Food Items	Number of Stomachs Containing Items	Number of Items Found	Volume of Items in Milliliters	Percentage of Volume of Major Items
Fish	29	100	13.0	77.4
Unidentified fry	13	48	3.6	
Unidentified sunfish	8	32	2.0	
Lepomis humilis	11	15	5.2	
Lepomis macrochirus	3	3	1.2	
Lepomis cyanellus	1	1	0.5	
Notropis lutrensis	1	1	0.5	
Crustacea	32		1.1	6.5
Eucopepoda	32	-		
Cladocera	15	-		
Ostracoda	15	-		
Insecta adults	4	17	0.6	3.6
Unidentified	3	3	0.2	
Homoptera				
Unidentified	1	1	0.1	
Cicadellidae	1	1	Trace	
Hemiptera				
Corixidae	4	5	0.1	
Gerridae	1	7	0.2	
Insecta larvae	29	900	2.1	12.5
Ephemerida	1	1	Trace	
Anisoptera	1	1	Trace	
Chironomus	22	45	0.2	
Ceratopogoniae	4	5	Trace	
Chaoborus	38	848	1.9	

VITA

William Edmon Burris
candidate for the degree of
Doctor of Philosophy

Thesis: STUDIES OF THE AGE, GROWTH, AND FOOD OF KNOWN-AGE, YOUNG-OF-YEAR BLACK CRAPPIE AND OF STUNTED AND FAST-GROWING BLACK AND WHITE CRAPPIES OF SOME OKLAHOMA LAKES

Major: Zoology

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Publications:

Burris, William E. 1952. The bottom fauna development of a newly constructed pond in central Oklahoma. Proc. Okla. Acad. Sci. 33: 129-136.

Moore, George A. and William E. Burris. 1956. Description of the lateral-line system of the pirate perch, Aphrododerus sayanus. Copeia. (1) 18-20.

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